BEFORE THE ENVIRONMENTAL PROTECTION AUTHORITY
AT WELLINGTON

IN THE MATTER	of the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012 (**EEZ Act**)
AND	
IN THE MATTER	of an application for marine consent under section 38 of the EEZ Act by Trans-Tasman Resources Limited to undertake iron ore and processing operations offshore in the South Taranaki Bight
BETWEEN	**Trans-Tasman Resources Limited** Applicant
AND	**Environmental Protection Authority** EPA
AND	**Fisheries Inshore New Zealand Limited, New Zealand Federation of Commercial Fishermen Inc, Talley's Group Limited, Southern Inshore Fisheries Management Company Limited and Cloudy Bay Clams Limited** Fisheries Submitters

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SUPPLEMENTARY STATEMENT OF EVIDENCE OF MR JORIS GERARD LEONARD JORISSEN FOR FISHERIES SUBMITTERS

Dated: 7th April 2017

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INTRODUCTION

1. My name is Joris Gerard Leonard Jorissen. I am a senior coastal engineer at Jacobs Australia Pty Limited in Brisbane, Australia.

2. I completed my primary statement of evidence on laboratory testing and sediment plume modelling on 23 January 2017. My qualifications and experience are set out at paragraphs [7] to [9] of my primary evidence.

3. I participated in the first expert conference on Sediment Plume Modelling on 13 February 2017,[1] and the second expert conference on Sediment Plume Modelling – Setting Worst Case Parameters - on 23 February 2017.[2]

4. In preparing this statement of evidence I have reviewed the following documents:

   (a) South Teranaki Bight Sediment Plume Modelling – Worst Case Scenario, NIWA prepared for Trans-Tasman Resources, dated 16 March 2017;

   (b) Expert evidence of Dougal Greer on behalf of Kiwis Against Seabed Mining, dated 27 March 2017;

   (c) Expert evidence of Dr Michael Dearnaley on behalf of Trans-Tasman Resources, dated 28 March 2017; and

   (d) Draft expert evidence of Dr Greg Barbara on behalf of Fisheries Submitters.

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1 Joint Statement of Experts in the Field of Sediment Plume Modelling, dated Monday, 13th February, 2017.

2 Joint Statement of Experts in the Field of Sediment Plume Modelling – Setting Worst Case Parameters, dated Thursday, 23rd February, 2017.

CODE OF CONDUCT

5. I have read the Environment Court Code of Conduct for expert witnesses and agree to comply with it.

6. I confirm that the topics and opinions addressed in this statement are within my area of expertise except where I state that I have relied on the evidence of other persons. I have not omitted to consider materials or facts known to me that might alter or detract from the opinions I have expressed.

PURPOSE AND SCOPE OF EVIDENCE

7. The Decision Making Committee (**DMC**) has requested a further statement of evidence addressing the *"materiality"* of the additional sediment plume modelling that was completed following the second conferencing session of Sediment Plume Modelling experts.

8. This evidence is prepared in response to the DMC's request and is directed specifically at the work undertaken to establish parameters for a worst case model scenario for the dredge plume modelling.

MATERIALITY OF MODELLING

9. The DMC requested a second conferencing session for Sediment Plume Modelling be held on 23 February 2017, in order to define a worst-case scenario for the plume modelling. A second joint witness statement was prepared to document the outcomes of this conferencing session.

10. The experts agreed that insufficient evidence was provided as part of TTR's application to assess sufficiently accurately a number of important aspects of the potential release of fine sediments, which meant that no agreement was reached on key input parameters for the worst case scenario. Consequently, it is uncertain whether or not the additional modelling undertaken will represent the assessment of the worst case sediment plume resulting from the proposed mining activity.

11. It was agreed by the experts that there was insufficient information to validate the assumptions made regarding the maximum release rate of fine sediment from the Integrated Mining Vessel (**IMV**). The experts have not

been provided with adequate evidence to determine the average particle size distribution (**PSD**) of the run of mine (**ROM**) and the variability in the PSD throughout the mining area.

12. TTR's experts have referred to the proposed mining activity as being akin to large scale dredging projects. Therefore, international best practice assessment approaches for dredging projects should be applied to the impact assessment for TTR's proposal. The Australian National Assessment Guidelines for Dredging (Australian Government, 2009) (**Guidelines for Dredging**) provides international best practice guidelines for sampling and analysis of sediments, including testing methods for particle size distribution investigations. I attach a copy of the Guidelines for Dredging to this statement as **annexure** "**A**".

13. The Guidelines for Dredging recommend laboratory testing is undertaken by experienced, registered laboratories that apply proven methods and have an appropriate quality assurance and quality control system. With regards to reporting of sediment analysis, the Guidelines for Dredging recommend that as part of any application for a dredging permit, a sediment sampling and analysis report is provided. All field and laboratory data, including laboratory certificates, is to be included in the sediment analysis report. This information was not provided with TTR's application, or TTR's evidence provided in support of application.

14. The Sediment Plume Modelling experts have also not been provided with adequate evidence on the mining operation to validate the effects of processing on board of the IMV on the PSD of the mining tailings, compared to the PSD of the ROM. TTR has advised that, due to onboard processing, a significant portion of the fine sediment is retained in the mined material and not returned to the seabed, but insufficient evidence is provided to validate this assertion.

15. TTR has advised that the highest ultra-fines (<8 µm) content that it could operate at for a period of weeks to one month is 2.25%, and TTR would not mine material with a ultra-fines content of 10%. Accordingly a condition was proposed during the conferencing to limit the ultra-fines (<8 µm) content of the material that would be discharged in the sea over any one week period to 2.25%.

16. It was agreed that in order to establish the worst case fine sediment release scenario the temporal variability in the suspended sediment release from the mining site must be considered. This includes consideration of variability in wave and current conditions, the bed material composition and mining operations.

17. The agreed approach was to include a time varying source term in the worst case model simulations where worst case variation was modelled over periods of weeks to a month, rather than hours to days. The experts agreed that the worst case model simulations should include 3 week periods during which the tailings would be released as a mound on the existing seabed (to represent the initial phase of a new mining lane), and model results were to be analysed at timescales corresponding to these periods of higher releases.

18. However, such analysis is not included in the worst case scenario modelling report, and thus it is unclear how periods of higher releases affect the median and 99^{th} percentile suspended sediment concentration impacts on timescales likely to be most relevant for assessment of the proposal's potential environmental impacts.

CONCLUSION

19. In conclusion, insufficient evidence was provided as part of TTR's application to appropriately assess a number of important aspects of the potential release of fine sediments, which means that there is significant uncertainty as to whether the sediment plume modelling undertaken provides a reliable assessment of the potential suspended sediment plume that could result from the proposed mining activity. Key components of the sediment plume investigation, particularly the assessments to characterise

the sediment properties of the tailings material, do not follow international best practice for assessment of sediment plumes by dredging.

Dated 7th day of April 2017

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Joris Jorissen

ANNEXURE "A"

AUSTRALIAN GOVERNMENT (2009), THE AUSTRALIAN NATIONAL ASSESSMENT GUIDELINES FOR DREDGING, COMMONWEALTH OF AUSTRALIA, CANBERRA, 2009

Australian Government

National Assessment Guidelines for Dredging

2009

National Assessment Guidelines for Dredging

2009

These guidelines were issued under the authority of the Department of the Environment, Water, Heritage and the Arts.

Assistant Secretary
Environment Assessment Branch
Department of the Environment, Water, Heritage and the Arts
GPO Box 787
Canberra ACT 2601

This document is also available on the Internet at:
http://www.environment.gov.au

For bibliographic purposes, these guidelines may be cited as:
National Assessment Guidelines for Dredging, Commonwealth of Australia, Canberra, 2009

Preface

A healthy marine environment is essential for Australia's current and future well being. Australia has entered international agreements and implements legislation to help preserve marine ecosystems and prevent marine pollution.

The international agreement relating to the dumping of wastes and other matter in Australian waters, including dredged material, is called the London Protocol.[1] Australia implements its obligations under the London Protocol through the Commonwealth *Environment Protection (Sea Dumping) Act 1981* (the Sea Dumping Act).

Through the Sea Dumping Act, the Australian Government assesses proposals to load and dump wastes and other matter at sea, permits acceptable activities, and places conditions of approval, to mitigate and manage environmental impacts.

The National Assessment Guidelines for Dredging set out the framework for the environmental impact assessment and permitting of the ocean disposal of dredged material. The framework includes:

- evaluating alternatives to ocean disposal
- assessing loading and disposal sites
- assessing potential impacts on the marine environment and other users, and
- determining management and monitoring requirements.

The Guidelines are intended to provide greater certainty about the assessment and permitting process as well as provide some guidance on opportunities for longer-term strategic planning.

These Guidelines should be read in conjunction with the Sea Dumping Act and its Regulations[2], the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), the *Great Barrier Reef Marine Park Act 1975* (GBRMP Act) and Australia's international obligations outlined in the London Protocol.

1 The *1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972*.

2 The *Environment Protection (Sea Dumping) Regulations 1983*.

Acknowledgements

The *National Assessment Guidelines for Dredging* (2009) have been prepared with the assistance of many organisations and individuals.

Particular thanks are extended to Dr Ian Irvine (Pollution Research Pty Ltd), the primary consultant for developing the technical component of the guidelines. Other important contributors were Dr Graeme Batley and Dr Stuart Simpson (CSIRO Centre for Environmental Contaminants Research), Ms Sue Fryda-Blackwell (Ports Australia) and Dr Rick Krassoi (Ecotox Services Australasia Pty Ltd). Many other agencies, organisations and individuals provided input through the public comment phase and stakeholder workshop.

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1. Introduction

The Australian Government's objectives under the Sea Dumping Act are to protect and preserve the marine environment from pollution related to dumping at sea, minimising impacts on marine living resources, human health and other uses of the marine environment.

The regulatory framework set out in these Guidelines is applied to ensure the impacts of dredged material loading and disposal are adequately assessed and, when ocean disposal is permitted, that impacts are managed responsibly and effectively.

Dredging in Australian waters occurs in a diverse range of environments involving a range of sediments, which vary from clean to contaminated. In areas remote from pollution sources, sediments are unlikely to contain contaminants, while in ports and harbours adjacent to urbanised or industrialised areas, sediments may contain high levels of contamination from metals or synthetic organic compounds. Some marine environments are also more sensitive than others, for example, coral reefs or fish nursery areas, and require a higher level of protection and/or management.

Port operators account for the majority of sea dumping permit applications. Ports are fundamental to Australia's economy and well planned dredging activities, in conjunction with timely and effective environmental assessments, are essential to maximise their efficiency.

The regulatory framework seeks to balance the needs of ports with the protection of the marine environment and the interests of other stakeholders. It provides for the case-by-case assessment of individual dredging proposals, but also encourages longer-term strategic planning, to align the needs and goals of ports with our shared objective of protecting Australia's marine environment.

The Guidelines seek to provide clear, consistent standards and criteria for assessment of dredged material. The Guidelines also seek to facilitate better decision-making by regulators, by improving the quality of information on which assessments are based.

1.1 Using these guidelines

The Legislative Framework includes guidance on the London Protocol and Australian legislation.

The Sea Dumping Permit Process outlines the permit process under the Sea Dumping Act.

The Assessment Framework outlines requirements through:

- Evaluation of Disposal Alternatives and Waste Minimisation
- Assessment of Sediment Quality
- Assessment of Loading and Disposal Sites and Potential Impacts, and
- Management and Monitoring.

Detailed guidance on various aspects of the assessment are provided in Appendices A to H.

2. The legislative framework

2.1 Australian Government responsibilities

There are three key Commonwealth Acts related to the regulation of ocean disposal:

- *Environment Protection (Sea Dumping) Act 1981* (the Sea Dumping Act)
- *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act), and
- *Great Barrier Reef Marine Park Act 1975*.

Figure 1 will assist proponents to identify what approvals are required for proposed activities.

2.1.1 *Environment Protection (Sea Dumping) Act 1981*

Under the Sea Dumping Act, the Australian Government regulates the dumping, and loading for the purposes of dumping, of wastes and other matter at sea.

The Sea Dumping Act applies in all Australian waters, and to all Australian vessels and Australian aircraft, anywhere at sea. Australian waters includes any waters on the landward side of the Exclusive Economic Zone (EEZ), or the Continental Shelf of Australia where it extends beyond the EEZ (**Figure 2**), except areas determined to be Internal Waters. Proponents should contact the Determining Authority to identify the boundaries of Internal Waters within their area of interest.

The Sea Dumping Act implements Australia's obligations under the *1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972* (the London Protocol). The London Protocol entered into force for its parties in 2006.

Annex 2 to the London Protocol sets out the assessment process that must be followed by countries assessing proposals for ocean disposal. Waste Specific Guidances have also been developed to assist in assessing each of the categories of materials that may be dumped under the Protocol. These processes are reflected in Australia's regulatory framework and within these Guidelines.

Australia reports annually to the International Maritime Organization on all permitted and emergency sea dumping activities in Australian waters.

2.1.2 *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)

The EPBC Act has streamlined the environmental assessment and approvals process for actions that are likely to have a significant impact on matters of national environmental significance. It also establishes an integrated regime for biodiversity conservation and the assessment and management of important protected areas.

An activity, or action, will require assessment and approval under Part 9 of the EPBC Act, if it is likely to have a significant impact on one or more of the following matters of national environmental significance:

- World Heritage Properties
- Ramsar wetlands
- Listed threatened species and ecological communities
- Listed migratory species

- The environment of the Commonwealth marine areas
- National heritage places
- Nuclear actions, and
- Actions on Commonwealth land or involving a Commonwealth agency.

FIGURE 1: Legislative framework and permitting requirements

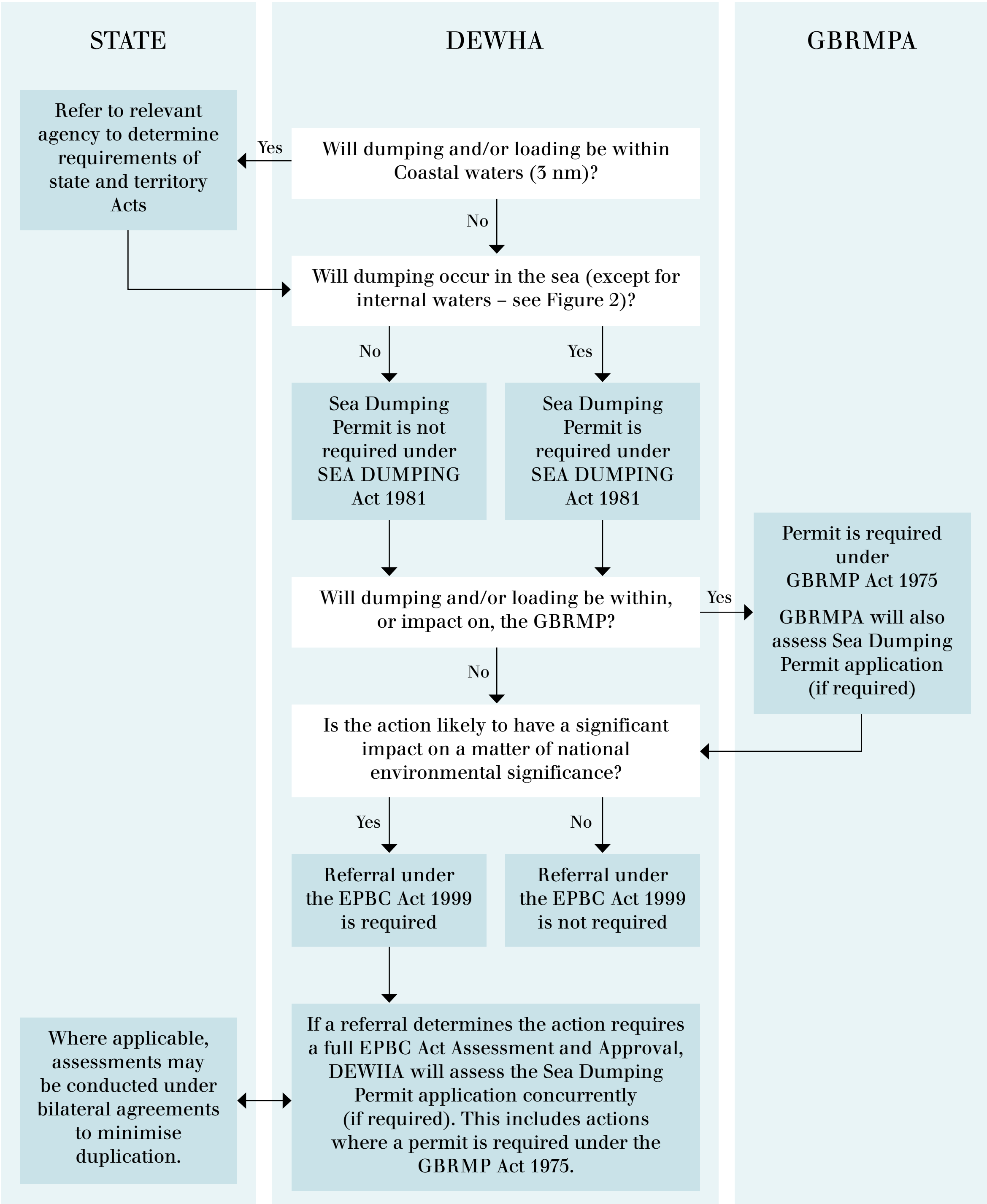
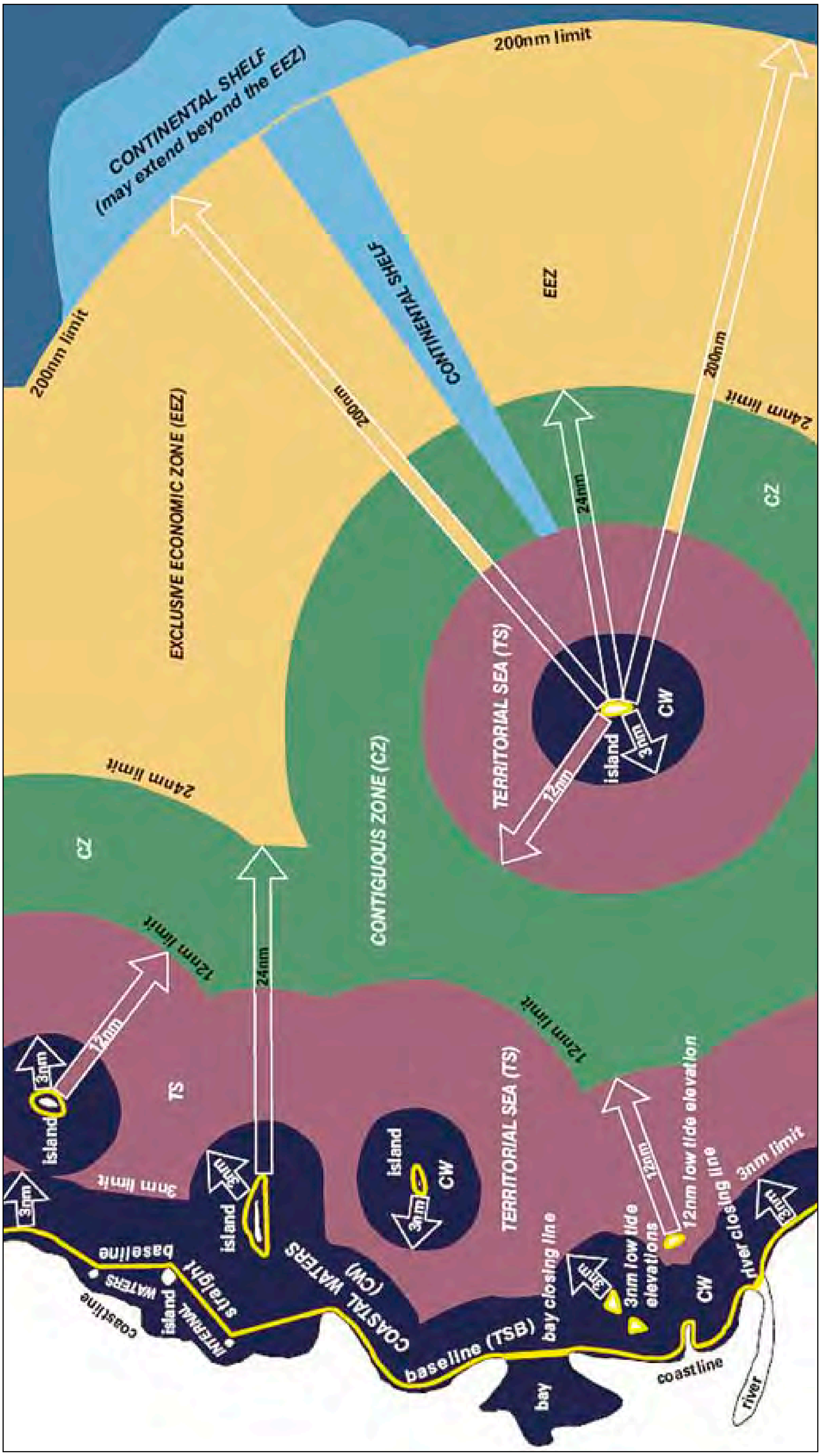


FIGURE 2: Maritime zones in Australian waters
(Copyright: Commonwealth of Australia, Geoscience Australia 2008 www.ga.gov.au)



The Commonwealth has accredited particular state and territory assessment processes under bilateral agreements for the purposes of some EPBC Act assessment provisions. This helps to reduce duplication where assessments are required by state/territory and Commonwealth legislation.

2.1.3 Interaction between the Sea Dumping Act and the EPBC Act

In assessing a permit application under the Sea Dumping Act, the Determining Authority must also consider advice from the Commonwealth Environment Minister (or delegate) (under section 160), if the action is likely to have a significant impact on 'the environment', including an impact within state or territory waters. In practice, an EPBC Act assessment is usually required for such actions, and the granting of a sea dumping permit is based on that assessment and any recommendations following from it.

Where assessment is required under both the Sea Dumping and the EPBC Acts, the assessment processes will be coordinated as much as possible. However, proponents should seek advice from the Determining Authority on the requirements of both Acts, to ensure the project is referred and assessed under both at the same time.

2.1.4 *Great Barrier Reef Marine Park Act 1975*

Within the boundaries of the Great Barrier Reef Marine Park, the Great Barrier Reef Marine Park Authority (GBRMPA) has been delegated authority under the Sea Dumping Act and has legislative authority under the *Great Barrier Reef Marine Park Act 1975* for a range of activities within and outside the Marine Park, including the loading and disposal of dredged material.

Proponents who wish to dredge or dispose of dredged material in the Great Barrier Reef Marine Park should consult GBRMPA[3] about potential direct or indirect impacts of their activities on the Great Barrier Reef Marine Park.

2.2 State Government responsibilities

The Sea Dumping Act does not apply where dumping is to occur entirely in Internal Waters, within the limits of a State or the Northern Territory. Such waters include rivers, the gulfs in South Australia, and some bays, such as Sydney Harbour and Port Phillip Bay. Further information on Australian maritime boundaries can be found through Geoscience Australia's website at www.ga.gov.au. If unsure of whether waters are within the limits of the state, contact the relevant Determining Authority.

For activities that occur 'within the limits', State and Northern Territory Governments are primarily responsible for regulating loading and dumping activities.

In most instances, the States and the Northern Territory have requirements under their own legislation for dredging and dumping that occurs within their adjacent coastal waters to three nautical miles. Proponents should contact the relevant State or Territory authority to determine the nature and scope of any approvals required in addition to the sea dumping permit, such as requirements relating to submerged lands.

There remains a requirement for approval under the EPBC Act, for dredging and dumping activities that occur within waters within the limits of a State or the Northern Territory that are likely to have a significant impact on a matter of national environmental significance.

3 Great Barrier Reef Marine Park Authority, Environment and Assessment Section, Phone: (07) 4750 0700, Email: info@gbrmpa.gov.au

3. The sea dumping permit process

3.1 Requirement for a permit

A permit is required under the Sea Dumping Act to authorise the dumping, and the loading for the purposes of dumping, of any wastes or other matter into Australian waters, or from an Australian vessel or platform, anywhere at sea.

Dumping, or loading for the purposes of dumping, other than in accordance with a permit, is a criminal offence under the Sea Dumping Act, and may incur a substantial penalty (Refer s.36 and s.37 of the Sea Dumping Act), including imprisonment.

At the time a permit is granted, or at any time while a permit is in force, the Minister or Delegate may impose, vary, suspend or revoke any conditions under the permit, and, in circumstances of a breach of the Act or a permit, or in order to properly regulate dumping, may vary, suspend or revoke a permit.

The holder of a permit may also apply for the variation of a permit, or the variation, revocation or suspension of a condition imposed in respect of a permit.

Application forms can be found at: www.environment.gov.au/coasts/pollution.

3.2 Permit process

Application and assessment

The steps involved in assessing permit applications are:

- the proponent considers alternatives to ocean disposal and consults stakeholders
- the proponent undertakes initial discussions with the Determining Authority, to discuss the scope of the project and the anticipated assessment requirements
- the proponent develops and submits a draft Sampling and Analysis Plan (SAP) to the Determining Authority for approval (see also **Appendix B**), unless an exemption from testing has been obtained
- the Determining Authority assigns a project officer, who reviews the draft SAP and its methods, and who may request clarification or further information before the SAP can be approved
- once approved, the proponent implements the SAP
- once the SAP analysis and report, and any baseline monitoring, have been completed, the applicant submits a completed permit application, including SAP results and details of stakeholder consultation, together with all other relevant supporting documentation
- the Determining Authority publishes notice of the application in the Commonwealth Gazette
- the Determining Authority undertakes an initial assessment to determine whether sufficient information has been provided to enable the application to be assessed, if not, additional information is formally requested from the applicant
- the Determining Authority determines whether or not the proposed dumping activity is likely to have a significant impact upon the environment and, if so, advice is sought under Section 160 of the EPBC Act, including an assessment under that Act

- the applicant may be required to undertake additional consultation with stakeholders, particularly once the sediment has been characterised
- once any additional information is received and found suitable, the Determining Authority prepares a final assessment and draft permit decision
- where applicable, the Determining Authority consults with the applicant on proposed conditions
- after comments on the draft permit are received and considered, the Minister or Delegate considers the draft permit and a decision is made
- after a decision is made, details are provided to the applicant – either a copy of the signed permit or a statement of reasons as to why the application was refused, and
- the Determining Authority publishes notice of the decision in the Commonwealth Gazette.

Permit implementation

Permits are granted with conditions which are appended to the permit and specify: approved activity, location and volume of the material to be dredged and location of the disposal site(s); loading and disposal methods and measures to mitigate impacts; environmental monitoring; and reporting. If a permit is granted, it is the responsibility of the permit holder to ensure any conditions required under the permit are incorporated into project planning and implementation. Permit implementation involves:

- undertaking the approved activity in accordance with the details specified in the permit including the volume and type of material to be dumped, location of the disposal site, loading and disposal methods
- development of an environment management plan or other plans (e.g. monitoring, contingency plans), to be approved by the Determining Authority (if required), before loading and dumping can commence
- providing monitoring, adaptive management and additional reporting (if required) during dredging and dumping, if adverse impacts are detected
- auditing of conditions or plans may be required, as may retention of records for audit purposes (the Determining Authority may also undertake its own audit), and
- providing a summary report of the dredging activity to the Determining Authority by 31 January each year to facilitate annual reporting of all dumping permits to the International Maritime Organization, in accordance with the London Protocol.

3.3 Permit duration

Capital dredging

If a permit is granted for capital dredging, it is issued for a period which reflects an appropriate timeframe for the works to be undertaken, determined in consultation with the proponent.

Maintenance dredging

The Determining Authority will grant long-term permits for maintenance dredging on the following basis:

- an assessment of the applicant's capacity to meet their obligations under the Act and any permit granted
- establishment of a Technical Advisory and Consultative Committee (TACC) for long-term management, and

- development and implementation by the applicant of a satisfactory long term Environment Management Plan (EMP) for loading and dumping activities, which provides for sampling and analysis to support future permit applications.

3.4 Fees

Fees reflect the cost of administering the permit process. Fees for permit applications and variations are prescribed under the *Environment Protection (Sea Dumping) Regulations 1983*. Permit application fees relate to the type of material being dumped and, in the case of dredge material, are classified in broad categories relative to the quantity and quality of the material and the duration of the permit sought.

In accordance with the Regulations, the application fee must be paid within 30 days of the application being made and a permit decision, including a permit variation, can not be made before the application fee is paid.

3.5 Timeframes

The statutory timeframe for a decision to grant, or to refuse to grant, a permit, is 90 calendar days from receiving the application. If additional information is required for the purpose of the application assessment, it will be requested in writing within 60 days. The statutory timeframe on the application may be stopped, pending receipt of the information requested. When sufficient information has been received, the statutory timeframe will re-start from Day 1.

3.6 Consultation

Proponents should consult with stakeholders prior to submission of an application. Consultation early in the project, when disposal options are still being evaluated, is preferable and can contribute to achieving broad acceptance of the best solutions.

Formal, written consultation should include providing stakeholders with all the details of the application such as: the alternatives investigated, the proposed location and timing, any contamination issues, predicted impacts, mitigation measures, and proposals for ongoing management and monitoring.

Applications should document the consultation undertaken, the stakeholders engaged, any issues raised and how they were addressed. For ongoing maintenance dredging and new capital dredging in a port, consultation through a Technical Advisory and Consultative Committees (TACC) is recommended. Further consultation may also be required during the assessment process as issues arise. Refer to **Appendix C** for further guidance on consultation.

3.7 Compliance and enforcement

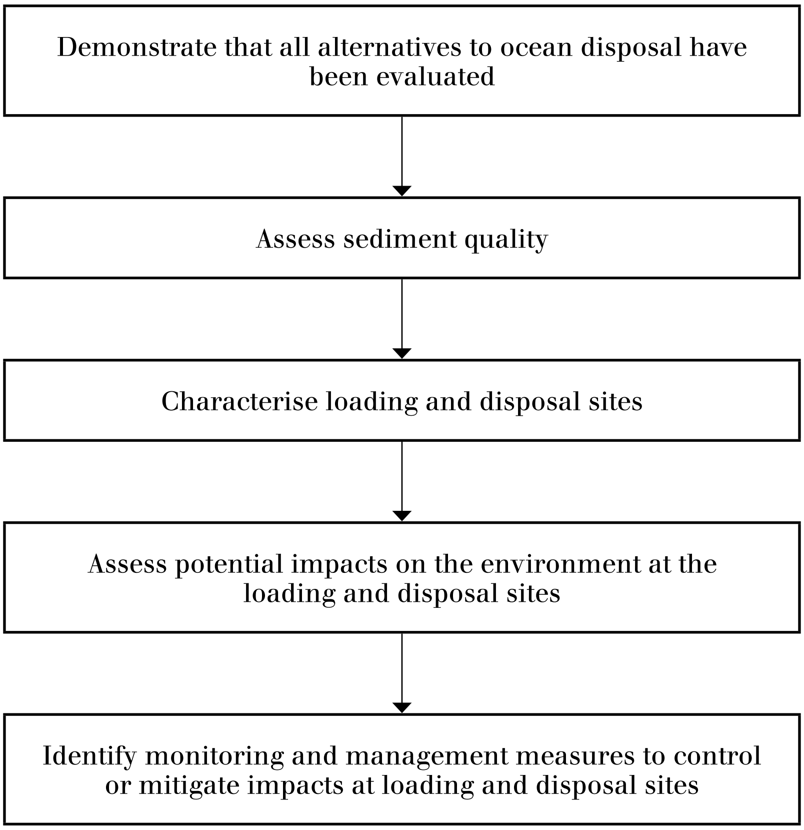
Compliance and enforcement activities under the Sea Dumping Act operate in accordance with the *Compliance and Enforcement Policy*[4]. This document sets out the policy framework used when dealing with possible contraventions of Commonwealth environment legislation.

The purpose of this policy is to inform proponents of the factors that will be taken into account in determining appropriate responses to contraventions, including whether legal proceedings will be pursued. The approach and procedures for individual cases may vary where there are specific legislative requirements.

4 http://www.environment.gov.au/about/policies.html

4. The assessment framework

The **Assessment Framework** involves the following steps:



4.1 Disposal alternatives and waste minimisation

The objectives of the London Protocol and the Sea Dumping Act include minimising pollution caused by ocean disposal. Evaluating the alternatives to ocean disposal and identifying and implementing measures to prevent pollution are important first steps in the assessment process.

4.1.1 Evaluating alternatives

All alternatives to ocean disposal need to be evaluated, including the environmental, social and economic impacts of each disposal option. Consultation with potentially affected stakeholders or potential users of the dredged material will be required.

Important elements of assessing disposal options for dredged material are:

- Are there opportunities to beneficially use or recycle such materials?
- If they have no beneficial use, can they be treated to destroy, reduce or remove the hazardous constituents?
- If hazardous constituents are destroyed, reduced or removed, do the materials have beneficial uses?
- What are the comparative risks to the environment and human health of the alternatives?
- What are the costs and benefits of the alternatives?

It is important to recognise the potential value of dredged material as a resource. Possible beneficial uses include engineered uses (land reclamation, beach nourishment, offshore berms, and capping material), agriculture and product uses (aquaculture, construction material, liners) and environmental enhancement (restoration and establishment of wetlands, upland habitats, nesting islands, and fisheries).

Material which is unacceptable for ocean disposal is, in many cases, quite acceptable for onshore disposal. Often the contaminants of concern will not readily leach in land disposal sites and the dredged material may even gain an inert or solid waste classification, rather than hazardous or industrial waste. Suitability and requirements for determining onshore disposal options should be discussed with State or Territory authorities.

A permit shall be refused if the determining authority finds that appropriate opportunities exist to re-use, recycle or treat material without undue risks to human health or the environment or disproportionate costs.

4.1.2 Waste prevention

A waste prevention audit must be undertaken to identify opportunities for preventing or minimising pollution and any future sediment contamination. The audit evaluates:

- The types, amounts and relative hazard of wastes generated
- The waste sources, and
- The feasibility of waste reduction and prevention techniques.

For dredged material, it should focus on identifying and managing controllable sources of sediment contamination, such as port loading and un-loading activities.

Port authorities would generally be in a position to reduce berth contamination due to careless handling of materials. Some port authorities routinely sample berth faces and adopt a ‘polluter pays’ approach by charging berth users the clean-up costs for any contamination found. This strategy encourages better performance by port users, minimising contamination levels and treatment/disposal costs for ports.

Waste prevention strategies and measures can be included in environment management plans, where they can be a focus for ongoing review and improvement (refer **4.4 Management and Monitoring**).

Application Information Requirements

Applicants need to clearly demonstrate that all alternatives have been evaluated. The above questions should be answered and a discussion of the environmental, social and economic impacts of all options should be included in the application. Reasons for why alternatives are unsuitable should also be included in the application.

4.2 Assessment of sediment quality

This Section provides a decision-tree approach for assessing potential contaminants, comprising five phases as summarised in **Figure 3**. The aim of this assessment is to determine the suitability of the dredged sediment for ocean disposal.

Results of sediment quality assessment can often be equivocal. Accordingly, data must be collected from several lines of evidence (e.g. chemical testing, toxicity testing, bioavailability testing) to allow meaningful assessment of dredged material contamination and its acceptability for ocean disposal. Samples of sediment must also be collected that adequately characterise the sediments to be dredged.

At various points, the material may be classified as suitable for ocean disposal, in which case a sea dumping permit may be sought without further chemical testing. In the very rare cases where a weight-of-evidence assessment may be necessary, it will rely on information provided by all the lines of evidence obtained through these phases.

Physical testing will still be required for the assessment of turbidity, and post-placement behaviour, unless it is demonstrated that the available data is sufficient.

4.2.1 Phase I – Evaluation of existing information

Phase I involves reviewing existing information on the material proposed for sea disposal, to determine which contaminants need investigation and to assess whether the existing information sufficiently characterises the sediments without further testing. Further detail is provided in **Appendix A**.

Existing chemical or toxicity data for the sediments of the area to be dredged will have a maximum currency of five years, where there is no reason to believe that the contamination status has changed significantly, after which new data would need to be gathered. New data will be required where contamination of the site is likely to have increased or new pollution sources are present (such as a new industry or accidental spills). Information and data older than 5 years may be useful in some parts of an assessment to demonstrate trends over time.

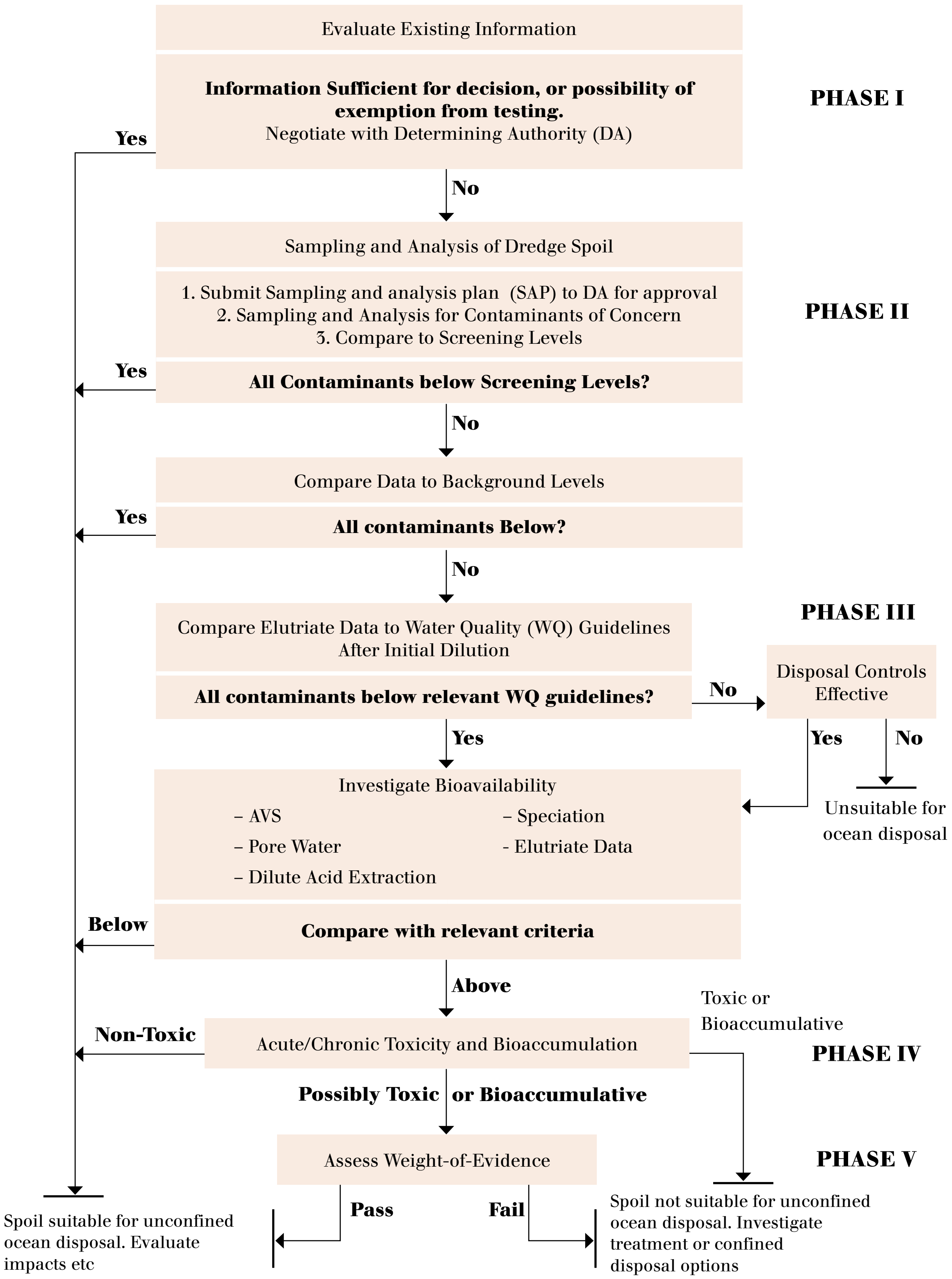
If the proponent believes further testing is not warranted, based on the evaluation of existing information, they should contact the Determining Authority prior to submitting a permit application to seek exemption from further testing.

Data needs to be collated and analysed, with evidence and supporting advice provided to the Determining Authority. Where there is insufficient valid information to identify and/or characterise potential contaminants, the assessment moves to Phase II.

Exemptions from Sediment Testing Requirements

Exemptions from some or all of the sediment testing requirements are possible under certain circumstances. All exemptions require approval from the Determining Authority.

FIGURE 3: Assessment of potential contaminants



Sediments which meet the following criteria may not require further chemical testing:

(a) Dredged material composed predominantly of gravel, sand or rock, or any other naturally occurring bottom material with particle sizes larger than silt, but only where this material is found in areas of high current or wave energy where the seabed consists of shifting gravel and sandbars, or

(b) The site from which the material is to be taken is sufficiently far removed from known existing and historical sources of pollution to provide reasonable assurance that the material has not been contaminated and the material is substantially the same as the substrate at the disposal site.

Example 1. An estuary whose catchment consisted entirely of undisturbed bushland distant from major urban, industrial and agricultural areas could be exempted from testing. However, an estuary with a catchment of undisturbed bushland near a major urban, industrial or agricultural area would not be exempted, nor would an estuary that was undisturbed save for a village or small town or transport corridor.

Example 2. Large capital dredging projects in remote or offshore areas, where there is currently no development which could have resulted in contaminated sediments, may be exempted from chemical testing on the basis that they represent clean natural materials.

The applicant is still required to consider issues such as turbidity, nutrients and environmental impacts despite being exempt from testing.

4.2.2 Phase II – Sampling and analysis of sediments

Phase II involves identifying and investigating the list of contaminants which could be present at elevated levels in the sediments of the dredge area and therefore require analysis (the contaminants list). While the ports and harbours of major cities are likely to contain a wide variety of chemicals, these will vary greatly due to historical and geographical factors. The sediments from smaller ports may be largely clean except in inner harbour and berth areas, or near outfalls and stormwater discharges.

The Determining Authority approves a Sampling and Analysis Plan (SAP) prior to sampling to ensure that adequate data are collected for the assessment process (**Appendix B**). The SAP outlines the dredging proposal (volumes and areas) then sets out the study objectives and the proposed sampling, analysis and quality assurance/quality control procedures.

The draft SAP will need to be reviewed by the Determining Authority and approved prior to sampling, and it is not uncommon for changes to the draft plan to be required. Sufficient time should be set aside for the SAP review process. Detailed guidance on SAP requirements is provided at **Appendix B**.

Where possible, the SAP should include procedures for later stages of the assessment shown on **Figure 3** (i.e. elutriate, bioavailability and toxicity testing). Otherwise, if these procedures are subsequently required, and have not been included in the initial SAP, a supplementary SAP will be required.

Guidance on sampling and analysis methods is provided in **Appendix D**, and on quality assurance and quality control in **Appendix F**.

Phase II assessment procedures include comparison to the Screening Levels at **Appendix A**, and to ambient baseline levels for sediments of comparable grainsize in the vicinity of the disposal site. Where these levels are exceeded, elutriate and bioavailability testing under Phase III is required.

4.2.3 Phase III – Elutriate and bioavailability testing

Sediment contaminants will generally be present in a variety of forms, but only the bioavailable fraction will impact organisms. This will vary with changes in sediment chemistry across an area, with depth, and over time due to disturbance of the sediment (either naturally or from human activity), or from seasonal changes in the sediments or its overlying water column.

Elutriate testing – Elutriate testing assesses impacts to water quality. Test results are normally compared to the relevant ANZECC/ARMCANZ (2000a,b) marine water quality trigger values for 95 per cent protection, or subsequent updates to these values, except where the water body has been zoned to have a higher (or lower) level of protection, in which case the relevant ANZECC/ARMCANZ (2000a,b) trigger values are to be used. If all contaminants are below the relevant guideline values after initial dilution (i.e. after four hours – See **Appendix A**), effects on organisms in the water column would not be expected during disposal. If any contaminants are present at levels above their relevant guideline values, loading and disposal could cause adverse effects on water quality, and loading and disposal controls are evaluated to determine if impacts can be mitigated. If they can be mitigated the assessment proceeds to bioavailability testing. If not, the dredged material is unacceptable for open water disposal.

Bioavailability testing – Bioavailability testing assesses potential impacts on sediment quality. There are a variety of methods available to investigate contaminant bioavailability. If tests indicate that the bioavailability of the relevant contaminants is below the specified criteria, the dredged material is chemically acceptable for ocean disposal. If the bioavailability is above the criteria, the sediment is potentially toxic and the assessment proceeds to Phase IV[5].

4.2.4 Phase IV – Toxicity and bioaccumulation testing

Toxicity testing – Acute and chronic toxicity testing is undertaken when results indicate that the sediment is potentially toxic, and employs a minimum of three sensitive test organisms, representing the main contaminant exposure routes. The proponent needs to justify why the selected tests are considered appropriate. If all tests are passed, the sediment is not considered toxic, and is chemically acceptable for ocean disposal. The guidelines in PHASE IV – TOXICITY AND BIOACCUMULATION TESTING (**Appendix A**) set out assessment criteria for situations where some tests, or some samples, show toxicity while others do not.

Where there are no appropriate toxicity tests which are sensitive near the Screening Levels for particular contaminants, pore water testing should be done and the data compared to the relevant ANZECC/ARMCANZ marine water quality trigger values. In the rare situation where there is no such guideline, or where scattered toxicity has been found throughout a dredge area, and it is not associated with any hot spot, a Phase V weight-of-evidence assessment may be undertaken.

Note that, for marine areas zoned for a high level of ecological protection, any significant toxicity may render the sediments unacceptable for ocean disposal in that area.

Bioaccumulation testing – Bioaccumulation testing is undertaken when the sediment contains bioaccumulating substances, such as mercury, dioxins or organochlorine pesticides, at levels exceeding the ANZECC/ARMCANZ SQG-High values in **Table 4**. Bioaccumulation may be a concern even where toxicity has not been identified. PHASE IV – TOXICITY AND BIOACCUMULATION TESTING (**Appendix A**) sets out assessment criteria for situations where some tests, or some samples, show bioaccumulation while others do not.

5 With the exception of tributyltin (TBT). Standard toxicity testing does not apply as the values for TBT in **Table 2** are based on chronic effects.

Very Small Dredging Programs – The Determining Authority can exempt very small dredging programs (less than 15 000 cubic metres) from toxicity testing in certain circumstances. However, screening, elutriate and bioavailability testing would be required and this exemption from toxicity testing would not apply where such sediments contain bioavailable contaminants exceeding the SQG-High values in **Table 4**. If the sediments contained bioaccumulating substances at levels greater than those set out in **Table 4**, bioaccumulation testing would also be required.

4.2.5 Phase V – Weight-of-evidence assessment

In rare circumstances, as noted above, it may be possible to go beyond the assessment of toxicity (or bioaccumulation) to make a more definitive evaluation of the potential effects of the contaminated sediment after disposal, using a weight-of-evidence assessment. This would occur in the rare situation when there are no appropriate toxicity tests which are sensitive near the Screening Levels for particular contaminants, and no relevant ANZECC/ARMCANZ marine water quality trigger value with which to compare pore water data. It would also occur where the results of toxicity or bioaccumulation testing are equivocal.

A weight-of-evidence assessment takes into account the outcomes of each available line of evidence. Lines of evidence may include:

- Sediment chemistry (including elutriate testing, porewater chemistry and dilute acid extract of metals)
- Toxicity (endpoint relative to negative control), each test type
- Bioaccumulation, and
- Ecology (e.g. benthic community structure).

Each line of evidence is tabulated, ranked, weighted, according to its reliability as an assessment tool and its ecological significance, and they are then combined to arrive at an overall assessment of whether the material is acceptable or unacceptable for ocean disposal**. Appendix A** provides more information on this approach.

Where sediments are found to be unacceptable for unconfined ocean disposal after the weight-of-evidence assessment, and should the proponent, after evaluating alternatives, still wish to consider ocean disposal, they will need to investigate management options, such as treatment, control measures and confined disposal, to see if impacts can be successfully mitigated (see **4.3 Assessing Potential Impacts on the Environment** and **4.4 Management and Monitoring**).

4.3 Assessing potential impacts on the environment

Once it has been determined that sediment is suitable for ocean disposal, an assessment of the potential impacts on the receiving environment should be undertaken. This assessment will inform proponents of the suitability of sites for disposal and will assist in the development of future mitigation and management measures.

Dredging activities may impact the marine environment from both loading and disposal operations. The loading and disposal techniques will influence the potential impacts and their extent, and therefore the information requirements for the assessment of the existing environment.

Potential impacts of loading and disposal elements may include direct and indirect physical impacts, biological impacts, and impacts on other users of the marine environment. The environmental impact assessment will define the nature, temporal and spatial scales, and duration of expected impacts.

Loading site

Sediment is considered 'loaded' once it has been removed from the bottom of the sea floor and has been taken up into the dredging mechanism. Loading site impacts may occur from events such as overflow dredging, clamshell spills and leaking hopper seals. Loading impacts do not include the physical impacts at the dredge head from material that is not loaded (e.g. agitation dredging).

If unsure whether the technique to be used constitutes loading, consult the relevant Determining Authority.

4.3.1 Site assessment

The existing environment needs to be assessed so the impacts of loading and disposal can be assessed and measured. Site assessments will include the collation of a detailed information base drawn from a range of sources from which to make informed decisions about the impacts. Assessments should be consistent with any relevant Commonwealth Marine Bioregional Plans. Assessments should also be made in consultation with users and other stakeholders of potential sites. Ideally, a number of alternative sites will be considered.

At existing loading or disposal sites, much of the assessment information required may already be available. In some cases, further investigation may be needed, where a change in the nature and/or volume of dumping is planned, or to provide data necessary for proper assessment of the environmental impacts at the site over time.

The impact assessment should provide a concise statement of the potential direct and indirect impacts of loading and disposal. These are likely to be influenced by the techniques used to load and dispose of dredged material and the physical properties of the sediment and sites.

There are four key elements to consider in identifying potential impacts.

1. Physical environment

Information required

Information regarding the physical, chemical and biological characteristics of the water column and seabed are required for potential sites. This will include marine surveys and benthic habitat maps as necessary. This may include details of:

- bathymetry and water temperature
- grain size analysis
- whether the disposal site is retentive or dispersive
- proximity to areas of special scientific or biological importance, such as sanctuaries or marine reserves
- extent and condition of existing marine habitats
- proximity to habitats with sensitive receptors such as coral or algal reefs or seagrass, and
- proximity to spawning, feeding, nursery, recruitment, migration and other critically important habitats.

Impact identification

Direct and indirect impacts may result from:

- temporary decreases in water transparency
- increased concentrations in suspended matter
- increased rates in sedimentation
- disposal of sediments with high organic matter
- changes to bathymetry
- changes to sediment composition
- removal or burial of sessile and motile organisms that are unable to burrow up through the deposited layer, and
- introduced marine pests.

Cumulative effects need to be taken into account when repeated or multiple dumping operations occur. It is also important to consider possible interactions with other disposal practices in the area, including historical, existing and planned disposals.

As a result of these effects, direct physical impacts may include:

- reduction of light penetration, leading to sub-lethal effects or death of light sensitive organisms and habitats
- changes to benthic community structures and habitats
- physical collision of the dredge with marine fauna
- reduced vitality or death of sessile benthic fauna through clogging of feeding mechanisms or smothering (especially filter-feeding organisms and sensitive habitats)
- alteration of current velocities and wave conditions affecting sediment regimes and leading to erosion of areas (such as seagrass beds), and
- a reduction in dissolved oxygen levels due to an increase in nutrient concentrations potentially resulting in anoxia/hypoxia.

At a retentive site the impact assessment will delineate the area that will be altered by the dumped material and identify effects to the area. In most cases, the primary dumping zone will be entirely smothered. In this case, the assessment should project the likely time scale of recovery or recolonisation after disposal, as well as the nature of recolonisation (i.e. whether the benthic community structure will be altered). The assessment should also specify the likelihood, scale and severity of residual impacts outside this primary zone.

At a dispersive site, impact assessment will define the area likely to be altered in the shorter term and the severity of any changes. Applicants should also specify the likely extent of long term transport of material from the disposal site, compare this flux with existing transport fluxes in the area and assess the likely scale and severity of effects in the long term.

2. Biological environment

Information required

Biological characteristics of a site may include important, listed, threatened species or communities and migratory species that use the area. Temporal/seasonal and spatial characteristics should be considered, to identify potentially critical times when loading or disposal should not take place including:

- periods of migration from one part of an ecosystem to another (e.g. from an estuary to open sea or vice versa), and
- growing, feeding, resting and breeding periods of sensitive or threatened species.

Impact identification

Potential impacts to the biology of species include

- disruption of the lifecycle (breeding, feeding, migration, resting) of a species
- adversely effecting the spatial distribution of a species
- fragmentation of an important population
- introduction of disease that may impact the population, and
- practices that interfere with the recovery of a species.

3. Other uses

Information required

Consultation with relevant Commonwealth and State environmental, maritime safety and fisheries agencies and other organisations may assist in determining the significance of the loading and disposal sites and nearby areas to other users. Other uses may include:

- shipping lanes and navigation
- military exclusion zones
- engineering uses of the seafloor, including mining or undersea cables
- public use of the shoreline
- prospective oil and gas exploration and development
- fishing, and
- areas of high aesthetic value or of significant cultural or historical importance (e.g. historic shipwrecks).

Impact identification

Potential impacts of the activity on other uses of the sea should be considered. These impacts could be seasonal, temporary or permanent. Displacement of other users may also result in environment impacts in other areas. Human health risks and exclusion of future uses are other considerations.

4. Economic and operational feasibility

Information required

The location and size of the disposal site and its proximity to the dredge site are important issues for the assessment. Information is required to demonstrate that it is:

- large enough, unless it is an acknowledged dispersion site, to have the bulk of the deposited spoil remain either within the site limits or within a predicted area of impact after dumping
- large enough to accommodate anticipated volumes of solid waste and/or liquid wastes to be diluted to near background levels before or upon reaching site boundaries
- not so large that monitoring would require excessive time and money, and
- large enough in relation to anticipated volumes for dumping so that it would serve its function for many years.

Impact identification

The assessment may consider the anticipated loading rates per day, week, month or year and the allowable reduction in water depth over the site from mounding of material. A comparison of the various potential sites will consider the economic and operational feasibility of each site.

4.3.2 Analysis of impacts

Following the identification of potential impacts, a risk assessment may be required. Analysis may be qualitative or quantitative. Methods for risk analysis are described in the Australian/New Zealand Standard for risk management (AS/NZS 4360:1999, HB 203:2000).

Quantitative analysis to address impacts of turbidity in sensitive environments includes physical tests of basic sediment characteristics (**Appendix A**) to predict the behaviour of material after loading and disposal. This would include full grainsize analysis both for the chemical assessment, for prediction of turbidity plume characteristics during and after disposal and to assess whether the material proposed for dumping is physically different to the substrate at the disposal site, so that the post-placement behaviour of the dredged material can be determined. In some cases fine sediments, particularly when removed by hydraulic dredging, can have a very high water content and low density, and can be prone to gravity flow across quite shallow slopes. Such sediments should also be tested in the processed condition (that is, after dredging). This needs to be taken into account in any modeling. It may also be necessary to provide evidence of the calibration and validation of any models using site specific forcing and input data. This will include sediment movement anticipated from loading and disposal, relative to existing sediment levels and movement.

It is considered that the potential for dredge vessels to translocate pest species, whether via spoil or attached to uncleaned equipment is high. Consequently the spreading of marine pests should be considered in all risk analysis of any new dredging operations. Introduced marine species are discussed further in **Appendix E**.

Application Information Requirements

Applicants need to clearly characterise both loading and disposal sites, to inform the assessment of how they may be impacted. This may require baseline assessment of sediments at and near the loading and disposal site as well as nearby sensitive elements of the marine environment and a consideration of other uses of the area.

4.4 Management and monitoring

Once the likelihood and consequence of potential impacts of the activity have been predicted, management measures should be evaluated to determine if the impacts can be controlled or mitigated. Monitoring of environmental impacts and the effectiveness of management measures will be important components in managing impacts. Consideration should be given to adoption of assessment and management approaches consistent with the Environmental Quality Management Framework of the National Water Quality Management Strategy (ANZECC/ARMCANZ, 2000a, b).

4.4.1 Management measures

A range of management options is available to reduce or control the impacts of loading and disposal. Some of these measures, such as the control of overflow dredging, apply during loading, while others apply at the disposal site.

Management measures include:

- *dredged material treatment* – to reduce levels of contaminants
- *loading and disposal management* – to reduce dispersal of turbid plumes in sensitive environments
- *changing the location and/or timing of dredging and disposal* – to avoid or reduce impacts on sensitive benthic communities
- *altering the time of year of dredging and disposal* – to avoid critical life-cycle phases such as coral spawning or whale calving periods, and
- *use of specialised dredge equipment* – such as 'turtle excluding devices', to reduce potential impacts on marine species.

Related issues which need to be considered include:

- availability of suitable equipment for proposed dredging/disposal options
- ability to control placement of the material, and
- ability to monitor the site adequately.

Sediment Treatment Options

Treatment of sediments to remove contaminants may be considered, although treatment methods may be prohibitively expensive. Treatment options include contaminated fraction separation, chemical separation, or instigation of natural geochemical interaction of contaminants with sea water or bottom sediment.

Management Options at the Point of Loading

The dredging method will have the greatest influence on impacts related to loading. Overflow dredging techniques may produce turbid plumes at the dredge site, however, management techniques, such as discharge at water level or below, can greatly reduce turbidity. Targeting particular tidal conditions can also reduce the impacts at sensitive receiving environments. Specialised dredge equipment, such as turtle-excluding devices or silt curtains, can reduce the likelihood of impacts, particularly from mobilisation of contaminated sediment. Silt curtains are ineffective in high wave or current conditions, and are likely to be impractical in large scale dredging.

Procedures for dealing with 'Hot Spots'

Where feasible, pollution 'hot spots' (i.e. a contaminated layer or area whose bulk composition exceeds the guideline values set out in **Appendix A**) will need to be separately handled and subject to effective disposal methods.

However, it may not be feasible to separate and remove the contaminated material in some circumstances. It may be permissible to dump it with uncontaminated material if the two combined materials meet the guidelines set out in **Section C,** e.g. a thin layer (less than 50 cm) of contaminated sediment is on top of or within a less contaminated layer, and the bulk composition of the two layers is acceptable for ocean disposal. The thin layer could not be readily removed by dredging techniques that are routinely available in Australia, which operate on a minimum thickness of approximately 0.5 m.

If contaminated material is unacceptable for unconfined ocean disposal, other options will need to be investigated (e.g. onshore disposal or confined ocean disposal).

Management Options at Disposal Site

Upon release, most dredge material will sink directly to the seabed or form a dense layer of suspended sediment just above it. Generally, this material will settle within hours or days, although if fine and of high water content, it is liable to be resuspended and could be dispersed by currents or waves. In high energy environments, such as those typically found in south-eastern Australia, even sand-sized material will be moved by current and wave action if deposited in water shallower than 60 metres.

However, some of the fines in the spoil will remain in suspension for days and weeks and may be carried long distances by currents before being dispersed. Large dredging programs can produce extensive plumes that cause elevated turbidity levels over large areas for months, with potentially significant impacts to sensitive marine areas or ecosystems. Deoxygenation of the water column may also occur and in shallow (poorly flushed) areas this may persist for significant lengths of time. These effects will require careful scheduling and management.

Where dispersal in the receiving environment is undesirable, disposal should be managed to reduce it in the water column or across the seabed. Options include modifying dredge equipment or timing, thin-layer placement, confined disposal, or the use of sites with particular characteristics (e.g. abiotic areas).

Dredging equipment and timing

Submerged diffusers may reduce water column impacts because they release the dredged material lower in the water column and reduce the velocity of discharge. This can reduce both the spread and re-suspension of fine sediments. Other controls could include changing the rate and timing of disposal.

Thin-layer placement

If burial of benthic organisms is a concern, thin-layer placement may be considered. Deposition of dredged material in a layer of less than 15 cm facilitates benthic organisms burrowing up to the surface and improves the rate of re-colonisation.

Confined disposal

Lateral containment can physically restrict material both during and after disposal, resulting in smaller areas of seabed being affected and also reducing the potential for release of contaminants. Such sites can include existing depressions or borrow pits, or constructed depressions.

Confined disposal, however, presents significant environmental risks and therefore investigation of both the cap and the contaminated materials to be capped would need to be done to a high level of certainty to ensure the long term stability of the material dumped.

Capping involves covering contaminated material with a suitable thickness (generally 1 metre or more) of clean material. This will prevent impacts of contaminants on benthic organisms after the site is recolonised. Capping can take place with or without lateral containment, but is best done in low energy environments where the cap is not susceptible to erosion. Capping in the sea via normal barge dumping is unlikely to be effective where the dredged material is fine material of high moisture content (slurry) as it is likely to be displaced from the depression by the capping process.

Management Plans

Management plans can be a useful way of planning for and implementing management actions to mitigate environmental impacts, as well as capturing management commitments and statutory requirements. For long-term maintenance dredging permits, environment management plans will be integral to the management of dredging, pollution control and reduction strategies, and further research.

Plans should set out the framework for management, mitigation and monitoring of impacts. They should detail the control strategies for the project, including environmental objectives, auditable performance criteria, corrective actions, responsible personnel, monitoring and reporting.

Management plans should generally include the following information:

- *overall management framework* – describe how the plan integrates with the overall management framework
- *context* – put the proposal in the context of the local environment, including history of dredging and dredge material disposal at the site
- *description of the project* – provide information on dredging and disposal for the term of the plan or permit, including the location, staging, and timing of activities
- *information on approvals* – provide details of any approvals, relevant conditions and any other statutory requirements
- *description of the existing environment* – characterise the dredging and disposal sites and adjacent areas, including its water column, sediments, biota, resources and other uses (existing and potential) of the area
- *description of the material for disposal* – provide a summary of sediment types, their status relevant to the values in these Guidelines
- *description of potential impacts* – address both potential short-term and long-term impacts and any uncertainties regarding the predicted impacts
- *management strategies and actions* – describe strategies and actions to mitigate impacts – including specific and auditable measures; performance indicators; monitoring requirements; corrective actions; and responsibilities and timing for management and monitoring activities
- *contingency arrangements* – identify corrective actions and contingency plans should undesirable or unforseen impacts occur
- *continuous improvement* – identify opportunities for continuous improvement to prevent, minimise or mitigate environmental impacts in the longer term
- *auditing requirements and reporting* – outline reporting and documentation standards, timing and responsibility of any auditing or reporting
- *review of management plan* – make provisions for a review of the management plan, including consultation with the TACC, to ensure it remains current.

4.4.2 Monitoring

Monitoring requirements are likely to be site and project specific. Monitoring programs should be developed in conjunction with stakeholders, usually through the TACC, and with the Determining Authority. Monitoring will be a key component of any environmental management plan.

In addition to any monitoring undertaken during the assessment, there are two types of monitoring – compliance monitoring and field monitoring. Compliance monitoring measures compliance with the approved project and permit conditions, while field monitoring measures the condition, and changes in condition, of the receiving environment.

Turbidity can have direct physical and ongoing effects (through resuspension and resettlement) and requires monitoring in sensitive areas during loading and dumping, as well as post-impact monitoring of the extent of sediment smothering, if any.

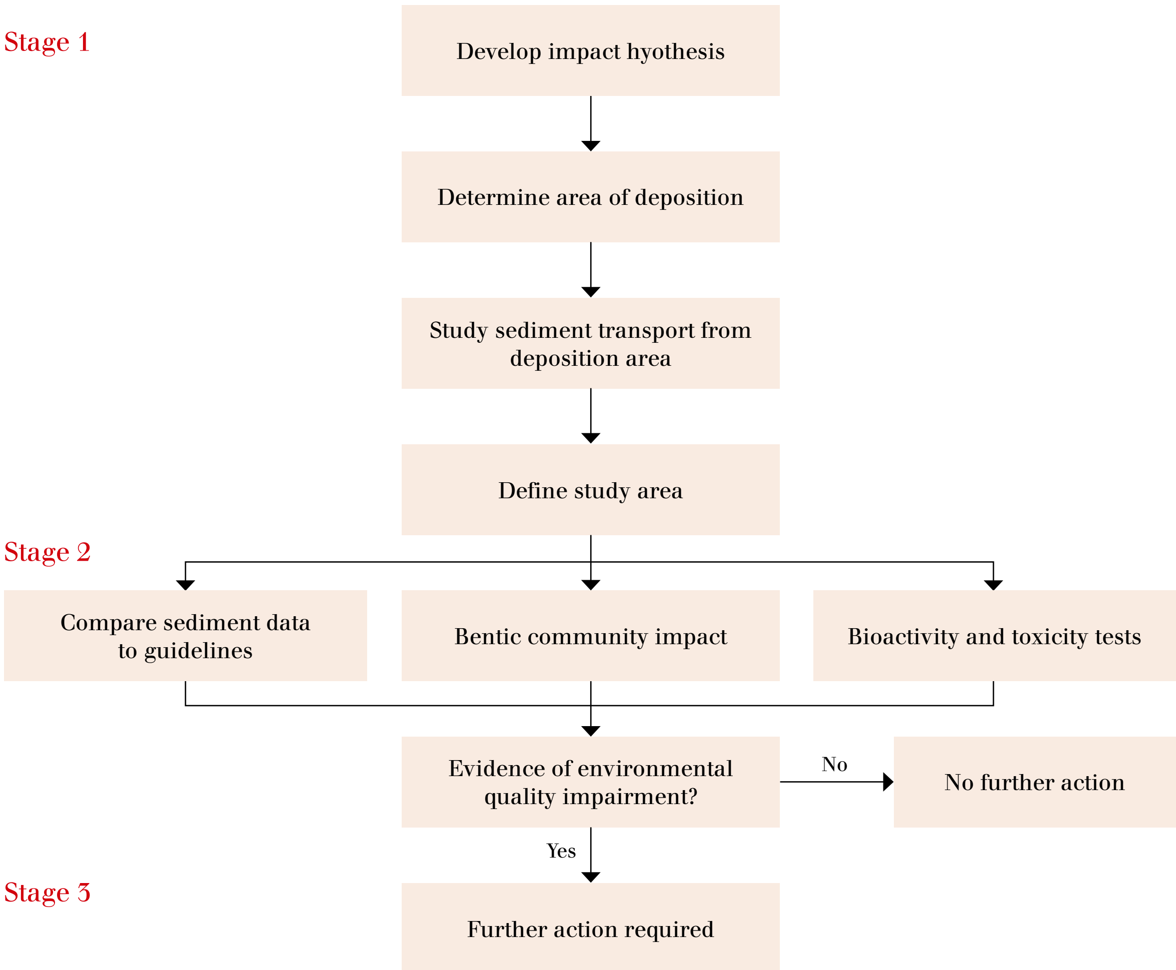
Monitoring the toxic contaminant effects on water quality and water-borne biota is generally not practicable and potential impacts are taken into account in elutriate testing. Therefore, monitoring generally concentrates on effects on the benthos.

A staged approach to monitoring is usually undertaken (see **Figure 4**). Note that not all stages are always required, and for some locations, site specific concerns may necessitate other kinds of investigations. **Appendix G** details examples of impact hypotheses and associate monitoring requirements.

Stage 1 of the investigation involves physical monitoring. It involves the collection of data on the areas of deposition, defining site boundaries, determining the extent of accumulation of material within the areas of deposition, and the transport of material away from the sites.

Stage 2 involves biological and chemical measurements.

FIGURE 4: Staged disposal site monitoring framework (after EC, 1996)



Stage 3 investigations would only be necessary where data collected in Stages 1 or 2 indicates that the environmental quality of the study area may be impaired. Investigations could include further chemical and biological assessment, investigation of the long-term stability of the disposal site or *in situ* biological investigations.

The assessment of impacts helps define post-operational monitoring. While monitoring will need to be tailored to each dredging and dumping site, general guidance is provided in **Appendix G**.

Application Information Requirements

If the proponent believes impacts can be mitigated, the application will need to include reasoning and supporting evidence as to why disposal would not cause adverse environmental impacts.

Proposed monitoring and management measures will need to be provided in sufficient detail to allow an assessment of their likely effectiveness. Submission of a draft management plan is one option for detailing management measures.

Appendix A:

Dredged material assessment – detailed guidelines

About these detailed guidelines

The guidelines in this appendix detail the sediment assessment framework. They should be used in conjunction with best practice, published and accepted scientific standards, such as marine water quality guidelines or *contaminated* soil guidelines. For example, the *Handbook for Sediment Quality Assessment* (Simpson *et al.*, 2005) summarises the latest science in relation to sediment quality investigation and assessment, with particular reference to Australian conditions.

The sediment assessment includes a decision-tree approach for assessing potential contaminants, comprising five phases:

Phase I – evaluation of existing information

Phase II – sampling and analysis of sediments

Phase III – elutriate and bioavailability testing

Phase IV – toxicity and bioaccumulation testing, and

Phase V – where necessary in rare cases, a weight-of-evidence assessment.

Figure 5 sets out the framework for investigation and assessment of dredge material.

Phase I – evaluation of existing information

The objective of Phase I is to review existing information to determine whether there is sufficient data for an informed assessment, or whether further testing is necessary. If further testing is required, the Phase I review will also assist the design of the sampling and analysis plan (see **Appendix B**).

Previous history of the area to be dredged and its catchment area

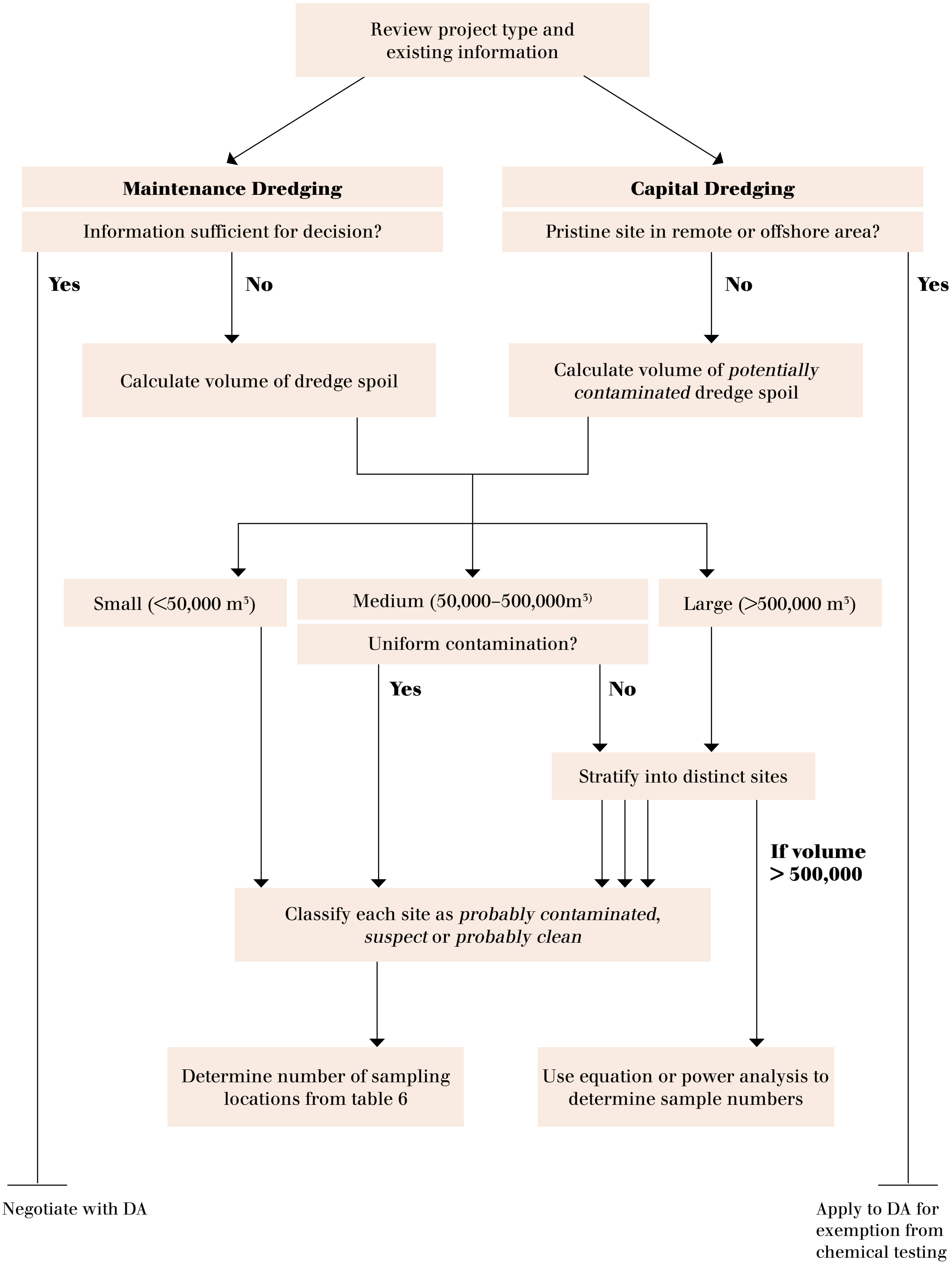
This should focus on potential pollution sources (such as mining, industry, agriculture, transportation or urban areas), the location of effluent or stormwater discharge points into the waterway, any discharges, leaks or spillages from port operations or nearby contaminated sites, as well as previous dredging, dumping, solid waste disposal or land-filling.

Useful References

Lists of industries and land uses associated with contamination can be found in El Saadi & Langley (1991), ANZECC/NHMRC (1992) and in detail in Shineldecker (1992). Edwards *et al.* (1994) present a detailed approach to the historical appraisal of contaminated sites.

The National Environment Protection Council's Assessment of Site Contamination Measure, NEPC 1999, and its individual Schedules B(1) – (10), all available on the http://www.ephc.gov.au/ website, set out current Australian guidelines for contaminated site investigations.

FIGURE 5: Sampling design decision tree for the assessment of contaminants



DA = Determining Authority

Site condition

Potential pollution problems from onshore sites may be identified by inspecting the site (ANZECC/NHMRC 1992). The presence of waste, oils or other materials in drains may also indicate contamination of adjacent sediments.

Previous studies of the area to be dredged

Sediments from major ports will have been studied previously, and even in small coastal towns and villages there may have been relevant investigations. A search should include files of government departments, the scientific literature, environmental and planning studies, unpublished consultant's reports and postgraduate theses for studies of sedimentology, sediment and water pollution, oceanography and marine ecology relating to the area to be dredged.

Relevant data includes bathymetry, chemical data, sediment grain size, distribution and layering, sediment transport, currents, waves, storm events and marine ecology. All data should be reviewed to determine its quality in terms of field sampling methods and quality assurance/quality control (QA/QC) procedures, as well as laboratory QA/QC and data validation.

Existing good quality data can significantly reduce the amount of sampling and analysis required. Preferably, data should be less than 5 years old. However, data of unproven quality should not be discarded, as it may still provide an indication of sediment chemistry, but less reliance can be placed on it. Information older than 5 years may also be useful to demonstrate trends over time.

Where testing has previously demonstrated the absence of certain substances (e.g. organochlorine pesticides or PCBs) but at less stringent Practical Quantitation Limits (PQLs) than those listed in **Table 1**, analysis of samples to the current PQLs would be necessary, if the site history indicates that such substances could be present.

Contaminants List

From the above data, the contaminants which need to be investigated can be identified (the Contaminants List). The Contaminants List should include:

- toxic substances known, from previous investigations, to occur in dredge area sediments at levels greater than one-tenth of the Screening Levels (**Table 2**), or
- based on the historical review, substances potentially present at such levels in the sediments to be dredged.

The investigation level is one-tenth of the Screening Level so as to pick up the key contaminants which could be present. If the investigation level were set higher, e.g. at the Screening Level, some potential contaminants might be omitted from analysis, yet could be present in the dredge sediments at significantly higher levels than have previously been found. That assumption, i.e. that the highest levels of contaminants in a dredge area had already been identified, is unwarranted and dangerous.

If, based on the evaluation of existing information, the proponent believes further testing is not warranted, they can contact the Determining Authority prior to their permit application, to seek exemption from further testing. This can avoid stopping the statutory timeframe to seek further information during the assessment.

If further testing will be necessary, specific testing requirements are set out in a Sampling and Analysis Plan (SAP), in Phase II of the assessment process.

Phase II – sampling and analysis of sediments

Sediment investigation aims to collect and analyse representative samples that adequately characterise the sediments to be dredged. Single samples plus a percentage of replicates are adequate for initial sampling, however for bioavailability and toxicity testing, a greater degree of compositing and/or replication is necessary to ensure representativeness, given the smaller number of samples taken. Screening Level values (**Table 2**) are used for the initial assessment. If they are exceeded, further testing (Phase III) is required to determine if the dredged material is suitable for ocean disposal.

Before any sampling takes place, the proponent develops a draft Sampling and Analysis Plan (SAP) (see **Appendix B**), to detail the proposed sampling and analysis methods, and submits this to the Determining Authority for approval. Where possible, the SAP should include procedures for later stages of the assessment shown on **Figure 3** (i.e. elutriate, bioavailability and toxicity testing). If these procedures are subsequently required, and have not been included in the initial SAP, a supplementary SAP will be required.

Each step of the study must employ appropriate QA/QC, including documentation. Guidance on sampling methods and design is provided at **Appendix D.**

ANALYTICAL PARAMETERS

Contaminants List

The potential contaminants are generally identifiable from the site history and previous sediment survey data. **Table 1** lists the principal groups of contaminants that could be present. Other contaminant groups may occasionally be present.

For large projects, where insufficient current information exists, a pilot study may be appropriate to determine the Contaminants List. In such a study, approximately 20 per cent of the sampling locations required to characterise the sediments (see Table 6) (randomly selected from the area to be dredged) would be analysed for all contaminants that are likely to be present, based on the site history. Where certain chemicals or chemical groups are not found at significant concentrations, these may, with the agreement of the Determining Authority, be removed from the analysis list for the remaining 80 per cent of the samples. The latter samples are to be analysed for all the chemicals or chemical groups remaining on the Contaminants List. The Determining Authority may add other contaminants to the list.

Once the list is determined, the number of sampling locations is based on the volume of potentially contaminated material to be dredged (see **Appendix D**).

Testing for other chemicals for which guideline values do not currently exist and inorganic and organic compounds may be required if a particular source is identified near a dredging site. For example, if mineral sand concentrates are being handled in bulk in an area, in may be necessary to analyse for radionuclides. Detection limits cannot be specified for all possible substances but, ideally, should be no greater than one tenth of the lowest value found in the sediments. Appropriate PQLs may be found in the scientific literature and need to be approved by the Determining Authority.

If the sediments to be dredged appear littered with significant amounts of garbage material (such as, bottles, cans or other street litter), the material may be unacceptable for ocean disposal. Again, the applicant should consult the Determining Authority.

Key Contaminants in Australia

The common metals and metalloids (e.g. copper, lead, zinc, chromium cadmium, nickel, mercury and arsenic) are the most widespread pollutants in Australia, being present in most contaminated sediments, sometimes at high levels.

Organotin compounds are common contaminants in ports and harbours and are frequently present at high levels in berths and inner harbour areas.

Petroleum hydrocarbons and polycyclic aromatic hydrocarbons (PAHs) are also common but are normally found at elevated levels only in restricted locations.

Organochlorine pesticides and polychlorinated biphenyls (PCBs) are common in a few harbours but absent from many.

Sediments in cities and near industrial areas commonly have multiple groups of pollutants. Other contaminants may only be associated with specific industries, for example, dioxins with pesticide or paper-making plants, radionuclides with mining or mineral processing, sulphate with mining, chlorinated compounds with chemical plants, non-organochlorine pesticides with agriculture or pest control.

Practical Quantitation Limits (PQLs)

The Practical Quantitation Limits (PQLs) set out in **Table 1** are those necessary to accurately determine contaminant concentrations at, or near, natural levels, or to reliably detect organic substances that may have impacts at very low environmental concentrations. Laboratories in Australia have demonstrated the ability to meet these PQLs. The applicant will need to select a laboratory that is capable of achieving these levels.

In some cases, detection of very low levels may be affected by matrix interference. In this situation, the laboratory should strive to achieve the lowest PQL possible in these samples and document this in the report.

TABLE 1: Practical quantitation limits for typical sediment contaminants, and other analytical parameters	
Parameter	Practical Quantitation Limit (PQL)
1. Basic Sediment Characteristics	
Moisture Content	0.1%
Total organic carbon	0.1%
Particle size and settling rate	Size distribution (sieve + hydrometer) and rates of settlement after 50% and 90% of settlement, in seawater if possible.
Bulk density of deposited sediment	
Shear velocities required for resuspending or remobilising the material.	
2. Organic Compounds	
Petroleum hydrocarbons	100 (mg/kg)
Phenol, phenolics	1 (mg/kg)
Volatile chlorinated hydrocarbons	0.05–5 (mg/kg)
Organochlorines including: total chlordane, oxychlordane, dieldrin, heptachlor, heptachlor epoxide, methoxychlor, endrin, DDD, DDE, DDT, alpha and beta BHC, endosulfan (total alpha, beta and sulphate), hexachlorobenzene, lindane, aldrin	1 (µg/kg=ppb) (each individual species)
Total PCBs	5 (µg/kg)
Polycyclic Aromatic Hydrocarbons, including: Napthalene, 2-methylnapthalene, acenapthalene, (each individual species) acenapthene, Fluorene, Phenanthene, Anthracene, Benz[b]fluoranthene, Fluoranthene, Indeno[1,2,3-cd]pyrene, Benzo[k]fluoranthene, Chrysene, coronene, Dibenz[ah] anthracene, Benzo[e]pyrene, benzo[a]pyrene, perylene, pyrene	5 (µg/kg)
Sum of PAHs	100 (µg/kg)
Chlorobenzenes	50 (µg/kg)
Other chlorinated organics	varies
Benzene, toluene, ethylbenzene, xylene	200 (µg/kg)
Non-organochlorine pesticides, including: organophosphates, carbamates, pyrethroids, herbicides	10–100 (µg/kg) each individual
Miscellaneous organics	varies according to toxicity
Dioxins	0.02 µg/kg
Organotin compounds	1 µgSn/kg*

Parameter	Practical Quantitation Limit (PQL)
3. Inorganic Compounds	
Metals and metalloids (mg/kg)	
Copper	1 (mg/kg)
Lead	1
Zinc	1
Chromium	1
Nickel	1
Cadmium	0.1
Mercury	0.01
Arsenic	1
Silver	0.1
Manganese	10
Aluminium#	200
Cobalt	0.5
Iron#	100
Vanadium	2
Selenium	0.1
Antimony	0.5
Cyanides	0.25 (mg/kg)
Nutrients	0.1 (mg/kg)
Ammonia	0.1 (mg/kg)

* Microgram tin per kilogram
\# Not toxic contaminants but included because they can be useful normalising elements

Physical Tests

When dredged material is released from a vessel, most of it will sink directly to the sea bed or form a dense layer of suspended sediment just above the sea bed. Generally this material will settle within a period of hours or days, although if fine and of high water content it is liable to be resuspended and may subsequently be dispersed by currents or waves. In high energy environments (e.g. southeastern Australia) even sand-sized material will be moved by current and wave action if deposited in water shallower than around 60m, and is likely to be dispersed over such a large area of the sea bed that monitoring will be unable to detect it.

Physical tests of basic sediment characteristics (**Table 1**) must be sufficient to determine the likely behaviour of dredged material after disposal. These tests include grainsize, settling rate (ideally done in water of the same salinity as exists at disposal site, although flocculation may preclude this), the bulk density of deposited sediment, and shear velocities required for resuspending or remobilising the sediment.

SAMPLE ANALYSIS

Laboratory Requirements

It is important to use experienced National Association of Testing Authorities (NATA)-registered laboratories with proven methods, with a high degree of quality assurance and quality control, and to check results with a reference laboratory.

Laboratories should have a current NATA registration for the specific chemical and physical parameters being analysed, except for specialised analyses for which no NATA-certification is available. They should be able to demonstrate expertise in analysing marine sediments, as some of the analytical problems encountered are different to those from analysing other environmental samples, and some laboratories are unable to achieve the required Practical Quantitation Limits in **Table 1**.

The transmittal sheet or chain-of-custody (CC) form that accompanies the samples should indicate clearly when the samples are of marine origin. The proponent should be satisfied that the laboratory is using methods designed to overcome interference from high salt levels. Written verification of methodologies and LORs should be sought and these verified against requirements prior to commencement of sampling/analysis, as use of unsuitable analysis methods is common even when the CC forms are clearly marked 'Marine samples'.

Laboratories must have an appropriate quality assurance and quality control (QA/QC) system in place.

Sample Pretreatment

For bulk sediment chemical analyses, the whole sediment sample should be analysed after removing gravel-sized (>2 mm) material and the sample should either be ground to ensure homogeneity or analysed wet if homogeneity can be demonstrated.

The transmittal sheet or CC form should specify removal of gravel, and homogenising of the sample if this is not done before submission to the laboratory.

For the non-volatile metals a standard, strong acid extraction is recommended (e.g. USEPA Method 200.8), as this is the most widely used extraction procedure, enabling comparison between the majority of data sets already available. USEPA (1991) states that the standard aqua regia extraction used in this method yields consistent and reproducible results, although it may provide lower metal recoveries in the presence of organic matter, and therefore Method 3050B, which includes peroxide in the digestion step, may be more appropriate.

Dilute acid extraction (e.g. with 1 M HCl) is not recommended because the Screening Levels in **Table 2** have been derived from strong acid analysis data, and such data are therefore needed for purposes of the comparison. However where the total metal values are known to exceed the Screening Levels, it would be acceptable to proceed directly to dilute acid extraction. Dilute acid extraction is also useful for bioavailability assessment of metals.

Volatile metals such as mercury should be analysed on wet samples.

For organics, most samples should be extracted wet, using a water-miscible solvent and, if dried and ground, air or freeze drying is recommended. Volatile organics such as petroleum hydrocarbons are determined on wet samples from glass containers with Teflon-lined lids, without homogenisation or sieving.

Sediments for bioavailability testing, and especially pore water testing, or speciation will require special handling procedures. Where in doubt, consult the analysing laboratory as to their particular requirements.

Chemical Analysis of the Total Sample

The recommended procedures are those specified in USEPA (1991 and subsequent updates) that are already widely used in Australia, or other standard methods suitable for marine sediments, for example, the UNEP Reference Methods for Marine Pollution Studies. The USEPA (1991) methods are based largely on USEPA (1986, SW-846) which is regularly updated and available online.

Laboratories may use alternative or modified procedures where these methods demonstrably provide the necessary performance characteristics and are validated on the USEPA methods using standard reference materials (as is current practice in Australia). This should be stated in the SAP. Up-to-date methods are available on the USEPA website.

Analytical methods are not specified further to ensure flexibility in choosing analysts. For most parameters there are a variety of acceptable methods and laboratories should be free to choose any standard method that provides the required quality of results. However, these methods should be clearly outlined in the SAP.

Tributyltin (TBT)

Analysis of sediment samples for TBT presents a range of difficulties which have to do with sample inhomogeneity (TBT may be present in paint flakes that may not be randomly distributed), sample extraction and analysis. This may lead to poor replication and hence difficulty in determining the true value of TBT in the sample.

Where the data from a site are highly variable, more samples or a significantly higher number of replicates is indicated. The number of samples required to adequately characterise an area can be determined, assuming there is existing data on TBT, by power analysis (**Appendix D**).

Total Organic Carbon

Total organic carbon (TOC) should be determined using a high temperature CO_2 analyser *after* dilute acid treatment to remove carbonates and bicarbonates. Proponents should check this has been done, as failure to remove carbonates is a common laboratory error. The loss on ignition method should not be used as it does not give reliable results on marine sediments[6]. Sediments which contain significant amounts of coal or coke waste will give erroneously high results using this method. Where coal or coke waste could be present, sediments should be visually inspected.

Where sediments contain high concentrations of hydrophobic organics, e.g. PAHs, the black carbon (i.e. soot) content may need to be determined as well as total organic carbon, as hydrophobic organics are typically much more strongly associated with black carbon than with other natural organic matter (Simpson *et al*., 2005).

All data for organic contaminants is normalised to the TOC concentration, which provides a measure of bioavailability.

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6 It can be affected by other substances that decompose at 550°C.

Physical Tests

Grain size analysis should be measured by wet sieving of the coarse fraction into standard geological size classes, followed by pipette or hydrometer analysis of the fines, or other standard methods.

Data Validation

Sediment surveys frequently require analysis for a great many metals, inorganics and organic compounds. The chemical matrix of sediments is complex and contains many compounds that can interfere with analysis. This is particularly so for analysis of organics because sediments frequently contain thousands of naturally-occurring organic compounds, some of which can generate a false positive (that is, a compound will appear to be detected that is not actually present).

False negatives can also occur if the signal from the compound being determined is swamped or suppressed by another very abundant compound. This problem is particularly acute for trace and ultra-trace organics, such as organochlorine pesticides, PAHs and other pesticide groups.

Evaluate the following factors when validating analytical data.

Blanks

Laboratory blanks are samples processed and analysed in the same way as the sediments, the aim being to detect any contamination resulting from sample preparation, extraction or analysis. Blanks should be at or near the detection limit of the method used. The statement of analytical results should note whether analyses are corrected for the blank values (analysis values within 5 times the blank values should be flagged as estimates rather than precise values).

Standards

Standard samples are sediments of known composition that are included in each batch as a check on analysis accuracy. Laboratories analysing marine sediments will already have appropriate standards for metals (see **Appendix F**). The values found by the laboratory should be within the certified value for the individual standard (typically 80–120 per cent of the certified value). Where recoveries lie outside this range the analyses should be qualified as either low or high. Obtaining standards for volatiles and many organics is not possible due to holding times, and laboratory control samples should be used instead (NEPC 1999), comprising either a standard reference material or a control matrix fortified with analytes representative of the analyte class.

Spikes

Matrix spikes should apply to all tests, including metals, before extraction or digestion, and are used to prove that an analyte can be added to and then detected in sediment samples. Given the substantial interferences that can occur at trace level this is a key Data Quality / Quality Assurance parameter and provides significant information. When the recovery of a matrix spike is below that expected for the analytical method performance this may indicate matrix interference or heterogeneity. Further investigation may be warranted including alternative methods to accurately measure the analyte in the extract. Matrix spike data should not be reported if the naturally occurring levels in the sample are greater than twice the spiking level (NEPC, 3B, 1999).

Where appropriate, e.g. chromatographic analysis of organics, surrogate spikes should be added to all analyses, before extraction. Surrogate spikes are known additions to each sample, blank, reference material, duplicate and matrix spike, of compounds that are similar to the target analytes of interest in terms of extraction, recovery and response. Surrogates however must be compounds which are not expected in real samples and will not interfere with quantification of target analytes. The purpose of surrogate spikes is to provide a means of checking every analysis to ensure that no gross errors have occurred at any stage of the procedure.

Recovery rates should be within the limits specified for the analysis method (typically 75–125 per cent). Duplicate samples are to be spiked and the duplicates should agree within the specified relative percent difference (RPD) for the method (typically ±30–35 per cent).

Replicate and duplicate samples

The precision (or repeatability) of the analyses is determined with duplicate samples. Laboratory duplicates (that is, separately extracted splits of a single mixed sample, not aliquot splits after extraction) should be within an RPD of ±35 per cent. If not, any batch of samples where the RPDs fall outside these limits are to be flagged as estimates rather than precise values.

Field replicates (that is, two separate samples taken at the same location) should agree within an RPD (or for three or more samples at the one location, the relative standard deviation, RSD) of ±50 per cent, although they may not always do so where the sediments are very heterogeneous or greatly differing in grain size.

Other factors that need to be monitored include:

- if the laboratory met the Practical Quantitation Limits required for all parameters
- whether holding times (that is, the maximum permissible time from sampling to analysis) were met, and
- completeness (that is, the amount of valid data obtained for the study). This can be affected by missing samples, analytical problems or data that are qualified under the above headings. Completeness should not normally be less than 95 per cent.

Appropriate care should be taken when entering the laboratory data into spreadsheets or databases. Ensure all data are checked for correct entry.

Outliers

It is not uncommon for outliers to occur in chemical data sets, particularly for TBT, and these may be due to laboratory or other errors. Outliers can be detected by standard statistical means such as box or scatter plots, or values exceeding two standard deviations. Where outliers are detected, the stored portion of the sample should be reanalysed in triplicate, and if the original result is not confirmed it can be discarded (TBT only) in favour of the mean of the triplicates e.g. if three replicate measurements of sediments give, 10, 15 and 500 µgSn/kg results (average = 175 µgSn/kg), whereas re-sampling and analyses result in (e.g.) <10, 14, 50 µgSn/kg, then the value of 500 can be completely discarded (average = (10+15+10+14+50)/5 = 20 µgSn/kg), but referenced as an 'outlier' that likely results from 'infrequent paint flakes' (or similar, as appropriate).

DATA ANALYSIS AND REPORTING

The laboratory analysis results should be tabulated with the actual field sample numbers used and the laboratory identification numbers. All quality assurance data (blanks, laboratory duplicates, spikes and statistical research methods) should be reported for each sample batch analysed. Completed results should be emailed to applicants and/or their consultant, for review so that any unusual values can be queried and the samples reanalysed before their holding time has expired. Holding times are presented in **Appendix H**. Holding times for certain substances may be considerably longer than those specified, however suitable references would need to be provided to justify reliance on them.

Include all field and laboratory data, including original laboratory certificates, in the SAP report. The report should also evaluate the quality control data, including whether the data quality objectives in the SAP were met, and which, if any, results were qualified because they failed to meet data quality guidelines.

After data validation, tabulated data should be compared to previous data for the dredge area and the disposal site (if available). Sediment quality data should be plotted to display trends visually, and compared to plots from previous surveys.

Sediment Quality Screening Levels

The acceptability of dredged material containing contaminants in excess of the Screening Levels is determined by proceeding through the decision-tree at **Figure 3**.

Interim sediment quality guidelines (ISQGs) were developed as part of the ANZECC/ARMCANZ Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ 2000a, b). These ISQGs are largely based on biological-effects-based guidelines developed overseas by Long *et al*. (1995), with some modifications to reflect Australian conditions (e.g. for arsenic) or more recent information (e.g. for TBT, PAH, petroleum hydrocarbons, radionuclides). While their suitability to Australian conditions has not been conclusively demonstrated, they were considered the best available guide to likely contaminant effects on Australian organisms[7]. Although the Screening Levels were developed partly from studies using multiple contaminants, they may not take multiple contaminants fully into account. This would be accounted for in toxicity testing.

The Screening Levels used in this document (**Table 2**) are the same as the ISQG-Low values in ANZECC/ARMCANZ 2000, as updated (in draft) by Simpson *et al.* (2008). The ISQG-High (also called maximum) values are not presented in this Table except for TBT, as it is now recognised that they are of uncertain ecological relevance. Instead, the acceptability of spoil containing contaminants in excess of the Screening Levels is determined by proceeding through **Figure 3**. For TBT a maximum value is presented as even the sub-acute toxicity tests currently available may be insensitive to TBT. This value may be used as a Maximum Value, not to be exceeded, or alternatively, the TBT levels in sediment pore waters may be determined, for comparison to the ANZECC/ARMCANZ marine water quality trigger value for TBT (see Bioavailability Testing, below). The comparison is not a perfect one, as the above guidelines relate to open, well-mixed waters, but it is the best available.

The levels in **Table 2** are less broadly based than guidelines for water quality, and will be revised in future editions of these Guidelines as international values are updated and/or specific Australian values developed.

The Australian sediment quality guidelines are to be revised as part of revisions to the ANZECC/ARMCANZ (2000a, b) guidelines, under the National Water Quality Management Strategy (NWQMS), and will be made available, as revision supplements, through the NWQMS website (Simpson *et al.*, 2008).

For other contaminants (not in **Table 2**), no level is available because the quality of the data used for guidelines development was poor or because guidelines developed using different methods were inconsistent. Where contaminants are found for which there are no Screening Levels, and these contaminants are present at levels exceeding regional ambient baseline levels in sediments of comparable grainsize, bioavailability, toxicity and, where appropriate, bioaccumulation testing will be required.

7 The Australian and New Zealand water quality guidelines for marine and estuarine waters are largely based on US toxicity data.

TABLE 2: Screening levels (mg/kg dry weight except where noted) For substances not listed, use the procedures set out in ANZECC/ARMCANZ 2000.	
Analytical Parameter	Screening Level (ISQG Trigger Value)
METALS & METALLOIDS#	(mg/kg=ppm)
Antimony	2
Arsenic	20##
Cadmium	1.5
Chromium	80
Copper	65
Lead	50
Mercury	0.15
Nickel	21##
Silver	1.0
Zinc	200
ORGANICS***	(µg/kg=ppb)
Total PCBs	23
Pesticides	
DDD	2
DDE	2.2
Total DDT	1.6
Dieldrin	280
Chlordane	0.5@
Lindane	0.32@
Endrin	10
Total polycyclic aromatic hydrocarbons (PAHs)	10 000
Total petroleum hydrocarbons	550 mg/kg
Tributyltin (as Sn)	9 µg Sn/kg@@
RADIONUCLIDES** (sum of gross alpha and gross beta)	35 Bq/g

Source: Simpson *et al.*, 2008

** Maximum (Bq/g is becquerels per gram)

*** Normalised to 1 per cent total organic carbon. Normalisation is only appropriate over the TOC range 0.2–10 per cent (equates to multiplication factors of 5 times–0.1 times, respectively. Outside this range, use the end value which applies (e.g. for less than 0.2 per cent TOC, use 5 times the TBT value measured).

For other metals, compare to ambient baseline levels for sediments of comparable grainsize in the vicinity of the disposal site.

Sediments in Australia commonly have high natural levels of As and Ni

@ Screening Level is below PQL (Table 1). Reporting results for the above substances should be either 'detected' or 'not detected' unless a PQL better than the Screening Level could be achieved.

@@ Where a numerical maximum value (ISQG-High) for TBT is required, the USEPA's final chronic value of 80 µg/kg may be used.

Appendices

Comparison of Data to Screening Levels

The upper 95 per cent confidence limit of the mean (95 per cent UCL) is used to determine compliance with the Screening Levels (**Table 2**). For the area to be dredged, or a distinct site within the area, the mean and standard deviation are calculated, and the upper 95 per cent confidence limit of the mean determined. The USEPA's ProUCL software can be obtained at http://www.epa.gov/esd/tsc/software.htm. ProUCL can calculate 95 per cent UCLs from data sets with or without non-detect observations.

Where the data are normally distributed, the arithmetic mean is employed. If the data are log-normally distributed (e.g. using the Shapiro-Wilks Test), the geometric mean is appropriate. However, if the data are log-normally distributed, the Jack-knife or Bootstrap methods should be used to calculate the 95 per cent UCL. Do not use the H-statistic, especially if the number of samples is less than thirty (USEPA 1997, Alaska Department of Environmental Conservation, 2003.

Values less than the PQL (Practical Quantitation Limit – see above) should be noted as half the PQL.

A Screening Level is exceeded if the upper 95 per cent confidence limit of the mean for a contaminant exceeds the value specified in **Table 2**. If the 95 per cent UCL does not exceed the Screening Level, this means there is a 95 per cent probability that the mean concentration of that contaminant within the material to be dredged will not exceed the Screening Level. If the 95 per cent UCL of a contaminant exceeds the specified Screening Level, it is a Contaminant of Potential Concern (COPC) and comparison to ambient baseline levels for sediments of comparable grainsize is then required.

Comparison of Data to Ambient Baseline Concentration

Ambient baseline concentrations can be determined either by (a) sampling at a new site prior to disposal (including nearby reference sites); or (b) sampling of sediment at reference areas in the vicinity of an existing disposal site, but beyond the dispersion pattern of dumped sediment. Such sites need to have similar sediments and oceanography to the proposed disposal site, but do not need to be pristine, as the aim is to determine the ambient concentrations of contaminants in the sediments. Where there is existing data available, it may be used in a power analysis (**Appendix D**) to determine the number of samples required to adequately determine ambient baseline concentrations. If not, power analysis may be done on the data from a pilot study. Because of the great variation in area, volume and history of offshore disposal sites, it is not possible to generalise as to the number of samples required, however even for a small site it should not be less than seven samples, the minimum number from **Table 6**. For large sites, the proponent should present a reasoned case for the amount of sampling proposed.

Where possible, the sediment at the reference areas should have comparable grainsize and TOC content, since these parameters are the dominant influences on contaminant levels in sediment. For naturally occurring elements, such as heavy metals, normalising to a reference element enables a better determination of ambient baseline level to be made, particularly where grainsize and TOC are not comparable.

The contaminant ambient baseline concentrations should be used as the assessment values, and the comparison is done using the 80^{th} percentiles for the dredge and reference site sediments. If the mean of the sediment concentrations for the substances in question are at or below the 80^{th} percentile of their ambient baseline levels in the vicinity of the disposal site (ANZECC/ARMCANZ, 2000), the sediment is considered to be chemically acceptable for ocean disposal even though the relevant Screening Level(s) were exceeded. If found to be above ambient baseline levels, again it is a Contaminant of Potential Concern and Phase III testing is then required.

For metals, the ambient baseline levels alternatively may be determined using trace element ratios, by normalising to 'non-pollutant' elements such as lithium (but not iron or aluminium in ports exporting such ores)(Loring and Rantula, 1992; Daskailis and O'Connor, 1995).

For organics of exclusively human origin, the ambient baseline (if any) will indicate the extent of dispersal by long range processes. The ambient baseline value may also be used to assess substances for which there are no Screening Levels. For anthropogenic substances not listed in **Table 2**, a suitable value may need to be calculated from the relevant ANZECC/ARMCANZ (2000a, b) water quality trigger values. Methods are set out in that document.

Phase III – elutriate and bioavailability testing

Phase III testing of samples containing the Contaminants of Potential Concern (COPC) requires both elutriate and bioavailability testing, to determine if a bioavailable fraction is present that would affect marine life.

The mean values from individual test procedures in Phase III will be compared to the specified assessment criteria. Reference to the ANZECC/ARMCANZ (2000a,b) marine water quality criteria usually refers to use of the 95th percentile level of protection, using methods and criteria for comparison as outlined in that document.Guidelines on the number of samples required, sampling and the degree of replication, are presented in **Appendix D** and **Table 7**.

ELUTRIATE TESTING

Elutriate testing is required where the dredged material data exceeds the Screening Level for any substance. The elutriate test is designed to simulate release of contaminants from a sediment during dredged material disposal. Release can occur by physical processes (e.g. directly from sediment pore water) or a variety of chemical changes, such as oxidation of metal sulfides and release of contaminants adsorbed to particles or organic matter. Testing is carried out using the USEPA's standard seawater elutriate test (USEPA 1991; Simpson *et al.*, 2005).

Sample collection and handling requirements are set out in **Appendix D**. Representative bulk or composite samples are to be tested using the elutriate test, which is briefly described below.

The elutriate test is carried out by shaking the sediment samples with four times the volume of seawater from the disposal site (where this can readily be obtained; if not, clean seawater from a nearby area) at room temperature for 30 minutes, then allowing the samples to settle for one hour. The supernatant is then centrifuged or filtered (0.45 μm) (and preferably centrifuged) within sixty minutes, and analysed using analytical methods appropriate for determining ultratrace levels in seawater (where possible, at least one tenth of the ANZECC/ARMCANZ marine water quality trigger values without interference from salt). The seawater used for the elutriate test should also be analysed by the same method, so that the results can later be corrected for the blank values. Strict adherence to the conditions of the test is required to ensure meaningful data are obtained.

The relevant ANZECC/ARMCANZ (2000a,b) marine water quality trigger values should not be exceeded after allowing for initial dilution, defined as 'that mixing which occurs within four hours of dumping'. Initial dilution will depend on a number of factors, such as depth, layering in the water column, and current velocities and directions.

Initial dilution may be calculated using the US Army Engineers Waterways Research Station STFATE model, or other appropriate models. Alternatively, it may be approximated as: 'the liquid and suspended particulate phases of the waste may be assumed to be evenly distributed after four hours over a column of water bounded on the surface by the release zone and extending to the ocean floor, thermocline or halocline, if one exists, or to a depth of 20 m, whichever is shallower,' (USEPA, 1991). Knowing the volume of material dumped on any occasion, the minimum initial dilution can readily be calculated.

The elutriate test uses a dilution of 1:4, wet sediment: added seawater, and will greatly overestimate water quality impacts given that, within the four-hour period, dilutions of the order of a hundred times or more (and often much more) would normally be expected. The test data are therefore corrected for the calculated dilution factor after the four-hour mixing period (after taking account of the test dilution of 1:4) to assess whether or not the water quality guidelines will be exceeded after disposal.

BIOAVAILABILITY TESTING

Sediment quality guidelines can only be used for screening purposes, because different sediments with the same concentration of a particular toxicant can have widely differing toxicity, depending on sediment characteristics. In particular, high levels of organic matter will reduce the availability of many organic compounds and some metals, while high levels of acid-volatile sulfides (AVS) decrease the availability of the metals Ag, Cd, Cu, Ni, Pb and Zn.

Sediment contaminants will generally be present in a variety of forms, but only the bioavailable fraction will affect organisms. There are a variety of methods currently available to investigate contaminant bioavailability, particularly for metals. The most generally useful test, because of its broad applicability, is to analyse pore water for the COPC and compare the data to the ANZECC/ARMCANZ 2000 marine water quality trigger values. The comparison is not a perfect one, as the above guidelines relate to open, well-mixed waters, but it is the best available.

Guidelines on the number of samples required, sampling and the degree of replication, are presented in **Appendix D** and **Table 7**.

The data from the available tests are assessed as follows:

(a) Dilute acid extraction of metals

The dilute acid metals data (95 per cent of UCL) can be compared to the Screening Levels as set out in **Table 2**. Although this will not be equivalent to the bioavailable fraction, it will be a closer approximation to it than total metal sediment data and will be a guide to bioavailability, particularly to sediment-ingesting organisms.

(b) Acid volatile sulfide and simultaneously extracted metals (AVS/SEM)

This procedure is only useful for a few metals, principally Ag, Cd, Cu, Ni, Pb and Zn (see Simpson *et al.*, 2005).

If AVS is in excess of SEM, on a molar basis, then it is assumed that the above metals are unlikely to be bioavailable. The data should be presented as SEM-AVS (subtraction) rather than the traditional SEM:AVS (division), which can misrepresent available concentrations of SEM at low AVS levels. SEM-AVS provides information on the absence, but not the presence, of bioavailable metals as there are many other metal-binding phases in sediments.

Caution is necessary to interpret AVS/SEM data as these ratios are likely to change over time. AVS/SEM ratios are also subject to seasonal changes, and the concentrations present in harbour sediments prior to dredging need not necessarily re-establish in sediments dumped offshore. Interpretation of the results is discussed in more detail in Simpson *et al.*, 2008.

(c) Pore water concentrations

Pore water is assumed to represent the major route of exposure to sediment contaminants by benthic organisms. Where pore water concentrations lie below the ANZECC/ARMCANZ (2000a, b) marine water quality trigger values 95th percentile it is thought unlikely that there would be adverse effects on such organisms. The concentrations in the pore water provide information on the potential bioavailability of contaminants in the spoil after deposition at the disposal site. The data can also be used to interpret toxic effects, especially those from the naturally-occurring stressors, ammonia and sulphide.

Pore water testing is particularly useful for determining the acceptability of TBT-contaminated sediments for disposal, since toxicity tests are unresponsive except at high levels.

(d) Elutriate test concentrations

Elutriate tests investigate desorption of contaminants from sediment particulates to waters. They are used to simulate the maximum contaminant release occurring during disposal of sediments at sea. In cases where it is not possible to obtain sufficient pore water for analysis, which needs to be established to the satisfaction of the Determining Authority, or where the chemical stability of pore water cannot be assured, the elutriate test may also be used to *estimate* the porewater contaminant concentrations (G. Batley, pers. comm.). In this case, the 1:4 elutriate test data (without allowance for initial dilution) would be compared to the ANZECC/ARMCANZ (2000a, b) marine water quality trigger values 95th percentile.

Phase IV – toxicity and bioaccumulation testing

If any of the Contaminants of Potential Concern (COPC) have been found to be bioavailable, toxicity testing is required.

TOXICITY TESTING

Sediment toxicity testing provides additional lines of evidence for predicting the bioavailability, toxicity and bioaccumulation potential of sediment-borne contamination during and subsequent to loading and disposal.

The principal difficulties with sediment toxicity tests lie in maintaining field chemistry under laboratory conditions, in the varying sensitivities of different test organisms to contaminants under different routes of exposure, and in collecting suitable control sediments.

Guidelines on the number of toxicity samples and tests required, sampling and the degree of replication, are presented in **Appendix D** and **Table 7**.

Test Types and Organisms

Test species should be widely occurring, readily available, sensitive to the COPC, ecologically or economically important, tolerant of a broad range of sediment types and easily handled in the laboratory (ASTM, 2003).

A small number of marine sediment toxicity tests are available in Australia. Tests are listed in Simpson *et al.*, 2005, although many of these are not in common use and some are no longer available. Other tests are in development. Ideally, NATA-registered laboratories and tests are preferred. However only a handful of laboratories in Australia carry out sediment toxicity testing, all are specialist laboratories in this field, and few of the tests used are NATA-certified at this stage (although generally test protocols are based on standard procedures, e.g. ASTM tests). These labs should be consulted as to the tests available at the time.

Whole sediment tests are preferred, where available, as these are considered more ecologically relevant. However, in some cases it may be necessary to use sediment porewaters or elutriates for toxicity testing.

Whole sediment marine tests (Simpson *et al.*, 2005).

There are presently only a few whole sediment toxicity tests in common use in Australia, i.e. benthic algae (*Entomoneis*), amphipod (*M. plumulosa*) and occasionally bivalve (e.g. *Tellina*, *Spisula*) tests).

Some sediment toxicity tests may only be relevant in restricted locations, while others have a broad geographical relevance. It is critical, therefore, to discuss the proposed testing with the laboratory so that appropriate tests and organisms may be selected.

There are also a number of tests which can be used to assess the toxicity of marine sediment pore waters and elutriates.

Marine water tests (Simpson *et al.*, 2005).

There are a small number of such tests in common use in Australia. Two tests are acute; the remainder are chronic or sub-chronic. All but one test, using a microalga, employ temperate organisms.

Toxicity testing for dredging proposals in tropical areas may need to use temperate test organisms, as tropical tests are not yet available for routine use. Some test procedures developed for temperate waters, e.g. the use of oyster larvae tests, could also apply in many tropical waters. Temperate tests may also be appropriate. The use of specific tests should be clearly justified by the applicant.

Where porewater or elutriate water are being used, microalgae and sea urchin or oyster larvae tests may be appropriate.

Test Procedures

Toxicity testing procedures are described in detail in Simpson *et al.* (2005). It is important to use a suite of tests (with a minimum of three different tests, and preferably more, including both acute and chronic endpoints, and at least one whole-sediment test) with different organisms having different feeding requirements, sensitivities and covering the range of exposure routes: (i.e. water (e.g. epibenthic algae); water plus sediment uptake (e.g. burrowing benthic bivalves or burrowing amphipods); and sediment ingesters). Ideally the test organisms used will be broadly relevant to the disposal site, though specific disposal site organisms can rarely be used because it would take a major and long term research project to identify suitable test organisms, if any.

Toxicity tests may be rendered invalid if inappropriate control sediments, which cause excessive mortality in the test organisms, are used. Appropriate control sediments must be obtained that are as closely matched as possible to the sediments being tested, are uncontaminated and not naturally toxic themselves, and are suitable for the test organisms. Simpson *et al.* (2005) set out criteria for test validity.

Where a toxicity test shows less than a 20 per cent effect in the endpoint (e.g. survival, growth) relative to the negative control, the difference is not significant and no toxicity is indicated. A 20–50 per cent effect in the endpoint compared to the control indicates a *significant* degree of toxicity, and a greater than 50 per cent effect indicates a *high* degree of toxicity.

If any test shows toxicity, the cause must be assessed. Toxicity is commonly due to either grain size effects or the presence of elevated levels of ammonia or hydrogen sulfide in the sediments, which can be of natural origin. These causes must be accounted for before toxicity can be attributed to sediment contaminants (e.g. by the laboratory doing a simple TIE test (Toxicity Identification and Evaluation), or by measuring the ammonia levels in the sediment porewater. The pass/fail criteria for the toxicity tests are those specified in the individual test protocols.

Ammonia is generally not regarded as an issue if the porewater ammonia is of natural origin, which is generally the case. However, it may be of concern in the case of organic-rich sediments such as those contaminated from industrial or urban discharges. In the latter case, the study should assess whether the porewater ammonia levels will remain high after dumping. If so, they are potentially toxic and should be assessed accordingly. If, however, the porewater levels are likely to drop to acceptable levels after dumping, no concern is indicated.

Where contamination is present, it is common for some tests to find toxicity while others show none, or for some tests sediments from a dredge area to show toxicity while others do not. Assessment procedures for this situation are set out in the section headed ASSESSMENT OF TOXICITY AND/OR BIOACCUMULATION DATA below.

For sediments containing TBT above the Screening Level, standard toxicity tests will fail to respond at TBT levels below the Maximum level specified in **Table 2**, because the guidelines are based on imposex effects on gastropods. Furthermore, there is no point doing pore water toxicity tests as these are also only responsive at high TBT levels. The appropriate procedure is to obtain sediment pore water (see Bioavailability, above), analyse for TBT and compare to the TBT ANZECC/ARMCANZ 2000 marine water quality guideline values.

In some cases, however (e.g. compacted fine sediments) it may not be possible to obtain sufficient pore water for testing (300–500 ml required) even from large sediment cores. In this case, after the unavailability of pore water has been demonstrated to the satisfaction of the Determining Authority, it will be acceptable to carry out a seawater elutriate test, analyse for TBT and compare data to the ANZECC/ARMCANZ 2000 marine water quality guideline value.

Alternately, the Maximum Value in **Table 2** can be used as a cut-off point for ocean disposal.

Note that, for marine areas zoned for a high level of ecological protection, any significant toxicity may render the sediments unacceptable for ocean disposal in that area.

BIOACCUMULATION TESTING

Initially, a desk study (literature survey plus calculations) should be carried out to determine which contaminants present, if any, may bioaccumulate (e.g. mercury, dioxins, organochlorines/PCBs). If bioaccumulating substances were present above the SQG-High levels (Table 4), bioaccumulation tests are required, and bioaccumulation may be of concern even where toxicity has not been identified. Further guidance on procedures and assessment can be found in Simpson *et al.*, 2005 and Simpson *et al.*, 2008, and in the ASTM guide E1688 (2007), *Standard Guide for Determination of the Bioaccumulation of Sediment-Associated Contaminants by Benthic Invertebrates*.

Metals

Bioaccumulation of metals by invertebrates is complex and variable. In some organisms, toxicity is due to the accumulation of lethal body concentrations (LBCs) or internal effect concentrations (IECs) in the organism, rather than the total metal concentration in water and sediment to which the organism is exposed. However, where organisms can sequester certain metals into non-toxic forms, or regulate metals, the use of body concentration data is not appropriate.

Evidence of metal accumulation in organisms exposed to *in situ* dredge or spoil ground sediments versus controls will indicate whether metals are more bioavailable at these sites and are, therefore, a legitimate line of evidence. However, because of the unknown exposure, it can be difficult to interpret such results. Laboratory or field exposure of test organisms to these sediments may be more valuable.

If metal bioaccumulation data are taken into account in the sediment quality assessment, an appropriate gut depuration interval must be used before analysis (typically 24 hours).

Hydrophobic Organic Chemicals

Many such contaminants are accumulated by marine organisms and, while some (e.g. some PAHs) are readily metabolised, others (such as PCBs) are resistant to degradation and can also biomagnify up the food chain.

Simpson *et al.* (2005) discuss various methods for assessing bioaccumulation. These include direct measurement of bioaccumulation in suitable organisms, and estimation of theoretical bioaccumulation potential, although the latter may overestimate or underestimate bioaccumulation. Direct bioaccumulation tests are preferred, where suitable tests are available for ecologically relevant organisms.

Bioaccumulation tests are generally run for 28 days, and use several test species. The requirements for these species are similar to those for toxicity testing (above) except that the organisms need not be sensitive to contaminants. In addition, test organisms must provide adequate biomass for analysis, ingest sediments and be inefficient metabolisers of contaminants, particularly PAHs. At least two bioaccumulation tests should occur on each sample. These should include a deposit feeding bivalve mollusc and a burrowing polychaete (Simpson *et al.*, 2005).

Alternatively, organisms collected from the site may be analysed, if appropriate animals are available, after a suitable gut depuration interval where whole organisms are to be analysed, typically 24 hours. Data would need to be compared to organisms from appropriate control sites.

Guidelines on the number of bioaccumulation tests required, sampling and the degree of replication, are presented in **Appendix D** and **Table 7**.

For bioaccumulation, if there are no significant differences in the bioaccumulation data relative to controls (treatments or sites), bioaccumulation is not a concern. For any contaminant where bioaccumulated concentrations are statistically greater than that measured in the controls (treatments or sites), bioaccumulation is a possible concern. Where bioaccumulated concentrations are three or more times greater than those measured in the controls (treatments or sites), bioaccumulation is a significant concern (Simpson *et al.*, 2008).

If the bioavailability, bioaccumulation or toxicity assessments indicate that significant effects from the contaminants are likely, they are considered to be Contaminants of Concern.

ASSESSMENT OF TOXICITY AND/OR BIOACCUMULATION DATA

For any dredge area, where toxicity (or bioaccumulation) is rated as very significant or significant (columns 2 and 3 of **Table 3**, below, respectively) *in any of the tests on any of the samples*, and toxicity is not considered due to natural causes (e.g. ammonia in sediments), if the proponent still wishes to dispose of this material at sea, they would need to investigate the toxicity by:

(a) checking existing data to see if a coincident hot spot (i.e. a cluster of two or more samples exceeding the relevant criteria) can be defined using the existing chemistry and/or toxicity data, and

(b) if no hot spot can be identified, doing step-out sampling and testing (chemistry and toxicity) around the sample location where toxicity was found, to determine if a local hot spot is present.

There are three possible outcomes of this assessment:

(1) If any hot spots are identified, the sediments within them are considered toxic and unacceptable for unconfined ocean disposal, and therefore would require separate handling and disposal as per the existing hot spot provisions. The sediment outside the hot spots would be acceptable for ocean disposal.

(2) If no hot spots can be identified, and toxicity is only found in a single sample, the spoil may be considered acceptable for ocean disposal on the basis that the bulk composition of the dredge area, considering the initial toxicity testing plus step-out testing, indicates that it is non-toxic.

(3) If no hot spots can be identified, yet toxicity is found at scattered locations throughout the dredge area, the toxicity of the sediments is still an issue. To resolve this, with the agreement of the Determining Authority the proponent has the option of carrying out a Weight-of-Evidence assessment which may include other lines of evidence, including benthic community assessment. Any Weight-of-Evidence assessment would be carried out following the procedures set out in Simpson *et. al*., 2008 draft *Revision of the ANZECC/ARMCANZ Sediment Quality Guidelines*, or updates to that document.

TABLE 3: Assessment criteria[#]			
Kind of Test	Ranking		
	Very significant Contamination	Significant Contamination	Uncontaminated
Chemistry			
Sediment chemistry (e.g. PAH, TBT, metals)	One or more analytes in a given category > SQG-High**	One or more analytes in a given category between SL and SQG-High	No analytes exceed SL*
Dilute acid extract of metals ##	One or more analytes in a given category > SQG-High **	One or more analytes in a given category between SL and SQG-High	No analytes exceed SL*
Elutriate chemistry after dilution	One or more analytes in a given category > 5 x WQG***	One or more analytes in a given category 1–5 x WQG	No analytes exceed WQG
Porewater chemistry (TBT, metals, organics etc, or elutriate used as surrogate)	One or more analytes in a given category > 5 x WQG***, or fails 90% protection guideline	One or more analytes in a given category 1–5 x WQG, or to 90% protection guideline	No analytes exceed WQG (95% protection)
Toxicity			
(endpoint relative to negative control[@@]), each test type	> 50% effect[@]	20–50% effect	< 20% effect
Bioaccumulation			
	Bioaccumulated concentrations are > 3 times that measured in the controls	Bioaccumulated concentrations are statistically greater than that measured in the controls	No significant difference relative to controls
Overall assessment			
	Significant adverse effects predicted due to: elevated chemistry and bioavailability; > 50% reduction in toxicological endpoints, and bioaccumulation.	Potential adverse effects predicted due to: elevated chemistry and bioavailability, > 20% reduction in toxicological endpoints, and bioaccumulation.	No significant adverse effects predicted.

Modified after Simpson *et al.* (2005), Simpson *et al.*, 2008).

Not all lines of evidence need be used.

Use this in preference to total metals.

See Simpson *et al.*, 2008 for statistical definitions of these terms.

* SL = Screening Level (**Table 2**).

** SQG-High, **Table 4**.

*** WQG = ANZECC/ARMCANZ 2000 marine water quality trigger values for 95% protection.

@ The %-ranges that define significant (>20%) and high (>50%) toxicity may be different for each toxicity test.

@@ See Simpson *et al*., 2008 for definition.

For the purposes of determining the sediment chemistry ranking in Table 3, the values in Table 4 may be used.

TABLE 4: Sediment Quality High Values

Contaminant	SQG-High
METALS (mg/kg dry weight)	
Antimony	25
Cadmium	10
Chromium	370
Copper	270
Lead	220
Mercury	1
Nickel	52
Silver	3.7
Zinc	410
METALLOIDS (mg/kg dry weight)	
Arsenic	70
ORGANOMETALLICS	
Tributyltin (µg Sn/kg dry weight, 1% TOC)	70
ORGANICS (µg/kg dry weight, 1% TOC)	
Total PAHs	50 000 (45 000)
Total DDT	46
p.p'-DDE	27
o,p'- + p,p'-DDD	20
Chlordane	6
Dieldrin	270 e / 620
Endrin	120 e / 220
Lindane	1.0
Total PCBs	–
Oils: Total petroleum hydrocarbons (TPHs) (mg/kg dry weight)	NA

Source: Simpson *et al.*, 2008. The values in this table should be replaced by relevant updates to this source.

Phase V – weight-of-evidence assessment

If the ecotoxicological and/or bioaccumulation assessment is ambivalent, or in other rare circumstances as noted in the previous section, a WOE assessment may help the proponent demonstrate their case to the Determining Authority. The WOE framework allows decisions to be reached when a single line of evidence is insufficient for making decisions, e.g. if sediment quality guidelines do not exist for the contaminants, if there are no appropriate toxicity tests that are sensitive to the contaminants of concern and no relevant ANZECC/ARMCANZ marine water quality guideline to compare pore water data to, or where scattered toxicity is found in some samples throughout a dredge area, but no hot spot can be identified.

The preferred WOE procedure is set out in the draft revision of the ANZECC/ARMCANZ sediment quality guidelines (Simpson *et al.*, 2008) and this report (as updated) should be referred to for the background and for further details of the procedure.

The WOE investigation should combine assessments of:

(i) sediment chemistry to measure contaminant concentrations, compare to sediment quality guidelines (if available) and identify COPCs. These measurements may include chemistry-based bioavailability tests (e.g. pore water measurements, AVS, or biomimetic approaches for hydrophobic organic contaminants)

(ii) toxicity testing (e.g. multiple species, varying exposure pathways, acute and chronic endpoints such as mortality, reproduction, development, growth, avoidance)

(iii) bioaccumulation/biomagnifications where this is considered, on the basis of the above assessment, to be an issue, and

(iv) where appropriate, and if suitable data are available, benthic community structure (e.g. ecological malfunction).

Not all of the lines of evidence listed will necessarily be used in any particular dredging assessment.

The WOE approach tabulates and ranks the results of relevant lines of evidence, such as sediment chemistry (e.g. exceedance of trigger values), elutriate and bioavailability testing (exceedance of the relevant criteria), toxicity testing (elevated toxicity compared to controls), bioaccumulation (significant differences compared to controls), and benthic community structure (reduced benthic diversity or abundance relative to controls).

The approach outlined builds on previous publications on WOE assessment frameworks (Chapman *et al*., 2002; Chapman and Anderson, 2005; Simpson *et al*., 2005; Wenning *et al*., 2005).

Appendix B:

Components of sampling and analysis plans and reports

The SAP needs to be developed in consultation with the Determining Authority for all phases of sediment assessment. For projects in remote or logistically difficult areas it may be more efficient to prepare a SAP that includes bioavailability, toxicity and (in some cases), bioaccumulation testing. Then, if these tests are required, they can be carried out without the time taken to prepare and approve a second SAP.

An approved SAP will contain the following information:

- the objectives of the SAP, including data quality objectives
- a brief description of the dredging proposal, including the planned dredging area or areas, the dredging depths, the types of sediments involved and the final volume of material to be removed (in cubic metres) for sea disposal
- an evaluation of the history of the dredge area and its catchment, and available data on the sediments to be dredged. This will identify where further information is required and any potentially *contaminated* sediments. At this stage it may be possible to rank sites or depths for potential contamination status, so that sites with different contamination types or levels may be sampled separately
- a table showing the amounts to be dredged for each separate dredge area, as well as differentiating between clean, contaminated and potentially contaminated materials.
- the *Contaminants List*, based on the history of the catchment and any previous sediment sampling
- consideration of environmental factors potentially affecting contamination in the sediments (such as currents, bathymetry, grain-size) or which may limit or hinder the sampling program (for example depth, currents or waves, rocky bottom, weather, wildlife such as sharks, crocodiles or stingers, remoteness)
- a rationale for the proposed sampling design, including maps showing the dredging area/s and the proposed sampling locations. This would include any necessary water quality or oceanographic sampling to be carried out concurrently as part of this assessment
- a contingency plan in case of adverse weather or critical failure of equipment
- the equipment (vessel, sampling, sub-sampling and testing gear, positioning equipment, sample containers, reports, charts and data forms) and personnel needed to implement the SAP, and a list of field measurements to be carried out
- a list of sample numbers, including field replicates and quality assurance samples, the approximate sampling locations and details of the position-fixing method, the proposed length of cores and depths of sub-samples from cores
- step-by-step procedures for sampling and sub-sampling consistent with **Appendix D**; the volume of sample required for analysis and the types and numbers of containers; procedures for collection of water and biota samples, where required; and procedures to ensure that samples (especially water samples for trace analysis) are not contaminated from pollution sources on the survey boat (for example lead weights, zinc anodes, galvanised or brass surfaces, metal-containing sunscreens, anti-fouling paints or exposure to fuels or engine exhausts)

- step-by-step procedures for sample handling, preservation, storage and QA/QC
- the laboratories to be used, a list of analyses required, the proposed analytical methods, the detection limits of the proposed methods, whether the methods will achieve the specified Practical Quantitation Limits (PQLs) in **Table 1**, laboratory replicates, certified reference materials, and QA/QC procedures, and
- procedures for data management, data quality validation and any statistical routines proposed to be used.

An SAP Report (the report detailing the sampling and analysis work carried out, and presenting and assessing the results) will contain the following information:

- Summary of the SAP, or SAP appended to report
- A description, supported by maps and tables, of the sampling carried out, along with the actual sample locations, sample numbers (including replicates and QA samples), completed CC forms, field logs and descriptions of the sediments, and any problems encountered or deviations from the procedures set out in the SAP (including justifications for deviations)
- Presentation and review of the results, including QA/QC assessment of both field and laboratory data, comparison to data quality objectives, and data validation. Graphs showing sediment contaminants over depth are particularly useful for identifying patterns of contaminant distribution and assist in practically separating material into acceptable and not acceptable for ocean disposal. Therefore presentation of results should include a visual presentation of contaminant distribution at depths and across the site. All laboratory and field data to be appended in full
- Assessment of the results in accordance with these guidelines
- Brief description of the disposal site and summary of sediment data for it, plus ambient baseline data for sediments of comparable grainsize in the vicinity of the disposal site, used for the 'Background' comparison
- Map and description of the marine communities in and around the area and their sensitivity to physical effects
- The environmental values and environmental quality objectives (including level of ecological protection) to be achieved, and
- Conclusions as to the acceptability or unacceptability of the spoil for open water disposal and/or recommendations as to further work required.

Appendix C:
Consultation on sea dumping proposals

Benefits of stakeholder consultation

Consultation can produce the following benefits:

- improved information base by accessing information held by other stakeholders, not just those promoting the project
- development of consensus by identifying and acknowledging shared views and objectives
- establishing ownership of the decision-making process and its outcomes
- resolution of different views through early and open discussion and through clear, transparent processes and procedures
- extending understanding of technical issues, such as physical processes and the changing nature of risk, and of the nature of the proposal, and
- establish links and networks useful in implementation of recommendations.

Issues for stakeholders

For the dumping of dredged material, there are a range of issues which stakeholders may have an interest in. For example:

- commercially or recreationally important biota may move out of areas used as disposal sites affecting local businesses
- seasonality of fishing periods, migrations and breeding times may be affected, which has implications for local fish stocks
- physical changes to the water column or the sea bed may also affect commercial and recreational fishing
- navigational changes may occur as a result of the dredging activities affecting fishing and other waterway users, and
- sea disposal may be incompatible with National Parks and with some zones or categories of Marine Reserves and other Marine Protected Areas.

Key stakeholders for sea dumping

Australian Government

Agencies that will generally need to be consulted include:

- Australian Fisheries Management Authority (AFMA)
- Australian Hydrographic Service
- Australian Maritime Safety Authority (AMSA), and
- Australian Quarantine and Inspection Service (AQIS).

State and Territory agencies

Applicants will also need to consult relevant state and territory agencies. Depending on the circumstances of the particular application, this may include agencies with the following responsibilities:

- environmental protection and marine conservation
- fishing and aquaculture
- native title, heritage protection and marine archaeology
- ports, harbours, marine transport and navigation safety
- offshore petroleum and mineral activities, and
- regional development and tourism.

Non-government bodies

It is usual practice to consult with national, State or Territory, or local environmental non-government organisations. Depending on the particular application, applicants should also consult:

- commercial and recreational diving, fishing, boating and marine tourism operators
- local and regional councils
- native title holders, registered claimants and local Indigenous groups
- local and regional environment groups and organisations, and
- chambers of commerce and other representative organisations.

Technical Advisory and Consultative Committees (TACCs)

Technical Advisory and Consultative Committees (TACCs) are an important consultative mechanism for dredging proposals. A TACC is intended to assist ports and other proponents and the Determining Authority to access local knowledge and reconcile various stakeholder interests.

Membership is drawn from relevant Commonwealth, State and Local Government, and non-Government organisations and community groups with expertise, responsibilities or an interest in the subject matter.

The TACC is intended to:

- provide continuity of direction and effort in protecting the local environment
- aid communication between stakeholders and provide a forum where points of view can be discussed and conflicts resolved
- assist in the establishment, as appropriate, of longer term permitting arrangements, including reviewing the development and implementation of Sampling and Analysis Plans, Long Term Management Plans and research and monitoring programs
- review ongoing management of dredging and dumping activities in accordance with these Guidelines and permitting arrangements, and
- make recommendations to the proponent and the determining authority as necessary or appropriate.

A TACC may also convene subordinate advisory groups, as necessary, to address particular technical issues or to facilitate prompt resolution of a particular issue.

Appendix D:

Sampling methods and design of sampling programs

Sampling methods

For maintenance dredging, where the full depth of sediment could be contaminated, material must be sampled throughout. For capital dredging, samples are needed from the full depth of contaminated as well as potentially contaminated[8] sediment. Full depth is taken to mean at least the top 1 metre of sediment, and more if contamination could be found deeper. It is not normally necessary to sample (for chemical analysis) consolidated natural geological materials underlying these surface sediments, although physical testing of such consolidated materials would still be required to assess turbidity movement and behaviours of the dredged material, post-disposal.

Sampling is normally carried out by coring. Suitable coring devices may include piston corers, vibracorers and, in certain situations, hand coring by diver or grab sampling. Piston corers and gravity corers are restricted to relatively short cores and soft sediments, and may not be practicable in oceanic environments or high currents.

Gravity corers, although widely used, are not recommended because, unless they are used carefully, the sediment can become disturbed or mixed. Loss of surface fines can be a serious problem when coring fine silts and muds because the impact of the corer with the bottom can push this material out of the way. Gravity corers can also enter the sediment at an angle resulting in a core that appears to have sampled the depth of the sediment but, in fact, represents only the surface layers.

Piston coring, in which the core tube contains an internal piston that rides up as the tube fills with sediment, is a widely used method that can produce good quality cores when used carefully. The trigger mechanism is set off when a weight suspended below the corer reaches the bottom, allowing the corer to free-fall a short distance and penetrate the sediment. The method can recover cores up to 3 metre length in firm, fine sediments under ideal conditions, and less in coarse or consolidated material. The sampling team should be satisfied that the corer has penetrated the sediment vertically otherwise the core would need to be retaken.

An alternate method of piston coring uses a corer with a drill string that can be extended by screwing additional lengths to the top of the string. The corer is then pushed or driven into the sediment from the sampling vessel. Because the initial entry speed can be carefully controlled the method should result in vertical entry and minimal disturbance of the loose surface material. The method is suitable only for relatively shallow (<20 m) and calm waters.

For coarse or firm sediment, or for sampling in the 3 to 6 metre depth range, vibracoring is recommended. Vibracoring of fine unconsolidated sediments is not recommended due to the risk of disturbance and mixing, although sometimes these materials can be cored without vibration, or minimal vibration, by using the weight of the corer. For sampling beyond the 6 m depth range, drilling will generally be needed, as is the case for stiff clays or consolidated materials.

Appendices

8 Sediment contiguous with areas of known sediment contamination, or sediment in areas of known contamination input, e.g. inner harbours, berth pockets, and other locations affected by solid, liquid or airborne waste inputs.

Hand coring by scuba diver can produce acceptable cores and has the advantage that the bottom conditions are observed and sampling site optimised, although the diver needs to treat the core with care during recovery to avoid disturbing or mixing the sample. In practical terms the method is limited to water depths of 20 m or less, unconsolidated sediments, low currents and an absence of dangerous marine creatures, and a sediment depth of no more than 2 m. Because of the numbers of divers required under work safety regulations diver coring is unlikely to be cost effective on large projects. Diver contact with contaminated sediments during sampling should also be considered and appropriate precautions taken.

For all coring methods, core tubing of at least 50 mm diameter should be used to provide sufficient sample for analysis and replication. If a large variety of analyses are required, 50 mm cores may not provide sufficient material and either a larger diameter core or replicate cores should be taken. Core liners should be of polycarbonate which are rinsed with dilute acid, deionised water and a suitable solvent. Cores should be examined after splitting to determine of material has been lost or greatly disturbed (e.g. deformation of sediment layers).

In some circumstances, grab samplers may be used, i.e. for maintenance dredging surveys in frequently dredged areas with substantial ship traffic. Here, because the sediments are mixed continually, samples taken with a grab sampler can be representative as long as the grab is designed to retain the entire sample. The proponent would need to provide sound reasoning that the samples are representative of the entire dredging depth, e.g. by comparison to previous core data. Grab samples should be examined for integrity, i.e. that grab has remained closed after sample, and fines have not been winnowed out.

Grabs may also be used for collection of reference and control sediments for toxicity testing (USEPA, 1991). Large grab samplers are preferable to smaller ones and should have a minimum gape size of 0.02 m^2. In some cases it may be appropriate to improve the representativeness of the samples by compositing a number of grab samples taken from the one location.

The sampler should be stainless steel, free of grease or corrosion, appropriately pre-cleaned and washed clean between samples. The applicant should initially demonstrate that the grab sampler retains the entire sample.

Sub-sampling of Grab Samples and Cores

Prior to use, the survey vessel must be thoroughly inspected and washed down. Any evident sources of contamination (such as copper or brass, or galvanised or oily surfaces) should be cleaned, covered in plastic and taped down to avoid accidentally contaminating any sample. Lead diving weights should be stowed away. Work surfaces should be covered with clean plastic sheeting.

When sampling (especially water sampling for trace metals), contact with zinc anodes, surfaces coated with antifouling paint, metal-containing sunscreens or engine exhausts must be rigorously avoided.

Disposable, powder-free gloves should be used and changed after each sample.

Specific QA/QC procedures include:

- prior to sampling – laboratory pre-cleaning of sample containers, and cleaning of sample equipment (appropriate to the specific analyses required)
- sampling and sub-sampling that avoids cross-contamination, and
- appropriate decontamination of equipment between samples and sub-samples.

Grab samples are to be sub-sampled directly from the grab, taking care to avoid sediment in contact with the sides. For composite samples, the material not in contact with the sides should be carefully removed and thoroughly mixed in non-contaminating bowls before sub-sampling.

Cores are to be split on recovery and sub-sampled on one split only. The other split is to be stored in appropriate conditions (typically at 4°C) for further testing, if required. Alternatively, additional samples may be collected and appropriately stored for later analysis if it is more convenient to do so at the initial time of sampling, e.g. in remote or logistically difficult areas, or in locations where sampling requires large vessels or heavy drilling equipment.

The thinnest layer that can be dredged reliably and handled selectively using equipment routinely available is approximately 50 cm, so sub-sampling at smaller intervals down the core is redundant.

In core sampling, the top 50 cm of the core (or to the depth of dredging if less than 50 cm) is to be used as a single sample for analysis. In many cases this material will contain the highest levels of contaminants. A second sample is to be taken from the 50 – 100 cm interval. Below 1 m, if contamination is known or suspected to be present, the core should also be sub-sampled at 50 cm intervals to determine the extent and maximum depth of contamination.

If there is no suspicion of contamination below 1 m depth in the core, the remainder of the core may be composited as a single sample. If contamination is subsequently found in this sample, the stored samples would need to be sub-sampled at 50 cm intervals to determine the extent and maximum depth of contamination.

Mixing

The individual core lengths may either be mixed thoroughly before supply to the lab, or supplied in an unmixed state with instructions that the samples are to be thoroughly homogenised before analysis. Mixing may be done by any method that ensures the sample is thoroughly mixed, for example, by homogenisation in a bowl until the sample is uniform in colour and texture. Samples for analysis of volatile compounds, or for chemical speciation (e.g. AVS:SEM) may not be mixed and should be taken in appropriate containers with no headspace, at the midpoint of each core section.

If the sediment shows distinct and thick strata (for example, mud overlying sand) it may be appropriate to sample these strata separately. This would only apply to layers of 50 cm or greater. Appropriate decontamination procedures are required when sub-sampling and homogenising samples to avoid cross contamination of samples.

Sample Volume

The approximate mass of material necessary for particular analyses is listed below (**Table 5**). These masses allow for analysis for a large variety of different contaminants as well as replicates and check samples. Sampling design should ensure that sufficient material is collected at each sampling site to meet testing requirements.

Large amounts of sediment are required for bioavailability and toxicity testing. This may necessitate collection of additional cores or grab samples. Two to three kilograms of sediment would generally be sufficient for all possible analyses, including toxicity and bioavailability testing.

TABLE 5: Amount of sediment required for various analyses*	
Analytical Parameter	Amount required (g, wet weight)**
Organic compounds	100–250
Metals	10–100
Miscellaneous analyses	50–200
Grain size	50–200
Total organic carbon	10–50
Toxicity testing	500–2000
Elutriate testing (metals)	200#
Elutriate testing, organics (contact lab)	up to 2,000
Porewater analysis	200–1000
Moisture content	10–50

Source: USEPA, 1991 (upper values) and Batley, 1994 (lower values) (pers. comm.), LC/SG 2001.

* In some cases, smaller amounts may be appropriate.

** Laboratory analysis of sediment is generally undertaken on the material less than 2 mm. If sediments contain a high proportion of gravel, the sample size should be increased appropriately.

\# Up to 1 litre of sediment may be required, plus four times the volume of seawater, from the disposal site.

Water Sampling

Water samples may be required for a variety of purposes, such as elutriate tests, and collection requires methods that eliminate contamination from the vessel or from sample-handling (that is the use of a non-contaminating pump or a discrete water sampler of the close/open/close type so that only the target water sample comes in contact with the inside of the water sampler). Sample handling surfaces should be clean and covered with clean sheeting.

Trace metal analysis – Seals should, preferably, be Teflon-coated and water sampling devices should be acid rinsed (10 per cent nitric acid) before sample collection.

Organic analysis – Devices should be solvent-rinsed before sample collection (USEPA, 1998).

Sample Handling, Storage, Preservation and Labelling

Where samples are to be sub-sampled or homogenised in a preparation laboratory, they should be stored at 4°C in the dark and transported to the laboratory within 72 hours (preferably 24 hours) of collection. Where in doubt as to procedures, always consult the laboratory which will be carrying out the tests as to their requirements.

For sediment samples containing TBT, mercury and other volatiles for chemical analysis, freezing to below –10°C within 12 hours of collection, and before their dispatch in a well-insulated cooler, improves laboratory storage life to eight weeks.

Sample handling techniques need to ensure that changes in the composition of the samples as a result of chemical, physical or biological action are minimised, that cross-contamination of samples does not occur during sub-sampling and subsequent handling, and that samples are not lost or mixed up between sampling and receipt by the analysing laboratories.

Australian guidelines for sample handling and analysis of contaminated land sites are described in the National Environment Protection Council's Assessment of Site Contamination Measure, NEPC 1999, Schedules B(2) and B(3), all available on the http://www.ephc.gov.au/ website. Some sample handling and preservation procedures for marine sediments have been drawn from USEPA (1991).

Generally, samples to be analysed for trace metals should not come in contact with metals, and samples to be analysed for organic compounds should not come in contact with plastics.

Pre-cleaned sample containers of an appropriate type and volume, plus lids, should be sourced directly from the NATA-registered laboratory which is to carry out the tests.

The containers should be completely filled with sample or, if there is insufficient sample, topped up with water from the site where the sample was taken, unless the sample is to be frozen, in which case the jar should only be filled to two-thirds of its volume and frozen immediately.

Samples for toxicity testing should have all macro-invertebrates removed using a 0.5 mm sieve.

Waterproof labels and pens should be used and preferably labels fixed with clear waterproof tape as well.

Details of sample collection, handling, preservation and storage for different kinds of tests are listed in **Appendix H**.

Bulk sediment samples for toxicity testing are to be stored in sealed containers with zero headspace. They must be protected from oxidation, which is likely to alter the toxicity of the sample.

Samples are to be kept cool (4°C) in the dark until ready for use, but must not be frozen.

Special sampling, sub-sampling and handling procedures are required for specialised bioavailability tests such as pore water analysis. If such tests are required, the analysing laboratory should be consulted for their specific requirements. See also Simpson *et al.* (2005).

Design of sampling programs

Samples must be:

- representative
- collected using appropriate techniques
- properly transported and stored, so as to minimise chemical and physical changes, until testing takes place, and
- tested by acceptable procedures.

In remote or logistically difficult areas, or in locations where sampling requires large vessels or heavy drilling equipment, it may be more efficient and economical to collect additional representative samples, for bioavailability and toxicity testing, at the time of initial sampling rather than returning to sample on a second occasion. Such samples need to be stored appropriately until they are analysed.

Phase II Investigation

The SAP sets out the number of sampling locations required for the Phase II investigation, based on the volume of known contaminated and potentially contaminated material to be dredged. For an existing port or harbour, the berth areas and inner harbour are more likely to contain contaminants, although they may also be present in outer harbour and channel sediments.

Contaminants may extend throughout the seabed layer of recent marine silts or sands, although they will rarely penetrate far into the underlying, undisturbed geological materials, especially if these are clay or rock (except in rare cases, such as where contamination has been carried there via groundwater from an adjacent contaminated land site). The sampling program must, therefore, aim to sample the full thickness of potentially contaminated sediment to be dredged.

In most cases, samples should be collected at random locations within each sampling site. In certain situations, however, e.g. where sampling of long, narrow channels or the tops of submarine dunes is required, sample locations should be selected to be representative of the bulk of material to be dredged.

Figure 5 sets out a sampling design decision-tree. At each sampling location, one or more core samples (or in certain cases, grab samples) will be collected. Cores longer than 0.5 m are to be sub-sampled at a range of depths which will depend on the depth of dredging for maintenance dredging, and the depth of contaminated and potentially contaminated material for capital dredging.

Maintenance Dredging

Sampling is required to the full depth of dredging.

(1) Small projects (less than 50 000 cubic metres of dredged material)

The entire dredge area should be treated as a single site and sampling should take place at randomly selected locations within it. The sampling locations number would depend on the volume of contaminated and potentially contaminated dredged material, as set out in **Table 6**.

Based on available data, the dredge site should be classified as either *'probably contaminated'*, *'suspect'* or *'probably clean'*[9]. Where good quality data for the site are already available to support the classification, the number of sample locations in the 'probably contaminated' and 'probably clean' categories may be halved[10]. Good quality data means current data (from the last five years) that has met QA/QC requirements comparable to those set out in these Guidelines (**Appendix A**) and where there are no new pollution sources.

(2) Medium-sized projects (50 000–500 000 cubic metres of dredged material)

If the distribution of contaminants is known (based on good quality data) to be relatively uniform, the whole dredge area may be treated as a single site and the approach set out in (1) above used.

Where the pattern of contamination may vary considerably over the dredge area, it should be stratified, i.e. divided into distinct sites based on their chemical characteristics. A common example occurs in maintenance dredging where the sediments of inner harbour or berth areas are known to be contaminated, the outer harbour sediments are suspect, and the shipping channel sediments are probably clean.

The number of sampling locations within each site would depend on the contaminated and potentially contaminated dredged material volume of that site and are set out in **Table 6**.

If the dredge area has been stratified, each site should be classified as either 'probably contaminated', 'suspect' or 'probably clean' as described in (1) above. Where good quality data for a site is available to support this classification, the number of sample locations in the 'probably contaminated' and 'probably clean' categories may be halved. Random sampling would then take place within each site. Note that a site so classified can be made up of a

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9 All three categories are considered potentially contaminated for the purposes of calculating the maintenance dredge volume.

10 When sample numbers are halved, fractions are rounded up.

number of discontinuous areas. For example, if a number of discrete berth pockets are classified as 'probably contaminated', they can be considered as one site for the purpose of sampling, with the proviso that at least two sampling locations would be required from each area making up the overall site.

TABLE 6: Minimum number of sampling locations*

Volume of Potentially Contaminated Material to be Dredged (cubic metres)**	Number of Sampling Locations#
0–10 000	6
10 000–17 000	7
17 000–23 000	8
23 000–30 000	9
30 000–37 000	10
37 000–43 000	11
43 000–50 000	12
50 000–58 000	13
58 000–67 000	14
67 000–75 000	15
75 000–83 000	16
83 000–92 000	17
92 000–100 000	18
100 000–141 000	19
141 000–182 000	20
182 000–223 000	21
223 000–264 000	22
264 000–305 000	23
305 000–346 000	24
346 000–386 000	25
386 000–427 000	26
427 000–468 000	27
468 000–509 000	28

Source: Environment Canada, 1995

* For 'probably contaminated' and 'probably clean' categories, where there is good quality current data (from the last five years) on sediment chemistry for the area or site, and the pollution status of the site has not changed, the number of sampling locations may be halved. After halving, fractions are to be rounded up.

** All three categories are considered potentially contaminated for the purposes of calculating the maintenance dredge volume. The sampling and testing required for large, complex projects would generally be determined on a case-by-case basis in discussions with the Determining Authority.

More sample locations may be desirable where the dredge area is geographically complex, where the sediments are very variable, or where the contamination has a complex distribution.

Appendices

(3) Large projects (greater than 500 000 cubic metres of dredged material)

For large projects it would normally be appropriate to divide the dredge area into a number of distinct sites based on their suspected contamination status. The number of sampling locations taken in each site would depend on the contaminated and potentially contaminated dredged material volume of that site, as set out in **Table 6**.

Each site should be classified as either 'probably contaminated', 'suspect' or 'probably clean'. Where good quality, current data for the site is already available to support this classification, the number of sample locations in the 'probably contaminated' and 'probably clean' categories may be halved. Note that a site so classified can be made up of a number of discontinuous areas. For example, if a number of discrete berth pockets are classified as 'probably contaminated', they can be considered as one site for the purpose of sampling, with the proviso that a minimum of two sampling locations would be required from each area making up the overall site.

Sample locations for each site would be selected as described above. Where the volume of dredged material in any site exceeds 500 000 m^3, the number of sample locations may be determined in either of two ways:

A. The following equation may be used to linearly extend **Table 6**:

$$y = 0.025x + 15.547$$

where: y is the number of sampling stations and

x in the volume of dredge material (x 1000 cubic metres)

B. In consultation with the Determining Authority, the number of sample locations may be determined by appropriate statistical means, such as power analysis.

The latter approach is likely to result in fewer samples, especially where the variance in the data is low, but requires pre-existing data on the chemistry of the sediments. Further information on such methods can be found in ANZECC/ARMCANZ (2000a,b), Monitoring Guidelines, Section A5.1.10.

Capital Dredging

Where a project involves capital dredging in a port or locality with existing contamination (e.g. one metre of contaminated or potentially contaminated sediment overlying 5 m of natural geological materials), rather than the total dredge volume, the number of sample locations (**Table 6**) should be based on the volume of contaminated and potentially contaminated dredged material (which includes the three categories of 'probably contaminated', 'suspect' and 'probably clean').

That is, the number of sample locations is based on the volume of the layer of recent sediments which *could* be contaminated, but does not include the volume of underlying natural geological materials which are, except for a thin boundary layer, expected to be uncontaminated.

In calculating the volume of contaminated and potentially contaminated material, proponents should use conservative assumptions to avoid the need for subsequent resampling.

The procedures set out in (1), (2) or (3) above, as appropriate, should be followed to determine the number of sampling locations.

Data will also be required on the physical properties of the full depth of sediment, including the natural geological materials, in order to assess turbidity impacts and the behaviour of the dredged material, post-disposal. This data could generally be obtained from the geotechnical samples taken for dredging planning.

Sample Location Selection

Sample locations should be selected by:

(a) laying a square grid over the dredge site, sized so that there are at least five times the number of grid squares as the number of sampling locations required. If the dredge site consists of a number of distinct locations, such as individual berth pockets, grid squares would be laid over each location *pro rata* to their proportion of the total dredging volume.

For example, for a project involving 50 000 m^3 of dredging, the number of sample locations required is 12 (**Table 6**) and the number of grid squares at least 60. If good quality, current data was available to support the initial classification, the number of sample locations could be reduced to 6.

(b) the grid squares would be numbered and random numbers used to select the required number of sample locations.

(c) samples would be collected at the centre of each of the selected grid squares.

If a different method is proposed, the rationale will need to be included in the SAP.

Phase III and IV Investigations

For elutriate, bioavailability and toxicity testing, lesser numbers of sample locations are required, as described below, however replication at each location is desirable to ensure that the samples collected are representative. For each location, samples should be representative of the full depth of contaminated sediment (as identified in Phase II) to be dredged, except where a discrete 'hot spot' layer has been identified, in which case it should be sampled separately.

Elutriate/bioavailability testing – sampling numbers

Table 7 should be used to determine the minimum number of sample locations for elutriate or bioavailability testing. Samples must be representative of the *overall* dredged material composition in the dredge area(s) which require these tests. Alternatively, if a defined sub-area of the dredge area has been selected for testing on the basis of elevated contamination levels, samples must be representative of this sub-area, including the most contaminated locations, and the sample selection process must be fully documented.

Where reliance is to be placed on previously collected elutriate data (within the 5-year data currency period) the proponent needs to demonstrate that this data is representative of the sediments from the area proposed to be dredged, i.e. that the previous data is from the same area and depth range, and that there are no new contamination sources for the dredging area.

Unrepresentative samples would invalidate the elutriate test data and require re-sampling and testing. Judgemental sampling may therefore be more appropriate than random sampling. Consideration should be given to a stratified sampling design based on the total contaminant concentration data for each sampling area to ensure that the samples are representative of all levels of contamination.

Ideally, a minimum of three replicate samples would be collected at each location for bioavailability analysis. Compositing of cores for this purpose is not recommended as exposure to air may affect the integrity of samples for certain bioavailability tests. If the dredging program contains a number of areas with distinctly different contaminants or levels, the numbers in the table would apply to each such area.

TABLE 7: Minimum number of elutriate, bioavailability, toxicity or bioaccumulation test sample locations for dredging projects of specified size, based on the volume of contaminated sediment involved#	
Volume of Potentially Contaminated Sediment to be Dredged (cubic metres)	Minimum Number of Sample Locations*
0–50 000	3
50 000–100 000	4
100 000–200 000	5
200 000–350 000	6
350 000–500 000	7
>500 000	2 per additional 250 000 cubic metres

If the dredging program contains a number of areas with distinctly different contaminants or levels, the numbers in the table would apply to each such area.

* Plus replicates, 20 per cent of the total, and a minimum of 1 replicate.

Toxicity/bioaccumulation test sampling requirements

The minimum numbers of sediment sample locations previously set out (**Table 7**) should be used in the suite of toxicity tests. Samples must be representative of the *overall* dredged material composition in the dredge area(s) which require these tests. Alternatively, if a defined sub-area of the dredge area has been selected for testing on the basis of elevated contamination levels, samples must be representative of this sub-area, including the most contaminated locations, and the sample selection process must be fully documented.

Unrepresentative samples would invalidate the elutriate test data and require re-sampling and testing. Judgemental sampling may therefore be more appropriate than random sampling. Consideration should be given to a stratified sampling design based on the total contaminant concentration data for each sampling area to ensure that the samples are representative of all levels of contamination.

As the bioaccumulation results must be compared statistically to controls, a minimum of three test locations and three reference locations is recommended. The same minimum numbers would apply in the case of field-collected and caged/transplanted organisms. The number of organisms used (e.g. caged oysters, filter-feeding bivalves) will depend on the specific bioaccumulation method(characteristics of the species, tissue mass, target analytes, analysis technique etc).

Further information can be found in the ASTM guide E1688 (2007), *Standard Guide for Determination of the Bioaccumulation of Sediment-Associated Contaminants by Benthic Invertebrates*.

Ideally, each individual sample sent for analysis would be a composite sample mixed from a minimum of three cores taken from the one location. If the dredging program contains a number of areas with distinctly different contaminants or contaminant concentrations, the numbers in the table would apply to each such area.

The following procedures for toxicity testing should be followed:

- The laboratory would need to be consulted on their sampling, sample handling and preservation requirements.
- Samples should be stored in the dark at 4°C and sent for testing as soon as possible, ideally within days.
- Sediments should not be frozen, as this may alter the bioavailability of some toxicants.
- Fresh sediment samples should always be collected for toxicity testing. These sediments may be stored in the dark under a nitrogen atmosphere for a maximum of eight weeks.
- The holding time must be reported along with the study results.
- Test sediments will also need to be analysed for their grain size, and other relevant parameters (e.g. natural toxicants such as ammonia and hydrogen sulphide). The testing laboratory will normally do this.
- These sediments must also be analysed for the *Contaminants of Potential Concern* if these are not included in the toxicity testing laboratory's program.
- Where sediment pore waters or elutriates are used instead of whole sediments, they should be centrifuged to remove particulates, rather than filtered, since filtered samples generally show lower toxicity, probably due to the removal of fine and colloidal fractions. The extracts should be cooled to 4°C immediately and used as soon as possible.
- On each sample, a minimum of three different toxicity tests should be done, and preferably more. Ideally these would be whole-sediment tests (i.e. where the organism is exposed to the test sediment directly). These are more ecologically relevant than pore water or elutriate tests because organisms are exposed to the whole sediment, however because there are so few whole-sediment tests available, pore water or elutriate tests are often used instead. Acute tests are generally cheaper, quicker and more robust than chronic tests. More acute tests should therefore be done, but some chronic tests should also be included.

Detailed procedures for bioaccumulation testing can be found in Simpson *et al.*, 2005 and 2008.

Appendix E:
Introduced marine pests

Introduced marine pests can impact a range of activities including fisheries and aquaculture production, human health, shipping and ports, tourism, coastal amenity, and species and ecosystem health and diversity.

Major introduced marine pest species with established populations in Australia include:

Asterias amurensis (northern Pacific seastar)

Carcinus maenus (European shore or green crab)

Musculista senhousia (Asian bag or date mussel)

Sabella spallanzanii (European or Mediterranean fan worm)

Undaria pinnatifida (Japanese seaweed)

Varicorbula gibba (European clam)

Hydroides sanctaecrucis (Caribbean tubeworm)

Maoricolpus roseus (New Zealand screw shell)

The main emphasis to date at the national level has been on the management of ballast water in international commercial shipping. Recent scientific evidence suggests that other vectors, such as hull fouling and recreational boating are also important and should be given a similar priority. Relocation of dredge material is also a potential vector for marine pests.

For most pest species it is not known to what extent they can survive the dredging process or disposal site environments. Species of particular concern include cyst-forming dinoflagellates, which may affect human health, and infaunal and benthic invertebrates, some of which can have major impacts on marine food chains.

Dredges can move rapidly between different areas of the world and may translocate species between geographic regions. While the risks from this source of exotic species does not appear to have been thoroughly assessed separately from international shipping, it is likely to be an area of significant concern due to the potential presence of sediment dwelling exotic species that could be readily translocated and potentially introduced into new locations with the movement of dredged material. Preliminary research indicates that the amount of unwanted sediment that trailer suction hopper dredgers (TSHDs) transport is likely to be greater than in most ballast tanks. There is a risk of introducing a different suite of exotic species from those carried in ballast water and biofouling. There is also the risk that a marine pest could be translocated not only in the debris that is collected in the dredge material but also within the water. The seriousness of this issue should not be underestimated, as introducing a single pest could have much more serious and long lasting impacts than the dredging itself.

Assessment

Exotic species that have the potential to be spread by dredging, and that may have some ecosystem impacts, have already been identified for those ports where an introduced species survey has been undertaken. The report to the relevant port authority will have recommended appropriate sampling of current and past spoil grounds and adjacent areas, to assess the distribution and survival of target or indicator species.

Where established populations of exotic species at a dredge or dump site have been detected, the assessment will need to address the potential impacts of translocating these species. Unsurveyed ports should be treated as containing established populations of any exotic species found in similar environments until a survey demonstrates otherwise. The scope of any subsequent monitoring or surveillance programs will depend, at least in part, on the 'pest' or other prescribed status (under current or future state and Commonwealth legislation) of the exotic species detected (or potentially present) in the port. To help facilitate this work, a marine pest monitoring manual has been prepared along with some related templates and tools that provide assistance in designing effective marine pest monitoring surveys.

For species that have well documented human health implications, or that have been shown to be highly environmentally damaging, an immediate re-evaluation of dumping options may be appropriate, unless the pest is already of widespread distribution in the marine environment. Specific methodologies are not specified here as these are set out by the responsible agencies.

Management

Management of introduced marine pests is being undertaken through the National System for the Prevention and Management of Marine Pest Incursions (the National System). The *Australian Ballast Water Management Requirements* have been developed under the National System and are available at www.daff.gov.au/aqis. Many ports have been surveyed for introduced marine pests or are in the process of doing so. If introduced marine pests have been identified or the port has yet to be surveyed, management measures to avoid spreading pests with a currently limited distribution would need to be considered.

Regardless of the pest-status of a port, all operators of vessels entering Australia need to manage ballast water according to current Australia's Ballast Water Requirements and comply with any Commonwealth or state biofouling requirements.

In Australia, operators should manage biofouling on their vessels according to the most current Biofouling management guidance for non-trading vessels which can be accessed at www.marinepests.gov.au.

To reduce the likelihood of translocating a marine pest through dredging activities, it is important when selecting a site to dispose of dredged material to consider:

- proximity of the loading site to the disposal site (increased proximity between the disposal site and loading site is likely to minimise the risk of transfer of an exotic species, given that the marine pest collected within the dredge material is likely to be already present at the disposal site)
- the similarity of the environment of the loading and disposal sites (including water depth and temperature)
- the suitability of the habitat at the disposal site for the survival of marine pests transferred from the loading site
- proximity of the disposal site to sensitive areas
- marine pests present at the loading site (if known)
- marine pests present at the disposal site (if known).

All states and territories have expertise in marine pest issues, and should be the first point of contact.

Appendix F:

Field and laboratory quality assurance and quality control

The guidelines for laboratory quality assurance and quality control (QA/QC) follow current Australian best practice. General guidelines are described in NEPC, (1999), the National Environment Protection Council's Assessment of Site Contamination Measure, NEPC 1999. More specific procedures are described in USEPA (1986, 1991, 1994 b, 1998) and available on-line. Procedures from these sources are specified here.

Quality Assurance and Quality Control

Quality assurance and quality control (QA/QC) procedures are essential to ensure that samples and data collected provide for a rigorous assessment. Quality scientific work is assured by having standard operating procedures. Quality control is assured by having documentation which shows that all procedures were followed successfully.

QA/QC procedures for field work and laboratory analysis and data management are set out in this Appendix.

Field Procedures

Prior to use, the survey vessel must be thoroughly inspected and washed down. Any evident sources of contamination (such as copper or brass, or galvanised or oily surfaces) should be cleaned, covered in plastic and taped down to avoid accidentally contaminating any sample.

Lead diving weights should be stowed away.

When sampling (especially water sampling for trace metals), contact with zinc anodes, surfaces coated with antifouling paint, metal-containing sunscreens or engine exhausts must be rigorously avoided.

Disposable, powder-free gloves should be used and changed after each sample.

Specific QA/QC procedures include:

- prior to sampling – laboratory pre-cleaning of sample containers, and cleaning of sample equipment (appropriate to the specific analyses required),sampling and sub-sampling that avoids cross-contamination, and
- decontamination of equipment between samples.

All field procedures are to be documented. Standard procedures should include:

- written standard operating procedures (SOPs) in the Sampling and Analysis Plan, with variations from SOPs and the reasons noted
- noting field conditions (weather, tides, currents), station locations, sampling methods and handling and storage methods, field numbers, date, time, and identity of sampler, in the field log
- field description of sediments as collected, including but not limited to physical appearance (for example, silty sand), colour, presence of foreign material, presence of shell fragments and/or biota (for example, seagrass). Where multiple samples are collected at a site, notes should be made on the variability between samples

- keeping a sample inventory log, a sample tracking log and a record of instrument maintenance and calibration, and
- chain-of-custody forms that list all sample numbers and locations, and the analyses and Practical Quantitation Limits required, to accompany each sample to the lab. At each stage of handling, samples are to be checked against the chain-of-custody forms. After receipt by the lab, a checked form is to be faxed or emailed immediately to the sampling organisation for rechecking.

Field quality control samples should include (per batch of 20 or fewer) the following:

- in cases where volatile substances e.g. some chlorinated organics, are being determined, one container (trip) blank filled with inert material such as chromatographic sand
- on 10 per cent of locations, one field triplicate (that is, three separate samples taken at the same location) to determine the variability of the sediment physical and chemical characteristics
- on five per cent of locations, samples should be thoroughly mixed then split into three containers to assess laboratory variation, with one of the three samples sent to a second (reference) laboratory for analysis, and
- one sample that has been analysed in a previous batch (if more than one batch is sent) to determine the analytical variation between batches.

Laboratory Quality Assurance/Quality Control

The laboratory quality assurance program should include the following quality control samples to be analysed in each batch (10–20 samples) or part batch. This is in addition to its own internal procedures to ensure analytical procedures are conducted properly and produce reliable results:

- one laboratory blank sample
- for metals, one Standard Reference Material (SRM), that is, a sample of certified composition such as MESS-1 or BCSS-1, or BEST-1 (for mercury), or a suitable internal laboratory standard calibrated against an SRM. The laboratory standard should be a ground sediment sample, not a liquid sample, to test both the recovery of the extraction procedure and the analysis
- for organics, one sample spiked with the parameters being determined (or a surrogate spike for certain organics) at a concentration within the linear range of the method being employed – this will determine whether the recovery rate of the analytical method is adequate or not (that is, that all the chemicals present in the sample are actually being found in the analysis), and
- one replicate sample to determine the precision of the analysis; the standard deviation and coefficient of variation should be documented.

Recoveries of surrogate spikes are to be documented and daily calibration data reviewed. The laboratory must review the quality control data and quality assurance documentation and a statement made in their report that the data meets the quality objectives specified by the method for that analysis (these are to be presented in the lab report, that is, the acceptable recovery range for spikes and SRMs, and the acceptable range of relative percent differences on duplicates). All of the quality assurance data (blanks, laboratory duplicates, spikes and SRMs) are to be reported for each batch of samples analysed with the analytical data. As soon as the analyses are completed the results should be emailed to the proponent's consultant for review so that any unusual values can be queried and, if necessary, reanalysis carried out before the holding time for the samples has expired.

The laboratory QA/QC procedures need to be appropriate for the low concentrations expected in marine sediments, which are frequently lower than those required for contaminated site investigations.

Appendix G:

Examples of impact hypotheses and associated monitoring programs

Example: Protection of Sensitive Areas (Coral Reef Ecosystems etc) and Human Use Areas such as Shipping Lanes

The disposal site was selected for its retentive characteristics in an area with a broad continental shelf and offshore coral reef ecosystems. Sensitive areas nearby included a Marine Park for the protection of coral reef ecosystems, a thriving tourism industry and areas of cultural as well as scientific significance. The Marine Park boundary was within 2 km of the site though the nearest sensitive areas were more than 5 km away. A shipping line was located near to the disposal site and there were other human uses of the area including submarine cables.

The spoil was essentially the same grainsize as the sea bed sediments but contained elevated levels of some contaminants, chiefly heavy metals. Further testing revealed that these were largely in biologically unavailable forms, hence the spoil was classified as acceptable for sea dumping (rewritten after Environment Canada, 1998).

Impact Hypotheses	Associated Monitoring Programs
During initial deposition, the spoil will not be carried through the water column to any sensitive area in amounts that would be harmful to the value or amenity of such areas.	Map initial area of deposition; determine if a sensitive area was reached by such deposition. If so, determine if scale of deposition is of concern in relation to physical impacts on valued components of the impacted area.
The deposited spoil will not subsequently reach any sensitive area (through resuspension and sediment transport) in amounts that would be harmful to the value or amenity of such areas.	Determine if transport is occurring in the direction of a sensitive area. If so, determine if the scale of transport is of concern in relation to physical impacts on valued components of the impacted area.
Disposal of spoil will not result in transport of contaminated material to any sensitive area, contaminant increases in the sediments of such areas, contaminant uptake by biota in such areas or ensuing effects on such biota.	If transport or deposition has reached any sensitive areas (above), study contaminant concentrations in the sediments of areas and, if elevated concentrations are found, assess the potential for effects on biota. If such potential is identified, investigate effects on relevant species.
The deposited spoil will not subsequently reach any sensitive area (through erosion, resuspension and sediment transport) in amounts that would cause unacceptable shoaling in shipping lanes or affect other human uses.	Determine whether or not transport is occurring in the direction of human use areas. If so, determine whether or not the scale of transport is of concern in relation to physical impacts on these areas.

Appendix H:

Guide to recommended procedures for sample collection, preservation and storage

(Notes: 1. some other procedures may also be suitable. 2. Holding times for some substances may be considerably longer than this, see e.g. USEPA 2005)

A. Sediment						
Test	Collection method	Typical volume required (less may be needed in some cases)	Container (Suitably pre-cleaned, must be supplied by analysing laboratory)	Preservation technique	Storage conditions (Some procedures can extend duration, e.g. freezing for total chemical analysis. Consult lab where necessary)	Storage duration (Some procedures can extend duration, e.g. freezing for total chemical analysis. Consult lab where necessary)
Physical						
Particle size Total solids/ specific gravity	Grab/corer	50–100 ml	Whirlpac bag	Refrigerate	<4°C	Undetermined
Chemical						
Metals	Grab/corer	100 ml	Pre-cleaned pre-weighed polyethylene* jar	Dry ice or freezer for extended storage, otherwise refrigerate	≤4°C	Hg – 28 days unless frozen. Others – 6 months
Organics (e.g. PCBs, pesticides, PAHs, TBT)	Grab/corer	250 ml	Solvent rinsed glass jar with Teflon lid	Dry ice or freezer for extended storage, otherwise refrigerate	≤4°C, in the dark	14 days if refrigerated
Total organic carbon	Grab/corer	50 ml	Heat-treated glass vial with Teflon-lined lid	Dry ice or freezer for extended storage, otherwise refrigerate	–20°C	Undetermined
Sediment for elutriate testing	Grab/corer	Depends on actual tests	Glass with Teflon-lined lid	Completely fill and refrigerate	4°C/dark/ airtight	14 days

Biological (that is, toxicity testing)						
Dredged material	Grab/corer	12–15 l per sample	Plastic bag or container	Completely fill and refrigerate; sieve	4°C/dark/ airtight	14 days. Up to 8 weeks if stored under nitrogen.
Reference sediment	Grab/corer	45–50 l per test	Plastic bag or container	Completely fill and refrigerate; sieve	4°C/dark/ airtight	14 days. Up to 8 weeks if stored under nitrogen.
Control sediment	Grab/corer	21–25 l per test	Plastic bag or container	Completely fill and refrigerate; sieve	4°C/dark/ airtight	14 days. Up to 8 weeks if stored under nitrogen.
B. Water and elutriate						
Chemical/Physical Analyses						
Particulate Analysis	Discrete sampler or pump	500–2000 ml	Plastic or glass	Lugol's solution and refrigerate	4°C	Undetermined
Metals	Discrete sampler or pump	1 l	Acid-rinsed polyethylene or glass jar	pH < 2 with HNO_3, refrigerate	4°C	Hg – 14 days; others, 6 months
Total Kjeldahl nitrogen (TKN)	Discrete sampler or pump	100–200 ml	Plastic or glass	H_2SO_4 to pH <2, refrigerate	4°C	24 h
Chemical oxygen demand (COD)	Discrete sampler or pump	200 ml	Plastic or glass	H_2SO_4 to pH <2, refrigerate	4°C	7 days
Total organic carbon (TOC)	Discrete sampler or pump	100 ml	Plastic or glass	H_2SO_4 to pH <2, refrigerate	4°C	<48h
Total inorganic carbon (TIC)	Discrete sampler or pump	100 ml	Plastic or glass	Airtight seal, refrigerate	4°C	6 months
Phenolic compounds	Discrete sampler or pump	1 l	Glass	0.1–1 g $CuSO_4$: H_2SO_4 to pH 2, refrigerate	4°C	24 h
Soluble reactive phosphates	Discrete sampler or pump	–	Plastic or glass	Filter; refrigerate	4°C	24 h

Extractable organic compounds (eg semi-volatiles)	Discrete sampler or pump	4 l	Amber glass bottle	pH <2, 6N HCl; airtight seal; refrigerate	4°C	7 days for extraction; 40 days for extract analysis
Volatile organic analysis	Discrete sampler or pump	80 ml	Glass vial	pH < 2 with 1:1 HCl, refrigerate in airtight, completely filled container	4°C	14 days for sample analysis if preserved
Total phosphorus	Discrete sampler or pump	–	Plastic or glass	H_2SO_4 to pH <2; refrigerate	4°C	7 days
Total solids	Discrete sampler or pump	200 ml	Plastic or glass	Refrigerate	4°C	7 days
Volatile solids	Discrete sampler or pump	200 ml	Plastic or glass	Refrigerate	4°C	7 days
Sulfides	Discrete sampler or pump	–	Plastic or glass	Refrigerate	4°C	7 days
Biological Tests						
Site water	Water sampler	variable	Plastic carboy	Refrigerate	<4°C	14 days, Dilution water. Water sampler, variable, Plastic carboy. Refrigerate <4°C, 14 days. BIOLOGICAL TISSUE Metals: Trawl/Teflon-coated grab, 5–10 g; Double Ziploc bags; Handle with non-metallic forceps; plastic gloves; dry ice ≤–20°C or freezer storage. Hg – 28 days; others – 6 months
Dilution Water	Water sampler	Variable	Plastic carboy	Refrigerate	<4°C	14 days

C. Biological tissue						
PCB's and chlorinated pesticides	Trawl/Teflon-coated grab	10–25 g	Hexane-rinsed double aluminium foil and double Ziploc bags	Handle with hexane-rinsed stainless steel forceps; dry ice	≤–20°C or freezer storage	14 days
Volatile organic compounds	Trawl/Teflon-coated grab	10–25 g	Heat-cleaned aluminium foil and watertight plastic bag	Covered ice chest	≤–20°C or freezer storage	14 days
Semivolatile organic compounds (e.g. PAH)	Trawl/Teflon-coated grab	10–25 g	Hexane-rinsed double aluminium foil and double Ziploc bags	Handle with hexane-rinsed stainless steel forceps; dry ice	≤–20°C or freezer storage	14 days
Lipids	Trawl/Teflon-coated grab	part of organic analyses	Hexane-rinsed aluminium foil	Handle with hexane-rinsed stainless steel forceps; quick freeze	≤–20°C or freezer storage	14 days

Source: Modified after USEPA, 1991, 1998

* or other appropriate material

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Glossary

Ambient Baseline Levels

Levels of chemicals or substances near a dump site prior to any disposal taking place. These are not necessarily the same as natural levels (see natural level) because the disposal site could have been contaminated by long-range transport and deposition of contaminants, e.g. via the atmosphere. Ideally, these sediments should be of comparable grainsize as the sediments to be dredged, to facilitate the comparison.

Australian Waters

See **Figure 2**. Australian Waters are defined in s.4 of the *Environment Protection (Sea Dumping) Act 1981* at s.4 and s.4.A. However, it is also a term in general usage. Australian Waters include:

- The Coastal Waters of a State are described in Schedule 2 to the *Petroleum (Submerged Lands) Act 1967* and constitute the first three nautical miles seaward of the (Commonwealth) territorial sea from the baseline; and any waters landward of the (Commonwealth) territorial sea from the baseline (that is, inside the baseline) and not within the limits of the State
- The Territorial Sea of Australia – a belt of water not exceeding 12 nm in width measured from the territorial sea baseline. The territorial sea around certain islands in the Torres Strait is 3 nm
- The Contiguous Zone – a belt of water contiguous to the territorial sea, the outer limit of which does not exceed 24 nm from the territorial sea baseline (12 nautical miles), and
- The Exclusive Economic Zone – an area beyond and adjacent to the territorial sea (12 nm) the outer limit of which does not exceed 200 nm from the territorial sea baseline, except in areas of agreed or potential delimitation with other countries: Indonesia Papua New Guinea, the Solomon Islands, France (New Caledonia and Kergulelen Islands) and New Zealand. The Australian EEZ is defined in the *Sea and Submerged Lands Act 1973* ('the SSL Act' – including the amendments to that Act made by the *Maritime Legislation Amendment Act 1994)*, and the outer limit of the Australian EEZ is set out in the Proclamation under the SSL Act.

Baseline

The term Baseline refers to the line from which the seaward limits of Australia's Maritime Zones are measured. The territorial sea baseline may be of various types depending upon the shape of the coastline in any given locality:

- The Normal baseline corresponds with the low water line along the coast, including the coasts of islands. The normal baseline corresponds to the level of Lowest Astronomical Tide (LAT). The baseline is drawn around low tide elevations which are defined as naturally formed areas of land surrounded by and above water at low tide but submerged at high tide, provided they are wholly or partly within 12 nm of the coast
- Straight baselines are a system of straight lines joining specified or discrete points on the low-water line, usually known as straight baseline end points. These may be used in localities where the coastline is deeply indented and cut into, or where there is a fringe of islands along the coast in its immediate vicinity, and
- Bay or river closing lines are straight lines drawn between the respective low-water marks of the natural entrance points of bays or rivers, subject to some limitations governed by the width of such indentations. Waters on the landward side of the baseline are referred to as the internal waters of the State or Territory.

Bioaccumulation

The retention and concentration of a substance by an organism.

Bioavailable

A substance in a chemical and physical form that allows it to affect organisms or be accumulated by them.

Biological Monitoring

Measurement of biological parameter/s (e.g, level of contamination of tissues or population abundance) through time, to determine if impacts have occurred.

Capital Dredging

Dredging for navigation, to enlarge or deepen existing channel and port areas or to create new ones. Dredging for engineering purposes, to create trenches for pipes, cables, immersed tube tunnels, to remove material unsuitable for foundations and to remove overburden for aggregate extraction, etc.

Clean Material

Clean material is material from locations distant from appreciable pollution sources (i.e. in pristine locations) as well as material composed largely (>95 per cent) of gravel, sand or rock, but only where this material is found in areas of high current or wave energy, where the seabed consists of shifting gravel and sandbars.

Confined Disposal at Sea

Disposal of material in a location where transport away from the disposal site is minimised; and contaminated material is covered with a layer of dredged material that is of acceptable quality for unconfined ocean disposal and of an appropriate thickness such that burrowing organisms would be unable to reach the contaminated material.

Contaminant

A substance, either inorganic or organic, present in the sediment at or near levels that could be toxic to some organisms.

Contaminated

Spoil is defined as contaminated if it contains contaminants of concern. Dredge sites will be classified as one of the following contamination levels: 'probably contaminated'; 'suspect', or 'probably clean'.

Contaminants List

This is the list of contaminants which could be present at elevated levels in the sediments of the dredge area, and therefore require analysis. The list includes those chemical substances for which sources are known or suspected in the dredge area or its catchment, based on the historical survey. Where good chemical data are available on the sediments, the list includes those toxic substances known, from previous investigations, to occur at levels greater than background concentrations or one tenth of the Screening Levels (**Table 2**) when the background data is below detection or, for substances which do not have Screening Levels, present at elevated levels.

Contaminants of Concern (COC) and Potential Concern (COPC)

The degree of contamination is split into contaminants of potential concern (COPCs) and contaminants of concern (COCs).

COPCs are those contaminants that exceed the background concentrations and the Screening Level (or elevated concentrations of contaminants for which guidelines do not exist).

COCs are those contaminants which exceed the background concentrations and the Screening Level and for which the bioavailability, bioaccumulation or toxicity assessments indicate that significant effects from the contaminants are likely. For COCs, definite actions are required. For COPCs, no immediate action may be required.

The contaminants are COPCs through Phase 1 and Phase 2 (**Figure 3**), and become COCs if they are 'above' at Phase III or IV.

Continental Shelf

The Continental Shelf is the area of the seabed and subsoil which extends beyond the territorial sea to a distance of 200 nm from the territorial sea baseline and beyond that distance to the outer edge of the continental margin as defined in Article 76 of the United Nations Convention on the Law of the Sea 1982 (UNCLOS). The continental shelf is largely coextensive with the exclusive economic zone within 200 nm from the territorial sea baselines. There are certain areas between Australia and Indonesia and Australia and Papua New Guinea where they are not coextensive, and there are eight areas in which it is likely that the continental shelf extends beyond the boundary of the EEZ. Australia has also declared a continental shelf off the Australian Antarctic Territory and some preliminary work has indicated that this is likely to extend beyond the 200 nm boundary in many places.

Determining Authority

The organization to which authority has been delegated to evaluate sea disposal applications and issue permits. At the time of publication, this is the Great Barrier Reef Marine Park Authority for disposal within the Great Barrier Reef Marine Park or Department of the Environment, Water, Heritage and the Arts for all other proposals.

Dumping

Under the London Protocol, dumping means:

- any deliberate disposal into the sea of wastes or other matter from vessels, aircraft, platforms or other man-made structures at sea
- any deliberate disposal into the sea of vessels, aircraft, platforms or other man-made structures at sea
- any storage of wastes or other matter in the sea-bed and the subsoil thereof from vessels, aircraft, platforms or other man-made structures at sea, and
- any abandonment or toppling at site of platforms or other man-made structures at sea, for the sole purpose of deliberate disposal.

Dumping does not include the disposal into the sea of wastes or other matter derived from the normal operations of vessels, aircraft, platforms or other man-made structures at sea. It also does not include placement of matter for a purpose other than the mere disposal thereof, provided that such placement is not contrary to the aims of the London Protocol.

Elutriate test

A test, which involves mixing sediment with four times its volume of seawater under specified conditions, to estimate the amounts of contaminants that will be released during dredging and during sea disposal.

Exclusive Economic Zone (EEZ)

The Exclusive Economic Zone is an area beyond and adjacent to the territorial sea. See **Figure 2**.

Exposure

Contact with a chemical, physical or biological agent.

In situ

In place or 'on site'.

Initial dilution

That mixing which occurs within four hours of dumping of a load of spoil.

Interstitial Water

Water contained within the pore spaces of the sediment, also called pore water.

Loading for the Purpose of Dumping (Loading)

Where material or substances of any kind are loaded on any vessel, platform or aircraft for the purpose of being dumped into the sea.

Maintenance Dredging

Dredging to ensure that channels, berths or other port areas are maintained at their designed dimensions.

Maritime Zones

For legal purposes, the sea is divided into zones extending from the mainland. The different zones are defined mainly in the *Seas and Submerged Lands Act 1973* and other legislation.

Natural Level

Levels of naturally occurring chemical substances (e.g. metals, hydrocarbons, PAHs) in the sediments of an area prior to any anthropogenic contamination.

Offshore Area

A marine area distant from land-based influences.

Pollution

The introduction, directly or indirectly, by human activity, of wastes or other matter into the sea which results or is likely to result in such deleterious effects as harm to living resources and marine ecosystems, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of seawater and reduction of amenities.

Port Waters

Port waters are not defined under the Commonwealth Sea Dumping Act. Port waters are defined under State and Territory legislation and this legislation differs from state to state.

Potentially Contaminated Sediment

Sediment that is contiguous with an area of known sediment contamination, or sediment exposed to known contamination sources.

Practical Quantitation Limit, PQL

The lowest chemical analysis level that can be reliably achieved within specified limits of precision and accuracy during routine operating conditions.

Precautionary Approach

Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

Pristine Site

A location which is distant from, and unaffected by, anthropogenic contaminants.

QA/QC

Quality assurance and quality control.

Reference Area

An area with similar sediment grainsize and oceanographic characteristics as the disposal site, and nearby but outside the area whose sediment chemistry could be affected by disposal at the site. Used for determining the ambient baseline concentrations.

Remediation

The cleanup or mitigation of pollution or contamination in sediments by various methods.

Risk

The probability that an adverse outcome will occur in a person, a group, or an ecological system that is exposed to a particular dose or concentration of a hazardous agent and dependant on both the level of toxicity and the level of exposure.

Screening Level

Level of a substance in the sediment below which toxic effects on organisms are not expected (**Table 2**).

Territorial Sea

The territorial sea of Australia extends 12 nm seaward from the territorial sea baseline. Under international law, Australia has sovereignty over the territorial sea except for the innocent passage of foreign vessels through it.

Toxicity

The quality or degree of being poisonous, or harmful, to plant, animal or human life.

Toxicity Testing, Sediment Bioassay

Procedures that evaluate the toxic effects of sediments on organisms.

Uncontaminated

Spoil is defined as being uncontaminated for the purposes of sea disposal if it comes from a pristine environment, or if, after assessment, it contains no Contaminants of Concern.

Waters within the Limits of a State

Waters within the limits of a State are those waters that lie within the constitutional limits of the State as determined by Letters Patent issued to the Governors of each of the States at Federation. They can include features such as bays, gulfs, estuaries, rivers, creeks, inlets, ports or harbours. Generally, the limits of the States are low water along the coastline together with bay closing lines (usually of no more than 6 nm in length) and also river closing lines. In some areas of the coastline, locating the limits of the State may be difficult. This can occur particularly where islands lie very close to the coastline and in relation to certain bays. In such cases there are detailed legal principles that must be applied to determine the exact location of the State limits.