Guidelines for Assessing and Managing Contaminated Gasworks Sites in New Zealand

Part One: Users' Guide

Part Two: Supporting Technical Information (on disk)

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MINISTRY FOR THE ENVIRONMENT
MANATŪ MŌ TE TAIAO

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Part One: Table of contents

Part two: Table of contents

Module 5 Generic acceptance criteria for groundwater and surface water

Appendices

Module 6 Site management

Please note:

Guidelines for Assessing and Managing Contaminated Gasworks Sites in New Zealand

Part One: Users' Guide

Background

In December 1996 the Ministry for the Environment released the Draft Guidelines for the Management of Contaminated Gasworks Sites in New Zealand for consultation. During the submission period, workshops were held in Auckland, Wellington and Christchurch to introduce and discuss the guidelines. The structure and content of this guideline incorporates the views of submitters and workshop participants.

The guideline has been separated into two parts - this Users' Guide, and Supporting Technical Information (on disk).

This Users' Guide provides a summary of the steps involved in assessing and managing contaminated gasworks sites in New Zealand. This includes a discussion of why we are concerned about gasworks sites, site sampling and assessment processes, generic soil and water acceptance criteria, and site management.

The technical information which forms the basis for most of the guidelines, has been condensed from the original draft guidelines and can be found on the disk accompanying this document.

Acknowledgments

Input into this document has come from a number of people. Of special mention are the members of the National Steering Committee who helped the Ministry for the Environment prepare this guideline. The members were as follows:

- Martin Ward — Independent Environmental Adviser (formerly of the Natural Gas Corporation)
- John Sherriff — Wellington Regional Council
- Roger Matthews — Auckland City Council
- Stuart McLaren — Ministry of Health

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I would also like to acknowledge the help of those who provided peer review comments on the draft guidelines and the Users' Guide:

- Peter Burrows — Gisborne District Council
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- Joe Lenihan — Ministry for the Environment
- Simon Hunt — Caltex New Zealand Limited

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Contaminated Sites Group

Abbreviations

ADI	Acceptable daily intake
AGA	Australian Gas Association
ANZECC	Australian and New Zealand Environment and Conservation Council
APHA	American Public Health Association
ASTM	American Society for Testing and Materials
B(a)P	Benzo(a)pyrene
BTEX	Benzene, toluene, ethylbenzene, xylene
CCME	Council of Canadian Ministers for the Environment
CDI	Chronic daily intake
DNAPL	Dense non-aqueous phase liquid
DOE	Department of the Environment
DQI	Data quality indicators
DQO	Data quality objectives
EM	Electromagnetic
EPRI	Electric Power Research Institute
EQL	Estimated quantitation level
GRI	Gas Research Institute
HASP	Health and safety plan
HQ	Hazard quotient
K_{oc}	Partition coefficient for octanol-water, corrected for organic carbon
K_{ow}	Partition coefficient of octanol-water
LNAPL	Light non-aqueous phase liquid
LOEL	Lowest observable effect level
MAV	Maximum acceptable values
MDL	Method detection level
MfE	Ministry for the Environment
MoH	Ministry of Health
MRL	Maximum residue levels
NHMRC	National Health and Medical Research Council
NOEC	No observable effect concentration
NOEL	No observable effect level
NSW EPA	New South Wales Environment Protection Agency
NZDWG	Guidelines for Drinking Water Quality Management in New Zealand
NZDWS	New Zealand Drinking Water Standards
OSH	Occupational Safety and Health
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyls
PID	Photoionisation detector
PPM	Parts per million
PTWI	Provisional tolerable weekly intake
PVC	Poly vinyl chloride
QAP	Quality assurance plan
QA/QC	Quality assurance/quality control
RfD	Reference dose
RfDc	Chronic reference dose
RM Act	Resource Management Act 1991
RME	Reasonable maximum exposure
SF	Slope factor
TCLP	Toxicity characteristic leaching procedure
TEFs	Toxic equivalence factors
USEPA	United States Environmental Protection Agency
Vic EPA	Victoria Environment Protection Agency
WHO	World Health Organization

1

Gasworks sites - what to expect

1.1 Introduction

There are believed is be approximately 54 gasworks sites in New Zealand. Between the late 1800s and 1988 gasworks were a familiar sight in towns and cities throughout New Zealand. During this time the production of gas from coal was a major source of fuel for heating, cooking and lighting.

With the setting up of a national natural gas reticulation system during the 1970s and 1980s, these gasworks were gradually closed.

The manufacturing process generated a number of by-products and wastes, such as coal tar, spent oxide, purifier waste, ash and clinker. These wastes have a number of substances within them that are potentially hazardous to human health, for example, phenols and polycyclic aromatic hydrocarbons (PAHs) in tar, cyanide and sulphides in spent oxide, and heavy metals in ash and clinker. Many of these wastes were disposed of both on and off site. In addition, when many of the sites were closed, underground structures containing many of these contaminants were left.

The environmental legacy of gas manufacturing is now becoming apparent in New Zealand and has highlighted the importance of providing guidance to those who are involved in the management of these sites. These guidelines, and the supporting technical information, are designed to provide those with an interest in contaminated gasworks management with information on assessing and managing soil and water contaminated by gasworks waste.

A risk-based approach has been adopted in the guidelines. It is hoped that this approach, if properly implemented, will facilitate a flexible approach to site assessment and management, focusing on the issues that pose the greatest risk to human health and the environment.

This Users' Guide provides a summary of the assessment and management of contaminated gasworks sites in New Zealand. More detailed technical information can be found on the disk accompanying this guide.

This first section covers the following aspects of site assessment:

- ➔ the status of these guidelines
- ➔ the suggested layout of gasworks sites based on historical information
- ➔ the contaminants of concern
- ➔ the waste products associated with the contaminants and sources of contamination
- ➔ patterns of contamination found at gasworks sites

1.2 Status of these guidelines

These guidelines, and the accompanying supporting technical information on disk, have no statutory effect and are 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.

The sections references contained in this publication cite only the principal relevant provisions of the legislation - they are not intended to provide a comprehensive index of all the relevant sections that may have a bearing on the matters covered in the preceding text.

Additional information on the characteristics of gasworks sites and the nature of contamination can be found in Module 1 on disk, including

- ▲ historical background (Section 1.1)
- ▲ the gas production processes (Section 1.2)
- ▲ the major process units (Section 1.3)
- ▲ the fate and transport of gasworks contaminants (Section 1.4)

1.3 Suggested site layout

Many gasworks sites were located near ports, rivers and railways, as this was how the coal feedstock was delivered. They were also generally laid out in a similar way. Figure 1.1 shows the common layout for a gasworks. This layout may provide some useful information for site assessment where there are few details about a particular site.

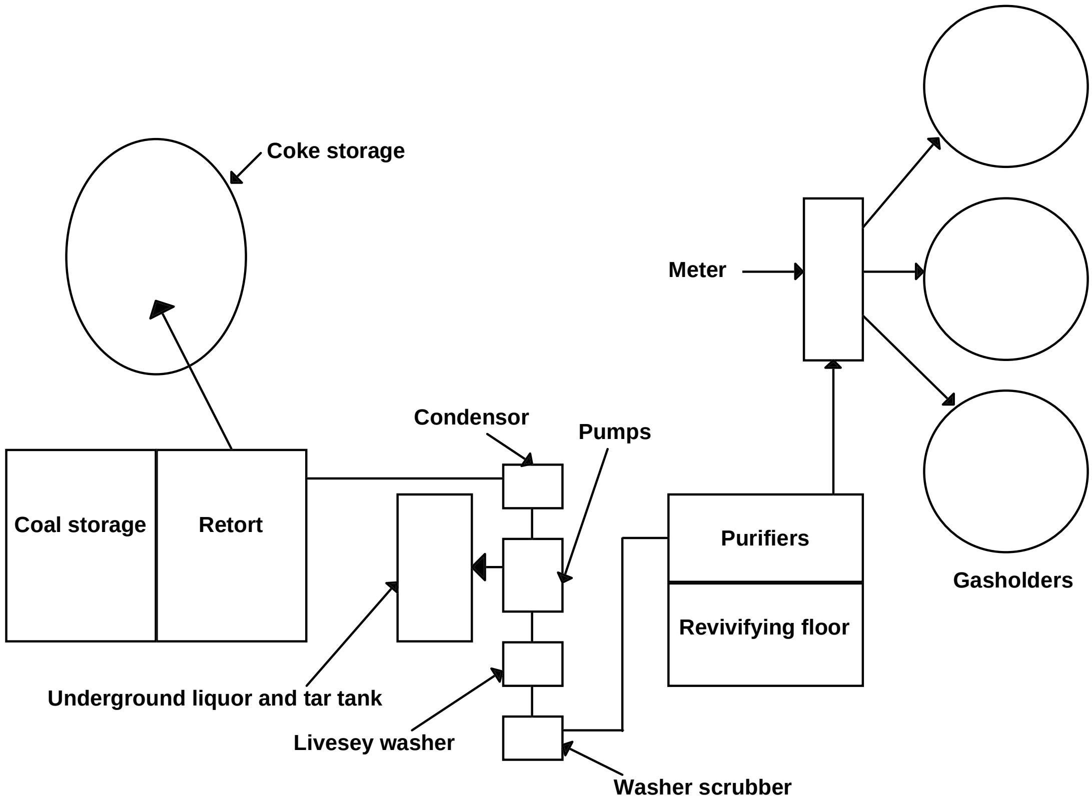

Figure 1.1 Common layout for a gasworks (adapted from Meade 1934)

Information on the processes and the major process units can be found in Module 1, Sections 1.2 and 1.3 on disk.

1.4 Contaminants of primary concern

Of the range of contaminants likely to be found at a gasworks site, several are of primary concern:

- polycyclic aromatic hydrocarbons (PAHs) - generally dominate clean-up requirements of near surface and surface soil

- benzene, toluene, ethylbenzene, xylene (BTEX) - can be significant groundwater contaminants and can be significant soil contaminants
- phenolics, i.e. phenol and cresol - can be significant groundwater contaminants. Also often present in soil but do not usually determine the remediation requirements for a site
- inorganics, including cyanide, sulphate, ammonia - can be significant groundwater contaminants.

Heavy metals are also frequently present at elevated concentrations in soils at gasworks sites. However, the overall risk to human health is usually governed by the carcinogenic PAHs. The presence of heavy metals and cyanide, while generally not defining clean-up requirements, may affect the selection of remedial techniques.

In general, the carcinogenic PAHs determine soil clean-up requirements, with phenols and some inorganics significant in groundwater contamination. Relatively small volumes of waste containing elevated concentrations of cyanide and other inorganics may also require careful consideration.

Information on the fate and transport of gasworks contaminants can be found in Module 1, Section 1.4 and Appendix 1A on disk.

1.5 Waste products associated with contaminants

The process of gas production varied between sites and not all the raw materials used were identical (e.g. coal from different sources varied in heavy metal content). As a result, contamination at the sites will differ depending on the process and residue variations, as well as the waste management practices (both on and off site).

Waste products typically included:

- organics, such as coal and oil tar, tar/oil/water emulsions and hydrocarbon sludges
- inorganics, such as coke and ash, spent oxide and lime wastes, and ammonium sulphate.

The degree to which the waste streams were treated and products recovered depended on whether there was a market for the recovered products, and whether recovery was economic. Ammonia may have been stripped from waste water and recovered as ammonium sulphate. Coal carbonisation plants often included on-site tar processing facilities. However, the market value of the by-products fluctuated significantly and the economics of recovery were at times unattractive. The recovery of by-products influenced the types of contaminants and waste products that may be found at gasworks sites.

1.5.1 Sources of potential contamination

“Normal” site operations of the time included many practices that would be very inappropriate by today’s standards. Industries operating during the period of the coal industry commonly disposed of residual wastes on site. Solid wastes were often used as reclamation material where sites were uneven, marshy or low-lying (Department of the Environment 1987). Liquid wastes were sometimes poured into the ground. Several activities that were part of the production process have also resulted in contamination.

The Department for the Environment (1987) identified a number of types of contamination which could be found at gasworks sites:

- coal particles underground at coal storage areas
- coke and coke breeze may still remain in areas used for storing by-products
- spent oxide may contaminate areas of the site. Of particular importance are

  - areas around purifier boxes and towers where treated oxide may have been spilt
  - areas where oxide was 'revivified', that is, spread out in thin layers to allow atmospheric oxidation
  - mechanical handling plants where oxides with various sulphur contents were mixed
  - storage areas where the spent oxide was accumulated pending sulphur recovery or disposal
- contaminated areas may result from the spillage of other by-products, e.g. coal tars, ammoniacal liquors and their derivatives
- leaks from coal-gas or spills of odorants added to oil-gas may have contaminated soil
- other raw materials used which may occasionally have contributed to land contamination included lime, sodium hydroxide, sodium carbonate and various catalysts and corrosion inhibitors, such as: nickel, zinc, copper, chromium, magnesium, uranium, vanadium and their compounds. Lead was used in paint, in caulking on gasholders, in pipework and roofing, and in batteries
- additional contamination may have resulted from common industry operations. Examples include spillages of lubricating and fuel oils or paints, dumping lead-acid batteries, lead contamination from pipework and pest or weed control operations.

The gas production systems were the same in New Zealand so the above are possible sources of contamination on all gasworks in New Zealand. In addition there are a few other potential sources of contamination that have been identified during gasworks site investigations in New Zealand:

- leaks of coal tar and ammoniacal liquor from underground tar wells and associated pipework
- off-site discharge of waste ammoniacal liquors
- on-site disposal of waste materials, both during plant operation and demolition
- liquid waste material left in underground tar pits, pipework and gasholder sumps when the gasworks closed down
- residual waste materials remaining on-site and off-site in stormwater drains, gas mains, peripheral gasholders and service pipes.

1.6 Patterns of contamination at gasworks sites

Historical records showing the layout of gasworks facilities can help to identify the nature and location of contamination, and assist in designing sampling and analytical strategies for assessing the site. Historical records may include:

- site maps and surveys
- site records of regulatory controls and waste management practices
- photographs of the site, especially aerial photographs taken over a number of years
- building and engineering plans and specifications
- information from past and present owners and employees.

Historical information relating to some gasworks sites in New Zealand can be found at the Alexander Turnbull Library in Wellington.

A site inspection may provide further information on the location of contamination. Features of significance include:

- empty chemical containers, tanks, pits, pipelines, sumps and drains
- fill material, especially coke breeze, with disturbed and discoloured areas of soil
- chemical or other unusual odours
- discoloured or poor quality surface waters
- evidence of waste treatment practices
- differences in vegetative growth compared with adjacent areas may be evidence of phytotoxicity.

Table 1.1 shows the potential sources of organic and inorganic contamination at gasworks sites.

Table 1.1 Potential contaminant sources at gasworks sites

Facility	Contaminants
Retort houses	Heavy metals, coke & coal wastes, sulphides, free tars & oils, PAHs, BTEX, phenolics, catalysts (nickel, uranium oxide)
Gasholders, Tar wells/pits, Tar/water separators, Scrubbers, Effluent tanks, Sludge disposal, Pipelines	Free tars & oils, PAHs, BTEX, phenolics
Condensers	Ammoniacal liquors, free tars & oils, PAHs, BTEX, phenolics
Ammonia liquor wells	Ammoniacal liquors
Coal dump	Coal wastes, sulphides & heavy metals
Gas cooling plant	Lighter aromatics
Purifiers	Lead, oxides of iron, iron cyanide complexes, sulphates
Spent lime & oxide disposal sites	Acid formed from sulphur, oxides of iron, iron cyanide complexes, sulphates
Waste material	Free tars & oils, PAHs, BTEX, phenolics, used catalysts
Oil storage tanks	Petroleum hydrocarbons, PAHs
Building rubble	Asbestos
Engine room, electrical equipment	Polychlorinated biphenyls (PCBs)

Contaminants can be distributed around gasworks sites as follows:

- organics may have migrated through higher permeability lenses in the soil and can contaminate soils and groundwater over a large area
- tars are often oxidised and solidified into rocky masses at or near the soil surface
- tar was accumulated in the gasholders during manufacturing, and in some plants tar and emulsions from the tar/water separator were pumped to the holders. During decommissioning, non-recoverable tar and emulsions were often left in place and covered with fill or scrap
- tar ponds and tar pits were also used to receive tar/water emulsions from carburetted-water gas operations. They were sometimes unlined and may have been filled with soil, rubble or ash. A zone of contamination usually occurs beneath the pond

- spills and leaks were common at most tar handling areas. Separating tanks and pipes may have leaked contaminating the soil
- tars and oils may be present as dense non-aqueous phase liquids (DNAPLs), light non-aqueous phase liquids (LNAPLs) or as dissolved phase liquids. Tars may appear as accumulations which can be pumped directly from the ground, particularly in the case of LNAPL. However, the recovery of DNAPLs is much more difficult
- free tars may accumulate in stratigraphic traps in the ground resulting in lateral migration. This can cause significant contamination over considerable areas of gasworks sites The most important sources of free tar are the tar wells (and other components of the tar recovery and processing facilities) and, to a lesser extent, the gasholders
- sometimes tar/oil/water emulsions and sludge from the separator were used for dust control
- typically gasworks sites have had extensive surface filling, ranging in depth from less than 0.5 m to several metres
- waste materials from the site (e.g. spent oxide, sludges) may have been used as fill
- purifier wastes can consist of a variety of materials, including iron-impregnated wood chips or spent lime. Wood chips may have been disposed off-site, spread around for dust control, or dumped in mixed waste areas
- sites with large coking operations may have large volumes of decomposed purifier wastes (typically stained blue by ferrocyanides)
- purifier wastes were often disposed off site and used for roading base and fill along river banks
- leachable metals may be associated with mixed wastes and fill due to the presence of coal and process residues
- heavy metal contamination tends to be associated with surface filling and waste disposal practices
- sulphates, cyanides and ammonia are frequently found in groundwater at gasworks sites, reflecting their mobility in the soil environment
- spent catalysts may be disposed of in drums or mixed with other wastes.

2

Risk assessment

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
- ➔ the link between the Users' Guide and the supporting technical information on disk

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 gasworks 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.

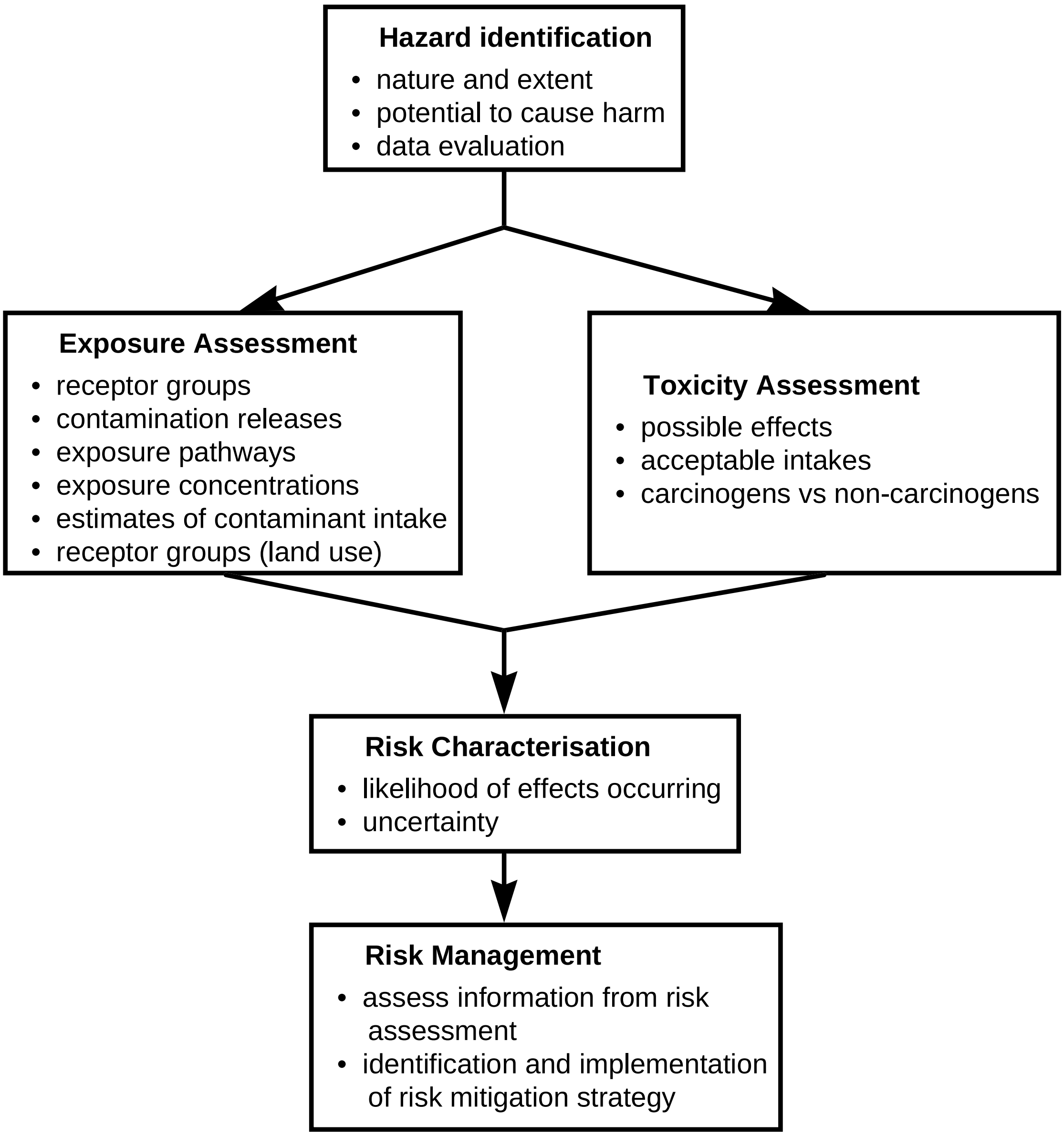

Figure 2.1 Risk assessment model

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.

In April 1997, the Victoria Environment Protection Agency (Vic EPA) released a *Draft National Framework for Ecological Risk Assessment of Contaminated Sites.* The framework is part of an overall national contaminated sites policy that revises the Australian and New Zealand Environment and Conservation Council *Guidelines for the Assessment and Management of Contaminated Sites* (ANZECC/NHMRC 1992).

The aims of the document are to:

- describe a clear framework for ecological risk assessment for chemically contaminated soils that can be readily used by the various states environment agencies and risk assessors in Australia
- provide a scientifically defensible methodology for deriving generic and site specific ecological impact levels for contaminants in soils that protects ecological values identified at a contaminated site.

This framework will be a useful resource document that can be used to develop ecological risk assessment for New Zealand ecosystems.

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 The 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 gasworks 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 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 Resource Management Act 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 is the management of contaminated sites when there is a potential risk to employees working at the site.

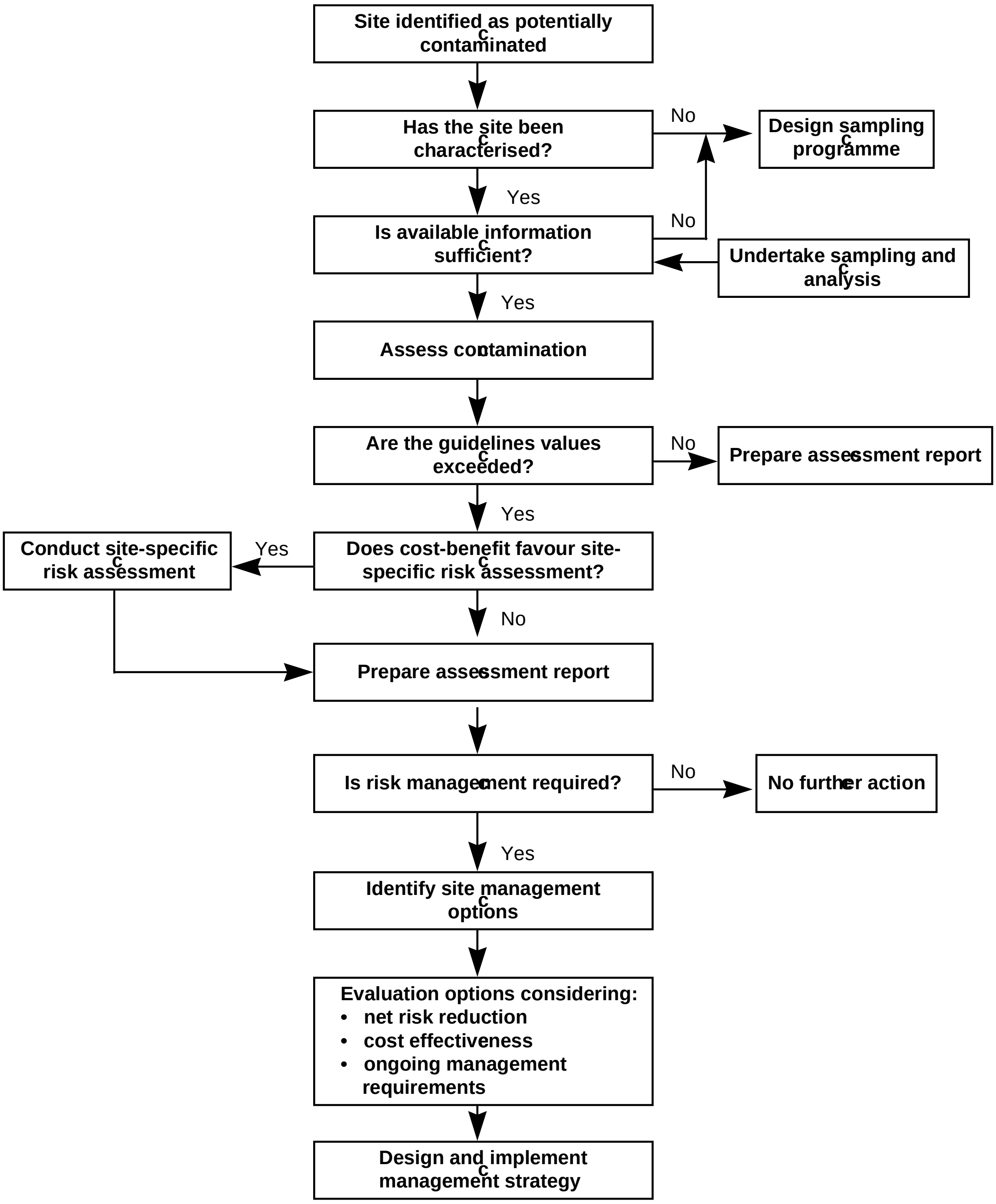

Figure 2.2 Outline of the site assessment and management process

2.8 The link between the Users' Guide and the supporting technical information on disk

The supporting technical information can be found on the disk accompanying this guideline. Figure 2.3 illustrates the links between the Users' Guide and the supporting technical information.

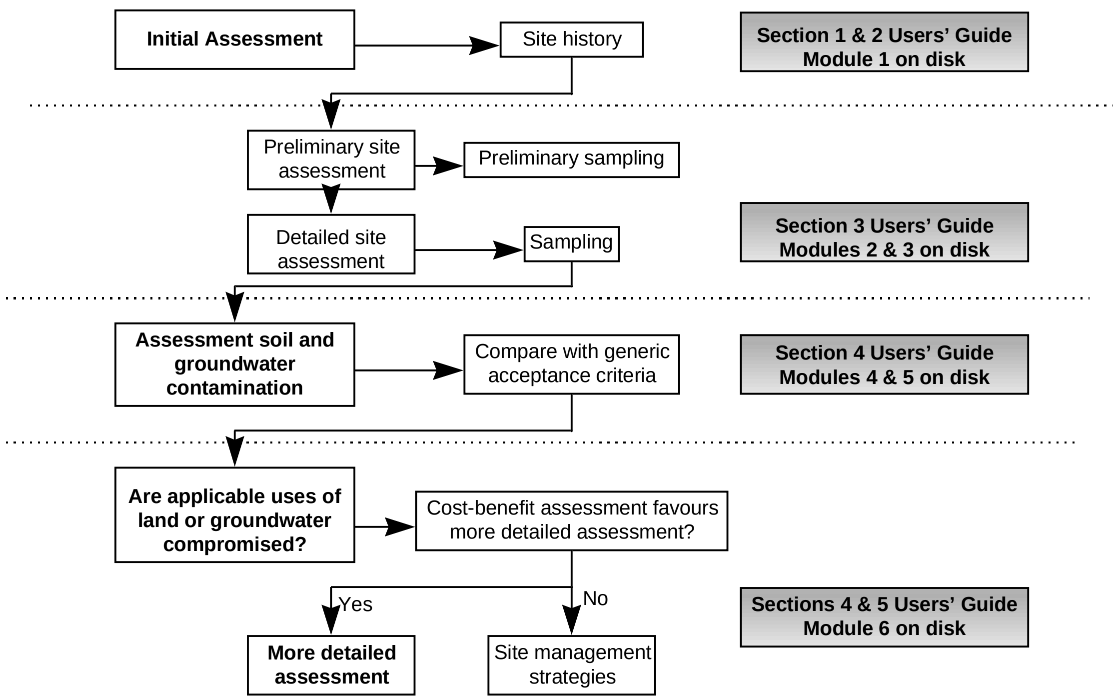

Figure 2.3 The link between the Users' Guide and the supporting technical information on disk

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 2 and 3 on disk, including:

- ▲ quality assurance/quality control framework (Section 2.2)
- ▲ sampling strategies (Section 2.3)
- ▲ general sampling requirements (Section 2.4)
- ▲ site assessment techniques (Section 2.5)
- ▲ soil, groundwater and surface water and sediment sampling (Sections 2.6, 2.7 & 2.8)
- ▲ the use of blank and duplicate samples (Section 2.9)
- ▲ documentation and record keeping (Section 2.10)
- ▲ field cleaning procedures (Section 2.11)
- ▲ disposal of sampling wastes (Section 2.12)
- ▲ analytical methods for organic and inorganic contaminants (Sections 3.2 & 3.3)
- ▲ analytical field methods (Section 3.5)

3.2 Site assessment process

The initial assessment of a gasworks sites 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 gasworks activities or processes carried out on the site, particularly the location of facilities such as gasholders, purifiers, and waste disposal tanks
- information on demolition procedure at the gasworks to determine facilities that may have been moved and buried
- 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 of tars 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 under-ground storage tanks on the site (including underground tar wells)
- 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 gasworks sites, it is not possible, or appropriate to provide general advice 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 run-off 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
- stored sludges, stockpiles, waste pits and water contained in site structures to determine disposal requirements.

Information on sampling locations can be found in Section 3.4.

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 run-off 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 10m, 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) and dense non-aqueous phase liquids (DNAPLs).

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 run-off 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 general, vapour and gaseous phase contamination does not pose a significant risk at gasworks sites. This is mainly due to the age of the sites and subsequent degradation of volatile contaminants. However, vapour issues, such as odour, may be important during site sampling and site management, and are addressed in this context in these guidelines. The *Draft*

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

Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand, due for release in August 1997, have more detailed information on volatilisation.

A potential problem during the assessment and management of gasworks sites is the presence of hydrogen sulphide. Care should be taken where this is an issue.

> Information on volatilisation can be found in the following guideline:
>
> *Draft Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand.* This document is to be released for submissions in August 1997.

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.

3.4.1 Sampling at gasworks sites - some specific issues

Contamination at gasworks sites is usually heterogeneous, reflecting the nature of gasworks wastes and waste disposal practices. Some of the specific issues associated with sampling as gasworks sites include:

Free tars and organic liquids	Free tars and other organic liquids (e.g. oil from gasholder seals) may be present at gasworks sites. For the purposes of this guideline it is assumed that free tars and organic liquids will always be contaminated and will therefore need to be disposed of appropriately. The focus should be on developing appropriate management options rather than sampling these wastes.
Tar clumps	Aged tar contamination in soil may be present as tar balls or clumps, resulting in uneven distribution of contaminants. Sampling of soil containing tar clumps can results in highly variable results and therefore care should be taken to note whether such material is present in a sample. These clumps may pose a risk to human health or the environment and need to be managed appropriately.
Spent oxide wastes	Spent oxide wastes are frequently found at gasworks sites, sometimes in a stockpile or used as general fill. Spent oxide waste should be managed as a waste material since the treatment options are limited.
Demolition rubble	Most gasworks sites will have been subject to several cycles of development and redevelopment, both as part of gas-making activities at the site and subsequent use. As a result concrete, bricks and other building materials frequently remain on-site as fill. Concrete building slabs may remain intact, and tar well and gasholder foundations may remain on-site. These features can make investigation of such sites more difficult, limiting the ability to sample at some locations and restricting the usefulness of some sampling techniques.

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 gasworks contaminants
- limiting off-site transport of contaminants by limiting exposure of contaminated soil and managing stormwater flows appropriately.

3.4.2 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 (e.g. retort house, gasholders, tar wells)
- 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 may be present that prevent sampling
Targeted Sampling	• a targeted sampling programme is highly dependent on site history • may recover samples from these sources – retort houses – gasholders – tar wells and other tar processing plants – condensors – purifiers – coal and coke storage – waste disposal areas • several samples should be recovered from the area surrounding each source to assess the heterogeneity of the distribution • 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 – gasholders may extend several metres below the ground surface – in the vicinity of other 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 wastes can assist in determining which samples should be analysed. For example, if a number of obviously tarry 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 wastes at gasworks sites.

3.4.3 Groundwater sampling

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

- upgradient 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
- downgradient of contaminated areas
- downgradient of site boundaries.

Issues which need to be considered when designing and implementing groundwater sampling include:

- 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 DNAPLs have been found, groundwater should be monitored at a range of depths, as the DNAPLs may be an ongoing source of dissolved phase groundwater contamination
- should consider installing nested bores at strategic locations to identify the impact of DNAPL contamination
- should also monitor for the presence of light non-aqueous phase liquids (LNAPLs) where DNAPLs have been found
- 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, drawdown and recovery or similar tests should be carried out on selected bores to determine aquifer characteristics.

3.4.4 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 waterbody should also be collected.

Issues which need to be considered when designing and implementing surface water and sediment sampling include:

- 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 targeted towards characterising the first flush of run-off, and during dry weather surface water contamination from groundwater inputs should be characterised

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

- 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 2, Sections 2.2 and 2.3 on disk.

3.5 Site sampling techniques

3.5.1 Soil sampling techniques

Soil samples may be recovered from gasworks sites 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 • limited occupational exposure • accurate recovery of samples • ability to sample at depth as required	• cost • time • need to carefully decontaminate equipment • limited ability to observe nature of the material encountered
Hand Auger	• low cost • quick	• limited depth • impractical in difficult soil conditions • care required to ensure quality of samples recovered • limited ability to observe nature of material encountered • labour intensive
Back Hoe Test Pit	• lower cost than boreholes • relatively quick • ability to make more detailed observations about the nature of materials encountered • able to accurately recover samples	• extent of soil disturbance and the effect on odour, occupational exposure, and compaction • limited to depth of 3 to 4 metres • 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 (subsurface foundations are often found at gasworks sites, limiting sampling)
- 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 are 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 outlined as follows:

- 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 DNAPLs 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

There are no particular techniques for sampling surface water and sediment.

> Additional information on typical soil,, groundwater, surface water and sediment sampling can be found in Module 2, Sections 2.6, 2.7 & 2.8 on disk.

3.5.4 Subsurface techniques

3.5.4.1 Geophysical surveying

Geophysical surveying is a remote sensing tool that is able 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.

3.5.4.2 Electromagnetics

Electromagnetic (EM) fields generated above the ground are used to induce currents in the ground that, in turn, set up secondary EM fields that are detected at the surface. The strength of these secondary fields is dependent on the conductive properties of the subsurface materials and therefore help detect and map lateral variations in subsurface conditions.

3.5.4.3 Magnetics

Magnetic surveying measures variations in the magnetic field at or above the ground surface which is affected by lateral variations in the concentrations of the magnetic minerals or man-made materials, such as pipes and tanks.

3.5.4.4 Resistivity

Resistivity surveying relies on the injection of electrical current into the ground and the measurement of the induced potential differences between points at the surface.

The four methods outlined above are generally employed in conjunction with a well-designed drilling or trenching programme to provide ground truth for the geophysical observations.

Additional information on subsurface assessment techniques can be found in Module 2, Section 2.5 on disk, or refer to the following publication:

Subsurface Assessment Handbook for Contaminated Sites, CCME, Report CCME EPC-NCSRP-48E, March 1994.

3.6 Field sampling procedures

Field sampling procedures need to be followed to ensure that the appropriate level of detail and care are taken while collecting environmental samples from a gasworks site. An important part of these field sampling procedures is quality assurance/quality control requirements.

Information on the field sampling procedures can be found in Module 2 on disk, including:

- ▲ general sampling requirements (Section 2.4)
- ▲ site assessment techniques (Section 2.5)
- ▲ typical soil, groundwater, surface water and sediment sampling procedures (Sections 2.6, 2.7 & 2.8)
- ▲ the use of blank and duplicate samples as quality assurance and quality control measures (Section 2.9)
- ▲ documentation and record keeping (Section 2.10)
- ▲ field cleaning procedures (Section 2.11)
- ▲ disposal of sampling wastes (Section 2.12)

3.7 Analytical programme

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

Table 3.2 Possible analytes

Analytes	Soil	Groundwater	Surface Water and Sediment
PAHs	✓	✓	✓
BTEX	✓	✓	✓
phenols and cresols	✓	✓	✓
petroleum hydrocarbons	✓	✓	✓
copper	✓	✓	✓
chromium	✓	✓	✓
cadmium	✓	✓	✓
lead	✓	✓	✓
nickel	✓	✓	✓
zinc	✓	✓	✓

ammonia	✓	✓	✓
sulphate, sulphide, total sulphur	✓	✓	✓
cyanide	✓	✓	✓
pH	✓	✓	✓
Electrical conductivity		✓	
Total suspended solids			✓

3.7.1 Soil

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

3.7.2 Groundwater

When analysing groundwater samples, emphasis should be placed on the more soluble parameters, such as BTEX, light-end PAHs, such as naphthalene, ammonia, and soluble heavy metals. 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, samples collected from these wells should not be analysed for organic parameters.

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.

Where non-aqueous phase liquids are detected in a bore the sample should not be analysed for dissolved phase contaminants as the analysis is unlikely to be reliable.

3.7.3 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).

3.8 Recommended approach to compositing

Generally it is not appropriate to composite soil samples from gasworks 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 sludge tank), 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 are as follows:

- 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.

3.9 Reference analytical methods[3]

Recommended methods for analysing each of the possible gasworks contaminants are given in the tables below. The tables include the method detection levels (MDLs). Laboratories wishing to use alternative methods should confirm for themselves (or their clients) that an equivalent level of performance, or MDL, is achieved. This should include selectivity of the method towards the analytes of interest, and recovery efficiencies in any extraction and clean-up steps.

Recommended methods for clean-up and extraction steps are also listed where applicable. The extraction and clean-up methods used should be chosen carefully to ensure that they are appropriate for the contamination concerned.

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 g/m^3.

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 ‘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.

Tables 3.3 and 3.4 show the reference methods for the analysis of organic and inorganic contaminants.

Additional information on the analyses of contaminants can be found in Module 3 on disk, including:

▲ analytical methods for organic contaminants (Section 3.2)

▲ analytical methods for inorganic contaminants (Section 3.3)

▲ sampling and sample preservation (Section 3.4)

▲ quality assurance requirements (Section 3.6)

Table 3.3 Reference methods for the analysis of organic contaminants

Analyte and Matrix	Clean-up Step	Extraction Step	Determination Step	Method Detection Limit

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.

PAHs and Semi-volatile Organics				
Soil/Sediment (low level contamination)	EPA 3630	EPA 3540 or EPA 3550	EPA 8270[4]	1 mg/kg
Water - contaminated	EPA 3630	EPA 3510 or EPA 3520	EPA 8270	10 µg/l
Water - drinking	EPA 525.1	EPA 525.1	EPA 525.1	
Volatile Organic Compounds (BTEX)[5]				
Soil/Sediment	n/a	EPA 5030	EPA 8260	1 µg/kg
Water - contaminated	n/a	EPA 5030	EPA 8260	0.03-0.1 µg/l
Water - drinking	n/a	EPA 524.2	EPA 524.2	0.03-0.1 µg/l
Phenols				
Soil	EPA 3650	EPA 3540 or EPA 3550	EPA 8270 or EPA 8041	1 mg/kg
Water-contaminated	EPA 3650	EPA 3510 or EPA 3520	EPA 8270 or EPA 8041	10 µg/l 0.15-0.3 µg/l[6]
Water - drinking	EPA 525.1	EPA 525.1	EPA 525.1	
Total Petroleum Hydrocarbons (TPH)				
Soil			RJ Hill Method	

Table 3.4 Reference methods for the analysis of inorganic contaminants

Analyte and Matrix	Clean-up Step	Extraction Step	Determination Step	Method Detection Limit
Total Cyanide				
Soil	APHA 4500 CN (C)	APHA 4500-CN (A2)	APHA 4500-CN (E) or EPA 9013	0.1 mg/kg
Water		APHA 4500 CN (C)	APHA 4500 CN (E) or EPA 9012	1 µg/l
Free Cyanide				
Soil	APHA 4500 CN (I)	APHA 4500 CN (A2)	APHA 4500-CN (E)	0.1 mg/kg
Water		APHA 4500 CN (I)	APHA 4500 CN (E)	1 µg/l
Metals[7]				

4 Estimated quantitation level (EQL) of Method 8270. EQL for wastes are from 1-200 mg/kg, dependent on sample matrix and method of preparation. EQLs will be proportionately higher for sample extracts that require dilution to avoid saturation of the MS detector. Sample EQLs are highly matrix dependent . The EQLs listed above are provided for guidance and may not always be achievable. Documentation for Method 8270 indicates that EQLs for high concentration soil may be 7.5 times greater, while those for non-water miscible waste may be 75 times greater. (EQL is generally 5 to 10 times the MDL).

5 EQL for groundwater is 1µg/l for all BTEX. EQL for low-level contaminated soil is 5 µg/kg. For other matrices, the EQLs may be greater than the value for low-level soil by 50 times for water miscible liquid waste, 125 times for high concentration soil and sludge and 500 times for non-water miscible waste.

6 EQLs can range from 10 to 10^5 times the MDL depending on the sample matrix.

Soil		EPA 3050, EPA 3051 or APHA 3030	EPA 6020 or APHA 3111-3	0.02-2 mg/kg[7]
Water		EPA 200.2 or APHA 3030	EPA 6020 or EPA 200 series APHA3111-3	0.02 - 0.4 µg/l[7]
Elemental Sulphur				
Soil			Method 31 ANZECC	
Sulphate				
Soil		Method 29 ANZECC	APHA 4110 or APHA 4500-SO_4	
Water			APHA 4110 or APHA 4500-SO_4	1 mg/l
Sulphide				
Soil			EPA 9030 or EPA 9031	
Water			APHA 4500-S^{2-} (D or G)	0.02 mg/l
Ammonia				
Soil		Method 10 ANZECC	APHA 4500-NH_3 (D or E)	
Water			APHA 4500-NH_3 (D or E)	0.01 mg/l
Acidity				
Soil			EPA 9045 or Method 6 ANZECC	
Water			APHA 2310	

3.9.1 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.

It is recommended that unstable or volatile contaminants not be analysed in the field.

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:

- ammonia

7 MDLs are dependent on the individual metal elements. These values are for samples of "clean" matrices and are subject to variation.

- nitrate, nitrite
- sulphate, sulphide, sulphite
- aluminium, copper, iron, chromate, manganese, molybdate, zinc
- pH, acidity, alkalinity, conductivity
- phosphate
- phenols (total)
- hydrocarbons (total), PAHs, BTEX

Additional information on the analytical field methods can be found in Module 3, Section 3.5 on disk.

3.10 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.

3.11 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 gasworks 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 and the Department of Labour have published *Health and Safety Guidelines on the Cleanup 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 gasworks 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 of this document are available from the Department of Labour.

3.12 Example of a typical site assessment plan

3.12.1 Introduction

The objectives of this typical site assessment are to:

- develop a general understanding of the nature and extent of contamination at a fictitious site
- determine whether the potential for off-site transport of contamination is significant
- identify the main areas and sources of contamination.

The proposed investigation is not designed to determine the full extent of contamination (for example, there are no off-site sampling locations), but rather to identify areas of contamination associated with known sources and to screen for contamination across general site areas.

3.12.2 Background to the site

- a small disused gasworks site
- no buildings or other aboveground structures remain
- holder pits were filled although not destroyed
- alluvial soils (sands and clays) are expected to be present in with groundwater to a depth of approximately 4 - 6 metres.

A review of site history suggests general filling across the site although no specific waste disposal/fill areas were identified.

3.12.3 Sampling plan design

3.12.3.1 Soils

A combination of grid and targeted sampling is proposed to screen general site areas for contamination and to focus on the contamination associated with known sources of contamination (see Figure 3.1).

- ***Grid sampling***

  The site are is approximately 0.5ha. A minimum of 13 sample locations are required to provide 95% confidence of identifying a "hot spot" of 23.1m diameter. Samples are to be recovered from a depth of 0.3m and 1m, or at 0.5m intervals to the base of the fill (whichever is the greater depth). They are to be analysed for PAHs, heavy metals, cyanide, and phenolics. The samples should be screened using a PID and those that report significantly elevated PID readings should be analysed for BTEX.

- ***Targeted sampling***

  Limited targeted sampling is proposed to address specific areas of concern at the site, including:

  - gasholders
  - tar well or tank
  - liquor pit
  - purifier boxes
  - laboratory and workshop
  - retort house.

  Unless the identified source is below ground, samples should be recovered as for the grid sampling above or to a depth below obvious signs of contamination (e.g. odour, discolouration). In areas where the source of contamination is below ground (e.g. gasholders, tar wells, and liquor wells) samples should be recovered from a depth greater than the base of the source. For example, if a gasholder foundation extends to a depth of 4m, samples should be recovered at 2m intervals to a depth of 6m. The proposed targeted sampling locations are shown in Figure 3.1. In total, eight targeted locations are proposed. Soil samples would also be recovered from the groundwater monitoring well locations during installation.

Targeted samples should be analysed for a range of samples consistent with the nature of the possible source of contamination.

3.12.3.2 Groundwater

Groundwater at the site is expected at a depth of four to six metres, with regional flow to the south. A total of five groundwater monitoring bores are proposed as follows (see Figure 3.1):

- upgradient/background bore
- downgradient of the holders and liquor well
- downgradient of the tar tank
- downgradient of the retort house
- downgradient of the purifier boxes.

Groundwater samples should be analysed for a range of contaminants including PAHs, phenolics, BTEX, ammonia, cyanides, and sulphate. In addition, general water quality parameters such as pH, total dissolved solids, temperature, redox potential and dissolved oxygen should be measured.

3.12.3.3 Soil sampling technique

A range of soil sampling techniques may be used to determine the nature and extent of contamination. Fill test pit sampling is particularly useful. Extended test pits or trenches may also be useful to find the extent of contamination, particularly near the holder pits. However, care must be taken to avoid penetrating subsurface structures that may still hold free tars. Soil sampling below a depth of 4m and installing groundwater monitoring bores requires the use of a drill rig.

3.12.3.4 Analytical programme

The analytical requirements for soil and groundwater samples are set out above. In practice the PAHs are expected to be limiting under most circumstances (with the exception of spent oxide and metals in the vicinity of workshops). Initially, a broad range of analytes should be screened with any follow-up work focussing on the specific contaminants of concern identified as part of the original investigations.

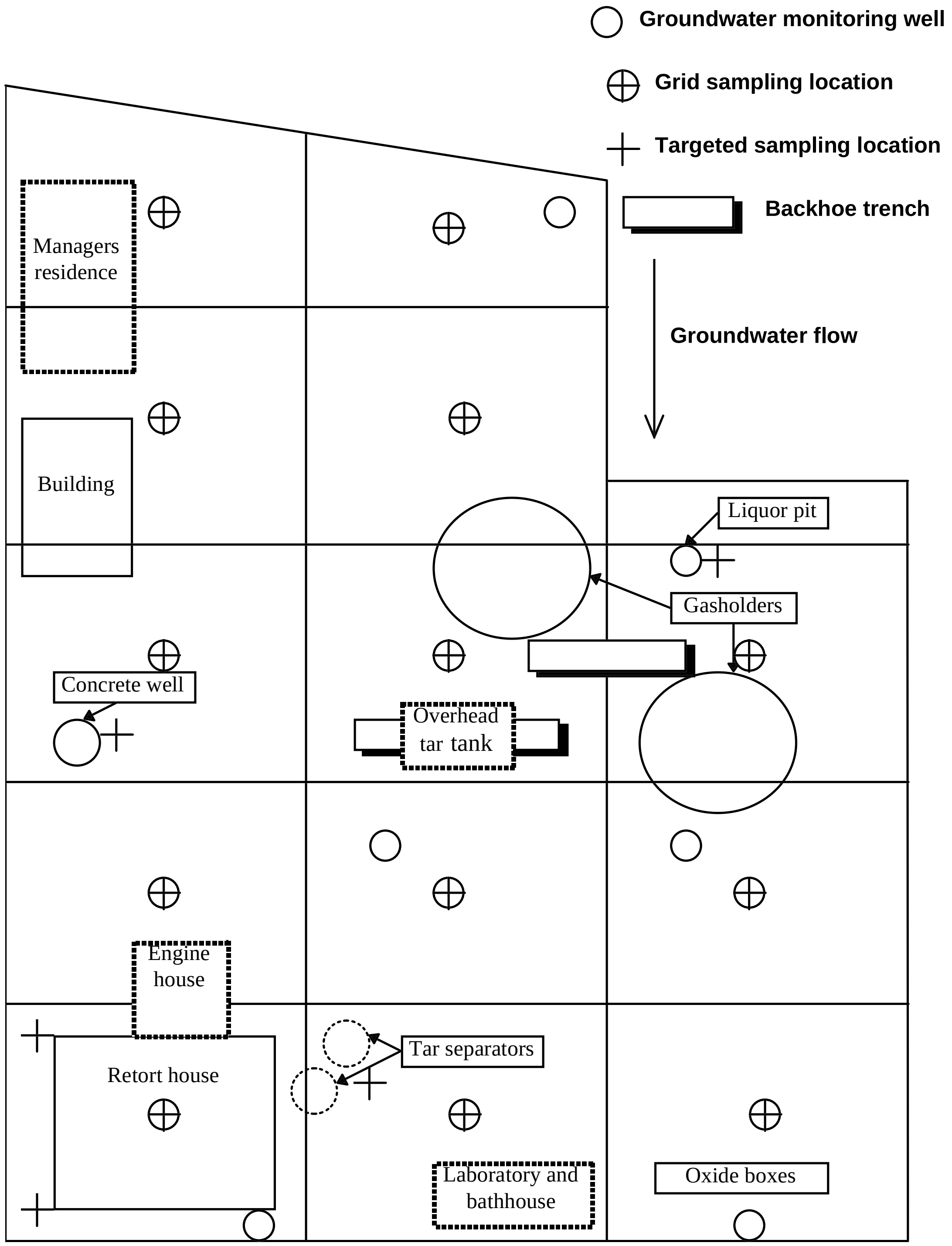


Figure 3.1 Sampling plan design

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 termed the '**generic acceptance criteria**'.

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

- ➔ development of generic soil acceptance criteria
- ➔ application of the generic soil acceptance criteria
- ➔ development of generic water acceptance criteria
- ➔ application of the generic water acceptance criteria
- ➔ development of site-specific acceptance criteria

> Detailed information on the development of the generic acceptance criteria can be found in Modules 3 and 4 on disk.

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 homegrown livestock and produce, and through direct contact with contaminated soil. It is assumed that residences do not incorporate basements.

Standard 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. It is assumed that residences do not incorporate basements.

High Density Residential

For high density residential areas it is assumed there are limited soil access opportunities, therefore there is significantly less soil and dust exposure by ingestion compared with a standard residential site. This scenario does not include consuming of produce grown at the site.

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.
Parkland/ Recreational	This land use reflects shorter exposure times but potentially on a regular basis. Opportunities for contact with soil will arise and children are the key concern in these areas.

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

Gasworks site wastes are complex mixtures of hydrocarbons and other compounds. It is therefore impractical to rigorously assess the concentration of, and risk associated with, each of the specific contaminants. 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 Contaminants of concern

Contaminant	Contaminants for Criteria Derivation
Carcinogenic PAHs • benzo(a)pyrene • benzo(a)anthracene • benzo(b)fluoroanthene • benzo(k)fluoroanthene • chrysene • dibenzo(a,h)anthracene • indeno(1,2,3-cd)pyrene **Non-carcinogenic PAHs** • naphthalene • fluorene • fluoranthene • acenaphthene • pyrene • anthracene • acenaphthylene • phenanthrene • benzo(g,h,i)perylene	benzo(a)pyrene[8] and non-carcinogenic PAHs
BTEX • benzene • ethylbenzene • toluene • xylene	benzene ethylbenzene toluene xylene
Phenolics	phenol cresol
Inorganics	free cyanide[9] complex cyanides
Heavy metals	none[10]

8 Carcinogenic PAHs may be considered in terms of a benzo(a)pyrene equivalent concentration, based on published Toxicity Equivalence Factors.
9 Cyanides are of most concern to human health.
10 Heavy metals concentrations are not the limiting consideration so generic acceptance criteria have not been developed for heavy metals.

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 Adult residents/on-site workers Maintenance workers
Residential - Standard and High Density	Child residents Adult residents/workers Maintenance workers
Commercial/Industrial	Adult workers Maintenance workers
Parkland/Recreational	Children Adults 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 Module 4, Section 4.2.3 on disk.

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 Exposure pathways

Exposure Pathway	Agricultural/ Horticultural		Standard Residential		High Density Residential	
	Surface	Subsurface	Surface	Subsurface	Surface	Subsurface
Ingestion of contaminated soil	✖		✖		✖	
Consumption of produce	✖		✖			
Dermal absorption	✖		✖		✖	
Inhalation of volatiles (indoors)	✖	✖	✖	✖	✖	✖
Inhalation of volatiles (outdoors)	✖	✖	✖	✖	✖	✖
Inhalation of particulates	✖		✖		✖	

Exposure Pathway	Commercial/ Industrial		Parkland/ Recreational	
	Surface	Subsurface	Surface	Subsurface
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 Module 4, Section 4.2.3.1 on disk.

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 concentration can be found in Module 4, Section 4.2.3.2 on disk.

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). Detailed information on this scenario can be found in Module 4 on disk.

Additional information on exposure estimation can be found in Module 4, Section 4.2.3.3 on disk.

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 on the development of the soil acceptance criteria.

Table 4.4 Exposure factors

Exposure Factor	Units	Agricultural		Standard Residential		High Density Residential	
		Child	Adult	Child	Adult	Child	Adult
Body Weight	kg	**15**	**70**	**15**	**70**	**15**	**70**
Exposure Duration	years	**6**	**24**[11]	**6**	**24**[12]	**6**	**24**[13]
Exposure Frequency	days/year	**350**	**350**	**350**	**350**	**350**	**350**
Soil Ingestion Rate	mg/day	**100**	**25**	**100**	**25**	**25**	**5**
Area of Exposed Skin	cm^2	**2625**	**4700**	**2625**	**4700**	**2625**	**4700**

11 A total of 30 years if the adult has lived on site since birth
12 A total of 30 years if the adult has lived on site since birth
13 A total of 30 years if the adult has lived on site since birth

Soil Adherence	mg/cm^2	**1**	**1**	**0.5**	**035**	**0.1**	**0.1**
Produce Ingestion Rate Proportion of Produce Grown On site	kg/day %	**0.13** **100**	**0.45** **100**	**0.13** **50**	**0.45** **50**	**NA** **NA**	**NA** **NA**
Indoor Inhalation Rate[14] Outdoor Inhalation Rate[15]	m^3/day m^3/day	**3.8** **3.8**	**15** **20**	**3.8** **3.8**	**15** **20**	**3.8** **3.8**	**15** **20**

Exposure Factor	Units	Commercial/ Industrial	Maintenance	Parkland/ Recreational	
		Adult	Adult	Child	Adult
Body Weight Exposure Duration Exposure Frequency	kg years days/year	**70** **20** **240**	**70** **20** **50**	**15** **6** **350**	**70** **24**[16] **350**
Soil Ingestion Rate	mg/day	**25**	**100**	**50**	**10**
Area of Exposed Skin Soil Adherence	cm^2 mg/cm^2	**4700** **1**	**4700** **1.5**	**2625** **1**	**4700** **1**
Produce Ingestion Rate Proportion of Produce Grown On site	kg/day %	**NA** **NA**	**NA** **NA**	**NA** **NA**	**NA** **NA**
Indoor Inhalation Rate[17] Outdoor Inhalation Rate[18]	m^3/day m^3/day	**10** **10**	**10** **10**	**0** **1.1**[19]	**0** **2.4**[20]

Additional information on exposure factors can be found in Module 4, Section 4.2.3.4 on disk.

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.

Information on the health effects summaries for gasworks contaminants can be found on in Module 4, Appendix 4A on disk.

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[21])

14 Based on a 24 hour period
15 Based on a 24 hour period
16 A total of 30 years if the adult has lived on-site since birth
17 Based on a 24 hour period
18 Based on a 24 hour period
19 Average or 10 year old child and 1 year old child
20 Average or 10 year old child and 1 year old child

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

Risk = CDI x SF

Where **CDI** = Chronic Daily Intake

SF = Slope Factor

The Ministry of Health has adopted an incremental cancer risk level of 1 in 100,000 per lifetime (1 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 1 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):

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

Where: **HQ** = Hazard Quotient

CDI = Chronic Daily Intake

RfDc = Chronic Reference Dose

Where sensitive population groups may be exposed, a HQ of 1 is appropriate to protect human health.

More information on non-carcinogens can be found in Module 4, Section 4.2.4.2 on disk.

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.

The generic health-based soil acceptance criteria are presented overleaf.

Details of the calculations underlying the health-based soil acceptance criteria can be found in Module 4, Appendix 4C on disk.

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

4.2.7 Summary of generic soil acceptance criteria

4.2.7.1 Agricultural/horticultural

Contaminant	Exposure Route					Protection of Plant Life[22]	Adopted
	Ingestion of Soil	Inhalation of Volatiles		Dermal Absorption	Produce Consumption		
		Surface	Sub-surface				
Phenolics							
Phenol	NA[23]			NA	33	(40)	**30[24]**
Cresol (o,m)	3900			3000	5	(5)	**5**
BTEX							
Benzene	520	2.3	2.4	190	0.3	(1)	**1**
Toluene	NA	200	210	NA	59	(130)	**60**
Ethylbenzene	7800	1000	1000	6000	51	(50)	**50**
Xylene	NA	150	160	NA	110	(25)	**100**
Non-carcinogenic PAHs							
Naphthalene	310	67	70	1200	1.7		**2**
Acenaphthene	4700			NA	86		**90**
Anthracene	NA			NA	870		**800**
Fluorene	3100			NA	81		**80**
Phenanthrene	2300			8900	88		**90**
Pyrene	2300			8900	150		**150**
Fluoranthene	3100			NA	320		**320**
Acenaphthylene	2300			8900	53		**50**
Carcinogenic PAHs							
Benzo(a)pyrene	2.1			3.8	0.2		**0.2**
PAH (Total)						(40)	**80[25]**
Inorganics							
Cyanide (free)	390			-	-	(20)	**400**
(complex)	980			-	-		**1000**

22 Dutch Intervention Values are presented for comparison only.
23 NA denotes calculated criterion exceeds 10000 mg/kg.
24 Lower concentrations of phenols may cause tainting of water in plastic pipes.
25 Based on estimated criteria for individual non-carcinogenic PAHs.

4.2.7.2 Standard residential (50% of produce homegrown)

Contaminant	Exposure Route					Protection of Plant Life[26]	Adopted
	Ingestion of Soil	Inhalation of Volatiles		Dermal Absorption	Produce Consumption		
		Surface	Sub-surface				
Phenolics							
Phenol	NA[27]			NA	65	(40)	**60[28]**
Cresol (o,m)	3900			6000	10	(5)	**10**
BTEX							
Benzene	520	2.3	2.4	380	0.5	(1)	**1**
Toluene	NA	200	210	NA	120	(130)	**130**
Ethylbenzene	7800	1000	1000	NA	100	(50)	**100**
Xylene	NA	150	160	NA	210	(25)	**150**
Non-carcinogenic PAHs							
Naphthalene	310	67	70	2400	3.4		**3**
Acenaphthene	4700			NA	170		**170**
Anthracene	NA			NA	1700		**1700**
Fluorene	3100			NA	160		**160**
Phenanthrene	2300			NA	180		**180**
Pyrene	2300			NA	310		**300**
Fluoranthene	3100			NA	650		**650**
Acenaphthylene	2300			NA	110		**100**
Carcinogenic PAHs							
Benzo(a)pyrene	2.1			7.5	0.4		**0.4**
PAH (Total)						(40)	**160**
Inorganics							
Cyanide (free)	390			-	-	(20)	**400**
(complex)	980			-	-		**1000**

26 Dutch Intervention Values presented for comparison only.
27 NA denotes calculated criterion exceeds 10000 mg/kg.
28 Lower concentrations of phenols may cause tainting of water in plastic pipes.

4.2.7.3 Standard residential (10% of produce home grown)

Contaminant	Exposure Route					Protection of Plant Life[29]	Adopted
	Ingestion of Soil	Inhalation of Volatiles		Dermal Absorption	Produce Consumption		
		Surface	Sub-surface				
Phenolics							
Phenol	NA[30]			NA	330	(40)	**300**[31]
Cresol (o,m)	3900			6000	52	(5)	**50**
BTEX							
Benzene	520	2.3	2.4	380	2.7	(1)	**1**
Toluene	NA	200	210	NA	590	(130)	**200**
Ethylbenzene	7800	1000	1000	NA	510	(50)	**500**
Xylene	NA	150	160	NA	1100	(25)	**150**
Non-carcinogenic PAHs							
Naphthalene	310	67	70	2400	17		**17**
Acenaphthene	4700			NA	860		**800**
Anthracene	NA			NA	8700		**9000**
Fluorene	3100			NA	810		**800**
Phenanthrene	2300			NA	880		**900**
Pyrene	2300			NA	1500		**1500**
Fluoranthene	3100			NA	3200		**3200**
Acenaphthylene	2300				525		**500**
Carcinogenic PAHs							
Benzo(a)pyrene	2.1			7.5	1.8		**1**
PAH (Total)						(40)	**800**
Inorganics							
Cyanide (free)	390			-	-	(20)	**400**
(complex)	980			-	-		**1000**

29 Dutch Intervention Values are presented for comparison only.
30 NA denotes calculated criterion exceeds 10000 mg/kg.
31 Lower concentrations of phenols may cause tainting of water in plastic pipes.

4.2.7.4 High density residential

Contaminant	Exposure Route					Protection of Plant Life[32]	Adopted
	Ingestion of Soil	Inhalation of Volatiles		Dermal Absorption	Produce Consumption		
		Surface	Sub-surface				
Phenolics							
Phenol	NA[33]			NA		(40)	**NA**
Cresol (o,m)	NA			NA		(5)	**NA**
BTEX							
Benzene	2100	2.3	2.4	1900		(1)	**2**
Toluene	NA	200	210	NA		(130)	**200**
Ethylbenzene	NA	1000	1000	NA		(50)	**1000**
Xylene	NA	150	160	NA		(25)	**150**
Non-carcinogenic PAHs							
Naphthalene	1300	67	70	NA			**70**
Acenaphthene	NA			NA			**NA**
Anthracene	NA			NA			**NA**
Fluorene	NA			NA			**NA**
Phenanthrene	9400			NA			**NA**
Pyrene	9400			NA			**NA**
Fluoranthene	NA			NA			**NA**
Acenaphthylene	9400						**NA**
Carcinogenic PAHs							
Benzo(a)pyrene	8.5			38			**7**
PAH (Total)						(40)	**9000**
Inorganics							
Cyanide (free)	1600			-		(20)	**1600**
(complex)	3900			-			**3900**

32 Dutch Intervention Values are presented for comparison only.
33 NA denotes calculated criterion exceeds 10000 mg/kg.

4.2.7.5 Commercial/industrial[4]

Contaminant	Exposure Route					Protection of Plant Life[34]	Adopted
	Ingestion of Soil	Inhalation of Volatiles		Dermal Absorption	Produce Consumption		
		Surface	Sub-surface				
Phenolics							
Phenol	NA[35]			NA			**-**
Cresol (o,m)	NA			NA			**-**
BTEX							
Benzene	5100	8.6	8.8	910			**8**
Toluene	NA	660	690	NA			**600**
Ethylbenzene	NA	3300	3400	NA			**-**
Xylene	NA	500	520	NA			**500**
Non-carcinogenic PAHs							
Naphthalene	8500	220	230	7600			**200**
Acenaphthene	NA			NA			**-**
Anthracene	NA			NA			**-**
Fluorene	NA			NA			**-**
Phenanthrene	NA			NA			**-**
Pyrene	NA			NA			**-**
Fluoranthene	NA			NA			**-**
Acenaphthylene	NA			NA			**-**
Carcinogenic PAHs							
Benzo(a)pyrene	20			18			**10**
PAH (Total)							
Inorganics							
Cyanide (free)	NA			NA			**NA**
(complex)	NA			NA			**NA**

34 Dutch Intervention Values are presented for comparison only.
35 NA denotes calculated criterion exceeds 10000 mg/kg.

4.2.7.6 Parkland/Recreational

Contaminant	Exposure Route					Protection of Plant Life[36]	Adopted
	Ingestion of Soil	Inhalation of Volatiles		Dermal Absorption	Produce Consumption		
		Surface	Sub-surface				
Phenolics							
Phenol	NA[37]			NA			
Cresol (o,m)	7800			6000			**600**
BTEX							
Benzene	1100	8.6	8.8	380			**8**
Toluene	NA	6600	690	NA			**600**
Ethylbenzene	NA	3300	3400	NA			**3300**
Xylene	NA	500	520	NA			**500**
Non-carcinogenic PAHs							
Naphthalene	6300	220	230	2400			**200**
Acenaphthene	9400			NA			**N/A**
Anthracene	NA			NA			**N/A**
Fluorene	6300			NA			**N/A**
Phenanthrene	4700			NA			**N/A**
Pyrene	4700			NA			**N/A**
Fluoranthene	6300			NA			**N/A**
Acenaphthylene	4700						**N/A**
Carcinogenic PAHs							
Benzo(a)pyrene	4.3			7.5			**2.7**
PAH (Total)							**4700**
Inorganics							
Cyanide (free)	780			-	-		**780**[38]
(complex)	2000			-	-		**2000**[39]

36 Dutch Intervention Values are presented for comparison only.
37 NA denotes calculated criterion exceeds 10000 mg/kg.
38 Includes consideration of maintenance workers.
39 Includes consideration of maintenance workers.

4.2.8 Ecological considerations

Ecological considerations are an essential part in assessing the impact of contamination at gasworks sites. However currently there is limited information on the impact of gasworks contaminants on ecosystems.

As discussed in Section 2.1.4. the Victoria EPA have released a *Draft National Framework for Ecological Risk Assessment of Contaminated Sites*. The framework is part of an overall national contaminated sites policy that revises the Australian and New Zealand Environment and Conservation Council *Guidelines for the Assessment and Management of Contaminated Sites* (ANZECC/NHMRC 1992). When more information on New Zealand species is available, this framework may be used to develop ecologically based generic acceptance criteria for New Zealand.

Where a site is ecologically significant it may be necessary to use published data on environmental soil quality guidelines. The Environmental Quality Objectives for the Netherlands, and the ANZECC Environmental Investigation Levels are presented in Appendix 4B of Module 4 on disk. Discretion should be exercised when using these numbers as they have not been developed for New Zealand conditions or species.

> More information on ecological considerations can be found in Module 4, Section 4.3 on disk.
>
> International ecologically based environmental quality objectives can be found on in Module 4, Appendix 4B on disk.

4.2.9 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 on gasworks sites can be found in Module 4, Section 4.4 on disk.

4.2.10 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 (e.g. 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, and
- 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 in this section 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.

4.2.10.1 Exposure to multiple contaminants

Gasworks wastes include complex mixtures of contaminants, and 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 of the impact and mechanism of action are similar, assume effects are additive - otherwise effects are assumed not to be additive.

At gasworks sites, the primary concern is exposure to a complex mixture of PAHs. The additive effects associated with exposure to the carcinogenic PAHs is addressed by using Toxicity Equivalency Factors (TEFs) as follows:

- develop risk-based criteria for benzo(a)pyrene, then
- measure carcinogenic PAH concentrations in the soil, then
- estimate the benzo(a)pyrene equivalent concentration based on the measured carcinogenic PAH concentrations in soils and the published TEFs (refer Table 4.5), then
- compare the benzo(a)pyrene equivalent concentration with the generic soil acceptance criteria for benzo(a)pyrene.

Some of the non-carcinogenic PAHs also act in a similar way and therefore exposure should be considered to be additive as follows:

$$\frac{C_1}{T_1} + \frac{C_2}{C_2} + \frac{C_i}{T_i} < 1$$

where C_i = measured concentration of species '*i*'
T_i = acceptance criterion for species '*i*'

In practice the non-carcinogenic PAHs are not usually limiting in terms of health risk and therefore the requirement to consider additive exposure for these chemicals is lessened.

Table 4.5 Toxic Equivalence Factors (TEFs) For Carcinogenic PAHs

Chemical	Adopted[40] TEFs
Benzo(a)pyrene	1.0
Benzo(a)anthracene	0.1
Benzo(a)fluoranthene	0.1
Benzo(k)fluoranthene	0.1
Chrysene	0.01
Dibenzo(a,h)anthracene	1.0
Indeno(1,2,3-cd)pyrene	0.1

4.2.10.2 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'.

40 USEPA (1993) "Provisional guidance for quantitative risk assessment of polycyclic aromatic hydrocarbons.

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 50m x 50m. 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.

4.2.10.3 Contamination at depth

It is common for contamination to be present to considerable depth at gasworks sites (e.g. 3 to 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 to 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 2m)
- excavation for sewers (to 3m - may vary depending on the location)
- excavation for a swimming pool (to 3m)
- excavation for single-level basement (to 3.5m), 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 to 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 outlined as follows:

- contamination in near surface soils (i.e. within the range typically encountered in day-to-day activities, say, 0 to 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 to 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.

4.2.10.4 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).

The soil acceptance criteria presented in this section do not consider the protection of groundwater quality. Rather, it is preferable to measure the groundwater quality directly when assessing the impact of soil contamination.

4.3 Generic water acceptance criteria

4.3.1 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
- primary contact recreation.

4.3.1.1 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 gasworks site 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

	Assumption
Water consumption rate	2 L/day
Body weight	70 kg
Proportion of RfD[41] assigned to drinking water	0.1

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

4.3.1.2 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 5A on disk.

4.3.1.3 Irrigation use

41 For information on the reference doses (RfDs) for gasworks contaminants, refer to Appendix 3 of Section 5 on disk.

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 homegrown produce (assume 100% of produce would be homegrown 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 5B on disk.

4.3.1.4 Aquatic ecosystem protection

Currently in New Zealand there is no definitive guidance on the protection of ecosystems. For this reason the ANZECC guidelines (ANZECC/NHMRC 1992) are used.

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

4.3.1.5 Primary contact recreation

There is limited published information on acceptable concentrations of contaminants in water to be used for primary contact recreation, such as swimming. The primary contact recreation criteria developed are based on a commercial swimming pool scenario assuming regular usage. Other values may be acceptable in the context of recreational bathing in a domestic swimming pool or bathing in surface waters, such as lakes, the sea etc.

More information on primary contact recreation can be found in Module 5, Section 5.7 and Appendix 5C on disk.

4.3.2 Summary of generic water acceptance criteria

Table 4.7 Acceptance criteria for water (mg/l)

Contaminant	Potable	Stock Watering	Irrigation[42]	Aquatic Ecosystem	Primary Contact Recreation
PAHs total		**3**		**0.03**	
Non-carcinogenic PAHs					
Naphthalene	**0.01**	**0.4**	**0.2**		**0.3**
Acenaphthene	**0.2**		**2.3**		**1.8**
Anthracene	**1**		**7.9**		**5.6**
Fluorene	**0.1**		**1.3**		**1.0**
Phenanthrene	**0.1**		**0.8**		**0.5**
Pyrene	**0.1**		**0.4**		**0.4**
Fluoranthene	**0.1**		**0.7**		**0.3**
Acenaphthylene	**0.1**		**1.0**		**0.7**

42 Based on domestic irrigation scenario. Dermal absorption by children playing is estimated to be limiting. Higher values may be acceptable in the context of use of water for agricultural irrigation.

Carcinogenic PAHs					
Benzo(a)pyrene	**0.0007**		**0.0002**		**0.00003**
BTEX					
Benzene	**0.01**	**10**	**0.3**		**0.3**
Toluene	**0.8 (0.024)**[43]	**20**	**13**		**15**
Ethylbenzene	**0.3 (0.002)**	**10**	**5.2**		**5**
Xylene	**0.6 (0.02)**	**18**	**8.8**		**8**
Phenolics					
Phenol	**2.1**	**60**	**44**		**150**
Cresol (o,m)	**0.18**	**5**	**4**		**10**
Cresol (p)	**0.0175**	**0.5**	**3.3**		**1.0**
Inorganics					
Ammonia	**1.5**				**1.8**
Cyanide as CN-					**5**
Free cyanide	**0.08**	**1**	**0.5**		
Complex cyanide	**0.07**	**2.5**	**1.2**		
Nitrate	**50**				
Nitrite	**3**				
Sulphate	**250**				

4.3.3 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.

4.3.3.1 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 downgradient 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.

43 Values in brackets indicate aesthetic based limits.

4.3.3.2 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.

4.4 Developing site-specific soil and water acceptance criteria

Where contaminant concentrations at a gasworks 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 the bioavailability effect (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.

4.4.1 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
- homegrown 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 gasworks sites 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 - 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 gasworks site the following factors need to be considered:

- underground structures, such as foundations, backfilled gasometers, tar wells etc., may be present on site
- backfill materials from the gasholders may need to be removed and replaced with engineered fill. Removing the backfill may pose a health and safety risk for site workers, as well as endangering the stability of the gasometer sidewalls
- most gasworks will be covered with a layer of uncontrolled fill that may be several metres thick. This fill may have to be removed because of its poor founding characteristics
- several gasworks contaminants will attack and degrade building materials if appropriate protection measures are not taken. These issues need to be discussed with the territorial authority
- 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 gasworks contaminant waste streams. The various waste streams, including contaminated soil, tar waste, 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 timeframe 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 gasworks 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(RM Act) is to promote the sustainable management of natural and physical resources. The RM Act 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 RM Act 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 RM Act 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 RM Act 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, and
- 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 at work. 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 at work.

5.5 Site management options

The site management options considered in these guidelines include:

- land use controls
- management controls
- intrinsic remediation
- 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.

Another mechanism which is being considered is the use of notation on title, where a notation could be placed against the land title to identify the presence of contamination or to restrict the land use. No decision had been made by the Government on this issue at July 1997.

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 Intrinsic remediation

Intrinsic remediation 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.

> The key issues associated with the use of intrinsic remediation can be found in Module 6, Section 6.2 on disk.

5.5.4 Containment options

Setting up barriers to prevent migration of contaminants is widely used in the management of gasworks sites in the United States and Europe. Containment focuses on mitigating risk by placing a barrier between the source of contamination and the receptor, and avoiding further migration of the contamination.

Containment systems should have the following characteristics to be effective:

- 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.

> Module 6 on disk discusses the key issues associated with the use of
>
> ▲ capping systems (Section 6.3.1)
>
> ▲ cut-off walls (Section 6.3.2)
>
> ▲ groundwater interception (Section 6.3.3)
>
> ▲ on-site repositories (Section 6.3.4)

5.5.5 Remedial treatment systems

Remedial treatment systems include the following:

- off-site disposal, where the contaminants are removed from the site and disposed of in a appropriately designed landfill
- stabilisation and solidification, where both the mobility of the contaminants and the exposure pathways through which adverse effects can occur are reduced. This can be done either in situ or ex situ
- 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 ex situ

- thermal desorption, where the soil is heated to approximately 450C in a rotary kiln or retort. The volatile contaminants are then destroyed in an afterburner
- incineration using mobile on-site incineration or cement kilns.
- soil washing, where a wash solution is injected into the soil to mobilise the contaminants. This can be done either in situ or ex situ.
- groundwater treatment either in situ or ex situ.

Module 6 on disk discusses the key issues associated with the use of

▲ stabilisation and solidification (Section 6.4.1)

▲ bioremediation (Section 6.4.2)

▲ thermal desorption (Section 6.4.3)

▲ incineration (Section 6.4.4)

▲ soil washing (Section 6.4.5)

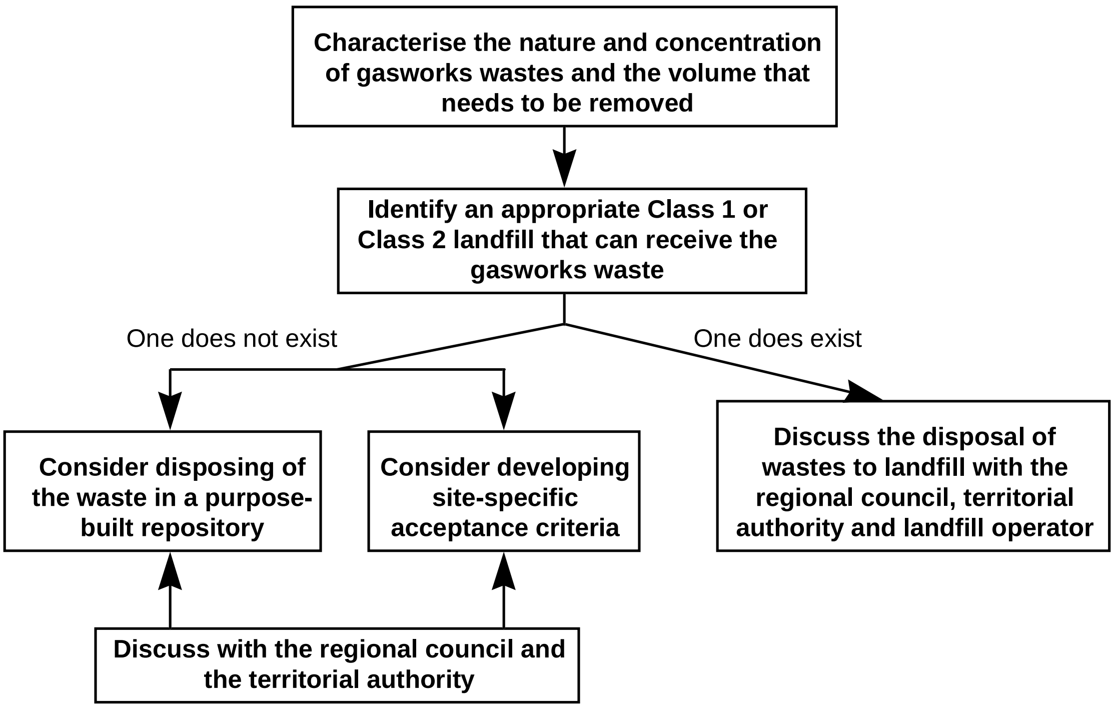
▲ groundwater treatment (Section 6.4.6)

5.5.6 Disposal of contaminants to landfill

The interim landfill acceptance criteria presented in the draft guidelines were based on preliminary leaching data from the US Electric Power Research Institute (EPRI). The Ministry for the Environment is currently trying to obtain the full data-set to develop a more robust set of numbers for landfill acceptance criteria. For this reason the preliminary landfill acceptance criteria are not provided in this document. These will be provided once the updated criteria from the full data set have been obtained.

5.5.6.1 General philosophy

Determining whether a particular gasworks waste can be landfilled, with minimal adverse effects, can be assessed using the simple steps as follows:



Additional information on the landfilling of gasworks contaminants can be found in Module 6 on disk, including:

▲ gasworks waste types, composition and nature (Section 6.5.1)

- ▲ landfill type and processes (Section 6.5.2)
- ▲ leachability testing (Section 6.5.3)
- ▲ landfilling of low-level gasworks wastes (Section 6.5.4)
- ▲ landfilling of high-level gasworks wastes in repositories (Section 6.5.5)

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 occuring.

The details of monitoring can be found in Module 6 on disk, including:

- ▲ post-investigation/pre-remediation monitoring (Section 6.6.1)
- ▲ remediation monitoring (Section 6.6.2)
- ▲ post-remediation monitoring (Section 6.6.3)
- ▲ monitoring determinands and frequency (Section 6.6.4)

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

1. ANZECC/NHMRC (1992). Guidelines for the Assessment and Management of Contaminated Sites.
2. CCME (1994). Subsurface Assessment Handbook for Contaminated Sites. Report CCME EOC-NCSRP-48E, March.
3. Department of the Environment (1987). Problems Arising from the Redevelopment of Gas Works and Similar Sites (Second Edition). Prepared by Environmental Resources Limited.
4. GRI (1987). Management of Manufactured Gas Plant Sites, Volume 1: Wastes and Chemicals of Interest. Gas Research Institute, Chicago.
5. Meade A (1934). The New Modern Gasworks Practice. Eyre and Spottiswoode, London.
6. Ministry for the Environment (1997). Draft Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand. Due for release in August.
7. Ministry for the Environment/Ministry of Health (1993). Draft Health and Environmental Guidelines for Selected Timber Treatment Chemicals.
8. Occupational Safety and Health Service (1994). Health and Safety Guidelines on the Cleanup of Contaminated Sites.
9. USEPA (1989). Exposure Factors Handbook. EPA/600/8-89/043.
10. Victoria EPA (1997). Draft National Framework for Ecological Risk Assessment of Contaminated Sites. Prepared for the Contaminated Sites Technical Review Committee for the ANZECC/NHMRC.