Central Dredging Association

Climate Change Adaptation As It Affects The Dredging Community

The Central Dredging Association is committed to environmentally responsible management of dredging activities and this paper – produced by the CEDA Environment Commission – seeks to raise awareness, to help the dredging community prepare for consequences of climate change, and to understand how dredging can contribute to adaptation measures

Climate change is now a fact. It is also now widely accepted that human activities are playing a role in the increase of greenhouse gas emissions that have accelerated global warming during the last century, although the significance of the human contribution is still a matter of debate. The related effects include:

- Sea level rise
- An increase in seawater surface temperature
- Changes in (seasonal) precipitation and hence river flow.

Climate change research moves rapidly and there is still a great deal of uncertainty: some new estimates project faster rates of sea level rise than those reported by IPCC in 2007 (*Rahmstorf, 2010*) whilst other (satellite) data suggest that rates of sea level rise may be slowing (*CU Sea Level Research Group, 2012*).

In addition to trends for an ongoing rise in global temperature and associated sea level rise, it is anticipated there will be an increase in the frequency of such extreme events as storms, surges, floods and droughts.

Climate change effects are also expected to increase in the coming decades, in part because of the relative lack of success to date in implementing mitigation measures (ie measures designed to reduce greenhouse gas emissions), and in part due to the thermal inertia of the oceans, the 'climate engine'.

Low-lying coastal areas worldwide face a large-scale increase in population density, urbanisation, industrialisation and agriculture with associated implications for land subsidence. These increasing pressures make coastal zones and deltas especially vulnerable to climate change impacts – not only flooding and erosion, but also implications for ecosystems (*Nicholls et al, 2010*) such as through intrusion of saline waters.

Adaptation strategies are therefore absolutely necessary to reduce the consequences of climate change by improving resilience and reducing vulnerability. And dredging will often be an important element in the adaptation 'toolkit'.

The dredging community comprises all those involved in any kind of activity related to dredging. This includes not only the dredging industry (contractors, manufacturers) but also port and water authorities, policy makers, regulators, consultants and stakeholder groups. Geographically, this CEDA position paper focuses on north-western Europe but other parts of the CEDA area may face similar challenges.

Mitigation measures designed to reduce the contribution of the dredging sector to greenhouse gas (CO_2) emissions (eg the use of alternative fuels and materials), whilst clearly important, are outside the scope of this paper, which:

- Firstly highlights the main implications of climate change for dredging
- Discusses potential preparatory and adaptation measures in general terms
- Elaborates on specific climate change issues and adaptation requirements/options in relation to three typical environments in which dredging takes place: open coasts; seaports, estuaries and access channels and inland waters.

Potential Climate Change Implications For The Dredging Community

Dredging activities mostly take place in rivers, canals, estuaries, ports and coastal areas. The morphology of these areas is influenced by sediment supply, currents, waves, winds, water levels and tidal range. Changes in these conditions due to global warming may induce changes in erosion and sedimentation patterns, with potential consequences for both inland and offshore dredging requirements.

The dredging community needs to be aware of the projected changes and the type of adaptations likely to be required.

Adaptation measures might relate to dredging volumes or locations, the type or number of dredging tools, or new dredging methodologies. Changes in technology may also be required – eg specific equipment may be required to dredge in harsh and isolated conditions, or different types of equipment may be needed to meet smaller scale, more isolated or more frequent dredging needs (*Jensen, 2007*).

The increased development of offshore windfarms, for example, is leading to more dredging activities offshore with a requirement for special equipment to optimise burial of the electric cables connecting the windfarms to the shore.

Uncertainty about the impacts of climate change and the occurrence of extreme events means that solutions have to be flexible – and regulatory regimes also need to be able to accommodate such flexible approaches. Meanwhile, the vulnerability of ecosystems to climate change may lead to a more stringent regulatory regime – with potential consequences for dredging.

In some cases, an increased frequency of extreme events may mean that more reactive dredging is needed than is currently done; in other cases proactive dredging may be more appropriate to deal with the implications of long term seasonal changes in flow. Careful planning to identify and deliver the most sustainable option in a site-specific context will be essential.

Sustainable solutions may involve more conventional dredging (eg where greater quantities of beach nourishment material are required) or they may involve less (eg where higher water levels mean that less dredging is needed or, in inland waters where integrated sediment management solutions such as buffer strips[1] or SUDS[2] are adopted instead of dredging to prevent sediments and associated contaminants from entering water bodies).

In some cases the most sustainable option may not involve conventional dredging practice at all (eg as a result of changes in flood defence policies). The dredging community needs to be prepared to seek new and innovative solutions. Climate change will provide new opportunities, but it will also pose challenges.

Adaptation Measures

Adapting to climate change means taking measures that help society prepare for, and adapt to, the anticipated effects by improving resilience and/or reducing vulnerability. However, adaptation measures are seldom taken in response to climate change alone; they are more often embedded in broader initiatives.

Adaptation measures should be sustainable, not only in environmental terms but also with regard to durability, affordability and cost-effectiveness. The selection of sustainable adaptation measures should be based on an integrated approach taking into account:

- Safety (eg flood risk management and navigation)
- Environmental protection and improvement
- Economics
- Societal interests.

Adaptation does not necessarily mean 'more of the same'. Adaptive management principles and philosophies like *Working with Nature* or *Building with Nature* will need to be embraced. Measures which use the dynamics of the natural system as the starting point for the design, and which make optimal use of natural processes, will usually be amongst the most sustainable.

In the short term, actions such as raising awareness, additional data collection and monitoring, provision for effective data management, and risk assessments will be critical elements of climate change preparation. Well-informed decisions about appropriate (ie timely and cost-effective) adaptation measures cannot be made without relevant, high quality, properly interpreted data, however. Preparedness will also include the development of scientific support to help understand and judge the effectiveness of proposed adaptations, and to consider climate change in forward planning activities.

For example, authorities responsible for potentially vulnerable ports and waterways may find it useful to work with the dredging industry to prepare contingency plans to ensure they can deal promptly with any problems (eg resulting from sediment movement associated with more frequent extreme rainfall or storm events).

Another important aspect of preparedness is to build climate change considerations into the design of new developments, particularly those with a design life extending to decades – a process often referred to as 'climate-proofing'. The design of new projects needs to accommodate the uncertainties inherent in many climate change projections/design parameters. This is likely to result in an increased requirement for flexibility in modern design.

Whereas in the short term adaptation activities will involve planning and monitoring, in the longer term decisions on more concrete measures will be needed – for example, the physical modification of infrastructure or changes in working practices. Wherever possible, 'no regrets' adaptation measures will be preferred: these are measures which will deliver benefits irrespective of the rate of change of climate-related parameters. 'Win-win' options (ie solutions that meet multiple objectives) will also need to be explored to help minimise costs whilst maximising benefits. Responding to climate change will involve a wide range of stakeholders if the optimal options in all aspects are to be identified and if inflexible or irreversible 'regrets' measures are to be avoided.

The potential implications of climate change for the dredging

[1] Buffer strips are planted strips of land, typically around field margins, where suitable vegetation is maintained to promote the trapping of sediments and hence to reduce diffuse pollution.

[2] SUDS - Sustainable urban drainage systems perform the same function but in the built environment.

community are discussed in more detail in the following sections covering different interconnecting environments – open coasts, seaports, estuaries, access channels and inland waters.

Open Coasts

Coastal areas are influenced by natural forces such as tides, surges, waves, winds and currents that may lead to coastal erosion, sediment accumulation and coastal flooding. Climate change is already manifesting itself in the form of sea level rise and altered wind patterns.

The consequences of climate changes are likely to include increased coastal erosion and an increasing risk of breaching of dikes and dunes and of flooding from the sea. Changes in sediment transport may lead to increased sedimentation in harbours, inlets and channels.

There are many associated challenges: the quantity of sand required for future strengthening or raising of dikes and dunes, for example, or for nourishing foreshores in low lying areas and along eroding stretches of coast. These are likely to increase in many situations and if this is the case, such materials may need to be sourced further offshore – in deeper waters and therefore in a harsher environment.

The uncertainties associated with climate change projections for extreme events can in turn result in significant uncertainties for basic design criteria for marine projects – such as extreme water levels and extreme waves – within the lifetime of a project. This need to take into account a wider range of projected future conditions may provide some additional design challenges.

Coastal zone management has evolved considerably over recent decades, facilitated largely by an ever-improving understanding of the littoral sediment transport processes that govern coastal change. Positive use of such natural processes by dredging contractors can help towards adaptive measures for climate change. Managing sediment balances through cyclic nourishment is a potentially relevant adaptation measure in which the dredging industry could play an important role.

Case Studies – Coastal Defence

An example of an adaptive management solution is the experimental mega-nourishment in the Netherlands called *The Sand Engine* (Figure 1), which combines safety requirements with space for nature development and recreation, and uses natural processes for distribution of sand (*Aarninkhof et al., 2010*).

This type of solution may become more commonplace under the scenario of climate change – building on innovative modern schemes and management plans implemented along our coasts and

Figure 1. The Sand Engine on the Dutch coast

Figure 2. Køge Bay Denmark

Figure 3: Profile nourishment in combination with reclamation of the subtidal (submerged) beach at De Haan Belgium for sustainable and integrated coastal defence

estuaries. Such schemes already have to be multi-functional, while at the same time satisfying the requirements of society, conserving the environment or even rehabilitating past environmental damage.

Other examples include the beach parks Køge Bay (Figure 2) and Amager in Denmark which combine flood protection with 'engineered nature' in the form of lagoons, and high quality artificial beaches (*Brøker and Mangor 2011*): such solutions, however, require specific conditions which may not be available in all locations.

Another example of an innovative approach combining profile nourishments with submerged feeder berm nourishments is illustrated in Figure 3. Restoration was necessary after a storm that caused erosion of dunes, tidal and subtidal beaches along the coastal stretch between Vlissegem, De Haan, Bredene (Belgium). By integrating the natural morpho-dynamics into the design a significant improvement in stability of the reclamation could be achieved.

A negative sediment balance in the coastal area is typically associated with erosion and an increased threat from flooding – a situation which is likely to be exacerbated as a result of climate change. EUROSION, a European initiative for sustainable coastal management, recommends that a source of future sediment be identified to help improve the long term resilience of affected areas. These 'Strategic Sediment Reservoirs' could be derived from offshore, coastal or hinterland areas, and in the case of the former, dredging may have an important role to play.

Such strategic reservoirs must also be subject to environmental impact assessment and must be cost-effective. Recent coastal hydrogeomorphological research has therefore focused on the mapping of marine relict sands which may be found at significant depths, potentially requiring further adaptation of dredging systems (*see, for example, Pranzini & Wetzel, 2008*).

Seaports, Estuaries And Access Channels

Seaports are necessarily situated in areas vulnerable to the adverse effects of climate change: at the coast which is susceptible to sea level rise and increased storm intensity, and/or at mouths of rivers which are vulnerable to flooding. An increase in global sea levels, combined with geological processes such as subsidence or glacial uplift, can result in differing local relative sea-level changes.

The majority of ports worldwide are concerned about the impacts of sea level rise, but are not yet implementing adaptation strategies (*Becker et al., 2011*).

Local relative sea-level rise may affect the tidal range and in some cases tidal wave propagation (*Flather et al., 2001*), hence the direction (and even intensity) of the dominating [cross-] currents. A modified wave-pattern or a modified tidal current pattern may influence sedimentation and erosion phenomena. Estuaries may also be influenced by changes in the intrusion of saline water, potentially changing the sedimentation patterns as well as the ecosystem. Rising sea levels can similarly lead to increased tide-locking of fresh water outflow with consequences for sediment deposition.

Local relative sea level change might result in a requirement for the adjustment of the constructed level of port terminals, quay walls and protection structures in the longer term, resulting in some increase in demand for reclamation volumes and construction materials.

In the shorter term, some ports may require new protection structures to cope with an increase in storm surges or tropical storms. Any changes in storm surge frequency could also result in changes in near shore erosion and sedimentation patterns: increased sedimentation in port basins and access channels would lead to a need for more dredging, and any increase in erosion might require extra repair and reclamation work.

The alignment of an access-channel is determined by the natural seabed-morphology, the hydro-meteorological regime of currents, waves and winds and, in general, the shortest possible track between the port and deeper water offshore. Any change in these conditions may affect the nautical accessibility and/or the maintenance dredging programme or strategy.

Figure 4. Humber Estuary in the UK

Case Study – Humber Estuary

The Humber Estuary (Figure 4) is a well-mixed, highly turbid, macro tidal estuary situated on the east coast of England. The Humber has a high suspended sediment load, and as a result a significant amount of sediment moves back and forth on every tide.

Requirements for maintaining the sediment balance within the estuary mean that sediments dredged from within it are deposited to other sites within the estuary, rather than being removed. Maintenance dredged sediment is placed at locations that disperse or redistribute the sediments around the estuary. Measures to deal with expected sea level rise include managed retreat of sea defences along the estuary and in the tidal reaches of the catchments. This approach has the potential to increase the depositional area for sediments in the estuary, leading to the dilution of any contaminants in the bed sediments. Managed realignment, if implemented to a considerable degree, has the potential to improve long-term water and sediment quality in the estuary, in addition to its flood defence payback.

Long-term changes in average seasonal rainfall may require planned changes in maintenance dredging requirements. Long periods of drought followed by heavy rainfall and flash floods can both influence fine sediment supply and the run-off of contaminants and nutrients – with dramatic changes in sedimentation potentially affecting activities in port basins and access channels.

Such events will increase the need for emergency dredging and emergency reclamation or repair works. Flexible responses will therefore be needed to help guarantee the year-round accessibility of affected seaports. Operational windows for dredging might similarly be reduced as a result of weather and wave conditions. Particularly with regard to long-term changes, integrated forward planning in potentially susceptible areas should help to identify suitable opportunities for proactive as well as reactive dredging. Such forward planning should also consider interactions up- and down-drift. Contingency planning will similarly be useful in some cases.

Inland Waters – Rivers, Canals, Harbours And Reservoirs

Climate change is projected to cause seasonal changes in precipitation: more extreme rainfall and droughts and higher water temperatures. High- and low-flow events in rivers are likely to become more extreme and frequent by 2050-2080, potentially exacerbated in some locations by the melting of glaciers and changes in mountain snow melt. Such changes may affect river hydro-morphological regimes. Other water bodies, manmade or natural (eg lakes, canals and reservoirs) may also be directly or indirectly affected by these changes.

Climate change will also have implications for inland waters in terms of navigation (*Hawkes et al., 2010*), sediment management, water resources and discharge (urban and rural) management and flood risk. The implications for nature conservation, and human activities such as recreation and agriculture, may in turn require changes in the management of water bodies.

Climate change adaptation will therefore bring with it both challenges and opportunities for the dredging of inland water bodies over coming decades. In some cases, experience from elsewhere in the world in dealing with extended wet or dry periods will help inform adaptation decisions; in other cases new or innovative solutions will be needed.

Figure 5. Dredging for flood management combined with sand and gravel mining in the river Meuse in the Netherlands

Opportunities for the dredging industry may arise if more dredging is required to reduce flood risks, to maintain safety of navigation, to retain maximum storage capacity in reservoirs, or where user requirements change as a result of global warming – for example if warmer weather leads to an increase in demand for recreational boating in Northern Europe.

An example of a flexible approach, reducing flood risk by providing the rivers with more space for the discharge of water, is the programme *Room for the River* in the Netherlands. An extensive dredging programme is in progress (Figure 5) to realise measures such as deepening and broadening of river beds, creating secondary channels and lowering floodplains (*Hakstege and van der Laan, 2010*).

The main challenges, meanwhile, seem likely to be related to climate change uncertainties. Two examples relate to how sensitive species or ecosystems will respond to warmer water temperatures and the specific interactions between climate change and vegetation growth. Potential issues include consequences for stream flows (ie if vegetation removal is required to prevent choking and ensure flood flow conveyance) and/or for navigation safety (ie if vegetation removal is required in order to prevent propellers becoming entangled or engines fouled).

The type of climate change adaptation measures needed in a particular situation will vary depending on:

- Geography – ie the effects of climate change are likely to vary regionally
- Scale – ie solutions for the major commercially navigable rivers may be different from those for small recreational water bodies
- The nature, extent and rate of change.

Nonetheless, it is likely that attention will need to be paid to measures which aim to:

1 Minimise restrictions on navigation due to seasonal changes in high or low flow conditions (eg dredging or otherwise modifying infrastructure to reduce vulnerability)
2 Reduce flood risk – whether by deepening the channel to increase flood conveyance capacity or improving resilience by raising and strengthening embankments or reducing water levels
3 Manage water resources (eg deal with changes in seasonal precipitation by dredging to restore design storage capacity, by creating new water storage facilities, or by promoting water conservation measures and reducing leakage, in turn supporting the water supply industry, hydropower, and canal systems)
4 Manage the run-off of surface water and reduce the run-off of sediments and associated contaminants from both urban and agricultural areas.

The role of dredging will depend on the selected adaptation measures. In the aftermath of extreme rainfall/run-off events, sediment removal will be important along with appropriate measures to deal with any re-mobilised contaminants.

Key Messages

CEDA's position on climate change adaptation is as follows:

- Climate change will bring both challenges and opportunities to the dredging community
- The magnitude or rate of change of some climate change parameters maybe greater or smaller than previously projected. These uncertainties are no excuse not to take action
- The dredging community has an important role to play in promoting integrated solutions for many of the consequences of climate change, and needs to be prepared to act
- Climate change adaptation measures need to be based on a well-informed, proactive and integrated approach; adequate monitoring and follow up programmes will be important
- Innovation and flexibility will be crucial factors for successful and sustainable adaptation both in terms of technical solutions and in the regulatory context.

CEDA will continue to facilitate and support the wider dredging community in meeting these challenges and delivering effective climate adaptation.

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Be aware that the references are current at the time of publication, but climate change is a fast-moving science and references may quickly become outdated.

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Acknowledgements

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This Position Paper is presented by the Central Dredging Association (CEDA), an independent, international, easy-to-access platform for the exchange of knowledge and experience on all aspects of dredging and marine construction. It has been prepared by the CEDA Working Group on Climate Change Adaptation under the remit of the CEDA Environment Commission, and reviewed by experts on dredging from various professional groups.

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