Evaluating Nature-Based Solutions

Best practices, frameworks and guidelines

HKV CONSULTANTS

BLUE LAND

Client

Rijkswaterstaat
Ministry of Infrastructure and Water Management

Interreg
North Sea Region
Building with Nature
European Regional Development Fund

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Final report

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Authors
Fredrik Huthoff
Wilfried ten Brinke
Ralph Schielen
Roy Daggenvoorde
Carolien Wegman

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Summary

A qualitative evaluation framework is proposed to assure that essential elements are included in projects with Nature-Based Solutions (NBS) and, next, the framework was applied to show how to get a general insight into the efficiency, effectiveness, flexibility and social support of three example NBS projects. Literature on NBS reveals that to evaluate NBS it is sensible to make a distinction between design and implementation aspects that relate to the efficiency and effectiveness of the project. Thereby, the extent to which outputs and outcomes are achieved can be assessed. Additionally, the project process and project flexibility should be considered and evaluated to make sure that social support is achieved and that co-benefits are identified and stimulated where possible.

It is a key challenge in many NBS to define and apply suitable indicators which serve to monitor progress and success of the project. Additionally, by keeping track of performance indicators of the NBS also more advantage could be taken of inherent flexibility of the NBS by alerting for and guiding possible interventions if needed. For this purpose, in the design phase the choice for a particular intervention needs to be clearly justified, uncertainties should be addressed and comparisons to the projected null-situation (do nothing), alternative grey solutions or otherwise undesired impacts should be made. These considerations should help to define the crucial indicators that allow to keep track of and adequately respond to the management and performance of the NBS during the implementation and operation phase.

Acknowledgements

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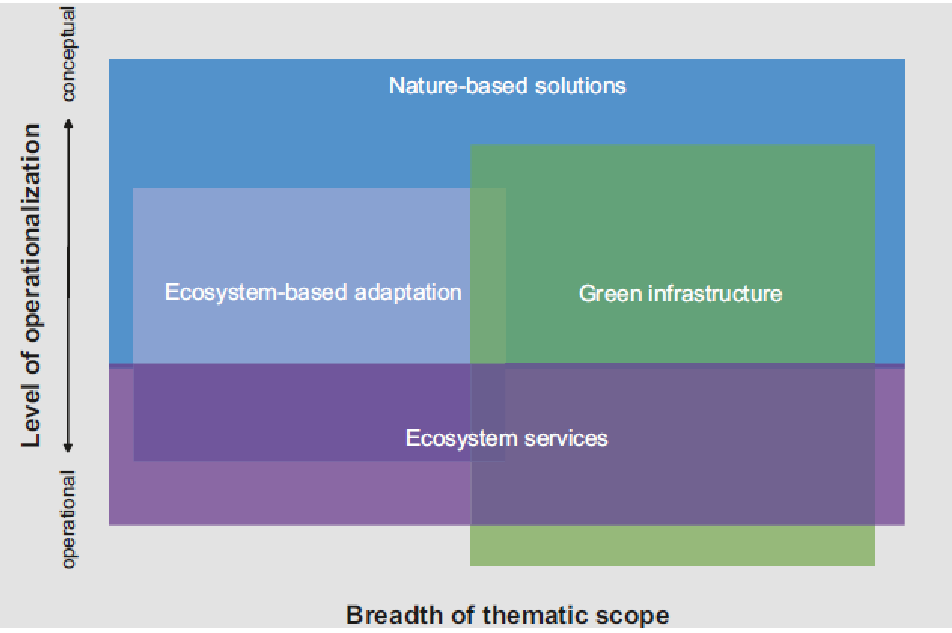
Table of contents

1 Introduction

1.1 Context

Nature-Based Solutions (NBS) have become a widely mentioned and promoted concept in civil engineering projects in recent years and have been described in many recent studies and articles, stating definitions, frameworks, experiences and insights from practice and science. Terminologies as Building with Nature (BwN), Nature-Based Solutions (NBS), Engineering with Nature (EwN), Working with Natural Processes (WWNP), Green Infrastructure or Natural and Nature-Based Features (NNBF) are often used almost interchangeably. In Kabisch et al. (2017) a scheme is included to distinguish between these commonly used terminologies in terms of "level of operationalization" and "breadth of thematic scope", see Figure 1. In this figure, Ecosystem-based adaptation can be related to the terminology NNBF and EwN and Ecosystem Services can be related to the terminology WWNP.

Figure 1 Level of operationalization and scope of different terminologies relating to Nature Based Solutions (from Kabisch et al. 2017).



In the scheme of Kabisch et al. (2017) the term NBS has the widest scope, and this is therefore the term that we will adopt here. Next, we follow Raymond et al. (2017) broad definition that **Nature-based solutions (NBS) are solutions to societal challenges that are inspired and supported by nature.** In particular, we refer to solutions or approaches that strive to use the forces of nature to deal with water-related objectives and challenges.

The main water management objectives can broadly be subdivided into (e.g. UN Water 2018):

1. enhancing water availability,
2. improving water quality and
3. reducing water related risks.

Within the context of the on-going Interreg VB North Sea Region Building with Nature project' (Interreg NSR BwN) that aims to "make coasts, estuaries and catchments of the North Sea Region (NSR) more adaptable and resilient to the effects of climate change" and to, ultimately, "better protect people, communities, infrastructure and economy from the impacts of flooding and coast erosion" we focus in our study on the third of the above listed objectives: reducing water-related risks. The considered hazards primarily are floods and droughts, but also ecological degradation and pollution, and, as such, the scope of this study is also indirectly linked to the other two water management objectives.

Already in 2008 the World Bank showcased the opportunities of NBS in a portfolio of the 6 Billion USD investments that had been made in that area up to then (World Bank, 2008). In 2017 a further guidance document was published (World Bank, 2017) to underline opportunities of NBS and to help implement such projects for flood protection. As this is only one of the many NBS frameworks that has been proposed in recent years, it is important that a consistent understanding of NBS is achieved and that a widely-accepted practical implementation and evaluation guide is established to assure that such projects are efficient and make sense.

Besides the question of how to properly implement NBS, a key question to be addressed is "why" NBS are needed and, specifically, solid evidence is needed on how the NBS give benefits over traditional "grey" engineering solutions (such as dikes, dams, and other hard infrastructures). Herein, the desired goals of the NBS, the outcomes and the achieved benefits or trade-offs incurred along the way must be reflected upon using predefined evaluation criteria, and the added value (or benefits) should be demonstrated in a systematic way. It is the objective of this study to provide such a framework for evaluation of NBS. It is clear that this is of added value for the projects that take part in the Catchments Work Package of the Interreg NSR BwN (WP4) but the framework should be applicable to general Nature Based Solutions.

1.2 Objectives and approach

The starting premise for this study is that there is an increasing tendency to implement NBS projects. **The objective of this study is to create a "preferred framework" for NBS, in order to compare and evaluate projects**, which would then demonstrate the added value of NBS compared with traditional (grey) solutions. This may help to improve the implementation of NBS and make the projects more efficient and effective.

To establish a preferred evaluation framework we carried out a literature study of recent scientific work and policy notes that are available on the subject. Next, we tested three recent NBS projects against this framework to see which aspects require further attention to assure effective management and implementation. For this purpose, we compared cases from the Netherlands, Scotland, and Belgium[1].

[1] Initially, a fourth case in Sweden was also intended to be included. However, because of lack of documentation in English we left that case out for now.

2 NBS concepts and frameworks

2.1 Green vs. grey solutions

Why should we consider NBS? According to Nesshöver et al. (2017) NBS overcome "a bias towards development alternatives with narrow perspectives that focus on short-term economic gains and effectiveness" and, thereby, NBS make "an explicit link to the pillars of sustainable development, putting social, environmental and economic dimensions […] at the same level of importance". Key concepts are thus long-term vision and sustainability, which are supposedly undervalued in traditional "grey" solutions. In essence, NBS acknowledge the balance of nature, they require placement of a particular challenge in a wide thematic context and they force us to consider long term functioning and impacts. In contrast, UNEP (2014) points out that grey solutions are often considered attractive because they offer immediate and high-visibility impacts. Grey solutions generally are ready to operate immediately after their construction is completed, and they will show their functioning directly after implementation. This is where crucial drivers for grey solution present themselves, which are sometimes lacking in the alternative of NBS:

1. Immediate impact of the solution (it solves the main problem right away)
2. Visibility of the solution (it shows something is done to the problem)

The urgency of the problem and the need for a quick solution (point 1) could in some cases also be offered by NBS. However, because of the relative few experiences with NBS (as compared to grey solutions), NBS approaches in general still require a testing, learning and adaptation phase. Furthermore, if natural processes are a key component of the solution, then the intended functioning of the NBS may require a "spin-up time". The question is whether such a spin-up (or delay) can be afforded for the problem at hand and whether the associated uncertainties can be properly managed. Next, visibility of the solution (point 2) seems more of a political issue, but is also closely related to the urgency of the problem. This aspect goes beyond the question of whether the solution is effective, but instead answers to the apparent need of stakeholders to see that something is being done to solve the problem. UNEP (2014) also points out common disadvantages to grey solutions, and these are aspects where opportunities for green solutions are more easily achieved:

3. Capital needed to build, operate, maintain and replace the solution
4. Ecosystem disruption or degradation created by the solution

Therefore, while NBS may – in general- not be as effective as grey solutions in achieving immediate visibility and quick results, **the advantages of NBS should be sought in longer term impacts and the sustainability of the solution: economically, socially and environmentally**. With regard to the final point 4 (ecosystem disruption), NBS by definition make use of natural processes and therefore the environment and ecosystem values are more likely incorporated in the functioning of the measure. In relation to point 3, especially the possibility to replace, upgrade or adapt the solution is one that appears to more easily achieved with NBS. NBS's are inherently flexible and will naturally adapt to changing conditions, thereby potentially maintaining, extending or even improving their functioning. Also, if additional intervention is needed, a NBS typically leaves open more options for adaptation or upgrading than hard grey solutions. In this context, Wesselink et al. (2015) warn for the "technological lock-in" that may arise from continued preferences for grey or "hard" solutions, where due to lack of flexibility in grey solutions alternative approaches become less and less feasible.

The potential advantages of NBS seem clear. It is necessary to systematically evaluate NBS against (grey) alternatives to demonstrate benefits of NBS and to be able to decide whether in certain situations NBS are indeed a preferred approach to a problem. Summarizing the general arguments that speak in favour of NBS, aspects to consider when trying to demonstrate the added value of NBS (against grey solutions) are:

- Short and long term functioning of solution (and need for maintenance)
- Short and long term economic, environmental and ecosystem impacts
- Flexibility, capability or options for solution to adapt to changing conditions
- Co–benefits and trade-offs offered by the solution

An additional aspect to consider may be the aesthetics of the solution. One may argue that aesthetics of nature-based designs are more likely to stand the test of time in relation to hard grey solutions. However, this aspect is difficult to quantify in a comparative evaluation procedure as it is highly subjective. It should, therefore, not be a leading evaluation principle and we will thus disregard it in our study.

Next, what is needed are practical tools for a critical and comparative evaluation of impacts and benefits, that would clearly show the added value of NBS compared with grey solutions for a particular situation (or vice versa), and guidelines on how to implement them. A general strategy for wider and successful implementation of NBS is thus twofold:

1. clearly demonstrate the benefits of NBS (comparative evaluation), and
2. offer design and implementation guidelines (including monitoring) how these benefits can be fully exploited.

In the following we consider approaches and frameworks that have been proposed to implement and evaluate NBS. Based on these works, we will propose a "preferred evaluation framework" that, in our opinion, combines strengths and is practical for implementation guidance and evaluation of NBS. In the next chapter we consider three existing NBS cases and see how they perform under the "preferred framework" and what lessons and best practices can be derived for future NBS.

2.2 Existing frameworks and approaches

From existing works on the broad theme of NBS we observed that the focus of studies and approaches can broadly be subdivided into three categories: (i) setting up NBS (design), (ii) putting NBS to practice (implementation) and (iii) assuring an effective and efficient process and to achieve social support. In our exploration of the existing literature on definitions, frameworks and guidelines on NBS we therefore distinguish three main aspects to group recommended practices:

1. Design: setting up and choosing a suitable NBS
2. Implementation: putting NBS into practice
3. Process: making sure NBS are (socially) accepted, and that they are efficient and effective.

In the next paragraphs we reflect in more detail on these aspects. We extract commonalities of proposed approaches and, next, compile essential elements that should be considered in an evaluation framework for NBS.

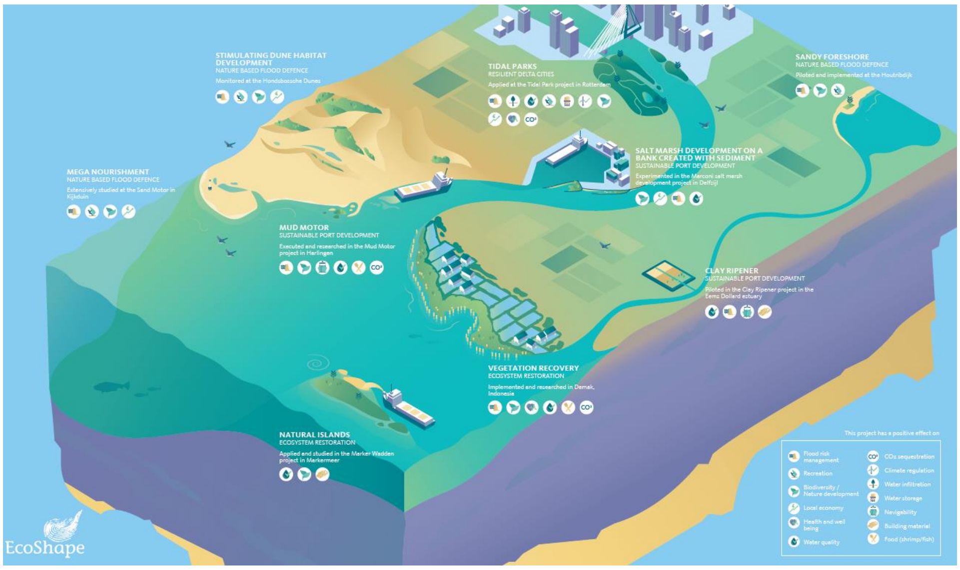
2.2.1 Design

Rogger et al. (2017) suggests that during the design phase it is important to study simplified approaches to be able to anticipate on impacts and understand cause-effect relationships of measures. In Ecoshape (2018) basic typologies are given of different types of NBS, and a suite of "tested concepts" or proven solutions is provided (see Figure 2). These are proposed as possible blueprints for repeated designs of NBS elsewhere. General design principles for new NBS are provided, which are summarized in five key steps:

1. understand the system,
2. identify realistic alternatives,
3. valuate the quality of alternatives and pre-select an integral solution,
4. elaborate selected alternatives,
5. prepare for implementation in the next phase on the road to realization.

In each of these steps simplified approaches should be applied that highlight the key processes and their impacts. This is needed to assure that main characteristics of the NBS are properly designed, which then allow further elaboration (adaptation) during or after implementation (for example based on monitoring results).

Figure 2
Overview of general NBS options ("Building with Nature projects") as proposed in the Ecoshape guidelines. (See appendix A for larger image).



The recommended steps by Ecoshape are similar to those mentioned in a brochure on NBS by the World Bank. As part of "understanding the system" and "identifying alternatives" the World Bank (2017) specifically stresses the importance of adopting a system-scale perspective, integrating with ecosystem conservation and to perform a risk-and-benefit assessment of a full range of solutions. Also IHOBE (2017) provides a similar methodology to identify and map both existing Nature-based Solutions and the potential for further deployment. Their guide gives an overview of types of interventions and on which scales they could then be implemented. A seven step (design) work sequence is proposed (see also Figure 3):

1. Defining objectives
2. Selecting the analysis level
3. Gathering the available information and data processing
4. Characterisation of the municipality/ units of analysis by their urban typology
5. Diagnosis of the natural capital using land cover
6. Analysis of the 'Nature-based Solutions': available and potential
7. Selecting and assessing the measures

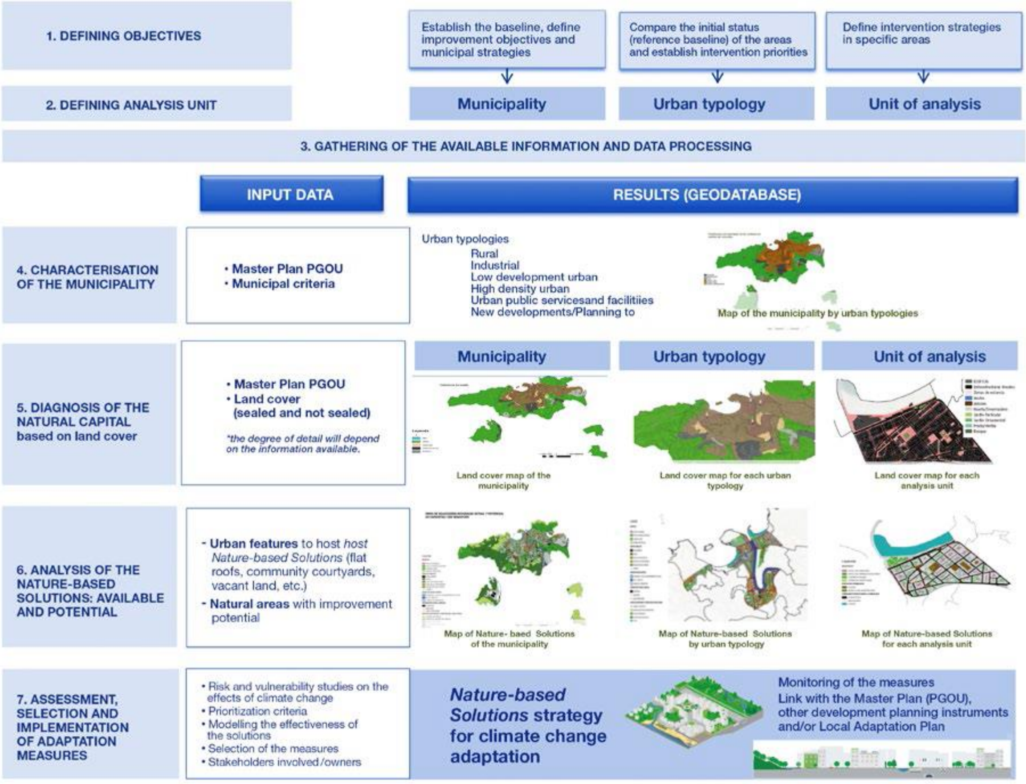


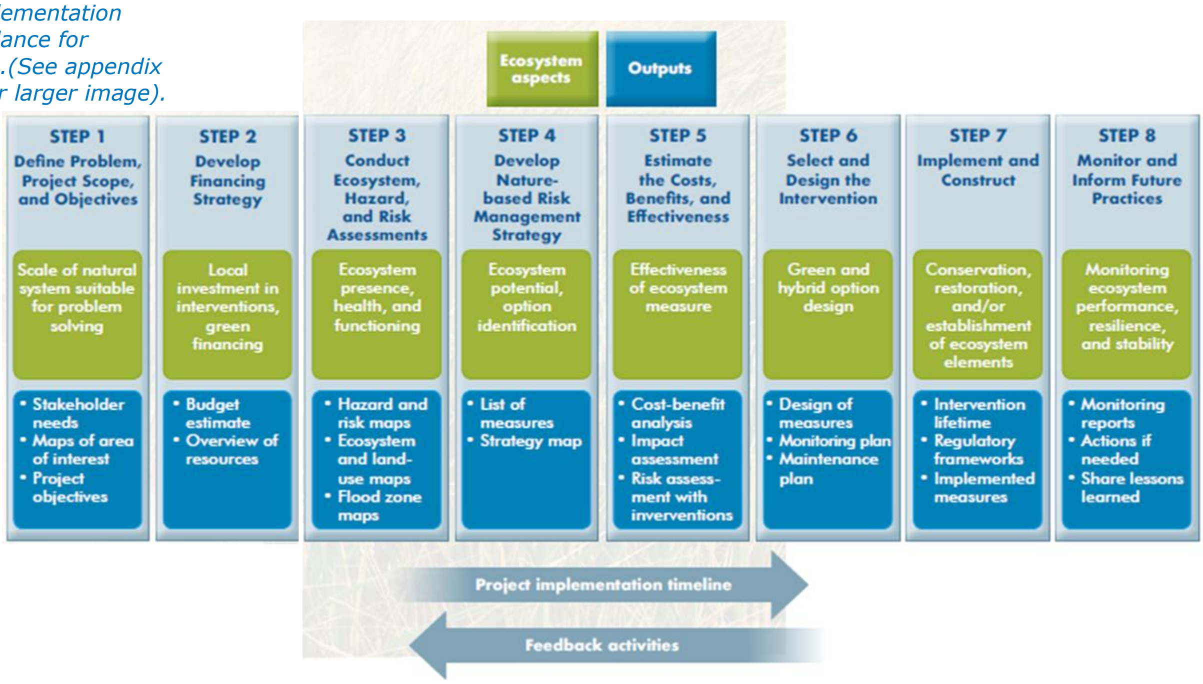
Figure 3
Design Framework for NBS according to IHOBE (2017).
(See appendix B for larger image).

A common characteristic of these approaches is the specific focus on problem definition and the setting of goals. Other key commonalities are adopting a system-wide (multi-sectoral) approach, and the consideration of different realistic solutions.

2.2.2 Implementation

In the previously mentioned brochure by the World Bank (2017) also an implementation guidance was provided, in summarized form presented in Figure 4. A key characteristic of this guidance is that in each step specific ecosystem aspects are addressed that should be taken into account. Per step specific outputs (products and deliverables) are given.

Figure 4
Summary WB's implementation guidance for NBS.(See appendix C for larger image).



The World Association for Waterborne Transport Infrastructure also proposed a "Working with Nature" implementation framework (PIANC, 2018). The six basic steps are illustrated in Figure 5 and contain similar components as in the World Bank's recommended approach, including design aspects and specific outputs per project step. Again, the need for thorough problem definition ("establish project needs and objectives") and a system approach ("understand the environment") are explicitly stated. Furthermore, both implementation guides stress the importance of monitoring and reflection to assure intended performance of solutions and to indicate possible intervention actions if needed. Thus, one should make use of the flexibility of the NBS and learn from observations to implement changes or adaptations. Also, the monitoring can provide evidence of co-benefits ("win-win situations"), which are a crucial aspect of NBS. Stakeholder involvement throughout the project is mentioned in all previously mentioned framework and implementation guides. We address this separately in the next paragraph.

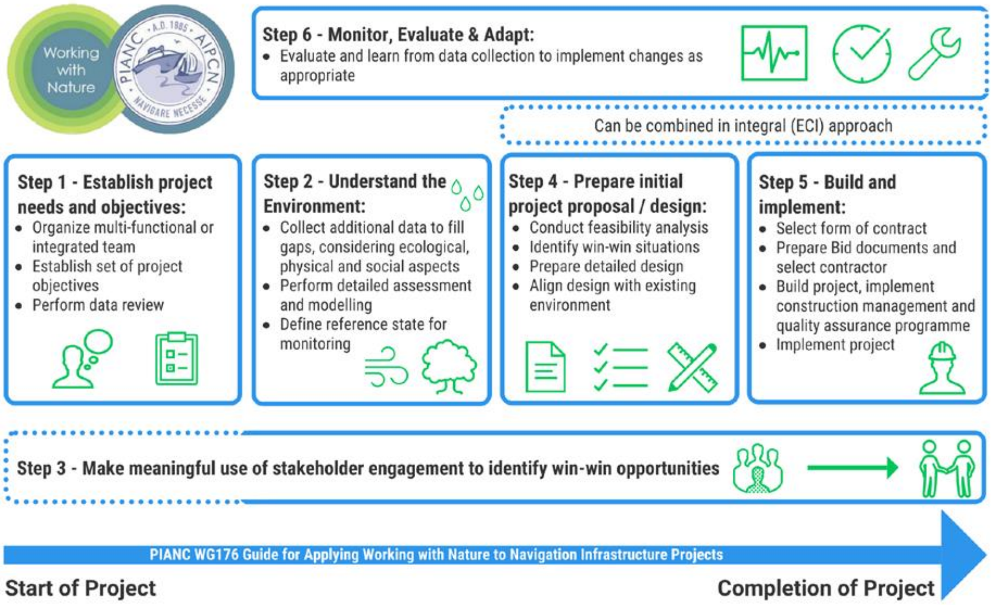


Figure 5
The NBS ("Working with Nature") implementation framework by PIANC (2018).
(See appendix D for larger image).

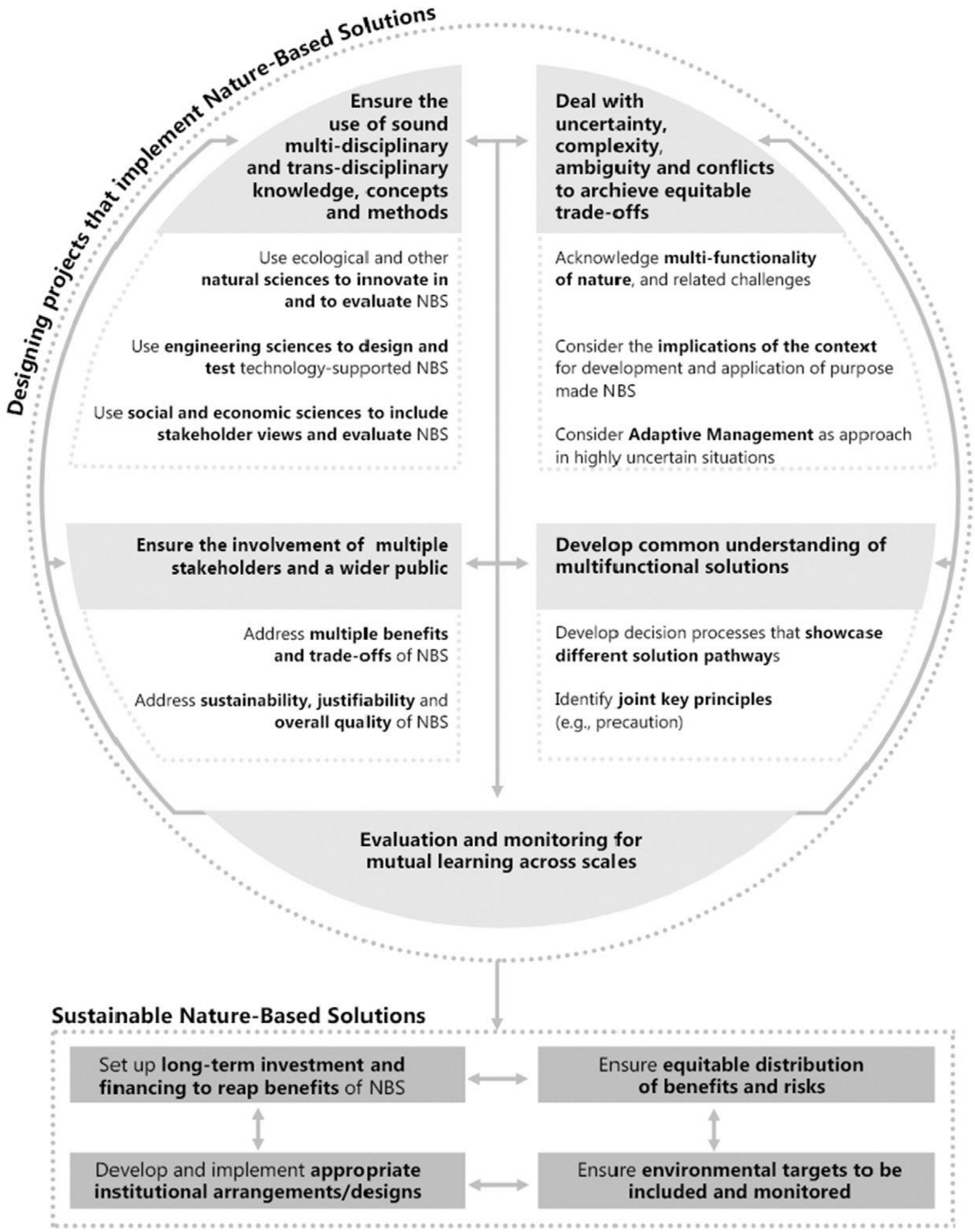
2.2.3 Process

Regarding the recommended process of design and implementation of NBS we consider aspects as stakeholder involvement, management of the project, evaluation of solutions and, if needed, ways and possibilities to intervene (flexibility and adaptation). Nesshöver et al. (2017) emphasize the following key process-elements:

1. Dealing with uncertainty and complexity
2. Ensuring the involvement of multiple stakeholders
3. Ensuring the sound use of multi- and transdisciplinary knowledge
4. Developing common understanding of multifunctional solutions, trade-offs and natural adaptation
5. Evaluate and monitor for mutual learning

These elements are further elaborated upon in Figure 6.

Figure 6
Key elements for assuring sustainable NBS (from Nesshöver et al., 2017).
(See appendix E for larger image).



In Naumann et al. (2014) specific attention is drawn to the need of wide and continual stakeholder involvement throughout the project. Herein, they differentiate between planning, conception and implementation phases of NBS. In Figure 7 an overview of success factors for each of these phases is given.

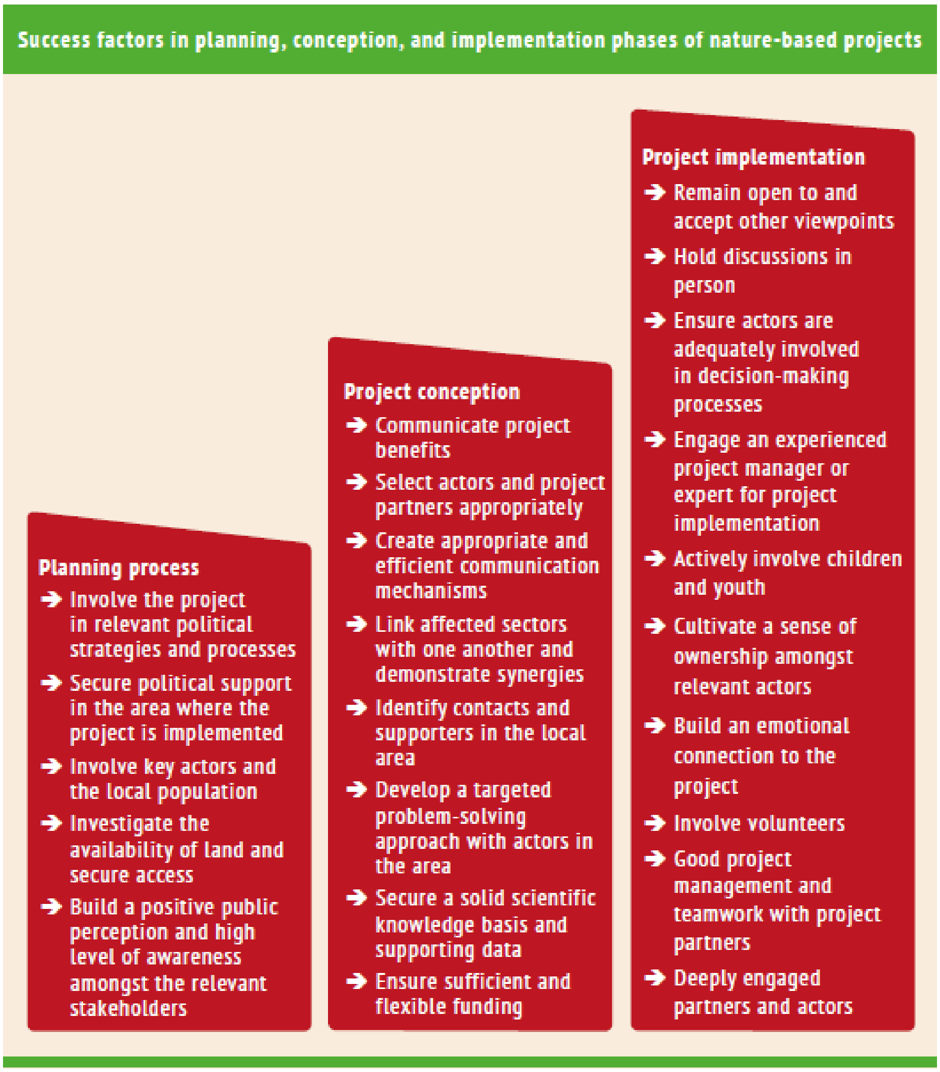


Figure 7
Process success factors for NBS (from Naumann et al., 2014).

In EKLIPS (2017) a thorough literature study was conducted from which an impact assessment framework was formulated, meant to help evaluate NBS. Below, a summarizing figure is shown "illustrating the relationships among elements of biophysical and social systems, climate resilience challenges and the NBS actions" together with a central role of indicators to assess impacts (Figure 8). The issue of appropriate indicators is reflected upon and it is acknowledged that there is a need to "develop indicators that crosscut challenges and are applicable within and across geographic scales" and "which can be easily compared among different projects and different case studies". Criteria or indicators need to be defined to quantify the functioning of the intervention and to guide maintenance and potentially needed adaptations. Furthermore, Nesshöver et al. (2017) state that "NBS need to be developed and discussed in relation to existing concepts to clarify their added value". Therefore, also the added values (co-benefits) need to be monitored and evaluated. Raymond et al. (2017) give an overview of examples of indicators to assess these co-benefits, see Figure 9.

Figure 8
NBS relationship-framework by EKLIPS (2017)

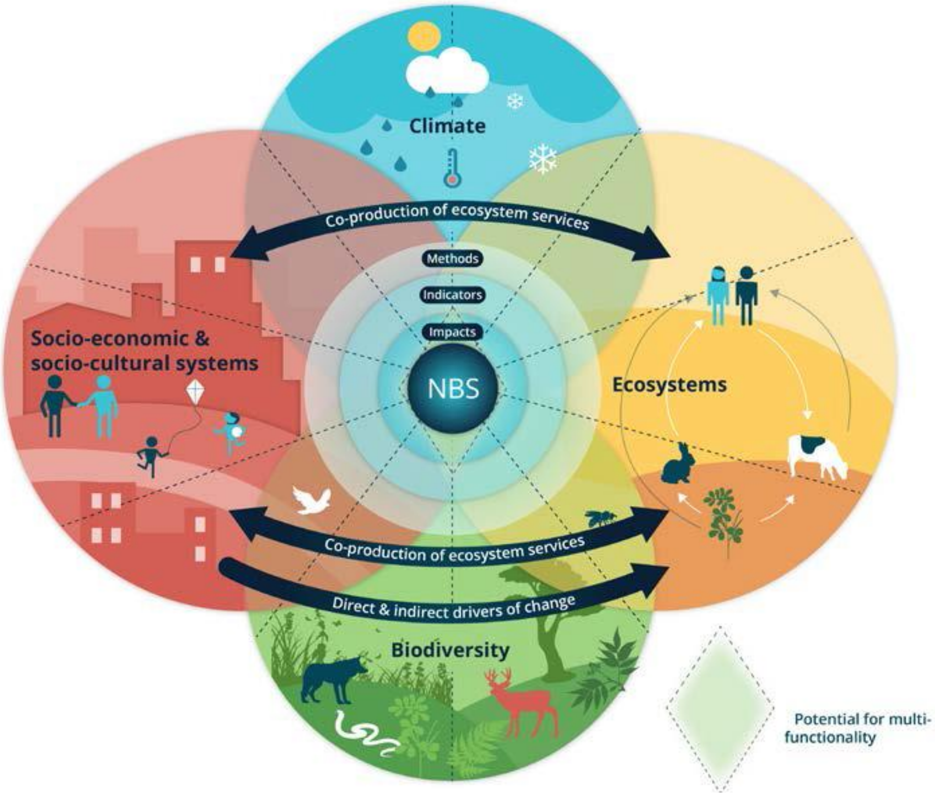


Figure 9
Examples of indicators to assess co-benefits of NBS (from Raymond et al., 2017).

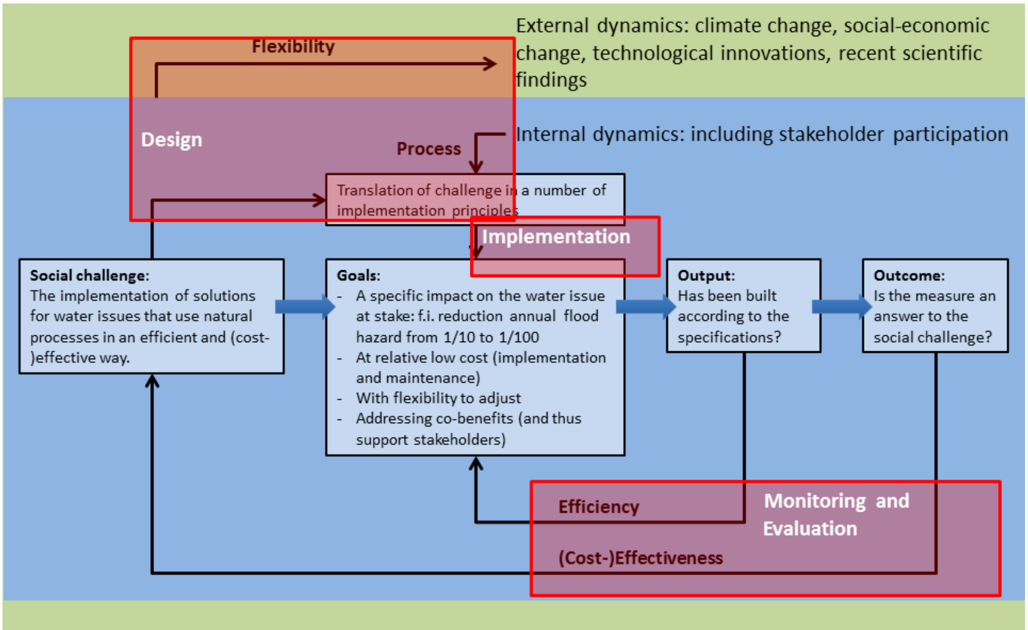
Challenge area	Example of indicators	Type of indicator	Unit of measurement
	Net carbon sequestration by urban forests (including GHG emissions from maintenance activities)	Environmental (chemical)	t C per ha/year
	Economic benefit of reduction of stormwater to be treated in public sewerage system	Economic (monetary)	Cost of sewerage treatment by volume (€/m³)
	Area remaining for erosion protection	Environmental (physical)	km² or m²
	Species richness of indigenous vegetation	Environmental (physical)	A count, magnitude or intensity score of indigenous species per unit area
	Annual amount of pollutants captured by vegetation	Environmental (chemical)	t pollutant per ha /year
	Index of ecological connectivity (integral index of connectivity	Environmental (physical)	Probability that two dispersers randomly located in a landscape can reach each other
	Quality of the participatory or governance processes	Social (process)	Perceived level of trust, legitimacy, transparency and accountability of process
	Accessibility to public green space	Social (justice)	% of people living within a given distance from accessible, public green space
	Level of involvement in frequent physical activity in urban green spaces	Social (physiological)	Number and % of people being physically active (min. 30 min 3 times per week) in urban green spaces
	Net additional jobs in the green sector enabled by NBS projects	Economic (productivity)	New jobs/specific green sector/year

In summary, the literature that focuses on appropriate process elements for NBS have in common that stakeholder involvement should have a central and continuous role throughout all project-phases, and that monitoring and evaluation (indicators) should be an integral part of the project for guiding possible interventions, assure efficiency and effectiveness of the project and to demonstrate co-benefits.

2.3 Essential elements for an evaluation framework

The objective of this study is to create a "preferred framework" for NBS to compare, evaluate and eventually help stimulate the implementation of projects. From our literature study, we compiled essential elements for this preferred evaluation framework. These findings are described below and summarized in Figure 10 (see appendix F for larger image).

Figure 10 Summary of essential elements for an evaluation framework of NBS.



The general framework outlined here and its essential elements are inspired by the framework that the Netherlands Environmental Assessment Agency has designed for the Dutch Delta Programme to monitor and evaluate future measures to climate proof the Netherlands (NL PBL, 2016). That framework includes projects that just like NBS are associated with a system wide approach, a central role for environmental aspects and long-term visions.

In the framework we separate design from implementation steps. In the design step the challenge, the objectives and goals should be clearly defined and co-benefits should be listed. This step includes the process of stakeholder participation (internal dynamics) and taking into account flexibility with respect to external dynamics. The process should fulfil particular conditions, in particular that wide stakeholder involvement is assured to make sure that co-benefits (and trade-offs) are known and considered throughout the project. The implementation step should result in outputs and outcomes, characterized by measurable indicators that can be monitored and evaluated to show efficiency and effectiveness of the NBS, to reveal co-benefits and to see if adaptation actions are needed. Key elements are addressed in more detail below.

Defining the scope and addressing uncertainties

The challenge, its scope and the goals need to be clear before suitable solutions (NBS) can be chosen, implemented and evaluated. This challenge is 'operationalized' into main objective(s), co-benefits and trade-offs. The main objective(s) may be reached by a green or grey solution, and both options should be considered. The co-benefits refer to the added value that a particular solution may have. In this 'operationalization' stakeholders are involved to assure social support. Important is also to address the uncertainties of considered solutions, how these relate to functioning of the intervention and how to manage these during design, and during and after implementation.

Define the reference situation to evaluate objectives and co-benefits

Nature-based solutions can be valuable because of their added value compared with (conventional) grey solutions. It is the added value, and how this can be reached, we are looking for, and we can only conclude this if we know the reference situation. This reference is different for the main objective(s) and the co-benefits:

- ⇒ For the main objective(s) the reference is the result we would have reached if we had chosen for a grey solution.
- ⇒ For the co-benefits the reference is the as-is situation.

Monitoring output, outcome, process and flexibility

Monitoring is necessary to provide evidence of performance and to be able to systematically compare NBS with traditional engineering solutions (see also Dadson et al. 2017). Klostermann (2018) recommends that for evaluation of solutions three types of indicators are needed to properly measure performance: 1) for process (how to do it), 2) for the output (measurable products) and 3) for the outcome (are the goals achieved). For process it is important to keep track on stakeholder involvement (social support) and the flexibility (adaptability) of a solution. Monitoring the output of a NBS is straightforward: verify that what has been built is what was agreed upon and keep track of the delivered products (efficiency of the solution). More challenging is to demonstrate that the project is effective and that also the outcome is achieved: is the implemented measure an adequate answer to the social challenge (the problem)? A positive score on the output is not necessarily a positive score on the outcome. For instance, the external dynamics may have changed such that what has been built is no longer effective in addressing the social challenge. Ideally, the indicators to judge the design and implementation phase are defined at the start of the project, and the process and output are monitored focussing on these indicators.

In summary, the essential elements of an evaluation framework for Nature-based solutions are then:

- **Output indicators** that describe whether the solution satisfies the specifications and principles of the design process. A positive score gives an impression of the **efficiency** of the implementation phase (to what extent has been delivered what was promised)
- **Outcome indicators** that describe whether the solution adequately answers the social challenge at the base of this measure. A positive score gives an impression of the **effectiveness** of the solution (to what extent is the solution an answer to the social challenge)
- **Process indicators** that describe whether all the right steps have been taken to ensure that the solution addresses all envisaged co-benefits. A positive score indicates that the solution is based on the **social support** of relevant stakeholders.
- **Flexibility (or adaptivity) indicators** that describe how easy (and at low cost) the solution can be adjusted in view of the internal and external dynamics of the social challenge, and how to deal with uncertainties.

The indicators (also called essential framework elements) summarized above should be defined such that by monitoring and evaluating them, the success of the NBS in reaching these objectives and co-benefits can be judged.

2.4 Preferred Evaluation Framework

Using the identified essential elements for evaluation of NBS we have compiled sets of qualitative indicators that can give a general impression of the efficiency (related to output), the effectiveness (related to outcome), the process and the flexibility of a NBS. Based on commonalities from the consulted literature on the subject (see section 2.2) these are:

Efficiency:
- Has the as-is situation been defined?
- Have system considerations (integral approach) been addressed?
- Have nature-inspired processes and methods been used?
- Have nature-friendly materials been used?
- Have uncertainties been addressed?
- Are success indicators of the intervention defined? Are they defined on different time-scales? For the goals and for the co-benefits?

Effectiveness:
- Is a clear and thorough problem definition available?
- Is understood which interventions could solve the problem?
- Have alternative (grey) solutions been considered?
- Are co-benefits, risk and threats addressed and identified?
- Are the advantages of a green solution identified?
- Did monitoring show that the NBS answered to the objective?

Social support:
- Is there a common understanding of the problem, solutions or goals?
- Was there wide stakeholder involvement? Throughout the project?
- Are institutional arrangements made?
- Was there attention for collaborative learning (education and knowledge exchange)
- Is review and reflection carried out in the project?

Flexibility:
- Is the intervention flexible?
- Are adaptation options included in the design?
- Is a plan available for monitoring and evaluation to guide adaptation if needed?

In the next chapter, we apply these qualitative indicators to three selected cases. Ideally, the indicators to characterize output (efficiency), outcome (effectiveness), process (social support) and flexibility are defined in a more quantitative way at the beginning of the design step of NBS. That way, performance of the NBS can be monitored "as sharp as possible" and the monitoring can then also guide possible intervention. The cases that are evaluated and compared in this study, however, have already been completed and at this point only a reflection on the design and implementation steps is possible. In this evaluation we therefore only *reflect* on the general functioning of selected NBS in terms of efficiency, effectiveness, social support and flexibility.

3 Comparison of NBS cases

3.1 Introduction

Weber et al. (2018) state that results of NBS have rarely been compared across projects thereby limiting our ability to identify factors that influence outcomes. Here we make an attempt at such a comparative evaluation. In the sections below we consider three NBS cases in Belgium, the Netherlands and Scotland, respectively, and subject these to the evaluation framework as set out in the Chapter 2. First we describe general characteristics per NBS case (sections 3.2 - 3.4). In section 3.5 we present a synthesis of the performance of these projects by applying the proposed evaluation framework.

3.2 Case 1: Belgium – River Kleine Nete

Along the Kleine Nete in Belgium the discharge function of the river is combined with a recreational function. In the past (in the 1970's), the river has been straightened, broadened and deepened. As a result of these changes it appears that the water safety and ecological value of the river system has declined. River restoration is therefore considered needed to create more storage capacity and to realise ecological added value. The intended NBS is to restore the historical structure of the watercourse (Figure 11).

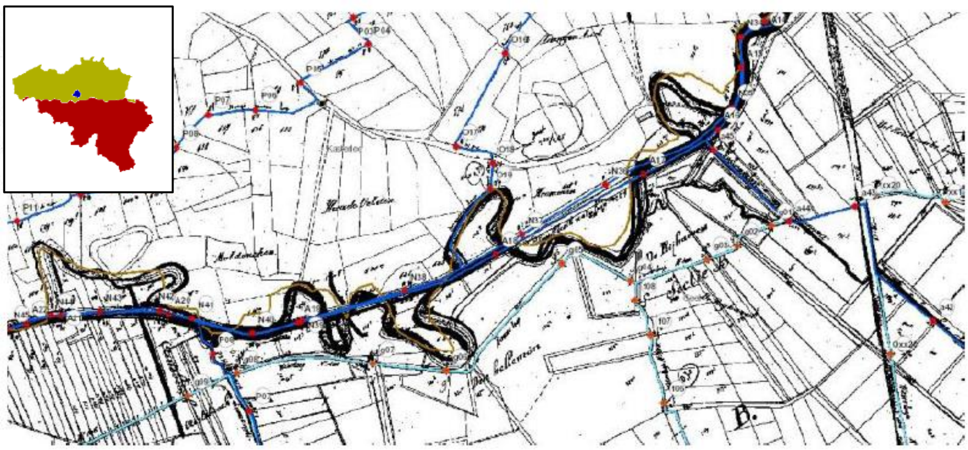


Figure 11 Location of the Kleine Nete (inset: map of Belgium) and its old meandering path (source: Flanders Environment Agency).

This project is focused on river restoration to achieve increased water storage and ecological diversity. Clearly defined quantitative goals have not been found in the available documentation of the project, nor have uncertainties for the plan been mentioned . A trade-off related to the project lies in the economic sector (recreational), which is not very willing to give up space to river adaptation works. The agricultural sector contests that an uneven trade-off is proposed and that a local amusement park (Bobbejaanland, recreational area) should contribute more by giving up space for the river. The challenge is to find innovative solutions for multifunctional use of space so that trade-offs and desired goals of the project are well balanced. The proposed solution is to rearrange the bank zone of the Kleine Nete and to create a win-win situation for both the river, agricultural activities and the recreational areas. Figure 12 gives an overview of key project components of the intended river restoration for the Kleine Nete.

Figure 12
Project components of river restoration program Kline Nete (source: Flanders Environment Agency)

From project documentation it appears that intensive stakeholder involvement has been carried out. For example, a committee was set up ("opvolgingscommissie" in Dutch) tasked to manage the process and communication between different plans and processes in the valley. The local authorities are present in the committee as well as the provincial government, two representatives of the agricultural sector and two environmental representatives of organization 'Natuurpunt'. Via the committee all stakeholders get an overview of the process, the linkage to associated projects and progress in the project itself. The committee also serves to signal issues in the communication or execution of the project. In May 2018, the Flanders Environment Agency came to an agreement for the pre-design stage of the project in collaboration with this committee.

3.3 Case 2: Netherlands - side channels (Room for the River)

In 2016 the Room for the River Programme in the Netherlands was completed[2]. At more than 30 locations, measures were taken to give the Rhine River and its distributaries more space to increase flood safety. At the

[2] Details on the entire Room for the River programme and individual projects can be found at ruimtevoorderivier.nl

same time, the measures are designed in such a way to facilitate as much as possible safe river navigation and, likewise, to enhance nature values and recreational space. One type of measure within the programme consists of creating more secondary channels along the main river branches. These secondary channels add additional flow capacity during flood events and thereby lower extreme flood water levels. Also, during less extreme flow conditions they give a more dynamic hydrological behaviour of the floodplains and thereby improve landscape quality and ecological diversity. Figure 13 gives an artist impression of one of such secondary channel projects.

Figure 13 Secondary channel next to a main channel with groynes (Geerling & van Kouwen, 2010)

In the design of the Room for the River measures a "River Assessment Framework" (in Dutch: "Rivierkundig beoordelingskader") was applied to systematically guide designs and test potential impacts of the measure in terms of flood safety (water levels, flow velocities), morphology (changes in river and floodplain) and impacts on nature and economic activities (in particular river navigation). Extensive hydro- and morphodynamic modelling was used to anticipate on expected impacts, assure flexibility in intended functioning of the project and on possibilities to intervene if monitoring results of post-implementation impacts would show the need for this. In some of the more complex projects also probabilistic analyses have been carried out. Special "stakeholder managers" (in Dutch: "omgevingsmanagers") have been assigned to individual projects to assure that relevant stakeholders were included and had a say in the project process, spanning all steps from project design to final implementation.

3.4 Case 3: Scotland – Eddleston water

The Eddleston Water project addresses the potential contribution that natural flood management can make to alleviate flood impacts and habitat degradation. The project was established in 2012 and has a completion horizon set for 2020. Several different measures are taken of which most contain a strong component for driving ecological diversity. Some measures specifically focus on increasing water safety (reduce floods) by using natural processes to temporarily store surface waters and delay peak floods, as well as through increased surface roughness and groundwater connectivity. For example, creation of several small ponds in the downstream zones of the project area (Figure 14) should locally reduce the discharge peak by an estimated 18-20% and delay flood peaks by up to 6 hours. Furthermore, also the introduction of large wood flow restrictors in the upper catchment is proposed to delay flood peaks by 30-60 minutes.

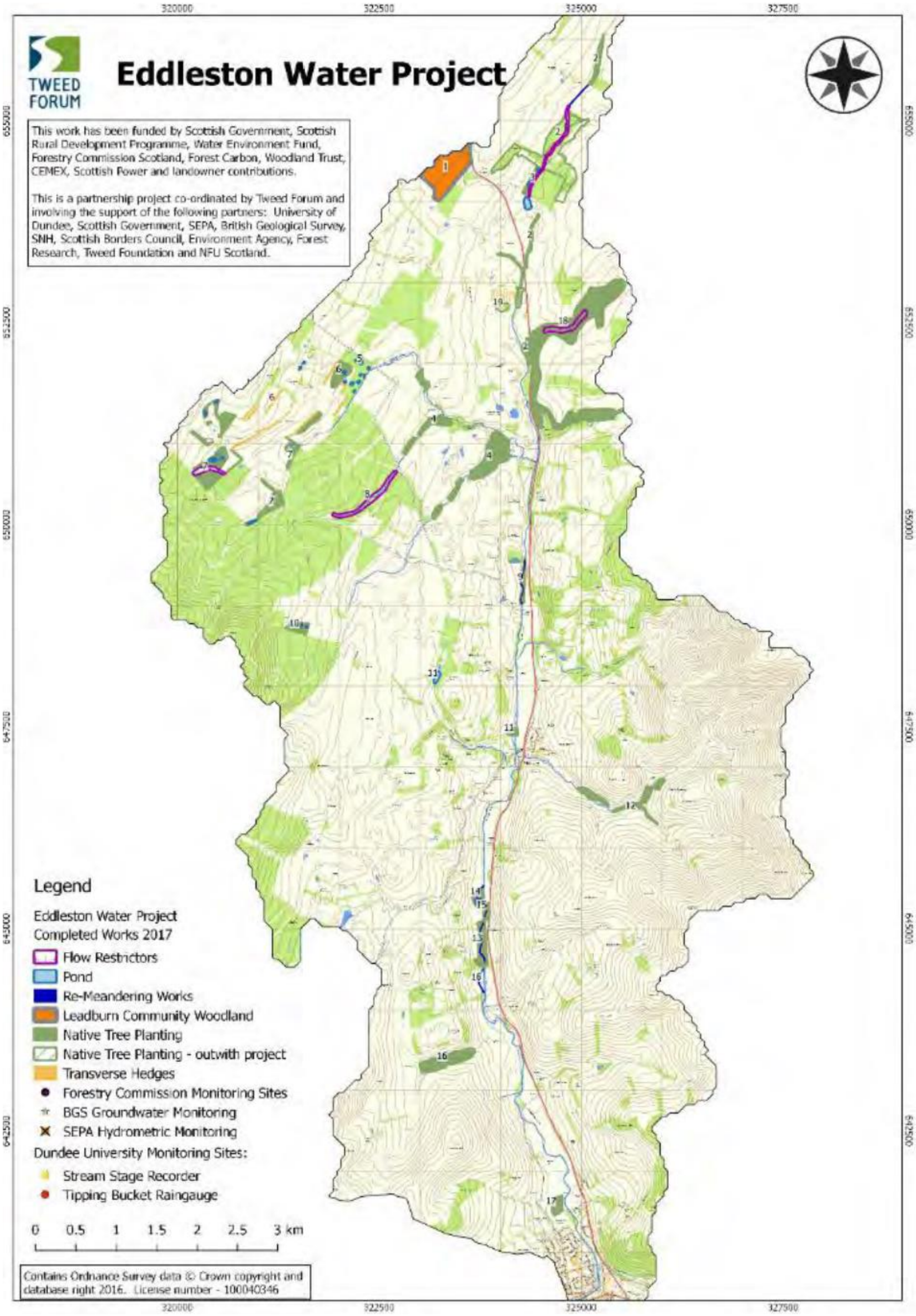


Figure 14 Overview of the Eddleston Water project area, showing locations of woodland planting, transverse hedges, flow restrictors and new ponds (source: Project team Eddleston Water, 2016)

The Eddleston Water project considers multiple measures to combine ecological diversity and reduce flood severity, such as strategic planting and retention areas. The system wide approach and particular attention to a monitoring scheme are considered strong points of this project. Moreover, the project team also focuses on the dissemination of the result to key audiences and local schools. By doing so they hope to increase awareness of flooding in the area and encourage pupils and teachers to learn about their catchment.

The project management of the Eddleston Water project consists of the Scottish government, the Scottish Environment Protection Agency and the University of Dundee (as the main science provider). There is a wider steering group of key stakeholders that includes nature organisations, representatives of farmers and the forestry commission. The partnership extends even wider with local famers and landowners of the Eddleston valley and the communities.

A crucial threat to this project is that it largely depends on the willingness of (private) landowners to change current land use and management practices. However, the project team has been successful in bringing 20 landowners on board and facilitating of a wide range of measures.

3.5 Synthesis: scoring of NBS using the evaluation framework

In the tables below we assign qualitative scores to the three NBS cases on process guidelines, flexibility and design and implementation principles as proposed in evaluation framework from section 2.4. We assign one of three scores to each of the qualitative indicators:

V = indicator is met (score +1)
X = indicator is not met (score 0)
~ = it is unclear if the indicator is met (score +0,5)

Scores of 1, 0.5 or 0 are assigned to each of the indicators and then added to evaluate whether the overall criteria relating to efficiency, effectiveness, social support, and flexibility have been met. We note that the assigned scores to each of the indicators could be different if more extensive documentation were consulted and more in-depth study of the characteristics on each of the NBS were performed. Here, we only evaluated the three cases superficially to be able to demonstrate how this evaluation framework could function. Specifically, each indicator that is now assigned a "~" (unclear if indicator is met, score 0.5), should be further investigated to either score 0 or 1.

In Table 1 the efficiency of the three projects is evaluated. It shows that in general the as-is situation is well described, which is a prerequisite to fully understand the problem or challenge of the problem. Also, system considerations have been taken into account, which allows integral solutions and identification of co-benefits. A clear challenge with NBS is how to define success indicators to monitor progress and success of the project.

Table 1 Evaluation of efficiency of NBS projects

Efficiency (output indicators)	Belgium	Netherlands	Scotland
Has the as-is situation been defined?	v	v	v
Have system considerations (integral approach) been addressed?	v	v	v
Have nature-inspired processes and methods been used?	~	v	v
Have nature-friendly materials been used?	~	~	v
Have uncertainties been addressed?	~	v	~
Have success indicators of the intervention been defined? On different time-scales? For the goals and for the co-benefits?	x	x	v
OVERALL SCORE:	**60% (3.5/6)**	**75% (4.5/6)**	**90% (5.5/6)**

Table 2 scores the effectiveness of the projects, which relates to the extent that project outcomes (achievement of objectives) are achieved and how they perform in relation to alternative (grey) options. It appears that problem definition, suitable interventions and justification of green solutions to solve the challenge have been considered, but that, generally, comparison to alterative grey options and evidence of monitoring of achieving the objective are absent. This is a crucial observation that requires much more attention to assure that NBS achieve a similar status for certain challenges compared with (some) grey solutions.

Table 2 Evaluation of effectiveness of NBS projects

Effectiveness (outcome indicators)	Belgium	Netherlands	Scotland
Is a clear and thorough problem definition available?	v	~	v
Is understood which interventions could solve the problem?	v	v	v
Have alternative (grey) solutions been considered?		~	
Have co-benefits, risk and threats been addressed and identified?	~	v	~
Have the advantages of a green solution been identified?	~	v	v
Did monitoring show that the NBS answered to the objective?	~	~	~
OVERALL SCORE:	**60% (3.5/6)**	**75% (4.5/6)**	**70% (4/6)**

Social support indicators are scored in Table 3, illustrating that common problem understanding, involvement of stakeholders and institutional arrangement are part of the project. Evidence of collaborative learning, and of review and reflection is still lacking, however.

Table 3
Evaluation of social support of NBS projects

Social support indicators	Belgium	Netherlands	Scotland
Is there a common understanding of the problem, solutions or goals?	v	~	v
Was there wide stakeholder involvement? Throughout the project?	v	v	v
Are institutional arrangements made? (enabling environment)	v	V	v
Is there attention for collaborative learning (education and knowledge exchange)	x	X	v
Is review and reflection carried out in the project?	~	~	~
OVERALL SCORE:	**70% (3.5/5)**	**60% (3/5)**	**90% (4.5/5)**

Flexibility of the three NBS projects is assessed in Table 4. It shows that generally little attention is given to explicitly describe the flexibility of the solutions. It is interesting to note, however, that a monitoring plan to guide adaption is commonly included, but that the appropriate adaptation options based on monitoring outcomes have not been described in great detail.

Table 4
Evaluation of flexibility of NBS projects

Flexibility indicators	Belgium	Netherlands	Scotland
Is the intervention flexible?	~	~	~
Are adaptation options included in the design?	x	v	~
Is a plan available for monitoring and evaluation to guide adaptation if needed?	v	v	v
OVERALL SCORE:	**50% (1.5/3)**	**80% (2.5/3)**	**70% (2/3)**

Table 5 summarises the overall score on criteria “Efficiency”, “Effectiveness”, “Social support” and “Flexibility” for the three NBS cases. It shows that there is room for improvement of efficiency in most NBS projects. This is mostly related to the apparent absence of definition of success indicators. This would also improve the “effectiveness” of all considered NBS projects, where in absence of these indicators it is difficult to show that projects have indeed answered to the original challenges. An important point to improve effectiveness of NBS is to make a comparison to grey alternatives. Social support is generally addressed quite well, but still a learning agenda could be strengthened. Finally, the flexibility, one of the key asserted strengths of NBS, generally requires more attention, such that appropriate actions can be taken (if needed based on monitoring of indicators).

Table 5
Overall score on criteria for NBS projects

Criteria	Belgium	Netherlands	Scotland
Efficiency	**60%** (3.5/6)	**75%** (4.5/6)	**90%** (5.5/6)
Effectiveness	**60%** (3.5/6)	**75%** (4.5/6)	**70%** (4/6)
Social support	**70%** (3.5/5)	**60%** (3/5)	**90%** (4.5/5)
Flexibility	**50%** (1.5/3)	**80%** (2.5/3)	**70%** (2/3)

4 Discussion

Below several points of attention and recommendations are given that are closely linked to dealing with NBS, but fell outside of the key focus of this project.

Inspired and supported by nature

'Nature-based' means that solutions are inspired and supported by nature (Raymond et al., 2017). Thus, natural/ecological processes or characteristics are used as (one of) the driver(s) to arrive at a solution. That is what makes the solution 'nature-based'. For instance, digging a secondary channel that improves the landscape or enlarges a certain habitat can only be considered a nature-based solution if there is another issue, such as flood risk, that this measures helps to relieve. This may seem obvious, but it serves to illustrate that you need to make a distinction first between main objectives and co-benefits in order to be able to evaluate the designed and implemented nature-based solution. In the example of the secondary channel, flood risk reduction is the main objective, and landscape improvement or habitat enlargement are co-benefits.

An important distinction that deserves attention within the context of NBS is whether the interventions are qualified as such because use is being made of natural materials or, conversely, if interventions are designed to stimulate beneficial natural processes (or both). A central challenge for an 'umbrella concept' like NBS and other frameworks is where to draw the line as to what is considered as 'nature' or 'natural' (Nesshöver et al. 2017). In the end, what matters is that interventions are placed in a wider temporal and spatial context, that sustainability is addressed, that uncertainties are addresses, that negative impacts are reduced and (co-)benefits are exploited. These aspects make any successful NBS project inherently multi-disciplinary and call for cooperation across disciplines.

Look ahead and deal with uncertainties

Before and during design and implementation of NBS one should anticipate on what may lie ahead. As was argued in chapter 2, grey solutions are commonly applied because the urgency of the problem requires immediate and visible action. NBS is then easily brushed aside under the premise of "no time to loose" and the need for implementation of proven concepts with immediate impact. Early identification of a problem, and thereby the possibility of gradual implementation of a solution, is the apparent prerequisite for NBS. Next, because of the "naturalness" of the solution, both its current functioning and its performance in the future are uncertain. It is essential to anticipate and see whether the system will function as intended under a range of projected futures. A plan should be made on how to deal with such uncertainties.

Monitor and be ready to adapt
NBS are implemented to solve a problem or situation by using natural processes or to stimulate a desired outcome, while at the same time providing various associated benefits (socially, ecologically, etc.). Inclusion of natural processes introduces uncertainties in finding the most suitable design and functioning of the NBS. Monitoring and options for adaptation of a solution should therefore be an inseparable component of a NBS.
Also, by monitoring the impacts of a NBS in a broader scope it becomes clear what the true overall benefits of the NBS are. These are needed to justify further implementation of NBS, especially if the immediate economic costs of NBS do generally not speak in favour of NBS over traditional grey solutions.

5 Summary and conclusions

Based on literature, we proposed an evaluation and assessment framework to be able to compare objectively NBS on different scales and in in different regions with different governance structures. The elements of the framework come from a literature review and can be considered as a common denominator of the key literature. The literature reveals that to evaluate NBS it makes sense to distinguish between design and implementation aspects that relate to the efficiency and effectiveness of the project. Thereby the extent to which outputs and outcomes are achieved can be assessed. Additionally, the project process and project flexibility should be considered and evaluated to make sure that social support is achieved and that co-benefits are identified and stimulated where possible.

A key challenge in many NBS is however to define and apply suitable indicators which serve to monitor progress and success of the project. Additionally, by keeping track of performance indicators of the NBS, also more advantage could be taken of inherent flexibility of the NBS by alerting for and guiding possible interventions if needed. For this purpose, in the design phase the choice for a particular intervention needs to be clearly justified and comparisons to projected null-situation (do nothing), alternative grey solutions or otherwise undesired impacts should be made. These considerations should help to define the crucial indicators that allow to keep track of and adequately respond to the management and performance of the NBS during implementation and the operation phase.

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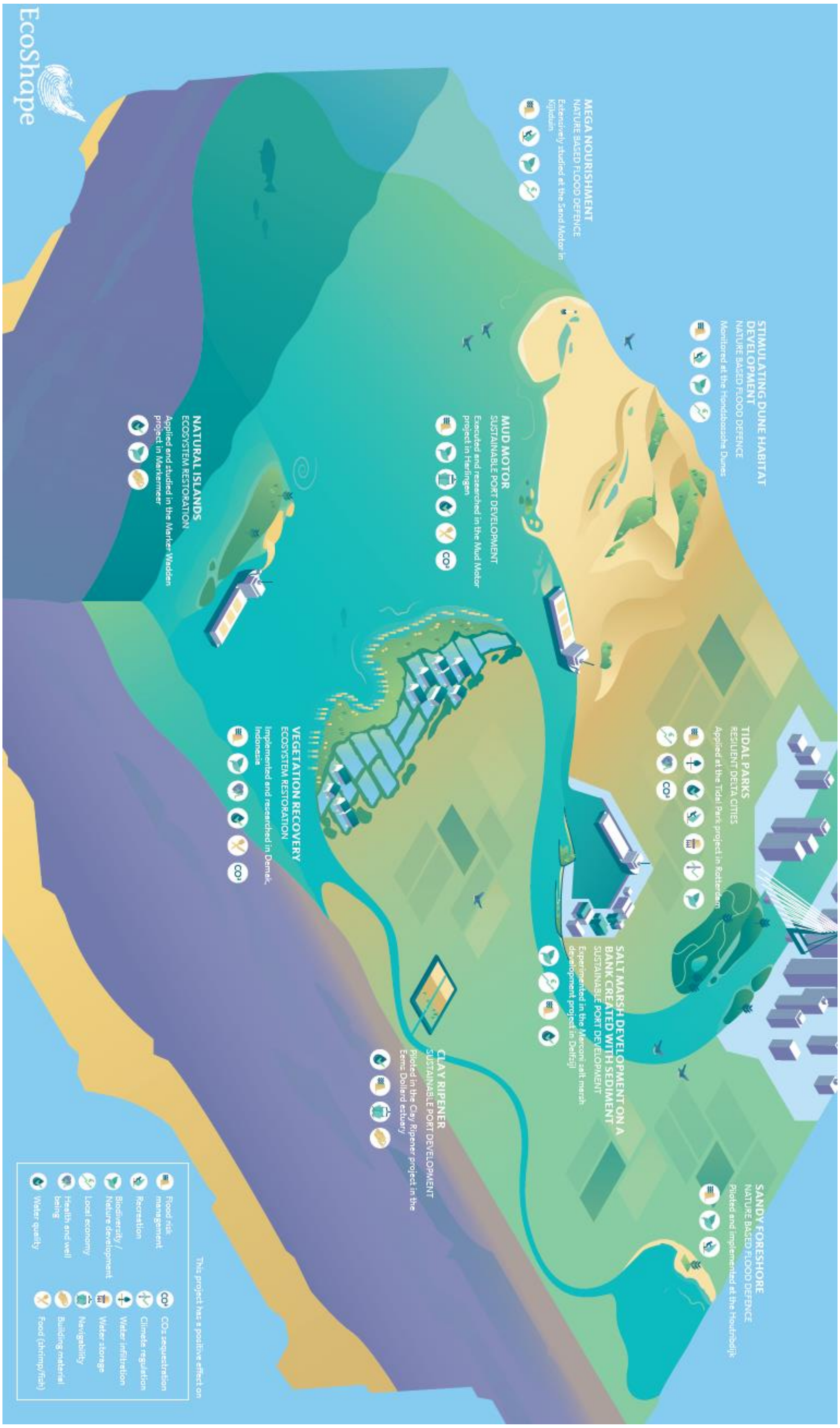
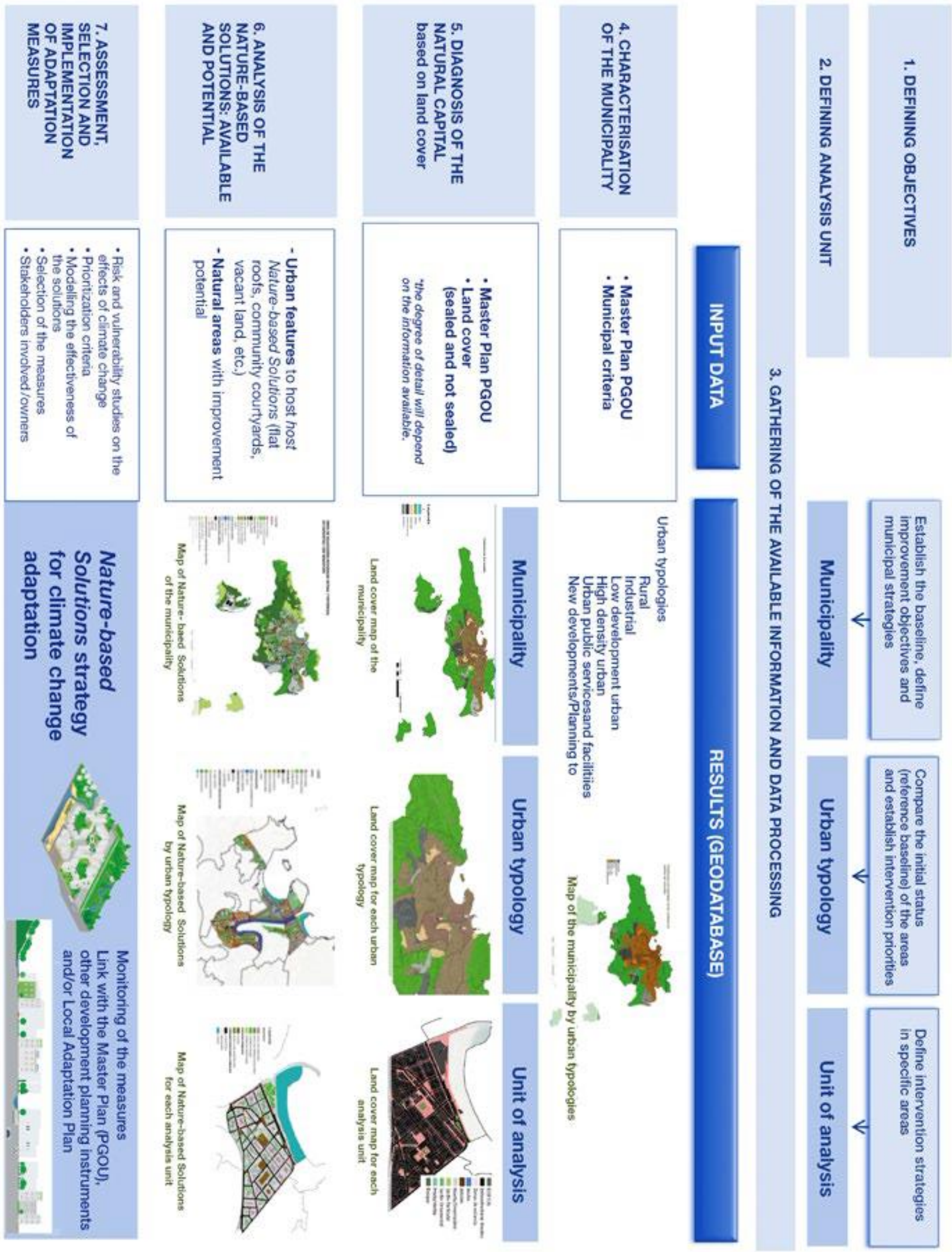
Appendices

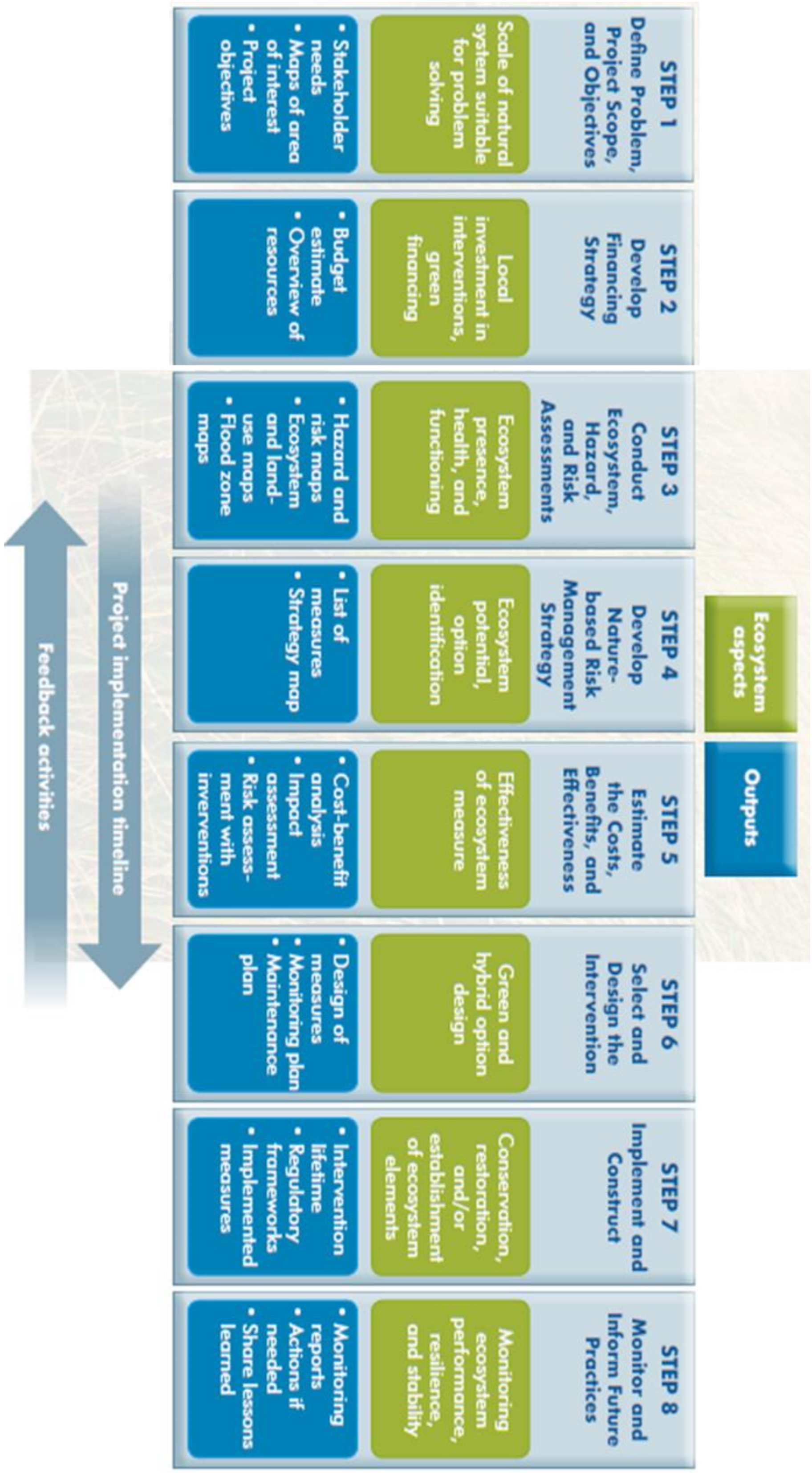
A Ecoshape NBS examples



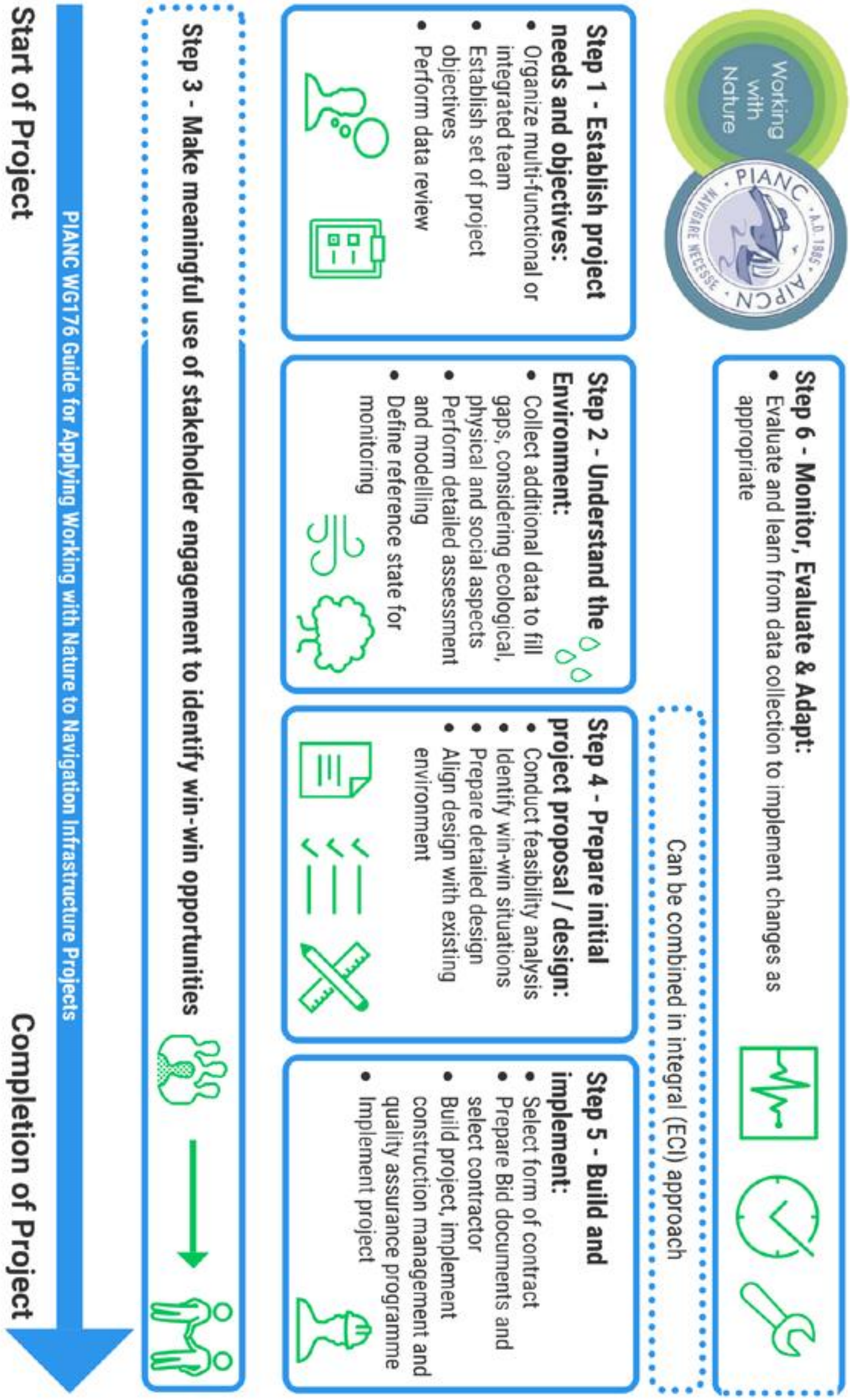
B IHOBE design framework



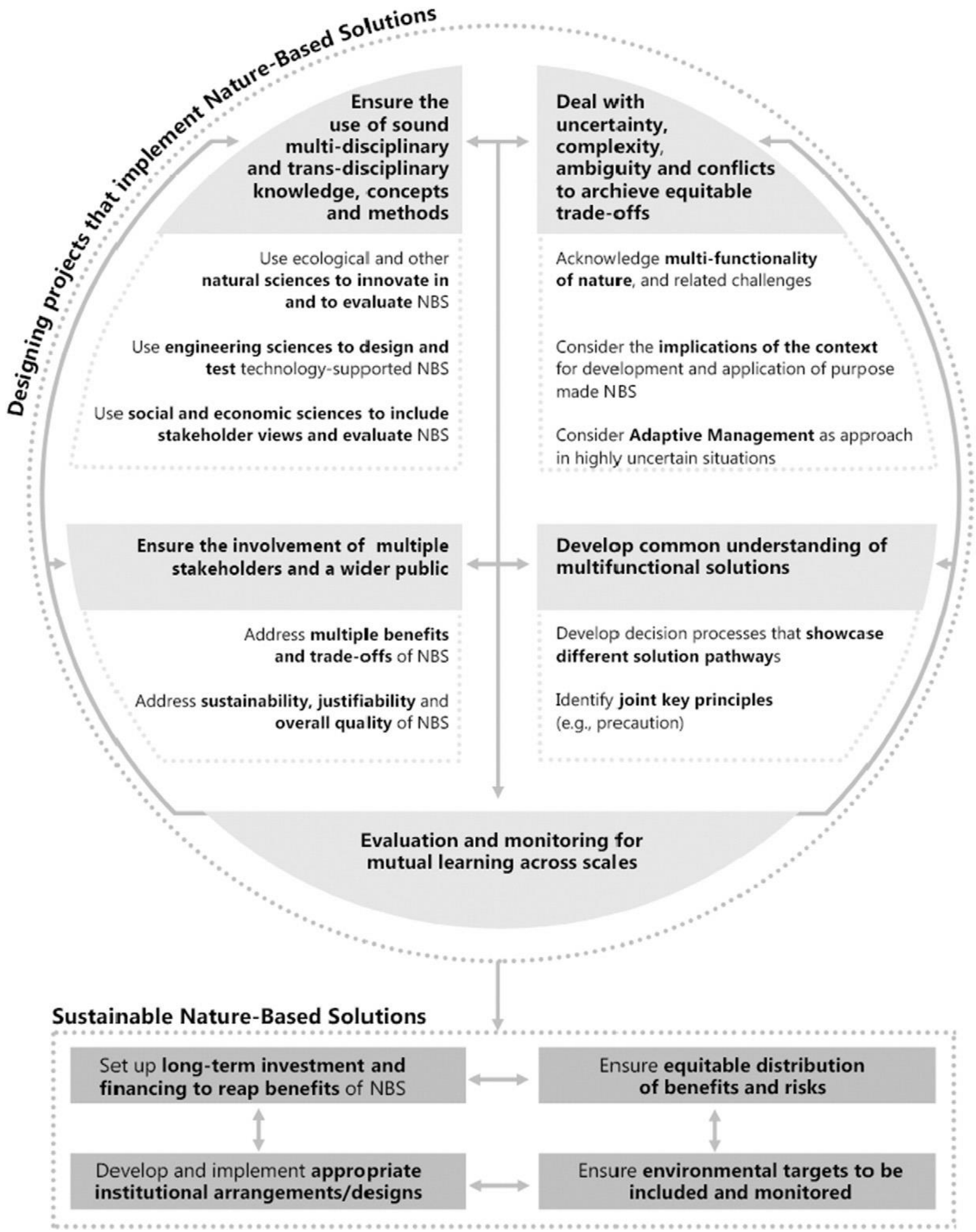
C World bank implementation guidance



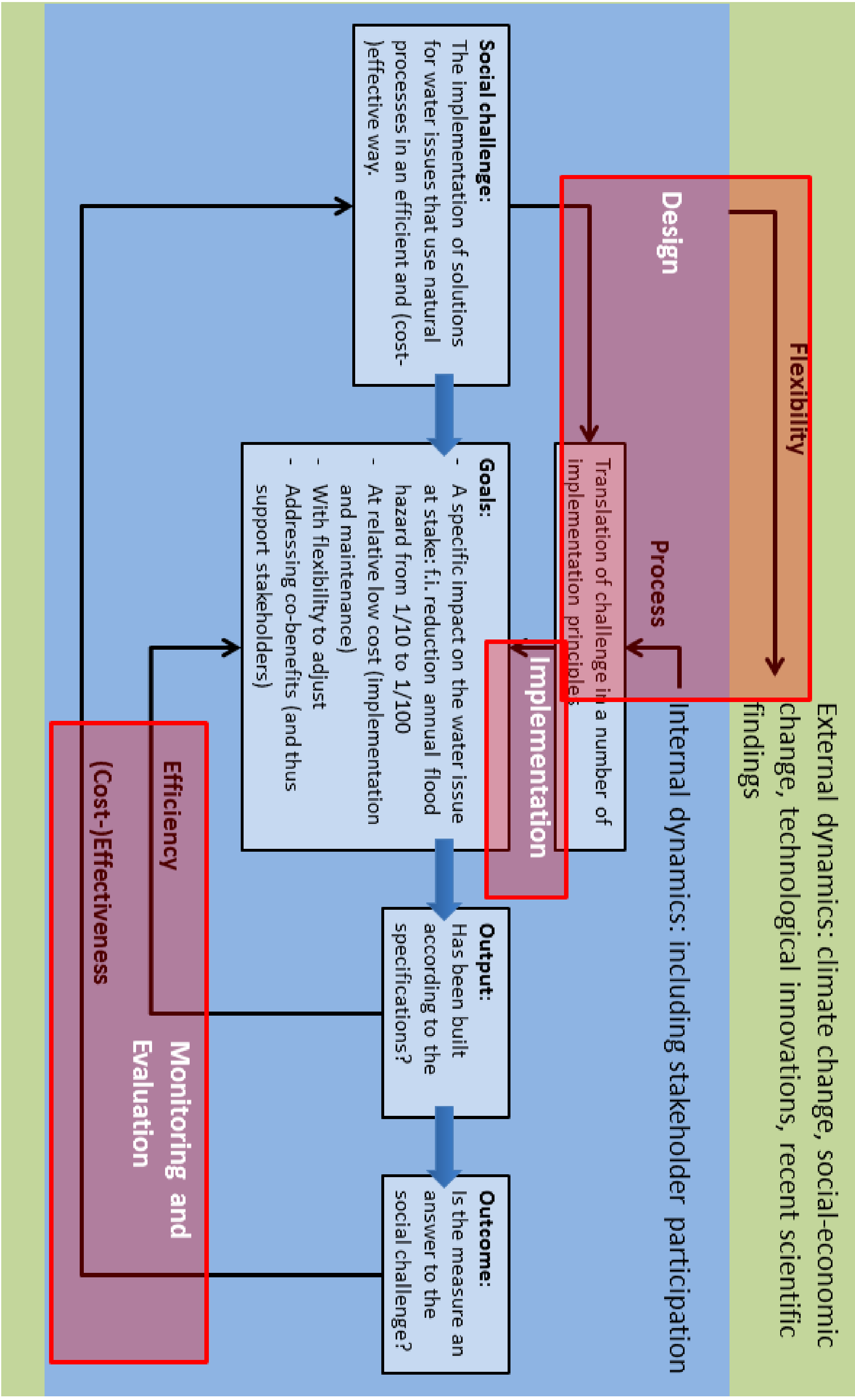
D PIANC implementation framework



E Nesshöver NBS framework



F Essential elements for NBS evaluation framework



Head office
HKV Consultants
Botter 11-29
8232 JN Lelystad
The Netherlands

PO Box 2120
8203 AC Lelystad
The Netherlands

Branch office
Elektronicaweg 12
2628 XG Delft
The Netherlands

+31 (0)320 29 42 42
info@hkv.nl
www.hkvconsultants.com