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Capital and maintenance dredging
A pilot case study to review the potential benefits for nature conservation

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CAPITAL AND MAINTENANCE DREDGING - A PILOT CASE STUDY TO REVIEW THE POTENTIAL BENEFITS FOR NATURE CONSERVATION

FINAL REPORT

Prepared for:- **English Nature**
Poole Harbour Commissioners

MARCH 1992

CAPITAL AND MAINTENANCE DREDGING - A PILOT CASE STUDY TO REVIEW THE POTENTIAL BENEFITS FOR NATURE CONSERVATION

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EXECUTIVE SUMMARY

■ Background

This report has been prepared by Posford Duvivier Environment in accordance with the specifications laid out in the contract document for English Nature commissioned research ES702. The project has also been partly funded and supported by the Poole Harbour Commissioners. The aim of the project is to review the options for and provide guidance on the beneficial uses of dredged material for nature conservation. In addition, a case study is used to investigate the physical, chemical and biological nature of sediment in the south-eastern section of Holes Bay, Poole Harbour, Dorset, and assess its potential for beneficial uses for nature conservation.

Capital and maintenance dredging are currently essential to the commercial viability of many of the U.K.'s ports and harbours. This situation is likely to persist into the foreseeable future as ports need to be able to accommodate deeper drafted vessels to maintain their competitiveness.

■ Dredging and Disposal Restrictions

The report identifies the potential environmental impacts which can arise during dredging and disposal, and identifies possible mitigating measures which attempt to alleviate some of these impacts. The dredging process can have potentially adverse environmental impacts including destroying benthic habitats, increasing turbidity, and resuspending contaminants, as well as knock on effects for coastal processes including erosion and bed-form changes.

Openwater (subtidal) disposal of dredged material may have environmental consequences including turbidity, smothering of benthos, changing bathymetry and, if present, introducing contaminants into the water column. Onland (terrestrial) or intertidal disposal may lead to changes in the physical and chemical conditions of the sediment, potentially rendering it toxic, and may have detrimental impacts on the flora and fauna previously present at the disposal site.

The primary legislation currently in force to control disposal of dredged material in the U.K. comprises the Water Resources Act (1991) and the Food and Environment Protection Act (1985) (dumping at sea), and the Town and Country Planning and Environmental Protection Acts, both 1990 (dumping on land or intertidal areas). Environmental constraints focus primarily on existing protection for the dredging or disposal site and on the possible requirement for an Environmental Assessment prior to disposal. Guidelines governing options for disposal and controls on the materials themselves are very limited. Adequate guidance is urgently required.

Increasing restrictions on disposal opportunities, imposed both by the above legal controls and limitations on available land-based disposal sites, confirm the pertinence of investigations into alternative disposal options based on the concept of dredged material as a resource. One such option involves the beneficial use of dredged material for coastal habitat creation. This option, as proven by experience in the United States, may offer a significant opportunity to redress, to some extent, historic losses of such habitats due to development and land claim, and anticipated future losses due to climate change and sea level rise.

- Habitat Development Opportunities

The need for and feasibility of habitat creation or restoration initiatives has been realised and demonstrated, notably in the USA where dredged material has been used for a variety of beneficial uses. To enable dredged material to be used beneficially, methods must be identified which do not destroy other valuable habitats, harm resident wildlife, reduce water quality, or cause unacceptable consequences in terms of erosion or deposition.

This study aims to assess the options available and consider the technical details which are necessary for habitat development. There are several physical, chemical and biological parameters which control the development of habitats whether in a natural or anthropogenic situation. The complex interaction of the processes operating determines the likely success of habitat development initiatives. Planning for beneficial uses of dredged material should therefore consider the physical, chemical and biological characteristics of both the dredged sediment and the site to be used for habitat creation.

Another consideration for habitat development opportunities concerns the economic criteria. The cost of habitat creation initiatives can vary considerably depending on the requirements of the proposed habitat. In particular, transport costs and the cost of protective structures such as breakwaters could potentially be prohibitive. A sheltered site, as close as possible to the dredging area is therefore desirable for such initiatives.

- Coastal Habitat Creation

The potential benefits to nature conservation that could accrue from retaining the dredged material within the near-shore system, or using it for environmentally beneficial land based schemes are examined in this study.

In this respect, habitat creation might also go some way to replacing what has already been lost to the development of intertidal areas. Possible achievements to be gained from habitat creation could include increasing diversity of habitats; maintaining biological productivity and optimum populations; and increasing habitats for endangered species.

Possibilities for beneficial habitat creation options using clean or treated dredged material include subtidal, intertidal and terrestrial uses. Examples of subtidal features include reefs, berms, gravel bars and shellfish flats. Intertidal opportunities centre around marsh and mudflat creation, using dredged material to raise the elevation or to provide a suitable substrate for the growth of saltmarsh vegetation or for colonisation. Relatively little is known, however, about the specific process requirements of some coastal habitats, notably mudflats, and research is necessary to establish in detail the processes currently operating at existing sites. Islands might also be created, notably islands for birds, using coarser grained sediments.

Dredged material can also be used beneficially for aquaculture, beach nourishment and land claim projects, among others.

- Contaminated Materials

In certain cases material may need some degree of treatment to render it "clean" enough for use in habitat development. The sediments dredged from some of the U.K.'s port and harbour waterways are contaminated with heavy metals, nutrients, organic pollutants and other substances, reflecting past and present land uses around the estuary. At present, there are no U.K. guidelines for disposal of contaminated dredged materials. This is clearly an area which needs further research.

Contaminated sediments require either treatment or disposal in a confined site. Case studies demonstrate, however, that potential for the beneficial use of some contaminated sediments does exist (e.g. the creation of sub-tidal habitats, capped with clean materials which provide a substrate for colonisation). The primary environmental issues associated with the openwater disposal of contaminated sediments relate to the bioaccumulation of toxins in aquatic organisms.

- Case Study

A case study of Holes Bay in Poole Harbour, Dorset, investigated the physical, chemical and biological characteristics of the sediments in order to determine possible viable beneficial uses should the area be dredged.

The results of the preliminary survey carried out demonstrated a chemically "clean", sandy silt. This material would potentially be suitable for the creation of intertidal habitats such as marshes or mudflats if the habitat creation site is in a low energy environment, close enough to the dredging site to ensure that transport costs are not prohibitive.

- Methodology Development

The study identified a methodological framework for decision making in respect of potential beneficial uses for dredged materials (see Figure overleaf). Technical and economic viability criteria are highlighted, ecological desirability is explored, and site characteristics, management implications and socio-political controls are discussed.

A thorough baseline survey and rigorous ongoing monitoring of habitat creation sites are critical in controlling habitat development and improving future applications of beneficial use techniques. Work in the United States indicates that careful planning and controlled implementation are also essential prerequisites to successful habitat creation.

- General Conclusions

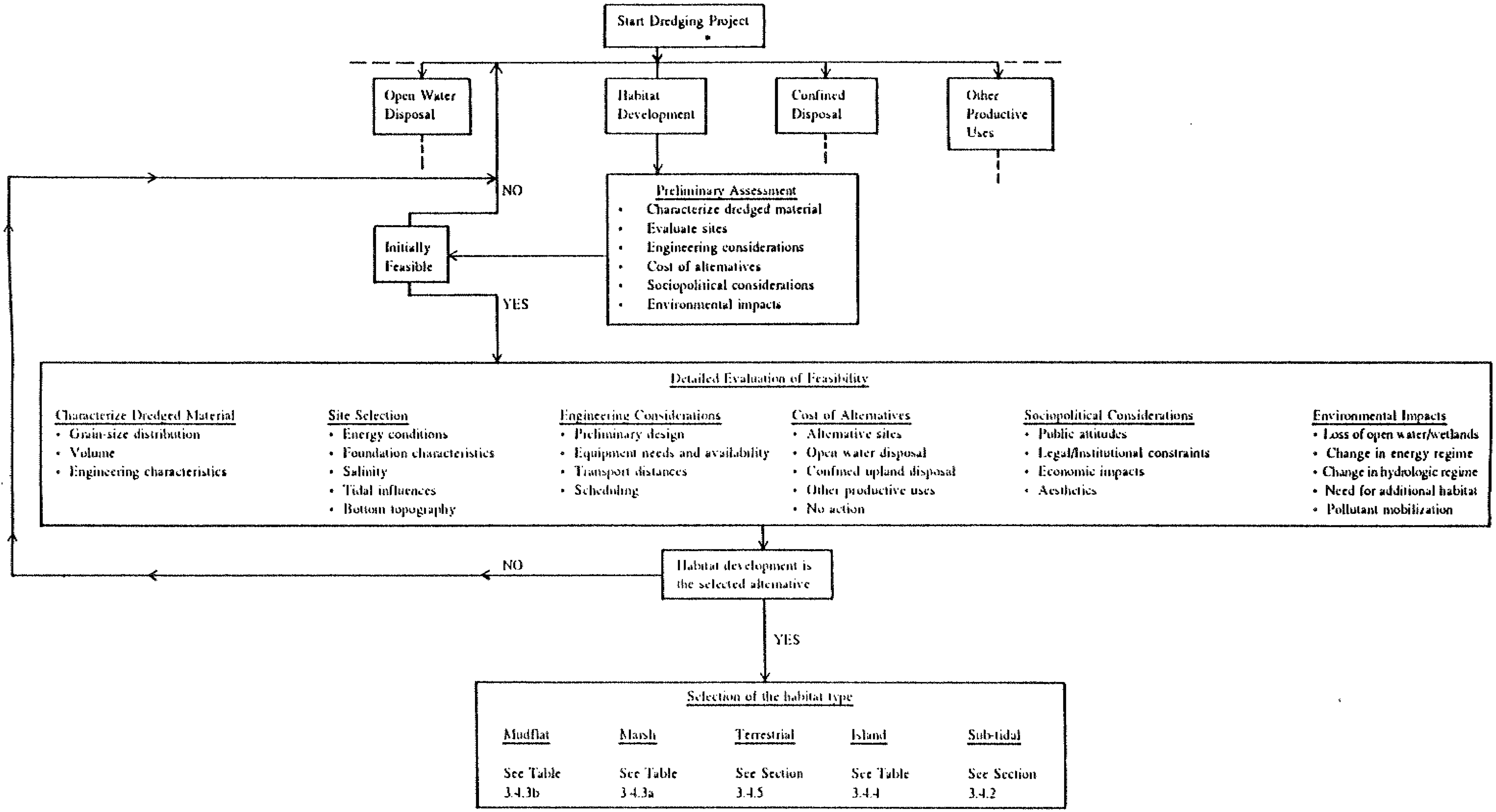
Overall, the report concludes that there is significant potential to use clean dredged material for coastal habitat creation in the U.K. and that, with careful planning, opportunities to use contaminated dredged material beneficially also exist.

- Recommendations

Recommendations which arise from the report indicate that, as there is little precedent for habitat creation using dredged material in the U.K., experimental pilot projects should be established.

There is also an urgent need for the development of U.K. guidelines (or quality standards) in respect of the disposal of dredged material and for a strategic policy on dredged material disposal concentrating on exploiting options for beneficial use.

Procedural guidelines for selection of habitat development alternatives



* - Assess degree of contamination of sediment. If sediment is contaminated treat or dispose of it in a designated dumping site. If it is clean enough to use for habitat development proceed to next stage.

Source: U.S. Army Corps of Engineers, date unknown.

The success of the majority of habitat creation initiatives will be dependent, to some extent, on technical criteria. It is therefore recommended that research be undertaken to establish the tolerance limits (e.g. chemical content, physical disturbance) of the species of plants and/or animals which it is hoped to attract to a particular habitat. Further recommendations suggest that detailed research is undertaken to develop an understanding of the physical, chemical and biological characteristics of existing coastal habitats, notably mud and sand flats.

SECTION 1 INTRODUCTION

1.1 Background

1.1.1 Background to Report

This report has been prepared by Posford Duvivier Environment in accordance with the specifications laid out in the contract document for the English Nature commissioned research ES702. The project brief is given in Appendix A.

The aim of the project is to provide guidance on the beneficial uses of dredged material for nature conservation. In addition, a case study is used to investigate the physical, chemical and biological nature of sediment in the south-eastern section of Holes Bay, Poole Harbour, Dorset, and assess its potential for beneficial uses for nature conservation.

1.1.2 Report Structure

Section 1 of the report introduces the beneficial uses of dredged material concept and reviews the need for such initiatives.

Section 2 deals with the environmental effects of dredging and disposal and possible mitigating measures which attempt to alleviate some of these effects.

Section 3 introduces the use of dredged material as a resource and reviews legislative, environmental, economic and technical considerations. Options are identified for potential uses and, where appropriate, case studies are provided.

Section 4 considers the use of contaminated dredged material, including aspects of disposal and related changes in the contaminated sediment characteristics, in the subtidal, intertidal and terrestrial environments. This Section also considers treatment and containment methods which could render the material available for a wider variety of uses.

Section 5 puts forward a methodology for determining viable beneficial uses of dredged material based on physical, chemical and biological characteristics. Requirements are given for survey and monitoring before, during and after beneficial use initiatives.

A case study is considered in Section 6 which outlines a procedure for the determination of a feasible use for dredged material. The study investigates physical, biological and chemical characteristics at the site and identifies potential uses for the sediment.

Conclusions and recommendations are given in Section 7 which include the need for further research in the U.K. to establish further guidelines for the beneficial uses concept.

1.1.3 Case Studies

For a project of this nature it was considered essential that case studies should be cited wherever possible to promote the feasibility of beneficial use options. However, due to the relative lack of experience of this concept in the U.K., it was necessary to draw on experience from overseas. From the literature reviewed it appears that the majority of work in this field has been carried out in the United States. Therefore many of the case studies are of sites in the United States. The feasibility of habitat creation, however, can be related to the U.K. and many of the principles are inter-related. A cautionary principle should nevertheless be applied as technicalities may differ to a certain extent.

1.2 The Need for Dredging

1.2.1 Dredging occurs throughout the U.K. for a variety of reasons. This study concentrates on capital and maintenance dredging as opposed to dredging for marine aggregates. Capital dredging involves working previously undredged areas be it for dock and harbour developments, marina construction, or a new navigation channel. Maintenance dredging occurs on a regular basis in order to keep shipping lanes and harbour channels open and navigable.

Dredging provides the sole solution to the maintenance of clear water access for many ports and harbours. It is carried out under the powers summarised in Appendix B. The environmental effects of such activities can often be detrimental to nature conservation. Common disposal practices involve depositing dredged material elsewhere in the aquatic or terrestrial environment, often causing severe impacts on these habitats. The total annual world-wide volume of material dredged from sea-ports and which is in principle considered for disposal at sea is estimated to be some 600 million cubic metres (Mm^3). Of this amount, 200 Mm^3 constitutes capital dredging and 400 Mm^3 results from maintenance dredging (Mulock Houwer, 1991). In the U.K., around 150 dredging disposal applications are received annually, resulting in a total quantity licensed for disposal of the order of 50 to 60 million tonnes. Since the introduction of the Food and Environment Protection Act (1985), licences have been valid for one year. Prior to this legislation licences were issued in some instances for three or five years (Campbell, 1991). In comparison with the amount of material extracted from the marine environment for aggregate, which is approximately 20 million tonnes per annum from England and Wales, the amount of material licensed for disposal from capital and maintenance dredging is relatively large.

1.3 Potential Beneficial Uses of Dredged Material

New environmental regulations (see Section 3.2) are restricting both land and water disposal options, while the amount of material dredged each year continues to rise. Costs of dredged material disposal have increased rapidly as disposal sites are located at greater distances from the dredging site and environmental controls are added.

Increased interest in dredged material as a manageable, beneficial resource is due partly to the tightening legislation on dumping at sea and partly to increasing urbanisation around waterways and ports, which has made it difficult to locate new sites for containment areas.

By considering dredged material as a resource, however, a dual objective can be achieved. The material can be disposed of with minimal environmental damage, and benefits can accrue from its use.

The need for and feasibility of habitat creation or restoration initiatives has been realised and demonstrated, notably in the USA where dredged material has been used for a variety of beneficial uses. To enable dredged material to be used beneficially, methods must be identified which do not destroy other valuable habitats, harm resident wildlife, reduce water quality, or cause unacceptable consequences in terms of erosion or deposition, yet would be stable enough to ensure an acceptable level of erosion back into the water course.

The potential benefits to nature conservation that could accrue from retaining the dredged material within the near-shore system, or using it for environmentally beneficial land based schemes are examined in this study.

In this respect, habitat creation might also go some way to replacing what has already been lost to the development of intertidal areas. Possible achievements to be gained from habitat creation could include:-

- increasing diversity of habitats;
- maintaining biological productivity and optimum populations;
- increasing habitats for endangered species.

SECTION 2 ENVIRONMENTAL EFFECTS OF DREDGING

2.1 The Dredging Process

2.1.1 The Requirements for Dredging

Capital dredging is a necessary requirement within many ports and harbours as it allows deeper drafted vessels to use the port than would otherwise be the case. This in turn allows greater efficiency and competitiveness on the part of the port authority or shipper. Depending on the nature of the local bed sediments, the sediment transport regime and the supply of new sediment whether from fluvial or coastal sources, this dredging may subsequently require maintenance.

With an increasing draft of vessels, the tendency for artificial deepening via dredging has increased, providing channel and berth depths further and further below those of the natural regime. The deeper channels will naturally fill at a faster rate. While there is a strong commercial need for this dredging to continue, there are various measures which can be taken to reduce the overall environmental effects of the dredging process.

2.1.2 Dredging Equipment

The dredging of sedimentary deposits within ports and harbours is usually accomplished by one of two techniques, hydraulic or mechanical.

Mechanical dredgers are very similar to their dry-land counterparts. Material is excavated and usually placed in an intermediate transport mode. This can be self-propelled or towed barges, trucks or even conveyor belts. Mechanical dredgers are typically used for materials where the physical nature of the material requires and permits distinct excavation zones. Examples of mechanical dredgers are the grab dredgers, bucket ladder dredger and the back-hoe.

Hydraulic dredgers use suction to raise the sediment via a fluidized slurry, typically with a 5-20% solids content. The suction action is often augmented by the use of agitators, a cutter head or a trailing drag arm. The dredged material is pumped through a pipeline either directly into a disposal facility or into an internal or external hopper. When the material has to be transported long distances, pipelines with booster pumps are used. Examples of hydraulic dredgers are the trailing suction hopper dredger and cutter suction dredger.

2.1.3 Environmental Effects of Dredging

The most environmentally acceptable dredging method to use in any instance will depend on local conditions, so the dredging process should be evaluated on the basis of its overall impact on the environment.

The potential environmental effects arising from dredging activities include:-

- destruction of the benthic habitat and disruption to adjacent areas.
- increased turbidity, the dispersion of fine particles and the contaminants which are possibly absorbed onto them.
  NB. This effect should be measured as a departure from the ambient turbidity and not just a standard figure for suspended solids.
- deterioration of water quality due to resuspension of contaminants.
- spillage of sediment (ie. the sediment is disturbed by the dredger but not removed).
- knock-on effects, including coastal erosion and deposition and slumping around the dredged area.
- changes in hydrodynamics of the system which can affect fauna and flora.

These effects are described in further detail in the following Sections.

2.1.4 Destruction of the Benthic Habitat and Disruption to Adjacent Areas

During the dredging process, the benthic habitat is destroyed by the action of the grab or pipe removing material from the sea-bed. This activity not only removes the habitat supporting the benthos but also removes the species/communities which occur there. In certain cases the species removed may be of nature conservation importance in terms of their rarity or the community which they support. Sabella pavonina, for example, is a species of worm of widespread distribution in the U.K. The reefs built by these tube-dwelling worms provide an important habitat for highly diverse communities of animals. Such species are adversely affected by dredging activity and, before dredging is carried out, it should be demonstrated that these communities also occur elsewhere in the near vicinity and that recolonisation will occur. Dredging activity may also cause disruption to adjacent areas, possibly caused by the slumping of adjacent material and by the smothering of benthos by dredging-induced turbidity.

2.1.5 Turbidity

One of the most widespread effects of dredging on the surrounding environment is an increase in turbidity. Dredging-induced turbidity can be a particular problem because it may result in the undesirable dispersion of contaminants or nutrients, or the smothering of marine life. The amount and extent of turbidity generated by dredging activity is dependent on three factors:-

- the nature of sediment
- the dredging technique
- the hydrodynamic conditions and water quality

Turbidity may be reduced by a good state of maintenance of equipment (e.g. ensuring that the grab is watertight), a few relatively simple technological modifications and the well managed execution of the work. Equally its impact may be controlled by judicious choice of dredger type or by dredging only at limited times during the tide.

Neither the long and short term effects of dredging on the ecosystem, nor the consequent threat to the food chain, are yet fully understood. Whether or not turbidity represents a threat in a particular environment will also depend on many other local conditions, including background turbidity caused by the stationary flow conditions, and the flow climate (tidal area, density flows). Further natural turbidity is generated, for example, by storms and by variations in discharge (floods, waves). The consequences of dredging must, therefore, be assessed in relation to all these parameters.

The effects of dredging-induced turbidity on the ecosystem are not always detrimental, but a study of these effects does provide a useful first assessment of the environmental impact of a dredging operation. The possible environmental impacts of turbidity during dredging might therefore be determined by establishing:-

- any potential migration of (contaminated) sediment from the dredging area.
- any possible burial or smothering of sensitive bottom life.
- any excessive availability of nutrients.
- any reduction of the translucence of the water.
- any exchange of contaminants between sediments brought into suspension and the water.
- any other physical and chemical changes in the local environment.

2.1.6 Deterioration of Water Quality

When sediment is disturbed during dredging activity this causes any contaminants adhered to the fine grained sediment to become resuspended in the water column and therefore available to aquatic organisms. Currents may also reallocate the contaminants during the dredging activity, therefore affecting living organisms outside the dredged area.

2.1.7 Spillage of Sediment

If sediment is spilt from the grab during removal from the benthic environment, (e.g. during transportation onto the boat) or the grab is not working efficiently and does not close properly, sediment may be disturbed but not removed from the seabed. This causes problems of disorientation and destruction to many of the benthic invertebrates which are disturbed. It may also cause the release of contaminants which were effectively "capped" by the overlying sediment.

2.1.8 Physical Effects on Coastal Processes

Dredging may cause slumping of material in nearby areas as material is deposited into the excavated area.

Sediment transport in the littoral zone takes two main forms, namely longshore transport and onshore-offshore transport. The former is wave and/or tide induced and refers to the movement of sediment along and parallel to the shore, whilst the latter is predominantly wave induced and refers to movements perpendicular to the shore.

The amount of wave induced longshore transport is determined by the magnitude and direction of travel of waves breaking at or near the shore. The rate of transport and its direction thus vary according to the wave conditions at the shore, which in turn vary throughout the year and from year to year.

Longshore transport can be interrupted by groynes or breakwaters resulting in the familiar "saw-toothing" effect (the difference in beach levels across a groyne). Though less obvious, longshore transport can also be interrupted by currents running across the shore, (e.g. estuaries, channels and other tidal inlets). Dredged channels can also act as a sink to sediment which might otherwise be transported across a tidal inlet.

Interruption of longshore transport by dredging has the effect of reducing sediment supply to downdrift beaches. This can result in a paucity of beach material. Low beach levels, in turn, provide less protection from storm waves to the coast or sea defences behind.

The effects of erosion are that larger waves can reach close inshore, often thus accelerating problems such as the deterioration of sea defence structures or exacerbating cliff erosion causing land which is valuable to man or wildlife to be lost to the sea. It may prove necessary to spend large sums of money to rectify the problem.

2.1.9 Changes to Hydrodynamics

Following dredging activity, the bathymetry of the excavated area will change, thus having a potential effect on any benthic invertebrates or pelagic species occurring there. A species or community of animals may have settled in a particular area because of the alignment of adjacent features or to the degree of exposure. If the regime is changed by dredging then this particular species may no longer be able to survive. The sediment type is one particular characteristic which is specific to the majority of benthic invertebrates, and which may be affected by dredging (e.g. the removal of gravel exposing silt).

2.1.10 Choice of Dredger Type

The physical and chemical nature of the sediments (e.g., coarse sand, fine-grained contaminated silt) controls the choice of dredging equipment, partly because of environmental concerns for release of material or associated contaminants during the actual dredging operation. Specialized requirements for transport to the disposal site resulting from the dredging equipment used, the transit route and the nature of the disposal option and site are also determining factors. Mechanical dredgers tend to cause the least disturbance to the materials being dredged and thus the minimum release into the surrounding waters. In particular, the bucket ladder dredger may cause the least disturbance of all types of traditional equipment and, because of this effect and the precision with which such equipment is able to operate, it is very often selected for maintenance dredging of port areas.

A typical problem with hydraulic dredging, however, is how to deal with huge volumes of water that are transported with the sediments. Frequently, special measures have to be taken to treat this water before it can be released (Davis et al, 1990).

It is also recognised that different types of dredger cause different degrees of turbidity. Table 2.1.10, which is compiled from three tables appearing in a paper on turbidity impact by Pennekamp and Quaak (1990), compares the turbidity declining with time and suspended sediment characteristics of three different types of technique, in each case dredging broadly similar materials. Turbidity is discussed further in Section 2.1.5.

Careful management of the dredging activity can generally ensure that any technique is broadly environmentally acceptable in many respects. Specifically, however, Table 2.1.10 indicates that the trailing-suction hopper dredger leaves little suspended sediment in the water column. The turbidity declining time is similar to that of a grab dredger, although the trailing-suction hopper dredger is capable of in situ production several orders of magnitude higher than that of the grab dredger.

The other major environmental advantages of the trailing-suction hopper dredger are that is causes much less gas to be released during the process (the latter can itself cause turbidity), and that the water in the hopper can be returned to the suction head rather than being discharged overboard to contribute to the erosive flow (Paipai and Brooke, 1990).

2.1.11 Dredging Contaminated Sediments

Accuracy and selectivity are extremely important when dredging contaminated sediment. Dredging may fail to remove all the contaminated sediment from the dredge site, or clean sediment may be included in the dredged material resulting in a larger volume of contaminated dredged material to be treated or disposed of in suitable dumping grounds.

The removal of the dredged material and its exposure to other physical and chemical conditions can also cause changes in the physical and chemical properties of the sediment. The substances present in the sediment may, for example, become mobile or volatile and therefore potentially dangerous. These issues are discussed further in Section 4.

2.2 The Disposal Process

2.2.1 Current Disposal Methods

To date, dredged material has generally been deposited in designated dumping sites offshore or on land, or used to claim intertidal land for development. In the U.K., the Ministry of Agriculture, Fisheries and Food are responsible for issuing licences to dispose of dredged material in areas below mean low water under the terms of the Food and Environment Protection Act, 1985 (see Section 3.2.1).

Table 2.1.10 Comparisons of turbidity and suspended sediment characteristics for three dredging techniques

Dredging Technique	Water Depth (m)	Bucket Volume (m^3)	Production in situ (m^3/h)	Gas Production (%)	Salinity (g/m^3)	Current (cm/s)	Water Regime	Turbidity Declining time (hr)	Suspended sediment (kg/m^3)	Silt % 16μm	Sand % 63μm
Open grab dredger (no silt screen)	11.0	1.1	90.0	11.0	1500	5.0	tidal	1.0	3.0	54	8
Watertight grab dredger (silt screen)	5.0	3.0	102.0	11.0	160	10.0	tidal	1.0	5.0	40	23
Open grab dredger (silt screen)	5.0	2.5	84.0	11.0	160	20.00	tidal	1.0	10.0	40	23
Watertight grab dredger (no silt screen)	5.0	3.0	166.0	11.0	160	4.0	tidal	1.0	20.0	40	23
Bucket ladder dredger	14.0	0.7	714.0	3.0	1700(@2m) 8500(@14m)	6.0	canal	1.0	20.0	65	16
Trailing suction hopper dredger (no lean mixture overboard)	13.0	6100	5400	3.0	20,000	none	tidal	1.0	4.0	58	5
Trailing suction hopper dredger (little lean mixture overboard)	9.0	803.0	1750	3.0	20,000	none	tidal	0.5	1.0	74	10
Trailing suction hopper (little lean mixture overboard)	9.0	803.0	1750	3.0	20,000	20	tidal	1.0	5.0	74	10
Trailing suction hopper dredger (lean mixture overboard)	13.0	6100	4125	3.0	20,000	none	tidal	1.0	13.0	58	5

Note: Other sediment parameters such as granular composition (silt %, sand %, insitu density kg/m^3), mineralogical composition (%), organic matter (%) were fairly similar for each dredging location.

(Source: Paipai, H. and Brooke, J., 1990)

No single method of disposal is suitable for every type of dredged material. All the possible alternatives need consideration at the planning stage to ensure that disposal has the smallest possible environmental impact. Figure 2.2.1 summarises a procedure for the evaluation of the environmental impacts of dredging and/or dumping.

The greatest potential for environmental problems associated with dredged material disposal relates to those which contain moderate to high concentrations of potentially toxic material. Material dredged from ports and harbours may be highly contaminated. This material, when removed from the aquatic environment and exposed to other physical and chemical conditions, may change in its own physical and chemical properties. The substances present in the sediment may become mobile or volatile and therefore available to other organisms. Contaminated sediments require treatment before use or, if they are to be disposed of, the sediment will generally need to be capped with clean material. Contaminated dredged material disposal is dealt with in detail in Section 4.

2.2.2 Dumping Sites

Dredged material can be disposed of in the aquatic subtidal, intertidal or terrestrial environments. The environmental effects of dumping material in each of these habitats is discussed below.

i) Subtidal (Offshore) Disposal

One of the most widely used methods for disposal of dredged material is through dumping at sea. This is variously referred to as subtidal, offshore or open water disposal. For larger quantities of material, such dumping is considered as being both a technically and economically viable solution.

Open water disposal of uncontaminated dredged material, if properly handled, appears to cause few problems in the long term (GESAMP, 1990). The short term environmental effects of dumping dredged material at sea, however, include:-

- increase in turbidity in the dumping area reducing light penetration and affecting filter feeding organisms.
- smothering of benthos destroying present communities.
- changes in bathymetry of the sea bed, affecting benthic and demersal communities and potentially affecting coastal processes.
- potential change in sediment size distribution affecting species composition, nursery and spawning grounds and recolonisation.
- water quality deterioration if sediment is contaminated.
- increase in bioavailability of chemicals (nutrients and pollutants), if present which may affect marine organisms.

ii) Intertidal Disposal

The potential environmental effects of dumping material in the intertidal zone are essentially the same as those in the subtidal zone, although there is the additional potential impact on the sediment when exposed to an aerobic environment at low tide levels. This may change the physical and chemical nature of the sediment, rendering it harmful to colonising biota.

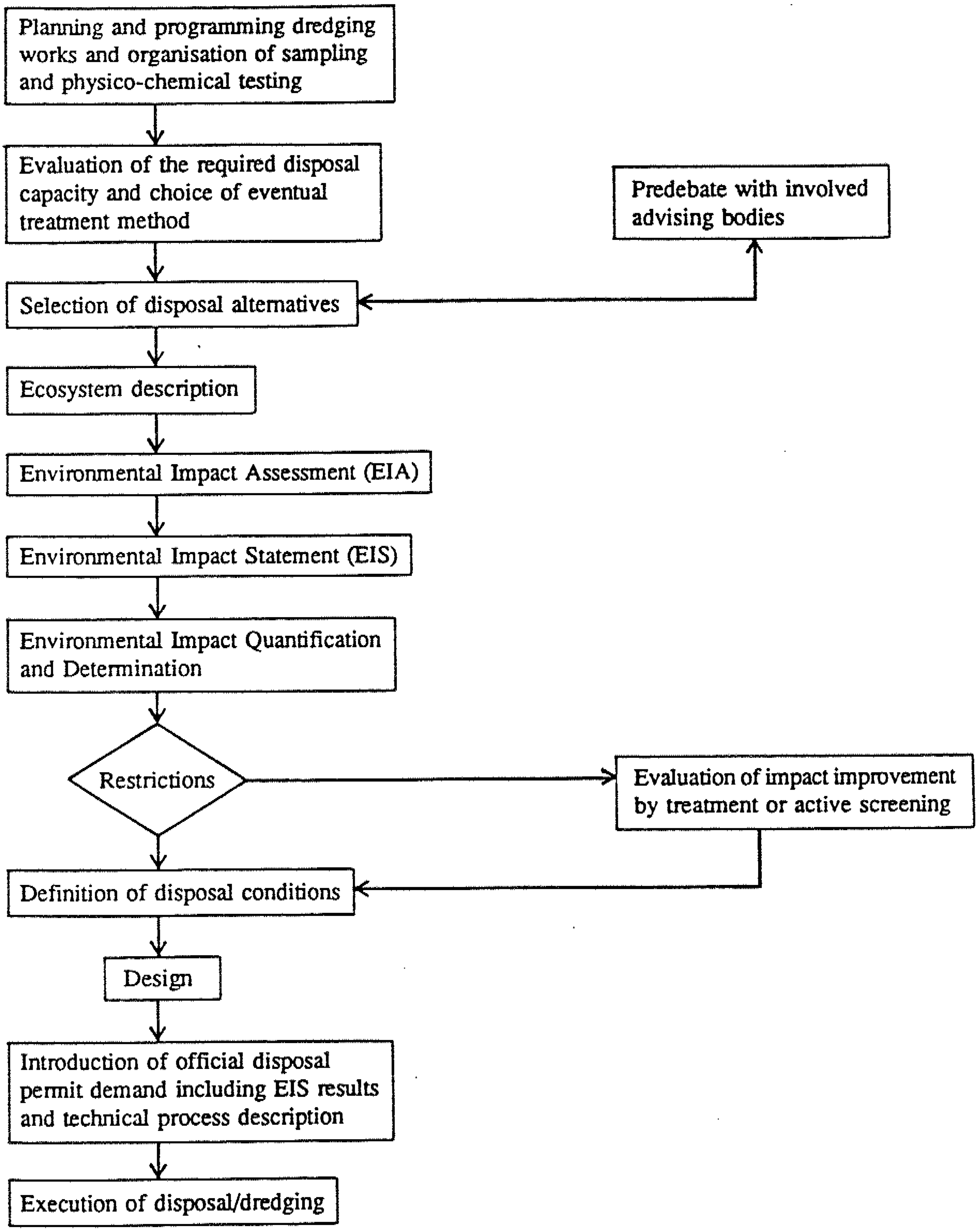


Figure 2.2.1: Ideal procedure to decide on environmental impact due to disposal/dredging operations. This procedure allows also decisions on disposal/dredging and treatment techniques.

Source: Malherbe, 1989

iii) Terrestrial (Upland) Disposal

Disposal of material on land, also referred to as terrestrial or upland disposal, may lead to environmental consequences such as:-

- smothering of existing communities.
- exposure to an aerobic environment, changing the physical and chemical conditions of the sediment, rendering it harmful to colonising biota.
- leachates potentially affecting adjacent land.
- the salt and nutrient content of the sediment placed on land may result in detrimental impacts on flora and fauna present on the site prior to placement of material.

2.3 Mitigating Measures

2.3.1 Mitigation in Respect of Dredging Activities

Advances in dredging equipment, due to a demand for greater efficiency, have led to many changes in dredging techniques. As indicated earlier, the ultimate selection of the operating system is based, inter alia, on sediment type, water depth, sea conditions, location and proximity of disposal area, and to some extent the availability of equipment. Mitigation measures are available and include the use of a silt screen around a dredge grab to prevent excessive turbidity in the surrounding area. The use of a watertight grab is a similar measure, although there are possible side effects which may have detrimental effects.

There have been several other recent developments to facilitate more "environmentally sound" dredging and disposal activities. Recent advances include the development of a small cutter dredger capable of dredging polluted silts and pumping them into barges at solid concentrations (Dredging and Port Construction, 1991). The vessel is able to operate in shallow areas and tracks may be fitted for use where water levels are too low. Other developments include vessels which can spread clean spoil in a thin layer over the adjacent land, and the use of silt curtains which prevent the dispersion of silt into areas adjacent to the dredged site.

2.3.2 Mitigation in Respect of Dumping

Various case studies have been carried out on the environmental issues concerned with dumping at sea (Malherbe 1989, Mitchell 1989). Conclusions drawn from these studies include the need for concentrating on increasing the primary dumping efficiency and decreasing recirculation. The primary dumping efficiency is determined by the adequacy of a dumping ground to receive the dredged material in question. To increase primary efficiency, one must first determine how much material is to be disposed of and what fraction will remain on the dumping ground. The degree of recirculation of material will determine the ecological impact of dumping either by lithological changes, by burial of benthic organisms, or by remobilisation of contaminants present in the material. To achieve the required goals may involve a modification of equipment.

Other options which should be taken into consideration when dumping material include increasing the density of the dredged mixture to improve the erosion resistance of the deposited material; or the confinement of the disposal area with retention dykes (above or below water, or in pits) (Malherbe, 1989).