

CHAPTER 2 ENVIRONMENTAL SAMPLING STRATEGY

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2. ENVIRONMENTAL SAMPLING STRATEGY

2.1 INTRODUCTION

2.1.1 Background

It is essential that a site assessment be capable of providing reliable information on the nature, distribution and propensity for movement of contaminants present. Because of the cost of site assessment there is inevitably some compromise to the ideal goal of achieving a high level of confidence about location and concentration. At the same time, sufficient knowledge is needed to enable sensible decisions on site management.

This chapter provides guidance on the adoption of a *targeted sampling approach* for the assessment of sites on which timber treatment chemicals have been used. The approach outlined is not the only one which may be appropriate.

Irrespective of the size or scope of the project, or the mode of assessment, it is important that data generated for the site be of known quality. Guidance is given in this chapter on quality assurance philosophy and framework.

2.1.2 Aim and Objectives

The principal aims of this chapter are:

- To provide direction to parties involved in the assessment of contaminated sites, on the adoption of a quality assurance strategy to assist in the production of data of a known quality.
- To provide guidance on the implementation of a specific sampling approach – the targeted sampling strategy.

2.1.3 Chapter Summary

Quality Assurance Strategy

A quality assurance philosophy and procedure appropriate to the assessment of sawmill and timber treatment sites is outlined. Practitioners are advised to:

1. Define the goal(s) of the assessment;
2. Define data quality objectives (DQOs) based on the desired quality of the data (e.g. accuracy, precision) appropriate to the nature of the assessment;
3. Formulate a quality assurance project plan for the site evaluation which is consistent with the requirements of the data quality objectives.

Targeted Sampling Strategy

A targeted sampling strategy is outlined:

- In the first phase pertinent site information is researched and reviewed to identify the likely contaminants from current and historical chemical use, the locations where contamination is likely to be found, and the potential for off-site migration of contaminant species. Check lists are provided relevant to each of these aspects.
- In the second phase a field investigation is conducted to evaluate the extent of site contamination. Advice is provided on the selection of sample sites and the choice of contaminant species for analysis for a number of field sample types including soils, groundwater, surface water, sediment and dust. Directions are given for the compilation of a contaminated land assessment report.

2.2 A QUALITY ASSURANCE/QUALITY CONTROL APPROACH TO SITE ASSESSMENT (CCME, 1991)

2.2.1 Overview

Regardless of the size or complexity of the site contamination or waste evaluation problem, management decisions need to be based on information of known quality. In essence this requires that “quality assurance” be an integral part of the overall site assessment process. The basis of a quality assurance/quality control (QA/QC)¹ programme is ensuring that data produced from any part of a study designed to evaluate the problem is sufficient to support the decision making process. The logical development of decision making is as much a part of QA/QC as the more commonly applied definitions of the quality of any single analytical result. Every “problem” evaluation should follow a pattern of development similar to that shown in Table 2.1.

¹ Quality assurance and quality control are concepts which have some degree of overlap. Quality assurance is seen as a system of activities that assures the producer or user of a product or a service that defined standards of quality with a stated level of confidence are met. Quality control differs in that it is an overall system of activities that controls the quality of a product or service so that it meets the needs of users. Simply, quality control consists of the internal day to day control and assessment of measurement whereas quality assurance is the management system that ensures that an effective quality control system is in place and working as intended.

Table 2.1
Steps Followed to Ensure the Decisions Made to Solve
a Problem are Based on Data of Known Quality

No.	Step
1	Define the goal or purpose of the study and how it will be achieved
2	Define the data quality objectives that specify the quality of the data that is acceptable
3	Design a QA programme plan defining overall QA policy
4	Design a QA project plan detailing specific QA and QC requirements for the study
5	Undertake study based on the stipulations established in the previous steps
6	Evaluate data and make decisions

It is important to recognise that decision making may not necessarily require information of the best possible quality. For example, a preliminary investigation of a potentially contaminated site might involve the use of a low-cost screening analytical technique, which although sensitive, might respond simultaneously to a number of different species, including the one of immediate interest. The technique could be considered to be one of lower specificity and accuracy, with a tendency for positive bias (over-estimation of results). From the outset of the study the investigator should be aware of the limitations of the technique. Its application should be appropriate to the objectives of the study (e.g. the rapid, cost-effective assessment of a potentially contaminated site to establish if contaminant levels exceed those which are likely to give rise to an unacceptable human health risk).

A preliminary screening study would require the definition of data quality objectives which accept a degree of positive bias in the study results. The QA/QC project and programme plans would set in place an evaluation of the technique's bias by comparison with a reference method or the analysis of a standard reference material. Consequently the final evaluation of the study results would be based on a defined set of objectives and on data of known quality.

Similar considerations can be applied to sampling strategies, allowing cost-effective site investigations to be carried out to achieve defined objectives.

The individual steps shown in Table 2.1 are discussed in more detail in the following sections.

2.2.2 Defining the Goal or Purpose of the Study

Definition of the study goal or purpose should be the first activity that is carried out. The goal or purpose should be defined concisely but with sufficient detail to permit clear understanding by all parties involved.

In New Zealand most studies will be directed towards fulfilling the requirements of the Resource Management (RM) Act (1991) and, to a lesser extent, the Health Act (1956). The RM Act is based on the philosophy of sustainable management and is very much an effects based piece of legislation. The timbre of the RM Act might be summarised as requiring that processes (current or historical) shall not cause an actual or likely adverse effect on human health or on the environment downstream of the operation.²

Currently there are no regulatory levels in the RM Act which define “adverse effect”. However, there are MFE guidelines in preparation (including this document). Guideline levels, where applicable, are clearly an essential component of any study and must be incorporated into study goal statements at an early stage. It is noted that studies undertaken as part of due diligence audits, transfer of land or in quantifying liability (whilst initiated in a legal, commercial context) must be designed with reference to the RM Act or the Health Act.

2.2.3 Data Quality Objectives

Data quality objectives (DQOs) are statements which describe the overall level of uncertainty that a decision-maker is willing to accept in results derived from environmental data. DQOs then allow for data of known quality to be generated as part of the study.

DQOs may be qualitative or quantitative in nature. Quantitative DQOs contain reference to specific quantitative terms such as standard deviations, percent recovery and concentration, whereas qualitative DQOs are descriptive in nature and may refer to specific actions that would be taken in a particular instance.

DQOs are developed for a study by stepwise consideration of a list of relevant issues. They might involve the following decision-making stages:

- State the problem to be resolved.
- Identify the decisions that need to be made.
- Identify the inputs to the decision.
- Narrow the boundaries of the study.
- Develop a decision rule.
- Develop uncertainty constraints.
- Optimise design for obtaining data.

² Note also, the RM Act S.107(g) refers to “Any significant adverse effects” on aquatic life.

One advantage of the DQO approach is clear communication at **the beginning of the study** between the teams involved with study management, sampling, analysis and data interpretation. The development of DQOs may involve completion of a mental checklist for a relatively simple site, or preparation of a separate scoping document for a large and complex investigation. They can be equated with good project management and become part of the record of due diligence.

Once programme goals and DQOs have been appropriately defined, a matching programme must be designed to meet them. QA and QC measures will be used to monitor the programme and to ensure that all data generated are suitable for their intended use.

An approach that has been found useful in developing a manageable structure for appropriate QA/QC measures is the preparation of separate QA programme and QA project plans which are described in Sections 2.2.5 and 2.2.6 respectively. Where possible reference has been made to later sections in this document which illustrate aspects related to specific points in the QA project plan.

2.2.4 Data Quality Indicators – The Link Between Data Quality Objectives and Quality Assurance Practice (Smith et al., 1988)

A data quality indicator is a property that can be used to assess data acquired in a sampling programme. Often conditions associated with certain data quality indicators are specified as data quality objectives. Accordingly data quality indicators form a means of assessing whether data quality objectives have been met. Quantifying or describing data quality indicators in effect dictates many of the quality assurance procedures that will be adopted during the sample design, collection and analysis programme. Data quality indicators therefore provide the conceptual bridge between specifying the data quality required and measuring it through quality assurance practices (such as the acquisition of blank samples, field replicate samples etc.).

The USEPA lists five data quality indicators that it considers important in contaminated site assessment: precision, bias, representativeness, completeness and comparability.

Precision: can be described as a “measure of mutual agreement among individual measurements of the same property”. More simply here it can be thought of as a measure of how greatly an analytical result varies on repeated analysis of a sample. It is best expressed in terms of a standard deviation or variance. In contaminated site sampling components associated with sampling design, sample collection and analysis will contribute to the overall estimate of precision. It is not possible to estimate the contribution from sampling design. Combined sampling and analytical precision can be estimated by collection and analysis of duplicate (i.e. co-located) samples. Analytical precision alone can be measured by repeated analysis of laboratory replicated samples.

Bias: can be defined as “the degree of agreement of a measurement (or an average of measurements) with an accepted reference or true value”. If “X” is the measurement value and “T” the true value then bias is often expressed as the difference between the two values (X-T), or a difference as a percentage of the reference or true value ($100 [X-T]/T$), or as a ratio (X/T).

For contaminated site evaluation, as with variance, the bias parameter may contain components from sample design, collection and analysis phases. Again the contribution from sampling design cannot be estimated. However, combined sampling and analytical steps bias can be estimated by using collected samples spiked in the field. In this process the field sample is sub-divided in the field, at least one fraction is spiked with a known quantity of the target analyte and each fraction is analysed. The percent recovery of the spike is calculated. By combining several such results an average percent recovery or bias is obtained (i.e. average percent recovery – 100%).

Representativeness: expresses the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point or an environmental condition.

For estimating an average concentration over some region, representativeness of a sample is assured by random sampling from the target population. Maximum concentration estimates over the same region require scientific judgement to choose sampling locations at or near the maximum. A strategy to achieve this for timber treatment sites is discussed in Section 2.3.3.

Completeness: is a measure of the amount of valid data obtained from a measurement system, compared to the amount that was expected to be obtained under correct normal conditions.

Use of the completeness parameter acknowledges that data may be lost by a number of different routes including specific sampling sites being inaccessible at the time of sample collection, breakage or spilling of sample during handling or shipping and sample holding time being exceeded before analysis.

Circumstances, such as where statistical parameter tests are used to assess data, may dictate a certain level of completeness requiring that contingency plans for resampling or reassessment of the sampling site be in place.

Comparability: expresses the confidence with which one data set can be compared to another.

Comparability between different monitoring exercises can be assessed by considering such variables as philosophy of sample site selection, how experimental results are reported (corrected to the same standard conditions e.g. dry weight, standard temperature and pressure etc.) and similarity of data quality measurement steps.

2.2.5 The QA Programme Plan

The QA programme plan is a document that commits the study overseers to a specific QA policy and sets forth the requirements for data needed to support programme objectives. The QA programme plan describes the overall policies, organisations, objectives and functional responsibilities for achieving data quality goals.

The five major parts of a QA programme plan are as follows:

- A statement of the purpose and importance of a QA plan.
- A description of the procedures that will be used to carry out the programme.
- A description of the resources committed to perform the QA work.
- An identification of the individual projects or packages of work in a study that require QA project plans.
- A description of how QA implementation will be evaluated.

2.2.6 The QA Project Plan

The QA project plan is a technical document that provides unified information on the project for all parties and provides details of specific QA and QC requirements. The QA project plan also specifies any QA/QC activities required to achieve the data quality goals of a project and describes how all data is to be assessed.

The QA project plan is readily divided into sections addressing different aspects of the assessment (e.g. sampling, analytical programme etc). Alternatively a number of generic stand-alone documents may be prepared, each addressing an aspect of the work, with a simple site specific work plan to be developed as part of each project.

A list of essential QA/QC activities and the area under which they would apply are presented in Appendix A.

2.2.7 Practical Implementation of the QA/QC Framework

Assessment phases at which QA/QC elements should be reviewed:

- on identifying the need for site assessment;
- on seeking proposals from consultants;
- on engaging a qualified consultant;
- on report back by the consultant;
- on deciding further action.

In the above context the timing and responsibility for each of the QA/QC tasks may be as follows:

- *Defining the goal or purpose of the study and how it will be achieved*
This activity should be carried out by the site owner operator before engaging the consultant to undertake the investigation. It is one of the principal items in the brief provided to consultants. Whilst definition of the study goal should be undertaken by the owner/operator, inputs should be sought from regulatory authorities and consultants on the legislative or regulatory requirements.
- *Data quality objectives*
The consultant needs to define the DQOs as an integral part of the quote for the study (refer to examples presented in Appendix B). The DQOs effectively define the scope of work which is necessary to cost such a study (e.g. how many samples to take, what analytical methods to use etc.).
- *QA programme plan*
The QA programme plan is effectively a statement of the overall commitment to QA for the study and the outline of how this will be implemented. It would often be included by the consultant in their proposal or documentation accompanying the quotation.
- *QA project plan*
Much of the information included in the QA project plan would normally be addressed as part of the following generic documentation:
 - internal company (consultant) quality assurance procedures, such as those complying with ISO 9000 (e.g. project organisation and responsibilities, project planning, management reporting of corrective action)
 - generic field sampling manuals or procedures developed by consultants as the documented procedures employed in site assessment field investigations. For an example of such procedures refer to Appendix C.
 - documented laboratory procedures (specific to each laboratory, and in accordance with relevant registration e.g. sample custody and storage, instrumentation).

In practice, it is also expedient to prepare a work plan that is site-specific. If an item that is normally addressed as part of the generic documentation needs to be altered (e.g. number of duplicate samples to be analysed by an independent laboratory) then this should be explicitly noted in the work plan. Other items that would normally be addressed as part of the work plan include: the chemicals of concern; QA objectives for experimental data (e.g. precision); experimental design and analytical procedures; use of statistical techniques for data evaluation; sampling network design and definition of sampling locations; and analytical detection limits.

2.3 TARGETED SAMPLING STRATEGY FOR THE ASSESSMENT OF TIMBER TREATMENT SITES

2.3.1 Introduction

If a significant assessment of contamination has not previously been undertaken, it is normal to approach a site assessment project in several stages:

1. identifying whether there is a problem;
2. fully defining the extent of the problem;
3. managing or cleaning up the problem.

This section provides guidance on Stage 1 of the assessment of soil and water contamination associated with timber treatment sites.

Given that judgemental or targeted sampling strategies are likely to take precedence over strict random or grid sampling strategies, at least for the first stage, this approach to assessment is discussed in greater detail.

The initial assessment of a timber processing site will usually consist of a two-phase approach:

Phase 1

A background study will first be carried out to identify the history of activities which could have resulted in contamination. The initial work generally consists of a site visit and a review of site history records and prior uses including, if possible, interviews with the present and previous site occupiers and employees.

Phase 2

A programme of field work will then be planned and carried out. This may include the collection of soil, groundwater and surface water samples, and their analysis. The extent of the investigation will be dependent on the type of site being evaluated, the exposure pathways and exposed population or environment; it will be based on the results of the background study and enable subsequent site characterisation.

The following sections of this report provide more detail on these two phases of work.

2.3.2 Objectives

The key goal/aim of a site contamination assessment programme is to identify:

- the general extent of soil, sediment, building dust, groundwater and surface water contamination and the potential adverse impact of such contamination on the health of workers on-site, the health and safety of the public, and the quality of the surrounding environment;

- sufficient information should be obtained to make an estimate of risk posed by contamination, to human health and the environment; and
- to determine whether remediation or mitigation measures are required in the context of current or likely future use of the site.

Information to assess specific contaminant migration pathways and environmental impacts (e.g. transport of contaminants in wind-blown dust) may also be required by the regulatory authorities.

As discussed in Section 2.2, the specific objectives of each site contamination assessment programme should be clearly and carefully defined at the start of each assessment.

The sampling and analysis strategy discussed in the following section provides guidance on how and where to sample, and what analyses should be undertaken. The strategy is designed to assist in the development of a detailed work plan for a particular site.

2.3.3 Basis for a Targeted Sampling Strategy

There are a range of sampling strategies that may be used as the basis for assessing a site. These strategies may be broadly classified as targeted (or judgemental), random or grid. Each of the strategies has advantages and disadvantages, and in practice usually a combination of these approaches is found to be most appropriate (e.g. sampling may be targeted toward the areas of primary concern, however, within each of these areas a small sampling grid may be established).

The overall aim of the first stage in the assessment process is to determine whether there is a problem (refer 2.3.2) as cost-effectively as possible. Data quality objectives would probably indicate that the most expedient approach (i.e. the least number of samples/locations) is to target the locations of those areas most likely to be contaminated. However, a targeted sampling strategy is only as good as the review of the site history on which it is based. If an area of potential contamination is not identified as part of the site history review, then it will not be addressed as part of a targeted sampling programme. Therefore, a targeted sampling programme should not be used where there is little or no site history to support the selection of sampling locations. In practice, taking into account possible uncertainties in site history information, a common approach is to take several samples at close grid spacings and within areas likely to be contaminated, and several samples at wider grid spacings across broader areas of the site where contamination is less likely.

It is difficult to statistically define the probability of recovering a contaminated sample from an area of significant contamination using a targeted sampling approach, but the number of samples required to achieve a similar notional level of confidence (or probability of detection) using a grid or random sampling approach is likely to be much greater- provided reasonable site history information is available. On this basis a targeted sampling approach is often more cost-effective than a grid or random strategy.

Noting the above constraints, a targeted sampling programme is suggested as the most appropriate approach for the first stage of the site assessment process.

2.4 BACKGROUND INFORMATION GATHERING – PHASE 1

2.4.1 General

All pertinent background information should be reviewed in order to identify the potential for on-site and off-site contamination. This phase of the work should be completed prior to commencing Phase 2.

The background information study should include:

- (a) The chronological history of previous site uses and industries; the activities or processes carried out on the site with respect to the timber industry, particularly the location and historical usage of timber treatment chemicals and associated operations such as chemical mixing.

Interviews with site personnel, past workers at the site and local residents can be an invaluable source of such information. Other sources of site history information include:

- past and present owners of the site;
 - aerial and ground photographs;
 - local government records (e.g. history of complaints, discharge or building permits);
 - trade and street directories;
 - local literature (e.g. newspapers).
- (b) Identification of equipment and areas where the likelihood of contamination resulting from historical or current work practices is high (e.g. accidental spillage of chemicals at mixing and treating facilities and at treated wood storage and conveying areas).
 - (c) Source information (e.g. current and past site management; engineers; workers) in order to establish raw material use, products, known chemical or treatment waste release history (spills, leaks, etc.) and waste disposal practices (i.e. on-site, off-site).
 - (d) Local hydrogeologic data including:
 - the extent, interconnection and use of aquifers in the area;
 - probable direction and rate of groundwater flow in each aquifer;
 - information on the site geology and soils at the site; and

- local municipal drinking water supply sources, and the location of private or industrial wells or bores, especially those supplying drinking water.
- (e) Surface water bodies (creeks, rivers, estuaries, wetlands) particularly where these may be adversely affected by contaminated groundwater or surface drainage from the site. Surface water bodies should be evaluated to determine environmental values, beneficial uses, sensitivity to change and physical, chemical and biological characteristics.
- (f) Any published or known information which establishes whether adjacent property owners are or have been potential sources of contamination (of the site soil and groundwater).
- (g) Location, age and construction material of above and underground chemical or fuel storage tanks on the site. If integrity testing of storage tanks has been undertaken, the results of such tests should be reviewed.
- (h) Locations and construction details of underground services including the site stormwater system (they may have a potential impact on future remediation activities or can act as preferential drainage pathways).
- (i) Present and likely future zoning of the site.
- (j) Contour or topographic maps – location of filling/earthmoving.
- (k) Likely future use of the site.
- (l) Potential cultural issues, e.g. iwi, archaeological, etc.

2.4.2 Potential Contaminant Sources

As part of the background information study, specific consideration should be given to the following areas or potential sources of contamination:

Anti-sapstain treatment – Na-PCP, and other antisapstain chemicals (e.g. carbendazim)

- bulk storage tanks for Na-PCP;
- anti-sapstain preparation areas – mix rooms;
- dip baths;
- green chain;
- timber drying and storage areas (dripping from timber);
- transportation routes for freshly treated timber;

- sludge and residue storage and disposal sites; and
- dry chemical storage areas.

Possible contaminants include PCP, chlorinated phenols other than PCP, dioxins and furans, and others depending upon site specific review of anti-sapstain preparations used.

Boron diffusion

- bulk storage tanks;
- dip baths;
- drip pads;
- timber storage areas (dripping from timber);
- transportation routes for freshly treated timber;
- sludge and residue storage and disposal areas; and
- dry chemical storage areas.

There is a need to consider what additives were used in the boron diffusion preparations. Possible contaminants include: boron, PCP, chlorinated phenols other than PCP, dioxins and furans, and organochlorine pesticides.

CCA treatment

- bulk storage tanks;
- chemical preparation areas;
- pressure treatment vessels;
- drip pads and drip areas (i.e. where timber was put immediately after removal from the vessels);
- timber storage areas;
- sludge and residue storage and disposal;
- treated timber residues and ash; and,
- transportation routes for freshly treated timber.

There is a need to consider additives or contaminants that may be in CCA preparations and sludges (e.g. PCP). Possible contaminants include: copper, chromium (hexavalent and trivalent) and arsenic.

(Note: additives and contaminants in CCA preparations are only likely to be present in soils at low levels).

PCP in oil pressure treatment

- bulk PCP storage tanks;
- bulk oil (diesel storage tanks);
- PCP in oil preparation areas;
- pressure treatment vessels;
- drip pads or areas (i.e. where timber was placed immediately after removal from the treatment vessel);
- transportation routes for freshly treated timber;
- treated timber storage areas; and
- sludge and residue storage and disposal.

Possible contaminants include PCP, chlorinated phenols other than PCP, dioxins and furans and petroleum hydrocarbons.

Creosote treatment

- bulk storage tanks;
- chemical preparation areas;
- treatment areas;
- drip pads and areas;
- freshly treated timber transportation route;
- treated timber storage areas; and
- sludge and residue storage and disposal.

Possible contaminants include petroleum hydrocarbons, polycyclic aromatic hydrocarbons, phenols and cresols.

Miscellaneous

Possible contamination sources include:

- bulk chemical storage tanks, preparation areas, treatment areas and treated timber storage associated with:
 - organochlorine pesticide treatment (e.g. chlordane and lindane)
 - LOSP process (possible contaminants: tributyl tin, petroleum hydrocarbons/monocyclic aromatic hydrocarbons, naphthenates and chlordane)

Note the LOSP is a relatively recent technology and contamination potential is reduced;

- underground and aboveground fuel storage tanks (possible contaminants: petroleum hydrocarbons, monocyclic aromatic hydrocarbons, polycyclic aromatic hydrocarbons);
- workshop and maintenance areas (possible contaminants: petroleum hydrocarbons, solvents, others);
- landfilled or stockpiled sawdust or wood chip;
- other waste pits on site;
- contaminated building and construction materials.

The potential for contamination associated with each of the above items should be evaluated as part of the investigation design. The sampling programme should be tailored to reflect the actual conditions, focussing on obtaining information about the areas of greatest risk, giving consideration to the available site history.

Note that in some cases consideration must be given to other sources or modes of transport of contaminants resulting in human or environmental exposure e.g. contamination of rain water supplies by contaminated dust fallout, transport of contamination in stormwater and stormwater sediments.

2.5 FIELD INVESTIGATION PROGRAMME – PHASE 2

The overall aim of the field investigation programme is to evaluate site contamination and provide sufficient information to assess possible site remediation, if found to be necessary.

The field investigation programme should be developed on a site-specific basis after the completion of the background study, and could include the following as appropriate:

- soil sampling, targeted to areas of likely contamination and some background locations;
- surface water and sediment sampling at locations to be determined following determination of site runoff patterns;
- groundwater sampling; and
- surface dust sampling from selected structures on-site.

Sampling of stored sludges, stockpiles or waste pits may also be required.

A site work plan should be prepared which sets out the requirements and objectives for the various field sampling activities and protocols for collection of samples. All field sampling and associated data collection must be supervised by a person experienced in the collection of environmental samples, and carried out in accordance with approved sampling procedures (Quality Assurance Plan (QAP), Chapter 3), and an approved site Health and Safety Plan (HASP).

Typical programmes for sampling soil, groundwater, surface water, sediments, and surface dust, and the associated analytical programmes, are outlined in the following sections.

2.6 SOIL SAMPLING

2.6.1 Objective

An assessment programme for the characterisation of soil contamination should:

- determine whether potential sensitive human receptors on and off-site (e.g. full and part time workers, maintenance workers, residents and recreational users) are possibly at risk from contact with contaminated soil;
- determine whether there are unsecured areas of contaminated soil which could be transported off-site as contaminated sediment in runoff or dust;
- determine whether the contamination is mobile within the soil environment, and with potential to leach to groundwater (off-site transport);
- determine the potential for other off-site impacts.

It may be appropriate to carry out the site investigation in stages so that information gained early is used to focus later investigations. Typically, up to three stages may be warranted:

1. Initial – a minimal level of sampling to indicate if there is likely to be any problem.
2. Indicative – an attempt to estimate the extent of contamination, vertically and laterally, based on contamination patterns identified in the initial investigations and the importance of exposure pathways identified during the initial investigation.
3. Quantitative – to determine volumes of soil and scope of remediation.

2.6.2 Field Sampling

Based on a review of site history, a targeted soil sampling programme can be implemented in areas considered likely to have been contaminated by past site activities. In addition, limited soil sampling may also be completed across areas considered more representative of the general site conditions. Typically, sampling across general site areas would be undertaken on a coarse grid basis³, the aim of which would be to identify broad areas of contamination rather than to identify relatively localised hot spots with a high level of statistical confidence.

³ Refer Gilbert (1987) for information on the design of grid and/or random sampling programmes.

For example, in order to identify a hot spot 12 metres in diameter with 95% confidence, a sampling density of 100 samples per hectare (or a 10 m grid) would be required (Standards Australia, 1994). Such a hot spot would clearly be significant for some site uses, however, identification using a grid sampling strategy would be prohibitively expensive. It is therefore necessary to use other techniques (e.g. site history, geophysics) to identify localised areas for targeted sampling, together with broad grid sampling to identify widespread contamination.

The site would be divided into investigation areas on the basis of site history and the nature of potential contamination. The sampling programme undertaken in each investigation area should be based on information gathered in the first assessment phase and should be a targeted approach (i.e. maximising the likelihood of identifying whether contamination is present, and to indicate likely contaminant distribution while minimising initial costs).

The initial programme must be designed on a site-specific basis, however, for a small site it typically may involve:

- between, say, four and eight sample locations from each investigation area (e.g. samples from four locations and, at least, two different depths around a Na-PCP mix room etc.), and from between, say, eight and sixteen locations across the general site⁴;
- typically two depths (say 0-100 and 300-500 mm) at each location with surface only testing in areas where penetration at depth is less likely or where there is no requirement for information regarding the depth of penetration.

Additional soil sampling to depths in the order of four metres or greater may be required in the vicinity of any underground storage tanks and pipework (where the initial sampling indicates that contamination has migrated downward) or in areas of historic waste disposal or filling.

The above is given as an indication of possible sampling requirements. The actual sampling programme for each site should be developed based on a consideration of the available information on the possible location and extent of contamination.

The initial location and number of sampling points will be based on known site use patterns. Detailed procedures for sampling of soils by hand auger, mechanical auger or backhoe are discussed in Chapter 3.

There are a number of possible scenarios that would lead to variation of the typical sampling programme, including:

⁴ Must be determined on a site-specific basis. Refer to Gilbert (1987) for advice regarding the statistical design of sampling programmes.

- specific consideration should be given to soil sampling at the groundwater interface where groundwater is relatively shallow. In particular, free phase hydrocarbons may accumulate at the groundwater interface.
- where little or no site history information is available, selected sampling locations may not reliably detect contamination and therefore it may be necessary to undertake a more detailed grid sampling programme across the site.

Compositing⁵ of soil samples prior to analysis is a useful tool. It increases the area addressed by the sampling programme without greatly increasing analytical costs. However, there are limitations to the use of this approach. Compositing of soil samples assumes that a valid estimate of the population mean of the characteristic under consideration can be obtained from this single analysis of the composite sample: i.e. all samples which form the composite are drawn from the same population; each sample contributes equally to the composite.

In general, in areas where contamination is expected, samples may be composited provided there is some basis for expecting similar contaminant concentrations in each sample (e.g. at the end of a dip tank), or where average contaminant concentration is specifically sought (e.g. estimating the average exposure of site users). In areas where contamination is not expected, compositing may be undertaken to reduce analytical costs.

Compositing should be limited to, say, four sub-samples to ensure exceedance of the guidelines by any sub-sample can be reasonably detected if required.

It is recommended that composite samples be prepared in the analytical laboratory from discrete, documented site samples which have undergone appropriate sample preparation stages (refer Section 4.5.3). Accordingly if significant contaminant concentrations are detected in the composite, it is possible to reanalyse the individual sub-samples to assist in identifying the source of contamination.

In the design of the sampling programme, it should be remembered that clean-up guidelines are generally based on estimates of long term average exposures; further sampling and analysis may be required to estimate such exposures. **Analysis of single samples may be advisable when characterising the extent of contamination.**

Further information regarding the sampling of contaminated soils may be obtained from published standard guidance (e.g. USEPA, ASTM) such as USEPA (1991) "Description and Sampling of Contaminated Soils: A Field Pocket Guide".

2.6.3 Analytical Programme

Sub-samples may be composited by the primary laboratory for analysis for each investigation area as defined in the sampling plan (part of the QA Project Plan). Any variations in the sampling plan must be discussed in the report.

⁵ Where a sample is made up from a number of sub-samples taken at different locations.

Primary and quality control analyses should be undertaken by laboratories that conform with the requirements for TELARC or equivalent (e.g. NATA) registration for the specific methods/compounds in question.

Samples should be analysed for those contaminants likely to occur in the area from which the sample was recovered, based on the results of the background information study.

Possible analytes include:

- copper
- chromium (hexavalent and trivalent)
- arsenic
- boron
- pentachlorophenol and other chlorophenols
- dioxins and furans (OCDD screen or full congener analysis)
- tributyl tin
- polycyclic aromatic hydrocarbons
- monocyclic aromatic hydrocarbons
- phenols and cresols
- organochlorine pesticides
- petroleum hydrocarbons
- other antisapstains
- others depending on chemicals used at a given site.

In practice, analyses should be directed to contaminants most likely to be present and of concern. It may be appropriate to omit other possible contaminants on the basis of a knowledge of the treatment chemicals used on the site, or to carry out preliminary screening on composite samples to exclude the need to carry out more extensive analyses.

Dioxin and furan contamination could be associated with areas subject to PCP contamination which has been ongoing over an extended period of time. In many cases, lower-cost screening methods of analysis may be sufficient for dioxin and furan characterisation, although an initial test to establish the full congener profile and the relevance of the screening method should be carried out. An example of such a dioxin screening method is the OCDD screen discussed in Chapter 4.

Where a site may be redeveloped for residential or agricultural use it is important that judicious use is made of the OCDD screen, given that dioxin concentrations may be limiting on some sites. Selected samples should be analysed for dioxins and furans, based on a review of the results of the PCP analyses. However, caution should be

exercised in this regard, given that elevated concentrations of dioxins have been reported in areas with relatively low PCP concentrations.

While PCP will be generally the contaminant which controls the overall health and environmental risk associated with contamination from PCP-based formulations, it is desirable to carry out an initial check of the range of chlorinated phenols present to ensure that PCP is the controlling chlorinated phenol.

Suggested maximum detection limits for various analytes are presented in Chapter 4. Analytical methods and practices appropriate for the assessment of soil and water contamination at timber processing sites are discussed in Chapter 4. For other parameters reference should be made to published methods (e.g. USEPA, ASTM and APHA).

2.7 GROUNDWATER SAMPLING

2.7.1 Objective

A preliminary groundwater investigation programme should be completed as part of the second phase investigation if groundwater is at a depth that may be affected by site contamination. Typically, if groundwater is at a depth of less than 10 to 15 m a groundwater monitoring programme should be considered, depending on site-specific factors including the nature of the overlying soils. The design of the groundwater investigations should be directed towards:

- determining the depth to groundwater, thickness of the near-surface aquifer, direction and rate of movement and probable discharge location of any contaminants to surface water (e.g. surface drains, streams, etc.); and
- determining whether contaminants are present in the groundwater and, if so, at what concentrations and in what form (both chemical and residues from timber wastes, such as leachate).

The groundwater monitoring programme will be designed to assess the impact of ground contamination and leachate (e.g. from filled areas or waste disposal sites) on the local groundwater quality, and the contribution of groundwater discharge on contaminant concentrations in surface water bodies.

Particular consideration should be given to the specific hydrogeological conditions at the site when designing the groundwater investigation programme. The possibility of contaminant migration along preferential flow paths and the need to use techniques other than conventional groundwater monitoring bores, as discussed below, should be considered on a site-specific basis.

2.7.2 Field Sampling

A limited groundwater investigation programme should be implemented where groundwater is at a depth that may be impacted by site contamination. Following a review of the available site history and a further review of the regional hydrogeology, the number and location of the groundwater monitoring bores should be determined. Typically, one bore should be installed upgradient of all known areas of major fill and significant contamination potential, and two to four bores may be located downgradient of areas of significant filling or contamination potential. This has the objective of measuring groundwater quality, direction and rate of movement on-site, and providing some indication of the contribution of groundwater discharge on surface water quality. The exact number and location of groundwater monitoring bores should be determined on a site-specific basis.

The groundwater monitoring bores should be installed under qualified supervision⁶ by suitably qualified drilling contractors in accordance with the installation, design and procedures defined in the field sampling plan and the documented quality assurance procedures (refer Chapter 3). Consideration should be given to the recovery of soil cores during monitoring bore installation, to allow for later laboratory analysis. The specific location and reasons for recovery of such samples should be defined in the site specific sampling plan.

Note that in some areas there may be a need to obtain a bore permit prior to drilling, with information on the bore position and stratigraphy (borelog) to be forwarded to the relevant authority, particularly if the aquifer is used as a drinking water supply.

For details regarding requirements for preservation and filtration of groundwater samples, refer to Appendix E.

Installation, development and purging of the monitoring bores and groundwater samples should be performed in accordance with the procedures outlined in Chapter 3. All monitoring bores should be located with reference to permanent site features and the standpipe levelled or surveyed, allowing re-establishment of the bore locations should it be destroyed. The depth to groundwater should be measured relative to top of the standpipe casing, prior to purging and sampling. Note that the top of the standpipe casing should be surveyed to determine its elevation, referenced to a common datum e.g. mean sea level.

During preliminary groundwater investigations, selected bores should be subject to drawdown/recovery or similar tests to assist in the estimation of aquifer characteristics. This is also a check on the quality of installation. If test results do not represent what would be expected in the aquifer, the installation may have to be redeveloped or replaced.

⁶ Under the supervision of an experienced engineer/geologist/scientist.

2.7.3 Analytical Programme

Selected groundwater samples should be analysed for pH and total dissolved solids. Additional unfiltered samples may need to be recovered to facilitate the analysis of groundwater samples for these parameters.

In addition, samples may be analysed for some or all of the parameters measured in soils (Section 2.6.3) based on the results of the background information study. The required analytical detection limits are outlined in Chapter 4.

It may be desirable to undertake an anion/cation balance on some samples as a check on the sampling and analysis procedures, and to assist in characterising the groundwater system (e.g. differentiation between water types, recharge, flow paths, etc).

It is noted that whilst groundwater samples may be filtered prior to analysis, in the case of dioxins, limited additional analysis of unfiltered samples from well-developed bores (i.e. representative of the aquifer in terms of turbidity) may be warranted to assess the contribution by transparent or fine suspended particulates within the aquifer.

2.8 SURFACE WATER AND SEDIMENT SAMPLING

2.8.1 Objective

As part of the overall review of site discharges, a preliminary surface water and sediment sampling programme should be implemented if there is a surface water body in the vicinity of the site and there is potential for contamination of this water body to occur. The programme should provide an estimate of contaminants (i.e. load and concentration) leaving the site via drains, surface water runoff and groundwater discharge to surface water bodies. It may include recovery of water samples and sediment samples from both site drains and nearby surface water bodies. Sediment sampling is a useful source of qualitative information regarding off-site transport of contaminants as some substances will partition preferentially into the sediments. The recovery of sediment samples will also assist in the assessment of contaminant transport as suspended particles. Some of the primary contaminants of concern exhibit very low solubility in water and will attach preferentially to suspended particles.

2.8.2 Field Sampling

The surface water sampling locations should be determined following a detailed review of surface water flow patterns on-site and likely groundwater flow direction and discharge. Surface water samples should be recovered from at least one location upstream and one downstream of the site, and from one or more locations adjacent to the site. In addition, at least one sample should be recovered from any potentially

contaminated drain discharging from the site. Additional samples may be required on a site-specific basis.

At least two separate rounds of surface water sampling may be completed in order to provide estimates of water quality under wet and dry weather conditions. The sampling regime should be targeted towards characterising the first flush of runoff during a wet weather event, and surface water contamination resulting from groundwater inputs during dry weather.

All surface water samples collected at each sample location, for each weather condition, would normally be composited to form one sample for analysis (i.e. one sample per location, per weather conditions for analysis). In some situations it may be appropriate to analyse several 'grab' samples to facilitate evaluation of variation in contaminant concentrations with time (e.g. first flush of runoff after a dry period).

One representative sediment sample should be collected from each sample location. This may require the collection of several sub-samples from one location, followed by compositing. Additional samples may be recovered depending on requirements to analyse samples for other constituents. Sediment should be recovered during relatively dry weather flow conditions, in order to assess the conditions to which aquatic species would normally be exposed. Any sediment laid down during wet water flows would also remain in place for sampling during dry weather. Usually, wet weather flows would result in scouring or removal of sediment, rather than deposition.

2.8.3 Analytical Programme

The analysis of surface water samples includes the same parameters as specified for groundwater with the addition of total suspended solids (TSS). Sediment samples may be analysed for a range of parameters as listed for the analysis of soil samples.

2.9 DUST SAMPLING

2.9.1 Objective

A preliminary programme of sampling dusts deposited on site structures should be undertaken where there is potential for contaminated dust accumulations to occur. The usual objective of this programme is to assess potential risks to human receptors. Where residences are located on-site or immediately adjacent to the site, consideration should be given to the potential for contamination of dust within the residence.

2.9.2 Field Sampling

Dust samples should be collected from selected structure surfaces and from residences on-site or immediately adjacent to the site. Two types of dust samples may be recovered, as follows:

- dust samples recovered from the living spaces of residences at, or adjacent to, the site and from the main work areas on-site.
- dust samples recovered from undisturbed areas, such as ledges and the roof space of residences.

Samples recovered from living spaces and the main work areas on-site are most useful in the assessment of risk to current workers or residents. Exposure to dusts within living spaces of residences and main work areas may occur through inhalation or ingestion of dust, or by the absorption of contaminants through the skin. In the first instance, the soil acceptance criteria derived for these exposure routes may be used to provide an assessment of the risk to residents and workers (refer Chapter 5). Whilst sampling of dust from the main work areas on site may provide some information regarding the risk to workers at the site, conventional occupational exposure monitoring provides a more direct measure of occupational risk. Advice on this should be sought from the Occupational Safety and Health Service of the Department of Labour.

Samples recovered from undisturbed areas provide some qualitative information regarding the possible risk to workers or residents in the event of disturbance of the dust e.g. demolition of buildings. The quantity of accumulated dust can also provide useful information regarding the possible magnitude of the risk.

Sample locations should be confirmed on a site-specific basis; however, initially it is anticipated dust samples should be recovered from, say, at least two locations within on-site timber processing buildings. Additional samples may be required where there are residences on-site or immediately adjacent to the site.

2.9.3 Analytical Programme

The analytical programme for dust samples should be confirmed following the results of the background information study. The programme may include chlorinated phenols, copper, chromium, arsenic, boron, dioxins and furans and other parameters as listed in Section 2.6.3. In addition, structural surface dust samples should be analysed to determine the particle size distribution, allowing the potential for inhalation of particulates to be assessed.

Compositing of dust samples may be considered where several samples are collected from a single work or use area and the aim of the investigations is to characterise the average contaminant concentrations to which workers or other site users may be exposed.

2.10 CONTAMINATION ASSESSMENT AND REPORTING

A contaminated land assessment report for a site should include (but not be limited) to the following:

- (a) a statement of the objectives, scope and limitations of the assessment and report;
- (b) a detailed description of the land, including ownership and occupier details etc;
- (c) a detailed history of the uses of the site. This should include a list which specifies the identities and locations on a premises of any known or suspected chemicals or any other substances which could be a hazard whether imminent or otherwise. Sources of information (documented and anecdotal) and validation of information should also be included;
- (d) likely current and future use of the land;
- (e) recording of any visual inspections of the site;
- (f) details of the geology and hydrology of the area, including physical characteristics of the soil (for example: type, porosity and sorptivity, transmissivity, areas of fill, variation of such characteristics with depth) and groundwater (depth, rate of flow), regional groundwater quality, use of the groundwater in the area. Copies of all bore logs, soil profiles and other records of field observations and measurements should be provided;
- (g) details of the condition and location on the site of buildings, sewer/drainage systems, natural water courses, underground storage tanks, waste disposal areas and other activities;
- (h) a detailed site plan including scale, north point and all relevant site features and sampling locations;
- (i) the sampling and analysis programme used to determine the extent and distribution of contamination, including:
 - basis for selection of chemicals included in the analytical programme;
 - rationale for sample locations and depths in each medium of concern (air, soil, groundwater, surface water);
 - sampling methods;
 - detection limits (levels chosen and how derived);
 - quality assurance (procedures);
 - quality control details; and
 - laboratory and analytical methods used.

(This programme will consist usually of two stages, an initial evaluation to confirm the presence of contamination and then a more comprehensive evaluation to determine the nature and extent of contamination.)
- (j) results of the sampling and analysis programme on which is based a conceptual model of how contaminants are moving on the site and their fate and transport characteristics in each media of concern.

- (k) information about any contaminants of concern, selected on the basis of the results of the sampling programme. This information should include an evaluation of:
- the fate and transport of each chemical;
 - the form or species present;
 - physical characteristics;
 - potential harm to humans, plants, animals and structures;
 - aesthetic impairment;
 - any detriment to any beneficial uses to be made of the site;
 - potential for adverse off-site effects; and
 - potential exposure pathways.
- (l) the results of the field investigations should be discussed with reference to the guideline values nominated for various site uses in Chapter 5 of these guidelines. Particular attention should be given to site-specific factors which may require modification of the nominated values.
- (m) recommendations including further activities required at the site to mitigate contamination, if necessary.

A typical table of contents for such a site assessment report is presented in Appendix F, for this chapter.

Particular care should be exercised when presenting and discussing the results of any sampling and analytical programmes. Wherever possible analytical data and field measurements should be presented in a tabular format or in graphs or site plans. Such presentation allows ready access to the available information and permits the reader to more easily visualise and comprehend the nature and extent of any contamination identified. Graphical presentation is particularly useful when examining variation in various analytes with time.

When assessing soil contamination it should be noted that the proposed soil acceptance criteria (refer Chapter 5) have been developed in the context of specific scenarios for each of the nominated land uses. In practice, the impact of soil contamination is influenced by a wide range of factors, some of which may not been considered in the development of the acceptance criteria. For example, where guidelines have been based on health risk considerations, the potential for contamination of groundwater or surface rainfall runoff should be considered on a site-specific basis, as this may determine the acceptable soil contamination concentration.

Site-specific factors which can affect the acceptability of contamination include:

- the extent and distribution of ground contamination;
- the extent of pavement or other ground cover limiting exposure of workers, residents etc. to ground contamination;

- off-site impact of contamination;
- site management and works practices;
- mixed waste sites for cases when contamination other than timber treatment chemicals is present.

The soil acceptance criteria (refer Chapter 5) have been based on the assumption of a largely unpaved, uniformly contaminated site. Where such an assumption is not valid, a site-specific review of the potential impact of ground contamination is required. In practice, limited areas of relatively higher-level contamination, together with more widespread areas of low-level contamination, is likely to be a typical pattern of contamination resulting from historical timber treatment activities.

Where chronic human exposure to soil contamination is the primary concern, it is appropriate to compare average contaminant concentrations (rather than the maximum concentration detected) with the acceptance criteria. In this regard, the area across which contaminant concentrations are averaged should be selected as being the typical area in which a person may spend most of his/her time exposed to soil contamination. In the case of a residential land use, the averaging area may be selected as the area of a typical backyard. The averaging area must be selected carefully, with reference to likely exposure patterns, to ensure that the significance of a localised hot spot is not obscured; e.g. it is unlikely that it would be appropriate to average contaminant concentrations across the entire site in an industrial context.

The health-based guidelines presented in Chapter 5 are based on estimates of the reasonable maximum exposure. The USEPA (1991b) indicates that a “conservative estimate of the media average concentration over the exposure period” should be used to estimate the reasonable maximum exposure. The average contaminant concentration used should be determined using appropriate statistical techniques, such as the 90th percentile confidence interval for the sample mean, where samples were obtained from a geometric sampling arrangement. The approach of comparing an average contaminant concentration with the acceptance criteria may not be appropriate where the given criterion is set based on, say, the protection of plant life.

Criteria set on the basis of phytotoxicity may be reduced in some situations depending on the soil type and chemistry and the tolerance of various plant species. Such variation must be evaluated on a site-specific basis.

Care must be exercised when applying statistical methods to the assessment of data from a sampling and analytical programme. Where samples are recovered from a grid or from randomly selected locations, statistical analysis of the resulting data is a relatively well-defined process. It should be noted that site data is not usually normally distributed, and may require less common but well-established methods, e.g. non-parametric methodology. Generally grid sampling is undertaken when the aim is to characterise contamination across broad acre areas without defined point sources of contamination e.g. general treated timber storage yards.

More frequently, samples are recovered from selected, targeted locations focussing on known sources of contamination, e.g. antisapstain dip tanks, especially as part of the initial sampling programmes. Whilst statistical techniques can be applied to the analysis of data from such programmes, the techniques required are complex and the results of such analysis are frequently compromised by the lack of data points or samples. For initial sampling programmes or preliminary site assessments it is considered that the application of professional judgement by suitably qualified personnel is a more cost-effective approach to the data assessment task. Simple statistical techniques are not appropriate in such circumstances and care should be exercised when comparing reduced data (e.g. sample means) from targeted sampling programmes to the proposed guideline values. Statistical design and analysis of more detailed sampling programmes is, however, a useful tool and should be applied where appropriate, drawing on professionals experienced in the application of statistics to environmental sampling programmes.

A detailed description of applicable statistical guidelines is beyond the scope of these guidelines. For information of the application of statistical techniques, reference should be made to one of the texts on this subject, for example, Gilbert R.L. (1987) "Statistical Methods for Environmental Pollution Monitoring" Van Nostrand Reinhold, New York.

Particular care is required to ensure that compositing or averaging as part of a statistical evaluation does not obscure the presence of a significant hot spot.

2.11 REFERENCES

CCME (1991) "Guidance Manual on Sampling, Analysis and Data Management for Contaminated Sites. Volume 1: Main Report". Canadian Council of Ministers of the Environment, Report CCME EPC-NCS62E, Winnipeg, December 1993.

Gilbert, R.L. (1987) "Statistical Methods for Environmental Pollution Monitoring" Van Nostrand Reinhold, New York.

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USEPA (1991) "Description and Sampling of Contaminated Soils: A Field Pocket Guide" EPA/625/12-91/002.

USEPA (1991b) "Risk Assessment Guidance for Superfund, Volume 1, HHEM, Supplemental Guidance, Standard Default Exposure Factors".

2.12 FURTHER READING

Guidance Manual on Sampling, Analysis and Data Management for Contaminated Sites. Volume 1: Main Report. Canadian Council of Ministers of the Environment, Report CCME EPC-NCS62E, Winnipeg, December 1993.

Chapter 1 – Quality Control, Revision 0 (1986) and Revision 1 (November 1990) and Chapter 9 – Sampling Plan, Revision 0 (September 1986) in Test Methods for Evaluation of Solid Wastes, United States Environmental Protection Agency Office of Solid Waste and Emergency Response, SW-846, Washington DC, November 1986.

Chapter 9 – Statistical Methods in Environmental Sampling, Chapter 10 – Soil Sampling Quality Assurance and the Importance of an Exploratory Study, Chapter 11 – Quality Assurance for a Measurement Programme in Environmental Sampling for Hazardous Wastes, edited by G E Schweitzer and J A Santolucito, American Chemical Society, Washington DC, 1984.

Guidelines for the Sampling and Analysis of Contaminated Soils, Australia and New Zealand Environment and Conservation Council, Melbourne, December 1993, draft for comment.

“Identification and Assessment of Contaminated Sites; Improving Site History Appraisal” South Australian Health Commission, 1994.

“Description and Sampling of Contaminated Soils : A Field Pocket Guide”, USEPA November, 1991. EPA/625/12-91/002.

APPENDIX A ELEMENTS OF A QUALITY ASSURANCE PLAN

Overall Project Management

- Project description
- Project organisation and designated responsibilities
- Quality assurance objectives for the experimental data in terms of precision, accuracy, completeness, ruggedness and comparability
- Experimental design and analytical procedures
- Ensuring on-going quality assurance reports to management
- Corrective actions
- Defining statistical techniques for assessing the experimental data.

Field Sampling

- Sampling network design
- Selection of specific sampling sites
- Sampling methodology – detailing procedures to be used in the field
- Sampling devices, storage containers and preservatives
- Sample custody, transportation, preservation and storage
- Replicate sampling
- Documentation needed
- Special operating conditions (e.g. heat, light, reactivity etc.)
- Providing information on health and safety practices in sampling and field testing operations
- Providing accepted procedures designed to control and define errors associated with field measurements.

Laboratory Analysis

- Sample custody
- Sample storage
- Instrument selection and use
- Analytical methodology, and standard operating procedures
- Calibration procedures and frequency

- Reference standards and quality control standards
- Internal quality control checks and frequency
- Replicate analyses
- Blank and spiked samples
- Intra- and inter-laboratory QC procedures
- Specific routine measures to be used to assess data quality
- Data reduction, validation, verification and reporting.

APPENDIX B DEVELOPMENT OF DATA QUALITY OBJECTIVES

Example of the Process of Developing Data Quality Objectives

- *State the problem to be resolved*
For example, to determine whether there is the potential for a significant adverse effect on human health or the environment associated with soil groundwater contamination at a timber treatment site.
- *Identify the Decisions that Need to be Made*
For example, does the site pose an immediate risk to human health or the environment? Is there a requirement for immediate remedial action? Is there potential for an adverse effect on human health or the environment in the longer term? Is there need for further, more detailed, investigation to define the extent of contamination, the current impact on human health and the environment and the specific requirements for any remedial action in the longer term?
- *Identify the Inputs to the Decisions*
For example, the contaminants that may be present at the site may be at concentrations that are of concern in relation to guideline levels; the concentration of contaminants in soil, groundwater, surface water, dust that may have accumulated on surfaces of structures, and in the air; the effects the contaminants may have on human health and the environment, and the concentration in each of the media at which those contaminants have the potential to have a significant impact on human health and the environment; the level of protection required for human health and the environment, i.e. is it a pristine ecosystem or an urban environment.
- *Narrow the Boundaries of the Study*
For example, to undertake a sampling programme targeted toward identifying contaminant concentrations in the areas most likely to be contaminated, in order to provide a cost-effective assessment of whether there is the potential for a significant adverse effect on human health or the environment.
- *Develop a Decision Rule*
For example, if the identified concentrations of contaminants in environmental media exceed the guideline values nominated in the Health and Environmental Guidelines for Selected Timber Treatment Chemicals, then further more detailed investigation to determine the extent of contamination is required.

- *Develop Uncertainty Constraints*
For example, that the Relative Percent Differences (RPD) shall be less than 30% for the results of QA/QC check analyses undertaken by an independent laboratory on duplicate samples; that the sampling programme will be designed such that there is a high level of confidence (notionally 95%) a significant area of potential contamination (say greater than 10 sq.m) would be sampled as part of the sampling programme, giving consideration to the quality of the site history and other background information (such confidence would be measured, in effect, by the independent review of the plan based on professional judgement of an experienced, senior professional in the site contamination area).

- *Optimise Design for Obtaining Data*
For example, review the sampling plan to ensure all areas of significant potential contamination have been targeted, and that the sampling within an area of potential contamination is such that the level of uncertainty about whether an area of significant contamination may be missed is consistent with the above uncertainty constraint.

- *Example Data Quality Objectives*
Example DQOs for a timber treatment site assessment are presented as follows:
 - That the investigation shall be sufficient to determine whether there is the potential for a significant adverse effect on human health or the environment.
 - That the data shall at least be representative of the higher contaminant concentrations that are likely to be encountered at the site, in order to determine whether a further detailed evaluation of the extent of contamination is required. (On this basis a targeted cost-effective sampling programme may be used to achieve this objective.)
 - That the level of confidence that a significant area of contamination shall be sampled shall be notionally greater than 90%.
 - If a contaminant concentration in a sample is reported as not detectable, the confidence that the actual concentration is less than one fifth the relevant acceptance criteria shall be greater than 90%.
 - That the reported concentration in a sample shall be representative (e.g. within +/- 50%) of the actual concentration in the media in-situ at the point of sampling (this can be notional only as it cannot be measured).
 - The RPD of duplicate samples analysed by independent laboratories shall be less than 30%.

APPENDIX C SAMPLING PLAN AND PROTOCOL CHECKLISTS

Table C1
Sampling Plan Checklist¹

What are your data quality objectives (DQOs)?

- What will you do if your DQOs are not met (i.e. resample or revise DQOs)?

Do programme objectives need exploratory, monitoring, or both sampling types?

Have arrangements been made to obtain samples from the sites?

- Have alternative plans been prepared in case not all sites can be sampled?

Is specialised sampling equipment needed and/or available?

Are samplers experienced in the type of sampling required available?

Have all analytes been listed?

- Has the level of detection (LOD) for each been specified?
- Have methods been specified for each analyte?
- What sample sizes are needed based on the method and desired LOD?

List specific good laboratory practice and federal, provincial or method QA/QC protocols required.

- Are there percentages or required numbers and types of QC samples?
- Are there specific instrument tuning or other special requirements?

What type of sampling approach will be used?

- Random, systematic, judgemental, or combinations of these?
- Will the type of sampling meet your DQOs?

What type of data analysis methods will be used?

- Geostatistical, control charts, hypothesis testing, etc.?
- Will the data analysis methods meet your DQOs?
- Is the sampling approach compatible with data analysis methods?

¹ Adapted from CCME Guidance Manual, Vol 1. – Sampling, Analysis, Data Management

How many samples are needed?

- How many sample sites are there?
- How many methods were specified?
- How many test samples are needed for each method?
- How many control site samples are needed?
- What types of QC samples are needed?
- Will the QC sample types meet your DQOs?
- How many of each type of QC samples are needed?
- Are these QC samples sufficient to meet your DQOs?
- How many exploratory samples are needed?
- How many supplementary samples will be taken?

Number of samples = Test + control + QC + Exploratory + Supplementary

- Test samples = Methods x Sample sites x Samples per site
- Control samples = Methods x Sample sites x Samples per site
- QC samples = Methods x Type of QC sample x % Needed to meet DQOs
- Exploratory samples = (Test samples + Control samples) x 5 to 15%
- Supplementary samples = (Test samples + Control samples) x 5 to 15%

Table C2
Sample Protocols Checklist⁽¹⁾

What observations at sampling sites are to be recorded?

Has information concerning DQOs, analytical methods, LODs, etc. been included?

Have instructions for modifying protocols in case of problems been specified?

Has a list of all sampling equipment been prepared?

- Does it include all sampling devices?
- Does it include all sampling containers?
- Are the container compositions consistent with analytes?
- Are the container sizes consistent with the amount of samples needed?
- Does it include all preservation materials/chemicals?
- Does it include materials for cleaning the equipment?
- Does it include labels, tape, waterproof pens, and packaging materials?

- Does it include chain of custody forms and sample seals?
- Does it include chemical protective clothing or other safety equipment?

Are there instructions for cleaning equipment before and after sampling?

- Are instructions for equipment calibration and/or use included?
- Are instructions for cleaning or handling sample containers included?

Have instructions for each type of sample collection been prepared?

- Are numbers of samples and sample sizes designated for each type?
- Are any special sampling times or conditions needed?
- Are numbers, types, and sizes of all QC samples included?
- Are numbers, types, and sizes of exploratory and supplementary samples included?
- Are instructions for compositing samples needed?
- Are instructions for field preparations or measurements included?

Have instructions for completing sample labels been included?

- Do they include maximum holding times of samples?

Have instructions for packaging, transporting, and storing been included?

Have instructions for chain-of-custody procedures been included?

Have safety plans been included?

Table C3
Examples of Nonmeasurable Sources of Error⁽¹⁾

- Biased sampling
- Sampling the wrong area
- Sampling the wrong matrix
- Switching samples prior to labelling
- Mislabelling sample containers
- Incorrectly preserving the sample
- Incorrectly aliquoting or weighing samples
- Incorrectly diluting or concentrating samples
- Incorrectly documenting any procedure
- Not recognising matrix-specific interferences
- Using the wrong method for analysis

APPENDIX D
SAMPLE CONTAINERS, VOLUMES AND HOLDING TIMES

Table D1
Sample Containers and Preservation for Constituents in Water

Parameter	Container	Minimum Volume (mL)	Preservative (if required)	Recommended Maximum Storage Time
Boron	P	100	Acidification permitted but not required	28 days
Metals – general	P	500	Add HNO ₃ to pH<2	6 months
Chromium (VI)	P	250	4°C	24 hours
Phenols	Brown glass	500	4°C ⁽¹⁾	Extract within 7 days; analyse extract within 40 days of sample collection
Dioxins and Furans ⁽²⁾	G	2000	4°C	Extract within 30 days; analyse extract within 45 days of sample collection

Abbreviations: P = Polyethylene
G = Glass

Notes: (1) In the presence of residual chlorine preserve with 0.08% Na₂S₂O₃
(2) Store samples in the dark.

Table D2
Sample Containers and Preservation for Constituents in Soil and other Solid Matrices⁽³⁾

Parameter	Container	Minimum Weight ⁽²⁾	Preservative (if required)	Recommended Maximum Storage Time
Boron	P	100 g	–	28 days
Metals – general	P or G	250 g	–	6 months
Chromium (VI)	P or G	100 g	4°C	48 hours
Phenols	G ⁽¹⁾	250 g	4°C	Extract within 14 days; analyse extract within 40 days of sample collection
Dioxins and Furans ⁽⁴⁾	G ⁽¹⁾	250 g	4°C	Extract within 30 days; analyse extract within 45 days of sample collection

Abbreviations: P = Polyethylene
G = Glass

- Notes:
- (1) Teflon or solvent washed aluminium lined cap.
 - (2) Where a sample is to be analysed for several components, 250g is usually sufficient.
 - (3) Typical only, depends on the requirements of the specific laboratory.
 - (4) Store samples in the dark.

APPENDIX E REQUIREMENTS FOR PRESERVATION AND FILTRATION OF GROUNDWATER SAMPLES

The primary objective of any groundwater or surface water sampling programme is to obtain sample(s) that are representative of conditions within the aquifer or surface water body. Secondly, it is important to deliver the sample(s) to the laboratory in unchanged condition (as far as practical). Some relevant considerations are as follows:

- Whilst it is the objective of a groundwater monitoring programme to recover relatively “clear” samples, occasionally this may not be possible from a particular monitoring bore. Many monitoring bores that initially produce turbid samples can produce relatively “clear” samples following an extended period of development. However, the practicality of obtaining a “clear” sample is dependent on the nature of the aquifer. For some aquifers, particularly low/yielding systems, it is not possible within the time constraints of most site investigations, to obtain “clear” samples. In most cases turbidity within the sample is derived from fine particulate in the aquifer material or overlying soil disturbed in the process of drilling or bore construction. If a turbid sample is analysed without first removing the particulate material, (e.g. by filtration), then potentially, an artificially high result may be obtained. For most parameters, however, a very turbid sample (e.g. 200 mg/L TSS) is required to give a significant increase in the reported contaminant concentration.
- Sampling and/or filtration of a sample can induce changes in the water chemistry of the sample. In particular aeration of groundwater samples, which can occur during sampling, can lead to the precipitation of iron oxides. The iron oxide precipitate has the potential to adsorb other heavy metals, stripping metallic contaminants from solution. This can result in artificially low metallic concentrations if the sample is filtered before analysis. The formation of iron oxide precipitates is relatively slow under slightly acid conditions (e.g. pH 5-6) although it can occur within a short period of time (3 to 4 minutes) at a pH of 7 to 8. The preservation of samples by acidification avoids the formation of iron oxide precipitates and also provides conditions that limit the adsorption of metals on particulates that may be present in the sample.
- If a groundwater sample is preserved without filtration, and the sample is relatively turbid, then the resulting acid conditions can lead to the dissolution/desorption of contaminants associated with the particles. Such dissolution/desorption may give rise to an artificially high sample concentration. **If a sample is filtered prior to preservation (i.e. in the field) it must be completed quickly so as to avoid the formation of iron oxide precipitates.**
- Filtering of groundwater samples in the field can be a slow and difficult process, potentially allowing iron oxides to precipitate, depending on the nature of the sample and the equipment available. Further, field filtering of groundwater samples may introduce a source of cross-contamination, although the potential for this is reduced by the use of disposable filtration equipment.

- Metal contaminants in water samples may adsorb onto the wall of glass sample containers, potentially reducing the measured concentration. Acid preservation of water samples avoids such adsorption, and acid pre-rinsing of water sample containers may also reduce the potential adsorption of metal species.

An important consideration in the discussion of filtration practices for water samples is the use of the water resource. In most cases, groundwater or surface water is used unfiltered (with the exception of filtered potable water supplies) and therefore it is important that sampling practices reflect contaminant concentrations in the water body prior to treatment. With groundwater it is considered that if particulates are present in a sample at significant concentrations, the particulates are most often an artefact of sampling rather than being typical of conditions within the aquifer. **On this basis it is important to remove particulate from turbid groundwater samples.**

Based on the considerations outlined above the recommended sampling, filtration and preservation practices for water samples are presented in Table E1.

It is noted that an alternative to filtration and preservation of groundwater samples in the field is to recover the sample without aeration and then to forward the sample to the laboratory without preservation. The sample may then be filtered under laboratory conditions or the clear supernatant may be decanted after the sample has been allowed to stand for a period of time. A sample may be recovered without aeration by placing the outlet tube from an appropriate sampling pump into the sample container (without preservation) and allowing the groundwater to overflow the container for several minutes (several sample container volume changes) before capping the sample container. The sample may then be forwarded to the laboratory for analysis. Sampling without aeration avoids the formation of iron oxides.

It is to be stressed that whilst occasionally it is necessary to filter or otherwise remove particulates from groundwater samples, the objective is to construct and develop groundwater monitoring bores in such a way that “clear” samples are produced.

The above discussion refers principally to groundwater and to metal contaminants given the requirement for preservation of samples to be analysed for heavy metals. **Samples to be analysed for organic contaminants should not be filtered.** Similarly surface water samples should not be filtered given particulates present in surface water samples are likely to be representative of those in the surface water body, rather than being an artefact of sampling.

Table E1
Summary of Filtration and Preservation Requirements
for Groundwater Samples to be Analysed for Heavy Metals ⁽²⁾

Sample Type	Filter		Preserve ⁽¹⁾	Comment
	Field	Laboratory		
Surface Water	No	No	Yes	Possibly slightly conservative approach
Groundwater				
– Clear Sample	No or No	No No	Yes No	Normal sampling Sample without aeration
– Turbid Sample	Yes (quickly) or No	No Yes or decant clear supernatant	Yes No	Normal sampling Sample without aeration

- Notes: (1) Acidify with concentrated nitric acid to pH = 2
 (2) Does not include hexavalent chromium. Samples to be analysed for hexavalent chromium should be filtered and preserved in the field (refer Section 4.7.6).

APPENDIX F
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