DREDGING

UPDATE 2025

THE FACTS

Dredging is vital to social and economic development. In particular, dredging is vital to the construction and the maintenance of much of the infrastructure upon which our economic prosperity and social well-being depend. So, what is, why, and how do we dredge?

UPDATED AND PUBLISHED BY CEDA

What is Dredging?
Dredging is the excavation of material from underwater, and then transporting and placing it at another location. Dredging is carried out to deepen or maintain water depth and/or to obtain valuable material. Dredged material can be placed underwater or on land, for use or to discard it.

What about dredging and the environment?

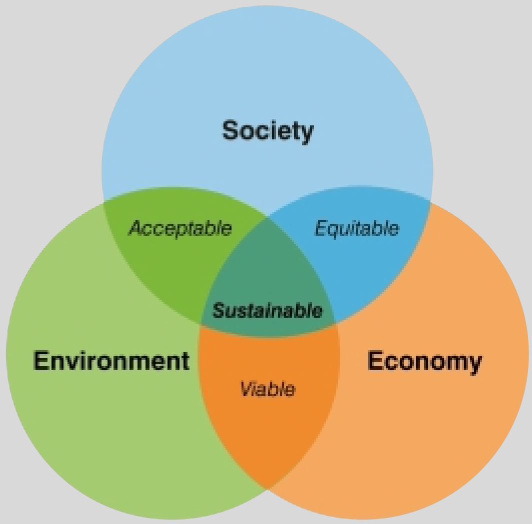
As dredging takes place in the natural environment (although one which frequently has already been modified by mankind) the environmental effects of dredging have the potential to be significant. In response to the growing awareness for the need to protect of our environment, the dredging community has critically reflected its activities and, by showing willingness to adapt and innovate, has taken enormous steps to reduce these effects to lowest possible levels.

Why we Dredge

DREDGING FOR A SUSTAINABLE INFRASTRUCTURE

Dredging and dredged material management are essential if we are to maintain and improve our flood safety, environment, quality of life and economic well-being. This is achieved through the creation and maintenance of water-based infrastructure by navigation dredging and reclamation; enhancing environmental quality by beach nourishment or environmental dredging to remove contaminated sediments; providing flood control; producing minerals and construction materials, and supporting offshore energy production, including renewable energy.

"By adhering to principles of sustainability that include working with natural systems to integrate these actions, the goals of environmental quality and economic prosperity can both be achieved" (quoted from WODA Principles for Sustainable Dredging, 2013), also aligned with several of the United Nation's "Sustainable Development Goals".

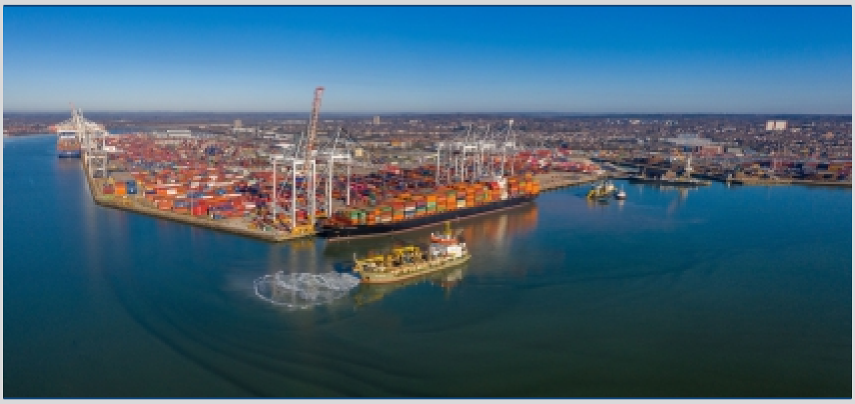


Three Pillars of Sustainability (*source: Dredging for Sustainable Infrastructure*)

DREDGING FOR NAVIGATION

From the very beginnings of civilisation, people, equipment, materials and commodities have been transported over water. Ongoing technological developments and the need to improve cost effectiveness have resulted in more ports and terminals as well as larger, more efficient ships. This, in turn, has resulted in the need to enlarge or deepen many of our rivers and canals, our "aquatic highways", in order to

Capital Dredging - Hong Kong



Maintenance Dredging - Southampton Port (*source: Boskalis*)

provide adequate access to ports and harbours. Nearly all the major ports in the world have at some time required new dredging works – known as capital dredging – to enlarge and deepen access channels, provide turning basins and achieve appropriate water depths along waterside facilities.

Many of these channels have later required maintenance dredging, i.e. the removal of sediments which have accumulated in the bottom of the dredged channel or basin, to ensure that they continue to provide adequate dimensions for the large vessels engaged in domestic and international commerce.

Rivers and river estuaries may also require dredging for the improvement and maintenance of navigable routes, as waterborne transport is vital to domestic and international commerce. It offers the most economical, energy efficient and environmentally friendly transportation of all types of cargo. Navigation projects must keep pace with waterborne transport needs in order to support and maintain local, national and regional economies.

DREDGING FOR CONSTRUCTION, RECLAMATION AND MINING

Dredging is an important way of providing sands and gravels for construction and reclamation projects. Over the past 50 years, the demand, and the associated cost of extraction, for offshore aggregates has significantly increased.

Dredged aggregates have a wide range of uses including:

- **Land reclamation**: pressures arising from population growth, and port and infrastructure developments in coastal areas have created a need to raise the elevation of low-lying areas and/or to construct new land areas. Such pressures are likely to continue, with new areas reaching deeper water, further offshore; and
- **Construction materials**: an increasing quantity of marine aggregate is being used in concrete and a fill material, including fill for reclamation projects.

Dredging, often removing poor quality material and replacing by good quality material, is also undertaken in order to:

- create underwater foundations for tunnels, caissons, platform- or tower-footings;

Reclamation- Port Tanjung Pelapas, Malaysia *(source: Boskalis)*

- facilitate the emplacement and protection of pipelines, cables or immersed tunnel elements;
- construct flood control structures such as dams, dikes and levees;
- ensure flood protection (by improving or maintaining the discharge capacity of watercourses); and
- create or maintain storage capacity in water supply reservoirs.

In addition, though perhaps less common, dredging may be used to recover minerals and precious metals, or to remove the overburden in order reach these. As with land-based extraction, attention needs to be given to the potential environmental impacts around marine aggregates extraction. Nonetheless, dredging can have distinct economic and environmental advantages in comparison to open pit quarrying (especially in relation to land-use impacts).

DREDGING FOR ENERGY

In supporting the offshore energy industry, both for fossil fuel and renewable energy, dredging plays an important role. For the fossil fuel industry, dredging can assist with:

- providing safe sites for winning platforms and wells;
- seabed preparation, trenching and backfilling of pipelines routes, and
- deepening and maintaining shipping routes and ports for transfer to land.

Alike activities might be deployed in supporting the hydrogen energy industry.

Similarly, for the renewable energy industry, dredging works might be required for:

- seabed preparation for foundation of (deep)sea footings for windfarms;
- levelling and trenching for construction and protection of cable routings;
- dredging for landfalls where cables or pipelines reach shore; and
- reclamation construction for supporting (energy)islands.

A further dredging activity for the energy sector may become the development of large basins for hydropower accumulation. Basically all these activities for the energy industry require specialised equipment, capable of operating in deep water, under rough offshore conditions.

Dredging for Offshore Windfarm *(source: Boskalis)*

DREDGING FOR ENVIRONMENTAL ENHANCEMENT

Dredging can be undertaken to benefit the environment in several ways.

Creation and Restoration of Natural Habitat

Specific projects aimed at restoring natural habitat in rivers, deltas and coastal areas are becoming more mainstream. These projects frequently aim at compensating loss of nature and specific ecological habitats and increasing biodiversity. The added value of such a project, for example through beneficial use of dredged material, flood safety, recreation, etc. often ensures that the business case is positive. In some case the creation of new nature areas is the sole objective for the dredging works.

Nature inclusive project design: adapting projects to nature, rather than the other way round.

Traditionally dredging is aimed at removing material for an engineered (economic and/or social) purpose, with an evaluation of the environmental implications and possible adaptations made at the end of the planning process. Lessons have been learned that this frequently "fighting against nature" is not the best way forward. By including nature and ecological habitats into the design at an early stage, projects can be designed, constructed and operated in a more sustainable manner. Many dredging works nowadays are performed in a way that also serves the environmental purpose, aiming to support one or several ecosystem services as a result of the dredging works.

Beneficial use of dredged materials

Dredged materials are frequently used to create or restore habitats. Where shorelines have eroded and valuable wetlands or intertidal habitats have diminished, returning sediments, in a diligent operation, to these regions provides a maintenance of ecological valuable areas, which may also act a carbon sink.

Beach Nourishment- Hondsbossche Zeewering (*source: Dredging for Sustainable Infrastructure*)

Furthermore it has nowadays become good practice to use suitable dredged materials for beach replenishment. These schemes are designed to prevent – or reduce the likelihood of – erosion or flooding, becoming even more important in the light of the ongoing sea-level rise. Such beach nourishment or recharge is achieved by placing dredged sand or gravel on eroding beaches. This represents a “soft-engineering” solution, an important alternative to – often more costly – structural solutions such as rock armour or concrete walls. Other uses of dredged materials are for agriculture, horticulture and forestry.

Contaminated sediment removal

Another environmental use of dredging has been in procedures designed to remove contaminated sediments, thus improving water quality and restoring the health of aquatic ecosystems. This so-called “remediation” or “clean-up” dredging is used in waterways, lakes, ports and harbours in highly industrialised or urbanised areas. The removed material may be treated and used afterwards, or disposed of under strict environmental controls. Under proper conditions a viable alternative to removal is in-situ isolation, i.e. the placement of a covering or a cap of clean material over the deposit of contaminated material.

The Dredging Process

Capital (or new) dredging projects can be both extensive and expensive. Maintenance dredging is often a regular, perhaps annual ongoing, long-term activity. In either case, what are the key elements of dredging?
The dredging process consists of the following three elements:

- **Excavation:** this process involves the dislodgement and removal of sediments (soils) and/or rocks from the bed of the water body. A special machine - the dredger – is used to excavate the material either mechanically, hydraulically or by combined action. The main types of dredgers are described below.
- **Transport of excavated material**: transporting materials from the dredging area to the site of utilisation, disposal or intermediate treatment, is generally achieved by one of the following methods: (a) in self-contained hoppers of the dredgers; (b) in barges; (c) pumping through pipelines; and (d) by using natural forces such as waves and currents.
  Once on land, dredged material might be further transported by trucks. Another, rarely used transport method is conveyor belt transport.
  The method of transport is generally linked to the type of dredger being used and to the potentially available routings to the placement site.
- **Placement**: utilisation or disposal of dredged material. In construction projects, placing dredged material is the objective of the operation, while in navigation and remediation dredging, the project is driven by the objective of removing the material from its original place, with the dredged material being seen as "burden". The main alternatives for the management of the dredged material are described later in this document.

The activities of taking up material at one location, transporting it and putting it down somewhere else shall always been designed and executed as one integrated operation.

Types of Dredgers

How do we dredge? With specialised dredging equipment which varies widely, coming in many sizes and types, and including mainly water-based and sometimes land-based machines.

Dredging equipment, classified according to the methods of excavation and operation, can be grouped into the following main categories:

- mechanical dredgers;
- hydraulic dredgers;
- special environmental dredgers; and
- hydrodynamic dredgers.

It is noted that several hydraulic dredgers also use mechanical means to improve the dislodging process.

Within the above categories further subgroups can be identified on the basis of propulsion, i.e. self-propelled versus stationary. The selection of dredging equipment for a particular project will depend upon a combination of factors, including:

- the requirement to execute the works in a safe and environmentally sound manner;
- the type of physical environment (accessibility, hydro/meteo conditions);
- the nature, quantity and chemical properties of the material to be dredged;
- the method of placement;
- the distance to the placement site; and
- economic, social and environmental criteria.

Over the past decades dredging equipment has undergone significant changes:

- growing demand for new land - large reclamations, for larger ports, for intensified levels of sea defence and growth of the offshore energy industry has led to larger, more powerful, more economic vessels.
- developments in automation, data acquisition / processing and positioning systems led to highly sophisticated and more accurate and efficient vessel control systems;
- environmental awareness and strict international regulations have led to cleaner, less disturbing dredging systems and vessels.

Also the smaller supporting equipment has undergone improving development, to keep pace with the "prime movers".

MECHANICAL DREDGERS

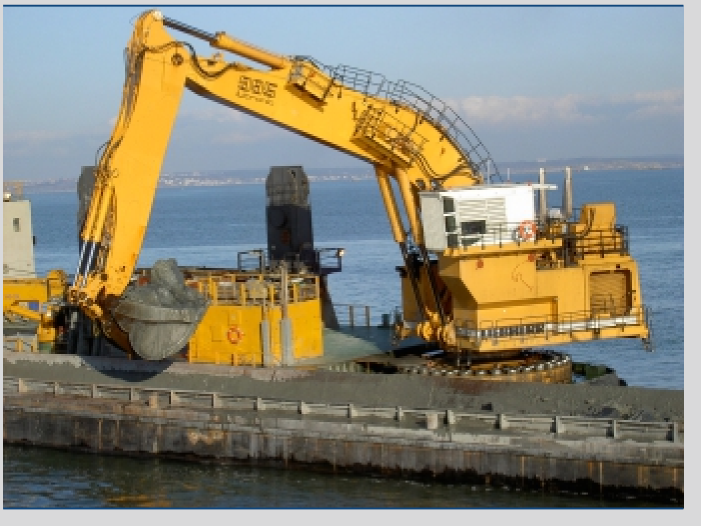
Two main sub-groups of mechanical dredger can be identified:

- backhoes; and
- grab dredgers.

A third type of mechanical dredgers, the bucket-ladder dredger, is nowadays hardly used anymore.

These dredgers are well suited to removing soft to hard-packed material, to working in confined areas and to deal with debris within the soils.

Mechanical tools (buckets, grabs) are used for excavation – dislodging the material and then raising it to the water surface – in a way similar to dry land excavation methods. Mechanically dredged sediments are generally transported by barges, with as little as possible additional water being added. Cohesive sediments, dredged and transported this way, usually remain intact, with large pieces retaining their in-situ density and structure through the whole dredging and placement process.



BHD Loading barge

HYDRAULIC DREDGERS

Three main sub-groups of hydraulic dredger are:

- stationary suction dredgers;
- cutter suction dredgers, and
- trailing suction hopper dredgers.

These dredgers use hydraulic centrifugal pumps to provide the dislodging and lifting force and remove the material in a liquid slurry form.

The pure-suction dredgers usually work well in loose, “unconsolidated” silts, sands, gravels and soft clays. In more cohesive materials waterjets may be applied for breaking up the material.

Cutterhead (*source: Jan De Nul*)

Trailing suction hopper dredgers (*source: Jan De Nul*)

Cutter suction dredgers are equipped with a cutting device to increase the dislodging force, thus combining mechanical breaking power with hydraulic transport flows. These "cutters" are suitable for use in high strength materials such as clays, packed or compacted sands and medium strength rocks. Cutter dredgers are capable of working with great precision and at high production levels. Their application might be affected by hydrodynamic conditions (high waves, strong currents) and by the obstruction they might create (with their floating pipelines) in busy navigable waters.

Transport methods associated with suction-and cutter dredgers are pipeline transport or pumping the materials into barges for further transport. The choice for one or the other system depends (amongst other) on the location of the material destination, the required transport distance and pumping power available.

Trailing suction hopper dredgers load the dredged material, which they have dislodged / "vacuum cleaned" from the underwater-bed, into their own hold or hopper, which they after having fully loaded transport themselves to the destination site, for subsequent release by bottom-door opening or through self-emptying systems ("rainbowing" or pumping ashore). "Trailers" are perfectly suited for work in open waters, busy shipping areas and for transporting large volumes of sand over larger distances. They also are able to create, and later backfill, long trenches for offshore cable- and pipeline installation.

Hydraulic dredging and transport methods "slurry the sediment", that is, they add large amounts of process water and thus change the original structure of sediments.

SPECIAL ENVIRONMENTAL DREDGERS

In past decades, for both mechanical and hydraulic dredgers "special versions" with "special devices" have been developed, built and used, with the aim of increasing precision, i.e. by reducing overdredging, and minimising the suspension of bed material. These dredgers have specifically been applied in projects where contaminated sediments had to be dredged in an environmentally acceptable manner, in particular ensuring that contaminants are not re-mobilised and/or released into the water column where they may detrimentally affect aquatic life. In recent times they have less been deployed, as with the "regular" equipment, with highly developed instrumentation and automation, the objectives of environmental care can well be attained.

HYDRODYNAMIC DREDGERS

A special group of dredgers are dredging machines that do not completely raise the dredged material above the water surface, but merely relocate the material in the same waterbody, with natural forces largely determining the destination of the released material. The dredging action is either achieved by hydraulic forces (water injection dredging and agitation dredging) or by mechanical action (underwater ploughing or bed levelling). Obviously these dredging methods are less costly, but also less controllable, with potential environmental implications. Yet these techniques may very well be used, especially when in support of other mechanical or hydraulic dredging activities.

Water injection dredging (*source: DEME*)

Transport Options

To transport dredged material from dredging site to (temporary or permanent) placement site several methods are available, each with their own specific technical, environmental and economic aspects.

- **Pipeline transport**: pumping a mixture of water and dredged sediment through a steel (or partly rubber) pipeline. Advantage of this method is the closed (pipe) system through which the transport takes place; disadvantage is the amount of water that usually is needed to transport the material and that needs to be drained from the placement site.

- **Hopper or barge transport**: carrying the dredged material in the hold of a vessel. Horizontal transport between the dredging site and the placement site

CSD with pipeline (*source: Van Oord*)

- can efficiently be done by navigation of barge or hopper, especially over larger transport distances. Main advantage of barge/hopper transport is the elimination of the need to transport water, although for the discharging action water might be needed again. It is a relatively environmentally friendly transport method, with environmental impact limited to engine sounds and the emission of exhaust gases.

- **Road transport**: carrying the dredged material in the hopper or dump-box of road- or offroad trucks. Road transport, over public roads or over project-exclusive work-roads, is sometimes the main transport mode, but mostly it is used in combination with or in continuation of pipeline or barge/hopper transport. Material can be loaded in trucks without addition of water; and transport is flexible for various destinations; but a large number of trucks will be required for larger outputs, potentially causing disturbance of local road and disperse exhaust and sound emissions.

CSD loading barge (*source: DEME*)

- **Conveyor belt transport**: this system is not commonly used in the dredging industry, as the installation costs of such a system are high. Furthermore, the basic characteristics of a wet dredging process are not compatible with the mechanical characteristics of the conveyor belt. However, in few specific cases it might be a feasible method.

Dredged Material Management Alternatives

When we dredge, what do we do with the dredged material, if not needed for a specific use? In the last fifty years this has become one of the crucial issues of dredging and there has been a continual dialogue amongst many nations and organisations on the subject. With the goal of protecting the environment and still furthering economic development, the parties involved have reached some significant agreements.

REGULATORY ASPECTS

Both dredging and disposal are now carefully regulated. In general the regulations provide a framework for the works to be carried out in a responsible manner. This implies that, besides the environmental special requirements, a regional, national or even trans-border permit will be needed for the execution of dredging and dredged material placement project. Such permit might regulate the permission to operate in certain areas, during certain times, to extract sediment from an area and possibly to turn water areas into new land.

In addition to national and regional legislation and policies, the most widely applicable international regulatory instrument is the London Convention 1972

(LC-72), which covers the marine waters of the whole world. In 2014 LC-72 adopted the Dredged Material Assessment Framework (DMAF), a widely reviewed and accepted approach to the assessment of suitability of dredged material for disposal at sea, as part of the London Convention and London Protocol. The contracting parties to the Convention, some 90 countries, are now expected to implement the DMAF accordingly. There are also regional conventions such as the Oslo and Paris Convention, the Helsinki Convention and the Barcelona Convention.

Legislation controlling placement on land (and in inland waters) is based on national regulatory systems often involving a great variety of laws prepared for various waste materials, e.g. sewage sludge, agricultural and industrial waste. As dredged sediment is not to be considered as a waste, several countries have now developed regulations specifically for dredged material. Within the EU this means that sediment has to meet "end of waste" criteria before becoming a building material.

Some dredging initiatives, particularly those which comprise regular operations such as annual maintenance dredging of a waterway, may not need to be the subject of detailed chemical investigations. Most major/new dredging or disposal projects should, however, have studies (Environmental Impact Assessments or alike) carried out in order to ensure that any potential adverse effects are identified in advance and dealt with in an appropriate manner. This includes the impact on the water quality (in Europe regulated by the Water Framework Directive). Such investigations include, for example, technical investigations of dredging and disposal options, physical process studies and environmental impact studies, based on the presence and potential emission of contaminants.

MANAGEMENT ALTERNATIVES FOR DREDGED MATERIAL

Management alternatives for dredged material can be grouped into the following categories:

- Beneficial use:
  - Environmental enhancement;
  - Engineering uses.
- Disposal alternatives:
  - Open-water disposal;
  - Confined disposal.
- Treatment.

Beneficial use

Dredged material is increasingly regarded as a resource rather than as a waste (in EU still technically classified as a waste, and so the Waste Hierarchy still applies). More than 90% of sediments from navigation dredging comprise unpolluted, natural, undisturbed sediment, which is considered acceptable for a wide range of uses. The DMAF recognises this and requires that, as a first step in examining dredged material management options, possible beneficial uses of dredged material be considered.

Beneficial use of sediment is herein defined as “the use of dredged or natural sediment in applications that are beneficial and in harmony to human and natural development”. Beneficial use may be defined as “placement of dredged material in such a way that it has environmental or socio-economic value”. Operational feasibility, that is, the availability of suitable material in the required amount at a particular time, is a crucial aspect of many beneficial uses.

A great variety of options are available, which generally fall in two groups of use:

Habitat Development - Marker Wadden

Environmental Enhancement

Sustainable relocation: Marine or fluvial sediments normally contribute to the sustainability of natural ecosystems. Their role in river, estuarine and coastal zone processes should be respected wherever possible. In environmental assessment therefore, as a first option, the relocation of sediment within an estuary, in the natural environment should be considered;

Habitat development: Dredged material can be used for development or upgrading of aquatic habitats, bird habitats, mudflats, wetlands, etc. An example is the backfilling of (anaerobic) deep lakes to create shallow lakes;

Amenity development: Landscaping of shore-areas or raising low-lying land can well be made with dredged material.

Engineering Uses

Flood and coastal protection: Sandy shorelines need to be maintained or strengthened with dredged sands. Such projects involve a.o. beach nourishment, onshore/offshore feeding or managed retreat. Flood and coastal protection can be combined with vegetation (wood or mangroves against waves) and is therefore linked with environmental enhancement;

Land reclamation: Similarly dredged sand can be applied for new land or for expanding existing areas for purposes as industrial development, housing, infrastructure, etc.;

Construction material: The production of construction materials, like concrete aggregates, bricks, clay, etc. can well benefit from dredged materials;

Construction works: When demand nicely meets supply, direct application of dredged material might be feasible, in construction works like foundation fills, road basements, dams and dikes;

Agriculture, horticulture and forestry might benefit from dredged materials becoming available for soil improvement or extension.

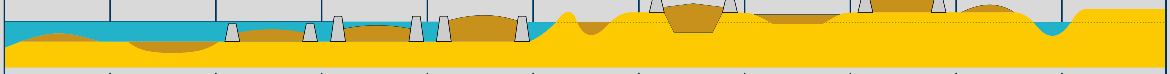
Disposal Alternatives

A large number of dredged material options exists for the placement of dredged material both under water and on land, and they include both beneficial uses and disposal options. The most common placement options for dredged material can be divided into two main categories:

Open-water disposal

Open-water disposal means that dredged material is placed at designated sites in oceans, estuaries, rivers and lakes such that it is not isolated from the adjacent waters during placement. Placement is generally via direct release from pipelines, barges or hoppers.

Open-water sites can be either dispersive or non-dispersive (retentive) depending on whether the sediment is transported out of the site or remains within



Dredged material placement options	Type A	Type B	Type C	Type D	Type E	Type F	Type G	Type H	Type I	Type J	Type K
Site characteristic	mound on bed	depression on bed (natural or created)	subaqueous berms	artificial atoll CDF	artificial island CDF	peninsula/ nearshore CDF	land-based CDF fully below groundwater	land-based CDF partly below groundwater	landfill fully above ground water	land-based CDF fully above ground water	river bank
Location	aquatic : marine or inland						land-based				
Placement type	unconfined	semi-confined		confined							unconfined
Placement type name	unconfined aquatic placement	semi-confined aquatic placement		CDF confined disposal facility							unconfined upland placement
Capping	Containment measures such as capping are possible for each placement type										
Physico-chem environment	Water saturated, anoxic, neutral in pH							Mixed	Dry, oxic, acidic		
Suitable for ... material	Mainly clean or mildly contaminated			Mainly contaminated							See A to C

Dredged Material Placement Options

the designated boundaries. Generally, clean or slightly contaminated sediments are disposed of in open-water sites. Open water placement might purposely be made as sustainable relocation, a Beneficial Use option.

Variants of open-water disposal include:

- unrestricted placement on an underwater-bed, either concentrated in mounds or spread out over a larger waterbody;
- placement with lateral containment in natural or man-made depressions, and
- placement with lateral containment behind constructed berms.

A cap of clean material over the dredged material can provide isolation from the benthic environment. If capping is applied over the mound formed by unrestricted placement, it is called level-bottom capping (LBC). If the capping is applied with lateral containment, it is called contained aquatic disposal (CAD).

Confined disposal

Confined disposal means that the dredged material is placed in an engineered containment structure, that is, within dikes or bunds, or in natural or constructed pits, or borrow pits, on land or underwater. This isolates the material from surrounding waters or soils during and after placement. Terms used in the literature for this type of placement include “confined disposal facility" (CDF), “diked disposal site” and “containment area”. CDFs may be constructed in open waters (known as island CDFs), at near-shore sites or on land.

The function of CDFs is to retain the dredged material solids whilst releasing the carrier water. For facilities receiving contaminated material, an additional objective is to provide the efficient isolation of contaminants from

Confined disposal facility, Amoras

the surrounding area.
To achieve this, depending on the degree of intended isolation, CDFs may be equipped with a system of control measures such as surface covers and liners, treatment of effluent, surface runoff and leachate.

Treatment

Treatment is defined as the processing of dredged material either to make the material better suited for the intended use or application, or to reduce its quantity and possibly the contamination level before disposal or use Treatment methods range from separation techniques, in which mud is separated from clean sand, to incineration. Some techniques are well developed and applicable at large scale, but others are still in stages of development or only applicable for smaller volumes, due to the often high cost of processing.

Hydrocyclone separation facility

Management of Environmental Aspects of Dredging

What about the environment? Is dredging good or bad? How do we find out? Dredging plays a vital role in the socio-economic development and the environmental health of many countries and regions in the world. Yet any infrastructure or development project can have impacts on the environment, and dredging is no exception.

The perception that dredging, by definition, is inherently bad for the environment, has been demonstrated to be incorrect. If properly studied, engineered, executed and managed dredging may well have many positive effects on the wider environment.

Understanding of what dredging does and how it can be controlled or managed is essential. The basis for such management comes from an Environmental Risk Assessment, appreciating and balancing all, both positive and negative, identified potential effects and impacts. When such effects are well understood, first measures can be taken to reduce or mitigate negative effects and even better, modifications can be adopted to stimulate the project to create an overall positive impact.

Marker Wadden (source: Boskalis)

EFFECTS OF THE DREDGING PROJECT AND PROCESS

Any project or development causes environmental impacts (both positive and negative), as it changes the present situation, no exception for a dredging project. Any effect created by the fact that a project is implemented, might be significant and long-lasting (up to decades or even centuries, which can be the intention of the project) and shall be assessed and engineered to the highest possible standards. Ultimately the overall impact should be positive and sustainable.

Direct or indirect environmental and socio-economic effects may be associated with any element of the dredging process – excavation, transport and disposal. The effects may be positive or negative, short term or long-term.

Project and process effects may include, amongst others, impacts on:

- water quality, e.g. changes to suspended sediment concentrations which can effect dissolved oxygen, turbidity and contaminant uplift during dredging or disposal;
- habitats and natural areas, e.g. alteration/ removal/ enhancement of ecologically important areas (such as spawning habitat) or changes to behaviour and/or movement during migration;
- carbon sinks: disturbance or enhancement of carbon sinks and/or the local carbon cycle;
- marine biodiversity/ecology, e.g. changes in animal movement and behaviour in response to exposure to sedimentary or noise-induced disturbance;
- local human communities, e.g. the effects of sound, smell or view; increased labour opportunities;
- greenhouse gasses; emissions of exhaust gasses by equipment engines but also due to changes in the environment;
- changes to bathymetry or topography;
- physical processes, e.g. alterations to waves, currents, or drainage, and hence erosion or deposition;
- archaeological assets (or "Underwater Cultural Heritage"), e.g. shipwrecks; and
- other maritime uses, like recreation (e.g. sailing, swimming and beach use)and economic activities (e.g. commercial fishing and improved infrastructure).

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Many of these effects are interlinked/interdependent. For instance, removal/alteration of habitats may affect local fish populations which then may affect the fishery; changes to bathymetry may lead to local hydrodynamic changes thereby impacting physical processes.

CONTROL OF DREDGING PROJECTS AND PROCESSES

Prior to undertaking dredging and/or disposal projects, a careful assessment to identify potential effects and to determine their significance is necessary. The "environmental impact assessment" (EIA) should highlight both positive and negative, short- and long-term impacts.

Where potentially significant effects are anticipated, management techniques should, where possible, be implemented, to reduce concerns. Practical, cost-effective mitigation measures may further be required for any residual effects, in order to reduce the considered impact to an acceptable level, or avoided altogether.

Potential actions that can be taken to improve the environmental performance of a scheme are:

- Options in selecting the right equipment, possibly with modifications (e.g. using a closed bucket);
- Options for process control and process adjustment (e.g. through flexibility in project planning); and
- Proactive actions to turn negative effects into positive opportunities (e.g. using dredged material for beneficial uses).

Environmental mitigation measures can be precautionary implemented from the onset of the project planning (without knowing whether they are really needed), or can be activated in an Adaptive Management approach.

This implies during the course of the project being prepared (also regulatory) for implementing changes to the process rather than continuing using the original procedures, in a manner demonstrated of being non-effective, as a result of findings from the ongoing environmental monitoring.

In case contaminated sediments need to be dredged, it seems obvious that the outcome of the project will heavily depend on the source of the pollution being controlled / terminated or not.

USE OF MODELLING AND MONITORING

In all phases of a dredging project modelling and measurements play an important role.

- During initiation and planning phase: for effect prediction in project design and for permission application; and
- During project execution phase: for effects evaluation and process adjustment.

Upfront modelling is to be calibrated with relevant measurements, and performance measurements are, for model-improvement, fed back into modelling.

Modelling can be made

- on physical parameters (currents, waves, suspended sediment, sound, etc);
- on biological and chemical parameters, on ecological parameters (health of flora/fauna, ecosystems and the impact of physical changes on these); and
- on socio / economic systems.

Modelling shall determine project effects on short and long term and in near field and far field. Thereto it shall look at:

- sources of the stressor (concentrations and dispersal);

Turbidity Plume survey

Underwater eco-survey

- the potential receptors (presence, abundance and health);
- the likely pathways between source and receptor;
- and thus to the likely level of impact, and
- also taking into account cumulative effects.

As part of the ongoing environmental assessment process, the subsequent monitoring of environmental parameters may also be needed in order to

- measure the magnitude of particular changes;
- compare such changes to those predicted, and
- and identify whether, when or where remedial actions are required.

WORKING WITH NATURE/ NATURE BASED SOLUTIONS

A current way of thinking about dredging is to see dredging and dredged material management as a means to create more sustainable projects and infrastructure. This has, within a good part of the dredging world, recently led to a paradigm shift, in which a more holistic approach is taken to take the three pillars of sustainability as basis for project development.

Building with Nature- Sand Engine (*source: Rijkswaterstaat*)

Starting from the United Nations' Sustainable Development Goals several dredging branch organisations (WODA/CEDA, IADC and PIANC) and national agencies, like USACE, have adopted the "Working with Nature" (or "Building with Nature" or "Engineering with Nature") concept as basis for their activities. This concept is based on design and execution methods using the forces of nature, instead of performing a job while nature acts to destroy it. When the forces of nature are properly integrated in the construction concept, a negative impact of the project to the environment is minimised and additional ecosystem values might be created. In fact also cost savings are well possible (if not on the short term than at least on the long term) and public acceptance may easily increase. One condition for successful application of "Working with Nature" is a full, open and transparent engagement with all engaged stakeholders.

IMPORTANCE OF STAKEHOLDER ENGAGEMENT

Early involvement of stakeholders during the planning and design stage of a project will provide valuable information on stakeholder's interests and on how additional values might be added to the overall value of the project. In this way the sustainability of the project (social, environmental and economic) can be increased, while the total project costs, expressed in both monetary as in non-monetary values, might be reduced.

INFORMATION ON DREDGING

LEARN BUT DO NOT COPY

CEDA, PIANC, IADC, SedNet and UNEP issue many relevant publications. But be alert: every situation is unique! The examples and case studies given in these publications are in most cases specific for a certain set of conditions. Readers should learn from them but should not copy them. Copying measures and solutions may lead to inappropriate solutions and unnecessary extra costs without any added social or environmental benefit.

KNOW WHERE TO FIND INFORMATION

The networks and publishing organisations — CEDA, IADC, IAPH, PIANC and SedNet — are fully committed to facilitating the design and implementation of environmentally, economically and socially sound dredging and reclamation projects by gathering and disseminating relevant, factual, good quality information. The World Organisation of Dredging Associations is similarly committed. The production of various integrated guidance documents on these aspects of dredging and dredging project related aspects seeks to achieve this objective. Publications and references to websites can be found on the following page.

UNEP through the UNEP/GPA Coordination Office and UNEP World Conservation and Monitoring Centre provide information on policy and action to conserve the living world.

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    - Adaptive Management
    - Beneficial Use of Dredged Material (with CEDA)
    - Building with Nature Coastal Protection
    - Confined Disposal Facilities
    - Creating a Sustainable Marine and Freshwater Infrastructure (with CEDA)
    - Dredged Material as a Resource
    - Dredging Around Coral Reefs
    - Dredging Management Practices for the Environment

- [Ecosystem Services]
  - Ecosystem Services
  - Environmental Equipment
  - Environmental Impact Assessments
  - Environmental Monitoring (with CEDA)
  - Models and Modelling for Dredging (with CEDA)
  - Site Investigations
  - Soil Improvement
  - Turbidity & Dredging
  - Underwater Surveys
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WEBSITES

- CEDA - www.dredging.org
- IADC - www.iadc-dredging.com
- PIANC - www.pianc.org
- European Sediment Network - www.sednet.org
- UNEP - Global Programme of Action for the Protection of the Marine Environment from Land-based Activities, https://www.unep.org/topics/ocean-seas-and-coasts/ecosystem-degradation-pollution/global-programme-action-gpa
- U.S. Army Corps of Engineers, Engineer Research and Development Center - Dredging Operations Technical Support Program, https://dots.el.erdc.dren.mil/
- US Army Corps of Engineers Environmental Operating Principles - https://www.usace.army.mil/Missions/Environmental/Environmental-Operating-Principles/

FINDING FURTHER INFORMATION ON DREDGING

This publication has been updated and published by CEDA, the Central Dredging Association. CEDA connects and empowers all stakeholders interested in dredging. We are the leading, independent platform where knowledge is shared, collaboration is encouraged, learning is promoted and new insights emerge.

Responsible dredging and disposal practices are in everybody's interest. The following organisations are actively involved in promoting responsible dredging and disposal practices. Each of these organisations is able to provide further information to help you understand the processes and the facts about dredging and disposal. If you have any questions about dredging or disposal, we encourage you to contact one or all of them.

CEDA is part of the World Organization of Dredging Associations (WODA); other members of WODA are the Eastern Dredging Association (EADA) and the Western Dredging Association (WEDA).

CEDA, Central Dredging Association
Email: ceda@dredging.org
Website: www.dredging.org

EADA, Eastern Dredging Association
Email: subra@pka.gov.my
Website: https://www.eada.asia/

WEDA, Western Dredging Association
Email: jbridges@westerndredging.org
Website: https://www.westerndredging.org/

IADC – International Association of Dredging Companies
Email: info@iadc-dredging.com
Website: www.iadc-dredging.com

IAPH – International Association of Ports and Harbors
Email: info@iaphworldports.org
Website: www.iaphworldports.org

PIANC – International Navigation Association
Email: secretary.general@pianc.org
Website: https://www.pianc.org/

SedNet
Email: secretariat@sednet.org
Website: https://sednet.org/

UPDATED AND PUBLISHED BY CEDA Central Dredging Association