Guidance for the cleanup and management of contaminated groundwater

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EPA acknowledges Aboriginal people as the first peoples and Traditional custodians of the land and water on which we live, work and depend. We pay respect to Aboriginal Elders, past and present.

As Victoria's environmental regulator, we pay respect to how Country has been protected and cared for by Aboriginal people over many tens of thousands of years.

We acknowledge the unique spiritual and cultural significance of land, water and all that is in the environment to Traditional Owners, and recognise their continuing connection to, and aspirations for Country.

Contents

1. Purpose of this guideline

1.1 Introduction

This advisory guideline outlines the concept of minimisation of risk of harm to human health and the environment in the context of the cleanup of contaminated groundwater. It has been prepared by the Environment Protection Authority (EPA) under section 203 of the *Environment Protection Act 2017* (the Act) to assist environmental auditors (auditors) appointed under Division 1 of Part 8.3 of the Act in conducting environmental audits (audits) in accordance with Division 3 of Part 8.3 of the Act. Appendix 2 provides a guide that should be applied when auditors are preparing the documentation to demonstrate whether clean up of contaminated groundwater so far as reasonably practicable has been achieved.

In addition, this guideline is also applicable for use by other parties who are undertaking cleanup of contaminated groundwater to minimise risk of harm to human health and the environment. Parties that may find this guideline useful may include:

- planning and other statutory authorities
- consultants undertaking site investigations and preparing site investigation reports (which could be part of an environmental audit report).

Those in management or control of a site (a 'duty holder' who may have specific legal duties under the Act) who wants to engage a consultant and/or an auditor to clean up contaminated groundwater that is not undertaken as part an audit, may also rely on this guideline but should visit EPA's website (https://www.epa.vic.gov.au/for-business/new-laws-and-your-business/manage-contaminated-land/about-contamination/understanding-your-contaminated-land-duties) for more information.

EPA may provide specific guidance to auditors or duty holders as requested to clarify any provisions in this guideline.

It is important to note that EPA can issue remedial notices that specify clean up measures and those may be different to what is outlined in this guideline.

1.2 Legal status

It is a requirement under section 190(2) of the Act that an auditor have regard to this guideline and any other guidelines issued by the Authority under Section 203 of the Act, any relevant Environment Reference Standard (ERS), any relevant compliance code, and any prescribed matter, when carrying out any function of an environmental auditor under the Act or any other legislation.

Failure to have regard to these guidelines may be considered by EPA in determining whether to reappoint a person as an auditor. Refer to *Environmental auditor guidelines for appointment and conduct* (publication 865) (https://www.epa.vic.gov.au/about-epa/publications/865-12)for further information.

2. Definition of groundwater and contaminated land

Groundwater is defined in section 3 of the Act and means any water contained in or occurring in a geological structure or formation or an artificial landfill below the surface of land.

Land is also defined in section 3 of the Act and means any land, whether publicly or privately owned, and includes:

- any buildings or other structures permanently affixed to the land; and
- groundwater.

Land[1] is defined to be 'contaminated' (under section 35 of the Act) if waste, a chemical substance or a prescribed substance is present on or under the surface of the land, and the waste, chemical substance or prescribed substance:

- is present in a concentration above the background level; and
- creates a risk of harm to human health or the environment.

It is important to note that under section 35(2) of the Act, land is not contaminated merely because waste, a chemical substance or a prescribed substance is present in a concentration above the background level in water that is on or above the surface of the land.

A background level of waste, chemical substance or a prescribed substance is the background level specified in, or determined in accordance with, the regulations or an environment reference standard. If the regulations or environment reference standard do not specify, or set out how to determine, a background level, it will mean the naturally occurring concentration on or under the surface of the land in the vicinity of the land.[2]

Refer to *Contaminated land: Understanding section 35 of the Environment Protection Act 2017* (publication 1940) for further information on contaminated land and information on background levels can be found on EPA's website (https://www.epa.vic.gov.au/for-business/new-laws-and-your-business/manage-contaminated-land/about-contamination/understanding-your-contaminated-land-duties#background-levels).

3. Maintaining groundwater quality in Victoria

Groundwater is an important and often overlooked part of the environment. Groundwater discharges to surface water supporting ecosystems (for example, rivers and wetlands), it also supports a range of environmental values (EVs) including extractive uses such as drinking, irrigation, stock watering, industrial, commercial, and geothermal energy uses. Groundwater also has non-extractive values that include supporting ecosystem functioning and Traditional Owner cultural values.

The protection of groundwater quality can be measured through achieving and maintaining the EVs set out in the Environment Reference Standard (ERS), with the aim of protecting human health and the environment from contamination of groundwater.

Contaminated groundwater can be identified by investigations prompted by the application of statutory tools (for example remedial notices and environmental audits), through actions following a pollution incident, compliance with duties under the Act, by investigations such as voluntary corporate risk management programs and transfer of land processes.

[1] Note for the purposes of Part 3.5 of the Regulations 2021 which sets out exemptions from certain permission activities, and Schedule 1 - Prescribed permission activities and fees, the definition of "land" does not include "groundwater". This change in definition does not otherwise apply.
[2] Section 36 of the Act.

4. Overview of the legislative framework for Groundwater

4.1 *Environment Protection Act 2017* (the Act)

The principles of environment protection guide EPA's administration of the Act. For certain decisions under the Act, the EPA or the Minister must consider the principles for environment protection. The principles set out in Part 2.3 of the Act will guide EPA's consideration of the appropriate standard of the clean up and/or management of contaminated groundwater to meet the objectives of the Act.

Section 25 of Part 3.2 of the Act outlines the general environmental duty (GED) which applies to a person who is engaging in an activity that may give rise to risks of harm to human health or the environment from pollution or waste and requires that person to minimise those risks as far as reasonably practicable. A breach of the GED could lead to civil or criminal penalties.

In addition to the GED, the Act introduces other duties which are described in *Contaminated land policy* (publication 1915) (https://www.epa.vic.gov.au/about-epa/publications/1915), *Assessing and controlling contaminated land risks: A guide to meeting the duty to manage for those in management or control of land* (publication 1977) (https://www.epa.vic.gov.au/about-epa/publications/1977), *Responding to harm caused by pollution* (publication 1991) (https://www.epa.vic.gov.au/about-epa/publications/1991) and industrial guidance available on EPA's website (https://www.epa.vic.gov.au/for-business/new-laws-and-your-business/manage-contaminated-land/about-contamination/understanding-your-contaminated-land-duties). Further information on determining what is reasonably practicable can be found in *Reasonably practicable* (publication 1856) (https://www.epa.vic.gov.au/about-epa/publications/1856).

The table below outlines the duties, who they apply to and outlines how this could apply to groundwater.

The Act reference	Duty	Who does this apply to?	Obligations for groundwater
Section 31	Duty to take action to respond to harm caused by pollution incident.	If a pollution incident has occurred as a result of an activity (whether by act or omission) and the pollution incident causes or is likely to cause harm to human health or the environment, a person who is engaging in that activity must, so far as reasonably practicable, restore the affected area to the state it was in before the pollution incident occurred.	So far as reasonably practicable restore the groundwater to the state it was in before the pollution incident occurred. This means bringing back or making reasonable attempts to bring back or re-establish the area(s) affected by the pollution incident to their previous state immediately before the incident occurred.
Section 32	Duty to notify the Authority of	A person who is engaging or has engaged in an	Must notify the Authority as soon as practicable after the person becomes aware or reasonably

The Act reference	Duty	Who does this apply to?	Obligations for groundwater
	notifiable incidents.	activity that results in a notifiable incident.	should have been aware of the occurrence of the notifiable incident. A notifiable incident for groundwater means a pollution incident that causes or threatens to cause material harm to human health and the environment or a prescribed notifiable incident. Material harm means harm that is caused by pollution or waste that has an adverse effect on human health or the environment that is not negligible; has an adverse effect on an area of high conservation value or of special significance; or results in, or is likely to result in, costs in excess of $10,000 or a higher amount prescribed by the Environment Protection Regulations being incurred to take action to prevent or minimise the harm or to rehabilitate or restore the environment to the state it was in before the harm.
Section 39	Duty to manage contaminated land	A person in management or control of contaminated land	Must minimise risks of harm to human health and the environment from contaminated groundwater so far as reasonably practicable, which includes (but not limited to) carrying out any of the following: (a) Identification of any contamination that the person knows or ought reasonably to know of; (b) Investigation and assessment of the contamination;

The Act reference	Duty	Who does this apply to?	Obligations for groundwater
			(c) Provision and maintenance of reasonably practicable measures to minimise risks of harm to human health and the environment from the contamination, including undertaking clean up activities where reasonably practicable; (d) Provision of adequate information to any person that the person in management or control of the contaminated land reasonably believes may be affected by the contamination, including i. Sufficient information to identify the contamination; and ii. The results of the investigation and assessment referred to in paragraph (b); and iii. The risks or harm to human health and the environment from the contamination. (e) Provision of adequate information to enable any person who is reasonably expected to become a person in management or control of the contaminated land to comply with the duty to manage contaminated land.

The Act reference	Duty	Who does this apply to?	Obligations for groundwater
Section 40	Duty to notify of contaminated land	A person in management or control of land must notify the Authority if the land has been contaminated by notifiable contamination as soon as practicable after the person becomes aware of, or reasonably should have become aware of, the notifiable contamination.	Under section 37 of the Act, notifiable contamination for contaminated land means contamination that is prescribed in the Regulations to be notifiable contamination; or if not prescribed, it is contamination for which the reasonable cost of action to remediate the land is likely to exceed $50,000 (or any other prescribed amount). This applies to contaminated groundwater

The concept of minimising risks of harm to human health and environment is established in section 6(1) of the Act, which states that a duty imposed on a person, to minimise (so far as reasonably practicable) risks of harm to human health and the environment, requires the person to eliminate risks of harm to human health and environment so far as reasonably practicable; and if it is not reasonably practicable to eliminate risks of harm to human health and environment, to reduce those risks as far as reasonably practicable.

The concept of 'reasonably practicable' is established in section 6 (2) of the Act and is described further in *Reasonably practicable* (publication 1856) (https://www.epa.vic.gov.au/about-epa/publications/1856).

The definition of 'clean up' is provided in section 3 of the Act and includes the following measures or activities:

(a) to investigate and assess the nature and extent of pollution or waste, including any harm or risk of harm to human health and the environment arising from the pollution or waste; and

(b) to remove, disperse, destroy, dispose of, abate, neutralise or treat pollution or waste; and

(c) to restore the environment to a state as close as practicable to the state it was in immediately before the discharge or emission of pollution or the deposit of waste, or to any other state, for the purposes of Part 10.9 of the Act; and

(d) for the remediation of contaminated land; and

(e) for the ongoing management of pollution or waste; and

(f) to do anything necessary for, in connection with, or in relation to, the measures set out in paragraph (a), (b), (c), (d) or (e).

4.2 Environment Protection Regulations (the Regulations)

Part 2.1 of the Regulations defines prescribed notifiable contamination in relation to contaminated land. For actual or likely contamination of groundwater, regulation 10 specifies that the entry, or likely entry, of a contaminant into groundwater is prescribed notifiable contamination if:

- the groundwater discharges, or is likely to discharge, to surface water, or
- the groundwater is used, or may be used, for human consumption or contact, stock watering or irrigation; and
- the concentration of the contaminant in the groundwater is, or is likely to be, above the default guideline value for that contaminant provided in the ANZG[3] or the guideline value for that contaminant specified in the ADWG[4]: and is likely to remain above that specified concentration.[5]

[3] ANZG means the Australian and New Zealand Guidelines for Fresh and Marine Water Quality, published by Australian and New Zealand Governments and Australian State and Territory Governments in 2018, as in force from time to time.
[4] ADWG means the Australian Drinking Water Guidelines, published by the National Health and Medical Research Council in 2011, as in force from time to time.
[5] Regulation 10.

The Regulations provide the definition of non-aqueous phase liquid (NAPL) and prescribe the presence of NAPL as notifiable contamination.

Regulation 15 requires a person in management or control of land where NAPL is present to clean up the NAPL so far as reasonably practicable and remove or control the source of the NAPL if the land is the source of the liquid (refer to section 7 of this guideline).

Overall, refer to *Notifiable contamination guideline: Duty to notify of contaminated land* (publication 2008) (https://www.epa.vic.gov.au/about-epa/publications/2008-1) for further information on prescribed notifiable contamination.

4.3 Environment Reference Standard (ERS)

The ERS is a reference tool that can be used to assess the nature and extent of the risk of harm to human health or the environment, including from contaminated groundwater. The objectives and indicators specified in the ERS should be considered before any alternative indicators or metrics.

For groundwater, the ERS identifies:

- segments determined according to the background level of total dissolved solids (TDS)
- environmental values for the various segments (for example, potable water supply, agriculture and irrigation, water-based recreation, industrial, commercial, and geothermal energy uses, and has non-extractive values that include water dependent ecosystems and species and Traditional Owner cultural values.)
- indicators and objectives to be used to measure, determine, or assess whether the environmental values are being achieved, maintained, or threatened.

The environmental values that apply to each segment of groundwater in Victoria are indicated in Table 5.3 of the ERS. Clause 15 of the ERS sets out some of the factors that may be considered when assessing the applicability of environmental values and the risks of harm to human health and environment from the presence of contamination. Section 13 (2) of the ERS provides a list of waters where the environmental values do not apply.

In referring to the ERS to assess if a chemical substance may create a risk of harm, all reasonable uses (existing and potential) of groundwater and the ecological functioning of the location (including potential for offsite impacts) should be considered.

The groundwater quality indicators and objectives for most of the environmental values apply at any point in the aquifer from which groundwater could be abstracted for use via a bore or intersected by a structure. For the environmental value of 'Water dependent ecosystems and species', the objectives apply within the aquifer where groundwater dependent ecosystems or species are identified or at the point of discharge to surface water (that is, prior to dilution and mixing with the surface water).

When considering the risks of harm from groundwater contamination, both existing and potential environmental values should be regarded:

- 'existing' environmental values are where there is an existing receptor (bore, spring or creek) in the vicinity of the site

- 'potential' environmental values are those that could be supported by the background groundwater quality. A potential environmental value is considered 'likely' in circumstances including, but not limited to, where:
    - groundwater is used for that environmental value in the same hydrogeological setting nearby
    - the existing and likely future land uses, both at the site and in the vicinity of the site, are compatible with the environmental value.

For example, groundwater in an area with reticulated water supply and no groundwater bores installed for the purpose of drinking or other extractive uses (such as irrigation) would still need risks of harm to be minimised if the natural background TDS is low enough to accommodate those uses.

5. Roles and responsibilities in the cleanup and management of contaminated groundwater

The duty to manage contaminated land, Section 39 of the Act, requires a person in management or control of contaminated land (who can be referred to as the 'duty holder') to minimise risks of harm to human health and environment from the contaminated land so far as reasonably practicable. The **duty holder** must comply with the obligations detailed in the Act even after some clean up has occurred if there is remnant contamination present at that land (which includes groundwater). When contaminated groundwater has continued to be identified, the duty holder should, for example, be able to demonstrate that:

- source removal/destruction or groundwater cleanup has occurred to eliminate the source, so far as reasonably practicable (refer Sections 7 and 8 in these guidelines)
- where elimination of risks of harm is not reasonably practicable, risks of harm are/have been reduced so far as reasonably practicable. Part of this process should include undertaking a risk assessment. The methodology used for the risk assessment must be adequate to characterise the risks of harm to human health and environment to inform level of any further clean up required (refer to Section 9 of this guideline for further information)
- any cleanup objectives need to be clear and justified (refer to Section 9 of these guidelines)
- the risk of harm posed by any residual groundwater contamination after clean up can be reasonably managed, for example:
    - by engineering controls, for example, passive barrier methods, hydraulic containment, or other active long-term management measures
    - by administrative controls, for example, the preparation and implementation of ongoing groundwater monitoring, generally the groundwater quality monitoring plan (GQMP) including monitoring scopes, trigger levels, contingency plans, controls on groundwater use and periodic review of practicability of clean up (refer Section 10 in these guidelines).
- where there is contamination remaining, a management plan needs to be in place to outline roles and responsibilities to manage and monitor risks to human health and the environment.

When a site does not contain the source of groundwater contamination, a **person in management or control** of the land is not necessarily excluded from having to comply with the duty to manage contaminated land. If groundwater contamination is migrating from an offsite source and affecting a person's site, the scope of action may be limited, however the person in management of control of the affected contaminated land must also eliminate or reduce the risks of harm so far as reasonably practicable, for example, by undertaking the steps described above.

Where groundwater remediation involves the injection of water or remediation chemicals into an aquifer, the duty holder must seek a permit to discharge or deposit of waste to aquifer in accordance with the Regulations. Information on direct injection of remediation chemicals will be provided on EPA webpage.

When contaminated groundwater is identified through a statutory environmental audit, the **environmental auditors** are expected to document the cleanup that has occurred and provide their opinion on the adequacy of this clean up. This should be documented as outlined in this guideline and included in the environmental audit report. Appendix 2 of this guideline outlines what EPA considers to be minimum documentation to demonstrate that 'clean up so far as reasonably practicable' (CUSFARP) has been achieved. It may be useful to consider this as an auditor's opinion which is intended to replace the EPA's 'CUTEP' determination which remained part of the environmental audit process under the *Environment Protection Act 1970* (1970 Act). Appendix 2 also includes example of a checklist labelled 'Attachment A' which auditors should present in their audit report when CUSFARP has been demonstrated. Examples of tables to consider environmental values and results are also included in Appendix 2.

When contaminated groundwater is cleaned up and/or managed through a statutory environmental audit, and there are recommendations to manage residual groundwater contamination on the environmental audit statement, the environmental auditor must include a management plan with the audit that outlines roles and responsibilities to implement that plan. EPA may in some instances, use its statutory tools to give effect to the recommendations of any environmental audit statement related to groundwater contamination.

In a situation where a site is cleaned up and not subject to a statutory audit or remedial notice, the person in management or control of the site must still comply with the duty to manage contaminated land where it applies. This guideline can be used by duty holders or their consultants when preparing documentation to demonstrate clean up and management of contaminated groundwater so far as reasonably practicable.

In some circumstances, EPA may request to review documentation and evidence of clean up contaminated groundwater to so far as reasonably practicable. EPA may use its statutory tools to require further cleanup of the site if the duty holder cannot demonstrate that the risk of harm to human health and the environment caused by groundwater contamination has been minimised so far as reasonably practicable.

Refer to *Assessing and controlling contaminated land risks: A guide to meeting the duty to manage for those in management or control of land* (publication 1977) (https://www.epa.vic.gov.au/about-epa/publications/1977) and *Understanding section 35 of the Environment Protection Act 2017* (publication 1940) (https://www.epa.vic.gov.au/about-epa/publications/1940) for further information.

6. Characterisation of groundwater and aquifers

A useful way to characterise groundwater and aquifers is to develop a conceptual hydrogeological model (CHM) and guidance on how to prepare a CHM is provided in *Hydrogeological assessment (groundwater quality) guidelines* (publication 668).

The CHM includes information on the nature, extent and degree of contamination and forms an essential part of the conceptual site model (CSM). A CSM provides the framework for identifying how the site and groundwater may have become contaminated and how current or potential receptors may be exposed to groundwater contamination. The CSM is integral when assessing the risks of harm to human health and the environment posed by the contamination and the design of cleanup activities. If an immediate risk of harm to human health or the environment is identified, the priority will be to clean up or take steps to reduce the immediate risk of harm prior to the completion of groundwater and aquifer characterisation and in such instances this may occur before the CSM has been fully developed.

The conceptual site model should be developed in accordance with the *National Environment Protection (Assessment of Site Contamination) Measure 1999 (the NEPM)* and *Hydrogeological assessment (groundwater quality) guidelines* (publication 668) (https://www.epa.vic.gov.au/about-epa/publications/668). A summary of groundwater and aquifer characterisation data required to develop a CSM/CHM is listed below:

- site geology and hydrogeology (for example, aquifer type and configuration, porosity type, identification of preferential pathways and receptors, and groundwater flow direction and velocity including spatial and temporal variability of these parameters)
- interaction with surface water bodies
- the lateral and vertical extent of the plume, the nature, spatial and temporal distribution of contaminants within the plume and surrounding media (for example, type and concentration ranges (and / or mass distribution) of the contaminant(s), contaminant phase distribution including non-aqueous phase distribution and partitioning between groundwater, aquifer material and gas, contaminant transformation processes including transformation rate estimates and sorption capacity)
- if applicable, the potential for vapour impacts to pose a risk to human health derived from the contaminated groundwater, and the nature, spatial and temporal distribution of vapour concentrations
- the current and potential impact of contaminants on groundwater environmental values (for example, background TDS, other relevant groundwater quality indicators and objectives, and aquifer yield data). This assists in determining the environmental values that apply to the groundwater and the potential for the plume configuration to change over time (for example, pumping from a nearby bore and tidal or seasonal influences).

Whilst the CSM/CHM is developed prior to any clean up occurring, it will be a useful tool to evaluate the effectiveness of clean up and demonstrate changes post-clean up and it is important to update the model throughout the process. Collection of sufficient and reliable groundwater monitoring data to establish representative contaminant concentrations and trends throughout the cleanup process is recommended. It is important to undertake monitoring events post-clean up to inform the condition of groundwater. EPA considers a sufficient number of monitoring events to be greater than three and temporally spaced to account for any seasonal

influence post-clean up (monitoring events are expected to be conducted to a minimum period of 6 months post-clean up). Post-clean up monitoring should be undertaken when the hydrogeological environment and contaminants of concern return (or near return) to steady state conditions and for this reason, groundwater monitoring immediately after the clean up event is in most circumstances not considered representative of steady state conditions.

7. Source removal and control

A critical step for any cleanup or management of contaminated groundwater is to identify the source of the contamination. In some cases, the source may be located beyond the site boundary (that is offsite) and in such cases it is important to document lines of evidence and demonstrate the audited site is a non-source site.

A primary source for groundwater contamination is any activity, plant structure, equipment, process, or system that releases contaminants into the environment resulting in groundwater contamination. Examples include (but are not limited to) unsealed storage or production areas, leaking product pipelines, historical waste disposal activities (for example, pouring liquid waste into quarries/unsealed areas/trenches), and leaking underground petroleum storage systems.

A secondary source of groundwater contamination could be the contamination mass in the matrix, for example, non-aqueous phase liquid (NAPL, that is petroleum products or solvents) in soil and groundwater and contaminated aquifer material (for example in soil or rock).

7.1 Source removal

The first step for cleanup or management of contaminated groundwater is to remove or control the primary and secondary sources. The extent of contamination can be greatly reduced by taking early action to locate, remove or control the source which can reduce the risk posed to EVs and the cost of any clean up. Meeting clean up or management objectives will likely be limited if a source remains that continues to discharge contaminants to the groundwater.

The presence of NAPL[6] in contact with (for example, floating on top of) groundwater or within the unsaturated zone is a source of groundwater contamination via the dissolution of water-soluble components of the NAPL into the groundwater. NAPL does not need to be present in a mobile form to be a source and may be residualised (or not movable from pore space) within the aquifer matrix or unsaturated zone.

The Regulations require that:

"A person in management or control of land where a non-aqueous phase liquid is present in soil or groundwater must, so far as reasonably practicable—

(a) clean up the non-aqueous phase liquid; and

(b) *if the source of the non-aqueous phase liquid is located on the land, remove, or control the source of the liquid.*[7]

6 Non aqueous phase liquids (NAPL) is defined in the Regulations

[7] Regulation 15.

If it is not reasonably practicable to remove all NAPL, the NAPL should be controlled or treated to prevent or reduce the NAPL acting as an ongoing source of dissolved contamination, refer to Section 7.2.

Examples of current source removal techniques include removal (or decommissioning in the cases that source removal is impracticable) of primary sources (for example, storage tanks/pipes), excavation and removal, pump and treat, flushing (in situ), soil vapour extraction and dual-phase extraction of secondary sources. A list of references that can be useful for cleanup methods is listed in Section 11 of this guideline.

7.2 Source control and/or treatment

In some cases, it may not be reasonably practicable to remove the complete source of groundwater contamination (for example light or dense NAPL within vadose zone or saturated zone). Section 8.2 of this guideline discusses the factors in determining when it is 'reasonably practicable' to remove the source and clean up groundwater contamination. Any assessment concluding that the source removal is impracticable should clearly document justifications and assumptions with reference to the factors set out in Section 8.2 and outline control mechanism to manage and mitigate the impacts to groundwater. Below are some examples of source control and source treatment measures:

For source control:

- The source must be contained and/or treated so that migration of contaminated groundwater is minimised (to onsite in most circumstances). Examples of containment technologies include the installation of a physical barrier system (such as capping or a slurry wall) or hydraulic containment. Source control must operate for the entire duration that the source is present until such time that the source degrades to a level where risks of harm posed to human health and/or the environment are minimised or that technology is available to remove the source.
- Any source control measure must be supported by groundwater quality monitoring that demonstrates that the risks of harm to human health and environment are minimised (for example the environmental values of the groundwater remote from the source are maintained (for example, at the site boundary)).

For source treatment:

- Examples of treatment technologies include the installation of a permeable reactive barrier, in-situ reduction/oxidation by chemical injection, bioremediation, thermal treatment, and desorption.

8. Cleanup of contaminated groundwater

As outlined in Section 6 of the Act, the concept of minimising risks of harm to human health and the environment imposes a duty on a person to eliminate risks of harm so far as reasonably practicable. The elimination of risks of harm is the highest level of control of contaminated groundwater and if elimination is not reasonably practicable then those risks must be reduced as far as reasonably practicable. EPA considers that the environmental values of land and groundwater are achieved or maintained when the objectives outlined in the ERS are met.

Where it is not reasonably practicable to eliminate risk of harm a site-specific risk assessment should be undertaken to determine the risk of harm to human health and the environment. The risk assessment should determine acceptable[8] levels and identify risk control measures (refer to section 9 of this guideline). Any alternative cleanup objectives must be derived to minimise the risk of harm so far as reasonably practicable (refer to section 8.2 in this guideline).

Cleanup objectives for 'water dependent ecosystems and species' should be derived for a site such that objectives outlined in the ERS are met at the receptor (for example at the groundwater dependent ecosystem, point of discharge to surface water, area(s) where stygofauna/troglofauna are present, etc.).

Where groundwater has been contaminated the duty to manage requires the duty holder to minimise the risks of harm to human health and the environment from the contamination[9], which includes (but is not limited to) any of the following:

- identification of any contamination that the duty holder knows or ought to reasonably know of (this may be aided by, for example, undertaking a preliminary site investigation in line with the NEPM)
- investigate and assess the contamination (for example undertake a detailed site investigation in line with the NEPM)
- provide and maintain reasonably practicable measures to eliminate, or, if elimination is not reasonably practicable, minimise the risks of harm to human health and the environment from the groundwater contamination. This includes undertaking cleanup activities where it is reasonably practicable to do so (and which should consider related exposure pathways such as vapour intrusion from that contamination). If impacts from the source site extend off site, clean up so far as reasonably practicable must occur and consider the offsite impacts
- provide adequate information to any person that the duty holder reasonably believes may be affected by the contamination including sufficient information to identify the contamination, results from investigations and assessment undertaken and the risk of harm to human health and the environment from the contamination.

When undertaking risk control measures to achieve the minimisation of risks of harm to human health and the environment, the 'hierarchy' of selecting risk control measures should be considered. The most effective measure is preferred if reasonably practicable. The following list outlines measures ranked from the most effective to least effective:

- Risk elimination – destruction / removal of sources (primary and secondary) of contamination, in some instances, this could be removal or cleanup of the entire area of affected soil and groundwater.
- Risk elimination – if the destruction / removal of sources is not reasonably practicable, reducing the concentration of any resulting dissolved contamination by cleanup activities to a level below what meets the definition of 'contaminated land' in section 35 of the Act.
- Control or treatment – implementation of practicable remediation technologies to reduce/control the extent and magnitude of sources of contamination (if source removal is

[8] Refer to *Assessing and controlling contaminated land risks: A guide to meeting the duty to manage for those in management or control of land* (publication 1977) for guidance on how to determine acceptable levels.
[9] Section 39 of the Act.

not practicable), and resultant dissolved contamination plumes to a level that the risk is acceptable for on- and offsite receptors.
- Use of engineering solutions to reduce the risks of harm to prevent / reduce exposure pathways to sources of contamination and the resultant dissolved contamination plume.
- Administrative management measures - implementation of protocols, procedures, and information that is practicable, enforceable, reliable, and pragmatic measures to prevent exposure of risks by groundwater contamination.

8.1 Selection of groundwater remediation technologies

Remediation technologies should be assessed for their ability to meet cleanup objectives, resulting in the most effective and practicable technology(s) being selected. When assessing the remediation technologies, consideration of the principles for environment protection will enable EPA to understand how any proposed or selected options helps fulfil the objectives of the Act.

Effective remediation technologies are identified following:

- the collection and analysis of groundwater and aquifer characterisation data and development of the CSM and CHM (see Section 6 in these guidelines)
- extensive review of groundwater cleanup technologies.

Examples of groundwater remediation technologies include pump and treat systems, air sparging, air stripping with activated carbon adsorption and permeable reactive walls, in-situ bioremediation, in-situ chemical reduction/oxidation etc. Options analysis may also include considering whether multiple successive technologies may be required to achieve cleanup. Monitored natural attenuation (MNA) is not considered to be a remediation technology but can be considered in parallel with any technology assessment. EPA expects that auditors keep up-to-date on emerging cleanup technologies and legislative requirements such as applications where any direct injection is proposed for remedial purposes. There are a few references of groundwater remediation technologies included in Section 12.

8.2 Minimising risk of harm to human health and the environment

EPA expects that different remediation technologies be compared using a hierarchical approach to ensure the most effective options are considered prior to considering less effective options. The principles of environment protection in Chapter 2 of the Act provides a framework of considerations that may assist in this process.

To determine what is (or what was at a particular time) reasonably practicable in relation to the minimisation of risks of harm to human health and the environment regard must be had to the five factors set out in section 6(2) of the Act. The following table shows examples on how this conceptual thinking can be considered when evaluating the clean up so far as reasonably practicable concept for groundwater. Refer to *Reasonably practicable* (publication 1856) (https://www.epa.vic.gov.au/about-epa/publications/1856) for further information.

What is reasonably practicable?

- The **likelihood** of the identified risks of harm to human health and the environment eventuating, for example:
  - Understanding the nature and extent of the contamination (in particular if the contamination extends beyond the site boundary) and how likely is it a receptor can be exposed to the contamination.
  - Understanding of acute and chronic exposure settings.
  - Identifying the sensitive receptors and any predominant direction in which the groundwater contamination is moving or is likely to move?
- The **degree of harm** that would result if those risks eventuated, for example:
  - What would be the consequence if no cleanup action undertaken?
  - What are the short- and long-term risks of exposure?
- **Knowledge** about the risk of harm and remediation technologies to minimise the risks, for example:
  - How well are the potential risks to human health and environment understood?
  - How well have risks from contamination been characterised?
  - What are the chemical and physical properties of groundwater contamination?
  - What are the groundwater and aquifer characteristics?
  - What does the risk profile and hydrogeological setting mean for remedial options?
  - Have all relevant remedial technologies been considered?
- **Availability and suitability** of remediation technologies to minimise the risk, including technical and logistical considerations: technologies capable of minimisation of risk, timeframe of implementation, access to the site, availability of materials and infrastructure, and the disposal of wastes.
- **Cost** consideration when minimising the risks including the cost of equipment, installation, maintenance and waste treatment; and the cost in comparison to the degree to which risks of harms would be reduced. The cleanup measures adopted must be cost-effective and commensurate with the significance of the environmental issues being addressed These considerations will be made with due consideration of approaches for other sites.

Clean up of groundwater to minimise the risks of harm to human health and environment should occur within a reasonable timeframe. The following considerations assist in defining a 'reasonable timeframe':

- the adequacy of interim measures to minimise risks of harm to human health and groundwater environmental values until human health is protected, and environmental values are achieved or maintained (for example, reliability of groundwater use controls during the cleanup process).
- whether cleanup will be achieved before contamination migrates offsite and/or affects existing receptors (for example existing extractive users of groundwater).
- affected community interests and the significance of contamination and the timing and extent of cleanup (particularly if the plume extends offsite).

Shorter timeframes to clean up contamination are warranted where there is a risk posed to human health and the environment (including the environmental values of groundwater). EPA's strong preference is for cleanup options that result in cleanup in a shorter time period to

minimise the risks of harm to human health or the environment arising from the groundwater contamination. The most effective and timely groundwater cleanup may be provided by a combination of individual technologies.

When an **opinion is formed on how to address any risks of harm to human health and the environment by cleanup and/or management measures**, EPA expects the following to be documented:

- the implementation of cleanup actions and the achievement/outcomes after implementation of those actions; and
- the extent to which further cleanup is/is not reasonably practicable
- evaluation of 'reasonably practicable' against each criteria set out in the Act
- where elimination of risk of harm is not reasonably practicable, residual groundwater contamination and the use of groundwater should be managed to reduce those risks so far as reasonably practicable.
- outline measures for how the practicability of groundwater cleanup be periodically reassessed and clean up be re-initiated where newer technologies or methods make such clean up reasonably practicable.

The purpose of documenting the view on cleanup is to enable the duty holder to demonstrate compliance with the duty to manage contaminated land, including enabling the duty holder to comply with section 39(2)(d) and (e)that require the provision of information.

9. Site specific risk assessment

Site-specific risk assessment is a component in determining the successful cleanup of contaminated groundwater, particularly when the elimination of risks is not reasonably practicable. Risk assessment may be used to inform further mitigation measures to prevent harm from residual risks after clean up so far as reasonably practicable has occurred. The mitigation measures should be proportionate to the risk, appropriate to the specific site circumstances and aligned with EPA's principles of environmental protection (Part 2.3 of the Act).

Site-specific risk assessments, conducted in accordance with *Schedule B4* , *The Guideline on Site-Specific Health Risk Assessment Methodology* of National Environment Protection (Assessment of Site Contamination) Measure, play an important role in determining the cleanup of contaminated groundwater so far as reasonably practicable. Site-specific assessments also inform the management of residual contamination in groundwater, as the nature and timing of the cleanup activities may be influenced by the risk posed by the contamination.

The site-specific risk assessment can be used for:

- demonstrating the groundwater environmental values are maintained/achieved that is the risks of harm to human health and environment are at an acceptable level without any risk control measures where contaminant concentrations are above the objectives outlined in the ERS
- decision-making to establish cleanup objectives where elimination of risks is demonstrated as not reasonably practicable

- deriving site-specific risk-based criteria of contaminants
- demonstrating the risks have been reduced to an acceptable level with or without mitigation measures, that is engineering control and administrative management measures.

The risk assessment should consider exposure pathways such as ingestion, dermal contact and inhalation, especially in the following circumstances:

- Vapour intrusion risk posed to on- and offsite receptors, including maintenance workers where groundwater is contaminated by volatile organic chemicals.
- Direct contact risks posed to on- and offsite receptors where groundwater is shallow, that is within 3 metres below ground surface.
- Extractive uses of the contaminated groundwater on- and offsite.

10. Managing contaminated groundwater

When cleanup of contaminated groundwater to eliminate risks of harm to human health and the environment is not reasonably practicable, or where cleanup has not yet occurred or is currently occurring, contaminated groundwater should be managed to ensure protection of human health and the environment. Management of contaminated groundwater includes the following key components:

- cleanup objectives (that reflect clean up so far as reasonably practicable)
- groundwater monitoring
- trigger levels
- a contingency plan
- sharing information of the contaminated groundwater
- any ongoing engineering risk control measures recommended to reduce the risk, for example physical barrier, permeable reactive barrier, vapour mitigation barrier etc; and
- periodic review of the practicability of the groundwater cleanup.

The preparation and implementation of any plan to manage contaminated groundwater should incorporate these key components. EPA can be consulted in the preparation of such a plan if needed.

10.1 Groundwater monitoring

The cleanup of contaminated groundwater is normally accompanied by a groundwater monitoring. A groundwater monitoring program should specify the location and frequency of sampling, as well as the measurements (that is, groundwater elevation and analyses) necessary to evaluate whether cleanup and/or management is performing as required. The groundwater monitoring program should provide for:

- monitoring of the groundwater elevation in each bore, enabling the determination of groundwater flow direction and rate that may indicate changes in any risks posed
- monitoring of the spatial and temporal variation in contaminant distribution, including detecting any unexpected expansion in the plume
- verification of the effectiveness of groundwater cleanup and management, and detecting changes in environmental conditions (for example, hydrogeological, geochemical and microbiological) that may reduce the effectiveness of the cleanup technology

- verification of the attainment of cleanup objectives
- confirmation that environmental values of groundwater are maintained / achieved outside the contaminant plume
- detection of new releases of contaminants to the environment that could impact on the effectiveness of the cleanup/management.
- identification of any potentially toxic and/or mobile transformation products from the cleanup process
- the frequency of groundwater monitoring must be determined on a site-specific basis and include consideration of the:
    - extent of the plume/contamination
    - contaminant type and properties
    - local and regional hydrogeology (for example, flow direction and velocity)
    - groundwater environmental values being utilised in the vicinity of the plume and timeframes of potential contaminant migration
    - quality of existing groundwater elevation and quality data.

The frequency of groundwater monitoring should be adequate to monitor the seasonal influence of contaminant concentration fluctuations; and to detect potential changes in the site conditions while allowing sufficient time to implement contingency plans to protect receptors if an unexpected change occurs.

Following the completion of cleanup of contaminated groundwater to minimise risk to human health and the environment so far as reasonably practicable, GQMP should be considered and/or recommended as a risk control measure to confirm the risk profile has not changed. The scope of the GQMP depends on a site-specific basis, that is proportionate and focus on key areas of risk, or potential changes in risk, to human health and the environment based on the residual plume extent and the nature of contamination.

Refer to *Groundwater sampling guidelines* (publication 669) https://www.epa.vic.gov.au/about-epa/publications/669) for guidance on groundwater sampling.

10.2 Trigger levels

A groundwater monitoring program should include 'trigger levels' which indicate when the current cleanup technology is not meeting, or will not meet, cleanup objectives or if there are changes to the risk profile identified in the CSM trigger levels specify a concentration of contaminant(s) that is unacceptable at a critical location. These triggers may signal unsatisfactory performance of the cleanup / management by indicating:

- an insufficient reduction in contaminant concentration
- an increase in contaminant concentration (possibly indicating a new release or rebound)
- migration and/or expansion of the plume
- a receptor is at risk, for example, changes to proximity of nearest private bore or level of concentrations changed.

Where trigger levels are exceeded, a contingency plan should be implemented that ensures cleanup objectives are attained (see Section 10.3 of this guideline).

10.3 Contingency plan

A contingency plan is a description of the response in the event of trigger levels being reached. It may involve the following:

- further/additional groundwater monitoring
- a review of risk assessment
- implementation of an alternative cleanup technology
- a modification of the selected cleanup technology.

Contingency plans should be prepared at the time of the initial technology selection and should be flexible, allowing for the incorporation of new information (for example, advances in cleanup technologies or toxicological data used to estimate the risk to groundwater receptors).

10.4 Sharing information regarding contaminated groundwater during cleanup and/or management

Under the duty to manage contaminated land, minimising risks of harm to human health and the environment from contaminated land includes (but is not limited to) the person in management or control of contaminated land providing adequate information to any person that they may reasonably believe may be affected by the contamination (Section 39(1)(d) of the Act).

The sharing of information is to assist those who may otherwise be exposed to the risks of harm from groundwater contamination present on- and/or offsite, to have adequate information to take appropriate actions to minimise the risk of harm to human health and environment and not extract groundwater for any uses that are not suitable.

Tools to assist the minimisation of use of contaminated groundwater may include:

- controls on groundwater use and bore construction
- placing legal agreements or covenants on land titles of affected premises for information.

Note that if a preliminary risk screen assessment statement or an environmental audit statement has been issued in respect of a site, the person in management or control of the site must provide a copy of the preliminary risk screen assessment statement or the environmental audit statement (as the case requires) to any person who proposes to become the person in management or control of the site (Section 214 of the Act).

Where there is potential vapour risk posed to offsite receptors from the contaminated groundwater, it is important to communicate with the affected third parties ensuring that the information they receive is clear, easy to understand and sufficiently detailed.

In all cases, a person in management or control of land must notify EPA if the land has been contaminated by notifiable contamination as soon as practicable after the person becomes aware of (or reasonably should have become aware of) the notifiable contamination (section 40 of the Act). EPA recognises that not all contaminants of concern have the regulatory requirement to notify, for example PFAS and other emerging contaminants. Such non-notifiable contamination may be reported to EPA voluntarily. Refer to the Regulations and EPA's guideline on the Duty to notify of contaminated land for further information.

In addition, under the framework of the 1970 Act and subordinate legislation groundwater quality restricted use zones (GQRUZs) were identified by EPA where residual groundwater contamination remains within an area after the clean up to extent practicable of contaminated groundwater

(CUTEP) determined. The GQRUZ addresses the residual risk posed by the remaining groundwater contamination and outlines recommendations on how the groundwater could be used without further treatment. EPA will retain the role of identifying such areas where groundwater use should be modified when it is considered necessary. Further information about this process is to be released.

10.5 Periodic review of the practicability of cleanup of contaminated groundwater

Where clean up of contaminated groundwater so far as reasonably practicable has been demonstrated to be achieved, periodic review of the practicability of groundwater cleanup should be undertaken by the person in management or control of the land to demonstrate that risks of harm remain minimised so far as reasonably practicable.

If cleanup has been undertaken as part of an audit, the auditor will include recommendations. This involves an assessment of information including:

- research of new/improved (and available) cleanup technologies
- data from the groundwater monitoring program (for example, geochemical data, plume/contaminant migration, contaminant concentrations and transformations)
- updated assessments of the risks of harm posed to human health and environment, both onsite and offsite (for example, toxicological data).

10.6 When can the management of contaminated groundwater cease?

The duty holder has a duty to continue management of contaminated groundwater (including groundwater quality monitoring) until the groundwater condition no longer meets the definition of 'contaminated land' in section 35 of the Act, that is the groundwater is not characterised as being contaminated.

Where a GQMP is recommended as a risk control measure to confirm the risk profile remained unchanged, if the following evidence is present, cessation of the application of a GQMP can be considered and a GQMP cessation report can be prepared:

- where there is the contraction or stabilisation of a plume of contaminated groundwater
- where review of the risk assessment demonstrating the risk caused by the contaminated groundwater remain unchanged and
- where there are no unexpected new risks of harm to human health and environment identified, and the development of such risks is unlikely.

EPA recommends that the GQMP cessation report is prepared by a suitably qualified environmental professional. The information checklist provided in Appendix B of this guideline needs to be included in the GQMP cessation report. The GQMP cessation report does not need to be reviewed or approved by EPA unless there is a specific requirement of a remedial notice for this to occur. However, EPA recommends that the report is retained by the duty holder as a record to demonstrate the duty holder's compliance with the duty to manage contaminated land and EPA may request to see this information as part of compliance and enforcement programs or activities.

If any new risks to human health or the environment arise from contamination (for example, as a result of a pollution incident) or the current risk to human health and the environment from contamination is changing or will be changing (for example as a result of land uses changes), the

duty to manage contaminated land would apply. In such cases, groundwater monitoring might be subsequently required to comply with the duty to manage contaminated land.

11. Regulatory requirements related to cleanup and management of contaminated groundwater

Some groundwater cleanup technologies will involve discharge to aquifers, surface water, land and/or air. When this occurs, the discharge must not contaminate the receiving environment. For example, cleanup technologies such as 'pump and treat' may involve the continual treatment and return of contaminated groundwater to the aquifer, where the level of contamination is reduced at each treatment cycle. Other cleanup technologies involve the discharge of water to the aquifer containing substances with contaminant reducing properties (for example, nutrients to assist the growth of bacteria that degrade some contaminants).

Undertaking cleanup activities may give rise to risks of harm to human health or the environment. As such, the GED (section 25 of the Act) applies and the person engaging in cleanup activities must minimise any risks of harm to human health or the environment from pollution or waste, so far as is reasonably practicable.

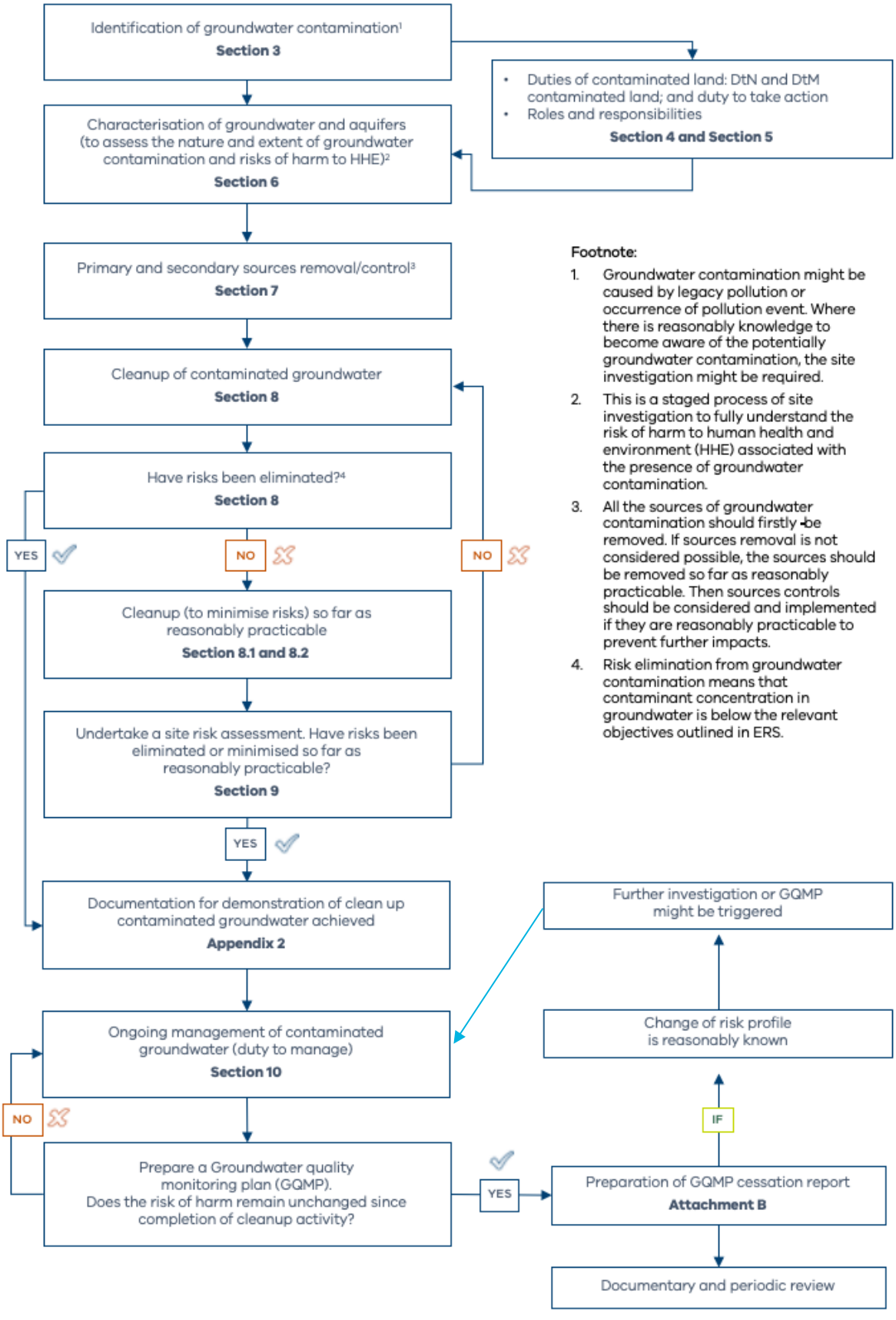
Cleanup technologies that involve discharge to an aquifer must comply with the Regulations.

12. References for further reading

- CRC Care National Remediation Framework, 2020
- Environment Protection Regulations 2021
- Environment Reference Standard 2021
- EPA publication 668, *Hydrogeological assessment (groundwater quality) guidelines*, September 2006 (https://www.epa.vic.gov.au/about-epa/publications/668).
- EPA publication 669, *Groundwater sampling guidelines*, April 2000 (https://www.epa.vic.gov.au/about-epa/publications/669).
- EPA publication 1915, *Contaminated land policy*, January 2021 (https://www.epa.vic.gov.au/about-epa/publications/1915).
- EPA publication 1940, *Contaminated land: Understanding section 35 of the Environment Protection Act 2017*, February 2021 (https://www.epa.vic.gov.au/about-epa/publications/1940).
- EPA publication 1977, *Assessing and controlling contaminated land risks: A guide for those in management or control of land*, June 2021 (https://www.epa.vic.gov.au/about-epa/publications/1977).
- EPA publication 1856, *Reasonably practicable*, September 2020 (https://www.epa.vic.gov.au/about-epa/publications/1856).
- EPA publication 1695.1, *Assessing and controlling risk: A guide for business*, August 2018 (https://www.epa.vic.gov.au/about-epa/publications/1695-1).
- EPA publication 1936, *Proposed methodology for deriving background level concentration when assessing potentially contaminated land*, February 2021 (https://www.epa.vic.gov.au/about-epa/publications/1936).
- National Environment Protection (Assessment of Site Contamination) Measure 1999
- USEPA 1999, *Treatment technologies for site cleanup: Annual status report (Ninth Edition)*, United States Environmental Protection Agency, EPA-542-R99-001, April 1999.

- USEPA 1998, *Abstracts of remediation case studies, volume 3*, United States Environmental Protection Agency, EPA-542-R98-010, September 1998.
- PFAS NEMP

Appendix 1: Flowchart for cleanup and management of contaminated groundwater



Footnote:

1. Groundwater contamination might be caused by legacy pollution or occurrence of pollution event. Where there is reasonably knowledge to become aware of the potentially groundwater contamination, the site investigation might be required.
2. This is a staged process of site investigation to fully understand the risk of harm to human health and environment (HHE) associated with the presence of groundwater contamination.
3. All the sources of groundwater contamination should firstly be removed. If sources removal is not considered possible, the sources should be removed so far as reasonably practicable. Then sources controls should be considered and implemented if they are reasonably practicable to prevent further impacts.
4. Risk elimination from groundwater contamination means that contaminant concentration in groundwater is below the relevant objectives outlined in ERS.

Appendix 2: Clean up so far as reasonably practicable information guide

While undertaking functions as an environmental auditor under the Act, auditors will need to provide an opinion in relevant documentation as to whether 'clean up so far as reasonably practicable' has been achieved. It may be useful to consider this as an auditor's opinion which is intended to replace the EPA's CUTEP determination which remained part of the environmental audit process under the *Environment Protection Act 1970* (1970 Act).

Appendix 2 outlines what EPA considers to be the minimum documentation required to demonstrate that 'clean up so far as reasonably practicable' to minimise risks of harm[10] to human health and the environment has been achieved.

EPA recommends that auditors keep a record of the documentation which they prepare as outlined in Appendix 2 and a copy of the checklist labelled 'Attachment A' for sites which they have advised on.

Appendix 2 also includes examples of tables to consider environmental values ('Attachment B') and displaying results ('Attachment C').

When cleanup is undertaken as part of an audit, auditors should include this documentation in their audit reports. If cleanup occurs to comply with the duty to manage contaminated land and there is no audit or remedial notice, EPA may seek to review this documentation as part of its regulatory activities.

1.0 Background

Provide the following:

- a site description (include the current site plan and details of the current certificates of title)
- a summary of the site history and use, including:
  - a summary of the reason for the need to clean up so far as reasonably practicable (for example, proposed change in site use or obligation through the duty to manage contaminated land or a remedial notice if that notice refers to this guideline etc)
  - a summary of the general site history and contaminating activities (past and current)
  - a summary of the current and proposed uses of the site and/or development plan if known
  - summary information on the key contamination issue underpinning the need for the clean up contaminated groundwater so far as reasonably practicable
  - a review of relevant surrounding land uses and nearby environmental audit reports (where regional groundwater information is applicable).

[10] Under Section 6 of the Act 'The concept of minimising risks of harm to human health and the environment'.

2.0 Site conditions prior to cleanup and conceptual site model

The conceptual site model (CSM) summarises the site setting and documents the condition of the site prior to any cleanup activities and must be supported by the information outlined below. Section 6 of this guideline describes the conceptual hydrogeological model (CHM) which should be developed to characterise the groundwater and aquifers.

The CSM and CHM should be developed in accordance with the National Environment Protection (Assessment of Site Contamination) Measure 1999 as amended from time to time, and *Hydrogeological assessment (groundwater quality) guidelines* (publication 668) (https://www.epa.vic.gov.au/about-epa/publications/668).

2.1 Geology and hydrogeology

An overview of the geology and hydrogeology of the site in its sub-regional setting should be included in the CSM. This overview should include a description of the following on a regional and local scale where relevant (with accompanying illustrations, cross-sections, and tabulated data as appropriate for the site):

- **Geology and aquifers** - a brief description of each lithological unit, for example, thickness, type and the identification of each aquifer, aquitard, and hydraulic properties of aquifer(s).
- **Groundwater occurrence and flow** - this includes the depth to groundwater, presence of any potentiometric surface, flow direction, estimated seepage velocity, hydraulic conductivity, transmissivity, and yield. Also describe any groundwater mounding, multiple aquifer interactions, preferential flow pathways, spatial and temporal variations in groundwater quality or contaminant concentrations (where present).
- **Groundwater chemistry** – identify the natural salinity/total dissolved solids (TDS) of the groundwater in each aquifer to identify the segment defined in the ERS. Additional information on the geochemistry of the aquifer may be relevant.
- **Groundwater resource utilisation** – a summary of current known bores and their use in the vicinity of the site (for example, within 2 km of the site) and presence of groundwater dependant ecosystems.

2.2 Source(s) of contamination

The conclusion that a site is (or is likely to be) a source of groundwater contamination is typically supported by one or more of the following key factors:

- Site history information indicates/confirms that the contaminant(s) of concern was once used at the site or activities at the site have altered natural conditions leading to the mobilisation of naturally occurring or anthropogenically introduced contaminants.
- The contaminant(s) of concern was detected in soil or vapour samples during the soil sampling program, noting that some contaminants may be difficult to identify in soil samples (for example, chlorinated hydrocarbons in shallow soils).
- Groundwater or surface waters is contaminated by the contaminant(s) of concern identified at the site.
- Upgradient or onsite sampling (current or data from surrounding sites) demonstrates the contaminant is not from a regional or alternate source.

A clear and logical description of the above factors should be provided for each contaminant that is subject to clean up so far as reasonably practicable. In addition, the nature and extent of contamination identified in soil (and/or soil vapour) and groundwater prior to cleanup should be summarised and documented (with relevant figures illustrating the contamination distribution).

Where a site is not considered to be the source of groundwater contamination, the suspected source of contamination should be identified, along with evidence to support any such conclusion. To do this, evidence from the site history review should be considered with the below:

- soil and groundwater data for adjacent sites (for example, where audit reports have previously been completed)
- soil and/or groundwater data collected offsite and beyond the influence of any contaminant from the site
- any other information deemed relevant to support the conclusion that the source of groundwater contamination is located offsite, or the contamination represents background concentrations exceeding relevant groundwater quality indicators and objectives.

Where the site is a contributing source to downgradient groundwater contamination, the risk assessment and management to offsite receptors still need to be considered in minimising the risk to offsite receptors.

2.3 Contaminant transport pathways and mechanisms

Discuss the mechanisms/pathways (and preferential pathways) by which the contaminant(s):

- has, or is likely to have, moved through the soil profile and contaminated the groundwater
- are dispersed within/by the aquifer. This should be linked to, and explain, the lateral and vertical extent of groundwater contamination prior to, and after, cleanup.

2.4 Potential receptors (human and environmental)

Discuss the potential human and environmental receptors which may be impacted by the contaminant(s):

- Provide information with respect to potential receptors including:
  - direct contact of groundwater if groundwater is shallow (less than 3 m below ground level)
  - groundwater extraction
  - groundwater discharge to surface waters or wetlands.
- Provide information on soil vapour related to groundwater contamination and associated potential migration and exposure pathways.
- In relation to surrounding groundwater extraction, note the type of use, the bore screening depth interval/aquifer, direction, and distance from the site.
- This discussion should include existing and potential future receptors / groundwater environmental values and include consideration of foreseeable changes to the site and surrounding site(s) that may create a new and/or altered exposure pathway(s).

3.0 Summary of cleanup works undertaken

A summary of all relevant cleanup works undertaken (including the removal, control, or treatment of primary and secondary sources) must be provided and documented.

Primary sources include any infrastructure from which pollution could be released to the environment, for example tanks and pipes. Secondary sources of groundwater contamination include the product released from the primary sources (for example NAPL) and the media (for example soil) surrounding the primary source that has been exposed to the pollution. For soil this should be a brief overview, and include the following:

- A summary of relevant soil remediation works - this summary should focus on the characterisation of the contamination status of the site and source removal (that is, soil remediation relevant to the identified groundwater contamination). For example, for a site where groundwater is contaminated with petroleum hydrocarbons, this would include removal of underground fuel storage tanks and associated petroleum hydrocarbon contaminated soil, but not other soil remediation activities unrelated to the groundwater contamination issue.
- A description of the nature and extent (including mass, where practicable) of contamination before and after remediation to demonstrate the effectiveness of remedial effort.
- Where complete source removal is/was not reasonably practicable, provide information:
    - with respect to how the risks posed to human health and environment have been reduced to a level that is acceptable with/without any control measures
    - on the evaluation of the five factors of reasonably practicable as per Section 7.2 of these guidelines, to eliminate or reduce risks posed by the contamination
    - with respect to any source control measures employed (if any)
    - to support the performance of any source control measure.

For groundwater this should be an overview, and include (but not be limited to) the following:

- justification/discussion of the type of cleanup/management technology employed (including a review of potential cleanup technologies considered)
- any cleanup benchmark or field trials and their results
- period of cleanup
- number of cleanup events and type
- effect of the cleanup undertaken, including discussion of any contaminant rebound/s or reduced concentrations of contaminants/reduction of contaminant source mass, that is, what evidence is there that the cleanup has been effective.

Where groundwater remediation is not considered reasonably practicable this must be evaluated against the principles of environment protection (Part 2.3 of the Act 2017). EPA expects documentation and evidence of the condition of the groundwater, multiple lines of evidence that explains why the reasonably practicable considerations cannot be met. Further, EPA expects identification and selection of risk controls that will address the risk of harm posed by the groundwater contamination. If groundwater contamination extends to offsite areas, there must be robust evidence on how risks will be mitigated and minimised.

4.0 Extent and nature of groundwater contamination after cleanup

Provide a clear description of the extent and nature of residual groundwater contamination post any soil and/or groundwater cleanup works (if any) that have occurred. As a minimum:

- Discuss the adequacy of the groundwater monitoring well network to assess the lateral and vertical extent of groundwater contamination identified.
- This discussion should refer to the guidelines for 'Delineating groundwater contamination' provided in Section 8.3, Schedule B2 of the NEPM 1999.
- Discuss the frequency and total number of groundwater monitoring events used to define the extent of groundwater contamination after clean up.

With respect to the frequency of groundwater monitoring, consideration should also be given to seasonal and tidal factors, and the potential for these factors to affect the groundwater monitoring results.

This discussion should also comment on the justification of the adequacy of groundwater monitoring being conducted post-clean up and the concentration trends in the groundwater data.

Where there are limitations to the installation of delineation monitoring wells, alternative approaches, that is modelling of future plume behaviour, should be used for the estimation of plume extent. Such limitations should be clearly documented.

- Provide a summary table for each environmental value that is impacted by the groundwater contamination, including the corresponding contaminant(s) causing the contamination (see Attachment B for an example). The summary table should also include background elevated (including natural occurring) analytes in groundwater, as well as regional contaminated analytes (see Attachment C for an example).
- Provide commentary on the likelihood of the environmental value(s) being realised, now or in the future, including those impacted by contamination.
- Provide a figure(s) showing the extent of groundwater contamination for each relevant contaminant of concern.
- Provide a discussion of risks posed by the groundwater contamination to human health and environment. The human health risk assessment needs to provide the conclusions of the risk assessment, including the estimated excess lifetime cancer risk and hazard quotient (where relevant to the type of risk assessment undertaken).
- Provide mitigation measures to be undertaken if there are changes to the risk profile.

5.0 Plume stability and future behaviour

Provide an assessment of plume stability and estimated/projected future plume behaviour. This should include an estimate of the time it will take for environmental values to be achieved without any further cleanup/management in the context of climatic and seasonal variability.

Several approaches are available for assessing plume stability and extent, and modelling/estimating the future behaviour of groundwater contamination. These range from simple data assessments through to complex mathematical modelling. The applicability of these

approaches is site specific and dependant on several factors, including site conceptualisation, data availability, purpose of the modelling and risk posed by the contamination.

Examples to predict plume behaviour are noted below:

- extrapolation and/or assessment of existing groundwater concentration data trends (for example statistical analysis, it is expected that at least three rounds of data is collected. If the risk profile is high, more rounds will be required to demonstrate that the risk profile is acceptable
- use of natural attenuation parameter data to estimate future trends
- analytical modelling of groundwater flow and contaminant transport
- numerical modelling of groundwater flow and contaminant transport.

6.0 Risk assessment

The risk assessment should include, but not be limited to, the following information:

- determination of the degree of existing exposure pathways to receptors and therefore the influence on the practicability and the urgency of the cleanup activities (see Section 5.2 in these guidelines)
- a clear statement of justification for the adopted objectives for risk assessment that are appropriate (for example, where groundwater quality objectives for organic toxicants for the beneficial use 'stock watering' default to criteria derived for drinking water to protect human health)
- where risk assessment derived objectives are intended to be used, the methodology and key assumptions should be clearly documented
- an opinion of whether the risks posed to human health and environment are demonstrated to have been minimised after cleanup
- any mitigation and management measures proposed to reduce the risks to an acceptable level, if required.

7.0 Assessment of the feasibility of (further) groundwater cleanup/management

In cases where no active groundwater cleanup actions have occurred, the feasibility of any potential groundwater cleanup needs to be assessed and discussed for the purpose of preparation of clean up so far as reasonably practicable documentation. In cases where groundwater cleanup has already occurred, then the feasibility of further groundwater cleanup to achieve and maintain the environment values must be provided.

- An assessment of the potential cleanup technologies that could be implemented should be provided. This assessment should include consideration of the key factors of what is reasonably practicable (which is referred to in section 6 of the Act). However, other criteria may also be considered and included based on relevant site-specific factors.
- Application of a staged screening process may also be appropriate in some cases. For example, step 1 may first screen out potential cleanup technologies that are not technically feasible without the need to provide a detailed discussion of logistical, cost and timeframe considerations.

- Documents used to support the screening process should be referenced; for example, the USEPA Superfund Remedy Report (http://www.epa.gov/superfund/remedytech/srr/).
- Step 2 may then further assess the technically feasible cleanup technologies against the other criteria.
- Where the proposed estimated cost of a particular cleanup technology is included, the itemised costs for components that make up the total cost should also be provided. It would also be relevant to disclose the costs of site cleanup expended to date. Note: the costs information provided should be directly related to the potential or expended cleanup works. For example:
  - capital cost
  - operation and maintenance cost per year
  - environmental monitoring and reporting costs (for example, groundwater monitoring).
- The expected timeframe for the environment value(s) to be achieved or maintained as based on the implementation of each proposed cleanup option should be provided.
- A cost-benefit analysis should be provided in relation to proposed further cleanup options, and the minimising of harm to human health and the environment.

8.0 Management of contaminated groundwater

Provide information about how the groundwater contamination will be managed through one or more a risk control measures once clean up so far as reasonably practicable has been demonstrated. This may include:

- a map showing the extent of the impacted groundwater
- if the cleanup is subject to an environmental audit, the proposed recommendation(s) to be included in the environmental audit statement related to the extraction of contaminated groundwater
- a summary of the ongoing management plan or requirements.

Where ongoing groundwater monitoring is proposed post-clean up, prepare a plan (for example, a groundwater quality management plan (GQMP)) or information detailing the following:

- background information relevant to provide an understanding of the purpose and scope of the ongoing monitoring a description of the proposed monitoring schedule, including:
  - the identification of each well to be sampled and/or maintained
  - the frequency of sampling proposed
  - the analytical schedule
  - the period of monitoring proposed.
- triggers and mitigation measures (further action) based on the results of the monitoring program (for example, occurrence of NAPL, concentration rebound of contaminants of concern, changes in flow direction, existence of new nearby groundwater users, etc.)
- reporting requirements for the monitoring program, including identification of the responsible party.

Where there is a GQMP in place the duty holder should ensure that it is followed. Any revisions to the GQMP (and this may include ceasing groundwater monitoring) should be assessed and undertaken by a suitably qualified environmental professional. If the GQMP is established under an environmental audit, the audit should have recommendations for how long the GQMP needs

to be in place and any revisions prior to that time should be discussed with EPA's environmental audit unit (environmental.audit@epa.vic.gov.au).

When audit conditions have been adhered to, there is no need to contact EPA to revise the GQMP, and the duty holder must ensure that they are meeting their obligations under the duty to manage contaminated land and keep records of all documentation. Any cessation of a GQMP must ensure that there are mitigation measures that address any changes to site conditions that could affect the risks to human health and the environment.

For example, changes to groundwater levels through increased rainfall, or from dewatering from on site or from surrounding sites, or changes of affected land uses may trigger the need to undertake further groundwater sampling to confirm there are no risks to human health of the environment. The duty holder should retain documentation and evidence which identifies how the duty holder is complying with the duty to manage contaminated land. EPA can through its regulatory activities request to review any such documentation.

Where ongoing groundwater monitoring is not proposed, a statement justifying this approach supported by multiple lines of evidence should be provided.

Attachment A – Information self-checklist

Site address: _____

Information included	Section/page discussed	Please tick off
1. Background information		
Title details		
Land area and site plan		
Current/proposed future use		
General site history		
Surrounding land use (north, south, east and west)		
Regional groundwater information, if available		
Key contamination issue(s)		
Relevant figures to show site boundary, site features/layout		
2. Site characterisation		
Geology information (local and regional):		
Hydrogeology information:		
(a) Groundwater depth (m) and flow direction		
(b) Aquifer type and properties		
(c) Nearest surface water receptor (distance and direction)		
(d) Bore search (2 km radius)		
(e) Groundwater chemistry and segment (note – most conservative segment should be used)		
(f) Environmental values of groundwater identified		
Sources of contamination		
(g) History and contaminating activities		
(h) contaminant of concern (on and off site)		
Soil condition prior to clean up (nature and extent, supported by soil contamination Map(s))		
Vapour condition prior to cleanup (if applicable) (nature and extent, supported by vapour contamination map(s))		
Groundwater condition prior to cleanup (nature and extent, supported by groundwater contamination map(s))		
Regional groundwater condition		

3. Conceptual site model			
Potential receptors (human and environmental)			
Contaminant transport pathways and mechanisms			
Relevant figures, i.e. hydrogeological cross-section(s) of the site showing (as a minimum) geology, groundwater levels, groundwater bores and any relevant features (e.g. USTs, excavations, utility services, building structures, etc.)			
4. Summary of cleanup works			
Removal of primary and secondary sources			
Groundwater remediation			
5. Groundwater condition post-clean up			
Groundwater monitoring post-remediation			
Contaminants distribution and concentrations			
An opinion on the source of all contaminants over criteria in the groundwater (e.g. onsite source, offsite source, co-source)			
Summary table of impacted environmental values, with associated contaminants, as per attachment B			
Water quality summary table showing results from all rounds of monitoring (ug/L)			
Separate table showing latest water quality results that are above guidelines (ug/L) as per attachment C			
Plume extent			
Relevant figures related to groundwater condition post-clean up			
6. Plume stability and future behaviour			
7. Risk assessment including vapour			
8. Feasibility of further cleanup			
Remediation options table	Detailed discussion of specific options		
	Technical feasibility		
	Logistical feasibility		
	Implementation and completion timeframe		
	Cost		
	Consideration of principles of environmental protection		

9. Management of contaminated groundwater			
GQMP	Responsible party identified		
	Cost – establishment and annual		
	Duration		
10. A figure outlining the extent of any remaining contamination in groundwater after cleanup so far as reasonably practicable has been achieved (this should be included in the audit report when this process occurs under the environmental audit system)			
Any other issues of significance (e.g. remedial notice, significant public interest)			
11. Opinion on whether clean up so far as reasonably practicable has been achieved, and a clear and concise executive summary providing all of the above information			

Note that:

1. This is the base level of information required for documentation indicating whether clean up so far as reasonably practicable has been achieved. More complex issues will require additional information.

2. Some aspects of this checklist may not be relevant in certain site scenarios. In this case, provide comments in the checklist, or in the relevant sections of the documentation with reference in the checklist.

Attachment B – GQMP cessation

To be attached to GQMP cessation submission made to EPA Victoria.

Site address: _____

Information included	Section/page discussed	Please tick off
Site address and land area		
Title details		
Background information (a) Date of CUSFARP/GQRUZ determined/identified (if applicable) (b) Environmental audit statement recommendation regarding GQMP (if applicable) (c) Environmental values of groundwater not maintained/achieved (prior to GQMP implementation) (d) A discussion on mechanism to cease monitoring (auditor verification or an environmental audit)		
GQMP requirements (e) Monitoring frequency and period, bore networks and analytes (f) Trigger conditions/contingency (g) End points or mechanism for monitoring cessation		
Summary of implementation of groundwater monitoring program (h) A total of groundwater monitoring events (GMEs) undertaken since GQMP (i) Level of compliance with GQMP		
Summary of groundwater monitoring results reviewed since GQMP implementation (j) Groundwater flow direction (k) Historical concentrations, trends of contaminant concentrations (l) Plume stabilisation (m) Groundwater quality summary table showing results (µg/L)		
Current groundwater conditions (n) Separate table showing latest water quality results that are above relevant guidelines (µg/L) (o) Maps of groundwater contamination, plume extent etc.		

Assessment of risks to environmental values, human health and the environment (p) Changes of groundwater uses in the vicinity of the site since GQMP implementation (q) Updated bore research information (r) Potential impacts to human health and the environment (s) Risks to environmental values		
Opinions on whether triggers (or end points) of GQMP have been met and GQMP can be ceased		
Opinion on whether the GQRUZ identified should be retained, amended or revoked (if applicable)		
Any other issues of significance (e.g. remedial notice, significant public interest)		
A clear and concise executive summary providing all of the above information		

*Note that this is the base level of information required for a GQMP cessation submission. More complex sites will require additional

Attachment C – Example of impacted environmental value summary table

Impacted environmental value	Contaminant(s)
Water dependant ecosystems and species	TPH (C_6-C_{36}), arsenic, zinc (B/N), nitrate (R)
Potable water supply	NA
Mineral water supply	NA
Agriculture and irrigation (irrigation)	TPH (C_6-C_{36}), arsenic, zinc (B/N)
Agriculture and irrigation (stock watering)	NA
Water based recreation (primary contact recreation)	nitrate (R)
Industrial and commercial use	TDS
Traditional Owner cultural values	NA
Buildings and structures	NE
Geothermal properties	NA

Notes:
(B/N)– background elevation
(R)– regional contamination
NA – Not applicable
NE – No exceedance

Attachment C – Example of current groundwater analytical results summary table

The following template should be reproduced for the following:

1. analytes considered to be background level and hence not contamination
2. analytes considered to be sourced/co-sourced from the site
3. analytes considered to be from an upgradient source
4. analytes considered to be representative of regional pollution

Concentration range (mg)/L

Guideline values (mg/L) (reference guideline)

Contaminant	Regional aquifer (Site aquifer formation, approximate depth to groundwater in mbgl)			Water dependant ecosystems and species – fresh water	Water dependant ecosystems and species – marine water	Potable water supply			Agriculture and irrigation (stock watering	Agriculture and irrigation (irrigation)
	Upgradient	Onsite	Downgradient			Desirable	Acceptable	Mineral		

Contaminant	Regional aquifer (Site aquifer formation, approximate depth to groundwater in mbgl)			Industrial and commercial use	Water-based recreation (Primary contact recreation)	Traditional Owner cultural values	Buildings and structures	Geothermal properties
	Upgradient	Onsite	Downgradient					

*Presented as two tables for ease of viewing.