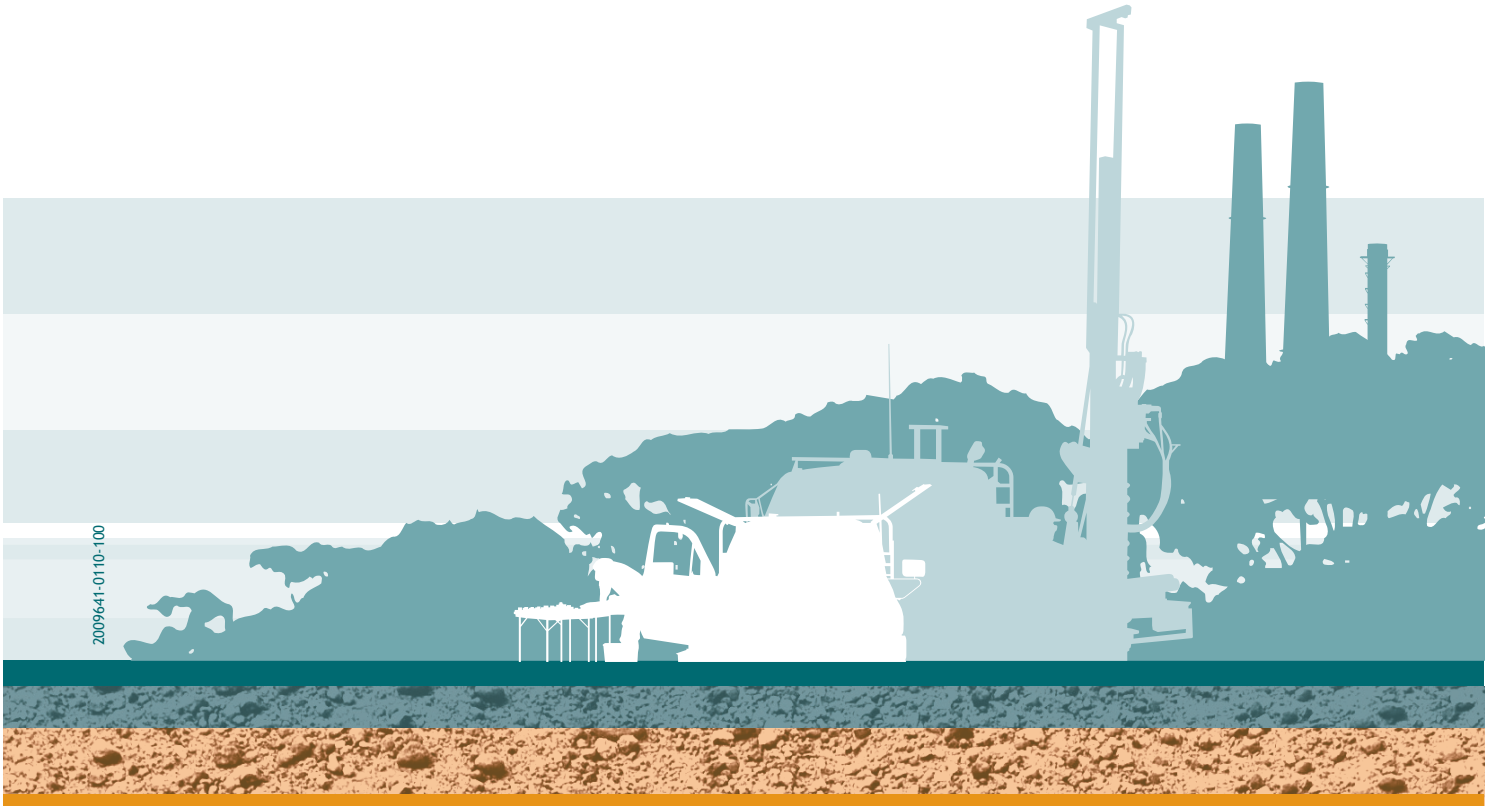
Department of
Environment and Conservation

Contaminated Sites Management Series

Assessment levels for Soil, Sediment and Water

February 2010



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Version 4, revision 1

To facilitate understanding of the various units used in laboratory reports, the following conversion table is provided:

Multiplication factor	Exponential notation	Scientific notation	Prefix	symbol
1,000	10^{3}	1.00E+03	kilo	k
100	10^{2}	1.00E+02		
10	10^{1}	1.00E+01		
1	10^{0}	1.00E+00		
0.1	10^{-1}	1.00E-01		
0.01	10^{-2}	1.00E-02	centi	c
0.001	10^{-3}	1.00E-03	milli	m
0.0001	10^{-4}	1.00E-04		
0.00001	10^{-5}	1.00E-05		
0.000001	10^{-6}	1.00E-06	micro	µ
0.0000001	10^{-7}	1.00E-07		
0.00000001	10^{-8}	1.00E-08		
0.000000001	10^{-9}	1.00E-09	nano	n
0.0000000001	10^{-10}	1.00E-10		
0.00000000001	10^{-11}	1.00E-11		
0.000000000001	10^{-12}	1.00E-12	pico	p

Contaminated Sites Management Series

Assessment Levels for Soil, Sediment and Water

Version 4, revision 1

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PREFACE

This updated version of the *Assessment Levels for Soil, Sediment and Water* guideline has been prepared by the Department of Environment and Conservation (DEC)[1]. It is designed to provide consultants, local government authorities, industry and other interested parties with information about the assessment levels used by accredited contaminated sites auditors and DEC to determine whether a site is potentially contaminated and whether further investigation is required.

Comments and suggestions to improve the clarity and usefulness of this document are welcome. All comments will be considered and, where appropriate, incorporated into the next version. Comments on this guideline should be forwarded to:

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Locked Bag 104
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or

emailed to contaminatedsites@dec.wa.gov.au

ACKNOWLEDGMENTS

DEC acknowledges the assistance of the Department of Health, Western Australia (DoH) in the preparation of this guideline.

LIMITATIONS

This guideline is intended for use only by persons assessing and managing contaminated sites. The contents herein provide guidance only and do not purport to provide a methodology for the assessment of sites. Competent practitioners should be engaged to provide specific advice in relation to the assessment and management of contaminated sites.

This guideline should be used in conjunction with the texts referenced herein, and any other appropriate references.

[1] Previously Department of Environment (DoE), and before that, Department of Environmental Protection (DEP)

DISCLAIMER

The information presented in this document is provided voluntarily as a public service. The information provided is made available in good faith and is believed accurate at the time of publication. However, the document is intended to be a guide only and should not be seen as a substitute for obtaining appropriate advice or making prudent inquiries. The information is provided solely on the basis that readers will be responsible for making their own assessment of the matters discussed therein and that they should verify all relevant representations, statements and information. Changes in legislation, or other circumstances, after the document has been published may impact on the accuracy of any information or advice contained in the document and readers should not rely on the accuracy of information presented in this document.

Information presented in this document does not constitute, and is not intended to be used as, legal advice nor used as an interpretive instrument. In the event of any inconsistency between this document and relevant legislation, provisions of the relevant legislation will prevail.

Neither the State of Western Australia (the State), nor any employee or agent of the State or any agency or instrumentality of the State, nor any authors or contributors to this document shall be liable for any loss, damage, personal injury or death however caused (whether caused by any negligent or other unlawful act or omission of, by or on the part of the State or otherwise) arising from the use of or reliance on any information, data or advice expressed or implied in this document.

CONTAMINATED SITES MANAGEMENT SERIES

This guideline forms part of the Contaminated Sites Management Series, developed by DEC to provide guidance on the assessment and management of contaminated sites in Western Australia. The series comprises:

- Assessment Levels for Soil, Sediment and Water
- *Assessment, Remediation and Management of Asbestos-Contaminated Sites in Western Australia (joint publication with DoH)*
- Bioremediation of Hydrocarbon Contaminated Soils in Western Australia
- Certificate of Contamination Audit Scheme
- Community Consultation
- Contaminated Sites Auditors: Guidelines for Accreditation, Conduct and Reporting;
- Contaminated Sites and the Landuse Planning Process;
- Disclosure Statements
- Development of Sampling and Analysis Programs
- Potentially Contaminating Activities, Industries, and Landuses
- Reporting of Known or Suspected Contaminated Sites
- Reporting on Site Assessments
- Site Classification Scheme
- The Use of Risk Assessment in Contaminated Site Assessment and Management: Guidance on the Overall Approach; and
- Use of Monitored Natural Attenuation for Groundwater Remediation

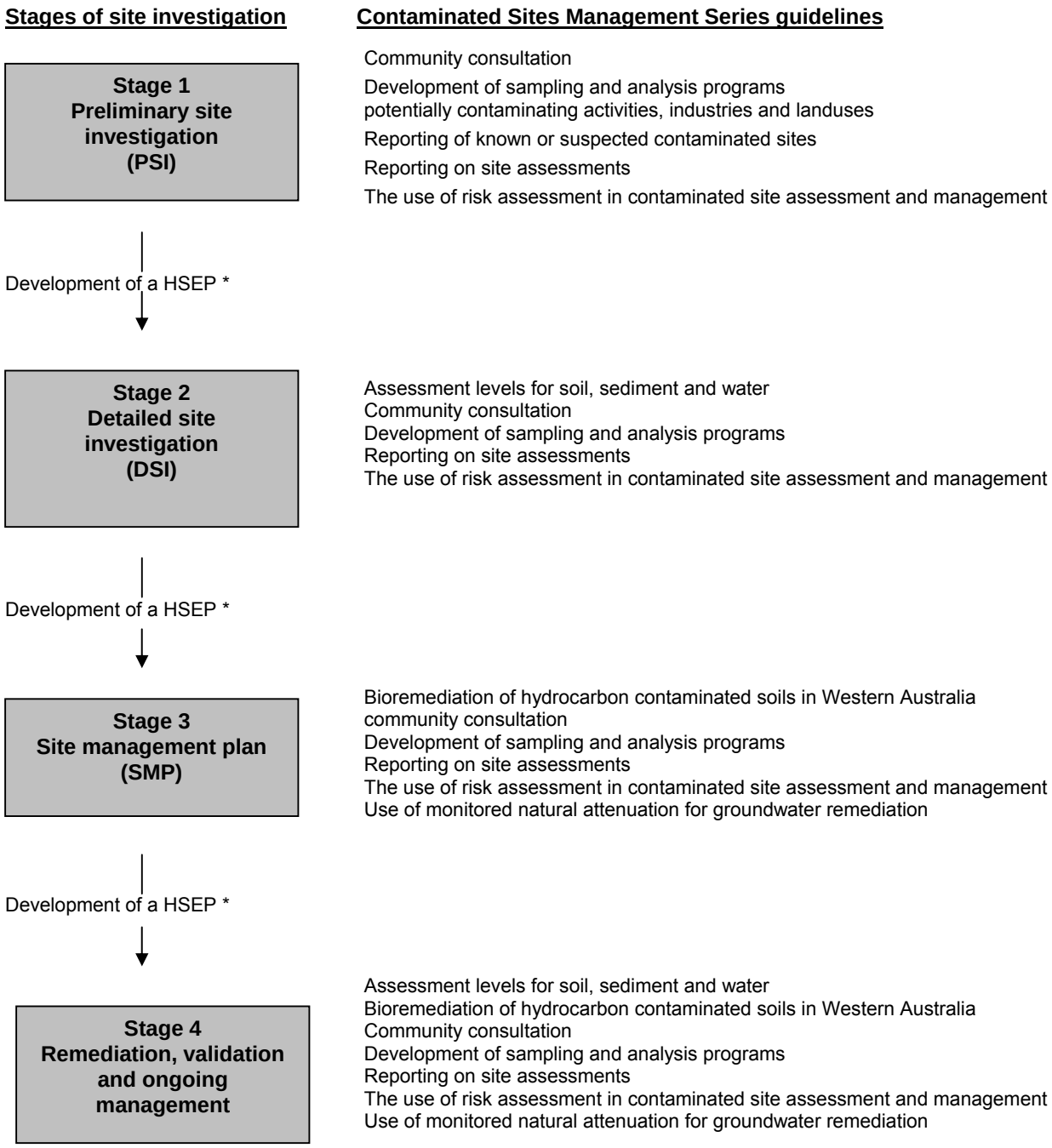
Copies of these guidelines can be downloaded from DEC's website at www.dec.wa.gov.au/contaminatedsites.

Limited stocks of the guidelines are also held by the DEC library:
Level 4, The Atrium
168 St Georges Terrace,
Perth.

STAGED APPROACH TO SITE INVESTIGATIONS

The Contaminated Sites Management Series of guidelines has been developed by DEC to encourage a consistent approach to contaminated site assessment and management. A **staged approach to site investigation** is a primary objective of the series in order that appropriate resources are allocated to contaminated site projects.

The flowchart below highlights the appropriate reference guideline(s) to be consulted during each of stage of site investigation.



*** Health, Safety and Environment Plan. Refer to *Guidance Note Occupational Safety and Health Management and Contaminated Sites Work* (Commission for Occupational Safety and Health, 2005).**

TABLE OF CONTENTS

LIST OF TABLES

1. INTRODUCTION

This guideline lists generic assessment levels adopted by the Department of Environment and Conservation (DEC) and provides guidance on the application of assessment levels to determine whether a site is potentially contaminated and whether further investigation is required. Selected key points are highlighted in bold text.

This guideline contains assessment levels for a range of substances commonly investigated at potentially contaminated sites in Western Australia. It is not an exhaustive list and analytes should be selected based on the potential or known occurrence of contaminants at a site. More information is available in *Potentially Contaminating Activities, Industries and Landuses* guideline (DoE, 2004).

Acid sulfate soils[2] (ASS) are not addressed in this guideline. Guidance on the assessment and management of ASS may be found at: http://www.dec.wa.gov.au/ass.

Asbestos is not specifically addressed within this guideline. Guidance on assessment of asbestos as a potential contaminant is provided in: Department of Health (DoH) (2009a) *Guidelines for the Assessment, Remediation and Management of Asbestos-Contaminated Sites in Western Australia* published jointly by the DoH and DEC. More information may be found on DoH's website at: www.public.health.wa.gov.au/2/656/2/contaminated_sites.pm.

This guideline only contains a brief summary of the process for the assessment of soils, sediments and waters. It is strongly recommended that guidance is sought from the references provided herein and from appropriately qualified practitioners to ensure that the correct methodologies are employed.

1.1 SOURCE OF ASSESSMENT LEVELS

The assessment levels listed in this guideline are sourced from various Australian and international guidance documents which were derived using a number of different methodologies and various toxicological data and assumptions. It is the responsibility of the user to select assessment levels that are appropriate to the site setting and to acquire sufficient site-specific data to support their correct application.

DEC has adopted assessment levels from (or based on) the following sources:

Soil

1. National Environment Protection Council (NEPC) (1999) *National Environment Protection (Assessment of Site Contamination) Measure (NEPM); Schedule B(1) - Guideline on Investigation Levels for Soil and Groundwater*.
2. Australian and New Zealand Environment and Conservation Council (ANZECC) and National Health and Medical Research Council (NHMRC) (1992) *Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites.*

[2] Acid sulfate soils (ASS) are naturally occurring soils, sediments and peats that contain iron sulfides, predominantly in the form of pyrite. Acid sulfate soils are benign when in a waterlogged environment; however, when exposed to the atmosphere, oxidation results in the production of sulfuric acid and the release of metals including aluminium and nutrients. These substances remain in the soil until rainfall or rising groundwater leaches them out. Flushing of acidic leachate to groundwater and surface waters can cause both on-site and off-site impacts.

3. Moen, J.E.T., Cornet, J.P and Evers, C.W.A (1986) *Soil protection and remedial actions: criteria for decision making and standardisation of requirements*, in Assink, J.W and van den Brink, W.M (1986) *Contaminated Soils, First International TNO Conference on Contaminated Soil, 11-15 November 1985.*
4. Victorian Environment Protection Authority (Vic EPA) (1990) *Acceptance Criteria in the Clean-up Notice for the Bayside Site, Port Melbourne.*
5. US Environmental Protection Agency, Region 9 *Preliminary Remediation Goals.*
6. United States Environmental Protection Agency Regions 3,6 and 9 *Regional Screening Levels for Chemical Contaminants at Superfund Sites* (RSLs) http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm (accessed 13 August 2009)

Sediment

7. ANZECC and ARMCANZ (2000) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality.*
8. Environment Australia, (2002) *National Ocean Disposal Guidelines for Dredged Material.*

Water

9. National Environment Protection Council (1999) *National Environment Protection (Assessment of Site Contamination) Measure; Schedule B(1) – Guideline on Investigation Levels for Soil and Groundwater.*
10. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (2000) *Australian Water Quality Guidelines for Fresh and Marine Waters*.
11. National Health and Medical Research Council and Agriculture and Resource Management Council of Australia and New Zealand (2004) *Australian Drinking Water Guidelines.*
12. Australian and New Zealand Environment and Conservation Council/National Health and Medical Research Council (1992b) *Australian Water Quality Guidelines for Fresh and Marine Waters.*
13. Department of Health (2006) *Contaminated Sites Reporting Guideline for Chemicals in Groundwater.*
14. Dove, M.C. (2003). Effects of Estuarine Acidification in Survival and Growth of the Sydney Rock Oyster *Saccostrea glomerata.* PhD thesis, University of South Wales.
15. Environment Protection and Heritage Council et al (2006). *National Water Quality Management Strategy – Australian Guidelines for Water Recycling: Managing Health and Environmental Risks* (Phase 1) – November 2006.
16. National Health and Medical Research Council (2006). *Guidelines for Managing Risks in Recreational Water.*
17. Department of Health (2009c) *Draft Guidelines for the Use of Recycled Water in Western Australia.*

The assessment levels adopted by DEC are the most relevant available at the time of publication. The assessment levels in this guideline will be periodically updated as new data become available, for example via the variation of the National Environment Protection (Assessment of Site Contamination) Measure (the 'NEPM') process currently under way. In particular, the adoption of assessment levels from sources (3), (4) and (5), is an interim approach until more appropriate values have been determined for Western Australian settings.

The assessment levels are presented for soil in Table 1 of this document, for sediments in Table 2 and in tables 3, 4 and 5 for water.

The tables in this guideline present frequently encountered potential contaminants of concern. However, they do not include all the substances/data available in the various source documents. It is the assessor's responsibility to consult the source documentation for information relevant to the application of the selected assessment levels.

Other contaminants not listed in this guideline may be present at a site and the suite of analyses undertaken should take into account knowledge of the site and the potential for contaminants to occur at the site based on the history of the site and surrounding area.

1.2 ALTERNATIVE ASSESSMENT LEVELS

The assessment levels in tables 1 to 5 of this document are to be used in the context of a Tier 1 screening risk assessment (DEC, 2006) to determine whether substances present at a site are at concentrations which may potentially present a risk to human health, the environment or an environmental value. However, where relevant assessment levels are not included in these tables (or are not available from the source documents listed in section 1.1), alternative assessment levels may be sourced from other jurisdictions or developed on a site-specific basis.

Where alternative assessment levels are adopted from other jurisdictions, the relevance of the exposure assumptions for the adopted assessment levels to the site being assessed must be justified and fully documented in the report. The documentation will be reviewed by the Contaminated sites auditor and/or DEC in consultation with other relevant government agencies (e.g. DoH) to ensure that the adopted assessment levels are acceptable.

Where site-specific assessment levels are developed, the methodology employed and underlying information, will be subject to a similar review process.

Sources of information

Guidance on the use of generic assessment levels and the development of site-specific criteria is available in:

- the *National Environment Protection (Assessment of Site Contamination) Measure* (NEPM)
- *Environmental Health Risks, Guidelines for assessing human health risks from environmental hazards* (enHealth, 2002)
- *Australian Water Quality Guidelines for Fresh and Marine Waters 2000* (ANZECC and ARMCANZ, 2000)
- *The Use of Risk Assessment in Contaminated Site Assessment and Management: Guidance on the overall approach* (DEC, 2006).

Ecological risk assessment

Additional information of particular relevance to ecological risk assessment is available from/in:

- Simpson *et al* (2005) *Handbook for Sediment Quality Assessment*. CSIRO. Bangor, NSW
- Heemsbergen *et al* (2009) The Australian Methodology to Derive Ecological Investigation levels in Contaminated Soils. CSIRO Land and Water Science Report 43/09 http://www.clw.csiro.au/research/biogeochemistry/organics/eil/index.html
- LandCare Research New Zealand – http://contamsites.landcareresearch.co.nz/about.htm
- New Zealand Ministry for the Environment – http://www.mfe.govt.nz/publications/hazardous/
- Canadian Council of Ministers of the Environment (CCME) – http://www.ccme.ca/publications/list_publications.html#link4
- Oakridge National Laboratory (USA) – http://www.esd.ornl.gov/programs/ecorisk/ecorisk.html
- USA Environmental Protection Agency –
    - http://www.epa.gov/ecotox/ecossl/
    - http://www.epa.gov/oswer/riskassessment/index.htm
    - http://www.epa.gov/superfund/programs/nrd/era.htm
    - http://www.epa.gov/ecotox

Human health risk assessment

Additional information of particular relevance to human health risk assessment can be found in (alphabetical order):

- Australian Pesticides and Veterinary Medicines Authority – http://www.apvma.gov.au/
- CSIRO Land and Water Science Report 43/09 – http://www.clw.csiro.au/research/biogeochemistry/organics/eil/index.html
- Department of Health and Ageing – http://www.health.gov.au/
- enHealth Council – http://enhealth.nphp.gov.au/
- Environment Protection and Heritage Council – http://www.ephc.gov.au
- NICNAS – http://www.nicnas.gov.au/About_NICNAS.asp
- Food Standards Australia New Zealand – http://www.foodstandards.gov.au/
- National Environment Protection Council – http://www.ephc.gov.au
- National Health and Medical Research Council – http://www.nhmrc.gov.au/
- Safe Work Australia – http://www.ascc.gov.au/
- State and Territories health and environment jurisdictions
- Worksafe – http://www.commerce.wa.gov.au/WorkSafe/

International jurisdictions (listed in order of acceptability to DoH with respect to the methodology employed to derive guideline values):

- World Health Organisation standards and guidelines – http://www.who.int/en/
    - Concise International Chemical Assessment Documents
    - Environmental Health Criteria
    - International Agency for Research on Cancer
    - International Programme on Chemical Safety
    - Joint Expert Committee on Food Additives
    - Joint Pesticide meeting on Pesticide Residues
- United Kingdom Department of Health – http://www.doh.gov.uk/
- United Kingdom Department of Environment, Food and Rural Affairs – http://www.defra.gov.uk/environment/land/contaminated/index.htm
- Netherlands National Institute of Public Health and the Environment (RVIM) – http://www.rivm.nl/en/

- Health Canada – http://www.hc-sc.gc.ca/ewh-semt/contamsite/index-eng.php
- New Zealand Ministry for the Environment – http://www.mfe.govt.nz/publications/hazardous/
- US Department of Health and Human Services Agency for Toxic Substances Disease Registry – http://www.atsdr.cdc.gov/
- United States Environmental Protection Authority – http://www.epa.gov/

Sources of toxicological data are also listed in section 7.2 of enHealth (2002).

Reference to documentation from non-Australian jurisdictions above does not constitute endorsement by DEC or DoH of individual assessment or guideline values within that document. Where alternative assessment levels are adopted, justification is required which demonstrates that the methodology of derivation and the exposure scenarios considered are relevant to the site being assessed.

1.3 APPLICATION OF ASSESSMENT LEVELS WITHIN A TIERED RISK ASSESSMENT FRAMEWORK

Information on the recommended overall approach to conducting risk assessments (including Tier 1 screening risk assessments) is provided in *The Use of Risk Assessment in Contaminated Site Assessment and Management: Guidance on the overall approach* (DEC, 2006).

In a *Tier 1 screening risk assessment*, site-analytical data are compared with generic assessment levels to identify which substances may pose a risk to human health, the environment or environmental values. If the concentration of a substance is lower than the relevant assessment level, then the substance is unlikely to represent an unacceptable risk (assuming that the data are correct and representative of the site, and the exposure assumptions used in the derivation of the assessment level are appropriate).

If one or more assessment levels are exceeded, then further investigation *(Tier 2 intermediate risk assessment)* is required to determine whether the identified substances of concern pose a risk in the existing or proposed site setting and to determine the scale and urgency of further action if appropriate. The greater the exceedence of the assessment level, the greater the likelihood that the substance will pose a risk to human health and/or the environment and/or environmental values.

A *Tier 1 screening risk assessment* comprises the following steps:

- development of a conceptual site model (CSM) which identifies all potential contaminant sources, exposure pathways and receptors
- preliminary assessment to determine whether complete pathways potentially exist between the identified contaminant sources and potential receptors
- selection of relevant assessment levels
- assessment of whether contaminant concentrations exceed the relevant assessment levels
- discussion of potential risks identified and sources of uncertainty (risk characterisation).

The selection of appropriate assessment levels is based on the environmental value of the site (where the environmental value is defined in the *Environmental Protection Act 1986* as the beneficial use and/or the ecosystem health condition) and/or the current or potential landuse(s) of the site. The process of developing a CSM will assist the user in determining which assessment levels are most relevant to the site circumstances and the level of protection required.

If the exposure pathways are assessed as incomplete, or if the concentrations of the substances do not exceed the relevant assessment levels, the risk assessment process is completed by the documentation of the decisions made and consideration of precautionary risk management measures. Guidance on the requirements for site investigation reporting is available in *Reporting on Site Assessments* (DEP, 2001a).

The assessment levels in this document should be used in the context of a *Tier 1 screening risk assessment* (DEC, 2006) to determine whether substances present at a site are at concentrations which may potentially present a risk to human health, the environment or environmental values. Where a substance is present above the relevant assessment level, further investigation is required to determine whether the site is contaminated.

1.4 CLEAN-UP/RESPONSE LEVELS

Where a site is found to be contaminated, DEC, consistent with the NEPM, supports the derivation of site-specific response/clean-up levels using accurate field and analytical results and appropriate ecological and health risk assessment (Tier 2 or Tier 3). The use of more detailed risk assessment is strongly recommended since the Tier 1 generic assessment levels incorporate a high degree of conservatism for most exposure settings.

Site-specific response levels and the site data and risk assessment results on which they are based will be subject to review by the auditor and/or DEC in consultation with other relevant government agencies (e.g. DoH) to ensure that they are acceptable.

Ecological investigation levels (EILs) and Health Investigation Levels (HILs) are screening assessment levels. If the screening assessment levels are exceeded, further risk assessment is required to determine whether the levels present are likely to pose an actual risk in the site-specific setting. EILs and HILs are not default clean-up or remediation levels.

1.5 DATA QUALITY

1.5.1 Field data

All observations and analytical results relied on in a site assessment should be obtained using correctly calibrated instruments and following appropriate field procedures. Data which do not meet these criteria should be treated as indicative only, and will not be accepted by DEC as being definitive results for a site. More information on field quality assurance and

quality control (QA/QC) requirements is provided in section 3 of *Development of Sampling and Analysis Programs* (DEP, 2001b).

1.5.2 Laboratory data

All results relied on in the assessment should be obtained using National Association of Testing Authorities (NATA) accredited methodologies. Data which do not meet this criterion should be treated as indicative only, and will not be accepted by DEC as being definitive results for a site. More information on laboratory QA/QC requirements is provided in section 3 of *Development of Sampling and Analysis Programs* (DEP, 2001b).

Details of laboratories that hold NATA accreditation for specific analyses can be obtained from the NATA website at http://www.nata.asn.au/go/accreditation.

1.5.3 Units of reporting

To facilitate understanding of the various units used in laboratory reports, the following conversion table is provided:

Multiplication factor	Exponential notation	Scientific notation	Prefix	symbol
1,000	10^{3}	1.00E+03	kilo	k
100	10^{2}	1.00E+02		
10	10^{1}	1.00E+01		
1	10^{0}	1.00E+00		
0.1	10^{-1}	1.00E-01		
0.01	10^{-2}	1.00E-02	centi	c
0.001	10^{-3}	1.00E-03	milli	m
0.0001	10^{-4}	1.00E-04		
0.00001	10^{-5}	1.00E-05		
0.000001	10^{-6}	1.00E-06	micro	µ
0.0000001	10^{-7}	1.00E-07		
0.00000001	10^{-8}	1.00E-08		
0.000000001	10^{-9}	1.00E-09	nano	n
0.0000000001	10^{-10}	1.00E-10		
0.00000000001	10^{-11}	1.00E-11		
0.000000000001	10^{-12}	1.00E-12	pico	p

1.6 LABORATORY LIMITS OF REPORTING/LIMITS OF DETECTION

In some situations, assessment levels may lie below the currently achievable limits of reporting (LORs) by NATA-accredited commercial laboratories for the suite of analyses in question. In particular, this may be an issue for pesticides where 99 per cent trigger values are used as assessment levels for fresh and marine waters (refer to Table 4 in this document and ANZECC and ARMCANZ, 2000). Where this occurs, DEC will accept the use of LORs as interim assessment levels provided that the chemical analyses are undertaken using the

most sensitive NATA-accredited technique available in Australia, and that an appropriate level of risk assessment is undertaken to characterise the potential risks to human health, the environment and environmental values. For some analytes this will involve sending samples interstate for analysis.

2. ASSESSMENT LEVELS FOR SOIL

Contaminated soils can arise from a number of sources including accidental spillage of chemicals, leaching of contaminants (for example from uncontrolled fill and uncapped/unlined landfills), leakage from damaged drums, tanks, pipework and drains and disturbance or inappropriate management of acid sulfate soils.

Potential sources of microbiological contamination include sewage sludge, 'night soil', landfills, animal and bird manures and buried animal carcasses. An assessment of microbiological risks via soil exposure is generally not required unless sewage treatment-related activities have been carried out on site (excluding domestic systems) or where intensive livestock operations or waste disposal (particularly large-scale disposal of manure or animal carcasses) are involved and a change to a more sensitive land use is proposed. Further information relevant to the assessment of microbiological risks from pathogenic organisms can be found in NHMRC (2006), Pedley *et al*. (2006) and CRC for Water Quality and Treatment (2004).

Contaminated soils can pose a threat to human health and the environment through direct exposure (dermal contact, ingestion and inhalation of soil particles) or indirect exposure (for example via groundwater contamination from the leaching of substances through the soil profile; inhalation of vapours via off-gassing of undisturbed contaminated soils or through exposure to surface water contaminated by the generation of air borne contaminated dusts or contaminated surface water run-off). Exposure may also occur through the release of hazardous dusts and vapours during reworking of soils, for example during site redevelopment.

Table 1 presents the soil assessment levels adopted by DEC for determining if soil is potentially contaminated. The table is divided into two sections: **Ecological Investigation Levels (EILs)** and **Health Investigation Levels (HILs)**.

EILs and HILs, as presented in Table 1, are to be used for the identification of potential contamination in a *Tier 1 screening risk assessment*. These criteria have not been developed as clean-up or remediations levels, nor are they 'desirable soil quality' criteria. If these generic levels are exceeded, the appropriate next step is to carry out further risk assessment to determine whether modified generic assessment level(s) (a *Tier 2 intermediate risk assessment*) can be developed which, although potentially less conservative, are nonetheless protective of human health, the environment and environmental values.

Site-specific assessment levels will need to be developed where:

- generic assessment values are not available for the substances of concern
- site conditions, receptors and/or exposure pathways differ significantly from those assumed in the derivations of the EILs or HILs (e.g. significant consumption of home-grown vegetables)
- significant ecological issues (e.g. critical or sensitive habitats, threatened or endangered species, national parks and nature reserves) are present.

2.1 ECOLOGICAL INVESTIGATION LEVELS

Where possible, the EILs for soils are sourced from the NEPM which are largely based on the Environmental Investigation Levels listed in the *Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites* (ANZECC/NHMRC, 1992). Where EILs are not listed in the ANZECC/NHMRC guidelines, values from Moen *et. al* (1986) (also known as Dutch 'B') and Victoria EPA (Bayside clean-up criteria (1990)) have been retained from the previous version of this guideline as interim investigation levels. This position will be re-evaluated following the variation of the NEPM which is anticipated to include revised EILs for selected metals, naphthalene and DDT for various land uses.

The NEPM-sourced EILs listed in Table 1 are based on phytotoxicity (copper and lead) and background soil survey data (barium, phosphorus and sulphur) from four Australian capital cities (not including Perth) and are intended for use in an urban setting. The ANZECC/NHMRC (1992) EILs ('ANZECC B') have been retained for antimony, tin, dieldrin, total PCBs and sulfate. The ANZECC B EILs were based on "phytotoxicity and threshold levels for uptake of contaminants which may result in impairment of plant growth or reproduction or unacceptable residue levels". The details of their derivation, however, have not been published. Table 1 also includes guideline values for cobalt, molybdenum, total phenols, pesticides, PAHs and cyanides which are derived from Moen *et al*. (1986).

The screening levels listed in Table 1 are intended for urban areas and may not be sufficiently protective where areas of high ecological value (such as national parks and nature reserves) are involved. Where wildlife are likely to be a significant receptor, alternative assessment levels such as the Ecological Soil Screening Levels (Eco-SSLs) developed by the United States Environmental Protection Agency (US EPA) for superfund sites (http://www.epa.gov/ecotox/ecossl/) can be considered. The US EPA has derived conservative screening levels for soil contaminants that are frequently of ecological concern for plants and animals at US hazardous waste sites. The Eco-SSLs are intended to be protective of ecological receptors which commonly come into contact with soil or ingest biota that live in or on soil and are intended to be used to identify contaminants of potential concern which then require further evaluation.

The EILs are only intended to be used in the context of an initial screening risk assessment to determine whether concentrations of substances in soil at a site potentially pose a risk to the environment or relevant environmental values. If screening assessment levels are exceeded, the appropriate next step is to carry out further investigation to determine whether the levels present are likely to pose an actual risk in the site-specific setting. This is particularly important where the relevance of the screening assessment levels to the site conditions may be uncertain, for example, where Dutch 'B' guidelines or Victorian EPA Bayside criteria have been adopted. The further investigation may take the form of a comparative assessment with background concentrations and/or consideration of site-specific factors which may affect contaminant availability.

The natural background levels of metals and other inorganic chemicals vary widely and this should be taken into account when applying the assessment levels. Where it can be demonstrated that *natural* background concentrations are elevated (e.g. heavy metal concentrations in mineralised areas), it would be appropriate to develop less stringent assessment criteria. However, care needs to be taken when establishing the level of the natural background and its natural variation as the local background may be influenced by historic mining and/or waste disposal activities.

The development of many of the EILs adopted in this guideline did not specifically consider the potential contamination of groundwater or surface water or the health of ecosystems supported by these water resources. In order to protect the sensitive ecosystems of Western Australia and, for compliance with the *Contaminated Sites Act 2003*, DEC requires that site investigations include a groundwater investigation and the results be compared with the relevant water assessment levels.

Potential environmental impacts should be considered in all Tier 1 screening risk assessments. Even if there are no on-site ecological receptors (e.g. a central metropolitan site without a garden or landscaped areas), the potential for soil contamination to leach and contaminate aquatic, including groundwater dependent, ecosystems should be considered.

2.2 HEALTH INVESTIGATION LEVELS

The health investigation levels (HILs) adopted by DEC and DoH are primarily based on the health-based soil investigation levels presented in the *National Environment Protection (Assessment of Site Contamination) Measure* (NEPM) (NEPC, 1999) which were developed through the enHealth Council.

The application process for the NEPM HILs is explained in Schedule B(7A) of the NEPM (NEPC, 1999), and requires that, for each exposure area, the arithmetic mean of the sample data is compared with the HILs which are listed here in Table 1. The results must also meet the following criteria:

- the standard deviation of the results must be less than 50 per cent of the values given in Table 1
- no single value must exceed 250 per cent of the relevant value given in Table 1.

The relevance of any localised elevated values should be considered and discussed in the report.

As in previous versions of this guideline, assessment levels have been sourced from the US EPA where HILs were not available via the NEPM. Regional screening levels for chemical contaminants at superfund sites (RSLs) published by US EPA Regions 3, 6 and 9 (US EPA, 2009) have now replaced Region 9 Preliminary Remediation Goals (PRGs). A detailed user's guide and supplementary tables for the RSLs may be downloaded from the Region 3 website at
http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm

RSLs have generally been adopted as interim assessment levels in this document, however, exceptions apply where there are concerns about the reliability of some of the toxicity data used and the apparent inconsistencies with the US Agency for Toxic Substances and Disease Registry (ATSDR) (DoH, 2009b). The exceptions comprise ethylbenzene, naphthalene and toluene. The assessment levels listed in version three of this guideline (DoE, 2003), have been retained for these substances with the exception of the commercial/industrial landuse value for toluene which has been relaxed from 520mg/kg to 5,200mg/kg (DoH, 2009b).

Health investigation levels for Total Petroleum Hydrocarbons (TPH)

Analytical methods which do not differentiate the aliphatic and aromatic hydrocarbon components are sometimes used in preliminary site assessments. Where this is done, the total hydrocarbon fraction result should be compared with the relevant HIL for the aromatic fraction. For example, the C_{15}-C_{28} plus C_{29}-C_{36} concentrations are summed and compared with the HIL for the C_{16}-C_{35} *aromatic* fraction (enHealth Council, 2001). Where TPH concentrations are found to exceed the relevant *aromatic* HIL, further analysis is required to determine the aromatic and aliphatic split, which can then be compared with the speciated HILs.

If soils are potentially impacted with petroleum hydrocarbons:

1. **Analyse soil samples for appropriate substances (e.g. TPH, BTEX, PAHs and any additional compounds relevant to the site).**
2. **Compare concentrations with the relevant HILs (Table 1) or site-specific criteria.**
3. **Sum hydrocarbon concentrations within the C_{16}-C_{35} range, e.g. C_{15}-C_{28} and C_{29}-C_{36} and compare with the relevant HIL for the C_{16}-C_{35} aromatic fraction.**
4. **If exceeded, carry out further analysis to differentiate the aromatic and aliphatic components.**

Health screening level for Methyl Tertiary Butyl Ether (MTBE)

The presence of MTBE in Western Australian soils and groundwater is an emerging issue. An MTBE screening level of 0.5mg/kg for soil has been adopted by DEC and DoH based on its high leachability and aesthetic (odour) grounds. As an interim approach until the occurrence of MTBE in Western Australian soils and waters is better understood, the detection of MTBE in water or soil at levels above the screening levels should be reported to DEC as soon as practicable and noted and discussed in assessment reports. DoH should be consulted through DEC where exceedances of the screening criteria are present as the preparation of a detailed human health risk assessment may only be necessary at much higher contamination levels.

2.3 ADJUSTING ASSESSMENT LEVELS FOR COMPOSITE SAMPLES

Composite sampling may be used as a preliminary screening tool and where the site history indicates that there are unlikely to be any point sources of contamination. Composite samples must be representative of the sample unit and preferably should only be taken from soil units which are homogenous.

Composite sampling will not be accepted by DEC for site validation purposes or for the investigation of semi-volatile or volatile substances.

It is possible for a sub-sample containing a high concentration of a substance to remain undetected due to its dilution in the compositing process. To overcome this, the appropriate assessment level (see Table 1) should be divided by the number of sub-samples making up the composite. Application of this procedure assumes the worst-case scenario that one sub-sample has a high concentration and all other sub-samples have concentrations below the reporting level. If the concentration of the composited sample exceeds the adjusted assessment level, then all sub-samples (across the site) should be analysed individually.

This method for adjusting assessment levels is adopted from the *New South Wales Environment Protection Authority Sampling Design Guidelines* (NSW EPA, 1995).

More information on composite sampling can be found in *Development of Sampling and Analysis Programs* (DEP, 2001) and Australian Standard AS4482.1 – 2005 – *Guide to the sampling and investigation of potentially contaminated soil – Part 1: Non volatile and semi-volatile compounds.*

TABLE 1. ASSESSMENT LEVELS FOR SOIL

	Ecological Investigation Levels	Health Investigation Levels			
		A[1]	D	E	F
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Metals/Metalloids					
Antimony, Sb	-	**31**[12]	-	-	**410**[12]
Arsenic, As	20[8]	100[8]	400[8]	200[8]	500[8]
Barium, Ba	**300**[8]	**15,000**[12]	-	-	**190,000**[12]
Beryllium, Be	-	20[8]	80[8]	40[8]	100[8]
Cadmium, Cd	3[8]	20[8]	80[8]	40[8]	100[8]
Chromium[2] (Cr III)	**400**[8]	**120,000**[8]	**480,000**[8]	**240,000**[8]	**600,000**[8]
Chromium[2] (Cr VI)	**1**[8]	100[8]	400[8]	200[8]	500[8]
Cobalt, Co	50[9]	100[8]	400[8]	200[8]	500[8]
Copper, Cu	**100**[8]	1,000[8]	4,000[8]	2,000[8]	5,000[8]
Lead, Pb	**600**[8]	300[8]	1,200[8]	600[8]	1,500[8]
Manganese, Mn	500[8]	1,500[8]	6,000[8]	3,000[8]	7,500[8]
Methyl mercury[3]	-	10[8]	40[8]	20[8]	50[8]
Mercury (inorganic), Hg	1[8]	15[8]	60[8]	30[8]	75[8]
Molybdenum, Mo	40[9]	390[12]	-	-	**5100**[12]
Nickel, Ni	60[8]	600[8]	2,400[8]	600[8]	3,000[8]
Tin, Sn	50[10]	**47,000**[12]	-	-	**610,000**[12]
Vanadium, V	50[8]	**550**[12]	-	-	**7,200**[12]
Zinc, Zn	200[8]	7,000[8]	28,000[8]	14,000[8]	35,000[8]
Other Inorganics					
Boron, B	-	3,000[8]	12,000[8]	6,000[8]	15,000[8]
Cyanides (complexed)[4], CN	50[9]	500[8]	2,000[8]	1,000[8]	2,500[8]
Cyanides (free)[4], CN	10[9]	250[8]	1,000[8]	500[8]	1,250[8]
Phosphorus, P	2,000[8]	-	-	-	-
Sulfur, S	600[8]	-	-	-	-
Sulfate[5], SO_4	2,000[8]	-	-	-	-
ORGANIC COMPOUNDS					
Methyl tertiary butyl ether, MTBE	-	**0.5**[13]	**0.5**[13]	**0.5**[13]	**0.5**[13]
Total Petroleum Hydrocarbons (TPH)					
C_6-C_9	100[7]	-	-	-	-
C_{10}-C_{14}	500[7]	-	-	-	-
C_{15}-C_{18}	1,000[7]	-	-	-	-
>C_{16}-C_{35} (aromatics)	-	90[8]	360[8]	180[8]	450[8]
>C_{16}-C_{35} (aliphatics)	-	5,600[8]	22,400[8]	11,200[8]	28,800[8]

	Ecological Investigation Levels	Health Investigation Levels			
		A[1]	D	E	F
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
>C_{35} (aliphatics)	-	56,000[8]	224,000[8]	112,000[8]	280,000[8]
Monocyclic Aromatic Hydrocarbons					
Benzene	1[10]	**1.1**[12]	-	-	**5.6**[12]
Toluene	3[9]	520[11]	-	-	**5200**[11]
Ethylbenzene	5[9]	230[11]	-	-	230[11]
Xylenes	5[9]	**600**[12]	-	-	**2600**[12]
Polycyclic Aromatic Hydrocarbons (PAHs)					
Total PAHs[14]	-	20[8]	80[8]	40[8]	100[8]
Anthracene	10[9]	**17,000**[12]	-	-	**170,000**[12]
Benzo[a]pyrene	1[9]	1[8]	4[8]	2[8]	5[8]
Fluoranthene	10[9]	**2,300**[12]	-	-	**22,000**[12]
Naphthalene	5[9]	60[11]	-	-	190[11]
Phenanthrene	10[9]	-	-	-	-
Pyrene	10[9]	**1,700**[12]	-	-	**17,000**[12]
Phenols					
Phenol[6]	-	8,500[8]	34,000[8]	17,000[8]	42,500[8]
2-methylphenol	-	**3,100**[12]	-	-	**31000**[12]
3-methylphenol	-	**3,100**[12]	-	-	**31000**[12]
4-methylphenol	-	**310**[12]	-	-	**3,100**[12]
Total phenols	1[9]	-	-	-	-
Polychlorinated Biphenyls (PCBs)					
total PCBs	1[10]	10[8]	40[8]	20[8]	50[8]
OC & OP Pesticides					
Individual organochloride pesticides	0.5[9]	-	-	-	-
Total organochloride pesticides	1[9]	-	-	-	-
Total non-chlorinated pesticides	2[9]	-	-	-	-
Individual non-chlorinated pesticides	1[9]	-	-	-	-
Aldrin plus dieldrin	-	10[8]	40[8]	20[8]	50[8]
Dieldrin	0.2[10]	-	-	-	-
Chlordane	0.5[9]	50[8]	200[8]	100[8]	250[8]
DDT + DDD + DDE	1[9]	200[8]	800[8]	400[8]	1,000[8]
Heptachlor (including its epoxide)	0.5[9]	-	-	-	-
Heptachlor	-	10[8]	40[8]	20[8]	50[8]

BOLD indicates a change from the previous version of this guideline

Key to source of assessment levels:

VIC EPA[7]	NEPM[8]	"Dutch B"[9]	ANZECC B[10]
DoH[11]	USEPA RSLs[12]		DEC/DoH[13]

Notes: Land uses as adopted from the *National Environment Protection (Assessment of Site Contamination) Measure (NEPC 1999)*

A. Standard residential with garden/accessible soil (home-grown produce contributing less than 10 per cent of vegetable and fruit intake; no poultry). This category includes children's daycare centres, pre-schools and primary schools.
D. Residential with minimal opportunities for soil access including dwellings with fully or permanently paved yard space such as high-rise apartments and flats.
E. Parks, recreational open space and playing fields, includes secondary schools.
F. Commercial/industrial includes premises such as shops and offices as well as factories and industrial sites.

– No assessment level available.

1. Site and contaminant-specific assessment required where there is substantial home-grown vegetable and/or poultry consumption. Exposure estimates may then be compared with relevant Acceptable Daily Intakes (ADIs), Provisional Tolerable Weekly Intake (PTWIs) and Guideline Doses (GDs).
2. Valency state should be established initially from assessment of the site history and likely environmental behaviour. If chromium VI could be present, speciation is required to evaluate the risk.
3. Need to determine form of substance from assessment of site history, analysis and knowledge of environmental behaviour.
4. The nature of cyanides on a site must be assessed. To use the HIL for complexed cyanides, no more than five per cent of free cyanides should be present (and vice versa for free cyanides).
5. For protection of built structures (as presented in NEPC (1999)).
6. Odours and skin irritation may occur at lower concentrations. PVC pipes may be affected at high concentrations with possible adverse effects on the water therein.
7. Victorian EPA (1990) Acceptance Criteria in the Clean-up Notice for the Bayside Site, Port Melbourne.
8. National Environment Protection (Assessment of Site Contamination) Measure (NEPC, 1999).
9. Dutch B (Indicative value for further investigation) from Moen, J.E.T., Cornet, J.P and Evers, C.W.A (1986) Soil protection and remedial actions: criteria for decision-making and standardisation of requirements, in Assink, J.W and van den Brink, W.M (1986) Contaminated Soils, First International TNO Conference on Contaminated Soil 11-15 November 1985.
10. ANZECC B (Environmental Investigation Levels) from ANZECC & NHMRC (1992) Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites.
11. DoH (2009b) refer to section 2.2 in the main text
12. US EPA (2009) Regional Screening Levels (RSLs) http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm accessed 13 August 2009.
13. DEC/DoH screening level
14. As a minimum, speciation for benzo[a]pyrene is required.

3. ASSESSMENT LEVELS FOR SEDIMENT

Contaminated sediments comprise organic and inorganic materials that accumulate on the bottom of water bodies which contain substances that may adversely affect human health, the environment or environmental values. Contamination of sediments may result from both point sources (e.g. drains and spills) and/or diffuse sources (e.g. aerial deposition, soil erosion and groundwater discharges). It is important to consider both sediment particles and sediment pore waters as contaminant sources when assessing sediments. The importance of these sources and associated exposure pathways varies depending on the nature of the sediment dwelling organisms and assemblages present.

The dual role of sediments as both a source and sink of dissolved contaminants is widely recognised. In addition to their influence on surface water quality, sediments represent a source of bioavailable contaminants to benthic biota, and hence bioaccumulation in the food chain. Contaminated sediments can therefore affect aquatic ecosystem health and may indirectly impact human health e.g. through consumption of contaminated shellfish.

Where aquatic ecosystems are considered to be pristine and, therefore, of high environmental value, such as in marine parks and marine sanctuary areas, a precautionary approach to assessment is required. In these ecosystems, there should be no detectable change from natural background conditions permitted (ANZECC & ARMCANZ, 2000).

Reference to the US EPA technical manual on *Methods for Collection, Storage and Manipulation of Sediments for Chemical and Toxicological Analysis* (US EPA, 2001) is recommended when designing a sediment sampling program. The manual provides a compilation of information and recommended techniques for collecting, handling and manipulating sediment samples for physicochemical characterisation and biological testing techniques that are most likely to yield accurate, representative sediment quality data based on extensive experience.

The sediment assessment levels (*Interim Sediment Quality Guidelines* or ISQGs) adopted by DEC, as presented in Table 2, are sourced from the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ, 2000). The guidelines contain two concentrations, the ISQG-Low concentration (or trigger value) and the ISQG-High concentration. The trigger value is a threshold concentration and below this concentration the frequency of adverse effects is expected to be very low. The ISQG-High concentration is intended to represent a concentration above which adverse biological effects are expected to occur more frequently.

ANZECC & ARMCANZ (2000) recommend a hierarchical approach to the assessment of sediments, with a focus on issue identification and implementation of mitigation measures to manage these issues. The hierarchical approach is based on an initial assessment of total contaminant concentrations against the ISQGs (i.e. a *Tier 1 screening risk assessment*), followed by further investigations/analysis if these levels are exceeded (equivalent to a *Tier 2 intermediate risk assessment* or, for more complex scenarios, a *Tier 3 detailed site-specific assessment*).

The ANZECC & ARMCANZ (2000) procedure recommends:

- where total metal concentrations or dilute-acid-soluble metal analysis are less than ISQG-Low, no action is required for metals

- where total metal concentrations or dilute-acid-soluble metal analysis exceed the ISQG-Low, but are below the ISQG-High, then an assessment against background metal concentrations should be made
- where measured contaminant concentrations are found to exceed either the ISQG-High or both the ISQG Low and background concentrations, then an assessment of the factors controlling bioavailability of the contaminants should be completed
- where the calculated bioavailable concentrations are found to be less then the ISQG-Low, no further action is required for that contaminant
- where the bioavailable concentrations are found to exceed the ISQG-Low, then toxicity testing is required, and contaminants found to be toxic will require remediation.

Where no generic assessment level has been developed for a specified contaminant of interest, this generally reflects the absence of an adequate data set for that contaminant. ANZECC & ARMCANZ (2000) suggests that an indicative value can be derived based on natural background concentrations multiplied by an appropriate factor (factor of two, but in highly disturbed ecosystems, a larger factor may be more appropriate but no larger than a factor of three). This approach is not applicable to organic contaminants of anthropogenic origin as these would not be expected to occur under natural conditions. An alternative approach is to apply water quality guidelines to sediment porewater. However, obtaining the necessary volume of porewater (and preserving the original redox conditions) is generally problematic.

The trigger levels are not intended for stand-alone use since exceeding the trigger level (ISQG-Low) concentration does not imply that adverse effects will occur. If one or more sample results exceed an ISQG value, further investigations are required (*Tier 2 risk assessment*) to clarify whether adverse effects are likely to occur.

Further information relevant to the assessment of sediments may be found in Simpson *et al*. (2005).

The *National Ocean Disposal Guidelines for Dredged Material (*Environment Australia, May 2002) should be consulted where the sediments being assessed are within marine waters, and are being assessed for dredging and ocean disposal. Note that these guidelines are not appropriate for assessing disposal of dredged sediment to land.

TABLE 2. ASSESSMENT LEVELS FOR SEDIMENTS[1]

Parameter	ISQG-Low[2] (Trigger value)	ISQG-High[3]
Metals/Metalloids (mg/kg dry wt)		
Antimony, Sb	2	25
Arsenic, As	20	70
Cadmium, Cd	1.5	10
Chromium, Cr	80	370
Copper, Cu	65	270
Lead, Pb	50	220
Mercury, Hg	0.15	1
Nickel, Ni	21	52
Silver, Ag	1.0	3.7
Zinc, Zn	200	410
Organometallics (μg/kg dry wt)[4]		
Tributyltin (as Sn)	5	70
Organics (μg/kg dry wt)[4]		
Acenapthene	16	500
Acenaphthalene	44	640
Anthracene	85	1100
Fluorene	19	540
Naphthalene	160	2100
Phenanthrene	240	1500
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (PAHs)[5]	552	3160
Benzo(a)anthracene	261	1600
Benzo(a)pyrene	430	1600
Dibenzo(a,h)anthracene	63	260
Chrysene	384	2800
Fluoranthene	600	5100
Pyrene	665	2600
High Molecular Weight Polycyclic Aromatic Hydrocarbons (PAHs)[6]	1700	9600
Total Polycyclic Aromatic Hydrocarbons (PAHs)	4000	45000
Total DDT	1.6	46
P,p'-DDE	2.2	27
o,p'- + p,p'-DDD	2	20
Chlordane	0.5	6
Dieldrin	0.02	8
Endrin	0.02	8
Lindane	0.32	1.0
Total Polychlorinated Biphenyls (PCBs)	23	-

Notes:

1. Extracted from the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC and ARMCANZ, 2000).
2. Interim sediment quality guidelines – low: Probable effects concentrations below which biological effects would rarely occur.
3. Interim sediment quality guidelines – high: Probable effects concentrations below which biological effects would possibly occur. Concentrations above these values represent a probable-effects range within which effects would be expected to frequently occur.
4. Normalised to one per cent organic carbon. If the sediment organic carbon is markedly higher than one per cent the guideline value should be increased accordingly, since additional carbon binding sites reduce the contaminant bioavailability.
5. Low molecular weight PAHs are the sum of acenaphthalene, anthracene, fluorene, 2-methylnaphthalene, naphthalene and phenanthrene.
6. High molecular weight PAHs are the sum of benzo(a)anthracene, benzo(a)pyrene, chrysene, dibenzo(a,h)anthracene, fluoranthene and pyrene.

Values are expressed as concentrations on a dry weight basis. This does not imply that samples should be dried before analysis resulting in potential loss of some analytes, but that results should be corrected for moisture content.

4. ASSESSMENT LEVELS FOR WATER

Contaminated surface waters and groundwater can arise from a number of sources including leaking underground fuel tanks, washing of spilled chemicals into stormwater drains and infiltration basins, leaching of contaminants from unlined landfills and disturbance of acid sulfate soils. Potential sources of microbiological contamination include septic tanks, wastewater systems, wastewater treatment plants, sewers, cesspools, landfills, livestock operations (animal manures and animal carcasses) as well as the application of biosolids in agriculture.

Contaminated waters can pose a threat to human health, the environment and environmental values through direct exposure (e.g. dermal contact and ingestion) or indirect exposure (e.g. consumption of food produced using contaminated irrigation water).

Tables 3, 4 and 5 present levels adopted by DEC for the assessment of surface water and groundwater quality in Western Australia. The chemical assessment levels are mostly sourced from the *Australian Water Quality Guidelines for Fresh and Marine Water Quality 2000* (ANZECC & ARMCANZ, 2000), the *Australian Drinking Water Guidelines* (NHMRC & NRMMC, 2004) (ADWG) and the DoH *Contaminated Sites Reporting Guideline for Chemicals in Groundwater* (DoH, 2006). DEC has adopted microbiological assessment levels from the *Australian Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ, 2000), *Guidelines for Managing Risks in Recreational Water* (NHMRC, 2006) the *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1)* (EPHC, NRMMC & NHMRC, 2006) (AGWR) and *Draft Guidelines for the Use of Recycled Water in Western Australia* (DoH, 2009c).

Where groundwater quality is being assessed, the most appropriate assessment level depends on the beneficial use of the groundwater resource itself (including the possible presence of stygofauna and other groundwater dependent ecosystems) as well as that at the discharge location. For example, where contamination is present in shallow groundwater (such as in the superficial aquifer in Perth), which discharges to a wetland that is adjacent to the site, then the guidelines for the protection of fresh water aquatic ecosystems (ANZECC & ARMCANZ, 2000) would be the most appropriate assessment levels to apply. Alternatively, where a site is located within an area where groundwater is abstracted for agricultural irrigation purposes, then the irrigation guidelines would be applicable.

Where the CSM indicates that there may be human exposure to microbiological contamination (e.g. irrigation using surface or groundwater which may be impacted by landfill leachate, intensive livestock operations, or sewage treatment plants) the initial assessment should include screening for *E. coli* (thermotolerant coliforms) as an indicator of faecal contamination and compared with the relevant assessment levels. More information regarding guideline values for compounds which may be associated with sewage can be found in EPHC, NHMRC & NRMMC (2008). These guideline values were derived by applying the principles described in the ADWG (NHMRC & NRMMC, 2004).

Where surface waters or groundwaters contain levels of substances above the appropriate assessment levels, further investigation should be carried out to determine the source and the nature and extent of contamination, and any risks posed to human health, the environment and environmental values.

In some situations, the assessment levels for a substance may be below the limits of reporting (LOR) which can be achieved by the most sensitive technique which is employed

by NATA accredited commercial laboratories undertaking the relevant chemical analysis. This may be the case where the 99 per cent protection values for certain pesticides are used as assessment criteria, in which case refer to the procedure outlined previously in section 1.6.

The selection of appropriate assessment levels for a site should be based on the beneficial use and management objectives of the water resource e.g. support for aquatic ecosystems, public drinking water supply, domestic non-potable water use or public/agricultural irrigation. Depending on the location of the site, and the exposure scenarios identified in the conceptual site model, assessment against more than one type of use may be required. The subsequent management actions must take into account all the relevant exposure scenarios.

Aquatic Ecosystem (Fresh and Marine) Guidelines

The Australian Water Quality Guidelines for Fresh and Marine Water Quality 2000 (ANZECC & ARMCANZ, 2000) lists trigger values at four different protection levels: 99 per cent, 95 per cent, 90 per cent and 80 per cent where the protection level indicates the percentage of species expected to be protected. The values listed in tables 3 and 4 are those which are most commonly applicable to *slightly – moderately disturbed ecosystems*. In most cases, the default values are 95 per cent species protection levels, however, in some cases 99 per cent protection levels have been selected to account for specific factors such as bioaccumulation or where the 95 per cent value provides inadequate protection for key test species (for further information refer to ANZECC & ARMCANZ, (2000)). The 99 per cent trigger values are also appropriate for *high conservation value environments*, for example Ramsar wetlands. Where surface waters are *highly modified*, less conservative assessment levels may be appropriate. However, the management objectives for the surface water body should be considered before a less conservative protection level is adopted. The site assessment report should contain a justification for the level of protection selected.

Exceeding the assessment levels does not necessarily imply that adverse effects will occur. However, further investigations are required to clarify whether adverse effects are likely to occur.

Assessment levels for chemicals of concern affecting aquatic ecosystem receptors that do not have published values should be developed on a site-specific basis using the framework outlined within ANZECC & ARMCANZ (2000).

Potable and domestic non-potable uses of groundwater

Drinking water is defined as water intended primarily for human consumption, either directly as supplied from the tap or indirectly in beverages, ice or foods prepared with water. Drinking water is also used for other domestic purposes such as bathing and showering.

Where a groundwater bore is present on a site, or the site is up-hydraulic gradient of one or more groundwater bores, which may be impacted by contaminated groundwater, then the assessment should consider whether the public (or site occupiers) may be exposed directly or indirectly to groundwater through potable (drinking and cooking) or domestic non-potable uses (e.g. filling of swimming pools, reticulation, vehicle washing, toilet flushing). Where scheme water is not available, it is reasonable to assume that groundwater may be used for potable purposes, after testing and any necessary treatment.

In accordance with DoH advice, groundwater (borewater) should not be used for drinking, bathing, filling swimming and paddling pools, food preparation or cooking unless it has been appropriately tested and treated. However, untreated groundwater may be used to irrigate gardens (including the growing of vegetables), flush toilets and wash cars and clothes (DoH, 2004).

The quality of groundwater used for potable purposes should be assessed against the requirements of the Australian Drinking Water Guidelines (ADWG). Tables 3 and 4 list the guideline values for chemical substances in drinking water. With respect to microbial quality, *E. coli* (or thermotolerant coliforms) should not be detected in a minimum 100mL sample of drinking water. For more information, refer to NHMRC & NRMMC (2004).

DoH has developed generic assessment criteria (DoH, 2006) to protect the public who may be using, or may be exposed to, groundwater containing chemical residues in a non-potable setting. The DoH (2006) guideline value is generally a factor of 10 times the corresponding ADWG Health value[3] (or Aesthetic value[4] where there is no Health Value) except in specific cases (odoriferous chemicals and most pesticides).

The ADWG and DoH (2006) criteria should be applied as assessment levels (investigation levels) at the point of monitoring, and as response levels at the point of use (i.e. abstraction), except in the case of pesticides. As many pesticide assessment levels are at the analytical limit of detection, the response level may be set at a higher value through consultation with DoH on a site-specific basis. Further reference should be made to the ADWG for acceptable detection limits.

The presence of MTBE in Western Australian soils and groundwater is an emerging issue. The US EPA regional screening level of 0.012mg/L for MTBE in tap water (US EPA 2009) has been adopted by DEC and DoH. Until the occurrence of MTBE in Western Australian soils and waters is better understood, as an interim approach, the detection of MTBE in water or soil above the screening levels should be reported to DEC as soon as practicable and noted and discussed in assessment reports. DoH should be consulted through DEC where exceedances of the screening levels are present as the preparation of a detailed human health risk assessment may only be necessary at much higher contamination levels.

Where contamination occurs in an area where the background water quality indicates that there is potential for the groundwater to be used as a drinking water resource (even where it is not currently being used for that purpose), the ADWG are the most appropriate assessment criteria to apply in a *Tier 1 screening risk assessment* to ensure that the groundwater resource is protected for future use. The feasibility of using the groundwater resource for potable use should be considered where a site-specific risk assessment (Tier 2 or Tier 3) is carried out.

Where natural background groundwater quality has reduced beneficial uses (e.g. hypersaline groundwater), DEC may agree to less conservative assessment levels being adopted on a site-specific basis. However, the adoption of less conservative criteria will not be appropriate in all circumstances e.g. a less conservative hydrocarbon clean-up value would result in increased treatment costs where there is a reasonable expectation that the groundwater could be desalinised for potable use. Desalinisation plants are currently operating in Coral

[3] The **ADWG health-related guideline value** is the concentration or measure of water quality that, on present knowledge, does not pose any significant risk to the health of the person consuming the water over a lifetime of consumption (ANZECC & ARMCANZ, 2000).

[4] The **ADWG aesthetic guideline value** is the concentration or measure of water quality characteristic associated with good water quality (ANZECC & ARMCANZ, 2000).

Bay, Denham, Leonora and Yalgoo and are planned for several more Mid West and Goldfields towns (Water Corporation (2008)).

Recreational guidelines

Where the conceptual site model indicates that there may be public exposure to contaminants via recreational activities e.g. water sports and swimming, the National Health and Medical Research Council's (NHMRC's) *Guidelines for Managing Risks in Recreational Water* (2006) should be consulted for advice on appropriate assessment levels and procedures. The DoH (2006) guideline may be applied for chemical substances as the guideline is consistent with the NHMRC recommended screening approach, i.e. "a substance occurring in recreational water at a concentration ten times that stipulated in the drinking water guidelines may merit further consideration".

Irrigation guidelines – Public open space, golf courses, sports grounds etc.

Where the public may be exposed to irrigation water, for example through inhalation of spray drift, the DoH's (2006) guideline may be applied for chemical substances (tables 3 and 4). The *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1)* (EPHC, 2006) and DoH (2009c) should be consulted for advice on assessing microbiological risks if groundwater is likely to be impacted, for example by landfill leachate and/or sewage treatment operations etc. (microbiological assessment levels are listed in Table 5).

Irrigation guidelines – commercial and agricultural applications

The ANZECC & ARMCANZ (2000) irrigation guidelines (listed in tables 3 and 5) apply to commercial and agricultural applications. They should be applied as assessment levels at the point of monitoring and as response levels at the point of use (i.e. abstraction). These guideline levels are trigger values below which there should be minimal risk of adverse effects. However, further investigation is required if a trigger value is exceeded, in order to determine the level of risk and the management actions which may be required.

The ANZECC & ARMCANZ (2000) irrigation guidelines have been developed with a view to maintaining agricultural productivity and minimising off-farm movement or leaching of potential aquatic contaminants. The values for heavy metals and metalloids have been developed to minimise the build-up of contaminants in surface soils during the period of irrigation and to prevent direct toxicity of contaminants in irrigation waters to standing crops. The trigger values assume that irrigation water is applied to soils and that these soils reduce contaminant bioavailability by sorbing contaminants and hence reducing concentrations in solution. Therefore, the values may not be suitable for plants grown in soil-free settings (e.g. hydroponics).

The likely timescale of the operation should be considered when applying the guidelines. The Long-Term Irrigation Water criteria listed in Table 3 refer to the application of irrigation water in agricultural settings for periods of up to 100 years. If irrigation is unlikely to be used for any significant period of time, the short-term irrigation guidelines (refer to Table 4.2.10 of ANZECC & ARMCANZ (2000)) may be more appropriate. The trigger values should be used in conjunction with the additional information provided in volume three of the ANZECC & ARMCANZ guideline.

More information relevant for exposure settings where water is used for aquaculture can also be found in ANZECC & ARMCANZ (2000).

TABLE 3. ASSESSMENT LEVELS FOR WATER EXCLUDING PESTICIDES

	ANZECC & ARMCANZ (2000)[1]		ADWG (2004)[2]		DoH (2006)[3]	ANZECC & ARMCANZ (2000)[1]	
	Fresh waters[4]	Marine waters[4]	Drinking water health value (HV)	Drinking water aesthetic value (AV)	Domestic non-potable groundwater use	Short-term irrigation water	Long-term irrigation water[5]
	(µg/L)	(µg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Metals/metalloids							
aluminium, Al	55	-	-	0.2	**2**	20	5
arsenic, As	24 as As(III) 13 as As(V)	- -	0.007	- -	**0.07**	2	0.1
barium, Ba	-	-	0.7	-	**7**	-	-
beryllium, Be	-	-	-	-	**-**	0.5	0.1
boron, B	370[6]	-	**4**	-	**40**	refer to guideline	0.5
cadmium, Cd	0.2	0.7	0.002	-	**0.02**	0.05	0.01
chromium, (unspeciated), Cr	-	-	-	-	**-**	1	0.1
chromium, Cr(III)	-	**27**	-	-	**-**	-	-
chromium, Cr(VI)	1[6]	4.4	0.05	-	**0.5**	-	-
cobalt, Co	-	1	-	-	**-**	0.1	0.05
copper, Cu	1.4	1.3	2	1	**20**	5	0.2
iron, (Total) Fe	300[12]	pH > 6, 1000[13] pH < 6, 300[13]	-	0.3	**3**	10	0.2
lead, Pb	3.4	4.4	0.01	-	**0.1**	5	2
lithium, Li	-	-	-	-	**-**	2.5 (0.075 for citrus crops)	2.5 (0.075 for citrus crops)
manganese, Mn	1900[6]	-	0.5	0.1	**5**	10	0.2
mercury (Total), Hg	0.06[7]	0.1[7]	0.001	-	**0.01**	0.002	0.002

	ANZECC & ARMCANZ (2000)[1]		ADWG (2004)[2]		DoH (2006)[3]	ANZECC & ARMCANZ (2000)[1]	
	Fresh waters[4]	Marine waters[4]	Drinking water health value (HV)	Drinking water aesthetic value (AV)	Domestic non-potable groundwater use	Short-term irrigation water	Long-term irrigation water[5]
	(µg/L)	(µg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
molybdenum, Mo	-	-	0.05	-	**0.5**	0.05	0.01
nickel, Ni	11	7	0.02	-	**0.2**	2	0.2
selenium (Total), Se	5[7]	-	0.01	-	**0.1**	0.05	0.02
silver, Ag	0.05	1.4	0.1	-	**1**	-	-
tributyl tin (as Sn)	-	**0.006**[6]	-	-	-	-	-
tributyl tin oxide	-	-	**0.001**	-	**0.01**	-	-
uranium, U	-	-	**0.02**	-	**0.2**	0.1	0.01
vanadium, V	-	100	-	-	**-**	0.5	0.1
zinc, Zn	8[6]	15[6]	-	3	**30**	5	2
Other Inorganics							
ammonia[8,9] (as NH_3-N at pH 8)	900[6]	910	-	-	-	-	
ammonia as NH_3	-	-	-	**0.5**	**5**	-	-
bromate, BrO_3	-	-	0.02	-	**0.2**	-	
chloride, Cl	-	-	-	250	**2500**	refer to guideline	refer to guideline
cyanide, CN	7[10]	4[10]	0.08	-	**0.8**	-	-
fluoride, F	-	-	1.5	-	**15**	2	1
hydrogen sulphide, H_2S	1[11]	-	-	0.05	**0.05**	-	-
iodide, I	-	-	**0.1**	-	**1**	-	-
nitrate (as NO_3)[9]	refer to guideline	refer to guideline	50	-	**500**	-	-
nitrite (as NO_2)[9]	refer to guideline	refer to guideline	3	-	**30**	-	-
nitrogen, N[9]	refer to guideline	refer to guideline	-	-	-	refer to guideline	5
total nitrogen, N[15]	2000 (1000)	-	-	-	-	-	-
total phosphorus, P[15]	200 (100)	-	-	-	-	-	-
phosporus (as P)[9]	refer to guideline	refer to guideline	-	-	**-**	refer to guideline	0.05

	ANZECC & ARMCANZ (2000)[1]		ADWG (2004)[2]		DoH (2006)[3]	ANZECC & ARMCANZ (2000)[1]	
	Fresh waters[4]	Marine maters[4]	Drinking water health value (HV)	Drinking water aesthetic value (AV)	Domestic non-potable groundwater use	Short-term irrigation water	Long-term irrigation water[5]
	(µg/L)	(µg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
sulphate (as SO_4)	-	-	500	250	**5000**	-	-
ORGANIC COMPOUNDS							
ethanol	1400	-	-	-	-	-	-
ethylenediamine tetraacetic acid (EDTA)	-	-	0.25	-	**2.5**	-	-
formaldehyde	-	-	0.5	-	**5**	-	-
methyl tertiary butyl ether (MTBE)	-	-		**0.012**[14]	**0.012**	-	-
Chlorinated Alkanes							
dichloromethane (DCM) (methylene chloride)	-	-	0.004	-	**0.04**	-	-
1,2-dichloroethane	-	-	0.003	-	**0.03**	-	-
1,1,2-trichloroethane	6500	1900	-	-	-	-	-
trichloromethane (chloroform)	-	-	-	-	-	-	-
tetrachloromethane (carbon tetrachloride)	-	-	0.003	-	**0.03**	-	-
trihalomethanes (total)	-	-	0.25	-	**2.5**	-	-
hexachloroethane	290[7]	-	-	-	-	-	-
Chlorinated Alkenes							
chloroethene (vinyl chloride)	-	-	0.0003	-	**0.003**	-	-
1,1-dichloroethene	-	-	0.03	-	**0.3**	-	-
1,2-dichoroethene	-	-	0.06	-	**0.6**	-	-
trichloroethene (TCE)	-	-		-		-	-
tetrachloroethene (PCE) (perchloroethene)	-	-	0.05	-	**0.5**	-	-

	ANZECC & ARMCANZ (2000)[1]		ADWG (2004)[2]		DoH (2006)[3]	ANZECC & ARMCANZ (2000)[1]	
	Fresh waters[4]	Marine waters[4]	Drinking water health value (HV)	Drinking water aesthetic value (AV)	Domestic non-potable groundwater use	Short-term irrigation water	Long-term irrigation Water[5]
	(µg/L)	(µg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Chlorinated Benzenes							
chlorobenzene	-	-	**0.3**	**0.01**	**0.01**	-	-
1,2- dichlorobenzene	**160**	-	**1.5**	**0.001**	**0.001**	-	-
1,3- dichlorobenzene	**260**	-	-	**0.02**	**0.02**	-	-
1,4- dichlorobenzene	**60**	-	**0.04**	**0.003**	**0.003**	-	-
1,2,3- trichlorobenzene	3[7]	-	0.03	0.005	**0.005**	-	-
1,2,4- trichlorobenzene	85[7]	20[7]	For individual or total trichlorobenzenes	For individual or total trichlorobenzenes	For individual or total trichlorobenzenes	-	-
1,3,5-trichlorobenzene	-	-				-	-
Other Chlorinated Compounds							
hexachlorobutadiene	-	-	0.0007	-	**0.007**	-	-
monochloramine	-	-	**3**	**0.5**	**0.5**	-	-
Monocyclic Aromatic Hydrocarbons							
benzene	950	500[6]	0.001	-	**0.01**	-	-
toluene	-	-	0.8	0.025	**0.025**	-	-
Ethylbenzene	-	-	0.3	0.003	**0.003**	-	-
xylenes	350 (as o-xylene) 200 (as p-xylene)	-	0.6	0.02	**0.02**		-
styrene	-	-	0.03	0.004	**0.004**	-	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
naphthalene	16	50[6]	-	-	-	-	-
benzo[a]pyrene	-	-	0.00001	-	**0.0001**	-	-

	ANZECC & ARMCANZ (2000)[1]		ADWG (2004)[2]		DoH (2006)[3]	ANZECC & ARMCANZ (2000)[1]	
	Fresh waters[4]	Marine waters[4]	Drinking water health value (HV)	Drinking water aesthetic value (AV)	Domestic non-potable groundwater use	Short-term irrigation water	Long-term irrigation water[5]
	(µg/L)	(µg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Phenols							
phenol	320	400	-	-	-	-	-
chlorinated phenols	-	-	-	-	-	-	-
2-chlorophenol	**340**[3]		0.3	0.0001	**3**		
4-chlorophenol	**220**		-	-	-		
2,4-dichlorophenol	**120**		0.2	0.0003	**2**		
2,4,6-trichlorophenol	**3**[7]		0.02	0.002	**0.2**		
2,3,4,6-tetrachlorophenol	**10**[7]	-	-	-	-	-	-
pentachorophenol	**3.6**[7]	**11**[7]	-	-	-	-	-
Polychlorinated Biphenyls (PCBs)							
Aroclor 1242	0.3[7]	-	-	-	-	-	-
Aroclor 1254	0.01[7]	-	-	-	-	-	-
Phthalates							
dimethylphthalate	3700	-	-	-	-	-	-
diethylphthalate	1000	-	-	-	-	-	-
dibutylphthalate	10[7]	-	-	-	-	-	-
di(2-ethylhexyl) phthalate	-	-	0.01	-	**0.1**	-	-
Other parameters							
Hardness as $CaCO_3$	-	-	-	200	-	-	-
pH	6.5 – 8.5	8.0-8.4	-	6.5 – 8.5	-	-	6.0 - 8.5 (groundwater) 6.0 - 9.0 (surface water)

DoH (2006) Contaminated Sites Reporting Guideline for Chemicals in Groundwater

10 x ADWG Health Value (or Aesthetic if no Health Value) applies — **10 X HV (AV)**

except for odoriferous chemicals where Aesthethic Value applies — **AV**

Table 3 notes:

Bold text indicates values have been revised or added since the previous version of this document**.**

This list is not exhaustive, and water quality assessment levels may be available for additional chemicals and environmental conditions. Reference should be made to ANZECC & ARMCANZ (2000) for guidance on how to assess additional parameters and site-specific conditions.

– No level available. This does not necessarily imply that no assessment can be made; consult appropriate source documents for information on how to derive site-specific assessment levels.

1. ANZECC & ARMCANZ (2000). *Australian Water Quality Guidelines for Fresh and Marine Water Quality.*
2. NHMRC & ARMCANZ (2004). *Australian Drinking Water Guidelines.*
3. DoH, (2006) *Contaminated Sites Reporting Guideline for Chemicals in Groundwater*.
4. Quoted values are 'trigger values' for *slightly moderately disturbed ecosystems*. Additional values applicable to *high conservation/ecological value systems* and *highly disturbed ecosystems* may be available in ANZECC & ARMCANZ (2000).
5. Long-term irrigation values are applicable to the application of irrigation water for up to 100 years in a non-domestic setting. For shorter irrigation periods, short-term irrigation guidelines may be more appropriate, refer to Table 4.2.10 of ANZECC & ARMCANZ (2000).
6. Figure may not protect key test species from chronic toxicity, refer to chapter eight of ANZECC & ARMCANZ, (2000).
7. Chemicals for which possible bioaccumulation and secondary poisoning effects should be considered. Refer to section 8.3.3.4 and 8.3.5.7 of ANZECC & ARMCANZ (2000).
8. For changes in ammonia value with pH refer to section 8.3.7.2 of ANZECC & ARMCANZ (2000).
9. Refer to Table 3.3.6 and other information in ANZECC & ARMCANZ (2000).
10. CN as un-ionised CN measured as [CN].
11. H_2S as un-ionised H_2S measured as S.
12. ANZECC & NHMRC (1992b).
13. DEC screening value based on Dove (2003).
14. US EPA (2009) Regional Screening Levels (RSLs) http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm [accessed 4 September 2009].
15. SRT (2003) Swan-Canning clean-up program short-term (and long-term) targets for median total nitrogen and total phosphorus concentrations in tributaries of the Swan-Canning river system.

TABLE 4. ASSESSMENT LEVELS FOR WATER – PESTICIDES

INSECTICIDES. HERBICIDES AND FUNGICIDES	ANZECC & ARMCANZ (2000)[1]		ADWG (2004)[2]		DoH (2006)[3]
	Fresh waters	Marine waters	Drinking water guideline value (GV)	Drinking water health calue (HV)	Domestic non-potable groundwater use
	(µg/L)	(µg/L)	(mg/L)	(mg/L)	(mg/L)
Aldrin plus dieldrin	-	-	**0.00001**	0.0003	**0.003**
Atrazine	13	-	**0.0001**	0.04	**0.0001**
Carbofuran	0.06	-	**0.005**	0.01	**0.005**
Chlordane	0.03[4]	-	**0.00001**	0.001	**0.01**
Chlorpyrifos	0.01[4]	0.009[4]		0.01	**0.01**
2,4-D	280	-	**0.0001**	0.03	**0.0001**
DDT	0.006[4]	-	**0.00006**	0.02	**0.2**
Diazinon	0.01	-	**0.001**	0.003	**0.001**
Dieldrin plus aldrin	-	-	**0.00001**	0.0003	**0.003**
Dimethoate	0.15	-	-	0.05	**0.05**
Diuron	-	-	-	0.03	**0.03**
Diquat	1.4	-	**0.0005**	0.005	**0.0005**
Endosulfan	0.03[4]	0.005[4]	**0.00005**	0.03	**0.03**
Endrin	0.01[4]	0.004[4]	-	-	-
Fenitrothion	0.2	-	-	0.01	**0.01**
Glyphosate	370	-	**0.01**	1	**0.01**
Heptachlor	0.01[4]	-	-	-	-
Heptachlor (including its Epoxide)	-	-	**0.00005**	0.0003	**0.003**
Lindane (γ-HCH)	0.2	-	**0.00005**	0.02	**0.2**
Malathion	0.05	-	-	-	-
Methomyl	3.5		**0.005**	0.03	**0.005**
Molinate	3.4	-	**0.0005**	0.005	**0.0005**
Parathion	0.004[5]	-	-	0.01	**0.01**
Parathion methyl	-	-	**0.0003**	0.1	**0.0003**
Permethrin	-	-	**0.001**	0.1	**0.001**
Simazine	3.2	-	**0.0005**	0.02	**0.0005**
2,4,5-T	36	-	**0.00005**	0.1	**0.00005**
Tebuthiuron	2.2	-	-	-	-
Thiobencarb	2.8	-	-	0.03	**0.03**
Thiram	0.01	-	-	0.003	**0.003**
Toxafene	0.1	-	-	-	-
Trifluralin	2.6[4]	-	**0.0001**	0.05	**0.0001**

DoH (2006) Contaminated Sites Reporting Guideline for Chemicals in Groundwater

In general, the ADWG Guideline Value applies to pesticides	**GV**
Persistent organochlorines no longer permitted, 10 x ADWG Health Value applies	**10 X HV**

Table 4 notes:

Bold text indicates values have been revised or added since the previous version of this document**.**

This list is not exhaustive, and water quality assessment levels may be available for additional chemicals and environmental conditions. Reference should be made to ANZECC & ARMCANZ (2000) for guidance on how to assess additional parameters and site-specific conditions. For additional pesticides, herbicides and fungicides for drinking water quality refer to NHMRC & NRMMC (2004).

- No level available. This does not necessarily imply that an assessment can not be made; consult the appropriate source documents for information on how to derive site-specific assessment levels.

1. ANZECC & ARMCANZ (2000). *Australian Water Quality Guidelines for Fresh and Marine Water Quality.*
2. NHMRC & ARMCANZ (2004). *Australian Drinking Water Guidelines.*
3. DoH (2006) *Contaminated Sites Reporting Guideline for Chemicals in Groundwater*.
4. Chemicals, for which possible bioaccumulation and secondary poisoning effects should be considered, refer to ANZECC & ARMCANZ (2000) for further information.
5. Figure may not protect key species from chronic toxicity; refer to ANZECC & ARMCANZ (2000) for further information.

TABLE 5. MICROBIOLOGICAL ASSESSMENT LEVELS FOR IRRIGATION WATERS

Intended Use	***E. coli*[1] (thermotolerant coliforms) (Trigger value)**
Agriculture[2]	
Raw human food crops in direct contact with irrigation water	<10cfu[4] / 100ml
Raw human food crops not in direct contact with irrigation water	<1,000cfu / 100ml
Pasture and fodder for dairy animals (without withholding period)	<100cfu / 100ml
Pasture and fodder for dairy animals (with withholding period of five days)	<1,00 cfu / 100ml
Pasture and fodder (for grazing animals excluding pigs and dairy animals)	<1,000cfu / 100ml
Silviculture, turf, cotton, etc (with restricted public access)	<10,000cfu / 100ml
Urban recreational areas, open spaces, parks and gardens[3, 5]	
Municipal use – public open spaces, sports grounds, golf courses etc. with unrestricted access and application	<1cfu / 100ml
Municipal use with some restricted access and application	<10cfu / 100ml
Municipal use with enhanced restrictions on access and application	<1,000cfu / 100ml

[1] *E. coli* to be used as a faecal pathogen indicator. Where salinity exceeds one per cent (10,000 ppm) *Enterococci* should be substituted for *E. coli*.
[2] ANZECC & ARMCANZ (2000)
[3] EPHC et al (2006)
[4] cfu = colony forming units
[5] DoH (2009c)

5. GLOSSARY

ADWG	Australian Drinking Water Guidelines.
Agent	Any chemical, physical or biological substance being assessed, unless otherwise noted.
AGWR	Australian Guidelines for Water Recycling.
Analyte	The physical or chemical element or compound, or other parameter to be determined.
ANZECC	Australian and New Zealand Environment and Conservation Council.
Aquifer	A geological unit (i.e. rock or unconsolidated materials) that can store and transmit water in reasonable amounts to a water well.
Aquatic Ecosystem	Any watery environment from small to large, from pond to ocean, in which plants and animals interact with the chemical and physical features of the environment.
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand.
Assessment levels	Guideline concentrations of analytes adopted by DEC to indicate the potential presence of contamination and to trigger requirement for further investigation and assessment of risk at a site.
Auditor	An accredited contaminated sites auditor under the CS Act.
Background concentration	Naturally occurring, ambient concentrations of substances in the local area of a site. The soil and water quality in the immediate area of a site may be affected by man-made factors, in which case, the background soil and/or water quality should be determined from a comparable geological/hydrogeological setting, which is minimally affected by anthropogenic activities. Also see 'local background'.
Beneficial use	The use of the environment, or of any portion thereof, which is: (a) conducive to public benefit, public amenity, public safety, public health or aesthetic enjoyment and which requires protection from the effects of emissions or of activities referred to in paragraph (a) or b) of the definition of 'environmental harm' in Section3A(2) of the EP Act; or (b) identified and declared under Section 35(2) of the EP Act to be a beneficial use to be protected under an approved policy.
Bioavailable	The fraction of the total of a chemical which can be taken up and assimilated by organisms or biota.
Bore/borehole	A hole drilled into an aquifer for the purpose of sampling, monitoring or extracting groundwater. Another commonly used term is 'well'.

BTEX	Benzene, toluene, ethylbenzene and xylenes. Includes o-, m- and p-xylene isomers.
Carcinogen	Chemical, biological or physical cancer-causing agent.
Competent person or professional	A person possessing the skills, knowledge, experience, and judgement to perform the assigned tasks or activities satisfactorily.
Composite sample	The bulking and thorough mixing of equal quantities (sub-samples) of soil samples collected from more than one sample location to form a single soil sample for chemical analysis.
Contaminant	A substance which presents or has the potential to present a risk of harm to human health, the environment or any environmental value.
Contaminated	In relation to land, water or a site, means having a substance present in or on that land, water or site at above background concentrations that presents, or has the potential to present, a risk of harm to human health, the environment or any environmental value.
CS Act	*Contaminated Sites Act 2003*
Conceptual site model (CSM)	A description of the site, geology, hydrogeology, sources of contamination, receptors and exposure pathways by which the contamination may reach and impact on receptors.
DEC (also DoE and DEP)	Department of Environment and Conservation, previously Department of Environment (DoE) and before that Department of Environmental Protection (DEP).
DoH	Department of Health
Detailed site investigation (DSI)	An investigation which confirms and delineates potential or actual contamination through a comprehensive sampling and analysis program and risk assessment.
Diffuse source	Geographically widespread area of contamination, such as agricultural areas or large industrial complexes, which contains numerous point sources.
Dose	A stated quantity or concentration of a substance to which an organism is exposed over a continuous or intermittent duration of exposure. It is most commonly expressed as the amount of test substance per unit weight of test organism/animal (e.g. mg/kg/body weight).
Dose-response assessment	Determination of the relationship between the magnitude of the dose or level of exposure to a chemical and the incidence or severity of the associated adverse effect.
Ecosystem	Unit including a community of organisms, the physical and chemical environment of that community, and all the interactions between those organisms and between the organisms and their environment.

Ecosystem health condition	A condition of the ecosystem which is: (a) Relevant to the maintenance of ecological structure, ecological function or ecological process and which requires protection from the effects of emissions or activities (as referred to in (a) and (b) of the definition of environmental harm). (b) Identified and declared under Section 35(2) of the EP Act to be an ecosystem health condition to be protected under an approved policy.
Ecological investigation level (EIL)	The concentration of a substance above which further appropriate investigation and evaluation of risks to the environment or environmental values will be required.
Endpoint	(a) An observable or measurable biological event used as an indicator of the effect of a chemical and the incidence or severity of the associated adverse effect. (b) Measured attainment response as applied to management goals.
Environment	Living things and their physical, biological and social surroundings and interactions of all these things.
Environmental harm	Direct or indirect – (a) harm to the environment involving removal or destruction of, or damage to: (i) native vegetation; or (ii) the habitat of native vegetation or indigenous aquatic or terrestrial animals; (b) alteration of the environment to its detriment or degradation or potential detriment or degradation; (c) alteration of the environment to the detriment or potential detriment of an environmental value; or (d) alteration of the environment of a prescribed kind as specified in the EP Act.
Environmental health	Those aspects of human health determined by physical, biological and social factors in the environment (also see ecosystem health condition).
Environmental value	(a) beneficial use; or (b) an ecosystem health condition.
EP Act	*Environmental Protection Act 1986*
EPHC	Environment Protection and Heritage Council.
Exposure	Contact of a chemical, physical or biological agent with the outer boundary of an organism e.g. inhalation, ingestion or dermal contact.
Exposure assessment	The estimation (qualitative or quantitative) of the magnitude, frequency, duration, route and extent (e.g. air concentration) of exposure to one or more contaminated media for the general population, for different subgroups of the population or for

	individuals.
Exposure pathway	The course a chemical or physical agent takes from a source to a receptor. An exposure pathway describes a unique mechanism by which an individual or population is exposed to chemicals or physical agents at a site or originating from a site. Each exposure pathway includes a source or release from a source, an exposure point and an exposure route.
Exposure route	The way a chemical enters an organism after contact e.g. by inhalation or dermal absorption.
Fate	Disposition of a substance in various environmental media (e.g. soil, sediment, water and air) as a result of transport, transformation and degradation.
Groundwater (also underground water)	All waters occurring below the land surface.
Hazard	The capacity of an agent to produce a particular type of adverse health or environmental effect, e.g. one hazard associated with benzene is that it can cause leukaemia.
Health investigation level (HIL)	The concentration of a substance above which further appropriate investigation and assessment of risks to human health will be required.
Hydraulic gradient	The change in the static head (of groundwater) per unit distance in a given direction.
Hydrogeology	The study of groundwater, especially relating to the distribution of aquifers, groundwater flow and groundwater quality.
Interim sediment quality guidelines – low (ISQG – low)	A threshold concentration, below which the frequency of adverse effects is expected to be very low.
Interim sediment quality guidelines – high (ISQG – high)	Probable-effects concentrations below which biological effects could possibly occur. Concentrations at or above the ISQG-High represent a probable-effects range within which effects would be expected to occur more frequently.
Investigation levels	The concentration of a contaminant above which further investigation and risk assessment will be required.
Landfill	A site used for disposal of solid material by burial in the ground that is licensed as a landfill under the EP Act.
Lifetime	Covering the average lifespan of an organism (i.e. taken as 70 years for humans).
Limit/level of detection	The minimum concentration or mass of analyte that can be detected at a known confidence level.
Limit/level of reporting	The lowest detectable concentration of a substance that can be reliably reported, using a specific laboratory method and instrument (also Practical Quantitation Limit). The value is calculated from the instrument detection limits and with appropriate scale-up factors applied. The scale-up factors are

	affected by the analytical procedures and methods and the size of the sample.
Local background	Concentrations of substances in the local area of a site which includes any diffuse contamination from anthropogenic activities.
Media	Environmental media include air, water, soil and sediment.
Model	A mathematical representation of a biological, physical or chemical system intended to mimic the behaviour of the real system, allowing description about empirical data and prediction about untested states of the system.
NATA	National Association of Testing Authorities.
NEPC	National Environment Protection Council.
NEPM	National Environment Protection Measure. In this document, means the *National Environment Protection (Assessment of Site Contamination) Measure (1999)*.
NHMRC	National Health and Medical Research Council.
NRMMC	National Resource Management Ministerial Council.
Pharmacokinetics	The study of the action of drugs in the body and includes the method and rate of excretion, duration of effects, etc.
Point source	Localised source of contamination such as leaking storage tanks and drums.
Potable water	Water suitable from both health and aesthetic considerations, for drinking and culinary purposes.
Practicable	Means having regard to, amongst other things, local conditions and circumstances (including costs) and to the current state of technical knowledge.
Practical quantitation limit (PQL)	The lowest concentration of a substance that can be reliably reported, using a specific laboratory method and instrument (also known as 'Limit of reporting').
Practitioners	Suitably qualified professionals with experience in environmental investigations and contaminated site management.
Preliminary site investigation (PSI)	An investigation consisting of a desktop study, a detailed site inspection and, where appropriate, limited sampling. The scope of a preliminary site investigation should be as necessary to determine whether contamination is present or likely to be present and to determine whether a detailed site investigation is required.
Public drinking water source area (PDWSA)	An area allocated for the collection/abstraction of water for public drinking water supply.
Quality assurance (QA)	The implementation of checks on the success of quality control (e.g. replicate samples, analysis of samples of known concentration).

Quality control (QC)	The implementation of procedures to maximise the integrity of monitoring data (e.g. cleaning procedures, contamination avoidance, sample preservation methods).
Receptor	An entity, such as a person or ecosystem, which potentially may be adversely affected by exposure to a contaminant.
Remediation	In general, means action taken to eliminate, limit, correct, counteract, mitigate or remove any contaminant or the negative effects of the contaminant on the environment or human health. With respect to the CS Act and a site that is contaminated, remediation includes: (a) the attempted restoration of the site to the state it was in before the contamination occurred (b) the restriction, or prohibition, of access to, or use of, the site (c) the removal, destruction, reduction, containment or dispersal of the substance causing the contamination, or the reduction or mitigation of the effect of the substance (d) the protection of human health, the environmental or any environmental value from the contamination.
Response level	Concentration of a contaminant at a specific site based on a site assessment for which some form of response is required, to provide an adequate margin of safety to protect public health and/or the environment.
Risk	Means the probability in a certain timeframe that an adverse outcome will occur in a population and/or ecosystem of a specified area that is exposed to a particular dose or concentration of a hazardous agent, i.e. it depends on both the level of toxicity of the hazardous agent and the level of exposure.
Risk assessment	Process of estimating the potential impact of a chemical, biological or physical agent on a specified human population or ecological system under specified conditions and timeframe.
Risk communication	An interactive process involving the exchange among individuals, groups and institutions of information and expert opinion about the nature, severity and acceptability of risks and the decisions taken to combat them.
Risk management	The process of evaluating alternative actions, selecting options and implementing them in response to risk assessments. The decision-making will incorporate scientific, technological, social, and economic information. The process requires value judgments, e.g. on the tolerability and reasonableness of costs.
Sediment	Unconsolidated particles of sand, clay, silt and other substances that settle at the bottom of a body of water.
Site	An area of land including underground water under that land and surface water on that land.
Stressor	A physical, chemical or biological entity that can induce an adverse response in a receptor. It includes any release of

	chemicals, other human actions and natural catastrophes.
Stygofauna	Subterranean aquatic fauna.
Threshold concentration	The lowest concentration above which some effect (or response) will be produced and below which it will not.
Tolerable daily intake (TDI)	An estimate of the intake of a substance which can occur over a lifetime without appreciable health risk.
Toxicity	The quality or degree of being poisonous or harmful to plant, animal or human life.
Uncertainty	The lack of knowledge about the correct value e.g. a specific exposure measure or estimate.
Validation	The process of demonstrating that a site has been remediated successfully. Involves the collection and analysis of samples to demonstrate that contaminant concentrations are below acceptable limits and do not pose a risk to human health, the environment or environmental values.
Volatile	Physical property of a chemical that indicates its potential to transform from an adsorbed, dissolved or liquid phase into a vapour phase under standard atmospheric conditions. Highly volatile substances have a low boiling point or subliming (high vapour) pressure.
Watertable	The surface of an unconfined aquifer or confining bed at which the pore water pressure is equal to atmospheric pressure. It can be measured by installing piezometers or groundwater bores into the zone of saturation and measuring the water level in those bores.
Well	Refer to bore.
Wetland	An area of seasonally, intermittently or permanently waterlogged or inundated land whether natural or otherwise; and includes lakes, swamps, marshes, springs, damplands, tidal flats and estuaries.

Adapted from enHealth (2002); NEPM, (1999); the *Environmental Protection Act 1986* and the *Contaminated Sites Act 2003*

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