Ministry for the Environment
Manatū Mō Te Taiao

# USERS' GUIDE

## Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand

June 1999

**Users' Guide to Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites In New Zealand**

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# 1 The Users' Guide

## 1.1 Introduction

This Users' Guide provides a summary of the information contained in *Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand* . Cross-references are provided to more detailed technical information in Modules 1-7 of the guidelines and their associated appendices. Figure 1.1 illustrates the links between the Users' Guide and the technical information in the guidelines.

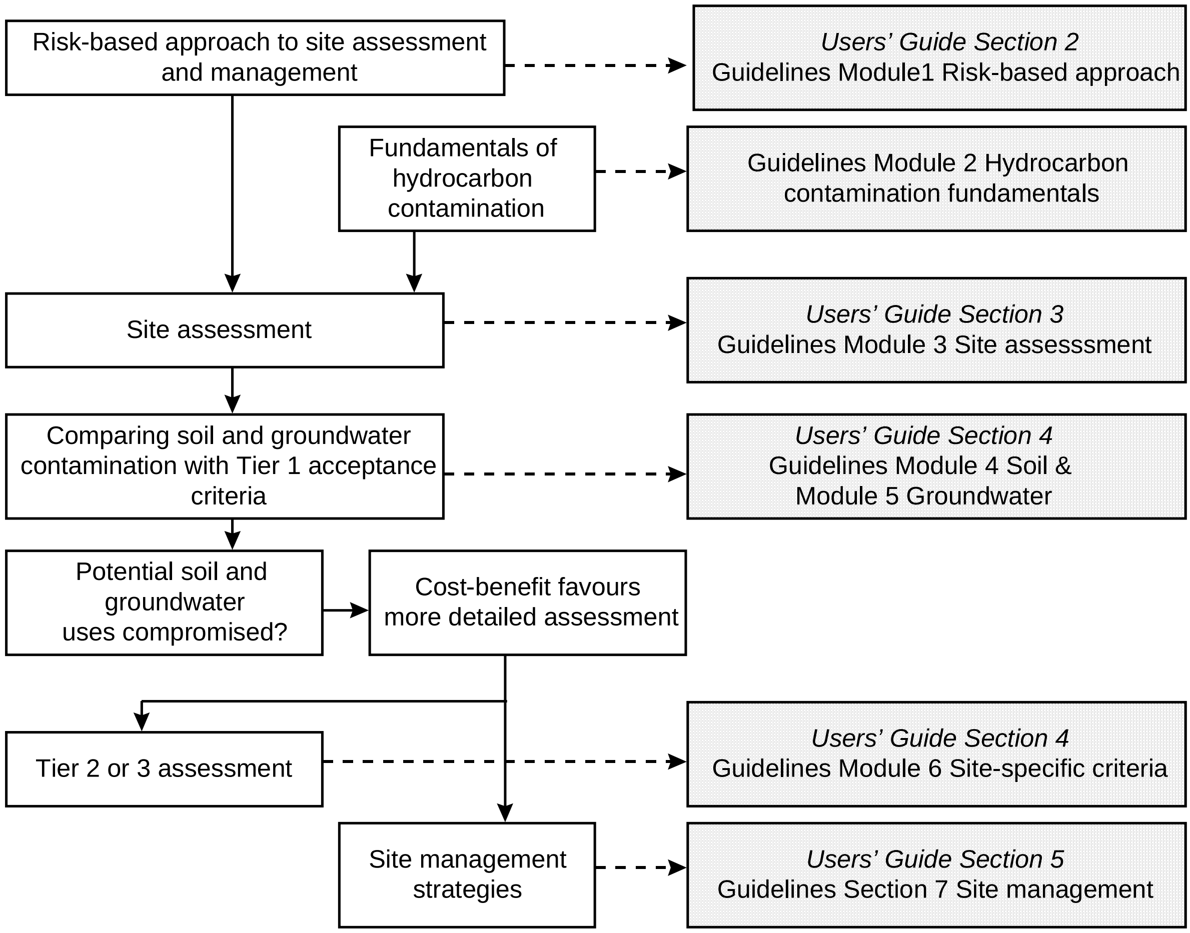


**Figure 1.1 Links between the Users' Guide and the supporting technical information in the *Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites***

## 1.2 Status of the guidelines

The document *Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites* has no statutory effect and is of an advisory nature only. The information should not be relied upon as a substitute for the wording of the relevant legislation or for detailed advice in specific cases, or, where relevant, as formal legal advice. If advice concerning specific situations or other expert assistance is required, the services of a competent professional adviser should be sought.

# 2 Risk-based approach to site assessment and management

Risk assessment forms the basis of these guidelines. This section covers the following:

- the risk assessment process
- the role of risk assessment in site management
- the importance of consultation

roles and responsibilities for contaminated sites management.

## 2.1 Risk assessment

Risk assessment is the process of estimating the potential impact of a chemical or physical agent on an ecosystem or human population under a specific set of conditions. It is a flexible tool that can be used at several stages in assessing and managing petroleum hydrocarbon contaminated sites. The principal applications of risk assessment are to:

- assess the risk to human health and the environment of contaminants found on the site
- develop land-use-based generic acceptance criteria
- assess the comparative risk of different site management options.

Risk assessment is a four-step process:

**Hazard identification**

The results of sampling and analysing soil, groundwater and other environmental media are collated and assessed to determine the nature and extent of contamination at the site.

**Exposure assessment**

Exposure assessment involves:

- identifying exposed groups both on-site and off-site (receptors)
- identifying complete pathways (from the contaminant source through to the exposed group)
- estimating the concentrations to which the receptors may be exposed
- estimating the degree of exposure likely to be experienced by receptors, whether human or environmental.

**Toxicity assessment**

This involves assessing the possible adverse effects that may be associated with exposure to a given chemical or mixture of chemicals, and the level of exposure associated with the onset of the adverse effects. This level is characterised using dose-response factors.

**Risk characterisation**

The results of the exposure assessment and toxicity assessment are combined to provide an estimate of risk to human health or the environment.

The use of a risk-based approach leads to site assessment and management actions that are appropriate for each site. Applying the risk-based approach ensures that all actions are focused to achieve the desired level of protection for human health and the environment.

### 2.1.1 Risk management

Risk management is the final step and involves assessing the information from the risk assessment and deciding what risk mitigation is required. When deciding on the most appropriate risk management options, consideration is usually given to scientific, legal, social, economic and political factors.

### 2.1.2 Risk communication

Risk communication is an important part of the risk assessment and management process. Well-managed risk communication will ensure that the messages you want to get across to the public are constructively formulated, transmitted and received, and result in meaningful action.

The risk assessment process is outlined in Figure 2.1.

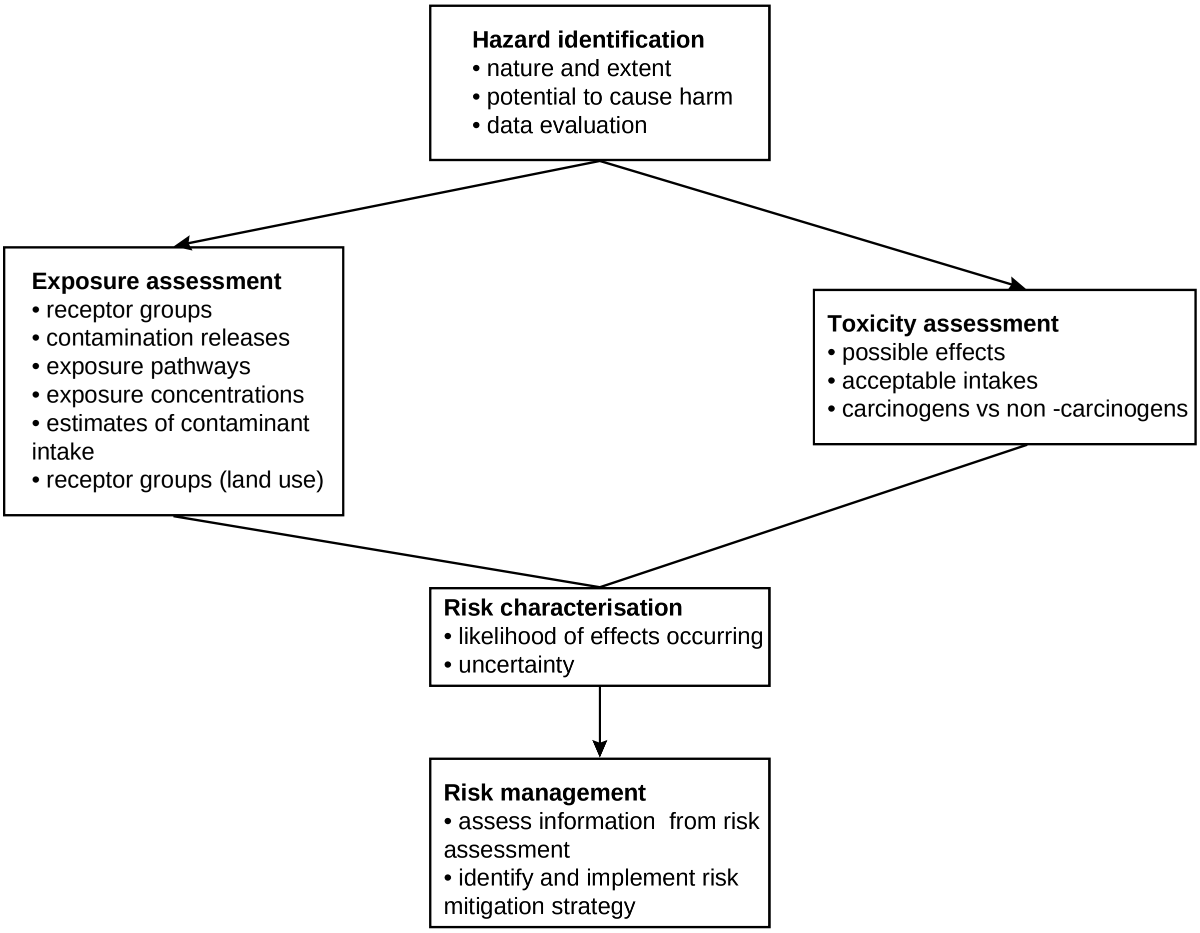


**Figure 2.1 Risk assessment model**

Risk assessment should not be seen as an end in itself, but rather as a tool in risk management. The objective of any site assessment programme is to manage or minimise risk rather than simply to assess the risk to human health and the environment.

### 2.1.3 Health risk assessment

Health risk assessment is the process of estimating the potential impact of a chemical or a physical agent on a specified human population under a specific set of conditions.

The underlying objective of health risk assessment is to effectively protect "almost all" individuals in the exposed population. This objective is demonstrated in the commonly adopted levels of acceptable cancer risk used for regulatory purposes. In New Zealand, an acceptable level cancer risk level of 1 in 100,000 per lifetime (one additional case of cancer per 100,000 people per lifetime) has been adopted by the Ministry of Health. This value is also used in these guidelines.

The aim of health risk assessment is to determine an individual's chemical intake, and whether it is less than or above a nominal dose that is considered acceptable. Exposure is estimated via a number of pathways, including ingestion of soil, inhalation of volatiles or particulates, dermal absorption and food chain exposure.

In assessing possible adverse effects on human health, consideration is given to a range of carcinogenic and non-carcinogenic effects.

### 2.1.4 Ecological risk assessment

Ecological risk assessment is the process of estimating the potential impact of a chemical or physical agent on a specified ecosystem under a specific set of conditions.

While the development of ecological risk assessment methods have been slower than the methods for health risk assessment (due to the complexity of ecosystems), the use of ecological risk assessment is increasing. Ecological risk assessment focuses on protecting populations of species and ecosystems rather than individual organisms. The methodologies most commonly used are similar to those used for human health risk assessment.

The first step in assessing ecological risk is determining whether there is a potentially complete exposure pathway and an ecologically relevant receptor. If there is no potential for the contaminants to reach surface water or soil surface, and there are no ecologically sensitive species or habitats, then there is no need to proceed further with an ecological risk assessment. However, if an exposure pathway is identified and there is likely to be an impact on surface water or soil, then a site-specific assessment may be necessary to assess the likely impact of the contaminants. This involves comparing exposure concentrations against toxic threshold values to derive a hazard quotient, if this is more than one, more specific investigations may be required (e.g. toxicity testing of contaminated soils, water or sediment).

Additional information on ecological risk assessment can be found in Module 4, section 4.6, a checklist for determining whether an ecological risk assessment may be required can be found in Appendix 41.

## 2.2 Role of risk assessment in site management

Risk assessment allows a comparison to be made of the risk posed by a site with agreed levels of acceptable risk. This helps to determine whether action is required. It also facilitates the ranking of sites in order of the risk posed to human health and the environment, and is a tool for comparing site management options.

Risk assessment may involve, in order of increasing detail and complexity:

- a screening level risk assessment, incorporating comparison of measured contaminant concentrations in soil and water with generic, risk-based acceptance criteria or guideline values
- a qualitative or semi-quantitative risk assessment, based on generic, risk-based acceptance criteria, including site-specific consideration of the relevance of exposure pathways assumed to exist in the derivation of the generic criteria, the impact of land use controls and a range of other factors that impact on the risk to human health and the environment
- a quantitative risk assessment, drawing on the approaches used to derive the generic criteria, and on other published methodologies, and incorporating as much detailed site-specific information as possible.

The information required and the cost of undertaking each of the levels of risk assessment increases as the detail and complexity increases. Further, not all sites warrant a highly detailed quantitative risk assessment; a screening level risk assessment may provide sufficient information to make sound risk management or site management decisions. It is sensible therefore initially to gather only enough data for a screening level assessment. The necessity for further, more detailed risk assessment, and the associated information requirements, may be determined from that. The site assessment and management process is illustrated in Figure 2.2.

## 2.3 Importance of consultation

Consultation with stakeholders, including regulators, site owners and neighbours, and other potentially adversely affected parties, is an important aspect of managing contaminated sites. It is important that these stakeholders are involved in the process of site assessment and management as early as possible. Consultation with regulatory agencies is particularly important, as they can provide guidance on any resource consents requirements for assessing and managing the site.

## 2.4 Roles and responsibilities

There are a number of organisations with an interest in contaminated sites. In most cases more than one agency will become involved in site assessment and management.

**Regional councils** Regional councils are responsible for specifying controls on contaminated sites when contaminants are being discharged into or onto land, air or water. In most areas the regional council is the first point of contact for those who are concerned about a site that may be adversely affecting the environment.

**Territorial authorities** Territorial authorities have responsibilities under the Health Act 1956 and Building Act 1991. They are involved in the control of contaminated sites when there are adverse effects on human health. They are also involved in issues relating to the use, development or protection of land, through their responsibilities under the RMA 1991.

**Public health agencies** Public health agencies have an interest in contaminated sites when there are adverse effects on human health.

**Occupational Safety and Health** Occupational Safety and Health are involved in contaminated site management when there is a potential risk to employees on site.

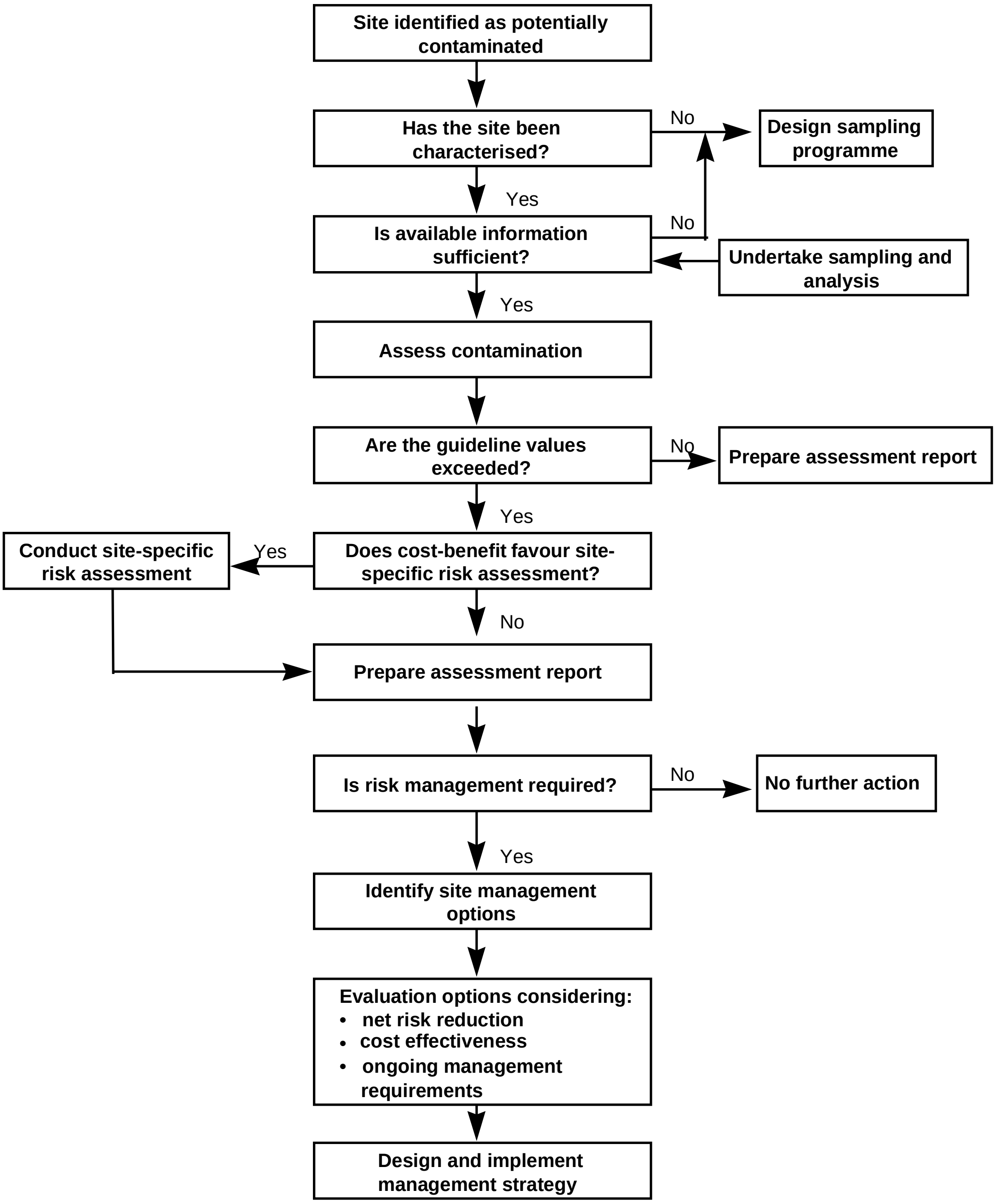


**Figure 2.2 Outline of the site assessment and management process**

# 3 Site assessment procedures

## 3.1 Introduction

A site assessment must provide reliable information on the nature, distribution, and fate and transport of contamination. This section covers the following aspects of site assessment:

- the site assessment process
- what media should be sampled
- recommended approach to sampling
- site sampling techniques
- field sampling procedures
- analytical programme
- recommended approach to compositing
- reference analytical methods
- site assessment reporting
- health and safety issues
- a typical site assessment plan

Additional information on site assessment can be found in Module 3, including:

- initial site assessment (Section 3.1)
- detailed site investigation (Section 3.2)
- sampling strategies (Section 3.3.)
- field investigation techniques (Section 3.4)
- soil, ground and surface water, and sediment sampling (Section 3.5). For more detailed information on sampling and analytical methods see *Sampling Protocols and Analytical Methods for Determining Petroleum Products in Soil and Water* on the Ministry for the Environment's web page www.mfe.govt.nz/issues/contam.htm
- data quality objectives (Section 3.6).

## 3.2 Site assessment process

The initial assessment of a site will usually consist of two phases:

**Phase one - background information study**

First, a background study should 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 two - field investigation programme**

A programme of field work can then be planned and carried out. This may include collecting soil, groundwater and surface water samples for analysis. The extent of the investigation depends 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 will contribute to subsequent site characterisation.

### 3.2.1 Phase one - background information study

All pertinent background information should be reviewed to identify the potential for on-site and off-site contamination. This phase of the work should be completed before commencing phase two.

The background information study should include:

- the chronological history of previous site uses and industries
- the activities or processes carried out on the site, and the location of facilities
- any past investigations or remediation carried out at the site
- any changes during the history of the site
- interviews with site personnel and past workers at the site. Other sources of site history information include:
  - records of regulatory controls and waste management practices
  - past and present owners of the site
  - aerial and ground photographs, and site maps and surveys
  - local government records (e.g. history of complaints, discharge or building permits)
  - trade and street directories
  - local literature (e.g. newspapers)
  - long-term adjoining owners
- identification areas where the likelihood of contamination resulting from past or current work practices is high (e.g. accidental spillage, leaks and waste disposal sites)
- source information 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)
- local hydrogeological 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
  - local municipal drinking water supply sources, and the location of private or industrial wells or bores, especially those supplying drinking-water
- location of 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
- published or known information which establishes whether adjacent property owners are or have been potential sources of contamination of the soil and groundwater of the site
- available information on geological, hydrogeological and pedological characteristics of the site and surrounding areas
- location, age and construction material of above- and underground storage tanks on the site
- location and construction details of underground services including the site stormwater system. These may have a impact on future remediation activities, and can act as preferential drainage pathways

- present and likely future zoning of the site
- likely future use of the site
- contour or topographic maps for locating of filling and earthmoving activities
- potential cultural issues, e.g. archaeological
- the location of any off-site underground services.

### 3.2.2 Phase two - field investigation programme

A field investigation programme should be developed for each site after completing the background study. Given the variability in size and complexity of sites, it is not possible, or appropriate, to provide general advice in this guide on developing field investigation programmes.

## 3.3 What media should be sampled?

The sampling programme should include the following:

- soil sampling
- groundwater sampling
- surface water and sediment sampling at locations to be determined following assessment of site runoff patterns.

Additional sampling could include:

- soil gas sampling to define the extent of contamination by volatile contaminants
- environmental media and potentially affected ecological receptors, e.g. ambient air, plant materials, aquatic biota.

Information on sampling locations can be found in Section 3.3 of Module 3.

A site work plan should be prepared setting out the requirements and objectives for field sampling and sample collection at the site. All field sampling and associated data collection must be supervised by an experienced person, and carried out in accordance with approved sampling procedures (Quality Assurance Plan (QAP) and an approved site Health and Safety Plan (HASP)).

### 3.3.1 Soil

An assessment programme for characterising soil contamination can be used to determine:

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

### 3.3.2 Groundwater

If hydrogeological conditions indicate there is potential for impacts from site contamination on groundwater, then a groundwater investigation programme should be completed as part of the second phase investigation. If groundwater is at a depth of less than 10 metres, a groundwater monitoring programme should be considered. However, other site-specific factors including the nature of the overlying soils[1] need to be considered.

If shallow or perched groundwater exists at a site, migration through underground service conduits should also be considered.

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 groundwater movement and location of possible surface waters connected to groundwater (e.g. surface drains, streams, wetlands, etc.)
- determining whether contaminants are present in the groundwater (both on-and off-site) and if so, at what concentrations and in what form (including light non-aqueous phase liquids (LNAPLs).

The groundwater monitoring programme should aim to identify the impact of contamination on current and future uses of the groundwater, the risk to groundwater users, the potential for off site impact and the impact on other receiving environments.

### 3.3.3 Surface water and sediment

The aim of surface water and sediment sampling is to determine contaminant concentrations of media to which human and ecological receptors may be exposed.

It is possible to extrapolate contaminant concentrations in surface water and sediments from groundwater and surface soil concentrations. However, direct measurement provides more reliable estimates of the potential human and ecological impacts.

The surface water and sediment sampling programme should provide an estimate of contaminants leaving the site via drains, surface water runoff and groundwater discharge to surface water bodies. Sediment sampling is a useful source of qualitative information about off-site transport of contaminants as some substances will partition preferentially into the sediments.

### 3.3.4 Air

This guideline does not specifically address sampling requirements for air. In many cases it is not possible or practical to directly measure levels in air (e.g. a house has not yet been built on the former service station site). For the purposes of Tier 1 assessment, it is assumed that concentrations will be measured in soil and groundwater, and fate and transport models used to predict indoor/outdoor air concentrations.

Vapour issues, such as odour, may be important during site sampling and site management, and are addressed in this context in these guidelines.

Information on volatilisation can be found in Sections 4.5.3.2 and Appendices 4D and 4M of Module 4, and in Section 5.7 and Appendix 5B of Module 5.

1 The potential exists for contamination of groundwater at depths greater than 10 metres where soil or rock permeabilities are high. For example, contamination of groundwater at depths greater than 15 metres readily occurs in fractured rock systems and permeable unconsolidated deposits. Notwithstanding this, the nominated value of 10 metres represents a pragmatic guideline based on general site conditions encountered.

## 3.4 Recommended approach to sampling

The information requirements for site assessment vary according to the size and complexity of the site. For this reason it is not possible to rigorously define the required sampling and analysis programme that will provide adequate information for risk assessment purposes.

The design of sampling programs should consider:

- minimising the disturbance of contaminated material to reduce odour impact beyond the site boundary
- appropriate health and safety protocols to minimise the exposure of investigation workers to contaminants
- limiting off-site transport of contaminants by limiting exposure of contaminated soil and managing stormwater flows appropriately.

### 3.4.1 Soil sampling

The following general approach is suggested for a soil sampling programme:

- Identify the areas likely to be contaminated based on site history and relevant information.
- Divide the site into a number of areas based on the likelihood of contamination.
- Adopt a targeted or systematic sampling strategy within those areas that are expected to be contaminated to develop an understanding of the likely contaminant concentrations and distribution within the contaminated areas.
- Adopt a systematic sampling strategy across the general site areas where contamination is not expected or specific contaminant sources have not been identified.

Some general comments on systematic and targeted sampling follow:

**Systematic sampling**

- Use for identifying hot spots in areas which are not expected to be contaminated.
- Use for estimating mean concentrations if an area is expected to be contaminated.
- Grid spacing of 10 - 30 metres may be appropriate depending on the sampling objectives and site details.
- Must be flexible when designing systematic sampling grids for instances where obstructions that prevent sampling may be present.

**Targeted sampling**

- A targeted sampling programme is highly dependent on site history.
- To assess the heterogeneity of the distribution, several samples should be recovered from the area surrounding each source.
- Usually combine targeted sampling with systematic sampling across general areas of the site.
- Samples should be recovered from a range of depths depending on the nature of the contaminant and the location of the source. For example:
  - tank pits
  - in the vicinity of surface facilities, samples should be recovered from depths up to 2 metres
  - in heavily contaminated areas, soils in the vicinity of the groundwater may need to be sampled to assess the potential for ongoing contamination of groundwater.

Visual assessment of soils can assist in determining which samples should be analysed. For example, if a number of obviously oily samples are recovered from a particular area and depth, only one or two may need to be analysed. These samples are likely to return high concentrations of contaminants, and the analyses of a limited number of samples would be sufficient to provide information about that particular area and depth. This visual analysis should be done by a person experienced in assessing these materials.

### 3.4.2 Groundwater sampling

The recovery of groundwater samples from the following locations may be warranted:

- up gradient of the site (one or more locations as background bores to assist in assessing groundwater quality and aquifer characteristics)
- adjacent to potentially major sources of groundwater contamination
- down gradient of contaminated areas
- down gradient of site boundaries.

Some issues which need to be considered when designing and implementing groundwater sampling:

- The number and location of monitoring bores depends on the complexity of the sites. However, for a simple site, at least five would be required to obtain a reasonable understanding of the groundwater conditions and the extent of contamination at the site.
- Where LNAPLs have been found, groundwater should be monitored at a range of depths, as the LNAPLs may be an ongoing source of dissolved phase groundwater contamination.
- Groundwater monitoring bores should be installed under the supervision[2] of suitably qualified drilling contractors.
- Soil samples may be recovered and analysed during bore installation to assist in assessing contaminant distribution.
- During preliminary investigations, draw-down and recovery or similar tests should be carried out on selected bores to determine aquifer characteristics.

### 3.4.3 Surface water and sediment 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, where the site is near to a flowing water body (e.g. stream)
- several locations at varying distances from the shore where the water discharges to a bay or other coastal or lake environment. A sample characterising the likely background conditions in the surface water body should also be collected.

Some issues which need to be considered when designing and implementing surface water and sediment sampling:

2 Under the supervision of an experienced geologist/hydrogeologist/environmental scientist.

- At least one sample should be recovered from any potentially contaminated drain discharging from the site.
- Several rounds of surface water sampling may be needed to provide an estimation of water quality under wet and dry weather conditions. During wet weather the sampling regime should be targeted towards characterising the first flush of run-off, and during dry weather surface water contamination from groundwater inputs should be characterised.
- A representative sediment sample should be collected from each sample location, where possible. Additional sediment samples may be recovered from drains from the site discharging to the surface water body.
- Sediment should be recovered during weather conditions to which aquatic species would normally be exposed.

Additional information on sampling strategies and quality control/quality assurance can be found in Module 3.

# 3.5 Site sampling techniques

## 3.5.1 Soil sampling techniques

Soil samples may be recovered by a range of techniques. The primary consideration in selecting sampling techniques should be the integrity of the samples, so that the quality of information is adequate for the assessment. Table 3.1 shows the advantages and disadvantages of various soil sampling techniques.

**Table 3.1 Soil sampling techniques**

| Technique | Advantages | Disadvantages |
|---|---|---|
| Borehole | • minor disturbances of soils<br>• limited occupational exposure<br>• accurate recovery of samples<br>• ability to sample at depth as required | • cost<br>• time<br>• need to carefully decontaminate equipment<br>• limited ability to observe nature of the material encountered |
| Hand auger | • low cost<br>• quick | • limited depth<br>• impractical in difficult soil conditions<br>• care required to ensure quality of samples recovered<br>• limited ability to observe nature of material encountered<br>• labour intensive |
| Back hoe test pit | • lower cost than boreholes<br>• relatively quick<br>• ability to make more detailed observations about the nature of materials encountered<br>• able to accurately recover samples | • extent of soil disturbance and the effect on odour, occupational exposure, and compaction<br>• limited to depth of 3 to 4m<br>• impractical in unstable soil conditions |

Selection of a sampling technique should consider:

- depth from which samples are to be recovered
- soil conditions (e.g. stability)
- current use or development of the site (e.g. to what extent can site disturbance be tolerated)
- presence of concrete slabs or foundations at or below the surface
- likely level of contamination and the likely health and safety implications associated with disturbance of contaminated material.

### 3.5.2 Groundwater sampling techniques

A wide range of techniques is available for recovering groundwater samples, with and without the installation of permanent groundwater monitoring bores. In environmental site assessments, groundwater is most often sampled by constructing permanent groundwater monitoring bores. Preferred sampling techniques should recover a sample representative of surrounding groundwater conditions.

Some issues in the assessment of groundwater contamination are:

- The technique adopted must avoid the introduction of contaminants from one zone into another. Hollow stem auger techniques are frequently used for unconsolidated materials, and percussion techniques are frequently used for consolidated materials.
- Bore construction materials must be selected to minimise impact on groundwater quality and chemistry. Screw-thread PVC standpipes are frequently used.
- Where nested bores, or sampling from a discrete depth interval below the water table is proposed, bores must be securely sealed, allowing sampling from the desired depth and minimising the potential for migration of LNAPLs through the space of the drilled hole and the bore casing. This is especially important where a confining layer is present.
- The water column in the monitoring bores should be carefully examined for free phase organics before purging and sampling.
- Bores must be properly developed and purged of stagnant water before sampling.
- Field measurements of groundwater quality (e.g. pH, dissolved oxygen) should not occur until these parameters have stabilised in the extracted water.
- Groundwater samples should be recovered in a manner that minimises loss of volatiles.

### 3.5.3 Surface water and sediment sampling techniques

Surface water samples should be taken from below the water surface to prevent accidental sampling of surface slicks. A suitable sampling device, able to recover samples from a designated depth and prevent ingress of surface water should be used.

Sediment samples are typically collected from the finest fraction of the sediment, unless sampling objectives indicate otherwise.

| |
|---|
| Additional information on typical soil, groundwater, surface water and sediment sampling can be found in Module 3. |

### 3.5.4 Subsurface techniques

A number of techniques are available to provide a cost-effective and efficient way of better defining the subsurface conditions at an investigation site. For the most part, geophysical methods are non-destructive and non-invasive, which can be extremely important for a site where little is known of past practices or locations of subsurface structures. A preliminary geophysical survey can locate subsurface structures that may otherwise present a health and safety hazard in drilling or trenching programmes designed on a random or grid basis.

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Additional information on subsurface assessment techniques can be found in: *Subsurface Assessment Handbook for Contaminated Sites*, CCME, Report CCME EPC-NCSRP-48E, March 1994.

## 3.6 Analytical programme

The analytical programme is based on the contaminants that are likely to be found. Table 3.2 outlines the possible analytes for the various media.

**Table 3.2 Possible analytes**

| Analytes | Soil | Groundwater | Surface water and sediment |
|---|---|---|---|
| Petroleum hydrocarbons | ✔ | ✔ | ✔ |
| BTEX | ✔ | ✔ | ✔ |
| PAHs | ✔ | ✔ | ✔ |
| Lead | ✔ | ✔ | ✔ |

### 3.6.1 Soil

Samples should be analysed for those contaminants identified in the background information study.

### 3.6.2 Groundwater

When analysing groundwater samples, emphasis should be placed on the more soluble parameters, such as BTEX, and light-end PAHs, such as naphthalene. These are contaminants that tend to be more mobile and may migrate some distance from the site, depending on the sites hydrogeological conditions. Where floating layers of separate phase liquids/hydrocarbons or hydrocarbon sheens are detected in groundwater monitoring wells, samples collected from these wells should not be analysed for dissolved organic parameters, rather the product sample should, if need be, be characterised using GC techniques.

Selected groundwater samples should be analysed for pH, total dissolved solids and other general characteristics to assist in determining the potential impact on current or likely future uses. This may require recovery of additional samples in conjunction with samples for chemical contaminant analysis.

### 3.6.3 Surface water and sediment

The analysis of surface water samples includes the same parameters specified for groundwater. For sediments, particular attention should be paid to the analysis of samples for constituents that are likely to bind strongly to particulate matter (e.g. heavier PAHs, heavy metals).

## 3.7 Recommended approach to compositing

Generally it is not appropriate to composite soil samples from petroleum hydrocarbon sites. Compositing soil samples assumes that a valid estimate of the contaminant concentration of the composited sample can be obtained from a single sub-sample analysis of the composite sample. A sub-sample containing a high concentration of contaminant may remain undetected due to dilution in compositing.

Where a site is heavily contaminated and the extent of contamination needs to be defined, the use of composite sampling is not appropriate, as sub-samples will have to be reanalysed where contaminant concentrations exceed the acceptance criteria. Composite sampling is also not appropriate where samples are to be analysed for volatile chemicals, such as BTEX, due to the possible losses during compositing.

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 base of a tank pit), or where an average contaminant concentration is specifically sought (e.g. estimating the average exposure of site users). In areas where contamination is not expected, samples may be composited to reduce analytical costs.

Some general rules for compositing:

- Compositing should be limited to no more than four sub-samples so that any sub-sample can be detected if it exceeds the guidelines.
- Composites should only be comprised of samples from immediately adjacent locations.
- Composites should only comprise samples from the same depth and of similar soil type.
- Samples should be homogenised prior to forming the composites. Samples that are not readily homogenised (e.g. clays) should not be used to form composites.
- Equal masses from each sub-sample should be used to form the composite.

## 3.8 Reference analytical methods[3]

Recommended methods for analysing each of the possible contaminants are given in *Sampling Protocols and Analytical Methods for Determining Petroleum Products in Soil and Water* (available from the Ministry for the Environment's web page http://www.mfe.govt.nz/issues/contam.htm).

Contamination concentrations in soil samples should be reported in mg/kg on a dry weight basis, with the moisture content included in the report. Results from water samples should be reported in grams per cubic metre.

Field methods are also discussed, but no reference methods have been proposed as the available methods are mainly suitable for investigation and screening purposes, rather than testing against any

3 The analytical method selected should be one that provides the greatest accuracy and reproducibility at concentrations close to the generic acceptance criteria. Where the detection limit of the method is close to the generic acceptance criteria it may be appropriate to develop site-specific acceptance criteria.

acceptance criteria. It is recommended that results from screening methods should be within at least 80% of the accuracy obtainable with a more thorough reference method.

### 3.8.1 Analytical field methods

Field testing may be required for several reasons:

- to ensure health and safety requirements are met
- to analyse unstable or very volatile contaminants
- where immediate analytical response is required, for example, for making on-site decisions on the progress of remediation activities.

A range of field analytical equipment is available, from simple colorimetric test kits to sophisticated portable versions of laboratory instrumentation. Many of these are now based on standard methods such as those in the APHA manual, and will be perfectly acceptable, provided the required levels of performance are achieved.

Test kits can be based on colorimetric chemical tests, used with either a visual colour comparator or a photometer, or on electronic chemical sensors, usually based on an electrochemical principle. Examples of parameters that can be measured by such field test kits are:

- pH, acidity, alkalinity, conductivity
- hydrocarbons (total), PAHs, BTEX.

## 3.9 Site assessment reporting

At the conclusion of the sampling and analytical programme, a formal report should be prepared. The report should include:

- a statement of the objectives, scope and limitations of the assessment and report
- a detailed description of the land, including ownership and occupier details, certificate of title etc.
- a detailed history of the uses of the site. This should include a list that specifies the identities and locations of any known or suspected chemicals or any other substances which could be a hazard whether imminent or otherwise
- sources and validation of information
- current and likely future use of the land
- recording of any visual inspections of the site
- 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 also be provided
- details of the condition and location of buildings, sewer and drainage systems, natural water courses, underground storage tanks, waste disposal areas and other activities on the site
- a detailed site plan including scale, dimensions of site, north point, relationship to streets and other properties, and all relevant site features and sampling locations

- details about the services on-and off-site (since these are potential routes for contamination to spread)
- the sampling and analysis programme used to determine the extent and distribution of contamination, including:
  - basis for selecting the 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 their derivation)
  - quality assurance procedures
  - quality control details
  - laboratory and analytical methods used
- results of the sampling and analysis programme on which a conceptual model is based of how contaminants are moving on the site and their fate and transport characteristics in each media of concern
- 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 possible beneficial uses of the site

– potential for adverse off-site effects

– potential exposure pathways

- the results of the field investigations should be discussed with reference to the guideline values nominated for various site uses. Particular attention should be given to site-specific factors which may require modifying the nominated values
- recommendations, including further activities required at the site to mitigate contamination, if necessary.

## 3.10 Health and safety issues

Under the Health and Safety in Employment Act 1992, a place of work must be investigated to identify the hazards present, these hazards must be assessed for their significance, and those identified as significant must be eliminated, isolated or minimised as appropriate. Existing documentation regarding safety practices, such as oil industry hot work and confined space permitting procedures and the codes of practice for petroleum sites, should be reviewed thoroughly before investigating site contamination.

Workers may be exposed to hazardous substances during the assessment and management of contaminated sites. The occupational health and safety hazards associated with this exposure may present a danger to human health and safety. Appropriate protection should be given to workers involved in site assessment and management.

The Occupational Safety and Health Service of the Department of Labour has published *Health and Safety Guidelines on the Clean-up of Contaminated Sites*. The guidelines, published in 1994, provide a general framework for employers, contractors, local authorities and others, for controlling exposure to hazardous substances which may be present at contaminated sites. These guidelines should be consulted prior to the assessment and management of a contaminated site.

Refer to the Occupational Safety and Health Service/Department of Labour document - *Health and Safety Guidelines on the Cleanup of Contaminated Sites* (1994). Copies are available from the Department of Labour.

# 4 Generic acceptance criteria

## 4.1 Introduction

The development of risk-based acceptance criteria requires the risk assessment process to be operated in reverse, starting at the target risk level and making assumptions regarding site conditions and land use. Risk assessment can then be used to determine the contaminant concentrations in various media corresponding to the target risk levels - these are the generic acceptance criteria.

This section describes the basis for developing generic soil and groundwater acceptance criteria for petroleum hydrocarbon contaminated sites in New Zealand. This section covers:

- development of generic soil acceptance criteria
- application of the generic soil acceptance criteria
- development of generic groundwater acceptance criteria
- application of the generic groundwater acceptance criteria
- development of site-specific acceptance criteria.

Detailed information on the development of the generic acceptance criteria can be found in Modules 4 (for soil) and 5 (for groundwater) .

## 4.2 Health-based generic soil acceptance criteria

### 4.2.1 Land uses

Land use is the key determinant of the extent to which site users may be exposed to soil contamination. The land uses selected for these guidelines are as follows:

**Agricultural/ horticultural**

Agricultural/horticultural land use is deemed to include all agriculture and horticulture, particularly those related to food production. The general public is protected by ensuring that soil contamination does not give rise to a concentration in produce that exceeds a published Maximum Residue Level (MRL). However, MRLs have not been nominated for most contaminants of concern. Therefore consideration is given to the risk associated with consuming 100% of produce from a contaminated source.

Consideration is also given to protecting the health of residents at any farm property, assuming that residents may be exposed by consuming home-grown livestock and produce, and through direct contact with contaminated soil. It is assumed that residences do not incorporate basements.

**Residential**

This is based on a low-density residential use, including rural residential use, where a considerable proportion of the total amount of produce consumed is grown at the site. No consideration is given to livestock uptake of contaminants. If livestock are kept at a residential site for human consumption, then consideration may be given to using the agricultural criteria. It is assumed that residences do not incorporate basements.

Many residential developments in urban areas effectively limit the amount of produce that may be grown (e.g. apartment blocks), reducing exposure to some contaminants. Where a significant quantity of produce cannot be grown, consideration may be given to the adoption of site-specific criteria excluding the consumption of produce (or reducing the proportion assumed to be sourced from the site), based on route-specific criteria presented in Tables 4.16 to 4.18 in Module 4.

**Commercial/ industrial**

This scenario is based on exposure conditions at a largely unpaved industrial site where workers may come in direct contact with contaminated soil. This scenario does not consider workers actively involved in excavation or similar activities. Where a site is largely paved, higher contaminant concentrations may be acceptable based on site-specific criteria.

**Maintenance workers**

For each of the above land uses there is potential for significant human exposure to ground contamination associated with subsurface maintenance works. While the duration of such work is generally much shorter than the other scenarios considered, the rate of intake of various contaminants is likely to be much higher and such exposure may be significant where undertaken routinely by the same person. This scenario assumes workers wear normal work clothes. The use of appropriate personal protective equipment may reduce worker exposure, allowing work within areas with contaminant concentrations in excess of the proposed criteria.

## 4.2.2 Hazard identification

As discussed in Section 2.1, hazard identification is the first step in the risk assessment process, and involves collecting information about the nature and extent of contamination at the site.

### *4.2.2.1 Contaminants of concern*

A group of compounds that are likely to pose the greatest risk to human health have been selected as indicators for assessing the overall level of contamination at a site. Table 4.1 summarises the contaminants of concern, and those which have been used for deriving the generic soil acceptance criteria.

**Table 4.1 Summary of product composition and contaminants of concern**

| Product | Composition | Indicator contaminants | Relevant analyses |
|---|---|---|---|
| Gasolines | C4 to C12<br>BTEX 10 to 20%<br>other aromatics 39%<br>aliphatics: 49-62%<br>lead (historical) | benzene, xylene, alkyl benzenes[1], n-hexane and other light alkanes, naphthalene | TPH, BTEX, lead |
| Diesel | C9 to C20<br>aliphatics: 64%<br>alkenes: 1 to 2%<br>aromatics: 35%<br>TEX:0.25 to 0.5% | alkylbenzenes,<br>higher alkanes, naphthalene and other PAHs | TPH, PAHs |
| Kerosene | C9 to C16<br>alkenes: 80%<br>aromatics: 5 to 20%<br>(mostly alkylbenzenes) | alkyl benzenes, naphthalene and other PAHs, heavier alkenes | TPH, PAH, BTEX |

Additional information on the contaminants of concern can be found in Section 4.3.1 of Module 4.

#### *4.2.2.2 Receptors*

The key human receptors considered in developing soil screening criteria are presented in Table 4.2.

**Table 4.2 Key human receptors**

| Site Use | Receptor Group |
|---|---|
| Agricultural/Horticultural | Child residents<br>Adult residents/on-site workers<br>Maintenance workers |
| Residential | Child residents<br>Adult residents/workers<br>Maintenance workers |
| Commercial/Industrial | Adult workers<br>Maintenance workers |

### 4.2.3 Exposure assessment

Exposure assessment is a measure of the likely exposure of the receptors. It involves identifying complete exposure pathways, measuring contaminant concentrations and estimating the dose likely to be experienced by each receptor.

More information on exposure assessment can be found in Module4, Section 4.5.

#### *4.2.3.1 Exposure pathways*

Soil contamination poses a risk to a receptor where there is potential for the receptor to come into contact with the contaminants i.e., an exposure pathway. There are a number of elements that make up an exposure pathway:

- source
- transport mechanism
- point of exposure
- exposure route.

The exposure pathways considered in developing the soil screening criteria are summarised in Table 4.3.

**Table 4.3 Summary of exposure pathways**

| Exposure pathway | Agricultural | | Residential | | Industrial | | Maintenance workers | |
|---|---|---|---|---|---|---|---|---|
| | Surface | Sub-surface | Surface | Sub-surface | Surface | Sub-surface | Surface | Sub-surface |
| Ingestion of contaminated soil | ✓ | | ✓ | | ✓ | | ✓ | ✓ |
| Consumption of produce | ✓ | | ✓ | | | | | |
| Dermal absorption | ✓ | | ✓ | | ✓ | | ✓ | ✓ |
| Inhalation of volatiles (indoors) | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Inhalation of volatiles (outdoors) | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Inhalation of particulates | ✓ | | ✓ | | ✓ | | ✓ | ✓ |

More information on exposure pathways can be found in Section 4.3.4 of Module 4.

#### *4.2.3.2 Exposure concentration*

To derive acceptance criteria, it is necessary to find the relationship between contaminant concentrations in soil and those in other media to which site users may be exposed. Estimating contaminant concentrations at the point of exposure is one of the most critical elements of the risk assessment. For most initial site assessments, it is assumed that contaminant concentrations will be measured in soil and groundwater.

Additional information on exposure concentrations can be found in Section 4.5.3 of Module 4.

#### *4.2.3.3 Exposure estimation*

Generic acceptance criteria for protecting human health, have been based on the Reasonable Maximum Exposure (RME) for a particular scenario (USEPA 1989).

Additional information on exposure estimation can be found in Section 4.5.4 of Module 4.

#### *4.2.3.4 Exposure factors*

The exposure factors adopted developing the soil acceptance criteria are consistent with those adopted for other New Zealand guidelines (for example, the Health and Environmental Guidelines for Selected Timber Treatment Chemicals). Table 4.4 presents the exposure factors used in the development of the soil acceptance criteria.

**Table 4.4 Summary of exposure factors**

| Exposure factor | Units | Agricultural | | Residential | | Commercial Industrial | Maintenance. |
|---|---|---|---|---|---|---|---|
| | | Child | Adult | Child | Adult | Adult | Adult |
| **General:** | | | | | | | |
| Body weight | kg | 15 | 70 | 15 | 70 | 70 | 70 |
| Exposure duration | yrs | 6 | 24 (30 total) | 6 | 24 (30 total) | 20 | 20 |
| Exposure frequency | d/yr | 350 | 350 | 350 | 350 | 240 | 50 |
| **Soil ingestion:** | | | | | | | |
| Soil ingestion rate | mg/d | 100 | 25 | 100 | 25 | 25 | 100 |
| **Dermal absorption:** | | | | | | | |
| Area of exposed skin | $cm^2$ | 2625 | 4700 | 2625 | 4700 | 4700 | 4700 |
| Soil adherence | $mg/cm^2$ | 1 | 1 | 0.5 | 0.5 | 1 | 1.5 |
| **Produce consumption:** | | | | | | | |
| Produce ingestion rate | kg/d | 0.13 | 0.45 | 0.13 | 0.45 | NA | NA |
| Proportion of produce grown on-site | % | 100 | 100 | 50<br>10(1) | 50<br>10(1) | NA | NA |
| **Inhalation:** | | | | | | | |
| Indoor inhalation rate(2) | $m^3/d$ | 3.8 | 15 | 3.8 | 15 | 10(3) | 10(3) |
| Outdoor inhalation rate(2) | $m^3/d$ | 3.8 | 20 | 3.8 | 20 | 10(3) | 10(3) |

Notes:
1. Alternative value more representative of behaviour in large urban centres.
2. Based on 24-hour period.
3. Based on 8-hour period

Additional information on exposure factors can be found in Section 4.5.5 of Module 4.

## 4.2.4 Toxicity assessment

Toxicity assessment involves analysing the possible effects, and acceptable intakes of the contaminants. This information has been sourced from a number of references.

Further information on toxicity assessment can be found in Section 4.2.4 of Module 4.
A summary of the health effects associated with each of the contaminants of concern can be found in Module 4 and in Appendix 4L.

## 4.2.5 Risk characterisation

Risk characterisation involves combining the outputs of the exposure assessment and the toxicity assessment to obtain an overall estimate of risk.

Calculating the level of risk that is acceptable or tolerable, in a regulatory sense, is essential to the risk assessment process. To further define the level of acceptable risk, chemical contaminants are divided into two broad groups according to their effects on human health - carcinogens and non-carcinogens.

### *4.2.5.1 Carcinogens (non-threshold[4])*

For carcinogenic contaminants an incremental lifetime risk of cancer, associated with exposure to a given chemical, is defined as follows (USEPA, 1989):

---

4 Non-threshold carcinogen - where the carcinogenic effects associated with the contaminant are evident from the lowest of doses, rather than from some threshold dose.

**Risk = CDI x SF**

| | | |
|---|---|---|
| Where | **CDI** | = Chronic Daily Intake |
| | **SF** | = Slope Factor |

The Ministry of Health has adopted an incremental cancer risk level of one in 100,000 per lifetime (one additional case of cancer per lifetime) for the derivation of similar guideline values. For the derivation of the soil screening criteria for non-threshold carcinogens a cancer risk level of one in 100,000 per lifetime has been adopted in these guidelines.

#### *4.2.5.2 Non-carcinogens*

It is common practice to consider the exposure to each substance separately. For non-carcinogens this is done using the hazard quotient (HQ). A chronic hazard quotient is defined as follows (USEPA, 1989):

$$\mathbf{HQ} = \frac{\mathbf{CDI}}{\mathbf{RfDc}}$$

| | | | |
|---|---|---|---|
| Where: | **HQ** | = | Hazard Quotient |
| | **CDI** | = | Chronic Daily Intake |
| | **RfDc** | = | Chronic Reference Dose |

Where sensitive population groups may be exposed, a HQ of one is appropriate to protect human health.

More information can be found in Module 4, Section 4.4.

### 4.2.6 Derivation of generic soil acceptance criteria

Contaminant concentrations corresponding to the target risk level have been estimated for each exposure route. The soil acceptance criteria developed are health based and are presented for each of the contaminants used for the derivation of the criteria, for specific exposure routes.

Details of the calculations underlying the health-based soil acceptance criteria can be found in Module 4 and associated appendices

The generic health-based soil acceptance criteria can be found in Module 4 as follows:

| | |
|---|---|
| Table 4.10 | Tier 1 soil acceptance criteria *Residential use* |
| Table 4.11 | Tier 1 soil acceptance criteria *Commercial/industrial use* |
| Table 4.12 | Tier 1 soil acceptance criteria *Agricultural use* |
| Table 4.13 | Tier 1 soil acceptance criteria for TPH *Residential use* |
| Table 4.14 | Tier 1 soil acceptance criteria for TPH *Commercial use* |
| Table 4.15 | Tier 1 soil acceptance criteria for TPH *Agricultural use* |
| Table 4.16 | Route specific soil acceptance criteria through INHALATION pathway *Residential agriculture use* |
| Table 4.17 | Route specific soil acceptance criteria through INHALATION pathway *Commercial use* |
| Table 4.18 | Route specific soil acceptance criteria OTHER PATHWAYS |
| Table 4.19 | Tier 1 soil acceptance criteria *Maintenance/excavation workers* |
| Table 4.20 | Soil acceptance criteria for PROTECTION OF GROUNDWATER QUALITY |

| | |
|---|---|
| Table 4.21 | Soil screening criteria for heavy-fraction TPH associated with diesel – sample calculation sand soil type/surface soils |
| Table 4.22 | Soil screening criteria for heavy fraction TPH associated with diesel *Residential use* |

### 4.2.7 Ecological considerations

Ecological considerations are an essential part in assessing the impact of contamination. Where a site is ecologically significant it may be necessary to undertake a site-specific investigation.

More information on ecological considerations can be found in Module 4, Section 4.6.and Appendix 41.

### 4.2.8 Aesthetic considerations

Some of the primary aesthetic concerns associated with contaminated soil include:

- odour
- discolouration
- changes in soil structure
- adverse effects on plant growth in a residential context.

Aesthetic impact is readily assessed on a site-specific basis, therefore generic acceptance criteria based on aesthetic impacts have not been developed.

More information on the impact of aesthetic considerations can be found in Module 4, Section 4.7.

### 4.2.9 Application of generic soil acceptance criteria

Contaminated sites vary greatly in their characteristics and in the risk they may pose to human health and the environment. Therefore it is important to adopt an approach which can be tailored to a particular site.

The use of generic acceptance criteria help and the following approach is proposed:

- The generic acceptance criteria provide an initial measure to compare with the site soil and water contamination.
- This comparison will help determine the significance of the contamination, and may be sufficient to decide a preferred course of action, particularly if the contamination is minor or easily dealt with.
- If the initial assessment indicates that the site contamination exceeds the generic acceptance criteria which could lead to a costly clean-up, more detailed field investigations and/or risk assessment may be justified (including incorporation of site-specific information in the risk assessment framework).

Generic acceptance criteria should not be regarded as fixed criteria that are not be exceeded. Frequently, site-specific considerations mean that the actual risk to human health and the environment as a specific site is substantially less than indicated by the preliminary criteria. However, generic criteria can streamline the assessment process, so that resources are not wasted in rigorously assessing contamination that is likely to pose only a very low risk. Where the preliminary criteria are exceeded, consideration should be given to completing a more detailed, site-specific assessment of the risk.

When generic acceptance criteria are used to assess the significance of soil contamination judgement must be applied, giving consideration to issues such as:

- the uncertainty in derivation of investigation levels and in sampling and analysis, so that there is not necessarily cause for concern if the investigation level is exceeded slightly
- the exact nature of the land use
- the natural barriers to exposure (paving)
- the depth of contamination
- the potential for off-site transport of contaminants
- the distribution of contamination
- whether single or multiple contaminants are involved
- the form of the contaminant and its bioavailability
- the likely duration of exposure given activity patterns at the site and the likely fate of the contaminants
- the uncertainties associated with the sampling design and any errors associated with sampling methodologies.

Primarily, the soil acceptance criteria presented are based on protecting human health. Other considerations that must be addressed include:

- ecological impacts
- aesthetic impact (e.g. odour)
- protection of groundwater quality.

Each of these considerations depends on site-specific factors and is best addressed on a site by site basis.

In applying the generic soil acceptance criteria it is important to understand how to deal with exposure to multiple contaminants, variable contamination, contamination at depth, and protection of groundwater quality. These are discussed in detail below.

#### *4.2.9.1 Exposure to multiple contaminants*

Site users may be exposed to multiple contaminants simultaneously. Where exposure to several contaminants occurs, there may be additive, synergistic or antagonistic effects. For most of the contaminants of concern, quantitative information on exposure to multiple contaminants is limited.

The following conventions may be useful in assessing exposure to multiple chemicals:

- **Carcinogens**

  Assume cancer risks are additive (for assumed non-threshold carcinogens consider as per non-carcinogens).

- **Non-carcinogens**

  If the site (i.e. target organ such as liver)of the impact and mechanism of action are similar, assume effects are additive - otherwise effects are assumed not to be additive.

#### *4.2.9.2 Variable contamination*

The pattern of soil contamination for some contaminants, such as PAHs, can be highly variable. For example, when PAHs are present in a discrete phase as particles in the soil, analysis may indicate a highly variable soil concentration. It may then be appropriate to consider the average concentration when estimating exposure, and thereby accept some higher values in localised areas. Where sampling had targeted a small patch of contamination (e.g. a visibly stained area), the contamination measurements may not be typical of the wider area of interest.

In assessing the impact of contamination on human health, consideration may be given to:

- long-term chronic effects, for which the long-term average exposure to contamination is important
- acute effects, for which short-term (hours to days) exposure may be important.

Generally chronic effects occur at much lower rates of exposure than acute effects, and therefore chronic effects and long-term average exposure are usually the limiting considerations. Hence, the risk should be assessed on the average soil (or water) concentrations across the area site users may occupy, after allowance for the uncertainty associated with the measurement of contaminant concentrations (e.g. use 95% upper confidence interval on the mean, rather than a simple mean). Concern about acute effects provides an upper limit on soil concentrations with localised areas, or "hot spots".

The following principles may be used to apply the health-based preliminary soil acceptance criteria:

- The average concentration for exposure estimation should be the reasonable maximum average concentration (e.g. as the 95 percentile upper bound of the mean).
- The area over which the averaging takes place should be based on the proposed land use:
  - For example, for residential land use an averaging area corresponding to the area of a residential backyard may be appropriate.
  - For other uses, such as for playing fields, a larger averaging area may be appropriate, such as 50 metres x 50 metres. Use of land for a railway yard may involve an even larger averaging area.
- Averaging should be used only where it can be expected that extreme concentrations of contaminants will not be present.
- Situations where a large averaging area can be responsibly applied have the potential to save considerable remediation costs, especially for larger sites where contamination is patchy, and it becomes costly to identify all of the areas of localised contamination and clean them up.
- The maximum contaminant concentration should not exceed a limit based on avoiding acute health effects, or chronic health effects should site activity patterns change so that site users spend a greater portion of their time in one section of the area over which contaminant concentrations were averaged. The National Environmental Health Forum (1996) indicates the maximum contaminant concentration should not exceed 250% of the acceptance criteria.

#### *4.2.9.3 Contamination at depth*

It is common for contamination to be present to considerable depth at oil industry sites (e.g. 3-8 metres). There is no formal policy in New Zealand on the depth to which clean-up may be required. Maximum depths of concern (with regard to the impact of soil contamination on surface use of the site) in the range of 2-5 metres have been nominated on different sites. The following principles for contamination at depth are drawn from current practice in the assessment and auditing of contaminated land:

- The depth of clean-up should be sufficient to avoid exposure or adverse effects to the site users under the range of activities which can be expected on the site, given the current land use and possible future land use (based on consideration of the surrounding land use and zoning of the site).
- The residual contamination will not affect persons or the environment off-site (e.g. through groundwater contamination).

By way of illustration, activities involving excavation to depth on residential land, which is within a predominantly residential area may be restricted to one or more of the following:

- excavation for services (typically to 2 metres)
- excavation for sewers (to 3 metres - may vary depending on the location)
- excavation for a swimming pool (to 3 metres)
- excavation for single-level basement (to 3.5 metres), if such basements occur in the area.

These various activities can involve digging up material from a depth and spreading it over the site, and thus there is potential for future exposure to the contamination present at depth.

Based on the above depths it may be possible to allow significant contamination on a particular residential property to remain at or below 3 - 3.5 metres, especially if the nature, extent and concentration of the contamination would not pose a major concern in the future if the material were to be dug up unexpectedly.

An approach to assessing the significance of contamination at depth is:

- Contamination in near surface soils (i.e. within the range typically encountered in day-to-day activities, say, 0 - 1.0 metres) should comply with criteria based on direct contact by humans, and a range of other considerations (e.g. plant life, aesthetics).
- Contamination of soil between the depth commonly encountered (1.0m) and the reasonable maximum depth likely to be disturbed by excavation (3.5m) is assessed using criteria based on direct contact with contaminated soil in conjunction with an adjustment factor to reflect the probability that the soil would be excavated and spread around (may typically range from 2 - 10 metres, on a conservative basis depending on depth).
- Contamination at depths greater than that likely to be disturbed by excavation should be assessed on the basis of protecting groundwater quality and protecting deep foundations from chemical attack.

The following considerations should be applied in addition to those outlined above:

- No soil within the zone where excavation is possible should pose an immediate (acute) concern to human health.
- The depth of groundwater and geological characteristics of the site will dictate whether soil contamination at depth will affect groundwater quality.
- Where volatile contaminants may be of concern, the impact of volatilisation of contamination at depth and migration to indoor or outdoor air, and the consequent impact on human health or site amenity (odour) should be considered.

#### *4.2.9.4 Protection of groundwater quality*

The protection of groundwater quality, consistent with the current and likely future uses of the groundwater, must be considered when assessing the significance of soil contamination at a site. The relationship between soil contamination and groundwater quality is complex. Some of the considerations include:

- nature of the chemical (solubility, $K_{oc}$)
- unsaturated zone characteristics (organic carbon content, permeability)
- recharge characteristics (e.g. net infiltration rate)
- aquifer properties (e.g. salinity, yield, hydraulic conductivity, hydraulic gradient)
- discharge characteristics (distance to point of discharge, nature of receiving water).

## 4.3 Application of Tier 1 soil acceptance criteria

- **Step 1 - Comparison with Tier 1 Acceptance Criteria for Combined Pathways**

Measured contaminant concentrations at a site may be compared with the Tier 1 acceptance criteria for BTEX and PAH chemicals for Residential, Commercial, Industrial and Agricultural land uses, as presented in Tables 4.10 to 4.12 of Module 4. Criteria for a number of soil types are presented, requiring the assessor to determine which of the generic soil types best reflect the conditions present on-site. A superscript on each criterion identifies the limiting pathway.

Tables 4.13 to 4.15 of Module 4 present Tier 1 acceptance criteria for TPH in diesel for all land uses. The intention is that the primary assessment of the condition of a site will be made based on comparison of TPH and BTEX concentrations with relevant criteria. The TPH criteria are intended primarily as an alternative approach where either BTEX or PAH analyses have not been undertaken. In the case of a diesel release, in the first instance TPH may be used as a surrogate measure of the risk associated with PAH contamination.

The criteria in Table 4.10 are based on produce consumption of 10% home-grown, consistent with a typical urban residential development. In the case of a rural residential development, the proportion of produce home-grown is more likely to be in the order of 50%. If a site may be regarded as rural residential, the assessor should proceed to Step 2.

If the contaminant concentrations in the soil on-site are less than the relevant acceptance criteria, then no further work is required on a human health risk basis. However, further consideration should be given to ecological assessment, aesthetic impact and to groundwater protection (refer Step 8).

It should be noted that criteria for pyrene are presented on the basis that it is a representative of lower volatility (compared to naphthalene) non-carcinogenic PAHs. Similarly, benzo(a)pyrene is considered as a representative of the carcinogenic PAHs in fuel. Refer to Section 4.4.3 of Module 4 for a discussion of benzo(a)pyrene equivalent concentrations and the use of Toxic Equivalent Factors (TEFs).

- **Step 2 - Review of Exposure Pathways**

A review of exposure pathways relevant to the site should be undertaken. If the future use of a site is known, then based on the review of exposure pathways, some of the pathways considered in the derivation of the Tier 1 criteria presented in Tables 4.10 to 4.15 (Module 4) may not be complete and therefore less stringent criteria may be applicable. For example, it may be known that a residential site will become a block of flats where consumption of home grown produce is not likely to be a relevant pathway.

Pathways considered in the derivation of Tables 4.10 to 4.15 include:

- volatilisation
- protection of maintenance and excavation workers for surface soils and soil at depths of 1 - 4 metres
- soil ingestion
- dermal contact
- consumption of home grown produce.

Tables 4.16 to 4.19 (Module 4) present Tier 1 acceptance criteria derived for individual pathways or exposure scenarios. For residential properties, produce ingestion must be selected for the appropriate scenario: urban residential (10% home-grown produce), rural residential (50% home grown produce). Agricultural sites have been derived on the basis of 100% home-grown produce.

After all of the relevant pathways have been reviewed, the lowest route-specific acceptance criteria is selected for comparison with the contaminant concentrations[5].

- **Step 3 - TPH Surrogates for PAH Contamination in Diesel Fuel**

The Tier 1 acceptance criteria presented in Tables 4.13 to 4.15 (Module 4) include consideration of the use of TPH as a surrogate measure of the risk associated with PAH contamination of soil resulting from diesel fuel. The Tier 1 acceptance criteria for TPH as derived in Tables 4.21 and 4.22 (Module 4) and as presented in Tables 4.13 to 4.15 correspond to the acceptable concentration of naphthalene and other non-carcinogenic PAHs in diesel fuel (refer Section 4.8.3 of Module 4).

If individual PAH concentrations are measured or TPH is not expected to be the limiting consideration for remediation, then use of a TPH surrogate is not necessary, and the route-specific Tier 1 acceptance criteria presented in Tables 4.16 to 4.19 (Module 4)may be used to assess potential health risk.

If the measured heavy fraction TPH has not resulted from a diesel release (e.g. release from a waste oil tank), the Tier 1 acceptance criteria for TPH, based on criteria for PAHs (i.e. using TPH as a surrogate), are not applicable and PAH concentrations should be measured directly.

- **Step 4 - Selection of TPH Surrogate Concentration**

Table 4.22 presents the calculated TPH acceptance criteria where TPH is to be used as a surrogate for PAHs, for all land uses and soil depths. The TPH fraction $C_{10}$-$C_{14}$ is used as a surrogate for naphthalene and the TPH fraction $C_{15}$-$C_{36}$ is used as a surrogate for pyrene and heavier PAHs. These are based on the Tier 1 acceptance criteria for naphthalene and pyrene in Tables 4.10 to 4.12. All pathways have been considered in the derivation of Table 4.22..

If the selected surrogate TPH criteria have been derived from a pathway that is not relevant to the specific site (note the superscripts indicate the limiting pathway), then consideration should be given to deriving a revised Tier 1 TPH criterion (refer Step 5). Otherwise, the TPH surrogate is accepted as another limiting criteria (go to Step 6).

- **Step 5 - Selection of a Revised TPH Criterion as a Surrogate for PAH in Diesel Fuel**

In response to Step 2 (Review of Exposure Pathways) revised Tier 1 acceptance criteria may be nominated for PAHs. Given that the Tier 1 acceptance criteria for TPH are based on the PAH criteria, any change in the relevant exposure pathways, should be reflected in revised criteria for TPH.

Naphthalene and pyrene Tier 1 acceptance criteria may be revised using Step 2 of this procedure. The revised PAH acceptance criteria are then used to calculate the TPH surrogate acceptance criteria using the example calculation presented in Table 4.21.

- **Step 6 - Selecting Revised Tier 1 Acceptance Criteria**

For BTEX, PAHs and TPHs the limiting acceptance criteria (lowest) based on the considerations outlined above is defined as the revised Tier 1 acceptance criteria. For TPH criteria this includes the surrogates for the protection from PAHs in diesel (only if applicable).

[5] It may be argued that the criteria for the remaining complete exposure pathways should be combined in such a way as to reflect the risk resulting from exposure via the combined pathways. In practice, rarely are more than one or two exposure pathways significant contributors to the overall risk and hence use of the lowest route-specific criteria is unlikely to significantly underestimate the risk.

- **Step 7 - Comparison of Revised Tier 1 with Measured Contaminant Concentrations**

The revised Tier 1 acceptance criteria may be compared with contaminant concentrations on site in soil. If the contaminant concentrations in the soil on site are below the revised Tier 1 acceptance criteria, then no further work is required on a human health risk basis. However, further consideration should be given to aesthetic impacts and to groundwater protection (refer Step 8).

If the measured contaminant concentrations exceed the Tier 1 acceptable criteria, then the available options include:

- consideration of a Tier 2 analysis or,
- remediation of the site to Tier 1 acceptable concentrations.

The cost-benefit considerations for this decision are discussed in Module 1.

- **Step 8 - Protection of Groundwater Quality**

Table 4.20 (Module 4) presents Tier 1 soil screening criteria protective of groundwater quality for:

- a range of soil types
- various combinations of the depth to the contaminated soil layer and groundwater
- potable water quality.

The Tier 1 soil screening criteria for protection of groundwater quality are only an indication of the possible impact of soil contamination acting as a source for groundwater contamination.

If the measured soil concentrations exceed the Tier 1 soil screening criteria for the protection of groundwater quality, then a Tier 2 assessment may be warranted, depending on the results of any groundwater monitoring undertaken as part of the Tier 1 assessment.

# 4.4 Generic groundwater acceptance criteria

## 4.4.1 Groundwater and surface water uses

The significance of water contamination depends on the uses and values of the water resources which are to be protected. Defining the potential uses of the water is an integral step in assessing water contamination. The following uses have been adopted for developing generic water acceptance criteria:

- potable
- stock watering
- irrigation
- aquatic ecosystem protection.

### *4.4.1.1 Potable use*

Guidelines for potable water generally consider:

- the protection of public health
- the aesthetics, including taste and odour
- the protection of the water supply assets (for example, corrosion of pipework).

The New Zealand Drinking-Water Standards (NZDWS) are used for most contaminants. However, in the absence of NZDWS values for any of the contaminants, the risk assessment approach is used.

The assumptions used in deriving the water acceptance criteria (Table 4.6) are the same as those used for deriving the NZDWS.

**Table 4.6 Assumptions for deriving water acceptance criteria for potable use**

| | Assumption |
|---|---|
| Water consumption rate | 2 L/day |
| Body weight | 70 kg |
| Proportion of RfD[6] assigned to drinking water | 0.1 |

More information on potable use can be found in Module 5, Section 5.3.

### *4.4.1.2 Stock watering use*

Development of acceptance criteria for stock water use may include:

- protection of stock health via the consumption of livestock products
- protection of human health
- palatability of water for stock.

The derivation of the criteria for stock water used is based on protecting stock health. The derivation is similar to that provided for potable use.

***Protection of stock health***

Cattle have been selected as representative of livestock since they exhibit a relatively high water consumption per unit body weight.

The following are assumed in deriving the stock water criteria:

- Cancer is not a relevant end point for cattle, given their relatively short lifespan compared with humans.
- Full protection of sensitive sub-populations is not required.

More information on stock watering use can be found in Module 5, Section 5.4 and Appendix 5C.

### *4.4.1.3 Irrigation use*

Water acceptance criteria for irrigation use are based on spray irrigation in a domestic setting. In this case, dermal absorption by children is considered to be the limiting factor. The following processes have been considered in deriving irrigation water criteria:

- contaminant loss by volatilisation due to spray irrigation
- inhalation of vapours and aerosols by site users
- dermal absorption and ingestion of water by children playing under sprinklers
- uptake of contaminants applied in irrigation water by plants, and consumption of home-grown produce (assume 100% of produce would be home-grown, to protect the general public in the absence of Maximum Residue Levels (MRLs).

In deriving the criteria, the following conservative assumptions have been made:

- no leaching or volatile losses of contaminants once they have entered the soil
- no metabolism or degradation of contaminants within the plant.

More information on irrigation use can be found in Module 5, Section 5.5 and Appendix 5A.

6 For information on the reference doses (RfDs) for contaminants, refer to Module 4 Appendix 4L .

#### *4.4.1.4 Aquatic ecosystem protection*

Currently there is no definitive guidance on the protection of aquatic ecosystems in New Zealand. The ANZECC guidelines (ANZECC/NHMRC, 1992) are under revision with input from the Ministry for the Environment. The draft revised guidelines should be available in the second half of 1999. In the interim, international guidelines values are provided for reference.

More information on aquatic ecosystem use can be found in Module 5, Section 5.6.

## 4.4.2 Application of generic water acceptance criteria

The water acceptance criteria have been developed principally on the basis of use. Water quality criteria may be sub-divided into direct uses (potable, stock watering) and indirect uses (ecosystem support) of groundwater.

#### *4.4.2.1 Direct use of groundwater*

If the aquifer is useable, groundwater contamination should be assessed on the impact on the potential use of the groundwater. Criteria pertaining to direct uses may be applied:

- to groundwater at the site boundary, or
- at some point further down gradient on the site, if use of groundwater in the immediate vicinity of the site is unlikely.

When assessing the risk consideration needs to be given to:

- assessing contaminant concentrations at the nearest current point of use of groundwater or
- assessing contaminant concentrations at the nearest point at which the water is likely to be used, and
- attenuation, degradation and dilution between the source and the point of use or potential use which may reduce the risk.

If groundwater use is probable and the acceptance criteria are exceeded at the point of use, groundwater clean-up, or removal of the source of contamination, could be required.

#### *4.4.2.2 Indirect use of groundwater*

Aquifers that are not of sufficient quality or yield to be used directly may discharge into a river or other body of surface water affecting its quality. Where this happens, the water quality should be assessed against preliminary acceptance criteria for the protection of aquatic ecosystems, or for other uses of the river.

When assessing the risk consideration needs to be given to:

- dilution which may prevent the criteria being exceeded in the water column
- groundwater clean-up or interception and treatment if river flow is small compared with the groundwater flow
- localised mixing zones, if the groundwater discharges to a river or lake through defined seeps at or above the water surface
- if the groundwater discharges into a water body, turbulence will usually mix the water body rapidly and completely
- protecting benthic organisms in sediments
- dilution and attenuation between the point of measurement and point of impact.

## 4.5 Developing site-specific soil and water acceptance criteria

Where contaminant concentrations at a site exceed the generic acceptance criteria, more detailed consideration of the significance of contamination on a site-specific basis, including the development of site-specific acceptance, may be warranted.

The health and environmental impacts of soil and groundwater contamination depend heavily on site-specific conditions that affect the exposure of human and ecological receptors to contamination.

The development of site-specific soil acceptance criteria focuses primarily on the exposure assessment component of risk assessment. This step has the greatest potential for variation between sites. The toxicological assessment of contaminants is site independent, with the possible exception of synergistic and antagonistic effects, and bioavailability (although this can be included in the exposure assessment component).

In developing site-specific acceptance criteria, the risk assessment procedures may be used in conjunction with site-specific exposure factors. Alternative site-specific exposure factors should be clearly documented and justified.

### 4.5.1 Refining exposure assessment

Site-specific information may be incorporated as follows:

- revising default exposure factors such as exposure duration, time spent outdoors, and soil ingestion rate, to reflect the conditions, receptors and activity patterns at the site being assessed, given the land use to be considered
- refined assessment of the fate and transport of contaminants, taking into account information regarding conditions at the site (e.g. soil type, depth to groundwater).

The significance of soil and groundwater contamination depends on contaminant concentrations in environmental media to which receptors (both human and ecological) may be exposed. The development of generic soil acceptance criteria involves simplified, conservative modelling of the volatilisation of contaminants and plant uptake of contaminants. Exposure estimates may be refined by directly measuring contaminant concentrations in relevant exposure media, including:

- indoor and outdoor air
- home-grown fruit and vegetables
- surface water and sediments (where discharge of contaminated groundwater is suspected).

Site-specific groundwater acceptance criteria may be developed by estimating attenuation between the site and the point of impact. Groundwater fate and transport modelling can be used to predict such attenuation. Groundwater fate and transport can be modelled at varying levels from simple analytical one-dimensional models accounting for advection and dispersion only, to detailed two- and three-dimensional numerical models including advection, dispersion, biodegradation, adsorption and separate phase organic liquids. Groundwater fate and transport modelling should be:

- undertaken at a level consistent with the available input data
- directed towards addressing specific issues of concern in the overall decision-making process for the site
- consistent with observations at the site over time (if possible).

# 5 Site management

## 5.1 Introduction

The objective in managing sites contaminated by petroleum hydrocarbons is to minimise the risk to human health and the environment. The range of site management options include:

- land use controls - controlling the use of land to avoid or limit the exposure to contaminants
- management controls - preventing activities that may result in unacceptable exposure
- intrinsic remediation/natural attenuation - leaving the contamination in place and letting it degrade over time
- containment - placing a barrier between the contamination and receptors
- remedial treatment systems - removing the contaminants
- disposal to landfill - removing the contaminants from the site and placing in a secure landfill
- monitoring - monitoring the movement of contamination to determine whether migration could lead to unacceptable risk.

## 5.2 Site management issues

When managing a site the following factors need to be considered:

- Underground structures may be present on site.
- Backfill materials may need to be removed and replaced with engineered fill. Removing the backfill may pose a health and safety risk for site workers.
- Dust and odours may be generated from work on site that could pose a human health risk and be a nuisance off-site.

## 5.3 Evaluation, selection and implementation of site management options

### 5.3.1 Evaluation

Site management options should be evaluated primarily on their ability to reduce risk, and then on their cost-effectiveness and the future site utility. The risks include those to site users, the general public, and the environment, during and after implementation of the management strategy.

Also important in evaluating site management options are:

- timing - if a site management option could take a long time to reduce contaminant concentrations, what are the risks to human health and the environment in the intervening period?
- failure - if the contamination is contained in situ, what will happen if the containment system fails?
- off-site disposal - if the contaminants are to be disposed of off-site what risks are associated with moving the contaminants?

### 5.3.2 Selection

The most appropriate management and remedial option(s) for a particular site should only be selected after the following have been determined:

- type and nature of contamination
- chemical and physical properties of the contaminants
- site-specific geology and hydrogeology
- lateral extent and depth of contamination
- potential for off-site migration, identification of migration pathways and receptors
- likely future use of the site and clean-up levels required
- resource consent requirements
- anticipated remediation project cost and project timing
- regional or national remediation and disposal infrastructure.

The site management options should also consider:

- workers
- the surrounding environment and neighbouring populations during and after implementation of the site management or remediation strategy
- future users of the site
- risks to human health and the environment when wastes are disposed off-site.

No one single remedy represents the optimal selection for all sites or all contaminant waste streams. The various waste streams, including contaminated soil, building rubble, and contaminated groundwater, may require different waste treatment or management strategies.

At each site, the remedial system design must:

- evaluate the practicality of using a specific remedial option
- attempt to evaluate the cost
- assess the problems that may be associated with that option
- assess the time frame for the treatment.

### 5.3.3 Implementation

Some of the concerns associated with implementing site remediation or containment options include:

- generating odours and volatile emissions from excavated soil. Such releases would only be a health risk in the immediate vicinity of the works (i.e. primarily an occupational issue) but odour impacts may extend further off-site
- generating contaminated dust through earthworks and traffic within the site area. Such dust releases may affect the public around the site
- air emissions resulting from soil or groundwater treatment systems such as thermal desorption, vapour extraction, and groundwater stripping
- transporting contaminated soils, tars and other waste materials through populated areas en route to landfill disposal or off-site treatment

- treatment of the wash water from truck movement off-site
- occupational exposure to high level wastes.

A range of strategies is available to minimise some of these concerns, and any remediation strategy should aim to minimise the risks.

# 5.4 Legislation

## 5.4.1 The Resource Management Act 1991

The purpose of the Resource Management Act 1991(RMA) is to promote the sustainable management of natural and physical resources. The RMA is the principal statute for the management of land, air, water, soil resources, subdivision of land, the coast, and pollution control. It clearly sets out the resource management responsibilities of individuals, territorial authorities, regional councils and the government. It sets up a system of policy and plan preparation and administration, including the granting of resource consents, which allows the balancing of a wide range of interests and values.

The provisions of the RMA relating to discharges to land, air and water, and the control of the use of land, are of most relevance in managing contaminated sites. Section 30 of the RMA requires regional councils to control discharges of contaminants into or onto land, air or water. They must also control the use of land in order to prevent or mitigate the adverse effects of the storage, use, disposal, or transportation of hazardous substances.

Section 31 of the RMA requires territorial authorities to control any actual or potential effects of the use, development, or protection of land, which includes preventing or mitigating any adverse effects of the storage, use, disposal, or transportation of hazardous substances.

### *5.4.1.1 Resource consent requirements*

A number of resource consents may be required for managing a contaminated site. They include:

- a discharge consent from the regional council for discharges into or onto land, air or water
- a land use consent from the territorial authority

Resource consents may be necessary at various stages in the site assessment and management process. It is important to contact the regional council and the territorial authority to determine what their particular requirements are, since these may vary throughout the country.

## 5.4.2 The Health Act 1956

Sections 29 to 35 of the Health Act provide that in certain cases where a nuisance is being caused within the meaning of the Act, an owner or occupier of the premises can be required to abate the nuisance. The primary responsibility for enforcing these provisions rests with the territorial local authority. In the event that the person creating the nuisance fails to comply with an abatement request there are legal remedies available.

A prosecution may be taken for failing to abate a nuisance. The prosecution may result in an order from a District Court judge requiring an owner or occupier of the premises to abate the nuisance effectively; prohibit the recurrence of the nuisance; both abate and prohibit the recurrence of the nuisance; or to carry out specified works to abate or prevent a recurrence of the nuisance.

If there is default in complying with an order, the territorial local authority, or the Medical Officer of Health on behalf of the territorial local authority, may carry out any works at the expense of the owner and occupier. The costs are deemed to be a charge on the land.

In instances where, in the opinion of the Engineer or Environmental Health Officer of a territorial local authority, immediate action for the abatement of a nuisance is necessary, those officers may, without notice to the occupier, enter the premises and abate the nuisance. Any costs incurred are recoverable as a debt from the owner or occupier.

### 5.4.3 The Building Act 1991

The Building Act also addresses site contamination but only where there is an intention to carry out building work. The purpose of the Act is to provide controls relating to the building work and the use of buildings to ensure that buildings are safe and sanitary. Under the associated Building Code F1 *Hazardous Agents on Site*, the objective is to safeguard people from injury or illness caused by hazardous agents or contaminants on a site. The Act requires that buildings shall be constructed to avoid the likelihood of people within being adversely affected by hazardous agents or contaminants on site. Code F1 requires that sites be assessed to determine the presence and potential threat of any hazardous agents or contaminants. The likely effect of these is to be determined taking account of:

- the intended use of the building
- the nature, potency or toxicity of the hazardous agent or contaminant
- the protection provided by the building envelope and building systems.

### 5.4.4 The Health and Safety in Employment Act 1992

The purpose of this Act is to prevent harm to employees and other people (e.g. visitors, contractors) while they are in a workplace. All organisations are required to comply with the minimum standards outlined in the Act. To do this, employers need to take all practicable steps to maintain a safe working environment. These include:

- minimising, isolating, or eliminating the hazards (or potential hazards)
- training staff in safe work practices
- ensuring employees are not exposed to hazards in the course of their work
- informing staff of what to do in an emergency.

Employees are also encouraged to be responsible and look after their own, and others, safety and health at work. Ways of doing this include:

- observing safe work practices
- following instructions given to them by their managers
- taking responsibility for their own and others safety and health in a workplace.

## 5.5 Site management options

The site management options considered in these guidelines include:

- land use controls
- management controls
- intrinsic remediation (natural attenuation)
- containment

- remedial treatment systems
- disposal to landfill
- monitoring.

It is important to note that the regional council and territorial authority should be involved in the site management process as early as possible. They will be able to provide guidance and advice on regulatory requirements.

### 5.5.1 Land use controls

Controlling the future use of a site to permit only less sensitive uses is one way of avoiding or reducing exposure to contaminants, and therefore enables higher contaminant concentrations to remain on site e.g. redevelopment of a site for commercial use rather than residential use. If significant contamination is allowed to remain on site, it must be shown that the contamination will not cause an unacceptable risk to human health and the environment. The land use controls available include:

| | |
|---|---|
| **Land Information Memoranda & Project Information Memoranda** | • Land Information Memoranda, issued under the Local Government Official Information and Meetings Act 1987, and Project Information Memoranda, issued under the Building Act 1991, can be used to release information on site contamination to interested parties. |
| **District plan** | • Structures or activities such as basements or pools, or their construction, can be controlled using the district plan. |
| **Regional plan** | • Activities on a contaminated site could be controlled through a regional plan. |
| **Memorandum of encumbrance** | • The memorandum creates a nominal mortgage in favour of the local authority and can be made binding on successors in title. It acts as a notification to those searching the title prior to purchase. The memorandum can be used as a condition of a resource consent. |
| **Notation on a district plan** | • A notation can be placed on the district plan identifying a site as being contaminated. This can be initiated by an individual, company or council. |

### 5.5.2 Management controls

Management controls are usually required where contamination is to be left on-site at depth or under structures or paving. Controls are necessary to avoid uncontrolled excavation in the future which could result in the contamination being exposed. Imposing management controls acknowledges that the land is not suitable for uncontrolled use.

An example of a management control may be the requirement that any subsurface maintenance work that involves penetrating the pavement in a contaminated area is conducted in accordance with a designated protocol and that appropriate health and safety precautions are implemented. For example, any excavations and re-use or disposal of material must be done in accordance with management protocols.

Management controls will usually be placed on a site by a local authority.

### 5.5.3 Natural attenuation

Natural attenuation relies on natural processes to reduce the levels of contamination, including:

- biological degradation of organic contaminants by indigenous bacterial populations
- volatilisation of volatile organic compounds and passive dispersion to the atmosphere
- dispersion and dilution of contaminants
- photodegradation of contaminants at the ground surface.

Intrinsic remediation is generally only applicable where human health and environmental risks are low and natural site conditions and processes result in the reduction of contaminants.

### 5.5.4 Containment options

Containment focuses on mitigating risk by placing a barrier between the source of contamination and the receptor, and by avoiding further migration of the contamination.

To be effective, containment systems should:

- provide sufficient separation of receptors and contamination to ensure risk reduction
- have sufficient durability to ensure the required performance
- control movement of contaminants
- reduce or prevent rainfall infiltration, which might otherwise increase contaminant leaching and off-site migration
- be resistant to erosion or slope instability
- be resistant to subsidence
- include appropriate management and monitoring systems.

Containment systems include:

- capping systems to reduce infiltration and direct contact between site users and the contaminated materials
- cut-off walls to prevent further lateral migration of contaminants
- interception trenches to reduce migration of contaminated groundwater
- construction of an on-site repository.

### 5.5.5 Remedial treatment systems

Remedial treatment systems for petroleum hydrocarbons include the following:

- off-site disposal, where the contaminants are removed from the site and disposed of in a appropriately designed landfill
- soil vapour extraction and sparging techniques used together to treat contaminated soil, groundwater, vapour and free product
- bioremediation, where the contaminant degradation is stimulated by the naturally occurring microorganisms in the soil and groundwater. Oxygen and nutrients are often added to stimulate biodegradation. This can be done either in situ or off-site.

- thermal desorption, where the soil is heated to approximately 450ºC in a rotary kiln or retort. The volatile contaminants are then destroyed in an afterburner
- incineration using mobile on-site incineration or cement kilns.
- groundwater treatment either in situ or off-site.

### 5.5.6 Disposal of contaminants to landfill

The Oil Industry Environmental Working Group is currently investigating landfill acceptance criteria for petroleum hydrocarbon contaminated materials as part of the Hazardous Waste Programme. In the interim, determination of whether a particular material contaminated by petroleum hydrocarbons can be landfilled, with minimal adverse effects, can be assessed using the steps as follows:

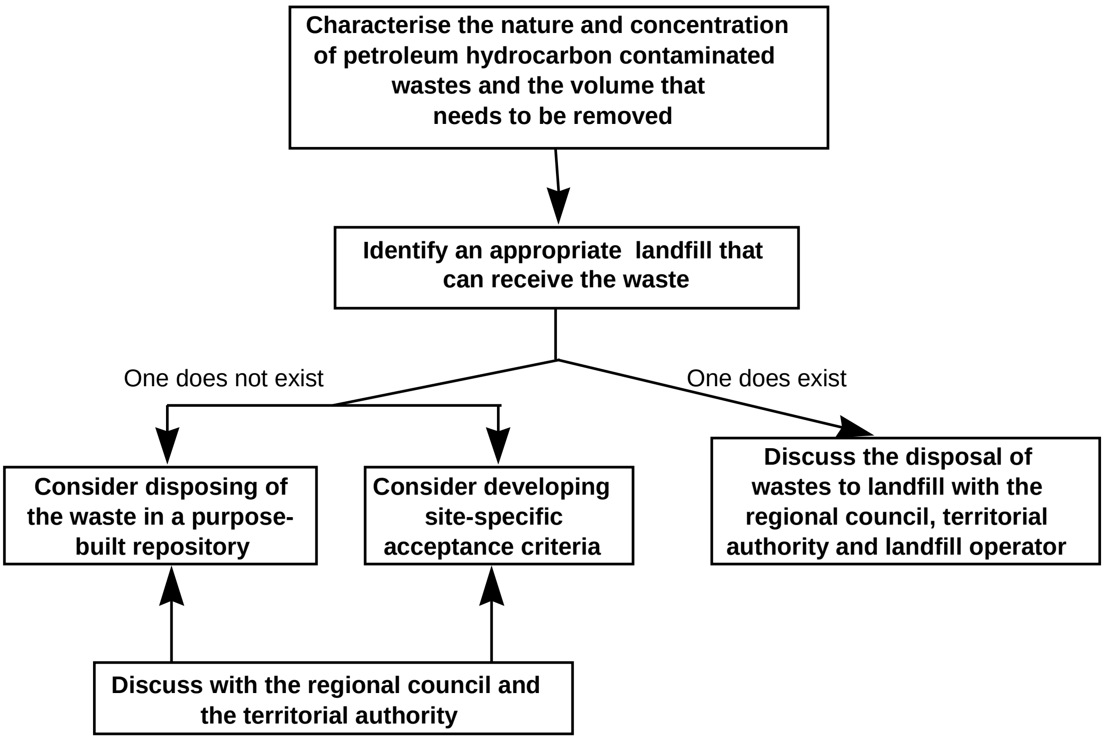


**Figure 5.1 Assessing suitability of landfill disposal**

### 5.5.7 Monitoring

Monitoring programmes may be implemented at various stages of site management and for a number of reasons, for example:

- to establish seasonal variations in groundwater flow and quality and to assist in deciding whether remedial works are necessary, and to determine the most appropriate method of remediation
- to determine remediation progress, and to demonstrate that remedial works have been effective and there are no adverse effects
- to monitor dust prior, during and after remediation to ensure that adverse effects are not occurring.

## 5.6 Site management plan

The site management plan is a summary, operational document designed to focus attention on the key issues associated with site management. The site management plan should provide statements on the following:

- site history
- the condition of the site, including contaminants of concern
- impact on on-site and off-site receptors (both human and environmental)
- current restrictions regarding use of the site
- site management controls necessary in the context of the current or proposed site use
- deficiencies in the current information and the need for additional investigation to facilitate decision-making
- risk mitigation or management requirements for site redevelopment
- requirements for ongoing monitoring
- any ongoing regulatory controls and reporting requirements
- the definition of the responsibilities for implementing and auditing ongoing management controls and monitoring.

### 5.6.1 Ongoing site management

One of the most important functions of the site management plan is the definition of responsibilities for future management of the site. This may range from responsibility for the design and implementation of further investigation or site remediation works, to responsibility for implementing an ongoing risk management strategy. Some of the important considerations in defining responsibilities include:

- responsibility for maintaining restrictions on site use, particularly following a number of sequential property transfers
- responsibility for ensuring controls on site activities are maintained (e.g. paving is maintained indefinitely as part of a medium or high density residential use, or personal protective equipment is worn by workers involved in sub-surface works)
- responsibility for maintaining and operating containment systems (e.g. capping, groundwater interception trenches)
- responsibility for conducting and reporting monitoring results.

# 6 References

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