The International Association of Dredging Companies (IADC) aims to inform the world about the fundamental need for dredging as well as advocating for an industry that makes the world a safer, better and more sustainable place to live. Adapted from the second chapter of the book, Dredging for Sustainable Infrastructure (2018), this article presents the concept of sustainability in relation to dredging projects. It describes the approaches and practices that are key to using dredging and dredge material to create more sustainable solutions and infrastructure – a modern way of thinking about dredging.

INTEGRATING DREDGING IN SUSTAINABLE DEVELOPMENT

The broad context
A dredge is a tool. For hundreds of years this tool has been used to shape and manipulate the interface between land and water in order to support a variety of human activities, including navigation, coastal protection, flood risk management, as well as residential, commercial, agricultural and hydro-power development. The use of dredging to achieve these purposes has always been guided by an understanding of the costs and benefits of applying the tool. However, in the last few decades, the understanding of what constitutes costs and benefits has evolved substantially beyond the direct monetary costs of using the tool and the direct monetary benefits of what the tool was used to create.

This evolution was aided by the environmental movement over the past five decades, where the costs (in a broad sense) of applying the tool was expanded to include the negative environmental impacts that can be associated with dredging. Environmental regulations were put in place in an effort to minimise negative impacts on ecosystems caused by dredging activities, and for the last few decades dredging has been at the centre of a conflict, where the water meets the land, between groups supporting development and the environment. However, attitudes and approaches are changing.

The environmental regulations that have been put into place over the last 50 years to eliminate, reduce, or control the impacts of dredging on the environment, have produced a range of outcomes, both positive and negative. It is undoubtedly true...
As a means for developing water resource interests, values, and objectives. A part of "The 2030 Agenda for Sustainable Development" (Figure 1). The organisational focus is an example of organisational focus and application of sustainability in relation to dredging and infrastructure can be seen in the Environmental Operating Principles (EOP) of the United States Army Corps of Engineers (USACE). The USACE endorses the WODA principles (Figure 2), which were subsequently updated in 2012. The organisational focus is a part of an agency regulation so that each organisation can communicate within USACE and codify the essential need to proactively and responsibly develop and operate its infrastructure development to the three pillars of sustainability, the importance of considering the long-term, life-cycle implications of agency actions and the essential need to openly engage the stakeholders and interests affected by its projects and programmes.

As a tool used to provide coastal protection and infrastructure supporting flood risk management, dredging clearly supports the protection of the United States Army Corps of Engineers (USACE) Environmental Operating Principles (EOP) of the USACE Environmental Operating Principles (EOP) of the USACE Environmental Operating Principles (EOP) of the United States Army Corps of Engineers (USACE). The USACE endorses the WODA principles (Figure 2), which were subsequently updated in 2012. The USACE Environmental Operating Principles (EOP) of the USACE Environmental Operating Principles (EOP) of the United States Army Corps of Engineers (USACE) recognise the relationship of the Corps mission. The USACE EOP recognise the relationship of the USACE mission and the essential need to proactively and responsibly develop and operate its infrastructure development to the three pillars of sustainability, the importance of considering the long-term, life-cycle implications of agency actions and the essential need to openly engage the stakeholders and interests affected by its projects and programmes. The sector-specific focus is a part of a goal and objective articulated within each of the six USACE EOP: (Figure 3).

With regards to sustainable dredging it states the following: "The Great Port goals related to sustainable dredging are primarily to keep the port’s natural access open, clean and safe. At the same time, the goals aim to: manage integrated dredging activities to create opportunities for improving environmental quality and at the same time creating and enhancing ecosystems; manage dredged material according to the philosophy of minimising quantity, enhancing quality and reuse with or without enhancement.}

Figure 1: The 17 Sustainable Development Goals (SDGs) are an urgent call for action by all countries – developed and developing – in global partnership.
In view of the processes, variability and extremes associated with climate change, there is renewed motivation to consider the long-term sustainability of water infrastructure.

WODA PRINCIPLES OF SUSTAINABLE DREDGING

Dredging and dredged material management are essential if we are to maintain and improve our 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 gains of environmental quality and economic prosperity can both be achieved.

WODA's objective is to achieve sustainable dredging through implementation of the following principles:

1. From the start and throughout each stage of a project, social, environmental, and economic objectives should be systematically considered and integrated.
2. Development of a project design should identify how to work with natural processes and the site-specific characteristics of ecosystems to achieve the project’s objectives, including understanding of the footprint of a dredging project.
3. Project proponents, regulatory authorities and the broad range of stakeholders should be engaged at the earliest conceptual stage in the development of dredging projects.
4. Scientifically based criteria, performance guidelines and environmental safeguards for dredging and dredged material management are essential to provide clear directions to project owners, planners and executing companies.
5. Dredging material management should be based on a holistic and systematic understanding of the ecosystem and natural processes. Beneficial use of dredged materials, such as placement of sediment to nourish shorelines or to enhance or restore wetland ecosystems/marshes and upland habitat, should be given priority.
6. Dredging can be a key solution for remediation and restoration of historically contaminated aquatic sites.
7. Analysis of monitoring and assessment information before, during and after project implementation provides a basis for effective and sustainable project management.

The application of these principles of sustainable dredging, WODA believes that dredging will contribute to sound solutions that improve our well-being and protect our aquatic environment for future generations.

Anders Jensen
Chairman WODA Board of Directors
6 June 2013
Brussels, Belgium

FIGURE 4

In the context of infrastructure development and dredging, we propose the following operational definition (in line with the definition proposed by Brundtland et al., 1987) "Sustainability is achieved in the development of infrastructure by efficiently investing the resources needed to support the desired social, economic, and environmental services generated by infrastructure for the benefit of current and future generations."

Here, we use the word infrastructure to refer to the diverse range of structures, features, and capabilities that are developed and through the use of dredging (e.g., navigation channels and waterways; ports and harbours; levees and dykes); and infrastructure-based, such as islands, beaches and dunes, wetlands, reefs and many other forms of habitat. In practical terms, the sustainability of an infrastructure project is increased by:

- Increasing the overall value of the project through the maximisation of social, environmental and economic benefits.
- Reducing costs associated with the project, where the word costs is being used in the broadest sense to include all of the monetary and non-monetary (e.g., environmental impacts) costs and resources consumed by the activity and:
- Balancing the distribution of the value and costs among the social, environmental and economic domains over time.

Some practical implications for dredging

The importance of vision and value creation

For the vast majority of the history of dredging, the nearly exclusive focus of the activity was to generate the economic benefits produced by infrastructure. The incorporation of environmental and social factors (the other two pillars of sustainability) into the decision-making and governance process is a relatively recent development, mostly concentrated within the last 50 years. During the last few decades, significant technological and operational advancements have been made that have improved the dredging process in relation to the environment. That said, one of the biggest opportunities for increasing the overall sustainability of the water infrastructure sector is for project proponents, dredging contractors and other stakeholders to invest more time and energy in up-front visioning to identify ways of creating more project value across all three of the pillars of sustainability. Such visioning facilitates the identification of generating economic benefits from infrastructure. Rather, it is more likely to reveal opportunities for increasing the economic value. By devoting more effort to identifying and developing positive social (e.g., recreational, educational and community) and environmental (e.g., ecosystem services, habitat, natural resource values, dredging and infrastructure benefits) and environmental (e.g., ecosystem services, habitat, natural resource values, dredging and infrastructure benefits) and environmental (e.g., ecosystem services, habitat, natural resource values, dredging and infrastructure benefits) and environmental (e.g., ecosystem services, habitat, natural resource values, dredging and infrastructure benefits) and environmental (e.g., ecosystem services, habitat, natural resource values, dredging and infrastructure benefits) and environmental (e.g., ecosystem services, habitat, natural resource values, dredging and infrastructure benefits) and environmental (e.g., ecosystem services, habitat, natural resource values, dredging and infrastructure benefits) and environmental (e.g., ecosystem services, habitat, natural resource values, dredging and infrastructure benefits) and environmental benefits associated with the activity and impacts were acknowledged to varying degrees. In the past, engineering was focused more on hydrodynamics than ecology. In this historical approach, the engineering design and economic costs were dominant factors and effects on nature were secondary considerations. However, important lessons have been learned. Effects on nature and impacts in the coastal zone and rivers were underestimated or partly ignored in many cases. Lack of knowledge regarding sediment processes and their role in geomorphology resulted in negative effects on engineering performance (e.g., higher than expected sedimentation in channels and reservoirs, erosion and scour around structures) and ecosystems (e.g., loss of habitat).

The ability to project long-term performance and effects was complicated by uncertainties, hard structures, separating fresh and salt water and wet and dry areas (e.g., regravels, breakwaters, dams, walls, dike etc.) were common engineering solutions, in order to manage the hydraulics. Rivers were trained and dams were built to facilitate navigation, manage high water and flooding, and generate large hydroelectricity. In many cases these solutions have disrupted sediment processes, which have given rise to long-term effects and current, ongoing engineering and ecological challenges (e.g., shrinking reservoir capacity due to sedimentation; shoreline erosion, loss of coastal landscapes and habitats, etc.). Past engineering projects have certainly delivered major economic, safety and human welfare benefits. As time has passed and the infrastructure projects have “begun to show their age”, the adverse effects associated with these projects have become more and more visible, casting at least a partial shadow over the realised benefits produced by their construction. In view of the processes, variability and extremes associated with climate change, there is renewed motivation to consider the long-term sustainability of water infrastructure.
Nature can be a stubborn and uncooperative collaborator when she is not adequately considered and consulted during the process of design. Winds, waves, and tides deliver force, water, and sediment against the products of our design with endless energy which prompts us to spend our effort, time, and money reacting to nature’s onslaught. We have learned the lesson countless times that taming nature can be an expensive proposition. Integrating the concept of sustainability into our infrastructure projects will help us identify opportunities to cooperate and collaborate with natural processes, rather than seek to control and counter them. Working in this way, we will adapt the port to the coastal ecosystem, the ship to the river, the local community to cycles of low and high water.

PIANC’s WwN philosophy incorporates ecosystem services and the interplay between physical processes, coastal conditions, and the surrounding ecosystem. The opportunity and need to more directly incorporate nature into our infrastructure development process can be viewed at two different levels: the scale of the system and the project. Our infrastructure projects are part of a system (e.g., an ecosystem), and the projects will both affect and be affected by the processes operating within that system. The more we are able to take these processes into account over the full life cycle of the project, the more sustainable the project can be. Therefore, we use construction and operational methods, including dredging, that intentionally incorporate natural processes and materials, the more sustainable the project.

The new nature-based design philosophies intentionally incorporate natural processes and materials, the more sustainable the project can be. The new nature-based design philosophies draw attention to the opportunity and need to enhance natural capital, over the short and long term. As the concept, techniques, and tools supporting ecosystem services are implemented as a part of infrastructure projects, we will be able to communicate about sustainability more effectively within our project teams and with the broader community of stakeholders interested in our projects.

Taking the long view

Water infrastructure projects, due to the amount of investment they require, are long-term propositions. While the state of scientific and engineering practice continues to advance, there will continue to be uncertainties regarding the behaviour of natural and engineered systems over the long term. Nevertheless, pursuit of sustainable infrastructure requires taking a broad and long-term view of a project’s life cycle. Taking this broad system view is necessary in order to determine whether the project can be expected to be sustainable over the long term, i.e., that the total value of the project over the three pillars of sustainability is judged to be sufficient in relation to the investment required to create that value. Performing such sustainability analyses could mean that some proposed projects will not be built, or that existing projects will be decommissioned and abandoned in favour of more sustainable projects. Some ports or waterways, for example, which cannot be efficiently sustained over time due to the effects of physical processes, coastal conditions, sedimentation, environmental impacts, etc., would receive reduced levels of investment in favour of ports and waterways situated in a more sustainable condition. When investment decisions are being made on the basis of the overall sustainability of the project, then we will know that the concept of sustainability has been successfully incorporated into the governance of infrastructure systems.

Three guiding principles of dredging for sustainability

Principle 1

Comprehensive consideration and analysis of the social, environmental and economic costs and benefits of a project is used to guide the development of sustainable infrastructure – Dredging is but one component of an infrastructure project, and any one piece of infrastructure functions as a part of a larger network of infrastructure as well as the surrounding ecosystem. Therefore, understanding the full set of costs and benefits of a project requires taking a system-scale view of infrastructure and the functions and services that infrastructure provides.

The costs (in the broad sense) of a project include all the resources, material and negative impacts associated with executing the project and/or producing and operating the system over time. Likewise, the benefits generated would include all the values, services, and positive outputs generated by the project and/or system over time. Defined in this way, costs and benefits will include both monetizable and non-monetizable quantities.

While traditional economic analysis can be used to develop an understanding of the more readily monetised costs and benefits, for other values within the social or environmental domain, different methods should be used to develop credible evidence about costs and benefits. Finally, one of the key opportunities for increasing the overall sustainability of water infrastructure is to seek opportunities to increase the total value of projects by identifying and developing benefits across all three of the pillars of sustainability.

Principle 2

Commitments to process improvement and innovation are used to conserve resources, maximise efficiency, increase productivity, extend the useful lifespan of assets and infrastructure – Innovations in technology, engineering, and operational practice provide opportunities to reduce fuel and energy requirements related to dredging and the operation of infrastructure. These same innovations can provide the means to reduce emissions (including greenhouse gases and other constituents) and conserve water and other resources.

By reducing the consumptive use of resources associated with dredging and infrastructure, the sustainability of projects is enhanced. In addition, using better technologies or improvements in operational practice in order to extend the useful lifespan and functional performance of an asset (e.g., a navigation...
Sustainability

Stakeholder engagement can produce opportunities to increase the overall value of a project.

Principle 3
Comprehensive stakeholder engagement and partnering are used to enhance project value – stakeholder engagement plays an important, even critical role in the governance of infrastructure projects. The level of investment and sophistication employed in the engagement process directly contributes to the degree of success achieved through the engagement. Early investment in stakeholder engagement should be used to inform the conception and design of a project.

Such engagement will provide important information about the values of interest to stakeholders and how those values can be generated by the project, in respect to the three pillars of sustainability. Furthermore, early engagement can help identify project partners who are interested in making contributions or investments toward particular values the project could produce (e.g., partnering with an NGO to perform ecosystem restoration as a part of the project). Pursued in this manner, stakeholder engagement can produce opportunities to increase the overall value of a project and to diversify the benefits produced across all three pillars of sustainability. This approach to stakeholder engagement is different from the historical use, which has been more focused on reducing conflicts over project costs, which in the context of this discussion includes the negative impacts associated with a project (whether social, environmental or economic).

For example, stakeholder engagement has been used as a means to proactively engage environmental interests concerned about port infrastructure, flood protection and dredging in order to minimise the risk of project delays and litigation. The information and knowledge that is produced through active and robust stakeholder engagement provides a basis for increasing the overall sustainability of the project.

When the information leads to actions that increase overall project value, sustainability is enhanced. When these actions lead to reducing total project costs (including all monetary costs and non-monetary impacts), while producing the same level of benefit, the result is a more sustainable project and system. Likewise, actions that increase project value (in terms of social, environmental and economic benefits) for the same (or lower) costs result in a more sustainable project.

Traditionally, dredging projects have been focused on a narrow set of functions and outcomes (e.g., land reclamation, port basins and channels, coastal development, flood protection, pipeline trenches). A design was made and the effects on the environment and other functions were assessed, where possible mitigated and, if needed, compensated. Stakeholders entered the project process late, during the permitting stage, where they were informed about the design, with limited opportunity to influence the design. This approach has frequently led to conflicts, project delays and frustration for the developer as well as stakeholders. Increasingly now, more and more projects are developed in a manner that is more inclusive of stakeholder perspectives.

At first, the focus on stakeholders was driven by aims to reduce the risk of project delays and lengthy procedural conflicts, but more recently this approach has evolved to include the mind-set of co-creation. In this mode of stakeholder engagement, values are created not only with regard to the primary motivation for the project (e.g., a particular set of economic outputs, but also to address stakeholder interests and values. This approach leads to value-added design and innovation, which will produce projects that are beneficial in regard to people, planet and profit (Elkington, 1997).

The practical contribution of dredging companies

Environmental impacts can have consequences that affect other marine users. The livelihood of local fishing communities may be affected by decreased fish stocks due to prolonged turbidity or deterioration of their fishing grounds. Coastal communities may be deprived from inhabitable land, cultural sites and natural wealth due to erosion or salinisation. Addressing these impacts is a requirement for project permits in many countries. Below are examples of dealing with these impacts.

Quantity of sand extracted

Between 1980 and 2023, dredged sediments were placed onto intertidal habitat to achieve both habitat restoration and coastal protection objectives at Horse Island on the eastern coast of England. Sand and silt from capital and maintenance dredging at the nearby ports of Harwich and Felixstowe was used to create a mix of habitats including mudflats, marsh and a shingle spit to be used by nesting birds. The project has demonstrated that the environmental benefits can persist over decades. More case studies were collected by the CEDA Working Group on the Beneficial Use of Sediments.

Nature-inspired design

In Atafalaya River (USA), dredged sediment is placed in the middle of the river. Just upstream a natural shoal, and contributes to the formation of an island. In 15 years, a 35 hectares natural shoal, and contributes to the formation of an island. In 15 years, a 35 hectares island was created that hosts a rich wildlife habitat with access for recreation and a better aligned navigation channel. Also prohibiting sand extraction in vulnerable habitats, has an inevitable impact on the livelihood of local communities. Even if these activities are illegal, they provide the means for survival of many of the local population.

Any change in regulation to protect the environment should therefore be accompanied by measures to provide local employment.
Construction of permeable dams by local contractor under supervision of the BwN team. On-the-job training is an important part of the BwN approach.

SUSTAINABILITY

Improved by different incentives:

• economy in the form of:
  - it contributes significantly to the local income tax on salaries);
  - tax revenues (import duties, royalties, rental); and
  - local expenses (office, housing, transport, catering);
• local workforce (salaries for local workforce; training of local workforce when gaps are identified between required and available skills; selection and training of local suppliers based on labour and human rights, biodiversity, emissions, waste management and business ethics; advertisement of supply opportunities in local media; unbinding of contracts into units that are tailored to the local market; and engagement in local community projects. Examples of these contributions are: Stakeholder engagement Port Phillip channel deepening project, Melbourne, that involved the removal of 23 min$^3$ of sediment at which 3 min$^3$ was contaminated, was met with strong engagement in local community projects. Examples of these contributions are:
  - onboarding and awareness training of local workforce with focus on health and safety, environmental care, diversity, equality and respect.
  - training of local workforce when gaps are identified between required and available skills.
  - selection and training of local suppliers based on labour and human rights, biodiversity, emissions, waste management and business ethics.
  - advertisement of supply opportunities in local media.
  - unbinding of contracts into units that are tailored to the local market; and engagement in local community projects.
Examples of these contributions are Stakeholder engagement Port Phillip channel deepening project, Melbourne, that involved the removal of 23 min$^3$ of sediment at which 3 min$^3$ was contaminated, was met with strong and continuous opposition. The client and contractor formed an alliance contract to share responsibilities and risks, and also the communication effort, leading to successful completion of the project. Stakeholder acceptance of the project was a result of the accurate and transparent public communications which included public consultations, public hearings, a dedicated website, a 24-hour toll-free telephone number, weekly press conferences, media releases, mailing lists, signage around the bay and notices to mariners. A vessel tracking system and online video data was used to prove that the operations proceeded in accordance with the environmental management plan.

Rebuilding villages after a flood
Around 70,000 people suffered from coastal flooding and erosion hazards in Demak, Indonesia and 14 villages have been swallowed by the sea. Many people have experienced a major loss in income, reaching up to 80–80% in some villages. Also, the agric–aquaculture sectors which are key economic engines in Indonesia have suffered multi-billion dollar losses. A project was launched to support the villagers through Building with Nature. The strategy for the area was to restore the sediment balance and through that, the mangrove habitat by constructing permeable bruteless dams. In the near future, these dams will be overgrown by the mangrove forest. The results of the current BwN activities in the Demak district are encouraging. Sediments are indeed being trapped, restoring the coastal sediment balance and the mangrove habitat locally. The first mangrove seedlings have naturally established.

Sustainability for dredging practice:

From philosophy to action
Dredging is connected to several SDGs, such as those related to navigation, coastal protection, and flood risk management. The dredging industry is increasingly recognising the need to incorporate these goals into the infrastructure development process and communicate how projects align with the SDGs.

Climate change continues, energy transition is a fact, the growing world population calls for more sustainable cities and the need for food will increase. The demand for dredging will only increase, therefore continuing with responsible dredging projects is key to sustainable development. The industry will continue to advocate for sustainability and promote dredging for sustainable infrastructure development along with conducting more research on the topic to better projects that truly contributes the UN Sustainable Development Goals.

References


