REVISED SPECIFIC GUIDELINES FOR ASSESSMENT OF DREDGED MATERIAL

(* Editing Note: Need to attribute photographs to sources)

PREFACE

Specific Guidelines for Assessment of Dredged Material addressed in this document are intended for use by national authorities responsible for regulating dumping of wastes and embody a mechanism to guide national authorities in evaluating applications for dumping of wastes in a manner consistent with the provisions of the London Convention 1972 or the London Protocol. Annex 2 to the London Protocol places emphasis on progressively reducing the need to use the sea for disposal of wastes, for example, through beneficial use of the dredged material. Furthermore, it recognizes that avoidance of pollution demands rigorous controls on the emission and dispersion of contaminating substances and the use of scientifically based procedures for selecting appropriate options for waste disposal. When applying these Guidelines, uncertainties concerning the assessment of impacts on the marine environment can be addressed through the use of an iterative approach to the evaluation process and a precautionary approach to management. These Guidelines should be applied with a view that acceptance of disposal in specific cases does not remove the obligation to make further attempts to reduce the necessity for dumping.[1]

Comment [p1]: Deleted footnote 1 which read "Article 3.1 of the Protocol

The London Protocol follows an approach under which disposal of wastes or other matter is prohibited except for those materials specifically enumerated in annex 1, and in the context of that Protocol, these Guidelines would apply to the materials listed in that annex. The London Convention 1972 prohibits the disposal of certain wastes or other matter specified therein and in the context of that Convention these Guidelines are designed to implement the requirements of its annexes for wastes not prohibited for disposal at sea. When applying these Guidelines under the London Convention 1972, they should not be viewed as a tool for the reconsideration of dumping of wastes or other matter in contravention of annex 1 to the London Convention 1972.

These Guidelines, which were adopted in 2013 by the 35th Consultative Meeting of the Parties to the Convention and the eighth Meeting of Parties to the London Protocol, are specific to dredged material. They update and replace the Guidelines adopted for dredged material in 2000 by the 22nd Consultative Meeting, which were based on the generic Guidelines of 1997 and replaced the "Dredged Material Assessment Framework" adopted in 1995 by the 18th Consultative Meeting (resolution LC.52(18)), which, in turn, replaced the *Guidelines for the Application of the annexes to the Disposal of Dredged Material*, adopted in 1986 by the Tenth Consultative Meeting (resolution LDC.23(10)).

These Guidelines are intended to provide additional clarification to enable compliance with annex 2 of the London Protocol, and represents neither a more restrictive nor a less restrictive regime than that annex.

(Editing Note: Secretariat will work out the format for referring to LC, LP, annex 2, etc. in the document as a part of editing.)

[1] Article 3.1 of the Protocol.

1 INTRODUCTION

1.1 Sediment is an essential component of freshwater, estuarine, and marine ecosystems. Sediment processes play important roles in determining the structures and functions of aquatic systems. Therefore, management processes applied to sediment, in relation to human activities, should recognize that sediment is an important natural resource.

1.2 Around the world, dredging of sediments is undertaken for several general purposes, including: 1) to support the development and maintenance of water-based infrastructure (for example, navigation systems, flood mitigation, water supply systems, etc.), 2) as part of remediation measures for areas of contaminated sediment, and 3) to restore structure and function to aquatic ecosystems (for example, through habitat restoration/creation). Some material removed during these activities may require disposal at sea.

1.3 Dredged material predominantly consists of sedimentary deposits of natural materials (for example, rock, sand, silt, clay and natural organic matter). Appropriate management actions for dredged material, including its end use or disposal, will be affected by many project- and site-specific factors, including the location of the dredging project, the geotechnical characteristics of the sediment, the degree of contamination present, potential environmental impacts, engineering constraints, monitoring operations, and costs.

Overarching considerations

1.4 Three overarching considerations should guide planning and permitting activities related to dredged material management, including disposal at sea, that are in keeping with the intent of the London Protocol and London Convention to protect and preserve the marine environment:

.1 Dredged sediment is a resource that should be used for beneficial purposes (as described in paragraphs 3.3 and 3.4) as an alternative to disposal in the ocean, when it is not contrary to the aims of the Convention and Protocol and is environmentally, technically and economically feasible to do so.

.2 Selection of management options for dredged material should be guided by "a comparative risk assessment involving both dumping and the alternatives" (annex 2 of the 1996 Protocol, paragraph 6) to dumping. This assessment should compare: the environmental risks; the economic, social and environmental benefits; and the costs for each of the management alternatives under consideration over the short and long term.

.3 Management actions for dredged material should "ensure, as far as practicable, that environmental disturbance and detriment are minimized and the benefits maximized" (annex 2 of the 1996 Protocol, paragraph 17).

Overview of dredging activities and the evaluation and management process

1.5 Some dredging activities may give rise to the need to relocate or dispose of sediments. The primary purpose of the dredging activity may be a relevant consideration when determining dredged material management options. The different purposes for dredging include:

Dredging for the purposes of development and maintenance of water-based infrastructure, includes:

.1 Capital (or new-work) dredging – for navigation this involves enlarging or deepening existing channel and port areas or creating new ones; for engineering purposes includes constructing trenches for pipes, cables, immersed tube tunnels, and removal of material unsuitable for foundations or for aggregate extraction; for hydraulic purposes this involves increasing the flow capacity of the waterway;

.2 Maintenance dredging – to ensure that channels, berths or construction works, etc. are maintained at their designed dimensions; and

.3 Dredging to support coastal protection/management – relocation of sediments for activities as beach nourishment and construction of levees, dykes, jetties, etc.

Dredging for the purposes of remediation includes:

.4 Environmental dredging – to remove contaminated sediment for the purpose of reducing risks to human health and the environment; construction of Confined Aquatic Disposal cells to hold contaminated sediments.

Dredging for the purposes of restoring structure and function to aquatic ecosystems includes:

.5 Restoration dredging – to restore or create environmental features or habitats to establish ecosystem functions, benefits, and services; for example, wetlands creation, island habitat construction/nourishment, construction of offshore reefs and topographic features for fisheries enhancement, etc.; and

.6 Dredging to support local and regional sediment processes – includes engineering to reduce sedimentation (e.g. construction of sediment traps), retaining sediment within the natural sediment system to support sediment-based habitats, shorelines and infrastructure.

1.6 In general, dredging projects should be considered in the broader context of the watershed and the regional sediment system where they occur. Ideally, dredging and associated sediment management projects should strive to optimize the production of economic benefits, ecosystem services, and social goals, while ensuring the protection of the marine environment. An example of the rationale for this approach can be found in the Working with Nature initiative described in PIANC (2011). Such an approach involves broad stakeholder engagement, from the very beginning of a project, in order to identify potential concerns, opportunities for avoiding negative environmental impacts, and ways to incorporate additional ecosystem benefits and services into the project design. This approach to project planning and execution can help streamline the permitting process while minimizing environmental detriments and maximizing environmental benefits.

1.7 The above dredging activities may generate dredged material that requires disposal at sea. Of the total amount of material dredged worldwide, most is similar to undisturbed sediments in inland and coastal waters. However, some dredged material is contaminated by human activity to an extent that specific management actions need to be applied when considering disposal or use of these sediments.

1.8 A training set is available on the LC/LP website (LC/LP 2007, http://www.imo.org/blast/mainframemenu.asp?topic_id=1654) to assist in the implementation of these Guidelines. The training set includes a tutorial booklet, an instructor's manual, electronic presentation slides, and an extension providing low-technology techniques for assessing dredged material disposal. The training set explains key components of the Guidelines and offers access to experience of Contracting Parties in regulating ocean dumping over the last 30+ years (LC/LP 2007; LC/LP 2011). In addition, an example application of the Guidelines is contained in Fredette (2005).

1.9 The schematic shown in figure 1 presents the steps involved in the application of these Guidelines where important decisions should be made. In general, national authorities should use this schematic in an iterative manner (revisiting steps in the processes as needed) to ensure that all steps receive appropriate consideration before a decision is made to issue or decline a permit. The following sections of this document describe the steps and activities relevant to these Guidelines.

Annex

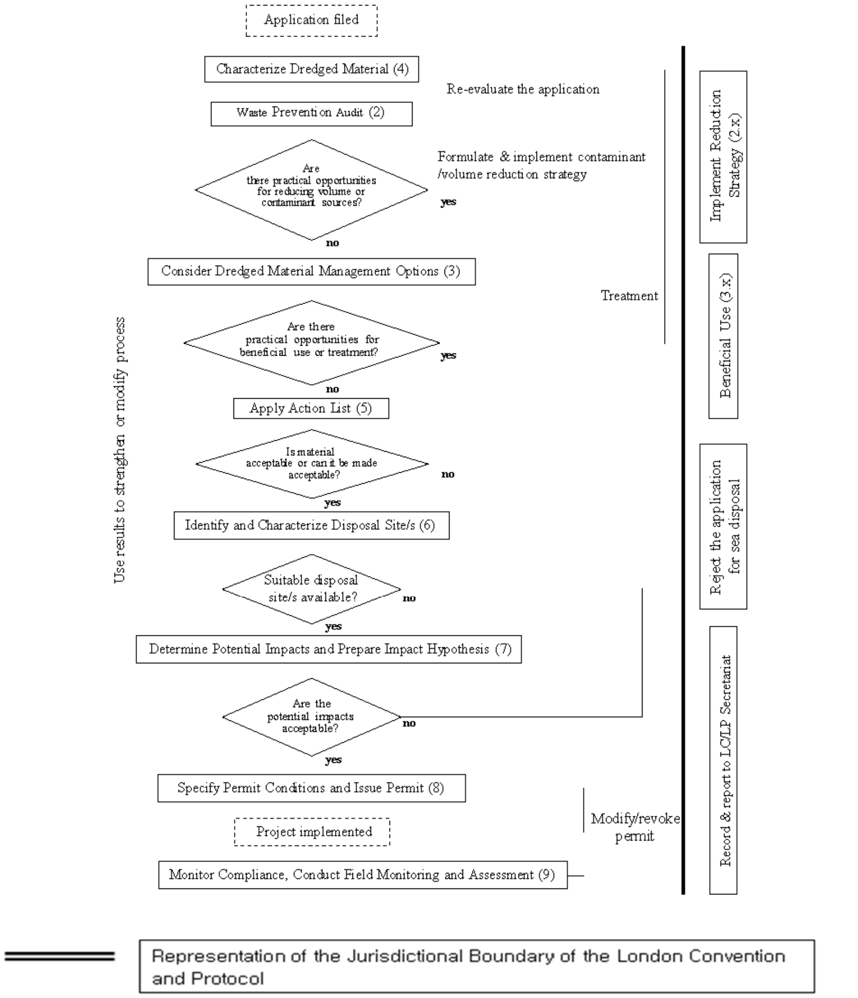

Figure 1. Dredged Material Assessment Framework. Schematic presents the major steps in the application of these Guidelines where important decisions, using an iterative process, should be made. Numbers in parentheses denote the sections in these Guidelines where explanatory text is located. Shaded boxes are actions undertaken primarily by project proponents and not by the national authority administering the permit program.

2 WASTE PREVENTION AUDIT

2.1 For dredged material, the goal of waste management should be to identify and control sources of contamination, including through implementation of waste prevention strategies. Until this objective is met, the problems of contaminated dredged material may be addressed by using disposal management techniques at sea or on land. In the context of sediment management, reducing detrimental effects on the marine environment and the need for dredged material disposal at sea can be accomplished through the following three activities:

.1 Controlling and reducing sources of contamination to water and sediments;

.2 Maximizing, to the extent practicable, the use of dredged sediments for beneficial purposes; and

.3 Minimizing the volumes of sediment that must be dredged by using improved engineering practices.

2.2 There is growing recognition for the need to pursue sustainable approaches to sediment management in coastal systems, approaches which emphasize the need to minimize the release of contaminants to the environment while maximizing the reuse of sediment for beneficial purposes. Examples of progress made toward utilizing sustainable sediment management can be seen in initiatives being undertaken by some Contracting Parties and Observers to the London Convention and London Protocol, including the Regional Sediment Management Program[2] in the United States, Working with Nature (PIANC 2011), Building with Nature,[3] and Engineering With Nature.[4]

2.3 Application of best engineering and operational practices to dredging operations will provide opportunities for minimizing the quantity of material that must be dredged and disposed of at sea and reducing the environmental impact of dredging activities (e.g. PIANC 2009). These practices include improved land-use management, the use of engineering to reduce sedimentation within navigation channels, accurate survey systems, and improvements to the dredging process by using the best suited dredging equipment and techniques and monitoring technologies.

2.4 Sediment is a valuable natural resource. Opportunities for beneficial use of dredged material (which are described further in sections 3.3 and 3.4) should be pursued to the maximum extent practicable. Beneficial use of sediments includes making use of opportunities for retaining clean sediment within natural sediment processes and cycles that support aquatic, estuarine, and marine systems.

2.5 Contamination of aquatic environments and sediments can lead to environmental impacts, increased costs for dredged material management, and reduced opportunities for beneficial use. For dredged material, an additional goal of waste management should be to identify, control, and reduce the sources of contamination to the sediment resource.

.1 Contamination of aquatic environments, both as a consequence of historical and present day inputs, presents a problem for the management of sediments. High priority should be given to the identification of sources, as well as the reduction and prevention of further contamination of sediments from both point and non-point sources. Sources of contamination include:

2 United States Army Corps of Engineers, Regional Sediment Management Program: http://rsm.usace.army.mil/

3 EcoShape, Building with Nature: http://www.ecoshape.nl/

4 United States Army Corps of Engineers, Engineering With Nature: http://www.EngineeringWithNature.org

.1 industrial and residential discharges;

.2 storm water;

.3 surface runoff from agricultural areas;

.4 sewage and waste-water treatment effluents; and

.5 transport from upstream contaminated sediments.

.2 In developing and implementing a source control strategy, appropriate agencies should take into account:

.1 the risks posed by contaminants and the relative contributions of the individual sources to these risks;

.2 existing source control programmes and other regulations or legal requirements;

.3 technical and economic feasibility;

.4 evaluations of the performance or effectiveness of measures taken; and

.5 consequences of not implementing source control.

.3 In cases where there has been historical contamination or where control measures are not fully effective in reducing contamination to acceptable levels, risk management approaches and technologies, including the use of confinement or treatment methods, may be required.

.4 Successful implementation of prevention strategies will require collaboration among agencies with responsibility for the control of contaminant sources. The Rhine Action Plan[5] is an example of progress that can be achieved through giving attention to source control.

2.6 In general terms, if the required waste prevention audit reveals that opportunities exist for waste prevention at source, an applicant is expected to formulate and implement a waste prevention strategy in collaboration with relevant local and national agencies which includes specific waste reduction targets and provision for further waste prevention audits to ensure that these targets are being met. Permit issuance or renewal decisions shall assure compliance with any resulting waste reduction and prevention requirements.[6]

3 EVALUATION OF DREDGED MATERIAL MANAGEMENT OPTIONS

3.1 The results of the physical/chemical/biological characterization (section 4) will provide the basis for the comparative assessment of dredged material management options, which will include determining whether the material is suitable for disposal at sea. In any evaluation of management options a holistic consideration should be given to the system in

5 http://www.iksr.org/index.php?id=258&L=3&pdfPage=1

6 Annex 2, paragraph 3.

which dredging will occur, placing the potential impacts of a given option into a broader perspective. The range of dredged material management options may include:

.1 Beneficial use;

.2 Confined upland disposal, e.g. in a confined disposal facility or landfill;

.3 Confined aquatic disposal, i.e. confinement in the aquatic environment beneath a cap of clean sediment;

.4 Open-water disposal; and

.5 No action, i.e. the sediment remains in place and no dredging and management is performed.

Treatment of the dredged material – through physical, chemical or biological means – may be used in combination with alternatives .1 to .4 above to reduce or control impacts to a level that will not constitute an unacceptable risk to human health, or harm living resources, damage amenities or interfere with legitimate uses of the sea.

A permit to dump wastes or other matter shall be refused if the permitting authority determines that appropriate opportunities exist to reuse, recycle or treat the waste without undue risks to human health or the environment or disproportionate costs.[7] The practical availability of other means of disposal should be considered in the light of a comparative risk assessment involving both dumping and the alternatives.

3.2 The comparative risk assessment to be performed will compare the management alternatives under consideration by using a set of relevant criteria that are selected as a part of project planning. Annex 2 of the London Protocol, paragraph 14 includes a list of the following concerns that should be considered in the selection of the criteria employed within the comparative assessment:

.1 human health risks (e.g. resulting from consumption of contaminated fish);

.2 environmental costs (that is, adverse impacts, e.g. sediment toxicity affecting benthic production and biodiversity);

.3 hazards (e.g. the potential for navigation accidents because navigable depths are not maintained in channels or at disposal sites);

.4 economics (e.g. the relative monetary costs of the management alternatives); and

.5 exclusion of future uses (e.g. adverse impacts on nearby fisheries or recreational areas).

Comparative risk assessments are performed by collecting information relevant to the selected criteria for each of the alternatives under consideration. The alternatives are compared using this information, which guides the selection of the management alternatives that will be used. Further technical information and examples of comparative assessments for dredged material have been published in the scientific literature (Kane-Driscoll et al. 2002; Cura et. al. 2004; Kiker et. al. 2008). The results of the comparative analysis are intended to support sustainable practices and sound management decisions by balancing risks and benefits, over the long term, to environmental, social, and economic considerations and objectives.

[7] Annex 2, paragraph 6.

Beneficial uses

3.3 It is important, recognizing the value of sediment as a resource, to consider opportunities for beneficial uses of dredged material, taking into account the physical, chemical, and biological characteristics of the material (PIANC 2009). Generally, a characterization carried out in accordance with these Guidelines will be sufficient to match a material to possible beneficial uses in water, at the shoreline, and on land. Examples of beneficial use opportunities include:

In water

.1 *Habitat Restoration and Development* using direct placement of dredged sediments for enhancement or restoration of ecosystem habitat associated with wetlands, other near-shore habitats, coastal features, offshore reefs, fisheries enhancement, etc.

.2 *Sustainable Relocation* by retaining sediment within the natural sediment system to support sediment-based habitats, shorelines, and infrastructure.

At the shoreline

.3 *Beach Nourishment* using dredged material (primarily sandy material) to restore and maintain beaches.

.4 *Shoreline Stabilization and Protection* through the placement of dredged material with the intent of maintaining or creating erosion protection, dike field maintenance, berm or levee construction, and erosion control.

On land

.5 *Engineered Capping* of soils or waste materials, e.g. landfill covers or remediation of former mining sites. (This form of beneficial use also applies to capping of contaminated sediments in aquatic environments.)

.6 *Aquaculture, Agriculture, Forestry, and Horticulture* involving direct placement of dredged material to create or maintain an aquaculture facility, replace eroded topsoil, elevate an area for improved site use, or otherwise enhance the physical and chemical characteristics of land.

.7 *Recreational Development* through direct placement of dredged material for the foundation of parks and recreational facilities; for example, waterside parks providing such amenities as swimming, camping, or boating.

.8 *Commercial Land Development* (also known as reclamation) using direct placement of dredged sediments to support commercial or industrial development activities, including "brownfield" redevelopment, as well as marine port, airport, and residential developments. These activities typically occur near navigational channels by expanding the land footprint or providing bank stabilization material.

.9 *Commercial Product Development* involving the use of dredged material to create marketable products such as construction materials, e.g. bricks, aggregate, cement, top soil, etc.

3.4 Factors relevant to the planning and execution of beneficial use projects include (USACE Engineer Manual 1110-2-5026; USEPA/USACE, 2007):

.1 *Engineering considerations*, e.g. the geotechnical characteristics of the sediment;

.2 *Operational factors*, e.g. timing and project schedule;

.3 *Cost*, e.g. related to the transportation of the sediment to the beneficial use site and other handling or treatment costs;

.4 *Environmental suitability*, e.g. in relation to the transport of sediment and the chemical, biological and physical characteristics of the sediment;

.5 *Additional environmental effects*, e.g. due to handling or pre-treatment (if required); and

.6 *Environmental benefits produced*, e.g. ecosystem services,[8] habitat and fisheries benefits, creation of habitats or ecosystems that function as carbon sinks (Nellemann, et al. 2009).

Additional information about beneficial uses of dredged material, including case studies, can be found at the U.S. Army Corps of Engineers' Dredging Operations Technical Support Program website,[9] the Beneficial Uses of Dredged Material website[10] sponsored by the U.S. Army Corps of Engineers and U.S. Environmental Protection Agency, and the Central Dredging Association's website.[11] PIANC (2009) provides technical information on the assessment of options for beneficial use and recommendations on how to overcome constraints based on "lessons learned" from numerous cases studies in different situations in various countries.

Management of disposal at sea

3.5 The design and conduct of a dredging operation, including associated disposal activities, will be informed by the results of the Dredged Material Characterization (section 4) and the comparative analysis of management options. The results of this analysis may indicate the need for using specific management actions and techniques as a part of disposal operations in order to meet the requirements of the Convention and Protocol. Such management actions can be used to reduce or control impacts to a level that disposal at sea will not constitute an unacceptable risk to human health, or harm living resources, damage amenities or interfere with legitimate uses of the sea. An evaluation of these additional management techniques during project planning will guide the selection of methods that will be used to reduce risks and impacts to acceptable levels (for example, USEPA/USACE, 2004; USACE Engineer Manual 1110-2-5025; CEDA & IADC 2008). The management actions that can be taken to minimize environmental disturbance and detriment include engineering and operational controls:

8 http://www.unep.org/maweb/en/Framework.aspx

9 United States Army Corps of Engineers' Dredging Operations Technical Support Program: http://el.erdc.usace.army.mil/dots/

10 U.S. Army Corps of Engineers and U.S. Environmental Protection Agency Beneficial Uses of Dredged
Material: http://el.erdc.usace.army.mil/dots/budm/budm.cfm

11 Central Dredging Association: http://www.dredging.org

.1 *Engineering controls* include actions involving the use of a physical construction technology or a physical modification to the dredging/disposal equipment to minimize environmental impact. Examples of engineering controls include:

.1 Selection of the most appropriate dredging equipment (e.g. mechanical vs. hydraulic dredge, dredge size/production capacity, which will affect the physical density, behaviour, and transport of the dredged material during disposal operations);

.2 Use of equipment, such as diffusers to perform submerged discharge and silt curtains to limit transport and mixing in the water column;

.3 Use of turtle-excluding dredge heads to protect large marine fauna;

.4 Treatment of the dredged material (e.g. physical separation of coarse from fine sediments, the use of amendments to stabilize contaminants, the utilization of geochemical interactions and transformations of substances in dredged material when combined with sea water or bottom sediments, etc.); and

.5 Use of capping techniques for confined aquatic disposal (CAD).

.2 *Operational controls* involve actions that can be undertaken by the dredge operator to alter conditions or processes that reduce environmental exposures and risks from the dredging and disposal operations. Example operational controls include:

.1 Scheduling of operations to avoid impacts to breeding or migrating organisms;

.2 Modifications to the timing of disposal operations (e.g. undertaking operations during specific parts of the tidal cycle or during specific river discharges can reduce the extent of dispersal of resuspended sediment);

.3 Modifications to the rate of discharge of the dredged material;

.4 Selection of the disposal site, or the location of discharge within the selected disposal site;

.5 Use of field monitoring as a basis for adjusting operations (e.g. suspended sediment monitoring, turbidity, light attenuation); and

.6 Use of sensing systems and observers to detect the presence of marine turtles and mammals in the vicinity of dredging operations.

3.6 Engineering and operational controls can be combined as a part of planning, designing and evaluating management alternatives for disposal operations that comply with the provisions of the London Convention and Protocol over the short and long term. Such engineering and operational controls are subject to site-specific conditions.

3.7 One of the most common engineering controls applied to contaminated dredged material is confined aquatic disposal (CAD), which has been successfully used at many sites around the world (e.g. Palmerton et al. 2002; Fredette 2006; Wolf et al. 2006, DEFRA 2009; USACE 2012). CAD involves first placing the dredged material on the bottom and then covering the dredged material with a layer of clean sediment. Palermo et al. (1998) provides detailed engineering guidance on the use and management of CAD operations. CAD can be employed by placing contaminated dredged material:

.1 Within depressions or pits on the sea bottom (e.g. specifically constructed pits, former borrow sites or aggregate mining sites, natural depressions) and then placing the capping layer of clean sediment over the top of the dredged material;

.2 Behind submerged berms constructed of clean dredged material, followed by capping;

.3 On a level bottom, followed by placement of clean sediment to create a mound.

Engineering design for application of CAD should include consideration of physical and environmental processes that could affect the long-term performance and stability of the cap (e.g. ordinary tidal currents, storm surges, high waves etc.). Monitoring technologies for capping projects, as well as a description of several capping case studies around the world, are included in Palermo et al (1998).

4 DREDGED MATERIAL CHARACTERIZATION

Organizing the characterization and assessment

4.1 Dredged material characterization is conducted in order to collect the information that will be needed to inform management decisions, including determining whether, and under what conditions, the material can be permitted for disposal at sea. Characterization is performed by collecting information about the physical, chemical and biological attributes of the sediment to be dredged. The specific data needs that will be satisfied by this effort will be determined by the nature of the dredging project and the management options that will be considered within the comparative assessment.

4.2 Evaluations of dredged material are most efficiently conducted following a tiered process that begins with collecting existing relevant information, sediment chemistry data, and results from simple screening approaches. The evaluation then progresses, as needed, to more detailed assessments, where information from multiple lines-of-evidence is collected to reach conclusions about contaminant exposure, effects, and ultimately the risks posed by the disposal of dredged material into the sea (PIANC 2006a; LC/LP 2007; LC/LP 2011). The term *line-of-evidence* is commonly used to refer to broadly defined categories of information, physical, chemical and biological data, e.g. sediment chemistry, toxicity test data, and benthic community survey results.

4.3 The initial tier of assessment begins with a planning phase that establishes goals for the assessment, develops a conceptual model for the project, and identifies assessment questions and hypotheses that will be tested during subsequent analyses. Existing information is then collected on the physical, chemical, and biological attributes of the material, which are then compared to guidelines/standards; this comparison may allow early conclusions about the potential risks posed by the material. If insufficient information is available to make a management decision regarding the material during an initial phase of assessment, then additional information will be collected on the physical, chemical, and biological characteristics of the sediment until sufficient information is available to understand the risks and benefits posed by each of the management options under consideration in the comparative assessment. A tiered approach is iterative, with information from one tier guiding not only actions taken in later tiers, but also informing, when necessary, reconsideration of conclusions made in previous tiers (PIANC 2006a; CEDA and IADC 2008).

4.4 The development of a project conceptual model during the planning phase of the project can be a useful tool for identifying the critical processes and data to be developed and evaluated in the assessment. The level of effort involved in developing a conceptual model will be determined by the needs of the project. A conceptual model is a written description or graphical representation of predicted relationships between receptors or resources in the environment (e.g. animals, plants, humans, human activities such as navigation) and the sources of effect or impact to which they may be exposed during the dredging and disposal operations. As a planning and decision-support tool, conceptual models can help dredged material managers, risk assessors, and regulators define the key elements of a project, contaminants of concern, sensitive organisms or activities (e.g. fish, shorebirds, humans, commercial fishing) in the environment that could be exposed and adversely affected by the project, and what processes and exposure pathways could potentially lead to the risk or adverse impact. Additional information about conceptual models and their use in sediments assessments, including examples, can be found in PIANC (2006a), Cura et al. (1999), and Bridges et al. (2005).

4.5 A simple example of a graphical conceptual model for use in a sediment assessment where contaminants associated with the sediment represent the focus of concern is shown in figure 2 (PIANC 2006b; Bridges et al. 2005). In this case, receptors in the environment are expected to come in contact with contaminants in the sediment through one of three primary pathways: (1) through contact with bedded sediment particles, (2) through contact with water that is contaminated via the sediment, and (3) through contact with contaminants that bioaccumulate within the food chain.

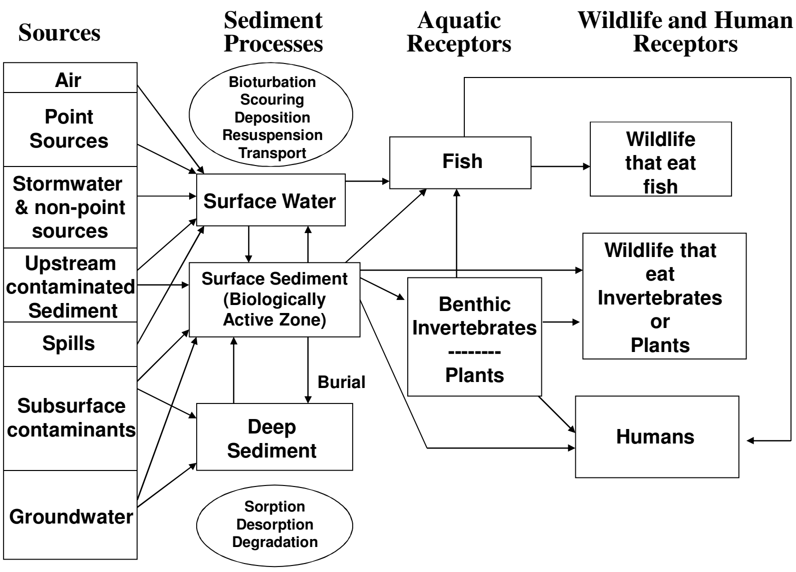

Figure 2. – Example conceptual model that highlights processes and pathways relevant to the assessment of contaminated sediment (based on PIANC 2006b).

4.6 The process of developing conceptual models that include the range of management options to be considered by the comparative assessment will guide the identification of the lines-of-evidence that will be needed to evaluate processes, reach conclusions about risks posed by the operation, evaluate the value of management actions that can be taken to reduce those risks, and establish permit requirements. In regard to the comparative risks assessment to be conducted, lines-of-evidence refer to the data and logic developed from the physical, chemical and biological characterization that will be used to develop conclusions about risks to the marine environment and its amenities. Assessments proceed by developing multiple lines-of-evidence to address the hypotheses and assessment questions that need to be answered to properly design the project and make permit decisions. A detailed technical discussion of the use of lines-of-evidence for sediment assessment is contained in Bridges et al. (2005) and PIANC (2006b).

4.7 There are three main lines-of-evidence that can be developed as a part of the characterization and evaluation process: physical, chemical and biological. An annotated list of the data to be collected and analysed during the characterization process should be developed on a project-specific basis. The annotations should explain what the data would demonstrate about the sediment to be dredged and how this information could be used in making management decisions (PIANC 1998). Sampling of sediments from the proposed dredging site should represent the vertical and horizontal distribution and variability of properties of the materials to be dredged – additional technical guidance on sampling of dredged material can be obtained from IMO (2005).

4.8 In order to develop sufficient evidence to support the selection of the most appropriate management options for dredged material, lines-of-evidence are typically developed in an iterative manner. By revisiting steps in the Dredged Material Assessment Framework (figure 1), as appropriate, and developing data over a sequence of phases or steps, critical uncertainties can be resolved in an efficient manner (PIANC 2006a). Collection and analysis of data and relevant lines-of-evidence should continue until sufficient information is developed to support confident conclusions that the selected management alternatives, including sea disposal, will not have significant adverse effects on human health or the environment.

Physical characterization

4.9 An evaluation of the physical characteristics of the sediment to be dredged is used to determine needs in regard to chemical and/or biological testing and to assist in the evaluation of management options. The basic physical characteristics required are the amount of material, particle size distribution and other geotechnical attributes of the sediment (e.g. specific gravity of solids). These data can provide useful information regarding the potential for the sediment to be a carrier of contaminants and for predicting the behaviour, fate, and transport of the sediment during and after placement or disposal (in combination with information about currents, waves, etc.).

Chemical characterization

4.10 Sufficient information for chemical characterization may be available from existing sources: in such cases new measurements may not be required to gauge the potential impact of similar material at similar sites. Time elapsed since previous analysis should be taken into consideration as sources and amounts of contaminants deposited in the system in the intervening time may be sufficient to make the material unsuitable for some management options.

4.11 Considerations for designing and conducting chemical characterizations of dredged material include but are not limited to:

.1 major geo-chemical characteristics of the sediment including redox status;
.2 potential routes by which contaminants could reasonably have been introduced to the sediments;

.3 data from previous sediment chemical characterization and other tests of the material or other similar material in the vicinity, provided this information is still reliable;

.4 probability of contamination from agricultural and urban surface runoff;

.5 spills of contaminants in the area to be dredged;

.6 industrial and municipal waste discharges (past and present);

.7 source and prior use of dredged materials (e.g. for beach nourishment); and

.8 substantial natural deposits of minerals and other natural substances.

4.12 Contaminants of concern can include those in the following categories (LC/LP 2007):

.1 heavy metals,

.2 polycyclic aromatic hydrocarbons (PAH),

.3 biocides (e.g. TBT); and

.4 chlorinated organics.

4.13 Chemical characterizations of sediment could also consider the role of bioavailability in exposure processes. *Bioavailability* can be defined as "being capable of being absorbed and available to interact with the metabolic processes of an organism" (USEPA 2004). The bioavailable concentration of contaminants in sediment that can cause toxicity in human or ecological receptors is commonly less than the total concentration of these contaminants in the sediment. A number of chemical processes can limit the bioavailability of contaminants, such as binding between the contaminant and different forms of organic carbon.

.1 Bioavailability considerations could be included in the comparative assessment of management options in order to obtain an accurate understanding of the potential for exposure and effect and to identify management actions that can be taken to reduce risks to human health and the environment (Interstate Technology & Regulatory Council 2011).

.2 The physico-chemical factors that can influence bioavailability vary depending on the chemical attributes of the contaminant, but include oxidizing and reducing conditions in the water column and sediment, the amount of organic carbon present in the sediment, the form of organic carbon present, as well as factors affecting the geochemical state of the sediment over time (e.g. bioturbation, physical disturbance of the sediment matrix, etc.) (NRC 2003; Wenning et al. 2005; CEDA and IADC 2008).

Biological effect characterization

4.14 Biological data represents the third possible line-of-evidence for assessing the potential for environmental effects related to dredged material management, including sea disposal. The potential for biological effects can be assessed directly, through the use of toxicity tests, and indirectly, through the use of inferences developed from physical and chemical lines-of-evidence. However, sediment is a chemically and physically complex matrix. This complexity places limitations on the use of physical and chemical data alone to estimate the bioavailability and toxicity of contaminants present in the sediment.

4.15 Biological tests provide a means to measure contaminant bioavailability, bioaccumulation of contaminants into tissues, and toxicological effects (e.g. mortality, reduced growth). Toxicity tests serve an integrative function given that adverse effects in organisms are caused by the cumulative influence of each bioavailable contaminant, including those that are not quantified by chemical analysis.

4.16 In order for biological characterization to provide an adequate scientific basis for determining the potential for adverse effects on marine life, human health and the environment, the evaluation should be responsive to the conceptual model developed for the project, e.g. in regard to the species known to occur in proximity to dredging operations, the disposal site, and the processes and pathways that could result in adverse effects.

4.17 Biological tests should incorporate species that are considered appropriately sensitive and ecologically relevant (in view of the management sites under consideration). As is true for all data collected in the characterization process, biological tests should be conducted using sediments that are representative of the project material to be dredged. The effects and processes of interest in a biological characterization include direct toxicity and indirect effects resulting from contaminant bioaccumulation and movement within the food chain. Specific processes and effects of interest include the potential for:

.1 acute toxicity;

.2 chronic toxicity such as long-term sub-lethal effects;

.3 bioaccumulation; and

.4 tainting

at and in the vicinity of the site following disposal. Further information and examples on the conduct of biological testing for dredged material and the use of such data in decision making can be found in PIANC (2006a) and USEPA/USACE (1991, 1998).

Exemptions from detailed characterization

4.18 Dredged material may be exempted from full chemical and biological characterization described in paragraphs 4.10 to 4.17, if there is strong evidence (e.g. historical data, lack of contaminant sources) that the material is not contaminated and it meets *one* or more of the criteria listed below:

.1 dredged material is excavated from a site that is spatially removed from existing and historical sources of appreciable pollution, so as to provide reasonable assurance that the dredged material has not been contaminated, *or*

.2 dredged material is composed predominantly of sand, gravel and/or rock, *or*

.3 dredged material is composed of previously undisturbed geological materials.

Dredged material that does not meet any of these criteria should be characterized further to determine its potential to produce contaminant effects.

5 ACTION LIST

Developing the Action List

5.1 Each Contracting Party shall develop a national Action list to provide a mechanism for screening candidate wastes and their constituents on the basis of their potential effects on human health and the marine environment. The Action List provides a mechanism for determining whether sediments from dredging projects are acceptable for disposal at sea, and is expressly required under annex 2 of the 1996 Protocol.

5.2 A dredged material Action List is a list or inventory of dredged material characteristics (e.g. physical, chemical, biological), how they are measured (e.g. concentrations) and their associated effect levels (e.g. benchmarks) that a jurisdiction decides are important to consider in order to make permit decisions. IMO 2009 provides detailed guidance on the development of Action Lists and Levels.

5.3 To develop an Action List, Contracting Parties should consider what potential environmental impacts may result from the disposal of dredged material and what ecological assets and marine resources need to be protected. The process begins with identifying the chemical, biological, or physical characteristics that will make up the Action List. This can be done by surveying relevant sources of contaminants in dredged material and reviewing information collected during previous Dredged Material Characterizations (i.e. section 4). For dredged material, national Action Levels could be established on the basis of contaminant concentration limits, biological responses, environmental quality standards, flux considerations or other reference values (IMO 2009). In selecting chemical substances for consideration in an Action List, priority shall be given to toxic, persistent and bio-accumulative substances from anthropogenic sources (e.g. cadmium, mercury, organohalogens, petroleum hydrocarbons and, whenever relevant, arsenic, lead, copper, zinc, beryllium, chromium, nickel and vanadium, organosilicon compounds, cyanides, fluorides and pesticides or their by-products other than organohalogens).[12] In addition to its use to inform permitting decisions, an Action List can also be used as a trigger mechanism to identify the need for source control to prevent sediment contamination.

5.4 To establish Action Levels, benchmarks are set for each characteristic on the Action List. These benchmarks are used to identify where environmental concern may be low or high for a particular characteristic. They are often developed using a reference-based approach or an effects-based approach:

.1 In a reference-based approach, benchmarks for physical, chemical, or biological characteristics can be set based on knowledge of background or ambient conditions in comparable areas that have not been impacted by past disposal activities or other sources of contamination. Reference-based levels are commonly used for setting lower benchmarks and Lower Action Levels (paragraph 5.6), as it is reasonable to expect that levels that are similar to background levels would be unlikely to cause unacceptable effects;

.2 In effects-based approaches, benchmarks for physical, chemical, or biological characteristics are based on knowledge of effects that can be

[12] Protocol, Annex 2, paragraph 9.

produced following exposure to dredged material. Such limits can be based on information concerning the likelihood or magnitude for an effect, such as through the use of toxicity tests (PIANC 2006a).

5.5 The Action List becomes a functional decision-making tool by integrating the relevant characteristics (the List) and benchmarks (the Levels) to form a decision rule. The decision rule can be as simple as a pass/fail criterion for single benchmarks or it can be a more complex rule that combines multiple lines of evidence in a weight-of-evidence approach (IMO 2009).

5.6 An Action List shall specify an upper level and may also specify a lower level. The upper level should be set so as to avoid acute or chronic effects on human health or on sensitive marine organisms representative of the marine ecosystem.[13] Application of an Action List will result in three possible categories of dredged material:

.1 dredged material which contains specified substances, or which cause biological responses, *exceeding* the relevant upper level shall not be disposed at sea, unless made acceptable for disposal through the use of management techniques or processes that will reduce risks to acceptable levels. A discussion of management actions that can be taken to reduce risks to meet the requirements of the Convention and Protocol are given in paragraphs 3.5, 3.6, and 3.7 above;

.2 dredged material which contains specified substances, or which causes biological responses, *below* the relevant lower levels should be considered to be of little environmental concern in relation to sea disposal; and

.3 dredged material which contains specified substances, or which causes biological responses, *below* the upper level but *above* the lower level require more detailed assessment before their suitability for sea disposal can be determined.

6 SITE SELECTION

Site selection considerations

6.1 Proper selection of sites where dredged material will be disposed is of paramount importance. Many of the selection factors discussed below could also be relevant in the selection of beneficial use sites.

6.2 Information to select a disposal site shall include:

.1 physical, chemical and biological characteristics of the water-column and the seabed;

.2 location of amenities, values and other uses of the sea in the area under consideration (e.g. proximity to navigation channels, shipping routes, fishing areas);

.3 assessment of the constituent fluxes associated with disposal in relation to existing fluxes of substances in the marine environment; and

[13] Protocol, Annex 2, paragraph 10.

.4 economic and operational feasibility.[14]

6.3 Additional considerations for selecting and managing disposal sites could include large-scale processes such as climate change (e.g. future storm and wave conditions affecting sediment movement) (e.g. PIANC (2008); CEDA (2012).

6.4 Prior to selecting a disposal site, it is essential that data are available on the oceanographic characteristics of the general area in which the site is to be located. This information can be obtained from the literature but fieldwork should be undertaken to fill the gaps. Information needs include:

.1 the nature of the seabed, including its depth, topography, geo-chemical and geological characteristics, its biological composition and activity, and prior disposal activities affecting the area;

.2 the physical nature of the water column, including temperature, possible existence of vertical stratification, tides, surface and bottom currents, wind and wave characteristics, suspended matter, and variability in these processes due to storms or seasonal patterns; and

.3 the chemical and biological nature of the water column, including pH, salinity, dissolved oxygen at the surface and bottom, chemical and biochemical oxygen demand, nutrients and their various forms, and primary productivity.

These site data will provide information about the short- and long-term fate of dredged material (e.g. under what conditions it would be transported away from the site) in addition to other site-selection factors.

6.5 Some of the important amenities, biological features, and uses of the sea to be considered in determining the specific location of disposal sites include proximity and relation to:

.1 the shoreline and bathing beaches;

.2 areas of beauty or significant cultural or historical importance;

.3 areas of special scientific or biological importance, such as sanctuaries and Marine Protected Areas;

.4 fishing areas;

.5 recreational areas, e.g. diving;

.6 spawning, nursery, and recruitment areas;

.7 migration routes;

.8 seasonal and critical habitats;

.9 shipping lanes;

.10 military exclusion zones; and

.11 engineering uses of the seafloor, including mining, undersea cables, pipelines, desalination or energy conversion sites.

14 Protocol, Annex 2, paragraph 11.

Size of the site

6.6 The size of disposal sites is an important consideration. They should be large enough:

.1 to have the bulk of the material remain either within the site limits or within a predicted area of impact after disposal; unless the site is planned to be dispersive, the size should be sufficient to minimize mounding;

.2 to accommodate anticipated volumes of dredged material so that the quantities of sediment or any constituents reaching site boundaries are below levels of concern; and

.3 in relation to anticipated disposal volumes so that it will serve its function for the duration of its intended use, including consideration of its use by multiple projects.

However, they should not be so large that compliance or field monitoring would require undue expenditure of time and resources.

Site capacity

6.7 In order to assess the capacity of a site, the following should be taken into consideration:

.1 the anticipated loading rates per day, week, month, or year;

.2 the degree to which the site is dispersive;

.3 the allowable reduction in water depth over the site because of mounding of material;

.4 volume changes as a result of water introduced into the material during dredging operations; and

.5 volume changes as a result of consolidation of both the dredged material and the underlying sea floor.

Potential impacts

6.8 An important consideration in determining the suitability of dredged material for disposal at sea is the degree to which this would result in exposures that would lead to unacceptable adverse effects.

6.9 The extent of adverse effects of a substance or condition is a function of the exposures of organisms (including humans) and the sensitivity of those organisms to that substance or condition. Exposure, in turn, is a function, inter alia, of input flux and the physical, chemical and biological processes that control the transport, behaviour, fate, and distribution of a substance.

6.10 One of the processes to assess potential exposure to contaminants in the dredged material is the mobility of contaminants, which is dependent upon several factors:

.1 type of matrix;

.2 form of contaminant(s);
.3 contaminant partitioning;

.4 physical state of the system, e.g. temperature, water flow, suspended matter;

.5 physico-chemical state of the system;

.6 length of diffusion and advection pathways;

.7 biological activities, e.g. bioturbation;

.8 disposal methods; and

.9 engineering and operational controls, including containment measures.

6.11 The presence of natural substances and the ubiquitous occurrence of contaminants mean that there will always be some pre-existing exposures of organisms to all substances contained in dredged material. Concerns about exposures to hazardous substances thus relate to additional exposures that could be caused by dredging operations and disposal.

6.12 The potential physical impacts of dredging and disposal operations should also be considered in determining suitable disposal sites. Impacts may result from:

- habitat destruction or alteration due to changes in bottom topography and disposal of sediment that is different from sediments at the disposal site;

- transportation of suspended sediment plumes from the disposal sites to sensitive areas, such as seagrass beds, algal beds or coral reefs;

- reduction of light penetration due to suspended sediments, leading to impacts on light sensitive organisms or habitats;

- burial of benthic organisms;

- collision with marine fauna, and

- alteration of currents and wave conditions.

6.13 Under the right conditions, opportunities may exist to optimize disposal site selection in order to produce positive effects. Examples of such effects include offshore mounds and berms that produce desirable effects on wave climate, the capping of historically contaminated marine sediments (e.g. the Historic Area Remediation Site in the USA) and reef effects produced by dredged material mounds (Reine et al., 2012).

6.14 Temporal characteristics should be considered to identify potentially critical times of the year (e.g. for marine life) when disposal operations should not take place. This consideration leaves periods when it is expected that disposal operations will have less impact than at other times. Managing the exposures and risks associated with disposal during critical times can also be addressed through the use of engineering and operational controls as described in paragraphs 3.5 through 3.8. An example of a risk framework used to assess and manage these effects is presented in Suedel et al. (2008). Biological considerations relative to the timing of disposal operations include:

.1 periods when marine organisms are migrating;

.2 breeding periods;

.3 periods when marine organisms are hibernating on or are buried in the sediments; and

.4 periods when particularly sensitive and possibly endangered species are exposed.

7 ASSESSMENT OF POTENTIAL EFFECTS

7.1 Assessment of Potential Effects provides a basis for deciding whether to approve as proposed, modify, or reject the proposed disposal option and for defining environmental monitoring requirements. The "Impact Hypothesis" outlines the expected impacts of the dredging project and can provide the basis for management measures and for targeted monitoring requirements, which can be specified in the permit. The assessment involves three distinct activities:

.1 Summarizing the dredged material characteristics and comparing to the Action Levels (from section 5), which, along with the disposal site characteristics, provides a basis for developing Impact Hypotheses;

.2 Preparation of Impact Hypotheses, from which management measures and the monitoring program can be designed and specified in the permit; and

.3 Assess actual impacts by evaluating the Impact Hypotheses using the data collected during monitoring).

7.2 The assessment of the potential for effects based on the lines-of-evidence developed during the comparative assessment should lead to a concise statement of the expected consequences of the selected management option(s), i.e. the "Impact Hypothesis". Impact assessment proceeds by establishing a hypothesis, or prediction, about the potential impact, and then testing it scientifically. An impact hypothesis is a prediction of the likely environmental impact of a given disposal event at a given disposal site. The assessment of potential effects should integrate information on the characteristics of the dredged material, disposal method, and the proposed site conditions, including potential pathways of exposure. It should comprise a summary of the potential effects on human health and ecological receptors, amenities and other legitimate uses of the sea, and should define the nature, temporal and spatial scales of expected impacts based on reasonably conservative assumptions (LC/LP 2007). For complex dredging projects, formal risk assessment procedures can facilitate the evaluation of potential effects including problem identification, exposure assessment, effects assessment, and risk characterization (PIANC 2006a, 2006b).

7.3 The conceptual model developed for the project under evaluation will assist in capturing the range of potential effects and formulating questions and hypotheses to be tested. Example questions that could be derived from the conceptual model include:

.1 How will sediment and any associated contaminants be transported and dispersed in the marine environment?

.2 How will the concentrations change as they disperse and settle?

.3 What marine organisms are present (or likely to be present, based on past monitoring or life history information) in the zone of exposure?

.4 What are the expected exposure pathways?

.5 How would acute or sub-lethal toxicity be expressed in terms of consequences for populations of organisms in the vicinity of the disposal site?

These questions can be rephrased as hypotheses that can be tested statistically with empirical data during and after the disposal of dredged material.

7.4 In constructing an Impact Hypothesis, particular attention should be given to, but not limited to, potential impacts on amenities (e.g. presence of floatables), sensitive areas (e.g. spawning, nursery or feeding areas), habitat (e.g. biological, chemical and physical modification), migratory patterns and marketability of resources. Consideration should also be given to potential impacts on other uses of the sea including: fishing, navigation, engineering uses, areas of special concern and value, and traditional uses of the sea.

7.5 The expected consequences of disposal should be described in terms of the habitats, processes, species, communities and uses that are expected to be affected. The precise nature of the predicted effect (e.g. change, response, or interference) should be described. The effect should be quantified in sufficient detail so that there would be no doubt as to the variables to be measured during field monitoring. In the latter context, it would be essential to determine "where" and "when" the impacts can be expected.

7.6 Emphasis should be placed on biological effects and habitat modification as well as physical and chemical change. However, if the potential effect is due to contaminants, the following factors should be addressed:

.1 estimates of statistically significant increases of the contaminants in seawater, sediments, or biota in relation to existing conditions and associated effects; and

.2 estimates of the contribution made by the contaminants to local and regional fluxes and the degree to which existing fluxes pose threats leading to adverse effects on the marine environment or human health.

7.7 In the case of repeated or multiple disposal operations, Impact Hypotheses should take into account the cumulative effects of such operations. It will also be important to consider the possible interactions with other waste disposal practices in the area, both existing and planned.

7.8 An analysis of each management and disposal option should be considered in light of a comparative assessment of the following concerns: human health risks, environmental costs, hazards (including accidents), economics and exclusion of future uses. If this assessment reveals that adequate information is not available to determine, with confidence, the likely effects of the proposed disposal option, including potential long-term harmful consequences, then this option should not be considered further. In addition, if the interpretation of the comparative assessment shows the disposal option to be less preferable compared to other management options, a permit for disposal should not be given.

7.9 Once the potential environmental effects have been formulated into Impact Hypotheses, the specific provisions of the field monitoring program can be designed (LC/LP 2007). Impact Hypotheses should be developed to address the effect of applying the management measures (i.e. engineering and operational controls). Modifications of dredging and disposal operations can be an effective means of controlling the potential for both physical and contaminant effects (Australia 2009).

7.10 An evaluation of alternatives for disposal operations could include a long list of exposure scenarios and possible effects. Impact Hypotheses cannot attempt to reflect them all. It must be recognized that even the most comprehensive Impact Hypotheses will not address all possible scenarios and unanticipated impacts. It is therefore imperative that the monitoring programme be linked directly to the hypotheses and serve as a feedback mechanism to verify the predictions and the adequacy of management measures applied to the disposal operation and at the disposal site. As a part of this process it is important to identify the sources and implications of consequential uncertainties.

7.11 Each assessment should conclude with a statement supporting a decision to issue or refuse a permit for disposal at sea.

8 PERMIT AND PERMIT CONDITIONS

8.1 A decision to issue a permit should only be made if all impact evaluations are completed, the monitoring requirements are determined (see section 9), and the results of the comparative assessment identify the acceptability of disposal at sea. The provisions of the permit shall ensure, as far as practicable, that environmental disturbance and detriment are minimized and the benefits maximized. Any permit issued shall contain data and information specifying:

.1 the types, amounts and sources of materials to be disposed;

.2 the location of the disposal site(s);

.3 the method of disposal; and

.4 monitoring and reporting requirements.

Permit conditions should be drafted in plain and unambiguous language to ensure that:

.1 only those materials which have been characterized and found acceptable for sea disposal, based on the assessment, are disposed at sea;

.2 the material is disposed at the selected site; and

.3 any necessary sediment management techniques selected during the comparative analysis are carried out.

8.2 If disposal at sea is the selected option, then a permit authorizing disposal must be issued in advance.

8.3 As a part of project planning and decision making, it is recommended that a consultation process be established with all relevant stakeholders, ensuring opportunities for public review and participation beginning from the earliest stages of the project through to completion, including the permitting process. Such coordination activities stimulate joint fact finding, often identifying opportunities to improve the overall project, including through identification of alternative sediment management options and beneficial use opportunities. An example of stakeholder involvement is the mutual gains approach (e.g. Susskind and Landry 1991), where issue mapping is used to identify key stakeholders, interests and points of view that should be considered in the decision making process.

8.4 The permit is an important tool for managing disposal at sea of dredged material and will contain the terms and conditions under which the disposal may take place as well as provide a framework for assessing and ensuring compliance. In granting a permit, the hypothesized impact occurring within the boundaries of the disposal site, such as alterations to the physical, chemical, and biological compartments of the local environment is accepted by the permitting authority.

8.5 Regulators should employ best available technologies and practices in order to minimize environmental changes as far practicable, given technological and economic constraints.

8.6 Permits and the permit assessment process should be reviewed at regular intervals, taking into account the results of monitoring and the objectives of monitoring programmes. Review of monitoring results will indicate whether field programmes need to be continued, revised, or terminated, and will contribute to informed decisions regarding the continuance, modification, or revocation of permits. This provides an important feedback mechanism for the protection of human health and the marine environment.

9 MONITORING

9.1 Monitoring plays an important role in preventing pollution of the marine environment from dredged material disposal operations. Monitoring provides further critical feedback on the effectiveness of individual permit conditions, the evaluation process used in the permitting process, and the management of specific disposal sites. It can also increase knowledge about environmental conditions and the effects of an activity which can then serve as a basis for better assessment of environmental effects during future disposal projects.

9.2 Monitoring is used to verify that permit conditions are met – compliance monitoring – and that the assumptions made during the permit review and site selection process were correct and sufficient to protect the environment and human health – field monitoring. It is essential that such monitoring programmes have clearly defined objectives.

9.3 Compliance monitoring involves providing assurances that (1) the material to be disposed is the same as the material authorized under the permit; (2) the material is loaded, handled, and transported in accordance with the permit; (3) the volume is consistent with the permit; and (4) the disposal location and method are the same as specified by the permit.

9.4 Field monitoring involves sample collections at or near the disposal site and measurements made over different spatial or temporal scales. What is monitored will depend directly on the Impact Hypotheses that were constructed during the assessment of potential effects (section 7). Monitoring should be conducted with a clear purpose, and the information should be used to assess and modify management actions (future project evaluations, ongoing project operations, or site management policies) and future permitting decisions, as appropriate (LC/LP 2007, IMO 2009, LC/LP 2011).

9.5 The Impact Hypothesis forms the basis for defining field monitoring. The measurement programme should be designed to ascertain that changes in the receiving environment are consistent with predictions. The following questions should be answered:

.1 What testable hypotheses can be derived from the Impact Hypothesis?

.2 What measurements (type, location, frequency, performance requirements) are required to test these hypotheses?

.3 How should the data be managed and interpreted?

9.6 Measurements should be designed to determine whether the zone of impact and the extent of change outside the zone of impact differ from those predicted. This can be accomplished by designing a sequence of measurements in space and time that gauges both the spatial scale and magnitude of any observable changes. Frequently, these measurements will be based on a null hypothesis – that no significant change due to disposal activity can be detected.

9.7 Basing monitoring programmes on null hypotheses is a prospective (and not retrospective) approach in that acceptable and unacceptable adverse impacts are clearly defined before sampling begins, predicting what environmental resources are at risk and the magnitude and extent of that risk from disposal of dredged material at the site. The thresholds at which impacts will be adverse should be clearly defined prior to monitoring (Fredette et al. 1986, 1990). Considerations in this regard include:

.1 the monitoring programme should involve sampling before, during (where and when feasible), and after material is disposed at the site and at appropriate reference sites.

.2 Sampling design needs to consider the number of samples necessary to statistically test the hypotheses. The amount and type of testing necessary to support the decision will vary from project to project. It is important that the scale of the monitoring relates to the extent of the perceived problem and that the physical, chemical, or biological components of the monitoring programme relate to the cause of interest or concern (PIANC 2006a; CEFAS 2003).

.3 The design of the monitoring programme should include identification of the physical fate of the disposed dredged material, as the first step, in order to determine if the dredged material is confined to the disposal site. This information will influence the design of sampling to test null hypotheses that address both physical and biological effects of the disposed materials.

.4 The monitoring programme should be designed to help ensure an appropriate balance between the data collection and analysis effort. It should also ensure the confidence needed to make judgments on whether permit conditions are being met and if management actions are needed. The programme should be progressive in that sampling results, as well as advances in technology and scientific understanding, can be used to adapt and modify the monitoring programme or modify the questions being addressed by the null hypotheses.

9.8 Different levels of monitoring intensity should be designed into the programme. Each level incorporates its own testable hypotheses, environmental thresholds, sampling design, and management options should the environmental thresholds be exceeded. Each level should be designed such that there would be no need to implement the next more intensive level unless the null hypotheses are exceeded. Information from each monitoring level should have direct application for the decision-making process. Monitoring results may lead to decisions to conduct additional confirmatory monitoring, initiate monitoring at the next level, make specific changes in disposal site management (such as the need to perform capping and/or permit modification/revocation). For example, if monitoring finds material outside of the disposal site, that finding could trigger the need to conduct sampling to assess the extent of transport outside of the disposal site and biological effects that may have resulted.

9.9 It may usually be assumed that suitable specifications of existing (pre-disposal) conditions in the receiving area are already contained in the application for disposal. If the specification of such conditions is inadequate to permit the formulation of an Impact Hypothesis, the licensing authority will require additional information before any final decision on the permit application is made.

9.10 The permitting authority is encouraged to take account of research information produced over time by academic institutions, government agencies, and other organizations that have performed studies relevant to dredged material management and disposal sites as authorities design and modify monitoring programmes.

9.11 The results of monitoring (or other related research) should be reviewed at regular intervals in order to determine the need for:

.1 modifying or terminating the field-monitoring programme;

.2 modifying or revoking the permit;

.3 redefining or closing the disposal site; and

.4 modifying the basis on which applications permits are made and assessed.

9.12 The monitoring activities described above require significant interaction between program designers, project managers, and regulators. Timely communication among these parties regarding monitoring progress and results is critical to understanding whether sampling within a particular level is sufficient, whether additional monitoring and assessment are needed, whether additional management actions should be undertaken, and to ensure the timely application of management actions when such actions are needed.

10 REFERENCES AND RESOURCE DOCUMENTS

(Editing Note: Formatting of references will occur as a part of editing and formatting for publication. Also, two sections will be created: 1) Literature Cited in the text and 2) Other Resource Documents.)

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Comment [p2]: Insert the missing reference from Australia

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