

Dredging for **SUSTAINABLE INFRASTRUCTURE**

Dredging for **SUSTAINABLE INFRASTRUCTURE**

Edited by **CEDA / IADC**



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CEDA / IADC



Central Dredging Association



INTERNATIONAL
ASSOCIATION OF
DREDGING
COMPANIES

Leading principle for writing:

*Our ambition is to achieve dredging projects
that fulfil their primary functional requirement,
while adding value to the (natural and socio-economic) system
based on a thorough understanding of the natural system and
the proactive engagement of stakeholders throughout.*

This book provides guidance to make this possible.

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Dredging for Sustainable Infrastructure

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1 Preface

1.1 The need for this book and scope

This book *Dredging for Sustainable Infrastructure* presents state-of-the-art guidance ‘to achieve dredging projects that fulfil their primary functional requirement, while adding value to the (natural and socio-economic) system based on a thorough understanding of the natural system and proactive engagement of stakeholders throughout’.

Implementation of water infrastructure involving dredging, such as port development, river deepening, canalisation, flood defence measures and reclamations, has traditionally been an essential activity in civilisation’s development and prosperity, and in fact still is. By its very nature, however, the act of dredging, with the excavation of material from the sea, river or lake bed and its relocation elsewhere, is an environmental impact. Societal response has been to evaluate any positive or negative impacts on the environment, both their short and long-term effects. In that way, international frameworks of legislation relating to dredging and the management of dredged material have been developed over the course of many decades. It has also been recognised that, given the right circumstances, dredging can be a useful tool for remedying historic environmental interference, such as contaminated sediments resulting from – nowadays unacceptable – industrial discharges. Yet, more recent approaches look beyond the scope of isolated dredging activities and embrace a wider context, by considering water infrastructure development projects as an opportunity to also add value to the (natural and socio-economic) system, in order to achieve more sustainable projects (Figure 1.1).

In the past 10 - 15 years, the international dredging community has really embraced this kind of thinking and the approach to dredging has in many ways been transformed. From mainly dealing with negative impacts, often at the end of the project design and the start of the construction phase, towards a much more proactive approach, where water infrastructure projects are being considered as part of the natural and socio-economic system in which they are situated, and stakeholders are being engaged much earlier in the project development process to facilitate the search for opportunities to create added value.

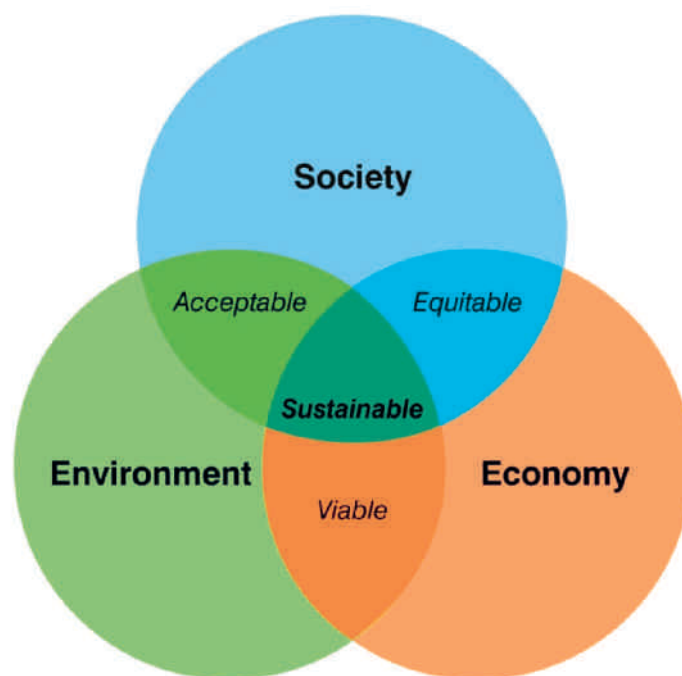


Figure 1.1: The three pillars of sustainability.

This change in attitude has a huge influence on the initiation, planning and design, execution and maintenance of water infrastructure projects. Comprehensive guidance on how to bring this into practice has to date been lacking. With this book, a wide range of professionals have attempted to collect and integrate their experiences and best practices, to deliver this state-of-the-art guidance on *Dredging for Sustainable Infrastructure*. The book aims to provide answers to the following questions:

- What is the role of dredging in the global drive for more sustainable development?
- How can we design more sustainable infrastructure that aligns with the natural and socio-economic system?
- How can we assess and stimulate the potential positive effects of infrastructure development and compare these with the potential negative effects?
- What equipment and which sediment management options do we have? and
- What tools and information do we have to make choices and control the project?

1.2 Target audience

Given the scope of the book, outlined in the previous section, there is a broad target audience. On the one hand, it aims to reach project financiers, project developers, regulators, policy makers etc. These are the people that can influence the demand side for more sustainable projects. This book aims to inspire them to take a more proactive view towards project sustainability and show how they can influence project development in this way, particularly in the earlier stages of project development. On the other hand, this book aims to reach designers, architects, engineers, biologists, contractors, etc. These are the people that can influence the supply side for more sustainable projects. If the dredging sector, as a whole, is to contribute to the overall Sustainable Development Goals (SDGs), change is needed at both the supply and the demand side of water infrastructure developments.

In addition, the book is also meant to educate and inspire young generations of engineers and ecologists entering the field of sustainable water infrastructure development. To that end, this book is warmly recommended for use as lecture material on university courses and professional education programmes.

1.3 Book structure

Given the wide scope (Section 1.1) and the broad target audience (Section 1.2) of this book, the editorial board decided to structure the guidance presented, from a broad and more conceptual approach in Chapters 2, 3 and 4, to a specific and more detailed one in Chapters 5 to 8. Figure 1.2 illustrates the book's basic structure and shows how the different chapters are bound together. To ensure that, at all times, the reader is aware of the position of each chapter in the overall book structure, we repeat Figure 1.2 in every chapter, highlighting the chapter itself in green.

We believe that readers who are involved with the demand side of sustainable water infrastructure may be most interested to focus on Chapters 2, 3 and 4. These provide more conceptual guidance on how to set sustainable infrastructure developments into motion and organise the process. Readers involved with the supply side of sustainable solutions will also be interested in the more detailed Chapters 5 to 8, which provide more quantitative guidance to support design and engineering of water infrastructure projects. Each chapter has been written to be readable on its own, and ample cross-references have been added to refer readers to other chapters and within the chapters to the literature where relevant.

Overall, the book shows how water infrastructure projects involving dredging can contribute significantly to sustainability. Chapter 2 describes the principles of sustainability and their implications for dredging projects. Most important is the recommendation to create added value for society, based on a thorough understanding of the natural system (hydrology, ecology and morphology), the potential of nature-based solutions and the proactive engagement of stakeholders. These essential requirements, for any project, are repeated and further detailed throughout the book.

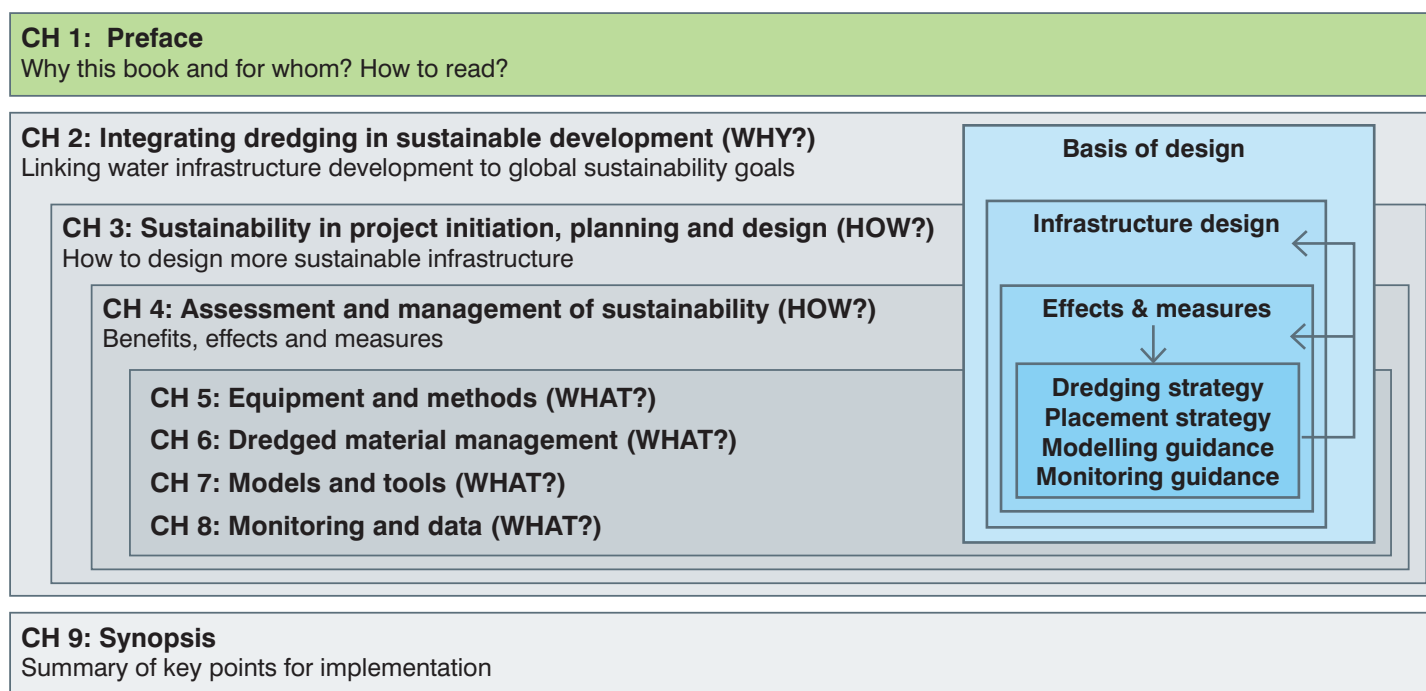


Figure 1.2: Basic structure of the book.

Very influential choices are made in the Initiation and Planning and Design phase of a project. Chapter 3 explains how incorporating additional design objectives into the conceptual and detailed design phases of a project will help you to promote added value that can be delivered by your design.

The philosophy, to use the momentum of water infrastructure development to create added value, and the notion, that many of the influential choices are made in the Initiation and Planning and Design phases of a project, inevitably lead to the realisation that, both negative and positive effects of projects need to be assessed and managed, for a project to successfully make it through the necessary approval procedures. Chapter 4 discusses how the standard Environmental Impact Assessment (EIA) process can be used to assess and manage project impacts.

Chapters 5 to 8 provide essential information for detailing the designs. Chapter 5 provides information on dredging processes and assists in the choice of the different dredging machines available by describing the capabilities and consequences. Chapter 6 describes the available options for dredged material management that can be considered after the dredging is completed. Options for beneficial use are described in detail, with the option of disposal included. Important is the additional attention for the assessment and management of positive effects and added value. An important thing is to regard dredged material as a valuable resource that can be used proactively, rather than a waste material that has to be disposed of. Chapter 7 describes models and tools that are available to inform the design and construction of sustainable infrastructure and to help identify win-win solutions. To feed the model predictions beforehand and to verify them during and after construction, monitoring and data collection is important. Chapter 8 provides information on how to design your monitoring programme, it identifies the variables which are most frequently of interest and it sets out the pros and cons of the instruments that are available to measure and record this data. Chapter 9 summarises the key aspects of this book in a final synopsis.

The book contains a lot of information on philosophies, methods and approaches. To make the information more concrete for the reader, three types of boxes have been included throughout the book:

- *Background boxes* – Providing more detailed information about a topic addressed in the general text;
- *Guidance boxes* – Providing guidance on how to perform a certain activity addressed in the general text; and
- *Example boxes* – Describing a practical example or project where a certain aspect, addressed in the general text, has been dealt with.

To make it easier for the reader to recognise the different boxes, they have been colour-coded: Background boxes are yellow, Guidance boxes are blue and Example boxes are green.

Finally, it is inevitable that terminology is used in this book. To make it easier for the readers to understand what is meant exactly, by a number of regularly used terms, a ‘Glossary’ is included at the end of the book.

1.4 About the development of the book

Finally, it is important to realise that the book that lies before you is the result of a long process involving a broad team of experts from academic institutes, dredging contractors, consultants and project owners. The book’s editorial board has taken the responsibility to integrate the inputs from all the participants into one coherent book. Both the initial and intermediate versions of the content of the book have been discussed with a much larger group of experts, originating from Central Dredging Association (CEDA) and International Association of Dredging Companies (IADC) partner institutes. Two well attended international workshops were organised to discuss the content of this guideline. One at the start of the process in Hamburg, Germany on the 10th of October 2014 and one in Brussels, Belgium on the 2nd and 3rd of February 2017. The outcomes of these workshops have contributed importantly to the scope and content of the present book. Furthermore, many of the Background, Guidance and Example boxes have been provided by this larger network of experts. As a result, we can truly state that the book is a product of the sector as a whole with a long list of contributors from a wide range of organisations.

We feel that, for the first time, this book integrates all visions and viewpoints that have been out there into one coherent vision on *Dredging for Sustainable Infrastructure*. We believe that, as humanity, we face the important challenge to match our desire for economic development with the long-term need for sustainability. This in turn requires a shift in thinking, from minimising negative effects mainly, towards using the momentum of water infrastructure projects to create added value to the (natural and socio-economic) system. We hope we can conclude, in a few years from now, that this book has made a crucial contribution to achieve the paradigm shift in thinking that is needed for a sustainable future.

2 Integrating dredging in sustainable development

2.1 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 last 50 years, 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 and this book is intended to both reflect and support that change toward a focus on sustainability. This chapter introduces the concept of sustainability in relation to dredging projects. It describes the approaches and practices that are key to using dredging and dredged material to create more sustainable solutions and infrastructure – a modern way of thinking about dredging. Figure 2.1 highlights the position of Chapter 2 in the overall context of the book.

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 that such regulations have helped to reduce negative impacts on the environment, in general. However, it is also true that the amount of environmental benefit produced by these regulations has not been

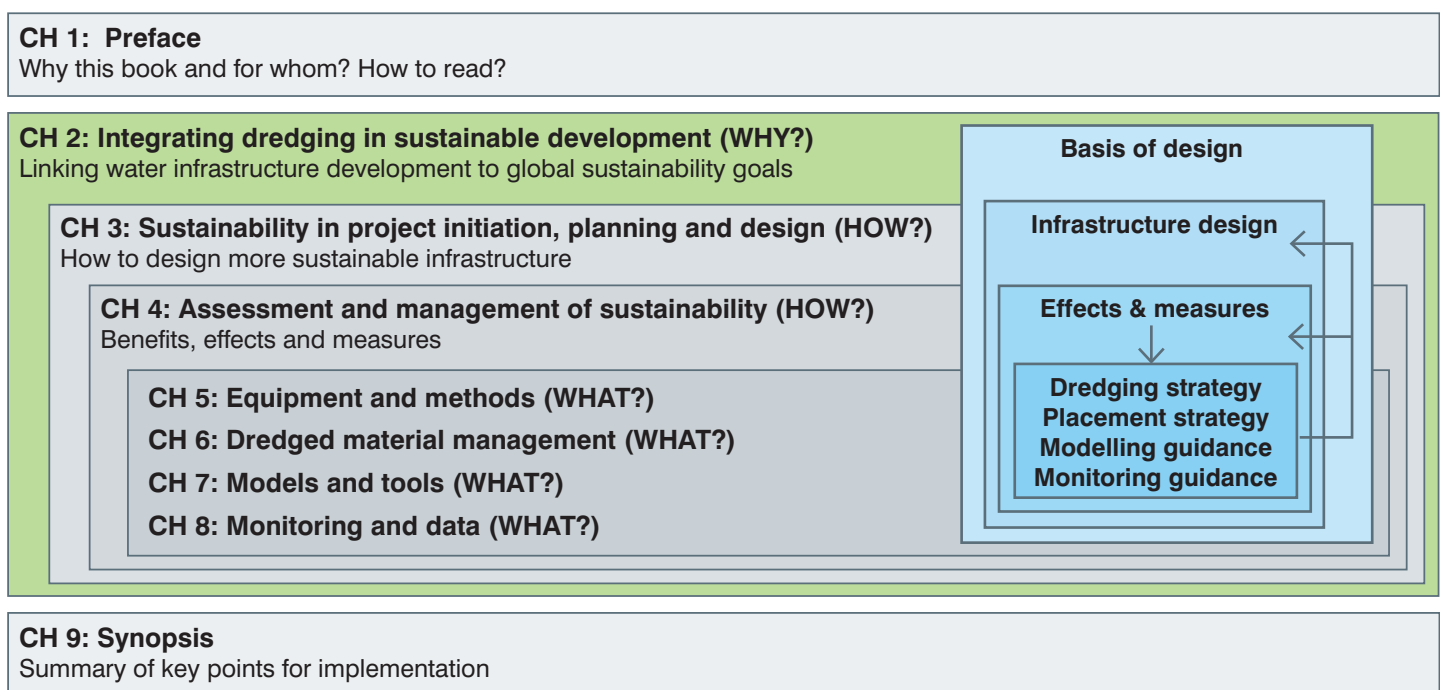


Figure 2.1: Position of Chapter 2 in the overall context of the book.

systematically quantified, nor have the environmental, social and economic costs of such regulation been fully assessed (e.g. related to trade-offs and transferring impacts within the system). Today, a paradigm shift is being embraced – a move toward a holistic approach for integrating values for people, planet and profit.

2.2 The growing focus on sustainability

The international focus – An increasing amount of attention is being given to the concept of sustainability as an approach to informing social, environmental and economic development. In 2015, the United Nations (2015) published its SDGs, as a part of ‘The 2030 Agenda for Sustainable Development’ (see Figure 2.2 and Background box 2.1). These 17 SDGs encompass a very broad range of interests, values, and objectives.



Figure 2.2: United Nations’ Sustainable Development Goals (SDGs) (United Nations, 2015).

Background box 2.1: United Nations’ Sustainable Development Goals.

Sustainable Development Goals as published by United Nations (2015):

Goal 01 End poverty in all its forms everywhere.

Goal 02 End hunger, achieve food security and improved nutrition and promote sustainable agriculture.

Goal 03 Ensure healthy lives and promote well-being for all at all ages.

Goal 04 Ensure inclusive and quality education for all and promote lifelong learning.

Goal 05 Achieve gender equality and empower all women and girls.

Goal 06 Ensure availability and sustainable management of water and sanitation for all.

Goal 07 Ensure access to affordable, reliable, sustainable and modern energy for all.

Goal 08 Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.

Background box 2.1 – continued on next page

Background box 2.1 – continued from previous page

Goal 09 Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.

Goal 10 Reduce inequality within and among countries.

Goal 11 Make cities and human settlements inclusive, safe, resilient and sustainable.

Goal 12 Ensure sustainable consumption and production patterns.

Goal 13 Take urgent action to combat climate change and its impacts.

Goal 14 Conserve and sustainably use the oceans, seas, and marine resources for sustainable development.

Goal 15 Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and biodiversity loss.

Goal 16 Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.

Goal 17 Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development.

As a means for developing water resources infrastructure, the relationship of dredging to each of the 17 SDGs varies. For example, the use of dredging to construct efficient and productive navigation infrastructure is directly connected to SDGs 2, 6, 7, 8, 9, 10, 11, 14, and 15. As a tool used to provide coastal protection and infrastructure supporting flood risk management, dredging clearly supports SDGs 1, 3, 6, 9, 11, and 13, among others. In the future, one of the opportunities that should be addressed by the dredging and water infrastructure community is to incorporate these goals into the infrastructure development process, while effectively communicating how such projects support the SDGs.

The organisational focus – 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, dredges approximately 250 million m³ of sediment annually (including permits for dredging issued through its regulatory programme). This level of dredging supports a network of nearly 40,000 km of navigation channel and the associated ports, in addition to flood risk management and ecosystem restoration projects. In 2002, the USACE developed and published its EOP, which were subsequently updated in 2012 (Background box 2.2).

Background box 2.2: USACE Environmental Operating Principles.

- Foster sustainability as a way of life throughout the organisation.
- Proactively consider environmental consequences of all Corps activities and act accordingly.
- Create mutually supporting economic and environmentally sustainable solutions.
- Continue to meet our corporate responsibility and accountability under the law for activities undertaken by the Corps, which may impact human and natural environments.
- Consider the environment in employing a risk management and systems approach throughout the life-cycles of projects and programmes.
- Leverage scientific, economic and social knowledge to understand the environmental context and effects of Corps actions in a collaborative manner.
- Employ an open, transparent process that respects views of individuals and groups interested in Corps activities.



World Organisation of Dredging Associations

**CENTRAL DREDGING ASSOCIATION
EASTERN DREDGING ASSOCIATION
WESTERN DREDGING ASSOCIATION**

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 goals 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 dredging 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 carbon 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. Active collaboration in the development of projects is the key to achieving maximum social, environmental, and economic benefits.
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. Dredged material management should be based upon 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 at 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.

Through 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 2.3: WODA principles

These principles were developed and disseminated by USACE as a means of advancing its stewardship of air, water, and land resources while protecting and improving the environment. These principles have been communicated within USACE and codified as a part of an agency regulation so that each of the more than 30,000 employees of the agency ‘understand his or her responsibility to proactively implement the EOP as a key to the Corps mission.’ (Bostick, 2012). The USACE EOP recognise the relationship of 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 – In 2013, the dredging sector itself, through the actions of the World Organization of Dredging Associations (WODA) (which includes the CEDA, the Eastern Dredging Association (EADA), and the Western Dredging Association (WEDA)), published its principles of sustainable dredging (see Figure 2.3).

The WODA principles reflect the importance of using dredging to create value across the three pillars of sustainability, considering the system-view of projects, including the ecosystem and natural processes operating within the system, and the role of engaging stakeholders (including project proponents, regulators, and the broader array of interests relevant to a project). Publication of the WODA principles has sparked a range of discussions and actions within the dredging sector in efforts to seek a balance between the economic development that is supported through dredging and environmental considerations and regulation.

Also, the recently published technical report ‘Sustainable Ports: A Guide for Port Authorities’ (PIANC, 2014), from the port sector illustrates this shift towards an integrated and sustainable approach. This guide is a joint report of The World Association for Waterborne Transport Infrastructure (PIANC) and International Association of Ports and Harbors (IAPH). It defines a sustainable port as ‘... one in which the port authority together with port users, proactively and responsibly develops and operates, based on an economic green growth strategy, on the Working with Nature (WwN) philosophy and on stakeholder participation, starting from a long-term vision on the area in which it is located and from its privileged position within the logistic chain, thus assuring development that anticipates the needs of future generations, for their own benefit and the prosperity of the region that it serves.’

With regards to sustainable dredging it states the following aims:

The Green Port goals related to sustainable dredging are primarily to keep the port’s nautical access open, clean and safe. At the same time, the goals aim to:

1. Manage integrated dredging activities to create opportunities for improving environmental quality and at the same time creating or enhancing ecosystems;
2. Manage dredged material according to the philosophy of minimising quantity, enhance quality, re-use with or without pre-treatment and long-term beneficial placement; and
3. Understand the local (and surrounding) environment and search for opportunities to use the natural processes including hydraulics, hydrology, geophysical, vegetation, benthos, etc. to maximise the efficiency of the dredging in both short and long-term.

2.3 Applying the concept of sustainability to water infrastructure development

The concept of sustainable development is based on the premise that the design for an action (in this case a development project that involves the use of dredging) will be informed by a full consideration of the values and costs of the proposed action across the three pillars of sustainability: society, environment and economy (see Figure 2.4).

The concept of sustainable development recognises the need to consider the full range of benefits and impacts related to human actions and the distribution of these benefits and costs across the social, environmental and economic domains. The relationships among these value domains are reflected by the goal to take actions (e.g. develop projects) that will balance the distribution of benefits and costs so as to produce socially equitable, environmentally acceptable, and economically viable outcomes. This balance is achieved through active and

consistent engagement with the stakeholders who will be affected by the proposed project, including government authorities, private sector interests, local/regional/national members of the public, and the special interest groups and perspectives that are relevant to the project.

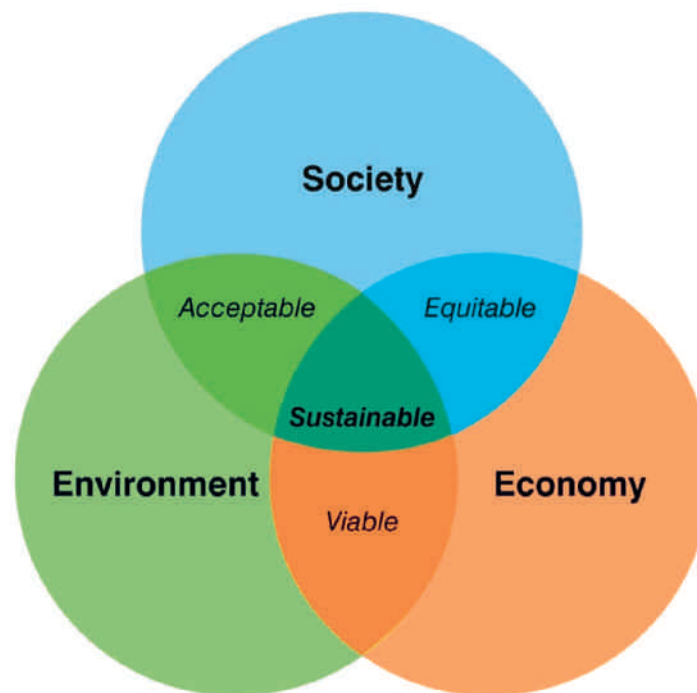


Figure 2.4: The three pillars of sustainability.

In order to aid our discussion of sustainability 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, environmental, and economic 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 through the use of dredging (e.g. navigation channels and waterways, ports and harbours, levees and dikes), and nature-based infrastructure 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:

1. Increasing the overall value of the project through the range of services it provides;
2. 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
3. Balancing the distribution of the value and costs among the social, environmental and economic domains over time.

2.4 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 will not diminish the importance of generating economic benefits from infrastructure, rather, it is more likely to reveal opportunities for creating additional economic value. By devoting more effort to identifying and developing positive social (e.g. recreational, educational, community resilience) and environmental (e.g. ecosystem services, habitat, natural resources) values, dredging and infrastructure projects will be able to avoid unnecessary conflicts with stakeholders while simultaneously developing a larger number of project proponents, advocates and partners.

Adapting projects to nature, rather than the reverse – Dredging is used to change or manipulate the physical structure of the environment to produce a feature or a function that nature didn't and wouldn't create on its own. For centuries, ports and waterway networks have been produced by creating a design for these systems and then imposing that design on the natural environment, with mixed results. Traditionally, designs were evaluated for their engineering performance and impacts on nature. Uncertainties related to performance and impacts were acknowledged to varying degrees. In the past, engineering was focused more on hydrology 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 the relation of these processes to local and regional 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. revetments, breakwaters, dams, walls, dikes 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 energy. 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 this approach to navigation infrastructure development and the Building with Nature (BwN) programme in the Netherlands (De Vriend and Van Koningsveld, 2012, www.ecoshape.org) and the Engineering with Nature (EwN)[®] initiative in the United States (Bridges et al., 2014, www.engineeringwithnature.org) are implementing these practices across a wide range of water infrastructure projects. 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 the project is part of and the means of constructing and operating 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. The more we use construction and operational methods, including dredging, that 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 concepts,

techniques and tools supporting ecosystem services are implemented as a part of infrastructure practice, 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.

2.5 Three guiding principles of dredging for sustainability

Number 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 monetisable and non-monetisable 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 domains 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.

Number 2. Commitments to process improvement and innovation are used to conserve resources, maximise efficiency, increase productivity, and 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 channel, an offshore island that supports coastal resilience), in a manner that lowers overall life-cycle costs, will increase the sustainability of infrastructure.

Number 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 to 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).

2.6 Sustainability for dredging practice: from philosophy to action

A dredge is a tool, an increasingly important tool for creating and sustaining value produced by water infrastructure. This chapter has introduced the now growing interest in sustainability and detailed how the ecosystem is leading. It outlined the philosophies and concepts of sustainability and their application to water infrastructure projects focusing on practical issues for dredging. In the following chapters of this book, the concept of sustainability is translated into practical approaches for designing, evaluating, operating, and monitoring water infrastructure projects involving dredging.