The value of waterharmonicas as landscape element

An assessment of the incorporation of landscape values of waterharmonicas within the decision-making processes and the policy landscape of the Netherlands

MSc thesis by Jildau van Dam

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The influence of landscape values of waterharmonicas:
An assessment of the incorporation of landscape values of waterharmonicas within the decision-making processes and the policy landscape of the Netherlands

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Abstract

The waterharmonica forms a link between the waste water treatment plant and the surface water. It can provide additional treatment and add more ecological value to effluent so it has less harmful effects on the downstream surface areas (Schomaker et al., 2005). Waterharmonicas can also have different roles in the landscape. They can have a social value due to recreation and education possibilities but they can also have ecological value by providing water treatment and increasing biodiversity (van den Boomen & Kampf, 2013). These landscape values can play a role in the decision-making process of a waterharmonica. This research looks into the role these landscape values play, which landscape values are most important and how the political landscape on global, EU, national and organisational level influence the perspectives on an individual level and with that the decision-making processes. The interactions between these levels and the corresponding policies, visions and perspectives on landscape values can influence the decision-making processes and the design of a waterharmonica.

To understand these interactions and the role of landscape values, different case studies were used. In Ede, a quickscan is done by Vitens and Waterboard Vallei and Veluwe to explore options for improving the effluent quality and making it suitable for drinking water. This case study was observed to establish which landscape values are important and how these are considered in the decision-making process. In addition to the Ede case, 3 other waterharmonica cases of waterboards de Dommel, Brabantse Delta, and Aa en Maas were researched to establish the importance of landscape values in the design and operating phases of waterharmonicas.

With reviewed policy documents, interviews and observations of meetings, an overview was made of the different landscape values as perceived by the actors and how these interact in the policy landscape. In the Ede case, water treatment was seen as the most important aspect. The aspects of ecological value, possibilities for landscape integration and societal value due to recreational and educational options were also mentioned as an added aspect while water treatment was the main goal. In the other 3 case studies, the main goal of the waterharmonica was to improve the ecological value of the effluent. In these cases, recreational and educational values were also included. Water treatment was seen as more of an added benefit and not the main goal.

This research shows that a waterharmonica can provide various landscape values and functions. The specific landscape values depend on the purpose with which the waterharmonica is constructed. In the case of Ede, water treatment is seen as most important while other landscape values like recreation, ecosystem values and possibilities for landscape integration are seen as nice added benefits that should not harm the main function of the treatment system. For the other researched waterharmonicas these aspects were more important and water treatment was less emphasised. In general, the waterharmonica can help achieve various goals on different levels, but the specific values depend on the aim with which the waterharmonica is constructed

Key words: waterharmonica, helophyte filter, landscape values, policy landscape, Ede

Preface

Before you lies the thesis report “The value of waterharmonicas as landscape element”. This thesis is based on interviews, observations and policy documents of several organisations and institutional levels among which Waterboard Vallei and Veluwe and drinking water company Vitens. It has been written to fulfil the graduation requirements of the masters International Land and Water Management at Wageningen University and Research. I was engaged in researching and writing this thesis from September 2021 till May 2022.

The research topic and research questions were formulated together with my WUR supervisor Saskia van de Kooij and the research topic was introduced by Coert Petri from waterboard Vallei and Veluwe. I would like to thank Coert for his help during this thesis process as he gave me insight into various different aspects of the topic. Furthermore, Coert gave me access to different meetings and actors which allowed me to write this thesis report. Lastly, his feedback and insights helped me in formulating my research topic and also in finalizing this thesis report.

I would also like to thank my supervisor Saskia for her excellent guidance and support during this process. During various struggles I encountered in this thesis process, her support and advice helped me in finding new pathways and maintaining motivation to finish this research. Furthermore, I also wish to thank all of the interviewees without whose cooperation I would not have been able to conduct this research.

Lastly, I couldn’t have completed this thesis research without the help and support of my friends and family that were always willing to help, keep me motivated and when needed provide distractions. If I ever lost interest or had difficulties continuing you were always there for a coffee break and some helpful tips.

I hope you enjoy your reading.

Jildau van Dam

Wageningen, May 22, 2022

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List of Abbreviations

Abbreviation	Meaning
BOP	Blauw Omgevings Programma
BOVI	Blauwe Omgevings Visie
GHG	Greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
MCA	Multi-criteria analysis
NbS	Nature-based Solutions
NF	Nanofiltration
NOVI	Nationale Omgevings Visie
pers. com.	Personal communication
PFAS	Poly- en perfluoroalkylstof
RO	Reverse Osmosis
SDGs	Sustainable Development Goals
STOWA	Stichting Toegepast Onderzoek Waterbeheer; research centre watermanagement
UNFCCC	United Nations Framework Convention on Climate Change
UWWTD	Urban Waste Water Treatment Directive
WB	Consultancy firm Witteveen+Bos
WFD	Water Framework Directive
WsAM	Waterschap Aa en Maas
WsBD	Waterschap Brabantse Delta
WsDD	Waterschap de Dommel
WsVV	Waterschap Vallei en Veluwe
WWTP	Waste Water Treatment Plant

1. Introduction

1.1 General introduction

With precipitation shortfall, rising temperatures, and changing seasons, the effects of climate change are becoming visible in the Netherlands (Philip et al., 2020). To tackle the effects of climate change, more attention is given to possible adaptation and mitigation measures. Hereby not only their potential and costs are considered, but also possible co-benefits like providing ecosystem services (de Bruin et al., 2009). Nature-based solutions (NbS)are increasingly mentioned as climate adaptation and mitigation measures. Nature can be used to tackle environmental, social, and economical challenges (Nesshöver et al., 2017). NbS often have fewer costs, are resource-efficient, and provide many other co-benefits, especially for the environment. Therefore, the EU intends to invest substantially in nature-based solutions (Maes & Jacobs, 2017). Especially for climate adaptation and mitigation measures like flood and drought management they are often promoted (Ruangpan et al., 2020).

In the Netherlands, Nature-based solutions also play a role in the innovation process (Philip et al., 2020). One of the recent developments is seen in the wastewater treatment sector. Currently, the wastewater is treated in Wastewater Treatment Plants (WWTP) and then discharged onto the surface water. This is often not yet without environmental consequences (Schomaker et al., 2005). As the effluent from the WWTP has different biological and chemical qualities than the surface water, it can disturb the ecosystem (Schomaker et al., 2005). Effluent lacks a natural daily oxygen rhythm and can therefore be seen as “dead water”. This water is hostile to various organisms and can have harmful effects on the surface water (Martijn et al., 2003). An additional treatment system can be used to improve the ecological quality of the effluent. The Nature-based solution of “De waterharmonica” uses sustainable, low energy consuming, and cost-effective techniques that can improve the water quality. It is a system placed between the WWTP and the surface water of the ecosystem that captures and treats the effluent so it can safely be discharged into the environment (Schomaker et al., 2005).

Since 1985, various waterharmonicas have been placed around the Netherlands to improve the quality of the effluent (van den Boomen & Kampf, 2013). Waterharmonicas consist of a combination of different ponds and a free surface helophyte filter. The effluent slowly flows through the wetlands, allowing different biological, physical and chemical processes to take place. The wetland consists of a sand or gravel layer with a combination of floating, submerged and emergent water plants (Bassan et al., n.d.). The constructed wetlands will provide additional cleaning to the WWTP, for example by removing nutrients like Nitrogen and Phosphorus from the effluent (Kampf et al., 2003). Waterharmonicas have proven to reduce the risks of toxic effects caused by the “dead water” from the WWTP and effectively remove disease-causing micro-organisms (Foekema et al., 2012). In the municipality of Ede, the use of waterharmonicas might be taken to a new level. Here research is done to see if a constructed wetland in combination with other additional treatments can increase the quality of the effluent so it can be used as groundwater recharge and indirectly as source of drinking water (C. Petri, pers. com., August 2021).

Aside from the effects on water quality, the waterharmonicas can have social, environmental, and economical value. Some systems are used to grow fish or are open for recreational purposes (Kampf et al., 2003). Also, research has shown that the waterharmonica has a positive effect on biodiversity in the area. In waterharmonica De Groote Beerze of waterboard De Dommel, various birds like the kingfisher were spotted (Schomaker et al., 2005). This system not only provides opportunities for nature development but can also serve as a water buffer and with that reduce drought and flooding problems (Schomaker et al., 2005).

The specific functions of a waterharmonica as a landscape element depend on the choices, needs, and expectations of the actors involved in the design (Baylan & -Karadeniz, 2003). Some actors might value climate adaptation purposes while others give more value to economic or social aspects. All these values and considerations make it a complex system of social interactions (Camargo-Borges & Rasera, 2013). To understand the decisions made and with that the eventual design of the waterharmonica, it is important to take the values of the different actors into account. What values do the actors deem most important, what is the support for waterharmonicas based on, and how does this influence the decision-making process to construct a waterharmonica?

The process of constructing a waterharmonica is not only influenced by individual actors and their perceptions and values. Processes within the organisations, countries, the EU and even globally can influence the decision-making processes (van der Brugge et al., 2005). Due to the changing climate and the corresponding adaptation and mitigation measures, nature-based solutions are becoming more popular (Ruangpan et al., 2020). This can influence the decision between a waterharmonica or a more efficient but also less sustainable engineered system. In the previously mentioned case of a waterharmonica in Ede, this consideration is made by exploring the options for a water factory that can either consist of a technical Nanofiltration system with a helophyte filter behind it or a fully technical Reverse Osmosis system (M. van der Kamp et al., 2021). This decision is not only influenced by the personal preferences of the actors, but also by global and national changes and policies on sustainability, circularity and biodiversity. A waterharmonica could add these additional (landscape) values but to what extent does this influence the final decision?

1.2 Research question and objectives

The main goal of this research is to analyse the interactions between actors and organisations on different levels, their values, and the design and functions of waterharmonicas to establish how different landscape values influence the eventual decision-making process of the waterharmonica. This goal led to the formulation of the following main research question:

> *How is the decision-making process of waterharmonicas in the Netherlands influenced by landscape values as perceived by the different actors and organisations?*

To reach the main goal of this research and to answer the main research question, the following objectives have been established:

1. Assess the policy landscape at global, EU, national and organisational level to establish which (landscape) values are important, for whom and how these influence each other;
2. Create an overview of the important landscape values as perceived by the different involved actors and organisations;
3. Assess how the different landscape values are expressed in the decision-making process of the waterharmonicas to understand how they influence the eventual outcome.

Firstly, the policy landscape on different levels is assessed based on the different (landscape) values included. Global, European and national changes can affect the changes on individual and organisational level and vice versa. Understanding these interactions helps in understanding the decision-making processes and how the individual and organisational values and policies are formed.

Secondly, the landscape values of waterharmonicas as perceived by the actors are assessed. These values influence the design and utilization of the landscape. Understanding the different values provides a better understanding of different perspectives of both actors and organisations and is needed to formulate optimal management and design strategies for the protection of waterharmonicas as landscapes (Baylan & -Karadeniz, 2003).

Thirdly, the waterharmonicas are assessed based on how the established landscape values are expressed in the design of the areas. For this, meetings are observed to establish often mentioned landscape values and the corresponding considerations. Furthermore, the design is assessed based on how the landscape values are expressed. This helps understand the decision-making process and how the different landscape values influence the eventual outcome of the project.

1.3 Background waterharmonica

The concept of a waterharmonica has a Dutch origin and was created in 1996 by Theo Claassen. It was created as a link between the water chain and the water system. A combination of ponds and free water surface wetlands is placed between the wastewater treatment plant and the surface water as shown in Figure 1. Together with Ruud Kampf, Claassen developed the concept and since 1996 multiple waterharmonicas have been constructed in the Netherlands (van den Boomen & Kampf, 2013). In total, 15 waterharmonicas were constructed in 2016 and plans were made for 5 more (Kampf & Water, 2016).

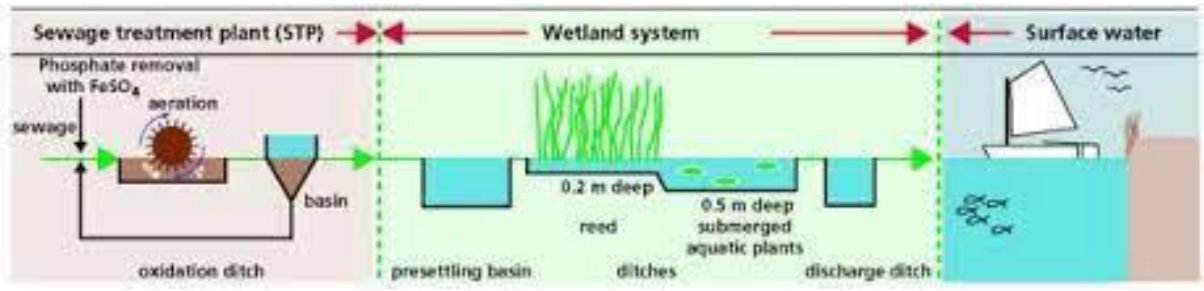

Figure 1: A schematic overview of set-up waterharmonica between the WWTP and the surface water (van den Boomen & Kampf, 2013)

The waterharmonica system as used in the Netherlands originally consists of a pre settling basin, a flee pond, a free water surface helophyte filter, a pond with submerged aquatic water plants and a fish pond. However, this concept changed over time as the waterharmonicas were constructed and designed for different goals. Some were created mainly for the buffering of water like in Tilburg-Noord, while others e.g. in Ootmarsum were made for “ecologising” the water. Some waterharmonicas are constructed for a combination of multiple functions, for example, buffering the water, nature development, recreation and improving the water quality (van den Boomen & Kampf, 2013).

Due to the different functions, the design of waterharmonicas can also differ. The concept of different ponds and a helophyte filter remains the same but not all systems have the same type of ponds and the size of the total system can differ. Some systems don’t have a flea pond or a fishpond for example while others do (van den Boomen & Kampf, 2013). This is also related to the available space for the construction of the waterharmonica and whether it will treat all effluent or only part of it. For example, the waterharmonicas of Aqualân Grou and Land van Cuijk only treat about 25% of the effluent from the WWTP (van den Boomen & Kampf, 2013). Figure 1 shows an example of a waterharmonica set-up in Elburg with first the WWTP, then the waterharmonica (settling pond, helophyte filter, submerged water plants) and then the surface water (van den Boomen & Kampf, 2013).

As the natural treatment system can consist of different ponds and filters, not all systems are the same nor are they constructed for the same reason. This research defines a waterharmonica as the natural link between the water system which consists of a helophyte filter, possibly but not necessarily, in combination with ponds and other natural treatment systems.

Waterharmonica as treatment system

The use of wetlands and other natural systems as a treatment system is not unique to the Netherlands and is internationally an often used method (Kadlec & Wallace, 2009). There are many different variants of a natural treatment system using plants and bacteria to treat the water. All of these systems have slightly different setups and different names. There are constructed wetlands, treatment wetlands, retention soil filters, vital urban filters and many other types of helophyte filters and man-made wetland systems (Interview expert constructed wetlands WUR). Within the wetlands with treatment capacity, 3 types of wetlands can be distinguished: free water surface, horizontal subsurface flow, and vertical flow. Free water surface flow wetlands closely mimic natural wetlands as it is a swamp-like system that can attract a wide variety of flora and fauna. This system is often used for advanced treatment of effluent from secondary or tertiary treatment processes (Kadlec & Wallace, 2009).

According to an interviewed wetland expert, a waterharmonica might not be the best system for removing micro-pollutants as it uses an open water system. A vertical helophyte filter has proven to remove more micro-pollutants than an open horizontal filter (Interview expert constructed wetlands WUR). Furthermore, the fish and flee ponds used in a waterharmonica do not necessarily provide a treatment function. When specifically looking at the chemical quality of the water, these parts of the waterharmonica do not add additional treatment but they do increase the area needed for the waterharmonica. Therefore, it might be better for the water treatment to leave these out and instead use a larger helophyte filter (Interview water technologist Tauw).

When looking at the biological quality of the water, the different components of a waterharmonica do have a beneficial impact. The different ponds and the open helophyte filter have more potential for the ecosystem as it adds biodiversity and can create a buffer between the effluent and the downstream waterbodies (Interview water technologist Tauw). A vertical filter is more closed off and of less interest for flora and fauna and therefore has less ecological value. A combination of a vertical and horizontal filter can provide both treatment and landscape values. This is however not yet included in waterharmonicas in the Netherlands (Interview expert constructed wetlands WUR).

When constructing a helophytefilter, you can not only use different types of filters but also different aeration techniques. With aeration, the removal of organic micro-pollutants will increase as more aerobic treatment can take place. This increases the treatment efficiency in all seasons, so it can compensate for the loss in winter (Ouellet-Plamondon et al., 2006). It will however also require a different type of maintenance. The plant and soil types can also make a difference in the treatment efficiency of the filter. "Y*ou must have a material that is not too fine so that it does not clog the system. Coarse sand or gravel or clay granules work for this. And for plants, it is important that they can stand with their roots in the water. But ordinary reed is perfectly suitable for this."* (Interview expert constructed wetlands WUR).

For optimal functioning of a waterharmonica as a wastewater treatment system, the removal rates of nutrients need to be sufficient. Phosphate binds to the soil, and after 15-20 years the soil can get saturated causing the phosphate removal to decrease. To restore the binding capacity, the soil needs to be renewed (Interview expert constructed wetlands WUR). The plants in the helophyte filter also take up part of the nutrients. For these nutrients to be fully removed from the systems, the plants also need to be removed and mowed often. This requires regular maintenance of the waterharmonica system (Interview wetland restoration ecology expert WUR).

2. Theoretical background

This thesis uses multiple concepts to establish which landscape values are important for which actors, how this is influenced by the policy landscape and how these interactions influence the decision-making process of waterharmonicas. The landscape value assessment framework is used to establish which aesthetic, perceptual, and experiential qualities of a waterharmonica are valued by the interviewees. The transition theory framework is used to assess how these landscape values are expressed and influenced by changes, visions and policies on global, national, organisational and individual level. Lastly, the landscape values on individual level and in the policy landscape are combined to establish how this influences the decision-making process of a waterharmonica.

2.1 Landscape value assessment

Landscape

In the European Landscape Convention, a landscape is defined as "an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors" (Landscape Institute, n.d.). So a landscape is a complex concept with different meanings and interpretations. Often a distinction is made between the 'place' and 'space' of a landscape (Stephenson, 2010). As a space, landscapes are seen as a physical and geographically described phenomenon while as a place landscapes are an expression of personal attachments and meanings. This leads to both tangible and intangible values of landscapes for example by valuing both the physical scenery and the sense of spirituality of a landscape (Stephenson, 2010). Waterharmonicas can be valued both as a space with its functioning as a treatment system and as a place by valuing its aesthetics and its spiritual and cultural function as a landscape. These values are interlinked and lead to different functions and services as provided by the waterharmonicas.

To evaluate landscapes, all functions and services must be considered with all corresponding material and immaterial aspects (Baylan & -Karadeniz, 2003). Landscape functions can be categorized into the following 3 categories: 1. Production functions: provision of natural products like nutrition, energy, and raw materials; 2. Regulating and maintenance functions: benefits provided by the ecosystem processes like water purification, life-support systems, and habitat protection; 3. Cultural functions: benefits provided via physical, intellectual, spiritual, symbolic, and other interactions with the ecosystem (Baylan & -Karadeniz, 2003). Waterharmonicas also provide a range of these different functions, for example, they clean water, increase biodiversity, and provide a place for recreation and interaction with the environment (van den Boomen & Kampf, 2013). It depends per person and organisation which of the different functions they value most. Some might value more the production functions of the waterharmonica while others value more cultural functions. These values can also change over time with different interests, knowledge, and perspectives (Klein & Kleinman, 2016).

Landscape value assessment

A quality or value of a landscape is anything that is considered a valuable or important aspect by an actor (Stephenson, 2010). The subjective understanding of a specific landscape depends on how they engage or experience that landscape. These values are linked to the activities undertaken in the landscape, the physicality of the landscape, and the associations established with and within the landscape (Butler, 2016b). This makes that everyone's perception of a landscape depends on multiple factors, including: religion, social structure, policy landscape, age, experience, gender, profession, and their relation to the landscape (Butler, 2016b). Waterharmonicas can be seen both as wastewater treatment systems and as nature areas. The viewers' perspective and background influence which values they deem most important.

As explained before, landscape functions can be categorized into 3 services: production, regulation and maintenance, and culture. With these services come different landscape values based on tangible and intangible aspects (Baylan & -Karadeniz, 2003). To fully understand the landscape value of waterharmonicas we must understand how these values relate to one another and how this differs per actor. For this, the Landscape Character Assessment framework will be used. This approach consists of two parts, characterization and judgment making (Stephenson, 2010). The characterization phase gives an objective overview of the different functions while in the judgment phase the actors give their subjective view on the landscape and establish which functions they value (Butler, 2016). This research focuses on the judgment phase in which the aesthetic, perceptual, and experiential qualities of the landscape are valued by the different actors (Stephenson, 2010) The characterization phase is not researched for this thesis but different functions of the waterharmonica are explained in literature and can be used as a cross-reference for the landscape values mentioned by the interviewees (Fleskens et al., 2016; Kampf & Water, 2016; Martijn et al., 2003; Schomaker et al., 2005).

2.2 Interactions actors and policies

Actor overview

An actor overview can be made to understand the interests, intentions, and influence the actors have on the decision-making and implementation processes (Varvasovszky & Brugha, 2000). When actors have different perspectives, interests or valuations of the functions of the waterharmonica, this can affect the design and success of a project. Therefore it is essential to understand the different perspectives of the actors and organisations involved (Grimble et al., 1995; Reed et al., 2009).

Grimble et al. (1995, p.3) defines stakeholders as “all those who affect, and/or are affected by, the policies, decisions, and actions of the system”. So this includes all actors that are involved in the decision-making processes or the current maintenance and operation of the waterharmonica. But it also includes everyone that makes use of the waterharmonica for recreation or any other purpose. Lastly, it includes those who are affected by the waterharmonica for example the previous owners of the land on which the waterharmonica is constructed and other local residents.

For the Quickscan in Ede, currently, only Vitens, Waterboard Vallei and Veluwe and Witteveen+Bos are involved as it was only in the starting phase and no decisions are made yet that will include other actors and organisations. Therefore they will be the main actors interviewed in this research as will be further explained in Chapter 4.2.2.

Transition theory

The decision-making process of a waterharmonica is not only influenced by individual actors but also by the policy landscape on multiple levels and their interactions (Geels & Kemp, 2000). To assess the interactions between the visions and values of individual actors and organisations and national, international and global policies and approaches, the transition theory will be used. A transition is a process in which a structural change occurs in the way a societal system operates. It is often a long-term process caused by different developments and events on different scale levels and domains (Geels & Kemp, 2000). According to the transition theory, there are 4 stages of transition as shown in Figure 2. It starts with a pre-development phase where there is not yet a visible change. When the thresholds are reached, the state of the system begins to shift and this accelerates in phase 3. Eventually, the speed of the change decreases and a new equilibrium is reached in the stabilization phase. This multi-stage transition occurs at multiple levels of the society as shown in Figure 3 (van der Brugge et al., 2005).

According to van der Brugge et al. (2005), the macro-level responds to relatively slow trends and developments influenced by changes in the macroeconomy, politics, natural environment and population dynamics. The meso-level is more influenced by changes in institutions, rules and norms. At micro-level, individual actors, social practices and technologies are distinguished (van der Brugge et al., 2005). Within these different levels, there are many interactions. For example, the strategies and expectations of individual actors are influenced by the rules and norms on the meso-level and by the developments globally and within the nation. However, changes made at micro-level can also lead to transformations of the existing regimes on meso level or can even create new ones. Eventually, this can lead to changes on macro-level (Geels & Kemp, 2000). According to Rotmans et al. (2001), changes start at the micro-level with deviations and variations to the status quo, for example, the use of new or alternative techniques and social practices. In the early phases of a transformation, the regime or organisation acts as inhibiting factor while in a later stage it can have an enabling role by providing capital and organizational power (Rotmans et al., 2001). Individuals can be the stepping stone for changes on meso and macro-level, but changes at global, national and company level can lead to changes at the micro-level as well. Changes in all 3 levels are necessary for a transition to occur (Geels & Kemp, 2000).

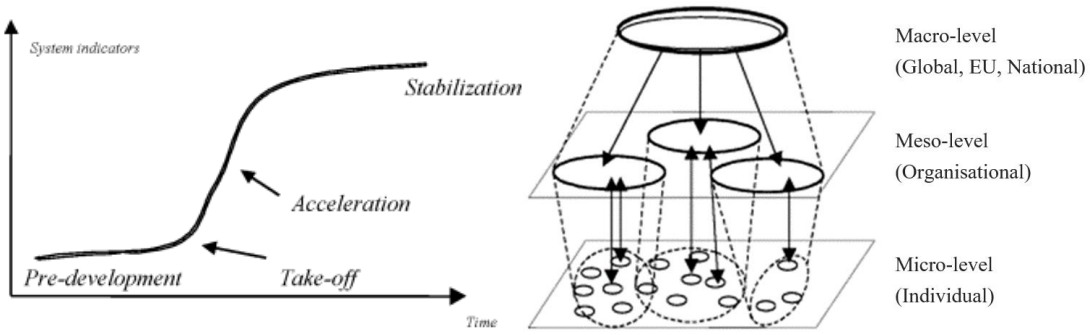

Figure 2 (Left): Multi-stage concept with 4 phases of the transition theory (Geels & Kemp, 2000);
Figure 3 (right): Multi-level concept of the transition theory (Adapted from Geels & Kemp, 2000)

In this research, the micro-level consists of the individual actors within the included stakeholder groups. The meso-level consists of the stakeholder organisations, as explained in the stakeholder analysis this will be Vitens and WsVV. Changes in the macro-level are caused by global changes like climate change, changes in Europe like the new guidelines for water quality (WFD) and changes at national level like the 'Nieuwe omgevings visie' (NOVI). An overview of these levels and interactions within this research is given in Figure 4. Figure 4 also shows how the different landscape values on the different levels and by different actors eventually influence the decision-making process of a waterharmonica but also that a waterharmonica can influence these values and policies.

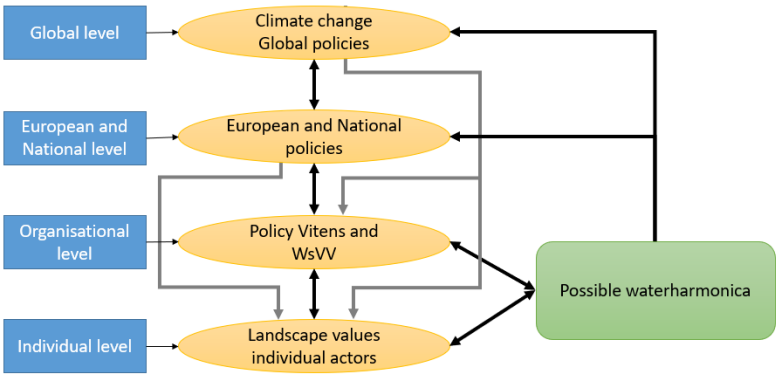

Figure 4: Overview of interactions between different levels and landscape values

3. Methods

This research makes use of multiple case studies to determine the landscape values of different actors and to establish how these values are expressed in the design of a waterharmonica. The Quickscan in Ede is used as the main case to analyse the decision-making processes. In addition, other case studies are reviewed to establish how landscape values are included in the design, operating and decision-making processes. These cases are used as supporting and comparative data for the Ede case.

3.1 Interviews and observations

The interviews were semi-structured as this helps guide the interview and ensures certain topics are discussed in all interviews but it also allows the interviewee to share their stories and insights (Rabionet, 2011). Annex I gives an overview of the included interviewees and in Annex II an interview guide is shown with some main questions that were asked and some possible probing questions for the interviews in the Ede case. Annex III shows the interview guide for the additional case studies. The interviews were recorded as this makes it easier to focus on the interview instead of making notes and it improves the quality of the analysis (Rabionet, 2011). To compare the results of the interviews, an interpretative analysis method is used. This indicates that the combination of language and non-verbal communication is interpreted and analysed during the project (Yanow & Kubik, 2014). The interpretative analysis methodology also allows for the researcher to continue learning throughout the research project, therefore openness and flexibility in the interview questions are needed. This was achieved in this project with the use of a semi-structured interview approach (Yanow & Kubik, 2014).

The interviews were transcribed with Amberscript. The transcribed interviews were coded with Atlas.ti. In the coding process, the interviews were scanned for the mentioning of different landscape values of a waterharmonica. This data was analysed combined with the non-verbal communication during the interview to establish the interviewees' vision of the different landscape characteristics. This also gave insight into the correlation between different actors and their perspectives (Kuroda et al., 2011).

For the case study of the Quickscan in Ede, observations were used in addition to the interviews. There were various meetings between Vitens, Waterboard Vallei en Veluwe and consultancy firm Witteveen+Bos in which the design of a possible system and the corresponding considerations were discussed. With help of a selective observation method, 4 meetings were observed. For every meeting, I made an overview of the participants, the setting of the meeting and the content discussed. During the meeting, I kept track of which landscape values are often mentioned, by whom, and in which context. With this, an assessment was made on how the different landscape values are included in the design and decisions made concerning the 4 different options. With the observations, the focus was mainly on the variants with NF and helophyte filter.

In addition to the interviews and observations, literature was used to establish how the landscape values are included in the policies and with that in the design and decision-making processes around waterharmonicas. For this, the following type of literature was used: A) Policy documents on global, European and National levels on policies, visions and climate adaptation and mitigation including documents on the COP, WFD and NOVI; B) Policy and vision documents of WsVV and Vitens; C) the Final report of the quickscan in Ede

3.2 Case studies

This research focuses mainly on the case in Ede in which Vitens and Waterboard Vallei and Veluwe considered the use of a helophyte filter among other systems to make the effluent from the WWTP in Ede suitable for groundwater recharge. For this, a quickscan was done by Witteveen+Bos to research the possibilities for water treatment and infiltration of the effluent from the WWTP in Ede (Witteveen & Bos, 2021). The specifics of the case and the quickscan are explained in Chapter 4.2.

With the results of the quickscan, Vitens and WsVV will decide whether to continue with this project and if so, which option they will use. To establish which values are important in the design and decision-making processes I observed various meetings and interviewed the involved actors. Herby the variant with Nanofiltration and helophyte filter was the main focus. With observations and interviews (see Chapter 3.1), an assessment was made on what landscape characteristics are valued by the different actors and how these values influence the eventual outcome of the process and when used in the design of the waterharmonica. In Annex II the used interview guide is shown.

Case studies of other waterharmonicas and expert interviews

In addition to the case in Ede, 3 other cases were studied as supporting information to the data gathered in the Ede case. These cases help place the Ede case into the broader picture of waterharmonicas in the Netherlands by establishing the important elements and values of other projects. It also shows how the values are currently expressed in the waterharmonicas.

3 different case studies were used for supporting data. These were chosen based on recommendations from interviewees or were mentioned in meetings. Multiple actors from Waterboard Brabantse Delta (WsBD) were interviewed about the waterharmonica in Nieuw-Vossemeer that is used since 2020. This case study gives insight into the starting phase and design of a waterharmonica and how landscape values are included in this process. In addition to Nieuw-Vossemeer, a representative from Waterboard Aa en Maas (WsAM) was interviewed about a possible waterharmonica near Helmond and Aarle-Rixtel. In this case, the waterboard is looking at the options for a waterharmonica so the interview gave insights into the landscape values within the decision-making phase. Lastly, a representative from Waterboard de Dommel (WsDD) was interviewed. This waterboard is currently responsible for 5 waterharmonicas, among which the waterpark Groote Beerze which many interviewees referred to. This interview gave insight into the role of landscape values within the operating phase of waterharmonicas.

In addition to the interviewees from the Quickscan in Ede and the other waterharmonicas projects, some additional knowledge and insights were gathered by observing meetings from other projects related to (natural) Waste Water treatment and by speaking to other experts. The used observation method is explained in Chapter 3.1. These meetings included 2 meetings of AquaConnect, a meeting of WsVV for a possible mini Nereda (treatment system) with waterharmonica in Putten and an explorative meeting at a ‘pasveersloot’ in Otterlo to explore opportunities to use the WWTP as waterharmonica. Furthermore, some experts on wetland systems and specifically waterharmonicas were interviewed to gain a broader understanding of the perspectives on waterharmonicas.

3.3 Actor overview

An overview of the different actors involved was created based on literature and communication with other actors. During the interviews and meetings, certain actors and organisations were mentioned that were either currently involved or will at some point be included in the process. An overview of all actors involved is shown in Figure 6 (Chapter 4.1.2). Annex I shows an overview of the interviewees, they were chosen based on their involvement in the quickscan. For finding the interviewees a snowball method was used in which other actors were asked to recommend new interviewees.

4. Results

The decision-making process of constructing a waterharmonica is influenced by many different factors. Changes on global, EU, national and individual level can have consequences for the legislations and motivations around such a system but also which landscape aspects are valued more and therefore how a possible waterharmonica is designed. This chapter first explains the changes on different levels within the policy landscape, after which the individual views on landscape values and waterharmonicas are explained and lastly these findings are verified with related waterharmonica projects and expert interviews. In Annex I an overview is given of the actors interviewed for this research.

4.1 Policy Landscape

As explained in Chapter 2, the policy landscape is formed by the interactions between multiple levels. Global changes can influence the policies on EU and national level which can lead to changes in projects and visions of organisations and individuals. But individual and organisational changes can also have an impact on national or even global level. This sub-chapter gives an overview of the changes on different levels, how these interact and what consequences these have on the construction of waterharmonicas.

Global changes

According to the Intergovernmental Panel on Climate Change (IPCC), global temperatures are rising at an unprecedented rate (IPCC, 2021). Human influence is likely the main driver for these temperature increases. IPCC estimates that human influence has likely led to an increase of 1.07 °C in global surface temperature (IPCC, 2019). Human-induced climate change is not only affecting the surface temperatures but also many weather and climate extremes like heat waves, heavy precipitation, droughts and tropical cyclones (IPCC, 2021).

Climate change exacerbates land degradation and desertification and with that impacts livelihoods, biodiversity and global food security (IPCC, 2019). To combat these difficulties, globally more focus is put on possible climate adaptation and mitigation options. This has led to an increased interest in possibilities for sustainability and circularity. Organisations like the United Nations Framework Convention on Climate Change (UNFCCC) and the IPCC organised global meetings to discuss possible actions for both climate adaptation and mitigation and to make agreements between different countries to decrease human-induced greenhouse gas emissions (Arora & Mishra, 2021). In 2015, all United Nations Member States adopted the 2030 Agenda for Sustainable Development which included the 17 Sustainable Development Goals (SDGs). These goals are aimed at tackling various economic, social and environmental challenges among which climate adaptation and mitigation (UN, n.d.).

The latest climate change conference, COP26, was in Glasgow on the 13th of November 2021. In this meeting representatives of almost 200 countries participated to sign the 'Climate Pact' and with that keep the Paris Agreement of 2015 alive (Arora & Mishra, 2021). In the COP26, agreements were made to reach the 4 goals of mitigation, adaptation, finance and collaboration. For mitigation, 153 countries put forward new emission targets for 2030 and agreed to come back next year with new strengthened commitments (UK COP26, 2021). 80 countries are participating in either Adaptation Communications or National Adaptation Plans. Also, a record amount of countries have pledged to a certain amount of adaptation finance (UK COP26, 2021). In addition, developed countries have made progress with achieving the climate finance goal of $100 billion. Lastly, the Paris Rulebook has been finalised and new commitments for collaboration have been made (UK COP26, 2021).

With the increasing global emphasis on climate adaptation and mitigation measures and nature-based solutions, more opportunities for projects like waterharmonicas are created. As countries globally are exploring options to meet the global agreements and tackle climate change together, knowledge exchange on sustainable solutions also increases (Maes & Jacobs, 2017). Knowledge exchange between countries on nature-based solutions like waterharmonicas can help increase the support base of these systems. Also within the Netherlands, we can learn from other countries and how they use natural treatment systems to treat waste water.

European policies

Within the European Union, legislations, targets and commitments have also been made to combat climate change. In 2020 a binding EU target was made for a net domestic reduction of at least 55% in greenhouse gas emissions by 2030 (European Council, 2022). This target is part of a bigger European Green Deal to become climate-neutral by 2050. With the green deal, the EU indicates that they will decrease Greenhouse Gas (GHG) emissions and make the transition towards green energy (Pérez De Las Heras, 2021). This legally binding deal will help create a more integrated climate policy, offers a guide for the transition to an economy with zero GHG emissions and can help preserve and protect natural capital. And it can further protect citizens' health and wellbeing from environmental risks (Pérez De Las Heras, 2021).

Over the past 10 years, there is increasing interest in the value of nature and Nature-based solutions (NbS), including waterharmonicas in addressing various social, economic and environmental challenges like climate adaptation and mitigation (Faivre et al., 2017). Therefore, it is believed that NbS can help in achieving the goals of both the Paris agreement and the Green Deal. (Pérez De Las Heras, 2021). In the EU a Research and Innovation agenda has been made on NbS to assess their potential. This agenda can contribute to several Sustainable Development Goals on nature and natural processes but also on social inequality and improving health and well-being (European Commission, 2015).

In 1991, the Urban Waste Water Treatment Directive (UWWTD) was adopted by the EU. This directive concerns the collection, treatment and discharge of domestic and industrial waste water and its objective is to protect the environment from the effects of the wastewater discharges (European Commission, n.d.). With the UWWTD, the EU Member States need to ensure that the wastewater is properly collected and treated and not just discharged onto the surface water. Data shows that in 2021 over 90% of the EU waste water is now collected and treated (Directorate-General for Environment, 2021). This is a significant improvement but some changes still need to be made to meet the European Green Deal and the Zero Pollution Action Plan. Especially on micropollutant removal and the sustainability of the WWTPs, improvements can be made (Directorate-General for Environment, 2021).

In 2000, the EU adopted a Water Framework Directive (WFD) aimed at safeguarding Europe's water sources. Its main objective is to protect and enhance the aquatic ecosystem in Europe and promote sustainable water use (Carvalho et al., 2019) The WFD uses a river basin approach and looks at both the ecological and chemical status of the water bodies. For the chemical quality, there are legislations to the maximum concentration of pollutants allowed in the water. In groundwater, no pollution is allowed so any pollution must be detected and stopped (European Commission, 2014). The ecological status of the waterbodies is defined by the abundance of aquatic flora and fauna, nutrient availability and morphological features like water quantity and the structure of the river beds (European Commission, 2014). Since implementing the Water Framework Directive in 2000, other EU policies have been adopted on biodiversity, renewable energy and flood management. Especially the focus on ecological status as introduced in the WFD is now better understood and accepted and also incorporated into the EU Biodiversity Strategy and the SDGs (Carvalho et al., 2019).

The nature-based solution of the waterharmonica can help tackle multiple of the EU goals as it improves the chemical and ecological water quality while it can also have a positive impact on the (aquatic) ecosystems and biodiversity. Multiple interviewees from WsVV mentioned that not only for WsVV but also for many other waterboards it is still a challenge to meet the WFD goals. This is partly due to the effluent that is harming the small waterways. A waterharmonica can reduce this impact by improving and 'ecologising' the effluent and therefore can help meet the WFD and biodiversity goals set by the EU.

Meeting the WFD goals is especially for waterboard Vallei and Veluwe a reason to participate in projects like the quickscan in Ede as WsVV is not yet meeting these requirements for multiple waterbodies. Multiple interviewees from WsVV also indicated that the WFD requirements are even too low and the EU could do more to improve the water quality. Especially as micropollutants like hormones, Poly- and Perfluoroalkylstof (PFAS) and medicines are not yet included in these regulations. An interviewed advisor of WsVV mentioned: "*We need to think both long and short term, we don't want our great-grandchildren to say that we did a bad job. So we cannot take any risks in this*." In this risk perception, a difference appears between the treatment experts and the other interviewees of WsVV). The interviewed treatment experts of WsVV appear to be more lenient with risks as it is sufficient when the effluent meets the quality requirements, while other interviewees would prefer an even higher quality standard than required by the EU. An expert from the WUR on freshwater ecology even stated that the WFD requirements are much too low and should be adapted.

For the Ede case, EU legislations on water reuse, infiltration and drinking water norms also need to be taken into account. On the 26th of June 2023, new rules will apply to the use of waste water that are expected to stimulate water reuse in the EU (European Commission, n.d.). These regulations form a blueprint that can help the EU member states when they are considering the reuse of waste water. It for example indicates which minimum quality parameters the reclaimed water must meet before it can be safely reused (EUR-Lex, 2020). Aside from the new water reuse legislations, there are also different EU norms for water infiltration and drinking water. This makes it difficult to establish the exact minimum quality standards for the reuse of effluent as an infiltration source and indirectly as a drinking water source (interview treatment expert WsVV)

Policies in the Netherlands

In response to global and European changes and policies, the Netherlands created a long term vision (Nationale Omgevingsvisie, NOVI) with which they aim to tackle challenges like climate change, the energy transition, circular economy and other societal issues (Rijksoverheid, 2020). The NOVI emphasizes sustainability and making the systems future proof. Furthermore, when possible the NOVI promotes combining different challenges so they can be tackled at once. Nature inclusivity is important in this as it integrates nature and landscape values with other developments. The Netherlands aims to increase the nature areas, connect them when possible and protect the landscapes (Rijksoverheid, 2020). With the NOVI, the Netherlands tries to uphold the Paris Agreement and the Green Deal by becoming climate neutral in 2050 and realise a circular economy (Rijksoverheid, 2020).

Currently, in the Netherlands, most waterbodies do not meet the WFD standards that need to be achieved by 2027. The Dutch Minister of Infrastructure and Milieu, Minister Harbers, stated that it is unlikely that we will meet these goals within 5 years (NOS, 2022). This can have major consequences for new projects and developments as measures will have to be taken to reduce emissions and improve the water quality. Also, large fines will have to be paid to the EU (NOS, 2022). According to Harbers, at this moment 30-50% of the waterbodies meet the biological parameters (algae, water flora and fauna) and about 55% meet the chemical parameters (nitrogen, phosphorus etc.) (Harbers, 2022).

To increase these numbers and improve the water quality in the Netherlands, many funds are available for the implementation of measures (Harbers, 2022). Even though minister Harbers doesn't expect that we can fully meet all WFD goals before 2027, he does expect the water quality to improve over time. National measures to reduce nitrogen emissions can also help with this. Some measures will only work in the long term and might not have sufficient impact yet before 2027 but can help reach the goals at a later stage (Harbers, 2022).

To improve the water quality in the Netherlands and meet the Global and European goals, waterharmonicas can be used. The waterharmonica reduces the impact of effluent on the downstream waterbodies and with that increases the biological and chemical quality of the water (Schomaker et al., 2005). To my knowledge, the specific measure of the waterharmonica is not mentioned in the NOVI or other national policy documents. However, the knowledge centre STOWA is researching the functioning of waterharmonicas (interview water technologist TAUW). Helophyte filters are included in more projects throughout the Netherlands. For example, within the project AquaConnect, research is done to explore the options of improving the water cycle and creating a more robust water supply (Interview coordinator AquaConnect). The coordinator of AquaConnect is doing research together with STOWA on the removal rates of helophyte filters and he is trying to incorporate this knowledge within the AquaConnect project to create a more circular system with both engineered and natural systems (Interview coordinator AquaConnect).

Waterboard Vallei and Veluwe

To meet the requirements from both National and European policies and to adapt to the changing climate, Waterboard Vallei and Veluwe is also making some changes. With de Blauwe Omgevings Visie (BOVI) WsVV tries to create a more sustainable, climate resilient and water robust vision of the future (Waterschap Vallei en Veluwe, 2021a). In addition, the Blauw omgevingsprogramma (BOP) is made to translate the BOVI into more concrete actions and tasks. For this, WsVV made multiple goals which can be categorized into the following 5 categories: water system, water treatment, water security, circular economy and energy transition (Waterschap Vallei en Veluwe, 2021b).

The area maintained by waterboard Vallei en Veluwe is quite diverse with different issues and different goals. So the waterboard has divided the area into 4 sub-areas with their own programme. Within the 4 sub-areas, different 'blue key areas' have been determined as areas where multiple goals can be combined both within the waterboard and for collaboration with partners (Waterschap Vallei & Veluwe, 2021a). The case in Ede is part of sub-area de Gelderse Vallei. The main attention points in this area are the water quality, protection of the water storage areas and drought sensitivity of the Veluwe and Utrechtse Heuvelrug. The WWTP in Ede is also included in the BOP as the water quality is causing difficulties with achieving the WFD goals (Waterschap Vallei & Veluwe, 2021a).

Circularity and sustainability are key aspects within the waterboard Vallei and Veluwe, they aim to be fully circular by 2050 and try to include this in many projects and decisions. Furthermore, WsVV aims to reduce the carbon footprint and tries to use green energy when possible (Waterschap Vallei & Veluwe, 2021a). As explained in the stakeholder analyse, WsVV's main motivation for the quickscan in Ede comes from the increasing drought problems and the aim to become more circular and sustainable. These motivations are related to the BOVI and BOP (Interview advisor water chain WsVV) the aspects of circularity and sustainability are also mentioned as important by most of the interviewees.

With the BOVI and BOP, waterboard Vallei and Veluwe is becoming more open to new and innovative ideas and projects. Most interviewees of WsVV indicated that a change is happening within the waterboard that makes it easier to implement sustainable alternatives and changes. Furthermore, there is more emphasis within WsVV on collaboration and involvement with other parties and actors which can lead to more inclusive and effective projects (interview water system advisor WsVV). Within WsVV a change is also occurring in the handling and assessment of projects. Projects will be assessed as a value case instead of as a business case. This indicates that less emphasis is put on choosing the option with the lowest costs and instead look for the option with the most added value. This can be added economic value but also societal or environmental value (Interview strategic advisor WsVV).

Multiple interviewees from WsVV mentioned that due to the changes in the waterboard, more sustainable and progressive projects are becoming possible. The interviewees mention this as a nice change and expect this process to continue leading to even more possibilities for sustainable and circular changes. Even though these changes are occurring and there is a shift from business cases to value cases, most interviewees still expect that the final decision will be made based on the costs and the efficiency and not on the most sustainable option that provides the most added value. 5 out of 8 interviewees from Waterboard Vallei and Veluwe mentioned that they expected costs would still be the main deciding aspect for the board.

Multiple interviewees of WsVV indicated that a waterharmonica can have additional environmental, social and ecological functions and values and the system can help tackle multiple goals at once. The combination of functions and goals can be a nice selling point for the system that can help create a support base and convince the board. As added functions and benefits, different ecological and social aspects are mentioned that are explained in more detail in Chapter 4.2.3. Some interviewees mentioned that adding an educational aspect would be nice as it promotes the waterboard, explains what WsVV does and raises more awareness of water issues and the value of water. WsVV tries to incorporate other visions and ideas into the projects which leads to more added functions not just for WsVV but also for other actors (interview landscape architect WsVV). However, costs are still mentioned by the interviewees as a key factor, the added benefits have to be sufficient to justify the costs. Furthermore, a programme manager of WsVV indicated that we should remain critical and be aware that greenwashing is not becoming the objective. Sustainable and innovative projects can also be used just to improve the image of the waterboard instead of having an actual sustainable value.

Some of the interviewees from WsVV indicated that they were working on exciting new and innovative projects or had worked on them in the past and said that they would like to make the change to more sustainable and circular options. However, the interviewees also indicated that many of their projects didn’t make it or probably wouldn’t make it due to high costs or difficulties with regulations. When joining other case studies like the Pasveersloot in Otterlo, it appeared that the success of these innovative and sustainable ideas often related more to finding the right people and the right time to pitch the idea instead of the project itself. The interviewees often seemed a bit negative about the prospects of their innovative projects, however, they still wanted to keep trying until something sticks and changes occur. This is also the case with the case study in Ede, many interviewees seemed not too positive about the success of this project due to experiences with previous projects. However, many actors did expect and hope that the quickscan may lead to more research or even a pilot and with that in the future it might eventually lead to the construction of a water factory or something similar.

Vitens

As a drinking water company, Vitens always needs to guarantee a safe, affordable and sufficient supply of drinking water. With the changing climate, Vitens needs to adapt to be able to meet an increasing water demand with a reducing water supply (Nijboer et al., 2019). Vitens' strategy of "Samen in beweging voor mens en leefomgeving" ("*Move together for people and the environment")* aims at guaranteeing a 24/7 reliable and affordable water supply in the future. Hereby Vitens emphasises the need for sustainability and the protection of their water sources (Nijboer et al., 2019). Nature is for Vitens an interesting added function for a water win area as it can help protect the water source and has ecological and societal benefits. The societal responsibility of Vitens not only addresses the responsibility for supplying drinking water but also the responsibility for reducing the negative effects of their water win areas and possibly even having positive effects. Maintaining the water win areas as a nature area adds to biodiversity and can have a societal benefit (Nijboer et al., 2019). When possible, Vitens tries to include other stakeholders and create a societal value, for example by adding walking routes or making the place suitable for certain flora and fauna (Interview ecologist Vitens).

Both Vitens and WsVV participated in the Green Deal Infranature, a project aiming at restoring and protecting biodiversity in the Netherlands. Hereby the 23 involved organisations agreed to include more natural variation when constructing and maintaining constructions (Green Deal, 2019). For Vitens participating in the Green Deal Infranature and their new policy of Drinking water and Nature led to an inspiration document for nature-inclusive construction and design. In this document, multiple examples are given for projects to become more nature-inclusive so it also has added value for the ecosystems and society (Vitens, 2020).

In addition to the strategy of "Samen in beweging voor mens en leefomgeving", Vitens also has the policy of "Elke druppel duurzaam" ("*every drop sustainable*") in which they aim to become fully sustainable by 2030. This policy includes: nature-inclusive construction and the maintenance of the constructions and water win areas, protecting and enhancing the quality of their water sources, reducing their climate footprint, improving circularity, transitioning towards sustainable energy and creating more awareness for the value of water (Vitens, n.d.).

Vitens established 9 boundary conditions that were based on the current laws and policies of their organisation and on a national level. These conditions are related to always being able to guarantee a sufficient and safe supply of water while diversifying and protecting their water win areas (M. van der Kamp et al., 2021). Considering a waterharmonica to treat the effluent for infiltration purposes can help increase the water supply and with that decrease the pressure on the drinking water sources. However, Vitens needs to meet their boundary condition of having a safe water supply, so the water quality of the infiltrating water needs to be guaranteed as the groundwater sources cannot be contaminated (M. van der Kamp et al., 2021). Furthermore, according to Vitens policy of 'elke druppel duurzaam', no negative impact on the environment can be caused by new water win areas. Also, when constructing a new water win area nature inclusivity is important (interview ecologist Vitens). A waterharmonica can be used for this as it is a natural system that can improve biodiversity and ecosystem value. An interviewed ecologist of Vitens also mentioned that the aspect of integrating the waterharmonica into the landscape can be a nice benefit. However, for this a place needs to be chosen that has a similar natural heritage, a waterharmonica should not be placed in the dunes or a dry area but more a natural wet area where a swamp would fit (Interview ecologist Vitens).

Individual actors

Policies and visions are created and adopted on global, national and organisational level but behind these policies and visions are individuals with their own visions and perspectives. So decisions, policies and designs are influenced by the involved parties and the socio-cultural and political environment, but also by the personal preferences of the individuals involved (Klein & Kleinman, 2016). For this research, different representatives of both Waterboard Vallei and Veluwe and Vitens were interviewed to establish their personal preferences and visions.

The interviewed actors in this research indicated that for them sustainability, circularity and making systems future proof were of high importance. For some actors, this was even more important than the number of costs involved when constructing a water factory. 8 out of 11 interviewees of both WsVV and Vitens mentioned the importance of sustainability, 3 interviewees mentioned the aspect of making systems future proof and 5 interviewees indicated that the construction of a water factory could help in the transition towards a circular economy. These aspects were also mentioned in various meetings.

When having to choose between a more natural and a more engineered wastewater treatment system, sustainability was often mentioned as one of the key benefits of a more natural treatment system like a waterharmonica. In a highly engineered treatment system like Reverse Osmosis, much more energy is needed and it has a higher carbon footprint than Nanofiltration with a helophyte filter. Furthermore, Reverse Osmosis systems produce much more brine (residue from the filtration). This highly chemical residue needs to be removed and discharged onto a large water body or treated. Nanofiltration produces much less brine compared to RO and therefore has less environmental impact (interview treatment expert WsVV). Helophyte filters can also have other benefits for the environment and the landscape but this will be elaborated on in Chapter 4.2.3.

4.2 Landscape values within quickscan Ede

The policy landscape as described in the previous chapter also has an impact on individual projects and cases. In this chapter the specific case is described in which waterboard Vallei en Veluwe and drinking water company Vitens researched the possibilities for a water factory in Ede. First, more information is given on the specifics of the case, secondly, an actor overview is shown and lastly, the landscape values mentioned in the interviews, meetings and final report are shown. In Annex I an overview is given of the specific actors interviewed for this thesis.

4.2.1 Background quickscan Ede

As explained in Chapter 4.1 Policy landscape, climate change and changes in policies and visions on multiple levels influenced the policies and visions of Waterboard Vallei and Veluwe and drinking water company Vitens. Both companies need to meet their long-term visions and circular ambitions to reduce water scarcity, give more value to the water and reduce the impact on the environment (M. van der Kamp et al., 2021). Vitens needs to meet the increasing water demand and guarantee a stable and clean water source while WsVV needs to improve the water quality to meet the WFD goals. As these are big issues that require large investments and projects, the 2 parties decided to collaborate. Together they have more knowledge and money so they can expand their research on the possibilities to close the water cycle (Interview initiator project WsVV).

This collaboration led to a Project in Epe to research possibilities for a water factory in which the effluent from the WWTP will be further treated and infiltrated for groundwater recharge (Lieten et al., 2020). For this project a quickscan was done, this is a global evaluation in which the most important opportunities, limitations and possibilities for improvement are mentioned (van Vollenhoven, n.d.). The quickscan in Epe was a success and the board members of WsVV and Vitens would like to continue with these projects to close the water cycle. This led to a new quickscan for a water factory at the WWTP in Ede (Interview strategic advisor WsVV).

Compared to Epe, in Ede problems are more urgent for both WsVV and Vitens. To meet future water demands, Vitens will need to increase its water production in the region of Ede. For this either new sources need to be found or the current sources need to be recharged (Interview advisor water chain WsVV). Currently, Vitens already has problems in Ede as sometimes they need to extract more water than is allowed by their current permits. However, they don't have a choice as they need to deliver. With climate change, these problems can occur more frequently so Vitens will need to invest in new water sources in Ede (Interview strategic advisor WsVV).

For Waterboard Vallei and Veluwe, investments need to be made at the wastewater treatment plant in Ede as it currently does not meet the WFD requirements. The ammonium and phosphate concentrations in the surface water are currently too high (Interview treatment expert WsVV). As the WWTP does not remove everything there are still high concentrations of nutrients in the effluent which is discharged onto the WFD waterbody de Zijdewetering. In the Zijdewetering the low water quality causes problems for the aquatic ecosystems, and more downstream it can cause difficulties in the Valleikanaal (Interview policy advisor clean water WsVV). Furthermore, in 2017 a hotspot analysis for medicine residue was done by the union of waterboards. This research indicated that in 8 out of 16 WWTPs of waterboard Vallei and Veluwe the toxic pressure of the medicine residue is likely causing problems for the water organisms (Interview policy advisor clean water WsVV). The WWTP in Ede was one of these high-risk locations with high toxic pressure. Due to the combination of medicines, ammonium and phosphate in the effluent, adaptations need to be made at the WWTP in Ede to improve the effluent quality (Interview policy advisor clean water WsVV).

As both Vitens and WsVV need to do investments in the same region, they decided to collaborate. With a water factory, the water cycle can be closed and both problems are tackled at once (Interview policy advisor water chain WsVV). In September 2021 consultancy Witteveen+Bos (WB) started with a quickscan to research the possibilities of closing the water cycle by infiltrating water from the water factory as groundwater recharge and with that compensate for the impact of drinking water extraction (M. van der Kamp et al., 2021).

Multi-criteria analysis quickscan Ede

As shown in Table 1, for the quickscan in Ede 5 different variants were researched and compared to the current situation. The first variant only increases the groundwater uptake in the Gelderse Vallei by Vitens but does not include any groundwater suppletion from effluent so no water factory will be used (M. van der Kamp et al., 2021). Variants 2A and 2B have Edese Bos as infiltration location and the variants 3A and 3B will infiltrate in Gelderse Vallei. The difference between the A and B variants lies within the treatment system. Variant A makes use of the more engineered Reverse Osmosis system while variant B uses Nanofiltration followed by a helophyte filter (M. van der Kamp et al., 2021).

Table 1: Overview of different variants in quickscan Ede

Variant	Treatment system	Location infiltration
Current	-	-
1	-	-
2A	Reverse Osmosis (RO)	Edese Bos
2B	Nanofiltration with helophyte filter	Edese Bos
3A	Reverse Osmosis	Gelderse Vallei
3B	Nanofiltration with helophyte filter	Gelderse Vallei

In a Reverse Osmosis (RO) system, a semi-permeable membrane is used. This allows the passage of water but will stop the majority of salts, organics, bacteria and pyrogens. The effluent is 'pushed' through the membrane with a high-pressure pump so the water molecules will go through but the contaminants stay behind (Puretec, n.d.). The reverse osmosis system is capable of removing up to 99% of the particles, ions, organics and other contaminants of the water (Mastropietro et al., 2021). The permeate water that is cleaned can now be considered demi-water. The residue water (brine) contains high amounts of contaminants and needs to be discharged. RO is highly efficient in cleaning the water, it does however also require large amounts of energy, has a high carbon footprint, has high costs and the water is so clean it can't be immediately discharged onto the surface water without causing harm for the aquatic ecosystems (Interview treatment engineer WsVV). Furthermore, the filtration process of RO leaves much residue (Brine) that is highly chemical and needs to be either discharged on large waterbodies or treated (interview policy advisor WsVV). For the case in Ede this indicates that the brine needs to be transported to the Rhine where it can be discharged, this also comes with high costs and many legal requirements (interview treatment engineer WsVV).

Nanofiltration (NF) works similar to RO, an applied pressure is used to overcome the system's osmotic pressure which causes the water to flow through the membrane (Dupont, n.d.). As shown in Figure 5, NF retains particles with a size greater than 1 nanometer while RO removes also the particles with a pore size of 0.1-1 nanometer (Yang et al., 2019). While with RO most contaminants are removed, in NF some ions still remain in the water. NF has a removal rate of 90-99% (Mastropietro et al., 2021). For example, not all ammonium is removed and some medicine residue also remains in the water (Interview treatment engineer WsVV). Since there is less filtration also much less brine is produced by NF than with RO. Therefore the NF variant has fewer issues with discharging or treating the highly chemical brine residue (Interview water quality expert WsVV)

As NF doesn't remove all contaminants, a helophyte filter will be placed behind the system which can provide some additional treatment. As explained in Chapter 1.3, the plants and bacteria in the filter can remove organic micros and nutrients. The removal rates of other particles like medicine residues and PFAS are still unclear but are being researched (Interview constructed wetland expert WUR). For both RO and NF research is done on the removal rates of PFAS with promising results. However, they are not yet able to guarantee PFAS levels under the drinking water norms (Mastropietro et al., 2021). One of the difficulties of the quickscan in Ede is that it is unclear what standards must be complied with before infiltration is allowed, see Chapter 4.1. This makes it difficult to determine the necessary water quality and whether or not NF filtration will be sufficient for this. Therefore the decision on the treatment system will also be influenced by the quality norms of the involved organisation. According to a treatment expert of WsVV, Vitens will have the final say in this as they will determine what risk they are willing to take and what water quality is needed for this.

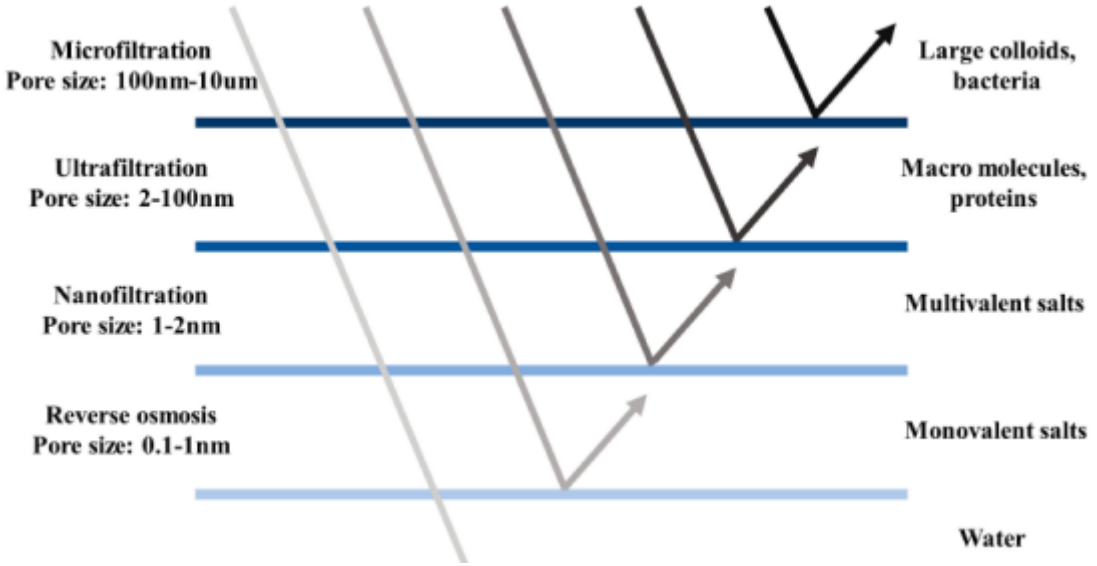

Figure 5: Classification of membranes for water treatment in terms of pore size and particles retained (Yang et al., 2019)

To assess the different variants a Multi-Criteria Analysis (MCA) is used. Table 2 shows the different criteria used in the MCA and the corresponding indicators. These criteria and indicators were used to score the different variants as shown in the 3rd column of Table 2. The criteria and indicators used were based on the criteria used for the Quickscan in Epe. These were determined by discussing the most important aspects with multiple involved actors and experts on all levels of the organisations and by looking at the visions and policies of the involved parties (Interview project leader WB).

The results of the MCA show that variant 3A with the RO system and infiltration in the Gelderse Vallei can guarantee the best quantity and quality of water. The RO treatment system scores best in removal rates and the infiltration location of Gelderse Vallei can have the most ecological impact. Variant 3A is however also the most expensive option in the quickscan and has the highest CO2 footprint (M. van der Kamp et al., 2021). In the MCA, water quality and quantity got a higher score than environmental and sustainable aspects, due to this RO scored better overall. The specific scores and the corresponding landscape values will be explained more in-depth in Chapter 4.2.4.

Table 2: Criteria and indicators of MCA quickscan Ede (based on M. van der Kamp et al., 2021)

Criteria	**Indicators**	**Scores**
Costs	Investment costs; operation costs; yearly costs	Total costs RO are about 1/3 higher than NF Maintenance of helophyte filter is more intensive than with RO
Sustainability	Environmental cost indicator (MKI) and CO2 footprint; other sustainability aspects (value creation and maintenance, residue)	RO has a higher CO2 impact and MKI score, mainly due to chemical and electricity use Helophyte filter produces biomass RO produces a higher water quality and with that has more environmental impact and less additional treatment is needed so a higher sustainability score
Impact on environment and ecology	Changing surface water flows; changing ground water flows; effects water quality and nature; effects agriculture, buildings, culture-historical aspects	Mainly concerns the area of infiltration; in Gelderse Vallei it can have the most environmental impact Less quality water of NF can have ecological consequences
Societal aspects	Acceptance and image; experience and imaging;	Mainly concerns the image of the use of treated effluent; Helophyte filter has a positive experience and imaging value as it is visible for residents and recreants For helophyte filter more land is needed

The outcome of this quickscan is or will be presented to the boards from both Vitens and WsVV after which a decision will be made on how to continue. When writing this report, the outcome is not clear yet as to my knowledge it has not been presented to the board yet. Many interviewees mentioned that they hoped it would lead to either a pilot or further research on different locations. Even though most interviewees were enthusiastic about the quickscan, some critical notes were also placed. Multiple interviewees from WsVV mentioned that the success of the quickscan depends on the motivation of both parties, not only to collaborate but also to cover the finances together. From WsVV one interviewee also mentioned that this is mainly a project for Vitens as they have the most to gain, so they should also carry most of the project and they'd have to want to continue with it. Furthermore, one interviewee from WsVV expressed concern that the project might mostly be used as greenwashing. So the parties involved would use the quickscan and maybe a water factory to show how sustainable and green they are while it costs a lot of money and does not necessarily contribute.

Despite some concerns and critical notes, multiple interviewees indicated they expected the project would lead to some commitment from the boards. This is since both parties have a problem in the Ede region and need to invest in the area. A strategic advisor from WsVV mentioned: "*if you want to implement transitions and changes, you need to look for a real problem, make it into a problem case and then there is urgency and people will want to tackle it".*

Considerations when using a helophyte filter

For the variant with Nanofiltration and a helophyte filter, some concerns were mentioned in the meetings and interviews. This was mainly about the placement and maintenance of a helophyte filter as it is slightly different from a 'normal' treatment system.

	WsVV						Vitens		Meetings
Space requirements									
Maintenance									

When opting for a natural treatment system, an often mentioned aspect concerns the required space. 8 out of 11 interviewees from both WsVV and Vitens mentioned that natural treatment systems often require more space than an engineered treatment system. Especially a helophyte filter can take up a significant amount of space as it works best with only a small layer of water (interview constructed wetland expert WUR). An interviewed ecohydrology expert of WsVV mentioned that the required size of a helophyte filter was one of the main reasons why some previous projects didn't succeed. Also for the quickscan in Ede the size of the filter seems to be an issue as it is unclear where this can be placed. There is not sufficient space next to the WWTP and when the filter is located elsewhere, the water needs to be transported first (interview treatment expert WsVV). Land is scarce and therefore it is difficult to find a space to place the filter as the land can also be used for nature and or housing. As a treatment expert of WsVV mentioned: "*why would you remove a forest to place a helophyte filter, just let it remain a natural area.*"

Required space is however also mentioned by 2 interviewees as a possible benefit as you'd have to buy out farmers for their land, which can help reduce the nitrogen problem. Also, when it is integrated into the landscape and can serve multiple purposes, the required space appears to be less of an issue. These aspects are explained more in-depth in Chapter 4.2.3. Spatial quality is not specifically included as a criterium in the final report of the quickscan, but parts of it are included in other criteria. For example, culture-historical aspects as an indicator of the impact on the environment and ecology is one of the aspects of spatial quality. The specific spatial quality aspects and considerations are dependent on the location and will be specified at a later stage of the project (interview project leader WB). When integrating a waterharmonica into the landscape, a spatial quality assessment can be used to determine the core qualities and aspects of the area. Hereby landscape experts and local residents can assess which aspects are most important to maintain the usage, experience and future value of the landscape and landscape elements (interview landscape and water heritage expert WB).

One of the other aspects mentioned when using a helophyte filter was the amount of maintenance required. This aspect was mentioned by 3 interviewees from WsVV and also came forward in multiple of the meetings. The maintenance of a waterharmonica is supposedly very time and money consuming as the reed needs to be cut and the waterways need to be cleaned and maintained. If this is not done properly the system will get stuck, water will flow less easily and in the end, the system will not function anymore (interview water quality expert WsVV). However, a policy advisor of WsVV mentioned that for reverse osmosis the membranes also need to be cleaned regularly and after a while, you have to buy new ones cause these won't function sufficiently anymore. This will also be the case for a nanofiltration system but this was not mentioned by any of the interviewees.

4.2.2 Actor overview Case Ede

Waterharmonicas are mainly designed and operated by waterboards. In some cases, the waterboards try to include other actors for example when it is related to additional benefits like nature development or recreational and educational purposes (interview landscape architect WsVV). In the quickscan in Ede, currently, only the waterboard and Vitens are involved. When this process will continue other parties like the province and the municipality will possibly get involved, and perhaps also other actors like nature organisations and citizens can be included in the process (Interview policy advisor water chain WsVV). An overview of the organisations and their involvement is shown in Figure 6.

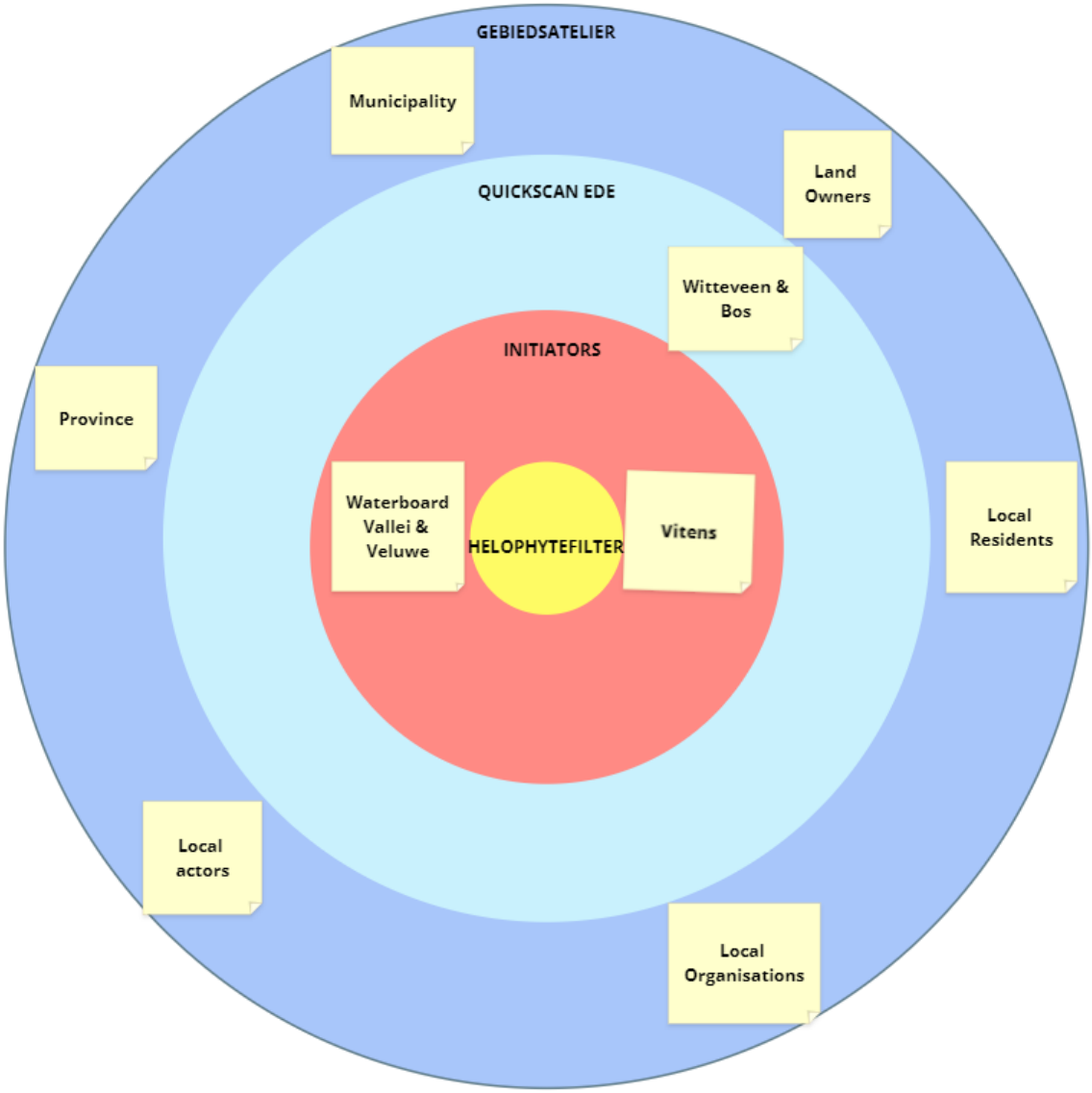

Figure 6: An overview of actor involvement in different stages of the project

Waterboard Vallei and Veluwe

Waterboard Vallei and Veluwe initiated the quickscan in Ede together with Vitens. Before this quickscan, WsVV and Vitens already did a similar project for the WWTP in Epe. Both boards were enthusiastic about the results but no further action was taken yet. In Ede, the problem is more urgent for both parties as explained in Chapter 4.2.1 so WsVV and Vitens decided to do a second quickscan for the WWTP in Ede (Interview initiator project WsVV).

The WWTP in Ede currently does not meet the WFD requirements and therefore some alterations are needed to improve the effluent quality. Mainly on ammonium, phosphorus and medicine residue changes need to be made (Interview treatment expert WsVV). There are various plans to improve the WWTP, for example, to construct a BODAC filter that uses granular active coal to further treat the water (Interview treatment expert WsVV). As large investments are needed for this, some people mentioned that afterwards the water could also be used for other purposes. Or as a policy advisor of WsVV put it: "*Why would we invest such amounts of water to make the water clean only to waste it by discharging it on the useless Zijdewetering?"*

Using the effluent for other purposes can however lead to WFD regulation difficulties as the Zijdewetering is largely dependent on the WWTP as a water source. Multiple interviewees of WsVV indicated that they would like to remove the WFD status of the Zijdewetering as it is currently *"only an effluent brook without any ecological or societal value".* Changing the status is a difficult legal and administrative process as the EU has various guidelines and regulations to protect the waterbodies (Aquo-kit, 2021). Therefore it was also discussed in the meetings to only use part of the water so there is still some water on the Zijdewetering. As this water will be of higher quality, the WFD goals could be met for the brook without having to remove its status (Interview policy advisor WsVV).

Furthermore, within WsVV there is some controversy around infiltrating 'foreign water'. This has a negative connotation as it suggests that it is not a safe water source and they don't want to contaminate the soil and protect the groundwater sources. The dike warden of WsVV also expressed that he doesn't want to use foreign water due to this negative connotation (Interview strategic advisor WsVV). In the meetings it was expressed that this is mainly due to the name itself, therefore they now used the phrases water, treated water or clean water. The negative connotation around the phrase 'foreign water' is also related to the national and EU principles of 'no pollution'. When discharging or infiltrating water, it has to be cleaner than the receiving waterbody. As the groundwater on the Veluwe is very clean, the infiltrating water also has to be of this quality or better before you are allowed to infiltrate it (Interview programme manager WsVV).

For waterboard Vallei and Veluwe, a possible water factory could provide opportunities for collaboration with parties like Vitens and to meet the WFD, BOVI and NOVI goals by improving the effluent quality, closing the water cycle and providing alternative water sources to reduce drought issues (M. van der Kamp et al., 2021).

Vitens

As a drinking water company, Vitens is obliged to always deliver a sufficient amount and a sufficient quality of water. With the changing climate and increasing drought, Vitens is getting more difficulties with meeting these requirements (M. van der Kamp et al., 2021). Therefore Vitens is looking for a new water source or water that can be used for recharging the current sources. The effluent from Waste Water Treatment Plants could be a solution for this as it can be used for groundwater recharge (interview initiator quickscan WsVV).

For Vitens a non-negotiable priority is to deliver a sufficient quality and quantity of water. Therefore they stress the importance of an efficient treatment system that can guarantee a water source that meets the quality requirements. A process engineer drinking water treatment of Vitens mentioned that for him the main focus is to deliver a safe water source. Any additional (ecosystem or social) benefits are nice but not the priority. It was however also addressed in the policy documents of Vitens, the interviews and the meetings that Vitens aims to become more sustainable and have no negative impact on the environment or preferably even a positive impact.

Witteveen+Bos

As a consultancy firm, Witteveen+Bos carried out the quickscan in Ede and wrote the final report. The quickscan report is based on literature, meetings and interviews with experts from WsVV and Vitens and their own knowledge and experience (interview project leader WB). As consultancy firm, Witteveen+Bos is not directly affected by the construction of a waterharmonica but by writing the report they could have influenced the final decision. The individual actors and the company Witteveen+Bos as a whole have their own personal preferences, knowledge and views on aspects. Even though the quickscan is supposed to be an unbiased report based on literature and expert interviews, the personal bias of those involved could have influenced some of the decisions and the content of the final report of the quickscan Ede and with that on possible future steps. Furthermore, the criteria used in the MCA are based on interviews with actors from WsVV and Vitens but also on expert knowledge within WB (interview project leader WB). The specific criteria used influence the outcome of the MCA and with that the outcome of the report. With this, the experts of WB that determined the specific criteria could have influenced the decision-making process of a water factory in Ede

Province and municipality

When constructing a waterharmonica, the province and local municipality will be involved to arrange the legal requirements and possible constraints. In the case of Ede, these parties are not yet involved as it is still a quickscan and no concrete plans are made. Some interviewees mentioned that when the boards have read the report and decide to continue with the project, the municipality of Ede and the province of Gelderland will be involved as they might also have an interest in it. Especially with the nitrogen crisis, the use of a waterharmonica can be interesting for these parties as land has to be bought from the farmers. This can help decrease nitrogen emissions in these areas while the water factory helps improve the effluent quality. As the province and municipality are both benefitting from improved water quality and fewer nitrogen emissions, this can help in creating a support base among these parties.

The province and municipality are not yet involved in the quickscan of Ede and therefore have no influence on this process and are not included in this research. However, it is important to mention them as an actor as they will be included in a later stage of the project as shown in Figure 6.

Other actors

As shown in Figure 6, in future stages of the project in Ede, other actors might also be involved like nature organisations and local inhabitants. Interviewees from both Vitens and WsVV mentioned that it is beneficial to combine multiple goals at once. When involving other actors like nature organisations and local inhabitants, their goals, ideas and needs can also be included in the project. For example, an interviewed ecologist from Vitens mentioned that Vitens collaborated with nature organisations in multiple of their water win areas so the areas could also be used for example as a habitat for a certain protected species.

To include different actors and organisations, a '*Gebiedsatelier*' can be used. In a *gebiedsatelier*, workshops are organised in which different actors come together and get involved in the design process so their knowledge and ideas can be directly included. They meet in various sessions in which they discuss the different challenges of the project (landscape architect WsVV). When the different actors are included like this, not only their expertise can be used but also multiple challenges and goals can be achieved with the same project (Interview landscape architect WsVV).

With a *gebiedsatelier*, different actors will not only get more involved, but the support base also increases and it makes it easier to tackle multiple goals with the same project. It is also much simpler, more efficient and also less expensive when you include more goals from the start instead of trying to make changes afterwards (Interview landscape architect WsVV). Waterboard Aa en Maas also currently makes use of a *gebiedsatelier* for the construction of a waterharmonica in Aarle-Rixtel (Interview process supervisor water management WsAM).

When a specific location is chosen for the waterharmonica, the current landowners will also get involved. At this moment, in the case of Ede, no specific location is chosen so these actors are not yet determined. With the waterharmonica in Nieuw-Vossemeer, the land already belonged to the waterboard which makes it easier and less expensive. In the cases of WsDD, the waterharmonicas were constructed based on the land available so they would fit most efficiently. This made the required land less of an issue. For a waterharmonica in Ede, this will most likely not be the case, so the land will have to be bought.

In the case of a water factory in Ede, future water users could also become a stakeholder. When the treated effluent is infiltrated it can be either directly or indirectly used as drinking water. Therefore, future water users are also affected by the project. For Vitens this is an important aspect as they need to guarantee safe and sufficient water for everyone. As a manager of Vitens mentioned, we don't want people to start buying bottles of water cause they don't trust the tap water or it is no longer halal or kosher so they cannot drink it anymore. No research is done yet in Ede on how future water users feel about the use of reclaimed water. As these aspects are mentioned in the interviews and meetings it is important to include future water users as an actor. However, these actors are not included in the interviews as they are not directly affecting the decision-making process around a waterharmonica.

4.2.3 Landscape values interviewees

In the interviews, various landscape values of waterharmonicas were mentioned. Table 3 shows the mentioned landscape values and by whom they were mentioned, see Annex I for a list of interviewees. Different colours are used to indicate whether the interviewee appeared positive, negative or neutral towards the landscape value. Green indicates that the interviewee mentioned it as a benefit, red is used when the interviewee was negative about this value or didn't see any added benefits from it and yellow is used when the interviewee remained neutral, mentioned both positive and negative aspects or it was unclear whether the interviewee perceived it as an added benefit or not. The white cells indicate that the interviewee didn't mention this landscape value about the waterharmonica. In the meetings several values were also mentioned, these are indicated in the lowest row, here no differentiation is made between who said what as it was difficult to retrace. Different aspects are included in this research when they were discussed by multiple people or mentioned in the slides.

Table 3: Landscape values per interviewee

		Landscape values														
	Function	**Water quality**	**Drought reduction**	**Biodiversity**	**Ecologisation**	**Aquatic ecology**	**Landscape integration**	**Societal function**	**Recreation**	**Education**	**Nitrogen and Phosphorus**	**CO2**	**Energy**	**Sustainability**	**Production**
WsVV	Groundwater maintenance and ecohydrology														
	Policy advisor planning, chemical advisor treatment systems														
	Senior policy advisor water chain and planning, treatment technologist														
	Policy advisor planning Clean Water, water quality expert														
	Strategic advisor														
	Senior policy advisor water system														
	Program manager implementation omgevingswet														
	Landschape architect, *gebiedsatelier* meester														
Vitens	Proces technologist drinking water treatment														
	Ecologist														
	Environment manager														
Meetings															

In this subchapter, the specific landscape values are explained more in-depth. They are categorized into hydrological aspects, ecological aspects, landscape aspects, societal aspects, environmental aspects and production aspects. For all aspects, an overview is given of the values and who mentioned them. For this, the same colour scale is used as for the table above.

Hydrological aspects

Water quality

	WsVV							Vitens			Meetings
Waterquality											

One of the main conditions for a water factory in Ede is to guarantee sufficient water quality. The treated effluent must meet certain quality standards to be used for infiltration and to become a safe (ground)water source. This is a priority aspect for both WsVV and Vitens, see Chapter 4.1. In meetings, interviews and the final report of the quickscan Ede emphasis was put on the treatment efficiency of the variants. 10 out of 11 interviewees of the quickscan Ede mentioned that water quality is an important aspect when choosing a wastewater treatment system. 6 interviewees even indicated that for them water quality is the most important aspect.

There is a high variability in how interviewees view the treatment capacity of a helophyte filter. The 2 interviewed water treatment experts of WsVV were positive about the treatment capacity of the helophyte filter. One of them indicated that it would provide less treatment than RO, but the combination with NF would still lead to a sufficient water quality for infiltration purposes. The other interviewed water treatment expert mentioned an experiment with small scale helophyte filters which led to promising results. She did however also mention that other systems could remove the same compounds and maybe even more efficiently. The other interviewees were less optimistic about the treatment capacity of a helophyte filter. 8 interviewees were neutral or negative about the water treatment provided by the helophyte filter. Of these 8, 3 interviewees indicated they don't believe the helophyte filter will provide sufficient treatment to the system and neither will nanofiltration.

As mentioned in Chapter 4.1, a distinction can be seen in the water quality standards and the risks people are willing to take with this. The interviewees that were positive or neutral about the treatment capacity of the waterharmonica often indicated that it is sufficient if the water meets the legal requirements. The interviewees that were more negative about the waterharmonica often want to be able to guarantee a higher water quality as they don't want to take any risks. The variant with NF and a helophyte filter can't guarantee this quality so the risk of this system is too high and these interviewees would prefer RO. As a strategic advisor of WsVV mentioned: "*For me the risk of possible contamination is unacceptable. The water needs to be clean and safe and RO is the only variant that can provide this guarantee.*"

The main concerns mentioned in the interviews are the concentrations of medicines, PFAS and organic micropollutants. As explained in Chapter 4.2.1, a helophyte filter can provide some treatment to the effluent, but it is unclear how efficient this treatment is. Especially in the removal of PFAS and medicines, there is a lack of data. For the quickscan in Ede, NF should be able to remove most of these particles before it enters the helophyte filter so maybe this is less of an issue, this was however not mentioned in the interviews. Also, a process engineer of Vitens mentioned that Bromate can form in the WWTP when ozonisation is used. This is a highly carcinogenic compound and there is no data available yet on whether this can be removed in a helophyte filter. According to a treatment expert of WsVV, currently, the WWTP in Ede does not make use of ozone so bromate should not be a problem. Lastly, seasonal fluctuations are often mentioned as an uncertainty of the waterharmonica. Plants grow less in winter which can influence the treatment capacity but it is unclear to what extent.

The lack of data and the possible seasonal variations make that most interviewees were not too optimistic about this treatment system. In the observed meetings, water quality is also mentioned by different actors from both WsVV, Vitens and Witteveen+Bos. Here the lack of research and data on the treatment efficiency of a waterharmonica are also used as main discussion points.

Water quantity

	WsVV					Vitens
Drought reduction						

Drought is one of the main reasons for the quickscan in Ede, see Chapter 4.2.1. The infiltrating water in the helophyte filter can directly be used to combat drought. 3 interviewees of WsVV directly mentioned that a helophyte filter could contribute to drought reduction, 2 interviewees of WsVV and Vitens implied it had a positive impact and 1 interviewee of WsVV questioned if it would actually contribute. Often in the interviews, it was not specified how a helophyte filter could help in drought reduction, it was more mentioned as an important aspect instead of as a specific function. Mainly the interviewees of WsVV mentioned drought as an aspect. From Vitens only an ecologist specifically mentioned possible infiltration due to a helophyte filter as a drought reduction option.

A water quality expert of Vitens mentioned infiltration within the filter, he did however not mention this in relation to drought but more as a concern that the infiltrating effluent might pollute the groundwater. This concern was also mentioned in the meetings of the quickscan. Especially when infiltration occurs near the ENKA area this might cause a problem. Pollution from the ENKA factory is still in the ground which could reach the groundwater when more water gets infiltrated (interview water quality expert WsVV). Furthermore, as mentioned before in Chapter 4.2.2 there is a discussion on the name of the infiltrating water as foreign water is a somewhat controversial term.

The ability of a waterharmonica to serve as a water buffer is often mentioned in literature as one of its main features. And it is often mentioned as reason for the construction of a waterharmonica (Fleskens et al., 2016; Schomaker et al., 2005; van den Boomen & Kampf, 2013). It was however not mentioned by the interviewees as landscape value nor was it mentioned in the meetings. In the final report of the quickscan Ede, water buffering capacities are briefly mentioned as the helophytefilter provides a larger buffer when the system is malfunctioning and the treatment efficiency decreases.

Ecological aspects

Biodiversity

	WsVV						Vitens		
Biodiversity									

Biodiversity was mentioned by 9 out of the 11 interviewees as an aspect in both the quickscan Ede and in a possible waterharmonica system. From Vitens, the interviewed ecologist and the environment manager mentioned that a helophyte filter can help with nature development and with that can help achieve other nature goals. The interviewed process technologist of Vitens was neutral about this landscape value as for him this was of less importance and he focussed more on the treatment capacity of the system while others could look into the ecological and social aspects.

Of WsVV, 6 interviewees mentioned biodiversity as a landscape value. An ecohydrologist of WsVV indicated that the reed and rushes can directly add to the biodiversity in the area. Other interviewees, mentioned that the helophyte filter can attract different animals. However, they can also influence the water quality. As three of the interviewees mentioned, birds can poop in the water and the animals might bring other bacteria and maybe even diseases. An example was given by a strategic advisor of WsVV: "*In Vlaanderen, they used a helophyte filter for drinking water but they had to cover it because there were geese pooping in it which polluted the water.*" A process technologist from Vitens mentioned that due to these outside influences Vitens often uses a closed-off treatment system to ensure the water quality. For a water treatment expert of WsVV, this outside influence was also a clear downside of a helophyte filter as afterwards the water would have to be treated again.

Even though the landscape value of biodiversity was mentioned by 9 out of 11 interviewees, most of them didn't seem to prioritize this aspect. Only 4 interviewees specifically mentioned the word biodiversity, the rest hinted at biodiversity as a value. In most of the interviews biodiversity was mentioned or hinted at in passing, so more of an already commonly accepted value. For example, a programme manager of WsVV mentioned the following: *"And a waterharmonica mainly takes up nutrients via the bacteria around the helophytes and the rootzones, that's it. I mean, we shouldn't make it sort of a, and that once in a while a harrier can fly over, sure, that's great, and that some additional treatment is added, fantastic, we should always do it."* A treatment engineer of WsVV mentioned the aspect of biodiversity more specifically but didn't go into the details of it: *"If you create a nice area with this that's recreation, that's nature, biodiversity and that has everything in it so to speak."*

Ecologising the water

	WsVV				
Ecological value					

Giving ecological value to the water or 'ecologising' the water, as it is often called in the waterharmonica scene, is often mentioned in literature as one of the key features of the waterharmonica (Fleskens et al., n.d.; Kampf et al., 2003; Schomaker et al., 2005). In the waterharmonica bacteria and insects will return to the water and a natural oxygen flow is created and with that the ecological quality of the water increases. Before entering the waterharmonica, effluent from the WWTP has a higher temperature than the surface water. In the filter, the water can cool down due to the shade of the plants and the exposure to the surface temperatures. The water will have reached a 'normal' temperature when discharged onto the surface water (Schomaker et al., 2005). Due to all of these processes, the water will have less harmful effects on the aquatic ecosystems when discharged onto the surface water (Schomaker et al., 2005).

5 interviewees of WsVV mentioned the positive effect a helophytefilter can have on the ecological value of the downstream water bodies and with that on the aquatic ecology. An interviewed groundwater expert of WsVV also specifically mentioned the shading effect and its beneficial impact on the water. One of the interviewed treatment experts of WsVV was a bit more critical because of the legal aspects and the question of who is responsible for the aquatic ecology. *"What if you get fish in there and a sort of ecology, but it can be that because it is such clean water that at some point they will just die. And I wonder, will the waterboard be held accountable. Like you have a helophyte filter and we have some nice nature and suddenly fish are dying or ducks that are there, then you created nature that might be dangerous at some point."* For the first part of the waterharmonica, this can indeed become an issue as it is only consisting of effluent. However, at the start, most aquatic life will consist of some bacteria and algae and maybe some birds that will sit there. Around the fish pond, the water will most likely have sufficient ecological value so it no longer causes harm. Furthermore, currently, the effluent is already discharged on surface water causing a drop in the ecological value of the Zijdewetering (Schomaker et al., 2005).

The interviewees from Vitens didn't specifically mention the aspect of ecologising the water. A water quality expert of Vitens did mention that Vitens would like a stable biological and bacteriological quality of their drinking water. And he mentioned that the infiltration within a filter can influence the groundwater quality but can also have a positive impact on the pathological quality and lowering the groundwater temperature.

Landscape aspects

	WsVV								Vitens			Meetings
Landscape integration												

When constructing a waterharmonica, a decision must be made whether to go for a closed-off strictly functional treatment system or a more open and accessible nature area. In waterharmonica de Groote Beerze, waterboard de Dommel decided to construct a waterpark that is open for recreational and educational purposes (van den Boomen & Kampf, 2013). For a helophyte filter in Ede, the preference seems to go to a closed-off treatment system as this has less disturbance and risks with the effluent. However, many interviewees also mentioned possible benefits of adding recreational functions.

All of the interviewees mentioned the possibility of integrating the waterharmonica into the landscape by having it represent a natural habitat. This will improve landscape development and can help create new nature areas which have both societal and ecological value. For the waterharmonica to fit into the landscape the location is important. 4 of the interviewees from both Vitens and WsVV mentioned that the system should be placed somewhere in a swamp-like or naturally wet area so it integrates with the natural habitats. Hereby an interviewed ecologist from Vitens mentioned that when constructing the system it is important to see if it can be combined with other nature goals and challenges in the area and with that tackle multiple goals at once. A landscape architect of WsVV also indicated this and explained how a *gebiedsatelier* can be used to bring multiple actors together and include them in the project. Multiple (nature) goals can be easily tackled together and the waterharmonica can serve multiple purposes for the landscape, ecosystems and society.

In the interviews, a distinction can be made between the interviewees that see the helophyte filter as a landscape (place) and those who see it as a functional treatment system (space). Especially in WsVV, this distinction is shown. One of the treatment experts indicated that for her it was strictly a treatment system and we should treat it as such. And a strategic advisor of WsVV mentioned: "*If it can have multiple functions that's possible but these cannot harm the original main function of the system.*" However, other interviewees described the filter more as a place with a combination of landscape functions. 2 interviewees from WsVV even mentioned they would ideally at some point create a large natural area in which all functions come together. So this would consist of agricultural, natural and recreational areas but can also have a treatment function. This view of seeing the treatment system as part of nature and part of the area differs largely from seeing it as just a closed-off functional treatment system and both systems would need a different design and functioning.

For a waterharmonica to function and treat the effluent efficiently, a large area of land is needed. Especially since the treatment works best with a small water layer, a long retention time and multiple ponds (interview constructed wetland expert WUR). In the Netherlands, this land requirement can be an issue, as mentioned in Chapter 4.2.1. However, when treating the waterharmonica as a landscape, it can also start functioning as a nature area and with that can have different societal and environmental functions. This is seen as positive by multiple interviewees. Although, one of the water treatment advisors of WsVV also questioned if it wouldn't be better to let the nature areas be nature areas instead of trying to create a new nature area that also functions as a treatment system. Hereby it can make a difference if a nature area is chosen or an agricultural area. As explained in the environmental aspects, choosing an agricultural area can also help with the nitrogen issues.

Another often mentioned aspect of a waterharmonica is the required maintenance, see Chapter 4.2.1. When treating the waterharmonica as a natural system, more maintenance is required than when treating it as a functional treatment system. As a landscape, preferably the system would have more natural shapes and vegetation which makes it more difficult to maintain than straightforward, linear ponds and waterways.

Societal aspects

	WsVV						Vitens	Meetings
Recreation								
Education								
Other societal functions								

7 out of 11 interviewees mentioned that a helophyte filter can have some societal value. Hereby possibilities for recreation are most often mentioned, this can be with walking paths either around or through the system and possibly cycling routes. Waterpark de Groote Beerze is often referred to as example of a waterharmonica with recreational purposes. In the park, multiple walking routes are placed as described in Chapter 4.3.1.

Similar to possible landscape integration, possible recreational options also can be divided into space and place related responses. Some interviewees were positive about this aspect as it is a nice nature area that can be shown to the public, people can walk through and enjoy the view. However, other interviewees indicated it still remains an effluent treatment area so the water is especially at the start of the system not yet of high quality. Therefore, people shouldn't come near the water and dogs shouldn't be able to drink from it or swim in it. This argument was used in interviews to close off (part of) the system so people cannot access the water itself. However, as the effluent is first treated by NF before it enters the waterharmonica it is already of better quality and this might not be an issue (interview treatment expert WsVV).

Furthermore, a distinction could be seen in the enthusiasm people expressed when mentioning the recreational value. Some interviewees were quite enthusiastic. For example, a policy advisor of WsVV mentioned that it could become a nice park with some benches that people can walk through and enjoy nature. Other interviewees were less enthusiastic and mentioned it more as a possibility. For example, an interviewed water systems advisor from WsVV stated the following: "*we could create a 'klompenpad' or make some awareness thing or something. But it is still a field of reed, we shouldn't make more of it than it is."* Also, a water treatment advisor from WsVV stated that it is nice to have a recreational option but the priority should be the treatment of the water and the rest is less important.

In addition to recreation options, 3 interviewees from WsVV mentioned possibilities for education. This was mainly mentioned as possibility to explain what the waterboard is doing and with that raise awareness and understanding of water boards, water systems and water treatment. One of the advisors of WsVV also mentioned that most civilians don't really understand what the waterboards do. With on-site education, this can better be explained and people can learn about the importance of water treatment and the recycling and separating of waste flows.

An interviewed landscape architect from WsVV mentioned that a waterharmonica could have societal value as the added nature can help people both emotionally and spiritually. *"Green is good for people, in general psychologically speaking watching green gives peace of mind. Also, a green environment aspires more to moving and exercise. So you can tackle health and social aspects with this."* However, he was not only positive about the societal aspects, he also added that the helophyte filter could lead to some stench which could be annoying for the neighbouring residents. This concern was also mentioned in one of the meetings and someone added that with the changing climate the standing water might attract more (dangerous) mosquitos. However, both of these claims were not supported by the interviewees from the existing waterharmonicas. And the interviewed senior advisor Water Quality of the Dommel mentioned that the WWTP produces more stench which covers a possible stench from the waterharmonica.

Environmental aspects

	WsVV					Vitens			Meetings
Nitrogen and Phosphorus									
CO2									
Energy									
Sustainability									

Globally more attention is given to possible climate adaptation and mitigation measures (Arora & Mishra, 2021). As described in Chapter 4.1, this is also the case for both Vitens and WsVV. Both of their policies indicate climate adaptation and mitigation as an important aspect to include in their projects and it was also a motivation for the quickscan in Ede (M. van der Kamp et al., 2021). In the interviews, multiple interviewees from WsVV and Vitens mentioned that a waterharmonica could help with climate adaptation and mitigations. The main aspects mentioned were: nitrogen, phosphorus and CO2 emissions, lower energy requirements, sustainability and increased circularity in the water system.

Nitrogen and Phosphorus were mainly mentioned by WsVV interviewees and in relation to the WFD guidelines. Currently, the effluent from the WWTP in Ede does not meet the WFD nutrient standards as there is too much nitrogen and phosphorus in it. So changes at the WWTP need to be made to remove them more efficiently. An added treatment system like a waterharmonica can help remove these nutrients (Interview treatment engineer WsVV). However, as explained in the hydrological aspects, multiple interviewees expressed concern for the treatment efficiency due to the seasonal fluctuations and the lack of available data.

In addition to reducing the nitrogen concentration in the effluent, the waterharmonica can also have other impacts on the nitrogen problems. As explained in the landscape aspects, a large area is needed for a waterharmonica to function properly. So land will have to be bought for the construction of this area. This can be combined with the provincial efforts of reducing nitrogen emissions by buying land from farmers and changing the landuse. With this collaboration, nitrogen emissions will be lower as less agricultural land is used, and the former fields will now be used to remove the nitrogen from the effluent and with that tackle the nitrogen issues on multiple levels. This possible collaboration and benefit was mentioned by 3 interviewees from WsVV and 1 from Vitens. Furthermore, it was also mentioned in the meetings by another actor as a possible collaboration that would increase the support base for a waterharmonica. According to one of the interviewees, especially the municipalities and province of Gelderland could be interested in this aspect as it also helps achieve their goals.

The CO2 footprint is mentioned as an aspect by 4 of the 11 interviewees. The variant of nanofiltration and helophyte filter uses less energy, has fewer emissions, less brine production and in general, has a lower CO2 footprint than the variant with Reverse Osmosis. One of the treatment experts of WsVV mentioned that for him it is very important that the CO2 footprint of the WWTP in Ede as a whole doesn't increase too much as the WWTP is trying to become CO2 neutral or even possibly CO2 negative. The RO filtration requires so much energy and has such a high CO2 footprint that it can damage these goals. The CO2 footprint is also included in the Multi-Criteria analysis of the final report of the quickscan Ede. Here it indeed shows that the CO2 footprint of the variant with a helophyte filter is about half of the variant with the RO system. The plants in the waterharmonica system could possibly take up some CO2 from the atmosphere as well and with that reduce the CO2 footprint even more. This aspect is however not mentioned in the interviews.

Similar to CO2 emissions, the difference in energy requirements of the variants is also mentioned by interviewees. The RO system has much higher energy requirements than the NF variant with the helophyte filter. 5 interviewees mentioned this as an important benefit of this system, 3 of which were from WsVV and 2 from Vitens. The energy requirements are often mentioned in relation to the energy transition, so becoming more sustainable, using less energy and transitioning to the use of (mostly) green energy. As a helophyte filter has no energy requirements this is seen as a benefit. When looking at a more advanced filter with aeration some energy is needed, but this is still much lower than the energy requirements of the RO system. In addition to higher CO2 emissions and energy requirements, the RO variant also produces more brine that needs to be discharged. This needs to be transported to the Rhine or another large waterbody. When it is discharged on a small water body like the Zijdewetering, the highly chemical brine with all the residue from the filtration can have damaging effects on the aquatic ecosystems (C. Petri, pers. com., May 2022).

All of the above-mentioned aspects of nitrogen, phosphorus, CO2 and energy requirements are related to the aspect of sustainability. As explained in Chapter 4.1, both Vitens and WsVV are aiming to become more sustainable and include this in their projects. The project of the quickscan in Ede is also promoted as a sustainable project that can help reach circularity (M. van der Kamp et al., 2021). Therefore it is interesting that 9 interviewees mentioned sustainability but only 5 interviewees specifically mentioned sustainability in relation to the waterharmonica. Nature-based solutions like waterharmonicas are often more sustainable due to the lower emissions and energy requirements (Maes & Jacobs, 2017). However, only 5 interviewees directly mentioned this as a beneficial value. Furthermore, some interviewees mentioned sustainability very often and related everything to sustainability and circularity, while other interviewees only briefly indicated it and mainly mentioned other aspects. From WsVV especially the strategic advisor and treatment expert that were also involved in the initiation of the quickscan Ede stressed the importance of sustainability and circularity.

Productional aspects

	WsVV		
Production			

A waterharmonica can also be used commercially. For example, Aqualân in Grou is used to grow certain fish species. This aspect seems to be less important for the interviewees of the quickscan Ede as it was only mentioned by a few actors and was not included in the meetings I joined nor was it mentioned in the final report. The interviewees of WsVV that did mention it either mentioned it concerning the AquaFarm ideas of cultivation in different steps of the treatment process or on a large scale production system. In 3 of the interviews, it was directly mentioned to harvest and sell the plants growing in the waterharmonica. When harvesting the plants, most of the interviewees didn't seem too enthusiastic or deem it realistically that the plants can be used for other purposes due to contamination by the effluent. Furthermore, it is still a relatively small area so it will probably not be of sufficient quantity to be commercially produced. In waterharmonica Soerendonk some of the reed from the waterharmonica was used to make a table but other than that it is not used at the moment nor was it used in the other systems.

4.2.4 Landscape values quickscan Ede

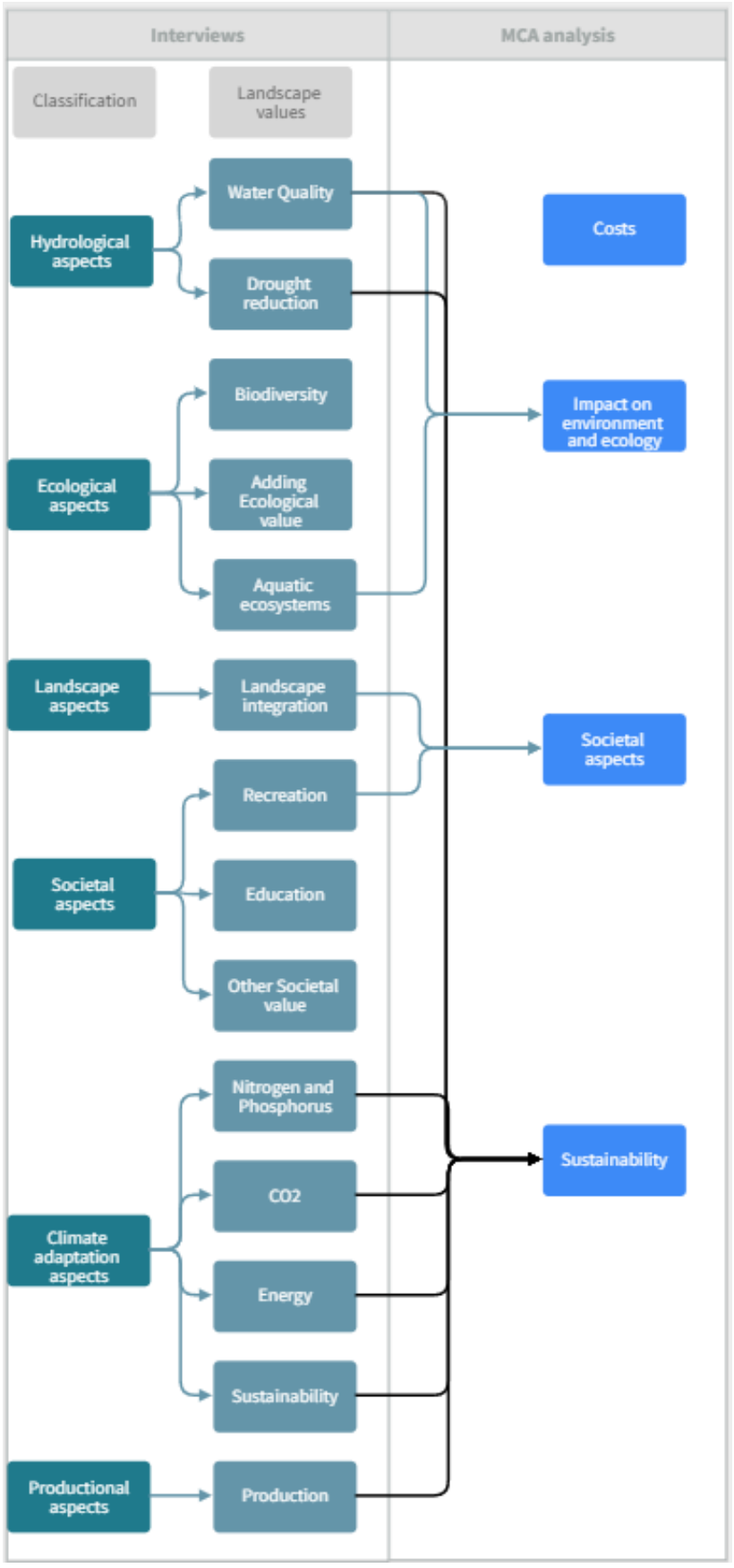

Figure 7: Landscape values included in MCA quickscan Ede

In the final report of the quickscan done in Ede, multiple landscape values were also included. Figure 7 shows the landscape values as mentioned by the interviewees related to the criteria mentioned in the multicriteria analysis of the quickscan. The main focus of the report and the MCA was the water quality delivered by the different treatment systems. This aspect was included in both the sustainability and the environmental impact criteria and in both of these criteria, the variant with RO appeared more promising. This is since RO can guarantee a higher water quality than NF filtration with a helophyte filter (M. van der Kamp et al., 2021).

The ecological value is mainly based on changes in the water flow of the surface and groundwater and the changes in water quality due to the water treatment. Hereby the main difference in variants is caused by the different locations as in Gelderse Vallei it will have more impact than in Edese bos. Furthermore, the impact of water quality on the environment is included and as RO can guarantee a higher water quality this variant gets a higher score (Interview project leader WB). Other ecological impacts are not included and the helophyte filter is not specifically mentioned. The added biodiversity and the higher ecological value of the water due to the helophyte filter are not included in the report of the quickscan. Overall the RO and NF with helophyte variants scored equal on the ecological value and the only distinction was made in the infiltration location

Societal value is included in the report of the quickscan but this is mainly based on the general view on using treated effluent as drinking water or infiltration water and whether people would accept this. In the societal value, the helophyte filter is specifically included in the MCA. As the helophyte filter will be visible it is mentioned that it will have some experience and imaging value for the local residents. However, there are also some negative social aspects mentioned. Due to the size of the filter, (agricultural) land will have to be bought. The aspect of land requirements was given a higher value in the MCA than possible recreational value. Due to this, the RO variant scored higher on societal value.

In the sustainability criterium of the MCA, the landscape values of water quality and production and the climate adaptation aspects were included. These landscape values are indicators of the sustainability value of the overall system and the produced products. In the case of a helophyte filter, biomass is produced so this is included in the score. The water quality produced by the RO filtration system is higher than that of the NF variant, so the value of the product is also higher. Also, when reusing it as drinkwater, less additional treatment needs to be done which leads to a higher sustainability score (Interview project manager WB). The research showed that the CO2 emissions of the RO variant were about 2 times higher than the CO2 emissions of the NF variant with a helophyte filter and in the MKI score RO also scored about 2 times higher due to the high energy requirements. However, the MKI score was not included in the final MCA analysis and due to the higher score on the sustainability of water quality, the RO and NF variant with helophyte filter got an equal score on the sustainability aspect.

4.3 Verification of results with related projects

To verify the results gathered for the quickscan in Ede and compare them to other situations, other experts have been interviewed from waterboards Aa en Maas, Brabantse Delta and de Dommel. In Aa en Maas plans are made for a waterharmonica in Aarle-Rixtel but this has not been constructed yet. In Brabantse Delta waterharmonica Nieuw-Vossemeer was opened in 2020. Waterboard de Dommel currently has 5 active waterharmonicas. Furthermore, other experts have been interviewed with knowledge of waterharmonica systems and/or related decision-making processes within WsVV.

4.3.1 Waterharmonica projects

As main motivation for the waterharmonicas, all 3 waterboards mentioned the added ecological value to the effluent and with that the positive effects on the downstream aquatic ecosystems. Near Helmond and Aarle-Rixtel, the waterboard Aa and Maas is making plans to construct a waterharmonica that will improve the ecological value of the effluent as it currently does not meet the WFD goals and has harmful effects on the aquatic ecosystems downstream (interview process supervisor WsAM). For the waterharmonicas of WsDD and WsBD, the added ecological value to the effluent was also the main motivation for constructing the system.

In multiple waterharmonicas of de Dommel, an increase in nature development is shown. For instance, in Sint-Oedenrode the area is now a place with many dragonfly species and different (water)birds. Also protected species like the kingfisher and the yellow wagtail have been spotted (Fleskens et al., 2016). In waterharmonica Nieuw-Vossemeer of Waterboard Brabantse Delta many waterbirds are spotted in the system. Also, a place for kingfishers and bats was made, but these have not been spotted yet by the caretaker (Interview engineer maintenance department WsBD). In the waterharmonica itself, the waterboard tries to increase nature development with a system of mowing in which they spare part of the grass and let it dry first before taking it away. Also, in spring there are many flowers that attract insects and make the system more attractive for people passing by (Interview engineer maintenance department WsBD). Waterboard Brabantse Delta plans to do a yearly ecological value assessment to see how the macrofauna and water plants develop, but as this is the first year of this waterharmonica no conclusions can be drawn from this yet (Interview ecologist WsBD).

Aside from the ecological value of a waterharmonica, Waterboard de Dommel tries to include other added goals. For instance, all 5 of their waterharmonicas are connected to walking routes so they have recreational value. Also, in multiple systems signs are placed that explain what is happening in the waterharmonica and the treatment plant (Interview advisor water quality WsDD). In waterharmonica Nieuw Vossemeer a cycling route is next to the waterharmonica with a viewing point over the system. Plans are made to place an educational sign on this viewing point, however, this has not been placed yet (interview engineer WsBD). For all 3 waterboards, it was mentioned as important to have the waterharmonica represent a natural system with natural shapes so it is integrated into the landscape. This makes it nicer for recreation and it helps increase biodiversity and restore natural value.

The treatment value of a waterharmonica was mentioned by the interviewees as an added benefit but not as the main reason for the construction. In Nieuw-Vossemeer and the waterharmonicas of de Dommel, the water quality is not specifically monitored. Some values are measured, for example in Nieuw-Vossemeer monthly samples are taken in 2021 for Chemical Oxygen Demand, Nitrogen, Phosphorus and E.coli. These results show that the waterharmonica provides efficient added treatment with average removal rates of 71% for nitrogen and 99,6% for E.coli (WS Brabantse Delta, 2021). Measurements of Waterboard de Dommel also showed a decrease in E.coli, metals and nutriënts along the waterharmonica. And measurements of waterharmonica Soerendonk showed that the oxygen flow is restored with a more natural day and night rhythm (Fleskens et al., 2016).

The interviewed process supervisor of WsAM was not very enthusiastic about the treatment efficiency of the waterharmonica due to a lack of research and data. He mentioned that to reach the WFD goals we shouldn't expect too much of the additional treatment of a waterharmonica. As this will not be the purpose of this waterharmonica, it is less of a problem compared to the Ede case.

All interviewees mentioned that the size of a waterharmonica can be an issue. However, for the waterharmonica Nieuw-Vossemeer, the waterharmonicas placed by waterboard de Dommel and the possible waterharmonica in Aarle-Rixtel, some land was available and the waterharmonica was adapted to the available space. Multiple interviewees also mentioned that these WWTPs were chosen due to the available space nearby the treatment plant.

In the interviews of the quickscan in Ede, maintenance was mentioned as a difficult aspect. These were mainly related to stories of the waterharmonica de Groote Beerze. A policy advisor of WsVV mentioned: *"Their maintenance department is quite bummed cause it costs a lot of money to prune, to mow and to dispose of the wood and that sort of things because you are just a sort of wild forest. So I don't think they would do that again soon."* A water quality advisor from WsDD mentioned that indeed there were some difficulties with maintenance, however, these were solved now. It was difficult to access the different departments of the waterharmonica and there was some sludge accumulating. As it took too long and was too difficult to maintain, the maintenance department sometimes skipped the waterharmonica. Eventually, the waterboard decided to redesign and reconstruct the entire waterharmonica so it is easier to access and maintain (Interview advisor water quality WsDD). In WsBD, the accessibility of the waterharmonica for maintenance was also an issue. The last pond was difficult to reach due to some trees and a small grass way. Therefore, WsBD decided to remove the trees so it would be better reachable For a new waterharmonica, the caretaker of Nieuw-Vossemeer mentioned that he had some suggestions that would make it even better to maintain (Interview caretaker WsBD).

Both waterboard de Dommel and waterboard Brabantse Delta mentioned difficulties with contractors that didn't know how to maintain a waterharmonica. Maintenance of a waterharmonica requires slightly different expertise than a 'normal' waterway. This is since the waterways are smaller, less deep and the plants need to be able to grow and keep functioning as a treatment system (interview caretaker WsBD). In waterharmonica Nieuw-Vossemeer, a contractor removed too much of the reed so there were some empty places in the waterways. Also, he removed them with roots and all instead of cutting them down. This led to a reduced functioning of the treatment system (Interview caretaker WsBD). The interviewee of waterboard de Dommel mentioned difficulties with a contractor that mowed too much of the reed so the stems were too low, water got in and they started rotting.

Both waterboards mentioned that it takes time to figure out how to best maintain the system. Hereby they mentioned that it could be beneficial if more communication took place between the different waterboards so they could exchange experiences, knowledge and ideas. The interviewed water quality advisor of waterboard de Dommel mentioned that he had tried to organise workshops for this but that it didn't work out. Some interviewees of Brabantse Delta indicated that they also would be interested in more communication and knowledge exchange.

Lastly, interviewees from both waterboard de Dommel, Brabantse Delta and Aa en Maas mentioned the importance of including multiple actors from the start of a project. These actors can be other organisations and individuals with an interest in the project. Waterboard Aa en Maas decided to include even more parties and actors at the start of the project by using a *gebiedsatelier* in which multiple parties are involved and can help in the design and decision-making processes. A *gebiedsatelier* can help increase the support base and helps the waterharmonica to tackle multiple goals at once (Interview process supervisor WsAM).

Also within the waterboard it is important to include multiple parties in the design and construction phase. As mentioned before, maintenance can be an issue so including the maintenance department from the start can help solve problems along the way. Furthermore, the water quality advisor of de Dommel mentioned that when everyone is aware of the functioning and efficiency of a waterharmonica, this not only increases the support base but it also helps in communication and the operation of a waterharmonica (Interview advisor water quality WsDD).

4.3.2 Perspective on waterharmonicas

In addition to the interviewees from Waterboard Vallei and Veluwe, Vitens, and the waterboards Aa en Maas, Brabantse Delta en de Dommel, some other experts were interviewed on the topic of waterharmonicas in the Netherlands. These interviews show that there can be many different connotations when using the word "waterharmonica". From the interviews of all actors and parties, a distinction can be made between those who are convinced of the functioning of a waterharmonica and those who are hesitant or have no faith in the system. This distinction is mainly due to the knowledge base and the framing of a waterharmonica. Those who are not convinced are often referring to the lack of research and that it is not proven yet how it specifically functions.

One of the wetland experts mentioned: "*There are many opinions on the system but hardly any data. And then I mean scientifically proven and published data. So data that is statistically tested and reliable. Now it is often not checked and just propagated how amazing it is."* This lack of convincement can also be related to the negative connotation around the name waterharmonica as mentioned before. This is since most of the people who were not positive about a waterharmonica did mention that helophyte filters are effective. Even the actors who specifically mentioned that a waterharmonica does not work and we should not construct it were enthusiastic about helophyte filters and other natural treatment systems. The actors that were convinced of the functioning of a waterharmonica were often enthusiastic about the sustainability of the system and the addition of ecological value to the water. For the existing waterharmonicas, this was mentioned as more important than the water treatment, so the lack of knowledge on treatment efficiency was less of an issue.

Since the original concept of a waterharmonica was created by Theo Claassen en Ruud Kampf in 1996, many developments have been made in technology and research. These new ideas could be applied to the original waterharmonica concept to create a new system with better water treatment capabilities and maybe even more added values. For example, a combination of a vertical filter and a free surface filter could add additional treatment while maintaining the landscape values as mentioned by the interviewees (Interview expert constructed wetland WUR). Furthermore, some new concepts like AquaFarm are researched in which the effluent is further treated by organisms and plants that could be used for productional purposes as well. Possibly the bacteria, organisms and plants used in AquaFarm could retrieve certain components of the effluent. This is however still in the research phase (Interview wetland expert AquaFarm).

The necessity to improve the water treatment depends on the goal of the waterharmonica. If it is constructed as a water buffer, a nice natural area or to improve the ecological quality of the effluent, a better chemical water quality is more of an added benefit. In this case, an improved water treatment system is not necessary and the focus of the waterharmonica can be on other aspects. Hereby the distinction between seeing water treatment as the main function or as an added value is important. In the case of the Quickscan Ede, water treatment is a main requirement and therefore combinations of treatments or other types of (aerated) helophyte filters could be used. In de Dommel, Brabantse Delta and Aa en Maas this is not a necessity as water quality is an added value of the waterharmonica.

5. Discussion

5.1 Discussion of data collection and analysis

Validation of research methods

For this thesis, policy documents were researched, meetings observed and interviews conducted. With these different research methods, some biases can occur which can influence the outcome of the data analysis. This can be due to the documents used but also the number of interviews and observed meetings and how these were observed and conducted.

In qualitative research and especially in interviews, there can be bias from both the interviewee and the interviewer. The interviewee might give answers based on what he/she thinks is a socially acceptable answer which is not necessarily the interviewee's own opinion. The interviewer can form leading questions which can lead to the expected answers (Steinar, 1992). In this thesis research, the interviewees might have been inclined to give answers based on the organisational and national guidelines. Especially sustainability and circularity aspects might have been more prominent due to this. Some interviewees were also more careful in answering certain questions or tried to remain neutral by mentioning both positive and negative aspects. Other interviewees did make more statements based on their perspectives and ideas.

I tried to avoid leading the interviews by making an interview guide with more open questions that would allow the interviewee to make their own interpretation. However, sometimes probing questions or additional explanation was needed to allow for a conversation. For all interviews, the interview questions were based on the same 2 interview guides, see Annex II and III. The specific questions were however adapted based on the interviewee, their expertise and the interview itself. During the interview, some questions were already answered or could be derived from context. Also, sometimes probing questions were necessary based on the direction of the interview. Due to these aspects, not all interviewees were asked exactly the same questions. Furthermore, throughout the interviewing process, some additional questions were added to the interview guide as some new topics arose. These questions were not asked to all the interviewees as they were added later.

The interviewees were found using the snowball sampling method. After every interview, I asked the interviewee whether he/she could refer me to some additional people to include in my research. This method had its benefits as it allowed for easy access to other actors and resources since there was no clear overview of actors to include. Furthermore, when mailing new possible interviewees I mentioned the actor who referred me. This could have given the new interviewee more trust in the validity of my research and they might have been more inclined to talk to me (Noy, 2008). The initial entrance to the interviewees and the meetings went via one of the actors of WsVV. This allowed me to attend the meetings of the quickscan and gave me access to many actors involved in the process. It could however also have influenced the independence of my research as the other actors could have had certain expectations of my research and could be more or less inclined to be included in my research and it could have influenced how they answered my questions.

As interviewer, I could also have become a topic of discussion among the network of interviewees. As they had contact with each other, they might have discussed me and the topic of my research and therefore interviewees could already have had a bias on the topic before the interview was conducted (Noy, 2008). During the interviews I didn't notice whether this had occurred or not, however, one of the possible interviewees did mention that when discussing my research with another already interviewed actor he concluded that he wasn't the best person for me to interview as he thought he couldn't provide me with the knowledge I needed.

Lastly, the snowball method could have given a biased image as people refer to others that are in their social network within the organisation. Therefore the social networks of the interviewees and their heterogeneity influence the types of results I'll get (Biernacki & Waldorf, 1981). As the sample group of people involved with the quickscan in Ede was not too big, the chain effect was a bit less prominent. Also, some interviewees specifically referred to people they knew who had a different opinion so I could get all sides of the story.

Validation of interviews and observations

Due to time limitations and in some cases a lack of response there was a limited amount of interviewees included in this research. From Vitens preferably I would have included more actors to get a better picture of their ideas as now only 3 were included. Furthermore, the initiator of the project on behalf of Vitens was absent unfortunately and could not be included in the interviews while this could have given many insights into Vitens' motivation and expectations of the quickscan. The other interviewees from Vitens did however also give insights into these aspects.

From Witteveen + Bos, only 2 actors were included in this research, one directly involved in the quickscan and one actor who gave more insights into the use and criteria of landscape values. Additional interviewees could have given a better picture however due to time constraints this was difficult. Especially an involved ecologist of Witteveen + Bos would have been nice to include but this was not possible due to absence and a short time frame.

Similar to Vitens and Witteveen + Bos, for the other case studies more interviewees would have given a better overview of the different perspectives. From Nieuw-Vossemeer, multiple interviewees from different functions were included, this gave a nice overview of the interactions. However, from waterboard de Dommel and waterboard Aa en Maas only 1 interviewee was included. Especially someone from the maintenance department of de Dommel could have helped gain a better understanding of the maintenance difficulties concerning the waterharmonicas. Luckily someone from the maintenance department of Brabantse Delta who was in charge of Nieuw-Vossemeer could give me more insights into his experiences of maintaining a waterharmonica.

In addition to the interviews, some meetings were observed. However, these were limited as I wasn't officially part of the quickscan and therefore could only join the meetings that my supervisor from WsVV (Coert Petri) invited me to. There were multiple other meetings and discussions that I wasn't able to join and therefore cannot include in this research. During the observed meetings, I tried to maintain an overview of the different landscape values mentioned. However, it was sometimes difficult to keep track of who mentioned which aspects and in which context. Therefore I chose not to link the landscape values in the meetings to a specific person. This could have been useful to check the link between what people said in interviews and what they mentioned in meetings and whether this corresponded or not. As I only joined a limited amount of meetings and it was difficult to keep track of what was mentioned I decided that this would not give a complete picture and I decided to only show what the general opinion was on that specific landscape value.

Interpretation of interview data

When conducting the interviews, I asked all interviewees whether it was okay to record the interview and use the data for my thesis research. I did try to maintain some anonymity of the interviewees in their statements and perspectives. This since I wanted to protect the interviewees and allow them to speak freely. It was however sometimes important to place the responses and statements into the perspective of their function and organisation. As stated by the disclaimer at the start of this report, the content of this thesis is based on my research and interpretation of the interviews and meetings.

My personal bias toward waterharmonicas could have influenced the data collection and analysis. As I am quite positive about nature-based solutions and already had an indication of certain landscape values this could have led the interviews in certain directions. During the interview, I tried to remain neutral and ask open questions that the interviewees could interpret themselves. However, with some probing questions and with my own responses and non-verbal communication I could have influenced the answers of the interviewees. A more structured interview could have reduced the influence of me as interviewee, however, this would not have allowed for the open answers and interpretations of the interviewees. During the interview process, I also gained more insights into the processes around a waterharmonica and how this is framed and which values are involved and to what extent. This knowledge made me more critical of the waterharmonica system and how it is used. But it also helped me realise that the motivation behind constructing a waterharmonica mostly determines its functions and design. With my own personal view and becoming more critical towards the functioning of a waterharmonica, I could have influenced the interviewees and their answers.

Aside from the interviews, in the analysis phase, my own bias could have also influenced the results and conclusion of this report. My personal knowledge and interpretations could have led to the signalling of certain code words while others remained more in the background. The coding was based on an interpretative analysis in which I signalled certain words and gave my own interpretation of how they viewed the landscape value. I tried to give an objective interpretation of the results and when the results were not clearly positive or negative I gave them a neutral value. A more objective coding method with pre-made signalling words could have removed the risk for personal bias affecting the research, however, this also could have led to less accuracy as open questions were asked and the interviewees gave different interpretations of the landscape values.

Framing of a waterharmonica

There appears to be some negative connotation around the name waterharmonicas briefly explained in Chapter 4.3.2 framing of the waterharmonica. While interviewing actors about the quickscan in Ede, I used the name helophyte filter as this name was used in the report and communication over the quickscan, using a different name could have led to confusion among the interviewees. However, some interviewees came up with the name waterharmonica themselves. Often this was mentioned as an example of what the helophyte filter could look like. This was often combined with the words "*It is quite a strange world of those waterharmonica people"*. It appeared that interviewees were often more hesitant with the use of the word 'waterharmonica' and referred to helophyte filters instead. This could be related to the connotation of the word and those who use it instead of the actual functioning of the system itself.

Due to the different connotations around the term waterharmonica, using this name instead of helophyte filter could have given a different result. With my current knowledge, I cannot claim to know to what extent the use of the name made a difference in my research. I expect that it had an influence and that using the name waterharmonica would have led to more mentioning of the ecological values and less of water quality. This since the term waterharmonica is a broader concept more related to ecological and landscape values while the term helophyte filter is a more technical name and can imply more of a technical treatment system. The different connotations around the name waterharmonica could have also led to different responses and maybe a more negative view of the system itself. However, these claims cannot be underpinned by my current knowledge and research. Also, it is unclear whether the interviewees who didn't mention the term waterharmonica themselves refrained from using it due to negative connotations or simply because they have never heard the term waterharmonica before and have never worked with the system.

5.2 Discussion of results

Landscape values mentioned in interviews and literature

In Chapter 4.2.3 multiple landscape values are shown that were mentioned by the interviewees. These are values that the actors expect a waterharmonica system can provide. This is however not necessarily similar to the values of the waterharmonica mentioned in literature and can also be based on their personal expectations. Also, it might not include all values a waterharmonica can provide. Research of the STOWA on waterharmonicas showed that they can provide the following functions:

Table 4: Overview of different functions of a waterharmonica (translated from Schomaker et al., 2005)

Production functions	**Regulation functions**	**Information functions**
Reuse of compounds	Water treatment	Gene reservoir
Nature development	Water storage/buffer	Education
Production of energy crops	Ecological stabilisation	Research
Wood production	Protection of communities	Social value (recreation, experience)
Food production		
Water extraction		
Landscape		

Of the production functions of a waterharmonica, the aspects of the production of wood, food and energy crops were only briefly mentioned by 3 interviewees and not in much detail. This is interesting as one of the arguments against a waterharmonica was that it takes up space that could also be used for agriculture. According to the production functions in Table 4, the waterharmonica itself can function as a productive area which can compensate for the land lost. This is also related to the AquaFarm project mentioned in Chapter 4.3.2 in which these aspects and the reuse of compounds are researched. The production functions of nature development and landscape were mentioned as important in the interviews. In the existing waterharmonicas of WsDD and WsBD, these are also included as the aim is to integrate the system into the landscape.

When reviewing the regulatory functions of a waterharmonica, water treatment is of main importance for the quickscan in Ede. The aspect of ecological stabilisation and protection of the aquatic ecosystems are also mentioned in the interviews. These were also indicated as most important for the other waterharmonicas. The aspect of water storage and water buffering is not mentioned in any of the interviews and meetings. This is interesting as in literature it is often mentioned as one of the main features of a waterharmonica (Fleskens et al., 2016; Schomaker et al., 2005; van den Boomen & Kampf, 2013). Especially considering the drought issues in the Ede case, and the overflow problems with extreme rainfall as mentioned by multiple interviewees, this could be an interesting function of the waterharmonica. It was however not mentioned in the interviews as landscape value. In the final report, the water buffering capacities are mentioned but this is in case of a malfunctioning of the other treatment systems that the waterharmonica gives a larger buffer time.

In the interviews and meetings, water quality was mentioned as an important aspect but it appeared unclear how much treatment a waterharmonica could provide. The main reason was the lack of research and the possible seasonal variation. Much research is done on the functioning of helophyte filters (Chen et al., 2009; Ghimire et al., 2012; Nanninga, 2011; Ouellet-Plamondon et al., 2006) for the waterharmonica specifically less research is done. Only STOWA did some research and published some reports. In a report of waterboard de Dommel, some findings on water quality are also mentioned and show promising results. For a few interviewees, this was mentioned as ‘non-scientific’ research and they would like to see more actual proven data. This data can be found when researching helophyte filters and other wetland systems but not specifically for waterharmonicas.

For water treatment, the inflowing water quality can make a difference. Usually, waterharmonicas directly treat the effluent from the WWTP which still contains many particles that need to be removed. When the waterharmonica cannot provide much treatment, this water will not be of sufficient chemical quality to be used for infiltration (C. Petri, pers. com., May 2022). For the Ede case, the effluent is first treated by Nanofiltration before it is discharged onto the helophyte filter. The effluent will already be much cleaner, so only a bit of additional treatment is required of the filter. Therefore in the Ede case, a waterharmonica could be sufficient for the last treatment step (C. Petri, pers. com., May 2022).

One of the often mentioned aspects in the interviews was the possibility to integrate the waterharmonica into the landscape by using more organic and natural shapes and placing it in a location where it is naturally more wet so the system represents the historical landscape. Nature development and reducing the impact on the ecosystems are included in the visions of both WsVV and Vitens. Landscape integration of the waterharmonica can help reach these goals. However, for infiltration purposes, a naturally more dry area with sandy soil is much more efficient as it can already easily infiltrate on-side. Therefore it will save costs and energy to place the waterharmonica in a naturally more dry sandy soil as it infiltrates much faster than in a naturally wetter area (C. Petri, pers. com., May 2022). When assessing the aesthetic, perceptual and experiential value of the waterharmonica, a naturally more wet area fits best as this better represents the culture-historical value of the area and the wetland system (interview landscape heritage expert WB)

Table 4 also indicates many informational functions provided by the waterharmonica. Of these functions, the educational and social aspects are mentioned by the interviewees. The research aspect and possibilities for a gene reservoir were not mentioned. Especially the research aspect could be interesting as many interviewees indicated that too little research was done concerning the waterharmonica. Interviewees from waterboard de Dommel and Brabantse Delta also indicated that they would like to measure more at their waterharmonicas but that this was difficult to get funded.

In the interviews of the quickscan Ede, some additional climate adaptation aspects were mentioned that were not included in the STOWA reports. These mainly concerned the options to close the water cycle and provide a sustainable solution with less energy use and CO2 emissions than more engineered treatment systems. Furthermore, the added biodiversity and specifically adding ecological value to the water were not mentioned in this table but they were mentioned at a later stage of the report as motivation for the construction of certain waterharmonica systems

Landscape values or landscape functions

In Chapter 2, a quality or value of a landscape is divined as anything that is considered a valuable or important aspect by an actor (Stephenson, 2010). This is closely related to the functions of the landscape as these are the goods and services provided by the landscape. It is difficult to determine when something is only a landscape function and when it is also a landscape value. For the case in Ede, water treatment was seen as an aspect that was necessary for the water to meet the quality demands. Therefore, it can be argued that water treatment was more a function than a value of the system. While in the other case studies water treatment was not necessarily the goal of the system and therefore more seen as an added value. For the waterharmonicas in WsBD and WsDD, the 'ecologising' function of the waterharmonica was the main goal of the system while in the Ede case this was less of a priority. Therefore in this case it can be argued that for these waterharmonicas the main function was to improve the ecological value of the water instead of a main value. While in the Ede case these aspects were not the main function of the system and could therefore be more of an added landscape value.

According to Penning-Rowsell (2007), landscape values by themselves are undefinable as they consist of many different aesthetic, use and appearance values. Therefore he claims that to make this distinction we need to identify what people believe are the facets of the landscape rather than what experts and researchers say it is (Penning-Rowsell, 2007). In this research, the interviewees mentioned various functions of the landscape that they deemed important. As these are the aspects the interviewees came up with as important and valued aspects, these aspects could be seen as landscape values and not just landscape functions.

Future of waterharmonicas

This thesis research has shown that a waterharmonica can have various values and functions as a landscape element. Constructing a waterharmonica can not only help achieve legislation and policies on different levels, like the WFD and the NOVI, but it can also provide many social, environmental and ecological values, see Chapter 4.2. Even though a waterharmonica can provide all these different functions and can help in achieving many goals, it is still not widely implemented around the Netherlands. Also outside of the Netherlands natural treatment systems are more often used but the term waterharmonica has not yet expanded abroad (interview water technologist TAUW).

There can be multiple possible explanations for why the concept of a waterharmonica is not commonly used around the Netherlands and abroad. An explanation can, for example, come from the connotation around the term waterharmonica and the people who are associated with the term as explained in Chapter 4.3.6. When different actors and organisations have a negative association with the term waterharmonica, they will be less inclined to consider the usage of the system. Another possible explanation can be found in the motivation to construct a waterharmonica. For the WWTPs of WsBD, WSDD and WsAM, the effluent was immediately discharged onto a small water body. Constructing a waterharmonica here can have a significant impact on the ecological water quality downstream and therefore the aquatic ecosystems as these are largely dependent on the effluent. Other WWTPs often discharge on larger water bodies where the lower ecological quality of the effluent has less impact and therefore there is less direct need to construct a waterharmonica (interview water technologist TAUW). Lastly, the concerns expressed in the Ede case around the treatment efficiency of the waterharmonica and therefore the chemical water quality delivered by the system can also play a role in the decision making processes of other cases. Possibly certain waterharmonicas were not constructed due to the lack of (scientific) research done on water treatment of waterharmonicas.

6. Recommendations

During the interview process, the interviewees from waterboards de Dommel and Aa and Maas gave some insights into the difficulties when constructing a waterharmonica. Furthermore, some experts also gave tips on the design and construction process to optimise the functioning of the system. For the case in Ede, various interviewees gave recommendations for other options to improve the effluent quality or to reuse the water for different purposes. This chapter gives an overview of the different recommendations mentioned in the interviews and some suggestions for further research.

Actor involvement

The waterharmonica system can have multiple landscape functions. These functions can help reach different goals, not only those of the waterboard but also those of other actors and organisations. With a *gebiedsatelier,* these actors and organisations can get involved from the start. By collaborating, the support base will increase, costs and responsibilities can be shared and multiple goals can be reached.

When looking at actor involvement, it is not only important to look into other stakeholders that can be included in the process, but also to involve different departments and actors from within the organisation. When constructing a waterharmonica, including the maintenance department from an early stage can help avoid maintenance issues later on. Furthermore, it was recommended by a water quality advisor of WsDD to make sure all involved actors and parties understand how the waterharmonica system functions and what it can contribute. This helps in the understanding of the waterharmonica system, why it was placed, and what is needed for it to keep functioning.

Designing and constructing a waterharmonica

As briefly explained in Chapter 4.2.1 when designing and constructing a waterharmonica as an effluent treatment system, the used soil and plant types can help improve the treatment efficiency of the system. Depending on the soil type, the soil can bind phosphate and with that remove it from the system. For this a soil structure is best that is not too fine as then it can get clogged easily, for example, sand or gravel can be used for a constructed wetland (interview constructed wetland expert WUR). However, for all soil types at some point, the soil will be saturated with phosphate and new soil will need to be placed to maintain the treatment efficiency (interview water technologist Tauw).

For the plants grown in the waterharmonica system, it is important to choose plants that can stand with their roots in the water. Normal reed can be used for this, the benefit of reed is also that they create oxygen-rich environments around the roots which leads to additional aerobic treatment (interview constructed wetland expert WUR). For the maintenance of the plants, how, when and how often the plants are mowed can make a difference. In the waterharmonicas of WsBD and WsDD, different contractors made mistakes in this which damaged the growth of the plants. In waterharmonica Nieuw-Vossemeer, too much of the reed was taken away causing gaps in the waterways and with that reduced functioning of the filter (interview caretaker WsDD). In the waterharmonicas of WsDD, the reed was mown too low so water got into the stems and they started rotting. Therefore, it is important to look into the specific plants used and how these can be maintained to optimise their functioning. When and how the plants are mowed can influence their growth and functioning.

To optimise the system as a whole, it can be beneficial to combine a vertical filter with a free water surface filter so the benefits of both systems are combined and it both treats the water more efficiently and has ecological and social value (interview constructed wetland expert WUR). To improve the landscape integration of the system, the waterharmonica can best be placed somewhere it fits the culture-historical landscape. As a waterharmonica is a swamp-like system, a naturally more wet area can be better suited than a dry sandy soil (interview landscape expert WB)

Alternative suggestions

The water from the water factory can also be used for other options like recharge for nearby brooks or as irrigation water for agriculture or other businesses. So less groundwater will be used and therefore indirectly more water will be available for Vitens. Furthermore, an often mentioned recommendation in the interviews was to focus on the source flows instead of the end-of-pipe solutions. For example, removing the rainwater from the sewage pipes will reduce the water flows to the WWTP causing fewer overflows. The rainwater is clean so does not have to be treated and can immediately be infiltrated with the help of Wadis or other infiltration pits.

To improve the WWTP in Ede, you can also opt for other technologies like a BODAC filter, a sand filter, or ultrafiltration. Furthermore, when looking at the ecological quality of the water for the Ede case, a waterharmonica can also be placed behind other treatment systems. Therefore, it can also be placed behind the RO system to improve the ecological and environmental value of the reclaimed water.

Recommendations further research

This thesis research showed that for many actors it is not significantly proven to what extent a waterharmonica can provide treatment to the effluent. There is much research done or currently being done to establish the treatment efficiency of a helophyte filter, however, this is hardly done for the treatment capacity of the waterharmonica. This knowledge gap allows for speculation on the research capacity of the system and in the Ede case, it could be a reason not to construct a waterharmonica. This knowledge gap can easily be solved by monitoring the chemical quality of the influent and effluent of a waterharmonica as there are several already used in the Netherlands. Solving this knowledge gap will allow cases like the quickscan in Ede to better choose which system delivers the required water quality.

This research has established the landscape values of different individual actors and those that are included in various policies, visions and regulations within the policy landscape. However, policies and visions do not necessarily indicate the extent to which a value is included in the eventual decision-making process. During the interviews, various interviewees indicated what they expected would be important for the board, but this is also based on their expectations and interpretations. To fully understand the decision-making processes, it is important to also establish the landscape values perceived by the different boards and to see how this is taken into account in the eventual decision. This was however not possible for this thesis research.

Lastly, as mentioned in the discussion of results, it is difficult to establish when something is a landscape value and when it is a landscape function. Further research could help distinguish the difference between those two and with that establish what values as mentioned by the interviewees are indeed aspects they value and which aspects are merely seen as a necessary function of the waterharmonica system.

7. Conclusion

The goal of this thesis is to analyse the interactions between the actors and organisations on different levels. Hereby the different landscape values of the different actors, organisations and policies are established to assess how these values influence the decision-making process of waterharmonicas. At the start of this thesis, the following main research question was established:

> *How is the decision-making process of waterharmonicas in the Netherlands influenced by landscape values as perceived by the different actors and organisations?*

This research showed that on all policy levels, the aspects of sustainability, nature inclusivity and circularity are seen as important and are included in various policies, visions and projects. For the waterharmonica as a nature-based solution and as a natural treatment system, different landscape aspects are valued by different actors. In the Ede case, water treatment is seen as most important as the water has to be of sufficient quality to be infiltrated and indirectly used for drinking water. Other landscape values like biodiversity, recreation and possibilities for landscape integration are also mentioned as interesting added benefits. For the waterharmonicas of WsDD, WsAM and WsBD, the main goal is to improve the ecological value of the water and with that reduce harm to the aquatic ecosystems. Other aspects like education, recreation and ecological value are also included in the design of the waterharmonica. The specific function of the waterharmonica determines which landscape values are included in the design and is influenced by the changes in policies, visions and regulations on all levels of the policy landscape.

Conclusion policy landscape

Changes in visions and policies on Global, EU, National, Organisational and individual level can influence the decision-making processes of projects like constructing a waterharmonica. On global level, agreements are made to reduce emissions, increase biodiversity and adapt to the changing climate. Also within the EU, more emphasis is put on circularity, sustainability and reducing the impact on the environment. This led to different policies and regulations like the Water Framework Directive and the Green Deal. The EU tries to reduce GHG emissions, make the transition towards green energy and safeguard Europe's water sources and other ecosystems. Both globally and in the EU, Nature-based Solutions like the waterharmonica are increasingly promoted as sustainable and promising climate adaptation and mitigation measures. Hereby, the most important values and functions of NbS are sustainability, promoting circularity, reducing emissions, helping in transitioning towards green energy, increasing biodiversity and having a positive or neutral effect on the ecosystems.

On national level, the NOVI is created to tackle challenges like climate change, circularity, energy transition and making systems future proof. Hereby nature inclusivity is also mentioned as an important aspect as it helps integrate natural and landscape values with other developments. Also within organisations, the global, EU and national policies need to be considered. For example, multiple waterboards need to improve the water quality to reach the WFD goals of the EU. Also, emissions need to be reduced and circularity and sustainability need to be included in projects to meet the national, EU and global goals. On individual level, the interviewees of WsVV and Vitens indicated that for them sustainability, circularity and making systems future proof were of high importance and they are trying to include these aspects in various projects like the project in Ede.

On all different levels of the policy landscape, the aspects of sustainability, circularity, nature inclusivity and making systems future proof were deemed important. Hereby nature-based solutions like the waterharmonica can help reach various goals by providing a sustainable and nature inclusive option.

Conclusion landscape values quickscan Ede

The policies and regulations as determined by different levels of the policy landscape influence the decisions made on organisational level. With the quickscan in Ede, Vitens and WsVV are exploring opportunities for a water factory that can help reduce drought issues, close the water cycle and improve the effluent quality. Hereby sustainability and circularity were mentioned as important motivational aspects for the quickscan.

The interviewees involved with the quickscan in Ede indicated that for them water quality was the most important aspect when considering a treatment system. The system needs to guarantee sufficient water quality and provide a safe water source that can be infiltrated and indirectly used as drinking water without environmental, ecological and legal consequences. RO seems to be preferred by the interviewees as this system can guarantee better water quality. However, NF with a helophyte filter is much more sustainable, has lower energy requirements and has less brine production. The sustainability aspect is mentioned by most interviewees, but they also indicate that the final decision will most likely be based on a cost assessment and the provided water quality of the treatment system.

When considering the variant with helophyte filter, other landscape values like societal value (recreation, education), ecological value (biodiversity, aquatic ecology), environmental value (CO2, nutrients, energy) and the possibility to integrate the filter into the landscape are often mentioned by the interviewees. They are however mentioned more as a side goal or added benefit while the main purpose of the filter is water treatment. These landscape values can be used to create a support base and include other stakeholders, but they should not harm the main function of the treatment system.

In the final report of the quickscan Ede, water quality is also mentioned as main aspect. Furthermore, societal values like the aesthetic value of the system and the loss of (agricultural) land due to the size of the filter are briefly mentioned. Sustainability aspects are also included, the variant with NF and helophyte filter has a significantly lower CO2 footprint and the filter can provide some biomass. However, due to the better water quality of the RO system, the environmental effect of this water is higher. Other landscape values of a helophyte filter are not specifically mentioned in the final report.

Overall, water treatment is seen as most important when choosing a treatment system. Other landscape values like recreation, education and biodiversity are seen as added benefits to create a support base and to tackle multiple goals at once. Sustainability is also deemed important by the interviewees, the quickscan and the policies and visions of the organisations. However, most interviewees still indicated that the final decision will be made on costs and water quality.

Conclusion verification of results with related projects

To verify the results found in the Ede case, three other case studies were researched of waterboards de Dommel, Aa en Maas and Brabantse Delta. In these cases, the main goal of the waterharmonica is to improve the ecological quality of the effluent so it has less harmful effects on the downstream aquatic ecosystems. Water treatment is not the main goal as is the case in Ede, but it is seen as more of an added benefit of the system and is not specifically monitored.

In the waterharmonicas of WsDD and WsBD, various landscape values were included in the design. Social value was created with education and recreation opportunities. Also, the waterharmonicas were designed to fit into the landscape and nature development is promoted with different mowing systems and by creating habitats for certain species. The issues with space requirements were less prominent as the waterboards adapted the design to the available space. This was more difficult for the Ede case as a certain space is required to provide the needed water treatment.

Interviews with experts on wetland systems and waterharmonicas showed that there are some different connotations around the word 'waterharmonica'. Some people indicated that the waterharmonica system does not function as a treatment system and only delivers some ecological value but that you shouldn't expect too much from it. Other actors were more enthusiastic about the functioning of the system as a landscape element. It seems that the word waterharmonica is more linked to landscape values like recreation and biodiversity while the word helophyte filter is more used for the technical treatment system.

Overall conclusion

To conclude, this research showed that landscape values can influence the decision-making processes as they help create a support base for the project and can help tackle multiple goals from multiple actors and organisations. Furthermore, the waterharmonica can help reach the policies and goals from different levels within the policy landscape. For example, improving the biological and chemical quality of the effluent can help reach the WFD goals of the EU for various water bodies. With changing visions on nature-based solutions, projects like water factories and waterharmonicas are considered more often. Hereby the possibility to sustainably tackle multiple goals at once helps create a support base and makes it easier for the project to succeed.

This research shows that even though many landscape values like education, recreation and ecological value are mentioned as important by the interviewees and are mentioned as important within the policy landscape, they are not necessarily the main aspect included in the final decision. According to multiple interviewees, the final decision of constructing a waterharmonica for the case in Ede will most likely be made on costs and water quality while the other aspects will be used to create a support base and promote the project as sustainable. Furthermore, the purpose of the waterharmonica also influences the design of the system and with that which landscape functions the system will have. In the Ede case, the main purpose of the system is to provide sufficient water quality for infiltration and indirectly for drinking water. Therefore other landscape values are less important and not necessarily included in the design. For the waterharmonicas of WsDD, WsBD and WsAM, the ecological value of the effluent was most important and with that other landscape values like social and environmental values were more included in the design and decision-making processes. The purpose of the waterharmonica and with that the specific values and functions of the systems are also influenced by the individual actors involved and which values they deem most important. When more actors are involved that value the ecological or social aspects, these aspects will be more prominent in the design of the system.

This research concludes that the global and national focus on sustainability, nature inclusivity and circularity makes it easier and more accepted to initiate projects like constructing a waterharmonica as they help reach various goals and regulations. The specific values of the constructed waterharmonica depend on the function for which the waterharmonica is constructed and the specific landscape aspects valued by the actors and organisations involved. Hereby the ecological, social and environmental values of recreation, education, ecologisation and integrating the system into the landscape are often valued while the valuation of water treatment depends on the function of the system. The aspect of a waterharmonica as a sustainable nature-based solution that helps achieve water circularity helps create a support base within and outside of the organisations and therefore provides an additional incentive to start or continue with such a project.

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Annex I: Overview of interviewees

Table 5: List of interviewees

Company	Function
	Groundwater maintenance and ecohydrology
	Policy advisor planning, chemical advisor treatment systems
	Senior policy advisor water chain and planning, treatment engineer
	Policy advisor planning Clean Water, water quality expert
	Strategic advisor
	Senior policy advisor water system
	Program manager implementation omgevingswet
WsVV	Landschape architect, gebiedsatelier meester
	Proces engineer drinking water treatment
	Ecologist
Vitens	Environment manager
	Project manager
Witteveen+Bos	Expert landscape and water heritage
	Expert in Wetland Restoration Ecology and Freshwater Ecology
	Postdoc Constructed wetlands vs. Micropollutants, AquaConnect
WUR	Head of Sustainable Water Management Programme within the Environmental Sciences group
TAUW	Water technologist
	Strategic advisor water quality
	Waterchain Engineer
	Senior Process Engineer
Brabantse	Senior Rural Engineer, maintenance department
Delta	Trainee Ecology and water quality
Aa en Maas	Process supervisor Water Management
De Dommel	Senior advisor Water Quality

Annex II: Interview guide case Ede

Doel: Het doel van deze case study is om te begrijpen hoe landschapswaarden het ontwerp en het beslissingsproces van een water harmonica beïnvloeden. Ik wil te weten komen wat de afwegingen zijn van de interviewee om voor een water harmonica te kiezen en of landschapswaarden hierbij een rol spelen. Verder wil ik begrijpen welke mogelijke landschapsfuncties van belang zijn voor de interviewee en waarom de interviewee deze waardeert. Als laatste wil ik te weten komen hoe deze afwegingen tot uitdrukking komen in het uiteindelijke besluit over het ontwerp en de keuze van de varianten in deze case.

- De interviewees worden niet bij naam genoemd in het rapport om zo veel mogelijk anonimiteit te waarborgen en de interviewees de mogelijkheid te geven hun mening te uitten
- Het uiteindelijke rapport wordt beschikbaar gemaakt voor alle geïnteresseerden
- Het interview wordt semi-structured zodat er een basis structuur is waarin ik een paar belangrijke vragen kan stellen maar er ook ruimte is voor het benoemen van andere onderwerpen en meningen

Tips voor mijzelf

- Begin met een introductie over mijzelf en het thesis onderwerp
- Leg uit wat ik met de data ga doen; benoem anonimiteit
- Vraag aan de interviewee of het goed is als ik het interview op neem
- Korte introductie van de vragen, hoe veel het er zijn en een inschatting van hoe lang het gaat duren
- Tijdens het interview maak aantekeningen in een notitieboek; rechterkant wordt gebruikt voor aantekeningen, linker kant voor observaties
- Herhaal soms tijdens het interview in andere bewoording wat de interviewee net gezegd heeft om te checken of jouw interpretatie klopt
- Benoem de laatste vraag om aan te kondigen dat het interview bijna afgelopen is
- Vraag of zij nog laatste opmerkingen, suggesties of vragen hebben

Heeft u hier nog vragen over of is er nog iets onduidelijk?

1. **Introductie interviewee**
   1.1. Kunt u mij iets meer over uzelf en uw achtergrond vertellen?
   1.2. U werkt momenteel voor … kunt u iets meer toelichting geven over uw precieze functie hier?
2. **Functie in de Ede case**
   2.1. Hoe bent u betrokken geraakt bij dit project?
   2.2. Wat is uw precieze functie/rol in dit project?
   2.3. <u>Aanvullende vragen:</u>
      2.3.1. Bent u tevreden met de rol die vervult in dit project?
      2.3.2. Is deze rol verandert gedurende het project?
3. **Perspectief op het project in Ede**
   3.1. Wat verwacht u van het project?
   3.2. Wat zijn voor u belangrijke punten om mee te nemen in het project?
4. **Perspectief op de varianten**
   4.1. Wat vind u van de verschillende onderzochte varianten?
   4.2. Wat is voor u een overweging om voor een bepaalde variant te kiezen?
5. **Perspectief op de variant met nanofiltratie en helofytenfilter**

5.1. Wat is uw perspectief op de variant met nanofiltratie en helofytenfilter?
5.2. Wat zijn voor u overwegingen omtrent deze variant?

6. Perspectief op helofyten filter specifiek

6.1. Mocht de variant met helofytenfilter gekozen worden, wat verwacht u dan van het helofyten filter?
6.2. En als we wat meer uitzoomen, wat verwacht u van de water harmonica in het landschap?
6.3. Aanvullende vragen:
6.3.1. Wat voor functies zou de water harmonica moeten vervullen in de regio?
6.3.2. Waarom zijn deze specifieke functies voor u belangrijk?
6.3.3. Denkt u dat uw kijk hierop is verandert in de laatste jaren?

7. Rol landschapswaardes in ontwerp water harmonica

7.1. U heeft een aantal functies en verwachtingen genoemd, in hoeverre beïnvloeden deze factoren uw overwegingen omtrent de keuze tussen de varianten?
7.2. Heeft u het idee dat die overwegingen de uiteindelijke besluitvorming en het ontwerp van een mogelijke variant beïnvloeden?
7.3. Aanvullende vragen:
7.3.1. Heeft u het idee dat uw overwegingen hierin voldoende worden meegenomen?

8. Volgende projecten

8.1. Zou u in eventuele volgende projecten de variant met helofytenfilter meenemen?

Dit waren de vragen die ik had voorbereid, heeft u nog aanvullende informatie die u mij mee zou willen geven? Of heeft u nog vragen voor mij?

Annex III: Interview guide other waterharmonica cases

Doel: Het doel van deze case study is om te begrijpen hoe landschapswaarden het ontwerp en het beslissingsproces van een bestaande water harmonica hebben beïnvloedt. Ik wil te weten komen wat de afwegingen zijn geweest van de interviewee om voor een water harmonica te kiezen en of landschapswaarden hierbij een rol hebben gespeelt. Verder wil ik begrijpen welke mogelijke landschapsfuncties van een water harmonica van belang zijn voor de interviewee en waarom de interviewee deze waardeert en of deze waardes verandert zijn sinds de bouw van de water harmonica. Als laatste wil ik te weten komen hoe deze afwegingen tot uitdrukking zijn gekomen in het uiteindelijke ontwerp van de water harmonica.

- De interviewees worden niet bij naam genoemd in het rapport om zo veel mogelijk anonimiteit te waarborgen en de interviewees de mogelijkheid te geven hun mening te uitten
- Het uiteindelijke rapport wordt beschikbaar gemaakt voor alle geïnteresseerden
- Het interview wordt semi-structured zodat er een basis structuur is waarin ik een paar belangrijke vragen kan stellen maar er ook ruimte is voor het benoemen van andere onderwerpen en meningen

Tips voor mijzelf

- Begin met een introductie over mijzelf en het thesis onderwerp
- Leg uit wat ik met de data ga doen; benoem anonimiteit
- Vraag aan de interviewee of het goed is als ik het interview op neem
- Korte introductie van de vragen, hoe veel het er zijn en een inschatting van hoe lang het gaat duren
- Tijdens het interview maak aantekeningen in een notitieboek; rechterkant wordt gebruikt voor aantekeningen, linker kant voor observaties
- Herhaal soms tijdens het interview in andere bewoording wat de interviewee net gezegd heeft om te checken of jouw interpretatie klopt
- Benoem de laatste vraag om aan te kondigen dat het interview bijna afgelopen is
- Vraag of zij nog laatste opmerkingen, suggesties of vragen hebben

Heeft u hier nog vragen over of is er nog iets onduidelijk?

1. Introductie interviewee

1.1. Kunt u mij iets meer over uzelf en uw achtergrond vertellen?

1.2. Ten tijde van dit project werkte u voor … kunt u iets meer toelichting geven over uw precieze functie hier?

1.3. <u>Aanvullende vragen:</u>

1.3.1. Waar werkt u op het moment?

1.3.2. Wat is uw huidige functie?

2. Functie in het water harmonica project

2.1. Hoe bent u betrokken geraakt bij dit project?

2.2. Wat was uw precieze functie/rol in dit project?

2.3. <u>Aanvullende vragen:</u>

2.3.1.Bent u tevreden met de rol die u heeft vervult in dit project?

2.3.2. Is deze rol verandert gedurende het project?

3. Perspectief op het project

3.1. Hebben jullie tijdens dit project nog andere methodes overwogen?

3.2. Wat waren voor u belangrijke overwegingen om voor een water harmonica te kiezen?

3.3. Als u kijkt naar de waterharmonica zoals hij op dit moment functioneert, voldoet deze aan de verwachtingen die u van te voren had en de overwegingen die u zojuist noemde?

3.4. Aanvullende vragen:

3.4.1. Zijn er sinds het bouwen van de waterharmonica veranderingen doorgevoerd om meer aan deze verwachtingen te voldoen?

3.4.2. Wat zou er moeten veranderen om hier wel of nog meer aan te voldoen?

4. Landschapswaarde van water harmonica

4.1. Wat voor rol speelt de water harmonica in het landschap?

4.2. Aanvullende vragen:

4.2.1. Wat voor functies zou de water harmonica moeten vervullen in de regio?

4.2.2. Waarom zijn deze specifieke functies voor u belangrijk?

4.2.3. Denkt u dat uw kijk hierop is verandert in de laatste jaren?

4.2.4. In hoeverre speelden deze aspecten een rol in het ontwerp en de besluitvoering over de water harmonica?

4.2.5. Erop terug kijkend zou u het toen anders aangepakt hebben?

5. Succes factor project

5.1. Er zijn over de jaren veel vergelijkbare projecten geweest maar bij niet allemaal is het uiteindelijk tot de bouw van een water harmonica gekomen. Wat denkt u dat de reden is dat dit project wel gelukt is?

5.2. INDIEN DIT BENOEMD IS: U benoemde dat meerdere functies die de water harmonica heeft van belang waren in de afwegingen, verwacht u dat dit heeft meegespeeld in het laten slagen van dit project?

6. Volgende projecten

6.1. Heeft u na dit project nog aan andere vergelijkbare projecten meegewerkt?

6.2. Zou in toekomstige projecten de water harmonica als potentiële optie zien?

6.3. Aanvullende vragen:

6.3.1. In hoeverre hebben de ervaringen uit dit project daar een rol in gespeeld?

6.3.2. Wat waren de overwegingen in dat project om voor een water harmonica te kiezen?

Dit waren de vragen die ik had voorbereid, heeft u nog aanvullende informatie die u mij mee zou willen geven? Of heeft u nog vragen voor mij?