Ministry for the
Environment
Manatū Mō Te Taiao

Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand (Revised 2011)

MODULE 1
Risk-based approach to site assessment and management

August 1999

Contents

Figures

1 Risk-based approach to site assessment and management

Module One presents an overview of the integrated risk-based approach to the assessment and management of soils and groundwater impacted by petroleum products.

1.1 Risk-based approach to the assessment and management of contamination

1.1.1 General

Use of an integrated risk-based approach leads to site assessment and management actions that are appropriate for each site, and that are consistent with the underlying risk management and policy decisions of the regulatory program. Application of the integrated risk-based approach insures that all actions are focused on achieving the desired level of protection for human health, ecological species and resources.

The integrated risk-based approach combines conventional site assessment and management approaches, with health and ecological risk assessment principles and tools. These traditionally separate activities are integrated into a streamlined approach to decision-making.

Health and ecological risk assessments provide the tools to assess the significance of soil and groundwater contamination, and may be used to:

- derive soil and groundwater concentrations that may be used as generic criteria identifying when an unacceptable impact may possibly occur, and
- assess the possible significance of contamination on a site-specific basis.

The use of a risk-based approach reflects the practical need to appropriately allocate limited resources to the assessment and management of sites. The application of a risk-based approach ensures that:

- resources are first applied to managing immediate and unacceptable threats to human health and the environment
- remaining resources are devoted to making sure conditions at all sites do not worsen
- any remaining resources are applied to the management of those sites posing long-term unacceptable threats to human health and the environment.

A tiered approach to the assessment of soil and groundwater contamination has been adopted to facilitate the cost effective use of health and ecological risk assessment principles. The level at which the possible effects of contamination are assessed depends on the likely significance of the effects. The assessment may range from a simple comparison with generic acceptance criteria, to a detailed, site-specific risk assessment.

The principles underlying a risk-based approach to site assessment and management are as follows:

- Decisions regarding site management should be based mainly on mitigation of unacceptable risks to human health or the environment. Such decisions should take into account the uncertainty in the assessment of risk.

- Site assessment activities should focus on collecting only that information required to determine the likely health and environmental impacts associated with the site, and to make risk-based decisions regarding site management.
- Where the risk to human health or the environment is considered unacceptable, a range of risk mitigation strategies should be considered. The selection of site management options should be based on the ability of the proposed strategy to minimise the risk to human health and the environment, the certainty with which the strategy can be implemented and the cost of implementation.
- The resources available for site management are limited and therefore there is a need to appropriately allocate resources based on the risk to human health or the environment.
- The immediacy of action at a site should reflect the magnitude of likely unacceptable impacts and the timeframe within which they may occur.

In summary, decisions regarding the allocation of resources to the investigation and management of sites should reflect the risk to human health and the environment posed by the site rather than on the basis of arbitrary standards.

1.1.2 Other considerations in integrated risk-based decision-making

Frequently decisions regarding investigation and management actions also require consideration of factors other than the risk to human health or the environment. Examples may include, legal liability, economic considerations, public or market perception (e.g. sale of land) and expediency (e.g. minimising the requirement for ongoing management).

1.2 Tiered approach to site assessment and management

The basis for a tiered approach to site assessment and management is presented. The aim of a tiered approach is to streamline the assessment and management of risk at individual sites. The tiered approach starts with a simple, low cost assessment of risk. It then proceeds to increasingly more complex and detailed approaches to the assessment of risk, as warranted by the risk posed and the cost of site management.

1.2.1 Overview

The tiered approach to the assessment and management of petroleum hydrocarbon contaminated sites is based on the assumption that not all sites pose the same risk to human health and the environment. Therefore, resources should be focussed on assessing and managing those sites where a significant impact is likely.

Use of a tiered approach streamlines the risk-based decision-making process and allows appropriate allocation of resources, by adopting increasingly sophisticated levels of data collection and analysis in accordance with the risk posed by the site.

The overall site assessment process, incorporating a risk-based approach to decision making, is summarised as follows:

Initial Assessment

1. Initial site assessment
2. Site classification and initial response action (i.e. does the site pose an immediate danger to health and the environment, and, if yes, what action is required to mitigate the danger).

Tier 1 Site Classification and Assessment Using Generic Tier 1 Criteria

1. Comparison of site conditions with Tier 1 generic soil and water criteria, and selection of a Tier 1 management strategy
2. Evaluation of Tier 1 results.

Tier 2 Development of Tier 2 Site-specific Acceptance Criteria and Site Management Plan

1. Expanded site assessment, reclassification and development of Tier 2 site-specific acceptance criteria
2. Development of Tier 2 risk-based site management plan
3. Evaluation of Tier 2 results.

Tier 3 Detailed Tier 3 Site–specific Risk Assessment and Site Management Plan

1. Expanded site assessment and development of Tier 3 site-specific acceptance criteria
2. Development of risk-based site management plan.

In the development of the tiered risk-based approach, the Tier 1 soil acceptance criteria have been developed in such a way as to be flexible enough that roughly 70%[1] of all sites can be addressed without proceeding to Tier 2 or Tier 3. Here "flexible" means that the Tier 1 acceptance criteria have already been developed for a wide range of possible site characteristics, as opposed to being developed for a single (most conservative) generic scenario as is often the case. The tiered approach to site assessment is illustrated in Figure 1.1.

1.2.2 Initial site classification

The assessment may begin with:

- a review of site history (including records of product loss)
- a review of the physical setting of the site including an initial assessment of the likely fate and transport of contaminants and identification of receptors
- the collection of information regarding contaminant concentrations in soil and groundwater at the site.

As information becomes available regarding site conditions, an initial classification of the site should be conducted, and then refined as further information becomes available. For example, based on information collected, the site may be classified as follows:

- immediate threat to human health, safety or sensitive environmental receptors
- short term (0-2 years) threat to human health, safety or sensitive environmental receptors

[1] Based on oil industry objectives to streamline the management of sites in New Zealand.

- long term (>2 years) threat to human health, safety or sensitive environmental receptors
- no demonstrable long-term threat to human health, safety or sensitive environmental receptors.

The purpose of the site classification and initial response selection is to ensure that:

- immediacy of action at a site is consistent with threats posed by the site (i.e. short-term threats are addressed immediately)
- unacceptable impacts posed by a site do not get worse with time as the site is being investigated and risk-management decisions are being made.

Decisions regarding:

- immediate action to mitigate impacts
- further investigations
- long-term management of the site,

should be based on the initial site classification and refined classifications as the tiered site assessment process continues. Table 3 "Site Classification Scenarios and Potential Initial Response Actions" in the ASTM RBCA standard[2] provides a useful tool for classification of sites and selection of initial response.

[2] ASTM (1995) *Standard Guide to Risk-Based Corrective Action Applied at Petroleum Release Sites (RBCA)* E1739-95

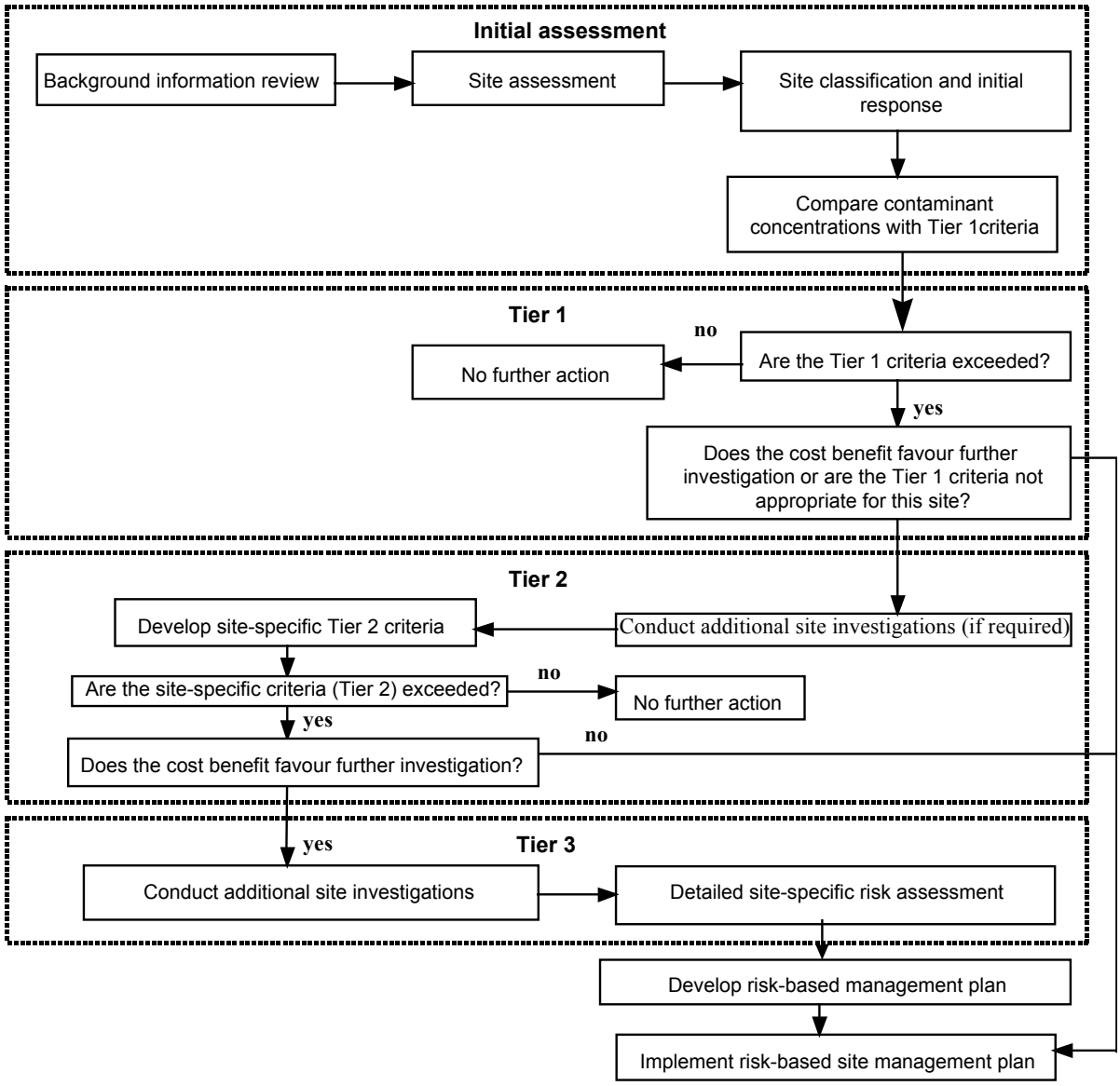

Figure 1.1 Site assessment and management process

1.2.3 Tier assessment

1.2.3.1 Assessment based on comparison with Tier 1 generic criteria

To assist in quickly identifying those sites that may pose a significant risk to human health and the environment, acceptance criteria have been developed for a number of generic scenarios, based on conservative assumptions. Where contaminant concentrations at a given site do not exceed the generic acceptance criteria, it may be concluded with a high degree of confidence, that the site does not pose a significant risk to human health or the environment.

The Tier 1 assessment is based on comparison of measured contaminant concentrations in soil and groundwater from the site with generic acceptance criteria developed for a range of land uses and groundwater uses. If the measured contaminant concentrations are less than the acceptance criteria then the site may be suitable for the nominated use.

The acceptance criteria presented in Module 4 are based only on consideration of human health risk. The user must also consider ecological protection, and site amenity (aesthetics). Guidance relating to the assessment of aesthetic impact, associated with soil contamination, is presented in Module 4.

In order to develop widely applicable criteria, many conservative assumptions have been incorporated. Therefore, if the Tier 1 criteria are exceeded this does not necessarily imply the actual risk posed by the site is unacceptable. Instead, it indicates that further investigation and site-specific evaluation of acceptance criteria may be warranted.

In order to increase the flexibility of the Tier 1 assessment process, criteria have been developed for a wide range of geologic settings and land use scenarios. Therefore, it is expected that final site management decisions can be made for the majority of sites using the Tier 1 acceptance criteria, and that few will need to progress to Tier 2 or Tier 3 analyses.

The Tier 1 criteria includes consideration of:

Land use	Agricultural, residential, commercial/industrial (including maintenance workers).
Soil Type	8 soil profiles
Depth of soil contamination	<1 metre, 1-4 metres, >4 metres
Depth of groundwater from ground surface	2-4 metres, 4-8 metres, >8 metres

Guidance on the application of Tier 1 soil and groundwater acceptance criteria is presented in Sections 1.3.3 and 1.3.4.

1.2.3.1 Tier 1 ecological evaluation

The Tier 1 soil acceptance criteria presented in Module 4 are derived primarily with reference to the protection of human health. The development of ecologically-based soil acceptance criteria is subject to considerable debate.

As part of the Tier 1 assessment, the potential for ecological impacts should be considered based on a review of:

- the location of potentially sensitive ecological receptors
- the completeness of relevant exposure pathways.

A checklist to assist in this process is presented in Appendix 4I. Where the potential exists for a significant ecological impact to occur, a site-specific evaluation of ecological impact or ecological risk should be undertaken.

1.2.3.2 Evaluation of Tier 1 results

When chemical concentrations at a site do not exceed the Tier 1 acceptance criteria, no further action is required. When chemical concentrations at a site exceed acceptance criteria, either:

- implement a management strategy to eliminate routes of exposure or to reduce chemical concentrations to the acceptance criteria, or
- progress to Tier 2 assessment to determine acceptance criteria more appropriate for site conditions, and then compare site conditions with these criteria.

Progress to a Tier 2 assessment when:

- the Tier 1 criteria can be shown to be inappropriate
- the Tier 2 criteria are likely to be significantly different from the Tier 1 criteria, or
- the cost of the Tier 2 analysis is less than the cost of management associated with the Tier 1 acceptance criteria.

1.2.4 Tier 2 - Developing site-specific acceptance criteria and site management plans

If the Tier 1 assessment indicates that there is potential for a significant risk to human health and the environment, then a Tier 2 assessment may be initiated. Usually a Tier 2 assessment would be initiated where the likely savings from use of site-specific criteria outweigh the cost of the Tier 2 assessment.

As part of Tier 2 assessment, the basis for the generic acceptance criteria used in the Tier 1 assessment may be reviewed in order to determine their applicability at a given site. For example:

- The limiting consideration with respect to naphthalene may be ecological effects. However, in the context of an urban residential site the decision may be made that full protection of the ecosystem within the boundary of the site is not required.
- The limiting consideration in assessing benzo(a)pyrene contamination is ingestion of contaminated soil and at a particular the site benzo(a)pyrene is not present in the surface soils, therefore higher contaminant concentrations may be acceptable on a site-specific basis.

As part of the Tier 2 assessment, site-specific acceptance criteria may be developed using an approach consistent with that adopted for the Tier 1 criteria (or using a range of other suitable risk assessment models), incorporating information on the exposure assumptions designed to reflect site-specific considerations.

Where consideration of site-specific factors suggest the assumptions used to derive generic, Tier 1 acceptance criteria are appropriate, it is expected that Tier 2 acceptance criteria would be similar to the Tier 1 criteria, although the point at which they are applied may differ.

Following the development of Tier 2 site-specific acceptance criteria and the assessment of contamination, a risk-based site management plan may be developed. As with the Tier 1 process, part of the Tier 2 decision-making process is the need to evaluate the results of the Tier 2 assessment and the cost-benefit relationship associated with implementation of the site management plan in relation to proceeding to the Tier 3 assessment.

1.2.5 Tier 3 - Detailed site-specific risk assessment and site management plans

A Tier 3 assessment may be initiated where:

- a Tier 2 assessment indicates that a significant risk to human health and the environment may exist, and
- the cost of remediation or other risk management strategies warrants further detailed consideration.

A Tier 3 assessment involves detailed, site-specific consideration of the relevant exposure pathways, and may entail additional sampling and analysis of environmental media.

A Tier 3 assessment is likely to be relatively costly and therefore is expected to only be implemented where possible refinements in the management strategy justify the additional expenditure.

1.2.6 Comparison of tiers

As example of the varying levels of effort involved in subsequent tiers of investigation, the level of sophistication in fate and transport modelling associated with each tier is illustrated as follows:

Tier 1 Generic criteria based on one-dimensional fate and transport modelling. No site-specific modelling.

Tier 2 One-dimensional or simple two-dimensional fate and transport modelling. Site-specific validation of input parameters, point of compliance or application of criteria may change.

Tier 3 Detailed two-dimensional or three-dimensional fate and transport modelling with site-specific validation of model predictions where possible.

See also Figures 1.2 and 1.3, which illustrate the relationships between the tiers.

1.2.6.1 Protection

Each of the Tiers is designed to provide a high level of protection to human health and the environment. While additional information may allow higher values for the acceptance criteria to be established in some cases under the Tier 3 assessment, the Tier 3 criteria are likely to be no less protective, i.e. the less stringent Tier 3 criteria reflect a lower degree of uncertainty rather than a lower level of protection.

1.2.6.2 Conservatism and uncertainty

Tier 1 acceptance criteria typically incorporate a high degree of conservatism in order to be more generally applicable to a wide range of site conditions and land-use scenarios. Therefore, there is a high degree of uncertainty associated with this indication of risk. The conservative nature of Tier 1 criteria biases the uncertainty so that we can be confident that actual risks posed by the site are most likely to be less than the risks indicated by a comparison with Tier 1 criteria. With progress to higher Tiers, there is less uncertainty in the relationship between acceptance criteria and adverse risks posed by the site. This is because site-specific characteristics are incorporated into the development of the acceptance criteria.

1.2.6.3 Cost of investigation and assessment

A Tier 1 assessment involves a simple comparison of measured contaminant concentrations with screening criteria presented in a “look-up” table, and therefore is the lowest-cost approach to assessment. The Tier 3 assessment may require considerable amounts of detailed site-specific information incurring significant additional cost. While the cost associated with assessment of contamination increases from Tier 1 to Tier 3, the objective is to spend the appropriate amount of money on the assessment of contamination in order to minimise the overall cost of site management.

It is anticipated that decisions concerning the future of most sites will be based on Tier 1 acceptance criteria, as these have been derived for a wide range of site conditions and land-use scenarios. The additional cost associated with a Tier 3 assessment is only likely to be justifiable at a small number of sites in New Zealand.

The above considerations are illustrated in Figures 1.2 and 1.3.

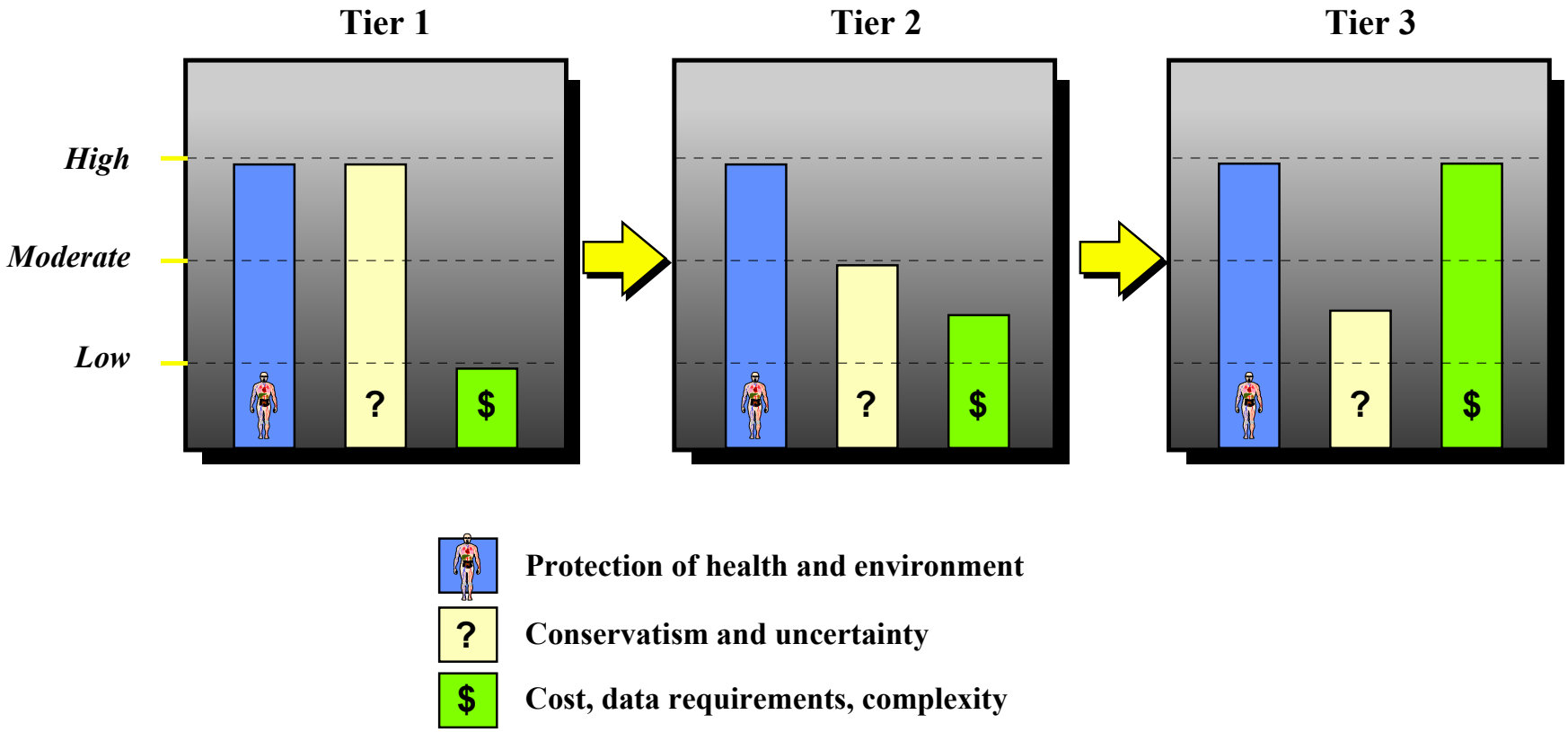

Figure 1.2 Comparison of cost, uncertainty and conservatism for tiered approach

Source: '*Guidance Manual for Risk-Based Corrective Action* Tier 2 RBCA" June, 1995

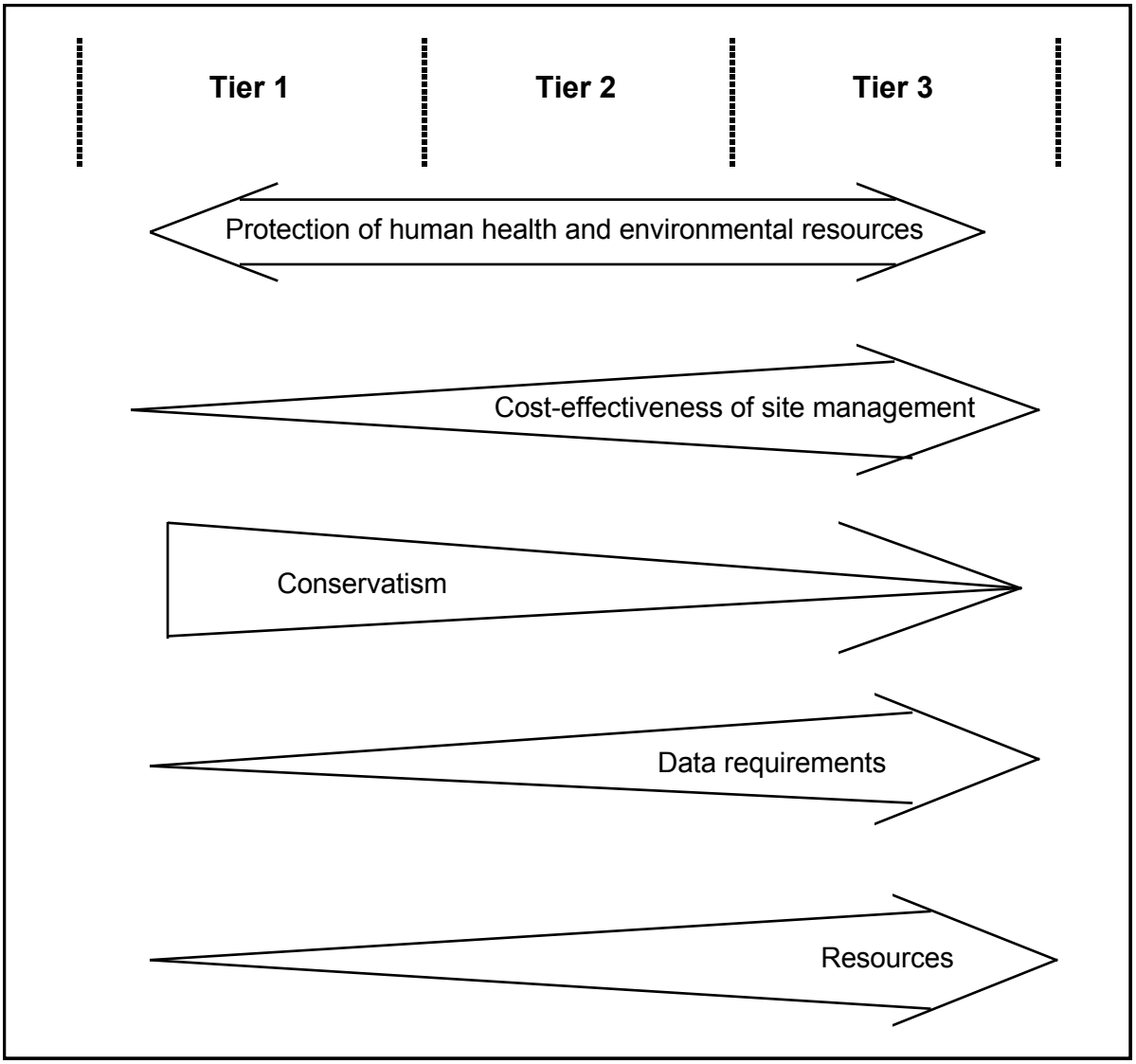

Figure 1.3 Summary of tiered site analysis

1.3 Considerations in risk-based site assessment

The use of generic Tier 1 acceptance criteria and the tiered approach to site assessment is illustrated. In particular, the use of soil screening criteria, based on groundwater protection, to determine whether groundwater sampling is required is discussed.

1.3.1 Overview

The development of acceptance criteria depends greatly on the context within the overall site assessment process. The use of the tiered approach to site assessment is outlined in Figure 1.4.

The decision to proceed from one tier to the next is primarily a cost-benefit consideration. In deciding whether to proceed from Tier 1 to Tier 2, or Tier 2 to Tier 3, the following considerations must be balanced:

- the likely cost saving associated with reduced remedial requirements resulting from a site-specific assessment of risk
- the cost associated with conducting the more detailed, site-specific risk assessment.

1.3.2 Risk-based investigation design

The overall aim of the site assessment and management process is to manage and minimise the risk to human health and the environment, through the cost-effective implementation of risk mitigation strategies. Risk assessment allows the most significant risks to be identified and addressed, and the more significant pathways to be identified, facilitating effective targeting of risk mitigation strategies.

Risk assessment provides the tools for assessing the significance of possible health and environmental impacts associated with soil and groundwater contamination which is the fundamental aim of site-assessment. It is essential that the site investigation programmes, including sampling and analytical work, be designed in the context of the information required for risk assessment.

As part of a tiered approached to site assessment and risk-based decision-making, the information collected as part of each tier is confined to that necessary to assess the risk and make decisions regarding site management.

For example, the information required may include:

Tier 1 Contaminant concentrations in soil and groundwater, delineation of extent of contamination.

Tier 2 As above, contaminant concentration in groundwater at the nearest point of use or potential use (may be measured or predicted), soil and aquifer properties, contaminant concentrations in other exposure media (e.g. soil, air), site-specific activity and use patterns.

Tier 3 As above, site specific.

1.3.3 Application of Tier 1 soil acceptance criteria

Module 4 presents soil acceptance criteria based on an assumed exposure scenario for each of the land uses. Each exposure scenario includes consideration of a range of exposure pathways which are assumed to be complete. Where contaminant concentrations exceed the nominated Tier 1 soil acceptance criteria, consideration should be given to the completeness of each of the assumed exposure pathways and the relevance of the exposure assumptions. For example:

- If an exposure pathway assumed as part of the derivation of acceptance criteria for a given land use is found to be incomplete (e.g. ingestion of soil by normal site users cannot occur because the site is paved) then the route-specific acceptance criteria presented in Module 4 should be reviewed to determine the limiting exposure route. Where a limiting exposure route is found to be incomplete, the next lowest route-specific criterion may be adopted.
- Where an exposure route based on cross-media transfer of contaminants is limiting (e.g. produce uptake, volatilisation), additional measurements may be taken to confirm the accuracy of the modelling underlying the criteria (although this would normally only be undertaken as part of a Tier 2 assessment). Where less efficient cross-media transfer occurs, higher criteria may be applicable.

- The point of exposure is in practice often located further from the site than assumed in the development of the Tier 1 acceptance criteria. Natural attenuation processes have been shown to reduce dissolved phase contaminant concentrations (particularly BTEX concentrations) significantly with time and distance from the point of release. Where an on-site source remains, natural attenuation has been shown to limit the maximum extent of the dissolved phase plume and to reduce contaminant concentrations with time once the source has been removed.

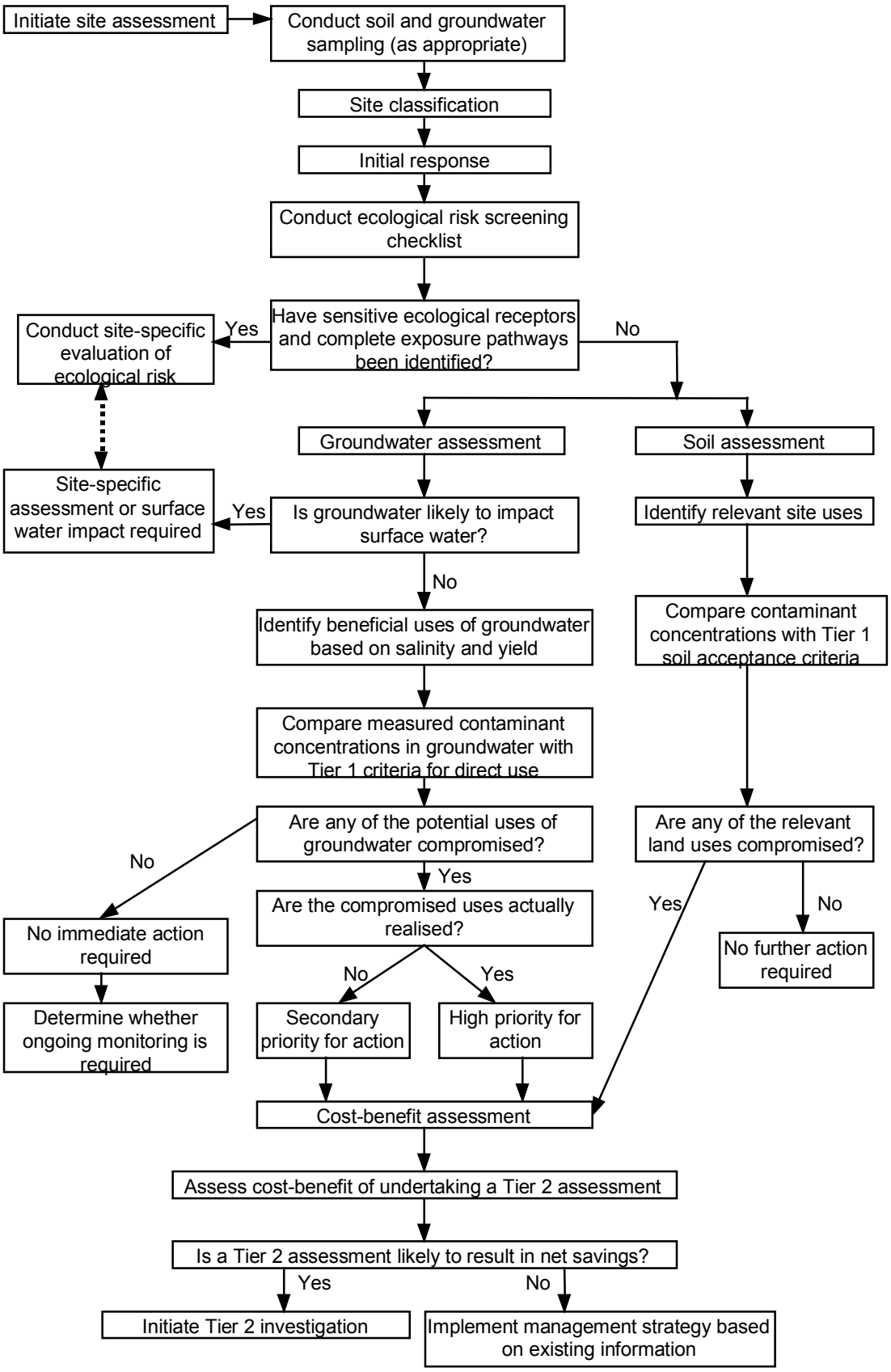

Figure 1.4 Sample application of Tier 1 acceptance criteria

- the impact of natural attenuation should be considered in estimating the-long term concentrations likely to be observed at a remote point of exposure.[3] Detailed consideration of natural attenuation including predictive modelling may form part of a Tier 2 assessment.

Where contaminant concentrations at a site exceed the Tier 1 acceptance criteria, the Tier 1 criteria should be critically reviewed, to determine whether the limiting exposure route is valid, before proceeding to a Tier 2 assessment. An exposure pathways diagram is presented in Module Four to assist in the critical evaluation and selection of complete pathways.

1.3.4 Consideration of groundwater contamination

Sampling and analysis of groundwater should be undertaken whenever there is the potential for groundwater contamination. An aquifer where use may potentially be affected by a petroleum release is referred to as a sensitive aquifer.

A sensitive aquifer is defined as an aquifer which is:

- not artesian (in practice true artesian aquifers are unlikely to be encountered as part of the shallow groundwater systems normally of interest at petroleum contaminated sites), and
- less than 10 metres below the source of the release (clean sands and gravels, fractured rock and other formations allowing very rapid migration of contaminants require further consideration), and
- of a quality appropriate for use, is capable of yielding water at a useful rate and from which extraction and use of groundwater may be reasonably foreseen,
  or
- within 100 metres of a sensitive surface water body[4].

In many circumstances sampling and analysis of groundwater is a more reliable indicator of a significant petroleum release than soil sampling and analysis alone. In this context groundwater monitoring can be a useful tool in identifying significant environmental issues, particularly where there is potential for a significant source to be missed by soil sampling.

For further details regarding the definition of a sensitive aquifer and the assessment of groundwater contaminant refer to Module 5.

1.4 Risk-based site management

A risk-based approach to the design and implementation of site management strategies arises out of an understanding of exposure pathway analysis. For a risk to human health to occur, a complete exposure pathway must exist between the source of contamination and the receptor.

[3] While consideration may be given to adopting an alternative point of exposure based on the actual patterns of groundwater use, the requirement to protect the groundwater resource for possible future use should be considered.

[4] A distance of 100 m reflects the observation that at most sites natural attenuation processes limit the extent of the dissolved phase plume to less than 100 m. Where due to the migration of free product or other site-specific conditions, contaminated groundwater extends more than 100 m from the source of contamination, contaminant concentrations in the groundwater would be sufficiently reduced such that dilution of groundwater on discharge to surface water would prevent an adverse impact. Sensitive surface waters with limited dilution of groundwater discharge may require separate consideration.

Where an exposure pathway is incomplete then there is no risk. An exposure pathway consists of a:

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

The development of an accurate conceptual model of the site is an important step in identifying complete exposure pathways.

Where the risk-based assessment of contamination indicates that an unacceptable risk to human health or the environment may exist, depending on the cost-benefit relationships and other considerations, the next step may involve:

- further investigation and site-specific assessment to refine the risk estimates and determine the requirements for further action. The process of increasingly higher tier assessment is discussed earlier.
- implementation of management strategies to mitigate the risk to human health and the environment.

Strategies for risk reduction should focus on rendering relevant exposure pathways incomplete or less efficient. For example:

- implementation of institutional controls that limit site access (relocating or eliminating points of exposure) or activities that may be undertaken at the site (possibly eliminating some exposure routes, or at least the rate of exposure)
- installation of barriers which interrupt relevant exposure pathways (e.g. capping layers)
- removal or destruction of the source of contaminants.

In terms of the effectiveness of risk reduction, each of the above strategies may be equally appropriate, with the selection of a strategy based on the reliability of risk reduction, practicality, cost and other considerations.

Where there is some uncertainty regarding the results of the assessment, ongoing monitoring and management may also be implemented to ensure that an unacceptable risk does not exist e.g. limiting future monitoring to confirm predictions regarding the behaviour of a dissolved phase hydrocarbon plume.

Natural attenuation is an important process limiting the effectiveness of exposure pathways. Frequently, natural attenuation is sufficient to render the transport mechanism ineffective and the exposure pathway incomplete. Natural attenuation of dissolved phase contaminants can limit the migration of, and extent of impact from, certain chemicals. In the case of BTEX compounds, studies have shown that natural attenuation processes generally limit the extent dissolved phase plumes to <100 metres (although examples of plume extending >100 metres under certain conditions have been documented). This may be sufficient to render groundwater migration pathways incomplete, when considering the impact on receptors (e.g. groundwater abstraction bores), further than 100 metres from the source. However, not all compounds are significantly attenuated, e.g. chlorinated solvents, MTBE.