More effective knowledge sharing of nature-based flood defense pilots

A knowledge base approach

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TU Delft

Deltares

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by

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to obtain the degree of Master of Science
at the Delft University of Technology,
to be defended publicly on Monday September 25, 2023 at 12:30 PM.

Student number:	5412064	
Project duration:	February 1, 2023 – September 25, 2023	
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Preface

This thesis found its inception in the second year of my MSc Management of Technology. I had elected to follow a course called Building with Nature as part of a Water and Delta systems specialisation. Building with Nature and nature-based solutions fascinated me and I decided to approach the lecturer for possible graduation projects. Together Jill Slinger and I came up with an idea to investigate building a database for nature-based solution pilots. Jill eventually became the chair of the graduation committee and linked me with Heleen Vreugdenhil at Deltares for an internship. Here we began developing the idea while I was writing a research proposal. Throughout the process of writing a research proposal and later on in this thesis, the aim and scope became more clear: I would develop a knowledge base for nature-based flood defense pilots in and around rivers!

It has been a tumultuous process for me that taught me many things. I was forced to learn how I can unwind. Secondly, when I lose the plot I should go back to pen and paper. Besides this, I am happy to have learnt a bit of web development. To be honest I knew that it was not my strong suit and had given up on two prior projects. By committing to such a design research it forced me to face the never ending troubleshooting and finicking that plagues web development.

Throughout the writing of this thesis, I have enjoyed learning more and more about nature-based solutions. After graduating I hope to stay involved with nature-based solutions as I strongly believe improving biodiversity and restoring habitats is important for the future. I am both frightful and excited for the future; frightful for what could be and excited about all the projects and programmes currently happening. An example of a programme I am particularly interested in is called NL2120 which is exploring how the Netherlands may look like in a hundred years time if nature-based solutions are employed.

Writing this thesis has not been an individual effort; acknowledgements are in order. Firstly, I am thankful and acknowledge how fortunate I am to have had a very active, engaged, and supportive set of supervisors. I am still amazed at the fact that you were willing to spend so much time guiding me: I truly appreciate every meeting we have had. The same goes for some distinguished individuals that have provided additional council along the way. It has really helped me that I had great study buddies to take breaks and walks with. I also want to thank my family, friends, housemates, and others in my support system for their continued interest and kindness. I am extremely grateful to all interview participants, I could not have done this research without their gracious time and input. Lastly, I would like to express my thanks to (those at) Deltares for the opportunity of an internship and the freedom to explore such an interesting topic.

I hope you enjoy reading this thesis. My main takeaway would be that a centralised knowledge base for Dutch nature-based flood defense pilots, which stores information in a standardised manner, will be invaluable for the future. As a teaser, below you may find the first nature-based solution pilot I have made: a pond in my grandma's garden. More coming soon.

Summary

This thesis looks at a specific type of project: nature-based flood defenses pilots. Nature-based flood defenses are a type of nature-based solution that are typified by providing benefits to human well-being, biodiversity net gain, and reducing flood risk. There are a few reasons why there will be a lot of nature-based flood defenses pilots coming in the future: a lot of innovation is happening as this is a relatively 'new' technology, nature-based flood defenses are not fully understood, they are not 'tried-and-true' like many conventional engineered infrastructure (e.g. dikes, dams, weirs, etc.), and they are very context-dependent so often one or more pilots are run to test the technology thoroughly.

Nature-based flood defenses (and nature-based solutions as a whole) are gaining in popularity and are increasingly recognised as important solutions to climate change. Since floods or extreme high water events are projected to occur more frequently, nature-based flood defenses will have more societal significance. Rijkswaterstaat, the operational part of the Dutch Ministry of Infrastructure and Water Management has also recognised that nature-based solution should be considered first when planning and designing new infrastructure. Currently, however there is no standardised process for monitoring and evaluation of nature-based flood defenses pilots. Therefore, they cannot be compared fairly with other nature-based flood defenses technologies and conventional solutions. This study looks at developing such a process by way of a monitoring and evaluation framework and knowledge base, using a research-by-design approach. A knowledge base is also developed to store the results of monitoring and evaluating and to effectively share knowledge about each pilot for future reference and other pilots.

Following a research-by-design approach, first literature study was performed and expert interviews held to define the problem and collect relevant information for development of a solution. This was analysed and informed a design and development phase for the monitoring and evaluation framework and knowledge base. This initial solution was then demoed after which feedback for improvement of the solution was elicited. Such design-feedback iterations formed an improvement loop. In total, the solution was subject to three iterations after which a final solution was validated.

The main research question was 'how can Rijkswaterstaat improve its monitoring and evaluation process of nature-based flood defense pilots in rivers and floodplains?'. In an aim to answer the main research question, sub-questions were investigated. It was found that monitoring and evaluation of Rijkswaterstaat projects is done through indicator-based assessment whereby evaluation questions are formed to decide on evaluation criteria for which monitoring indicators are chosen. There is however not (yet) a standard monitoring and evaluation process for this type of pilot (project) with standard criteria and indicators. Based on previous pilots it was found that monitoring mostly focused on hydraulics, morphology, and ecology while neglecting the social and political context. Monitoring may receive too little resources and attention. To be able to suggest improvements for monitoring and evaluation, important considerations for nature-based flood defense pilots were compiled. Findings indicate that monitoring should be done on the biggest spatial scale possible, long-term, and at moments that align with natural changes. Other such considerations are that evaluation should occur not only after completion but throughout and focused on for example flood risk, ecological impact, economical impact, and social effects. All these considerations were incorporated into a M&E framework that also combined two existing evaluation frameworks: one general evaluation framework from OECD and a framework from IUCN for NBS. Besides monitoring and evaluation, the third sub-question looked at the requirements for a knowledge base that stores information of nature-based flood defense pilots. In essence this boiled down to the question 'what do intended users want to know about previous pilots?'. Through interviews and literature, various pieces of meta-information that should be included e.g. photos, the problem, eventual implementation, costs, a timeline, implementing partners, the project leader, contact details, etc., etc.

Results of this study looked to validate the current solution and findings indicated that a knowledge base approach with a monitoring and evaluation framework has merit. All interview participants thought that saving information and evaluations online in a standardised way has added value. All but one

thought that such a knowledge base is a good idea for better knowledge sharing. Based on the current design, a large majority of the interview participants would (already) like to use the knowledge base to search for information about previous nature-based flood defense pilots. Results also indicated that the knowledge base still has room for improvement and efforts should be made to develop the M&E framework further to address specific needs and wants from Rijkswaterstaat practitioners and other stakeholders. All in all, a knowledge base approach is probably based on correct presumptions (could not be tested on a sample of statistically significant size) and the primary intended users of such a knowledge base are interested and the final solution shows a lot of promise but it is advised to continue development while researching other aspects to include and parts that may be excluded.

As a final recommendation, results indicate that Rijkswaterstaat could adopt the monitoring and evaluation framework that is developed in this study as a template in their organisation-wide innovation process and store information on a knowledge base (the developed prototype as an example) after each evaluation moment of a nature-based flood defense pilot.

It is necessary to acknowledge that this study had limitations. The most notable limitations were the interview participant sample size, recurring participation, and the scope. The sample size is a limitation as six interviews provided the majority input on which development was based, five interviews provided feedback for improvements, and validation results were elicited in five last interviews. Interviewees that participated in the first round of interview were also asked to give feedback for subsequent improvement. This means that results of their interviews can show a bias: their views were already incorporated into the design so they are more likely to not find fault with the solution. Lastly, the scope was limited to researchers but due to the multidisciplinary nature and small sample size, perspectives from a lot of relevant social sciences and other disciplines were not incorporated which results in a limited view. Moreover, many other stakeholder groups of nature-based flood defense pilots

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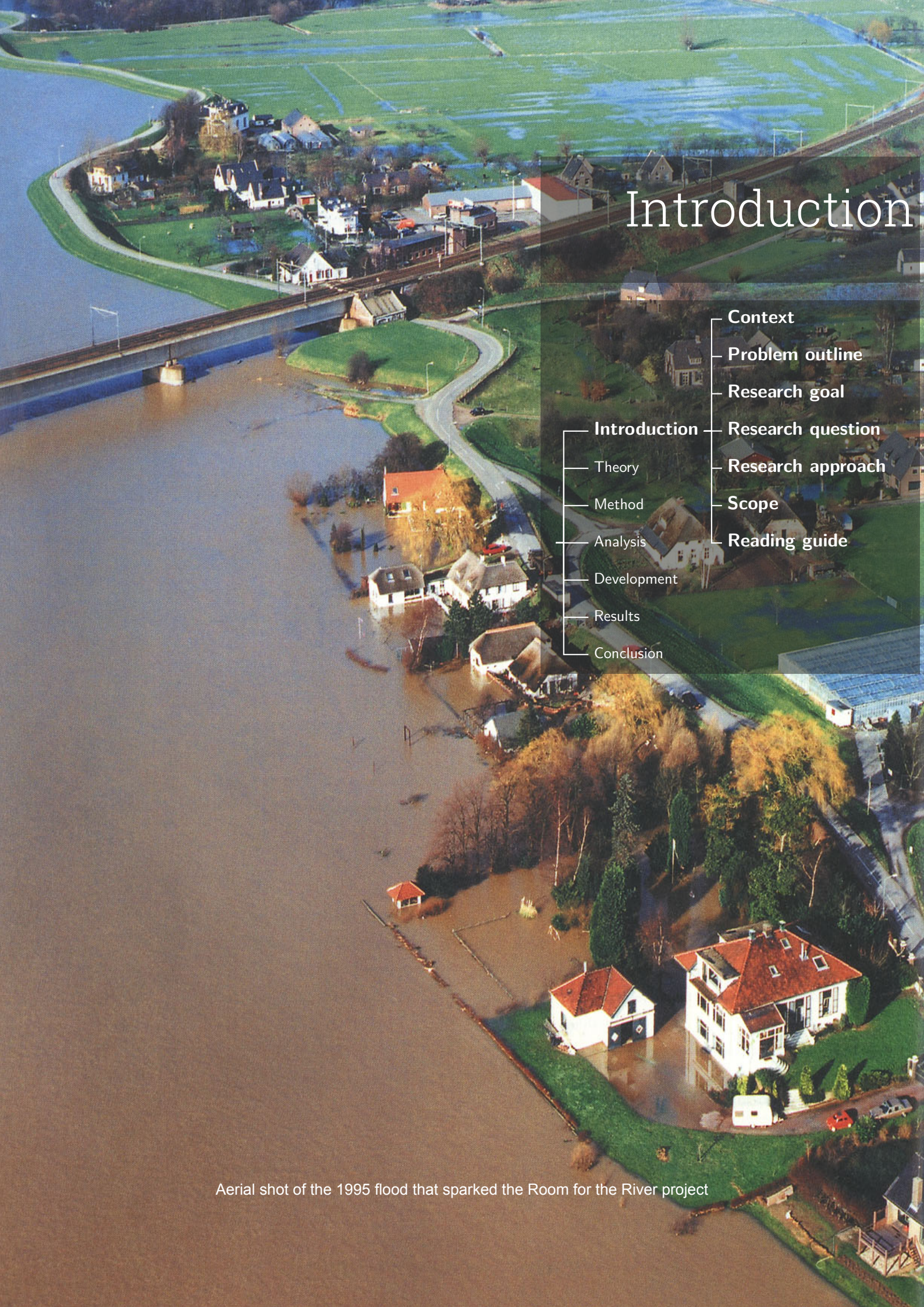
Nomenclature

Abbreviations

Abbreviation	Definition
NBS	Nature-based solution
NBFD	Nature-based flood defense
FRM	Flood risk management
R&D	Research & development
BACI	Before-After and Control-Impact monitoring approach
RWS	Rijkswaterstaat
HWBP	Hoogwaterbeschermingsprogramma
PAGW	rogrammatische Aanpak Grote Wateren
MWTL	Monitoring Waterstaatkundige Toestand des Lands
TRL	technology readiness levels
SRL	stakeholder readiness levels
WFD	Water Framework Directive
IUCN	International Union for Conservation of Nature
OECD	Organisation for Economic Co-operation and Development
PIU	primary intended user
UI	user interface
ICT	Information and communications technology

Introduction



Aerial shot of the 1995 flood that sparked the Room for the River project

1.1. Context

We are currently in a planetary crisis.

You may have your own preconceptions about the aforementioned planetary crisis; you may have immediately thought about climate change. Currently, there are more crises happening at the same time. The United Nations Environment Programme speaks of a nature crisis [9] and the United Nations mentions that we are a facing an interlinked triple planetary crisis [10] looking at climate change, biodiversity loss, and pollution. So unfortunately, climate change is not our only worry.

Natural disasters are also occurring more frequently due to climate change [11]. Nine times out of ten, changes induced by climate change manifest itself in water-related disasters such as flooding [12]. This is a major challenge as floods are the most frequent and damaging natural disasters, globally [13]. Managing floods is delegated to 'flood risk management' which focuses on managing three categories of flooding: coastal, pluvial, and fluvial floods. All types of flooding are projected to increase in risk and damage potential [14]. Flood defense has always been (vitally) important for the Netherlands as it has a large coastline, lies in the river basin delta of four international rivers, and large parts of the country lie below sea level, making it extra vulnerable to flooding [15, 16]. Increased incidence and severity of fluvial or river flooding is, thus, very worrying. Fluvial floods are therefore an important part that needs to be addressed in climate change adaptation strategies.

Rijkswaterstaat (RWS), part of the Ministry of Infrastructure and Water Management, is responsible for flood protection through construction and maintenance of flood defense structures [17] and active monitoring of water levels [15]. Historically, RWS has managed rivers with large dams, levees, canals, etc. Although there are benefits to these conventional approaches of riverine flood risk management with built infrastructure, such as less uncertainty and variability through careful control, but there are also downsides: they can have negative effects on ecosystems, there are huge costs involved, they are not very adaptable, they can actually increase flood risk or merely shift the locality of exposure, etc. [13]. Nature-based solutions (NBS) can provide the solution here as an alternative to the conventional built infrastructure approach by way of hybrid methods or fully natural 'green infrastructure' i.e. only using ecosystem elements [13]. NBS are a more natural way of decreasing flood risk that costs less for construction and maintenance and comes with many added ecosystem service benefits whereas built infrastructure often provide a singular benefit. In this way, NBS represent 'low regret' or 'no regret' climate adaptation strategies and that is why NBS solutions are gaining traction [13]. However, there remain a lot knowledge gaps and evidence for the 'reversibility, flexibility, cost-effectiveness and feasibility, and/or long-term sustainability' [18] of NBS which poses a barrier to larger scale adoption.

Nature-based solutions are also one of the possible answers for the biodiversity crisis as, by definition, NBS provide a biodiversity net gain. Some experts say that biodiversity loss is a crisis even more critical than climate change [19] as *"the biodiversity crisis (i.e. the rapid loss of species and the rapid degradation of ecosystems) is probably a greater threat than global climate change to the stability and prosperous future of humankind on Earth."*. The biggest driver to the loss of species and degradation of ecosystems is due to human use of the land and sea or habitat destruction by converting natural habitats such as forests and wetlands for agricultural and urban uses [9, 20]. Rivers are important for wildlife and for biodiversity [21] and NBS in the rivers would counter-act this by conscientious land/river 'use'. Many different types of habitats are found near and in rivers and streams. Rivers provide a pathway for organisms to travel and often link fragmented habitats. This connection is important because organisms need to move between habitats during the life cycle (e.g. seeds drifting downstream or fish migrating to spawning sites) but they also move with changing river conditions (e.g. find shelter during floods). Another type of connection that is important for rivers are the hydrological connections to floodplains to provide essential nutrient inputs. Any break in the links of the chain can adversely affect the biodiversity of the entire river [21]. NBS can play an important role in restoring the biodiversity and functioning of rivers.

In sum, NBS potentially have a positive effect on biodiversity and climate change. What about the climate change induced effect of increased flood hazard? Nature-based solutions can also defend, prevent or mitigate flood risk. These are called nature-based flood defenses (NBFD). Since these interventions are relatively new and unconventional approaches to flood risk management and highly context-dependent for its implementation, they need to be tested before they can be implemented more widespread (i.e. scaling up). This study looks at how such NBFD pilots should be monitored and evaluated in the context of Dutch rivers and how knowledge gained throughout a pilot can be shared effectively using a knowledge base.

1.2. Problem outline

As mentioned in the previous section, floods among other water-related disasters have been showed to occur more frequently and with increasing severity [22]. With ongoing climate change, flood management is becoming more challenging and demanding [22]. Conventional flood defenses (such as dikes, dams and, floodgates) are already costly to maintain and due to increasing flood risk but they will need to 'grow' ever higher and wider [23]. Preparing for more extreme floods in the future is going to be driving costs of infrastructure up a lot [24, 25] while such built infrastructure also lack the flexibility, sustainability and resilience needed for the future [26]. This is a concern but NBS can be a cost-effective solution more effective for an uncertain future [26] that can provide flood risk reduction and have multiple other benefits such as a positive effect on biodiversity and climate change mitigation [22]. This is sorely needed since up to 90% of European floodplains no longer maintain functioning ecosystems, both increasing flood risk and culling habitats with high biodiversity [24].

For a sustainable future, it is necessary to innovate and transition to nature-based approaches [25]. Why then are NBS not implemented more widespread? A lot of NBS opportunities remain unseized [27] and according to literature, this is mainly due to a lack of *"sufficient technical references, design standards and guidelines"* [22]. For conventional infrastructure, there are standards and guidelines that also allow for evaluating effectiveness but for NBS that has not yet been adopted into regulations or standards [13]. A more substantial knowledge and evidence base is needed to accelerate uptake [22]. This would also help answer many of the knowledge gaps surrounding NBS [28]. For example, there is not enough information about the performance of NBFD under extreme conditions [13] but others have found that NBS can be less effective during extreme events [29]. Other knowledge gaps that relate to uncertainty are about the level of flood safety, how long it takes to become fully operational, and the level of resilience with respect to concurrent extreme events [29]. Conventional solutions are more certain also with regards to extreme conditions so that is why it is not necessary to remove existing infrastructure, NBS can also work in redesigns or hybrid solutions [3]. Further research into the performance evaluation of individual NBS and in hybrid solutions will be beneficial [22]. Additionally, the interaction of flood mitigation and protection solutions, on multiple spatial scales, are not fully discerned [30].

NBS take a longer time to provide a designed or required level of operational service: mangroves, for example, need to grow before providing protection [31] In addition to the previous knowledge gaps, firstly, there is a need for assessment frameworks, with appropriate long-term monitoring indicators to provide evidence of the intended (eco-)benefits [32]. Effective monitoring is also need for performance assessment and finding evidence for best practices with regards to NBS [8]. There is also among all the other knowledge gaps pertaining to NBS, a need for standardised cross-site comparison [28, 33]. It has also been reported that more investment is needed in communication of results for the enhancement of flood risk management strategies [30] and more knowledge of NBS should be broadcasted [13]. Often project knowledge is stored in knowledge bases [34] and there is a need for representations in knowledge bases that balance *"rich descriptions of cases on the one hand, and comparability and transferability of results, on the other"* [35].

1.3. Research goal

Floods are expected to occur more frequently but NBS under the effects of extreme conditions are less certain. More research results are needed through evaluation of individual and hybrid solutions. It was found that there is need for an evidence base and knowledge base for NBS. Moreover, there is also need for a standardised assessment framework and standardised indicators for cross-site comparison; this would help in future decision-making about most suitable solutions. Assessment however should be done via long-term monitoring as NBS performance evolves and it takes some time to provide the multitude of benefits.

This research tries to combine these insights to develop a specific knowledge base for NBFD pilots which incorporates a M&E framework for long-term monitoring and standardised assessment for cross-site comparison while providing rich descriptions of each case. Additionally, the M&E framework should tie into the current monitoring & evaluation procedure of RWS, since RWS is the responsible party for flood protection of major rivers in the Netherlands.

1.4. Scope

Pilot projects are a special type of project [36]. Pilots are an important tool in exploring or evaluating innovations [37]. The results of a pilot can be dissected by looking at its effect on three levels [36, 38]. This scope is confined to the first level (biophysical, tangible results and changes in the network of actors and stakeholders) and the second level (knowledge gained and created during the pilot project).

This study looks at pilots of nature-based solutions with a primary focus on flood defense/mitigation/control that are in and along Dutch rivers. In the Netherlands, the connection between the river and its floodplain has been largely severed by dikes, after the main rivers in the Netherlands were channelised, as illustrated in Figure 1.1. That is why the specific scope is the rivers and (what remains of) their floodplains constrained by dikes.

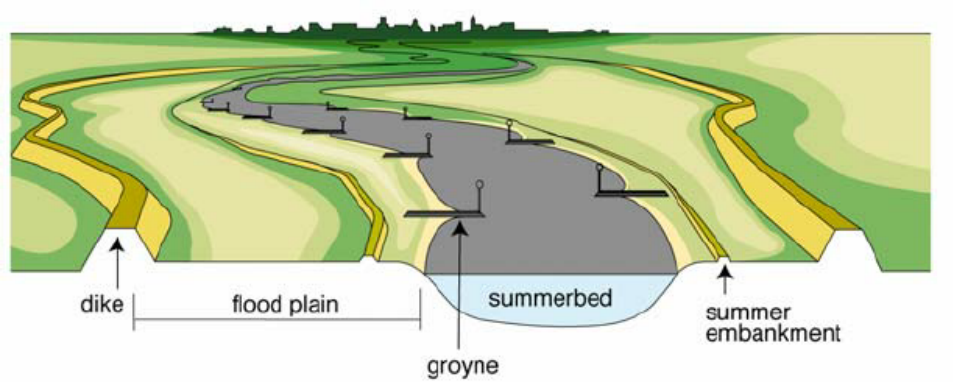


Figure 1.1: Cross-section of a typical Dutch Rhine branch [1]

An all-encompassing definition of evaluation is chosen as the scope. There are many types of evaluation to choose from but it was left open during the research. It was investigated what type of information intended users wanted to know from an evaluation, be it process-related, impact, product, the design, etc. Initially, the scope was ex-post evaluations but during analysis it was decided to broaden the scope.

Lastly, the knowledge base that is developed is intended for researchers. At first it was intended for RWS practitioners and researchers but it became apparent that this would be too big of a scope for this research. At the end, there are many suggested changes for the knowledge base to accommodate RWS practitioners.

1.5. Research question

Addressing the knowledge gaps and research goal, the main research question for this thesis is defined as follows.

> How can Rijkswaterstaat improve its monitoring and evaluation process of nature-based flood defense pilots in rivers and floodplains?

Answering the following sub-questions helps inform the overall research question.

- What is the current monitoring and evaluation process at Rijkswaterstaat for nature-based flood defense pilots in rivers and floodplains?
- What are important considerations for monitoring and evaluation of nature-based flood defense pilots in rivers and floodplains?
- How to construct a knowledge base for effective knowledge sharing of nature-based flood defense pilots in rivers and floodplains?

1.6. Research approach

An iterative research by design approach Figure 1.2 has been adopted and modified for this research. Where at first the problem to be solved is defined, information is collected and analysed, a solution

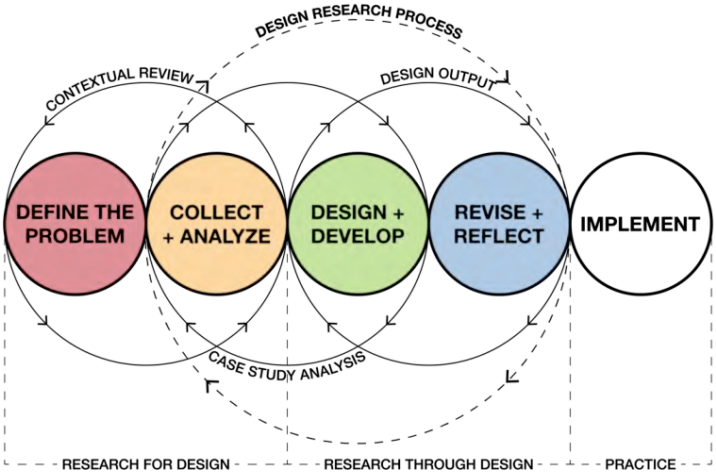


Figure 1.2: Research by design approach [2]

is designed and developed, which is then revised based on feedback until satisfaction, and lastly the solution is put into practice.

To show the link with this research by design approach, the scheme adopted in this research approach was illustrated in Figure 1.3 using the same colours and style. This research approach started with a Phase I where research is done *for* design i.e. before design starts. A review was done on existing literature relevant to the research question **(1)**. Following this, interviews were done with practitioners and researchers **(2)** to gain an insight into the goings-on at RWS and find out what aspects of NBFD pilots in rivers should be evaluated **(3)**. The next Phase II is the research through design loop. Having a better understanding of the current goings-on, an improved evaluation framework can be developed and proposed **(4)** by combining garnered insights and best practices found in literature. Following this, a database and website are developed **(5)** to showcase an evaluated pilot using the proposed evaluation framework. Thoughts and opinions on this online demonstration of can be collected through an online questionnaire to relevant parties **(6)**. This feedback is analysed **(7)** and fed back into the development of the evaluation framework and database **(4-5)**, to create an iterative development and feedback cycle for two more iteration to ultimately land on a refined model. The last Phase III is to compile all results, findings, recommendations, implications, and discussion of the results in a report **(10)**. This is concluded

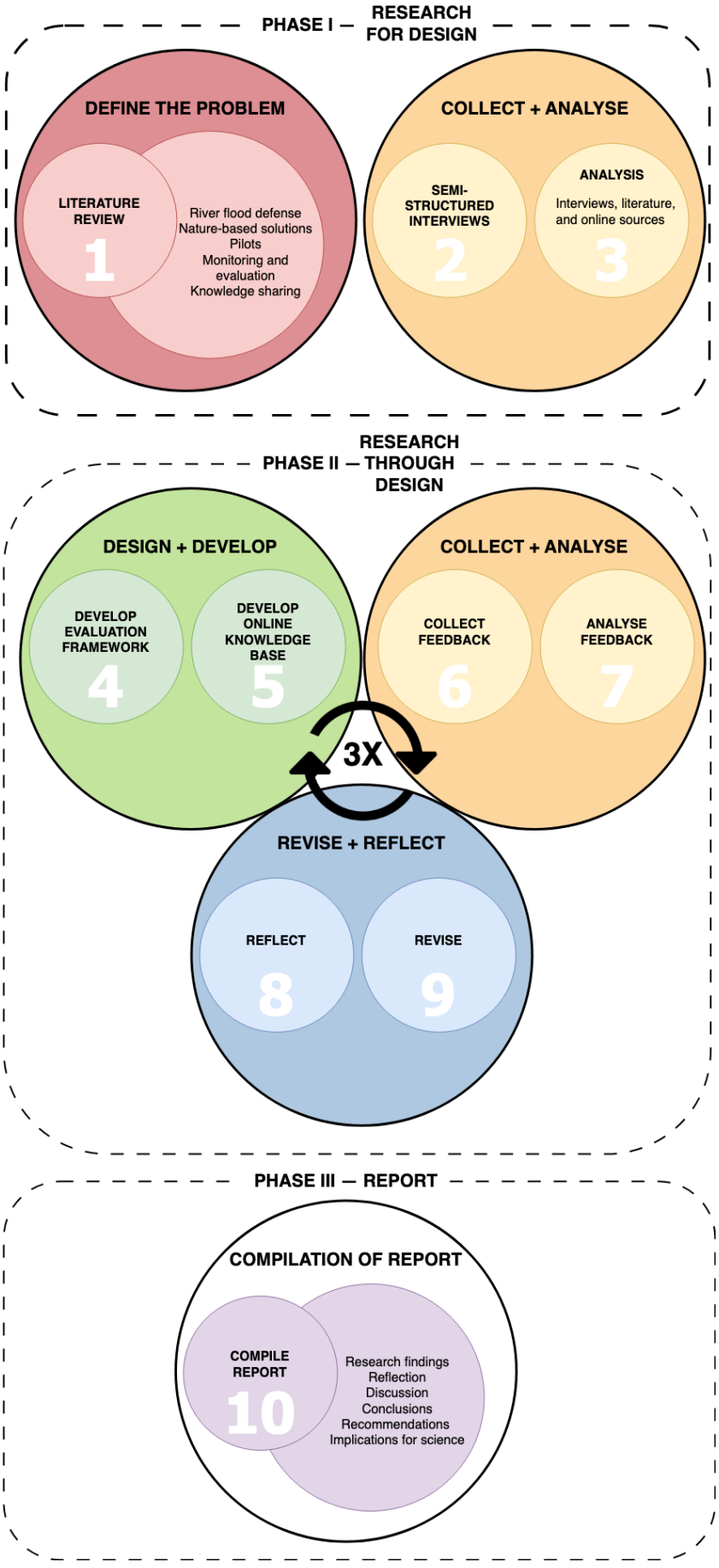


Figure 1.3: Research approach

1.7. Reading guide

Firstly, to remove any confusion about the use of both the terms NBS and NBFD throughout the text: it was decided to keep the term NBS in statements derived from sources writing about NBS in a general sense, as to not assume that their findings would be completely applicable to NBFD (although likely). The reader can presume mentions to apply to NBFD but it would be wrong to assume so.

Throughout the report, care is given to help the reader by providing visual context information. Therefore, at the start of each chapter, a navigable tree graph shows an overview of the sections (click on the nodes to hop over to the selected section). Also, using an overview of the research approach, steps taken in said chapter are indicated. Additionally, throughout the report you will find little breadcrumbs like this ● that aid in the telling of the overall story. These breadcrumbs mark the end of an important statement that is used later in the report or (partly) answer one of the research questions.

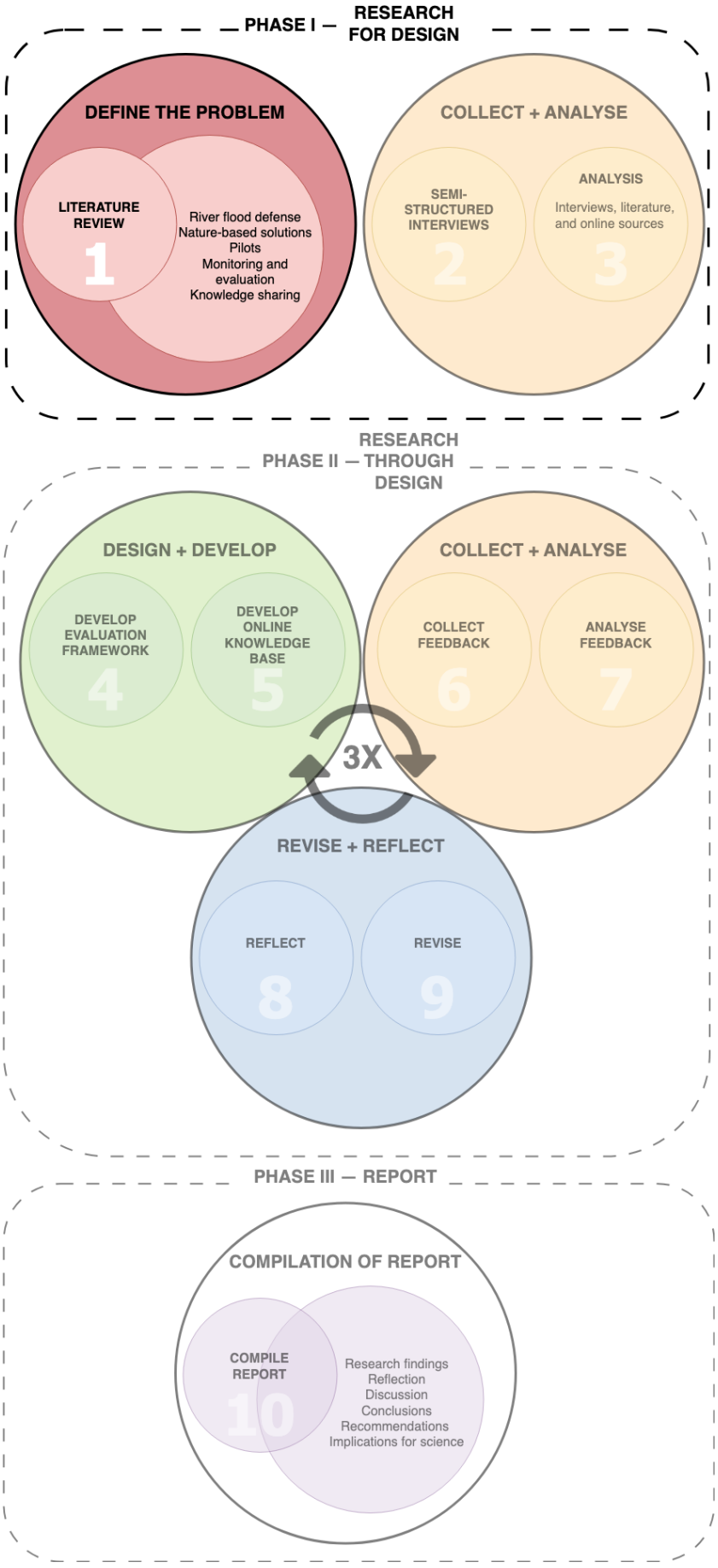
This particular breadcrumb ● means the end of an important statement, that was used in answering the main research question. Similarly, you may find ● indicating interesting notes about the first sub-question. At the end of statements that are important for the design of a monitoring & evaluation framework, this breadcrumb ● is used. The last sub-question pertains to the development of a knowledge base and the reader is advised to look out for this breadcrumb ● Near the end of this report there is a section that describes possible avenues for further development (section 7.3) of the knowledge base. Interesting statements that were not implemented in the eventual solution but have merit for further development are indicated with this breadcrumb ● Lastly, findings that warrant closer inspection and further research are highlighted as such ●

● Main
● Sub1
● Sub2
● Sub3
● Further development
● Future research

NB the colours of the breadcrumbs correspond with the colours used to differentiate the phases in the research approach.

Theory

- Introduction
- **Theory**
  - **FRM**
  - **NBS**
  - **M&E**
  - **Knowledge sharing**
- Method
- Analysis
- Development
- Results
- Conclusion


PHASE I — RESEARCH FOR DESIGN
DEFINE THE PROBLEM
LITERATURE REVIEW
1
River flood defense
Nature-based solutions
Pilots
Monitoring and evaluation
Knowledge sharing
COLLECT + ANALYSE
SEMI-STRUCTURED INTERVIEWS
2
ANALYSIS
Interviews, literature, and online sources
3
PHASE II — RESEARCH THROUGH DESIGN
DESIGN + DEVELOP
DEVELOP EVALUATION FRAMEWORK
4
DEVELOP ONLINE KNOWLEDGE BASE
5
COLLECT + ANALYSE
COLLECT FEEDBACK
6
ANALYSE FEEDBACK
7
3X
REVISE + REFLECT
REFLECT
8
REVISE
9
PHASE III — REPORT
COMPILATION OF REPORT
COMPILE REPORT
10
Research findings
Reflection
Discussion
Conclusions
Recommendations
Implications for science

2.1. Dutch riverine flood risk management

Rijkswaterstaat the Ministry of Infrastructure and Water Management (RWS) and the water boards are responsible for preventing floods in the Netherlands [39]. Rijkswaterstaat is responsible for water management of the larger rivers, which includes: maintenance of water management structures such as dikes, dams, weirs, and the famous storm surge barriers, and giving more room to rivers [39]. The water boards are responsible for flood protection of regional waters such as channels [39].

2.1.1. Policy context

Previously, the water system of major rivers was highly dynamic and the course of rivers changed quite frequently [40].Floods occurred regularly in the rivers area, so various measures were taken from 1850 onwards: spillways were constructed, rivers were channelised to increase the rate of discharge, the rivers Meuse and Waal were disjointed, and levees were raised. These measures reduced the frequency of flooding [40] but it also produced a unique situation; nowhere else is flood protection so tightly controlled by institutions and regulations [40]. A short recap and overview of the policy context is given below.

In 1956 a mathematician proposed to build dikes not based on highest measured water level but to base it on statistics of water levels [41]. This was later developed into acceptable flood hazard norms from 1:300 to 1:100,000 and now there are questions investigating possible added value derived from flood protection works [41].

In 2008, water safety or 'waterveiligheid' was defined by the Delta commission which is about *"preventing casualties, societal disruption, and prevents damage to the economy, landscape, nature, culture, and reputation"* [42]. To ensure national water safety, the Delta Programma launched a new FRM approach called 'risicobenadering' where the level of safety is defined by the chance of flooding as well as the consequences thereof [43].

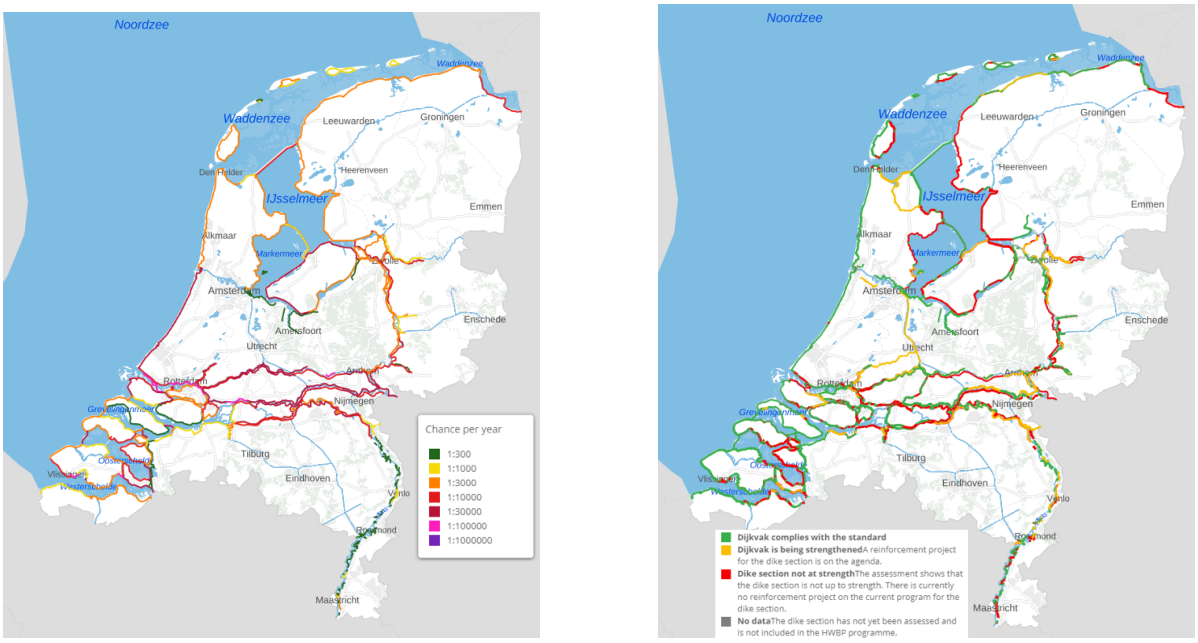
Current policy in the 'Nationaal Waterplan 2016-2021' that was inspired by the 'risicobenadering' is characterised by a multi-layer or tiered approach for safety called 'meerlaagsveiligheid' [44]. The first 'layer' encompasses efforts that prevent floods from occuring (voorkomen is beter dan genezen). Current policy still has a core focus on minimising flood risk using strong dikes [45] but it is now combined with spatial development around rivers [46]. If one or more of the flood defenses is breached however, it is tried to preemptively minimise damage and consequences using spatial planning in layer two [45]. The last layer of providing safety comprises preparations and evacuation measures in case events turn sour to minimise casualties through crisis management [45] and overall improvement of crisis response plans and the acting organisations [46].

In 2018 with 'Deltaplan Ruimtelijke Adaptatie' it was agreed that the Netherlands had to adapt its spatial planning to accommodate climate change [47]. Currently, a new document 'Nationaal Water Programma 2022-2027' is being drafted that aims to integrate national water policy and water management, which were previously separate guidelines [39].

2.1.2. Measures

Rijkswaterstaat employs flood defenses and many flood prevention measures to manage flood risk [48]. Flood prevention aims at taking away flood risk [49]. Defense and prevention are the dominant approaches to FRM in the Netherlands but other strategies could include mitigation/protection, preparation, and recovery [50] partly included in layer two of the multi-layer approach.

Water safety pertaining to rivers is tackled using floodplain management, the Room for the Rivers project, Meuse project, local projects, and the Hoogwaterbeschermingsprogramma (HWBP, translation: high water protection programme) [51]. The position and details, and corresponding norm specifications of all structures pertaining to flood risk management are documented in 'Legger rijkswaterstaatwerken' [52].



(a) Water safety norms per dike stretch [59]

(b) dike stretch safety norm status per 2023 [59]

Figure 2.4: Three simple graphs

Flood defenses

For flood defense, RWS makes a distinction between primary flood defenses and regional flood defenses [53]. The Netherlands has about 3000 km of primary flood defense structures and about 14,000 km of regional flood defenses [14]. Inland primary flood defenses are found along the four major rivers Ems, Schelde, Meuse, and Rhine. For each of these international river basins an individual flood risk management plan has been developed [54] as directed by the 'European Directive on the assessment and management of flood risks' [55]. Regional flood defenses are found along shipping channels and comprise mostly dikes along canals and structures like locks [56].

The Delta Programme introduced a new safety standard policy that 'tolerable flood risk level for everyone living behind a dike should be at least 1 in a 100,000 per year' [14, 16, 57]. Since each area has different levels of consequence, there are also differing levels of tolerable risk of flooding specified in six norm classifications [57] (refer to Figure 2.4a). For regional defenses the provinces with water authorities have defined regional standards [57]. The risk associated with regional defenses are lower so regional standards are lower than for primary defenses [14]. Currently, not all primary flood defenses meet the safety standard levels so a programme, the HWBP, was introduced strengthen or reinforce the lacking structures by 2050 [58, 59] (see Figure 2.4b).

Flood prevention

RWS monitors the rivers automatically at many locations for the water level, water discharge rates, wave height, and flow speed [60]. This acts as a national warning system for high waters but there is also an additional European Flood Awareness System (EFAS) [61]. Based on this data and information from upstream riparian countries via EFAS, RWS can determine the best measures to employ in case of extreme high water events and possible floods which is vital for flood risk management [60]. In case a flood warning is given, a suite of emergency solutions can be employed from the portfolio of 'Solutions for Emergency Flood Protection' [62]. Examples of such emergency measures are temporary flood barriers, movable bridges, high capacity pumps, etc. These measures are all part of flood disaster management which also includes disaster plans, evacuation drills, and communications for locals [63].

Another way of preventing floods is by managing the floodplains [24]. With respect to the floodplains, RWS manages vegetation as to effect higher flood discharge rates [64]. In the 'Omgevingswet', which provides context for the previously mentioned 'Legger rijkswaterstaatwerken' an additional 'vegetatielegger' has been defined for vegetation [65], and a provision has been made for dynamic objects such as natural banks to provide a spatial delineation in which it is allowed to 'move' [52]. Vegetation

management also ensures safe and unimpeded shipping which is another top-priority for RWS [66] ● ● Sub1

Another way for flood prevention to reduce flood risks is by zoning [49], where people are relocated or not allowed to live in flood prone areas [63]. National government has prohibited building new houses in floodplains [67]. Similarly, consequences can be mitigated through the way houses are built [63].

Due to extreme rainfall, Limburg province was flooded in 2021 and such extreme events are more likely to happen again so the minister of Infrastructure and Water Management founded a council 'Beleidstafel Wateroverlast en Hoogwater' to advise on water disturbance and floods [16]. This council has stated that our current water systems can not prevent crises at such extreme events, *but* prevention measures are needed and changes should be made in the spatial domain, awareness, and crisis management [16]. Current functions and requirements of the spatial domain along rivers might change as (radically) different designs [68] will be needed to accommodate the energy and sustainability transitions.

Since the early 1990s a large number of secondary channels have been dug in Dutch rivers [69], often implemented as part of a larger project/programme/strategy [70]. Secondary channels are waters that branch off from a river or waters that flow along [71]. Natural secondary channels are often the shallower parts along islands or old main channels that haven't completely closed off yet after meandering. Secondary channels are no longer naturally present in Dutch river after the historical normalisation works [71]. Constructing a secondary channel is done by profiling the land and inserting structures that enhance flood water flow or ecology [72]. The flood conveyance capacity is enhanced [72] as the floodplain gets a better and bigger flow profile [71]: better as vegetation will be more parallel to the water flow and bigger as the floodplain is lowered when digging a secondary channel [71]. As they can have multiple functions such as flood protection and supplying fresh water [70] or nature conservation [71], construction of an artificial secondary channel often serves multiple goals [71] and it can enhance the natural, recreational, and cultural value of its surroundings [72].

2.1.3. Limitations of conventional measures

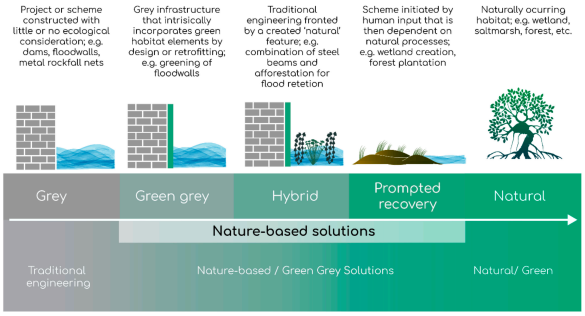
Current highly engineered flood defenses are costly to maintain and due to increasing flood risk (from human population growth, climate change, levee-effect) they need to 'grow' ever higher and wider [23]. Preparing for more extreme floods in the future is going to be driving costs of infrastructure up a lot [24, 25]. This also means that these structures are often static and unable to adapt to for example sea level rise or increased flood discharges [23, 73]. In addition to these problems, conventional flood defenses can disrupt ecosystem functioning and local ecology [74], affect biodiversity [75], can shift flood risk to other locations [76]. Combined with the levee-effect, these safety measures can actually incur greater losses when they fail [76]. That is why traditional infrastructure is more and more seen and criticised as unsustainable [77]: Dutch channelised rivers may no longer be feasible or economical [25] with regards to the future.

Taking all these limitations into account, it is no wonder why there is a paradigm shifts [78] towards more natural flood management with NBS. NBS in contrast are considered win-win or no-regret measures [13, 79]. NBS may even prove *"a cost-effective approach to an uncertain scenario by delaying or avoiding lock-ins"* [24].

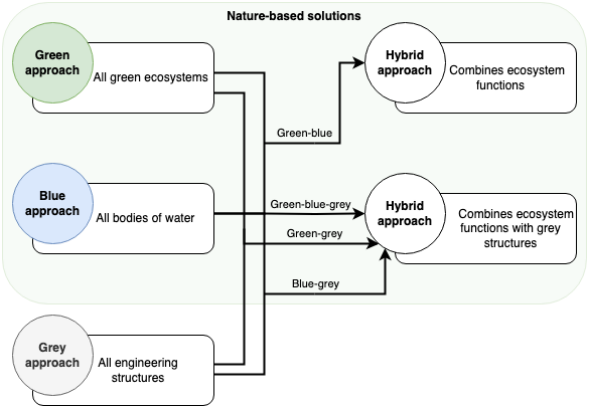
Nature-based solutions

2.2. What are nature-based solutions?

Nature-based solutions as a concept is rather broad and can be vague initially [80]. Due to the vague nature of the concept, there have been many different definitions introduced [18]. The term 'nature-based solution' was first used to identify conservation actions that contribute towards climate mitigation and climate adaptation [81]. It tried to positively link and promote nature as a solution for societal problems [80]. NBS has become an umbrella concept [18, 33, 82–85], that encompasses many different terms in different dimensions. Due to the vagueness of what is natural or 'nature' it is difficult to distinctively delineate NBS [80], it can be seen as a sliding scale as illustrated in Figure 2.5a but the most general overview of NBS and their types was found in a paper by Debele et al. [85] that found all combinations of approaches NBS, except for pure grey approaches.



(a) The grey-green continuum of infrastructure approaches [86]



(b) Overview of general NBS types, based on Debele et al. [85]

A definition of NBS, given by the International Union for Conservation of Nature (IUCN), one of the leading organisations with regards to NBS, is as follows *"actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits"* [87]. To summarise, NBS have to address societal challenges while providing benefits for human well-being and biodiversity. From literature several other components can be distilled from various definitions of NBS: natural solutions are designed to address societal challenges [83], they provide key infrastructure needs [88], they are resource-efficient and sustainable interventions that are adapted to the local system, leading to multiple benefits [84] and supporting sustainable development and resilience [89], the actions can also be inspired by nature, supported by or mimick nature [90], improve biodiversity and resilience [18], they are dynamic, multi-functional, context specific, and innovative [25].

Effectiveness of NBS in a system depends on its context [25, 85]: location, design, typology, green species and environmental/climate conditions. Therefore NBS work best when the whole underlying system is understood on a large scale from different disciplines e.g. soil, water management, climate, land use and social structures [91]. Due to the many disciplines need to work together, NBS rely on a systems-based approach. Inversely, Moons et al. [25] state that every system-based approach should include NBS as NBS have demonstrated to deliver multiple direct and indirect system benefits. One surprising economic benefit, that was come across, that nature restoration via NBS can increase the measure with which the economy can grow without damaging nature [92]. Incorporating NBS in FRM has many additional economic, social, and environmental co-benefits [3]. It was also emphasised to look at the ecosystem services that NBS provide for FRM, for example *"the storm protection function of wetlands* [90].

2.2.1. Ecosystem services

Ecosystem services are *"the conditions and process through which natural ecosystems, and the species that make them up, sustain and fulfil human life"* [93] i.e. benefits humans get from ecosystems [94]. There are four types of ecosystem services [94]: (1) provisioning services (products obtained from ecosystems), (2) regulating services (benefits obtained from regulating ecosystem processes), (3) cultural services (non-material benefits obtained from ecosystem processes), and (4) supporting services (services necessary for the production of all other ecosystem services). The supporting services are very important as they maintain the conditions for life on earth [94].

2.3. Nature-based flood defenses

Nature-based flood defenses are NBS that reduce flood risk [95]. NBFD aim to *"reduce runoff and/or improve the ability of rivers and their floodplains to manage flood water"*, reduce the flood peak downstream, and delay or buffer so the flood peak is slower downstream [32, 96]. Reducing the maximum water height, or flood peak, reduces the scale and magnitude of a flood. With regards to slowing the flood peak down, this allows for more time to prepare. Certainty about the effect on flood risk reduction depends on the location of the NBFD [96]; at the headwaters there is less certainty than NBFD that are implemented downstream [96]. Therefore, the type of applicable NBFD measures differ between headwaters, mid-watershed, and downstream [3].

NBFD are most commonly green and blue hybrid approaches [97] to NBS followed by the 'pure' green and blue approaches [85]. Hybrid approaches are prevalent as NBFD as blue and/or green infrastructure is often combined with conventional grey engineering infrastructures for optimal flood protection [98] depending on the risks and urgency involved [29]; NBFD can often enhance grey flood infrastructure [3]. That is why, in Europe, NBFD are the most commonly built NBS, to address climate change related risk [99].

Besides reducing flood risk, NBFD can provide multiple benefits [95] (like other NBS): benefits for people and wildlife, helping restore habitats, improve water quality and helping make catchments more resilient to the impacts of climate change.

2.3.1. How do NBFD work?

The 'natural' components of NBFD (green or blue) reduce flood risk by making use of natural dynamics [90]. NBFD mostly have a buffering effect on river flow, slow runoff, enhance groundwater storage, reduce sediment deposition in the river channel [73, 96], reduce flow velocity, or allow more room for the river, by increasing the ability of channels to convey floodwater [73, 76]. This is achieved as NBFD integrate hydrologic, hydraulic, morphological, and ecological principles to reduce flood risk [3]. NBFD work best when a system-based approach or catchment-based approach is taken, to manage a river from source to sea; natural processes can then be employed throughout the catchment to work together with existing grey infrastructure [95]. This system-based approach also reduces the chances of transferring risks either downstream, upstream, or to surroundings [3].

A less obvious way that NBFD reduce flood risk is through zoning, to reduce flood exposure [73]. Exposure is also reduced by avoiding changes in vegetation that could alter hydrologic flows [73].

A tangible example of the benefits of a natural approach to flood defense is restoration of natural streams: "A natural stream valley acts like a sponge, during times of heavy rainfall it absorbs lots of water, and in times of drought it ensures that the water gradually becomes available again. But in the past we straightened out many of our streams and turned the gentle slopes of natural stream banks into steep walls. This causes the water to flow in one great wave." [91].

2.3.2. NBFD categories

As seen before, there are many definitions and ways of classifying NBS. Similarly, there are many ways of classifying NBFD. Currently, there is not yet an agreed upon categorisation for NBFD in Dutch rivers and floodplains ● Categorisations can often be found at the catchment scale of abstraction (e.g. categorisations by [3, 76, 96, 100, 101]; in these categorisations, reforestation and afforestation are often included but, for the downstream situation of the Netherlands, those NBFD are not really options for implementation. The categorisation for NBS by a Dutch organisation called Natuurlijke Klimaatbuffers [102], was also lacking with regards to possible NBFD in Dutch rivers and floodplains. ● Future research

Recently, international guidelines were written for NBFD that distinguished five categories in river

systems, see Figure 2.6. This general categorisation was deemed most relevant for the context of this study, excluding urban runoff management and rural runoff management for the major rivers.

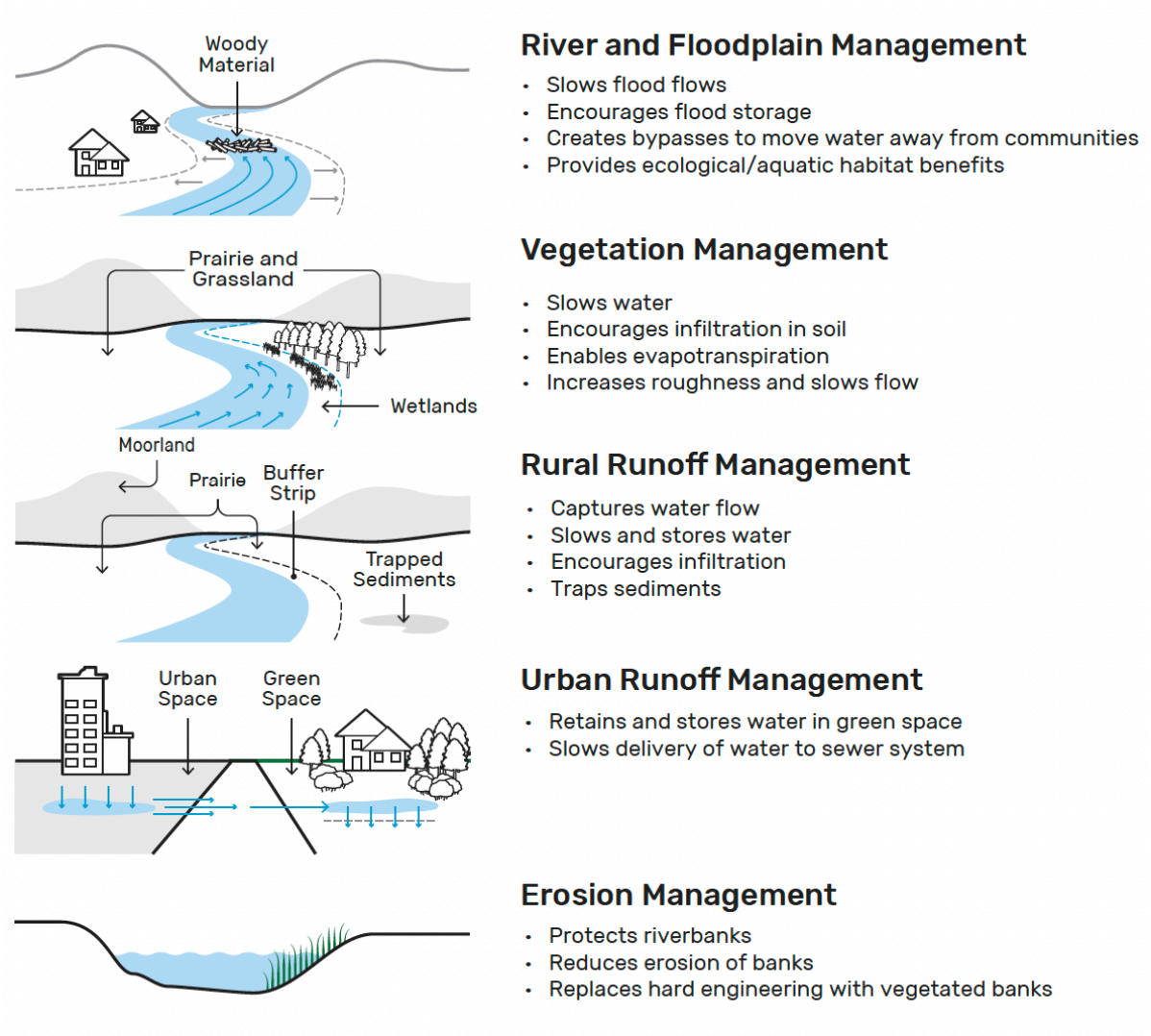


Figure 2.6: NBFD categories in river systems [3]

Examples of 'river and floodplain management' in the Netherlands can be found in a large-scale programme called 'Room for the River'. It consisted of many measures such as floodplain lowering, dike relocation, groyne lowering, summer bed deepening, water storage, bypasses and floodways, high-water channels, removal of hydraulic obstacles, and dike strengthening [22]. Another example would be vegetated foreshores, as part of 'vegetation management' or 'erosion management', could reduce flood risk in addition to existing grey infrastructure [90]. An example of 'rural runoff management' can mostly be implemented in the outer reaches of smaller rivers in the Netherlands by remeandering, restoration of swamps, peat or forest areas [103]. For reference, photos are included below to show how NBFD may look.

Levee setback or dike relocation: reinstating floodplain storage capacity, thereby reducing flood heights

High-water channel: allowing more discharge capacity during high waters [104]

Water retention area and vegetated foreshore: reducing flood height through water retention and reducing flood wave action [105]

Wetland forests: combined with levees or dikes can reduce wave heights while providing habitat value and supporting biodiversity [106]

Restoring swamp, peat, or forest area: a NBFD applicable for smaller rivers or upstream, reducing floods through water retention [103]

Renaturalisation of polders: allowing better water storage in watercourses inside the polder, as well as increased biodiversity [107]

2.3.3. NBFD compared with grey infrastructure

As mentioned before grey infrastructure have many limitations, but NBFD are not a cure-all and will not replace many forms of (critical) grey infrastructure [3]. Although many of the protective functions of NBFD can be fulfilled by built infrastructure, the high flexibility and adaptive capacity of NBFD are specific advantages [73]. Furthermore, NBFD are able to adapt to changes in water level, allowing them to grow when the water level increases [90]. Moreover, grey infrastructure is often built for a single purpose or function of flood risk management whereas NBFD is able to deliver multiple functions [18, 22, 25, 108] through soft measures coming at the cost of some more uncertainty due to natural variability [77]. Another important benefit is that NBFD can also protect against multiple hazards at the same time, which is very useful as hazards can take place simultaneously or follow each other [108]. When built, grey infrastructure is immediately operational but stays static compared with the evolving functions and benefits (ecosystem services explained below) that are provided as NBFD settle in and grow after construction [77, 109–111]. Many reports mention a lack of cost-effectiveness assessment methodologies but Debele et al. [85] have found that NBS, specifically for hydrometereological hazards, were very much cost-effective when compared with grey measures. Natural capital also grows higher over time when compared with grey solutions (see Figure 2.7a).

A drawback of NBS is the difficulty measuring effectiveness due to context-dependency [29]. Due to context specificity, there is uncertainty related to the evidence individual NBS can provide [29]. Also, for NBS that affect the floodplain, there is a challenge that it may change a river's morphological response causing sedimentation of the main (shipping) channel [3]. Other downsides that relate with uncertainty are about the level of flood safety, how long it takes to become fully operational, the level of resilience with respect to concurrent extreme events, NBS can be less effective high magnitude events, etc. [29]. Additionally, many benefits (i.e. ecosystem services) can not be measured easily and expressed in monetary terms [112]. Especially NBS that restore (badly) degraded ecosystems, can be slow to provide the full range of benefits and its use functions [29, 112, 113]. NBS are often used for climate adaptation and mitigation but paradoxically the solution may be sensitive to climate change as well [29].

There has also been research looking into the costs between hybrid solutions and grey solutions for flood control: Denjean et al. [31] note that the investment costs are similar but more spread over time as implementation takes longer than grey solutions but maintenance and operation costs are lower for hybrid solutions; overall costs can be lower but still money should be reserved for problems due to its inherent uncertainty. Grey solutions are immediately fully operational but the maximal service level deteriorates slowly over time [113] (see Figure 2.7b). NBS take a longer time to provide a designed or required level of operational service: mangroves, for example, need to grow before providing protection [31] (see Figure 2.7c). Both facts that NBFD require money over a longer period and take longer to reach the required level of service are problematic for standard financing loans: normally the contractors get paid after construction/implementation and the intervention delivers the required level of service, but for NBFD the delayed remuneration makes it more risky [31].

In practice, there have been many pilot projects in NBFD but that has not resulted in large scale adoption and implementation [114]. Janssen et al. [114] noted that this is due to a social dilemma at the policy level: *"while a multi-functional nature-based solution is attractive to a coalition of actors, it is not the most beneficial option for individual actors. Hence, they are faced with the dilemma of opting for their maximum benefit or opting for the greater societal benefit which is less favourable to them"*. This can be explained because natural flood management is a classic example of a wicked problem [115].

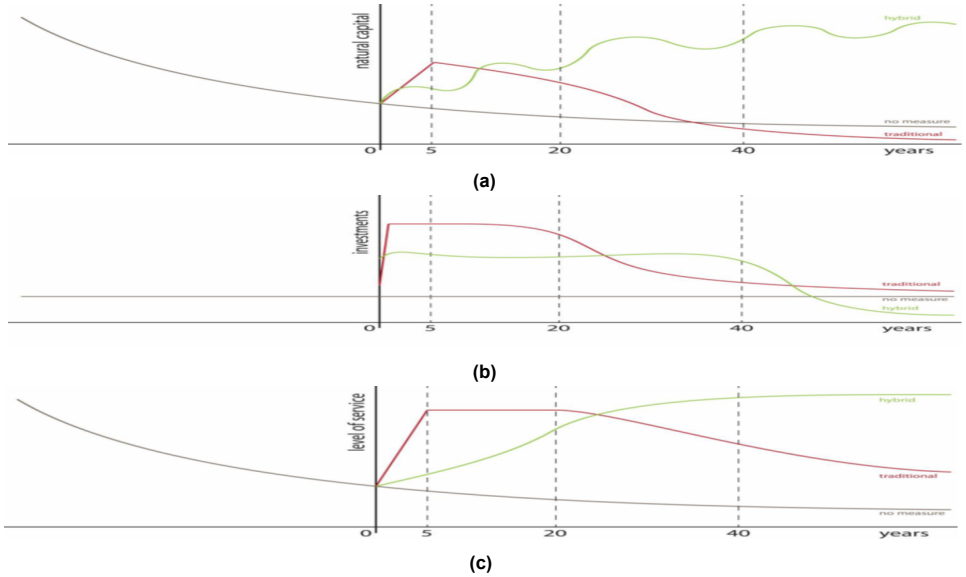


Figure 2.7: Hybrid versus grey solutions [4]

2.3.4. Policy related to NBFD

There has been increasing awareness of NBFD [97]; there are many global policy documents that now explicitly mention NBS or one of its related terms [33]. After the IUCN created an NBS framework, a bit later the EU even adopted NBS as one of the key areas of their research and innovation programme [116]. Following this, EU policies now support NBS implementation and uptake [33] although the degree of support varies from low to strong explicit support [97]. There are many policy documents from various fields that touch on NBS [117] but there are only two that directly touch on 'water': the European Water Framework Directive and Flood Directive. The Floods Directive does not mention NBS because it is an older policy document [22]. The European Water Framework Directive is one of the biggest driving forces of ecological restoration in and around rivers but there is also Natura 2000 which has allowed for more ecological consideration [71]. NBFD can also contribute towards the objectives of the Action Plan on the Sendai Framework for Disaster Risk Reduction 2015-2030 and EU Strategy on Adaptation to Climate Change [22].

For Dutch policy, Veraart et al. [118] have found many possible links with policy for nature restoration via NBS and NBFD such as *"Deltaprogramma, Klimaatakkoord, Kaderrichtlijn Water, Natura 2000, Nationaal Natuurnetwerk, Programmatische Aanpak Grote Wateren, Nationaal Waterplan, Nationale Adaptatie Strategie, Programmatische Aanpak Stikstof"*. January 1 2024, a new law will come into effect called 'Omgevingswet' [119]. This law will require more efforts for climate adaptation at different levels of government and more integral working [120]. There are also chances in the law to require how projects and new housing developments should deal with climate adaptation and biodiversity [121]. It is not mentioned explicitly but this law may work out to support NBFD.

Monitoring & Evaluation

2.4. Why monitoring AND evaluation?

Evaluation and monitoring are inextricably linked [122] and distinct yet complementary [123]. Monitoring pertains to the checking of an intervention's use of resources and progress or achievement of objectives by collecting data on specific indicators which in turn can inform management [123]. During monitoring, data is collected that can be used for following evaluations and sometimes parts of a following evaluation already occur during monitoring [122, 124]. Evaluation is a form of retrospective assessment of an intervention's design, implementation, and results [123, 124]. Both monitoring and evaluation assess, therefore the main differences lie in the timing and the focus of said assessment [122]; monitoring is continuous and assesses current goings-on whereas evaluation is retrospective in nature and conducted at discrete points during and after an intervention focusing on 'how well the intervention went' and 'the difference it made' [122], ergo the impact it had [125]. Since data and information affect the quality of monitoring and evaluation [126], often a monitoring and evaluation (M&E) system is employed.

Why is monitoring & evaluation important for NBFD? As mentioned before, NBFD designs evolve after initial construction [77, 109]: the benefits (ecosystem services) and its primary flood protection use function 'grow' to their designed service level [4, 31]. Monitoring of this growth and performance is essential for proper management [90]. Bridges et al. [3] note that optimal performance of a NBFD is due in part to a well-developed monitoring plan. However, often monitoring is underestimated or has been allocated too little budget [3]. There are also large knowledge gaps that can be filled with proper M&E, and the data will be useful in informing policy and boosting uptake of new NBS for upscaling and replication [18]. With proper monitoring, evidence can be found for best practices [8]. The M&E phase of a NBS project can show the pros and cons of the impacts in a systematic way [18], to understand benefits and trade-offs, and the goal is to analyse the outcomes at various levels. Interreg called this a need for assessment frameworks [32]. Upscaling and replication are major challenges for NBS due to lack of standardised monitoring methods [18].

2.4.1. M&E systems

M&E systems are an important part of project management [122], that supports implementation due to better informed management and decision-making. An additional benefit of M&E systems is enhanced organisational learning and knowledge sharing through lessons learnt [122]. These systems fill a gap that was present in management systems: a feedback component that can track consequences of actions [123]. M&E is often carried out by the implementing agency [124] but there is also a form of participatory M&E [125].

2.4.2. Information needs

During and after a project, stakeholders have different information needs with regards to communication and reporting. It is important to understand the information needs and priorities [122] of those interested in an intervention. More specific to evaluations, end-users also have different information needs so designing for a specific target audience ensures relevance and facilitates use [123]. Using an M&E system can help find the information needs and assist in the planning and dissemination for communication to and reporting of relevant information. It can be very useful to have a database for a project's M&E system. In the long-term it could store all relevant data that could be used for future improvement and policy [123]. A database can also fulfil information needs of stakeholders for decision making and reporting [123] (more on databases in chapter 2.6.3).

Baxter and Braverman [127] have identified three different types of information need: namely strategic, tactical, and operational information where: strategic information is relevant for or about an organisation's mission, values, goals, and allocation of resources. Tactical information needs relate back to objectives. Operational information needs derive from project activities [127]. It has also been found that the information needs of stakeholders change along with project progress i.e. different needs at different stages of a project [123].

2.5. Monitoring

Monitoring is the act of comparing outcomes and the current status with specific targets, by way of collecting empirical data on conditions of system through repeated observations [88], which can promote accountability, dialogue [124], and learning [128]. Monitoring often involves indicators, baselines, and targets for the outcomes [129]. In short, monitoring is data collection and assessment of said data. Effective monitoring therefore requires strict and consistent procedures for the data collection, processing, and reporting [128] and requires measurable and clear goals [118, 130].

Monitoring information feeds into the evaluation in a M&E framework [129]. Documentation and reporting of the monitoring process, with effects on the system are crucial to learn from pilots [130] ● Monitoring thus supports decision making and can provide evidence for improvements in practice via R&D [88]. It has been found that for evaluation, a monitoring plan should be developed in tangent with design of the NBS [84]. ● Sub2

A monitoring plan is essential for evaluation and can support interventions and measures to disseminate or scale up as the possibilities and limitations are more well-known [130]. A monitoring plan should include the following [129]: identification of the focus area, development of performance indicators and targets, identifying data collection processes and tools, determining responsibilities and time frames. IUCN also detailed additional requirements for a monitoring plan [84]: budget, frequency and duration of monitoring, types of analysis for evaluation, data storage protocols, and how lessons learnt will be shared. Other things to consider when forming the plan are the research question(s), the level of precision, the spatial scale as not every method can be used for every location/context, the temporal scale, and which sites to use for treatment, control, and reference [130, 131].

Markiewicz and Patrick [129] have written extensively on developing a M&E framework: evaluation criteria have to be defined before a monitoring indicator is defined. Additionally, an indicator is only used for evaluation of a corresponding criterion, monitoring indicators should not be used for planning only used for evaluation ● ● Sub2

When choosing monitoring indicators, it is advised to limit the initial number ● More can always be added later so as to not risk forming an unachievable monitoring plan. Moreover, monitoring budgets are often tight [3]; in these cases, it is prudent to choose indicators that correspond with the most important objectives of the pilot. This is especially the case for NBFD which often have many objectives [80, 132, 133]. Monitoring indicators can be bot quantitative and qualitative in nature [129]. ● Sub2

2.5.1. NBFD monitoring

Generally, monitoring of flood risk for grey infrastructure is done on flood defense strength, hydraulic load, and safety [134]. Monitoring looks at flood hazard norms [135] and signalling values which act as a warning to indicate whether a safety norm might be exceeded [134].

Monitoring of NBFD is more challenging [8, 88]: there are often very many and diverse project goals associated [80, 132, 133], monitoring is more challenging due to the long time scales needed, change across time, and inherent uncertainty of environmental management. Many countries have too broad goals with respect to NBS that are not measurable [132]. Additionally, monitoring of NBFD is challenging as the intervention changes and integrates with ecological systems and has to adjust to its local environmental conditions [110, 111]. Lastly, the combination of uncertainty of environmental management, the dynamic nature of NBFD, many goals associated with NBFD, and time needed to provide required levels of service lead to uncertainty what and how to monitor [8]; more frequent or adaptable monitoring may be needed compared with grey infrastructure [8]. Above-mentioned challenges may explain why there is a historic lack of proper monitoring done on Dutch river restoration projects: in an evaluation of all Dutch restoration projects [5], that were documented between 2006 and 2019, it was found that most did not have a monitoring plan that was sufficient to judge the effectiveness of the intervention. The authors also found that the effects were often not tested statistically. When monitoring is not done with the additional aim of improving future implementations, it was found that the results would not support decision making or management [8].

Rees et al. [8] have defined three main types of monitoring for NBFD (see Table 2.2) ● ● Main

	Initial performance monitoring	Long-term performance monitoring	Research & development monitoring
Focus	Short term verification that a project meets its needs and design specifications	Used to ascertain the need for repair replacement or adaptive management and monitor longer term processes and endpoints that cannot be observed in less than five years	Test hypotheses and provide an evidence base for interdisciplinary learning. Targeted monitoring and assessment for improving future projects.
Scale of benefits	Project scale	Project or regional scale	Regional or interdisciplinary scale
Time frame	1-5 years	5+ years	Question-dependent
Who	Project team	Outside agency	Outside agency (scientific)

Table 2.2: Monitoring characteristics of NBFD [8]

Bridges et al. [3] recommend to invest in long-term monitoring of at least ten years looking at ecological, morphological, flood risk, social support and mentioned that monitoring should start at the planning stage.

A paper investigating the NBFD of forest restoration found that monitoring often uses lagging indicators (indicators that look at the short-term past outcomes) but Ota et al. [136] recommend using lagging and leading indicators (indicators that show the likelihood of a certain outcome in the future); leading indicators can help in goal progress projection and management towards said goal [136] ● ● Further development

What to monitor?

As mentioned before, for conventional flood defenses, there are existing standards, guidelines, and regulations. For hybrid solutions incorporating grey infrastructure, these documents and instruments can inform at least part of what should be monitored. A toolbox, called BOI, has been developed for the assessment and design of primary flood defenses [137] which includes all relevant laws and regulations, guiding documents, technical guidelines, flood risk analysis methods, appropriate software, etc. [138]. A well-known law called the 'Waterwet' used to house laws and regulations for water management [139] but as of the first of 2024, a new law called the 'Omgevingswet', incorporated the 'Waterwet' and many separate laws in the spatial domain. An important change as the norms for primary flood defenses went from laws to governmental decrees (Algemene Maatregel van Bestuur) which means that changing the norms is not a responsibility of parliament anymore [139].

In 1998 it was decided that the provinces had to form safety norms for the regional flood defenses in collaboration with the regional water authorities [56]. Assessment of regional flood defenses is therefore rather similar to that of primary flood defenses; there are flood safety norms and standards that are assessed and tested such as: 'Leidraad Toetsen op Veiligheid Regionale Waterkeringen' (LTV2015) and VTV2016, a memo 'Vaststelling uitgangspunten t.b.v. planning Toetsen Regionale Waterkeringen', and 'Leidraad Waterkerende Kunstwerken voor Regionale Keringen' [56].

From EU legislation there are three mandatory policies that pertain to monitoring of NBS: the Environmental Impact Directive which mandates the conduct of environmental impact assessments and visual impact of projects (to preserve historical and cultural heritage and the landscape), the Floods Directive, and the Water Framework Directive that requires reporting and monitoring [97]. There is a monitoring manual for hydrobiology in the Netherlands for how to assess ecological quality [130]; this comprehensive manual describes relevant hydrobiological research and assessment methods for each biological group in the Netherlands (primarily used for WFD) [140]. The manual looks at the mico level of ecology (plankton, algea, diatoms) and macro level (fish, vegetation, macrofauna) [141].

Ecosystem services are often not reported [133]. Indicators that can be considered should relate to goals regarding the biophysical context and ecosystem services [80]. Biodiversity should therefore be monitored as changes can influence many (provisioning) ecosystem services [94]. IUCN recommends to monitor NBS at the catchment scale to see effects on the physical habitat and other biological, economic, and social responses [21] ● ● Sub2

How to monitor?
A standardised framework should be used allowing comparison between projects [8]. This is easier said than done as smaller local NBS can be monitored and related to its influence on the surrounding context but larger NBS have an effect on bigger geographical scales which requires different monitoring as there are confounding influences on results [80]; monitoring should be appropriate to the scale of the intervention [80]. Also, since ecosystems are inherently variable and subject to change long-term measurements are needed to draw meaningful conclusions and recognise patterns [3, 5] ● The MERLIN project mentions that it is recommended to use a 'Before-After and Control-Intervention' monitoring approach (BACI), to compare the effects of an intervention with a control site so you can definitively attribute change to the intervention [142]. Although contested, Noord et al. [5] state that one of the best methods to try and eliminate bias is to employ a BACI monitoring approach. Noteworthily, Figure 2.8 shows that for previous restoration projects in the Netherlands, very few measures included a BACI approach and none at all met the most stringent requirement of three years of monitoring data before and after the intervention in combination with a control site (BACI±3). ● Main

Onderzocht maatregeltype	BACI ±3 jaar	BACI	BA	CI	Geen BACI/ BA/CI	Totaal aantal rapporten
Aangepast beheer	-	-	1	4	5	10
Bronherstel	-	-	1	-	-	1
Grindinbreng	-	-	-	1	-	1
Herintroductie	-	-	-	-	2	2
Hermeandering i.c.m. grootschalige herinrichting	-	1	11	5	15	32
Hermeandering i.c.m. kleinschalige maatregelen	-	2	5	-	2	9
Hermeandering i.c.m. vismigratie	-	-	2	-	-	2
Houtinbreng	-	1	1	2	-	4
Nevengeul (i.c.m. vooroever)	-	-	-	1	5	6
Nieuw habitat	-	1	-	-	12	13
NVO rivieren (i.c.m. vooroever)	-	-	5	22	4	31
Vismigratie	-	-	1	1	2	4
Waterberging	-	-	-	-	5	5
Zandsuppletie	-	-	-	3	-	3
3 of meer maatregelen	-	-	-	1	-	1

Figure 2.8: Number of reports per Dutch nature restoration measure and their research approach (2006-2019) [5]

2.6. Evaluation

2.6.1. What is evaluation?

An earlier definition stated that evaluation is about "retrospective assessment" but what is the purpose and what does evaluating entail? Firstly, an evaluation tries to determine the relevance and achievement of objectives [123]. It should also try to prove that the achievement of said objectives was due to the intervention [124]. Evaluations also aim to inform subsequent decision making by providing "lessons learnt" [123] and improve effectiveness of future activities [125]. These "lessons learnt" derive from the review of how and why activities succeeded, failed, or were changed [125]. Lastly, an evaluation looks at the technical, economic, and procedural aspects [125]. To check the quality of an evaluation, a quality standard can be used that was developed by the Development Assistance Committee of the OECD [143]. As mentioned earlier, evaluation builds on monitoring information but adds other information to come to an eventual assessment.

2.6.2. How to evaluate?

Simister and Scholz [144] have detailed many different general types of evaluation. These evaluation methodologies can be distinguished by five categories: the purpose of the evaluation (summative or

formative), who conducts the evaluation (external, internal, joint, peer, and participatory), when the evaluation is carried out, the general evaluation approach used, and cross-cutting themes.

The role of an evaluation changes depending on the moment you review in the project (cycle) [125, 145]: there are mid-terms, final, end of phase, ex-post, and real-time evaluations [144]. Midterm evaluations after the planning stage, during implementation, provide more information for management and the stakeholders [125]. After a project's completion there is ex-post evaluation, followed by dissemination (more on that in the next chapter 2.6.3). The timing of evaluations and its approach should be considered as NBS and NBFD take a longer time to evolve and show results [73] ● Ex-post evaluations ● Sub2 are usually done between six months and ten years after completion and are almost exclusively summative in nature [144] i.e. retrospective as to assess a pilot's performance over a certain period [129].

Evaluation tries to answer certain (research) questions that are formulated as evaluation questions. Based on these evaluation questions, evaluation criteria are determined [129] ● OECD has found that ● Sub2 there are five classes of evaluation questions: appropriateness, effectiveness, efficiency, impact, and sustainability.

A monitoring & evaluation framework supports both formative and summative evaluation ● A M&E ● Future framework uses (performance) indicators, baselines, targets alongside other measures for evalua- research tion ● More balanced assessments are rendered from the combination of monitoring and evaluation. ● Sub2

2.6.3. NBFD evaluation

Uncertainty regarding performance of NBFD are similar to conventional infrastructure, only natural variability of NBFD is greater [3]. There is a need for a holistic evaluation framework that looks at benefits, co-benefits, and challenges allowing fair and informed cost-benefit analysis [146] between grey infrastructure and hybrid solutions such as NBFD. A comprehensive overview of the benefits and co-benefits per NBFD category are detailed in [76]. Bridges et al. [3] have found that NBFD evaluation should look at ecological aspects and use a source-pathway-receptor-consequence conceptual model to evaluate the performance in terms of FRM, social aspects, and economical aspects ● The performance of FRM, ● Sub2 social outcomes, and economic outcomes of a NBFD depend heavily on the ecological functioning [3]. That is why, performance evaluation(s) should be done at a frequency relevant to the natural dynamics i.e. ecological functioning of the NBFD [3] ● Wesenbeeck et al. [13] mention that M&E of NBS should ● Sub2 show what works, what does not work, and why some things do not work ● which begs the question ● Sub2 'what should be monitored and evaluated?': review all project components with special attention to risk reduction effectiveness, community impact, and environmental impacts. The evaluation should also include contextual influence, a judgement on the functional performance based on standards and objectives [13] ● Buyck [147] mention that learning should also be evaluated when assessing progress ● Sub2 and impacts ● ● Sub2

Veerkamp et al. [99] have investigated many evaluation frameworks and assessed their pros and cons. Based on these insights, the authors have developed a comprehensive framework for assessing NBS, that affect climate change adaptation and disaster risk reduction. This framework details many possible evaluation methodologies suitable for NBFD pilots. Certain decisions have to be made before choosing a method, however [99] ● : what is the intended use for the evaluation? Who are the users? ● Sub2 What is the scale? What is the level of stakeholder engagement? Will the evaluation be comparative, about design options, or just the pilot? Will it be retrospective, a current state assessment or future looking?

Nesshöver et al. [80] state that evaluation should be done over a longer time period when the scale of the pilot is larger ● Smaller NBFD can be monitored for a shorter duration. Different scales can be ● Sub2 used from a paper called 'a review of vulnerability indicators for deltaic social–ecological systems' [148] that resulted in a framework that looked at multi-hazards on the ecological levels: ecosystem, sub-delta, delta, and lastly the basin level. In addition, it also mapped the impacts on the social system, province level, country, and river basin organisations. The MOVE framework looks mainly at exposure and vulnerability of society to hazards at from the international scale down to local scale [149].

Veerkamp et al. [99] details the purposes for ex-post evaluations of NBFD as follows: impact assessment, return on investment, societal benefits achieved, costs and negative effects, but most importantly the purpose of a *knowledge base for informing future designs, funding and implementation approaches for NBFD* ● ● Sub3

A report for the World Bank [13] has detailed five principles for NBS in FRM on which a NBFD pilot can be assessed and evaluated. The adaptive management cycle then provides a basis for developing

knowledge development such as lessons learnt [13].

Other things to consider when evaluating NBFD are that the ecological evaluations can also be done according to a value system as determined by Marchand et al. [42] ('natuurwaardesysteem') or on the basis of expert opinions for qualitative criteria. Expert opinions are useful when considering the nature of processes, diversity of desired ecosystems and species, and connectivity [42] ● ● Sub2

Evaluation criteria

Evaluation criteria should be based on the evaluation questions [129]. Many sources mention social, economic, and ecological criteria. Veerkamp et al. [99] recommend looking at the following criteria: environmental impacts/benefits, social, human, cultural, economic,technical, physical performance of NBS. Bridges et al. [3] mention a FRM component more specifically; their main criteria are FRM, social aspects, and economical aspects. OECD [150] has defined six evaluation criteria to evaluate a public intervention (a project in this regard): relevance, efficiency, effectiveness, impacts, coherence, and sustainability. The purpose is to allow for consistent evaluation through a common framework [6].

Care should not only be given to ecological goals and its criteria: social, cultural, and economic criteria should be monitored for restoration interventions [133]. Nesshöver et al. [80] mentions, however, that these three categories (social, cultural, and economic indicators) can result in less easily measured indicators being neglected.

Social indicators are important as not only natural dynamics influence a NBFD, also social dynamics (e.g. stakeholder perspectives, politics, economic activity, etc.) [25].

different components that determine the overall habitat integrity of rivers: biology, hydrology, morphology, and water quality [21]

Water security related evaluation metrics should be selected by looking at the interests of stakeholder groups [73]; outcomes may be valued quite differently depending on the stakeholder perspective [80].

To evaluate whether an 'intervention' qualifies as an NBS, the IUCN Global Standard can be used to evaluate the process and effects [84]. The Standard features eight criteria with corresponding indicators and tries to ensure that no compromises are made with respect to nature and societal benefits when delivering a project [84]. A thesis written by Berg [7] compared the Standard with 21 relevant assessment frameworks of NBS and highlighted both the strengths and weaknesses of the IUCN Global Standard.

There are two HORIZON 2020 projects that have developed relevant evaluation frameworks. By combining two frameworks a OPERANDUM developed a conceptual framework for vulnerability and risk assessment looking at the social-ecological system [151]. RECONECT has developed a framework for evaluating large-scale NBS for hydro-meteorological risk [152]. The evaluation framework includes identification of evaluation criteria and ex-ante and ex-post evaluation.

Knowledge sharing

2.7. Reporting and dissemination

Reporting involves documenting evidence in a written format and dissemination is sharing reports with others [123]. It has been found that the evidence base of nature restoration project is likely subject to reporting bias [133]: it is likely that failures are under-reported and successful results selectively shared That is unfortunate as less successful projects can still provide useful information *on what prevented success, as understanding and addressing the causes of failure is a key process in improving ecological restoration practices* [133]. Lessons learnt are also rarely shared between projects; new projects can not learn how to avoid making certain mistakes with such a lack of knowledge sharing. Sub3

For these reasons Eger et al. [133] have developed a reporting framework that ensures results are not selectively recorded but all relevant information is stored [133]. This framework uses a FAIR approach to data dissemination (Findable, Accessible, Interoperable and Reusable) which would *"allow information to be easily communicated across regions, disciplines, and languages, [...], accelerate the uptake of valuable lessons learned, and work to build a stronger global restoration community"* [133] Sub3

2.8. Learning

As mentioned above, gaining knowledge is one of the reasons for evaluation and it is also part of the effects of pilot projects. Evaluation and analysis of 'lessons learnt' is important in every business sector [153]. When an organisation learns and changes how it acts, it is called organisational learning [154]. Often organisations are the entity expected to learn from evaluation, not individuals, which is paradoxical as organisational learning is the sum of individual learning [155].

2.8.1. Organisational learning

Organisational learning is part of knowledge management which is about all aspects of managing knowledge as an asset e.g. creating a repository and enhancing knowledge acquisition [156]. Knowledge management is an important factor for project success and sharing of information and knowledge between projects [157]. Re-using knowledge and learning from project experience is a key challenge for project-based organisations and knowledge management also helps in such situations to mitigate knowledge loss and support decision-making [157]. Said knowledge sharing between projects is called cross-project learning [158], detailed in the next subsection. Cross-project learning is linked with organisational learning as organisations learn from doing, observing, imitating, and from incorporating knowledge from other organisations which is often done through trial and error processes [155].

For governments' effective management of resources and organisational learning, cross-project learning and knowledge transfer is [159]. It has been found that organisational learning could also be important for successful projects that involve risk management [160] but not all external knowledge is necessarily useful [158]. This begs the question 'when should organisations not learn from other projects?'. When evaluations are considered mandatory and done to follow the rules and nothing more, then conclusions for improvement are not relevant [155].

There is an evaluation technique of organisational learning, based on the most significant change technique [161] and the insight that *"those who do evaluation learn from evaluation"* [162]. The methodology involves four stages: (1) preparation for evaluation, (2) story generation of stakeholders using the question *"Looking back over the last month or so, what do you think was the most significant change that occurred for you?"*, (3) analysis, selection and feedback of lessons learnt from the stories, and lastly (4) meta-evaluation of the process to improve it for the next iteration [162].

2.8.2. Cross-project learning

Sharing knowledge between projects can contribute to project success and could prevent potential future mistakes [157]. It has been found, however, that often experience from previous projects is

not used and people tend to reinvent the wheel [34, 157]. For this, it should be investigated how all stakeholders learn, at the start of a project [155]. Cross-project learning can then be facilitated by communicating project evaluations focused on 'lessons learnt' with regards to the processes and procedures [163]. Through helping others learn, by sharing and giving access to knowledge organisations can build trust and provide credibility of results [164]. Having shared and communicated knowledge, it can help in future cases when a project team can not solve a problem with their current knowledge and expertise [163]. Since sharing of knowledge and information is important [165] for cross-project learning, many organisations use review documents as 'boundary objects' to communicate results. IKI for example integrates its knowledge management (cross-project learning) with evaluation by communicating insights from projects to all relevant people [166]. A project with a knowledge programme called Natte Kunstwerken [167] also hosts workshops and seminars to share knowledge. An evaluation paper of European water management pilots showed that knowledge access can be technical but also about understanding of information, data, and perspectives [164]. Often knowledge transfer from projects in the form of 'lessons learnt' are evaluated and put in a database [34] (see the next subsection for databases). However, often the knowledge collected in databases is irrelevant, unhelpful, outdated, and fragmented [158].

A critical note was made by Newell [163] that ICT is not always effective for cross-project learning. Usually different teams are not able to see, which knowledge is available from other projects because no procedures of knowledge sharing is implemented in the organization. Lack of proper organizational structure that supports strategy of learning from experience is viewed as an important barrier [157]. Organisations can address this by holding meetings to share experiences between projects after milestones and invite (internal) experts to give trainings [158]. Other organisational support can be in the form of changing incumbent corporate culture, commitment from top management, and better ICT use [157].

A number of other barriers to cross-project learning have been described that can be organised in three categories [157]: organisational barriers, human barriers, and project-related barriers. Examples include inhibiting organisational or project structures, lack of time for knowledge sharing, and temporary organisations are usually focused on product delivery [157].

2.9. Knowledge bases

The difference between a database and knowledge base is that the former is a data structure for data storage and retrieval whereas the latter contain actual information about 'something' [168]. As mentioned above, databases and repositories can be used to enable enhanced organisational learning. Zhao et al. [158] mention that organisations should store garnered knowledge and stimulate and encourage project members to absorb knowledge from previous projects. For this, a knowledge base or database is not the only option; another possibility was highlighted by Connop and Nash, a spatial dataset portal that aggregates all information sources in one portal could be useful for evaluations with diverse methods and information sources [169].

But what should be stored on a knowledge base? Technical project data, understanding of information, perspectives [164], 'Lessons learnt' [34], 'lessons learnt' with regards to the processes and procedures that have been successfully used [163], and process knowledge with context information (and interesting solutions of previous projects) [158].

It is important to collect experiences and lessons learnt and Ecoshape has developed a framework that helps structure lessons learnt for better dissemination [25] ● Storing information on a knowledge base is a form of dissemination. ● Sub3

Knowledge bases are cost-effective and allow important information to be stored even when a pilot is finished and perhaps the website is no longer operational [35]. No information is lost that way. Knowledge bases also allow the integration of other data sets [35]. It has also been found that data quality increases when a knowledge base attracts more users; more people are likely to spot and correct problems in data [35].

2.9.1. Why is there a need for a NBFD knowledge base?

There is a lot of information about NBS on the internet. For specific projects, information is often stored and shared in a local language which makes it less accessible. Secondly, often project websites cease to be, making it difficult to trace back information [35]. Many NBS case studies also remain

in reports and are not added to central knowledge bases. Their information and knowledge are not broadly shared and stored. That is why, despite the increasing number of NBS being implemented, the research and evidence base required to improve implementation of new projects remains limited [8]. There have already been several knowledge bases developed but Dushkova and Haase [35] have found them lacking in a few regards e.g. they are scattered, do not have a standard data format (they are incompatible), and access is sometimes limited (no public access) [35]. Debele et al. [85] have found additional gaps in knowledge bases for natural hazards that hinder research: not enough data that has high precision and a long time span, the data is incompatible, the data is not in an easy to use data format, and limited accessibility.

Connecting Nature [35] has found several knowledge gaps with regards to knowledge bases, the most relevant gaps include: NBS projects could benefit from (mixed) evaluation methods that showcase the multitude of benefits as well as show the synergies and the trade-offs between NBS. Secondly, there is a need for representations in knowledge bases that balance *"rich descriptions of cases on the one hand, and comparability and transferability of results, on the other"* [35].

An analysis of all EU funded NBFD projects found that a platform or knowledge base should be developed (and of course kept up-to-date) for NBFD that stores information on *lessons learnt and their implementation costs (e.g., construction, monitoring, operation and maintenance and decommissioning costs* [22] ● IUCN has also mentioned that projects should share knowledge to aid other and future ● Sub3 projects [21].

Lessons learned may offer valuable insights for future NBS projects [3]. Such shared learning will lead to better NBS implementations in other fields and it can also provide a basis for establishing best practices when implementing NBFD [83]. Another influencing factor of NBFD are natural processes; understanding how these change over time is very valuable to store and share [22].

There is a particular need for a Dutch knowledge base a comprehensive review of Dutch restoration projects found that often seemingly obvious and specific information was omitted or remained in internal documents, inaccessible to the public and therefore even harder to track down with the passing of time [5]. Furthermore, for some projects it was not clear whether a BA or CI were used especially when it was not mentioned in the methodology; a standardised reporting form and database entry could help with this. Lastly, other activities and interventions that could have an effect on (long-term) results should be described, which does not always happen [5].

Dushkova and Haase [35] have stated that when a knowledge base is developed, it should be designed with a good balance between complete descriptions and generalised information for comparability and transferability ● ● Sub3

2.9.2. NBS knowledge bases

An investigation of possibly relevant knowledge bases yielded the following list of knowledge bases Table 2.3, that will be analysed in chapter 4.6.

Relevant NBS and NBFD knowledge bases			
MERLIN	EngineeringwithNature	UK government	Urban Nature Atlas
Panorama	EquatorInitiative	UNEP	BiodivERsA
Klimaatadaptatienederland	IUCN	ConnectingNature	BISE
ClimateADAPT	NetworkNature	IKI	ThinkNature
TKI	UNFCCC	INSPIRE	NWRM
Ecoshape	WaterActionHub	Geoportal	weADAPT
OPERANDUM	JNCC	EM-DAT	Nature of Cities
NBSinitiative	UrbanNatureAtlas	Munich RE	ClimateScan
Oppla	RECONECT	Swiss RE	PEDRR
naturebasedsolutions	NBS Bangladesh	Natural Hazards - NBS	WorldBank
Disaster Risk Management Knowledge Centre	PREVIEW Global Risk Data Platform		

Table 2.3: List of relevant databases and knowledge bases

Method

- Introduction
- Theory
- **Method**
  - **Research strategy**
  - **Research approach**
  - **Validity**
  - **Ethics**
- Analysis
- Development
- Results
- Conclusion

3.1. Research strategy

A research strategy is a general orientation to the conduct of research and it is often distinguished by quantitative or qualitative research, however there is also the combination called a 'mixed methods' research strategy [170]. This study employs a mixed methods research strategy: both qualitative interviews and quantitative surveys are used to collect data to answer the research questions. It has been proved that a mixed methods research strategy can be 'fruitful' even though the methods may seem incompatible [170].

Interviews are likely the most used method in qualitative research [170], the main types being semi-structured and unstructured. In quantitative survey research, the most widely used methods are the structured interview and self-completion questionnaire (hereafter called 'questionnaires'). There are many different ways and aims to combining quantitative and qualitative research [170] and this study falls in the category where a mixed method is used to answer different research questions with a relevant corresponding strategy.

Mixed methods are not in any way superior to a single strategy and there are also a few concerns [170]: the combination is likely to demand more time and resources, research efforts may be diluted, and one paper found that not all researchers may have the skills and training to conduct quantitative and qualitative research. There are many reasons for choosing a mixed methods strategy [171], for example it can be used to expand the study scope, for the development, or for triangulation [171, 172]. This mixed methods strategy logically follows from the research approach in this study because of the sequential design [173] it can be used for the development of the subsequent strategy [171]. There are two types of mixed methods, namely mixed data–collection studies (two or more data types) and mixed data–analysis studies (two or more analytical strategies) [173]. This study falls in the mixed data-collection category, per the definition of Small [173] *"at least two kinds of data or two means of collecting them"*.

3.1.1. Phase I: qualitative interviews and analysis

At first, literature research was done as a thorough understanding is needed of river flood defenses, NBS, NBFD in rivers, pilot dynamics, evaluation processeses, and the current modus operandi at RWS. Secondly, exploratory qualitative research was done using semi-structured interviews because this interview process is flexible [170]: the interviewee has a lot of freedom in the way and time they answer the questions and the emphasis on how an interviewee frames topics and views what is important [170]. During this phase, it was tried to answer the first sub-question about the current evaluation process at RWS in addition to partially answering the second sub-question.

3.1.2. Phase II: design research process

Subsequently, design research is done using a user-centered design methodology, similar to the approach used by Varner et al. [174], where iterative rounds of development and formative evaluation or validation are used to improve the design. User-centered design bases the design of an innovation on elicited information regarding the end-users who eventually use the innovation [175]. This has several advantages such as more creative solutions, more efficient and effective solutions, less redesign, and faster integration [176]. There are also some possible drawbacks to using this research strategy where some types of data are difficult to convert into design and the design can be overly specific for certain end-users [176]. This study uses a user-centered design research strategy as it is a form of generative design research which does not rely on participants to construct design artefacts [177]; participants of this study are professionals who might not have time to sit down and design an 'ideal' evaluation of a NBFD pilot. With regards to the iterative rounds of development, one paper found that at least two iterations are needed to yield three versions, before a product is good enough for release although more iterations are better [178]. That is why it was decided to do two iterations for improvement and a third for final design validation.

Design validation can be used to improve the design during the iterations and provide the final results; design validation is used as opposed to design verification as there were no a priori requirements stated, the design choices are assumed to be of merit and validated by the feedback [179]. Design validation entails evaluating a product for the requirements of end-users or stakeholders and the purpose is to ensure and provide evidence that the product is useful and applicable in a user's environment i.e. satisfies user needs [180]. Validation looks at the consistency and completeness of design [180].

There are many possibilities for design validation [181, 182]: demonstration is a good way to validate requirements and functionalities [180], heuristics analysis is also a good method for validation where empiric rules of thumb or principles are judged [181], questionnaires and structured interviews are also possible and commonly used [182]. Questionnaires and structured interviews are very similar as research methods, but differ mostly in the fact that the respondent must read and answer the question themselves [170]. Questionnaires do have some advantages as they are quicker to administer and are removed of interviewer bias. That's why it is considered the easiest method to gather data from a (substantial) number of people in limited time [183]. Questionnaires are also more often used to ascertain attitudes by inquiring about (personal) thoughts, feelings, or behaviours [184]. The choice for questionnaires does have some common drawbacks [170], the most relevant of which include: lower response rates, greater risk of missing data, and not being able to prompt and probe. These questionnaires then provide confirmation or redirect the findings for the second sub-question regarding the construction of a database.

Due to the timing of this study, during summer break, response rates of a self-completion questionnaire were expected to be low with many respondents on leave. Also, a small questionnaire pre-test indicated that there might be confusion without proper introduction of the tool. Therefore, it was decided to elicit design feedback using structured interviews after the design is demonstrated. The structured interview was done by showing the questionnaire and the interviewer asking the questions. This approach of helping the respondent through the questionnaire like a structured interview has the benefit that any questions can immediately be answered by the interviewer. This removes the possibility of erroneous answers based on misinterpretation. Secondly, it allows the interviewer to capture offhand comments that might be useful and make changes to the elicitation process where respondents may have had trouble understanding the intent or question(s). Thirdly, the most common sources of error in survey research [170] can be avoided using this strategy. Lastly, another benefit is that the findings are stored online ready for both qualitative and quantitative analysis. One caveat is that the interviewees have to be given exactly the same questions, otherwise reliability of the responses is lower due to different cues. The interviewer therefore read the questions word-for-word to provide identical cues only then could the responses be aggregated [170]. The questions could be read on the screen as well.

3.2. Research approach

Usually, in a methodologies chapter one can find a section about data collection and a section about data analysis. Due to the step-wise sequential nature and recurring data collection/analysis of this research approach, the methodologies and reasoning are listed per step for a better overview. Below, a schematic overview is provided in Figure 3.9 followed by a detailed account in the subsequent sections.

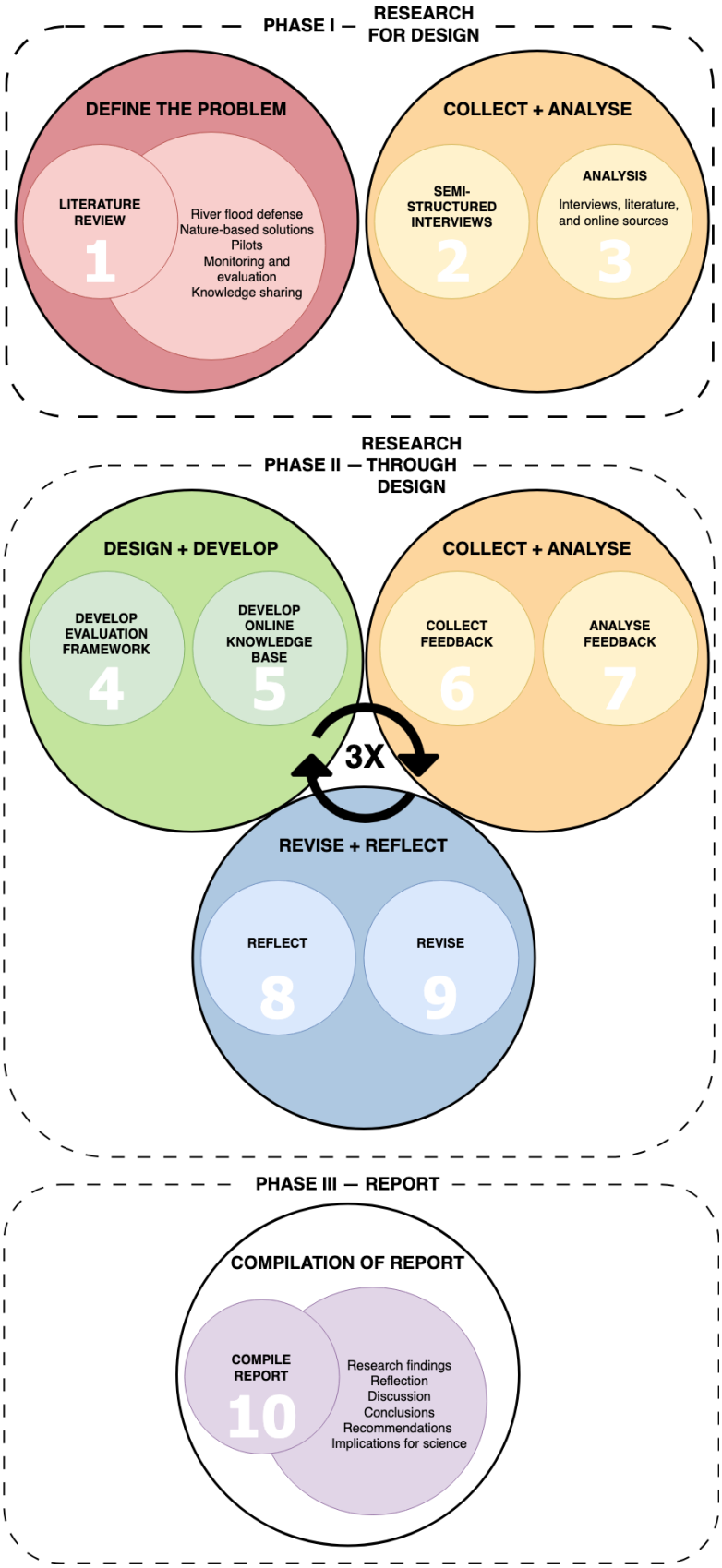


Figure 3.9: Research approach

3.2.1. Step 1: literature review

This study started off with a thorough literature review followed by a project proposal, as defined by Jesson et al. [185], which resulted in a problem statement and some knowledge gaps which lead to the formulation of research questions.

3.2.2. Step 2: semi-structured interviews

Interviews were held in a semi-structured way to include focused questions and allow for unforeseen remarks and perspectives to alter subsequent interviews. The interviews were recorded with permission of the participant and transcribed. The professionals that were asked to participate include: practitioner employees at RWS, NBS experts, researchers, and (past) project members of a NBFD pilot (refer to Table 3.4 for an anonymised list). Participants were selected from Deltares and Rijkswaterstaat due to ease of access. This is a straight-forward purposive sampling of participants that will provide the best information [186] combined with the ”snowball” approach [187] insofar as time allowed. All interviews were done one-on-one, either online or face-to-face, and all interviews took between thirty to sixty minutes.

Interview	Organisation	Profession
1	Deltares	NBS expert
2	Deltares	FRM expert
3	Rijkswaterstaat	Programme manager and ecologist
4	Deltares	Hydrologist and river research
5	Rijkswaterstaat	Innovation & knowledge management advisor
6	Deltares	Ecologist and water quality expert

Table 3.4: List of interviewees

During the interviews, two main questions were posed to all the interviewees: (1) what they think has to be evaluated when doing NBFD pilots in rivers and (2) what information they want to know if they research previous NBFD pilots. The rest of the questions varied per person due to the different perspectives and professional expertise, each interview comprised targeted questions.

Interview	Main topics	Subjects
1	NBS in rivers, MERLIN, IUCN, Monitoring & evaluation	Nature-based solutions
2	FRM in rivers, Room for the Rivers, Monitoring & evaluation, NBFD, NBS challenges	FRM, Pilots
3	Rijkswaterstaat operations, MERLIN, IRM, NBS in rivers, MERLIN evaluation methods	Monitoring & evaluation, Rijkswaterstaat
4	River research in general, Flexibele Kribben, Houten Schermen, NBS in rivers, Monitoring & evaluation, Knowledge sharing	Knowledge sharing
5	Innovation process at RWS, Scaling up of pilots, Pilot paradox, TRL, SRL, Knowledge sharing	
6	MERLIN, Beuningen, NBS in rivers, MERLIN monitoring, IUCN, Knowledge sharing	

Table 3.5: List of interviewees

3.2.3. Step 3: analysis

The interviews were held to begin answering the sub-questions. A full account of this step can be found in the next chapter. section 4.1 aims to answer sub-question 1 ’what is the current monitoring and

evaluation process at Rijkswaterstaat for nature-based flood defense pilots in rivers and floodplains?'. Analysis was conducted using an inductive data-driven coding approach of the transcripts, not based on a pre-supposed theoretical framework. The interviews were analysed a second time using a deductive approach by way of concept-driven coding for the other two sub-questions. chapter 4.2 delves into evaluation criteria and monitoring indicators that were mentioned in the interviews and chapter 4.6 analyses for the development of a knowledge base.

Sub-question 1: inductive coding

It was decided to use data-driven coding with a grounded theory approach as that is one of the most commonly used methods [188]. Grounded theory is an inductive approach where new theories or hypotheses originate from data (here transcripts) so the theories are 'grounded' in said data [188]. This approach can be used when there is no pre-existing literature or theory. It should be tried to ground everything in the data without initial preconceptions while interpreting the data although it is recognised that no one can do this completely objectively without introducing personal biases, motives, values, preconceptions, etc. by the fact that the researcher is a human being. This danger of introducing such fallacies is a danger prevalent in all forms of coding and theory building. In addition to the concern of introducing researcher influences, care should be given that the codes do not unconditionally accept interviewee opinions and views as truth [188].

There are three coding stages for grounded analysis [188]. The first step is called open coding where one reads the transcripts to identify possibly relevant categories. Afterwards, axial coding is applied to refine categories and related categories were searched. The last step to grounded theory is selective coding where core categories were defined.

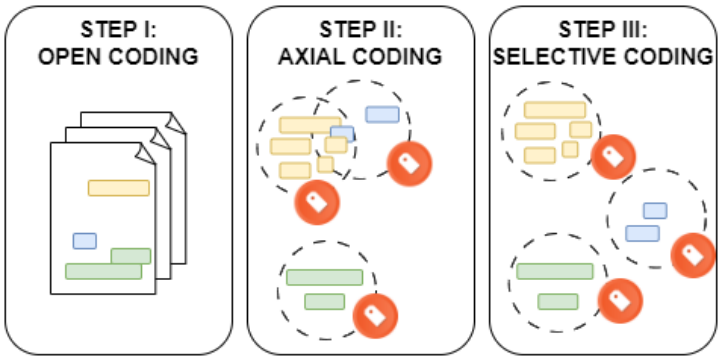


Figure 3.10: Inductive coding scheme used for interview analysis

The coding categories that were selected are: (1) organisation context, (2) innovation, (3) pilots, (4) monitoring, and (5) evaluation. The insights gained from the interviews are presented using these categories and can be found in chapter 3.4.

Sub-question 2+3: deductive coding

It was chosen to code the interviews a second time in the context of a clear theoretical framework for all questions and answers that could be used to answer the sub-question 2 and sub-question 3. Gibbs [188] mention that it is a good idea to start with a framework from research literature or hunches to start with a collection of possible code categories. These can be changed and added to later or during analysis as new categories are detected [188]. The chosen framework for coding is a general evaluation framework developed by the OECD, shown in Figure 3.11; a focus is placed on evaluation criteria as monitoring follows what will be evaluated. People that are familiar with NBS must be wondering whether the IUCN Global Standard was considered. It was decided to opt out of using the IUCN Global Standard as the manual states that it should not be used to evaluate but merely used to test whether something qualifies as an NBS [84]. Therefore, the more general OECD evaluation framework was used as it aids to *"determine the merit or worth of an intervention (policy, strategy, programme, project or activity)[...] and can be used to make evaluative judgements"* [150].

As the coding scheme can grow, it was decided to use the OECD framework for coding of both the monitoring & evaluation framework and the knowledge base; the monitoring & evaluation framework

is to be a part of the knowledge base so any relevant codes that do not find in the former may find its place in the latter.

Figure 3.11: OECD: six evaluation criteria [6]

Sub-question 3: feature and design discovery

Another small part of the analysis for sub-question 3, before the development of the knowledge base can commence, is to look at the relevant knowledge bases found in chapter 2.1.3 for additional feature and design discovery. Although there are a lot of possible features to be developed that were found in the interview analysis [189], it is good to glean best practices from other knowledge base design and their features. Their developers have undoubtedly put in a lot of thought as well; commonalities can be assumed to be some sort of standard.

3.2.4. Step 4: develop a monitoring & evaluation framework

This step can be found in section 5.1. The analysis, in chapter 4.2, using deductive interview analysis, augmented by findings from literature, provided the basis for possible design requirements of the initial M&E framework. In collaboration with supervisors, the number of possible information fields from the interviews was reduced based on empirical confidence of use. This yielded the start of a product backlog with prioritised elements that were absolutely necessary to include in the framework (still assumptions then to be validated) and the other information fields can be picked up in later iterations by remaining on a list without being forgotten.

3.2.5. Step 5: develop an online knowledge base

Step 5 is similar to step 4 and be found in the next section chapter 5.1. The initial knowledge base is based on findings from the interview analysis, literature, and initial elements to include were chosen empirically after deducing best practices from other relevant online knowledge bases. Elements that were left out also found their way on a product backlog.

The online knowledge base was developed using a Scrum approach where for each iteration features were chosen from the backlog to be implemented.

3.2.6. Step 6: collect feedback

In total three design-feedback iterations were done. The first two iterations served mostly to improve the design using open-ended questions while at the same time eliciting feedback that could be used for validation at the end. The third design-feedback iteration served as a validation step where feedback was mostly quantitative in nature. The sample size was too small for statistically significant validation but it was used as an indication for drawing conclusions whether the eventual solution was going in the right direction.

As mentioned above, there are many methods for validating a design [181, 182], and it was decided to use a combination of demonstration and structured interviews for user feedback by filling in a

Interview	Organisation	Profession
1	Deltares	FRM expert
2	Deltares	NBS expert
3	Rijkswaterstaat	Project manager
4	Rijkswaterstaat	Innovation & knowledge management advisor
5	Rijkswaterstaat	Project leader
6	Rijkswaterstaat	Programme manager and ecologist
7	Deltares	Water quality and ecosystems expert
8	Deltares	Programme manager water safety and infrastructure
9	Rijkswaterstaat	Advisor sustainable river management
10	Rijkswaterstaat	FRM expert

Table 3.6: List of interviewees for design feedback

questionnaire.

The questionnaire was supposed to be constant through iteration one and two. After the first interview, however, it was decided to make the questionnaire shorter and change some wording. The essence stayed the same and could be used for future comparison. Version one can be found in Appendix C, version two in Appendix D, and the last questionnaire for validation can be found in Appendix E.

The questionnaires feature open-ended questions and rating scales as to allow for quantitative analysis and scales are more appropriate to measure attitudes [184]. From the possible types of scales, Likert scales is one of the most popular approaches for generating reliable scales in terms of internal consistency [184]. A plethora of authorative sources report that a five-point Likert scale is the way to go, although Malhotra et al. [190] have found that seven-point items is optimal [184]. The anchor points should not feature absolute/extreme texts [191] e.g. ”completely true” should instead be labelled ”mostly true” [184]. For the anchor points, 5 or 7 should always be labelled the positive end and 1 being the negative end [192].

All the items that are added to the M&E framework and knowledge base are assumed to be added value. The feedback provides validation of these assumptions [179]. Same for the proposed improvement of the monitoring and evaluation process of RWS (main research question), this proposal was validated. Operationalisation of these three concepts (M&E framework, knowledge base, and proposal) allows for empirical variables to be tested by forming targeted questions in the questionnaires for which the following empirical variables are determined, shown in Table 3.7.

Abstract concept	Measure
M&E framework	design validity
Knowledge base	design validity, usefulness for primary intended users
Proposal	proposal validity, proposal appropriateness

Table 3.7: Operationalisation of concepts to allow for quantitative analysis of questionnaire responses

This resulted in the following Likert scales at the end of the questionnaires (Table 3.8).

Question	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree	Measure tested
Saving information and evaluations online in a standardised way has added value	○	○	○	○	○	proposal validity
This proposal is a good idea for better knowledge sharing	○	○	○	○	○	proposal appropriateness
For this proposal the design of the webpage needs to be changed	○	○	○	○	○	design validity
For this proposal the monitoring and evaluation framework needs to be changed	○	○	○	○	○	design validity
I would use the knowledge base to search for information about previous nature-based flood defense pilots	○	○	○	○	○	usefulness for PIU

Table 3.8: Likert scale questions at the end of questionnaires with the corresponding operationalised measure

In the last iteration, instead of open-ended questions for improvement, feedback was elicited for heuristics analysis for usability. The Interaction Design Foundation [181] advise to use 3-5 evaluators and determine 5-10 heuristics. This study uses five evaluators and five heuristics: three Nielsen-Molich heuristics [181] are used for the design in addition to two self-defined concepts to validate:

Nielsen-Molich

- **Clarity:** information is shown in ways users understand from how the real world operates, and in the users' language
- **Consistency:** be consistent so users aren't confused over what different words, icons, etc. mean
- **Relevance:** have no clutter, containing only relevant information for current tasks i.e. each part of the knowledge base does not have unrelated information within that part

Self-defined

- **Appropriateness:** all parts of the knowledge base are relevant for NBFD pilots
- **Completeness:** no relevant information missing
- **Ease of use:** it is easy to learn about previous NBFD pilots from the knowledge base

3.2.7. Step 7: analyse feedback

During iteration I and II, no in-depth analysis was done. For the design validation in iteration III, heuristics analysis was done by using slider scales for quantitative feedback and Likert scales (that were also part of iteration I and II).

To analyse Likert scales, there are two main statistical techniques called exploratory factor analysis and confirmatory factor analysis. The former is used when a researcher does not have hypotheses regarding the number and types of underlying factors that will emerge in the solution and the latter can be used when the questionnaire is set-up with hypotheses regarding underlying factors [184]. Confirmatory factor analysis follows literature review to work out the best representation and phrasing of items [184]. Likert scale items provide ordinal data, many parametric statistical techniques for normally distributed data can be used [184]. The sample size for this study is too small for statistically significant

conclusions to derive from statistical techniques. Therefore a more pragmatic investigative approach is used called exploratory data analysis [193].

3.2.8. Step 8: reflect

Before revision of the product backlog, it is good to reflect on the interviews and possibly draw connections with comments in previous interviews or previously read literature. This will help with prioritisation.

3.2.9. Step 9: revise

In this step, the list of possible changes (product backlog) and additions is revised. This revision is done by ranking all the actionable feedback based on a combined score of complexity of implementation and confidence that this change will be used (as mentioned in [194]). As a result, at the start of the next iteration, design and development can be done initiated based on the product backlog item priority.

3.3. Validity, reliability, and replicability

Validity

There is validity of a study itself and validity of measurement. There are two general types of validity of a study: internal and external validity. Internal validity is mostly used for proving relationships of independent and dependent variables in experimental research [184]. In non-experimental studies the internal validity is often lower, the same holds for this study and is also addressed in the discussion of the results (see section 7.2). External validity, also called generalisability questions whether the gathered results in one study can be applied to other settings.

To ensure external validity, during the semi-structured interviews of Phase I it was tried to feature a general set of questions that were common across all participants and additional questions that were tailored to the expertise and profession/position of the interviewee. In practice the only questions that were common between all interviewees were: (1) 'what should be evaluated for NBFD pilots in rivers?' and (2) 'what information would you look for in an online knowledge base about NBFD pilots in rivers?'. For Phase II, external validity is higher due to the structured approach and exact phrasing of questions.

Measurement validity, or construct validity, is about how valid the use of a measure is with respect to the theoretical construct one aims to study [184]. It says something about the results of a measure and whether they fit with theories which a test is based on. Construct validity actually consists of component parts [184]: face validity (not always recognised), content validity, criterion validity, convergent validity, and discriminant validity.

It is important to be aware of the threats to measurement validity that are called response biases that influence results: mood, social desirability, language difficulty, extreme-response sets, acquiescence. Taking this into account, to ensure construct validity for the survey, difficult words and jargon were removed from questionnaire questions, Likert scales did not feature extreme options, and there were some negatively worded questions introduced. Content validity is rather low due to the breadth of investigation (three constructs) and shortness of survey.

Reliability

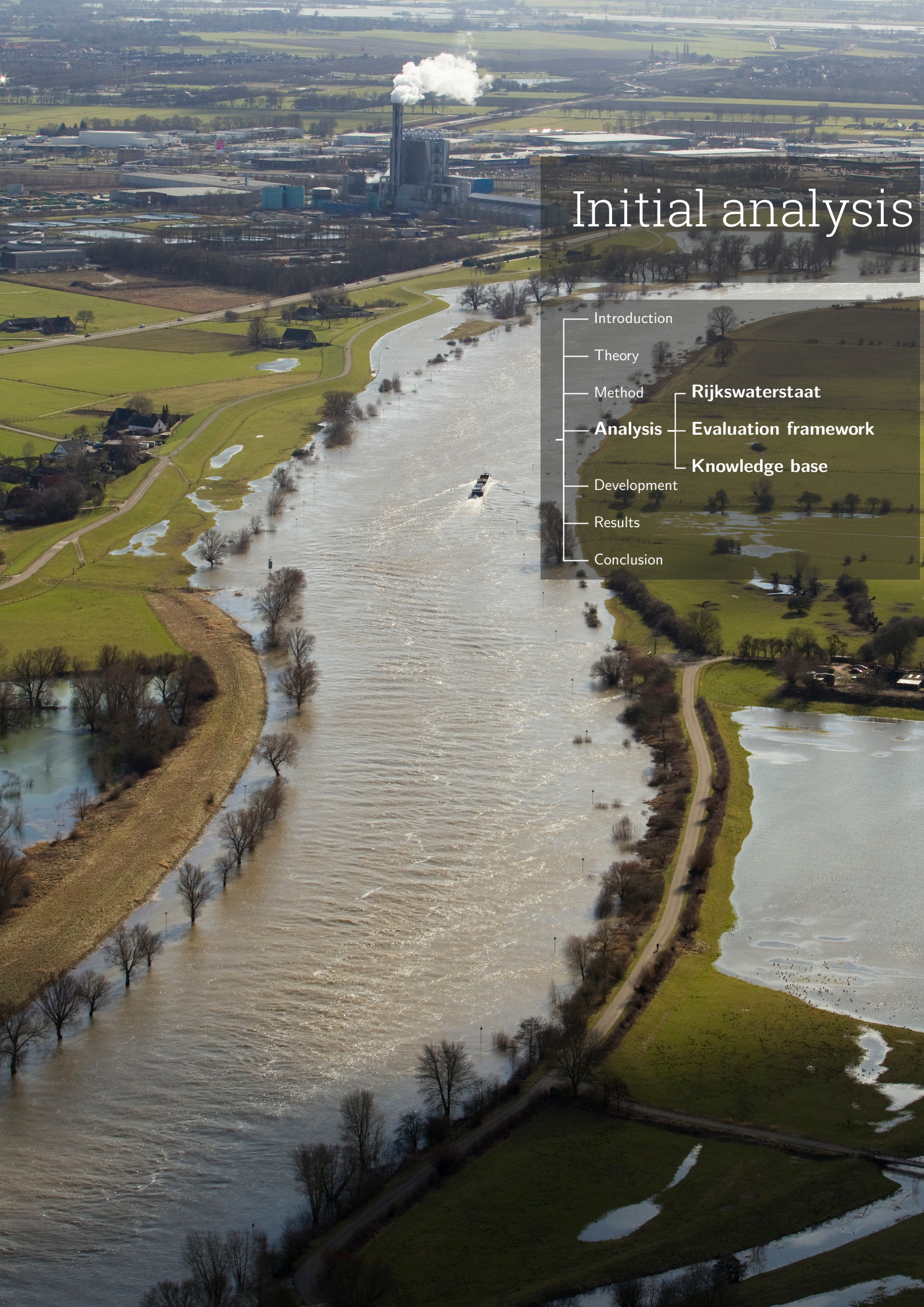
Reliability is about whether results can be repeated and the consistency of assessment [184]. Reliability is more often used for experimental research [170]. Due to the interview setup (nonexperimental and noncontrolled), results will not be repeatable for this study: results of the interviews will undoubtedly be different.

Replicability

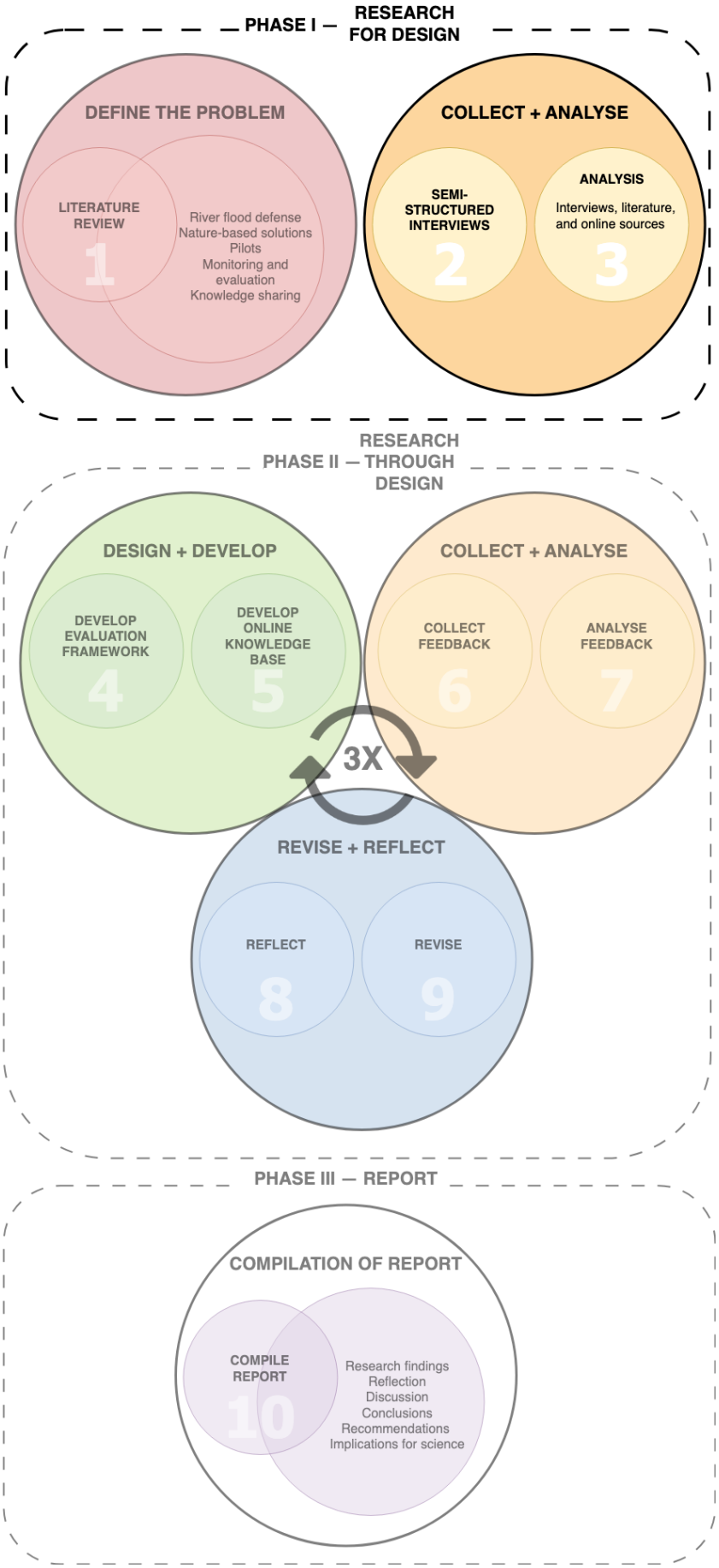
Replicability pertains to the extent to which other researchers can follow the procedures taken and try to replicate a study [170]. It was tried to make the method chapter as comprehensive as possible with all methodologies listed per step in the research approach. Throughout the thesis, great effort has been put in making figures to illustrate relatively abstract concepts, make diffuse information easier to interpret, and it was tried to make each figure intelligible as a stand-alone piece of information. Replicability is deemed to be high although the reliability of results is lower.

3.4. Ethics and privacy

To ensure that this research complies with the Human Research Ethics policy at the TU Delft, HREC approval is needed and participants signed an informed consent letter (see Appendix B). There are not many immediate risks associated with the type and content of this research; most important for this study will be that data collection and storage complies with EU and national data protection laws [195]. Appropriate measures were taken to safeguard the privacy of participants: collected personal data was stored offline and deleted at the moment of study completion. Explicit personal information was anonymised.



Initial analysis


PHASE I — RESEARCH FOR DESIGN
DEFINE THE PROBLEM
LITERATURE REVIEW
1
River flood defense
Nature-based solutions
Pilots
Monitoring and evaluation
Knowledge sharing
COLLECT + ANALYSE
SEMI-STRUCTURED INTERVIEWS
2
ANALYSIS
Interviews, literature, and online sources
3
PHASE II — RESEARCH THROUGH DESIGN
DESIGN + DEVELOP
DEVELOP EVALUATION FRAMEWORK
4
DEVELOP ONLINE KNOWLEDGE BASE
5
COLLECT + ANALYSE
COLLECT FEEDBACK
6
ANALYSE FEEDBACK
7
3X
REVISE + REFLECT
REFLECT
8
REVISE
9
PHASE III — REPORT
COMPILATION OF REPORT
COMPILE REPORT
10
Research findings
Reflection
Discussion
Conclusions
Recommendations
Implications for science

Rijkswaterstaat

This section is an analysis of the current situation at RWS and aims to detail all relevant information regarding the first sub-question 'what is the current monitoring and evaluation process at Rijkswaterstaat for nature-based flood defense pilots in rivers and floodplains?'. It quickly became apparent that, in fact, there is no formalised monitoring & evaluation protocol specific for NBFD ● This shifted the ● Sub1 focus to identifying relevant processes that a suggested protocol could tag onto. The insights (below) are grouped based on the coding categories found during the inductive interview analysis. *Garnered interview insights (in italics)* are woven together with literature and online sources (normal typeface) to form a story. There were a few bits of important information that informed the other sub-questions; these are marked with breadcrumbs.

4.1. Interview insights

4.1.1. Organisation context

RWS is the executive organisation of the Ministry of Infrastructure and Water Management [196]. RWS is responsible for a lot of tasks and is therefore a large organisation with more than ten thousand employees [197]. *As RWS is such a large organisation, it has been organised at national level, regional, and 'dienstkringen' for more local area management.* For the context of NBFD, RWS mostly works on a project basis as it is part of the Grond-, Weg- en Waterbouw (GWW) domain [198]. Projects of this domain are structured along five phases [199]: initiation, exploration, elaboration, realisation, management and maintenance. RWS employs a specific set of managers for each project, namely [200]: at least one project manager, project controller, surroundings manager, technical manager, and contract manager. When a project has been clearly defined, the scope is determined as well as the methods of tendering and contracting [198]. The type of contracting depends on the expected risk of the project [201]. RWS collaborates a lot and often becomes a client by outsourcing. Not everything is outsourced as RWS does perform some tasks itself; for each project it has to be decided whether to outsource or not since outsourcing is not always the best and cheapest option[202]: this type of public-private cooperation can involve complicated contracts and may take more time and money [202].

4.1.2. Innovation

RWS collaborates with many external parties for innovation. One such collaboration is called 'Leerruimte SSRS' where RWS works together with market parties and knowledge institutes to develop innovations in rivers. Previously, RWS was actively innovating on many fronts but the innovation efforts were (rather) scattered. An innovation agenda was developed because it was deemed that the innovation efforts should be more focused based on priorities and what contributes most towards RWS's overall goals. Four focal points were chosen for which roadmaps were developed indicating a sort of path how to achieve its goals. The focal points are [203]: Replacement and Renovation, Sustainable Infrastructure, SmartMobility, and Data and information services. A fifth focus point, climate adaptation, was added after this interview. *RWS has often gotten feedback that innovation takes too long so the innovation agenda also helps communicating to stakeholders that it is actively trying to improve the innovation process. Innovation management at RWS is seen from multiple levels of abstraction: first you have the whole network, then the organisation (RWS), the focal point, and lastly the individual innovation. At every level different tools and methods are available to engage with an innovation.*

As previously mentioned, innovation development often take a long time at RWS; it was found that the cause is often a lengthy process of scaling up or 'uniformering' that encompasses all dealings that ensure an innovation can be adopted into standard organisation structures, processes, and way of working. It deals with making sure an innovation is ready for use so guidelines are changed, it should be introduced with management and maintenance, etc. A very well received innovation took a long time to adopt into the organisation as it turned out that it touched on eleven frameworks, procedures, and guidelines in five different organisational units that all had to be amended. That can make it rather com-

plex. To combat this, the Board of RWS has said that innovations should follow a standardised way of innovation, scaling up, and adoption into standard practice called 'Innoveren-uniformeren-produceren' (IUP).

Innoveren-uniformeren-produceren

Every innovation has to follow this IUP process of which pilots are just a component part. IUP is specifically targeted at the focal point level (innovation portfolio) and individual innovation level. At the moment, this process is still being developed: not everybody uses it yet and the team is now helping people on a case-by-case basis to scale up. They are also developing standardised formats for each of the distinct stages in the IUP process. There is a format for the initial exploration but not yet for the pilot. An example of a NBS innovation that could be suitable for this IUP process is the willow coppices that attenuate wave action on a dike.

Innovatieaanpak

In addition to the IUP process, an innovation approach 'innovatieaanpak' was also developed in parallel that was less focused on scaling up but mostly looked at the innovation component part. These are separate but it will be tried to combine them in the future.

Technology readiness level

RWS has a scale to indicate the technology readiness level (TRL) for scaling up an innovation. It is a scale from one to nine often used as a general indication where an innovation is in the development process: one to three is exploratory development, four to six is testing with a pilot in a controlled environment, seven is when an innovation is brought to an operational setting, eight is a pilot is tested and validated in operational setting, and nine indicates that an innovation is ready: the innovation performs as it should after testing in an operational setting, and a decision should be made to scale up or not. At this stage it can still be unclear about the breadth of application because it was tested in operation at some locations but you may not have had the opportunity to investigate all elements and aspects. Additionally, in practice often some corners are cut to be able to implement a pilot. To really test everything and to know all of an innovation's functions, TRL 8 or 9, takes quite a long time.

Stakeholder readiness level

Often the problem for scaling up, the problem is not the technology but adoption within the organisation. With organisations as big as RWS, it is a challenge 'how do you get this technology embedded in the processes and instruments?' and 'how do can you ensure that the organisation is ready to start working with this technology in "standard operation"?'. That is where SRL comes in, it was developed for this purpose. The Stakeholder readiness level (SRL) tool was developed by RWS to show how prepared the organisation and stakeholders are to start using a new innovation [204]. It looks at five components to see whether any aspect may pose a problem or bottleneck in the innovation and subsequent adoption process: the level of support, the value for end users, costs, compatibility and risks [204]. RWS recommends paying close attention to TRL and SRL at the earlier stages of an innovation ● . This was ● Sub1 corroborated in one interview *it is important to look at both the TRL but also the SRL before starting a pilot: the decision to start is partly dependent on the answers to 'what has to happen before this innovation can be adopted for implementation?' and 'how difficult will it be?'.* Although the SRL can be useful throughout several stages of the innovation process it can also be instrumental for monitoring [204]; the SRL tool can assist in monitoring progress if it were to be used periodically ● ● Sub2

Pilot paradox

The pilot paradox is noticeable at RWS. The last couple of years, more and more attention is being paid to the necessary support base when trying to scale up. It is sometimes tried to get more people involved using initiatives like living labs that create a sort of ecosystem around pilots. You need support from (upper) management but that is easier if they see that there is a larger group of people supporting an innovation. Frequently, a decision to scale up is made without fully knowing what it entails to adopt the innovation. Then you don't know how long it will take if this decision to implement is made, without fully knowing the consequences. In the scaling up phase, often an innovation is tried out again in smaller trials before jumping to large scale. In doing so, the innovation can also be tweaked while scaling up. This can be because it might not fit the organisation perfectly or the innovation is improved just a bit further.

4.1.3. Pilots

It was mentioned that the biggest difference between a pilot and a normal project lies in the fact that pilots can procure permits more easily. The specifics and distinction of a pilot at RWS can be a bit confusing: e.g. before a pilot, PAGW (an investment programme) sometimes does a pre-exploration (pre-verkenning), looking at the bottlenecks of ecological functioning in an area and how they can be solved, as a preliminary investigation (vooronderzoek). Another programme called IRM is also running pilots in key areas to test their methodology. So, in an area called the Gelderse Poort there is a preliminary investigation from PAGW called Gelderse Poort and an IRM pilot called Gelderse Poort. They co-exist with quite some overlap and collaboration but they are distinctly separate entities. Confusing names and sometimes vague boundaries aside, testing in a river is often quite costly so pilots are often resigned to a single location. However, innovations can be context-dependent and should be tested at multiple locations before more general conclusions can be drawn. That is also why there are phases such as phase one of the pilot Flexibele Kribben which had to meet an important requisite for continuation. After evaluation and some changes it was decided to start phase two. However, some pilots do not continue to the next phase simply because it costs too much money.

If there is a lot of water in the floodplain during winter (because ecologists would prefer that) and a flood wave is seen in Germany, the floodplain has to be empty. This is a trade-off made between ecology and storage capacity. Interestingly, previously projects would not have happened if there was such a conflict of interest but increasingly the mindset at RWS has shifted to looking at 'in what form would it still be possible?'.

4.1.4. Monitoring

RWS has a programme called 'Monitoring Waterstaatkundige Toestand des Lands (MWTL)' that continually collects monitoring data in the sea and rivers for operational water management: it aids in determining trends, provide reports, and it allows for testing against standards [205]. This programme monitors the morphology, water quantity at more than 450 locations and chemical quality, biology, and stray litter of the major water bodies and surroundings at more than 170 locations [60, 205]. *One of the monitoring instruments mentioned during the interviews was the 'Vegetatie Monitor' which allows RWS to survey the vegetation in the flood plain using satellite imagery and test whether the current vegetation will pose a problem in case of high waters.* RWS has developed comprehensive regulations for the various methods of measurement needed for monitoring, called Rijkswaterstaat Standaard Voorschriften (RWSV's), that apply also to contractors and are suitable for monitoring outside of the MWTL programme [206] Additionally, RWS does have a protocol for the monitoring and assessment Sub1 of surface water bodies in light of the WFD [207]. In this document, they also mention two instruments that are not regulation but are related: a guidebook how to monitor biology in freshwaters [141] and a guidebook for monitoring hydromorphology [208].

For projects, RWS also requires contractors to do architectural monitoring to ensure that the environment/surroundings are not damaged during construction [209]. In the case of damage, this aids also in determining the extent and liability for compensation [209]. Interestingly there is no prescribed method for this type of monitoring [209]. *During the interviews it was mentioned that often there is too little money or time dedicated or available for special monitoring programmes of a pilot's effects An example would be the 'Langsdammen', a specific project in the Waal, that had to be monitored* Sub1 *ecologically and morphologically ("what happens to the river bed and more or less erosion?"). Multiple universities took up the monitoring but there was not a suitable long-term monitoring programme set up by the project organisation. Another example of too little time was seen during a pilot called 'Houten Schermen' which saw wooden fences placed in the river to reduce erosion. This was a NBFD pilot with a monitoring time frame of one year. The aim was to see the performance and functions at high water conditions. Unfortunately, the functions it was supposed to have were not conclusively found, but "it could be that one year was too short".* The last example to illustrate the point that monitoring does not always get enough attention and means was shown in the case of a pilot in the IJssel called 'Flexibele Kribben' where an innovative approach to river groynes was tested. *For this pilot, ecological monitoring was done in a pragmatic fashion where an ecologists was on-site for a few days.* When asked whether that was enough, the interviewee mentioned that *to really know the effects, on the smaller and larger animals or just the fish, you need more extensive monitoring. It was considered that NBS sometimes need more time to become fully functional, but still monitoring was constricted to one or two days* Sub1

4.1.5. Evaluation

A wide variety of things were noted regarding the evaluation of a project. *For a start, knowledge institutes that help with the monitoring are often also involved with the evaluation. It was also mentioned that evaluators were asked to evaluate and report the innovation development progress using the TRL scale* Sub1

All but one interviewee had worked on some aspect of a riverine pilot or project. Their experiences and impressions thus derive from specific cases or generalities. The following are accounts of different projects or pilots. *For the cyclic floodplain rejuvenation pilot project at Beuningen, an interviewee mentioned that the high water function was evaluated, using the Vegetation Monitor. Ecotope maps are also 'always' made. The interviewee did not known whether it was evaluated ecologically. For the Flexibele Kribben, an outside knowledge institute, Deltares, performed monitoring, presented their findings multiple times, and later drafted an evaluation report. Deltares had the role to keep the bigger picture in mind as an independent knowledge institute and 'do the comparison' for evaluation. In doing so, Deltares was able to provide critical notes in the evaluation that were used to first determine whether to continue and later helped shape the second phase. The evaluation report was shared quite widely, not only within the innovation team. This was actually an important requisite set by the funding organisation TKI, which provided a subsidy for the pilot, that findings should be public information. Conversely, an evaluation report made for the 'Houten Schermen' pilot, was used/shared in a smaller group. The interviewee said that it was a brief report detailing the fact that something was built and the effects of a high water event (flood?). 'Ruimte voor de Rivier', a special large scale programme had a unique quality team which both coached and evaluated during and after the programme ended. This quality team was introduced due to the special nature of the programme and spatial quality being a primary goal, which is not normally the case. Additionally, multiple evaluations were done by different third parties when the programme ended. Lastly, a special international project called MERLIN required each country's representative projects to perform the following evaluation steps: a SWOT, GAP analysis, optimisation strategy, and a regional scalability plan to learn from the past.*

Besides the actual effects, it is important to consider the context of trade-offs and decisions made during implementation of a pilot. A good example: secondary channel designs are often not allowed to draw too much current away from the main channel, otherwise the main channel will have its river bed raised through increased sedimentation which is bad for navigation. RWS does not want nor allow that, thus, making a secondary channel less effective ecologically and affecting its 'performance' when eventually evaluating. This context should be taken into account when determining 'how well it performs' for a good evaluation. So, the context during implementation is important to take into account Similarly, it was mentioned that, that water management is dominant: there is not a single tree in the floodplain that is not 'allowed' to be there. Another type of context to consider is the policy context of the (near) future which is often disregarded: current evaluation practices do not yet take into account what might happen if Germany were to change their policy and its ramifications on the Netherlands downstream. Main

Lastly, it was stated that NBS and NBFD pilots and projects should be evaluated the same as conventional solutions. As of yet this is impossible as the standard ('Richtlijnen Ontwerp Kunstwerken (ROK)') and design prerequisites for conventional solutions do not recognise NBS yet in the list of possible civil works [210]. *Additionally, two interviewees brought up the fact that there is sometimes confusion when something can be regarded as a 'nature-based' solution.* Incorporating the IUCN Global Standard [84] into the M&E framework could remedy this fact as it explicitly indicates whether the pilot could be considered an NBS Sub2

4.2. Concluding remarks

There is not one standard for monitoring and evaluating riverine NBFD pilot projects. Through current innovation efforts in the IUP process, a template will be developed for pilots. Suggestions made in this report could provide a good starting point. The pilot paradox is already known and recognised within the organisation as the IUP process aims to combat this. For stakeholders the SRL and TRL can be a good frame of reference to gauge the development stage of an innovation. It could be helpful if a similar guide is developed for the overall IUP process as there was not a clear standard or delineation for phases across the projects e.g. it differs per project what 'phase one' and 'phase two' mean.

Monitoring is important and should receive necessary attention and resources. This will only make

evaluations better ● Extra monitoring of NBFD pilots, outside of the operational/standard monitoring done by MWTL, predominantly looks at hydraulics, morphology, and ecology (i.e. vegetation, macrofauna, and fish). Theory however mentions that it is best to also look at social monitoring indicators, but that has not been found ● From interview comments and pilot reports it appears that leading indicators are not always used. ● Main ● Sub1

Going through evaluation reports, it can be noted that evaluation and monitoring aim to answer predefined questions ● . Interestingly, by and large evaluations of interventions do not consider the context in its entirety or neglect the social and political context ● Documents referred to in the evaluation reports could not always be found on the internet. Years after a pilot is completed and evaluated, sometimes it is decided to revisit and evaluate again [70]. Additionally, it can sometimes be hard to discern when a pilot started and when it was considered 'completed'. Pre-existing changes and history as a context can be hard to backtrack and may obfuscate the scope. Additionally, pilot locations can continue to be maintained and/or evolve. This way a 'simple' demarcation of time, corresponding activities, and effects is not easily done unless well specified in documents. Getting a clearer picture of the past is also made difficult by the fact that older documents are sometimes hard to find or go missing ● ● Sub1 ● Sub1 ● Sub3

In personal communication it became apparent that, although there was interest from the interviewees, in the idea of an online knowledge base, one interviewee mentioned that they personally saw a knowledge gap for a knowledge base of NBFD pilots and projects; however, employees at RWS probably do not want an additional platform or tool. Armed with this insight, it is recommended to look at possibly combining and/or augmenting existing tools or platforms. This could be done with a formalised procedure such as the IUP process ● ● Main

Monitoring & evaluation framework

After the inductive analysis of RWS, the interviews were analysed again trying to answer sub-question 2: 'what are important considerations for monitoring and evaluation of nature-based flood defense pilots in rivers and floodplains?'. The interviews were analysed using a deductive approach, as mentioned in chapter 2.9.2, starting off with the six OECD evaluation criteria framework as the theoretical 'lens' and general coding categories including one category 'monitoring'. While analysing the interviews, a large number of potential evaluation questions were found that fit in the OECD criteria. This is understandable as the criteria were elicited from respondents with a diverse range of professions and interests. This is also indicative of the multidisciplinary nature of the water sector and public planning sector that are relevant for NBFD pilots in rivers and floodplains.

Figure 4.12: OECD: six evaluation criteria used as coding scheme [6]

Firstly, the coded transcripts are analysed for monitoring. This is followed by useful insights and possible evaluation questions garnered during analysis regarding evaluation; these are listed per coding category i.e. the OECD criteria (definitions and explanations come from the guidelines of the OECD framework OECD [6]). For reference, a long table is included at the end listing all evaluation questions that were found in the transcripts Table 4.9. Then other relevant comments for sub-question 2 are detailed followed by concluding remarks.

This is merely the analyis, implementation of these insights, into the design and development of a M&E framework, can be found in the next chapter, section 5.1. Statements marked by a breadcrumb indicating further development did not make it into the final implementation.

4.3. Interview insights: monitoring

During the interviews, not a lot was mentioned about monitoring. Some were very brief but clear about what should be monitored for NBFD pilots: *You should monitor: the biotic environment, physio-chemics, morphology. Another mentioned ecological effects and morphological effects. Also, only about five to ten percent of the projects provides hard evidence to the monitoring of either floods, droughts, and biodiversity.*

One interviewee mentioned how they had a lot of trouble finding out how a certain (biodiversity) value for a specific region was derived. Nobody could explain the method of arriving at this value from monitoring data. That should never happen in theory but in practice people make choices that are not reproducible. As a researcher and scientist, that is a bit weird. Policy indicators should come directly from data but, apparently, that is not always the case.

One interviewee said that for every pilot, a proper long-term monitoring programme should be set up otherwise it should not be called a pilot or you should not even execute the plan. This was said with practical experience in mind that monitoring does not always get enough resources. Therefore they wanted to know *'how long will the pilot be monitored after implementation?'.*

4.4. Interview insights: evaluation

4.4.1. Relevance

The most important element of relevance is to what extent the needs and priorities of central stakeholders are met. Defining the stakeholders is therefore necessary for evaluating relevance. Stakeholders were recognised in a few interviews but other elements like the context were mentioned more often.

4.4.2. Coherence

This is a relatively smaller criterion with only one possible evaluation question found in the interviews. There was one question about future goals with respect to adaptive pathways. These pathways are internal to the organisation strategy so it is quite relevant. Internal coherence looks at how well the pilot would fit within wider policies and alignment with other pilots/projects/programmes in the area by RWS. No evaluation questions were mentioned for external coherence which consider the commitments to external policy (such as SDGs) and other organisations' efforts.

4.4.3. Effectiveness

Effectiveness evaluates the achievement (or degree of achievement) of its objectives. This criterion can also help to pinpoint whether the cause may lie in the implementation or design.

Varying importance of objectives and results has to weigh the objectives when not all have been achieved to evaluate effectiveness. This element can build on the evaluation of relevance and identification of stakeholders. A conclusion could be that a pilot was effective for some stakeholders and for others not so much. This element was not found in the interviews.

Differential results across groups considers inclusiveness and equity of results between stakeholder groups. No evaluation questions were related to this element of analysis.

4.4.4. Efficiency

This criterion tries to evaluate and justify the results of a pilot based on the resources used or spent. This type of justification is often of practical and political importance. The resources considered are not only financial but also human resources, environmental resources, and time resources for which a comprehensive economic cost can be calculated. This way alternatives can be compared for cost-effectiveness. There were very few questions about efficiency mentioned during the interviews. Possibly because of the professions interviewed i.e. no project managers or project leaders that deal with the financials of pilots. An interesting evaluation question posed was about the operational efficiency of the pilot with regards to cooperation of involved parties and their communication.

4.4.5. Impact

Interviewees posed the most evaluation questions related to impact i.e. a pilot's effects. Mainly, the evaluation questions pertained to higher-level effects and benefits. No one mentioned anything that could be coded in the sub-category of differential impacts. This element of analysis looks at possible negative distributional effects (commonly among gender) [6] hidden behind seemingly positive effects. So, while the effects seem positive or neutral, is one group suffering? A surprising example of this would be the snow clearing routine in Sweden that was proved to be sexist [211]. Therefore, it could be worthwhile to investigate the relevance of the element further for NBFD pilots ● Future research

Another element that was foregone, transformational change, examines the extent to which changes in systems or norms have been effected e.g. whether traditional gender roles have changed. This element of analysis seems a bit less relevant for NBFD pilots.

4.4.6. Sustainability

This criterion regards sustainability as looking at future prospects: 'are the net benefits of the pilot expected to continue financially, economically, socially and environmentally?'. In almost all interviews future-minded evaluation questions were suggested.

This all ties into the enabling environment which can be strengthened through stakeholder engagement, public consultation, political engagement, political will, political commitments, (changed) policies, etc. One short comment was made about the enabling environment and was quite vague. For future evaluation this could be made more clear.

Criterion	Element of analysis	Knowledge base fields
Relevance - Is the intervention doing the right things?	responding to needs, policies, and priorities	Which stakeholders are important? Which stakeholders actually use evaluations of rivers, flood safety, and biodiversity?
	being sensitive and responsive to context	What is the problem? What was the cause? Can you alter the cause? What about flood risk (hazard, exposure, vulnerability)? Flooding is no problem unless there are people. So what about the people? Why are they there? Can't they build and live somewhere else? What kind of damage will occur? What kind of hazard? What about the enabling environment? What about the political context? What about social acceptance? Is the land owned? What are the policies? What about permits? What is the legal framework?
	quality of design	What were the objectives/goals of the pilot? What were the goals, with their motivation, and KPIs defined at the start?
	responsiveness over time	For what time horizon was the intervention designed? How does it look now?
Coherence - How well does the intervention fit?	internal coherence	What is the future goal and how does this project contribute towards an adaptive pathway?
	external coherence	—
Effectiveness - Is the intervention achieving its objectives?	achievement of objectives	How did the pilot perform with respect to its primary goal? How did the pilot perform with respect to future goal(s)? Were the initial goals realised? To what extent were the objectives not met?
	varying importance of objectives and results	—
	differential results across groups	—
	understanding the factors that influence outcomes	Did you have to adjust goals (and why?)? What trade-offs were made?
Efficiency - How well are the resources being used?	economic efficiency	What were the costs?
	operational efficiency	How well did the parties work together and communicate?
	timeliness	What was the project duration?

Impact - What difference does the intervention make?	higher-level effects	How was the technical performance? What is the ecological performance? What is the influence on shipping? What is the effect on other sectors? What is the effect on floods, droughts, and biodiversity? How does the vegetation influence floods? What is the effect on human health? What is the effect on people? Does the pilot reduce flood height? Does the pilot reduce the extent/exposure? What are the social effects?
	significance	What are the socio-economic benefits? What are the co-benefits? Which policy decisions will be made based on this evaluation?
	differential impacts	—
	unintended effects	What are the off-site effects? What are the effects on the sectors?
	transformational change	—
Sustainability - Will the benefits last?	understanding the components of the enabling environment	What about the enabling environment?
	continuation of positive effects	Were lock-ins and lock-outs prevented? What might be relevant future scenarios? How does the intervention perform under these scenarios? How may politics influence the future? Can transboundary decisions/policy affect the pilot site?
	risks and trade-offs	What kind of trade-offs were made? What went wrong? How was it solved? How can you avoid these mistakes? Are certain activities provoked or disincentivised? The things that did not meet the objectives, may they pose a problem or risk later?

Table 4.9: Important evaluation questions mentioned in interviews

4.5. Relevant comments

The following is a collection of sentiments about NBFD, monitoring, or evaluation that did not quite fit as a single evaluation question. They are included as they were deemed to make up important context to answering sub-question 2.

There is often a lot of context that plays into determining whether a measure performs well. But that is a good evaluation at the level of a measure (pilot in this case) to be able to implement it well later on. But it really depends a lot on the person you ask at which scale and level of detail they would like to know information and indicators. An example: if you are someone in The Hague looking at all measures in the Netherlands with general aims to improve biodiversity, then you need very much aggregated data that still shows how well a measure performs and its effects and also able to see trade-offs with climate change or like they do in the Green Deal: shipping or recreation. That is a way higher level of abstraction so it would be interesting to know which stakeholders are important and which stakeholders actually use evaluations of rivers, flood safety, and biodiversity? ● *This does mean that there are innumerable levels of abstraction for which criteria and indicators can be determined based on scale and different information needs. when you combine different measures in one strategy at landscape scale, you need stakeholder engagement at every level and step.* ● Future research

During a project, often times, trade-offs are made and only the results of such 'key' considerations are visible. You can not properly evaluate the outcome of a trade-off without knowing the considerations, which is also a concern mentioned: 'If you only evaluate afterwards, you might lose insights about considerations around choices' ● ● Sub2

One interviewee mentioned that a pilot should also be evaluated in light of future scenarios ● ● Further development De Bruijn et al. [212] advise not to use more than four scenarios and to look at the main drivers of increasing flood hazard, namely climate change, economic growth, population growth, and land use change. *Using such climate change scenarios can also be misleading for evaluation of a pilot as even under the most favourable scenarios a water board may not meet the goals of the Water Framework Directive. Sufficient fresh water may not even be guaranteed all year-round.* Lastly, using scenarios with NBFD can however be difficult *as there is always a sort of evolution in long-term effects.* A similar sentiment to above-mentioned use of scenarios is that more than one function should be evaluated. *Many papers only evaluate on one use function. As mentioned before, almost no project monitored floods, droughts, and biodiversity at the same time and could evaluate those use functions. Almost nobody does it yet, although the extremes will be more prevalent in the Netherlands with floods and droughts. Flood and drought resilience can both be seen as ecosystem services and those are evaluated in the Greendeal criteria; there are quite a few links between Greendeal criteria and ecosystem services.*

It is also important to look at the effect on the sectors like shipping ● The sectors that MERLIN looks at are agriculture, hydropower, insurance, navigation, peat extraction, and water supply [142]. Interestingly, the financial sector is disregarded. *If any part of the enabling environment is not in order, then your solution can work perfectly technically but then it won't work well in the end.* ● Sub2

The IUCN Global Standard was mentioned in a few interviews. It is considered a good instrument for evaluation that helps broaden the scope at which an evaluator should regard NBS. It was developed by more than 700 experts so it is well thought-through but that also brings generality. There is also quite a bit of overlap with the Greendeal criteria. It does not allow for technical assessment of 'how well did this NBS perform?' but is a good guideline for 'is this pilot doing the right things?'. It can also help in the design of NBS and you are forced to look at social aspects which might not immediately be on your radar if you are an ecologist, for example. At a project level the IUCN works well for evaluation ● *On the scale of the whole country, it might also be a good instrument for comparison between projects; however, this depends on the aim of evaluation: is it for optimising NBS designs or for example looking at climate goals and how to better integrate them into projects? You need to know the (policy) decisions that will be made based on an evaluation to be able to ascertain if an evaluation was apt* ● *The IUCN Global Standard is also good for providing a realistic view of the extent of NBS: 'under which circumstances do nature-based solutions work?' and 'if NBS do not perform well with 1:200 year rains; then hybrid solutions have to be considered.'.* ● Sub2 ● Future research

A last and interesting comment was made by one interviewee that they found spatial quality one of the most important things when evaluating a NBFD pilot. This was the second objective of 'Ruimte voor de Rivier' and is not seen much in other evaluations ● ● Future research

4.6. Concluding remarks

A few general types of monitoring were mentioned that were not necessarily mentioned in questions about evaluation. It stands to reason that the interviewees also meant that these types have to be evaluated.

The monitoring method of getting and transforming the data is important to report clearly ● There are too many criteria to choose from and information needs differ, so it might be worthwhile to introduce selective 'views' for different types of intended users e.g. researchers, practitioners, and policy makers ●

Analysing literature pertaining to the M&E framework , in chapter 2.3.4, it was decided to use an indicator-based assessment approach to evaluation ●

● Sub2
● Further development
● Main

Knowledge base

Analysis for the design and development of the knowledge base, Phase II step **(6)** in the research approach, was done through deductive interview analysis, a review of other relevant (online) knowledge bases, and concluding remarks.

4.7. Interview insights

Content analysis of the interviews, started with the deductive approach for the monitoring & evaluation framework (chapter 4.2). The initial theoretical framework used for coding was the OECD evaluation framework. Since this framework is focused on evaluation, of course many code categories were missing. Missing categories extended the coding scheme to reflect the information people want to see on a knowledge base. In addition to information that fit in the OECD evaluation criteria, it was found that interviewees wanted more specific information about the project itself and a reflection on the project/process. This resulted in the coding scheme to the right (Figure 4.13). The subsequent investigation of other online knowledge bases resulted in only one additional coding category 'Additional information'.

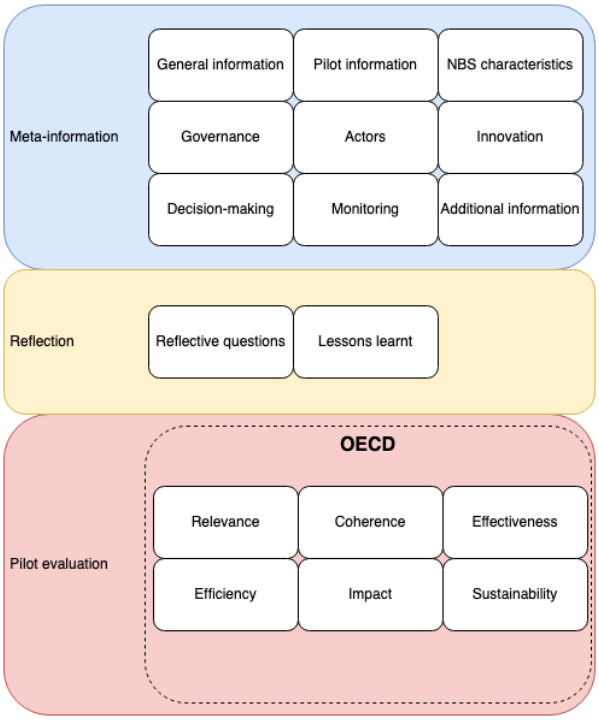


Figure 4.13: Extended coding scheme for interview analysis framework

Category	Important questions for knowledge base
General information	What was implemented?
Pilot information	How was it constructed?
NBS characteristics	In which (eco)system does the pilot take place?
Governance	which disciplines and organisations worked together?
Actors	Which parties implemented the solution?
Innovation	What is the TRL? What about the SRL?
Decision-making	What were key considerations around important decisions?
Reflective questions	What went well? What did not go well?
Lessons learnt	Lessons learnt, dos and don'ts

Table 4.10: Important questions mentioned in interview

4.8. Online knowledge bases

Relevant knowledge bases were analysed for feature discovery to get an overview of the information fields conventionally shown. The investigation was done on 31 of the 42 identified knowledge bases: MERLIN, Panorama, Klimaatadaptatienederland, Climate ADAPT, TKI, Ecoshape, OPERANDUM, NbS initiative, Oppla, Naturebasedsolutions, World Bank, Think Nature, Engineering with Nature, Equator Initiative, IUCN, Network Nature, UNFCCC, Water Action Hub, JNCC, Urban Nature Atlas, RECONECT, NBS Bangladesh, Naturebasedsolutionsevidence, NWRM, UK government, UNEP, Connecting Nature, and IKI. The resulting collection of information fields is categories per group of the extended coding scheme.

Category	Knowledge base fields
General information	Description – What Did the Project Do?, Summary, introduction, overview, Abstract, project information, acronym, The project, Description of project, site name, key facts
Pilot information	project type, Measures included, options implemented, solutions, implemented actions, nbs actions, actions, activities, what is the solution, Construction, what does it involve?, original research information, main driver
NBS characteristics	Description of nature-based solutions, NWRMs implemented in the case study, theme, type of restoration, nbs classification, nature-based solutions type, type of action, nature-based solution type, Broad type of intervention considered, adaptation sector theme, application scale, adaptation element, sustainable development element, nature element
Governance	Operation and Maintenance, governance, legal aspects, contracts, procurement, design contractual arrangement, urban and disaster risk management
Actors	Project funders, donors, lead entity, lead country, type of organisation, key actors, team leader, instigators, participants, involved parties, design team, organisations, implementing partners, about the implementing organisation, implementing agency, design authority, scientific partner, implementation partners, Collaborators, partner countries, desired partner, Project partners, political partner, business engagement approach, stakeholder participation, Stakeholder Engagement & Co-creation, sectors, client, public consultation, design consultation activity
Monitoring	Type of data, data provided, monitoring and evaluation, ratings, SDG, monitoring, SDGs, Report effects GHG mitigation, Experimental evaluation done?, impact estimation method, impact estimation information, Does the study report economic costs/benefits?, results framework (project development objective indicators, intermediate results indicators)
Innovation	Innovation description, innovation type, TRL, innovation information, key innovation and potential for upscaling
Decision-making	services needed
Additional information	Main contacts, contacts, point of contact, Reports, downloads, publications & reports, sources, resources, documents, in-depth description file, project source, demonstrator poster, Links, website, References, project website, Further Information, key words, topics, news and media, Further reading, Links of interest
Reflective questions	—
Lessons learnt	Lessons learned, best practices, good practices, knowledge gaps, policy pointers

Table 4.11: Fields found in online knowledge bases

Criterion	Element of analysis	Knowledge base fields
Relevance - Is the intervention doing the right things?	responding to needs, policies, and priorities	Stakeholders with an Interest In the case study, key sectors that benefit from the case study
	being sensitive and responsive to context	hazard, vulnerability &risk, multi-hazard, hydro-meterological risks, flood risk problems, other environmental problems, Type of challenges addressed (channel instability, land use change, water quality degradation, loss of flora and fauna, saltwater intrusion, removal of vegetation, loss of floodplains and wetlands, hydraulic structures), constraints
	quality of design	scalability
	responsiveness over time	performance timescale
Coherence - How well does the intervention fit?	internal coherence	a description of the restoration innovations that have been applied previously, What measures had already been taken?, socioeconomic/historic context
	external coherence	related nature-based solutions, similar cases by ecosystem, related projects, SDGs, Aichi targets, climate change impacts addressed, design land use change
Effectiveness - Is the intervention achieving its objectives?	achievement of objectives	mission, objectives, motivation, goals, main objective of the nature-based solutions, Development objectives, focus, Intended benefits, project objectives,
	varying importance of objectives and results	—
	differential results across groups	—
	understanding the factors that influence outcomes	Ready to scale?, Transferability of results, transferability of the result, replicability
Efficiency - How well are the resources being used?	economic efficiency	Total cash cost of the project, estimated monetary cost, estimated monetary benefits, finance, funding programme, commitment amount
	operational efficiency	Budget utilisation, budget expenditure (people, land, climate)
	timeliness	phase, implementation time, start/end date, Construction date, Initiation, Planning and design, status, project timeline, time frame, Project progress, duration, project stage, installation date

Impact - What difference does the intervention make?	higher-level effects	expected results, Impacts, potential impacts/benefits, NbS benefits, effectiveness on climate change, effectiveness on ecosystem health, effectiveness on socioeconomic outcomes, study results, Compare effectiveness of intervention, environmental impacts, sustainable development impacts, effect of nature-based intervention on climate change impact , the value of the case study (e.g., flood management and biodiversity) green deal criteria, costs and benefits, cost-benefit, social benefits, environmental benefits, Flood Risk Impacts of the Project, risk reduction benefits, economic benefits, NBS benefits, Environmental and societal benefits, NbS effectiveness
	significance	relevance of adaptation, awards, significance
	differential impacts	—
	unintended effects	Co-Benefits of the Project, potential co-benefits, additional benefits
	transformational change	—
Sustainability - Will the benefits last?	understanding the components of the enabling environment	size, location, scope, scale, region, area characterisation, geographical coverage, country, geographic region, transboundary?, catchment description, favourable preconditions, ecosystems, environment, type of ecosystem, type of area, climate conditions, Environmental and Geographic context, habitats, environmental category, climate zone, mean annual rainfall, success and limiting factors
	continuation of positive effects	Acceptance of nature-based solutions
	risks and trade-offs	trade-offs and limitations, societal challenges, key challenges, societal challenges

Table 4.12: Information fields found in online knowledge bases that fit in the OECD framework

4.9. Concluding remarks

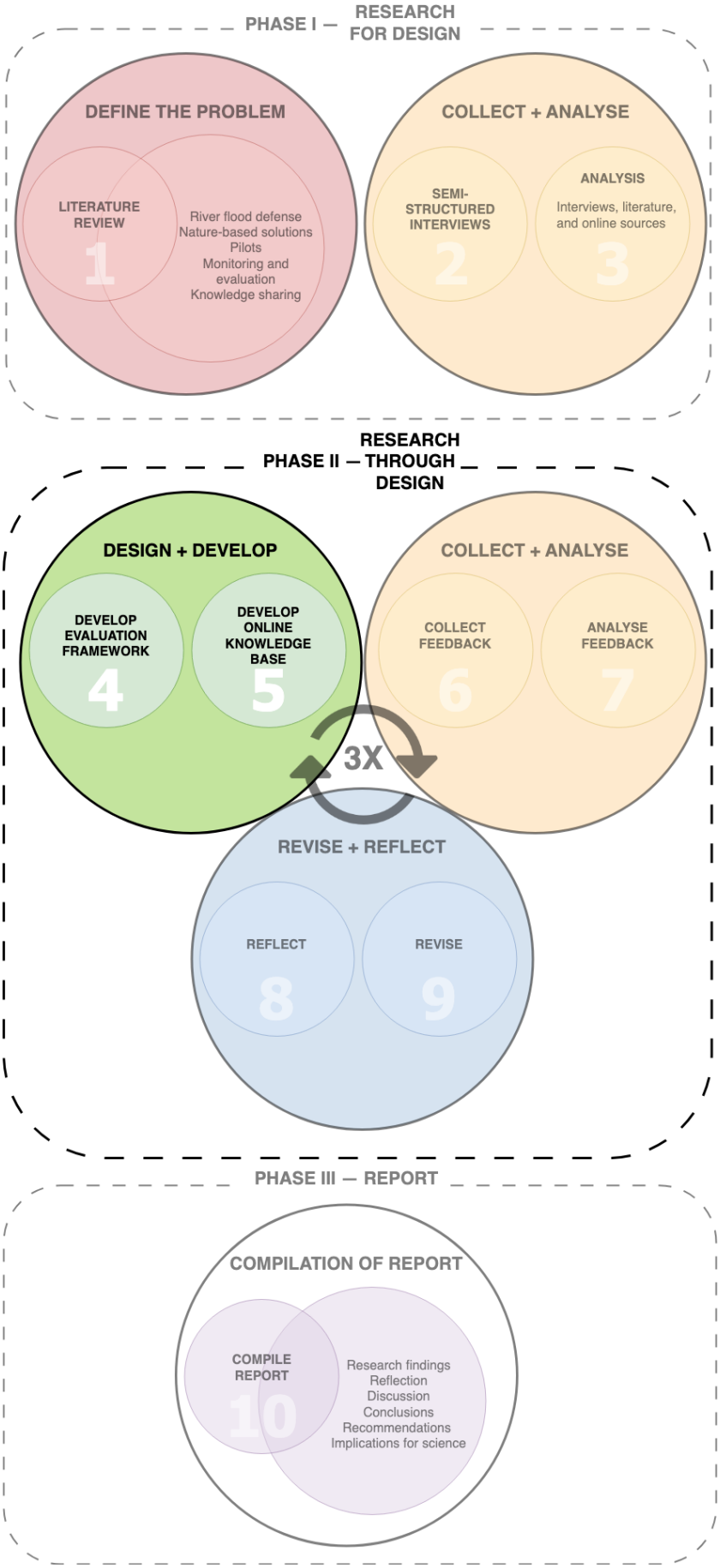
For knowledge base development, eleven categories of information were found. Although the interview yielded surprisingly few questions, the online knowledge bases had plenty of examples that can supplement. The most important insight was that it is important to include lessons learnt if other people are to benefit from past experience as well as dos and don'ts ● Going over the other online knowledge bases, the following was noted. ● Sub2

Most knowledge bases show information of a pilot in isolation of its context. No information is given about nearby projects/pilots and its relation to or with broader programmes. Many knowledge bases stick to providing basic facts that do not enrich the information or assist the reader in reaching conclusions by providing analysis or evaluation. For example, there are knowledge bases that state the objectives, effects, the costs, and some other meta-information but do not relate how well the process of piloting went, whether initial goals for the pilot were met and to what degree. Although there are quite a few that have adopted a section for lessons learnt (or something a similar), these were found to be largely general. It could do with a more critical reflection of the process and decision-making as a whole. It was not found in any lessons learnt that a mistake was admitted and the changes that were made to remedy the effected problem. It was also found that often lessons learnt lacked a normative perspective e.g. "it was found that if you try to implement this piloted technology in this environment, it would be better to use specific type of tree". It is a shame that other knowledge bases give few regards for the future use of a technology as to save others from making similar mistakes.

Not many reflective questions were found that did not fit in evaluation or lessons learnt. Additionally, the elements that remained empty in the analysis of the interviews for the M&E framework (varying importance of objectives and results, differential results across groups, differential impacts, and transformational change) also were not considered on other online knowledge bases. This is noteworthy and could be due to many reasons: it may be less relevant for NBFD pilots, coincidence, due to oversight, some form of a knowledge gap or something else ● ● Future research

Development

- Introduction
- Theory
- Method
- Analysis
- **Development**
  - **Evaluation framework**
  - **Knowledge base**
- Results
- Conclusion


PHASE I — RESEARCH FOR DESIGN
DEFINE THE PROBLEM
LITERATURE REVIEW
1
River flood defense
Nature-based solutions
Pilots
Monitoring and evaluation
Knowledge sharing
COLLECT + ANALYSE
SEMI-STRUCTURED INTERVIEWS
2
ANALYSIS
Interviews, literature, and online sources
3
PHASE II — RESEARCH THROUGH DESIGN
DESIGN + DEVELOP
DEVELOP EVALUATION FRAMEWORK
4
DEVELOP ONLINE KNOWLEDGE BASE
5
COLLECT + ANALYSE
COLLECT FEEDBACK
6
ANALYSE FEEDBACK
7
3X
REVISE + REFLECT
REFLECT
8
REVISE
9
PHASE III — REPORT
COMPILATION OF REPORT
COMPILE REPORT
10
Research findings
Reflection
Discussion
Conclusions
Recommendations
Implications for science

Initial monitoring & evaluation framework

As found in section 4.1, RWS does not have a standard M&E framework for NBFD pilots in rivers. Therefore, it is tried to develop and propose a wholly new M&E framework.

The design and development of the initial M&E framework marked the start of design-feedback iteration I. This section looks specifically at the design and development of the initial framework. Collected feedback and changes made for improvement during the design-feedback loop, are considered intermediate results described in chapter 5.1.3.

5.1. Conceptual M&E framework

Among the possible types of evaluation for NBS [99], it was decided to go with indicator-based assessment for the evaluation method. This means that evaluation criteria are informed by monitoring indicators that are based on evaluation questions. Quantitative analysis can be done when baselines, and targets for the outcomes are defined [129]. Analysis of the monitoring is summarised per evaluation question before an overall judgement is made [129]. It was decided to use a five-point scale for ultimate scoring as suggested in an interview by taking 'Ruimte voor de Rivier' as an example.

Of course, the OECD evaluation criteria that were used for coding were used as a start; the OECD has expressed that their framework can be used for this purpose: *"[...] for defining frameworks and indicators for monitoring and results management, [...] , particularly to improve future interventions"* [6]. Therefore the OECD criteria can be augmented to allow for more specific NBFD performance evaluation as detailed by the International Guidelines for NBFD Bridges et al. [3]. For impact assessment, the following performance categories are included: FRM, ecological, social, and economical.

The host of possible evaluation questions gathered from the interviews, grouped per evaluation criterion, was reduced in collaboration with the supervisors of this thesis based on empirical confidence of use. The resulting choices, made during this discussion, can be found in Appendix F. Evaluation questions from the interviews were included as 'general questions', illustrated in Figure 5.14.

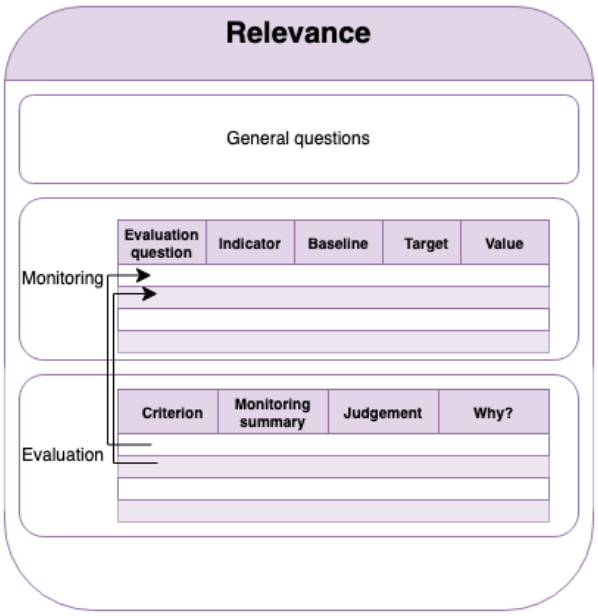


Figure 5.14: M&E framework for each OECD criterion (relevance criterion as an example)

Initial knowledge base

The knowledge base was developed based on a free template from Vercel using React, Typescript, and Tailwind. Software development was done using GitHub for version control using Git. The knowledge base was also deployed to Vercel using GitHub integration; you can access the latest project at `https://nbfd-knowledge-base.vercel.app/` (so long as Vercel keeps it online). The idea was to build the whole knowledge base architecture with a back-end but due to time constraint and for demo purposes, a single demo page for a pilot was added using mostly static plain text information and images ● The first version is included below.

● Further development

5.1.1. What is implemented?

A web page was developed with general sections that derived from the coding scheme, of the interview analysis in chapter 4.6, combined with empirical best practices gleaned from the investigation into all other relevant knowledge bases. Two of the most comprehensive and insightful knowledge bases were from NWRM [100]. The easiest to navigate and best categorisation was found on Panorama [213]. The classifications at the top of the page were modelled after Panorama. This yielded the following sections and the origin of their contents (in concept, not the source of the demo information).

Section	Content	Origin
Introduction	What was implemented? How was it constructed?	Interview analysis, feature discovery
Involved parties		Interview analysis, feature discovery
Goals		Interview analysis, feature discovery
Classifications	Location	Feature discovery
	NBFD categories	Literature [3]
	Ecosystems	Other KB [35]
	Pilot type	Literature [37]
	Status	Interview analysis, feature discovery
Photos		Interview analysis, feature discovery
Map		Interview analysis, feature discovery
General information	Monitoring	Interview analysis, feature discovery
	TRL	Interview analysis
Monitoring & evaluation		Developed, see section 5.1
Decision-making		Interview analysis
Lessons learnt		Interview analysis, feature discovery
Additional information		Interview analysis, feature discovery

Table 5.13: Knowledge base sections that were implemented, its contents, and the origin of inspiration

It was decided to include a section on lessons learnt that stuck with some basic statements as seen in most online knowledge bases (mentioned in chapter 4.6). In the design-feedback iterations, it can be tested whether respondents would like to know more applied lessons or more general lessons.

5.1.2. M&E framework integration

During development of the knowledge base, it became apparent that there were very many information fields to fill in. Future contributors therefore have to spend a lot of time. To solve this issue, it was

decided that at the start of a pilot, meta-information can be filled in and information for the monitoring & evaluation framework provided after each evaluation moment i.e. before, during, and after implementation (ex-ante, mid-term, ex-post). The idea to store evaluations online after each evaluation moment was formulated as a proposed (partial) solution to the main research question and tested using the questionnaires ● ● Main

5.1.3. Selected demo pilot

A specific NBFD pilot was chosen to feature as an example: a cyclic rejuvenation pilot on the Ewijkse Plaat near Beuningen. Not all information was available online so some fields were supplied with dummy text.

Voorbeeld pilot

Wat is er geïmplementeerd?

In de Beuningse Uiterwaarden hebben de gemeente Beuningen, ARK Natuurontwikkeling, Rijkswaterstaat en andere partijen tussen 2013 en 2018 een nieuwe klimaatbuffer aangelegd om overstroming als gevolg van hoogwater in de Waal tegen te gaan. Daarnaast wilden ze de natuur verbeteren, de biodiversiteit vergroten en het gebied aantrekkelijker maken voor bezoekers. Deze nieuwe klimaatbuffer was ook nodig omdat eerdere maatregelen in het gebied nog niet genoeg beschermden tegen hoogwater.

Hoe is de interventie geconstrueerd?

Om hoogwater tegen te gaan past ARK samen met Rijkswaterstaat sinds 2011 een nieuwe vorm van natuurbeheer toe op de Ewijkse plaat: cyclische verjonging. Dit betekent dat ARK hoge begroeiing aan de oever tegengaat en de natuur op deze manier om de zoveel tijd ‘verjongt’. Het doel hiervan is om natuurlijke erosie en de biodiversiteit te stimuleren. Daarnaast heeft Rijkswaterstaat geulen gegraven die ze hebben aangesloten op openingen in de oeverwal. Al deze maatregelen zorgen ervoor dat het rivierwater bij hoogwater sneller kan wegstromen. Maar toch zijn extra maatregelen voor een nieuwe klimaatbuffer nodig geweest.

Classificaties

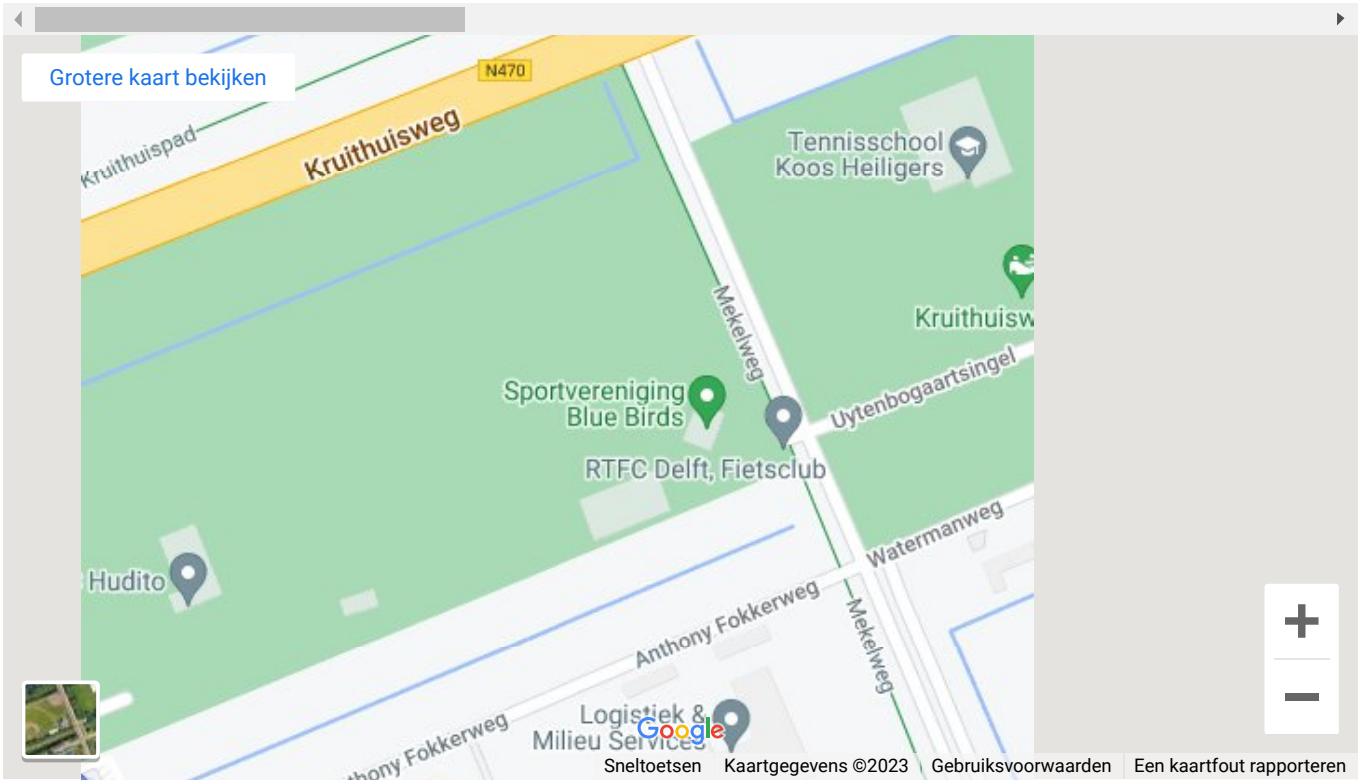
Regio	Gelderland
NBFD categorieën	Floodplain reconnection, Vegetation management
Ecosystemen	Bos, Zoetwater, Rivier
Pilot type	Research, Managerial, Political-entrepreneurial
Status	Afgerond

Betrokken partijen

- ARK Natuurontwikkeling
- Gemeente Beuningen
- Rijkswaterstaat
- Waterschap Rivierenland
- Staatsbosbeheer
- de Dienst Landelijk Gebied & Bureau Stroming

Doelen

1. Hoogwater verlagen
2. Natuur verbeteren
3. Biodiversiteit vergroten
4. gebied aantrekkelijker maken voor bezoekers



Algemene informatie

Algemene monitoring informatie

Was er een officieel monitoring programma?	Nee
Wie heeft gemonitord?	Radboud Universiteit
Is de biotische omgeving gemonitord?	Ja
Is er fysio-chemisch gemonitord?	Geen info
Is er morfologisch gemonitord?	Ja

Algemene

Algemene monitoring informatie

Is er ecologisch gemonitord?	Ja
Is biodiversiteit gemonitord?	Geen info
Is het proces gemonitord?	Geen info
Op welke momenten en frequentie is er gemonitord en waarom?	Geen info
Hoe lang zal er na implementatie gemonitord worden?	Geen info
Met welke praktische methode is data vergaard?	Geen info
Hoe is de data verwerkt?	Geen info

TRL

Het concept is uitgebreid getest en gedemonstreerd in een relevante testomgeving. Het concept heeft goed inzicht gegeven in de werking van alle componenten tezamen.

Monitoring & Evaluatie

Relevance +

Coherence +

Effectiveness +

Sustainability +

Impact +

Efficiency +

Besluitvorming

Algemene besluitvorming informatie

Zijn er doelen aangepast? Waarom?	Tekst
In hoeverre zijn doelen niet gehaald?	Tekst
Hoe is er omgegaan met doelen die niet zijn gehaald?	Tekst
Wat waren de meest belangrijke beslissingen op cruciale momenten?	Tekst

Belangrijke lessen

- we hebben dit en dat geleerd
- en dit ook
- oh en niet te vergeten

Downloads

Rapporten

2015

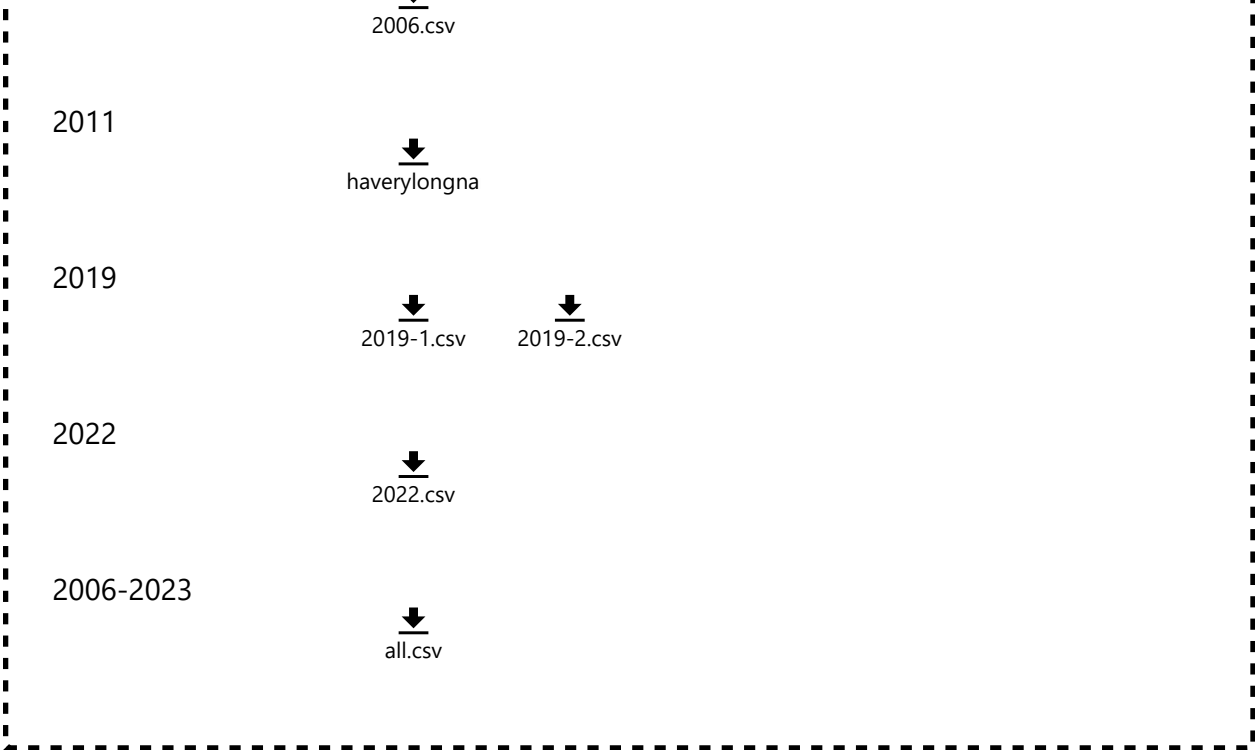
test1.pdf test2.pdf test3.pdf

2016

test4.pdf test5.pdf test6.pdf

Data

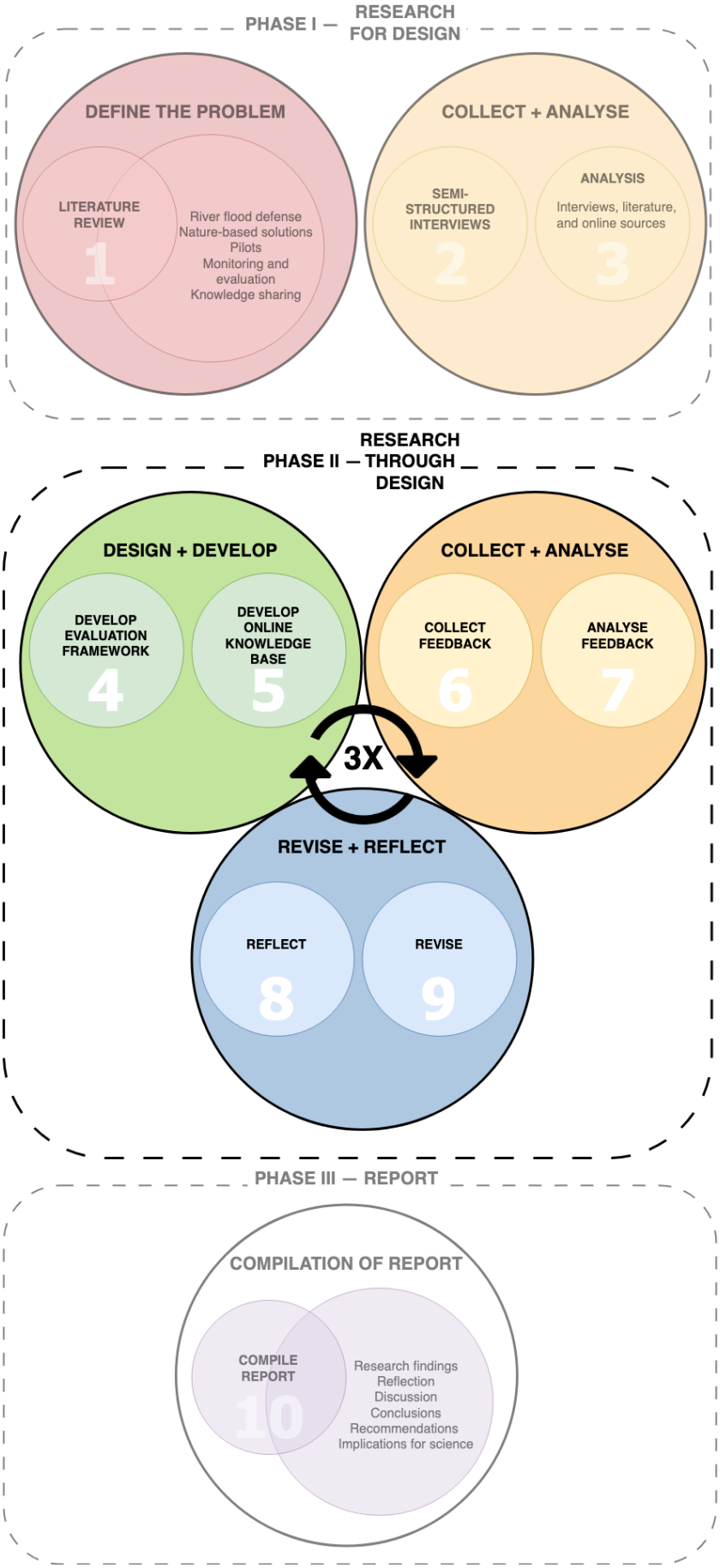
2006



Based on a free example by Vercel

Results

- Introduction
- Theory
- Method
- Analysis
- Development
- **Results**
  - **Feedback rounds**
  - **Validation**
  - **Reflection**
  - **Further development**
- Conclusion


PHASE I — RESEARCH FOR DESIGN
DEFINE THE PROBLEM
LITERATURE REVIEW
1
River flood defense
Nature-based solutions
Pilots
Monitoring and evaluation
Knowledge sharing
COLLECT + ANALYSE
SEMI-STRUCTURED INTERVIEWS
2
ANALYSIS
Interviews, literature, and online sources
3
PHASE II — RESEARCH THROUGH DESIGN
DESIGN + DEVELOP
DEVELOP EVALUATION FRAMEWORK
4
DEVELOP ONLINE KNOWLEDGE BASE
5
COLLECT + ANALYSE
COLLECT FEEDBACK
6
ANALYSE FEEDBACK
7
3X
REVISE + REFLECT
REFLECT
8
REVISE
9
PHASE III — REPORT
COMPILATION OF REPORT
COMPILE REPORT
10
Research findings
Reflection
Discussion
Conclusions
Recommendations
Implications for science

6.1. Design-feedback iterations

There have been three iterations: two feedback rounds for improvement and a last validation round. To reiterate, in the questionnaires there were questions for three concepts: the M&E framework, knowledge base, and the proposal. In iteration I and II, improvements for the M&E framework and knowledge base were elicited as well as Likert scale questions about the proposal and validation questions. In iteration III, the questionnaire featured sliding scale questions for heuristics analysis and the same Likert scale questions about the proposal and for validation.

That is why in the sections about iteration I and II, only details feedback about the M&E framework and knowledge base. The feedback is numbered and grouped by possible changes to the M&E framework and knowledge base and missing features. To indicate, based on which feedback certain improvements were made, the corresponding number is added as a tooltip visible by hovering over the icons in the improvement table (Example: hover over the following icons of changes ⇄, additions ⊕, and removal of features ⊖). All feedback for improvements in the tables with possible changes and missing information that do not have this icon ☁ were not implemented in either iteration II (version 2 or v2 for short) or iteration III (version 3 or v3 for short). All these comments are still viable for future development ● ● Further development

In iteration III the results of heuristics analysis are investigated and all validation questions were looked at. This also included the Likert scale questions at the end of questionnaires of iterations I and II.

6.1.1. Iteration I: feedback

For the first iteration, two experts gave feedback which was already sufficient to make great improvements. It was decided to use short design iterations as to prevent possibly redundant and duplicate information. Another benefit to this approach is that feedback is given on the most up-to-date design.

Feedback I: possible changes		
	M&E framework	**Knowledge base**
1	The OECD framework is in English, sustainability has a different and more broad meaning in Dutch. Change it to Dutch criteria labels ☁ v2	Would be nice to have the goals at the top ☁ v2
2	Secondly, the criteria are not homologous, not at the same level of abstraction and importance. Possibly, relevance, effectively, and impact could be combined to form a single criteria: due to its impacts it meets the objectives (effectivity) and that provides its relevance. Combined with the fact that efficiency in Dutch can be reduced mostly to monetary terms, it was advised to look at 'doelmatigheid' meaning 'does it do what it is supposed to?' and 'doeltreffendheid' which means 'cost-benefit analysis' ☁ v2	Translate the classifications section to Dutch ☁ v3
3	Another recommendation would be to keep the evaluation criteria simple for the primary intended users (people that have to provide the information) and they should not have to fill in the same information twice and not too much information overall ☁ v2	Lastly, the respondent mentioned that the 'Besluitvorming' and 'Downloads' components of the knowledge base could get a more apt Dutch title such as 'Correcties' and 'Rapporten & Gegevens' ☁ v3
4	For reference, it would be nice to have definitions and explanations of criteria and terms. At a glance every reader can have different associations with relatively broad terms. What are criteria, goals, indicators? Additionally, the general question of the OECD framework could be added to the clickable panels of each criterion ☁ v3	For the downloads section, the data might not be very relevant as they are often added to bigger databases. It would be an added benefit to store all information that is excluded from the larger databases such as special monitoring data that would otherwise remain on someone's computer and be forgotten. This type of data that is outside the norm is often more interesting and special ☁ v3
5	The indicators at the monitoring section should be called KPIs	Expand the goals to include KPIs
6		Add information about the decision-making process

Table 6.14: Iteration I: feedback for changes and in which iteration it was implemented ☁

Feedback I: missing information		
	M&E framework	**Knowledge base**
7	It would be good to use monitoring indicators from the MERLIN project. ☁ v2	It would be nice to add the SRL. ☁ v2
8	For completeness this framework could be augmented by including questions from the IUCN self assessment tool ☁ v3	It would be nice to add the names of the project leader at the time of the implementation and a contact person ☁ v3
9	It would also be nice to see what the secondary effects are (positive or negative), not necessarily its primary intended effects ☁ v3 (added to knowledge base)	At first, I want to know how much lower the water is at peak flow (in cm) as well as see how many hectares of 'nature' has been created This would help with deducing the scale and efficacy of the solution. Not withstanding that a NBFD that does not reduce the water level a lot compared to its larger size, it still created a lot of area for habitats. So maybe its second objective for biodiversity net gain would be met ☁ v3
10	Trade-offs do not only have to be economical/monetary in nature ☁ v3	How big is the area? ☁ v3
11	It would be nice to include the aspect of impact on the broader society from the Theory of Change	What is the source of financing? ☁ v3
12	For the effectiveness, the contents could be more about technical performance and hard quantitative monitoring	Is the management monitored? ☁ v3
13		How were the local citizens engaged? ☁ v3 (added to M&E framework)
14		How was financing and responsibilities considered?
15		What are the agreements with regards to management of the area (beheerafspraken)?
16		How was management considered during the design of the pilot?

Table 6.15: Iteration I: feedback for missing information and in which iteration it was implemented ☁

Relevant comments

- The evaluation scores should not be percentages and at most a scale of 1-10 but 1-5 would be best.
- For the downloads section, the data might not be very relevant as they are often added to bigger databases. It would be fan added benefit to store all information that is excluded from the larger databases such as special monitoring data that would otherwise remain on someone's computer and be forgotten. This type of data that is outside the norm is often more interesting and special.
- The lessons learnt can also be gathered from anecdotes in interviews.

6.1.2. Iteration II: improvements

Based on the feedback, a prioritised list of changes to the M&E framework and knowledge base was made. To reiterate, the prioritisation of changes was made both on complexity of implementation and confidence of use. The changelog below,Table 6.16, reflects all changes made to both the M&E framework and the knowledge base. For the start of the second iteration there was not much time for redesign and development. the most important improvements were implemented. The improvements to the website and its design can be seen clearly when comparing version one (Appendix G) and the improved version two (Appendix I).

M&E framework changelog	
⇄	Changed the criteria labels from English to Dutch
⇄	Sustainability is now a criterion dedicated to future-related evaluation
⇄	Combined several criteria: relevance and coherence, as well as efficiency and impact
⊕	Added MERLIN monitoring indicators
⊖	Removed similar questions

Knowledge base changelog	
⇄	Goals at the top
⊕	Added a section about SRL

Table 6.16: Iteration II: improvements made to the M&E framework and knowledge base (hover over the icons ⇄/⊕/⊖to see corresponding feedback reference numbers)

6.1.3. Iteration II: feedback

Feedback II: possible changes		
	M&E framework	**Knowledge base**
17	Adding too many fields will quickly become too much for the person filling in the information. Maybe make the goals more concise and let people choose relevant evaluation questions for their pilot per goal ☁ v3	About the TRL: in what type of situation can the piloted technology be applied? Which information is useful for the reader that might want to use derived knowledge? ☁ v3
18	It would be good that every pilot can choose the relevant fields, criteria, and monitoring indicators ☁ v3	About the TRL: advice for the next phase for example TRL 8-9 would be a good addition ☁ v3
19	In the introduction the word 'interventie' is used. That should be changed ☁ v3	About the TRL: might be nice to know the history of going from TRL 1-7 as at the end of every pilot it should be at TRL 7
20	There are too many questions hidden behind the monitoring panels ☁ v3	For the general monitoring information it would be nice to inform readers whether a report of the monitoring data can be requested and how
21	SSRS looks at the innovation process from three levels: task, problem, and innovation	On the knowledge base there are too many fields to fill in
22	Monitoring can be done at multiple levels: such as technical and system level	Platform WOW [214] has practical examples on their website that might be good to look at as to develop this knowledge base more for operational users at RWS
23	What are the research questions? These can be defined at multiple levels and should determine the monitoring	It would be nice to have before and after pictures
24	Ensure that data can be compared to ultimately be able to show systemic change ('systeemverandering')	The current effects neglect to show the effects on other important aspects of water management such as shipping, backwater ('opstuwing'), high water, and low water
25	KPIs are nice but can you show the actual difference the pilot made to provide visual evidence of the results?	

Table 6.17: Iteration I: feedback for changes and in which iteration it was implemented ☁

Feedback II: missing information		
	M&E framework	**Knowledge base**
26	The social IUCN parts regarding society could be included. An important social sciences part is missing ☁ v3	I'm missing the 'why' of the pilot: why was this pilot done? ☁ v3
27	Information about stakeholder engagement is missing ☁ v3	A catchy title ☁ v3
28	Impact at the different layers of society is missing	The implications from SRL e.g. shipping guidelines have to be changed which means another pilot is needed to test the changes before changing the whole system ☁ v3
29	It would be nice to include monitoring guidelines. For example, if you are facing problem X with system constraint Y, you should use model Z	Demands/requirements/constraints and/or ambitions of partners (e.g. Rijkswaterstaat does not want sediment coming into the fairway)
30		At the start, information which problem this pilot tries to tackle and what has the pilot yielded?
31		The knowledge base is not fully geared towards practice and operational knowledge sharing such as the details of contracts
32		Often when project leaders want to start a pilot, one of the biggest hurdles is a contract. It could be very helpful to provide an example or parts of the contract to show how a similar pilot might be realised
33		Was it the intention to implement an NBS from the start?

Table 6.18: Iteration II: feedback for missing information and in which iteration it was implemented ☁

Relevant comments

- RWS already saves all relevant information of pilots. It is just not accessible to the public. Also, data is stored all over the place ● Sub3
- This knowledge base needs to be moderated and curated by the organisation that would most benefit from the storage and sharing of information ● Future research
- Rijkswaterstaat often outsources and many organisations monitor using a specific methodology and store the information in a distinct format. That means that as a whole, at a higher level many pilots are incommensurable; thus findings and results can not be validated by comparing with aggregate results and it is more difficult to make decisions regarding scaling up.
- It would be good to put more emphasis on the lessons learnt and try to formulate them in terms of guidelines or suggestions for others if they want to implement a similar intervention. This would be good for scaling up and diffusion. Of course these lessons remain based on knowledge from M&E
- On the knowledge base there are too many fields to fill in. In a similar project it was decided to go from 57 to 21 questions.

- One interviewee explicitly stated that they saw a knowledge gap for a knowledge base of NBFD pilots and projects. But there are already a lot of platforms and databases. Employees might not be waiting for another to add to the mix. Another organisation might be better suited to host and moderate
- □If a pilot scores low on some aspects of SRL i.e. a bottleneck has been identified, those aspects should thenceforth be monitored ● ● Further development
- For better knowledge sharing, it might be good to include 'prestatie-eisen', information about the application of the pilot, contract requirements, 'if I were to do this pilot again, what would I do differently?', 'how would I apply for such a pilot in the future?'. Also, readers of the knowledge base need to be triggered through their own interests, their ambition, dependence, or urgency only then will people look at the knowledge base .

6.1.4. Iteration III: improvements

The changelog below, Table 6.19, reflects all changes made to both the M&E framework and the knowledge base. In the appendix, the last version of the website is included, **??**

M&E framework changelog	
⇄	Changed the general questions to be optional for evaluation
⊕	Merged the IUCN Global Standard evaluation questions with the OECD framework
⊕	Added IUCN trade-offs and adaptive management
⊖	Removed overlapping questions with IUCN
⊖	Removed the confusing term 'interventie'

Knowledge base changelog	
⇄	Changed title
⇄	Changed introduction
⇄	Translated classifications section
⇄	Changed 'Downloads' section to 'Rapporten & Gegevens'
⇄	Changed the 'Rapporten & Gegevens' section to include information about open access data banks
⇄	Added management monitoring question
⇄	Changed TRL section
⇄	Changed SRL section
⊕	Added project leader and contact person
⊕	Added effects and secondary effects
⊕	Added scale information [215]
⊕	Added financing information
⊕	Added financing information
⊕	Added tooltip information in relevant places

Table 6.19: Iteration III: improvements made to the M&E framework and knowledge base (hover over the icons ⇄/⊕/⊖to see corresponding feedback reference numbers)

6.1.5. Iteration III: feedback

Essentially, this round is intended purely for validation; it was not intended to elicit possible improvements of the design. Throughout the interviews, interviewees did sometimes share their opinion on what could be improved, in off-hand comments. These were included in section 7.3, when relevant.

Relevant comments

- Often people feel that they need to fill in all the information and may feel bad or stop when they cannot fill in everything. It is important for them to know that it is okay not to fill in everything ● Having no information can also be valuable meta-information e.g. no information on how monitoring data was processed tells you that data reliability may be questioned. ● Further development

- It is important to quantify goals and define indicators from day one. Secondly, look at including KPIs and the monitoring structure.
- It would be nice to have a short introduction on the main page of the knowledge base introducing the term nature-based flood defenses and what requirements a pilot has to fulfil in order for it to be stored. An outsider might not know that nature-based solutions have to provide both benefits for human well-being and biodiversity net gain. Nature-based flood defenses are a part of this umbrella term with a primary focus on flood defense ● Further development
- The IUCN indicators are in English and it might be difficult to translate them to Dutch and fully capture the meaning but it could help with adoption within the organisation.
- Another interviewee also stressed this but it should be clear that 'it is okay if not all information is filled in'.
- The evaluation criterion 'Toekomst' in the M&E framework should be renamed to 'Toekomst-bestendigheid'.
- Rijkswaterstaat is currently relying heavily on asset management which also has monitoring & evaluation. It might be better to base and augment the M&E framework on this asset management framework ● Further development

6.2. Validation

The following sections look at validating the design through heuristics analysis data from iteration III and Likert scale questions for validation from iteration I,II, and III. Before analysis of the final results, feedback on the proposal are included as context. To reiterate, the proposal posed to the interviewees was: Rijkswaterstaat should store evaluation information on the knowledge base after every evaluation moment.

6.2.1. Feedback about the proposal

Nine interviewees gave feedback on the proposal. Some feedback pertains to the proposal but other responses give feedback for further development. Unfortunately, the latter are less useful for validation of the proposal.

- The first interviewee mentioned that 'if you want this to work, make sure you are at the top of Google search results about NBFD pilots' ● Further development
- At RWS there are now overviews of the numerous overviews of data/dashboards/platforms etc. meaning that it is so hard to get an overview, there are overviews of overviews. Therefore, it might be difficult to have RWS maintain and keep the information up-to-date. It might be best to look for a party that is incentivised and benefits from moderating the knowledge base. It could be good for knowledge sharing if it was possibly linked to an existing pilot knowledge base as Ecoshape has. But even then, the large number of information fields should be made more manageable.
- It needs to be clear why you want to save this type of information in a standardised way.
- For intended users at RWS, the knowledge base can be tested further with people in specific projects that are related to rivers such as Resirivers and the programme PAGW.
- I recommended to explore the possibility of reusing information/data from other web pages and other sources such as databases. In the same vein, it is good to think about future re-use of information, on the knowledge base, by allowing exporting or linking to other platforms.
- You need to think about the process of information input 'what path are they taking?'. Secondly, in my experience the premise that there is not a big enough evidence base for NBS is less of a bottleneck to the implementation of NBS than actual laws and regulations such as Natura 2000 that sometimes hinder ● Future research
- It would be nice if the pilots would be monitored and evaluated in an even more standardised fashion. Also, if the criteria for NBS are not too strict/stringent, maybe this knowledge base could also be used for projects that are contributing towards sustainability but are not NBS per se; this would allow for a larger support base.
- It would be great if this knowledge base could be filled. It is better than current innovation portfolios that work with files such as spreadsheets to store and share information.
- It is recommended to use 'NBS in river projects', as the term NBFD may be confusing: NBS is a term that is still gaining in popularity and adoption. At RWS the term NBS is also more readily used at the moment. On another note, Berg [7] has shown that projects evaluated using the IUCN Global Standard can be plotted in a radar chart. This could be a good way to visually evaluate and compare projects ● Further development

6.2.2. Heuristics analysis

Five interviewees helped with heuristics analysis. The interviewees were chosen as possible primary intended users, and the results corroborated that, in fact, they were by and large interested in using the knowledge base (statement three in Figure 6.20). The selected people are not design experts by profession but it was decided that as PIU, the design should be understandable for them. All five have a research background but individually, the interviewees had distinct perspectives, through profession and experience, that was the 'lens' with which they looked at the knowledge base: interviewee one is an expert at RWS regarding NBS and ecology, interviewee two is currently developing a knowledge base, the third is specialised in disaster risk management and has worked extensively on evaluation of dikes, the fourth has worked on sustainable river management, and the last is an expert on flood risk management.

Interviewees were asked to score each heuristic separately, by going through the web page to judge again for each heuristic.

Content heuristics

Interviewees gave high marks for appropriateness, of the knowledge base for storing NBFD pilot information specifically. This means that the answer to sub-question three at least partly passed the check Scores were more disparate about the completeness of information. Interviewee 3 gave a lower score and mentioned that this was due to the fact that the water boards and RWS practitioners would miss practical implementation information such as KPIs, 'areaal', and biotope. Sub3

Lastly, the ease of use for finding information about a NBFD pilot validates whether the knowledge base is a suitable medium through which information is shared and the overall story conveyed. Again, sufficient marks were given.

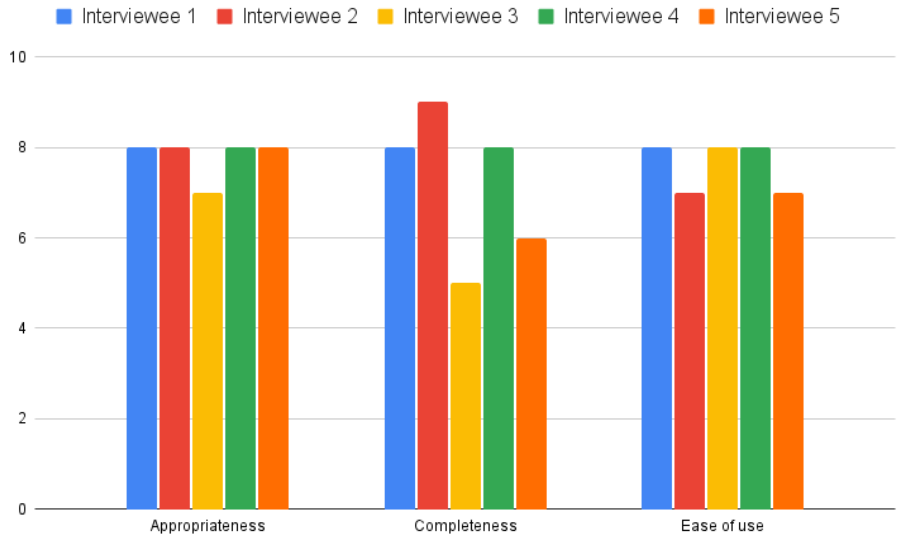


Figure 6.15: Feedback on content heuristics

Nielsen-Molich's design heuristics

Validation of the UI design was done using three heuristics for clarity, relevance, and consistency. Clarity looks at how understandable all information is on the web page as a whole. All three have found the content sufficiently clear. Each section, separately, only featured relevant content without introducing irrelevant bits. Taking both relevance and completeness into account simultaneously, it would seem that two interviewees found that most of all possibly relevant information was there while interviewee three found that not much irrelevant information was provided but the subset of all possibly relevant information was too small. Consistency of design shows that the UI elements were consistently used. This validates that users will be less prone to confusion by using the knowledge base from design elements and are able to focus on the content. Clarity of information and elements were given positive scores so the conclusion can be drawn that the UI does not distract from the content and is consistent. This ties back into the content heuristic 'ease of use' and shows that, indeed, users can find information on the web page easily without the design forming an obstacle.

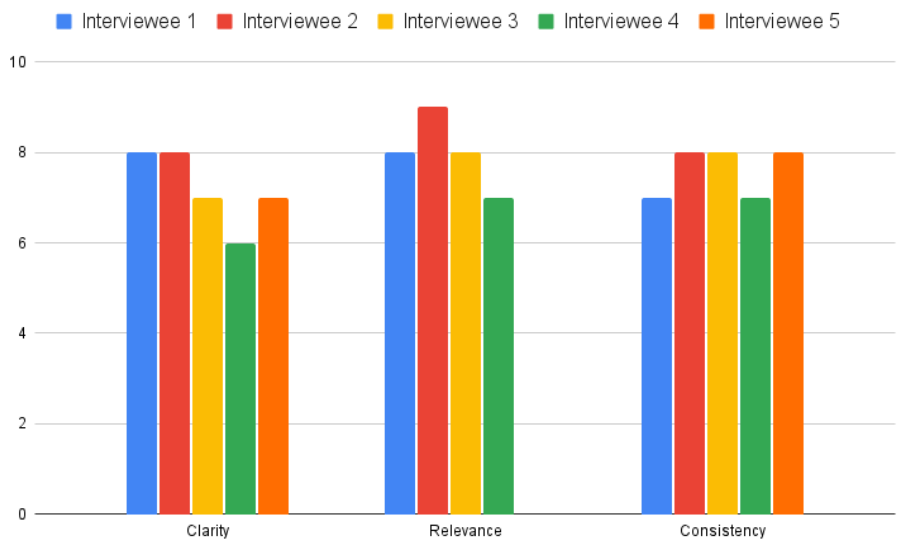


Figure 6.16: Feedback on Nielsen-Molich's design heuristics

6.2.3. Likert analysis

During the design-feedback iterations there were a total of ten interviewees. In the first iteration one interviewee could not complete the final validation questions due to time constraint. Therefore, validation looks at the responses of nine interviewees. A preliminary overview is given in Figure 6.17.

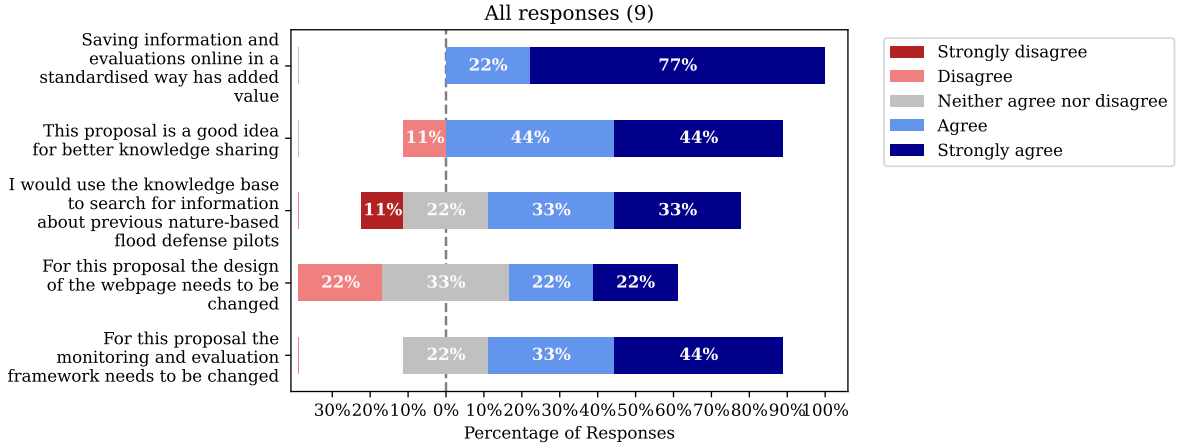


Figure 6.17: All feedback

There were two questions that aimed to validate the two premises this research relies on: 'saving information and evaluations online in a standardised way has added value' and 'this proposal is a good idea for knowledge sharing'. By and large, the responses have been positive about the premise that 'saving such information and evaluations online in a standardised way has added value'. Additionally, responses are predominantly positive with respect to the second statement 'this proposal is a good idea for better knowledge sharing'. To round off and validate whether the primary intended users would use this knowledge base , there was only one negative response. The interviewee that responded as such, explained (without prompt from the researcher) that they would just Google and see whatever information they could find about the NBFD pilot they might be investigating.

The interviewees are in accord about statement one, although they all had suggestions *how* and *what* information needed to be saved and shown. This shows in the responses to statement four and five, 'for this proposal the design of the web page needs to be changed' and 'for this proposal the monitoring and evaluation framework needs to be changed' respectively.

The responses per iteration are shown below in Figure 6.18, Figure 6.19, and Figure 6.20. At first glance, there seems to be a positive trend from iteration I to III, at all five statements. This looks promising but caution must be paid because the number of responses is too low to say much about trends. Also note that, statement four and five are worded as such that negative responses actually mean that the design of the current M&E framework and knowledge base are good. For example, the fourth statement in the second iteration shows one response 'Disagree' this shows that the knowledge base does not need to change much in their opinion; this reflects positively on the design of the knowledge base. Still in the last iteration, three out of five responses were neutral whether the design of the knowledge base has to be changed and two out of five neutral to the M&E framework requiring change.

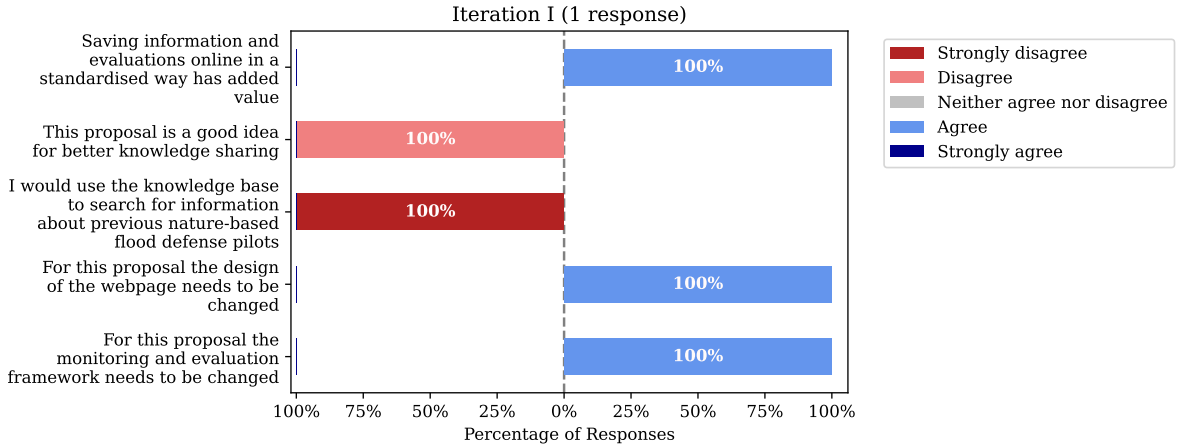


Figure 6.18: Feedback iteration I

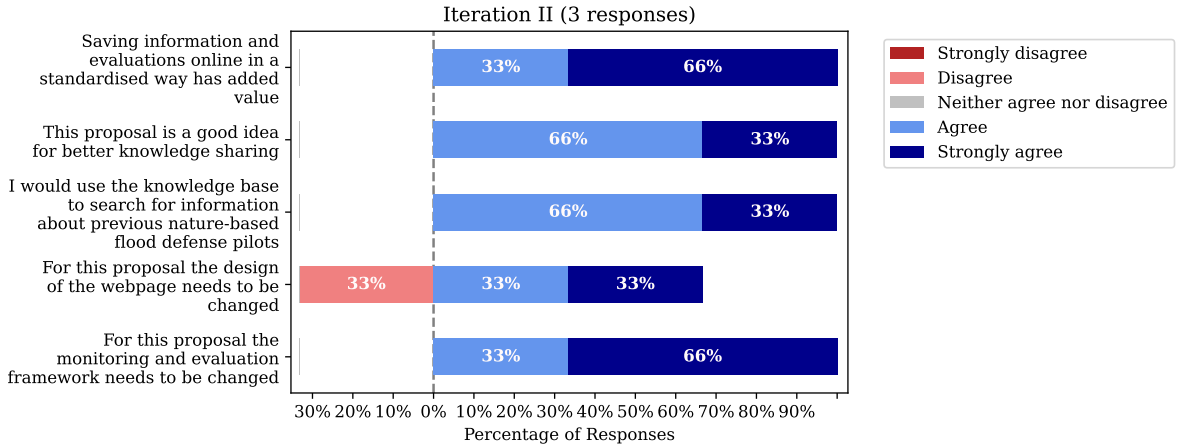


Figure 6.19: Feedback iteration II

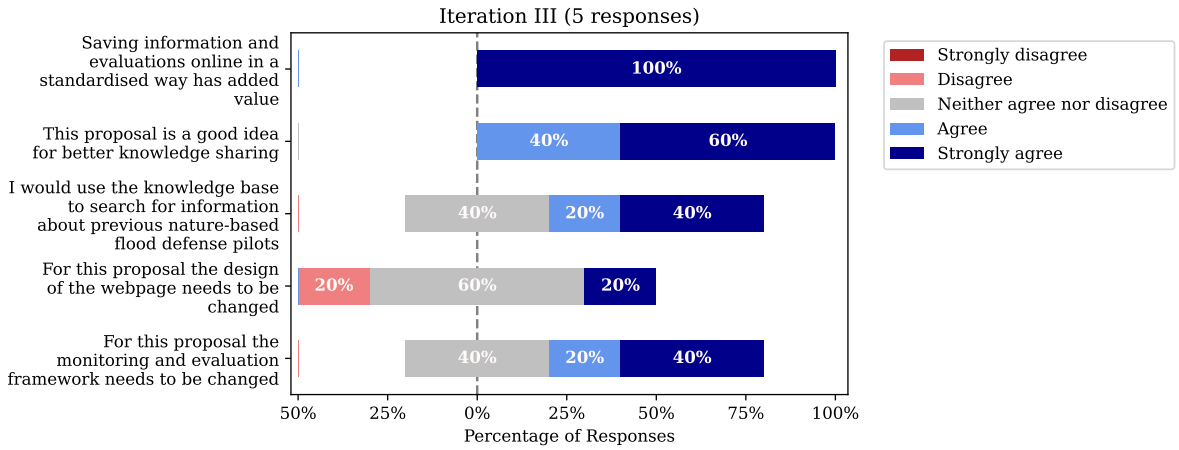


Figure 6.20: Feedback iteration III

To illustrate how the responses of individual interviewees correspond to the different statements, the following sankey diagrammes are included below (Figure 6.21, Figure 6.22, and Figure 6.23). Figure 6.21 shows how that everybody agrees with statement one (left), and almost all thought that the proposal is a good idea for better knowledge sharing (right). From this we can glean that the proposal could be a good solution to saving information online in a standardised way. Although, one person may have thought that another solution might be better.

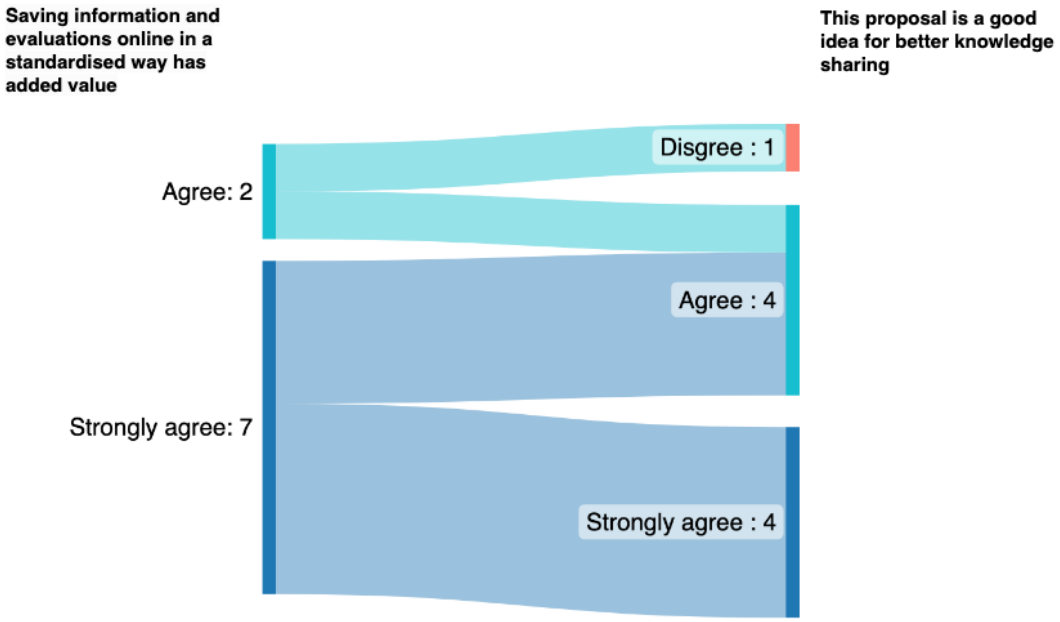


Figure 6.21: A sankey diagramme of the responses of Likert statement one and two

Figure 6.22 shows that out of the six interviewees that would use the knowledge base, three thought that it needed to be changed and two thought so strongly. The others were neutral or didn't think it necessary. Two responses showed a neutral stance towards possibly using the knowledge base in the future but they also did not find it necessary to change the knowledge base.

Figure 6.23 is included to show that the interviewees that wanted changes made to the knowledge base , mostly wanted changes to the M&E framework as well. Keep in mind that this data is aggregated and changes may have been implemented in subsequent the iterations. The responses also show that the M&E framework requires more attention for change than the knowledge base i.e. seven responses (strongly) agree versus four in favour of changing the knowledge base.

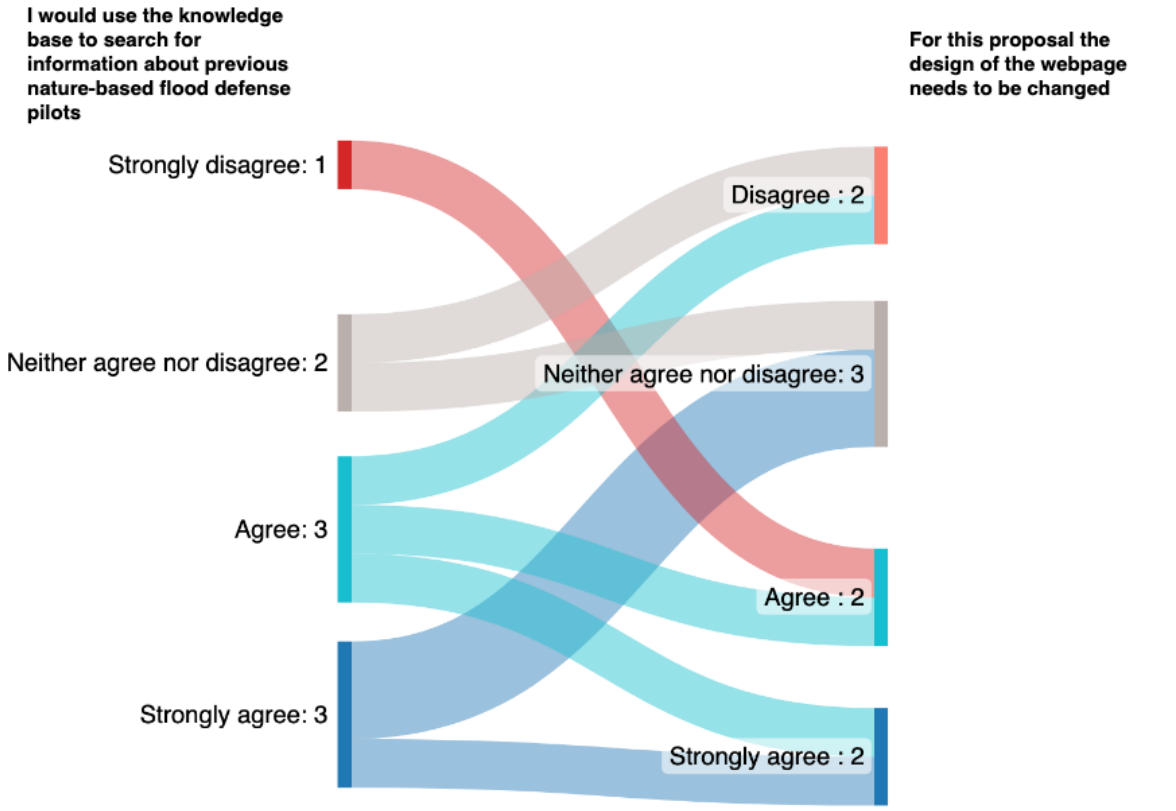


Figure 6.22: A sankey diagramme of the responses of Likert statement three and four

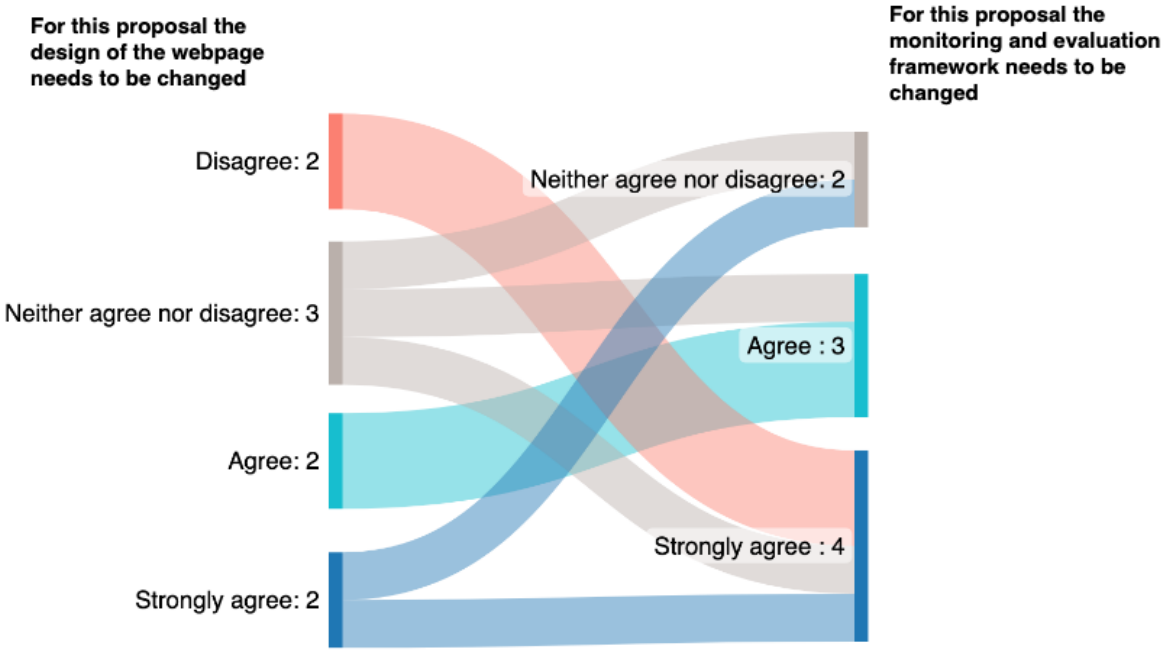


Figure 6.23: A sankey diagramme of the responses of Likert statement four and five

6.3. Reflection

Feedback on the proposal (to save all evaluation information on the knowledge base after each evaluation moment) discussed in subsection 6.2.1 is unfortunately not usable for validation; the open-ended responses were mostly unrelated to the proposal. This could be due to a variety of reasons. Probably

the question was not clear enough, the introduction and explanation of the proposal was insufficient, it was not clear due to the context of preceding questions, and it could also be due to lack of time or attention for the very last question of the questionnaire.

Numeric data from the questionnaires can be used for preliminary validation, although there are too few responses for statistically significant validation. The heuristics analysis shows promising results of the current design. However, the heuristic of completeness indicates that for some intended users, not all relevant information was available. The provided information was appropriate for NBFD pilots and ease to browse. Secondly, the design was clear, consistent, and relevant.

The questionnaires of iteration I, II, and III all featured the same five Likert scales at the end. The first statement validates the premise on which the proposal is based 'saving information and evaluations online in a standardised way has added value'; all responses agree or agree strongly so it stands to reason that this validates the premise. Validation of the proposal is further bolstered by statement two 'this proposal is a good idea for better knowledge sharing'. All but one interviewee agreed. Note however, that due to the varied feedback on the proposal, interviewees may not all have had the same understanding of what the proposal entailed. That notwithstanding, there was interest with the primary intended users to use it in the future. These three findings do validate that a knowledge base approach is based on correct presumptions and the primary intended users are interested.

The fourth and fifth statements aim to validate the current solution. It is evident that the current solution is not yet perfect and changes still need to be made to both the M&E framework and knowledge base. Every iteration, interviewees seemed to feel less strongly that changes need to be made; although there is too little data to substantiate this claim of a trend, development seems to be progressing in the right direction. The focal point of further development should be the M&E framework, as three out of five responses still agreed that changed need to be made.

Conclusion

- Introduction
- Theory
- Method
- Analysis
- Development
- Results
- **Conclusion**
  - **Conclusions**
  - **Discussion**
  - **Further development**
  - **Future research**

7.1. Conclusions

This study has developed a monitoring and evaluation (M&E) framework that was integrated into a knowledge base to store and share relevant information about nature-based flood defense (NBFD) pilots. The knowledge base was developed for researchers in the Netherlands with a focus on NBFD pilots in Dutch rivers and its surrounding floodplains. The final solution flowed from a research by design approach (see Figure 7.24), whereby development and design followed after initial research and the solution was iteratively improved by collecting feedback and revision.

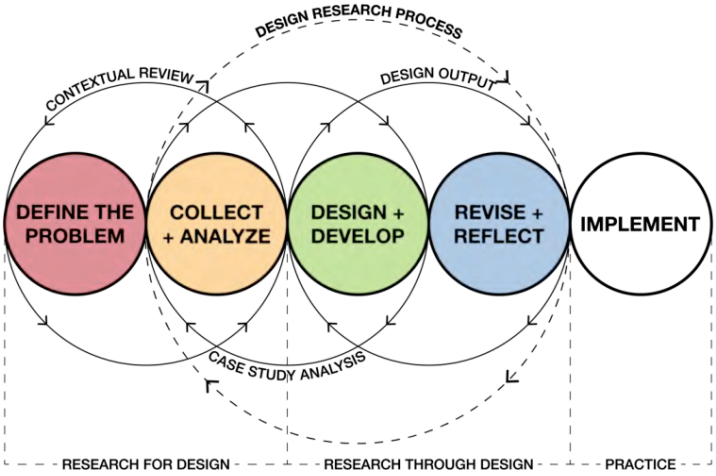


Figure 7.24: Research by design approach [2]

First a synthesis of the whole study is given, after which the sub-questions are answered by following the breadcrumb trail, and then the main research question is addressed. The answer to the main research question and overall research should be looked at in the context of its limitations, discussed in section 7.2, below. Suggestions made throughout the report to improve the current solution can be found in section 7.3. Lastly, insights that warrant additional research are detailed in section 7.4.

7.1.1. Synthesis

It was found that floods are expected to increase in frequency and magnitude. NBFD are likely to provide part of the solution as a 'no-regret', cost-effective solution with multiple benefits. A knowledge gap was found for a standardised assessment framework of NBS allowing the comparison of pilots and there is a need for a knowledge base that allows for storing and sharing of knowledge as well as comparing of pilots. This culminated in the research goal to develop a specific knowledge base for NBFD pilots which incorporates a M&E framework for long-term monitoring and standardised assessment for cross-site comparison while providing rich descriptions of each case.

Literature review was done and interviews were held with six relevant experts to elicit information about the three sub-questions as to inform the development of the M&E framework and knowledge base. After analysing the interviews inductively for sub-question 1 and deductively for sub-question 2 and 3, design-feedback iterations were started. After an initial prototype was ready for feedback, possible future users of the knowledge base were interviewed and queried whether they missed information or wanted changes. Additionally, validation data of the proposed solution was gathered. After two improvement iterations, the third and last design-feedback iteration was done as a final validation step which focused more on quantitative scoring the design and overall solution.

For the M&E framework an evaluation framework from OECD and the IUCN Global Standard were combined and augmented with insights gained from literature, online sources, and interviews. The M&E framework was developed as one component part of a knowledge base, which was also developed through analysis of literature, interviews with experts, and by investigating existing knowledge bases. The knowledge base was developed using web development and deployed at `https://nbfd-knowledge-base.vercel.app/posts/example-pilot`. The proposed solution is that RWS saves all pilot information on a knowledge base , such as this prototype, after each evaluation moment.

Feedback was overwhelmingly positive and the results indicate that a knowledge base like this has merit. It has been demonstrated that there is a need for a knowledge base of NBFD pilots; it could provide added value for researchers if RWS adopted suggestions made for the M&E framework of NBFD pilots and stores relevant information at each evaluation moment. RWS is developing an IUP process to standardise their approach to innovation and scaling up new technologies which is a big task due to the varied nature of their innovation agenda and portfolios. This study could provide a starting point for an evaluation template of NBFD innovations. If so, it is recommended that it will be made part of the formal pilot procedure of IUP that all reports, reviews, evaluations, and other documents are stored in a knowledge base for future reference and knowledge sharing. There should also be provisioning for later additions of monitoring and evaluation results to keep the knowledge base up-to-date.

7.1.2. Following the breadcrumb trail

To answer the main research question (subsection 7.1.3, below), the sub-questions can be answered first by looking at key points made throughout the report: one only has to follow the breadcrumb trail! A full list of all breadcrumbs per research question can be found in Appendix J.

> **Sub-question 1:** what is the current monitoring and evaluation process at Rijkswaterstaat for nature-based flood defense pilots in rivers and floodplains?

Right now, there is no set procedure for evaluating and monitoring NBFD pilots. It is different for every pilot depending on for example the budget and scale. Evaluation is done using evaluation questions, evaluation criteria, and monitoring indicators. A lot of general policy, regulation, and guidelines have been found that can (partly) apply to NBFD for both monitoring and evaluation. Extra monitoring of NBFD pilots mainly measures hydraulics, morphology, and ecology. Social and political indicators are often not explicitly monitored. Also, it was mentioned that monitoring often does not receive enough attention by way of budget, time, human resources, etc. NBFD take a longer time to become fully functional but still monitoring and subsequent evaluation is often done on a shorter time frame. Lastly, for innovations, RWS has two useful tools for assessing progress: technology readiness levels (TRL) and stakeholder readiness levels (SRL).

> **Sub-question 2:** what are important considerations for monitoring and evaluation of nature-based flood defense pilots in rivers and floodplains?

Before deciding on the methodology of a M&E framework , several decision should be made concerning the use, users, scale, stakeholder engagement, etc. A M&E framework should use indicators, baselines, targets, evaluation criteria, and evaluation questions. Monitoring indicators should be based on evaluation criteria and each evaluation criterion is based on an evaluation question.

Monitoring should be done on the biggest scale possible, long-term, and at a frequency relevant to the ecological function of the NBFD in its context. Quantitative monitoring is good but sometimes qualitative judgements from experts can be a useful addition e.g. for diversity or connectivity. Interestingly, it was found that monitoring indicators should not be used for planning, only for evaluation. Then, based on the evaluation planning can be changed if need be. Sharing information found while monitoring such as effects on the pilot or effects on the surroundings are crucial to learn from pilots. Also, the monitoring method should be reported clearly.

Evaluation should not only be done after completion of a pilot (ex-post evaluation); important insights, considerations, and trade-offs might not be taken into account. There are different moments in the project cycle when a pilot can be evaluate and the role or purpose of the evaluation differs. The timing of evaluation should also be considered closely especially for NBS and NBFD because results/-effects take longer to establish than conventional solutions. Many assessment and evaluation frameworks have been found. Most evaluate NBS in a technical way by looking at the impact or 'performance' based on ecology, economy, and some form of social effects. For NBFD a flood risk component should be added. Furthermore, it was found that for evaluation, there are many other aspects or questions that can be addressed e.g. 'what works and what does not work and why?' or contextual influence, 'what is the effect on important sectors like shipping?', etc. Additionally, a large list of possible evaluation questions was compiled through interview analysis, which can be seen as a partial answer to this sub-question. Lastly, there have been many sources that stated that lessons learnt, do's and don'ts, and similar knowledge and experiences should be shared.

Sub-question 3: how to construct a knowledge base for effective knowledge sharing of nature-based flood defense pilots in rivers and floodplains?

NBS projects are subject to reporting bias where failures are under-reported; care should be given that all pilots and knowledge is shared. A good way to addressing this problem could be to use a FAIR approach to data dissemination which also helps sharing information internationally and improve cross-project learning. It was found that 'lessons learnt' are very important to share and Ecoshape has developed a framework specifically for this. Other information to store, in addition to 'lessons learnt', is at least, implementation costs and decommissioning costs. A balance should be struck between developing a very complete, fine-grained overview and a more general knowledge base that allows comparing between pilots. Moreover, a knowledge base should provide a good timeline of events for reference and store relevant documents that otherwise might be lost to time. Additionally, RWS already has so much data saved in various locations, information of NBFD pilots does not need to be elicited a second time if said data is sourced properly. To conclude, validation results seemed to indicate that the current solution is an at least semi-decent answer to this sub-question.

7.1.3. Answering the main research question

How can Rijkswaterstaat improve its monitoring and evaluation process of nature-based flood defense pilots in rivers and floodplains?

The main research question is 'how can Rijkswaterstaat improve its monitoring and evaluation process of nature-based flood defense pilots in rivers and floodplains?'. It was found that there is no standard practice for monitoring and evaluation of NBFD pilots (yet). Based on previous pilots, it was found that most monitoring focused on hydraulics, morphology, and ecology while neglecting the social and political context. However, literature and experts note that social and political aspects are important to monitor for NBFD pilots. Moreover, monitoring should receive more time and resources to ensure long-term monitoring and a better evidence base.

Rijkswaterstaat is already using an indicator-based assessment approach to evaluation whereby evaluation questions are formed, evaluation criteria based on the questions, and monitoring indicators chosen to inform the evaluation criteria. Improvements for evaluation would be to have a standardised process that evaluates at moments that are aligned with the natural frequency and variance of the NBFD pilot and context. Secondly, for NBFD it would be good to look more at 'what works and what does not work and why?'; this emphasis on sharing 'lessons learnt' and also reporting failures is necessary. The result of each evaluation in addition to other pilot information should be shared on a knowledge base. The overall recommendation would be that RWS uses findings of this study as a template for the formal NBFD pilot procedure of IUP that all reports, reviews, evaluations, and other documents are stored in a knowledge base for future reference and knowledge sharing.

Design of the knowledge base should allow provisioning for later additions of monitoring and evaluation results to keep the knowledge base up-to-date. The current knowledge base is not yet perfect, as validation results have shown, so it is advised to look at further development and future research, section 7.3 and section 7.4 respectively. An example would be changing the OECD framework as it is not well-known and it might be better to use an asset management framework that is currently being used at RWS. As a final recommendation, it is recommended to keep the IUCN self assessment to not forget the social aspects and explicitly evaluate social impacts and stakeholder management.

The next steps for RWS to establish a usable knowledge base would be to find a second organisation that has incentive to moderate it while RWS plays a big part in providing information. Suggested parties for this collaboration would be Ecoshape, Deltares, Natuurlijke Klimaatbuffers, other knowledge institutes, or establishing a new platform such as Kennisportaal Klimaatadaptatie that is more geared towards researchers and practitioners. Much of the information could be ported directly from RWS databases and project management systems but other manual information input should be kept to small batch jobs: input of evaluations, for example, should not require providing too many pieces information at the same time. This will result in less people being willing to provide information and less people using the knowledge base . This means that the M&E framework itself cannot have too many fields.

7.2. Discussion

7.2.1. Limitations

Interviews, demos, and questionnaires

The interviews were all done in Dutch so there might be some errors introduced during translation and the words may carry a slightly different meaning. Although it was tried to keep this to a minimum, the researcher had to make some educated guesses about the hidden meaning of some remarks. Secondly, it was decided to show the insights in question-form for uniformity and they will eventually be used as evaluation questions; sometimes people answered with statements like 'you should evaluate social effects' and others answered with figurative questions like 'what are the social effects?'.

Another limitation in the first phase was the sampling choice: stakeholders of NBFD pilots were not interviewed. Although the knowledge base is geared towards researchers, design and development decision of the M&E framework still should be informed by all relevant stakeholders of a NBFD pilot; the M&E framework may now lack aspects that should be considered according to some stakeholder perspectives. Similarly, only researchers of RWS and Deltares were interviewed but in the multidisciplinary space many other organisations and types of researchers could have been asked to participate which in itself is grounds for future research to adapt the current M&E framework after interviewing researchers from other sciences e.g. social scientists and geologists ● Moreover, the sampling size was too small to derive statistically significant conclusions. A larger scale study should be done to validate these findings. ● Future research

For the results, one of the biggest points of contention would be that there were recurring interviewees: four out of six interviewees that were interviewed in phase I also submitted feedback on the design in phase II. It can be said that their view might be over-represented and scores biased. Their feedback and judgement may also be influenced by the first interview so they are not unbiased or a 'blank slate' like the other interviewees that were not involved before. Also, they are more inclined to like a product that used parts of their input as initial design requirements. In sum, this may all result in higher scores than if only uninvolved people were asked to participate.

The demo information about that specific pilot was incomplete leading to the inclusion of dummy text. Were the information complete, the matter experts could give more pointed advice based on the content and what (context) they might miss. The results could be influenced by this fact.

Another influencing factor was highlighted through feedback: one interviewee mentioned that there was a lack of information about stakeholder engagement or effects on stakeholders i.e. social sciences aspects. This lack of perspective was introduced at the time of development where criteria were chosen and left out. Unfortunately, when copying evaluation questions from the analysis to the development environment, some were erroneously left out. This remained through iteration I and II. In the M&E framework , hidden behind the panel of the impact criterion there were still three evaluation questions: 'what is the effect on human well-being?', 'what are the social effects?', and 'what are the effects on people?'. In that regard, the effects on stakeholders were included but it may have been overlooked as the demo showed everything but did not linger long on each part of the knowledge base . In iteration III with the inclusion of IUCN Global Standard indicators, stakeholder management was more explicitly included. There may have been other aspects that were missed or forgotten by the interviewees, due to having a lot of information and impressions sent their way, in a short time span. It is unsure in what way the results could be influenced due to this overload; scores may have been higher or lower.

During the first two feedback rounds, the researcher gave a demo by sharing their screen remotely. After the demo, the interviewer while still broadcasting, guided the interviewees through the questionnaire and filled in the responses. In hindsight, this created a situation of social desirability bias, where the respondent might not have been able to give their 'unsalted' opinion in an anonymous way.

During the demo, before respondents gave feedback, the researcher showed all the different sections of the knowledge base, highlighted, but most importantly gave explanations and sometimes reasoning behind some of the sections or design choices. Interviewees sometimes also asked questions about particular decisions. The fact that reasoning was sometimes given must have influenced the consideration of interviewees.

Another influencing factor of the analysis is the fact that there were three different surveys. With questionnaires, the sequence with which concepts and questions follow each other change responses. Measurement validity is lower due to this. Also, in the first two surveys there was not option to opt-out of answering such as a 'not applicable' option.

Heuristics analysis was not done by professional UI or UX designers. The scores should be considered an indication of validation.

The terms 'web page' and 'knowledge base' have been used interchangeably in the questionnaire. This could have introduced confusion and makes construct validation of the knowledge base concept less valid.

To make it more understandable for interviewees, the concept of knowledge base was reduced to 'webpage'. This makes it less easy to validate the concept. It however may have preemptively reduced confusion.

Design and development

It was decided not to implement an operational and tactical/strategic view, as that would introduce confusing levels of abstraction and a lot more information to somehow convey. Practically, the design that was decided upon did not lend itself well for another type of slicing of the information. A more practical view that would be relevant for a project leader at RWS requires a lot information on the type of tendering, contracting, quality requirements, etc. but they have access to these details. With regards to knowledge sharing and awareness of NBFD, a knowledge base with information geared towards researchers and the public would provide more added value.

It was decided to try and keep the number of information fields for the M&E framework and knowledge base manageable for information input. This does mean that certain information had to be left out and that resulted in design choices for the M&E framework whereby the interview questions became optional for those who evaluate. This makes pilot evaluation and subsequent comparison less standardised.

Validation

The current solution whereby a M&E framework is part of a knowledge base is not explicitly tested. The first Likert statement 'saving information and evaluations online in a standardised way has added value' tries to validate the premise that this is a good idea but is insufficient in validating whether a knowledge base approach is the right way or other options should have been chosen. Moreover, the statement also does not validate that the combination of M&E framework in a knowledge base is good.

7.2.2. Implications for science

This study contributes by introducing a novel combination of evaluation frameworks and evaluation questions, from a plethora of sources, into a new M&E framework for NBFD pilots that is part of a knowledge base. There are currently no knowledge bases solely dedicated to NBFD pilots. The NBS community as a whole will benefit tremendously from more standardised storage and effective knowledge sharing. It has been found that there is a need for standardised comparison, a knowledge base , and an evidence base of NBS projects. This knowledge base approach with integrated M&E framework tackles these knowledge gaps all at once. If a centralised Dutch knowledge base for NBFD or NBS pilots would be made as proposed, the hope is that dissemination will perpetuate knowledge and enhance cross-project learning as well as overall information retained long-term. Moreover it would serve as an evidence base that can be instrumental to the mainstreaming of NBS as it can provide a fair comparison with conventional solutions as to allow informed political decisions. This knowledge base can also help mainstreaming NBFD as it allows standardised comparison of technologies/solutions that are being innovated, tested, and piloted right now in finding possible dominant and 'best practice' designs for the Netherlands. Furthermore, there are many opportunities to improve pilot comparison, discussed in section 7.3 and section 7.4. Such pilot comparisons could also help in establishing a comprehensive categorisation of possible NBFD in Dutch rivers and floodplains. This is a current knowledge gap. In essence, the developed knowledge base can be used for all projects in and around rivers with a flood risk component and an aim to improve ecology or biodiversity. It is not sure whether this M&E framework and knowledge base would be globally relevant as feedback was all gathered from Dutch professionals working in the Netherlands. The whole research approach does lend itself for developing a global knowledge base or for lower level governments, water boards, etc.

The validation results showed a positive response to the integration of a M&E framework and knowledge base. This means other existing M&E framework frameworks can also be tried. Due to the limitations and design choices that were made, it stands to reason that there is room for improvement. The OECD evaluation framework might not have been the best basis due to its broad approach.

7.3. Further development

Throughout the report, breadcrumbs highlighted important statements that are either useful for the design and development of a M&E framework and/or knowledge base . The results indicated that the overall prototype, developed was somewhat successful. The feedback shown in section 6.1 that was not implemented, is all viable for further development, if one were to be so inclined, of the prototype or development of a new knowledge base for NBFD pilots. Further development can also draw lessons from the following.

7.3.1. Added value for RWS

Development to ensure added value for RWS and practitioners (such as project leaders and others interested in the operational sides of NBFD pilots), the knowledge base can be extended or changed to accommodate for the following:

- Rijkswaterstaat is currently relying heavily on asset management which also has monitoring & evaluation. It might be better to base and augment the M&E framework on this asset management framework
- From the interviews with RWS employee's it was glanced that practical demands, terms, conditions, performance specifications, contract details could be included
- It would be good to compare the more practical websites of Waterwindow and Platform WOW and incorporate good elements from their knowledge base
- For better knowledge dissemination, the prototype could be improved to comply with the FAIR framework

7.3.2. Interaction and maintenance

Many comments were made about the process and people that would supply the required information about the pilots. So further development really has to consider this aspect. Such improvements for how people interact with the knowledge base is detailed below.

- People filling in information need to be informed that it is fine not to fill in all possible fields
- If pilots are ultimately required to fill in information of a pilot on this knowledge base, it is recommended to allow for the use of additional indicators and optional questions specific to that pilot.
- Access database in the back-end for researchers to play with and try to dissect characteristics by taking slices themselves. This suggestion ties well with another suggestion to develop an API that can easily read in Excel files or another format like csv to upload old or running pilots. Making the process of inputting information as easy as possible is important for continued use and longevity of the knowledge base. This API would then be a good way for other knowledge bases, websites, or researchers to import or export (parts of) the data.
- One insightful suggestion was made to find a primary process at RWS or another organisation, that may maintain/moderate the knowledge base, where the input of data could naturally latch onto or assimilate. An example would be a simple addition of some missing information fields to the system where project leaders have to officially register a project and track the number of resources and hours. In this way, information only has to be filled in once and can be extracted from a primary process already existing in the organisation. New pages for pilots that are happening or are planned can be made automatically based on information from this system. Other people could fill in missing information or they could revisit omitted questions later on.
- The idea was to build the whole knowledge base architecture with a back-end but due to time constraint and for demo purposes, a single demo page for a pilot was added using mostly static plain text information and images
- Although it would again add many more information fields, it would be very interesting to see whether the information shown on the NWRM case studies knowledge base [100] could be linked with this knowledge base. There is a lot of overlap and sharing information is a good thing and it would provide a lot of extra information and awareness of NBFD.
- If you want this to work, make sure you are at the top of Google search results about NBFD pilots
- Try to have people fill in as little information as possible at a time

7.3.3. Extra functionality

Additional functions, features, and improvements:

- It would be nice to have a short introduction on the main page of the knowledge base introducing the term nature-based flood defenses and what requirements a pilot has to fulfil in order for it to be stored.
- One interviewee stressed the importance of looking at the effects of pilots on floods, droughts, and biodiversity. These were indeed included and retain a prominent place in the M&E framework but the effects could be shown more clearly with pictures as to provide evidence with before and after photographs. One possibility would be to have a section dedicated to effects where each claim of supposed effects is supported by pictures/illustrations or other types of evidence and descriptions.
- One interviewee mentioned that a pilot should also be evaluated in light of future scenarios advise not to use more than four scenarios and to look at the main drivers of increasing flood hazard, namely climate change, economic growth, population growth, and land use change.
- At a minimum, NBS should include a variable, action, quantity, and time-period for each management target for conservation or restoration of biodiversity/nature. In the current design of the knowledge base, this information is scattered and it would be best to combine it somehow in one block [84].
- For policy-makers, information on the financing structures, contracts, conservation management agreements, more in-depth policy and regulatory implications, and lastly a good cost-benefit analysis for fair comparison with conventional grey infrastructure could be included.
- There are too many criteria to choose from and information needs differ, so it might be worthwhile to introduce selective 'views' for different types of intended users e.g. researchers, practitioners, and policy makers
- Recommend using lagging and leading indicators (indicators that show the likelihood of a certain outcome in the future); leading indicators can help in goal progress projection and management towards said goal
- monitoring frequency based on the natural variance
- Ecosystem services were not incorporated into the design. Frankly, this was due to the fact that there was not enough space and already so much information to fill in for supposed contributors. A design decision had to be made. Resi rivers has a lot of research and information on ecosystem services in rivers so relevant benefits can be sourced from there, Bridges et al. [3] have defined a benefits wheel with relevant ESS for NBFD (although very general), and NWRM also has a comprehensive overview of impacts and benefits per measure [216].
- If a pilot scores low on some aspects of SRL i.e. a bottleneck has been identified, those aspects should thenceforth be monitored
- Currently, the lessons learnt are not structured using the framework of Ecoshape. It would be good to adopt this in the process somehow
- Projects evaluated using the IUCN Global Standard can be plotted in a radar chart. This could be a good way to visually evaluate and compare projects as shown below in Figure 7.25
- On the knowledge base it would be a great addition to add when the pilot started and ended. This would allow for comparison between pilots of the same category, location, and time frame. An illustration of this idea is show below in Figure 7.26. Additionally, future pilots or pilots that are currently running would be easier to find, hopefully sparking more collaboration.

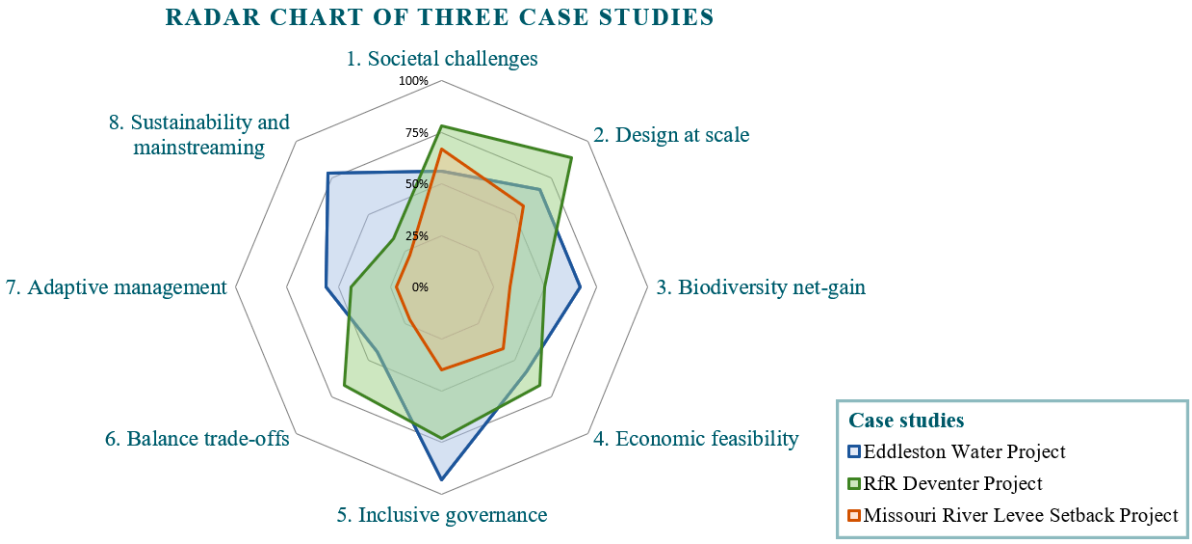


Figure 7.25: Radar chart comparing three pilots [7]

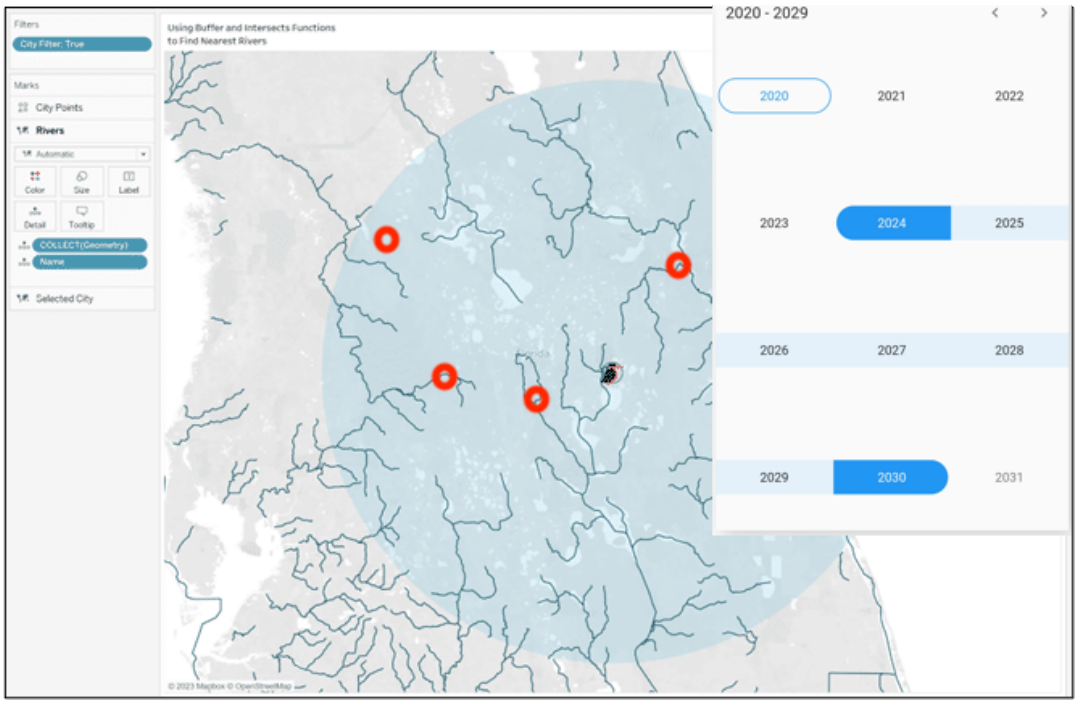


Figure 7.26: Example of a map with pilots within a demarcated area filtered on selected years

7.4. Future research

Possible avenues for future research:

- The IUCN Global Standard was not developed purely for performance evaluation/assessment but it is possible to adapt it (slightly) for this purpose. Further research could look into adopting it for the context of the Netherlands with emphasis on the major river deltas and their areas of influence.
- A specific categorisation for NBFD possible in Dutch rivers should be developed.
- Normally evaluation is retrospective and a judgement of the current status but not so much forward-looking. Assessment of NBFD pilots that incorporate a M&E framework similar to the one developed in this study could benefit from prospective information. Thus, further research

is warranted in the incorporation of leading and lagging indicators. This would tie well into the progression of evaluation moments from ex-anto, mid-term, to ex-post.

- It would be nice if mandatory standardised storage of pilot information in a knowledge base could be required of larger scale NBS research programmes such as ISBAM, IRM, NL2120.
- One interviewee mentioned that a lack of NBFD implementation is not due to missing evidence and knowledge, as literature might say, but due to hindrance of guidelines, laws, rules, regulations, standards, etc. (i.e. institutions).
- Only researchers of RWS and Deltares were interviewed but in the multidisciplinary space many other organisations and types of researchers could have been asked to participate which in itself is grounds for future research to adapt the current M&E framework after interviewing researchers from other sciences e.g. social scientists and geologists.
- *'In my experience the premise that there is not a big enough evidence base for NBS is less of a bottleneck to the implementation of NBS than actual laws and regulations such as Natura 2000 that sometimes hinder'*. This was an interesting statement that could be investigated further.
- Future research could look into who actually reads evaluations. Following this up would be to see what kind of information needs they have and at what abstraction level. Zingraff-Hamed et al. [217] have found seven stakeholder groups of NBS: governmental authorities, political representatives, civil society, private sector, academia and research sector, media, and international and transnational organisations.
- The intricacies of pilots in water management were investigated by Vreugdenhil [37]. It could be worthwhile to test whether storing information about the unique pilot descriptors and third level of pilot effects has added value to intended users of the knowledge base. The third level of pilot effects that was not in the scope: how institutions such as policy, regulation, rules, and routines are changed [38]. In the interviews it was mentioned by RWS employees that this could be worthwhile for project leaders at RWS.
- Adding onto the point made above, if the knowledge base were to store more meta-information about the pilot with regards to its pilot type, organisation, management structure, and status at regular intervals, research could be done on best practices for pilot management, upscaling, and being able to predict where a pilot may find challenges in the future when compared to similar pilots. An overview of possible information synthesised from Vreugdenhil [37] is illustrated below, Figure 7.27

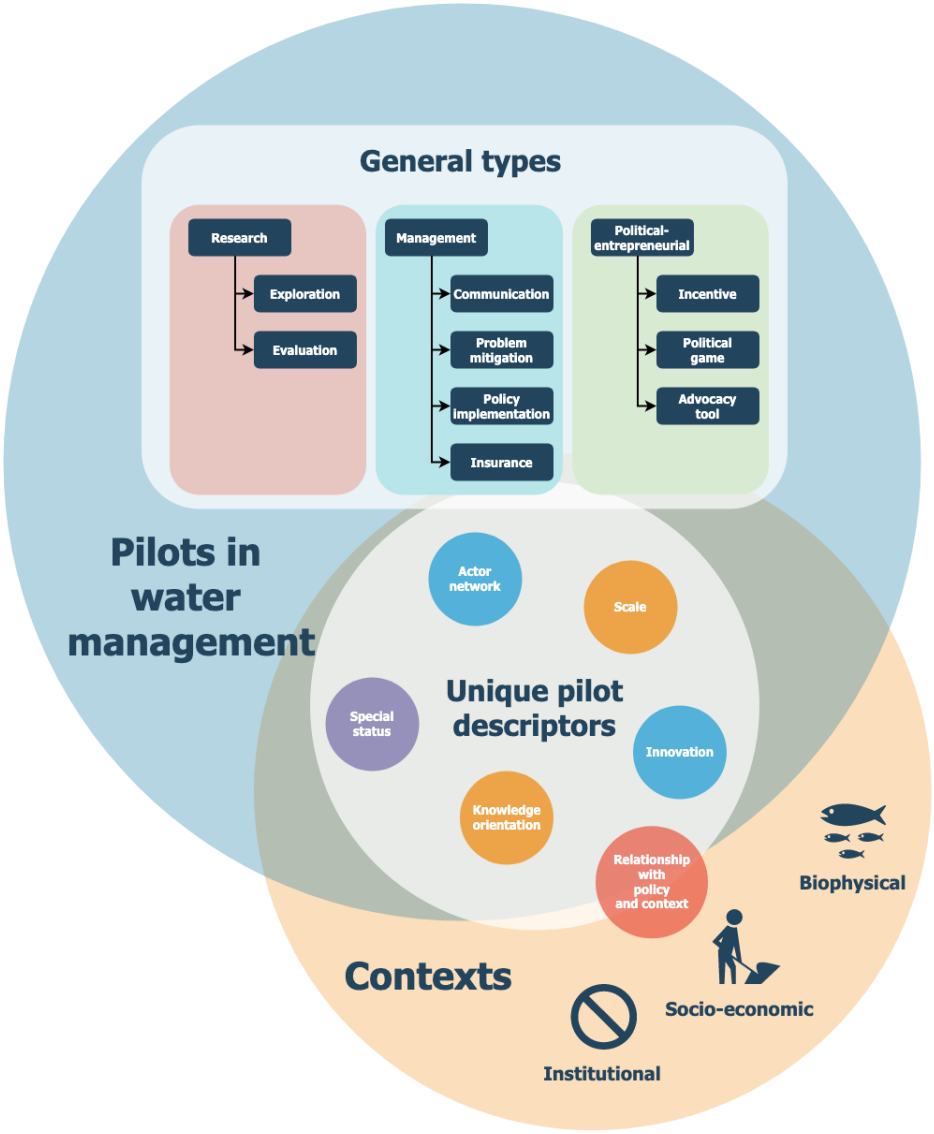


Figure 7.27: Pilot project ontology

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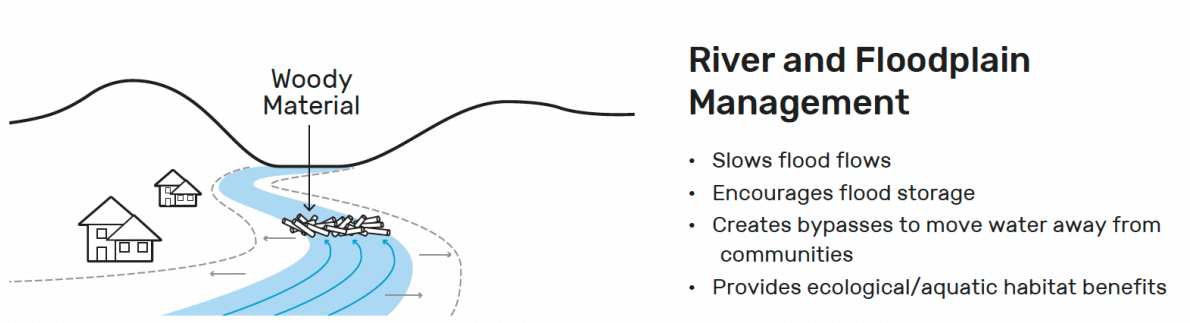
A

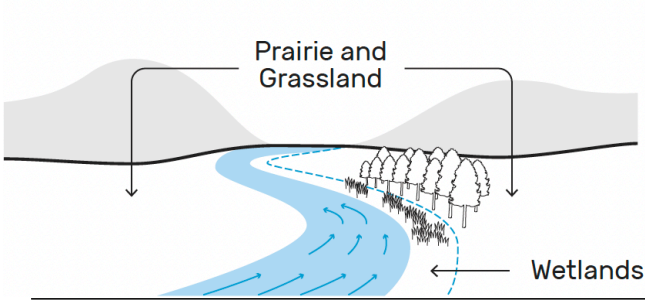
NBFD measures

For completeness' sake, fluvial NBFD categories of Bridges et al. [3], that are relevant for this study, are included below. Illustrations and photos showcasing the measures can be found in their report. Explanations were copied and unaltered.



Measure	Explanation
Riparian buffer corridor area	Riparian buffer strips along the tops of banks of watercourses can help to slow the flow of water off the land into the river. This can also help trap sediment and pollutants. Riparian buffer strips can also act as corridors for fauna and flora.
Off-line storage areas	Off-line storage areas are floodplain areas adapted to retain and attenuate floodwater in a managed way. They usually include a containment bund and an inlet, an outlet, and potentially a spillway mechanism.
Floodplain restoration and reconnection (breaching and removal of embankments)	Floodplain restoration aims to restore the hydrological connection between rivers and floodplains so they are inundated and store water during times of high flow. This can involve removing flood embankments and other barriers to floodplain connectivity.
Reconnection of oxbow lakes	Rivers have been altered throughout time; in many cases, old paleochannels and oxbow lakes can still be seen in the landscape. When rivers and floodplains are restored, there is the potential to restore the river along its old route, connecting it up past oxbow lakes.
Levee notching	If there is no infrastructure behind a levee, holes can be added to allow water to access the floodplain during a flood and take the peak off the hydrograph.

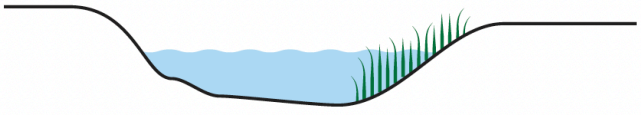
Removing obstacles from the floodplains	In the past, many different structures have been constructed in floodplains that hinder the flow at high discharge. These can include, for example, small levees to protect farmland, local regulation works, hideaways for livestock, and ramps of bridges. Removing these obstacles increases the discharge capacity of the floodplain and lowers flood levels.
Longitudinal dams	Longitudinal dams are structural walls that create a secondary channel in a river system. Although it is a gray solution, longitudinal dams involve creating side channels that can have a high ecological value. Conditions are more suitable for fish spawning (because the dam also limits the effects of ship□induced waves) and helps increase biodiversity. Longitudinal dams decrease flood levels (causing less friction than the groins) and ensure more navigational depth in periods of low discharge.
Renaturalization of polder areas	A polder is a low-lying tract of land enclosed by embankments or barriers known as dikes. Dikes form an artificial hydrological entity in which there is no connection between the watercourse and the land on the other side of the dikes, other than through manually operated devices. Renaturalization involves enhancing polders to better store water and provide habitat co-benefits.
Lowering floodplains	Over the past decades, navigation channels in many engineered rivers have been eroding at a rapid rate due to the use of river training measures and also due to sediment becoming blocked by dams or impoundments. This has resulted in floodplains becoming disconnected from the river system. Floodplain lowering reconnects the floodplains to the main channel, creating a more natural situation whereby the discharge capacity is increased and flood levels lowered. Floodplains also flood more frequently, with sediment being deposited on them.
River restoration (remeandering, bed and bank renaturalization)	Rivers have been physically modified through a variety of means for the purposes of navigation, drainage, and industrial development. River restoration is the reinstatement of the natural physical processes (e.g., renaturalizing flow and sediment supply regimes by removing weirs) and NNBF (e.g., adding wood, altering river shape, and introducing sediment gravel) that are characteristic of a river.
Constructing side channels	Side channels are a popular measure. They enlarge the discharge capacity of a river while improving biodiversity and creating habitat (e.g., spawning grounds for fish). Side channels often have weirs at the upstream entrance to control the capacity. They have a tendency to aggrade, so maintenance (dredging) is often necessary. They also have morphological consequences in the main channels.
Modifications to dams and weirs	Many watercourses are impounded. These structures can be altered to, for example, enable the passage of fish.



Vegetation Management

- Slows water
- Encourages infiltration in soil
- Enables evapotranspiration
- Increases roughness and slows flow

Measure	Explanation
Prairies and floodplain meadows	Grasslands in the floodplain (referred to as prairies or floodplain meadows) are highly biodiverse habitats that support many plants and animals. Restoration of this habitat alongside alterations to levees and embankments can restore these habitats to help reduce flood risk.
Watershed-wide woodland planting	Watershed-wide woodland is defined as the total area of all woodland within a watershed. It combines general woodland cover of all types and species, including plantations, plus specific forms where present, such as cross-slope, riparian, and floodplain woodland.
Floodplain and riparian woodland planting	Floodplain woodland refers to all woodland lying within the fluvial floodplain that is subject to an intermittent, regular planned, or natural flooding regime. Its main role is to slow down and hold back flood flows within the floodplain, as well as to enhance sediment deposition and thereby reduce downstream siltation. Photograph
Woody dams in streams and riparian zone	Woody dams and barriers usually consist of pieces of wood, occasionally combined with some living vegetation, that accumulate in river channels and on riverbanks and floodplains. They occur naturally along rivers as a result of trees falling locally into watercourses. Similar structures can also be engineered by humans to restore rivers and floodplains to slow and store flood water.



Erosion Management

- Protects riverbanks
- Reduces erosion of banks
- Replaces hard engineering with vegetated banks

Measure	Explanation
Aquatic and riparian vegetation management	Native plants well adapted to living in streams can be used to protect the banks and toe of the riverbank by retarding flow velocities and providing root reinforcement to the toe and banks.

Vegetated gabions and mattresses	Gabions and mattresses are wire-mesh baskets filled in situ with stone, with woody vegetation inserted as posts and poles through the basket. They are used to stabilize the bank toe by piling up on top of each other or are extended on the bank to retain it.
Coir matting and rolls	Coir matting and rolls are made of biodegradable material from natural fibers (such as coir) pressed into shapes including matting or sausage-shaped elements (rolls). They provide a rooting base for vegetation to establish. Rolls can be used to stabilize the toe of the slope.
Vegetated reinforced earth	Grasses or live cut branches intermixed with soil wrapped in a natural fabric or geotextile to protect the bank face.
Longitudinal peaked stone toe protection	Longitudinal peaked stone toe protection includes bioengineering and an erosion-control blanket.
Vegetated riprap	Layers of stone and boulders with poles, brush-layers, or live□staking are used to stabilize the bank and toe.
Staking	Live or dead stakes are used to reinforce banks, promote vegetation regrowth, and anchor other vegetated measures until they are fully developed. Staking is also used at the toe as scour protection.
Willow plantings	Willow plantings can form a fence-like structure backfilled with soil or in hurdles to deflect flow away from the bank and promote nearbank deposition.
Vegetated concrete blocks	Vegetated concrete blocks are articulated block systems with vegetation inserted through the openings in the blocks into the soil beneath them.
Woody materials (including bundles of wood, fascines, and brushwood)	Bound pieces of untreated wood, fascines, and brushwood are used to slow the nearbank flow and trap sediment. Woody material from felling trees can also be installed in the bank to deflect the flow and promote sediment deposition.

B

Informed consent

Opening statement

You are being invited to participate in a research study titled Nature-based Solutions pilots in River flood defense. This study is being done by Casper Klein Essink from the TU Delft and Deltares.

The purpose of this research study is to develop an evaluation framework and database for Rijkswaterstaat pilot projects in river flood defense, and will take you approximately *45* minutes to complete. The data will be used for exploratory research. We will be asking you to describe your professional experience and try to relate it to the studied topic of NbS pilots in river flood defense.

As with any online activity the risk of a breach is always possible. To the best of our ability your answers in this study will remain confidential. We will minimize any risks by storing only your name and other (indirectly) identifiable information offline until completion of the study. A transcription of the interview can be included at the time of publication, after anonymisation and review by you.

Your participation in this study is entirely voluntary and you can withdraw at any time. You are free to omit any questions. Data can also be removed per request at any time until publication (preliminary planning 07-07-2023).

Researcher contact details:
Casper Klein Essink
[redacted]
c.j.kleinessink@student.tudelft.nl

Explicit Consent for interviews

Please make sure that you select (and amend as necessary) any Explicit Consent points which are relevant to your study and exclude those which do not apply. You should also add further points and necessary to address your specific research situation.

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
A: GENERAL AGREEMENT – RESEARCH GOALS, PARTICPANT TASKS AND VOLUNTARY PARTICIPATION		
1. I have read and understood the study information dated [*DD/MM/YYYY*], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	☐	☐
2. I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	☐	☐
3. I understand that taking part in the study involves	☐	☐
• *An audio-recorded interview about your professional experience*		
4. I understand that the study will end 07-07-2023		
• *Preliminary publication date is 07-07-2023*		
B: POTENTIAL RISKS OF PARTICIPATING (INCLUDING DATA PROTECTION)		
5. I understand that taking part in the study also involves collecting specific personally identifiable information (PII) and associated personally identifiable research data (PIRD) with the potential risk of my identity being revealed.	☐	☐
• *Name* • *Position* • *Company*		
6. I understand that the following steps will be taken to minimise the threat of a data breach, and protect my identity in the event of such a breach […]	☐	☐
• *The audio file will be saved offline and deleted after transcription.* • *The transcription will be saved offline deleted after publication.* • *All data can be removed per request at any time until publication.* • *The transcription can be anonymised and sent for review by you.*		
7. I understand that personal information collected about me that can identify me, such as [*name, position, company*], will not be shared beyond the study team.	☐	☐
8. I understand that the (identifiable) personal data I provide will be destroyed […]	☐	☐
At the time of publication 07-07-2023		
C: RESEARCH PUBLICATION, DISSEMINATION AND APPLICATION		
9. I understand that after the research study the de-identified information I provide will be used for [*see points below*]	☐	☐

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
• *Publication*		
10. *(optional)* I agree that my responses, views or other input can be quoted anonymously in research outputs	☐	☐
11. *(optional)* I agree that my real name can be used for quotes in research outputs	☐	☐
D: (LONGTERM) DATA STORAGE, ACCESS AND REUSE		
12. I give permission for the de-identified interview transcription that I provide to be archived in TU Delft Education repository so it can be used for future research and learning.	☐	☐
13. I understand that access to this repository is open	☐	☐

Signatures

_____	_____	_____
Name of participant [printed]	Signature	Date

I, as researcher, have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

_____	_____	_____
Researcher name [printed]	Signature	Date

Study contact details for further information: [*Casper Klein Essink,* [redacted] *c.j.kleinessink@student.tudelft.nl*]

C

Survey I

Opening statement

Opening statement

U bent uitgenodigd om mee te doen aan een onderzoek naar **nature-based flood defense pilots in rivieren**. Dit onderzoek wordt uitgevoerd door Casper Klein Essink, als onderdeel van een MSc thesis vanuit TU Delft bij Deltares, onder begeleiding Heleen Vreugdenhil (TU Delft, Deltares), Nick Leung (Deltares) en Jill Slinger (TU Delft). Het doel van dit onderzoek is om een evaluatie framework en knowledge base te ontwikkelen voor Rijkswaterstaat specifiek voor nature-based flood defense pilots in rivieren.

Na interviews en literatuuronderzoek is een eerste evaluatie framework en knowledge base ontworpen. De knowledge base is een website waarop pilots een eigen informatiepagina krijgen. Hopelijk wordt zo de kennis van pilots beter opgeslagen en verspreid. **De vraag aan u is om naar de webpagina van een voorbeeld pilot te gaan en feedback te geven van uw eerste gedachten en indrukken**. De data van deze vragenlijst wordt gebruikt om het eerste ontwerp te verbeteren van de knowledge base en het evaluatie framework. Deze vragenlijst is ontworpen om **ongeveer vijf tot tien minuten** te duren.

De link en corresponderende vragen vindt u op de volgende pagina.

Bedankt voor uw deelname!

Informed consent

Uw antwoorden worden anoniem opgeslagen en verwerkt. Voor verwerking wordt de response data opgeslagen op Google Drive totdat het onderzoek afgelopen is. Uw deelname aan dit onderzoek is volledig vrijwillig en u kan op elk moment stoppen. Het is mogelijk om vragen leeg te laten. U kunt op elk moment een verzoek doen om antwoorden of informatie te verwijderen.

Contactinformatie

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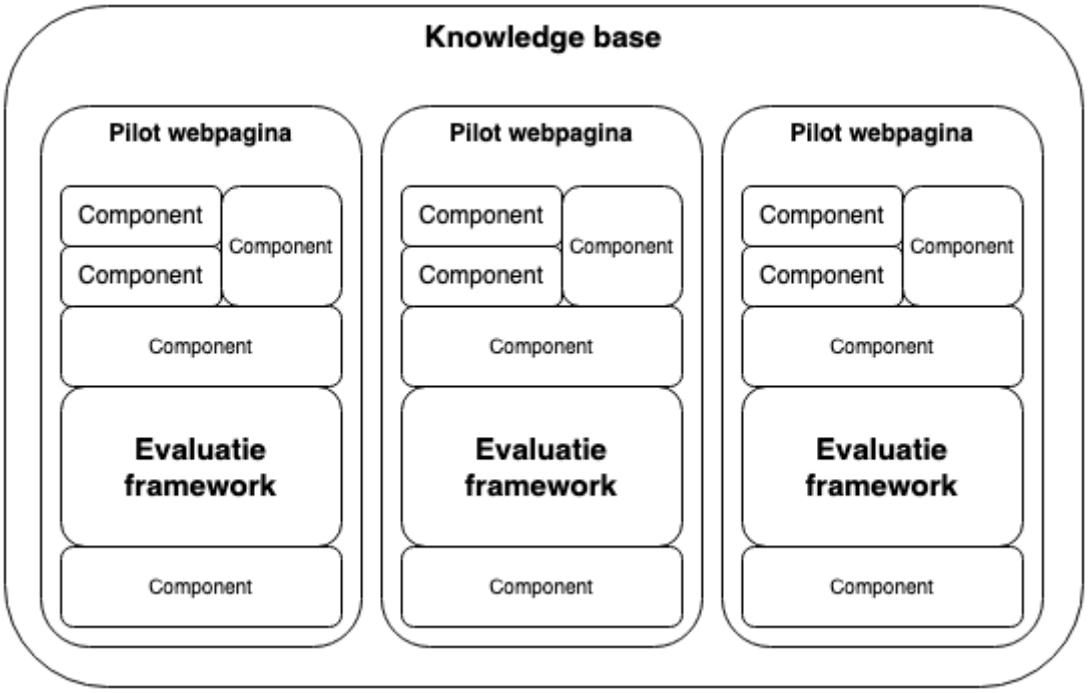
Context

Context informatie

Elke pilot heeft een eigen webpagina op de knowledge base. Op elke webpagina zijn meerdere componenten te zien en het evaluatie framework is daar een van (zie onderstaande figuur ter illustratie). Andere componenten zijn bijvoorbeeld een inleiding, informatie over de projectdoelen, een component met foto's van de pilot, een kaart met de locatie, informatie over monitoring, belangrijke lessen en projectdocumenten.



Graag vraag ik u eerst naar een webpagina te kijken van een voorbeeld pilot: https://nbfd-knowledge-base.vercel.app/posts/example-pilot

Hierna kunt u de vragenlijst invullen.

Evaluation framework

Wat vindt u van het monitoring en evaluatie framework component?

	Sterk niet mee eens	Een beetje niet mee eens	Niet mee eens en niet mee oneens	Een beetje mee eens	Sterk mee eens
Ik mis criteria in het evaluatie framework (e.g. een sub-criterium van biodiversiteit, hydro-metereologisch criterium, etc.)	○	○	○	○	○

	Sterk niet mee eens	Een beetje niet mee eens	Niet mee eens en niet mee oneens	Een beetje mee eens	Sterk mee eens
Dit evaluatie framework kijkt naar alle relevante aspecten van nature-based flood defense pilots	○	○	○	○	○
Voor alle criteria in het evaluatie framework zijn de goede modellen gebruikt	○	○	○	○	○
Een of meerdere criteria zouden met een ander model geëvalueerd moeten worden	○	○	○	○	○
Dit evaluatie framework is goed van toepassing op nature-based flood defense pilots in Nederlandse rivieren	○	○	○	○	○
Dit evaluatie framework is globaal toepasselijk	○	○	○	○	○

(optioneel) Missen algemene vragen?

(optioneel) Missen evaluatievragen?

(optioneel) Missen monitoringindicatoren?

(optioneel) Mist een criterium?

(optioneel) Welk criterium zou u anders evalueren?

Knowledge base

Wat vindt u van het knowledge base template?

	Sterk niet mee eens	Een beetje niet mee eens	Niet mee eens en niet mee oneens	Een beetje mee eens	Sterk mee eens
Een of meerdere componenten missen (e.g. een samenvatting, video, tijdlijn, etc.)	○	○	○	○	○
Het template heeft alle relevante componenten	○	○	○	○	○
Een of meerdere componenten zijn overbodig	○	○	○	○	○
Binnen een of meerdere componenten zou ik andere informatie willen zien	○	○	○	○	○

	Sterk niet mee eens	Een beetje niet mee eens	Niet mee eens en niet mee oneens	Een beetje mee eens	Sterk mee eens
Binnen een of meerdere components zou ik informatie op een andere manier willen zien (e.g. video/audio/ander format in plaats van text)	○	○	○	○	○
Binnen de componenten is informatie op de meest toepasselijke manier weergegeven	○	○	○	○	○

(optioneel) Mist u een component?

(optioneel) Welk component is overbodig of zou u anders vormgeven?

Right type of medium

Er zijn meerdere evaluatiemomenten bijvoorbeeld voor, tijdens en na afronding van de pilot. Het voorstel voor Rijkswaterstaat is dat voor pilots na elk evaluatiemoment de evaluatie opgeslagen wordt op de knowledge base.

Wat denkt u van dit voorstel?

	Sterk niet mee eens	Een beetje niet mee eens	Niet mee eens en niet mee oneens	Een beetje mee eens	Sterk mee eens
Ik denk dat het meerwaarde heeft om alle informatie en evaluaties gestandaardiseerd online op te slaan	○	○	○	○	○
Dit voorstel is een goed idee voor betere kennisdeling	○	○	○	○	○
Voor het voorstel moet het knowledge base template aangepast worden	○	○	○	○	○
Voor het voorstel protocol moet het evaluatie framework aangepast worden	○	○	○	○	○
Ik zou de knowledge base gebruiken om informatie op te zoeken van voorgaande nature-based flood defense pilots	○	○	○	○	○

(optioneel) Heeft u feedback over het voorstel?

Powered by Qualtrics

D

Survey II

Opening statement

Opening statement

U bent uitgenodigd om mee te doen aan een onderzoek naar **nature-based flood defense pilots in rivieren**. Dit onderzoek wordt uitgevoerd door Casper Klein Essink, als onderdeel van een MSc thesis vanuit TU Delft bij Deltares, onder begeleiding Heleen Vreugdenhil (TU Delft, Deltares), Nick Leung (Deltares) en Jill Slinger (TU Delft). Het doel van dit onderzoek is om een evaluatie framework en knowledge base te ontwikkelen voor Rijkswaterstaat specifiek voor nature-based flood defense pilots in rivieren.

Na interviews en literatuuronderzoek is een eerste evaluatie framework en knowledge base ontworpen. De knowledge base is een website waarop pilots een eigen informatiepagina krijgen. Hopelijk wordt zo de kennis van pilots beter opgeslagen en verspreid. **De vraag aan u is om naar de webpagina van een voorbeeld pilot te gaan en feedback te geven van uw eerste gedachten en indrukken**. De data van deze vragenlijst wordt gebruikt om het eerste ontwerp te verbeteren van de knowledge base en het evaluatie framework. Deze vragenlijst is ontworpen om **ongeveer vijf tot tien minuten** te duren.

De link en corresponderende vragen vindt u op de volgende pagina.

Bedankt voor uw deelname!

Informed consent

Uw antwoorden worden anoniem opgeslagen en verwerkt. Voor verwerking wordt de response data opgeslagen op de cloud van Qualtrics totdat het onderzoek afgelopen is. Uw deelname aan dit onderzoek is volledig vrijwillig en u kan op elk moment stoppen. Het is mogelijk om vragen leeg te laten. U kunt op elk moment een verzoek doen om antwoorden of informatie te verwijderen.

Contactinformatie

Casper Klein Essink
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Heleen Vreugdenhil
heleen.vreugdenhil@deltares.nl

Evaluation framework

Vragen over het monitoring en evaluatieframework

(optioneel) Wat zou u veranderen aan het monitoring en evaluatieframework?

(optioneel) Mist u iets in de algemene vragen?

(optioneel) Mist u iets in de monitoring framework?

(optioneel) Mist u iets in het evaluatie framework?

Vragen over de algemene webpagina

(optioneel) Mist u iets op de webpagina (e.g. een samenvatting, video, tijdlijn, etc.)?

(optioneel) Is een onderwerp overbodig of zou u een onderwerp anders vormgeven?

Right type of medium

Er zijn meerdere evaluatiemomenten mogelijk. Bijvoorbeeld voor de pilot, tijdens de pilot en na afronding van de pilot. Het voorstel is dat Rijkswaterstaat voor pilots na elk evaluatiemoment de evaluatie opslaat op de webpagina.

Wat denkt u van dit voorstel?

	Sterk niet mee eens	Een beetje niet mee eens	Niet mee eens en niet mee oneens	Een beetje mee eens	Sterk mee eens
Ik denk dat het meerwaarde heeft om alle informatie en evaluaties gestandaardiseerd online op te slaan	○	○	○	○	○
Dit voorstel is een goed idee voor betere kennisdeling	○	○	○	○	○

	Sterk niet mee eens	Een beetje niet mee eens	Niet mee eens en niet mee oneens	Een beetje mee eens	Sterk mee eens
Voor dit voorstel moet de opzet van de webpagina aangepast worden	○	○	○	○	○
Voor het voorstel moet het monitoring en evaluatie framework aangepast worden	○	○	○	○	○
Ik zou de knowledge base gebruiken om informatie op te zoeken van voorgaande nature-based flood defense pilots	○	○	○	○	○

(optioneel) Heeft u feedback over het voorstel?

Powered by Qualtrics

E

Survey III

Opening statement

Opening statement

U bent uitgenodigd om mee te doen aan een onderzoek naar **nature-based flood defense pilots in rivieren**. Dit onderzoek wordt uitgevoerd door Casper Klein Essink, als onderdeel van een MSc thesis vanuit TU Delft bij Deltares, onder begeleiding Heleen Vreugdenhil (TU Delft, Deltares), Nick Leung (Deltares) en Jill Slinger (TU Delft). Het doel van dit onderzoek is om een evaluatie framework en knowledge base te ontwikkelen voor Rijkswaterstaat specifiek voor nature-based flood defense pilots in rivieren.

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Bedankt voor uw deelname!

Informed consent

Uw antwoorden worden anoniem opgeslagen en verwerkt. Voor verwerking wordt de response data opgeslagen op de cloud van Qualtrics totdat het onderzoek afgelopen is. Uw deelname aan dit onderzoek is volledig vrijwillig en u kan op elk moment stoppen. Het is mogelijk om vragen leeg te laten. U kunt op elk moment een verzoek doen om antwoorden of informatie te verwijderen.

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Heleen Vreugdenhil
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Block 3

Click to write the question text

	0	1	2	3	4	5	6	7	8	9	10	Niet van toepassing
Begrijpt u alles op de pagina? Geef een cijfer van 0-10 voor duidelijkheid												☐

	0	1	2	3	4	5	6	7	8	9	10	Niet van toepassing
Is het gebruik van termen, iconen en andere elementen consistent? Geef een cijfer van 0-10 voor consistentie												☐
Heeft elk onderdeel van de pagina alleen maar relevante informatie voor dat onderdeel? Staat er niets irrelevants dat kan afleiden? Geef een cijfer van 0-10 voor relevantie												☐
Hoe geschikt is deze knowledge base opzet specifiek voor NBFD pilots? Geef een cijfer van 0-10 voor geschiktheid												☐

	0	1	2	3	4	5	6	7	8	9	10	Niet van toepassing
Stel u zoekt informatie over een voorgaande pilot, zou u via deze pagina alle informatie vinden die u zou willen weten? Geef een cijfer van 0-10 voor compleetheid												☐
Hoe makkelijk vond u het om Welk cijfer van 0-10 geeft u voor de kwaliteit van de pagina?												☐

Right type of medium

Er zijn meerdere evaluatiemomenten mogelijk. Bijvoorbeeld voor de pilot, tijdens de pilot en na afronding van de pilot. Het voorstel is dat Rijkswaterstaat voor pilots na elk evaluatiemoment de evaluatie opslaat op de webpagina.

Wat denkt u van dit voorstel?

	Sterk niet mee eens	Een beetje niet mee eens	Niet mee eens en niet mee oneens	Een beetje mee eens	Sterk mee eens
Ik denk dat het meerwaarde heeft om alle informatie en evaluaties gestandaardiseerd online op te slaan	○	○	○	○	○
Dit voorstel is een goed idee voor betere kennisdeling	○	○	○	○	○
Voor dit voorstel moet de opzet van de webpagina aangepast worden	○	○	○	○	○
Voor het voorstel moet het monitoring en evaluatie framework aangepast worden	○	○	○	○	○
Ik zou de knowledge base gebruiken om informatie op te zoeken van voorgaande nature-based flood defense pilots	○	○	○	○	○

(optioneel) Heeft u feedback over het voorstel?

Powered by Qualtrics

F

Miro board


Relevance
What is the problem?
KPIs defined at the start
what were the objectives/goals of the pilot?
For what time horizon was the intervention designed?
long-term effects
Can you alter the cause?
What kind of hazard?
What was the cause?
What kind of damage will occur?
Goals with motivation
What about flood risk (hazard, exposure, vulnerability)?
Flooding is no problem unless there are people. So what about the people? Why are they there? Can't they build and live somewhere else?
How does it look now? There is always a sort of evolution
Coherence
What is the future goal? With respect to coherence and other projects in the area
How does this project contribute towards an adaptive pathway?
Effectiveness
were the initial goals realised?
effectiveness with respect to the primary goal
future goals: will we reach future goals?
Efficiency
trade-offs
Costs
What was the intended project duration? Did things take longer?
How well did the parties work together and communicate?
Impact
socio-economic benefit
which policy decisions will be made based on this evaluation?
human health
Social effects
technical performance
Floods, droughts, and biodiversity
co-benefits
Resilience: droughts
influence on the sectors
Benefits: droughts
effect on people
off-site effects
Sustainability
What might be relevant future scenarios? How does the intervention perform under these scenarios?
trade-offs
What went wrong? How was it solved? How can you avoid these mistakes?

Knowledge base v1

Voorbeeld pilot

Wat is er geïmplementeerd?

In de Beuningse Uiterwaarden hebben de gemeente Beuningen, ARK Natuurontwikkeling, Rijkswaterstaat en andere partijen tussen 2013 en 2018 een nieuwe klimaatbuffer aangelegd om overstroming als gevolg van hoogwater in de Waal tegen te gaan. Daarnaast wilden ze de natuur verbeteren, de biodiversiteit vergroten en het gebied aantrekkelijker maken voor bezoekers. Deze nieuwe klimaatbuffer was ook nodig omdat eerdere maatregelen in het gebied nog niet genoeg beschermden tegen hoogwater.

Hoe is de interventie geconstrueerd?

Om hoogwater tegen te gaan past ARK samen met Rijkswaterstaat sinds 2011 een nieuwe vorm van natuurbeheer toe op de Ewijkse plaat: cyclische verjonging. Dit betekent dat ARK hoge begroeiing aan de oever tegengaat en de natuur op deze manier om de zoveel tijd ‘verjongt’. Het doel hiervan is om natuurlijke erosie en de biodiversiteit te stimuleren. Daarnaast heeft Rijkswaterstaat geulen gegraven die ze hebben aangesloten op openingen in de oeverwal. Al deze maatregelen zorgen ervoor dat het rivierwater bij hoogwater sneller kan wegstromen. Maar toch zijn extra maatregelen voor een nieuwe klimaatbuffer nodig geweest.

Classificaties

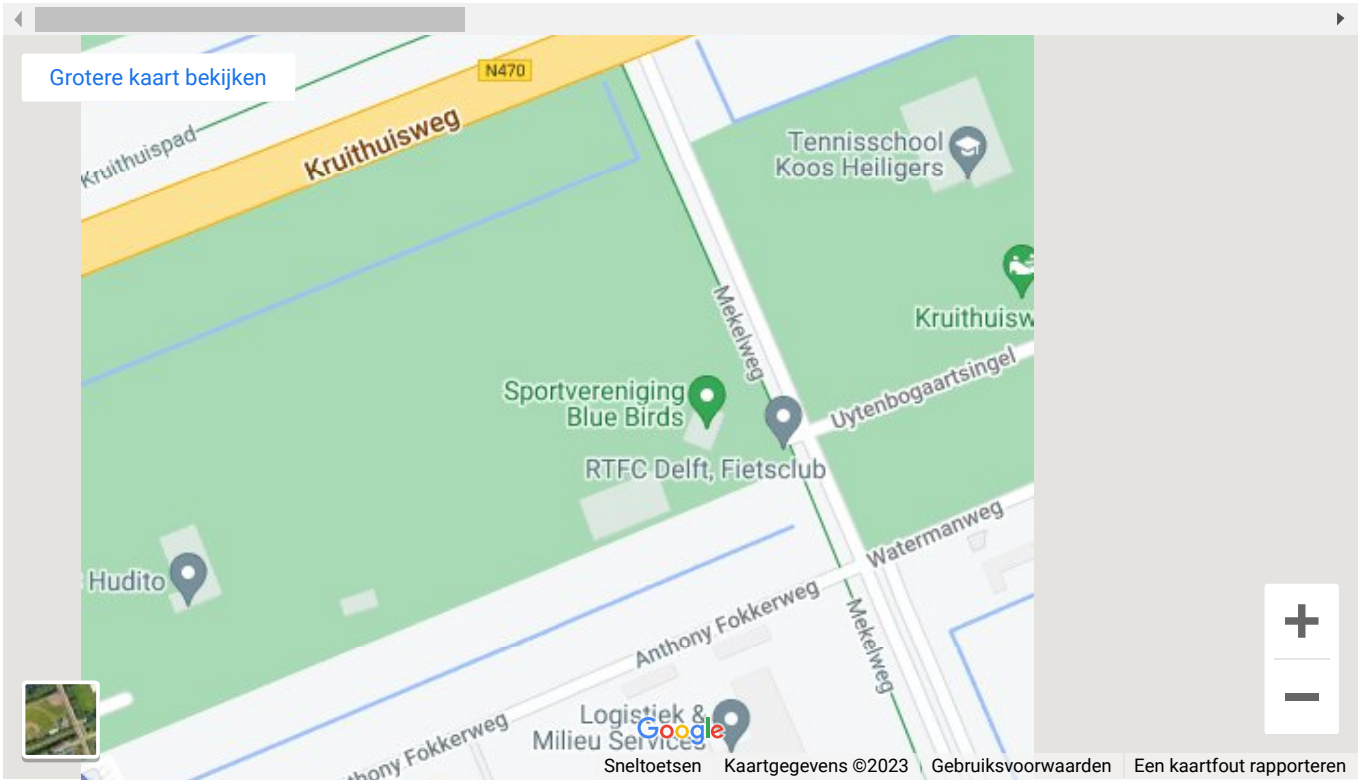
Regio	Gelderland
NBFD categorieën	Floodplain reconnection, Vegetation management
Ecosystemen	Bos, Zoetwater, Rivier
Pilot type	Research, Managerial, Political-entrepreneurial
Status	Afgerond

Betrokken partijen

- ARK Natuurontwikkeling
- Gemeente Beuningen
- Rijkswaterstaat
- Waterschap Rivierenland
- Staatsbosbeheer
- de Dienst Landelijk Gebied & Bureau Stroming

Doelen

1. Hoogwater verlagen
2. Natuur verbeteren
3. Biodiversiteit vergroten
4. gebied aantrekkelijker maken voor bezoekers



Algemene informatie

Algemene monitoring informatie

Was er een officieel monitoring programma?	Nee
Wie heeft gemonitord?	Radboud Universiteit
Is de biotische omgeving gemonitord?	Ja
Is er fysio-chemisch gemonitord?	Geen info
Is er morfologisch gemonitord?	Ja

Algemene

Algemene monitoring informatie

Is er ecologisch gemonitord?	Ja
Is biodiversiteit gemonitord?	Geen info
Is het proces gemonitord?	Geen info
Op welke momenten en frequentie is er gemonitord en waarom?	Geen info
Hoe lang zal er na implementatie gemonitord worden?	Geen info
Met welke praktische methode is data vergaard?	Geen info
Hoe is de data verwerkt?	Geen info

TRL

Het concept is uitgebreid getest en gedemonstreerd in een relevante testomgeving. Het concept heeft goed inzicht gegeven in de werking van alle componenten tezamen.

Monitoring & Evaluatie

Relevance +

Coherence +

Effectiveness +

Sustainability +

Impact +

Efficiency +

Besluitvorming

Algemene besluitvorming informatie

Zijn er doelen aangepast? Waarom?	Tekst
In hoeverre zijn doelen niet gehaald?	Tekst
Hoe is er omgegaan met doelen die niet zijn gehaald?	Tekst
Wat waren de meest belangrijke beslissingen op cruciale momenten?	Tekst

Belangrijke lessen

- we hebben dit en dat geleerd
- en dit ook
- oh en niet te vergeten

Downloads

Rapporten

2015

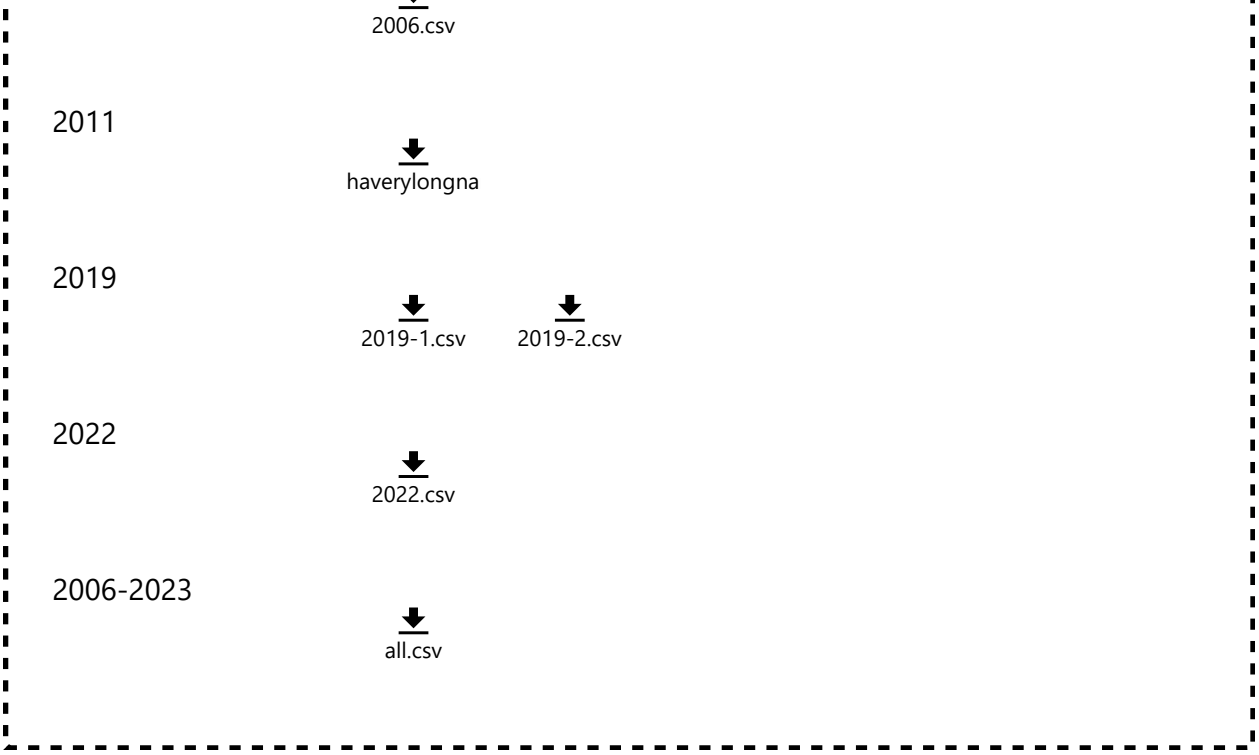
test1.pdf test2.pdf test3.pdf

2016

test4.pdf test5.pdf test6.pdf

Data

2006



Based on a free example by Vercel

Knowledge base v2

Voorbeeld pilot

Wat is er geïmplementeerd?

In de Beuningse Uiterwaarden hebben de gemeente Beuningen, ARK Natuurontwikkeling, Rijkswaterstaat en andere partijen tussen 2013 en 2018 een nieuwe klimaatbuffer aangelegd om overstroming als gevolg van hoogwater in de Waal tegen te gaan. Daarnaast wilden ze de natuur verbeteren, de biodiversiteit vergroten en het gebied aantrekkelijker maken voor bezoekers. Deze nieuwe klimaatbuffer was ook nodig omdat eerdere maatregelen in het gebied nog niet genoeg beschermden tegen hoogwater.

Hoe is de interventie geconstrueerd?

Om hoogwater tegen te gaan past ARK samen met Rijkswaterstaat sinds 2011 een nieuwe vorm van natuurbeheer toe op de Ewijkse plaat: cyclische verjonging. Dit betekent dat ARK hoge begroeiing aan de oever tegengaat en de natuur op deze manier om de zoveel tijd ‘verjongt’. Het doel hiervan is om natuurlijke erosie en de biodiversiteit te stimuleren. Daarnaast heeft Rijkswaterstaat geulen gegraven die ze hebben aangesloten op openingen in de oeverwal. Al deze maatregelen zorgen ervoor dat het rivierwater bij hoogwater sneller kan wegstromen. Maar toch zijn extra maatregelen voor een nieuwe klimaatbuffer nodig geweest.

Betrokken partijen

- ARK Natuurontwikkeling
- Gemeente Beuningen
- Rijkswaterstaat
- Waterschap Rivierenland
- Staatsbosbeheer
- de Dienst Landelijk Gebied & Bureau Stroming

Doelen

1. Hoogwater verlagen
2. Natuur verbeteren
3. Biodiversiteit vergroten
4. gebied aantrekkelijker maken voor bezoekers

Classificaties

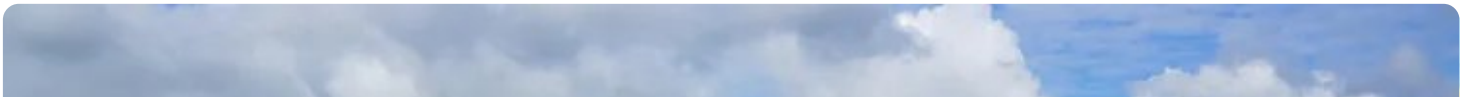
Regio: Gelderland

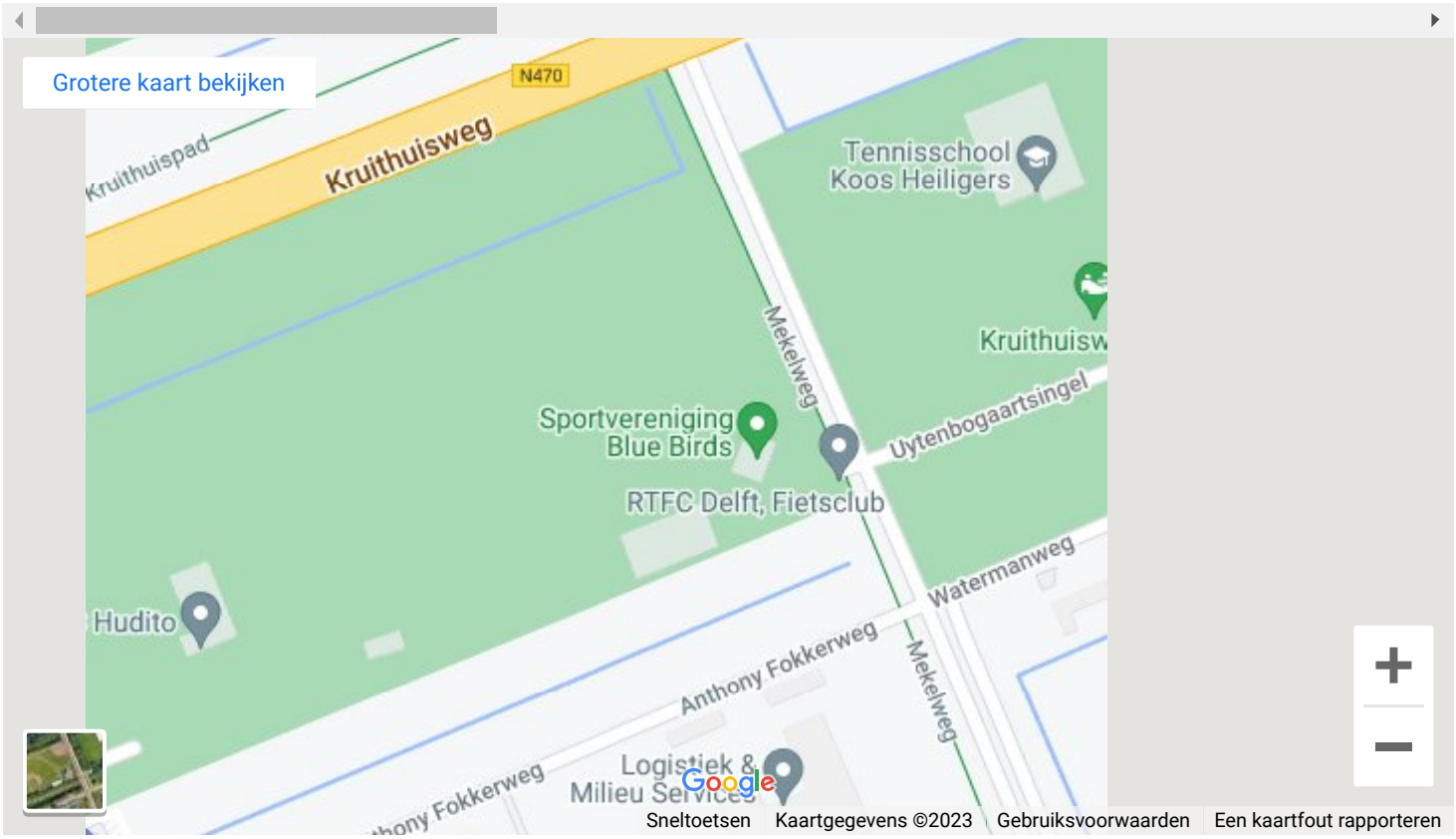
NBFD categorieën: Floodplain reconnection; Vegetation management

Ecosystemen: Bos; Zoetwater; Rivier

Pilot type: Research; Managerial; Political-entrepreneurial

Status: Afgerond





Algemene informatie

Algemene monitoring informatie

Was er een officieel monitoring programma?	Nee
Wie heeft gemonitord?	Radboud Universiteit

Algemene

Algemene monitoring informatie	
Is de biotische omgeving gemonitord?	Ja
Is er fysio-chemisch gemonitord?	Geen info
Is er morfologisch gemonitord?	Ja
Is er ecologisch gemonitord?	Ja
Is biodiversiteit gemonitord?	Geen info
Is het proces gemonitord?	Geen info
Op welke momenten en frequentie is er gemonitord en waarom?	Geen info
Hoe lang zal er na implementatie gemonitord worden?	Geen info
Met welke praktische methode is data vergaard?	Geen info
Hoe is de data verwerkt?	Geen info

TRL

Het concept is uitgebreid getest en gedemonstreerd in een relevante testomgeving. Het concept heeft goed inzicht gegeven in de werking van alle componenten tezamen.

SRL

Er is veel draagvlak en goede inpasbaarheid ten opzichte van lage kosten.

Monitoring & Evaluatie

Doelen en fit met context +

Overstroming en droogte +

Milieu +

Maatschappij +

Economie +

Toekomst +

Besluitvorming

Algemene besluitvorming informatie	
Zijn er doelen aangepast? Waarom?	Tekst
In hoeverre zijn doelen niet gehaald?	Tekst
Hoe is er omgegaan met doelen die niet zijn gehaald?	Tekst
Wat waren de meest belangrijke beslissingen op cruciale momenten?	Tekst
Hoe goed werkten de partijen samen en hoe was de communicatie?	Geen info

Belangrijke lessen

- we hebben dit en dat geleerd
- en dit ook
- oh en niet te vergeten

Downloads

Rapporten

2015

test1.pdf test2.pdf test3.pdf

2016

test4.pdf test5.pdf test6.pdf

Data

2006

2006.csv

2011

haverylongna

2019

2019-1.csv 2019-2.csv

2022

2022.csv

2006-2023

all.csv

Knowledge base v3

Pilot cyclische verjonging klimaatbuffer Beuningen

Waarom is de pilot uitgevoerd?

In de Beuningse Uiterwaarden hebben de gemeente Beuningen, ARK Natuurontwikkeling, Rijkswaterstaat en andere partijen tussen 2013 en 2018 een nieuwe klimaatbuffer aangelegd om overstroming als gevolg van hoogwater in de Waal tegen te gaan. Daarnaast wilden ze de natuur verbeteren, de biodiversiteit vergroten en het gebied aantrekkelijker maken voor bezoekers. Deze nieuwe klimaatbuffer was ook nodig omdat eerdere maatregelen in het gebied nog niet genoeg beschermden tegen hoogwater.

Wat is er geïmplementeerd?

Om hoogwater tegen te gaan past ARK samen met Rijkswaterstaat sinds 2011 een nieuwe vorm van natuurbeheer toe op de Ewijkse plaat: cyclische verjonging. Dit betekent dat ARK hoge begroeiing aan de oever tegengaat en de natuur op deze manier om de zoveel tijd ‘verjongt’. Het doel hiervan is om natuurlijke erosie en de biodiversiteit te stimuleren. Daarnaast heeft Rijkswaterstaat geulen gegraven die ze hebben aangesloten op openingen in de oeverwal. Al deze maatregelen zorgen ervoor dat het rivierwater bij hoogwater sneller kan wegstromen. Maar toch zijn extra maatregelen voor een nieuwe klimaatbuffer nodig geweest.

Hoe is de pilot gemaakt?

Pilot informatie

Regio	Gelderland
Schaal	Segment
Effecten	Waterstanddaling: 13-14 cm Natuur: x hectare
Neveneffecten	Klimaatadaptatie Recreatie
NBFD categorieën	Uiterwaardenbeheer Vegetatiebeheer
Ecosystemen	Bos Zoetwater

- Aanleg van het oostelijke deel van de hoogwatergeul, te beginnen direct westelijk van de toegangsweg naar de Bunswaard en zover mogelijk in westelijke richting. Begonnen wordt op het terrein van Staatsbosbeheer.
- Er wordt een kleischerm ingegraven in het deel van de nevengeul dat aan de rivierdijk grenst, om de bodemweerstand tegen kwel en piping zo groot mogelijk te maken.
- De hoogwatergeul wordt gevormd met een tweetal eilanden, die er toe leiden dat er zoveel mogelijk ecologisch waardevol ooibos ingepast kan worden.
- Aanpassing toegangsweg Bunswaard t.b.v. doorstroming. Twee duikers worden per geul onder de kade gebracht, vooral voor de verbinding van de wateren ter weerszijden van de weg.
- Herinrichting steile oevers grindplas. Om de kans op afslag te verminderen wordt grond uit het project gebruikt om onderwateroevers te verflauwen.

Betrokken partijen

- ARK Natuurontwikkeling
- Gemeente Beuningen
- Rijkswaterstaat
- Waterschap Rivierenland
- Staatsbosbeheer
- de Dienst Landelijk Gebied & Bureau Stroming

Doelen

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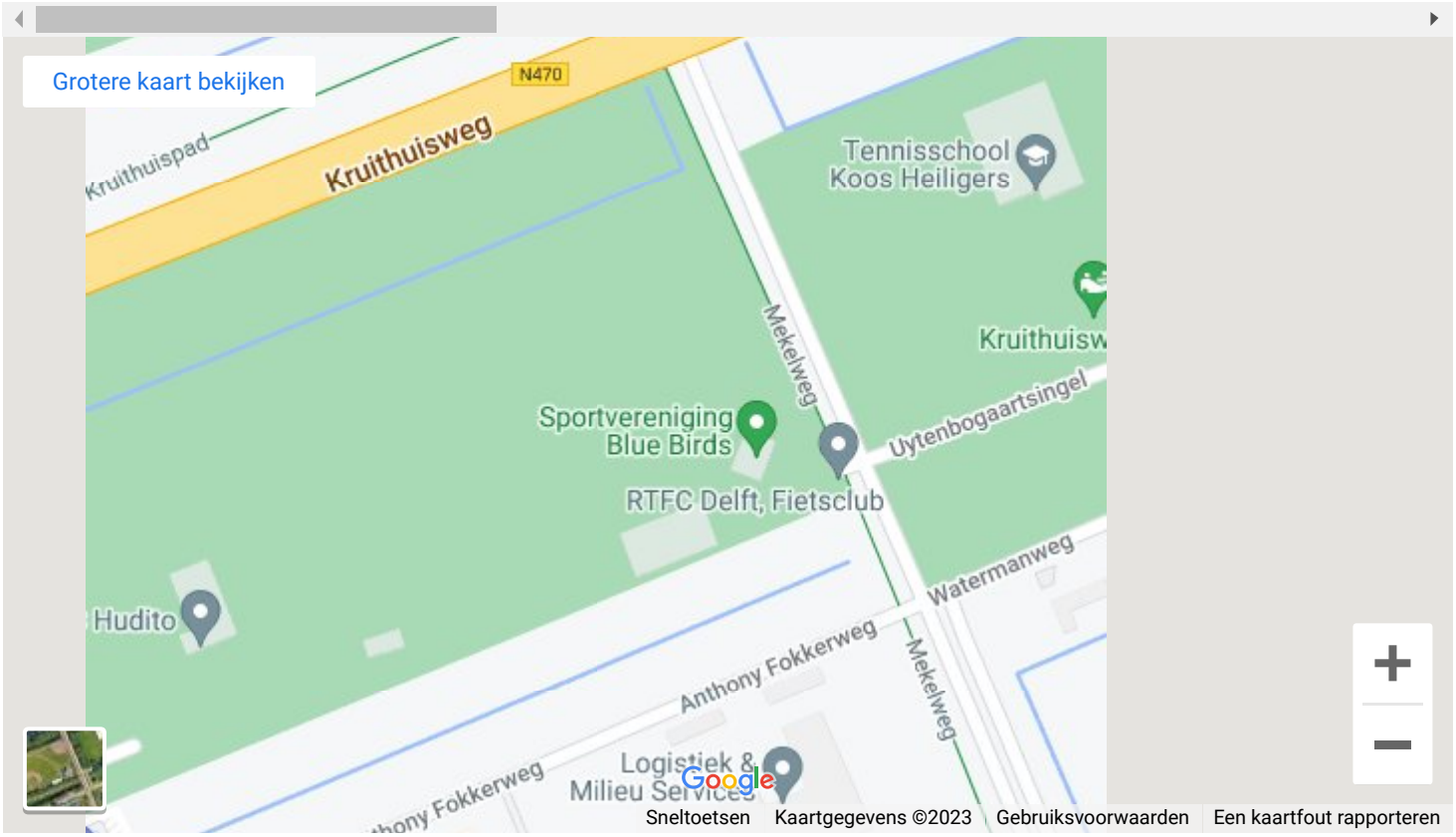
2. Natuur verbeteren
3. Biodiversiteit vergroten
4. Gebied aantrekkelijker maken voor bezoekers

Rivier

Pilot type	Bestuurlijk
Financiering	Provincie Gemeente
Status	Afgerond
Projectleider	Demo Achternaam
Contact	Demo Achternaam demo@beuningen.nl 06-3154 9485



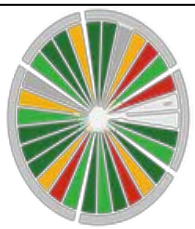
TRL

- TRL score
- Klaar om op te schalen?
- Advies voor de volgende fases
- In welke situaties kan deze technologie toegepast worden?

SRL

- SRL score
- Knelpunt(en)

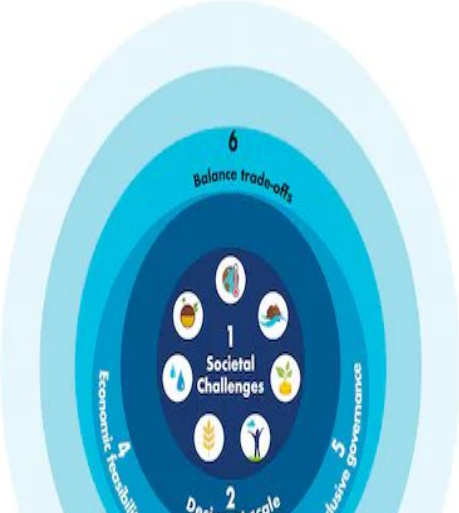
Mogelijke interventies



Algemene monitoring informatie

Was er een officieel monitoring programma?	Nee
Wie heeft gemonitord?	Radboud Universiteit
Is de biotische omgeving gemonitord?	Ja
Is er fysio-chemisch gemonitord?	Geen info
Is er morfologisch gemonitord?	Ja
Is er ecologisch gemonitord?	Ja
Is biodiversiteit gemonitord?	Geen info
Is het proces gemonitord?	Geen info
Is het management van de pilot gemonitord?	Geen info
Op welke momenten en frequentie is er gemonitord en waarom?	Geen info
Hoe lang zal er na implementatie gemonitord worden?	Geen info
Met welke praktische methode is data vergaard?	Geen info
Hoe is de data verwerkt?	Geen info

Monitoring & Evaluatie



Doelen en fit met context +

Overstroming en droogte +

Milieu +

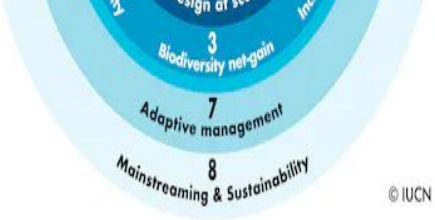
Maatschappij +

Economie +

Toekomst +

Trade-offs +

Adaptive management +



Besluitvorming

Algemene besluitvorming informatie

Zijn er doelen aangepast? Waarom?	Tekst
In hoeverre zijn doelen niet gehaald?	Tekst
Hoe is er omgegaan met doelen die niet zijn gehaald?	Tekst
Wat waren de meest belangrijke beslissingen op cruciale momenten?	Tekst
Hoe goed werkten de partijen samen en hoe was de communicatie?	Tekst

Belangrijke lessen

- we hebben dit en dat geleerd
- en dit ook
- oh en niet te vergeten

Rapporten & Gegevens

Rapporten

2015

test1.pdf test2.pdf test3.pdf

2016

test4.pdf test5.pdf test6.pdf

Monitoring gegevens

Bodemhoogte informatie in de uiterwaarden wordt ingewonnen via het programma Actueel Hoogtebestand Nederland (AHN). De bodemhoogtegegevens worden als vergridde gegevens opgeslagen in het Rijkswaterstaat Landelijk Opslagsysteem Lodingen (LOL) en zijn altijd opvraagbaar via de Servicedesk Data van Rijkswaterstaat. Ook kunt u voor gegevens over de vegetatie naar de Vegetatiemonioringstool uiterwaarden. Voor **overige speciale informatie** kunt u onderstaande gegevens downloaden.

Speciale gegevens

2006

2006.csv

2011

haverylongna

2019


2019-1.csv


2019-2.csv

2022


2022.csv

2006-2023


all.csv

Based on a free example by Vercel

J

Breadcrumb trail

Breadcrumb trail for sub-question 1: what is the current monitoring and evaluation process at Rijkswaterstaat for nature-based flood defense pilots in rivers and floodplains?

- It quickly became apparent that, in fact, there is no formalised monitoring & evaluation protocol specific for NBFD
- Vegetation management also ensures safe and unimpeded shipping which is another top-priority for RWS
- RWS has developed comprehensive regulations for the various methods of measurement needed for monitoring, called Rijkswaterstaat Standaard Voorschriften (RWSV's), that apply also to contractors and are suitable for monitoring outside of the MWTL programme
- Extra monitoring of NBFD pilots, outside of the operational/standard monitoring done by MWTL, predominantly looks at hydraulics, morphology, and ecology (i.e. vegetation, macrofauna, and fish). Theory however mentions that it is best to also look at social monitoring indicators, but that has not been found
- To really know the effects, on the smaller and larger animals or just the fish, you need more extensive monitoring. It was considered that NBS sometimes need more time to become fully functional, but still monitoring was constricted to one or two days
- RWS recommends paying close attention to TRL and SRL at the earlier stages of an innovation
- Evaluators were asked to evaluate and report the innovation development progress using the TRL scale
- Going through evaluation reports, it can be noted that evaluation and monitoring aim to answer predefined questions
- Interestingly, by and large evaluations of interventions do not consider the context in its entirety or neglect the social and political context

Breadcrumb trail for sub-question 2: what are important considerations for monitoring and evaluation of nature-based flood defense pilots in rivers and floodplains?

- A M&E framework uses (performance) indicators, baselines, targets alongside other measures for evaluation
- Evaluation tries to answer certain (research) questions that are formulated as evaluation questions. Based on these evaluation questions, evaluation criteria are determined
- An indicator is only used for evaluation of a corresponding criterion, monitoring indicators should not be used for planning only used for evaluation
- Documentation and reporting of the monitoring process, with effects on the system are crucial to learn from pilots
- When choosing monitoring indicators, it is advised to limit the initial number
- IUCN recommends to monitor NBS at the catchment scale to see effects on the physical habitat and other biological, economic, and social responses

- Expert opinions are useful when considering the nature of processes, diversity of desired ecosystems and species, and connectivity
- The SRL tool can assist in monitoring progress if it were to be used periodically
- The monitoring method of getting and transforming the data is important to report clearly
- Certain decisions have to be made before choosing an evaluation method: what is the intended use for the evaluation? Who are the users? What is the scale? What is the level of stakeholder engagement? Will the evaluation be comparative, about design options, or just the pilot? Will it be retrospective, a current state assessment or future looking?
- NBFD evaluation should look at ecological aspects and use a source-pathway-receptor-consequence conceptual model to evaluate the performance in terms of FRM, social aspects, and economical aspects
- Performance evaluation(s) should be done at a frequency relevant to the natural dynamics i.e. ecological functioning of the NBFD
- Incorporating the IUCN Global Standard [84] into the M&E framework could remedy this fact as it explicitly indicates whether the pilot could be considered an NBS
- *'If you only evaluate afterwards, you might lose insights about considerations around choices'*
- The timing of evaluations and its approach should be considered as NBS and NBFD take a longer time to evolve and show results
- Evaluation should be done over a longer time period when the scale of the pilot is larger
- 'what should be monitored and evaluated?': review all project components with special attention to risk reduction effectiveness, community impact, and environmental impacts. The evaluation should also include contextual influence, a judgement on the functional performance based on standards and objectives
- M&E of NBS should show what works, what does not work, and why some things do not
- NBFD evaluation should look at ecological aspects and use a source-pathway-receptor-consequence conceptual model to evaluate the performance in terms of FRM, social aspects, and economical aspects
- *'It is also important to look at the effect on the sectors like shipping'*
- *'At a project level the IUCN works well for evaluation'*
- It is important to include lessons learnt if other people are to benefit from past experience as well as dos and don'ts

Breadcrumb trail for sub-question 3: how to construct a knowledge base for effective knowledge sharing of nature-based flood defense pilots in rivers and floodplains?

- It has been found that the evidence base of nature restoration project is likely subject to reporting bias [133]: it is likely that failures are under-reported and successful results selectively shared
- This framework uses a FAIR approach to data dissemination (Findable, Accessible, Interoperable and Reusable) which would *"allow information to be easily communicated across regions, disciplines, and languages, [...], accelerate the uptake of valuable lessons learned, and work to build a stronger global restoration community"*
- It is important to collect experiences and lessons learnt and Ecoshape has developed a framework that helps structure lessons learnt for better dissemination
- Storing information on a knowledge base is a form of dissemination
- An analysis of all EU funded NBFD projects found that a platform or knowledge base should be developed (and of course kept up-to-date) for NBFD that stores information on *lessons learnt and their implementation costs (e.g., construction, monitoring, operation and maintenance and decommissioning costs*
- When a knowledge base is developed, it should be designed with a good balance between complete descriptions and generalised information for comparability and transferability
- Additionally, pilot locations can continue to be maintained and/or evolve. This way a 'simple' demarcation of time, corresponding activities, and effects is not easily done unless well specified in documents. Getting a clearer picture of the past is also made difficult by the fact that older documents are sometimes hard to find or go missing

- RWS already saves all relevant information of pilots. It is just not accessible to the public. Also, data is stored all over the place
- Interviewees gave high marks for appropriateness, of the knowledge base for storing NBFD pilot information specifically. This means that the answer to sub-question three at least partly passed the check