CRC for Contamination Assessment and Remediation of the Environment

National Remediation Framework

Guideline on establishing remediation objectives

Version 0.1: November 2018

National Remediation Framework

The following guideline is one component of the National Remediation Framework (NRF). The NRF was developed by the Cooperative Research Centre for Contamination Assessment and Remediation of the Environment (CRC CARE) to enable a nationally consistent approach to the remediation and management of contaminated sites. The NRF is compatible with the *National Environment Protection (Assessment of Site Contamination) Measure* (ASC NEPM).

The NRF has been designed to assist the contaminated land practitioner undertaking a remediation project, and assumes the reader has a basic understanding of site contamination assessment and remediation principles. The NRF provides the underlying context, philosophy and principles for the remediation and management of contaminated sites in Australia. Importantly it provides general guidance based on best practice, as well as links to further information to assist with remediation planning, implementation, review, and long-term management.

This guidance is intended to be utilised by stakeholders within the contaminated sites industry, including site owners, proponents of works, contaminated land professionals, local councils, regulators, and the community.

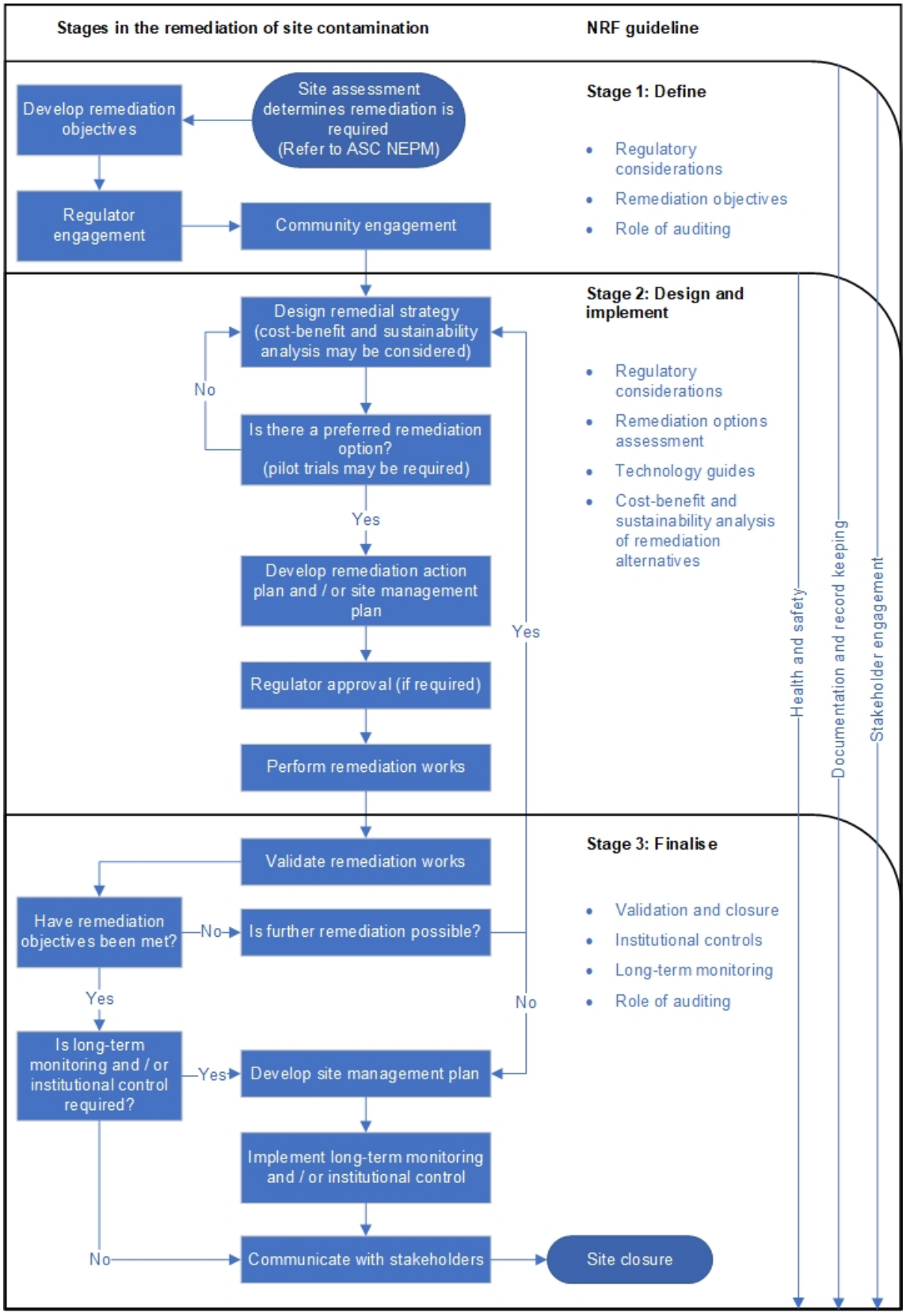
The NRF is intended to be consistent with local jurisdictional requirements, including State, Territory and Commonwealth legislation and existing guidance. To this end, the NRF is not prescriptive. It is important that practitioners are familiar with local legislation and regulations and note that **the NRF does not supersede regulatory requirements**.

The NRF has three main components that represent the general stages of a remediation project, noting that the remediation steps may often require an iterative approach. The stages are:

- Define;
- Design and implement; and
- Finalise.

The flowchart overleaf provides an indication of how the various NRF guidelines fit within the stages outlined above, and also indicates that some guidelines are relevant throughout the remediation and management process.

It is assumed that the reader is familiar with the ASC NEPM and will consult other CRC CARE guidelines included within the NRF. This guideline is not intended to provide the sole or primary source of information.


Stages in the remediation of site contamination
NRF guideline
Site assessment determines remediation is required (Refer to ASC NEPM)
Develop remediation objectives
Regulator engagement
Community engagement
Stage 1: Define
Regulatory considerations
Remediation objectives
Role of auditing
Design remedial strategy (cost-benefit and sustainability analysis may be considered)
No
Is there a preferred remediation option? (pilot trials may be required)
Yes
Develop remediation action plan and / or site management plan
Regulator approval (if required)
Perform remediation works
Stage 2: Design and implement
Regulatory considerations
Remediation options assessment
Technology guides
Cost-benefit and sustainability analysis of remediation alternatives
Yes
Validate remediation works
Have remediation objectives been met?
No
Is further remediation possible?
Yes
No
Is long-term monitoring and / or institutional control required?
Yes
Develop site management plan
Implement long-term monitoring and / or institutional control
No
Communicate with stakeholders
Site closure
Stage 3: Finalise
Validation and closure
Institutional controls
Long-term monitoring
Role of auditing
Health and safety
Documentation and record keeping
Stakeholder engagement

Executive summary

Establishing clear remediation objectives should ensure that on completion of the remediation process, that the site is suitable for the specified uses and provides adequate protection of human health and the environmental values.

Current and future uses of the site, and the risks that contamination may pose to receptors and environmental values must be established early in the process. The development of a robust CSM, which identifies the source pathway receptor linkages that need to be addressed, is a critical tool in identifying the objectives and end-points for the remediation activities.

The level of effort and resources expended to gather and integrate the information for remediation and/management decision-making need to be commensurate with the:

- Risk assessment (i.e. likelihood and level of risk and the severity of the consequences taking into consideration the sensitivity of the site use and the environmental setting;
- Extent, mobility and nature or complexity of the contamination; and
- Regulatory requirements.

In addition to effects on human health and the environment, the following may need to be considered prior to finalising the remediation objectives:

- The effects of contamination, including toxicity, the potential for bioaccumulation and persistence;
- The potential risk posed by residual contamination, and the effectiveness and acceptability to stakeholders of any controls that might be involved; and
- The expected effectiveness, practicability and outcome of the proposed remediation and management strategy.

Remediation objectives typically include specific and measurable end-points for each element of the remediation activities, which serve as practical targets to be achieved by the remedial activities and, when met, signify the end of these activities. It is also important to recognise that pre-existing legal documentation (e.g. notices, licences, leases, commercial requirements) may significantly influence remediation objectives.

It is not always practical or cost-effective to have all the necessary information to establish remediation criteria prior to commencing remediation. In this regard establishing final remediation objectives may be a staged or iterative process, where the targets for clean-up (and post-remediation targets) need to be re-considered. End-points may need to factor in contingencies in case objectives are not met with the adopted technology(ies), or to incorporate uncertainty / responsive actions as further information is obtained.

The timeframe to achieve the remediation objectives may be one of the constraints influencing the selection of remediation options.

When remediation objectives have been achieved and no further active remediation is required at a site, regulators would consider whether a site can be closed based on the data and information that is provided.

Abbreviations

Abbreviation	Expansion
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AS/NZS ISO	Australian and New Zealand International Standard Organisation
CRC CARE	Cooperative Research Centre for Contamination Assessment and Remediation of the Environment
CSM	Conceptual Site Model
EIL	Ecological Investigation Level
ESD	Ecologically Sustainable Development
EU	European Union
GIL	Groundwater Investigation Level
HIL	Health Investigation Level
HSL	Health Screening Level
LNAPL	Light Non-Aqueous Phase Liquids
NAPL	Non-Aqueous Phase Liquid
NEPC	National Environment Protection Council
NHMRC	National Health and Medical Research Council
NSW	New South Wales
NT	Northern Territory
QLD	Queensland
RAP	Remediation Action Plan
SA	South Australia
SMP	Site Management Plan
WA	Western Australia

Glossary

Ambient background	The condition of soil and/or water representative of the area surrounding the site not attributable to an identifiable point source(s). Definition includes the impacts of widespread diffuse sources of groundwater contamination.
Background quality	The condition of soil and/or water in the vicinity of a site which is the sum of the ambient and natural background (ASC NEPM 2013). Jurisdictional definitions may vary
Beneficial use	A particular value or use of the environment or any element or segment of the environment which: · is important for a healthy ecosystem; · is conducive to public benefit, welfare, safety, health or aesthetic enjoyment which requires protection; or · is declared in state or territory environment protection policy to be a beneficial use. Definitions for 'beneficial use' or 'environmental value' may differ among jurisdictions (e.g. may include additional considerations for 'environmental harm' as defined in jurisdictional legislation See also "Environmental value"
Concentration	The amount of material or agent dissolved or contained in unit quantity in a given medium or system.
Conceptual site model	A representation of site-related information including the environmental setting, geological, hydrogeological and soil characteristics together with the nature and distribution of contaminants. Contamination sources, exposure pathways and potentially affected receptors are identified. Presentation is usually graphical or tabular with accompanying explanatory text.
Contaminant	Any chemical existing in the environment above background levels and representing, or potentially representing, an adverse health or environment risk.
Contaminated site	A site that is affected by substances that occur at concentrations above background or local levels and which are likely to pose an immediate or long-term risk to human health and/or the environment. It is not necessary for the boundaries of the contaminated site to correspond to the legal ownership boundaries.

Contamination	The presence of a substance at a concentration above background or local levels that represents, or potentially represents, a risk to human health and/or the environment.
End-point	Targets (preferably numerical values) that need to be achieved to demonstrate that remediation has been effective. Also known as technology or remediation end-points or remediation clean-up criteria. A multiple lines of evidence approach may be used to demonstrate the effectiveness of remediation.
Environment(al) protection authority / agency	The government agency in each state or territory that has responsibility for the enforcement of various jurisdictional environmental legislation, including some regulation of contaminated land.
Environmental value	A particular value or use of the environment or any element or segment of the environment which: · is important for a healthy ecosystem; · is conducive to public benefit, welfare, safety, health or aesthetic enjoyment which requires protection; or · is declared in state or territory environment protection policy to be a beneficial use. See also "Beneficial use"
Fit-for-purpose	The intended use of the site may be a consideration when allowing for the level of acceptable risk that may be permitted to remain on the site (also taking into account potential risks existing off-site).
Groundwater	Water stored in the pores and crevices of the material below the land surface, including soil, rock and fill material.
Investigation and screening levels	The concentrations of a contaminant above which further appropriate investigation and evaluation will be required.
Multiple lines of evidence	Uses a combination of information from several independent sources (or lines of evidence) to provide sufficient support to demonstrate success in situations where no one individual line of evidence provides sufficient certainty. Also known as a weight of evidence approach.
Natural background	The condition of soil and/or water derived/originating from natural processes in the environment as close as possible to natural conditions, exclusive of specific anthropogenic activities or sources (ASC NEPM 1999, Sch B6).

Practitioner	Those in the private sector professionally engaged in the assessment, remediation or management of site contamination.
Precautionary principle	Where there are threats of serious or irreversible damage to human health or the environment, lack of scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation or human exposure.
Proponent	A person who is legally authorised to make decisions about a site. The proponent may be a site owner or occupier or their representative.
Remediation	An action designed to deliberately break the source-pathway-receptor linkage in order to reduce the risk to human health and/or the environment to an acceptable level.
Remediation objective	An objective established for a specific site to be met by the implementation of a Remediation Action Plan and, if appropriate, ongoing site management.
Residual contamination	Concentrations of the contaminants of concern remaining following completion of remediation.
Risk	The probability that in a certain timeframe an adverse outcome will occur in a person, a group of people, plants, animals and/or the ecology of a specified area that is exposed to a particular dose or concentration of a specified substance, i.e. it depends on both the level of toxicity of the substance and the level of exposure. 'Risk' differs from 'hazard' primarily because risk considers probability.
Risk assessment	A process intended to calculate or estimate the risk to a given target organism, system, or sub-population, including the identification of attendant uncertainties, following exposure to a particular contaminant, taking into account the inherent characteristics of the agent of concern as well as the characteristics of the specific target system (ASC NEPM 1999, Sch B6).
Risk management	A decision-making process involving consideration of political, social, economic, and technical factors with relevant risk assessment information relating to a hazard to determine an appropriate course of action.
Site	A parcel of land (including ground and surface water) being assessed for contamination, as identified on a map by parameters including Lot and Plan number(s) and street address. It is not necessary for the site boundary to correspond to the Lot and Plan boundary, however it commonly does.

Site management plan	Contains information on the necessary management required to manage ongoing issues as a site (usually following remediation activities).
Sustainability	Generally, refers to achieving a balance between meeting the needs of the present without compromising the ability of future generations to meet their own needs. In specific reference to the remediation of site contamination, sustainability refers to achieving an acceptable balance between the impacts of undertaking remediation activities and the benefits those activities will deliver in terms of the environmental, economic and social indicators relevant to the site.

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1. Introduction

Remediation objectives are those objectives established for a specific site to be met by the implementation of a remediation action plan (RAP) and, if appropriate, ongoing site management. The remediation objectives provide a clear indication of what remediation needs to achieve:

- To address unacceptable risks to relevant environmental values from contamination; and
- For the remediation to be considered complete.

When remediation objectives have been achieved and no further remediation is required at a site, regulators may agree that the site can be closed i.e. site closure.

This guideline provides a framework for establishing remediation objectives, including:

- Outlining the principles underlying the establishment of remediation objectives;
- Providing guidance for developing remediation objectives for remediation and management based on common jurisdiction expectations; and
- Including case studies to demonstrate the approaches used by different jurisdictions.

This guideline provides the key considerations that are generally acceptable for achieving reasonable and cost-effective remediation and/or management. It is envisioned that this guidance will assist in the harmonisation of the approaches used for establishing remediation objectives nationally.

While the aim of this guideline is to provide a practical and up-to-date resource that can be used at contaminated sites across Australia, it does not replace specific laws, regulations and guidance provided at the jurisdictional level.

This guideline also takes considerable care to avoid conflicts with State, Territory and Commonwealth legislative requirements. In time, these differences in legislative approach may decrease as jurisdictional legislation is reviewed and updated. However, the updating of legislation is a lengthy process and consequently practitioners need to be familiar with relevant local jurisdictional legislation and policy. This **guideline does not supersede jurisdictional legislation and policies, nor existing legal or contractual agreements**.

In the context of this guideline, “site contamination” refers to both the land and groundwater at the site, and surface water and sediment where these are present at the site.

Site contamination can have significant health, environmental, social and financial risks, and potentially significant liability for site owners, occupiers or other parties with an interest in such sites. Contamination impacts may also present a perception of ‘blight’, which can present an obstacle to future uses, development or transfer of a site.

This guideline has been developed through consideration of the existing approaches to remediation and management currently being applied in jurisdictions in Australia with a view to identifying commonalities across jurisdictions. This guideline recognises that site contamination assessments (including conceptual site models) remain integral to the decision-making processes during remediation and/or management.

Establishing appropriate remediation and/or management objectives is fundamental to risk management. Risk management refers to a coordinated set of activities and methods that are used to direct and to control risks, with the likelihood that specified objectives can be achieved. In the context of risk assessment, the ASC NEPM states that risk management is a decision-making process involving the consideration of political, social, economic and technical factors with relevant risk assessment information relating to a hazard to determine an appropriate course of action.

The fundamental requirement is to protect humans and the environment. Consistent with some of the statements in the ASC NEPM, overly conservative scenarios for determining risks can result in unnecessary remediation activities. ASC NEPM, Schedule B1 states that the use of investigation and screening levels as default remediation criteria may result in *'increased development costs, unnecessary disturbance to the site and local environment, and potential waste of valuable landfill space'*. Similarly, the use of investigation and screening level as default remediation criteria should not be interpreted as 'condoning discharges of waste up to these levels'.

1.1 Principles underlying remediation objectives

When developing remediation objectives, stakeholders are encouraged to consider the principles incorporated into the NRF, which have been based on principles described in the following national documents:

- ASC NEPM;
- National Water Quality Management Strategy (ANZECC 2015)
- Intergovernmental Agreement on the Environment (IGAE) 1992, and
- Jurisdictional requirements.

Within the NRF, the overarching principles which provide the underlying basis of all remediation and/or management decision-making, including establishing remediation objectives were agreed to in the early stages of the development of the NRF. They are:

- Precautionary principle;
- Prevention;
- Risk management during remediation and site management;
- Options hierarchy;
- Sustainability; and
- National and international obligations

Each of these principles is described in more detail within Appendix A *Principles underlying the NRF*. Readers are also directed to the NRF *Introduction to the National Remediation Framework* for more detail on the philosophy underlying these principles.

2. Overview of remediation process and remediation objectives

Important considerations for remediation and/or management, in broad terms, are:

- Protection of human health and the environment, expressed in terms of protection of beneficial uses or environmental values, and
- Risk reduction.

The remediation objectives for a site provide a clear indication of what remediation needs to achieve:

- To address unacceptable risks to environmental values from contamination; and
- For the remediation to be considered complete.

The remediation objectives need to incorporate the primary intention that unacceptable risks to environmental values both on-site and off-site (as well as residual risks) will be eliminated or controlled. The suitability of a site and the surrounding environment for use are important considerations in all jurisdictions.

The remediation objectives are generally stated in qualitative terms (restoration of a particular land use or use of groundwater for non-potable purposes, for example) and may be aspirational targets. They typically include specific and measurable end-points for each stage of the remediation activity, which serve as practical targets to be achieved by the remedial activities and, when met, signify the end of these activities. Together these endpoints must be sufficient to achieve the remediation objectives. Remediation end-points are also known as remediation criteria.

The establishment of remediation objectives usually commences during the risk assessment process. It is important to start formulating remediation objectives during the site investigation phase, when dialogue with key stakeholders (e.g. regulatory agency, auditors, advisers, affected site owners) about the priority considerations for the site during and beyond when remediation is initiated. These may form the basis of preliminary objectives can be refined as more information becomes available.

In developing remediation objectives, it is important to determine the triggers and drivers of proposed remediation and/or management measures (see Section 2.2), and to establish the specific risks to environmental values which need to be managed in the context of a robust conceptual site model (CSM). The remediation objectives should ensure that on completion of the remediation and validation process, that the site is suitable for the specified uses and provides adequate protection of environment values. The remediation objectives and management strategy should address residual contamination and off-site contamination. The person undertaking remediation may not have liability for offsite issues. It is noted that liability considerations are an important issue, which are however outside of the scope of this guideline.

When remediation objectives have been achieved and no further active remediation is required at a site, regulators may agree that the site can be closed. This is referred to as site closure.

Each jurisdiction has guidelines which assist proponents to meet regulatory requirements. A summary of jurisdiction-specific definitions and directions for setting remediation objectives is outlined in the Appendix B *Remediation objectives in jurisdictions*. While it is important to understand jurisdiction-specific variations and requirements (eg case studies included in Appendix C *Jurisdictional requirements: case studies*), the process for setting remediation objectives is similar.

Expectations of individual jurisdictions may include such things as:

- The fundamental basis for any remediation is the adequate protection of human health and the environment; this requirement may be framed in terms of protecting particular environmental values or beneficial uses;
- All environmental media need to be considered, as applicable, to the site-specific conditions (soil, water, sediment, soil vapour and ambient air);
- The implementation of a fit-for-purpose philosophy to determine which environmental values may need to be protected can be useful, and should consider:
    - The suitability for current and potential uses in the case of groundwater;
    - Current or proposed land uses in the case of soil;
    - Sensitive receptors off-site; and
    - Jurisdictional requirements
- The remediation plan must also account for unexpected finds during remediation works, which may result in a re-consideration of the details of the RAP;
- The development of remediation objectives should include consideration of relevant issues, described within other NRF guidelines such as:
    - Identification and selection of remediation technologies;
    - Cost-benefit sustainability analysis;
    - Regulatory considerations;
    - Stakeholder engagement;
    - Health and safety;
    - Contingency actions;
    - Long-term monitoring; and
    - Validation and closure.
- If there is residual contamination expected on the site, remediation objectives should include considerations to control risks to an acceptable level.

2.1 Remediation action plans and site management plans

A RAP provides details of the remediation work that will be required at a site to protect human health and the environment from unacceptable risks, and often detail performance criteria for the remediation activities, and contingency actions. A RAP will include the remediation objectives for a site.

Jurisdictions may have specific requirements for RAPs.

An SMP or environmental management plan (EMP) is often utilised in place of a RAP for sites where the remediation activities are:

- Relatively limited;
- Ongoing; or
- Principally address environmental protection activities (as opposed to remediation activities).

The terms 'remediation' and 'management' are sometimes used interchangeably in literature.

Jurisdiction-specific deviations include differing terminologies including: SMP, EMP or site remediation plan (SRP). Whilst these different terminologies include some jurisdiction-specific variations and requirements, they do not affect the process for setting remediation objectives, which is the focus of this guidance.

A RAP (or SMP) includes a set of actions which assists in managing the environmental impacts during remediation works (e.g. managing noise from earthmoving activities, which may cause a nuisance for neighbours). If residual contamination following the remediation of a site poses unacceptable risks to environmental values, then further remediation may be required or a SMP will need to be developed which details specific ongoing management of the residual contamination.

Jurisdictions may have specific requirements for developing a RAP or an SMP.

For more information readers are directed to the NRF* Guideline on documentation, record keeping and reporting*, as well as relevant jurisdictional guidelines.

As more site-related information becomes available there may also be a need to transition from a SMP to a RAP, to address newly identified unacceptable risks to on-site and/or off-site receptors, or to enable a change to a more sensitive land use.

2.2 Triggers and drivers for remediation and/or management

The underlying basis of remediation:

'should be to render a site acceptable and safe for long-term continuation of its existing use or proposed used where a change of land use is part of the remediation strategy, and to maximise to the extent practicable its potential future uses' (NEPC – not dated).

Remediation and/or management processes may be triggered by contamination being identified either close to the source, or by reaching or about to reach an identified receptor and causing, or about to cause, harm. The process is often prompted by regulatory, planning and/or development requirements, or as a result of a specific contamination event such as a product spill, incident or chemical loss.

The setting of remedial objectives will generally be based on one driver or a combination of drivers, for example:

- Regulatory based remediation drivers, based on state or territory policies related to the clean-up of soil and groundwater;
- Risk-based remediation drivers to reduce risks of exposure or impact from contamination; or
- Non-risk-based remediation drivers to meet specific or arbitrary targets in reducing contaminant presence (e.g. light non-aqueous phase liquid).

In general, jurisdictions will require notification of environmental harm. Some triggers for remediation and/or management and their implications in relation to developing remediation objectives are outlined in Table 1 as examples. Often the overall remediation objective can be framed in terms of making the site fit for its intended purpose, as shown in Table 1. Specific site zoning should be considered to ensure that the range of potential uses is considered in the remediation//site management strategy.

Appropriate precautionary measures are needed when decommissioning industrial premises and developing sites where potentially contaminating activities have taken place.

Table 1: Possible triggers for remediation and/or management and their implications in developing remediation objectives

	Implications on developing remediation objectives	
Trigger	**No change in use, or change to a more or less sensitive use is possible:**	**Change to more sensitive use is not possible:**
Redevelopment of a site(s) and identification of contamination that is a potential risk	Depending on the risks to human health and the environment (on-site and off-site), remediation objectives can consider a fit-for-purpose approach. Unacceptable risks to off-site receptors need to be addressed.	If the environmental values cannot be protected, then the current or potential use of the site may not be appropriate. The use of the site may need to be managed, or a less sensitive land use proposed. Unacceptable risks to off-site receptors need to be addressed. Note: There may be an expectation to return the site to its baseline state or to make the site suitable for the range of uses for which it was suitable prior to the commencement of an activity, after site closure [1]. For large-scale industrial precincts, for example, remediation must address environmental values relevant for industrial use. This may be a restricted subset of environmental values on-site but should also consider off-site human health and environmental impacts.
Decommissioning of an industrial plant or activity and identification of site contamination that is a potential risk.	Depending on the risks to human health and the environment (on-site and off-site), it may be sufficient to appropriately monitor risks until such time when the site is redeveloped. Unacceptable risks to off-site receptors need to be addressed. Remediation objectives can consider a fit-for-purpose approach once the future use of the site has been determined.	
Change in existing use of a site (e.g. change in lay-out or chemicals handled) and associated identification of contamination that is a potential risk.	Remediation objectives should be developed to ensure that the site is fit-for-purpose for the new activity, and address risks to human health and the environment (both on-site and off-site).	

[1] Site owners or operators may wish to document the baseline state of the soil and groundwater at the site of operation prior to commencement of activity. If this is relevant (refer to jurisdictions), it is important to ensure that relevant stakeholders have inputs and necessary approvals are obtained. The EU Industrial Emissions Directive (2010/75/EU, 24 November 2010) provides useful information on this matter - See *Guidance for Preparation of the baseline report on the state of soil and groundwater.* The EU guidance is for information only

2.3 Stakeholder engagement

Stakeholder engagement is crucial to setting effective and acceptable remediation objectives. The NRF *Guideline on stakeholder engagement* provides guidance on when and how to engage with stakeholders throughout the remediation process (*guessing a bit here*). The term 'stakeholder' refers to anyone with who has an interest in, or may be affected by, remediation of site contamination. The term includes:

- Site owners;
- Proponents of works;
- Contaminated land practitioners;
- Subject matter experts;
- Contractors;
- Regulators;
- Government departments;
- Environmental interest groups;
- Industry; and
- Community.

It is important to differentiate between stakeholders and decision-makers. While decision-makers are also stakeholders, they have the additional responsibility of having decision-making power for one or more aspects of the remediation project. Not all stakeholders will also be decision-makers, and this is important to establish at the beginning of the relationship to avoid unmet expectations or misunderstandings.

Community engagement is particularly important during the establishment of remediation objectives, as it is the time of the project that allows the most flexibility in accommodating the needs of all stakeholders. In addition, early engagement ensures that the community will have some control over and involvement in the risk management process, which is more likely than not to lead to community acceptance of the decisions that are made.

It is important that the affected community are informed about and understand and accept the potential risks associated with any residual contamination on the site and accept the remediation objectives, proposed uses of the site and any restrictions on use that may be applied to the site to ensure that human health and the environment are protected. Without this acceptance the overall outcome of the remediation process may be compromised.

The accuracy of risk estimates can be affected by many assumptions (e.g. validity of methods, degree of conservatism built into the process), and it is important that risk communication strategies address the need to explain to the community the meaning of 'acceptable risk' suited to the local conditions, including the derivation of site-specific risk-based remediation criteria. This is especially so in cases where social acceptance of remediation works can affect the selection of remediation strategies, including the establishment of remediation objectives.

Readers are directed to the NRF *Guideline on stakeholder engagement* for detailed information on engaging stakeholders, including specific sections on community

engagement. Readers are directed to the *NRF Guideline on performing cost-benefit analysis of remediation options* for methodology to incorporate stakeholder preferences into the decision-making framework.

3. Developing remediation objectives

The key steps in developing and / or revising remediation objectives and the tasks relevant to each step are described in Figure 1 below. Steps 1-3 are essential and steps 4-5 may depend on the complexities at a site and should be discussed with regulators. Each of these steps are discussed in detail in the following sections.

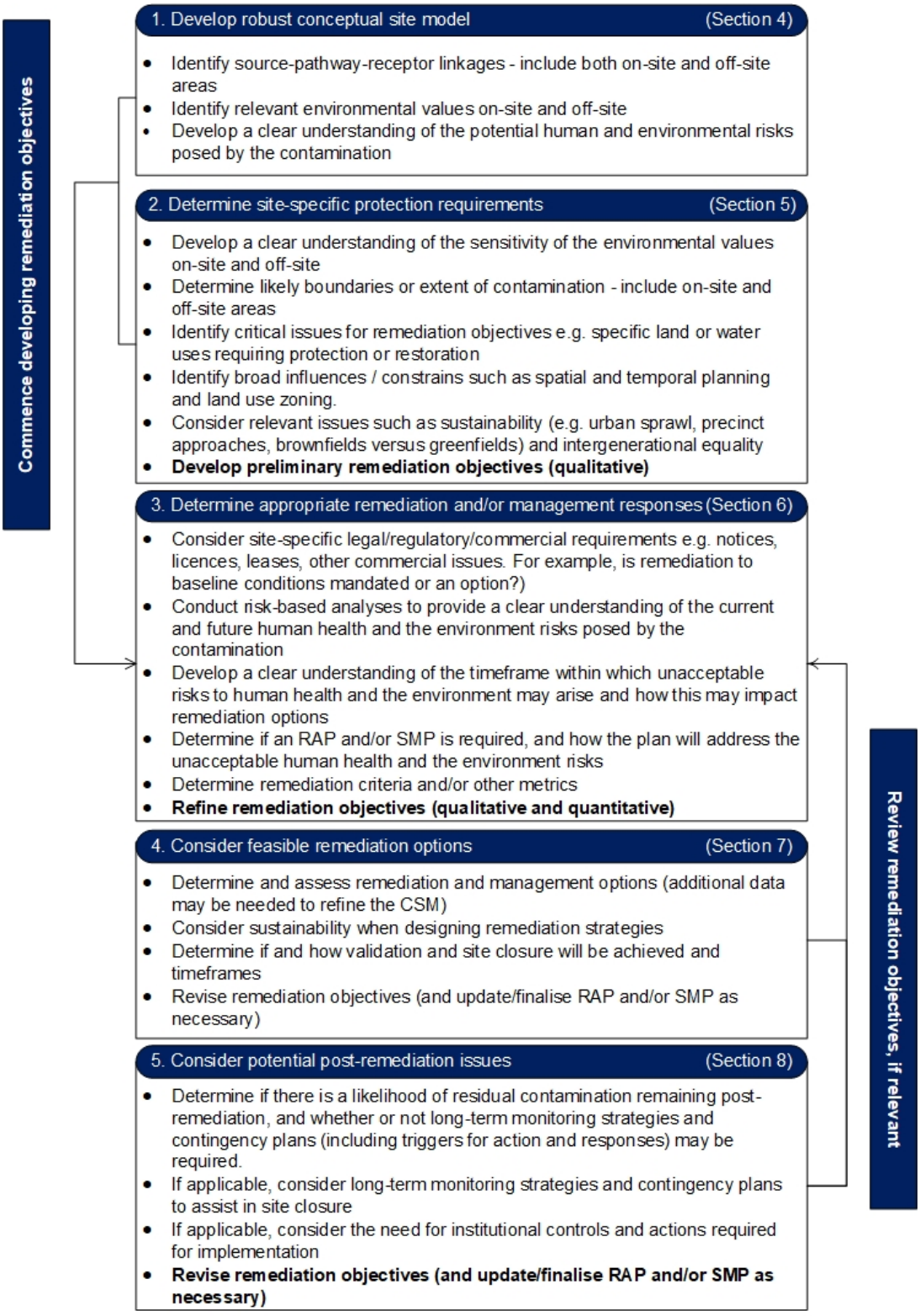

Figure 1: Five step process for developing remediation objectives

4. Step 1 - Develop a robust conceptual site model

The iterative development of a robust conceptual site model (CSM) during the site assessment phase should sufficiently identify the source, pathway, receptor (SPR) components to inform the appropriate level of risk assessment for the site (see ASC NEPM 1999 Schedule B2). A well-defined CSM can reduce potential conservatism in remediation / management responses.

The development of a robust CSM is the starting point for risk-based approaches to remediation and/or management design. The CSM may need refinement to inform setting of realistic remediation objectives. This is because the information required to inform a cost-effective RAP is often more detailed than that required to understand broad site investigation concepts such as the nature and extent of contamination.

Consequently, developing remediation objectives can also involve an iterative process for complex sites or situations: as potential effects and risks are identified (and any previously unidentified contamination is discovered), more detailed assessment will be undertaken to better understand the situation and remediation requirements, and this may lead to an adjustment of the objectives reflecting the practicability and acceptability of the remediation.

5. Step 2 - Determine site-specific protection requirements

Environmental value[2] (or beneficial use) refers to a use that is conducive to public benefit, welfare, safety or health, and ecological health and which requires protection from the effects of pollution, waste discharge and deposits. The environmental setting and land use of the site determine the environmental values to be protected.

The environmental values to be protected should be identified from the CSM. In order to do so, identify those receptors and/or land uses/activities where source-pathway-receptor linkages are complete, or potentially complete, and consider the extent of on- and off-site contamination) and the use(s) for the site and the nature of off-site receptors.

Depending on the site and its environmental setting, not all environmental values may be relevant. A fit-for-purpose approach (including site suitability for various uses) may be acceptable in some jurisdictions (check jurisdictional requirements) to determine what needs to be protected – for example, industrial land use allows for the protection of environmental values associated with generally highly modified ecosystems, human health, and buildings and structures (provided that there are no other sensitive uses). However, some larger industrial precincts or other commercial land use such as a major airport may also include ecologically sensitive areas such as wetlands and rivers which would require a higher level of protection.

The approach for protecting all relevant environmental values should be determined on a site-specific basis. For example, when the current or proposed land use requires more than one environmental value to be protected, then either the most sensitive use could be adopted as the remediation objective for the whole site, or alternatively, remediation objectives may be developed for sub-areas which in turn ensure that all relevant receptors are protected, including the on- and off-site environmental values.

The sensitivity of the use depends on the environmental values requiring protection. Once again this includes mitigation of risks beyond the site to include any off-site issues.

The environmental values to be protected will require confirmation from the relevant regulator and engagement with affected stakeholders. The remediation objectives will also need to be clearly understood in the context of local planning, and perhaps even wider sustainable development goals. Intergenerational equity and ESD principles are applicable to these considerations. All relevant environmental media (e.g. soil, water, sediment, soil vapour and ambient air) need to be considered.

The ASC NEPM defines environmental values for different land use scenarios (refer to jurisdictional requirements as these may differ). The environmental values for soil, as defined in the ASC NEPM, that may need to be protected, based on current or proposed land use, include:

[2] The document adopts the term ‘environmental value’ as this is consistent with the ASC NEPM and includes ecological health. Definitions may vary among jurisdictions, such as inclusion of aesthetics.

- Human health including consumption of garden produce;
- Terrestrial and aquatic ecosystems;
- Buildings and structures;
- Aesthetics;
- Cultural and spiritual values; and
- Air quality (indoor and ambient) in areas where contaminated soil releases volatile vapours.

Jurisdictions may have specific requirements in relation to environmental values for soil that need to be protected.

The ASC NEPM describes the environmental values that may need to be protected for groundwater, based on current and realistic future use, to include:

- Drinking water;
- Groundwater ecosystems;
- Non-potable water use (e.g. watering gardens or parks, flushing toilets);
- Aquatic ecosystems;
- Recreational use;
- Agricultural use (e.g. stock watering or irrigation);
- Industrial use; and
- Air quality (indoor and ambient) in areas where contaminated groundwater plumes release vapours.

Jurisdictions may have specific requirements in relation to environmental values associated with groundwater that need to be protected.

In some situations, groundwaters are naturally high in salts and/or trace metals making them unsuitable for specific uses.

Sediment impacts will also need to be considered where contamination has occurred (refer to ANZECC and ARMCANZ (2000)). The environmental value associated with sediments can relate to whether the contaminants of concern would affect ecological health, aquaculture and collection of aquatic organisms for food. It may be appropriate to consider the partitioning of contaminants between sediment and water, pore water, and mass flux into overlying water. In the case of persistent organic pollutants, the potential to bioaccumulation in aquatic organisms can be one of the key factors that influence the requirements for remediation (see Simpson et al 2013).

The ASC NEPM requires that due regard should be given to sites of cultural or spiritual significance the significance that indigenous people attach to land. The approach taken in New South Wales, is that all other environmental values of the land are protected then the cultural and spiritual values of the land are also considered to be protected (NSW DEC, 2007). Where relevant, practitioners should check with the relevant regulator regarding the most appropriate approach.

Depending on the site-specific circumstances and environmental setting, the following environmental values may also need to be considered:

- Protection of building and structures from groundwater contaminants that can degrade building materials and infrastructure such as service piping through contact with acidic waters;
- Food quality including garden produce and meat/eggs (soil quality and water quality);
- Aquaculture (surface water quality and groundwater quality); and
- Air quality - potential explosive atmospheres or asphyxiation risk in enclosed spaced from ground gases.

6. Step 3 – Determine appropriate remediation and/or management responses

The level of effort and resources expended to gather and integrate the information and data for remediation and/or management need to be commensurate with the:

- Risk assessment (i.e. likelihood and level of risk and the severity of the consequences taking into consideration the sensitivity of the site use and the environmental setting;
- Extent, mobility and nature or complexity of the contamination;
- Value of the site before and after remediation; and
- Regulatory requirements.

Expert technical advice may assist in making some of the risk-based decisions, especially to assist in identifying low risk sites or scenarios. Decision-making (including expert advice) for high risk sites and scenarios is more difficult, especially if the cost of remediation and management is also unaffordable or unsustainable.

Further data and information may be required to improve the CSM at this stage to identify cost-effective and feasible remediation and/or management strategies.

Depending on the situation (and regulatory requirements), remediation and/or management techniques may sometimes be used to reduce the risks to receptors without necessarily reducing the contamination load at the site (e.g. for contaminants for which alternate remediation technologies/techniques are not readily available in Australia). Such approaches may not result in site closure and instead require long-term monitoring (e.g. periodic re-assessments) and/or institutional controls.

Decision-making frameworks for remediation and/or management can be adapted from the ASC NEPM Schedule A based on the level of investigation/sufficiency of information available to inform risk-based remediation strategies.

The level of investigation undertaken is informed by the:

- Level of certainty required for risk-based decision-making (and consequent information and data requirements);
- Subsequent site remediation and/or management plan requirements following a risk-based approach; and
- Information required to develop site-specific risk-based criteria.

Figures 1-3 illustrate the use of tiered risk assessments in the development of assessment criteria.

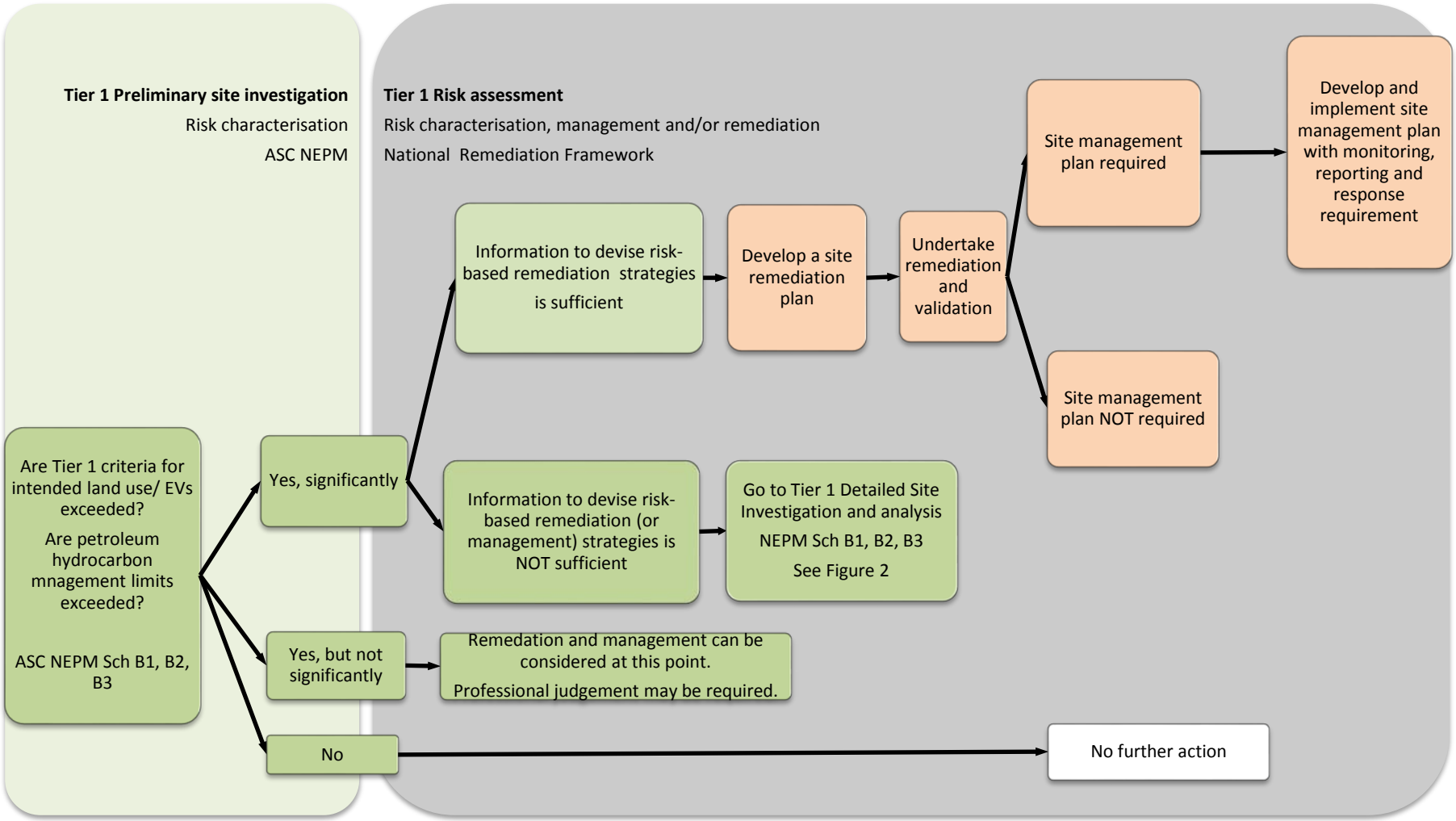

Figure 2. Tier 1 Preliminary investigation and remediation and/or management pathways.

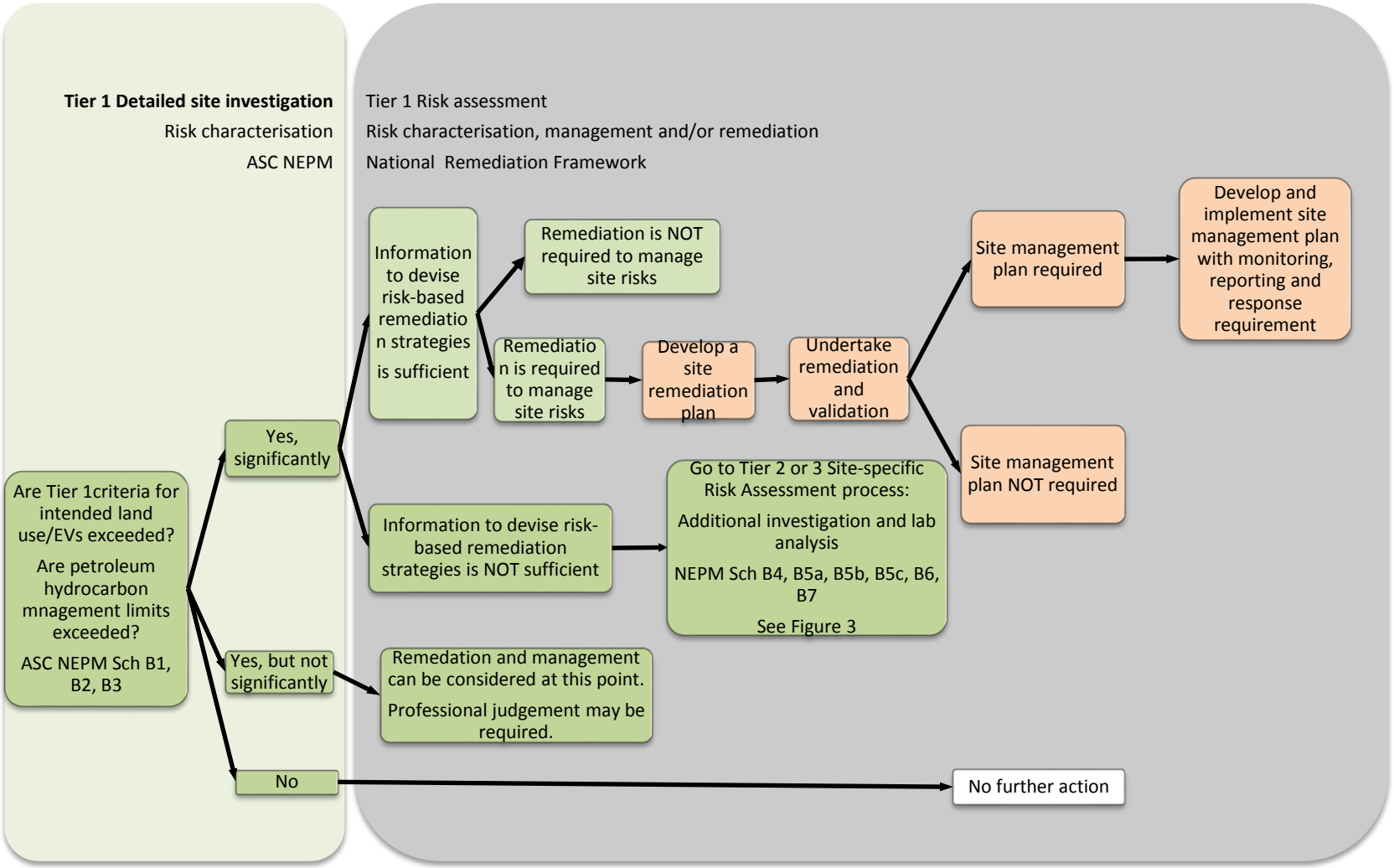

Figure 3. Tier 1 Detailed investigation and remediation and/or management pathways.

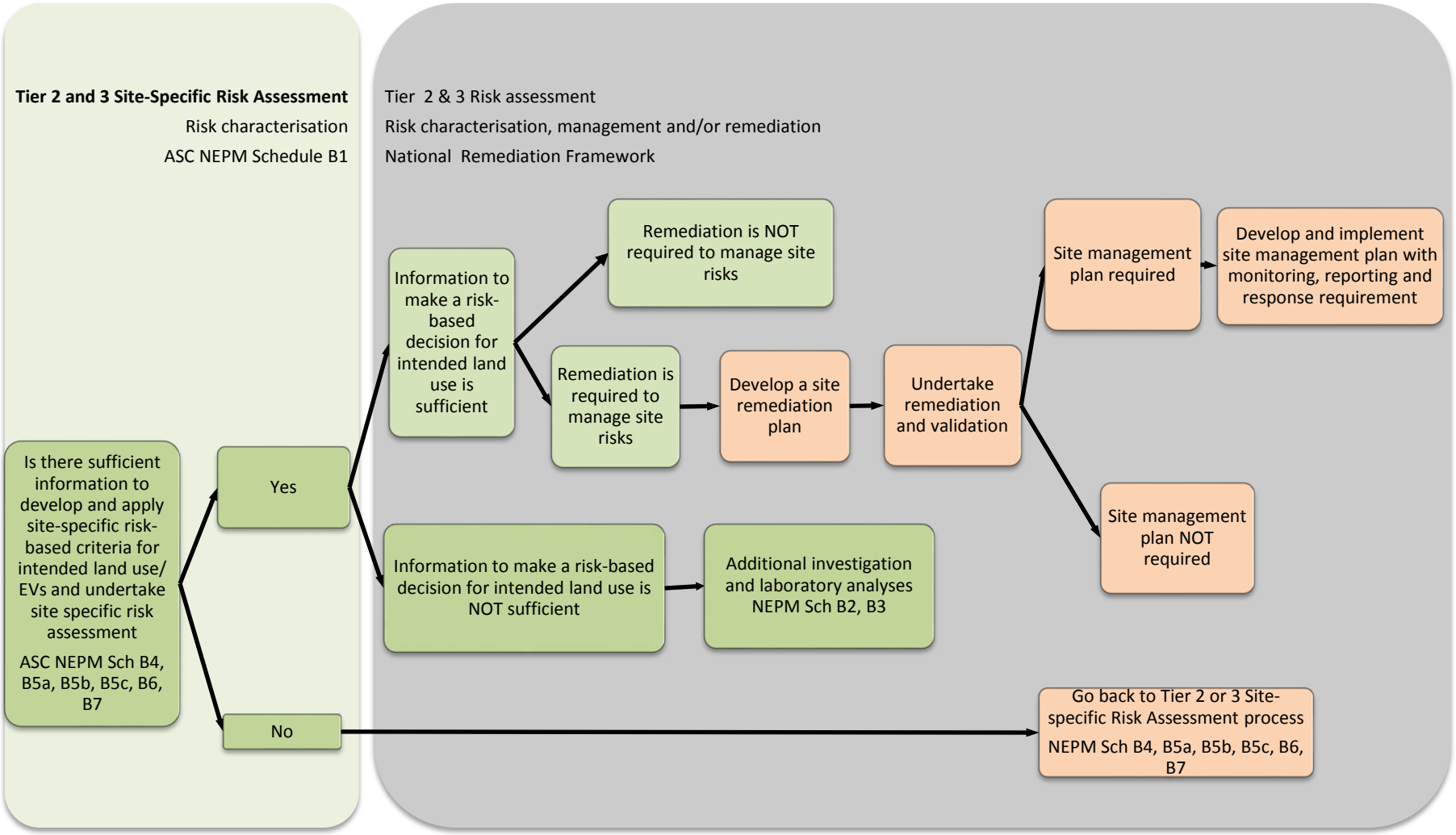

Figure 4. Tier 2 and 3 Investigation and remediation and/or management pathways.

The next sections outline a generic approach to developing remediation objectives with a focus on numerical criteria. They provide guidance for associated remediation decision-making. Remediation end-points may be considered, for example, based on risk-based criteria (section 6.1; see Appendix D *Tiered risk assessment and development of criteria*) and/or baseline and background conditions (sections 6.2 and 6.3), in agreement with regulators. Remediation objectives may be subject to conditions or criteria, such as stipulated in agreed legal documentation eg leases (see sections 6.4 and 6.5).

6.1 Site specific risk-based criteria

Site-specific risk-based criteria are generic numerical criteria modified for site-specific conditions based on a Tier 2 site-specific risk assessment, or criteria developed based on the Tier 3 site-specific risk assessment (as described in ASC NEPM). These criteria may be concentration-based criteria determined in the site investigation and risk assessment process.

Appropriate remediation end-points are the clearly defined targets that need to be achieved to demonstrate that remediation has been effective using a multiple lines of evidence approach (see section 6.3 on background conditions). Remediation end-points need to be acceptable to regulators and/or auditors and may be used in site validation i.e. to evaluate whether a site has been remediated effectively.

Site-specific risk-based criteria may be used as remediation end-points (also known as clean-up or remediation criteria), if appropriate. Remediation end-points need not be limited to concentration-based criteria. For example, remediation end-points can be developed as part of a multiple lines of evidence approach to:

- Monitor performance of a remediation technique to understand the remediation efficiency over the long term (using performance-based metrics e.g. mass flux); or
- Monitor residual contamination over time as a part of an institutional controls process.

The approaches described below do not supersede jurisdictional legislation and guidance. Regulators should be consulted in relation to the remediation required.

Jurisdictions may establish numerical criteria for particular contaminants.

The ASC NEPM approach for generating Tier 1, 2 and 3 investigation criteria is considered Appendix D *Tiered risk assessment and development of criteria*. While the ASC NEPM does not endorse investigation and screening levels as remediation

criteria,[3] they may be considered in specific situations where the generic exposure scenarios (refer schedules B4 and B5b) are conservative for the site-specific conditions, if it is cost-effective i.e. it does not lead to unnecessary costly remediation.[4]

Tier 1 investigation levels in the ASC NEPM may not be applicable for the site-specific conditions, for example, beyond a specified depth of soil or groundwater given that the hazard and associated risks may change considerably (For example, deep excavation would not be a cost-effective remediation strategy if the unacceptable risk for the remediation is direct ingestion of topsoil).

Treatment performance (and analytical achievability of some very low concentration-based criteria) may limit application of concentration-based criteria as the only basis for evaluating whether the remediation objectives have been achieved (see section 6.4). For example, for some sites targets for evaluating whether the remediation objectives have been achieved may be determined through considering and measuring mass flux and mass discharge (see CRC CARE Technical Report 37 *Flux-based Groundwater Assessment and Management* and the NRF post-remediation guidelines).

6.2 Baseline and background contaminants

Baseline conditions

Baseline conditions refer to the state of the soil and groundwater at the site of operation prior to commencement of activity. A baseline survey (an investigation to characterise the condition of a site prior to a particular activity) may be required or voluntarily undertaken so that contamination that occurs during the current site operation can be distinguished from historical impacts and if necessary, remediated.[5] For sites being decommissioned, there may be a licence or lease condition that the site is returned to its baseline state for site closure. If contamination is present and differs from the baseline condition, then a fit-for- purpose approach based on current/proposed land use may be applicable (depending on jurisdictional requirements) will affect remediation requirements.

6.3 Background contamination

Background contamination includes both natural background contaminant levels as well as ambient background contamination from diffuse sources caused by human activities (jurisdictional definitions vary). The ability to restrict the use of the site should

[3] The ASC NEPM, Schedule B1, s 2.1.2 states that *'the use of investigation and screening levels as default remediation criteria may result in unnecessary remediation and increased development costs, unnecessary disturbance to the site and local environment, and potential waste of valuable landfill space. Similarly, the inclusion of an investigation and screening level [in the ASC NEPM] should not be interpreted as condoning discharges of waste up to these level'.*

[4] According to NEPM, generic screening levels should also not be interpreted as condoning discharges of waste up to these level.

[5] Operators may wish to document the baseline state of the soil and groundwater at the site of operation prior to commencement of activity, or significant change in activity that may result in the potential release of contaminants into the environment. If this is relevant, it is important to ensure that all relevant stakeholders have inputs and necessary approvals are obtained. The EU Industrial Emissions Directive (2010/75/EU, 24 November 2010) provides useful information on this matter. See Guidance for Preparation of the baseline report on the state of soil and groundwater. The EU guidance is provided for information only.

background levels pose a risk to human health and the environment is an important consideration in determining appropriate land use. In some areas elevated levels of metals, for example arsenic in gold mining areas, might already exceed health criteria at levels that may pose an unacceptable health risk under certain land uses. It may be that the background contamination will restrict the range of environmental values that can be protected in the region; in such cases this restricted range of environmental values should be considered when determining the objectives for the local site.

If the background levels of a contaminant are higher than the applicable criteria to protect the identified environmental value established for the site, then it may be that managing the use of the site is the only practicable way forward.

In some cases, background levels may be used to determine numerical criteria (refer to ASC NEPM; ANZECC and ARMCANZ 2000). Some examples include:

- Sites where the natural background levels of some metals are higher than the HILs and/or EILs in the ASC NEPM (e.g. arsenic in gold mining areas);
- In the absence of sediment criteria, ANZECC and ARMCANZ (2000)[6] suggest deriving a value based on background concentration ('natural background', or for 'globally distributed contaminants like DDT', use 'background' concentration) multiplied by an appropriate factor (a factor of two is recommended, but up to a factor of three can be allowable in some highly disturbed ecosystems). Values derived using this method are considered low reliability. An alternative is to apply the water quality guideline values to sediment pore waters (ANZECC and ARCANZ 2000). The adoption of any approach would depend on the local conditions and the nature and behaviour of contaminants.

6.4 Performance-based metrics/monitoring

A multiple-lines-of-evidence approach may be used to determine the effectiveness of a remediation technique and may be incorporated in the remediation objectives. Remediation and/or management performance-based metrics can be designed to monitor performance as work progresses and utilised as technology end-points for specific remedial activities.

For example, concentration data alone are sometimes not sufficient to fully understand the behaviour or impact of a plume over time. Mass flux and mass discharge estimates are important tools to help practitioners and regulators characterise and remediate groundwater contamination. Their inclusion within remedial design and optimisation, when relevant, may ultimately result in time- and cost-efficient groundwater remediation programmes. For the application of flux-based see CRC CARE Technical Report 37 *Flux-based Groundwater Assessment and Management*. Further to the guidance, numerical site-specific metrics for mass flux and mass discharge may need to be developed on a site-specific basis.

[6] Refer also to Simpson, S.L.; Batley, G.E.; Chariton, A.A. 2013, Revision of the ANZECC/ARMCANZ Sediment Quality Guidelines, CSIRO.

Non-aqueous phase liquid (NAPL) is a good example where performance-based metrics may need to be developed because NAPL in the subsurface may provide an ongoing source of contamination of soil and groundwater. NAPLs can become very difficult to remove from some aquifers, hence ongoing NAPL remediation can become an issue of the technical and financial practicability of further recovery versus the magnitude of the environmental issues being addressed.

Some jurisdictions require NAPL to be removed as far as practicable; however, the general requirement will be that the residual contamination post-remediation does not pose unacceptable risks. As such, the extent to which NAPL can be remediated may depend on the practicable constraints of the adopted technology(ies) to extract it, and the risk posed by the residual NAPL, including use of management controls to reduce any residual risks.

Some examples of performance-based metrics used for light non-aqueous phase liquid (LNAPL) remediation are:

- LNAPL recovery analysis (e.g. decline curve analysis);
- Stabilisation of groundwater dissolved phase plume;
- Absence of vapour partitioning or migration risks;
- LNAPL saturation profile based on treatment; and
- LNAPL / vapour (and / or water) recovery ratio.

6.5 Pre-existing legal requirements

Depending on the site-specific circumstances, it may be important to consider what regulatory/legal agreements apply to the site. This may take the form of obligations to comply with regulatory notice/order requirements and/or licence/lease conditions.

Depending on the nature of the obligations, these agreements may affect or add to the remediation objectives.

7. Step 4 – Consider feasible remediation options to refine remediation objectives

The process of developing remediation objectives provides an opportunity to help determine the best risk management strategy. Depending on the complexity of site contamination and the environmental setting, additional information may become available during remediation and/or management design or during remediation works. Consequently, the CSM and remediation objectives (in the RAP and/or SMP) may also need to be refined, in consultation with regulators.

Reviewing remedial options helps refine remediation objectives in a two-way process to consider option limitations and impracticalities. During remediation planning, feasible remediation options can be reviewed and used as a basis to refine remediation objectives to consider limitations. Sometimes, complexities at the site require a staged approach to setting remediation objectives (See Section 7.2). Once a remediation option has been selected and remediation works commenced, issues in relation to the impracticability of clean-up, for example, may require that the remediation objectives are re-considered (See Section 7.5).

7.1 Remediation option screening and selection

The ASC NEPM provides a preferred hierarchy of options for site remediation and management (Principle 16). Within this hierarchy of options, feasible remediation and/or management strategies/options need to be underpinned by robust site data.

Determining clear and measurable objectives for remediation at the outset prior to options appraisal enables criteria to be set, against which the viability of specific treatment options can be assessed.

For more information on identifying and selecting remediation options, readers are directed to the NRF *Guideline on remediation options assessment*, and *ANZECC Guidelines for the assessment of on-site containment of contaminated soil* (ANZECC 1999). Furthermore, options hierarchy for soil and groundwater may be different:

Contaminated soil

It is preferred that contaminated soil be either treated or managed on-site to reduce the risk to an acceptable level, or the contaminated soil treated off-site and returned for re-use at the site after the risk has been reduced to acceptable levels (ASC NEPM).

“Cap and contain” on site or disposal of contaminated material to an approved waste disposal facility or landfill may be preferred if this can be undertaken in an environmentally acceptable manner and:

- Treatment of the contaminated material is shown or demonstrated to not be effective, practicable, or provides a less sustainable solution; or

- The risk of disturbance of the contaminant (e.g. environmental harm being caused by excavation) exceeds the risk of leaving the contaminated soil on- site.

It should be noted that there can be specific jurisdictional requirements regarding on- site containment of contaminated soil, and this may limit the options that are available (see also ANZECC 1999).

Contaminated groundwater

For contaminated groundwater, it is preferred that in-situ treatment or Monitored Natural Attenuation be adopted where this is feasible and can achieve an acceptable level of risk within an acceptable timeframe.

Where this is not acceptable or practicable, extraction of contaminated groundwater and disposal or treatment and disposal of the contaminated groundwater may be preferred where feasible and the timeframe is acceptable.

Where the risks and timeframe are such that a reduction in 'down-gradient' risk is required, options such as hydraulic containment, interception, or the application of a barrier system may be preferred.

Prevention of groundwater contamination in particular remains paramount given the inherent difficulties associated with remediation and management of groundwater contamination.

The ASC NEPM emphasises that the appropriateness of any particular option will vary depending on a range of local factors. Acceptance of any specific option or mix of options in any particular set of circumstances is a matter for the responsible jurisdiction.

If there are limited remediation options for a site, the objectives may need to be re-assessed for pragmatic alternatives. For example, one outcome, if acceptable to regulators, could be to propose a less sensitive on-site land use, provided that off-site receptors remain protected.

The extent of information used to establish remediation objectives (such as technical feasibility, social acceptability, cost, and timeframe) is site-dependent, and needs to be sufficient to enable the selection of remediation options.

Identifying viable remediation options is typically based on:

- Identification and preliminary screening/evaluation of remediation options (such as treatment, removal or containment of the contamination);
- Treatability studies, including bench tests and pilot trials, to evaluate feasibility and potential effectiveness of preferred remediation options;
- Consideration of institutional controls or restrictions on land or groundwater use (as determined by regulators) that will allow higher concentrations of the contaminants to remain;

- Consideration of remediation options (including soil amendments) that will reduce risk to acceptable levels for a particular use by reducing bioavailability or bioaccessibility (hence allowing higher concentrations of contaminants to remain on-site);
- Requirements for design and expected cost of the selected remediation option. It is noted that this may require additional information regarding extent, volume and nature of the contamination, and that further investigation and treatability studies may need to occur before a remediation method can be fully designed, costed and implemented;
- Consideration to secondary effects of remediation works, including their risk and sustainability.

The RAP (or SMP) may include strategies to minimise secondary impacts from remediation works such as:

- Risk relating to transport of contaminated material for disposal;
- Minimising the usage of resources including landfill space;
- Occupational health and safety;
- Community concerns, including acceptability of technologies;
- Reduction of greenhouse emissions;
- Release of emissions such as dust and odour; and
- Optimising the economic value of the contaminated/remediated land.

7.2 Iterative remediation objectives

It is not always practical or cost-effective to obtain all the necessary information to establish final remediation objectives and end-points for a remedial option prior to commencing work.

The development of remediation objectives should consider the implications of uncertainties and information gaps from the outset to the extent practicable. When new information becomes available because of assessment, monitoring or remediation activities which lead to significant changes to the CSM, remediation objectives or performance criteria may need to be updated. Alternatively, it may be more realistic to acknowledge the uncertainty in the RAP upfront and make allowance in the remediation objectives to undertake additional / reactive remediation options if required, as further data is obtained. For example, a periodic RAP update may be included as a future milestone in the RAP schedule, once gaps/uncertainties are investigated further and efficacy of remediation options can be critically appraised.

It is nonetheless important to develop preliminary remediation objectives prior to commencement of works. If the remediation objectives are preliminary and liable to change because of the findings during the remediation work, then it is important that their preliminary nature be recognised at the outset and agreed with the regulator and stakeholders

For some complex sites, consultation with the relevant regulator and/or auditor, and a re- evaluation of the potential future land use(s) for the site (and possibly environmental values that may be protected) may be needed. For example, a desired initial set of objectives might be to make the site suitable for residential use without any restriction on activities that can be carried out at the site. However, if it is not practicable to achieve this condition, a more restricted objective might be to remediate the site so that it is suitable for a less sensitive use (such as industrial or commercial), together with controls such as the requirement for a barrier layer to protect against vapour intrusion.

7.3 Technology fails to achieve the objectives

In situations where there is uncertainty that the remediation objectives will be met because the remediation criteria (and post-remediation targets) need to be re-considered, e.g. based on the proven practicability of the remediation technology(ies) for the site-specific conditions, establishing final remediation objectives may be recognised as a staged or iterative process in the RAP. A contingency plan may need to be incorporated into the RAP to address the scenario that the adopted remediation option is not as effective as expected and performance monitoring indicates that it will not achieve the remediation objectives and end-points in the expected timeframe.

7.4 Acceptable timeframes

The timeframe to achieve the remediation objectives may be one of the constraints influencing the selection of remediation options. In some cases, an urgent response may be needed firstly to mitigate imminent risks, while longer term remediation planning is undertaken simultaneously.

The remediation timeframes must be commensurate with mitigating the unacceptable risks posed by the contamination to receptors, and the sensitivity of the receiving environment.

The acceptability of the remediation timeframe may also be influenced by the needs of the affected stakeholders and the regulator.

Depending on the site-specific conditions, the following factors may be relevant when developing remediation timeframes:

- Assessment outcomes;
- Remediation strategy;
- Design and capabilities of the remediation technology;
- Reliability of exposure controls;
- Availability of treatment and/or disposal options;
- Social, economic and/or environmental opportunities arising from remediation works;
- Whether the contamination has migrated off-site;
- Community preferences (if appropriate); and

- Financial resources of the person who has liability for site contamination.

In determining appropriate timeframes for remediation of the site contamination, the following issues need to be considered:

- The adequacy of the interim measures to protect receptors until protection of the environmental values is achieved;
- Whether remediation will be achieved before the site contamination migrates off-site and/or affects the existing environmental values; and
- Stakeholder (including regulator) views on the timing and extent of remediation (particularly if the plume is off-site).

Long timeframes may be acceptable when there are adequate reliable controls to protect human health and the environment, if a monitoring program is implemented and, depending on the nature of the contaminant, when contamination has not migrated off-site. For groundwater, longer timeframes may only be appropriate if the plume has been appropriately contained.

The most effective and timely remediation may be provided by a combination of remediation technologies, which is discussed in the NRF *Guideline for conducting a remediation options assessment.*

Community engagement and acceptance of any management approaches may be critical to ensure understanding and acceptance of the proposed actions within the expected timeframes. This may also assist in obtaining regulatory approval.

8. Step 5 – Post-remediation considerations

Well considered remediation objectives ensure that there is a clear pathway towards site closure. The development of remediation objectives should consider the implications of uncertainties and information gaps from the outset to the extent practicable. When new information becomes available because of assessment, monitoring or remediation activities which lead to significant changes to the CSM, remediation objectives or performance criteria may need to be updated. Alternatively, it may be more realistic to acknowledge the uncertainty in the RAP upfront and make allowance in the remediation objectives to undertake additional or reactive remediation options if required, as further data is obtained. For example, a periodic RAP update may be included as a future milestone in the RAP schedule, once gaps/uncertainties are investigated further and efficacy of remediation options can be critically appraised.

When a site needs to be closed out, all important information and date should be provided to demonstrate how remediation objectives have been met i.e. any unacceptable risks have been managed (see NRF *Guideline on validation and closure*). The data and information that are provided to regulators would assist in decision-making about whether a site can be closed, and if additional and/or long-term control measures are required. Readers are directed to the NRF *Guideline on implementing long-term monitoring* for more information.

Longer term issues which may be considered during the remediation objective development phase include:

- Increased sensitivity of land use (due to change in legislation and/or rezoning or redevelopment);
- Nature and concentration of any residual contamination; and
- Failure of remediation or management in the longer term.

Where the restoration of environmental values, or the achievement of designated environmental values, is not feasible, then institutional controls may be required to ensure that the site is not used or developed in the future for uses for which it is not suitable.

The ASC NEPM requires that authorities in jurisdictions which consent to developments, or changes in land use, ensure a site is suitable for its intended use.

If residual contamination (including in groundwater) is present, then it may restrict the use of a site (check with jurisdictions). This information needs to be recorded and ideally made publicly available and linked to the planning system as part of the ongoing management of site contamination to ensure that:

- The land use is appropriately restricted to protect environmental values identified for the site;
- Groundwater use is appropriately managed/restricted, both on-site and off-site; and

- Restrictions may need to be linked to the title of the land so that any future redevelopment to a more sensitive use requires a new site-specific risk assessment and remediation to ensure that any environmental values identified for the site can be realised.

When remediation objectives have been achieved and no further remediation is required at a site, regulators would consider whether a site can be closed based on the data and information that is provided.

Auditors provide an independent review of the investigations, assessments, monitoring and remediation works.

Depending on the situation (and regulatory requirements), remediation and/or management techniques may sometimes be used to reduce the risks to receptors without necessarily reducing the contamination load at the site (e.g. for contaminants for which alternate remediation technologies/techniques are not readily available in Australia). Such approaches may not result in site closure and instead require long-term monitoring (e.g. periodic re-assessments) and/or institutional controls.

Where residual risks are considered likely to remain after remediation, the remediation objectives will need to address long term monitoring or management of the site. When remediation objectives have been achieved to the extent practicable, and further active remediation will not result in any material reduction in risk to receptors, long term monitoring and/or institutional controls may be required if residual risks require management to ensure that these are kept within acceptable bounds. For example, risk management strategies such as on-site containment require long term monitoring (and maintenance) to ensure their continued effectiveness. Readers are directed to the NRF *Guideline on implementing long-term monitoring* for detailed information.

In other cases, where residual contamination remains on-site, it is important that remediation objectives include the consideration of measures (e.g. legal / engineering) to ensure that the relevant site (and the surrounding environment) is maintained appropriately in the future. Readers are directed to the NRF *Guideline on implementing institutional controls* for detailed information.

9. Revision of remediation objectives due to unforeseen circumstances

Legislative requirements may change during the lifetime of a remediation project, or there may be relevant scientific advances or technological developments which can result in improved outcomes which can be reasonably expected to be incorporated into the remediation process. This may lead to the revision or further refinement of remediation objectives.

New information may become available during iterative site investigation/assessment phases, or over the course of a remediation project, which will trigger review and potentially revision of remediation objectives (including endpoints). For example:

- Changes to site use or zoning;
- Changes to policy/regulation;
- Evolving groundwater plume;
- Changes to toxicity reference value; or
- Unexpected finds during the implementation of remediation works e.g. unexpected discovery of a geological feature during excavation may mean that proposing a different purpose for the site would prove more cost-effective than completing the remediation as planned.

Appendix A – Principles underlying the NRF

The following sections outline the principles underlying the NRF. Readers are directed to the NRF *Introduction to the National Remediation Framework* for more detail on the philosophy underlying these principles.

Precautionary Principle

Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation or human exposure. In addition, often there can be considerable uncertainty as to the requirements relating to remediation, including uncertainty relating to the existence of contamination, the potential for adverse effects, and the effectiveness of remediation and management methods.

In the context of developing remediation objectives, the application of the precautionary principal in remediation and management decisions should be guided by:

- Careful evaluation to avoid, wherever possible, serious or irreversible damage to the environment; and
- An assessment of uncertainty and the risk-weighted consequences of various options, considering any likelihood that adverse effects will occur, and the likely magnitude of these effects.

Prevention

Contamination, or further contamination, of a site should be prevented. Action should be taken to minimise the creation of additional site contamination and to prevent the further contamination of already contaminated sites.

Appropriate precautionary measures should be taken when decommissioning industrial premises and developing sites where potentially contaminating activities have taken place. Precautionary measures should also be taken throughout investigation and remediation activities to prevent the spread of contamination.

Risk management during remediation and site management

Risk management refers to a coordinated set of activities and methods that are used to direct and to control risks with the likelihood that any specified objectives can be achieved.

In AS/NZS ISO 31000: 2009, the term *risk management* also refers to the architecture that is used to manage risk. This architecture includes risk management principles, a risk management framework, and a risk management process.

In the context of risk assessment, the ASC NEPM states that risk management is a decision-making process involving the consideration of political, social, economic and technical factors with relevant risk assessment information relating to a hazard to determine an appropriate course of action.

Options hierarchy

Regarding contaminated soil:

- It is preferred that contaminated soil be either treated or managed on-site to reduce the risk to an acceptable level, or the contaminated soil treated off-site and returned for re-use at the site after the risk has been reduced to acceptable levels (ASC NEPM);
- *"Cap and contain"* on site or disposal of contaminated material to an approved waste disposal facility or landfill may be preferred if this can be undertaken in an environmentally acceptable manner;
- Treatment of the contaminated material is shown or demonstrated to not be effective, practicable, or provides a less sustainable solution; or
- The risk of disturbance of the contaminant (e.g. environmental harm being caused by excavation) exceeds the risk of leaving the contaminated soil on-site.

It should be noted that there can be specific jurisdictional requirements regarding on-site containment of contaminated soil, and this may limit the options that are available. Readers are directed to ANZECC (1999) for more detail.

Regarding contaminated groundwater

- For contaminated groundwater, it is preferred that in-situ treatment or Monitored Natural Attenuation be adopted where this is feasible and can achieve an acceptable level of risk within an acceptable timeframe;
- Where this is not acceptable or practicable, extraction of contaminated groundwater and disposal or treatment and disposal of the contaminated groundwater may be preferred where feasible and the timeframe is acceptable;
- Where the risks and timeframe are such that a reduction in 'down-gradient' risk is required, options such as hydraulic containment, interception, or the application of a barrier system may be preferred; and
- Prevention of groundwater contamination remains paramount given the inherent difficulties associated with remediation and management of groundwater contamination.

The ASC NEPM emphasises that the appropriateness of any option will vary depending on a range of local factors. Acceptance of any specific option or mix of options in any set of circumstances is a matter for the responsible jurisdiction

Sustainability

The ESDSC (1992) recognises the following definition for ecologically sustainable development (ESD) in Australia:

'using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased'.

Thus, ESD is development which aims to meet the needs of Australians today, while conserving the ecosystems for the benefit of future generations. This is similar to the definition of sustainable development in WCED (1990):

'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'

In the context of remediation and management of contaminated sites, under the NRF, 'sustainability' means:

'an integrated assessment of the environmental, economic, and social impacts of remediation activities which meets the needs of the present without compromising the ability of future generations to meet their own needs'.

Under the NRF, sustainability includes:

- Ensuring that decision-making processes effectively integrate both long and short- term economic, environmental, social and inter-generational and intra-generational equity considerations;
- Planning for the future through long term contaminated sites management strategies and policies;
- Recognising and considering the global dimension of environmental impacts of actions and policies;
- Acknowledging the need to develop a strong, growing and diversified economy which can enhance the capacity for environmental protection;
- Acknowledging the need to maintain and enhance international competitiveness in an environmentally sound manner;
- Adopting cost-effective and flexible policy instruments such as improved valuation, pricing and incentive mechanisms; and
- Ensuring that decisions and actions provide for broad community involvement on issues which affect the community.

National and international obligations

The landscape of environmental obligations continues to evolve at the national and international level, and practitioners should ensure that the most up-to-date approaches are adopted, in consultation with regulators.

Additional principles relevant to site contamination identified among States and Territories may include:

- Conservation of biological diversity and ecological integrity;

- Improved valuation, pricing and incentive mechanisms;
- Shared responsibility;
- Product stewardship;
- Waste hierarchy;
- Integrated environmental management;
- Enforcement;
- Accountability;
- Inter-generational equity;
- Polluter pays;
- Full lifecycle costs;
- Waste minimisation; and
- General environmental duty (i.e. a person must not carry out any activity that causes or is likely to cause environmental harm, unless measures to prevent or minimise the harm have been taken).

Appendix B – Remediation objectives in jurisdictions

Table 2: Remediation objectives in jurisdictions. Refer to updated jurisdictional information.

Jurisdiction	Requirement
Queensland (Qld)	A RAP is not a contaminated land investigation document (CLID) under Qld legislation. The remediation objectives are to be outlined in the validation report or may a RAP may be attached to the validation report. The validation report must also describe how the validation criteria were developed, and explain why the criteria were considered appropriate for the site's particular circumstances. The criteria must be consistent with the contaminated land NEPM, the EPP (Water), and any other applicable standards and technical guidance. The validation report must describe the contamination levels recorded on the land before and after the work was carried out; and compare the contamination levels to the remediation objectives and validation criteria that were used to evaluate the effectiveness of the remediation. The report must describe how the residual contamination levels were validated, and demonstrate that the methods were appropriate and statistically robust. Also, the validation report must assess any residual risks to human health and all environmental values as a result of the remediated state of the land (DES 2018, Content Requirements for Contaminated Land Investigation Documents, Certifications and Audit Reports). Where remediation objectives constrain uses or are associated with management measures, continued listing on a Contaminated Land Register or Environmental Management Register[7] and a SMP applies[8].

7 Environmental Management Register (EMR) is a land-use planning and management register. The Contaminated Land Register (CLR) is a register of risk sites (proven to be cause, or may cause, serious environmental harm. The EMR and CLR are public registers which list contaminated, or potentially contaminated land. Other jurisdictions will have similar registers.

8 Refer to https://www.qld.gov.au/environment/pollution/management/contaminated-land/

Jurisdiction	Requirement
New South Wales (NSW)	The *New South Wales SEPP 55* (2014) states that the remediation objectives are to be outlined in the RAP and should reduce risks to acceptable levels appropriate for the future use of the site, whilst considering possible human health and environmental impacts. The *Guidelines for Consultants Reporting on Contaminated Sites* (NSW OEH 2011), gives an overview of what should be addressed in a Detailed Site Investigation and a RAP and provides a checklist for what headings to be included and thus the subjects that should be covered. This document indicates that site-specific remediation criteria, or 'site specific clean-up levels' can be developed and presented within either of these documents. The *Guidelines for the NSW Site Auditor Scheme* (NSW EPA 2006) also provides advice on what is required for derivation on remediation objectives.
South Australia (SA)	The *Guidelines for the Assessment and Remediation of Site Contamination* (SA EPA 2018) states remediation objectives (further to remediation goals) 'provide the foundation of what remediation will be necessary, including the likelihood for long-term management measures and stakeholder involvement and expectations'. The document provides a list of factors that practitioners should consider in this process, such as benefit of remediation options, technical success, logistics, financial and capital considerations, social impacts and risk perceptions, and the risk that the site poses to human health and the environment (SA EPA 2018).
Tasmania	*The State Policy on Water Quality Management* (SPWQM 1997) requires remediation or management to be carried out if contamination is found to pose an actual or potential risk to human health and/or the environment, either on- or off-site. This may include where soil contamination poses an ongoing source for migration to groundwater. Under a Notice (see SPWQM 1997), the remediation objectives are to be provided in a Goals Paper which must contain a conceptual site model, receptors, specific remediation goals in the form of target values to protect the identified receptors and details regarding how the goals were derived, what the goals will achieve and graphical representation of the areas to which the goals apply.
Northern Territory (NT)	The *Northern Territory Contaminated Land Guideline* (NT EPA 2013) requires the remediation objectives to be outlined in the RAP, and to ensure that the site is suitable for the proposed use and will pose no unacceptable risk to human health or the environment.

Jurisdiction	Requirement
Australia Capital Territory (ACT)	The *Contaminated Sites Environment Protection Policy* (ACT EPA 2009) states remediation objectives are to be developed on a site-specific basis and are intended to utilise best practice methodology and remediation techniques, to remediate land which presents or is likely to present a significant risk of harm to human health or the environment. The remediation objectives are to be outlined in the RAP. Economic, social or environmental factors all play a role in deciding which approach is most suited to the site. For example, there would be no benefit in remediating a site in an industrial area to a level suitable for residential housing under the 'suitable for any use' approach, where the 'fit for-use' approach would suffice.
Victoria (Vic)	The document *The cleanup and management of polluted groundwater* (EPA Publication 840.2) (Vic EPA 2016) outlines EPA's expectations regarding clean-up or remediation objectives for groundwater and states that: *"The goal for any clean-up of polluted groundwater is to restore the protection of beneficial uses of the groundwater both on-site and offsite. Restoration of the beneficial uses of groundwater is achieved when the groundwater quality objectives of the State Environment Protection Policy (Groundwaters of Victoria) [Groundwater SEPP] are met.* *Where clean-up to meet Groundwater SEPP objectives is not practicable (Section 6.2 in these guidelines), alternate clean-up objectives should be derived that reflect clean-up to the extent practicable; considering the extent and degree of pollution, likelihood of detriment to beneficial uses and the efficiency of the selected clean-up technology."* N.B. Where EPA Victoria becomes aware of groundwater pollution, it may require clean-up and/or management of polluted groundwater (consistent with EPA Publication 840.2) by Notice under Sections 31A/B and 62A of the *Environment Protection Act 1970* and in accordance with the Groundwater SEPP. Where polluted groundwater is identified through a statutory environmental audit, EPA may use its statutory tools to give effect to the conditions of any Statement of Environmental Audit related to groundwater pollution, or to otherwise require clean-up.

Jurisdiction	**Requirement**
Western Australia (WA)	WA requirements are detailed in the guidance document *Assessment and Management of Contaminated Sites (*WA DER 2014). If the risk assessment process identifies unacceptable risks to human health, the environment and/or environmental values, some form of remediation (clean-up and/or management) is required to mitigate those risks. The remediation objectives are to be included in the RAP (and SMP as relevant), and must ensure once fulfilled, that the site is suitable for the current/ proposed land use and poses no unacceptable risk to human health, the environment and environmental values. This requirement applies to both on-site and off-site receptors.
Airports - Commonwealth	The *Airports (Environmental Protection) Regulations 1997* (AEPR) provides for the development of a RAP which is to include remediation objectives.

Appendix C – Jurisdictional requirements: Case studies

In this section, jurisdictional case studies are provided to assist practitioners in the application of this guideline in different jurisdictions, given some important differences in approaches to contaminated site decision-making.

A hypothetical petrol station scenario presented in Table 3 was provided to jurisdictions to elicit their responses to demonstrate how each state would go about remediating/managing the site (with consideration of any off-site issue). The jurisdiction-specific responses are provided for illustration purposes only. Always refer to the most updated jurisdictional requirements by checking the EPA website and consult with jurisdictions directly for any clarification.

Table 3: Hypothetical service station scenario

Case study: **Contamination from a service station activity next to residential property**	
Summary of issues	• Significant groundwater contamination discovered by/reported to the environmental regulator and a requirement to investigate the cause was issued. • The proponent was asked to disclose information and a notice was issued (does not apply to all jurisdictions) to investigate the source, cause and extent of hydrocarbon contamination and risk to public safety and the environment. • Cause was thought to be leaking underground fuel lines from the underground storage tank. • Recent groundwater monitoring results indicate contamination has worsened and further spread into the neighbouring residential property. • Additional investigations are necessary to check for possible additional causes and establish how far the now enlarged groundwater pollutant plume has travelled and its impacts.
Potential impacts / risks	The environmental harm caused or threatened primarily relates to • (i) risks to environmental values of surface waters and ground waters including public amenity; and • (ii) public safety via risk of explosive atmospheres forming from migration of hydrocarbon vapours into service trenches and other confined spaces on-site and nearby premises and services e.g. stormwater drainage and telecommunications.
Customer actions	Following an initial period where the operator of the service station was reluctant to admit the contamination problem which triggered enforcement action, the operator has undertaken and commissioned significant studies.
Task	To outline the general approach to developing site-specific remediation objectives from the regulators' perspective. **Some questions to consider…** • *What are the relevant references in legislation and policy?* • *How would the site remediation objectives be established (from both process and mathematical perspectives)?* • *What are the likely remediation objectives (e.g. qualitative and/or quantitative), or the process for establishing these?*

Typical process in New South Wales

The sections below demonstrate the typical process in New South Wales in relation to the example site. This process assumes that the site continues to be used as a service station and is not proposed for redevelopment.

Section 60 Notification of Contamination under the CLM Act

Under section 60 of the Contaminated Land Management Act 1997 (CLM Act) there is a statutory obligation to report the contamination at the site to the NSW Environment Protection Authority (EPA) as the contamination satisfies the triggers for reporting.

Section 12 Assessment under the CLM Act

Once notified, the EPA assesses whether the contamination warrants regulation under the CLM Act. The EPA cannot declare a site to be significantly contaminated land unless it has taken into account guidelines endorsed under s105 of the CLM Act whenever they are relevant and considered the matters listed under section 12 of the CLM Act.

The EPA's assessment of the contamination is a key aspect in developing regulatory requirements and hence ultimately remediation objectives. Under section 12 of the CLM Act, the EPA needs to consider the following matters:

- Whether the substances have already caused harm;
- The nature of the substances (i.e., the toxicity, persistence, bioaccumulative properties of the substances, and whether they are present in large quantities or in combinations);
- Whether there are exposure pathways available to the substances;
- Whether the uses to which the land and land adjoining it are currently being put are such as to increase the risk of harm from the substances;
- Whether the substances have migrated or are likely to migrate from the land; and
- Whether there are reasonably foreseeable future circumstances of occupation/use, consistent with the current or approved use of the land, that could cause possible harm to come into existence.

In this example, the plume has impacted groundwater, is spreading off-site and has "worsened". The primary source (e.g., leaking UPSS) may not have been addressed yet, and secondary sources are likely to exist.

The contamination consists of petrol/fuel, it will therefore have toxic substances (e.g., benzene as a confirmed human carcinogen) and the substances occur in combination. As the domestic use of groundwater in New South Wales does not require approval (i.e., it is a basic landholder use right), the EPA has to consider risks from the current or potential future use of groundwater.

Use of groundwater for domestic purposes is only one of the exposure pathways available and the EPA has to consider whether other exposure pathways are available to the substances. This is generally done on the basis of a conceptual site model (CSM) that determines any active source-pathway-receptor linkages (an example of this is provided in Table 4).

Based on the available information, the EPA's assessment under s12 of the CLM Act may find that:

- The primary source (i.e., the UPSS) may not have been identified/addressed yet;
- Secondary sources are present;
- Groundwater contamination spreads off-site;
- The off-site contamination may pose risk to adjacent residents (e.g., via vapour intrusion or the current or potential future use of groundwater);
- The contamination may also pose a risk to workers carrying out excavations or maintaining underground services; and
- The contamination may discharge into nearby waterways and affect ecological receptors

On the basis of the above findings, the EPA would conclude that the contamination is significant enough to warrant regulation under the CLM Act and would declare the land (under section 11 of the CLM Act) to be significantly contaminated land.

Section 11 Declaring land to be significantly contaminated land

The declaration is made by notice published in the Gazette and posted on the public record at http://www.epa.nsw.gov.au/clm/publiclist.htm.

Among other things, the notice must:

- Describe with reasonable particularity the land;
- Specify the substances that contaminate the land; and
- State the harm that the EPA has reason to believe has been, or may be, caused

The EPA would use the findings of its assessment under section 12 of the CLM Act to state the harm that the EPA has reason to believe has been, or may be, caused by the substances.

The outcome of the EPA's assessment under section 12 of the CLM Act would be the main driver for establishing remediation objectives. These objectives would form the objectives outlined in a management order or an approved voluntary management proposal (VMP), which is further discussed below.

In the example provided a number of issues were identified during the section 12 assessment of contamination. These are presented in Table 1, below with the corresponding objectives that would be specified in a management order or VMP. These comprise both investigation and risk assessment objectives as well as the remediation objectives.

Sections 14 and 17 Regulation of the Site via Management Order or Voluntary Management Proposal

As mentioned above, after a site has been deemed contaminated enough to warrant regulation under the CLM Act, and the EPA has declared the site as significantly contaminated land, and determined its requirements, the EPA may issue a management order in writing to the "appropriate person" as defined in the CLM Act (in

this example, the operator or site owner) under section 14 of the CLM Act or approve a voluntary management proposal under section 17 of the CLM Act. The objectives would be as outlined in Table 4 and the EPA would ensure that there are key milestones for the investigation, remediation, and other actions, as well as clear performance criteria and timelines for the works and submission of reports. Once the objectives for investigation, remediation and/or management have been addressed and the EPA believes that the contamination no longer warrants regulation under the CLM Act, the EPA would lift its declaration of the site.

Table 4: NSW - How the Section 12 Assessment relates to the remediation objectives

Matters identified during the Section 12 Assessment	Corresponding risk assessment and investigation o bjectives	Corresponding remediation or management objectives
The primary source (i.e., the UPSS) may not have been stopped;	Cease operation on-site and undertake line and tank integrity testing.	If a leak or fault is identified, ensure that it is either rectified or the broken or leaking tank or line is decommissioned.
There is a secondary source (soil and groundwater)	Investigate the potential vapour risks to adjacent residents by undertaking vapour monitoring and comparing results with the relevant established criteria and/or establishing site specific criteria in accordance with the ASC NEPM 1999 as modified in 2013. If a risk is identified remediation/management will be required. Identify potential source-pathway-receptor linkages (pollutant linkages). Each of these will require a quantitative assessment of risks comparing soil and groundwater concentrations against established criteria and/or establishing site specific criteria in accordance with the ASC NEPM 1999 as modified in 2013. If a risk is identified, remediation or management will be required.	Remediate and manage soil and groundwater to mitigate any risks identified. This may include establishing appropriate concentration levels. The lowest of these should be used as the end-point for remediation in order remain protective of all identified receptors. If should be noted that full remediation may not be possible as, for instance, some residual LNAPL may be entrained in the subsurface. In this case, risks need be managed. This may include cleaning up to extent practicable. Remaining contamination must be shown not to present a risk. The principles of such risk management are covered in *the Guidelines for the Assessment and Management of Groundwater Contamination*, March 2007.
Groundwater contamination spreads off-site		
The off-site contamination may pose a risk if groundwater were to be extracted and used		
The off-site contamination may pose a vapour intrusion risk to adjacent residents		
The contamination may discharge into nearby waterways and affect ecological receptors		

Matters identified during the Section 12 Assessment	Corresponding risk assessment and investigation o bjectives	Corresponding remediation or management objectives
The contamination may also pose a risk to workers carrying out excavations or maintaining underground services,	Compare the concentrations on-site with the relevant established criteria. If a risk is identified, remediation or management will be required.	If a risk is identified, this may have to be managed using health and safety measures which will be required to be included in an ongoing Environmental Management Plan (or Site Management Plan). Impact near services are also required to be notified to the Dial Before You Dig service (DBYB) which can point workers to information about the nature of the contamination and appropriate work safety measures required to mitigate risks.

Typical process in Tasmania

Some key issues:

- A private abstraction bore on the residential property requires assessment/requirement to cease use;
- Removal of LNAPL would be required especially given this site has an expanding plume and sensitive receptors. Also there is a suggestion of LNAPL presence on the residential land i.e. BTEX at 50 mg/L thus exceeding the >20mg/L criteria from CRC Technical Report 23 that indicates LNAPL presence;
- The summary of "potential impacts/risks" doesn't include the risk to health in the residential property through vapour inhalation. There is a soil vapour well next to the house but results aren't provided. Given explosive risks are stated as a potential concern we would be seeking more information as to the risk posed to occupants in the house;
- The site remediation objectives are established in the Remediation Goals Paper this Division would require from the polluter. The paper would need to specify the environmental values to be applied in each zone e.g. commercial use, residential use and the groundwater protection goals. This would lead to the development of site specific clean-up criteria for each zone. With regards to human health risk the HSLs are often referred to by consultants as the remediation goal or they calculate the goal based on-site specific conditions using the Excel toolbox model. The environmental value to be applied to groundwater is based on the State Water Quality Policy and consideration must be given to the potential use of the water e.g. with reference to salinity levels and flow rates and also to any receiving environments; and
- The Remediation Action Plan would follow the above document and is outlined below in the Notice conditions.

Example of regulatory response:

Issuance of a Remediation Notice (RN).

- A RN is issued under Section 74C of Environmental Management and Pollution Control Act 1994 (EMPCA) to the polluter or if the polluter cannot be found another party as defined under 74F of EMPCA; and
- A Site Management Notice may also be issued on the landowner of the residential property to prevent use of the private abstraction bore; this would depend on assessment of risk regarding the likelihood of this bore becoming contaminated.

Specific requirements related to the hypothetical scenario:

- Given the source of contamination has not been definitively determined, conditions to test tanks and define "extent" (as contamination levels have increased) would be included;
- A condition requiring a survey of vapour accumulation in service trenches etc would be required; requirement on-site owner to contact Dial Before You Dig

with information to be provided to contractors in area; and Council to be informed; and

- A requirement to assess the current risk to workers in enclosed spaces on the service station would also be included e.g. conduct indoor vapour testing but would be dependent on the building structure.

The RN could contain the following conditions: LNAPL recovery

- Groundwater remediation must commence within 4 weeks of the date of issue of this notice through the recovery of Light Non-Aqueous Phase Liquid (LNAPL);
- A statement outlining the steps taken to remove and monitor LNAPL must be provided to the Director within 6 weeks of the date of issue of this notice, or by a date otherwise approved, in writing, by the Director;
- Cessation of LNAPL recovery must be approved, in writing, by the Director. Approval will be provided on submission of a report demonstrating that LNAPL has been removed to the extent practicable.

Remediation Goals Paper

A remediation goals paper (RGP) must be submitted to the Director for approval within 4 months of the date of issue of this notice, or by a date otherwise approved, in writing, by the Director.

The RGP must contain the following information, unless otherwise approved in writing by the Director:

- A conceptual site model showing source-pathway-receptor linkages taking into consideration the protection of human health and ecosystems from unacceptable impacts;
- A description of the receptors that are potentially adversely impacted by the release of pollutants;
- Specific remediation goals in the form of target values to protect the identified receptors. More than one remediation goal may need to be proposed for a receptor to provide multiple lines of evidence that the receptor will be protected;
- Details must be included to demonstrate:
    - How the remediation goals were derived;
    - What the remediation goals will achieve (i.e. which receptor(s) will be protected under which scenario(s) for a particular land use);
    - The area to which each remediation goal will apply (in the form of a map); and
    - The timeframes within which the remediation goals will be achieved.

The RGP must be amended in accordance with any written requirements of the Director and then re-submitted for approval within 4 weeks of the Director's request to do so.

Remediation Action Plan

A Remediation Action Plan (RAP) must be submitted to the Director within 4 weeks of the Director providing final written approval of the RGP, or by a date otherwise approved, in writing, by the Director.

The RAP must include, but not be limited to:

- Identification of persons likely to be affected by the remediation works and a process for ensuring they are engaged during the implementation of the RAP;
- An assessment of remediation options which analyses remediation technologies and techniques for each area of contamination and includes a recommendation as to the preferred option;
- Details of the monitoring and validation sampling that will be undertaken to measure the effectiveness of the remediation;
- Details of the standards and guidelines that the remediation, validation sampling and monitoring will follow;
- Details on how any residual pollution will be managed; and
- A schedule for the commencement and completion of all remediation works and implementation of post-remediation management works.

Commencement of Remediation Works

Remediation works must commence within 4 weeks of the RAP being submitted to the Director, or by a date otherwise approved, in writing, by the Director.

Remediation Progress Report

A progress report must be submitted to the Director, within 3 weeks of the Director's request to do so. The progress report must include, but not be limited to, provision and interpretation of monitoring data including soil, groundwater and/or vapour contaminant levels, and a discussion on progress of remediation in relation to achieving the remediation goal(s) as defined in the approved RGP and must contain any other information as specified in writing by the Director.

Final Site Remediation and Validation Report

A Final Site Remediation and Validation Report must be submitted to the Director within 24 months of the date of issue of this notice, or by a date otherwise approved, in writing, by the Director. This report must demonstrate that:

- All sources of pollution have been identified and emission of further pollutant(s) prevented; and
- Remediation has been completed by demonstrating that:
    - The remediation goals in the RGP have been achieved; or
    - Remnant contamination can be appropriately managed so there is no unacceptable risk to ecosystems or human health for current use(s) of the area of land and adjacent areas of land; and
- That the degree and extent of the remnant pollution is decreasing and is likely to continue to do so; and

- There has been no adverse impact to the groundwater from the use of direct chemical injection (where applicable); and
- Environmental nuisance associated with the pollution is not occurring nor is likely to occur.

The Addition of Chemicals or Agents into an Aquifer:

Where remediation will result in the addition of chemicals or agents into an aquifer:

- Chemicals or agents must not be added to the aquifer without prior written approval from the Director; and
- Any request for the Director's approval must include, but not be limited to, the following information:
  - Geology - local and regional.
  - Nature of the aquifer(s) - local and regional - including, but not limited to, direction of groundwater flow, depth to water table or segment, yield, salinity and pH.
  - Nature, extent and magnitude of the pollution.
  - Nature and proximity of current sensitive receptors (surface water bodies, extractive groundwater use, vapour receptors).
  - Details of current and proposed monitoring wells with consideration of cross contamination of aquifers and associated impacts.
  - The sources of any water to be used (i.e. tap water or extracted groundwater or other).
  - Nature of the remediation chemicals or agents including but not limited to details of the ecotox work done, degradation rates and by-products.
  - The volumes, concentration and/or mass load of reagents of chemical or agents (i.e. the wet volume (not dry mass)) to be injected.
  - Expected breakdown products of the existing pollutants and remediation chemicals or agents.
  - The sequencing of remediation methods.
  - Period of time over which remediation using the addition of chemicals or agents is to occur.
  - Period of time over which monitoring is to occur.
  - Contingency plans - including monitoring in sentinel bores, contingency triggers and actions and reporting requirements.
  - Consideration of whether use of this technology may inhibit further clean-up (e.g. may cause aquifer clogging or reduce biological activity).
  - A statement addressing the potential for plume displacement.

Requirements of Actions and Reporting

- All actions and reporting required under this notice must be undertaken in accordance with the NEPM; and

- All reports submitted to satisfy this notice must be written by or reviewed by a person who is either certified under the Site Contamination Practitioners Australia (SCP Australia) Scheme, or is an auditor accredited under the following legislation:
  - Contaminated Land Management Act 1997 (New South Wales)
  - Environment Protection Act 1993 (South Australia)
  - Environment Protection Act 1970 (Victoria)
  - Contaminated Sites Act 2003 (Western Australia)
  - Environmental Protection Act 1994 (Queensland).

Typical process in Victoria

An example of a possible escalation of the scenario:

EPA receives odour pollution reports from neighbouring residents but is unable to confirm the source of the odours in its investigations. A few months later, a report is received from the Water Authority that strong petrol odours have been detected in nearby sewage treatment plant.

EPA investigates and confirms odour at the plant, then traces the odour back to a sewerage line adjacent to service station. EPA issues verbal directions to take immediate action to investigate the source of pollution. WorkSafe and the Metropolitan Fire Brigade assist in responding and venting of sewer, due to potentially explosive vapour levels in the sewerage line.

A Remedial Notice is issued to require clean-up of pollution. EPA conducts frequent inspections of premises during clean-up activities, which finds the source of pollution is a leaking underground storage tank, impacting groundwater and the sewerage line via a corroded rubber seal. EPA considers the case for proceeding with prosecution of the site operator relating to the environmental hazard.

A Clean-up Notice would typically be issued to require some immediate clean-up action, and the preparation of a more “refined” clean-up plan, that is informed by on-site data and a conceptual site model (CSM). This clean-up plan would typically be verified by an EPA-appointed Environmental Auditor. The use of environmental audits in regulating contaminated sites may include the use of 53X and 53V environmental audits, but this depends on the situation. Certainly, Auditors are often engaged to verify clean-up plans and subsequent clean-up work. In the scenario of polluted or affected residential premise/s, EPA would likely require the polluter to complete a s53X environmental audit of that residential premises, to ensure it is suitable for ongoing use, following clean-up. For this scenario, following clean-up activities the premises was issued with a remedial notice to continue groundwater monitoring and complete other maintenance works, to ensure an acceptable risk was remaining at the site and relating to off-site pollution.

Other relevant information:

Soil and groundwater contamination, such as that described in the scenario above, may come to the Authority’s attention a number of ways, such as:

- 1.A notification of a pollution incident (from a third party such as neighbouring site owner, a leak to a stormwater/sewer main tracked back to the site, a site inspection for another related issue);
- 2.The duty holder makes a voluntary approach to EPA to inform them of a pollution incident at the site;
- 3.An environmental audit is required at the site via an Environmental Audit Overlay or is undergoing a change of use which has triggered an environmental audit (guidance on what may trigger an environmental audit is available in the General Practice Note on Potentially Contaminated Land).

The information is presented on the basis of the current policy, noting the potential for regulatory reforms in the future. EPA Victoria recommends duty holders contact EPA Victoria where they are aware that pollution may pose a risk to human health and the

environment. Under the Environment Protection Act 1970 there is a requirement for all persons to prevent pollution.

In situations 1 and 2 above, if there is evidence of pollution of land, air or waters (in accordance with the Environment Protection Act 1970), EPA can issue a remedial notice to require action to respond to that pollution. Action may include: preliminary site assessments, detailed site assessments, human health risk assessments, environmental audits (s53V and s53X environmental audits), clean-up plans, clean-up/remediation activities, site and environmental management and ongoing monitoring plans etc., to agreed timeframes. The remedial notices issued are either Clean-Up Notices (where pollution has occurred, to require clean-up of that pollution) or Pollution Abatement Notices (where the potential for pollution exists, and requires action to be undertaken to mitigate that potential risk). Where contamination/pollution is confirmed, a Clean-up Notice is the typical remedial notice used. Where contamination is suspected, but not confirmed, EPA may use a Pollution Abatement Notice to further investigate the suspected contamination.

Description of s53X/53V environmental audits

A full description of the types of environmental audits (under s53X/53V) in Victoria and their various applications is available on the EPA website (http://www.epa.vic.gov.au/our- work/environmental-auditing/types-of-environmental-audit) and should be used as the most up-to-date source of information.

Description of Underground Petroleum Storage Systems (UPSS) in Victoria

A full description of the regulations of UPSS in Victoria is available in EPA Publication

888.4 Guideline for environmental management, Leaks and spills, Land, Water 2015 (http://www.epa.vic.gov.au/our-work/publications/publication/2015/august/888-4) and a compliance project focussing on UPSS is also available on the EPA website.

Typical process in Western Australia

Regulatory context

The service station-site and the adjacent residential property are required to be reported to the WA Department of Water and Environmental Regulation (DWER) in accordance with section11 of the Contaminated Sites Act 2003 (CS Act). Section 11 of the CS Act identifies persons who have a duty to report the site (via a statutory form) and the timeframes for reporting. [Refer to sections 5 and 6 of DWER guideline 'Identification, reporting and classification of contaminated sites in Western Australia' (DWER, 2017)]

Site classification

DWER has an obligation to classify the reported site within 45 days of receipt of the statutory form. The service station would be considered to meet the definition of a "source site" and the adjacent residential property an "affected site" (as per s.3 of the CS Act). Part 3 of the CS Act includes provisions for the remediation of contaminated sites and s. 24 sets out a hierarchy of persons responsible for remediation. Under s. 27(2)(a) of the CS Act, a person who is responsible for remediation of a source site is also responsible for remediation of related affected sites. For the purposes of this case study, it is assumed that the operator of the service station is responsible for remediation but is not the owner of the site. [Refer to section 3.4 of 'Identification, reporting and classification of contaminated sites in Western Australia' DWER (2017)].

In view of the risks from petroleum hydrocarbons to surface waters, groundwater, site workers and the occupiers of the adjacent residential property, the source site would be classified as contaminated – remediation required under s. 13 of the CS Act. This classification would require a memorial to be registered on the certificate of title. This memorial may include a restriction on the registration of an instrument affecting the land (sale, lease or mortgage) without DWER consent (s 58(5) of the CS Act). The site classification of contaminated – remediation required, would result in the site being listed on the public (on-line) contaminated sites database.

The affected site could be classified as possibly contaminated – investigation required, contaminated – remediation required or contaminated – restricted use depending on the site-specific circumstances. In this case, contaminated groundwater extends on to the property and is unsuitable for non-potable use. It is likely that the property would be classified as 'contaminated-restricted use' with restrictions applying to the use of groundwater and a memorial registered on the certificate of title. This site classification would also result in the affected property being listed on the public (on-line) contaminated sites database and a memorial registered on the certificate of title [Refer to section 7 of 'Identification, reporting and classification of contaminated sites in Western Australia' to be published by DWER in 2017].

Mandatory Auditor's Report

Pursuant to r. 31(b) of the Contaminated Sites Regulations 2006, a mandatory auditor's report (MAR) is to be provided to DWER with every report containing information relevant to the investigation, assessment, monitoring or remediation of a source site. DWER recommends that a contaminated sites auditor is engaged at the start of the site assessment process to provide the necessary oversight and endorsement of the assessment and remediation process.

DWER Contaminated Sites Guideline, 'Requirements for Mandatory Auditor's Reports' (DWER, 2016) provides guidance on the timing for submitting a MAR. In effect, this means that a MAR will be required at the completion of each milestone/major stage of the contamination assessment and remediation process. For example, a MAR would be required at the completion of the detailed site investigation (DSI), completion of the detailed human health and environmental risk assessment (if not included in the DSI) and when the remediation action plan (RAP) has been finalised. [Refer to section 2 of 'Requirements for Mandatory Auditor's Reports' (DWER, 2016)]

Regulatory notices

Investigation (s. 49 CS Act) and clean-up (s. 50 CS Act) notices are served at the discretion of DWER. In the normal course of events, the site classification process is used by DWER to specify the nature of the action required, the time frame for completing the actions and any restrictions on use of the site pending completion of the relevant actions. If the person responsible (in this case the service station operator) does not undertake the works to address the site classification within an appropriate time frame, then an investigation and/or clean-up notice could be served under the CS Act.

Process for establishing remediation objectives

Establishing remediation objectives forms part of the development of the RAP for the site. The RAP should include consideration of acceptable time frames and initial evaluation of remediation options that are likely to be feasible [Refer to section 12 of 'Assessment and management of contaminated sites' DER 2014]. Issues that should be taken into consideration include, but are not limited to:

- The risks to be mitigated and the desired outcomes;
- The time frame available to carry out the remedial works;
- The sensitivity of the current or proposed land use and the environmental values applicable to the site;
- The views of stakeholders, particularly the owners of affected sites; and
- The acceptability of post-remediation institutional controls such as ongoing site management or a memorial on the certificate of title.

The remediation objectives should consider what environmental values are relevant for the site setting (including ecological receptors) and differentiate between the source site and the affected site(s)

A basic framework for the establishment of remediation objectives is provided in Figure 5.

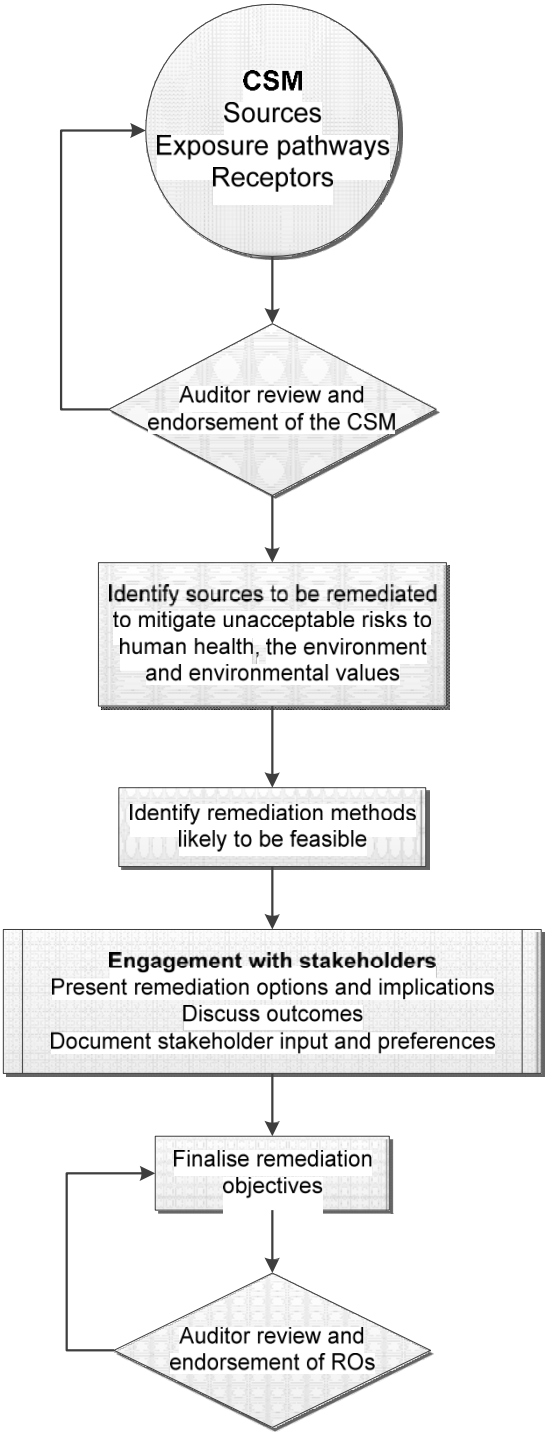

Figure 5: WA – Framework for process of establishing remediation objectives

Remediation objectives

Remediation objectives should be established in consultation with stakeholders with an interest in the source site and the affected site and endorsed by the contaminated sites auditor engaged to prepare the MAR for the RAP. As a minimum, stakeholders would include the owners and occupiers of the affected site, the source site and the adjacent property to the south of the service station who may be affected by the remediation work [Refer to Schedule 8 of the ASC NEPM and section 14 of 'Assessment and management of contaminated sites' DER 2014].

In the first instance, DWER would expect the remediation objectives to include achieving a classification of decontaminated for the affected site within a reasonable timeframe unless the affected site owner(s) agreed to a permanent restriction on groundwater use. A 'decontaminated' site classification would require the affected site to be rendered suitable for all land uses (i.e. no restrictions on land use including sensitive land uses such as residential, child care centres and pre-primary/primary schools) and restoration of all relevant environmental values, i.e. that the site is capable of supporting ecosystem functions appropriate for the land zoning (in this case residential), and groundwater is suitable for its current and reasonable future uses such as domestic garden irrigation. In effect, the remediation objectives should include addressing on-site risks and achieving retraction of the plume and stabilisation within the boundaries of the source site [Refer to section 12.2.1 of 'Assessment and management of contaminated sites' DWER 2014].

Remediation objectives to manage on-site risks may allow for residual contamination to be managed through restrictions on use applied through a revised classification under the CS Act (a site management plan may be necessary), provided this does not compromise achieving the remediation objectives for the affected site. The source site objectives must be agreed to by all stakeholders with an interest in the source site, including any owners not responsible for remediation. Alternatively, the remediation objective for the source site could be to render the site suitable for all land uses and restore all relevant environmental values.

In developing the remediation objectives listed below, it has been assumed that the owner and the occupier of the source site have reached agreement that the service station-site should be remediated to the extent that it is suitable for continuing commercial/industrial land use and that any residual groundwater contamination can be managed through a restriction on groundwater abstraction on-site.

The site-specific remediation end-points need to be consistent with the remediation objectives and the desired classification of the source and affected sites under the CS Act once remediation is complete. Site-specific remediation targets may be set at different levels of risk assessment based on a cost-benefit analysis [Refer to Figure 3, section 10 of 'Assessment and management of contaminated sites' DER 2014

Table 5: WA - relating remediation objectives to remediation targets or criteria based on receptor

Receptor	Remediation objective	Remediation target / criteria
On-site – human health	Remediate soil and groundwater contamination to mitigate the risk from hydrocarbon vapours to building occupiers, and maintenance workers accessing service trenches and other confined spaces to enable continuing commercial/industrial use	ASC NEPM HSL-D (or tier 2 or tier 3 site-specific target levels)
	Remediate soil and groundwater contamination to ensure that the hydrocarbon plume is stable or declining in extent and contained on-site	Stable or declining plume as validated by monitoring data combined with statistical analysis of trends[1]
Off-site – human health	Remediate groundwater contamination to mitigate the risk from hydrocarbon vapours to residential occupants	ASC NEPM HSL-A (or tier 2 or tier 3 site-specific target levels) applied to monitoring wells on the residential property
	Remediate groundwater contamination to protect the environmental values of abstracted groundwater based on current and reasonable future beneficial uses[2]	Tier 1: domestic non-potable use guidelines (or Australian drinking water guidelines if the aquifer is used for drinking water or is likely to be used in the future for drinking water) or tier 2 or tier 3 site-specific target levels.
	Remediate groundwater contamination to protect the environmental value of surface water used for recreational purposes	Tier 3 site-specific target levels calculated to achieve the *Guidelines for Managing Risk in Recreational Waters* applied at the point of groundwater discharge to surface water body.
Ecological receptors	Remediate groundwater contamination to protect terrestrial and aquatic ecosystems	Example targets would be: Tier 1 - apply ANZECC freshwater quality guidelines to groundwater at the site or Tier 3 – contaminant fate and transport modelling to derive site-specific target to meet ANZECC freshwater quality guidelines applied at the point of

Receptor	Remediation objective	Remediation target / criteria
		groundwater discharge to a surface water body / wetland ANZECC freshwater quality guidelines applied at the water table below the site to protect stygofauna (if relevant for the aquifer and site location).
	Remediate soil to protect terrestrial ecosystems	ASC NEPM ESL for commercial/industrial purposes on-site and ESL for residential purposes off-site
1.Refer to 'Use of monitored natural attenuation (MNA) for groundwater clean-up' (DoE 2004) note revised version to be published by DER in 2017 2.Refer to sections 11.7.2 and 11.7.3 of 'Assessment and management of contaminated sites' DER 2014		

Site-specific remediation targets developed to meet one objective may be numerically lower than that necessary to achieve a less sensitive objective. For example, fate and transport modelling may indicate that site-specific remediation targets necessary to ensure the environmental values of surface water at a nearby receptor are protected are much lower numerically than those necessary to render the source site suitable for commercial/industrial land use. In this circumstance, each remediation objective is still valid but the most conservative (sensitive) remediation target will drive the remediation required to meet all the remediation objectives.

General approach to remediation and management

The remediation objectives should be documented in a RAP which also details stakeholder engagement, the evaluation of remediation options, development of remediation targets and target timeframes, the results of any pilot trials or modelling, detailed remediation design, monitoring to be carried out during remediation, contingencies and a detailed plan (including a sampling and analysis quality plan or (SAQP) for validation of the remediation. Some of the information (such as a community engagement plan, risk assessment used to develop remediation targets and pilot trials or modelling) may be documented in separate stand-alone reports. Guidance is provided in *Assessment and management of contaminated sites'* (WA DER 2014).

Typical process in the Commonwealth Department of Infrastructure and Regional Development (DOIRD): Airport site

Background

To understand the remediation process followed by all federally leased airport sites this site and its information needs to be put into context from a federally leased airport perspective.

All federally leased airports and airport land are leased by the Commonwealth DOIRD to the Airport Lessee Company (ALC). Part of this lease agreement with the Department is that each Airport is assigned an environmental Regulator, the Airport Environment Officer (AEO). The AEO's role is to ensure the ALC and their tenants or occupiers follow the Airport (Environment Protection) Regulations 1997. The ALC subleases the land to the tenants and is responsible for all environmental management of its sites.

In the above scenario both the petrol station owner and residential home would be a sublease tenant on Commonwealth land. Under the AEPR Regulation 4.01 General duty to avoid pollution, the petrol station owner is required to undertake groundwater monitoring of their UST. The tenant is also required to report any pollution identified through monitoring undertaken in accordance with AEPR Regulation 6.04 Additional reporting requirement to the AEO.

In this scenario because the owner has shown reluctance to admit the contamination problem and because the site investigation has revealed that the BTEX levels are above the water pollution accepted limits as prescribed in Schedule 2 Water pollution – accepted limits of the AEPR (490µg/L) the AEO could issue a Direction under AEPR Regulation 6.09 Expert site examination this regulation requires the tenant to undertake an assessor (auditor) investigation of the site.

If the assessor's report to the AEO (AEPR Regulation 6.13 Occupier may prepare remediation plan) concludes that groundwater and/or soil pollution has occurred the tenant could then be issued an environmental remediation order Direction under AEPR Regulation 6.18 Power to order remediation work directing the tenant to follow AEPR Regulation 6.14 Occupier may prepare remediation plan for the remediation process.

Remediation process on Commonwealth owned airports

The fundamentals of the remediation objectives for federally leased airport sites are all covered within the AEPR. They are focused on a qualitative approach.

Division 3 Remediation plan for soil pollution

Regulation 6.14 Occupier may prepare remediation plan

The plan must be developed in consultation and agreement with the assessor who has reported the pollution regarding;

- if the plan is for cleaning up - the soil quality standards that can be reasonably achieved, and a timetable for a clean-up that will:
    - end migration of pollution from the area occupied(if that is occurring) within the shortest time reasonably and practicable; and
    - restore all affected beneficial uses within the meaning of subregulation 2.03(1) before the occupier ceases occupation; and

  - restore all beneficial uses within the meaning subregulation 2.03(1), of subterranean groundwater (if any) before the occupier ceases occupation: or

- otherwise an appropriate risk management program that will at least:
  - end migration of pollution from the area occupied(if that is occurring) within the shortest time reasonably practicable; and
  - ensure that any ongoing effects on the pollution are minimised.

AEPR's sub regulation 2.03(1) defines soil pollution and identifies any impacts on beneficial uses from contamination. All impacts are considered when restoring the beneficial use for both soil and groundwater.

The AEPR defines "beneficial use" as "a use conducive to public health, safety, aesthetic enjoyment or other benefit." The definition of "beneficial use" within the CRC CARE Site Specific Remediation Objectives Guideline is considered to be the same.

In the case of the petrol station scenario the first option for the objectives for remediation would be end the migration of pollution and to restore all affected beneficial uses as well as restoring beneficial uses of subterranean ground water as referenced in AEPR Regulation 6.14 Occupier may prepare remediation plan (a).The decision making highlighted in Figure 2 of The Site Specific Remediation Objectives Guideline would provide sufficient information to make a decision if AEPR Regulation 6.14 option (a) could be reasonably achieved. If the information proved that option (a) could not be achieved then AEPR Regulation 6.14 option (b) is considered. This option refers to an appropriate risk management program. The CRC CARE guideline site specific remediation objectives is considered an appropriate risk management program that will take into account 6.14(2)(b)(i-ii). The shortest time reasonably practicable referenced in Regulation 6.14(2)(b)(ii) can also be defined in the CRC CAREsite specific remediation objectives guideline Section 2.3.5 Acceptable timeframes.

To complete the remediation plan and to meet the requirements of the AEPR Regulation 6.14(2)(b)(i)and (ii). The tenant /occupier would follow the CRC CARE site specific remediation objectives guideline.

Other AEPR requirements to consider when preparing a Remediation Plan on an Airport site:

- Regulation 6.14 (3) After a plan has been sent to the Airport Environment Officer the Airport Environment Officer has 30 days to approve or refuse the plan
- Regulation 6.15 (1) Until a plan has achieved its objectives the tenant/occupier must give the AEO a 6 monthly progress report.
- Regulation 6.15 (2) When a plan has achieved its objectives the occupier must give an Airport Environment Officer a report giving details of the achievement of the objectives.
- Regulation 6.16 An Airport Environment Officer who approves remediation plan must monitor the implementation of the plan

Appendix D – Tiered risk assessment and development of criteria

The use of concentration-based criteria provides a widely accepted and objective basis (even if not the only metric) to determine whether the remediation has achieved the objective of protecting relevant environmental values.

Three options for determining concentration-based criteria or other acceptable conditions can be considered, as in the ASC NEPM 1999:

- Tier 1 criteria - Generic screening levels, if they are relevant for the site, and the environmental setting of the site. These are concentration-based;
- Tier 2 site-specific risk-based criteria. These are concentration-based;
- Tier 3 approaches; and
- International criteria may be considered if applicable to the site-specific exposure setting (e.g. in the absence of Tier 1-3 criteria) in specific circumstances and where agreed with the relevant regulator.

Table 6 summarises the tiered risk assessment process and criteria. The tiered approach is intended to '*provide a process for addressing site contamination methodically, with the level of complexity and cost proportional to the significance of the risk*' (ASC NEPM Sch B4, p14).

Table 6: Summary of tiered risk assessment process and criteria

Level of assessment	Type of assessment	Notes/exemptions	Action / outcome
Tier 1 assessment and criteria	Risk-based analysis comparing site data with generic published screening criteria (Tier 1 criteria) for various environmental values. Expert advice may be required in some cases e.g. some mixtures of contaminants.	Exemptions: • If one or more contaminants exceed Tier 1 criteria • If there are no appropriate Tier 1 criteria[9] • If there are unresolved and significant uncertainties limiting the reliability of assessment such as the generic CSM applicable to the screening criteria is not representative/conservative for the site circumstances. • Note: For any of the above circumstances, Tier 2 assessments are typically required.	• Comparison with appropriate generic screening levels. • Generic screening levels may be used especially at sites where the remediation is affordable and technically feasible to meet clean-up levels that may potentially be conservative (exceptions apply). • Long-term monitoring may be required until the remediation objectives have been met.
Tier 2 assessment and criteria	Site-specific assessment[10] in which the published generic screening criteria are adapted for site-specific conditions (site- specific risk-based criteria) for comparison with site data.		Comparison with site-specific risk-based criteria, together with references to the CSM, provides more certainty that the risks will be controlled to an acceptable level. Long-term monitoring may be required until the remediation objectives have been met.

[9] That is, there are no risk-based guidance levels for a contaminant; the land use applicable to the site is not covered by the risk-based guidance level; or, the physical characteristics of the site are such that the risk-based guidance levels may not be appropriate (NEPM, Sch. B4, s.2.4.1)
[10] Risks to potentially exposed populations are assessed using site-specific data on pathways, and characteristics of the exposed populations.

Level of assessment	Type of assessment	Notes/exemptions	Action / outcome
Tier 3 assessment and criteria	An iteration of the Tier 2 evaluation. Examines the specific risk-driving factors in more detail. This often involves additional data collection to determine whether receptors are affected and may incorporate more sophisticated modelling techniques. In Tier 3, the site-specific risk- based criteria are refined and then compared with site data.	In a forward assessment[11] the risks associated with the contaminant are estimated by comparing an estimated dose that a receptor may receive with no significant observable impact to health (eg. HIL). This is used to identify potential risks on the site. It is possible to undertake the modelling in reverse (a backward assessment), starting with the dose considered to result in no significant observable impact to health to calculate 'tolerable' contaminant concentrations at the site. These concentrations can be used as remediation or 'clean-up' criteria.	Used at sites where more information is required regarding the impact of contaminants such as effects on flora and fauna. Use of mass flux and mass discharge concepts along with concentration-based criteria may assist in understanding the potential for impact and the result of remediation options and eventually site closure. Level of detailed information for CSM and providing sufficient certainty regarding potential for effect may vary. Long-term monitoring is often required until the remediation objectives have been met.

[11] Refer to ASC NEPM 1999 Sch B4 s.2.4

A: Tier 1 assessment criteria

Relevant environmental values should be investigated using a risk-based tiered approach. Human health, groundwater and ecological investigation and screening levels may be used as Tier 1, as appropriate. According to the ASC NEPM 1999, Tier 1 Assessment Criteria refer to investigation and screening levels and (interim) petroleum hydrocarbon management limits.

Jurisdictions may adopt further criteria, and/or guidelines to vary investigation and screening levels to local conditions. Consequently, interpretation and application of the screening levels may need to be consistent with the ASC NEPM *and* any jurisdictional guidelines.

The GILs in the ASC NEPM 1999 have been generally drawn from water quality criteria for toxicants from the National Water Quality Management Strategy documents. Water quality criteria for additional toxicants is provided section 8.3.7 of the ANZECC and ARMCANZ (2000) guidelines. The GILs in the NEPM apply to moderately disturbed waters.

It is suggested that such values could be also adopted, where applicable, as conservative Tier 1 generic assessment criteria:

- Australian Drinking Water Guidelines (ADWG), (NHMRC 2016);
- Guidelines for Managing Risk in Recreational Waters (NHMRC 2008);
- Australian Water Quality Guidelines for Fresh and Marine Systems (ANZECC and ARMCANZ 2000). This guideline includes sediment criteria for a limited number of contaminants, and a default approach for others (see ANZECC and ARMCANZ 2000, s 3.5.4.3). A more recent Revision of the ANZECC/ARMCANZ Sediment Quality Guidelines (Simpson et al 2013) is also available.

The ADWG provide criteria for protection of human health and aesthetics. The aesthetic guidelines are based on odour, taste and appearance. In some cases, these are more stringent than the human health criteria and may need to be applied when potable water is the proposed use. For example, toluene is a highly odorous substance. The health-based ADWG is 0.8 mg/L while the odour based ADWG is much lower at 0.025 mg/L. If the remediation objective is to restore use of groundwater for potable use, then the odour-based criterion will be the limiting factor in achieving this outcome. If only the health-based criterion were to be used, then the groundwater would still be unsuitable for potable use on aesthetic grounds.

Tier 1 assessment criteria generally provide a conservative approach for protecting environmental values (exceptions apply, see Table 3). The magnitude of any exceedance should be considered in the context of the CSM (that is, whether the exposure pathways are plausible and whether exposure will result in harm). In cases of minor exceedance, a qualitative risk assessment may be sufficient to evaluate the potential impact and justify whether remediation is necessary. Under circumstances where the exceedance of Tier 1 Assessment Criteria is marginal, and the cost of remediation is small, it may be more cost effective to undertake the remediation to close out the site. In all circumstances, clear and transparent documentation should be provided to the relevant regulator in accordance with jurisdictional requirements.

Schedule B1 of the ASC NEPM 1999 states *inter alia* that:

> ***HILs establish the concentration of a contaminant above which further appropriate health investigation and evaluation will be required. Levels slightly in excess of the HILs do not imply unacceptability or that a significant health risk is likely to be present. Exceeding a HIL means further investigation is required and not 'risk is present, clean-up required'. (p5)***

also that:

> ***HILs are not intended to be clean-up levels. The decision on whether clean-up is required, and to what extent, should be based on-site-specific assessment triggered by an exceedance of the HIL. (p5)***

If the site contaminant level is less than the HIL for current or proposed land use as described in the ASC NEPM 1999, no further investigation may be necessary to protect human health (except if a more sensitive use applies). If this is the only environmental value that needs to be considered at that site, then remediation is not likely to be required. Expert advice may be required in some cases, for example, where synergistic or other effects of mixtures of contaminants may pose an unacceptable risk.

Further risk assessment is not likely to be required if generic Tier 1 criteria are considered conservative for the site-specific circumstances (ASC NEPM Schedules B1, B2, B6) and all relevant receptors and environmental values have been considered.

B: Site-specific risk-based criteria (Tier 2 and Tier 3 risk assessment)

Site-specific risk-based criteria are developed from the results of the risk assessment to establish a concentration (Tier 2) or other acceptable conditions (Tier 3) corresponding to an acceptable risk to human or ecological receptors. Progression to a Tier 2 or 3 risk assessment is typically required if:

- One or more contaminants exceed generic screening criteria; or
- There are no appropriate screening criteria (or the substance is an emerging contaminant of concern); or
- The assumptions on which the Tier 1 criteria are based are not appropriate for the site; or
- where the bioavailability or bioaccessibility can be demonstrated to be less than that assumed in the development of the Tier 1 criteria.

Depending on the contaminant, the Tier 1 assumptions may be overly conservative, with adsorption, the aging of contaminants, soil properties, contaminant speciation, pH and other factors potentially giving rise to reduced bioavailability (over the long term). The acceptance of reduced bioavailability and bioaccessibility depends on the

availability of suitable laboratory methods and/or published data. For example, the HIL for arsenic assumes 70% oral bioavailability (Schedule B7 Appendix 1). However, sufficient reliable information is available regarding the bioavailability of arsenic in soils in historical gold mining areas around Bendigo, Victoria to reliably conclude that there is low bioavailability (and leaching) of arsenic, and soil arsenic is unlikely to be hazardous to biota (see Noble, 2005). Other factors (apart from bioavailability and bioaccessibility) can affect the toxicity of a contaminant to receptors. For example, toxicity of contaminants may also depend on valence state – for example, trivalent arsenic is more toxic than pentavalent arsenic (Marlborough and Wilson, 2015). Arsenic speciation may drive risk-based corrective action depending on the concentrations of arsenic species and site conditions. Ecological risk assessments based on the concentration of trivalent species will lead to more restrictive remediation requirements compared with those for pentavalent species, but these may not adequately reflect the actual risk profile if the site setting (e.g. aerated surface soils) means that pentavalent forms predominate and are stable (Marlborough and Wilson, 2015). Such understanding can be used to inform the development of site-specific risk-based criteria.

The ASC NEPM should be referred to in relation to further information on the requirements and applicability of Tier 2 and Tier 3 risk assessments.

The ASC NEPM provides guidance for the assessment of risk to human health (ASC NEPM Schedule B4 and B7), ecological systems (ASC NEPM Schedule B5a, b & c) and groundwater (ASC NEPM Schedule B6) that can be applied in the development of site-specific risk-based criteria. The ASC NEPM also refers to the enHealth (2012) for further guidance.

The CSM together with the source-pathway-receptor exposure pathways may need further refinement (see ASC NEPM 1999 Schedule B2, s 4.3). Developing a CSM can be an iterative process (Figure 3), with the level of detail being commensurate with the tier of risk assessment and sensitivity of the site (and adjacent sites, as relevant), extent, mobility or complexity of contamination, and the value of the site.

Any proposed site-specific risk-based criteria will need to be discussed with and approved by the relevant regulatory body or auditor in the jurisdiction where the remediation will be undertaken, to ensure acceptability. enHealth (2012; s5.10) states that, while establishing a level of acceptable risk is necessary for decision-making purposes, establishing the numerical value is a social-political matter, requiring extensive consultation with stakeholders. Stakeholders include the community likely to be affected by the environmental hazard and those responsible for managing or ameliorating the risks.

Undertaking a Tier 2 assessment will involve additional cost and time, which may not be warranted, particularly for simple sites. Sometimes a more detailed assessment will not give rise to significant increases in the criteria (i.e. allow higher contaminant concentrations to remain on the site), particularly where there is an insufficient basis for varying the assumptions that underlie the Tier 1 criteria.

Where adopting Tier 1 criteria results in a high remediation cost, it is more likely that a Tier 2 or 3 Assessment will be justified on technical and cost grounds.

Tier 3 assessments may be required where Tier 1 and Tier 2 approaches are not suitable for a site (e.g. pathways of exposure, receptors, nature of contaminants,

receptors or other site characteristics differ). Tier 3 assessment can involve investigations that can be quite complex and time consuming and require a considerable body of data to provide sufficient information for risk-based decision making (and to manage uncertainties). For example, if specific terrestrial animals are potentially affected, then it might be relevant to undertake toxicity testing or studies to determine the extent and significance of effects in the ecosystem, or perhaps direct sampling of potentially affected animals and plants to determine uptake and whether food standards are exceeded.

For potentially high-risk sites, Tier 2 or 3 Assessments may be justified on technical and cost grounds. This is less likely for low risk (or simple) sites where a qualitative assessment may be sufficient. Expert advice may be needed to determine if further investigation is warranted.

In addition to effects on human health and the environment, the following may need to be considered prior to finalising the remediation objectives:

- The effects of contamination, including toxicity, the potential for bioaccumulation and persistence
- The potential risk posed by residual contamination, and the effectiveness and acceptability to stakeholders of any controls that might be involved (see NRF *Guideline on Institutional Controls*)
- The expected effectiveness, practicability and outcome of the proposed remediation and management strategy, and the resulting risk in terms of potential exposure through failure of management controls, and the social, economic and environmental benefits and costs and other factors that result from the strategy.

Where there are critical gaps and uncertainties in the understanding of risk acceptability, particularly at Tier 2 and Tier 3, further risk assessment may be required including additional investigation and laboratory analyses (see ASC NEPM 1999 Schedules B2 and B3).

Particular considerations for human health

For human risk assessments, all exposure pathways – ingestion, inhalation, dermal – that are relevant to the proposed use and environmental setting of the site need to be considered. ASC NEPM 1999 Schedule B4 provides guidance on the assessment of specific exposure pathways. Using this guideline, an acceptable concentration of a contaminant in soil (or groundwater) can be calculated based on the acceptable level of risk at a targeted receptor from an identified SPR linkage relevant for the site. In addition, the use of sensitivity analyses approaches may provide insight on the validity of data inputs and the level of uncertainty in the derived criteria (enHealth 2012).

Refinement of the CSM and improved understanding of the site conditions will mean that the Tier 2 (and Tier 3) assessment can focus on the risk drivers for the site. This is because, dependent on the proposed land use for the site (and sensitivities off-site), some exposure pathways may not be relevant.

The ASC NEPM, consistent with enHealth 2012, specifies that carcinogenic risk from environmental contaminants should not exceed 1 in 100,000 as an excess lifetime cancer risk. This risk level applies to cumulative cancer risk from all contaminants. In

back-calculating a site-specific remediation criterion, the 1 in 100,000 cumulative cancer risk may need to be taken into account for a site with multiple carcinogenic contaminants with the same mode of action in order to be consistent with the ASC NEPM. Table 4 below demonstrates this through a case study.

Table 7: Case study on considerations for human health

Case Study: Trichloroethylene (TCE) contamination
A site has been identified as being contaminated by TCE. TCE is a known human carcinogen through inhalation and oral exposure pathways. The exposure at the site can occur through direct contact with the soil or through inhalation of vapour (dermal contact is considered less important since it is not likely to cause toxic effects under normal conditions; and ingestion is considered a minor pathway). The proposed use for the site is apartment block development with a basement carpark. Direct contact with the soil will be minimised by construction of sealed pavements, minimising the risk from this exposure pathway. Restrictions will apply to the use of groundwater both on- site and offsite. The risk posed by residual contamination will be determined by the potential for vapours to enter buildings now and in the future (and for potential off-site issues), and the requirements for remediation of the soil and groundwater will be determined on that basis. The remediation objective is to remediate the site so that it is suitable for an agreed density of residential development with basement car parking and common landscaped area with no exposed soil. A site-specific clean-up target for TCE is determined focussing on addressing the vapour intrusion risk with a lifetime cancer risk not exceeding 1 in 100,000.

Contaminant fate and transport

Remediation/management strategies can benefit from a good understanding of the mobility of contamination. Contaminant fate and transport modelling may be useful for the development or refinement of the site-specific risk-based criteria.

Fate and transport models may be developed to evaluate spatial and temporal source-pathway-receptor linkages. Or, they may be developed specifically to investigate the pathway from the source to identified receptors, and to consider the velocity of contamination and whether there are any retardation processes active along this pathway (e.g. biodegradation, adsorption onto organic carbon or clay materials, dispersion, dilution).

For example, soil-sediment-water partitioning may be a useful consideration for some contaminants depending on the site scenario. Sensitivity and uncertainty analysis may need to be undertaken as part of the application of risk-based models to determine parameters with the greatest influence on-site-specific risk-based criteria (See ASC NEPM, Schedule B2).

Contaminant fate and transport modelling may be especially required or cost-effective for:

- Sites where there is a source of groundwater contamination and a critical factor is whether the contaminant plume is migrating off-site and can affect sensitive receptors; and
- Sites for which the groundwater contamination will persist and management is required for a long time (e.g. when employing monitored natural attenuation), or when groundwater flow is very slow and this is a factor limiting the risk to receptors.

C: Application of international criteria

If Tier 1 assessment criteria are not available, international criteria may be considered. International criteria may also be refined in the development of site-specific risk-based criteria in Tiers 2 and 3.

All environmental standards and numerical criteria incorporate a range of assumptions, including the inherent level of risk. Should international criteria be considered, it is important to understand and clarify the assumptions used in their development to ensure that any criteria adopted for the site are consistent with the protection of the environmental values identified for the site and consistent with the parameters used in the ASC NEPM and are acceptable to the relevant regulator or environmental auditor.

In general, the basis for criteria should protect the most sensitive receptor (human or ecological) consistent with the processes established in the ASC NEPM. The ASC NEPM Schedule B4 provides international sources that could be considered for this purpose.

The ASC NEPM refers to the *Guidelines for Environmental Health Risk Assessment* (enHealth 2012) for further guidance on the application of international sources of data for risk assessment purposes. Appropriate justification would have to accompany a proposal to use international criteria and approval may need to be sought from the relevant regulatory body or auditor.

In the case of protection of human health, the carcinogenic risk associated with the international criteria for protection of human health may need to be adjusted to be consistent with the ASC NEPM criteria of not exceeding 1 in 100,000 excess lifetime cancer risk. For example, the USEPA regional screening levels used at Superfund sites are based on a lifetime cancer risks between 1 in 10,000 and 1 in 1,000,000. The RIVM maximum permissible risk levels for humans (RIVM, 2013) are based on a 1 in 10,000 excess lifetime cancer risk. The HILs in the ASC NEPM are based on a 1 in 100,000 excess lifetime cancer risk, and consider cumulative risk for cancer causing agents (if they have the same mode of action). It is clear from this example that dependent on which criteria sourced from overseas jurisdictions, the risk assumptions associated with the levels of clean-up at a site can differ significantly.

Appendix E – References

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