Chapter 1
Nature-Based Solutions

Abstract This chapter proposes a definition of Nature Based Solutions (NBS), reviews NBS in terms of the circular economy and proposes a methodology for implementing NBS projects. The circular economy of water (CEW) prioritises the concepts of resource recovery and resilience within water resource management. The CEW operating within planetary boundaries, is waste free and resilient and is by design restorative of ecosystems. NBS can form an integral component of this new approach. This publication defines NBS as both natural and constructed systems which utilise and reinforce, physical, chemical and microbiological treatment processes. These processes form the scientific and engineering principles for water/wastewater treatment and hydraulic infrastructure. NBS may be low cost, minimise energy for operation and maintenance, generate low environmental impacts and provide added value through the benefits that accrue to humanity (ecosystem services). These benefits include biodiversity, mitigation of the effects of climate change, ecosystem restoration, amenity value and resilience. This chapter defines and characterises nature based solutions in terms of water source, contaminants, removal mechanisms and resource recovery potential. It will also propose an NBS Methodology.

Keywords Nature Based Solutions · Circular Economy of Water · Ecosystem Services

1.1 Introduction

The methodology of how human society has interacted with the environment has evolved over the last 40 years. Following on from Rachel Carson's work in the 1960s society was concerned with minimising environmental damage (Carson 1962). This had as an underlying principle, the prevention or mitigation of damage to the environment, stated as "do the least possible harm". This gradually led to the adaption, in the 1990s, of the principle of *"sustainability"* and the need to preserve resources and to hand them on intact to future generations (Bruntland Commission 1987). This approach was enshrined within subsequent Environmental Impact Assessment (EIA) procedures (Directive 2014/52/EU). This is the process by which the anticipated effects on the environment of a proposed development or project are measured. If the likely effects are unacceptable, design measures or other relevant mitigation measures can be taken to reduce or avoid those effects.

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Fig. 1.1 Characteristics of the circular economy of water (CEW)

The current system of water supply and management is based on a linear approach, focusing on commodity sourcing, treating, using and disposing. Currently, water demand is typically met by importing large volumes of water across long distances from neighbouring catchments. Simultaneously, rainwater is discharged unused via expensive storm water drainage systems. Similarly, wastewater treatment systems involve collection, treatment and discharge. This contrasts with the objectives of the circular economy as described on the next section.

1.2 The Circular Economy of Water (CEW)

The circular economy has introduced, in the last few years, the concepts of resource recovery and resilience. The circular economy is by design restorative of ecosystems. In the linear approach to water, products are disposed of after use. The circular economy, operating within planetary boundaries, is waste free and resilient. The circular economy of water (CEW) sees water and its contents, as a resource (Fig. 1.1).

1.3 Nature-Based Solutions

The term 'nature-based solutions' (NBS) has been adopted to inform policy and discussion on biodiversity and conservation, climate change adaptation, and the sustainable use of natural resources (Potschin et al. 2015). The term NBS appears to have first been used in the early 2000s, in the context of solutions to agricultural problems. NBS has also been used in discussions on land-use management and planning and water resource management, i.e. the use of wetlands for wastewater treatment and the value of harnessing ecosystem services from wetlands as a form of nature-based solution for watershed management (Guo et al. 2000; Kayser and Kunst 2002; Brink et al. 2012). The NBS concept was also used to describe industrial design and biomimicry. The term "biomimicry" has also been used for green infrastructure and other soft engineering approaches, which have been used as nature-based solutions to urban water management problems. Here the term refers to learning from nature, rather than finding strategies based on nature that would contribute to its conservation (Grant 2012).

More recently NBS have been selected as a priority area for the European Commission (EC) Horizon 2020 Research Programme, though more than one definition of NBS can be found in related literature. The EC Expert Group on NBS suggests that the NBS concept "*builds on and supports other closely related concepts, such as the ecosystem approach, ecosystem services, ecosystem-based adaptation/mitigation, and green and blue infrastructure*" (EC 2015). Another report for Horizon 2020's Societal Challenge 5 (EC 2014) proposes that NBS and the utilisation of biomimicry be used to position the EU as a world leader in the development of industrial and technological solutions *"inspired by, using, copying from or assisted by nature*". This idea is also included in the aforementioned EC Expert Group Report on NBS definition as follows: "*NBS therefore involve the innovative application of knowledge about nature, inspired and supported by nature"* (EC 2015). It is further stated in the report that industrial challenges and environmental problems caused by human activities can be resolved "*by looking to nature for design and process knowledge*", but these aspects are not strongly emphasised. The EU BiodivERsA (www.biodiversa.org) also view NBS as being a way to "*conserve and use biodiversity in a sustainable manner*" (Balian 2014). There are, however, some differences in emphasis on the components and aims of NBS.

These different perspectives are largely compatible. However, what is not clear, is how NBS differs from other concepts associated with improving human well-being, i.e. by managing ecosystem services and natural capital in appropriate ways. Yet, a clear link between NBS and these concepts is needed to ensure consistency and avoid redundancy or confusion.

When NBS are considered from a water management viewpoint, and with the focus on natural technologies and systems that replicate scientific and engineering principles, the following definition can be proposed. This links ecosystem services, natural capital and NBS.

The authors propose the following definition:

Nature-based solutions are both natural and constructed systems, which utilise and reinforce, physical, chemical and microbiological treatment processes.These processes form the scientific and engineering principles for water/wastewater treatment and hydraulic infrastructure. Nature based solutions may be low cost, require low energy for operation and maintenance, generate low environmental impacts and provide added value through the benefits that accrue to humanity (ecosystem services). These benefits include biodiversity, mitigation of the effects of climate change, ecosystem restoration, amenity value and resilience.

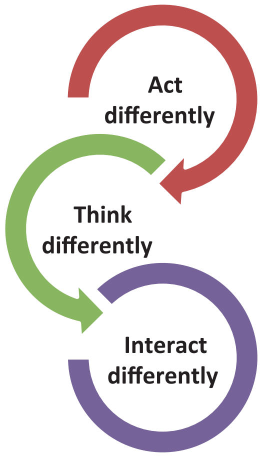

Fig. 1.2 New approach required to implement a NBS

1.4 Are There Nature-Based Solutions?

Nature – can be considered as relating to biodiversity as a totality or the individual elements of biodiversity (individual species, habitats, ecosystems), and/or ecosystem services.

Nature-based– can be considered as referring to ecosystem approaches, ecosystem-based approaches, biomimicry, or direct utilisation of elements of biodiversity.

Solutions –recognisable solutions to a specific problem or challenge.

It is the latter term that distinguishes the NBS approach from other previous terminology, such as sustainable solutions and resilience. When responding to a challenge in the past, the normal approach was to define the problem being addressed. This involved, understanding the context, and then reviewing the technological solutions available. This approach often led to a single focused technological solution. The proposal of a nature-based solution requires that the problem be solved using a multidisciplinary approach (Potschin et al. 2015). The innovation supplied by the nature-based approach is that the question that is addressed may not have a purely technological solution. The review of possible alternative solutions start with the question '**is there a nature-based solution?**'. Thus, the field of possible solutions and the range of options considered are broadened. This then facilitates exploring a NBS centred design methodology.

Problem solvers or opportunity finders

A review of EIP case studies has led to the conclusion that to initiate and promote NBS, a change has to be made in the way we act, the way we think and the way we interact when considering water infrastructure projects (De Vriend and Van Koningsveld 2012). Figure 1.2 illustrates this approach graphically.

Act Differently

To effect a change in how we act, and to facilitate using NBS, it is necessary to consider the context of the project not only in terms of the physical site (both biotic and abiotic), but also in terms of the socio-economic and the governance issues surrounding the problem. This approach, which also takes into account the context as an open ecosystem, is in marked contrast to the traditional problem solving approach followed by project designers, which tends to focus on a single aspect (technological).

The traditional approach can be said to focus on function and to solve a narrowly defined problem in a given timeframe and for a given cost. This traditional method, best described as linear, sought to first define the problem, before progressing to review and propose alternative solutions. These alternatives would then be evaluated using such metrics as EIA, Lifecycle Analysis (LCA), Cost Benefit Analysis (CBA) and others. This method produced a preferred solution. If there was no solution forthcoming, designers returned to defining the problem and proceeded as before until a solution was reached.

In following an NBS methodology, which is a circular approach, the context of the project is dealt with by adopting a multidisciplinary outlook from the beginning. The multidisciplinary approach involves bringing together social scientists, governance representatives, scientists and engineers together with end users to define the problem. This management group then define multi-functional opportunities within the context of the project. These opportunities are also referred to as ecosystem services, as they are the benefits that accrue to humans from using an NBS methodology. These opportunities not only solve the engineering problems but also supply added value. This added value is typically given in terms of ecosystem services. These benefits can include any or all of the following:

- Adaption to climate change,
- Wastewater treatment,
- Ecosystem restoration or resource recovery,
- Biodiversity,
- Recreational amenities.

Think Differently

NBS not only deliver the primary functions for which the project was designed, but also provide added value from both an ecological and economic perspective. For example, the issue of flooding in a particular catchment might be defined by a technical review which defines the problem as one of limited capacity within a river system for certain storm events. The solution may focus on methods of online or offline storage and may proceed to evaluate and rank the possible solutions in terms of Environmental Impact assessment (EIA), Lifecycle Analysis (LCA), Cost Benefit Analysis (CBA) and others. Prerequisites, such as budget and time constraints, often narrow the scope of a project and preclude or hamper innovative solutions. The preferred solution, may be the most technically feasible to solve the narrow problem (increase storage locally) with least environmental impact and minimal cost. Adopting an NBS methodology may widen the scope of the project and offer new perspectives and opportunities. The issue of flood protection may be seen to offer possibilities to create new habitats. The example of the Green Gate project in Rotterdam illustrates the possibility of combining engineering solutions with ecosystems for bank protection and ecosystem services (Deltares 2015a).

A change in thinking involves incorporating the characteristics of NBS from the start. These characteristics include:

1. **Considering multifunctional solutions.** This may involve catering for more than one function in a project and therefore extending traditional proven design approaches using dynamic natural or environmental processes.
2. **Considering the project as a dynamic entity** that is in flux and open to change. Natural processes are not static. Therefore resilience has to be built in. Though the project may be built in a natural setting, i.e. **building in nature**, the change in thinking involves **building nature in**.
3. **Addressing the level of uncertainty** that is increased when dynamics and multi functions are considered. Natural systems involve the introduction of uncertainty and may increase some levels of risk. Uncertainty can be allowed for and dealt with by a knowledge base, which increases the available information. However contingency measures and flexibility are required as built-in adaptive measures to increase the feasibility of the solution.
4. Incorporating the increases in risk that follow on from dynamic and natural systems. Such concepts as uncertainty are what mainstream project designers seek to avoid and the **idea of learning by doing**, which is an underlying principle of NBS, is not widely accepted (Deltares 2015b).

The European Innovation Partnership (EIP) action group NatureWat was set up to promote NBS, and to make available a knowledge base on various NBS technologies. This group has a portfolio of NBS, which aim to make available the NBS technologies and methodologies. This technology portfolio consists of demonstration plants, which while serving to supply ecological and economic services, also function to further the understanding of how to best implement a NBS. ***These demonstration plants are tactile, practical and easily accessible in terms of access to the plant and its environs but also in access to the technology used and the scientific and engineering principles underlying the technology. They serve to promote the NBS approach by demonstrating how the problem was identified and how the solution was arrived at. The demonstration sites also illustrate the NBS methodology.***

Interact Differently

To effect a NBS methodology, a change is required in how we interact, and this requires interdisciplinary collaboration and active stakeholder involvement (De Vriend and Van Koningsveld 2012). Water-related infrastructure projects are likely to affect the interests of a variety of stakeholders, especially in densely populated areas. **"Building Nature In"** also means building with society. Stakeholder involvement is important for two reasons:

- Traditional infrastructure projects often encounter growing resistance from people who will be affected by the project. It is easy to dismiss such resistance as the "Not In My Backyard", or NIMBY syndrome. However, project developers have to recognise that they are interfering with these people's social habitats.
- Local people know a lot about the area where they live, and their knowledge base can be very useful for understanding natural systems and processes, and how they will interact with hard engineering structures. Stakeholder involvement can inspire surprising new solutions. Involving the public provides valuable insights into local systems and processes, and so is more likely to lead to better solutions that stakeholders are more likely to accept. Rather than opposing ideas that have been precooked in some faraway 'ivory tower', people take ownership of projects and even promote them. Therefore the interaction could be summed up as the community participatory approach (CPA), where the community is involved in all aspects of the project.

There is also a need to develop a *"hybrid engineer"*. This is an engineer who has a background in social science, ecology and environmental services. Such individuals, and they can also be hybrid architects and hybrid planners, allow a greater nature-based input as a result of their training and experience in green projects. The inclusion of legislators and governance has been mentioned. Such flexibility can also be incorporated into the design and build stage of the project or into such other existing procurement methods such as Design Build (DB), Design Build Operate (DBO) and Design Build Operate Finance (DBOF). Further innovations may involve management and operation. It is essential that the primary function of infrastructure be aligned with the interests of both nature and stakeholders, in order to arrive at sustainable and socially acceptable solutions.

1.5 Towards a Nature-Based Solutions Methodology

NBS challenges project developers, designers and users to think, act and interact differently. Each project provides a unique opportunity to induce positive change and NBS can be introduced in any phase of any project. The case studies in Chapter 3 describe projects that have been realized using NBS. These projects taken together form a knowledge base of NBS systems.

They also serve to suggest an NBS methodology and taken together with other studies can assist in drawing up a set of principles for NBS project implementation (De Vriend and Van Koningsveld 2012):

1. **Understand the context of the problem/project**. This stage differs from conventional engineering analysis in that it involves a multidisciplinary consultation group made up of engineers and non-engineers including stakeholders. The problem is evaluated in a holistic manner from viewpoints of the many disciplines involved in the project. This includes the environmental, technical, societal and aesthetic aspects of the project. This involves identifying ecosystem services, potential and actual.
2. **Identify realistic alternative solutions** that where possible, use NBS or that provide or use ecosystem services.
3. **Evaluate each alternative**, from an engineering and ecosystem point of view and format a multifaceted solution yielding added value.
4. **Consider** the proposed NBS design analysis in terms of practical limitations and governance. Fine tune where necessary.
5. **Finalise Initial Design Phase** – prepare the solution for implementation in the next phase of the project.

The general design process may be approached from the perspectives below:

The natural environment perspective
In any project, opportunities for NBS are to be found in the natural environment or ecosystem in which the project is to be embedded. Each environment is unique, with its own characteristics, related ecosystem services and associated opportunities.

The project perspective
Each phase of a project presents an opportunity to introduce NBS. Project phases include: initiation, planning and design, construction, and operation and maintenance.

The governance perspective
The governance context, involves the complex set of legislation, regulations, decision-making processes, etc. It also involves networks, regulatory contexts, knowledge contexts and realization frameworks.

The knowledge base
The knowledge base, consists of a wide range of tools, demonstration sites, case studies and other examples. The tools include methods, concepts and strategies that can be used in the different project phases and design steps. Together, the example cases form a technology portfolio of NBS as they have been implemented in projects. The knowledge pages contain information on the various topics and issues that have been addressed during the programme.

1.6 Further Information

EcoShape is a consortium of Dutch companies that include international dredging contractors, public bodies and engineering firms and research institutes such as Deltares. They have developed course materials and tutorials that are being used in workshops and training courses at various collaborating education institutes, i.e. Delft University of Technology, Wageningen University and Research Centre, and the Zeeland and Van Hall Larenstein Universities of Applied Sciences (www.ecoshape.nl).