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Beneficial Uses of Dredged Material: Yesterday, Today and Tomorrow

Abstract

Contrary to popular beliefs, the vast majority of dredged material around the world is not significantly different from the sediment found naturally in rivers, estuaries and seas. Since the 1980s, a number of NGOs including CEDA, PIANC and IAPH, as well as several Contracting Parties to the London Convention, have been arguing the case that dredged material generally should be regarded as a resource and not a waste. Therefore much of the dredged material is suitable for relocation within the natural ecosystem and/or some other form of beneficial use with or without treatment. This paper attempts to re-define the word "beneficial" and gives a survey of present beneficial use activities and suggestions for future options.

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Introduction

The great majority of the world's goods are transported over water. Ports and inland waterways are therefore major revenue earners and creators of employment. Many waterways have recreational value and provide amenity uses to the general public. Thus waterways have considerable socio-economic value, which brings prosperity to thousands of communities around the world. In the majority of the world's waterways dredging is essential to provide safe navigation routes to ports and harbours. Undoubtedly, the effects of dredging and operations on environmental resources

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should be subject to a robust and rigorous study, but equally the suitability of the dredged material for some sort of beneficial use must be part of the same study. Why? Because the vast majority of dredged material around the world is not significantly different from the sediment found naturally in rivers, estuaries and seas.

Natural processes bring soil down the river and into the estuaries and seas, and natural processes bring weathered rock material along the coast and up the estuary. In other words, this material is basically a natural resource and should not be regarded as a waste material that has to be disposed of. Much of that material therefore must be suitable for relocation within the natural ecosystem and/or some other form of beneficial use with or without treatment.

The phrase “beneficial uses of dredged material” first began to appear in dredging conference proceedings in Europe in about mid 1980s although it had begun to be used in the USA before that. To some extent it was a response to the London Convention (LC). In those days it was called the London Dumping Convention — which implied that any dredged “spoil” was a waste. A number of NGOs including CEDA, PIANC and IAPH, as well as several Contracting Parties to LC, began to argue the case that dredged material generally should be regarded as a resource and not a waste.

The London Convention’s Dredged Material Assessment Framework (DMAF) recognises that dredged material is increasingly regarded as a resource and it requires possible beneficial uses to be considered before a licence for sea disposal may be granted. The principle of “dredged material is a resource not a waste” was embodied in the first draft of the Dredged Material Assessment Framework produced in the Los Angeles inter-sessional working group in the early 1990s and has been generally adopted by Contracting Parties. Sadly, because the procedure is called “specific guidance for dredged material” under the “Waste Assessment Framework” the word “waste” has reappeared in its title. It is to be hoped that this does not inhibit constructive thought about beneficial uses of this plentiful resource.

TYPES OF BENEFICIAL USE OF DREDGED MATERIAL

The disposal of dredged material, whether from capital dredging or maintenance dredging, provides opportunities for a number of environmental, economic and aesthetic uses, including a number of innovative beneficial uses mainly with the fine grained dredged material. The following is a list of beneficial uses of dredged material:

- Sediment cell maintenance (more applicable to maintenance dredging);
- Construction and other engineered uses (e.g. land reclamation for port/airport development, residential development, redevelopment of confined disposal facilities);
- Construction material (e.g. dredged material mixed with cement, manufacturing of bricks)
- Replacement fill;
- Shoreline stabilisation and erosion control
 - beach nourishment
 - coastal realignment
 - muddy shore profile engineering
 - offshore berms (eg. feeder berms, hard and soft berms)
- Amenity
 - beach nourishment
 - derelict land restoration
 - recreation (e.g. hills for walks and picnic areas)

- landscaping (parks and other commercial and non-commercial landscaping applications)
- Capping (one of the early beneficial uses of clean dredged material was to cap contaminated dredged material in offshore disposal sites)
- Habitat restoration, enhancement and/or creation (e.g. saltmarshes, mudflats, wetlands, bird islands, gravel bars, oyster sandy/gravelly beds) (Figure 1)
- Aquaculture
- Agriculture (e.g. cotton fields)
- Horticulture (e.g. orchards, ornamental plant nurseries)
- Forestry
- Strip mine reclamation and solid waste management

In the early days there was a widely held perception that beneficial uses would only ever be applied to small quantities in tailor-made situations. However, with increasing pressures under the regulatory systems, the use of some creative thinking, and the development of new technologies there is now widespread use of dredged material for beneficial purposes. It might also be said that there has been some re-definition of the word “beneficial”.

BENEFICIAL USE OPTIONS BY MATERIAL TYPE

Rock is a valuable construction material and whether or not it can be used economically depends on its quantity and size.

Gravel and sand are generally considered the most valuable material for reuse that a dredging project can provide. They can find wider application as a resource material to a number of engineered uses, and most frequently without the need to sort (or pre-wash) the material prior to being used. The engineered uses mainly are land reclamation, construction material, replacement fill, land improvement, capping, beach nourishment, and offshore berms. “The range of engineering applications for dredged material is diverse, being limited only by the ingenuity of the designer” (PIANC, 1992).

Clay and silt are the most common materials acquired from maintenance dredging in rivers, canals and ports. Consolidated clay can find more engineered uses than soft clay, whereas silt in particular is more suitable for agricultural/horticultural purposes and all forms of habitat creation and/or enhancement. The economical use of clays and silt differs from that of rock mainly in terms of preparation work prior to their beneficial use; silt and soft clay needs dewatering unless appropriate dredging equipment removes them almost in-situ density. Also, silt, being fine-grained sediment, can contain contaminants in quantities, which necessitate a certain degree of pre-treatment prior to a beneficial use.



Figure 1. Wetlands restoration is a beneficial use option which encourages long-term habitat development.

Pre-treatment of dredged material to facilitate and optimise their beneficial uses can, however, be costly and co-ordination and cost sharing may be very difficult to achieve. These difficulties, however, can be overcome by discussion between the interested parties and stakeholders from policy-makers to the dredging industry who are left to do the work. Co-operation is more likely where a defined regional policy exists which positively encourages the beneficial use of dredged material (PIANC, 1992).

DECISION-MAKING CONSIDERATIONS FOR BENEFICIAL USES OF DREDGED MATERIAL

Defining "beneficial" is not easy. "The context in which the phrase was coined has probably emphasised beneficial to the environment rather than beneficial to man in particular. It still poses the question of what will benefit." (CEDA/IADC, 1999).

Indeed, the construction of offshore berms for purposes of improved coastal protection may be regarded by many as a serious threat to shellfisheries resources. A serious threat it may be, but a comprehensive investigation of the physical, chemical and biological characteristics of the dredged material, of the way it is expected to behave after placement and of the hydrodynamic regime, which will determine its behaviour can significantly contribute to a successful beneficial use. Such information is essential for evaluating the suitability of the dredged material for numerous beneficial use applications, as well as for the identification of preventative measures to ensure the minimum environmental impact and maximum beneficial use chance.

Environmental impact assessment studies, sediment

transport modelling studies and ecological models are some of the tools, which nowadays can facilitate the decision-making process for beneficial uses of dredged material. Environmental legislation requires the use of such tools for all dredging and disposal projects particularly when they are located in or near sensitive natural resources. It also emphasises the importance of timing of such studies early on in the project in order to prevent and/or reduce negative environmental impacts and maximise the potential for mitigation measures. Early consideration of beneficial use options in a dredging project can have the dual benefit of a successful beneficial use application and minimum environmental impact.

Science alone, however convincing, cannot guarantee the successful application of beneficial use options for dredged material. The main reason for this is the large number of interests of an equally large number of stakeholders involved in a dredging project, who are trying to reach a consensus particularly in terms of timing and costs. Such difficulties can be overcome by long-term planning. The key to success for the beneficial use project planner is to identify how, when and where dredged material from a navigation project can fulfil an economic need, whilst paying due regard to environmental considerations and limitations. Identification of economic and/or social benefits may help overcome some environmental opposition to the use of dredged material. A multi-criteria analysis where ecology, geology, hydrogeology, economy and society are considered is the route to an effective screening down to an appropriate number of beneficial use options.

A large number of countries are already engaged in such type of projects, however the beneficial use of dredged material is not as widely applied as many in the dredging industry would like. Why not? There are

a number of reasons including:

- Dredged material is legislated in a “peripheral” way; disposing of dredged material on land is subject to legislation on soil;
- First and foremost there is different legislation for dredged sediment management between rivers and coast;
- Unless a use is identified, dredged material in the eyes of environmental law is a waste;
- Where dredging is most frequently required (i.e. where low-energy hydrodynamic regimes allow settling of suspended sediment) is where contaminants entering watercourses upstream tend to settle down along with the fine sediments.

BENEFICIAL USE OPTIONS FOR CONTAMINATED DREDGED MATERIAL

Obviously, the degree of sediment contamination, being a decisive factor in any management process for dredged material, plays an even bigger part when considering beneficial use. Without treatment, highly contaminated sediments will normally not be suitable for most proposed beneficial use applications, particularly where wildlife habitat development projects are proposed. The exception to this may be the processing of highly contaminated sediment for the purpose of creating a usable construction product (e.g. ceramic, aggregate, and such) or the beneficial end-use of a confined disposal facility (CDF) where contaminated dredged material is disposed. However, moderate and slightly contaminated sediments may be appropriate for many beneficial uses, possibly after pre-treatment and/or covering with clean material. What determines whether or not contaminated dredged material can be used beneficially is the compatibility between the physical, chemical and biological properties of the dredged material and those of the intended beneficial use, as well as the potential for impacting on sensitive natural resources.

PIANC in its Working Group 17 report on “Handling and Treatment of Contaminated Dredged Material from Ports and Inland Waterways” has come up with the Contaminated Dredged Material Technical Framework (CDMTF) (Figure 2). This framework is an “international road map” for nations to follow when developing and evaluating the appropriate options for dredging and management of contaminated dredged material, including the options for a beneficial use. CDMTF comprises a number of functional steps, aiming to assist project developers and regulators to approach, in a systematic and logical way, the development of alternative uses of dredged material, that are both environmentally and economically feasible. “The assessment of the potential for a beneficial use of dredged material that is contaminated is a functional step early on in the CDMTF, demonstrating the

significance of regarding dredged material as a resource rather than as a waste” (PIANC, 1996).

In both The Netherlands and Germany, dredged material, which cannot be relocated in the water system or be used directly as a soil substitute, is regarded as waste. European legislation sets the priority on the beneficial use option but pre-treatment (e.g. dewatering) is almost certainly required. If the costs for pre-treatment are prohibitive or it proves to be technically not feasible, the only option left is disposal either offshore or in confined disposal facilities. Management of such sites nowadays includes the re-use of dredged material from within the confined disposal facility, after some form of treatment and/or the identification of an end use for the site.

In The Netherlands in particular, dredged material has always been regarded, and in many cases, used as a resource. At present, relatively clean material is returned to the North Sea where from they move north and feed the Waddensea in areas where soft sediment is needed for benthic productivity. Its usefulness was first realised well over 30 years ago when farmers used it as a growing medium, and polders were filled up with it. Later on houses were built on land where dredged material was used as engineering fill. Dried sediment from rivers was used to make building blocks.

All that, however, was stopped when in the 1980s the seriousness of the contamination levels in the sediments was realised. In response to this significant problem and in realisation of the potential of such a resource, the Dutch Government decided to address the problem at its root and targeted the industrial discharges into the waterways, which were the major culprit for the sediment contamination. In addition, confined disposal facilities were built and research into treatment technologies was becoming increasingly active. The ultimate goal of this conscious activity was to reduce contamination levels in dredged material as much as it was necessary to enable their beneficial use.

In 1995, the Dutch Government set a target of 20% of dredged material to be used beneficially. Dutch policy now aims to increase the amount of contaminated dredged material to be treated and reused as construction materials in order to save on disposal capacity in confined disposal facilities and to produce new building materials. Although research and active projects demonstrated that technically, chemically and biologically treatment of contaminated sediment could enable its beneficial use, the target percentage has not yet been reached because the biggest problem was public perception. In order to make the public aware of what is possible with contaminated dredged material, people had to learn about contamination and its implications. The result was that people were still suspicious of treated dredged material.

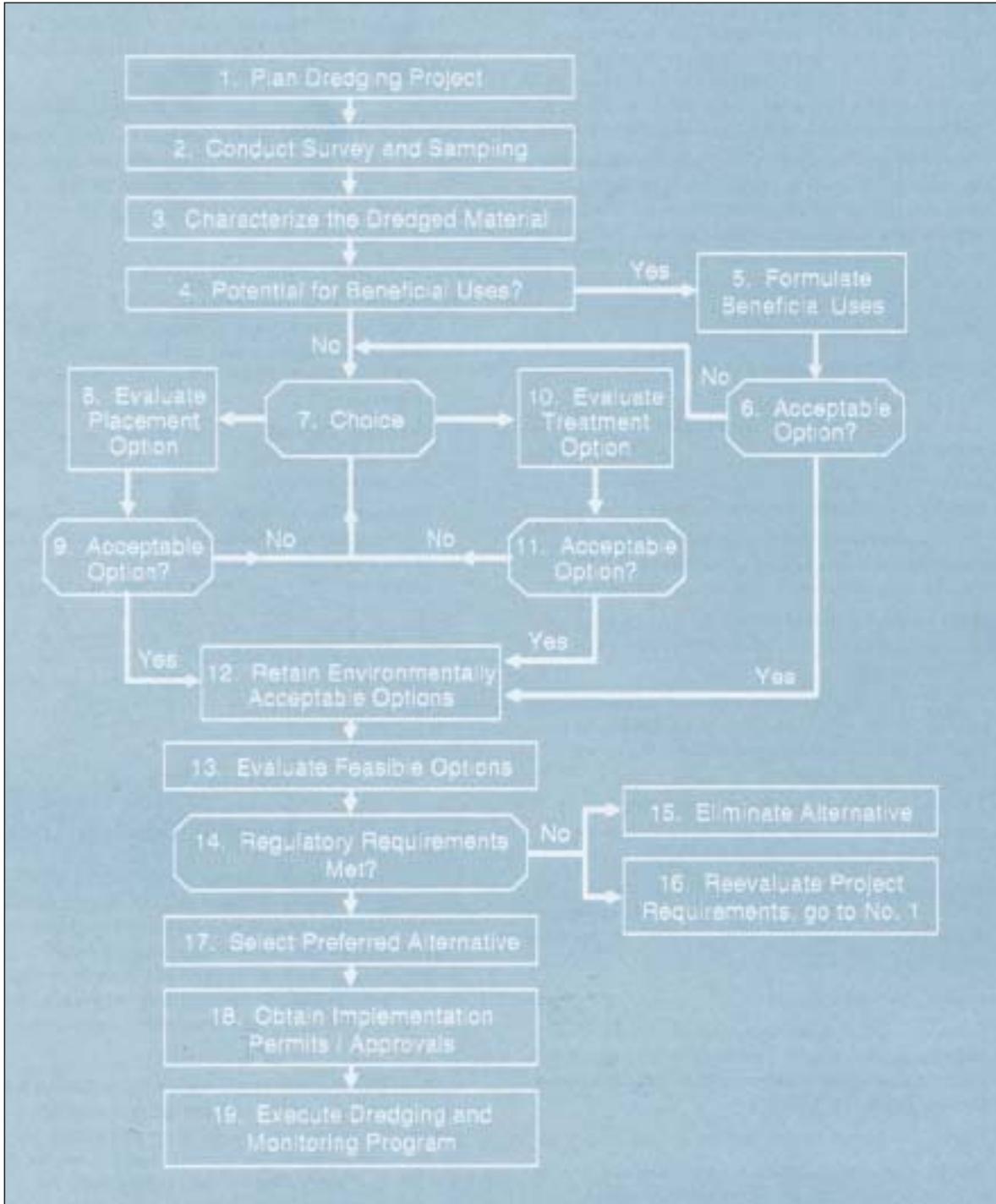


Figure 2. Contaminated Dredged Material Technical Framework (CDMTF) from PIANC's PTC I - Report of Working Group no. 17 Supplement to Bulletin no. 89 1996, Handling and Treatment of Contaminated Dredged Material from Ports and Inland Waterways "CDM".

At present, the Dutch Government subsidises the beneficial uses of contaminated dredged material. The subsidy scheme and pilot project are part of a more comprehensive programme to encourage treatment, which also includes an environmental tax on the disposal of easily treatable contaminated dredged materials and promoting the sale of these products (Hakstege and Heynen, 2003).

BENEFICIAL USES OF FINE-GRAINED DREDGED MATERIAL

Over the last 10 years or so, dredging and disposal licensing authorities, conservation and environmental protection authorities in the UK have largely contributed in the change in view that only sand and gravel may be used beneficially. Fine-grained materials are now seen

as a valuable resource, and this was evident by the number of opportunities to use capital and maintenance dredged material. In 1992, 0.07% of fine-grained dredged material was used beneficially in the UK, whereas in 2000 0.47% was used beneficially. In 1998, when Harwich Harbour Approach Channel in the east coast of England was deepened, the amount of fine-grained material used beneficially went up to 0.78%. Fine-grained dredged material is mainly used for flood and coastal defence, sediment cell maintenance and habitat conservation or enhancement (Table I).

The soft coastlines of various parts of the UK, particularly in the southeast of England are eroding, some of them at an alarming rate. These soft coastlines comprise saltmarshes and mudflats, which help protect and stabilise sea walls by buffering wave action. The Environment Agency, which is responsible for the flood protection measures in the UK, see two alternative solutions to the coastal erosion problem: either maintain and build bigger sea walls, at huge costs, or adopt a sustainable approach of working with coastal processes such as using beneficially fine-grained maintenance dredged material (DECODE, 2002). Dredged material has been shown to successfully combat erosion and even create new saltmarshes, which eventually become capable of functioning like natural systems. In a similar way, fine-grained maintenance dredged material can be used to create mudflats or, more usually, to enhance biologically poor mudflats and in time turn them into much more productive systems than before.

INNOVATIVE BENEFICIAL USES OF FINE-GRAINED DREDGED MATERIAL

The recent success of beneficial use schemes has significantly contributed to an increasing willingness to

identify novel methods of intertidal placement of fine dredged material. One of the main drivers was the assurance of the regulators and nature conservation bodies that the retention of the material within an estuarine system is one of the more appropriate applications for beneficial use.

In many tidal estuaries there is a net balance between the amount of material being deposited and eroded. It is a dynamic and self-regulating process for excessive erosion and accretion. The balance it achieves may be disturbed as a result of dredging. Continuous removal of fine material by dredging may eventually lead to the permanent loss of intertidal banks and saltmarshes. Fine-grained maintenance dredged material can be (this is the current practice in the UK) returned to a tidal estuary in order to minimise perturbations to an estuary's cell maintenance of soft sediment during essential dredging works.

Between October 1998 and April 2000 the approach channel to Harwich Haven Ports, in southeast England was deepened. The Department of the Environment, Transport and the Regions issued consents for the works under the Coast Protection Act, 1949, part of which was the "Mitigation and Monitoring Package". One of the detailed objectives for mitigation defined in the "Mitigation and Monitoring Package" was to create 16.5 hectares of intertidal habitat in the Stour and Orwell Estuaries Special Protection Area (SPA) (protected under the European Directive for the Protection of Birds) and to prevent the loss of up to 5 hectares per annum of intertidal habitat owing to the increased rate of erosion. This objective is to be achieved through the implementation of a sediment recycling initiative associated with maintenance dredging campaigns in the Stour and Orwell Estuaries and is being implemented by several means of returning fine-grained sediment in the estuarine system. These involve direct subtidal

Table I. Quantity of silt deposited at sea and beneficially between 1992 and 2000 in England.

Year	Total tonnage disposed in England and Wales	Beneficial use tonnage	% used beneficially
1992	28,976,381	20,800	0.07
1993	28,487,422	20,800	0.07
1994	39,132,395	40,950	0.1
1995	40,247,625	26,000	0.06
1996	51,251,367	36,140	0.07
1997	41,241,324	80,600	0.2
1998	28,849,142	226,000	0.78
			(Harwich Haven Approach Channel first deepening)
1999	57,305,868	426,000	0.74
2000	52,274,543	245,000	0.47

Source: CEFAS (Centre for Environment, Fisheries and Aquaculture Science), Burnham Laboratory, Remembrance Avenue, Burnham-on-Crouch, Essex, CM0 8HA, tel: +44 (0)1621 787200, fax: +44 (0)1621784138. E-mail: s.j.bolam@cefass.co.uk, <http://www.cefass.co.uk>



Figure 3. Schematic presentation of subtidal placement and water column recharge of fine-grained dredged material

placement, increased overflow during dredging operations and water column recharge (sprinkling). The latter is the most novel of the recharge techniques being applied in the Stour and Orwell estuarine system. The process is subject to ongoing refinement as field data is obtained and used to improve the knowledge of sediment budgets within the system (Figure 3).

THE CHALLENGE TO WIDER APPLICATION OF BENEFICIAL USES OF FINE-GRAINED MATERIAL

Compared to capital dredged material, which typically comprises relatively coarse material, the behaviour of deposited fine-grained maintenance material tends to be less predictable. It is possible to reduce this unpredictability by engineering the placement site so that it confines the deposited fine dredged material.

At present, the beneficial placement of maintenance dredged material within the UK is limited to small-scale trials. There are several reasons for this. Firstly, there are concerns over subsequent movement and hence the potential for interference with other uses/users of the sea. These concerns arise from our current lack of understanding of the biological processes following deposition: phyto- and zoobenthic re-colonisation may have profound effects on the stability of sediments, and hence, the fate of deposited material in both the short and long term. Secondly, our lack of knowledge of the rates of invertebrate recovery, and how they are affected by other factors, limits our ability to predict

the effects of sediment placement on bird and fish populations. This is particularly important as the majority of beneficial use schemes are in estuarine intertidal habitats, areas important for sustaining such populations (Bolam, 2000).

The impacts of sediment disposal on benthic communities vary depending on many factors including the amount, frequency and nature of the disposed sediment, water depth, hydrography, time of year, the types of organisms inhabiting the disposal area and the similarity of the dredged sediment to that of the disposal area (Harvey et al., 1998). Where dredged material has been placed, for instance for habitat enhancement, and temporary upsetting or localised loss of benthos has followed, the sequence of changes towards recovery appeared to be dependent upon many factors, including:

- the availability of colonisers;
- the characteristics of the deposited sediment;
- the survival of the disposal site community and/or exotics (species introduced with the disposed material); and
- the timing of any later depositions.

The complex nature of the intertidal communities makes prediction of their post-placement behaviour inherently difficult. However, the observed succession patterns have been shown to be similar following many types of disturbances, even though the actual mechanisms operating during the succession dynamics of fine-grained sediments remain uncertain. In general, following the local elimination of the macrofaunal community, the re-colonisation process begins with the



Figure 4. In 1998 and 1999 fine-grained dredged material was placed at Titchmarsh Marina in the UK to create mudflats and saltmarshes. Seen here, the placement stage.

recruitment of opportunistic species, typically small, tube-dwelling polychaetes and oligochaetes, which may reach very high densities. Their near-surface activities act beneficially as they gradually “condition” the sediments allowing the successful colonisation of less opportunistic species. Consequently, later succession species are able to survive and the community functionally resembles the one prior to disturbance (Figures 4, 5 and 6).

THE FUTURE

Understanding the factors influencing the colonisation of fine-grained sediment after intertidal disposal

In the UK, CEFAS, the Centre for Environment, Fisheries and Aquaculture Science, is heavily engaged in research work to better understand the factors influencing the colonisation of fine-grained sediment after intertidal disposal. There is a fundamental need to develop a better predictive ability at the community level in order to assess the ecological consequences of disturbances, and design successful beneficial use schemes (Bolam, S., 2000). In general, from the very few studies in the intertidal zone, invertebrate community responses to the deposition of maintenance dredged material occur much more slowly than those reported for subtidal (particularly estuarine) systems. The fine sediments relocated during beneficial use schemes tend to be very unconsolidated with very high water contents and it is possible that this may inhibit initial re-colonisation. Invertebrate community responses are likely to depend on factors such as the frequency and intensity of dredged sediment deposition, type of

material deposited and the nature of the recruiting assemblage.

There are, however, still very important questions that need to be addressed in order to improve our understanding of the biological processes following deposition, our knowledge of the rates of invertebrate recovery, and how they are affected by other factors. Answers to the following questions should enable successful applications of large-schemes of beneficial uses of fine-grained dredged material (Waldock et al., 2002).

These questions include:

- How does the nature of dredged material (particle size distribution, organic content) affect survival of species at the deposition site and succession dynamics following deposition?
- Does the degree of consolidation of relocated sediments affect the initiation of re-colonisation?
- How does the rate of deposition of the dredged material affect survival of species and succession dynamics?

Wider application of beneficial uses of fine-grained (muddy) dredged material

There is undoubtedly a fundamental need to improve our understanding and predicting ability of how factors influence the rate of colonisation of fine-grained material after intertidal placement in order to increase the degree of success of beneficial use schemes, and particularly with fine-grained dredged material. At present, the beneficial placement of fine-grained dredged material within the UK is still limited to small-scale trials because of the largely unknown factors that



Figure 5. Titchmarsh Marina: Growth starting to appear.

contribute to the colonisation by plants and animals of the disposal site after placement.

In the meantime, however, visible results mainly from small-scale schemes in a relatively short time, increase our confidence in beneficial use schemes using fine-grained material in intertidal areas, and drive attempts to identify new techniques in retaining such material within sediment cells. Large-scale schemes of beneficial use of fine-grained material, which provide the opportunity to closely observe and understand the factors influencing the re-colonisation process at the disposal site, should also contribute to further widening the spectrum of beneficial uses of dredged material and give confidence to regulators that such schemes are feasible.

Such a scheme has recently been commissioned by DEFRA (the Department for Environment, Food and Rural Affairs) in the southeast of England. The physical, chemical and biological processes of this large-scale scheme will be monitored by HR Wallingford and CEFAS. In addition, the practicalities of large-scale placement of fine-grained dredged material will be part of the study as well as lessons learned from other similar projects worldwide.

The water column recharge (sprinkling) in the Stour Estuary in the UK is an innovative and promising technique that uses fine-grained material. Ongoing studies will show whether this is an effective method of returning material to the intertidal areas despite its negative, yet short-lived, aesthetic impact. Up until now, observations indicate that it is likely to be the most efficient way of returning fine sediment to the intertidal areas.

Figure 6. Titchmarsh Marina: Diverse saltmarsh vegetation has colonised the recharged area successfully.



Sediment management

The primary limitation of more beneficial use application, in the experience of Germany and The Netherlands, is the contamination levels of dredged material. Those responsible for dredging are not responsible for the contaminants in the waterways, which is why source control to reduce contamination input must be seen as the only effective future solution to the ongoing problem of dredged material disposal. Germany believes that source control can solve the problem of contaminated sediments. The International

Commission for the Protection of the River Elbe foresees that the sediments shall be clean by the year 2010 in a way that they can be used beneficially, for example, for agricultural purposes.

For a greater emphasis and more effective application of beneficial uses of dredged material, handling of sediments (including treatment and confined disposal) has to be more effectively recognised and represented in the legal framework (Dutch-German Exchange on Management of Dredged Material, 2002). On the European level this is not the case. For example, the Landfill Directive does not take into account the special properties of dredged material and the sub-aquatic confined disposal is not accepted as an effective way of storing and confining contaminants.

Contrary to conventional waste, fine-grained dredged material, which has a very low permeability, when stored in anoxic and sub-aqueous environment, provide its own "sealing capacity" (both in terms of physical and geo-chemical properties) and thus groundwater protection. Yet the Landfill Directive requires that confined disposal facilities for contaminated dredged material should be lined with artificial liners. There is however no known artificial liner with more than 25 years of lifetime; in other words effective ground and groundwater protection is guaranteed up to a maximum of 25 years. Thus wider recognition of the properties of dredged material and its post-disposal behaviour, as well as legislative harmonisation in terms of how and where dredged material can or cannot be disposed of on land, is required for a more successful application of beneficial uses of dredged material and particularly fine-grained dredged material.

Conclusions

The development of beneficial use options for dredged materials contributes to a sound economy and ecology. Yet these options remain acutely underdeveloped. In general, relatively coarse, capital dredged material is more easily utilised because it is more predictable. For the intertidal placement of fine-grained maintenance dredged material, however, a fundamental need remains to identify innovative methods. This means developing a better predictive ability to assess the ecological consequences of disturbances caused by fine-grained sediment. Recent small-scale schemes in the UK and elsewhere give reason for optimism. In addition, large-scale pilot studies are in the planning or under way.

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be seen as the most effective future solution to the ongoing problem of dredged material disposal. In addition, the handling of sediments, including treatment and confined disposal, has to be more effectively recognised and represented in the European and international legal framework.

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