Overcoming challenges for the implementation of swale monitoring

An overview from the current practice to implementation

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by

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Cover: Swale at the municipality of Nissewaard

TU Delft

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Summary

Extreme weather events such as heat waves and heavy rainfall are becoming more frequent due to climate change, threatening the liveability of urban environments. High building and infrastructure densities and impervious surfaces intensify heat and flood risks. This vulnerability has led to an increase in climate adaptation strategies, which often include the implementation of Nature based Solutions (NbS). In the Netherlands, one of the most widely used NbS is the swale, a green ditch that facilitates drainage, infiltration, and rainwater storage. Swales are seen as cost-effective and no-regret measures that, just as other NbS, can have multiple functions which provide multiple benefits. Despite these potential benefits, practitioners struggle with the design, development and maintenance of swales, partly due to limited local monitoring practices.

The research had two main objectives: (1) to explore current practice in research and in Dutch municipalities to identify performance criteria and monitoring techniques for swales to track the key functions of swales, and (2) to investigate motivators and challenges for municipal swale monitoring and develop a communication tool to address these. Four main research questions guided the research:

1. How can swales be monitored on their key functions?
2. What is the current practice for swale design and monitoring in Dutch municipalities?
3. What are the current motivators and challenges for the implementation of swale monitoring in Dutch municipalities?
4. What communication tool can help overcome these challenges?

A systematic literature review identified five key swale functions: water quantity, water quality, biodiversity, liveability and wellbeing. Water quantity and water quality functions are relatively well studied, with swales proven to reduce runoff and remove certain pollutants when properly designed and maintained. However, research is still lacking for the functions biodiversity, liveability, and wellbeing. The connections between the different functions were also explored, which showed the importance of recognising the connections and the influences of the different functions on each other. From this review, eight criteria were identified: infiltration rate, soil moisture, in- and outflow of pollutants, soil quality, vegetation development, temperature, resident experience and resident usage. For each criterion, quick-scan and in-depth monitoring techniques were proposed.

A survey among municipal workers who are involved with urban water management (mainly from South Holland) found that swales are seen as multifunctional objects, where water quantity and biodiversity are the most important functions. Monitoring is not part of the current practice, and swales are often only assessed on the functions during the design. However, there is interest in the implementation of monitoring, especially for water quantity and water quality. The main motivators for monitoring are to know the effect of swales on the long term and the ability to identify problems in time. The main challenges are keeping track of data and ensuring sufficient resources, like staff and budget.

To overcome these challenges, a workshop was designed to motivate practitioners to start monitoring the multiple swale functions. The workshop is aimed at municipal staff responsible for the organisation of maintenance for the different functions. By learning about the different functions and monitoring possibilities, the participants can create a monitoring plan that serves as a starting point for the actual implementation of monitoring. Evaluation by experts indicated that this workshop can motivate the target audience, because it increases the audience's awareness of swales, encourages them to consider

the different functions and lets them practice with measuring, monitoring and retrieving data. It also provides them with a concrete and practical output that can be used in practice.

This study offers a framework to improve swale monitoring in the Netherlands. An overview of performance criteria with corresponding monitoring techniques is provided together with a communication tool that can bridge the gap between knowledge and practice.

Contents

List of Figures

List of Tables

I

*

*

Introduction

1
Introduction

1.1. Introduction to the research

Extreme weather events such as heat waves and heavy rainfalls are becoming more frequent due to the effects of climate change. This poses a threat to the liveability of the urban environment, which is more vulnerable to the effects (KNMI, 2023; Masson-Delmotte et al., 2021). Relatively high building and infrastructure densities create urban heat islands (Bornstein, 1968; Kleerekoper et al., 2012), and impervious surfaces increase the chances of flooding (Gill et al., 2007). This vulnerability has led to an increased awareness of the necessity of climate adaptation, resulting in strategies to reduce these effects, while maintaining (or enhancing) healthy environments and the quality of life (O'Donnell et al., 2021).

The implementation of Nature based Solutions (NbS) is often included in adaptation strategies. The concept of NbS was introduced to promote nature as a means for providing solutions to climate mitigation and adaptation challenges (Cohen-Shacham et al., 2016; Nesshöver et al., 2017). Currently, it is seen as a broader concept where problems related to climate change and biodiversity conservation and management are tackled in combined solutions (Dorst et al., 2019). The ability to provide this multifunctionality is seen as one of the key benefits delivered by NbS (Lähde et al., 2019). Next to this, NbS systems are also often perceived as more aesthetically attractive than traditional grey infrastructure (O'Donnell et al., 2021).

A swale is one of the more popular types of urban NbS in the Netherlands. A swale can be defined as a green ditch that can simultaneously facilitate drainage, infiltration and storage of rainwater (Koning & Boogaard, 2024). Swales have been implemented over the past 25 years, but their popularity has increased in the last decade because of the focus on climate adaptation (Koning & Boogaard, 2024). It is seen as a cost-effective and no-regret measure partly because, just as other NbS, a swale can have multiple functions and can provide multiple benefits.

However, two main challenges affect the implementation of swales. The first challenge is that practitioners often struggle with how to effectively design, develop, and maintain swales (Voskamp et al., 2021). While various design guidelines exist (e.g. CIREA, 2016), the design objectives can differ between projects, and the guidelines do not always fit the local conditions (Ekka et al., 2021). As a result, the envisioned benefits of multifunctionality are not developed or maximised in the original design (Fenner, 2017). The second challenge is that asset management for the NbS is underdeveloped. They are typically overlooked by asset managers, which has an impact on the performance and service life of swales

(Langeveld et al., 2022). Several practitioners have expressed concerns about the build-up of problems over time regarding hydraulic functioning and soil pollution of swales (Koning & Boogaard, 2024). A way to address both challenges is through the collection of local empirical data. This data can be used to improve the local design guidelines for swales (Ekka et al., 2021), and it provides insight into their performance, supporting asset management. But there is still a lack of monitoring techniques needed to obtain this data on a local scale for the various benefits (Koning & Boogaard, 2024; Langeveld et al., 2022).

1.2. Research questions

This research explores how swales can be monitored and how such monitoring can be implemented in practice. It is guided by two main objectives. The first objective is to explore the current practice in research and within Dutch municipalities to identify performance criteria and provide monitoring techniques to track the key functions of swales. The second objective is to explore the motivators and challenges for the implementation of municipal swale monitoring in the Netherlands, and explore how these challenges can be overcome with a communication tool. These two objectives are summarised in four research questions, which all have corresponding sub-questions.

Question 1: How can swales be monitored on their key functions?

This research question is related to the first objective and focused on the exploration of the monitoring techniques. Three corresponding sub-questions are used to answer the main question.

Sub-question 1a is meant to define the key functions associated with the various benefits of swales to provide a framework for the research. Sub-question 1b then researches what is currently known about the ability of swales to contribute to these defined functions. The overview of this knowledge is the starting point for sub-question 1c, which identifies the key factors that influence the swale performance are defines the relevant performance criteria. For these criteria, monitoring techniques are explored to answer sub-question 1d. The answers to the sub-questions lead to the answer to the 1.

Sub-questions for research question 1:

(a) What are the key functions and associated benefits of swales identified in current research?
(b) What is currently known about the ability of swales to contribute to these functions?
(c) What are the relevant criteria that indicate the performance of swales for the key functions?
(d) What monitoring techniques are available to measure these criteria?

Question 2: What is the current practice for swale design and monitoring in Dutch municipalities?

This research question is also related to the first objective, but focused on the current practice in Dutch municipalities. Three corresponding sub-questions are used to answer the main question. These three questions are used to explore the current practice of swale design and monitoring from different angles.

Sub-questions for research question 2:

(a) Which functions are important for Dutch municipalities in swale design?
(b) How do municipalities currently assess the designed swale functions?
(c) How do Dutch municipalities want to monitor swales?

Question 3: What are the current motivators and challenges for the implementation of swale monitoring in Dutch municipalities?

This research question is related to the second objective and focused on finding the current motivators and challenges for the implementation of swale monitoring. Two corresponding sub-questions are used to answer the main question. The two questions are meant to explore the different motivators and challenges, which are then filtered to answer research question 3.

Sub-questions for research question 3:

(a) What would motivate Dutch municipalities to implement monitoring?
(b) What are the challenges for the implementation of swale monitoring in Dutch municipalities?

Question 4: What communication tool can help overcome the challenges for the implementation of swale monitoring in Dutch municipalities?
This research question is also related to the second objective and focused on the design of a communication tool that can overcome the challenges defined in question 3. Two corresponding sub-questions are used to answer the main question. The two questions are meant to explore the different options for the design of the communication tool.

Sub-questions for research question 4:

(a) What is needed to overcome the challenges for the implementation of swale monitoring?
(b) How can communication be used to overcome the challenges for the implementation of swale monitoring?

1.3. Methodological approach

The process to answer the research questions is set up into two phases. These phases are based on the double diamond approach, which is a method for design-based research developed by the Design Council (2004). This method follows two consecutive diverging and converging stages meant to explore problems on a broad scale, followed by focused action. Figure 1.1 shows how the research questions were answered following this double diamond approach. The first diamond is a bit larger than the second diamond, because the research had more focus on the first phase to gain a good view of the current practice of swales.

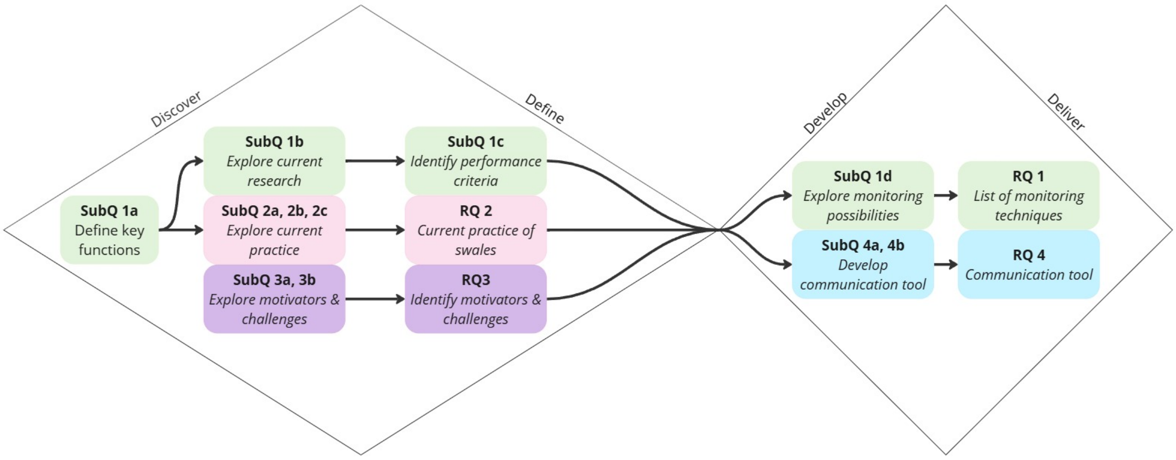

Figure 1.1: Overview of research questions in the double diamond.

In the first phase of the research, the current practice of swales is explored. This is done both in research and in practice, by performing a literature study and a survey. This helps to identify performance criteria for swales and the current motivators and challenges regarding the implementation of the monitoring, which will lead to the second phase of the research. In this phase, several monitoring possibilities for the performance criteria are explored, resulting in a list of different monitoring techniques. Next to this, a communication tool is developed that can support the implementation of monitoring.

1.4. Structure of the report

The report is divided into four parts. Part II addresses research question 1. It shows the current knowledge on the key functions of swales, and the relevant criteria and corresponding monitoring possibilities within these functions. This is followed by part III, which addresses research questions 2 and 3. This part gives insight into the current practice regarding the design and monitoring of swales in Dutch municipalities and discusses the current challenges and motivators for the implementation of swale monitoring. The next part, part IV, addresses research question 4, discussing the development of a communication tool to help overcome the challenges. Finally, part V contains the conclusion to the research, and the findings are put into perspective.

II

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Monitoring of the swale functions

Overview Part II

This part gives an overview of the current research on the key functions of swales, and it provides monitoring techniques that can monitor performance criteria for swales to answer research question 1: *"How can swales be monitored on their key functions?"*. This question contained the following sub-questions:

(a) What are the key functions and associated benefits of swales identified in current research?
(b) What is currently known about the ability of swales to contribute to these functions?
(c) What are the relevant criteria that indicate the performance of swales for the key functions?
(d) What monitoring techniques are available to measure these criteria?

This part starts with the research overview of swale functions in chapter 2. This chapter describes the framework for the multifunctionality of swales in this research to answer sub-question 1a, and it contains an overview of the research for the different functions to answer sub-question 1b. Chapter 3 shows the relevant criteria to monitor swales and corresponding monitoring techniques to answer sub-questions 1c and 1d. The final chapter in this part, chapter 4, contains the answer to research question 1.

2 Research overview of the swale functions

This chapter shows the key functions of swales and describes what is known in research about how swales can provide different benefits, to answer the sub-questions 1a and 1b. First, the literature review that was performed to answer these questions is described in section 2.1. This is followed by the first part of the results in section 2.2, which shows how the multifunctionality of swales can be approached and the framework used in this research and defines the key functions to answer sub-question 1a. This is followed by the second part of the results in section 2.3 and section 2.4 to answer sub-question 1b. First, the existing knowledge on the functions individually is described, and then an overview of the connections between the functions is given.

2.1. Method

A systematic literature review was performed to identify the key functions and to examine the important factors related to these functions. The article of Koning and Boogaard (2024) served as a starting point for the review. Thirty additional articles were gathered based on relevant references in the text. In addition, there were three main searches conducted in Scopus, and several articles were provided by supervisors and experts. Further articles were identified through snowballing.

The following searches were defined in Scopus:

- **First Search**
  Search fields: Article title, Abstract, Keywords
  Search terms: swale AND biodiversity
  Search filters: None
  This search was done to find papers that gave insight into more functions than water quantity. In this search, there were 40 documents. It was quickly discovered that biodiversity had been understudied and often led to the same source, which is Kazemi et al. (2011).
- **Second Search**
  Search fields: Article title
  Search terms: monitoring AND swale
  Search filters: None
  This search was done to get an insight into documents that discussed swale monitoring. The

search resulted in four documents, of which one was deemed relevant.

- **Third Search**
  Search fields: Article title, Abstract, Keywords
  Search terms: ”Grass swale” OR ”Bio-swale” OR ”Infiltration swale”
  Search filters: Year – Limited to: 2022, 2023, June 2024
  This search was done to find papers that also studied other types of swales, next to grass swales. This search had 18 documents, of which one was deemed relevant.

The articles were assessed in three steps. In the first step, the title and abstract were read. Articles were deemed relevant if they contained information about grass swales or bioswales and discussed one or more aspects of the functions. In a second step, the articles were scanned and categorised per function. Some articles contained information about multiple functions and were also part of multiple categories. If the articles didn’t contain relevant information, they were dropped. In the third step, the articles were read in-depth and relevant information was coded in Atlas TI to create an overview of the information from the different sources.

Four review papers were deemed most relevant. These are Ekka et al. (2021), García and Santamarta (2022), Jones et al. (2022) and Säumel et al. (2016). Ekka et al. (2021) was used for the functions water quantity and water quality. The other three articles were mainly used for the functions liveability and wellbeing.

2.2. Multifunctionality of swales

The provision of multifunctionality is seen as one of the key benefits delivered by NbS (Lähde et al., 2019). In NbS research, two frameworks are commonly used to describe multifunctionality. The first framework focuses on the capacity of NbS to provide multiple ecosystem services (ES) (Liquete et al., 2015). The second framework is based on the CIREA SUDS guidelines (CIREA, 2016). SUDS are Sustainable Urban Drainage Systems, a term often used for NbS that are situated in the urban environment, such as swales. These two frameworks were used to define the key functions in this research.

2.2.1. Ecosystem services

The ES are the benefits that humans recognise as obtained from ecosystems that support, either directly or indirectly, their survival and quality of life (Harrington et al., 2010). There are different ways to capture the ecosystem services, but the typology that is most frequently used is the one from the Millennium Ecosystem Assessment by Reid et al. (2005). This typology categorises the benefits gained from the ecosystems into four services: regulating, cultural, provisioning and supporting services. The regulating services refer to the benefits obtained from the regulation of ecosystem processes, such as water regulation or water purification. Cultural services are the non-material benefits from ecosystems, like recreational opportunities. The provisioning services entail the products obtained from ecosystems, such as materials or food. Finally, the supporting services are necessary for the production of all the other ecosystem services, such as nutrient cycling or soil formation.

García and Santamarta (2022) created a framework of the main ES provided by SUDS with the typology of Reid et al. (2005). The ES and related benefits that they identified for swales are shown in table 2.1.

Table 2.1: Main Ecosystem Services and related benefits of swales based on García and Santamarta (2022).

Ecosystem Services	Related Benefits from Swales
Regulating services	Water regulation: Maintenance of the hydrological cycle and stormwater mitigation Water purification: Improve water quality Habitat and biodiversity: Pollination, creation of new urban habitats, increase of urban species Climate regulation: Reduction of the urban heat island effect and mitigation of the effects of climate change
Cultural services	Improvement of the urban landscape Recreation and health: Multifunctional open spaces for physical and mental wellbeing Cognitive development and knowledge preservation, educational value, and encouragement of environmental awareness
Provisioning services	No known benefits
Supporting services	Groundwater recharge Noise reduction Air quality improvement

2.2.2. CIREA guidelines for SUDS

CIREA (2016) defines the multifunctionality of SUDS in its guidelines for SUDS. Their main principle for the design of SUDS is that surface water runoff should be managed for maximum benefit. The benefits that can be achieved by SUDS are split up into four different categories: water quantity, water quality, biodiversity and amenity. Each category has a design objective that needs to be taken into account (see figure 2.1).

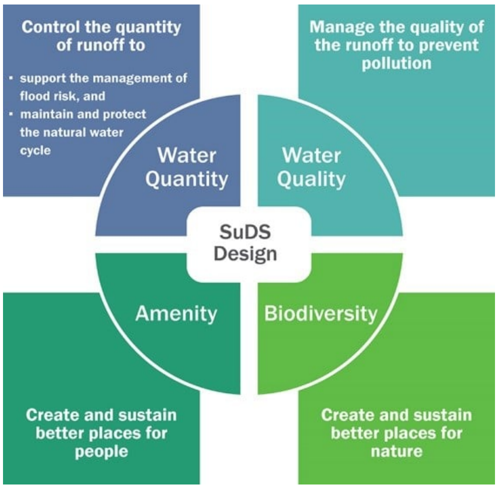

Figure 2.1: The four categories of SUDS design and the design objectives (CIREA, 2016).

The design objective for the water quantity category consists of two parts. The quantity of the runoff should be controlled to support the management of flood risk and maintain the natural water cycle. The water quality design objective is to manage the quality of runoff and to prevent pollution. This is done by reducing the urban runoff and improving the water quality of that runoff. Amenity is defined as a useful or pleasant facility or service, and the design objective is to create and sustain better places for people. This category includes tangible services, such as air quality improvement or noise reduction, and less tangible services, such as education and recreation. The design objective for the biodiversity category is to create and sustain better places for nature. For this category, SUDS need to be designed to support and protect natural local habitats and species, and contribute to habitat connectivity.

2.2.3. Multifunctionality framework in this research

Both frameworks showed the different benefits that can be provided by swales and other NbS. García and Santamarta (2022) categorised these benefits through the ES, while CIREA (2016) used design categories. Table 2.2 shows how the ES align with the design categories. Comparing the two frameworks shows that water quantity, water quality, and biodiversity mainly correspond with the benefits in the regulating ES, whereas the remaining benefits fall within the amenity category, which results in a broad category.

Table 2.2: Comparison of the frameworks of CIREA (2016) and García and Santamarta (2022).

Design category	Regulating ES	Supporting ES	Cultural ES
Water quantity	Water regulation	Groundwater recharge	
Water quality	Water purification		
Biodiversity	Habitat and biodiversity		
Amenity	Climate regulation	Noise reduction Air quality improvement	Improvement of the urban landscape Recreation and health Educational value and cognitive development

Since water quantity, water quality, and biodiversity are often explicitly addressed in NbS design, the design categories of CIREA (2016) served as a basis for the framework. To provide more focus in the amenity category, this was divided into two functions: liveability and wellbeing. Liveability covers the tangible benefits, such as climate regulation, noise reduction and air quality improvement, while wellbeing contains the cultural ES, which are less tangible. Table 2.3 shows the definitions of the five key functions in this framework and the corresponding benefits. The benefit of the educational value and cognitive development was left out in this research framework, because it did not fit within the objective to study monitoring.

Table 2.3: Framework of multifunctionality of swales in this research

Function	Description
Water quantity	The goal of this function is to control the quantity of runoff to support flood risk management, while also protecting the natural water cycle.
Water quality	The goal of this function is to improve the water quality. By reducing the runoff and improving the quality of runoff, pollution can be prevented.
Biodiversity	The goal of this function is to create and support local habitats, contribute to habitat connectivity and promote the increase of urban species. This can improve the biodiversity in the environment.
Liveability	The goal of this function is to improve the quality of life for people by providing climate regulation, noise reduction and improving the air quality.
Wellbeing	The goal of this function is to provide space for recreation and health, through physical activity, stress reduction and cognitive restoration, while also improving the urban landscape.

2.3. Individual functions

This section shows the current knowledge of swales in each function individually. It outlines the main factors influencing the performance of a function. If research is limited on certain aspects or services of a function, the main mechanisms in related research are described.

2.3.1. Water quantity

The design goal for this function was to control the quantity of runoff to support flood risk management, while also protecting the natural water cycle. Research has shown that swales can reduce runoff volumes and peak runoff rates, provided they are properly designed, constructed, and maintained (Ekka et al., 2021). The effectiveness of swales in reducing runoff volumes, particularly from small storms, is well documented (e.g. Davis et al., 2012; Shafique et al., 2018; Yu et al., 2001). Observations show that swales can reduce peak runoff rates within a range of 4% to 87% (Deletic & Fletcher, 2006; Rujner et al., 2018) and runoff volumes from 15% to 82% (e.g. Lucke et al., 2014; Rujner et al., 2018; Winston et al., 2019). This wide variation can be explained by various factors that are influenced by the design, construction and maintenance.

The design influences factors such as the infiltration rate, soil moisture conditions, soil characteristics, and channel roughness. Swales are often designed to reduce the runoff rates and volumes by infiltration. When a swale has a low infiltration rate, it influences its ability to reduce the (peak) runoff (Rujner et al., 2018; Shafique et al., 2018). The soil moisture conditions and the soil characteristics influence the infiltration rate. Experiments conducted by Rujner et al. (2018) in Luleå, Sweden, showed that the runoff volume with a low initial soil water content was reduced up to 82%, while for a high initial soil water content, the volume reduction was 15%. The soil characteristics, like permeability, also influence the hydrologic performance of swales. Depending on soil permeability, a swale may require check dams to extend the hydraulic retention time in well-draining conditions, or an underdrain when drainage is poor (Ekka et al., 2021). The channel roughness is influenced by the grass height and grass density of a swale. It influences the hydraulic resistance in swales, which is important not only for hydraulic performance but also for pollutant removal efficiency (Bäckström, 2002; Deletic & Fletcher, 2006). Since the slope of swales in the Netherlands is often low-gradient, the channel roughness is less relevant.

The construction can influence the compaction of the swale bed. The compaction of the soil inevitably impacts the infiltration capacity of a swale (Ahmed et al., 2015; Gregory et al., 2006; Pitt et al., 2008). Therefore, proper construction techniques that minimise compaction to maintain the soil permeability are important.

The maintenance is important to sustain the swale's performance. Sañudo-Fontaneda et al. (2020) showed that a lack of maintenance resulted in a silt build-up at the discharge point. The removal of litter and debris is also important to avoid blockages. The removal of nuisance plants and grass cuttings influences the channel roughness.

2.3.2. Water quality

The design goal for this function was to improve the water quality of the runoff. The ability of swales to provide water quality treatment has been well documented (Boogaard et al., 2024; Chen et al., 2023; Ekka et al., 2021). The main pollutant removal mechanisms for swales are gross filtration, settling and sedimentation of particles in runoff (Bäckström, 2002; Barrett et al., 2004); infiltration (Yu et al., 2001); and chemical precipitation, microbial degradation and vegetation uptake (Gavrić et al., 2019).

Two main sources contribute to the influx of pollutants in swales. The first source is the pollutants travelling in the runoff of the contributing drainage area, and the second source is atmospheric deposition (Chen et al., 2023). The pollutants from these sources are primarily associated with roads, the leaching of building materials and activities such as industry, commerce and construction (Boogaard et al., 2024; Folkeson et al., 2009; Rahman & Singh, 2019). Both sources contribute a range of pollutants to swales. Research has mainly examined four pollutant categories concerning swales: solids and sediments, nutrients, heavy metals, and bacteria and pathogens. For other pollutants that are common in stormwater, like hydrocarbons, research has been very limited.

Solids and sediments

Research has shown that swales improve stormwater quality by capturing and removing sediment with particle sizes greater than 6-15 μm and sediment-borne pollutants (Bäckström, 2002; Luell et al., 2021; Winston & Hunt, 2017). Due to limited hydraulic retention times, smaller particles are difficult to trap with swales (Deletic & Fletcher, 2006). Although modelling-based methods have been developed, there remains a lack of specific, evidence-based design guidance for sediment removal that practitioners can apply (Ekka et al., 2021). Fardel et al. (2019) recommended further research, and the collection of empirical data from controlled experiments is needed to get better guidelines.

Nutrients

There is uncertainty in the effectiveness of swales in treating nitrogen and phosphorus, and more research is therefore needed (Ekka et al., 2021). Bioswales are most likely better for the removal of these nutrients compared to grass swales.

For nitrogen, some researchers observed that total and dissolved fractions of nitrogen were reduced in grass swales (Deletic & Fletcher, 2006; Luell et al., 2021), but Lucke et al. (2014) observed no reduction. Because bioretention and stormwater wetlands are popular NbS to remove nitrogen in runoff (Collins et al., 2010; Yu et al., 2013), their swale counterparts (bioswales and wetswales) are better at removing nitrogen than standard grass swales (Ekka et al., 2021). Bioswales and wetswales are better at removing nitrogen because anaerobic conditions are required for the nitrification-denitrification reactions (Hunt et al., 2012).

For phosphorus, field monitoring showed the removal and net export from swales (Deletic & Fletcher, 2006; Luell et al., 2021). Approximately 80% of the phosphorus in roadway stormwater runoff was attached to sediments (Kayhanian et al., 2012; Vaze & Chiew, 2004; Winston & Hunt, 2017). The phosphorus that is attached to the sediments is treated in the swale by filtration and sedimentation, but the dissolved part remains untreated. Bioswales are likely the best choice for capturing phosphorus, since research has shown that forcing water to percolate through engineered media reduces the phosphorus concentrations in other NbS (Blecken et al., 2010; Davis et al., 2006). Next to this, the addition of check dams will increase the reduced amount of both dissolved and total phosphorus loads. Check dams generally increase the water quality performance of a swale (Yu et al., 2001) by increasing water storage and hydraulic retention time in the swale beds (Stagge et al., 2012). This idea was verified by Purvis (2018), who observed a significant reduction in a controlled plot study.

Heavy metals

In stormwater, metals like zinc, copper, nickel, and cadmium occur in dissolved forms, while lead and chromium are typically particle-bound (Huber et al., 2016; Stagge et al., 2012). The division between dissolved and particulate forms of the metals is highly variable (Galfi et al., 2017). Because of this, grass swales can attenuate a peak metal load, but do not have high removal rates, especially for the dissolved forms of metals (Bäckström, 2003; Bäckström et al., 2006). Still, well-maintained grass swales are reported to have a better removal of metals than bioswales and wet swales (Gavrić et al., 2019). If other (non-metal) pollutants are targeted, bioswales and wet swales can be used (Ekka et al., 2021).

Bacteria and pathogens

Since bacteria and pathogens are typically not a pollutant of concern in highway or road runoff, the performance of swales treating these pollutants is not well researched (Ekka et al., 2021). The most common bacteria removal mechanisms are filtration, soil adsorption, dessication and predation (Stevik et al., 2004). Bioswales have more of these pollutant removal mechanisms compared to grass swales. A study by Purvis et al. (2018) observed that a bioswale removed more than 55% of faecal indicator bacteria from stormwater runoff. This supports the concept that bioswales are most likely the optimal swale type for this pollutant.

2.3.3. Biodiversity

The design goal for this function was to improve the biodiversity of the environment by creating and supporting local habitats, contributing to habitat connectivity and promoting the increase of urban species. Overall, the research on biodiversity and swales is limited (Chen et al., 2023; Su et al., 2024). Most biodiversity and SUDS research is focused on green roofs and retention ponds (Monberg et al., 2019; Pille & Säumel, 2021). Research has shown that green infrastructure improves biodiversity compared to the original grey infrastructure (Filazzola et al., 2019) and also that bio retention swales are better than traditional urban green spaces (Kazemi, Beecham & Gibbs, 2009).

When swales are designed with structural diversity and heterogeneity of habitats, this will support the biodiversity (Kazemi, Beecham, Gibbs & Clay, 2009; Monberg et al., 2018). Monberg et al. (2019) found that the creation of species-rich grassland increased the floral resources in a short period of time. In a span of two years, the study showed the potential of SUDS to enhance the ecological value of grasslands. But the targets for ecological enhancements must be integrated into the design of the SUDS. Another important factor for habitats is connectivity (Jones et al., 2022; Kazemi, Beecham & Gibbs, 2009). Bjørn and Howe (2023) found that bio retention basins can provide foraging habitats and functional connectivity for pollinators.

Ecological assessments of bioswales are sparse (Chen et al., 2023), but Kazemi et al. (2011) found that converting planting strips to bioswales enhanced invertebrate communities. Nevertheless, extensive insights into the increase of urban species are still lacking.

Next to biodiversity on a macro level, soil microbes also play a key role in the ecosystems. The role of these microbes is important for plant productivity and species richness (Van Der Heijden et al., 2008). Gill et al. (2017) showed that bioswales had distinct bacterial communities, including taxa associated with pollutants. This showed that swales can shape the diversity and activity in soil communities, but additional research is needed to gain insight into these communities and to understand the effects of these microbes on the plants, the soil and the microbes on swale performance (Chen et al., 2023).

2.3.4. Liveability

The goal of the liveability function is to improve the quality of life for people by providing climate regulation, noise reduction and air quality improvement. Research on the relationship between these services and swales, as well as other NbS systems, has been limited. However, a central argument supporting the potential of NbS systems to deliver these benefits is grounded in the (additional) presence of vegetation.

Climate regulation

Heat mitigation via vegetation occurs through multiple mechanisms, but mainly via evapotranspiration and shading (Jones et al., 2022; Kleerekoper et al., 2012). Vegetation cools the environment actively by evapotranspiration. For short vegetation, the evapotranspiration is the main mechanism and has positive effects on the temperature compared to concrete asphalt or bare soil (Bowler et al., 2010;

Onishi et al., 2010). The mechanism is dependent on the amount of water that is available for the vegetation (Säumel et al., 2016; Schmidt, 2006). Shading by trees cools down the environment passively by shading surfaces that would have otherwise absorbed short-wave radiation and been re-radiated (Jones et al., 2022; Kleerekoper et al., 2012; Upmanis et al., 1998).

Research into the specific impact of NbS has been limited. Xing et al. (2017) stated that detailed sensitivity analyses are required to quantify the urban heat island reduction. For swales specifically, Sañudo-Fontaneda et al. (2020) monitored the temperature of a swale for three years. This showed that the temperature behaviour around the swale was consistent and no high extreme values were registered. Still, more research is needed to provide insights into how swales contribute to climate regulation.

Noise reduction

There are two main mechanisms via which vegetation can attenuate noise. The first mechanism is the absorption of the energy of the sound pressure waves. Soft green vegetation can absorb the energy, but this is mainly limited to high frequencies (Aylor, 1972; Van Renterghem et al., 2014). The soil under trees tends to be relatively soft, which absorbs the energy more than a hard surface such as concrete (Aylor, 1972; Van Renterghem et al., 2012). The second mechanism is by redirecting and scattering of the sound waves. Larger woody structures such as trunks and stems reflect and scatter the sound (Aylor, 1972; Van Renterghem et al., 2014). This mechanism is responsible for the majority of the noise reduction (Jones et al., 2022). Larger woody vegetation belts have a larger effect on attenuation than grasslands or fields (Kragh, 1981), and the effects are increased when the belts have a higher density and width (Fang & Ling, 2003).

There have been no empirical studies that recorded the capabilities of swales or other SUDS to attenuate noise (García & Santamarta, 2022). The influence of swales on noise reduction is probably low, since the involvement of trees is important for the attenuation (Jones et al., 2022). However, the perception of natural sounds, such as the bird sound, can reduce the perceived amount of traffic noise (Coensel et al., 2011; Hong & Jeon, 2013; Säumel et al., 2016).

Air quality

Vegetation can have both positive and negative impacts on the air quality. Vegetation can reduce levels of gaseous air pollutants and particulate matter (PM) (Fowler, 2002), which is a positive effect. However, some vegetation releases pollen, which aggravates allergies (Hartig et al., 2014). Additionally, trees and dense shrub layers can also contribute to local air pollution in narrow streets, due to a reduction in wind speed and near-surface exchange (Buccolieri et al., 2009; Vos et al., 2013).

The largest health benefits that can be gained by the removal of urban air pollutants by vegetation are associated with the removal of fine PM (diameter is 2.5 μm or less) (Jones et al., 2019). There are three main mitigation mechanisms in green spaces for PM: deposition (settling on the surface of vegetation), dispersion (influencing the direction and speed of PM in the air), and modification (altering properties of PM, like its size) (Diener & Mudu, 2021).

Trees are more effective for the removal of PM compared to lower vegetation, and the influence of swales on air quality is therefore probably low (Jones et al., 2022). But design choices, such as the number and placement of trees or vegetation species (mainly regarding pollen), do have an effect.

2.3.5. Wellbeing

The design goal of the wellbeing is to provide space for recreation and health, while also improving the urban landscape. Research from Miller and Montalto (2019) showed that these services are highly valued by practitioners and residents. Most studies that fall into the wellbeing function are focused on the perception of NbS by the residents and how to educate them about the systems, since they don't always have a positive perception of the techniques. Studies that verify if they improve health or if they are used for recreational purposes are still limited (García & Santamarta, 2022).

Improvement of the urban landscape

The attractiveness of an area has an impact on how people enjoy their environment. NbS in urban areas are seen as a way to improve the urban landscape since people generally prefer urban areas with higher levels of vegetation over urban settings with little vegetation (Suppakittpaisarn, Jiang et al., 2019). Next to this, the presence and quality of urban greenery affect the property values of adjacent houses (Crompton, 2005).

Research by Suppakittpaisarn, Larsen and Sullivan (2019) showed that laypeople prefer NbS over conventional lawns, but landscapes that had trees and flowers were even more preferred. A characteristic that impacted the preferences is the perceived messiness. Plants used for stormwater management can sometimes appear messy compared to conventional urban landscapes, and this can be associated with traces of neglect (Nassauer, 1995). However, if the intention is made clear,NbS can still be approved by residents (Tzoulas & James, 2010; Weber et al., 2014).

Recreation and health

NbS can provide recreation and health through physical activity, social interaction, stress reduction, and cognitive restoration.

Swales that are designed as playgrounds or sports fields can offer the services of physical activity or social interaction, but this often requires more maintenance because it influences the other functions of the swale. Another way of providing some physical activity and social interaction is via footpaths along a swale (Jones et al., 2022). Social interaction can also be offered by encouraging residents to get involved in the maintenance and monitoring of swales (Miller & Montalto, 2019), which also gives an educational benefit.

NbS that provide rest and relaxation can promote stress recovery and cognitive restoration (Hartig et al., 2014). Designs that have more diverse and natural features are considered to deliver a greater benefit in this aspect of recreation (Marselle et al., 2019).

2.4. Interconnection of functions

In the previous section, the swale functions were described individually, but since they can provide multiple functions, it is also important to look at the connections between the functions. Hansen et al. (2019) showed that if these connections are not recognised, potential conflicts between the functions might be overlooked. The multifunctionality of swales should be considered early to maximise the potential of the different functions and prevent a loss in the benefits (CIREA, 2016; Fenner, 2017; Lähde et al., 2019).

2.4.1. Individual connections

Lähde et al. (2019) studied the interconnections between the different design functions of CIREA (2016). Using their findings together with additional insights obtained in section 2.3, six types of connections were determined. These connections are: hydrological processes, ecological processes, effects of pollution, impacts of recreation, potential via design and temporary effects.

Hydrological processes

The hydrological processes include infiltration, evaporation and runoff. These processes take place in the water quantity function and influence the water quality, biodiversity and liveability functions (see figure 2.2).

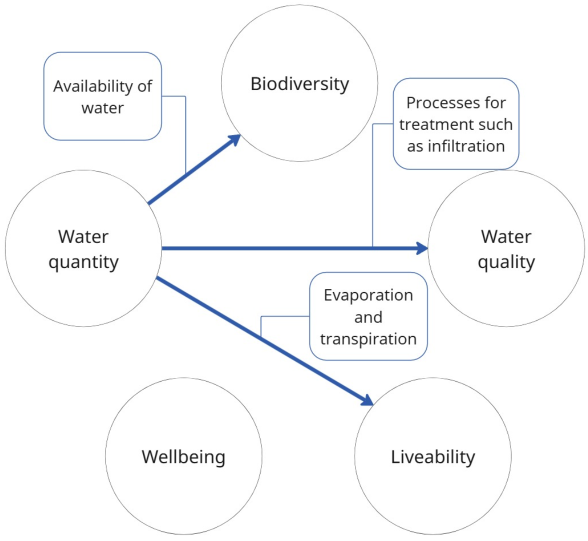

Figure 2.2: Connections with hydrological processes.

The link to biodiversity is based on the availability of water, which influences plant growth. The relation to water quality arises because the filtration occurring because of infiltration is one of the main pollutant removal mechanisms, while the hydraulic retention time influences its capacity to capture sediments. Liveability is linked to water quantity because of climate regulation. The availability of water influences a swale's ability to cool the environment via evaporation and transpiration. Designs that prioritise the drainage for flood risk management can limit water availability during dry periods and reduce hydraulic retention time, thereby impacting biodiversity, water quality, and liveability functions.

Ecological processes

Ecological processes include nutrient cycling, decomposition and fluxes of nutrients and energy (Lähde et al., 2019). Hydrological processes are also part of ecological processes, but are seen as a separate connection in this research. The ecological processes are all related to biodiversity and linked to the water quantity and water quality functions (see figure 2.3).

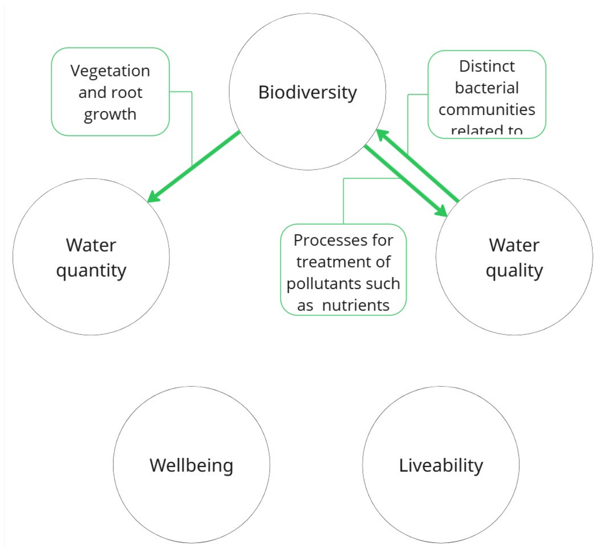

Figure 2.3: Connections with ecological processes.

The relation to water quantity is made through the role of vegetation growth in the nutrient cycle. This affects the water quantity function in two ways. Root growth influences the permeability of the soil, and the presence and height of vegetation influence the channel roughness. Designs that prioritise biodiversity can simultaneously take these effects into account. Choosing vegetation that provides sufficient root growth and height has a positive effect on the water quantity function. Biodiversity and water quality are both linked to each other through ecological processes. Part of the water treatment mechanisms in the swale are ecological processes, but swales also have distinct bacterial communities that are associated with some pollutants and influence the biodiversity.

Effects of pollution

Swales can treat the runoff water to prevent pollution of surface water, but this leads to the accumulation of pollutants in the topsoil of swales since the filtered particles are trapped there (Boogaard et al., 2024). This causes the water quality function to affect the water quantity, biodiversity and the wellbeing function (see figure 2.4). The relation to water quantity is made because the filtration of sediments can cause clogging, which can negatively influence infiltration. The link to wellbeing is because the soil pollution has raised concerns among practitioners, especially when swales are located in areas intended for recreation, such as playgrounds, where children may come into contact with polluted soil. The polluted soil can also impact the biodiversity in a negative way, since it can affect plant growth. By replacing the topsoil after a certain number of years, the negative effects of the pollution can be limited.

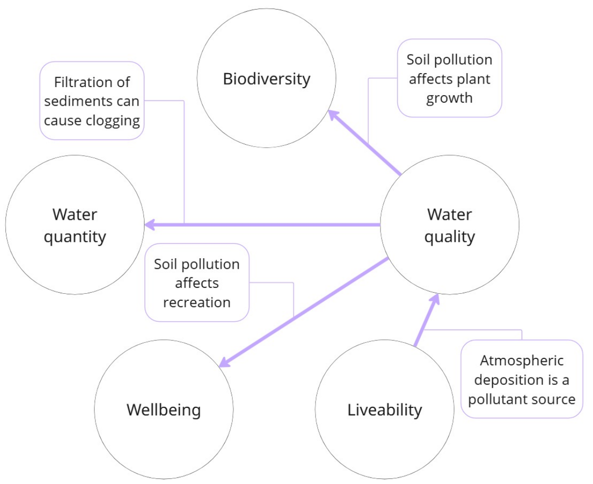

Figure 2.4: Connections with effects of pollution.

Water quality influences these functions, but liveability influences the water quality function (see figure 2.4). Atmospheric deposition is one of the pollution sources. Dust particles settle on the leaves of vegetation, which improves the air quality, but when it rains, these particles will be washed away and flow into the swale.

Impact of recreation

The impact of recreation relates to the use of swales by residents. The connections are all related to the wellbeing function and linked with water quantity, biodiversity and water quality (see figure 2.5). A swale designed for recreational purposes, like a playground or sports field, can lead to additional pollution and compaction of the soil. The additional pollution can cause clogging, which influences the water quantity, water quality and biodiversity functions. Maintenance can be carried out to prevent the clogging and remove the additional pollution in time. Compaction occurs when people walk on the swale of the soil, and the performance of the water quantity function.

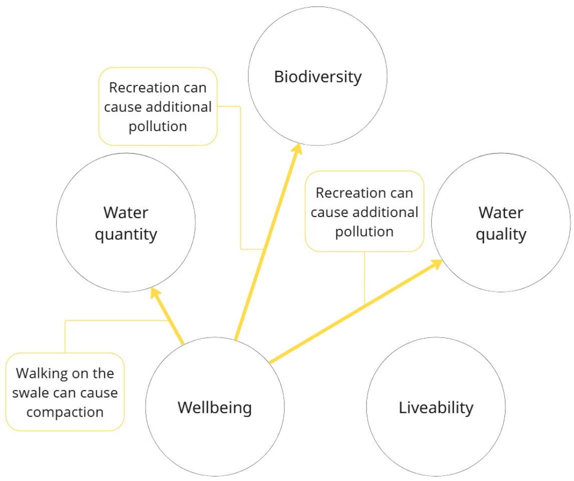

Figure 2.5: Connections with the impacts of recreation.

Potential via design

Potential via design means that a swale can provide opportunities for a linked function, but this depends on design and maintenance choices. This differs from other types of connections, as the swale is intentionally designed for one function, which in turn influences another. In this type of connection, a design choice for one function directly affects the performance of the other. This type of connection links the biodiversity, wellbeing and liveability function (see figure 2.6).

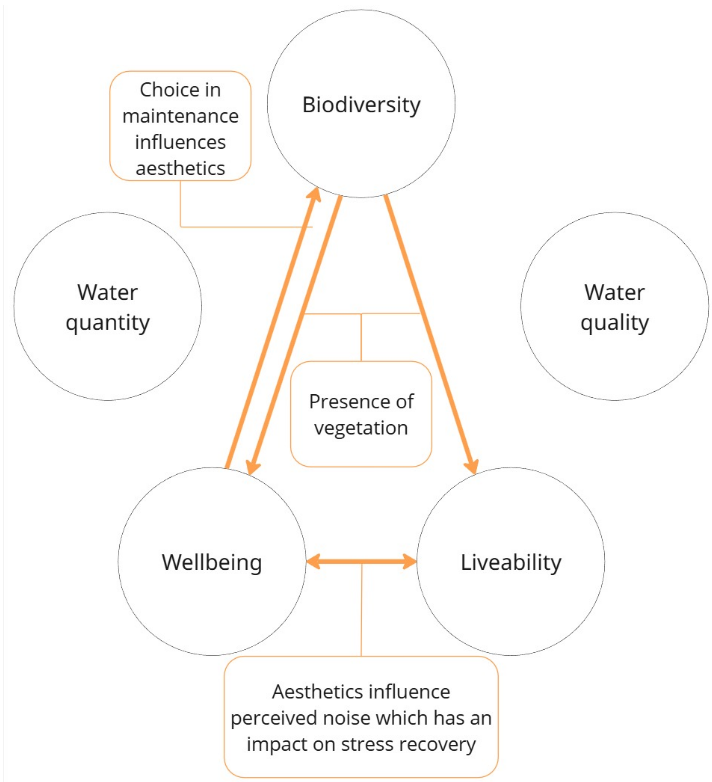

Figure 2.6: Connections with potential via design.

The link from biodiversity to liveability is made because the benefits of liveability are dependent on the presence of vegetation. The vegetation choice thus influences a swale's performance for liveability.

The connection from biodiversity to wellbeing is made because of the presence of natural elements such as vegetation. These elements influence the aesthetics of the swale and promote stress recovery and cognitive restoration. The choice in the maintenance of the vegetation influences the perceived messiness. As discussed in section 2.3.5, vegetation used for stormwater management can be associated with traces of neglect. This is also why biodiversity is influenced by wellbeing, if tidy aesthetics are preferred, this could influence vegetation choice or maintenance, which then influences the biodiversity. The link from wellbeing to liveability is made because aesthetics can influence the perceived noise. For example, the presence of natural bird sounds can reduce the perceived amount of traffic noise as explained in section 2.3.4. Conversely, the perceived noise also has an effect on stress recovery and cognitive restoration.

Temporary effects

Temporary effects are those that occur for a certain time and are mainly related to the weather conditions. This connection is made from water quantity and liveability to wellbeing (see figure 2.7) The link from water quantity to wellbeing is made because of the aesthetics and recreation benefits, which are affected after a rainfall event. The presence of open water has a positive influence on the aesthetics, but since the swale is meant to drain the water, this effect is temporary. Similarly, if a swale is designed as a playground or sports field, recreational opportunities become temporarily unavailable if the swale stores water. The link from liveability to wellbeing relates to climate regulation service, particularly during warm days. If the swale is a cooler environment, then other places residents could use it for recreational purposes.

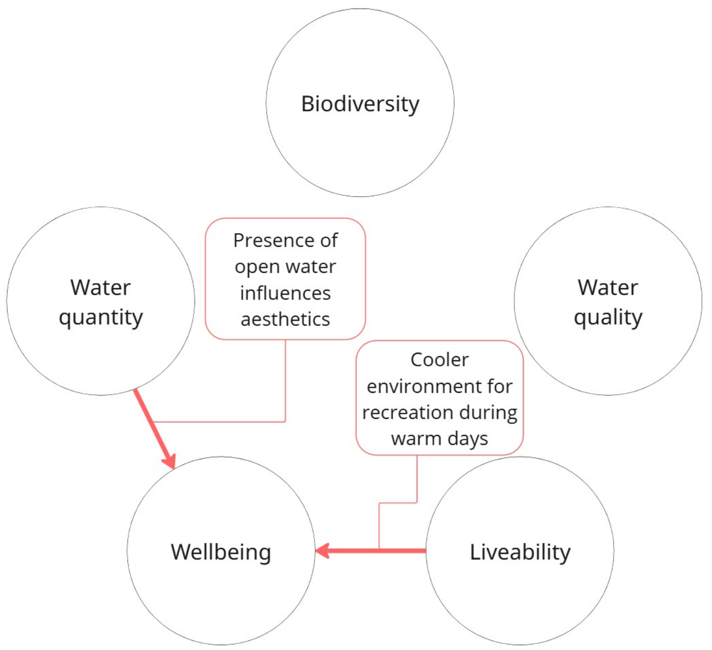

Figure 2.7: Connections with temporary effects.

2.4.2. Overview of the interconnections

Figure 2.8 shows the overview of all six types of connections and how they connect the different functions. This figure emphasises the importance of recognising the connections between the different functions. Each function influences another function, and if these are not considered in the design or after implementation, it is likely that the benefits might not be maximised or could even be lost. This overview of the different connections forms the basis for identifying the criteria that indicate swale performance in the next chapter.

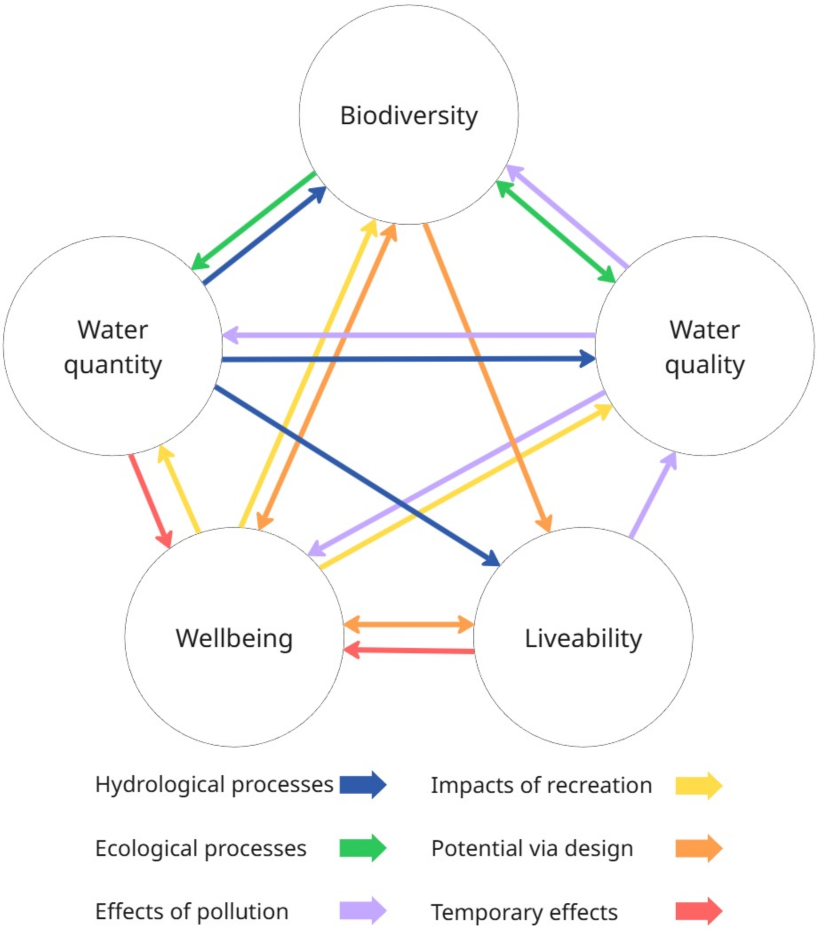

Figure 2.8: The interconnections between the five key functions adapted from Lähde et al. (2019) by using additional insights.

3

Criteria and Monitoring

In the previous chapter, the key functions were studied individually, and their interconnections were mapped as a first step toward identifying relevant criteria. Building on this overview, this chapter defines the criteria that can indicate swale performance across the key functions and presents techniques for measuring these criteria, addressing sub-questions 1b and 1c. Section 3.1 discusses the relevant criteria and how they were selected. This is followed by section 3.2, which gives the known monitoring techniques that can be used to measure the criteria.

3.1. Relevant criteria

To select the criteria that can indicate swale performance, three steps were taken. First, the factors that influence the performance of a function were outlined and connected based on the information in chapter 2. This overview can be found in appendix A. The next step was to filter the factors based on three things: Is the factor important for the designed performance of the function itself, is the factor important for the designed performance of the other functions, and is the factor a design choice or something that can be monitored (e.g. type of vegetation is a design choice).

Based on this selection, eight criteria were selected that can indicate the performance of a swale in its designed function. Figure 3.1 shows the eight criteria and how they are connected to the functions. The monitoring of noise reduction and air quality improvement is left out, since the effect of swales is most likely very low, and they are often not designed for this purpose.

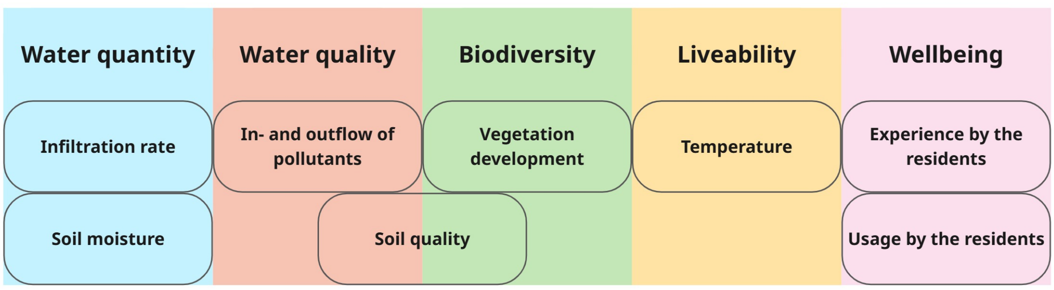

Figure 3.1: Overview of the criteria connected to the function

- **Infiltration rate**
  The ability of a swale to temporarily store and infiltrate water to reduce (peak) runoff is the main

criterion for the water quantity function. By monitoring this criterion, it can be tracked if the swale can infiltrate the water within the designed time frame.

- **Soil moisture**
  The soil moisture conditions affect the ability of swales to infiltrate water. If the soil is either very dry or wet, this can reduce the infiltration rate. The soil moisture conditions also influence the vegetation development. By tracking the soil moisture conditions, it can be identified how much they influence the infiltration rate and when this is known, it gives a better overview of what the infiltration rate is under different circumstances.
- **In- and outflow of pollutants**
  To monitor the ability of swales to provide water quality treatment, the in- and outflow of pollutants can be measured. This can give an indication if a swale can treat a certain pollutant and if the treated water meets the right requirements.
- **Soil quality**
  The soil quality relates both to the water quality and the biodiversity function. By treating the water for certain pollutants, the soil gets polluted. The soil quality can be monitored to see when it is too polluted. Next to this, the soil quality influences vegetation development and the life within the soil, which are important factors for the performance of the biodiversity function.
- **Vegetation development**
  The vegetation is connected to the performance of multiple functions, but the vegetation itself is mainly important for the biodiversity function. The root depth of the vegetation influences infiltration, and the coverage influences the benefits of the liveability function. Although the choice of vegetation is made in the design phase, the development can be monitored to see if the vegetation is growing as designed.
- **Temperature**
  To monitor the impact of the swale on the temperatures in the local environment, surface and air temperatures can be measured. Additional weather conditions can also be measured to get an indication of the apparent temperature. This gives an indication of how the swale is performing for the climate regulation benefit.
- **Experience by the residents**
  To get an insight into whether the residents also experience the swale as an improvement of the environment, the experience of the residents can be monitored. This is meant to give insights into how they perceive the swale.
- **Usage by the residents**
  To get an insight into whether the residents are using the swale as designed, the usage by residents can be tracked.

3.2. Monitoring techniques

In this research, monitoring is defined as the systematic collection of data through measurements, followed by analysis to evaluate performance. This section gives an overview of possible monitoring techniques for the criteria mentioned in the previous section. Multiple techniques are available to measure each criterion, requiring different levels of resources. These differences are mainly reflected in the use of low- or high-cost sensors and in time efficiency. Experiments are generally more time-intensive than continuous monitoring with sensors.

3.2.1. Infiltration rate

The infiltration rate can be measured via infiltration tests. These tests can be done on a small-scale or the full-scale. An example of a small-scale infiltration test is the Modified Phillipe-Dunne (MPD) method. The principle of this test is that a column is sealed to the surface and filled with water to provide a positive head. The height of the initial water level is measured, and then the time to infiltrate the water is recorded. With a full-scale infiltration test, the swale is filled as a whole, and then the time to empty the swale is measured. Venvik and Boogaard (2020b) compared both methods and showed that full-scale tests tend to give a better indication of the real infiltration capacity, since small-scale tests are prone to local variability. To overcome this local variability, small-scale tests can also be repeated throughout the swale.

It is also possible to measure the infiltration rate with sensors, which gives an overview of how the swale behaves when it is in actual use during a rainfall event. To measure the infiltration rate, the water level in the swale needs to be measured. This can be done via a camera setup or water level sensors.

3.2.2. Soil moisture

There are three different ways to measure the amount of water in soil. It can be measured based on the soil water tension, the volume of the water (volumetric water content) or the mass of the water (gravimetric water content) (Morris et al., 2022).

The soil water tension is the amount of energy needed to pull the water out of the soil and is often used in agriculture, because this energy is also needed by the roots of the plants. The tension can be measured by tensiometers. Tensiometers are low-cost, easy to install and don't necessarily need electricity, but maintenance is required to keep them working.

The volumetric water content is the volume of water per volume of soil and can be measured with dielectric sensors. There are two main types of these sensors: frequency domain reflectometry (FDR) sensors and time domain reflectometry (TDR) sensors. Both of these sensors can be very accurate and can be used in a wide range of soils, but they require careful installation, and they do need electricity. FDR sensors are less expensive than TDR sensors, but both of them require data loggers, which vary in price.

The gravimetric water content is the mass of water per mass of dry soil. This can be measured by taking soil samples and measuring them in a lab. This method is accurate, but requires lab equipment and has long waiting times. The gravimetric water content can also be calculated from the volumetric water content.

3.2.3. In- and outflow of pollutants

Section 2.3.2 showed different pollutants that could be treated in swales. To get an idea of how a swale is treating the water, it is possible to look at the inflow and outflow of a swale. This can be done in various ways, and multiple parameters can be measured.

The water can be measured in situ with installed sensors or by taking samples. Measuring the outflow depends on the type of swale. If swales have a drain installed, sensors can be placed in the drain, and samples can be collected in the drain. If there is no drain in place, sensors can be installed in the native soil under the swale, or a piezometer could be installed in the native soil to collect samples.

Multiple parameters can be measured to get insights into the water quality. To get a basic level of understanding, the electro conductivity (EC) can be measured. The EC can be used to estimate the Total Dissolved Solids (TDS). EC sensors can vary in price, but low-cost options are available. Next to EC, various parameters can be measured via test strips, for example, nitrate or dissolved iron. These test strips are simple in use and a quick way to get an overview.

To get a more in-depth understanding of the water quality, specific pollutants can also be measured. This can be done by measuring collected water samples with available test kits, such as colour disc test kits. These sets aren't as easy as the test strips, but are still simple and relatively low-cost. Another method is lab analysis, which is often expensive. The pollutants can also be measured with sensors. These sensors often require proper installation and are variable in cost, but most can be qualified as high-cost sensors.

3.2.4. Soil quality

Since the soil quality is important for both water quality and biodiversity, different indicators can be monitored. These can be split up into biotic and abiotic soil indicators. The biotic indicators include the organisms living in the soil, while the abiotic indicators include the non-living characteristics (Rutgers et al., 2014).

Some biotic soil indicators can be seen by the naked eye, like worms, but many of the organisms are less visible. The visible organisms can be monitored by counting the number of organisms in a specified area. This can also be done with the community and using citizen science methods, such as the method used by the Soil Animal Days ('Soil animal days', 2023). For a more in-depth analysis of the soil and to get insights into the indicators that are not visible by the naked eye, soil samples need to be taken. These can then be analysed in a lab via various methods.

There are various abiotic indicators, such as soil pH, infiltration rate, soil moisture and specific pollutants such as heavy metals. A soil health indicator that is important is the soil pH. This can be measured with on-site sensors. To determine heavy metal pollution in soil, Venvik and Boogaard (2020a) used an X-Ray Fluorescence (XRF) scanner to scan the accumulation in the topsoil of swales. This scanner allows for a quick analysis of the soil, but it is important to compare the measurement with a reference measurement to exclude the natural elements. Just as with the biotic indicators, if a more in-depth analysis of the soil is preferred, soil samples need to be analysed in a lab.

3.2.5. Vegetation development

To monitor vegetation development, several aspects can be assessed, such as root depth growth, canopy or ground coverage, and the development of species.

To measure the root depth, a representative section of soil can be dug out and the roots can be measured (AHDB, n.d.). There are also sensors being developed to measure root depth (e.g. Tei et al., 2024), but these developments are mainly focused on agricultural purposes.

To get some first insights into the vegetation coverage and species development, pictures can be taken regularly and compared to see the change in the landscape. For a better analysis of the development quadrant, surveys can be performed. These are surveys where the plants in a specific area are studied.

3.2.6. Temperature

There are different ways to measure the temperatures of the swale and the surrounding environment. Surface temperatures can be measured to indicate the swale temperature and air temperatures to study the effect of the swale. To determine the apparent temperatures, additional parameters such as wind speed and humidity need to be measured.

Surface temperatures can be obtained via contact and non-contact measurements. With contact-based measurements, a sensor is placed on the surface of the object to be measured, and for non-contact measurements, the surface of the object is analysed using sensors such as infrared thermometers or thermographic cameras (Testo Sensor GmbH, n.d.). To measure air temperature, a thermometer can be installed above the ground between 1.2 and 2 meters (NIST, 2025). To determine the apparent temperatures, wind and humidity can be measured by a weather station that measures these variables.

Sensors for all three temperature types can vary in price, from low-cost to expensive sensors. These measurements can also be done via a citizen science approach, similar to the Thermo-staat project

(Thermo-staat, n.d.)

3.2.7. Experience and Usage by the residents

The experience and usage by residents can both be monitored with surveys, interviews or other interactions with residents.

To get insight into the experience, residents can be asked questions that relate to how they perceive their environment and the swale specifically. These questions can relate to the aesthetics (e.g. do they find it pretty or messy) and if they experience any problems, such as flooding or additional insects. Experience can also be tracked by complaints to the municipality. To assess usage by the resident, they can be asked whether they perform recreational activities in the swale, particularly if it was designed for an activity (e.g., a playground). They can also be asked whether the environment around the swale provides a place for relaxation.

4

Summary and Conclusion of Part II

The purpose of this part was to provide an overview on the current research on the key functions of swales and to provide criteria and techniques to monitor swales on these functions to answer research question 1: *"How can swales be monitored on their key functions?"*. A systematic literature study was performed to answer this question.

First the key functions were determined by comparing and combining the frameworks used by García and Santamarta (2022) and CIREA (2016). This led to the five key functions, water quantity, water quality, biodiversity, liveability and wellbeing. Then the ability of swales to contribute to these five functions and the interactions between the functions were studied. This research showed that there is knowledge about the ability of swales to perform for the functions of water quantity and water quality. It has been documented that they are able to reduce runoff volumes as long as they are properly designed, sized, constructed and maintained. Next to this, swales have various pollutant removal mechanisms and are able to treat heavy metals, solids and sediments, but not all pollutants have been studied to the same extent. Additional research is needed to develop improved guidelines which also include the other pollutants. Research into the functions of biodiversity, liveability and wellbeing is lacking, but there is potential to contribute to these functions. Next to the individual functions, it is also essential to acknowledge the interconnections between the functions. Figure 2.8 showed that the five functions are all connected and influence each other, and emphasised the importance of recognising these connections.

Based on what is known about the functions individually and their connections, an overview was created that linked the various factors. These factors were then filtered based on the importance of the function itself and other functions, and whether it is a design choice or something that can be monitored to get an overview of the relevant criteria. This led to a list of eight criteria, which serve as a basis to monitor swales on the five functions. For each criterion, various monitoring possibilities were explored, including possibilities that can give a quick scan and techniques that give a more in-depth analysis. This resulted in an overview of various techniques per criterion that can be used to monitor swales on the five functions.

III

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Swale monitoring in municipalities

Overview Part III

This part gives insight into the current practice of the design and monitoring of swales in Dutch municipalities to answer research question 2: *"What is the current practice for swale design and monitoring in Dutch municipalities?"*. This question contained the following sub-questions:

(a) Which functions are important for Dutch municipalities in swale design?
(b) How do municipalities currently assess the designed swale functions?
(c) How do Dutch municipalities want to monitor swales?

This part also addresses the current challenges and motivators for the implementation of swale monitoring to answer research question 3: *"What are the current motivators and challenges for the implementation of swale monitoring in Dutch municipalities?"*. This question contained the following sub-questions:

(a) What would motivate Dutch municipalities to implement monitoring?
(b) What are the challenges for the implementation of swale monitoring in Dutch municipalities?

To answer the questions, a survey was conducted. This part starts with a description of the design and analysis of the survey in chapter 5. This is followed by chapter 6, which shows the results of the survey and answers the sub-questions. The final chapter in this part, chapter 7, answers research questions 2 and 3.

The full question list of the survey can be found in appendix C and the full results in appendix D.

5
Method

This chapter describes the method of the design and analysis of the survey. Based on the findings from exploratory interviews, a survey was selected as the research method. The main takeaways from these interviews are described in section 5.1. The following section contains a description of the target audience and distribution method of the survey. Section 5.3 describes how research ethics were taken into account to ensure the ethical use of the participant data. The setup of the survey can be found in section 5.4, which gives an overview of the survey build-up and the main intention of each question block. Finally, section 5.5 describes how the responses were analysed and how the data was used.

5.1. Exploratory interviews

At the start of the research, preliminary interviews were conducted with three municipal workers, all from maintenance departments responsible for swales in their municipality but holding different job roles. Two were found via personal contacts, and one was approached by contacting a specific municipality.

The preliminary interviews were semi-structured and explored the participants' perspectives on swales, as well as how swales are designed, implemented, maintained, and monitored within their municipalities. These interviews provided several key insights into how swales are currently used and managed in practice, which served as a starting point for the research.

1. **Organisational differences**
   The interviews showed that each municipality has their own organisational structure. This also has an effect on the way decisions are made and how maintenance is done. At one municipality, the maintenance was more segregated than at another municipality.
2. **Choice for swales**
   The choice and design of swales often come from an external party involved in the (re)development of a residential neighbourhood or an area that is dealing with flood issues. Although municipalities are involved in the process and have input on design decisions, particularly because they are ultimately responsible for maintenance, the initiative typically comes from the external designers.
3. **View on multifunctionality**
   The ability of the swales to provide multiple functions was mentioned as a benefit of choosing them. One of the interviewees was a bit more sceptical about this ability and favoured other solutions.
4. **Swale monitoring**
   The municipalities that were interviewed do not have swale monitoring implemented yet. At one

municipality, the first steps were being taken, and all of them see the value in it, mainly in regard to asset management.

5. **Involvement of maintenance**
   The interviewees were also asked if they were involved in the design of a swale. They mentioned that they are involved in different stages of the design, because the maintenance is taken into account for the design.

These key insights gained from the preliminary interviews led to the decision to conduct a survey, because the insight regarding the organisational differences showed the benefit of gathering input from multiple municipalities. A survey makes it possible to identify common challenges across municipalities while reaching multiple respondents and gathering diverse perspectives in a short time. The second insight led to the selection of the target group, namely municipal workers, who are primarily involved in urban water management. The third and fourth insights helped determine the focus of the survey. Since monitoring is not yet implemented, the main focus is on searching for what the municipalities want and see as challenges in relation to monitoring. But since the multifunctionality seems to be a reason to implement them, questions were added to gain better insights into the view of the different functions of swales.

5.2. Target audience and distribution

As mentioned in the previous section, the target group were municipal workers who are involved with urban water management. The survey was not only meant for municipalities with swales. Those without swales were also invited to participate to better understand their perspective on swales. All municipalities in South Holland were targeted, as well as some located in North Holland and Utrecht. The municipalities in North Holland were included if they were in the waterboard "Hoogheemraadschap van Rijnland", and the ones in Utrecht were either on the east of Utrecht city or in the waterboard "Waterschap Rivierenland". This resulted in a total of 63 targeted municipalities. Figure 5.1 shows the map of the chosen municipalities.

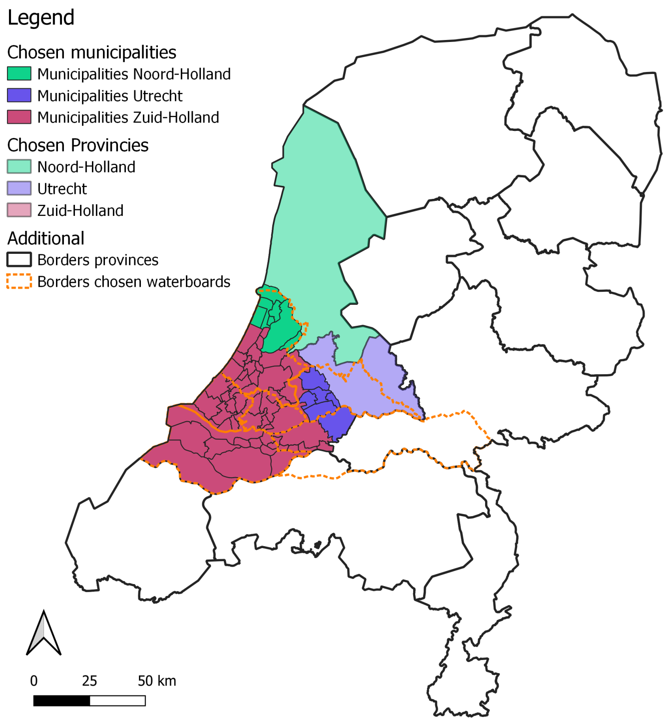


Figure 5.1: Map with chosen municipalities for the target group.

The survey was distributed through two main channels. The first was through the contact forms of municipalities or, if there were no forms available, via email. The message provided a brief overview of the survey, specified which municipal officer was in the target group, and included a one-page invitation letter as an attachment. Additionally, RIONED, the foundation for urban water management in the Netherlands, posted about the survey on LinkedIn. This message did not target a specific area but highlighted municipal workers involved in the maintenance of swales.

The survey was available from November 13 to December 4, 2024. In this time, 34 responses were gathered, of which 29 could be placed in the target area. This was seen as sufficient since almost half of the target area was reached.

5.3. Research Ethics

To ensure ethical use of participants' data, an ethical application was approved by the human research ethics committee of the TU Delft. This application contained an ethical checklist to show the identified risks together with mitigation actions, a data management plan that described how data is used and stored, and an informed consent form to inform the participants of the use of their personal data.

Ethical risk mitigation plan

The ethical checklist was filled in to identify the risks associated with the research and the mitigation actions. The main risks are shown in table 5.1.

Table 5.1: The main identified risks and mitigation plan for the survey.

Identified risk	**Mitigation plan**
The survey is conducted on the survey platform Qualtrics, which is a third-party data-gathering service. This could lead to an external data breach where the answers might be leaked and used by someone else.	The data that was collected for the survey was downloaded as soon as possible and then the answers were removed from the platform.
Data breach, such as a stolen computer or someone other than me using my computer leading to the wrong uses of data.	The data was stored on a protected drive which was only available to me and my supervisors. This data was deleted after processing the research data.

Data management plan

A data management plan was made to describe how the survey data was stored. This plan was also checked by a faculty data steward from the TU Delft. The responses of the survey were anonymous and the retrieved data were only accessible to the researcher and the supervisors. Email addresses for follow-up research were collected in a separate survey to ensure they could not be linked to the survey responses.

Informed consent

Since the participants' personal data was used, informed consent was necessary. The participants were informed via an opening statement in the survey, which can be found in appendix B. They were informed why the survey was being conducted and how their data was going to be used.

5.4. Survey goal and setup

The survey was designed to gain insight into the current practice for swale design and monitoring, and to identify the current motivators and challenges for the implementation of swale monitoring, to answer research questions 2 and 3. The sub-questions of these research questions are all connected to one or more of the question blocks. To avoid survey fatigue, the survey included multiple flow paths that allowed participants to skip irrelevant questions. The full question list together with the flow paths within the blocks can be found in appendix C.

5.4.1. Survey structure

The structure of the survey consists of five different question blocks and four main flow paths. The main flow path was determined by the start question (Q0), which can be read below. Each flow path had the same question blocks, but some did not contain all the questions of a certain block. Figure 5.2 gives an overview of the main flow paths in the survey and the connected questions.

Question Q0: Does your municipality have swales or is your municipality considering installing them?

- Yes there are swales
- We will soon be constructing one or more swales for the first time
- We are considering constructing swales
- No

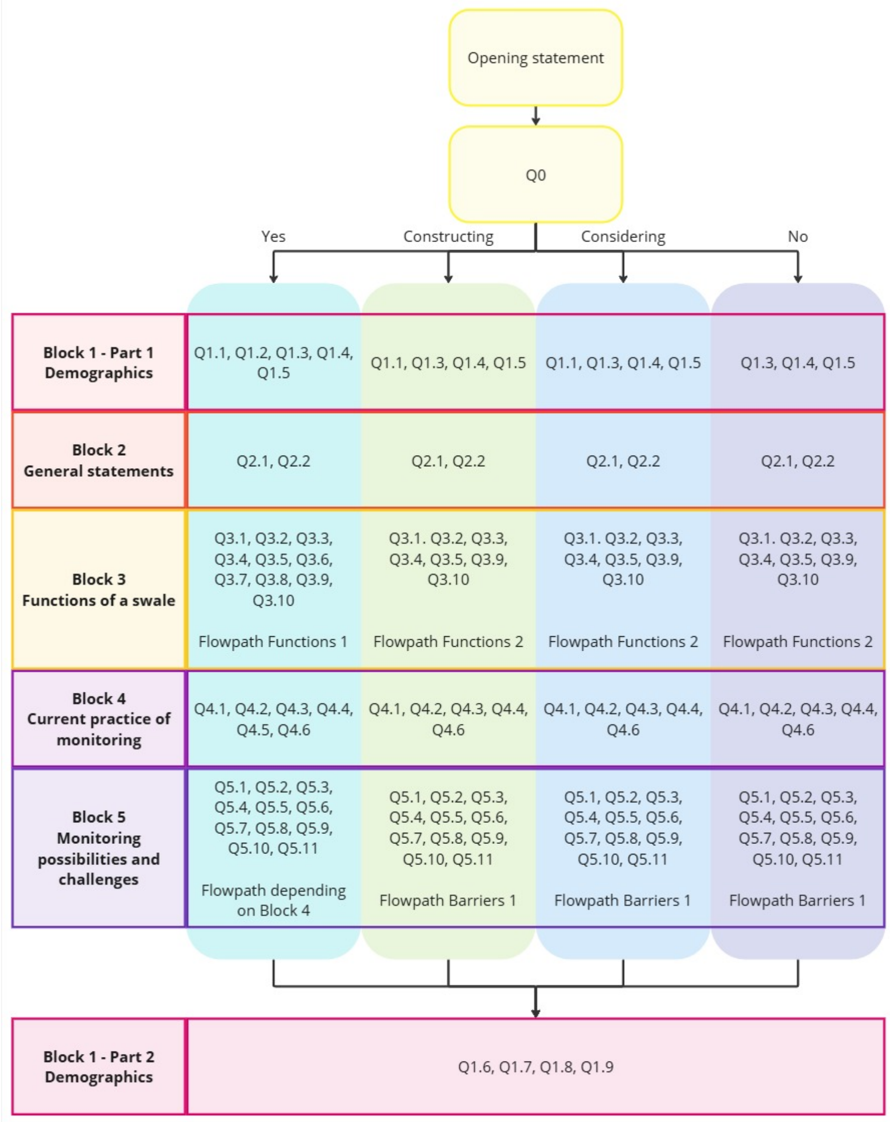


Figure 5.2: Overview of the main flow paths and question blocks of the survey together with the connected questions.

5.4.2. Question blocks

The question blocks of the survey are all related to a sub-question, except for the demographics block. Both quantitative and qualitative questions were included. Quantitative questions were asked to get an overview of the opinion, and the qualitative questions were asked to get a motivation or reason for this opinion. Each question block is explained in its corresponding section.

Demographics

The first block is the demographics block. This block is meant to gather information about the municipality's experience with swales (Q1.1, Q1.2), the respondent's experience at their current municipality and their familiarity with swales (Q1.3, Q1.4) and the involvement of the respondent with swales within the municipality (Q1.5). Next to this, it was asked what the province (Q1.6), population size (Q1.7), population density (Q1.8) and the waterboard (Q1.9) are of the municipality.

For the population size and the population density, it is asked to give the scale of the size and density. The population size scale is based on the scales used in the "gemeentelijke monitor sociaal domein" by the Vereniging Nederlandse Gemeente (VNG, 2023). The population density scale is based on a scale used by the Centraal Bureau voor de Statistiek (CBS, n.d.).

This block is split up into two parts in the actual survey. This choice was made in case a respondent did not complete the survey. Questions Q1.1, Q1.2, Q1.3, and Q1.4 are at the beginning of the survey, while questions Q1.6, Q1.7, Q1.8, and Q1.9 are at the end of the survey. These questions were included to see if the group of respondents was representative and if answers could be compared.

General statements

The second block is meant to obtain information to answer sub-question 2a. It contains questions with some general statements about swales, which are related to the services connected to the functions as defined in section 2.2.3. This block is meant to gather the respondents' opinions on what they think a swale should be designed for (Q2.1) and if they think a swale is able to provide the specific benefit (Q2.2).

These questions were included because one of the insights from the preliminary interview suggested that people potentially have differing views on the multifunctionality of swales. The answers can help to get more insight into the importance of the different functions.

Functions of a swale

The third block is meant to obtain information for sub-questions 2a, 2b and 3a. In this block, the benefits are combined into the five key functions, which are explained to the respondents. The aim is to gather information on which functions the swales are designed for (Q3.1, Q3.2), whether their performance is assessed (Q3.3), and, if so, when and how this is done (Q3.4, Q3.5). In addition, respondents are asked if the swales perform as intended (Q3.6), why or why not (Q3.7), and what their answer is based on (Q3.8). If they are unsure about the swales' functioning, they are asked if they want to know and why (Q3.9, Q3.10).

Questions Q3.1 and Q3.2 were included to assess the importance of the functions (sub-question 2a), Q3.3 to Q3.8 are used to get information about the current assessment of swales (sub-question 2b) and Q3.9 and Q3.10 are used to gain insight into possible motivators for monitoring (sub-question 3a).

Current practice of monitoring

The fourth block contains questions about the monitoring of swales and is used for sub-question 2b. This block is meant to determine if municipalities currently monitor their swales (Q4.1) and, if so, what they monitor (Q4.2) and how they do it (Q4.3, Q4.4). Question Q4.5 asks if the monitoring was planned in the design or if it was implemented later (Q4.5). Question Q4.6 asks if the respondent has any additional comments regarding the monitoring of swales.

Monitoring possibilities and challenges

The fifth block is meant to obtain information for sub-questions 2c, 3a and 3b. It is meant to gather information on what the respondents would want to monitor and what they see as challenges and motivators regarding the implementation. The block starts with statements that ask about the importance of monitoring on a function (Q5.1) and if the respondents know how to monitor the function (Q5.2). Next, respondents are asked who should be responsible for monitoring (Q5.3, Q5.4) and what they would like to monitor (Q5.5, Q5.6, Q5.7). Then it is asked what is needed for the implementation of monitoring (Q5.8) and what they see as challenges and motivators (Q5.9, Q5.10). Finally, question Q5.11 asks for any remaining comments regarding the challenges for the implementation of the monitoring of swales.

Questions Q5.2 to Q5.7 were included to gain more insights into what municipalities would like to monitor and how they would want to have it implemented (sub-question 2c). Q5.8 to Q5.11 focused on the motivators and motivators for the implementation of monitoring (sub-questions 3a and 3b).

5.4.3. Feedback for the survey

The survey was refined through several iterations based on feedback from supervisors, an external expert and peers. Halfway through the design, an external expert was asked to provide feedback. This expert conducts interdisciplinary research where social sciences are combined with water management and has experience with surveys. The feedback provided mainly related to some clarifications to prevent misunderstanding. At the end of the design, the survey was pre-tested by peers, which revealed some technical flaws in the survey flow and some additional need for clarification. The testing showed that the survey could be completed within 10 minutes, though more elaborate answers could make it longer. Therefore, respondents were informed in the survey invitation that it would take 15 to 25 minutes to complete.

5.5. Method of analysis

The survey consisted of quantitative and qualitative questions. The quantitative questions were analysed using descriptive statistics. The focus was primarily on the frequency of answers to identify patterns within the data. Because there were 34 respondents, with 28 completing the survey, the data set was insufficient to perform statistical tests. The data retrieved from the qualitative questions were coded using half-open coding. The survey was structured in such a way that the answers would already be connected to a function. The answers were coded by categorising the responses to a specific question, and then the different arguments were analysed.

The demographic data of the survey was used to see if the group was representative and to see if groups could be specified to compare answers between them. The data on the number of swales (Q1.1), the age of swales (Q1.2), the involvement with swales (Q1.5), and the size of the municipality (Q1.7) were used to compare the different questions, but no significant difference was identified between these groups.

6
Survey Results

This chapter presents the results of the survey, which address sub-questions 2a, 2b, 2c, 3a, and 3b. The first section, section 6.1, provides a general overview of the survey, followed by respondent demographics in section 6.2. Section 6.3 discusses the respondents' views on the different functions of swales, corresponding to sub-question 2a. This is followed by section 6.4, which outlines how municipalities currently assess and monitor swales, addressing sub-question 2b. Section 6.5 describes what municipalities see as possibilities for monitoring, related to sub-question 2c. After this, the motivation for the implementation of monitoring is discussed in section 6.6, corresponding to sub-question 3a, followed by an overview of the current challenges for the implementation in section 6.7 related to sub-question 3b. The full overview of the results can be found in appendix D.

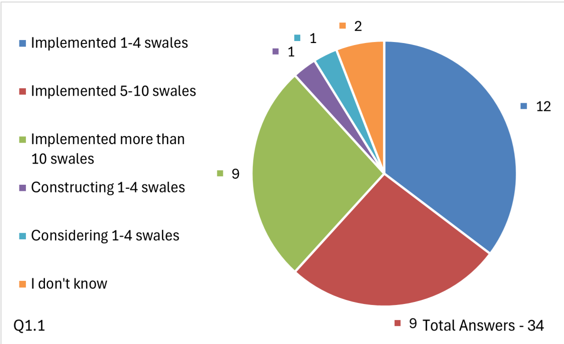
6.1. General overview

The survey was filled in by 34 participants, of whom 28 finished the survey. Of those 28 participants that finished the survey, 26 followed the "Yes" flow path, 1 the "Constructing" flow path and 1 the "Considering" flow path. The 6 participants who did not finish the survey started the "Yes" flow path. Their answers have been used until the last fully answered question that was not linked to a follow up question they did not answer.

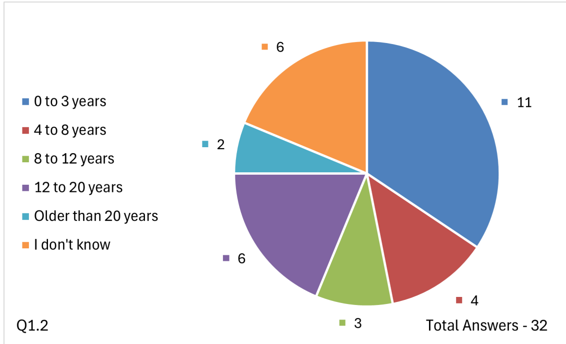
6.2. Demographics

The experience with swales of the municipality from the respondents is spread. Twelve respondents have 1-4 swales in their municipality, nine have 5-10 swales, and another nine have more than 10 swales (see figure 6.1a). In most municipalities, the oldest swale is 0 to 3 years old, but fifteen respondents work at a municipality that have a swale that is older than 4 years (see figure 6.1b).

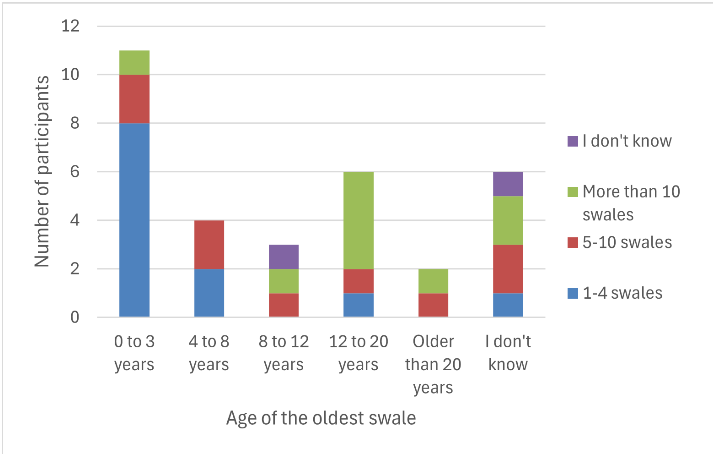
This data shows that for some municipalities, swales are still something new, while for others, they have been implemented for quite a while. The municipalities that have recently implemented swales also have fewer swales compared to the municipalities that have older swales (see figure 6.1c). This could mean that the municipalities that have had swales for a longer time, had a positive experience with the first swales and decided to implement more.



(a) The number of swales that are (going to be) implemented at the municipalities of the respondents.



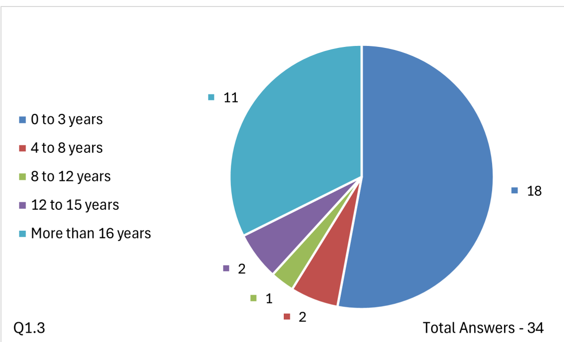
(b) The age of the oldest implemented swale in the respondents' municipalities.



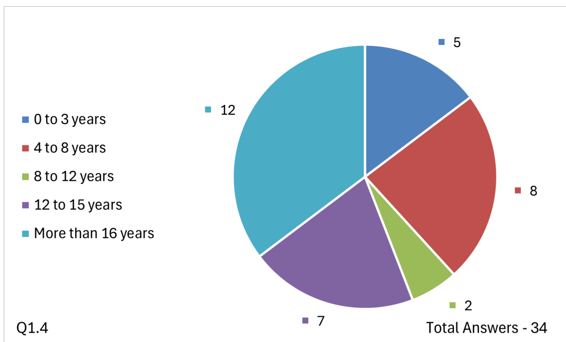
(c) Overview of the age of the oldest swale versus the number of implemented swales.

Figure 6.1: The experience of municipalities with swales (Q1.1 and Q1.2).

The working experience of the respondents at their current municipality can be split into two main groups. Eighteen respondents have been working for 0 to 3 years at their current municipality, while eleven have been working at their municipality for more than 16 years (see figure 6.2a). This gap in employment among the respondents could be explained that some respondents just started working or switch jobs more frequently, while others do not switch jobs. Almost all respondents have been familiar with swales for more than 4 years (see figure 6.2b), but for some, it is still something new. This can be explained by the increase in awareness of climate adaptation over recent years.



(a) Experience of the respondents at their current municipality.



(b) The time that respondents have been familiar with swales.

Figure 6.2: The experience of the respondents at their municipality and with swales (Q1.3 and Q1.4).

Most respondents are involved at multiple moments during the development of a swale (see figure 6.3). Fourteen participants are involved in design, maintenance, and policy related to a swale, and one participant is also involved in these three areas, as well as construction. Next to this, six participants are involved during two moments, either design and maintenance (four participants), maintenance and policy (one participant) or design and realisation (one participant). Seven participants are only involved with the maintenance of a swale, and five participants are only involved with the policy of a swale. The combination of maintenance and additional tasks is consistent with the outcomes of the interviews, where the participants were also involved during multiple moments.

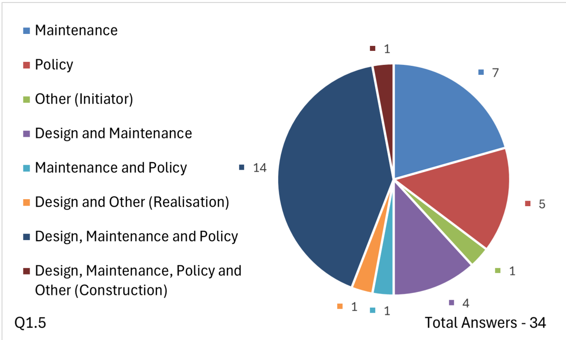
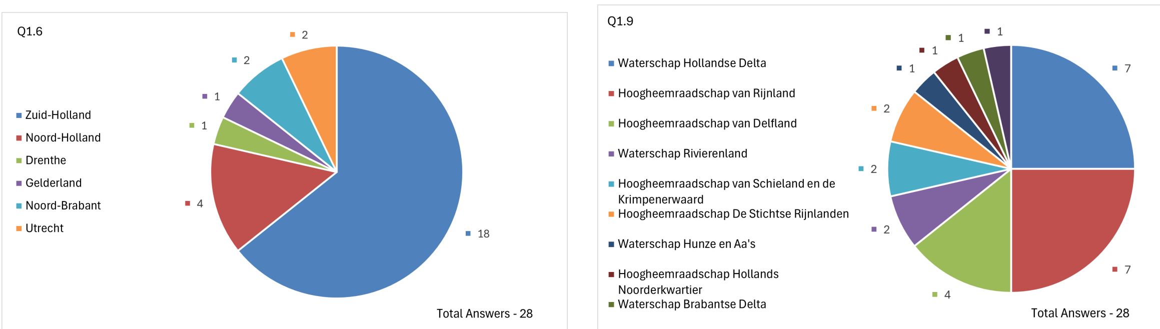


Figure 6.3: The involvement of the respondents with swales in their municipality (Q1.5).

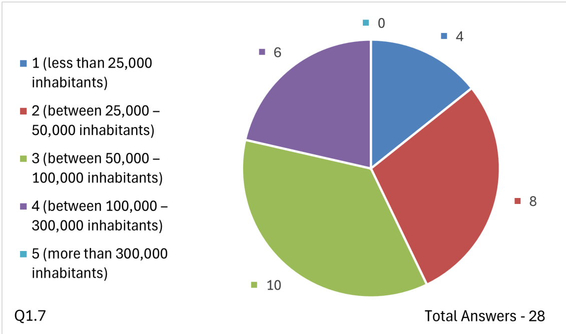


(a) The provinces where the respondents' municipalities are located. **(b)** The waterboards where the respondents' municipalities are located.

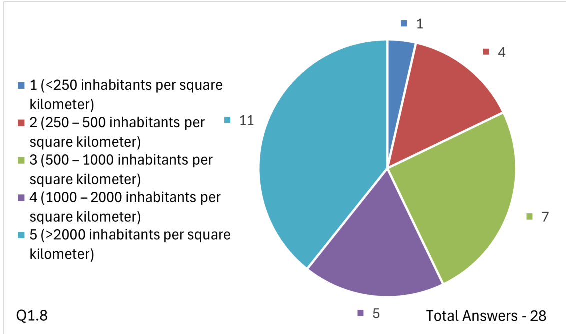
Figure 6.4: Location of respondents' municipalities by province and water authority (Q1.6 and Q1.9).

Almost all respondents work at a municipality in the target area of the survey. Most municipalities are located in the province of South Holland and are located in a targeted waterboard area (see figure 6.4).

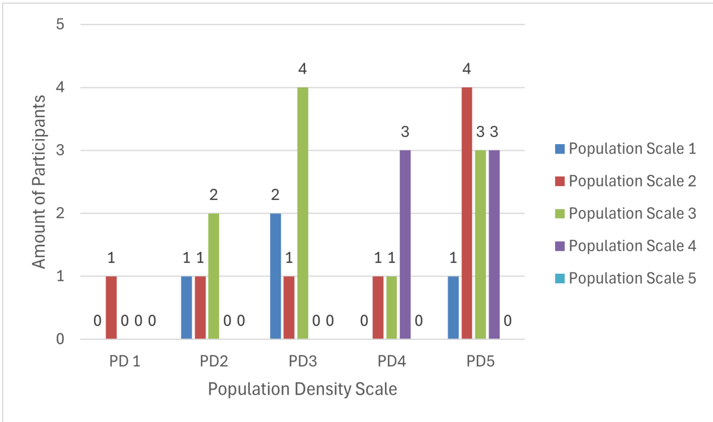
The population scale of the respondents' municipalities is spread over the categories, except category 5, but most respondents do work at a municipality with a high population density (category 4 or 5) (see figure 6.5). Still, the population scales are spread over the different density scales (see figure 6.5c).



(a) The population scales of the respondents' municipalities based on the scales of VNG (2023).



(b) The population density scales of the respondents' municipalities based on the scales of CBS (n.d.).



(c) Overview of the population scale (PS) versus the population density scale (PD).

Figure 6.5: Overview of the population scales and population density scales of the respondents' municipalities (Q1.7 and Q1.8).

6.3. Functions of a swale

Figure 6.6 shows the view of the respondents on the functions of a swale. Overall, it can be seen that the water quantity function is the most important for the respondents. The respondents agreed most with the statements related to this function in the general questions, and this was also most important for the design. Biodiversity is in second place. The results show that the respondents value the possibility of improving biodiversity, and the opinion on the general statements was positive. Water quality comes in third on the general questions; the respondents were moderately positive about the related statements, but this function is a bit less important for the design of swales compared to liveability. Since the opinions on the general statements for liveability were a bit more conflicting, this is placed fourth. Wellbeing is placed last because of the conflicting opinions about recreation. This is also reflected in the function's design.

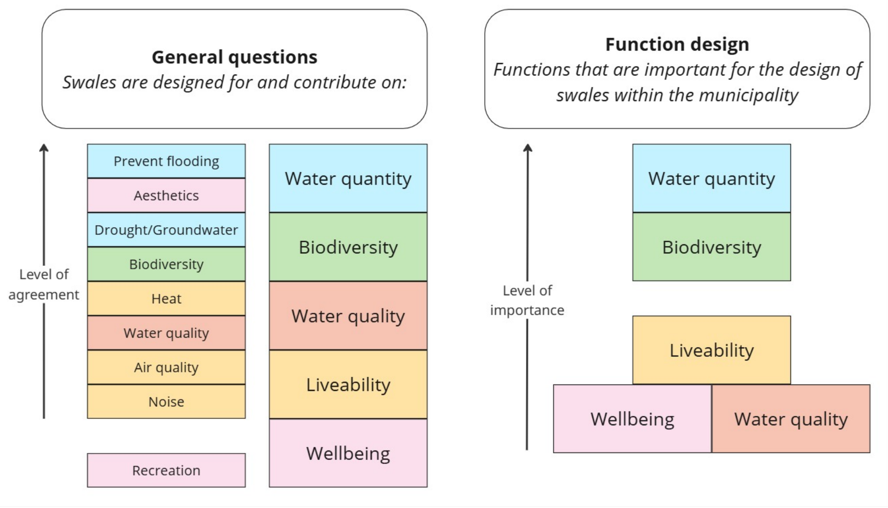


Figure 6.6: Overview of the respondents' opinion about the different functions of swales, based on the results of questions Q2.1, Q2.2, Q3.1 and Q3.2.

Most respondents see swales as objects that can contain multiple functions (see figure 6.7). In most combinations, the functions water quantity and biodiversity are combined with either liveability, water quality and/or wellbeing.

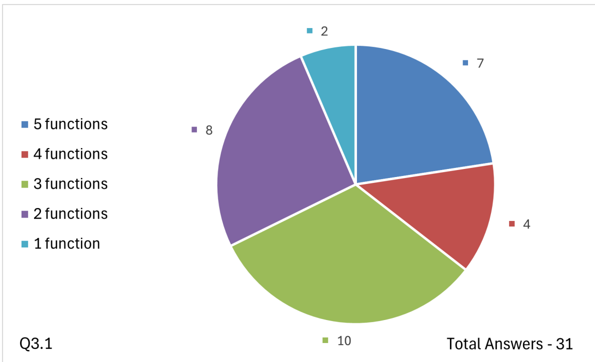


Figure 6.7: The number of functions that are important for the design of swales in the respondents' municipalities (based on Q3.1).

6.4. Current assessment and monitoring

Although the different functions are important for and often included in the design of a swale, it is not always assessed whether they meet the design requirements after the implementation. Currently, the assessments are mainly being done on the water quantity and biodiversity functions (see figure 6.8). The respondents were also asked if the swales perform as desired on the designed functions. Around the same amount of respondents that marked that they assessed a function also says it is working or partly working as desired (see figure 6.9).

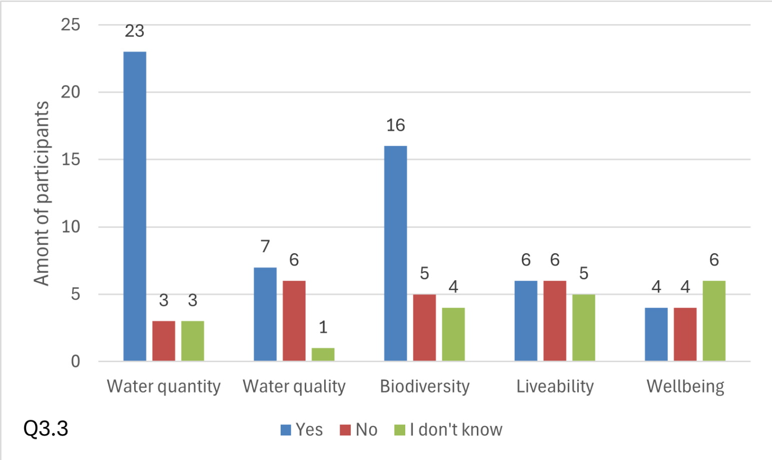


Figure 6.8: Number of respondents assessing their swales for the design criteria of the different functions (Q3.3).

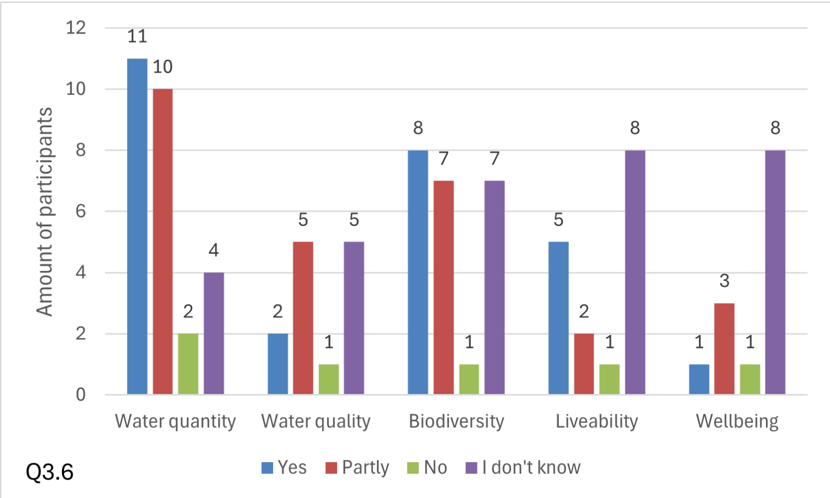


Figure 6.9: View of the respondents on whether the swales perform as desired on the designed functions (Q3.6).

6.4.1. Current assessments of the functions

The respondents have mentioned six different ways in which the swales are assessed on the functions, or which were given as a reason why swales are (not) performing as desired. Table 6.1 shows an overview for which functions the assessments are used, and if they were used to indicate the performance of the swale.

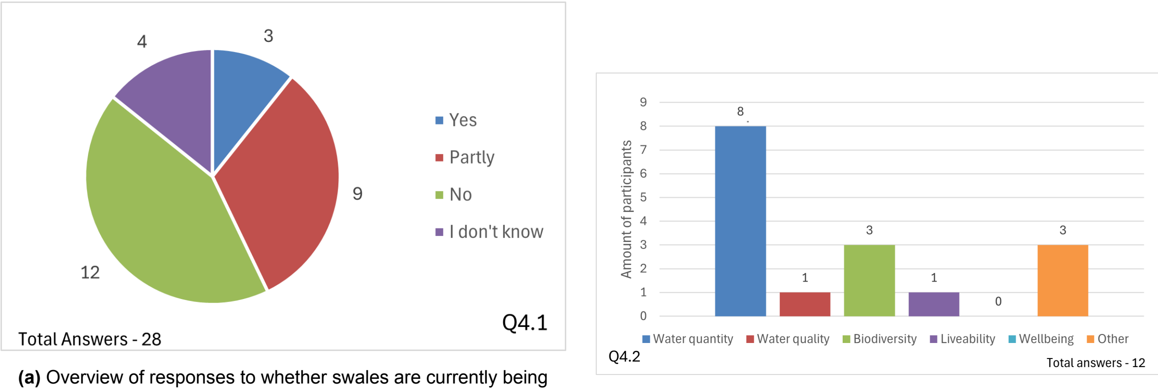
Table 6.1: Overview of types of assessments done by the respondents and whether the swales do (+), partly (∼) or do not (–) perform as desired on that function. Based on the results of questions Q3.4, Q3.5, Q3.6, Q3.7 and Q3.8.

	Water quantity	Water quality	Biodiversity	Liveability	Wellbeing
Design	+	∼	+	+	+
Design goal	+ ∼ –		+ ∼		+
Field visits	+ ∼	∼	+ ∼		
Complaints	+ ∼			∼	
Maintenance	∼ –		–		
Research is needed	∼	∼	∼ –		

1. **The design**
   The design is often mentioned for all five functions. Calculations in the design showed that a swale should perform for the design goals. One respondent did mention that practice is often different from design. One respondent also mentioned that in the design, it is assumed that it will have an effect on biodiversity and liveability.
2. **Design goal**
   Several respondents mentioned a design goal as a reason why the swale is or is not performing. For water quantity, the emptying time was mentioned; for some respondents this was as designed, but for others, water is draining slower than desired. For biodiversity, respondents mention that a biodiverse vegetation was chosen and that time is needed to see the effects. One respondent for wellbeing mentioned that children are playing in the swale.
3. **Field visits**
   Field visits are mentioned for several functions. For water quantity, the swale is visited after heavy rainfall, to check if the water is draining. One respondent for water quality mentioned that the water infiltrates and because of that it gets filtered, another respondent also mentioned field visits, but without any further explanation. For biodiversity, one respondent spotted certain types of vegetation, insects and amphibians. Another respondent mentioned that volunteers and colleagues are performing measurements in the field.
4. **Complaints**
   The number of complaints is also mentioned by some respondents. One respondent mentioned that there are no complaints and that is why it functions, while another respondent said that complaints are a reason why the swale partly functions.
5. **Maintenance**
   The wrong maintenance is given as a reason why swales don't work as designed. One respondent mentioned that proper maintenance has not been done, and another mentioned that the maintenance is difficult.
6. **Research is needed**
   Multiple respondents mentioned that more research is needed to be sure if the swales are performing on their functions.

6.4.2. Current practice of monitoring

In most municipalities, swales are not being monitored. Only three respondents said swales are being monitored, and nine answered they are partly being monitored (see figure 6.10a). From the respondents who monitor their swales, most of them monitor the water quantity function. This is mostly done by checking if a swale empties in time after rainfall, which is checked with field visits. A reason to monitor the swale is if there are complaints about its performance regarding water quantity. The respondent who monitors water quality does this with real-time measurements, which are part of a pilot project. Biodiversity is being monitored by counting species during the right season. Other aspects that are being monitored are related to maintenance, like mowing and keeping the swale clean.



(a) Overview of responses to whether swales are currently being monitored in the respondents' municipalities.

(b) Overview of what functions are being monitored.

Figure 6.10: Overview of the current practice of monitoring (Q4.1 and Q4.2).

6.5. Possibilities for monitoring

Although monitoring is not yet part of the current practice, the respondents are interested and do understand the importance of monitoring. This creates possibilities for the implementation of monitoring, but it is important to know how they want to monitor and who should be responsible for it.

6.5.1. Preference of monitoring

Figure 6.11 shows the overview of respondents' views regarding monitoring the functions. Water quantity is seen as the most important function and also the one that most respondents want to monitor. The respondents also want to monitor this function most often. The biodiversity and water quality functions are seen as equally important. The respondents say they have more knowledge about monitoring biodiversity, but more respondents want to monitor water quality. Liveability and wellbeing are ranked last on all of the questions.

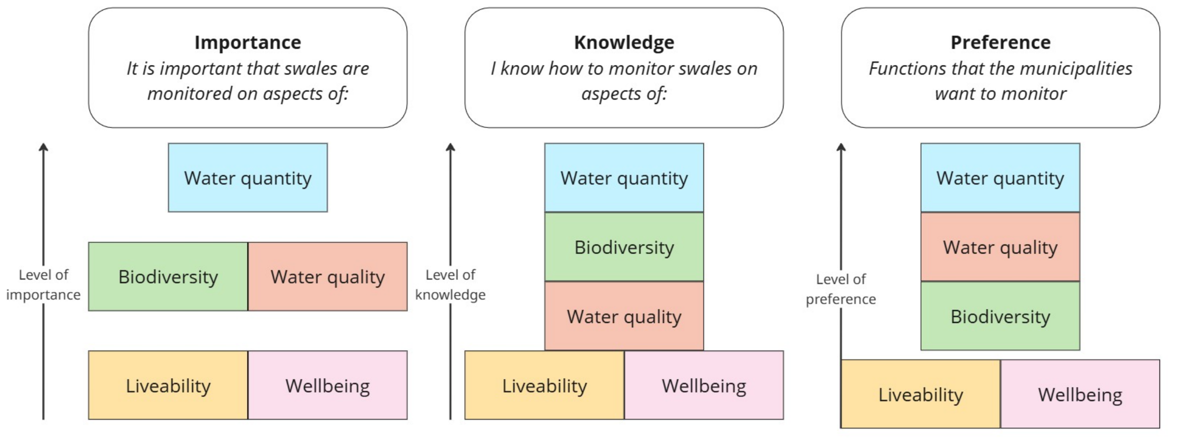


Figure 6.11: Respondents' views on the importance, knowledge, and preferences regarding the monitoring of swales, based on questions Q5.1, Q5.2 and Q5.5.

The elaborated answers showed two main insights. The first insight is related to the knowledge. Most respondents do not know how to monitor the liveability and wellbeing functions, but for the monitoring of water quantity, biodiversity and water quality, it was also mentioned multiple times that some still have a lot to learn. The second insight is regarding the importance and preference. Water quantity is considered the main function of a swale, and the other functions are often seen as additional benefits. Although some respondents did mention that if you want to improve something, you should also monitor it, the monitoring of these functions is not seen as a priority.

The respondents mentioned several variables that they would want to monitor for the different functions. These are presented in table 6.2. The preferred measurement frequency for these variables is yearly; some mentioned they want to do it based on projects or combined with other scheduled inspections. A few respondents indicated that they don't know what the right frequency is, and some want it to be monitored more often (e.g. continuous or monthly) or less frequently (every 3 to 5 years).

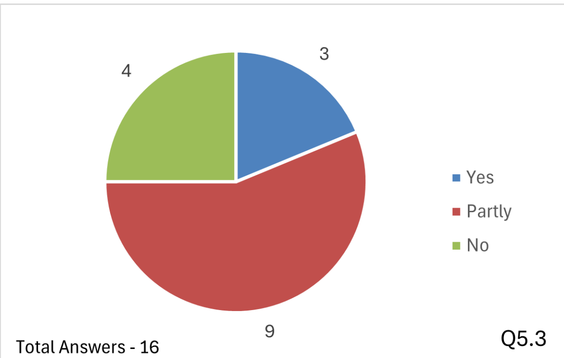
Table 6.2: Overview of the suggested variables per function, based on question Q5.6

Water quantity	Water quality	Biodiversity
Water storage / capacity	pH and Turbidity (NTU)	Amount of species
Infiltration	E. coli	Target species
Discharge time	Pak	Variable species
Use over time in case of filling	Nutrients	Insects
Flow rate	Heavy Metals	Plants
Groundwater level	PFAS	Effect on trees
Sediment	Polluting and toxic substances	Strength of plants
		Effect on soil permeability

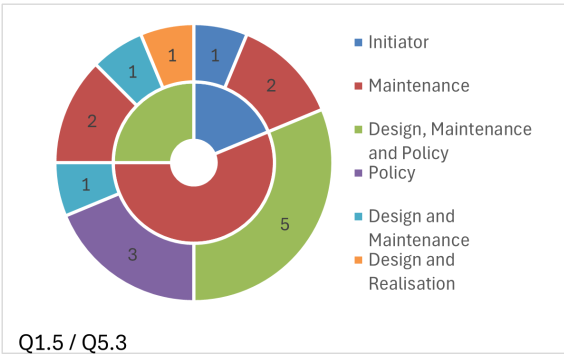
Liveability	Wellbeing	Other suggestions
Apparent temperature	Experience and safety	Influence on groundwater quality
Noise reduction	Opinion from local residents	
Air quality	The use as a meeting place	
	The use by children	

6.5.2. Responsibility of monitoring

The respondents who are not monitoring the swales in their municipality were asked if they wanted to be responsible for the implementation. Most respondents want to be partly responsible (see figure 6.12a). Figure 6.12b shows the participants' current involvement with swales in relation to their willingness to be responsible for the implementation. This shows that the respondents who were responsible for the design or policy do not want to be involved, or partly want to be involved. The respondents who are involved with maintenance are spread.



(a) Number of respondents who want, partly want, or do not want to take responsibility for implementing monitoring



(b) Willingness to the responsibility for the implementation of monitoring combined with the current involvement with swales.

Figure 6.12: The willingness of the respondents to be responsible for the implementation of monitoring combined with their current involvement with swales (Q5.3 and Q1.5).

The respondents who marked that they did not or partly want to be responsible were asked who (else) should be responsible for the monitoring. The answers were categorised into four different groups:

1. **Employees responsible for the field of expertise**
   Multiple answers mention that the different maintenance areas should work together. So, for the water quantity function, people responsible for drainage should be involved, and for biodiversity, someone who is responsible for the vegetation.
2. **Employees related to maintenance**
   Some of the respondents who are involved in policy mentioned that the colleagues in maintenance should be involved, since they can also perform the monitoring.
3. **Tactical managers**
   One respondent specifically mentioned the tactical managers. This could be the manager who is close to the maintenance personnel, but has more of an overview.
4. **Volunteers, residents and users**
   One respondent mentioned that volunteers, residents or other users could help out. This respondent also already has experience with this method, since biodiversity is monitored with a group of volunteers.

6.6. Motivation for monitoring

Next to knowing what they want to monitor, it is also important to have an overview of why they would want to monitor, since this helps with the implementation of monitoring.

In section 6.4, the results showed how the respondents assessed the functions and whether their swales were working as desired. The respondents who did not know if their swales were working were asked whether they would like to know this. Most respondents would like to know if their swales are performing as designed, and four categories could be made of the reasons why they do (not) want to know this:

1. **Importance additional benefits**
   The respondents who would like to know if the swales are performing on the functions where the current performance is unknown mention the value of knowing whether the swale is also performing on these functions. Others mentioned they see these functions as additional benefits and see water quantity as the more important. The respondents who answered with this reason often did not know if their swale was performing on biodiversity, liveability and wellbeing.
2. **Budget and policy**
   Some of the respondents who would like to know if they work to some extent mention that there is no budget available and that policy is not ready yet, because the KPIs have not been developed and embedded in the organisation.
3. **Not my task**
   Some of the respondents who would like to know if they work to some extent or don't want to know it, mention they are not interested because it doesn't fall within their job tasks. In all cases, this was related to either biodiversity, liveability and/or wellbeing.
4. **Complaints**
   One respondent wants to know to some extent if swales function for water quantity and quality, but as long as there are no complaints, it is not a priority.

6.6.1. Main motivators

In the survey, there was one question that asked what advantages would motivate to monitor swales. The answers to these questions are ranked in figure 6.13. Knowledge about the long-term effect of swales and the ability to identify problems in time are the two main motivators to implement monitoring. Knowledge about the short-term effect of swales and the possibility to improve the communication from the municipality to residents around the swale can also motivate, but was marked less often. Four respondents selected the option 'other' and gave a different reason. Answers that were given in this were getting more knowledge about swales, which motivates other disciplines for the implementation of swales, getting more insights for maintenance, to get input for future swale design and maintenance and to be able to maintain and improve the functioning of swales.

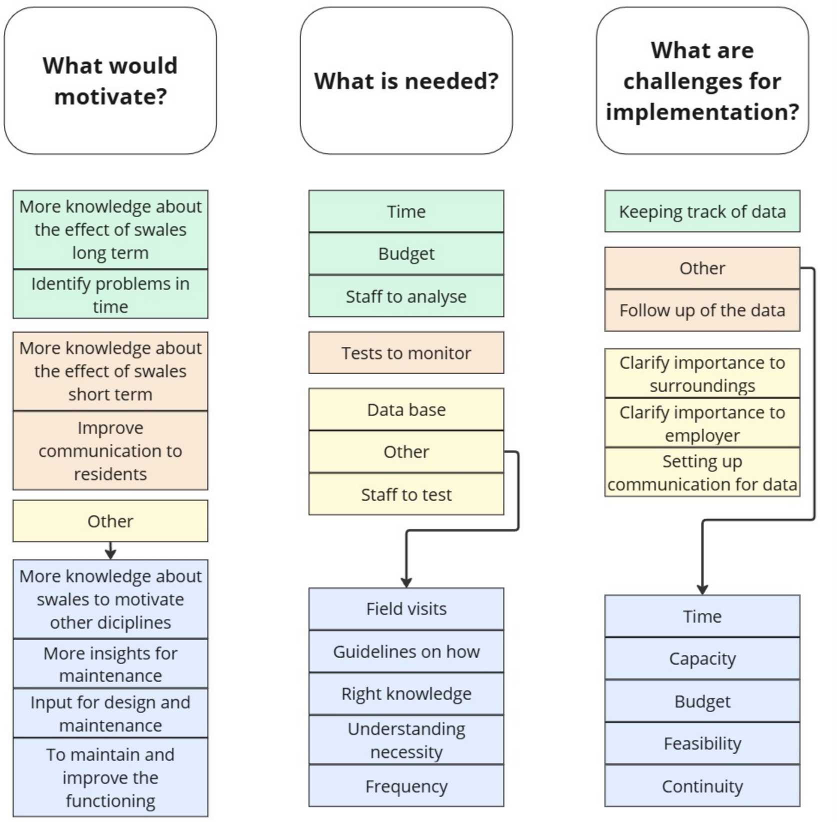


Figure 6.13: Challenges and motivators for the implementation of monitoring, based on questions Q5.8, Q5.9 and Q5.10.

6.7. Challenges for implementation

In the survey, two questions specifically asked about the challenges for the implementation of monitoring. It was asked what the respondent thinks is needed to be able to monitor swales, as well as what they see as the biggest challenge to implement monitoring and what would motivate them to do so. The answers to these questions are ranked in figure 6.13.

There are different things needed to be able to monitor swales. The respondents marked time, budget and the availability of staff that is able to analyse data as the three most important things. Another part of the respondents marked tests to be able to monitor as important. A database to store information and staff to test are less important to the respondents. There were five answers for the 'other' option: field visits during or after rainfall, guidelines on how to monitor, the right knowledge, frequency, and understanding of utility and necessity.

Keeping track of the data is answered most often as the biggest challenge for the implementation of monitoring. Second is the option 'other', and here, reasons as time, capacity, budget, feasibility and continuity were given. Respondents also marked the follow-up of the data as important. Clarifying the importance to surroundings and employer and setting up communication within the municipality for data transfer were seen as less important.

7 Summary and Conclusion of Part III

The purpose of this part was to give insight into the current practice of the design and monitoring of swales in Dutch municipalities and to address the current challenges and motivators for the implementation of swale monitoring. This was done to answer research question 2, *"What is the current practice for swale design and monitoring in Dutch municipalities?"*, and research question 3, *"What are the current motivators and challenges for the implementation of swale monitoring in Dutch municipalities?"*. To answer these questions, a survey was conducted with municipal workers who are involved with urban water management and mainly work in the region of South Holland.

The respondents of the survey see swales as multifunctional objects, but the water quantity function is the most important function for the design, while biodiversity is placed as second. The water quality, liveability and wellbeing functions are seen as less important for the design of swales. Currently, swales are mostly assessed during the design, and the design is also often given as a reason why a swale should perform as desired in a function. Other assessment types that have been conducted to determine if the swale is meeting its design goal include field visits and the number and type of complaints. A few respondents mentioned that they have implemented monitoring, but most respondents are not monitoring their swales.

Although monitoring is not part of the current practice yet, the respondents are interested. Again, water quantity is seen as the most important function to monitor and is also the most preferred. The biodiversity and water quality functions are seen as equally important, but the respondents prefer monitoring water quality over biodiversity. The preference for monitoring water quantity and water quality could be related to the target group of the survey. Since the survey was sent to urban water managers, these functions are more related to their job than the biodiversity function. The respondents mentioned different categories of people who could be responsible for the implementation of monitoring. Results mainly showed that the monitoring of swales should be done in a multidisciplinary way, where the different fields of expertise are used and that the maintenance personnel should be involved to perform the monitoring.

There are two main motivators for the respondents to monitor their swales. The first motivator is that they want to know the effect of swales on the long term. Secondly, they want to be able to identify problems in time. Some challenges need to be overcome for the implementation of monitoring. The results showed that the main challenges seen by the respondents are keeping track of data and ensuring sufficient resources, like staff and budget. Next to this, the respondents see time, budget, and staff to analyse as the most important things needed to be able to implement monitoring.

IV

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Design of the workshop

Overview Part IV

This part discusses the development of the communication tool that is meant to overcome the challenges related to the implementation of monitoring to answer research question 4: *"What communication tool can help overcome the challenges for the implementation of swale monitoring in Dutch municipalities?"*. This question had the following sub-questions:

(a) What is needed to overcome the challenges for the implementation of swale monitoring?
(b) How can communication be used to overcome the challenges for the implementation of swale monitoring?

This part will start with chapter 8, which shows the design process. This chapter contains information about the selection of the design form and gives an overview of the literature that was used for the development of the tool, to answer sub-questions 4a and 4b. Chapter 9 shows the final design of the workshop, which is followed by chapter 10, which contains the feedback on the design and how this feedback was used. The final chapter in this part, chapter 11, answers research question 4 and gives a summary of this part.

8

Design process

This chapter describes the different steps and insights that led to the final design. Section 8.1 first describes the problem statement, which combines the information obtained in part II and part III and leads to the design goal. This is then described in section 8.2, together with the selection of a suitable design form. Section 8.3 and section 8.4 describe the development of the workshop by using insights from literature and practice.

8.1. Problem statement

The literature study showed that swales are NbS that could provide multiple functions, but it remains uncertain as to what extent they can provide these functions. Research for the functions biodiversity, liveability and wellbeing is lacking, and also the water quantity and water quality function still require more research. The connections between the different functions need to be recognised, because otherwise, potential conflicts might be overlooked.

The survey revealed that multiple functions are crucial for effective design in municipalities. But it is unknown if the swales function on the designed functions, since evaluation practices like monitoring are not yet in place. Currently, swales are mainly assessed in the design phase. This was one of the main reasons given by the survey respondents for why a swale is performing as desired. This results in uncertainty in the performance of swales, since practice can be different from design. The respondents marked that they do want to know how their swales are performing and what the effect of swales is in the long term. Monitoring of swales gives the opportunity to get this knowledge and also gives the ability to evaluate swales on their design, so new designs contain less uncertainty. Water quantity is seen as the main function to monitor, but there is also interest in monitoring the other functions in combined teams.

Still, some challenges need to be overcome to implement monitoring as an evaluation mechanism. The survey showed that the main challenges seen by the respondents are keeping track of data and ensuring enough resources, like staff. Next to this, the respondents see time, budget and staff to analyse as the most important things needed to be able to implement monitoring.

8.2. Selection of design form

The problem statement leads to the design goal. The design needs to focus on overcoming the challenges to the implementation of the monitoring of swales. Chapter 3 showed different monitoring possibilities, but to overcome the challenges, more is needed. The main design goal is to motivate practitioners to start monitoring the multiple functions of swales. This will help to take the first step in monitoring swales, leading to a better evaluation of them.

The target audience of the design is chosen based on the information from the survey and the interviews. The audience is the municipal workers who organise the maintenance of swales for the different functions. They work closely with field staff who carry out the maintenance activities. Since the municipalities have different organisational structures, the people that are targeted differ per municipality, but they should perform the job of a strategic or tactical manager. These managers are often involved during the design, since maintenance is taken into account during this phase, and then remain involved after implementation, where they are responsible for the performance of the swale. Different types of maintenance take place for swales, resulting in multiple people who are responsible for the maintenance. Water management is often done by the urban water managers, while green maintenance is done in a different division.

8.2.1. Criteria for design form

Different ideas were created that would be able to reach the design goal. These are:

- Videos with monitoring instructions
- Infographic or prompting board (praatplaat in Dutch)
- Lecture to inform about monitoring possibilities
- Monitoring workshop to learn how to monitor
- Build-your-own-plan workshop

These ideas were explored based on four criteria that were created based on the design goal and insights gained from research questions 2 and 3. For each design idea, it was evaluated how it could accommodate the criterion.

Accommodate different disciplines

The design form should have the ability to accommodate the different disciplines that are correlated to the different functions. From the survey and the exploratory interviews, it became clear that the maintenance is often split up into different teams, which correlate to the different functions. To be able to implement monitoring for the different functions, the different fields of expertise will come into play. The different perspectives from these teams need to be used to create a multidisciplinary approach for the implementation of monitoring, which will create a higher chance of motivating them to implement it in practice.

All five ideas could accommodate the different disciplines, but the lecture and the workshops give more room to create a multidisciplinary approach with each other, since the audience will be together.

Provide choice for different resources

The design form should give the audience a choice for different resources. One of the main challenges was ensuring enough resources, by showing the audience different options, they can choose what suits their resources. This can motivate people to implement monitoring in their own municipality.

All the ideas provide an element of choice in some way. From the videos and the infographic, you can choose to focus on the information you see as important. The monitoring workshop and the lecture makes you see everything, and then you can choose to only use the information that is important. The build-your-own-plan workshop provides more flexibility and lets the participants make decisions during the workshop. They are also able to see all the options and have to choose to use the ones that suit the organisation.

Provide two-way communication

The design form should provide two-way communication. It should be able to inspire, by informing the audience about monitoring and the effect of it, but also needs to give room for feedback to get a better idea how monitoring can be implemented in practice, which can also improve the design. To make sure this can happen a form of two-way communication is necessary.

The videos and the infographic mainly provide a one-way communication, which is informative. The lecture can give some room for questions and reflection depending on the format, but the main goal from a lecture is informing. The workshops give a possibility to interact with the audience which provides a two-way communication.

Provide tools for monitoring implementation

The design form should be able to provide the audience tools for monitoring implementation. Since the target audience are people that organise the maintenance for swales, they know where and when monitoring could be implemented. But they need to know what is important to be able to implement monitoring.

All the ideas can help the audience with the implementation of monitoring, but the lecture and the workshops give a bit more insights and tools into the actual practice of monitoring. The build-your-own-plan workshop gives the audience also the opportunity to combine the maintenance schedule with the monitoring.

8.2.2. Chosen design form

Based on the design form criteria, it was decided to focus on the development of a workshop that provides managers with the opportunity to build their monitoring plans. This can motivate the target audience to implement monitoring into the current practice. Elements of the lecture and monitoring workshop should be included to provide room for informing the audience about the different functions and their monitoring possibilities, to ensure the monitoring plan includes multiple functions.

8.3. Development of workshop structure

The first step is to create the workshop structure, this structure serves as the basis for the design. Literature and some personal insights were used to create the basis for the structure. The different activities to support the learning activities will be determined based on the structure.

8.3.1. Insights from literature

Since the design of a workshop can be compared to the design of a lesson the handbook for teachers by Geerts and van Kralingen (2016) was used to get insights into the creation of a good structure of a workshop. This led to the use of the didactic analysis model en the direct instruction teaching model. Next to this the self determination theory was used to get insights in motivation.

Didactic analysis model

The didactic analysis model from Van Gelder et al. (1979) was developed with a focus on the organisation of activities that students can learn from. This is done by connecting the subject matter, didactic methods and learning activities. The model consists of four core components: learning goals, initial situation, learning processes and evaluation. De Corte et al. (1981) emphasised the cyclic nature of the didactic action, which means that all components influence each other (see figure 8.1).

- **The learning goals**
  Learning goals clarify what the desired outcome of a lesson should be. This helps with the question of how the goals can be achieved.

- **The initial situation**
  This is about all the things that can influence achieving the learning goals of the lesson. The initial situation involves prior knowledge of students, as well as other aspects such as the time of day and the relationship with the students.
- **Learning processes**
  This is the content of the lesson. The subject matter, teaching materials and didactic methods must support each other and need to align with the learning goals and the initial situation. The context is also important for the processes. It is important to think, for example, which location or number of students suits a certain method.
- **Evaluation**
  The evaluation is meant to check if the students have achieved the learning goals. This can be checked at the end of a lesson, and when the students take the test, it is also checked. It is also meant to reflect on the learning processes and the initial situation, and improve the lesson.

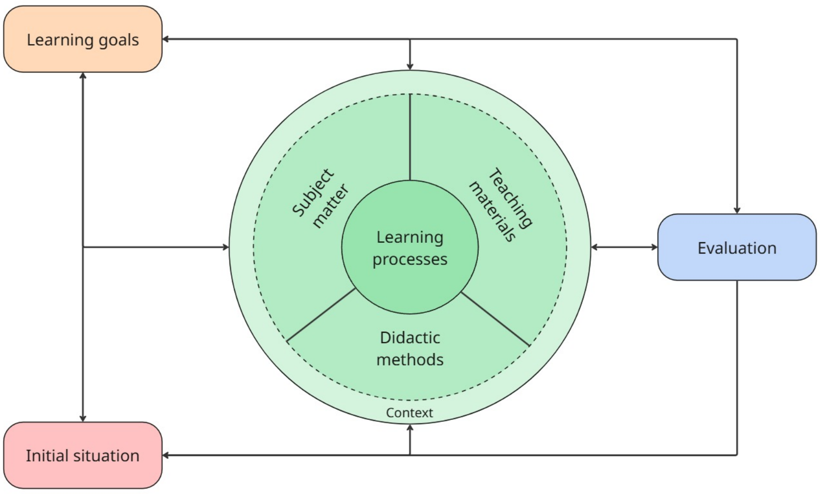

Figure 8.1: Didactic analysis model. Figure from Geerts and van Kralingen (2016) based on De Corte et al. (1981) and Van Gelder et al. (1979)

The four core components are often part of lesson preparation forms. Lesson preparation forms help teachers to organise a lesson systematically. The classic lesson preparation form is based on the didactic analysis model. This format promotes a clear lesson structure and forces the teacher to think about the learning goals and the corresponding activities of the students. The format was adapted to suit the needs for the design of a workshop. The original format is shown in table 8.1 and the adapted version in table 8.2. The most important change to take into account is the initial situation. This is most likely unknown and the opening should pay attention to this.

Direct Instruction

Direct instruction (DI) is a teaching model that is used by many teachers. It was originally developed by Siegfried Engelmann and first implemented in the 1960s (Ros, 2023). It is a teaching model in which teacher guidance plays an important role and where many different didactic methods can be used (Geerts & van Kralingen, 2016). The model consists of seven phases.

- **Phase 1: Focus on lesson objectives and activate prior knowledge**
  In this phase, the usefulness of the lesson objective is explained or shown. It is important to connect the lesson objective with the prior knowledge.
- **Phase 2: Provide information or explanation**
  In this phase, new information is given. It is important to think of the different steps in the explanation.

Table 8.1: The classical lesson preparation format (Geerts & van Kralingen, 2016)

Class:				
Subject:				
Date:				
Initial situation:				
Learning goals:				
Preparation:				
Phase	**Time**	**Activity students**	**Activity teacher**	**Media and materials**
Opening				
Core				
Closure				
Evaluation:				

To prevent losing attention, the explanation itself should not be too long.

- **Phase 3: Check if they understand the important concepts**
  This is a small phase where the teacher can check if the students understand the important concepts.
- **Phase 4: Provide instruction on learning activity**
  To make sure phase 5 is followed, clear instructions on what the students need to do are necessary. It is important to explain the what, how, who can help, time, what to do with the outcome and what to do when finished.
- **Phase 5 & 6: Practice under supervision and independently**
  The students can first practice (part of) an exercise together with the teacher, which is used to check if the students are ready to work independently. If that works out, the students can work by themselves. Students can also work together in this phase.
- **Phase 7: Conclude on key concepts and look ahead to the next lesson**
  In this phase, the teacher looks back on what the students should have learned, and if time checks the assignments. Next to this, the teacher looks ahead to the next lesson so the students know what to expect and how it will connect to this lesson.

These different phases can be used in the different moments of the workshop, which were shown in the workshop framework. Phases 1 and 7 are the opening and closure of the lesson, but the core could consist of multiple activities. If information is explained, phases 2 and 3 should be taken into account, so the different steps of explanation are clear and there is a small feedback moment to see if they understand it. If an learning activity or teaching method is used, it is important to provide clear instructions (phase 4), and then the participants will work (phase 5 & 6).

The six roles of the teacher

The model of the six roles of the teacher was developed by Slooter (2018) and is based on research into the effective behaviour of successful teachers. Successful teachers can apply the different roles at the right phase of the lesson. This gives a structure for the students, but also for the teacher, since it gives a guideline on what type of behaviour needs to be implemented and trained to become a better teacher. The six roles are:

1. **The host** welcomes the students and makes a connection.
2. **The presenter** gets the attention the the students and makes sure the objective of the lesson is clear.
3. **The didactician** teaches the students knowledge, attitudes and skills.
4. **The pedagogue** ensures a safe climate in the classroom.
5. **The closer** lets the students reflect and concludes the lesson effectively.
6. **The coach** is an experienced teacher who is skilled in the five other roles and focuses on the learning process of the individual student.

These different roles serve as a guideline for the role of the workshop facilitator in the different phases of the workshop. During the opening of the workshop, the roles of host and presenter are central. In the core phase, the facilitator takes on the roles of instructor and educator. In the closing phase, the facilitator acts as a closer. The role of the coach is left out, since this is more focused on individual learning trajectories.

Constructive alignment

Constructive alignment by Biggs et al. (2022) is a principle that is used to design education. Constructive alignment connects the learning objectives, learning activities and assessment (see figure 8.2). The learning objectives serve as the basis for designing the learning activities and assessments. If all three are aligned, an environment is created that supports that what and how students learn will lead to the intended results.

For the design of the workshop, the learning objectives should also serve as the basis for the design of the activities. The assessment can be an activity at the end of the workshop to assess the learning objectives on the spot and how they would want to use the obtained information moving forward. Next to this, an evaluation activity can be done after the workshop to see if the main objective is actually achieved.

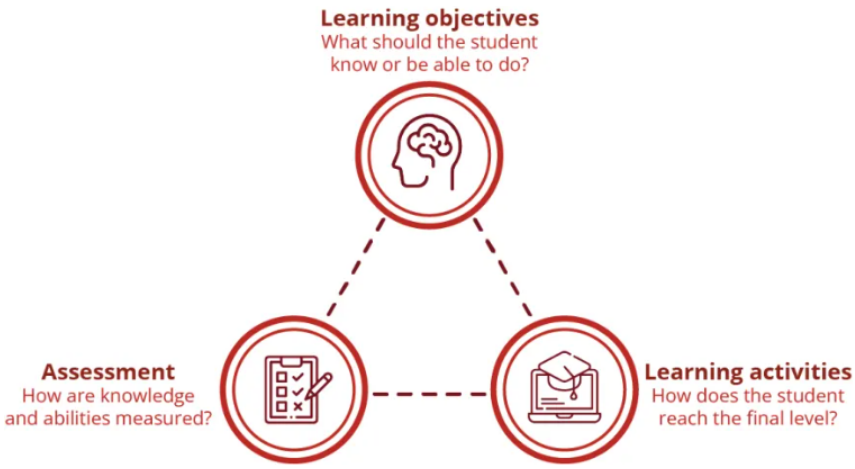

Figure 8.2: Triangular relationship for constructive alignment. Figure from Radboud University (n.d.) based on Biggs et al. (2022)

Self determination theory

The self determination theory (SDT) by Ryan and Deci (2000) is a meta theory of theories about extrinsic and intrinsic motivation. The theory does not treat the extrinsic and intrinsic motivation as two entities with nothing in between, but more as a continuum with different types of extrinsic motivation. Figure 8.3 shows this continuum.

Intrinsic motivation gives the most pleasure out of an action, but identified and integrated regulation already give a person more autonomy. Kusurkar (2020) mentioned that if a student perceives the information with high value, this can result in identified regulation. This can give similar results as students that have intrinsic motivation. To create motivated students they say that it is important to show the relevance to them, so they can see the value of what they are learning.

Next to the different types of motivation Ryan and Deci (2000) also provides three basic psychological needs that need to be fulfilled for a person to be intrinsically motivated. The first need is the feeling of autonomy, which means having the feeling of choice and action. The second need is the need of competence, a person needs to have the feeling that they are capable of doing it. The third need is the need of relatedness, a person needs to have a sense of belonging to the group.

For the design of the workshop, the three needs must be taken into account, along with showing the relevance of the topic. The feeling of autonomy was already an important aspect in the choice of design form and can be taken into account throughout the different phases of the workshop. The workshop also needs to provide a feeling of competence, which can mainly be done in the core phase, where the focus is on learning. Next to this, it is important to know the prior knowledge of the participants so that the new content keeps them motivated. Providing a feeling of relatedness can mainly be done in the opening, by letting the participants and the facilitator introduce themselves. But group work and other activities can also contribute to this need. Finally, the workshop needs to show the relevance. This is important in the opening of the workshop to have the participants motivated, but the relevance of what is being learned is also important to make sure they apply it in their work. In the core phase, the relevance of why something was included needs to be shown, and in the closure phase, the relevance of what was learned is repeated.

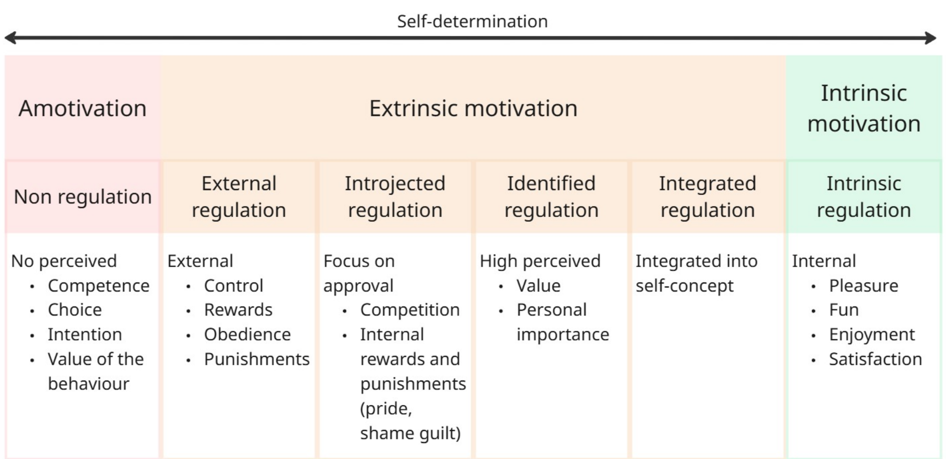

Figure 8.3: The self determination continuum (Ryan & Deci, 2000)

8.3.2. Basis for workshop structure

The didactic analysis model, DI model, constructive alignment, and the SDT were used to create the basis for the workshop. First, the learning goals were thought out to create a clear objective for the lesson. These learning goals serve as the basis for the content and learning activities of the workshop. Combined with the other additional insights, these were used to create a step-by-step overview of the aspects that need to be addressed in the workshop, both for the learning activities and evaluation. This overview is shown in table 8.2.

Learning goals

The main design goal is to motivate the target audience to start monitoring the different functions of swales. To motivate them, the SDT showed that a feeling of autonomy, a feeling of competence and a feeling of relatedness are important, together with seeing the value. The learning goals focus on creating a feeling of competence and autonomy, and making the participant understand the value.

The content of the workshop consists of three parts: swale functions, swale monitoring and the creation of the monitoring plan. The swale functions part is meant to emphasise the value of the different functions, to prevent the participants from only focusing on one function. The swale monitoring part needs to emphasise the value of monitoring and to give the participants a feeling of competence on how they can monitor. The creation of the monitoring plan is meant to give the participants a feeling of autonomy to ensure they can implement monitoring in their own municipality. Next to this, they also learn what is important for a monitoring plan, which can give them a feeling of competence. The corresponding learning goals per part are shown in table 8.2.

Workshop structure

Table 8.2: The workshop structure in the format based on the didactic analysis model, with insights from the DI teaching model and SDT

(a) General information

Subject:
Date:
Location:
Amount of attendants:
Expected initial situation: The actual initial situation should be discovered in the opening, but the participants should be familiar with what swales are and understand the basic principles of how they work.
Learning goals: *Swale functions:* • The participant knows what the different swale functions are. • The participant knows how the swale functions interact with each other. • The participant understands the importance of the interconnection of the different functions. *Swale monitoring:* • The participant knows what monitoring means and understands the importance of monitoring. • The participant knows the different criteria that can be monitored and how they can be monitored. • The participant can perform monitoring tests for several performance criteria. *Creating a monitoring plan:* • The participant knows what is important to create a monitoring plan. • The participant knows what is needed to implement monitoring in their municipality. • The participant can explain why they want to implement monitoring.
Preparation:

(b) Workshop Structure and Activities

Phase	Time	Activity participants	Activity facilitator	Media and materials
Opening Introduce goal(s) and schedule of the workshop Explore prior knowledge of participants Get to know the participants and facilitator to create relatedness			Role of host and presentor	
Core *Keep in mind:* Use phase 2 & 3 of DI for new concepts Use phase 4, 5 & 6 of DI for activities and exercises Show the relevance of each goal Make sure participants feel comfortable in group work by creating relatedness *Content in core:* Introduce the swale functions Introduce swale monitoring and let participants perform tests Let participants create a monitoring plan			Role of presentor, didactician and pedagogue	
Closure Look back on learning goals / what participants have learned Focus on the next steps for the participants			Role of closer	

(c) Evaluation

Evaluation: The evaluation is important to get insights into the effectiveness of the workshop and to improve the workshop. An evaluation activity after the workshop can be useful to see if the participants took the next steps discussed in the closure of the workshop. Based on the outcome, the workshop can be improved.

8.4. Development of learning and evaluation activities

The workshop framework serves as the starting point for the structure of the workshop and leads to four parts in which learning activities can be used. These are the opening, and the three parts of the core. The closure contains an evaluation activity, which should also be connected to the evaluation activity after the workshop. Literature and existing learning activities are used as an inspiration to create the activities that are meant to achieve the learning goals.

8.4.1. Inspiration for opening

In the opening, the prior knowledge of the participants needs to be explored, and the participants and facilitator need to get to know each other.

Initial interaction rituals, such as telling where you are from, are designed to facilitate the development of common ground and reduce uncertainty. These rituals can be explained by the common ground theory and the uncertainty reduction theory. The common ground theory by Clark and Brennan (1991) states that effective communication depends on the degree to which people share common ground. Common ground relates to mutual knowledge, beliefs and assumptions. Knowing the common ground reduces the uncertainty in a conversation. The uncertainty reduction theory by Berger and Calabrese (1975) explains the different ways in which people gain information to reduce the uncertainty in a new situation and when meeting new people. Information can be obtained via a passive (observing), active (from a third party) and interactive way (from the source). Initial interaction rituals take the interactive route, where the information is obtained directly from the source, but also provide a passive route for other people in the conversation.

In the opening phase of the workshop, an activity should be included that allows the participants to introduce themselves. This activity can also be used by the facilitator to explore the prior knowledge, and by that also reduce the uncertainty around the initial situation.

8.4.2. Inspiration for swale functions

The main goal for this part is to let the participants understand the importance of the interconnection between the different functions. Two learning activities are used as inspiration for the workshop activity.

Different learning activities can be used to show connections between different concepts. The first activity is by using concept mapping. A concept map is a diagram where the relationships between different concepts and ideas are visually represented. The concepts are connected by lines or arrows, and these lines are labelled with connecting words and phrases that clarify the connection (Wevers & Geurts, 2019). Another activity is the snake. In this activity, participants receive a stack of cards. Each card contains a question and an answer, but the answer doesn't match the question on the same card. The task is to find the card that has the correct answer to your question, and in doing so, form a continuous chain, or "snake," where each question connects to the correct answer on another card (Bruggink, 2017).

8.4.3. Inspiration for swale monitoring

The main goal for this part is to let the participants learn how monitoring can be done, but this is also a moment for the facilitator to learn how monitoring can be implemented in practice. This part can be split up into two activities.

The first activity is meant to give insights into how monitoring can be implemented and what important insights from practice are to keep in mind. This activity should not be too extensive, but by giving an interactive presentation using a tool (e.g. Mentimeter), feedback can be obtained. This feedback can be used to have a conversation with the participants and to learn from the perspectives of the different disciplines.

The second activity is meant to get hands-on experience with the monitoring tests to let the participants apply the theoretical knowledge into practice. This can strengthen their theoretical knowledge, improve their skills and competencies, and increase their motivation and commitment (Wij-leren, 2024). For the organisation of this, equipment should be available, just as a location to do the tests. During the workshop, time management is important.

8.4.4. Inspiration for creation of monitoring plan

The main goal for this part is that the participants create a monitoring plan and that they are able to explain why they want to implement the monitoring plan they created.

The creation of a monitoring plan is seen as an iterative process, just as the creation of an explanation

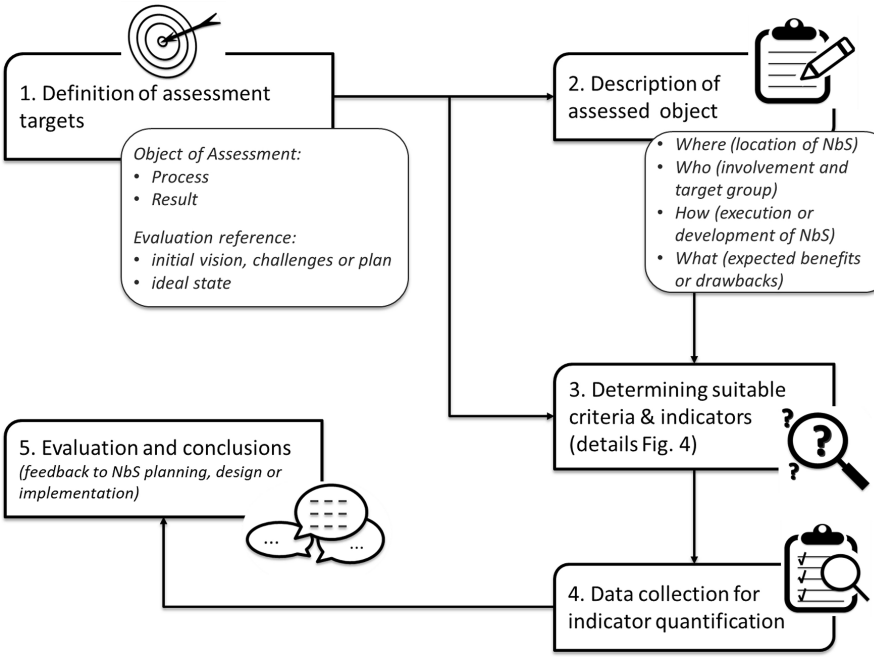

Figure 8.4: Five-Step procedure for finding appropriate criteria and indicators (Rödl & Arlati, 2022)

of why they would want to do it. To be able to provide a structured way within this iterative process, the communication spectrum developed by Wehrmann and van der Sanden (2007) was used as inspiration. In this tool, a strategy is designed through different phases by looking at different aspects that are important, such as the intended effect and the content of the message. This is combined into a strategic narrative.

For the design of the activity, the layout of the communication spectrum tool is used as inspiration. The key aspects necessary for the creation of the strategic narrative are used as inspiration to create the message of why the participant wants to monitor.

For the content of the activity, the structure developed by Rödl and Arlati (2022) is used. They described a structure that could be used to identify indicators for the evaluation and monitoring of NbS projects. There were two key insights taken into account. First, they stress that it is important to make a clear distinction between evaluation and monitoring. Evaluation takes place from the initiation of the project till implementation, when the swale is in function it changes into monitoring. The evaluation is mainly to see the quality and efficiency of the (co)creation process. They also developed a five-step procedure for finding the appropriate criteria and indicators, which is shown in figure 8.4. This procedure can be used as a guideline in the activity.

8.4.5. Inspiration for closure and evaluation activity

The closure of the workshop is meant to reflect on the learning goals and look forward to the next steps. A learning activity that is often used by teachers is the exit ticket. There are different variations, but often the students are asked what they learned (e.g. Bruggink, 2017; Peeters, 2019). These exit tickets are used as feedback for the teacher to see if the students learned what was intended. For the workshop, an exit card or poll can be created which contains the question regarding what they learned and how they would want to use it moving forward. The answers to these questions can serve as a starting point for an evaluation activity after the workshop.

9

Final design

This chapter describes the final design of the workshop. First, the general information is described in section 9.1. This is followed by a description of the workshop structure and activities in section 9.3. Finally, section 9.4 describes the evaluation activity that can be done after the workshop.

9.1. General Information

The general information outlines the workshop setting and the goal of the workshop.

Subject and Learning goals

The subject of the workshop is: Introduction to Swale Monitoring: Understanding Functions, Methods, and Implementation. The goal of the workshop is to motivate the audience to start monitoring the different functions of swales. To support this, learning goals were developed. As described in section 8.3.2, the learning goals are split into the three categories: swale functions, swale monitoring and creating a monitoring plan.

Swale functions:

- The participant knows what the different swale functions are.
- The participant knows how the swale functions interact with each other.
- The participant understands the importance of the interconnection of the different functions.

Swale monitoring:

- The participant knows what monitoring means and understands the importance of monitoring.
- The participant knows the different performance criteria that can be monitored and how they can be monitored.
- The participant can perform monitoring tests for several performance criteria.

Create a monitoring plan:

- The participant knows what is important to create a monitoring plan.
- The participant knows what is needed to implement monitoring in their municipality.
- The participant can explain why they want to implement monitoring.

Time and Location

The location of the workshop should be either close to a swale or give the opportunity to perform experiments in something similar. Next to this it is preferred that the location of the workshop is an inspirational environment, preferably something related to climate adaptation. The envisioned time for the workshop is set to be 3 hours and 15 minutes.

Audience and initial situation

As explained in section 8.2 the audience of the workshop are municipal workers that are involved in the planning and organisation of maintenance in municipalities. The group should contain people who have various responsibilities, such as green management or water management. The group size should be between 8 - 12 people to ensure possibilities for dialogue, but at the same time have the possibility for various perspectives.

The audience is expected to have prior knowledge of swales and a basic understanding of how they function. They also should know what maintenance is been carried out in their municipality.

9.2. Preparation

To get better insights into the expectations of the participants and to get to know their prior knowledge an intake can be done. This can be a survey connected to the registration form or something that is send a week upfront of the actual workshop. In this survey the participants are asked about their experience, job, knowledge about swales, and their expectations for the workshop. This the facilitator to focus on the right information.

As a preparation for the workshop the materials and equipment should be prepared in advance. This contains:

- An interactive presentation. Use of tools such as mentimeter.
- Pens and markers
- Post-its
- Workshop materials necessary for the exercises. Part of it can be found in appendix E.
- Monitoring equipment necessary for the fieldwork

The participants are asked to bring one or more examples of swales from their municipality, along with the design criteria used. This is necessary for the exercise in part 5.

9.3. Workshop Structure and Activities

The workshop consists of six parts each with different activities which were developed based on the inspiration outlined in section 8.4. An overview of the workshop can be found in table 9.1.

Table 9.1: Overview of the workshop.

	What	**Time**
Part 1	Introduction to the workshop	15 minutes
Part 2	Introduction to swale functions	30 minutes
Part 3	Introduction to monitoring	15 minutes
Part 4	Introduction to the fieldwork	5 minutes
	Break	10 minutes
Part 4	Practice with monitoring tests	60 minutes
	Break	15 minutes
Part 5	Creation of the monitoring plan	30 minutes
Part 6	Closure and moving forward	15 minutes

9.3.1. Part 1 - Introduction to the workshop

At the start of the workshop, an introduction to the workshop is given. This is done by telling the goal of the workshop and what is expected that they will learn and by showing the schedule of the workshop and the different activities that are related to this. Next to this, the attendees will also introduce themselves. The goal of this part is to introduce the workshop and to get to know the attendees.

Overview

1. The facilitator welcomes and thanks the attendees for participating in the workshop.
2. The facilitator shows the goal of the workshop and a schedule of what will happen in the workshop.
3. The facilitator asks the attendees to introduce themselves by telling their name, municipality and job. The participants are also asked to tell why they joined the workshop, and they have to answer a question from an introduction card. To make clear what the participants need to say, the facilitator gives an example by starting the introduction round.
   Examples of questions on the introduction cards:
   - What is your favourite aspect of swales?
   - What is your favourite swale?
   - What is the biggest advantage of a swale?
   - If a swale could provide any additional benefit, what would you choose?
4. The facilitator thanks everyone for introducing themselves and continues to the next part.

9.3.2. Part 2 - Introduction to swale functions

The second part gives an introduction to the different functions of swales and what is needed to facilitate these functions, as described in section 2.2 and chapter 2. The goal of this part is to let the participants understand the importance of the interconnection between the different functions, by creating clear definitions of the functions and inform them how they are connected.

Overview

1. The facilitator introduces the functions that are common in NbS/SUDS design (water quantity, water quality, biodiversity, liveability and wellbeing).
2. Per function
   - The participants are asked what they know about the function and how they think swales can contribute to this function, by using the interactive presentation.
   - The facilitator discusses the results with the attendees and elaborates with information from section 2.3.
3. The facilitator introduces the interconnection of the different functions and the different types of connections, as discussed in section 2.4.
4. The facilitator introduces the connection activity, and the participants execute the activity. (see below)
5. The facilitator asks if the participants are missing any connections.
6. The facilitator asks if there are any remaining questions, answers them and then continues to the next part.

Connection activity

The connection activity is meant to show the connections between the different functions. For the activity, you need cards as shown in appendix E.1 and a ball of wool (or another type of rope) that is minimum 40 meters long.

The participants are asked to stand in a circle and are then divided into five groups, each representing one of the functions. Each group receives a stack of cards. These must remain closed and should not be shuffled. The Water Quantity group also receives the ball of wool.

Then, the activity proceeds as follows:

1. When a group receives the ball of wool, they open the top card from their stack, which shows the name of a function (not their own).
2. The group should then explain one reason why they think their function influences the function on the card in the context of swales, so not in general.
3. After the explanation, they hold onto part of the string and pass the ball of wool to the group representing the function shown on the card.
4. This continues until all cards have been revealed.

As the wool is passed from group to group, a web of connections is formed, demonstrating how the functions are interconnected and dependent on one another

To clarify the activity for participants, the first card can be used as an example. The first card for Water Quantity is Biodiversity. An example explanation could be: ”The availability of water influences plant growth.” If a participant or group cannot come up with an explanation, it is encouraged to ask the other participants. In the instructions of the activity, also refer back to the different types of connections explained before.

9.3.3. Part 3 - Introduction to monitoring

The third part gives an introduction to monitoring and informs them about the different possibilities for monitoring as described in chapter 3. The goal of this part is to let the participants get acquainted with the different criteria that can be monitored and how they can be monitored. For this part, the interactive presentation is used again.

Overview

1. The facilitator asks what the participants see as monitoring and evaluation by using the interactive presentation and then explains what it entails.
2. The facilitator asks the participants how they currently keep track of how their swale performs, and what they measure.
3. The facilitator introduces the important criteria that could be monitored and shows the corresponding possibilities as described in chapter 3.
4. The participants are asked, by using the interactive presentation, which criteria they would want to monitor and why.
5. Per criteria

9.3.4. Part 4 - Practice with monitoring tests

The fourth part lets the participants practice with monitoring , depending on the location and equipment two to three tests can be shown. This is meant to get the participants acquainted with the possibilities and practice what can be done.

Overview

1. *Before the break*
2. The facilitator introduces the assignment to the participants.
3. The participants are asked to create 2 - 3 groups in which the disciplines are mixed. The group size needs to be around 4 - 6 people.
4. *After the break*
5. The participants go outside and perform the different monitoring exercises.
    - The participants either get guided by an expert or get a guideline on how to perform the test.

9.3.5. Part 5 - Creation of the monitoring plan

The fifth part lets the participants create their monitoring plan combined with a story. The goal of this part is to create a starting point for the participants to start monitoring by creating a monitoring plan and letting them write down their motivation.

Overview

1. The facilitator introduces the activity to the participants, and the participants are asked to create groups. (see below)
2. The participants start by individually completing the first three steps of the worksheet.
3. They then discuss what they filled in within their groups and continue filling in the same steps to make them more complete.
4. After that, the participants are asked to write down the final step.
5. Each participant is then asked to share their monitoring motivation pitch.

Making your monitoring pitch

The activity is meant to use the motivation to make it easier to remember the importance of monitoring and their created monitoring plan. The worksheets for this exercise can be found in appendix E.2. Each monitoring plan will be based on the swale that participants brought as preparation.

Participants are asked to form small interdisciplinary groups of 3–4 people, preferably different from those in part 4. Each participant receives two worksheets and a pen.

The worksheet consists of the following steps:

1. Participants first describe their swale by writing down what was important in its design and identifying the related performance criteria.
2. They then list the selected criteria and specify who is involved in maintaining or measuring them, how the criteria will be measured, how frequently, and what resources are needed.
3. Next, they explain why each criterion is important, why they want to monitor it, and what will be done with the collected data.
4. Finally, the participants summarise their thoughts and write down their motivation for monitoring on the second sheet.

9.3.6. Part 6 - Closure and moving forward

The sixth part is meant to close the workshop together. A summary is given of what has been done, and it asks the participants what they learned in the workshop and what they will use in their daily practice.

Overview

1. The facilitator summarises what has been done during the workshop.
2. The participants are asked what they have learned and how they will use it in their daily practice, by using the interactive presentation.
3. The facilitator asks the participants if there are any remaining questions.
4. The facilitator thanks all the participants for joining.

9.4. Post workshop evaluation

After the workshop, the participants will receive an overview of the results of the workshop together with some workshop material. This will remind them of what was done in the workshop. A survey can be sent to get feedback on the workshop and to ask if they have put something into practice. To see if the workshop affected the implementation of monitoring, an additional session can be held, either online or in person. In this session, the participants share experiences and ask questions.

10

Iteration & evaluation of the design

To evaluate the design and see whether it can achieve the goal of motivating the practitioners, feedback was obtained from two outside experts (section 10.1). Next to this, the design was evaluated with fellow students (section 10.2).

10.1. Feedback from experts

Two outside experts were consulted to obtain feedback on the design, both of whom have experience as teachers in higher education. Next to this, they work as advisors in the Dutch water sector and have experience in designing workshops for municipalities.

10.1.1. Expert 1

The first expert gave feedback on several points, which were taken into account for an updated version of the final design.

Achieving the goal

The workshop will increase audience's the awareness of swales, encourage them to consider the different functions, and lets them practice with measuring, monitoring and retrieving of data, or at least encourages them to consider what data can be retrieved. All of this creates an experience and it gets people excited. Ultimately, employees will start thinking about their role and responsibilities regarding monitoring.

The expert also notes that participating in this workshop could lead to assigning the responsibility of monitoring to a single person, because they have the budget or because they are the only one who sees the necessity. Swale monitoring is often incorporated in the water management tasks and it will be interesting to see what the green department will do with it.

It is also important to make the urgency of monitoring clear; the bigger the problem appears to be, the more willing the participants are to do something about it.

Structure of the workshop and activities

The workshop has a logical structure, but the time allocation can be critically reviewed. In the first part, the audience must listen for 45 minutes; the presentation could be shorter or made more interactive by alternating between the theory, discussion and play.

The interaction can be accomplished with activities where the audience can think about the different functions, how a design incorporates these functions, and what the risks and limitations are for the design. In the introduction to monitoring, they can then be asked how they track the functions. Next to this, it is important to write down every step of each part. This helps to avoid surprises and helps the facilitator.

Time management
Time management is very important, especially when going outside. Currently, there is time for 45 minutes, but a little more time is suggested.

Results
It was suggested that if information and results are to be collected, it is important to provide clear requirements upfront on how they are collected, so they can still be understood afterwards.

Audience
Different target groups, because of the different functions, also mean different people who have different goals, needs and processing speeds. Carefully consider who is invited. Maintenance staff are, by definition, less accustomed to sitting for long periods compared to policy advisors. And it is also important that the information can be understood by everyone in the group.

10.1.2. Expert 2
The second expert gave feedback on several points. Some points are used as recommendations, and others are taken into account for an updated version of the final design.

Achieving the goal
The workshop gives the audience a concrete and practical output that can be used in practice and provides them with answers to their questions. The additional motivational elements, such as an inspiring location, help with obtaining additional motivation.

Target audience
The expert mentioned that his workshop often has a mixed audience, containing a combination of policy workers combined with maintenance staff. This results in the possibility of them seeing each other's views, and it helps to work together.

Initial situation
To get a better view of the prior knowledge of the participants and to be able to prepare accordingly, an intake can be done upfront of the workshop. This can also help to shape the workshop to the needs of the participants better.

Location
The suggested location was confirmed to be a good location. The expert often performs the workshops close to swale districts or climate adaptation field labs.

Content and activities
There were several suggestions for the workshop's content and activities. For the content, this was mainly related to current guidelines from parties such as RIONED and the use of examples from practice. This is especially relevant when the participants are unaware of the guidelines for the design of the swale, and providing this information can help to continue the workshop and allow them to execute the activities. This point is used as a recommendation.

Additionally, it was suggested for part 3 to present the criteria as suggestions rather than as important to the facilitator. This would then allow for discussion on what performance criteria are important to the participants.

10.2. Feedback from peers

The final design was discussed with four fellow students from both master programs, all with different backgrounds. The general outline of the workshop was discussed, and both the connection activity and the story activity were practised. The aim was to get an impression of the workshop and to get recommendations for adjustments.

General comments

The workshop idea was very clear, and the outline made sense and is a nice structure. The combination of different activities is fun and interesting. It was suggested to make the breaks a bit longer to provide for some room in the schedule. Next to this, each step in the activities needs to be clearly explained, so the participants do what they are intended to do.

Part 1

The introduction round with the additional questions was seen as a good idea and was helpful to get the participants thinking about swales.

Part 2

The activity was practised and led to a nice web of connections as intended (see figure 10.1). To get the explanations as intended, it is important to stress that the connections need to be made concerning swales and not just in general, and a clear explanation about the various possible connections is also important.

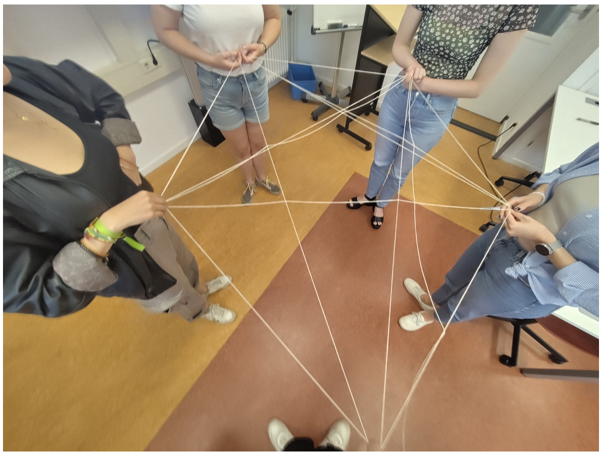

Figure 10.1: Result of the connection activity during the practice session with peers.

Part 3

This part seemed to be repetitive, especially if the same steps (showing possibilities and then asking participants) are repeated for each criteria. It was suggested to make a distinction between the criteria that are usually monitored or more likely to be used. To gain the feedback from participants in this part, it was suggested to first discuss it in groups to also have less listening.

Part 4

To make a smooth transition to the break into part 4, it was suggested to give the introduction to the assignment and the group division before the break, while everyone is still seated. This helps with the clarity of the assignment and makes sure the participants are preparing to go outside during the break.

Part 5

The monitoring story exercise was clear in general, but there were a few suggestions. First, the different steps on the first worksheet need to be made clear; this can be done by providing numbers on the sheet.

Some questions on the sheet also need a bit more explanation (e.g. make a clear distinction between requirements and criteria). It was also recommended to call the final step a pitch instead of a story. This creates a bit more clarity that they need to be convinced by why they want to monitor.

Part 6

To get a better idea of what the participants learned, it was suggested to ask the same question in the introduction and the closure to see what the difference is. This can be done via a word cloud in the interactive presentation.

11

Summary and Conclusion of Part IV

This part discussed the development of the communication tool that is meant to overcome the challenges related to the implementation of monitoring to answer research question 4: *"What communication tool can help overcome the challenges for the implementation of swale monitoring in Dutch municipalities?"*.

The results from part II and part III were combined in a problem statement, which led to the design goal. The main challenges seen by the respondents are keeping track of data and ensuring enough resources. Chapter 3 already showed different monitoring possibilities for different resources, but to overcome the challenges, more is needed. Therefore, the design goal was to motivate practitioners to start monitoring the multiple functions of swales. These practitioners are the target audience, and are specifically the municipal workers who organise the maintenance of swales for the different functions.

Multiple ideas came around that would be able to fulfil the design goal, which resulted in the chosen design form being a workshop that provides managers the opportunity to build their monitoring plans. This idea was chosen because it is able to accommodate different disciplines that are correlated to the different functions, it can provide the audience a choice for different resources, it provides a two-way communication and provides tools for the implementation of monitoring.

As a first step in the design, the workshop structure was developed. This was done by using different educational models and additional insights. The literature led to a workshop structure where the learning goals are used as the basis for the development of the content and activities in the workshop. The development of the learning goals led to a workshop structure which could be divided into six parts. For each part, activities were developed based on additional insights from literature.

The final design of the workshop was evaluated by two external experts and discussed with fellow students. Both the experts and the peer group gave feedback that was used to improve the workshop. Next to this, the experts both confirmed that the workshop is able to motivate the target audience to start monitoring, because it increases the audience's awareness of swales, encourages them to consider the different functions and lets them practice with measuring, monitoring and retrieving of data. It also provides them with a concrete and practical output that can be used in practice.

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Conclusion and Discussion

12

Conclusion & Discussion

This chapter is a conclusion to the whole research. First, the research questions are answered in section 12.1. Then the findings of the research are discussed and put into perspective in section 12.2, together with some recommendations.

12.1. Conclusion

This research started with two objectives. First, the current practice in research and within Dutch municipalities was explored to identify performance criteria for swales and to provide monitoring techniques to track the key functions of swales. Secondly, the current motivators and challenges for the implementation of monitoring were explored, and a communication tool was designed that is meant to overcome these challenges.

A systematic literature study was performed to identify the key swale functions and to give insight into what is currently known in the literature about the swale's ability to provide the benefits of these functions. To get insight into the current practice of the design and monitoring of swales and to find the current challenges and motivators for the implementation of swale monitoring, a survey was conducted. This survey was conducted with municipal workers who are involved with urban water management and mainly work in the region of South Holland.

The literature study identified five key swale functions: water quantity, water quality, biodiversity, liveability and wellbeing. The study also showed that more research is needed to know how swales can be designed and maintained to be able to provide within the functions of biodiversity, liveability and wellbeing. More is documented for water quantity and water quality, but especially for certain pollutants, more research is needed. The research also showed that the functions cannot be seen separately and that they are connected.

Based on the information obtained in the literature study the following criteria were selected, which serve as the basis to monitor swales on the five functions:

- Infiltration rate
- Soil moisture
- In- and outflow of pollutants
- Soil quality
- Vegetation development
- Temperature

- Experience by residents
- Usage by residents

By monitoring these criteria, more knowledge can be obtained about the swale's performance. Each criterion was provided with several monitoring techniques for different resources.

The survey showed that swales are seen as multifunctional objects by the respondents. The water quantity function is considered most important, and biodiversity comes second. The monitoring of swales is not really part of current practice yet. Swales are mainly assessed during the design and are only checked if complaints occur. A few respondents mentioned that they have some monitoring in place, but this is only for the water quantity function. Although monitoring is not part of the current practice, the survey respondents are interested in it and also see the importance of monitoring. In this case, monitoring the water quantity function is seen as the most important, but they are also interested in water quality and biodiversity.

The main motivation of the respondents to have monitoring is that it gives insight into the effect of swales long term, and it helps with the ability to identify problems in time. The main challenges that need to be overcome for the implementation of monitoring are keeping track of data and ensuring sufficient resources, like staff and budget.

All obtained information was combined to create the design goal for the communication tool. The goal of the tool is to motivate practitioners to start monitoring the multiple functions of swales. These practitioners are the target audience and are specifically the municipal workers who organise the maintenance of swales for the different functions. The chosen design form was a workshop where the audience gets the opportunity to learn about the different functions and the monitoring of swales, and also build their own monitoring plan. This design was evaluated by two external experts who confirmed that this workshop is able to motivate the target audience, because it increases the audience's awareness of swales, encourages them to consider the different functions and lets them practice with measuring, monitoring and retrieving of data. It also provides them with a concrete and practical output that can be used in practice.

12.2. Discussion and recommendations

This study has provided a framework that can improve the implementation of swale monitoring in the Netherlands. The outcomes of this research have provided an overview of relevant criteria and corresponding monitoring techniques, together with an overview of the current motivators and challenges for the implementation of monitoring. Next to this, a communication tool was developed to bridge the gap between knowledge and practice. However, there were some limitations within this research.

The literature study mainly looked into the general literature, which gave an overview of what is currently known, but it is lacking the specific knowledge from the Netherlands. This was partly obtained in the survey, but to get a better perspective on the different functions, more local research needs to be done by looking into already implemented swales and experiences from practitioners. The research into the different monitoring techniques was also limited to techniques that are already more commonly used. New methods might be available that could be useful. Next to this, the monitoring techniques should also be provided with guidelines and clear instructions. These instructions should be tested by the people responsible for the monitoring and improved based on their feedback. Currently, the monitoring techniques mainly provide an overview of how to measure the different criteria, but the guidelines should also include how the data should be interpreted and evaluated.

The survey had multiple limitations. First, it is unknown if the survey was only filled in by the municipal workers involved with urban water management, since in most cases, the survey was sent via contact forms and not directly to the respondent. If the person responsible for the administration of the forms did not fully understand the description, this could have resulted in a different answer. It could also be that the topic of the survey was seen as something that belonged to someone responsible for the sustainability department, which is not part of the target group. Secondly, the number of participants also limited the research. The demographic data was obtained, but due to the number of responses, the answers could not be grouped to identify patterns. Thirdly, some participants misunderstood the difference between wellbeing and liveability. This could have affected the results, especially since the respondents were very divided about the recreational aspect of wellbeing. In the survey, the definitions were given multiple times, but the participants might have skipped over them. Finally, the qualitative answers were interpreted, but it could be that the respondent had a different meaning. For some questions, it was unknown what the respondent meant because the elaboration was very short. Another limitation of the qualitative data is that when an elaboration was optional, it was often provided by the same respondents. Other respondents could have had a different opinion, but since it was not provided, this was not taken into account.

The final design still has its limitations. The design was evaluated by experts, but to fully validate whether the workshop can achieve its intended goal, it should be implemented in practice. This will also give feedback on the practicalities and show other needed improvements. The practical knowledge of the workshop participants should also be used to improve the information in the workshop.

The research also revealed a difference between the functions that are present in research and those prioritised in current practice. While research has mainly focused on water quantity and water quality, the survey respondents considered water quantity and biodiversity important. The focus of research could be explained by the closer connection between the research fields of water quantity and water quality. However, it is strongly recommended that the other functions receive more attention, especially biodiversity, since it is seen as an important function for the design of swales.

Further research could examine the ability of swales to provide the functions individually and combined. If swales are being monitored by municipalities, this data could be used to see how they perform. In particular, the functions of biodiversity, liveability and wellbeing should be studied. But additional research should also be done in an open-air lab such as MESUDA. To get better insight into the current practice in the Netherlands, a follow-up survey or interviews can be conducted. It is recommended to target the different disciplines related to the different functions to see if there is a difference in experience and preference for monitoring. Finally, further research can also explore the expansion of the workshop. A follow-up workshop could be designed, or another additional communication tool can be developed that supports the workshop and helps the participants with the implementation.

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VI

Appendices

A
Monitoring Criteria Selection

The overview shown in figure A.1, shows the factors and connections between the different factors that are important for the swale performance. Based on this overview, the criteria were chosen as described in section 3.1.

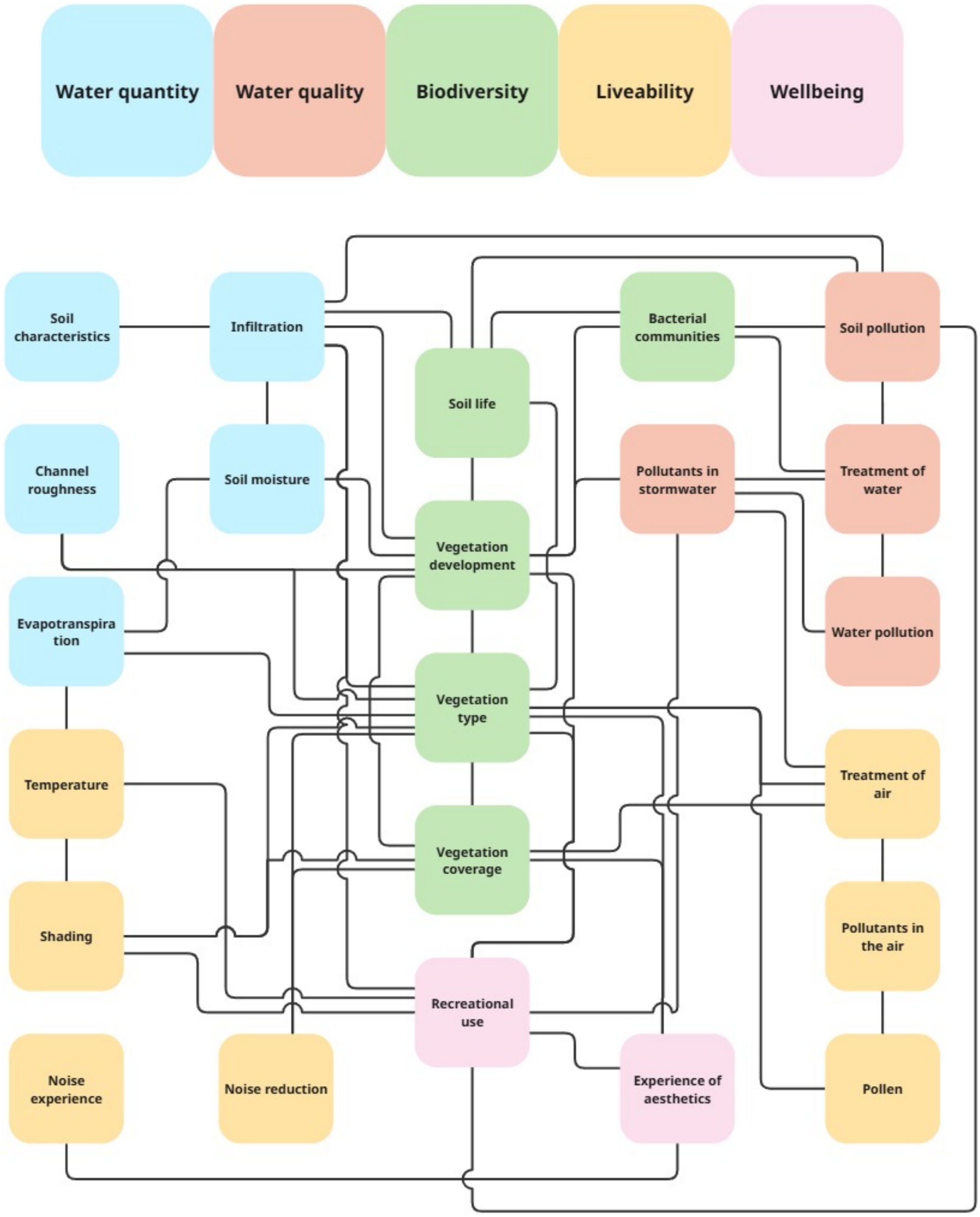


Figure A.1: Overview of relevant factors for the swale performance and the relevant connections.

B
Opening statement

Dank u wel voor uw deelname aan dit onderzoek. Voordat u start met de enquête, zou ik u graag wat achtergrondinformatie willen geven. Daarna vraag ik u om toestemming voor uw deelname en het gebruik van uw persoonlijke data.

Wie ben ik?
Mijn naam is Sophie de Wolff, ik ben een student aan de TU Delft waar ik op dit moment mijn afstudeeronderzoek uitvoer voor de gecombineerde master watermanagement en wetenschapscommunicatie.

Waarom deelnemen
Deze enquête is een deel van mijn onderzoek naar de mogelijkheden voor de monitoring van wadi's. Dit onderzoek wordt gedaan om beter inzicht te krijgen in het gedrag en ontwikkeling op de lange termijn, zodat deze beter ontworpen en beheerd kunnen worden.

Ik wil in mijn onderzoek erachter komen wat de praktijk is rondom de implementatie en monitoren van wadi's. Met deze enquête wil ik graag weten wat u als uitdagingen ziet. Uw input wordt gebruikt om het resultaat van het onderzoek te laten aansluiten bij de praktijk.

Datacollectie
De verzamelde informatie wordt vertrouwelijk behandeld en zal direct worden geanonimiseerd. Alle data wordt opgeslagen op een beveiligde locatie die alleen toegankelijk is voor de mij en mijn begeleiders. Achteraf wordt de geanonimiseerde data verkregen uit de enquête gedeeld. Geen enkele individuele deelnemer zal worden geïdentificeerd in rapporten of publicaties die uit deze studie voortkomen.

Aan het einde van de enquête wordt gevraagd of u geïnteresseerd bent in deelname in het vervolg van dit onderzoek. U kunt hiervoor uw email adres achterlaten, het emailadres is niet gekoppeld aan antwoorden van de enquête.

Duur
De enquête bestaat uit 50 vragen en duurt ongeveer 15 minuten om in te vullen. Uw input en tijd worden erg gewaardeerd.

Contact informatie
Mocht u vragen hebben kunt u contact opnemen met mij of mijn begeleiders.

Hoofdbegeleider Watermanagement – Prof. Dr. Thom Bogaard – t.a.bogaard@tudelft.nl
Hoofdbegeleider CDI – Drs. Caroline Wehrmann – c.wehrmann@tudelft.nl

Met vriendelijke groet,
Sophie de Wolff

Bevestiging
Als u akkoord gaat geef dan uw bevestiging hieronder.
□ Ik bevestig hierbij het bovenstaande te hebben gelezen en ga akkoord met het gebruik van de gegevens.

C

Survey questions

This appendix shows the questions of the survey per question block. Figure C.1 shows the full overview of the survey flow and which questions were in which flow path. If a question had a different version in another flow path the additional options are also shown.

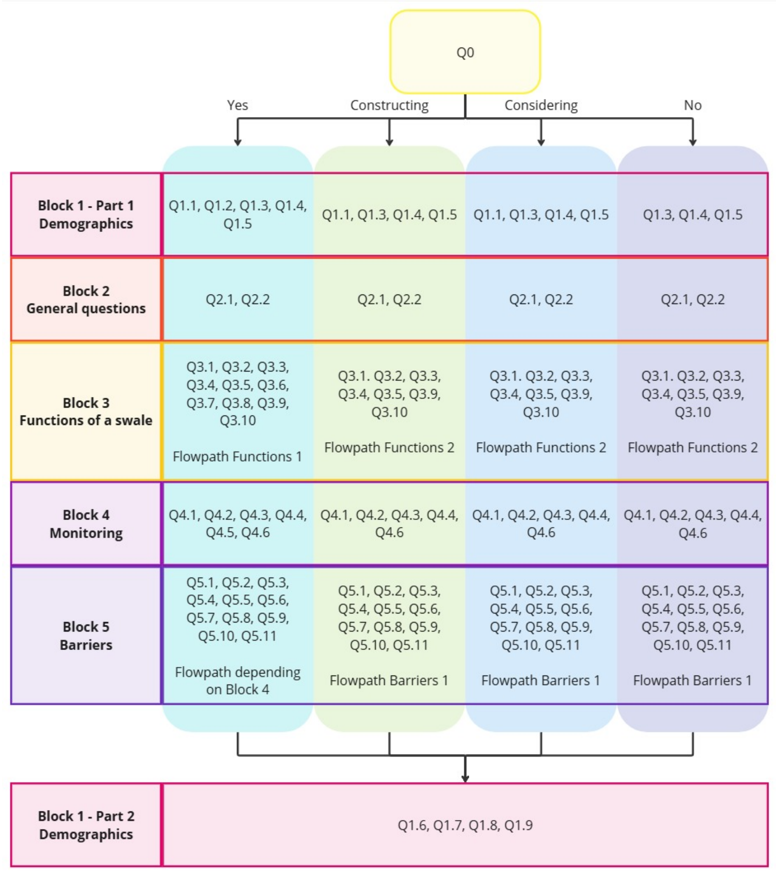


Figure C.1: Main flow paths of the survey

C.1. Block 1: Demographics

Q1.1: How many swales does your municipality have?
- 1-4
- 5-10
- More than 10
- I don't know

Additional phrasings Q1.1:
Constructing: How many swales are being constructed in your municipality?
Considering: How many swales is your municipality considering constructing?

Q1.2: How old is the oldest swale in your municipality?
- 0 to 3 years
- 4 to 8 years
- 8 to 12 years
- 12 to 20 years
- Older than 20 years
- I don't know

Q1.3: How long have you been working for your current municipality?
- 0 to 3 year
- 4 to 8 years
- 8 to 12 years
- 12 to 16 years
- Longer then 16 years

Q1.4: How long have you been familiar with swales?
- 0 to 3 year
- 4 to 8 years
- 8 to 12 years
- 12 to 16 years
- Longer then 16 years

Q1.5: At what points are you involved in a swale?
Multiple options are possible
- Design
- Maintenance
- Policy
- Other: ...

Q1.6: In which province is the municipality where you work located?
- *All provinces in the Netherlands are a possible choice*

Q1.7: What is the scale of the population size of the municipality where you work?
- 1 (less than 25,000 inhabitants)
- 2 (between 25,000 – 50,000 inhabitants)
- 3 (between 50,000 – 100,000 inhabitants)
- 4 (between 100,000 – 300,000 inhabitants)
- 5 (more than 300,000 inhabitants)

Q1.8: What is the scale of the population density of the municipality where you work?
- 1 (<250 inhabitants per square kilometer)
- 2 (250 – 500 inhabitants per square kilometer)
- 3 (500 – 1000 inhabitants per square kilometer)
- 4 (1000 – 2000 inhabitants per square kilometer)
- 5 (>2000 inhabitants per square kilometer)

Q1.9: In which water board is the municipality where you work located?
- *All waterboards that are in the marked province are a possible choice*

C.2. Block 2: General questions

Q2.1: To what extent do you agree with the statements below and why?
For each statement there was an open textbox to answer the why question

I think it is important that swales are designed

- to prevent flooding.
- to limit the effects of drought.
- to improve water quality.
- to improve biodiversity.
- to prevent heat nuisance in the area.
- to prevent noise nuisance in the area.
- to improve air quality in the area.
- to improve the living environment.
- to offer opportunities for recreation.

Answer options

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree
- I don't know

Q2.2: To what extent do you agree with the statements below and why?
For each statement there was an open textbox to answer the why question

I expect that most swales

- contribute to preventing flooding.
- contribute to replenishing the groundwater level.
- improve the water quality of the incoming water.
- improve biodiversity.

I expect that for most swales

- improve the liveability in the area during hot weather by contributing to cooling in the area.
- improve the liveability in the area by dampening noise.
- improve the liveability in the area by improving the air quality.
- local residents find their environment more beautiful.
- local residents use the wadi for recreation.

Answer options

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree
- I don't know

C.3. Block 3: Functions of a swale

Q3.1: Which functions of a swale are important for the design of a swale in your municipality?
- Water quantity
- Water quality
- Biodiversity
- Liveability
- Wellbeing
- None of the above

Additional phrasings Q3.1:
Considering/No: Which functions of a swale would be important for the design of a swale in your municipality?

Q3.2: Are there other functions that are important in your municipality that are not mentioned and why are they important?
- *Open answer*

Q3.3: Is it assessed whether swales meet the design for the important functions?
This question was answered per function marked in Q3.1
- Yes
- No
- I don't know

Additional phrasings Q3.3:
Considering/No: Will it be assessed whether swales meet the design for the important functions?

Q3.4: When is it assessed whether a swale meets the design for the function: [Function]?
This question was shown individually per function for which "Yes" was answered in Q3.3
- During the design
- Before completion
- Directly after completion
- Annually
- After a calamity
- Other: ...

Q3.5: How is it assessed whether a swale meets the design for the function: [Function]?
This question was shown individually per function for which "Yes" was answered in Q3.3
- *Open answer*

Q3.6: Do the swales function as desired on the designed functions?
- Yes
- Partly
- No
- I don't know

Q3.7 & Q3.8: You indicated that the swales do/partly/don't function on the designed function(s): ...
Why do the swales function/partly function/not function on this/these function(s)?
- *Open answer*

What do you base your assumption that the swales do/partly/don't work on this/these function(s)?
- *Open answer*

Q3.9 & Q3.10: Do you want to know whether the swales function as desired on this function(s)?
- *Open answer*

Why?
- *Open answer*

Additional note Q3.9 & Q3.10:
Yes: For the yes path, this was asked for the functions marked as I don't know in question Q3.6

Flow paths Block 3

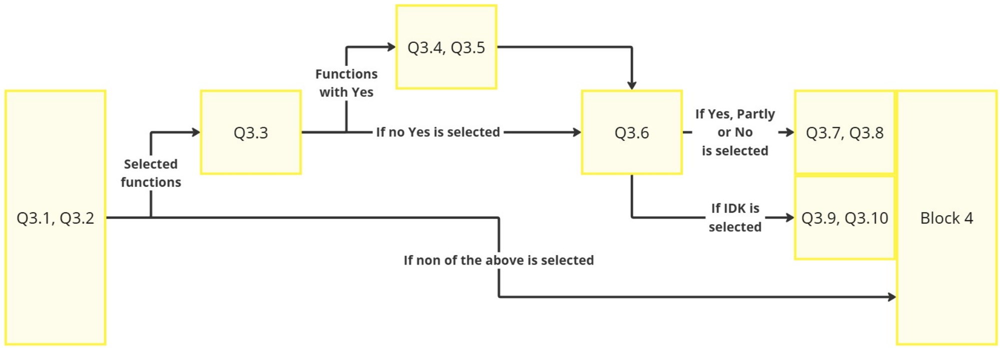


Figure C.2: Flow path Functions for the "Yes" main flow path

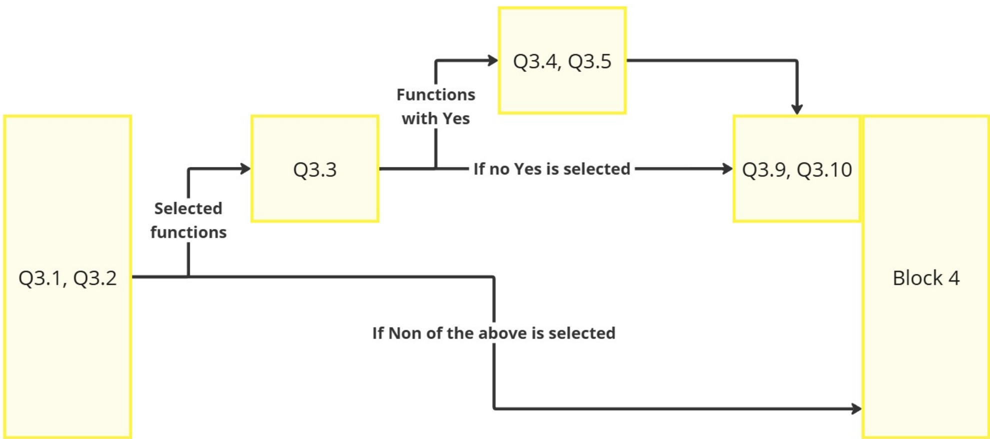


Figure C.3: Flow path Functions for the "Constructing", "Considering" and "No" main flow path

C.4. Block 4: Monitoring

Q4.1: Are swales monitored in your municipality?
- Yes
- Partly
- No
- I don't know

Additional phrasings Q4.1:
Constructing: Will the future swales be monitored in your municipality?
Considering / No: If swales are constructed, would they be monitored?

Q4.2: For which functions are the swales monitored?
- Water quantity
- Water quality
- Biodiversity
- Liveability
- Wellbeing

Q4.3 & Q4.4: How are swales monitored on:[Function]?
These questions were shown individually per function, which was marked in Q4.2
How is [Function] monitored?
- *Open answer*

When and/or how often does this monitoring take place?
- *Open answer*

Additional phrasings Q4.3 & Q4.4:
Considering / No:
- How will wadis be monitored for [Function]?
- When and/or how often will this monitoring take place?

Additional note Q4.3 & Q4.4:
If an answer was given in Q3.5 this was shown to prevent survey fatigue and double answers. The respondent was asked to give an addition if something was missing.

Q4.5: Was the monitoring of [Function] taken into account in the design or was it implemented later?
This question was shown individually per function which was marked in Q4.2 How is [Function] monitored?
- *Open answer*

Q4.6: If you have any additions to the monitoring of swales within your municipality, you can post them here.
- *Open answer*

Flow paths Block 4

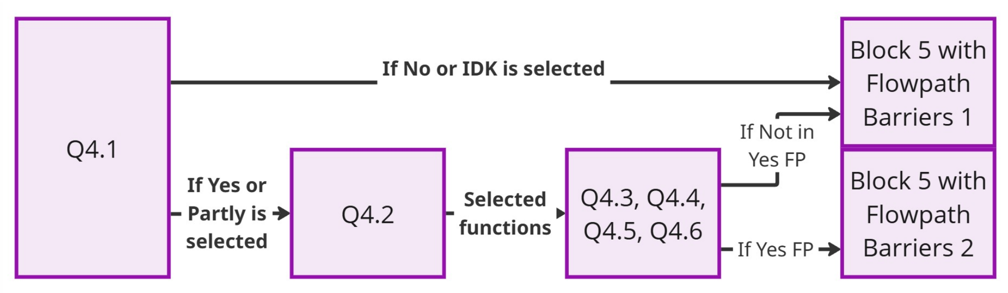


Figure C.4: Flow path Block 4

C.5. Block 5: Barriers

Q5.1: Indicate to what extent you agree with the statements below and why.
For each statement there was an open textbox to answer the why question

I think it is important that swales are monitored on aspects of:
- Water quantity
- Water quality
- Biodiversity
- Liveability
- Wellbeing

Answer options
- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree
- I don't know

Q5.2: Indicate to what extent you agree with the statements below and why.
For each statement there was an open textbox to answer the why question

I know how swales can be monitored for aspects of:
- Water quantity
- Water quality
- Biodiversity
- Liveability
- Wellbeing

Answer options
- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree
- I don't know

Q5.3: Would you like to be responsible for implementing monitoring of swales within your municipality?
- Yes
- Partly
- No

Additional phrasings Q5.3:
Considering / No: Would you like to be responsible for implementing monitoring of swales within your municipality if there are swales?

Q5.4:
Q5.3 is "Partly": Who else should be responsible for implementing monitoring?
Q5.3 is "No": Who do you think should be responsible for implementing monitoring?
- *Open answer*

Q5.5: Which swale functions would you like to monitor within your municipality?
- Water quantity
- Water quality
- Biodiversity
- Liveability
- Wellbeing
- Other: ...

Additional note Q5.5:
If a municipality already (partly) had monitoring, the respondent was asked if there were additional functions that they wanted to monitor. The functions marked in Q4.2 were shown.

Q5.6: Which variables would you like to monitor within [Function]?
This question was shown individually per function marked in Q5.5
- 3 possible open answer boxes, min 1 answer

Q5.7: How often would you like to monitor the variables?
This question was shown individually per variable answered in Q5.6
- Weekly
- Monthly
- Annually
- I don't know
- Other: ...

Q5.8: What do you think are the most important things that are needed to be able to monitor swales?
Choose at least 1 and a maximum of 3
- Tests to be able to monitor
- Staff that can test
- Staff that can analyse data
- Database to store the information
- Time
- Budget
- Other: ...
- Other: ...
- Other: ...

Q5.9: What do you see as the biggest challenges to being able to implement monitoring?
Choose at least 1 and a maximum of 3
- Clarify importance to employer
- Clarify importance to environment
- Keeping track of data
- Follow-up of the data
- Setting up communication within the municipality for data transfer
- Other: ...
- Other: ...
- Other: ...

Q5.10: Below are some advantages of monitoring swales. Which of these advantages would motivate you to monitor swales?
Choose at least 1 and a maximum of 3
- More knowledge about the effect of swales in the short term
- More knowledge about the effect of swales in the long term
- Being able to identify problems with a swale in time
- Improve communication from the municipality to residents around a swale
- Other: ...
- Other: ...
- Other: ...

Q5.11: Do you have any other comments regarding challenges of monitoring swales?
- *Open answer*

Flow paths Block 5

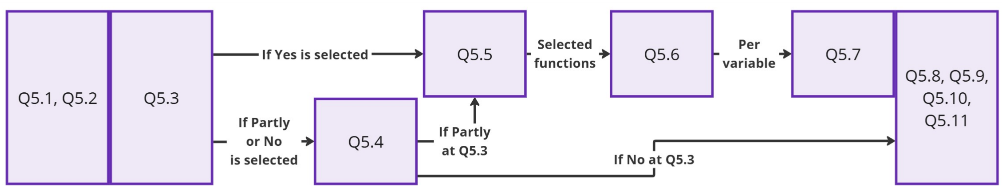


Figure C.5: Flow path Block 5 if there is no monitoring in place or if there are no swales

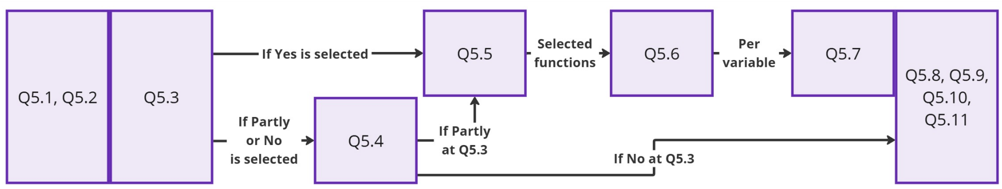


Figure C.6: Flow path Block 5 if there is already monitoring in place

D

Survey results

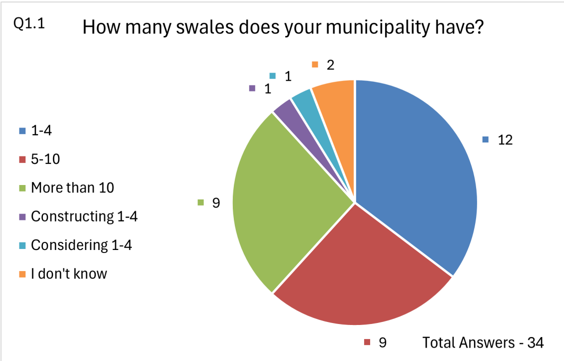
This appendix shows the results from the survey per question block

D.1. General overview

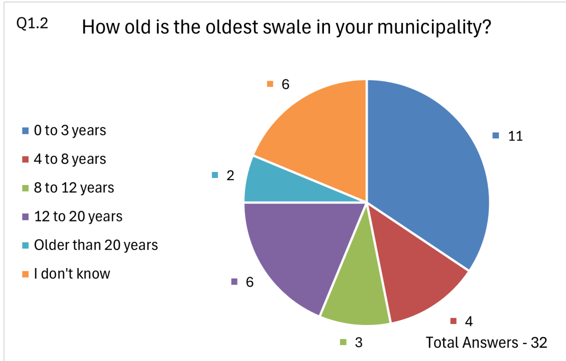
The survey was filled in by 34 participants of which 28 finished the survey. Of the 28 participants that finished the survey, 26 followed the ”Yes” flow path, 1 the ”Constructing” flow path and 1 the ”Considering” flow path. The 6 participants who didn’t finish the survey started the ”Yes” flow path. Their answers have been used until the last fully answered question that wasn’t linked to a question they didn’t answer.

D.2. Demographics

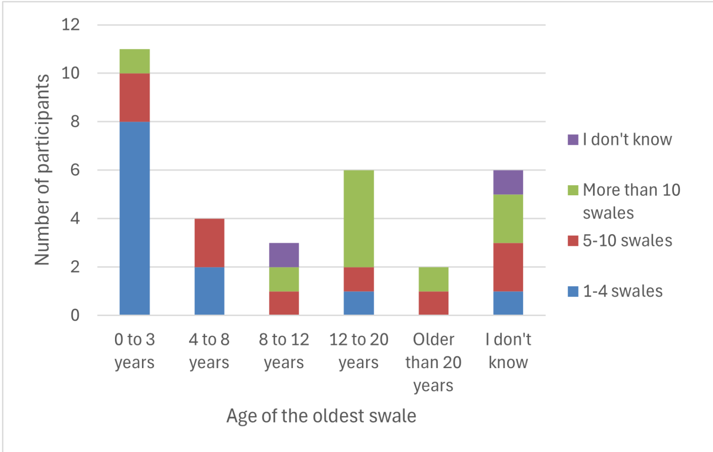
The demographic question block was meant to gather information about the respondent and the municipality where they work. The number of swales that the municipalities have and the age of the oldest swale are spread. Twelve respondents have 1-4 swales in their municipality, nine have 5-10 swales, and another nine have more than 10 swales (see figure D.1a). In most municipalities, the oldest swale is 0 to 3 years old, but fifteen respondents work at a municipality that have a swale older than 4 years (see figure D.1b). Figure D.1c shows that the municipalities that recently implemented swales also have less swales then the municipalities that have older swales.



(a) Q1.1 - How many swales does your municipality have?



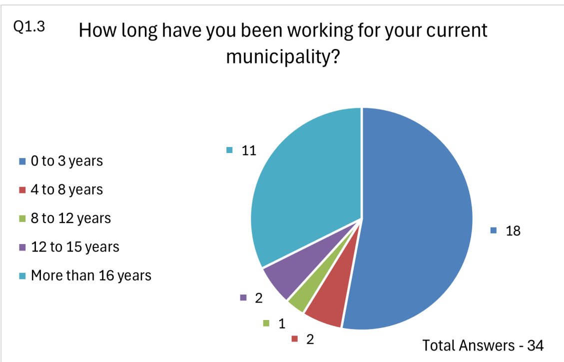
(b) Q1.2 - How old is the oldest swale in your municipality



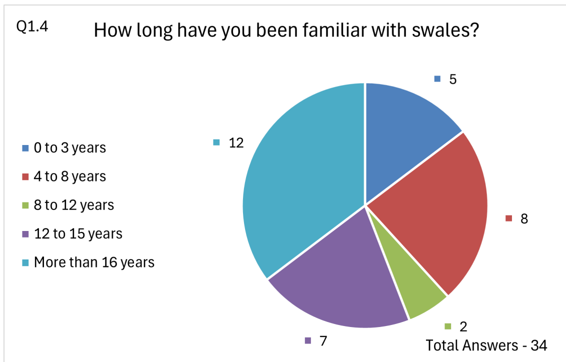
(c) Overview of the age of the oldest swale versus the number of implemented swales by combining the answers of Q1.1 and Q1.2

Figure D.1: Results Question Q1.1 en Question Q1.2

The working experience of the respondents at their current municipality can be split into two main groups. Eighteen respondents have been working for 0 to 3 years at their current municipality, while eleven have been working at their municipality for more than 16 years (see figure D.2a). Almost all respondents have been familiar with swales for more than 4 years (see figure D.2b), but for some, it is still something new.



(a) Q1.3 - How long have you been working for your current municipality?



(b) Q1.4 - How long have you been familiar with swales?

Figure D.2: Results Question Q1.3 en Question Q1.4

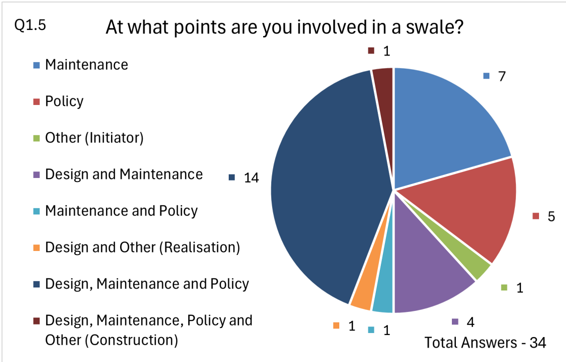
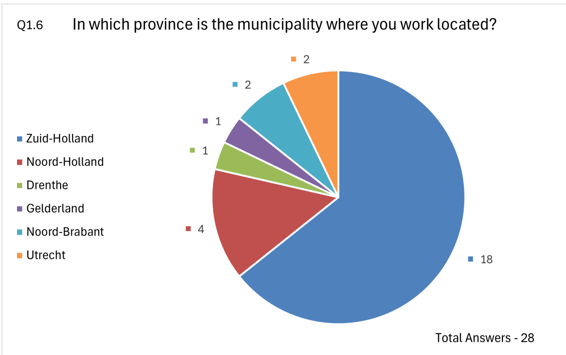


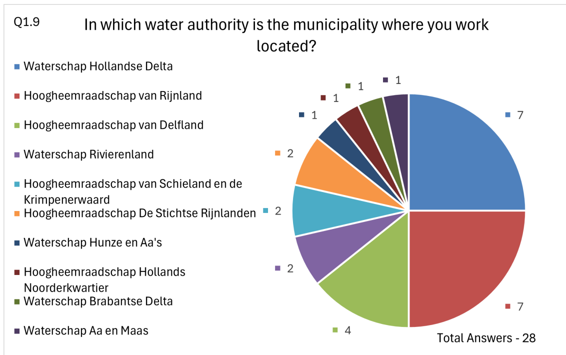
Figure D.3: Question Q1.5 - At what points are you involved in a swale?

Most respondents are involved at multiple moments during the development of a swale (see figure D.3. Fourteen participants are involved in design, maintenance, and policy related to a swale, and one participant is also involved in these three areas, as well as construction. Next to this six participants are involved during two moments, either design and maintenance (four participants), maintenance and policy (one participant) or design and realisation (one participant). Seven participants are only involved with the maintenance of a swale, and five participants are only involved with the policy of a swale.

Figure D.4 shows where the municipalities of the respondents are located. Most municipalities are located in the province of South Holland and at a targeted water board.



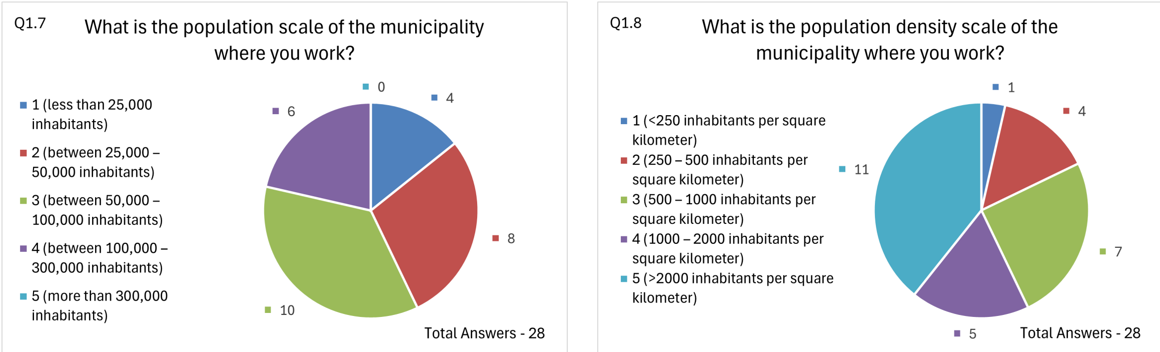
(a) Q1.6 - In which province in the municipality where you work located?



(b) Q1.9 - In which water authority is the municipality where you work located?

Figure D.4: Results Question Q1.6 en Question Q1.9

The population scale of the municipalities of the respondents is spread. Most respondents work at a municipality that can be placed in category 2 (25,000 - 50,000 inhabitants) or category 3 (50,000 - 100,000 inhabitants) (see figure D.5a). The respondents mostly work at a municipality with a higher population density. Eleven municipalities are placed at a scale of category 5 (more than 2000 inhabitants per square kilometer) and five municipalities have a scale of category 4 (1000 - 2000 inhabitants per square kilometer) (see figure D.5b). Figure D.6 shows that the different population scales are spread out over the population density scales.



(a) Q1.7 - What is the population scale of the municipality where you work?

(b) Q1.8 - What is the population density scale of the municipality where you work?

Figure D.5: Results Question Q1.7 en Question Q1.8

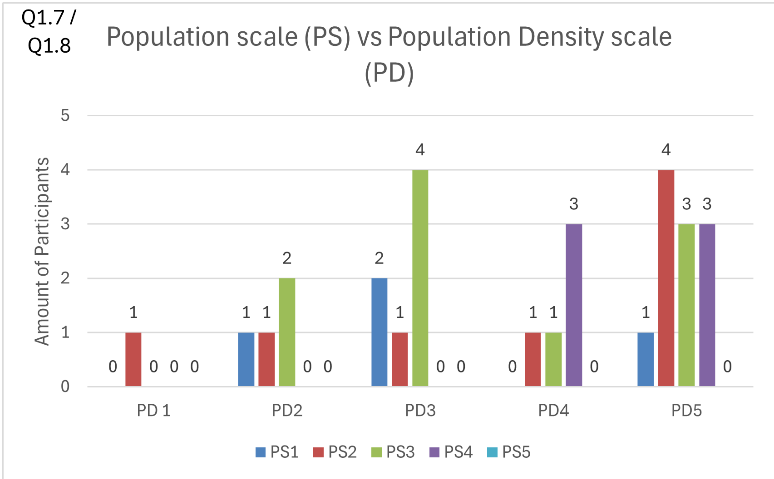
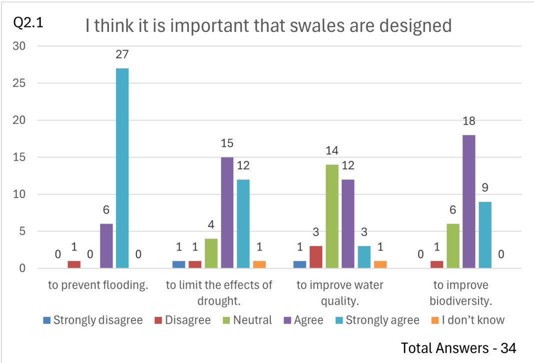


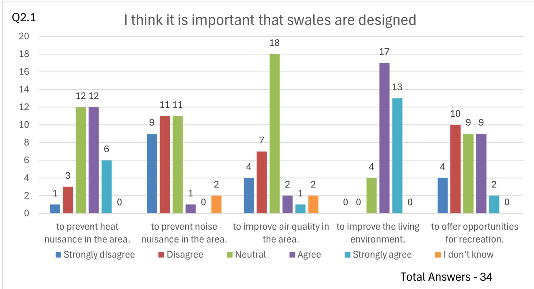
Figure D.6: Results Q1.7 and Q1.8 combined. Population scale versus the Population Density scale

D.3. General statements

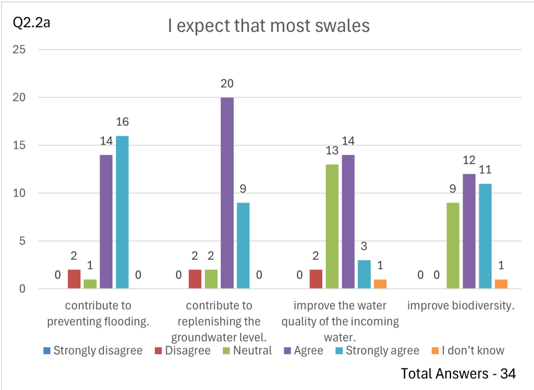
The general questions block was meant to gather the respondents opinion on swales based on several statements related to the functions. Question Q2.1 contained statements about where a swale should be designed for and question Q2.2 asked what a respondent thought that a swale could actually do. The results of the statements are shown in figure D.7. The tables with the elaborated answers of questions Q2.1 and Q2.2 are shown per subsection.



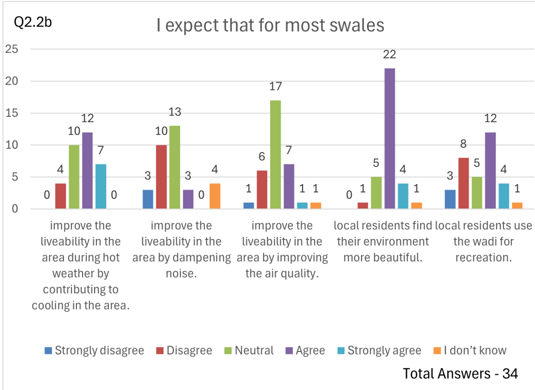
(a) Q2.1 - Statements on flooding, drought, water quality and biodiversity



(b) Q2.1 - Statements on heat nuisance, noise nuisance, air quality, living environment and recreation



(c) Q2.2 - Statements on flooding, groundwater level, water quality and biodiversity



(d) Q2.2 - Statements on heat nuisance, noise nuisance, air quality, living environment and recreation

Figure D.7: Results questions Q2.1 and Q2.2

D.3.1. Water quantity

The statements that are related to the water quantity function are the statements about flooding, drought and groundwater. The opinion on the statements is overall positive, most participants agree or strongly agree with the statements.

For the flooding statements, the reasoning is that swales are designed to temporarily retain water, helping to prevent flooding during heavy rainfall. Respondents R22 and R25 do mention that it is important that the swale is properly designed and at the right location.

Although the opinion on the drought statement is positive, two elaborated answers show why they disagreed with the statement or were neutral. Respondent R18 strongly disagrees with the statement and mentions that swales are often constructed in areas that are already green. Limiting of the effects of drought can therefore not be the main reason. Respondent R25 is neutral and mentioned it depends on the design, soil and type of the swale.

The elaborated answers on the groundwater level statement show that the respondent thinks the effect of a swale will be minimal (R21). Respondent R18 disagrees and mentions during normal rainfall it won't differ as much from a grass field.

Table D.1: Elaborated answers for water quantity Q2.1 and Q2.2

Response number	Answer	Elaboration in Dutch
Q2.1 - Flooding statement		
R5	Strongly agree	berging van water
R7	Strongly agree	Slim ruimte gebruik
R16	Strongly agree	Om piekbuien op te vangen en het stelsel te ontlasten
R19	Strongly agree	Wij zetten wadi's in om water vertraagd af te voeren om overlast tijdens piekbuien te voorkomen.
R21	Agree	Geeft beperkte bufferruimte
R22	Strongly agree	Volumeberekening afhankelijk van risico's omgeving
R25	Agree	afhankelijk doel wadi
R29	Strongly agree	Water kan tijdelijk geparkeerd worden op plekken waar het niet tot overlast leidt.
Q2.2 - Flooding statement		
R5	Strongly agree	berging
R21	Disagree	Bij een serieuze bui zal het de wadi niet snel genoeg bereiken
R22	Strongly agree	Mits goed ontworpen
R25	Agree	Afhankelijk locatie
Q2.1 - Drought statement		
R5	Strongly agree	infiltratie
R18	Strongly disagree	wadi's worden vaak aangelegd in een gebied dat al groen is. droogte beperking is dus niet de voornaamste reden.
R25	Neutral	Ligt aan het ontwerp en opbouw bodem en type Wadi
Q2.2 - Groundwater statement		
R5	Strongly agree	infiltratie
R18	Disagree	niet meer dan een grasveld doet ondwr normale buiomstandigheden.
R21	Agree	Effect zal gering zijn

D.3.2. Water quality

The opinion on the statements about water quality are moderately positive. Most participants are neutral or agree with the statements. The elaborated answers for the statement in question Q2.1 mention that a swale can capture the first dirt (R7). Respondents R21 and R25 mention that the design, layering of the soil and construction are important. Respondent R9 is neutral and mentions that there are insecurities and conflicting things said about this aspects. The elaborated answers for the second statement show some confusion about the phrasing of the statement itself.

Table D.2: Elaborated answers for water quality Q2.1 and Q2.2

Response number	Answer	Elaboration in Dutch
Q2.1		
R7	Agree	Afvangen eerste vuil
R21	Agree	Mits goed aangelegd
R25	Neutral	Ligt aan het ontwerp en opbouw bodem en type Wadi
R29	Neutral	Veel onzekerheden en verschillende uitspraken over dit aspect
Q2.2		
R5	I don't know	welk instromen water?
R27	Neutral	instromend waar?

D.3.3. Biodiversity

The opinion for the statements about biodiversity are positive. Most respondents agree or strongly agree with the statements. The elaborated answers show that the respondents agree as long as the right vegetation is chosen (R21, R22, R25). Respondent R18 mentions that it depends on the type of swale (a grass swale will have less effect). Respondent R21 also mentions that the construction is important.

Table D.3: Elaborated answers for biodiversity Q2.1 and Q2.2

Response number	Answer	Elaboration in Dutch
Q2.1		
R5	Agree	kan
R18	Agree	niet overal (bv graswadi)
R19	Neutral	De wadi zetten wij voornamelijk in voor water, met een goede biodiversiteit als bijkomst.
R21	Agree	Mits er ook de juiste beplanting gekozen wordt
R22	Agree	Inzaaien met inheems gras-bloemen-kruidenmengsel en/of beplanten
R25	Agree	afhankelijk van wat men plant
Q2.2		
R5	I don't know	wat bedoel je precies
R18	Agree	hangt af van de soort wadi.
R21	Agree	Mits juiste aanleg

D.3.4. Liveability

The statements that are related to the liveability function are the statements about heat, noise and air quality. The opinions of the different statements don't fall in one category.

The opinion for statements about heat nuisance is moderately positive. Most respondents are neutral or agree with the statements. The elaborated answers show that it is more related to the greening of the area and not necessarily the swale itself (R17, R22). Respondent R18 mentions that swales are often implemented in areas that are already green and then the influence will be little. Another thing that is mentioned is that the effect during drought might cause the opposite effect. Respondent R5 mentions it only has an effect if it is raining. Respondent R20 mentioned that they did measurements during a dry period on a grass swale. The temperature of the swale was higher then the grey side walk tiles.

The opinion for the statements about noise nuisance is negative. Almost all respondents are neutral, disagree or strongly disagree with the statements. The elaborated answers show that some respondents didn't know about this possible benefit (R5, R19, R29). Respondents also mention that it depends on the choice of vegetation (R9, R18), often low vegetation is chosen (R21). Swale are also often implemented at a location that was already green and because of that the opinion is that it doesn't have as much influence (R21, R22).

The opinion for the statements about air quality is neutral. For the statement in Q2.1 most participants are neutral with the statement, after that the respondents disagree or strongly disagree with this statement. For the statement in Q2.2 most respondents are neutral with the statement, after that the respondents either disagree or agree with the statement. The elaborated answers refer the effect on air quality to the greening of the area. It is mentioned that it only has effect if the implementation of the swale also results in more green in the area (R6, R22). Respondent R21 mentions that the effect can be neglected. Respondent R18 mentions that the effect is not as much different compared to a normal grass field, although it depends what type of vegetation is chosen.

Table D.4: Elaborated answers for liveability Q2.1 and Q2.2

Response number	Answer	Elaboration in Dutch
Q2.1 - Heat statement		
R5	Agree	door langzame verdamping en infiltratie
R18	Strongly disagree	wadi's worden vaak aangelegd in een gebied dat al groen is. Hittebeperking is dus niet de voornaamste reden.
R19	Disagree	De wadi zetten we in voor wateroverlast.
R21	Neutral	Geringe invloed
R25	Neutral	dit is vooral lokaal ligt ook aan het ontwerp
Q2.2 - Heat statement		
R5	Agree	alleen als er ook veel water valt
R6	Neutral	Alleen als de wadi ook extra vergroening betekent
R17	Disagree	Groen wel Wadi niet en als er geen wadi aangelegd is was het groen gebleven
R18	Disagree	niet veel meer dan bij een normaal grasveld, al hangt dit natuurlijk wel af van het type beplanting in de wadi.
R19	Neutral	Is afhankelijk van wat er anders zou worden geplaatst. Een boom werkt meer tegen hitte vanwege de schaduw.

Continued on next page

Table D.4 continued from previous page

Response number	Answer	Elaboration in Dutch
R20	Neutral	Ik heb tijdens een hittegolf metingen gedaan naar de oppervlakte temperatuur bij verschillende oppervlakten. Ook bij een gras wadi met drainage eronder. Deze was dusdanig droog en het gras was dor dat de zwarte grond zorgde voor hoge oppervlakte temperatuur. Hoger dan grijze stoeptegels. Bij een wadi met hogere begroeiing verwacht ik het wel
R22	Strongly agree	Tenzij die omgeving al groen was
Q2.1 - Noise statement		
R19	Strongly disagree	Ik ben niet bekend met deze bijvangst.
R21	Strongly disagree	Over het algemeen hele lage begroeiing
R22	Neutral	Omgeving is al groen, verwacht weinig meerwaarde van wadi tegen geluidsoverlast. geluids
Q2.2 - Noise statement		
R5	I don't know	is dat zo?
R9	Neutral	Afhankelijk van de omgeving en hoeveelheid vegetatie.
R13	Strongly disagree	volgens mij dragen wadi's hier niet aan bij.
R18	Neutral	niet veel meer dan bij een normaal grasveld, al hangt dit natuurlijk wel af van het type beplanting in de wadi.
R19	Strongly disagree	Dit wist ik niet.
R22	Agree	Tenzij die omgeving al groen was
R29	I don't know	Onbekend nog nooit vanngehoord
Q2.1 - Air quality		
R21	Neutral	Invloed zal verwaarloosbaar zijn
R22	Neutral	Omgeving is al groen
Q2.2 - Air quality		
R5	Neutral	de luchtkwaliteit of de vochtigheidsgraad?
R6	Neutral	Alleen als de wadi ook extra vergroening betekent
R18	Neutral	niet veel meer dan bij een normaal grasveld, al hangt dit natuurlijk wel af van het type beplanting in de wadi.
R22	Strongly agree	Tenzij die omgeving al groen was
R29	I don't know	Onbekend

D.3.5. Wellbeing

The statements that are related to the wellbeing function are the statements about the living environment and recreation. The opinions of the different statements are not the same.

The opinion for the statements about the improvement of the living environment are positive. For the statement in Q2.1 most respondents either agree or strongly agree with the statement and for the statement in Q2.2 most respondents agreed with the statement. The elaborated answers from respondents R18 and R22 relate this to the functions biodiversity and water quantity. Respondent R18 mentions that improving biodiversity and preventing flooding improves the living environment. Respondent R29 mentions for the first statement that the experience of the environment is also important. The opinion of the residents is also mentioned. Respondent R2 agrees with the statement, but mentions that citizens can look at it differently. Respondent R5 mentions that there are also complaints.

The opinion for the statements about recreation is divided. For the statement in Q2.1 most respondents either disagreed, are neutral or agreed with the statement. The statement in Q2.2 had more respondents that agreed, but also respondents disagreed. The elaborated answers show the different perspectives. Respondents that agree with the statements mention that water collection in combination with recreation are good to combine (R1, R19). Respondents R21 and R22 mention that a swale is not meant for recreation and R6 mentions that they are not implementing recreation as a function for swales yet. Respondent R18 agrees with the statement that residents use the swale for recreation, but is not happy with this. For the first statement R18 also mentions that if a swale is designed for recreation it also increases the maintenance task.

Table D.5: Elaborated answers for wellbeing Q2.1 and Q2.2

Response number	Answer	Elaboration in Dutch
Q2.1 - Environment statement		
R5	Neutral	ook veel klachten
R18	Strongly agree	versterken van biodiversiteit en voorkomen van wateroverlast verbeterd de leefomgeving.
R22	Agree	Wadi's combineren met biodiverse begroeiing (ook rondom de wadi).
R29	Strongly agree	Beleving van een gebied, zeker belangrijk
Q2.2 - Environment statement		
R2	Agree	burger kijkt daar wisselend naar
R5	Neutral	weet ik niet er zijn ook veel klachten
R22	Neutral	Als de omgeving al groen was
Q2.1 - Recreation statement		
R1	Strongly agree	speelobject
R18	Disagree	soms wordt een wadi ingericht als speelterrein, echter vergroot dit de onderhoudsopgave van de wadi
R19	Agree	Spelen/recreëren en wateropvang gaat oged samen
R21	Strongly disagree	Een wadi is niet voor recreatie
R22	Strongly disagree	Wel recreatie voor insecten ;-)
Q2.2 - Recreation statement		
R1	Strongly agree	vooral jeugd
R5	Disagree	zeker niet, men vindt het meestal vies
R6	Disagree	Bij onze gemeente houden we recreatie/spelen en wadi's tot nu toe gescheiden
R18	Strongly agree	helaas wel.
R19	Agree	Afhankelijk van de invulling.
R22	Disagree	Gaat ten koste van biodiversiteit. Wel bankjes rondom.

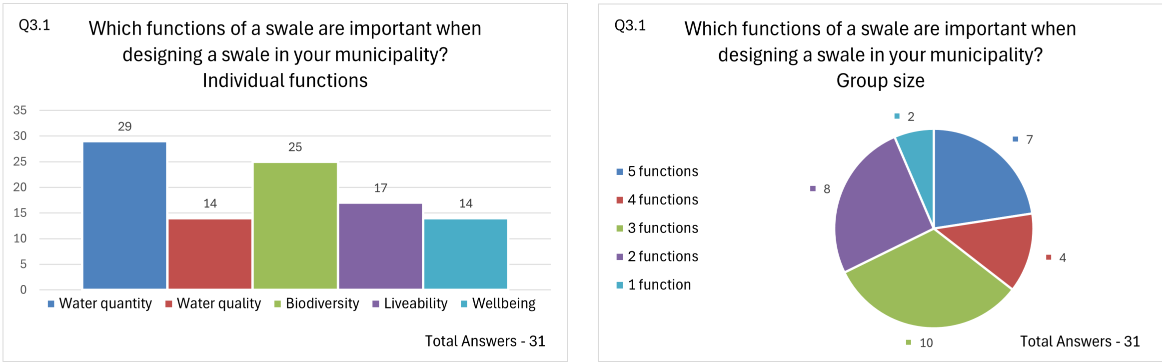
D.4. Functions of a swale

This section contains the results of questions from the functions of a swale question block. This block was meant to gather information on which functions are important for the design of a swale and if it is assessed if the swales function on these functions and if so, how this is done. Next to this questions were asked if the swales function as desired on the designed functions and why.

D.4.1. Designed functions

For the design of swales the different functions are important for the design of a swale, but water quantity and biodiversity are most often mentioned. This is visible in figure D.8a. Most respondents marked three functions as important. This is shown in figure D.8b. Figure D.9 shows the the different combinations in the case of multiple functions. It is visible that often the water quantity and biodiversity function are combined with either liveability, water quality or wellbeing.

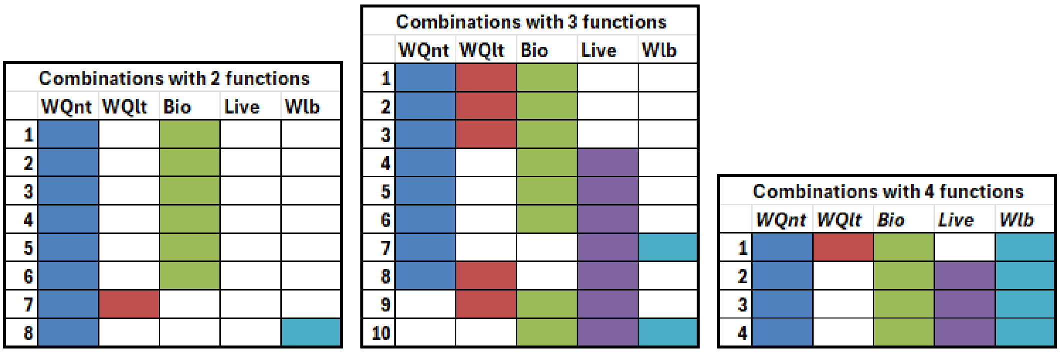
It was also asked if the respondents had any additional functions that were important at their municipality. These are shown in table Responded R19 mentioned the additional function of education which is mentioned in section 2.2.3 as well, but was not included in the survey.



(a) Individual functions

(b) Amount of functions answered

Figure D.8: Results Question Q3.1 - Which functions of a swale are important when designing a swale in your municipality?



(a) Two functions

(b) Three functions

(c) Four functions

Figure D.9: Results Question Q3.1 combinations per group size

Table D.6: Q3.2 - Are there other functions that are important in your municipality that are not mentioned and why are they important?

Response number	Answer Q3.1	Dutch answer
R1	Water quality, Biodiversity, Liveability	spelen
R8	Water quantity, Biodiversity	water gaat snel met een drain naar het oppervlaktewater vanwege de kleiondergrond en infiltreert daardoor matig.
R17	Water quantity, Water quality, Biodiversity	Een wadi vertraagd de afvoer van regenwater naar de polderstructuur waardoor de peilstijging minder pieken vertoond
R18	Water quantity, Biodiversity, Liveability, Wellbeing	schakel in het groen blauwe netwerk die nodig is voor de afvoer en berging van hemelwater
R19	Water quantity, Water quality, Biodiversity, Liveability, Wellbeing	Meer aandacht voor water en het watersysteem. Educatie voor kinderen door borden bij een wadi met speelmogelijkheden te zetten.
R22	Water quantity, Biodiversity	Oppervlakkige infiltratie en zichtbaar influent ivm nabijheid grondwaterwinning (grondwaterbeschermingsgebied)
R24	Water quantity	Andere functies zijn van belang maar zijn kansen die per project mee gekoppeld kunnen worden. Hoofdtaak van een wadi is puur het verminderen/voorkomen van wateroverlast door infiltratie

D.4.2. Assessing the functions

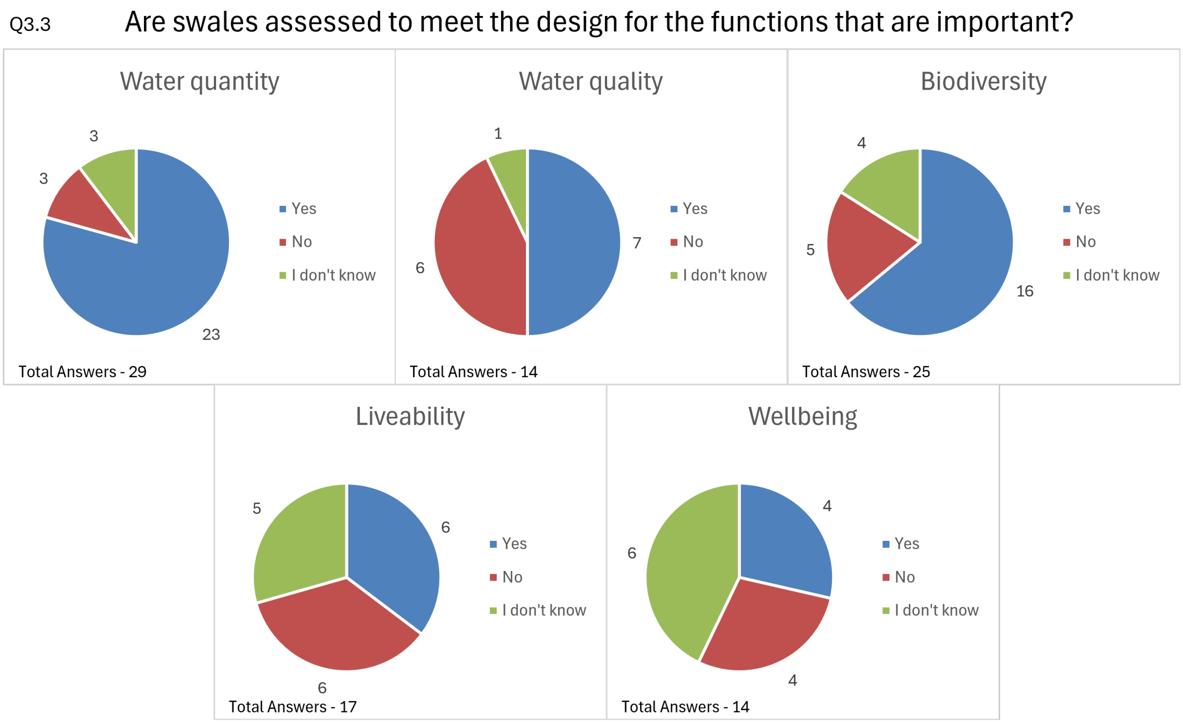


Figure D.10: Results Q3.3 - Is it assessed whether swales meet the design for the functions that are important?

Although the different functions are important for the design of a swale, it is not always assessed if they meet that function's design. Figure D.10 shows the results of question Q3.3. The water quantity function is most often assessed and the biodiversity function is also quite often assessed. Water quality is not always assessed but 7 out of the 14 respondents say that it is being done. Liveability and wellbeing are not very often assessed or the respondent doesn't know if it is being done.

The functions are mostly assessed via the design. For all functions, this is given as a reason. The water quantity function is also evaluated via visual inspections after heavy rainfall and in one case some measurements are being done. The water quality function is in one case also assessed via real-time measurements from a pilot project. Biodiversity is in some cases monitored by an ecologist, but some respondents also mention it is an assumption. Liveability is also assessed based on the number of complaints, but also for this function, some respondents mention it is an assumption. Wellbeing is only assessed via the design.

The functions are also mostly assessed during the design. Next to that, before completion or directly after completion are also often marked. Biodiversity is also often assessed annually.

The full answers from question Q3.4 and Q3.5 about the assessment of swales can be found per function in the figures and tables on the following pages.

Water quantity

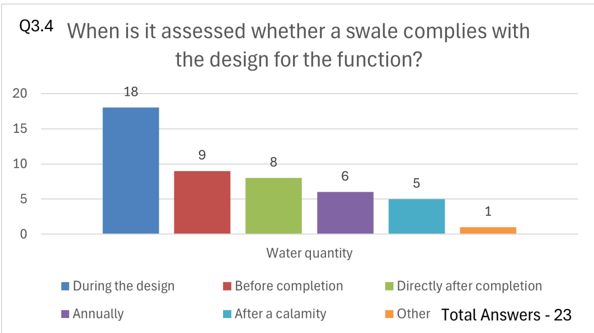


Figure D.11: Q3.4 - When is it assessed whether a swale meets the design for the function water quantity?

Table D.7: Q3.5 - How is it assessed whether a swale meets the design for the function water quantity?

Response number	Dutch answer
R2	ontwerp in de Lior
R3	Ontwerp wadi (m3 en Q) en plek in het systeem (BRP)
R6	Capaciteitsberekening door ingenieursbureau
R7	Komt wateroverlast op deze locatie voor
R8	voldoende afschot om water te ontvangen, slokop aanwezig en drainerende basis (ondergrond)
R9	Tijdens en na hevige buien wordt de wadi periodiek gecontroleerd.
R10	Civieltechnische randvoorwaarden, berekeningen
R12	visuele beoordeling
R14	voldoende berging, type infiltratie, noodoverlaat
R16	Hydraulisch doorgerekend in ontwerp fase en bij oplevering visueel
R18	bij een gebiedsinrichting is de wadi onderdeel van de gebiedsstresstest waarin wordt gekeken of de berging voldoende is. Bij het ontwerp wordt gerekend met een bepaalde afvoersnelheid.
R19	Eerst een uitgangspunt vaststellen: hoeveel water moet erin kunnen worden opgevangen. Dan met modelberekeningen vaststellen wat de benodigde afmetingen zijn.
R20	hydraulische berekening tijdens het ontwerp. En meting en/er ervaring van beheerder of omwonende als er iets geconstateerd wordt, dit is niet alleen na een calamiteit ook bijvoorbeeld als we zelf zien dat een wadi (te) lang vol blijft staan
R21	Berekening
R22	Volumeberekening (netto berging voor neerslag, met eventuele aftrek van bewust 'natte' delen)
R23	Standaard ontwerp in het LIOR
R24	Tijdens ontwerpfase wordt een wadi beoordeeld aan het beleid voor waterberging
R25	door de ontworpen bergingscapaciteit te controleren
R26	moet nog gebeuren, net opgeleverd
R29	Ontwerp Berekening VS bestek
R32	Wadi's passen we toe op locaties met wateroverlast. Dit zijn vaak knelpuntenlocaties waarvoor doorrekening is gedaan hoeveel water op straat staat bij een theoretische bui en hoeveel water dient te worden geborgen in de wadi. Bij ontwerp en voor oplevering zijn dit de uitgangspunten waaraan wordt getoetst.
R33	beheertoets en oplevering
R34	voldoende doorstroming van het water binnen 48 uur moet het water uit de wadi zijn

Water quality

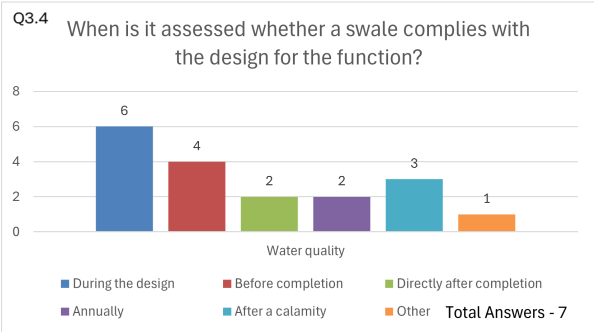


Figure D.12: Q3.4 - When is it assessed whether a swale meets the design for the function water quality?

Table D.8: Q3.5 - How is it assessed whether a swale meets the design for the function water quality?

Response number	Dutch answer
R2	Lior
R3	Realtime metingen bij pilot, naar diverse waarden
R21	Meting
R23	Standaard ontwerp uitgangspunten
R25	Voor het ontwerp te meten wat de kwaliteit is en er na
R26	moet nog gebeuren, net opgeleverd
R29	Jaarlijks meten op bepaalde aspecten

Biodiversity

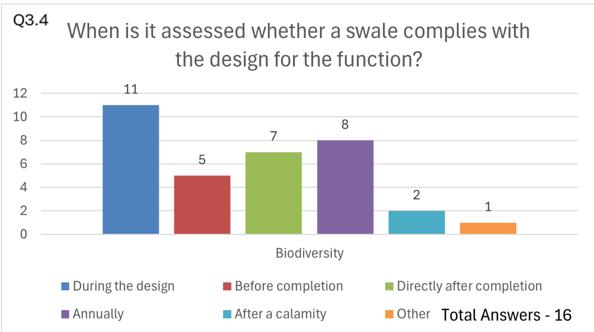


Figure D.13: Q3.4 - When is it assessed whether a swale meets the design for the function biodiversity?

Table D.9: Q3.5 - How is it assessed whether a swale meets the design for the function biodiversity?

Response number	Dutch answer
R1	aanname
R3	Niet, gewoon vergoenen
R6	Check door ecoloog
R7	Welken soorten komen er voor en hoe ontwikkel die zich
R8	getoetst wordt of het voorgestelde kruidenmengsel voldoet
R9	Monitoring flora en fauna
R10	voldoen aan kpi
R12	waarneming
R18	Pas nadat de wadi is aangelegd kan er worden gekeken of deze ook haar doelstelling heeft behaald.
R19	Er worden inheemse planten bedacht in een plantenplan die bijdragen aan de biodiversiteit. Welke planten dit zijn wordt getoetst door onze afdeling groenbeheer, waarin experts zitten met veel ervaring.
R21	Plantkeuze
R22	Soorten beplanting (inheems en veerkrachtig buj langdurige neerslag en bij langdurige droogde), tellen insecten, wildcamera's.), veerkrachtig soms
R23	Standaard ontwerp uitgangspunten
R25	Voor af te monitoren wat voor populatie ecosysteem er en het geweest populatie ecosysteem te omschrijven en ver volgens te monitoren
R33	beheertoets
R34	door een wadi maar maximaal 2x per jaar ecologisch te maaien geef je de vegetatie een kans om zich te ontwikkelen

Liveability

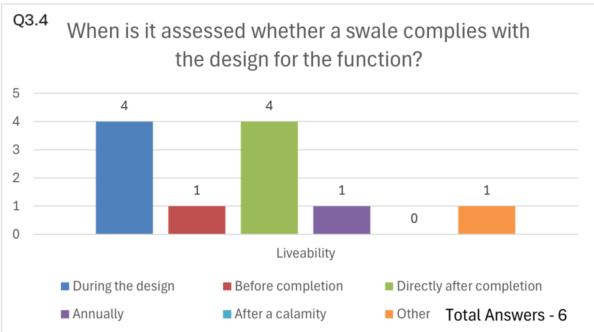


Figure D.14: Q3.4 - When is it assessed whether a swale meets the design for the function liveability?

Table D.10: Q3.5 - How is it assessed whether a swale meets the design for the function liveability?

Response number	Dutch answer
R1	aanname
R9	Op basis van meldingen
R10	Weet ik niet
R23	Standaard ontwerp uitgangspunten
R25	Voldoet aan de gesteld eisen leefomgeving
R26	moet nog gebeuren, net opgeleverd

Wellbeing

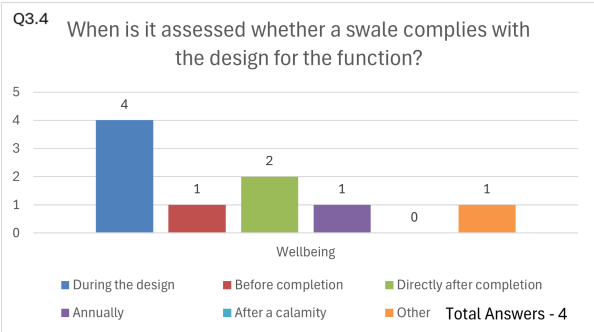


Figure D.15: Q3.4 - When is it assessed whether a swale meets the design for the function wellbeing?

Table D.11: Q3.5 - How is it assessed whether a swale meets the design for the function wellbeing?

Response number	Dutch answer
R3	Afhankekijk van zijn plek
R20	Door de stedebouwkundige of landschapsontwerper. Geen harde normen
R23	Standaard ontwerp uitgangspunten
R25	Voldoet de functie Spelen met betrekking waterkwaliteit herkomst direct of in direct daken of rijweg.

D.4.3. Do swales work as desired?

Figure D.16 shows if the swales function as desired on the different functions. For water quantity most respondents mention that the swales are working or partly working as desired. For water quality most respondents either say they partly work or they don't know if they work. For biodiversity, eight say they are working, seven say they are partly working and seven don't know. For liveability half of the respondents don't know if the swales are working and for wellbeing more than half of the respondents don't know if they are working. Two responses didn't receive this question, since they don't have swales in their municipality yet.

In the following sections the summarized answers as to why they do/partly/don't work are given per function. At the end the full answers of Q3.7 and Q3.8 are given in table D.12, table D.13 and table D.14.

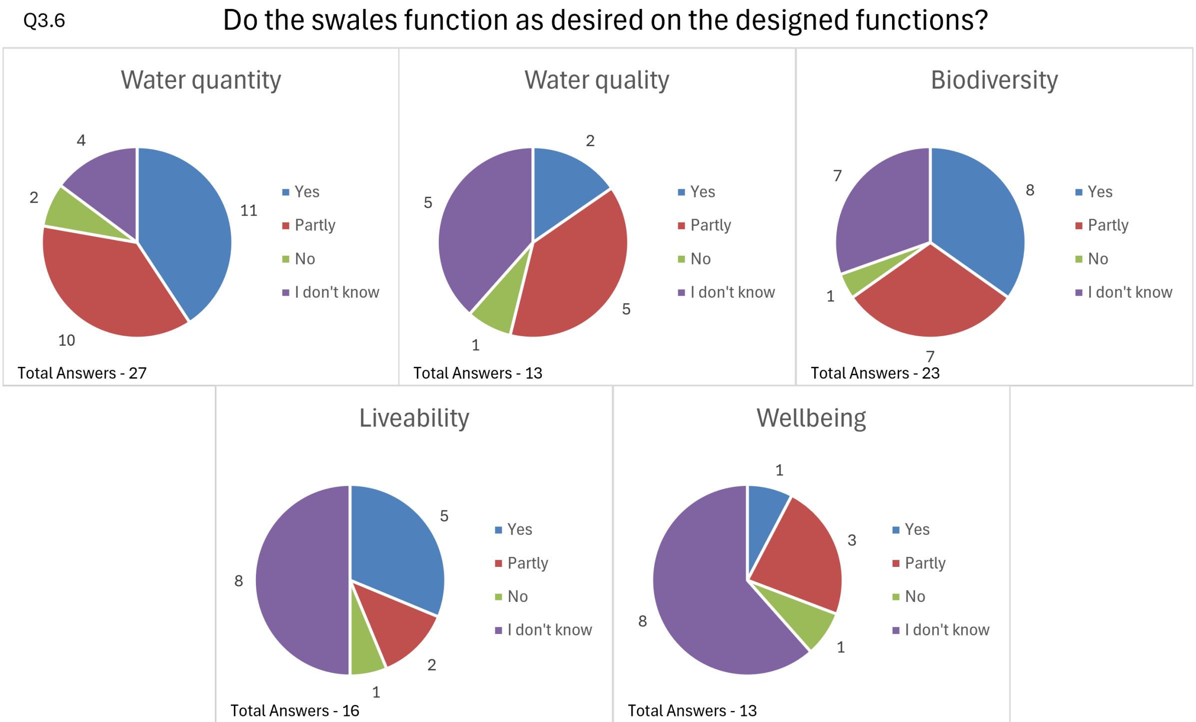


Figure D.16: Results Q3.6 - Do the swales function as desired on the designed functions?

Water quantity

For the water quantity function, different reasons were given as to why the swales (partly/not) worked. These reasons are categorised and shown below.

1. **The design**
   Three answers mention the design as a reason. Respondents R15 and R22 give the design as a motivation why they should work, while respondent R21 thinks the swales partly work and mentions that practice is often different than design.
2. **Time to empty**
   Multiple answers mention the time it takes for a swale to empty. The swales empty fast enough for respondents R3 and R8, while for R22 it takes a bit longer. For respondents, R16, R18 and R24 the water doesn't always infiltrate properly and as a result it stays in the swale too long. Respondent R6 mentioned that they had to adjust some swales because they didn't function and the water stayed in the swale too long.
3. **Complaints**
   Two respondents mention complaints from citizens. Respondent R9 mentions that there are no complaints as a basis of why the swales function for water quantity. While respondent R24 mentions complaints as a reason why it partly functions.
4. **Field visits**
   Field visits are mentioned four times as a basis of why the swales do/partly function. Respondent R25 mentions that the swale is checked after heavy rainfall. Respondents R20 and R24 also checked the swale and saw that it is not yet functioning as expected.
5. **No flooding**
   Respondent R7 mentions that flooding hasn't happened since the implementation of the swale. Respondent R32 says there is less water on the street during rain and a bottleneck has been solved.

6. **Maintenance**
   Two responses mention maintenance in there answers. Respondent R13 mentions that proper maintenance hasn't been done and that this is the reason why the swale doesn't work as designed anymore. Respondent R12 mentions that maintenance is difficult and because of that the swales don't stay intact.
7. **More research is needed**
   Two respondents who said the swale works partly for water quantity need further proof to be sure. For respondent R7 more research needs to be done to be sure if the swale functions. Respondent R10 mentions that the swale still needs to prove itself. Respondent R17 says the swale doesn't work for this function with the reason that they don't measure it.

Water quality

For the water quality function, different reasons were given as to why the swales (partly/not) worked. These reasons are categorised and shown below.

1. **The design**
   Multiple answers mention the design. Respondent R21 thinks the swales partly work and mentions that practice is often different than design. For respondent R23 the swale was first designed for the water quantity function, now other aspects are also taken into account.
2. **Field visits**
   Field visits are mentioned four times as a basis of why the swales do/partly function. Respondent R11 mentions field visits as a basis for the reasoning but without further explanation. Respondent R2 says it is visible that the water infiltrates and thus gets filtered.
3. **More research is needed**
   Two respondents who said the swale works partly for water quality need further proof to be sure. For respondent R7 more research needs to be done to be sure if the swale functions. Respondent R2 mentions it is difficult to measure the water quality function. R17 says the swale doesn't work for this function with the reason that they don't measure it.

Biodiversity

For the biodiversity function, different reasons were given as to why the swales (partly/not) worked. These reasons are categorised and shown below.

1. **The design**
   Four answers mention the design as a reason. Respondents R15 and R22 give the design as a motivation why they should work. Respondent R21 thinks the swales partly work and mentions that practice is often different than design. For respondent R23 the swale was first designed for the water quantity function, now other aspects are also taken into account.
2. **Vegetation choice**
   The choice of vegetation came back in two answers. Respondent R32 mentioned that the swale gave an opportunity to design the swale and surrounding area more biodiverse vegetation. For respondent R9 swales work partly for biodiversity because in the past the right vegetation was not always planted.
3. **Field visits**
   Field visits are mentioned two times as a basis of why the swales do/partly function for biodiversity. Respondent R1 mentions that certain vegetation, insects and amphibians are spotted. Respondent R15 mentions it is visible as a basis for the reasoning but without further explanation.
4. **Time**
   Respondent R8 says that more time is needed to see the effect, but expects that the vegetation will work.

5. **Maintenance**
   Respondent R12 mentions that maintenance is difficult and that the swales are difficult to keep intact.
6. **More research is needed**
   Two respondents who said the swale works partly for water quality need further proof to be sure. For respondent R7 more research needs to be done to be sure if the swale functions. R17 says the swale doesn't work for this function with the reason that they don't measure it. Respondent R22 mentions that measurements are being done by volunteers and colleagues to get inside into this function.

Liveability

For the liveability function, a few reasons were given as to why the swales (partly/not) worked. These reasons are categorised and shown below.

1. **The design**
   Three answers mention the design as a reason. Respondent R15 gives the design as a motivation why they should work. For respondent R23 the swale was first designed for the water quantity function, now other aspects are also taken into account. Respondent R7 also mentions that is was not taken into account during the process.
2. **Complaints**
   Respondent R9 mentions that there are no complaints as a basis of why the swales function for water quantity and liveability.
3. **Measurements**
   Respondent R5 mentions that measurements show that the humidity is higher, which results in lower temperatures during heat.

Wellbeing

For the wellbeing function, a few reasons were given as to why the swales partly or not worked. These reasons are categorised and shown below.

1. **The design**
   Two answers mention the design as a reason.For respondent R23 the swale was first designed for the water quantity function, now other aspects are also taken into account. Respondent R7 also mentions that it was not taken into account during the process.
2. **Use of swale**
   Respondent R1 mentions that children are playing in the swale.

Full answers Q3.7 and Q3.8

Table D.12: Q3.7 and Q3.8 - Why do the swales function on this function(s) and what do you base your assumption that the swales do work on this function(s)?

Response number	Functions	Why does it function?	Bases of assumption
R1	Biodiversity, Liveability,	waarneming van oeverplanten, insecten en amfibieën	spelende kinderen
R2	Water quantity, Biodiversity,	vilteren	ruimte/ berging om rustig de bodem in te gaan
R3	Water quantity, Water quality, Liveability,	Ledegingstijd ok	binnen 24 uur na vulling leeg
R5	Water quantity,		berging en infiltratie
R8	Water quantity,	de eerste wadi is aangepast en dient als voorbeeld voor de anderen	er staat niet lang water in
R9	Water quantity, Liveability,	Geen overlast	Geen meldingen
R11	Water quantity, Water quality, Biodiversity, Liveability, Wellbeing	Wadi vult zich in natte periodes en voert het vertraagd af naar de ondergrond of via slokop.	Veldbezoek
R15	Water quantity, Biodiversity, Liveability,	zijn aangelegd volgens het ontwerp	zichtbaarheid
R22	Water quantity, Biodiversity,	Ontwerp+beheer	Ad hoc monitoring na zware regenval (leeglooptijd blijkt trager dan beoogd). Biodiversiteit: metingen/monitoring (door vrijwilligers en werkgroep biodiversiteit)
R23	Water quantity,	Ontworpen specifiek voor de functie. De latere ontwerpen kennen bredere ontwerpkaders	Na een flinke regenbui, buiten kijken. :)
R25	Biodiversity,		
R32	Water quantity, Biodiversity,	Het knelpunt op gebied van wateroverlast is verholpen en de aanleg van de wadi heeft de mogelijkheid geboden om bestaand groen meer biodivers in te richten.	Minder tot geen water op straat bij buien. Bestaand knelpunt m.b.t wateroverlast verholpen.
R33	Water quantity, Biodiversity,	de capaciteit van de wadi wordt gemeten,	op de capaciteit

Table D.13: Q3.7 and Q3.8 - Why do the swales partly function on this function(s) and what do you base your assumption that the swales partly work on this function(s)?

Response number	Functions	Why does it partly function?	Bases of assumption
R2	Water quality,	moeilijk meetbaar	zichtbaar dat het water wegzakt en dus gefilterd word
R5	Wellbeing	luchtvochtigheid neem t toe waardoor verkoeling ontstaat	bij metingen in den lande zie je dat er qua hitte minder hoge temperaturen optreden
R6	Water quantity,	Gaat meestal goed, maar een paar wadi's zijn later aangepast omdat ze niet goed bleken te functioneren	Water dat te lang blijft staan
R7	Water quantity, Water quality, Biodiversity,	Te weinig onderzoek en er moet intensiefst worden gemonitord	Wateroverlast is tot dus ver niet mee voortgekomen
R8	Biodiversity,	biodiversiteit moet de tijd hebben	de verwachting dat de planten goed aanslaan
R9	Biodiversity,	Niet altijd de juiste soort vegetatie gepland in het verleden	monitoring
R10	Water quantity,	De aangelegde maatregelen moeten zich nog bewijzen.	De aangelegde maatregelen moeten zich nog bewijzen.
R12	Biodiversity,	onderhoud is moeilijk	wadi's blijven moeilijk intact
R13	Water quantity,	eigenlijk weten we niet goed of de wadi's voldoende functioneren. We hebben heel recent een eerste inspectie uitgevoerd (nulmeting) naar de wadi's die er in onze gemeente zijn. Hier kwamen diverse gebreken aan het licht. Vooral omdat wadi's niet onderhouden worden en gaan dichtslibben, instroom dichtgegroeid is etc. etc	onderhoud is niet uitgevoerd dus gaat de werking achteruit
R16	Water quantity, Biodiversity,	Door onze kleiachtige ondergrond valt infiltratie nog wel eens tegen.	Omdat deze langer vol blijven staan dan wenselijk
R18	Water quantity,	er is soms gewoon een verlaging in het maaiveld aangebracht zonder na te denken over bergingshoeveelheid,afvoer en onderhoud.	wadi's blijven lang vol met water staan
R20	Water quantity, Wellbeing	Sommige wadi's lopen te langzaam leeg	veld inventarisaties
R21	Water quantity, Water quality, Biodiversity,	Praktijk is vaak anders dan ontwerptafel	Onvoldoende werking
R23	Water quality, Biodiversity, Liveability, Wellbeing	In het begin alleen een functioneel ontwerpen. In de huidige tijd wordt er meer naar andere aspecten gekeken.	Bewoners informeren en openstaand voor suggesties. Stedenbouwkundige betrekken. Landschapsarchitect betrekken.
R24	Water quantity,	Sommige wadi's infiltreren/ledigen niet goed waardoor de bergingscapaciteit die is berekend niet benut wordt bij langdurige re-	Visuele inspectie van wadi's in oosterhout + meldingen van bewoners van wateroverlast

Table D.14: Q3.7 and Q3.8 - Why do the swales not function on this function(s) and what do you base your assumption that the swales do not work on this function(s)?

Response number	Functions	Why does it not function?	Bases of assumption
R7	Liveability, Wellbeing	Niet meegenomen in het proces	Niet meegenomen maar n het proces
R12	Water quantity,	onderhoud moeilijk	wadi's blijven niet intact
R17	Water quantity, Water quality, Biodiversity,	Wij toetsen daar niet op maar als er ruimte is brengen wij ze aan hoofddoel is vertraagend afvoeren	

D.4.4. Do we want to know if they work?

For the different functions respondents not always know if they swale functions as desired. Questions Q3.9 and Q3.10 asked if participants want to know if the swale works. Six respondents would like to know if the swale works on certain functions, three respondents want to know but into some extent. One respondent doesn't want to know and two respondents give other reasons. All of the reasons mentioned are categorised and shown below. The full answers are given in table D.15.

1. **Importance additional benefits**
   Four answers mention the additional benefits. Respondent R6 says it is important what the additional benefit in practice for biodiversity. R32 finds it valuable to know if swales also reach the the desired impact for liveability and wellbeing. For respondent R20 water quality is also important. For respondent R26 it is important to acieve the aimed goal.
2. **Policy**
   Two answers mentioned policy. Respondent R27 would like to know if the swales work for the functions, but there is no budget for monitoring. Respondent R10 refers to the KPI's (kritieke prestatie indicator) within the organisations. These are not yet well developed and embedded in the organisation.
3. **Not my task**
   Four answers are not interested in certain functions because it is not their task. Respondent R4 mentions that as an sewer manager, preventing flooding is most important the other functions are less important. The same upholds for respondent R3, R13 and R18.
4. **Complaints**
   Respondent R29 partly wants to know if swales function for water quantity and quality, but as long as there are no complaints it is not a priority.

The question was also asked to the two respondents (R19 and R34) who don't have swales yet. They both would like to know if swales work on the designed functions. R19 mentions that data is always useful in convincing others and seeing how the swale works. These insights are also important for the right implementation of maintenance.

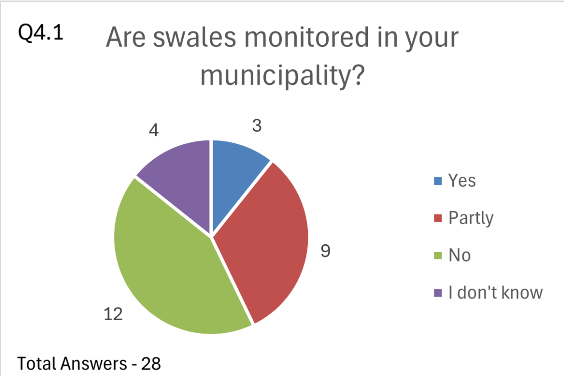
Table D.15: Q3.9 and Q3.10 - Do you want to know whether the swales function as desired on this function(s) and why?

Response number	Functions	Do you want to know if it functions	Why?
Yes			
R6	Biodiversity,	Ja	Belangrijk om te laten zien wat de toegevoegde waarde van wadi's in de praktijk is voor biodiversiteit
R13	Liveability, Wellbeing	ja maar heeft geen prioriteit	Ik houd me als beheerder Water vooral bezig met de waterkwantiteits-aspecten
R20	Water quality, Biodiversity,	ja	Als adviseur water en riolering wil ik wel weten wat een wadi doet tav kwaliteit.
R26	Water quantity, Water quality, Liveability,	Ja	doel halen
R27	Water quantity, Biodiversity, Liveability, Wellbeing	ja, maar op dit moment hebben we geen kosten ingecalculeerd voor monitoring	beleidskwestie
R32	Liveability, Wellbeing	Ja	Wadi's worden aangelegd om bijvoorbeeld opgaven rondom waterkwantiteit aan te pakken, maar bieden tegelijk ook kansen om de openbare ruimte op leefbaarheid en welzijn te verbeteren. Na aanleg van een wadi is het zeker waardevol om te horen of de wadi ook de gewenste resultaten bereikt voor deze functies
Partly			
R4	Biodiversity, Liveability, Wellbeing	Een beetje	Ik ben als rioolbeheerder het meest gebaat bij het voorkomen van wateroverlast. De andere functie zijn voor mij minder belangrijk.
R18	Biodiversity, Liveability, Wellbeing	niet vanuit mijn vakdiscipline, maar kan me voorstellen dat ecologie dat wel wil weten.	ik kijk alleen naar berging
R29	Water quantity, Water quality,	Ja en nee	Geen klachten dan geen prio, geen tijd om actief te beheren
No			
R3	Biodiversity, Wellbeing	Nee	Ik ga over de riolering
Other			
R1	Water quality,	nooit onderzocht	
R10	Biodiversity, Liveability,	De KPI's zijn nog niet uitgewerkt en geborgd in organisatie.	De KPI's zijn nog niet uitgewerkt en geborgd in organisatie.

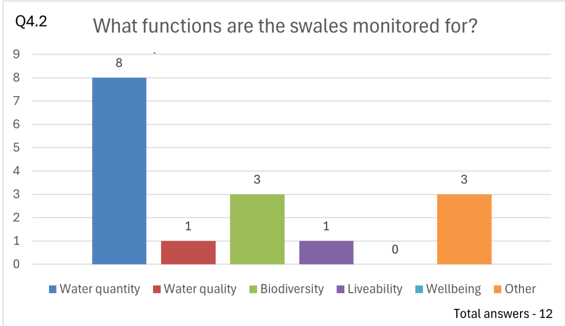
D.5. Current practice of monitoring

This section contains the results from the monitoring question block. This block was meant to gather information about how municipalities currently monitor and how they do it.

Current practice of monitoring



(a) Q4.1 - Are swales being monitored



(b) Q4.2 - For which functions are the swales monitored?

Figure D.17: Results Question Q4.1 en Question Q4.2

In most municipalities, swales are not being monitored. Only 3 respondents said swales are being monitored, and 9 respondents answered they are partly being monitored, this is shown in figure D.17a. Figure D.17b shows which functions the 12 respondents who mentioned that swales are (partly) monitored in their municipality are monitoring. The monitoring is, in almost all cases, implemented later.

Eight respondents are monitoring on the water quantity. This is mostly being done in relation to flooding. Respondent R8 mentions it checks if the swale empties in time in case of complaints. Respondent R32 mentions that they collect reports of places where there is flooding and they check locations where there are known problems related to water quantity. Next to this it is also often checked in person. The frequency is more incidently, either during field visits or after heavy rainfall. The one respondent that is monitoring on water quality does this via real-time measurements. Three respondents are monitoring on biodiversity of which two have implemented it. This is being done by counting. R12 mentions that this is being done during the season. One respondent is monitoring on liveability but mentions something about water quantity. Three respondents are monitoring on something else. Respondent R5 mentions that they monitor on maintenance aspects, like mowing and keeping things clean. They also monitor the drains. They took this into account in the design. Respondent R8 mentions that they are working on a monitoring plan. Respondent R17 mentions they measure the water level of the swale every 10 minutes during rainfall via sensors.

Question Q4.6 asked if respondents had any additional comments regarding monitoring. Respondent R4 mentions that they have just started with monitoring and that it is still very new. R8 mentions that as long as there are no complaints daily maintenance will be done. Monitoring will be used to learn if they are on the right track.

The full answers from questions Q4.3, Q4.4 and Q4.5 about how swales are monitored can be found in table D.16 and table D.17. The answers for question Q4.6 can be found in table D.18.

Table D.16: Q4.3, Q4.4 and Q4.5 - How are swales monitored, how often are they monitored and since when are they monitored?

Response number	Monitoring in place?	How are they monitoring?	How often?	Since when?
Water quantity				
R7	Partly	Maaten van wateroverlast	1 x per maand	Nee deze is pas later geïmplementeerd
R8	Partly	op tijd leeg	bij klachten	Anders: monitoring wordt nu geïmplementeerd
R9	Partly	Vast houden en vertraagd afvoeren	ca. 2 x per jaar	Ja er is rekening mee gehouden in het ontwerp
R11	Yes	Fysiek	na iedere grote bui	Nee deze is pas later geïmplementeerd
R12	Partly	visueel	bij onderhoudsronde	Nee deze is pas later geïmplementeerd
R20	Partly	veldinventarisatie en soms worden (grond)waterpeilen gemeten	veldinventarisatie continu, als een beheerder rondrijdt en iets opvalt. Het meten alleen zeer sporadisch	Nee deze is pas later geïmplementeerd
R21	Partly			Nee deze is pas later geïmplementeerd
R32	Partly	Bij hevige neerslag verzamelen we meldingen van water op straat en/of controleren we bekende knelpuntenlocaties om te zien of problemen op gebied van waterkwantiteit voorkomen.	Incidenteel	Weet ik niet
Water quality				
R3	Partly	Doormiddel van real time meting	Realtime	Nee deze is pas later geïmplementeerd
Biodiversity				
R8	Partly	monitoring wordt nu opgezet.	dat zal jaarlijks zijn verwacht ik	Anders: deze wordt nog geïmplementeerd
R9	Partly	Telling	durf ik je niet te zeggen	Ja er is rekening mee gehouden in het ontwerp
R12	Partly	visueel	tijdens seizoen	Nee deze is pas later geïmplementeerd
Liveability				
R4	Partly	Ja	Ter plaatse kijken bij veel regenval of ze inderdaad het water bergen	Weet ik niet

Table D.17: Q4.3, Q4.4 and Q4.5 for the Other category of Q4.2 - How are swales monitored, how often are they monitored and since when are they monitored?

Response number	Monitoring in place?	What are they monitoring?	How are they monitoring?	How often?	Since when?
R5	Yes	beheer aspecten, maaien en schoon houden en werking en evt ofde werking van de slokops nog goed is	visueel na maaien en na grotere buien	na buien en na maaien	Ja er is rekening mee gehouden in het ontwerp
R8	Partly	monitoring moet nog worden opgezet	we zijn druk met het antwoord	nog niet	Anders: deze wordt nog geïmplementeerd
R17	Yes	op niveau of de wadi gevuld wordt tijdens regen	Doormiddel na niveausensoren	Doorlopende om de 10 minuten	Nee deze is pas later geïmplementeerd

Table D.18: Q4.6 - Additional comments regarding monitoring

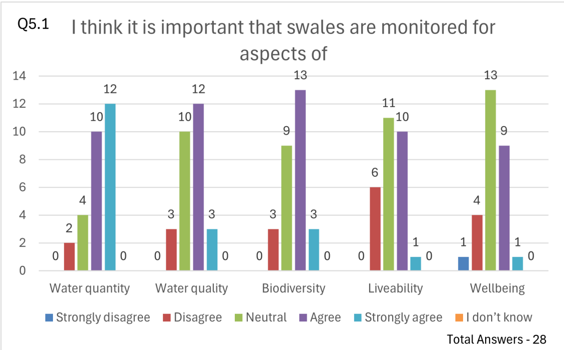
Response number	Dutch answer
R3	Wij monitoten na een keten van wadi, voordat water filteren en in dietebronnen opslaan (zwemwaterkwaliteit).
R4	Nee, het staat bij ons nog in de kinderschoenen. Bij nieuwe projecten wordt het meer toegepast en zal er ook meer monitoring plaats gaan vinden.
R5	er wordt rekening mee gehouden maar tijdens het beheer gaat het niet altijd zoals bedoeld
R8	als er geen klachten komen wordt er grotendeels alleen dagelijks onderhoud uitgevoerd. Montoring zal plaatsvinden om te leren of we op het juiste pad zijn bij het ontwerp.

D.6. Monitoring possibilities and challenges

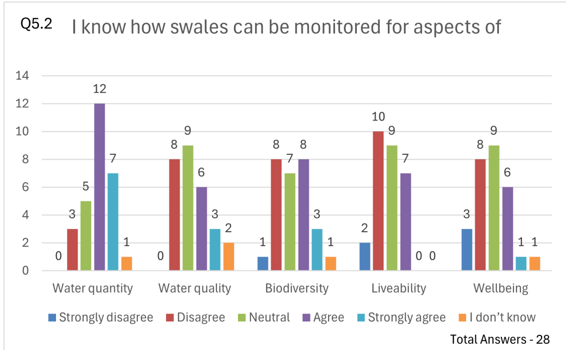
This section contains the results of the questions from the monitoring possibilities and challenges question block. This block was meant to gather information on what the respondents would want to monitor and what they see as challenges and motivators regarding the implementation.

D.6.1. Importance of monitoring

Although monitoring is not really being done, the participants find it important to monitor certain functions, but don't always know how to do it. This is shown in figure D.18. Each function is elaborated in its corresponding subsection.



(a) Q5.1 - Opinion of the importance of the monitoring of swales per function



(b) Q5.2 - Knowledge of the monitoring of swales per function

Figure D.18: Results Question Q5.1 en Question Q5.2

Water quantity

The respondents found the water quantity function to be the most important one to monitor. Respondent R5 wants to know if the swales work, and respondent R22 mentions that if monitoring shows that the swales are not working as expected, the design should be changed. Of the 28 respondents, 19 agree or strongly agree that they also know how to do the monitoring. Respondent R19 mentions it is within its field of expertise, and respondent R22 shows logical steps to do monitoring. Respondent 13 agreed with the statement but did mention they still had a lot to learn. For respondent R24 it is also not completely clear how this monitoring can be done.

Table D.19: Elaborated answers for water quantity Q5.1 and Q5.2

Response number	Answer	Elaboration in Dutch
Q5.1		
R5	Strongly agree	de werking
R22	Strongly agree	Anders aanpassing ontwerp nodig (als onvoldoende)
Q5.2		
R13	Agree	heb hier nog veel over te leren
R19	Strongly agree	Dit is mijn vakgebied als waterbouwkundige.
R22	Agree	Aangesloten verhard oppervlak | volume wadi | neerslag meten | leeglooptijd bepalen. Eventueel test met tapwater maar dat vind ik verspilling.
R24	Ik weet het niet	Er is deels bekend hoe dit gedaan kan worden, vraag alleen is wat is de beste manier van monitoren.

Water quality

The water quality function is also seen as important. Of the 28 respondents, 12 agreed with the statement and 3 strongly agreed, 10 of the respondents were neutral. Respondent R18 agreed with the statement and mentioned it might be necessary because of the UWWTD (Urban Waste Water Treatment Directive). Respondents R19 and R22 were both neutral. R19 mentions that it is not the main function of a swale. For R22 monitoring depends on the related risks. Respondent R5 disagrees and asks how you could do this. This also shows in the results of Q5.2 where only 9 out of 28 respondents (strongly) agrees with the statement. Respondent R13 agrees with the statement, but still mentions that they still have to learn about this. Respondent R22 mentions that they don't how to do it and that it is complicated.

Table D.20: Elaborated answers for water quality Q5.1 and Q5.2

Response number	Answer	Elaboration in Dutch
Q5.1		
R5	Disagree	hoe zou je dit willen doen?
R18	Agree	mogelijk vanuit de UWWTD moet dit wel
R19	Neutral	Is mijn inziens bijvangst en niet de hoofdreden voor de wadi.
Q5.2		
R13	Agree	heb hier nog veel over te leren
R22	Ik weet het niet	Zanderige grond, grondwater -20m. Gecompliceerd om de effecten op het grondwater te meten.

Biodiversity

The biodiversity function is seen as important to monitor. 13 respondents agreed with the statement and 3 strongly agreed, 9 respondents were neutral. Respondents R13 and R22 were neutral. R13 mentions that it is not within its job description and R22 mentions there is no legal or constructional obligation. R18 agrees with the statement and says that if you have a goal for biodiversity it is also important to monitor it. R5 disagrees with the statement it is mere guesswork and sees biodiversity as a container concept. For the question if the participants know how to monitor biodiversity the answers are a bit more divided. 8 respondents disagree but also 8 respondents agree. Respondent R19 disagrees and mentions that it is dependent on other people. Respondent R22 agrees and mentions counting insects and small animals and using wild cameras.

Table D.21: Elaborated answers for biodiversity Q5.1 and Q5.2

Response number	Answer	Elaboration in Dutch
Q5.1		
R5	Disagree	dit is natte vingerwerk, als je wilt dat het verbeterd dan is het ook zo, geldt bij alle containerbegrippen(ook bv duurzaamheid)
R13	Neutral	zit niet in mijn takenpakket als beheerder water
R18	Agree	als je een doelstelling hebt qua biodiversiteit,m moet je deze ook monitoren.
R22	Neutral	Is voor ons beleid, bijvangst. Geen wettelijke/bouwkundige verplichting.
Q5.2		
R19	Disagree	Ik ben afhankelijk van anderen hiervoor.
R22	Agree	Telling insecten en kkeine dieren/wildcamera’s

Liveability

For liveability, the opinion about the importance of monitoring is more neutral compared to the first three. Respondents R13, R22 and R32 are all neutral. R13 mentions that it is not within its job description and for R22 the swales are constructed in areas that were already green. For R32 it would be interesting to know if the liveability improves, but it is not a priority to monitor this. Most participants don't know how to monitor the liveability. R22 mentions that it could be done via interviews or surveys, but it has never been done.

Table D.22: Elaborated answers for liveability Q5.1 and Q5.2

Response number	Answer	Elaboration in Dutch
Q5.1		
R5	Disagree	hoe?
R13	Neutral	zit niet in mijn takenpakket als beheerder water
R22	Neutral	Onze wadi's liggen al in bestaand groen
R32	Neutral	Het is interessant om te weten of leefbaarheid ook daadwerkelijk verbeterd als gevolg van de aanleg van een wadi. Maar dit is niet prioriteit om te monitoren.
Q5.2		
R22	Agree	Interview/enquête gebruikers/omwonenden? Nog nooit gedaan bij ons voor zover ik weet.

Wellbeing

The respondents found the wellbeing function least important to monitor. Of the 28 respondents, 13 were neutral and 9 agreed. Respondents R13 and R32 were neutral. R13 mentions that it is not within its job description. For R32 it would be interesting to know if the liveability improves, but it is not a priority to monitor this. Respondent R21 strongly disagrees and mentions a swale is not for recreation. R22 strongly agrees and mentions safety as a reason. Water should not be in the swale too long. Most participants also don't know how this function can be monitored. Respondent R5 strongly agrees and mentions measuring the temperature (which relates to the liveability function). R22 mentions that it could be done via interviews or surveys, but it has never been done.

Table D.23: Elaborated answers for wellbeing Q5.1 and Q5.2

Response number	Answer	Elaboration in Dutch
Q5.1		
R5	Neutral	hoe?
R13	Neutral	zit niet in mijn takenpakket als beheerder water
R21	Strongly disagree	Een wadi is niet voor recreatie en spelen
R22	Strongly agree	Veiligheid (geen lang stilstaand water)
R32	Neutral	Het is interessant om te weten of welzijn ook daadwerkelijk verbeterd als gevolg van de aanleg van een wadi. Maar dit is niet prioriteit om te monitoren.
Q5.2		
R5	Strongly agree	meten van temperatuur
R22	Agree	Zie vorige toelichting

D.6.2. Responsibility of monitoring

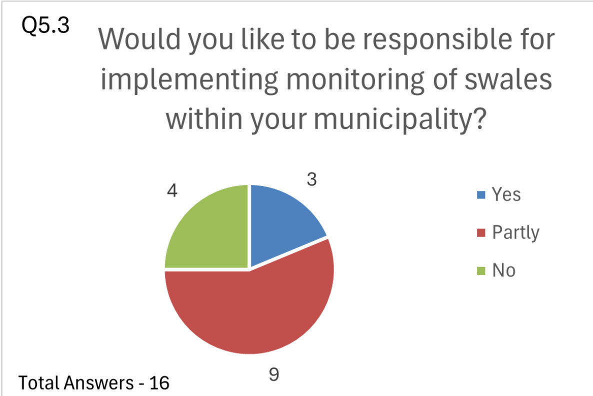


Figure D.19: Q5.3 - Responsibility for implementation of monitoring

The respondents who didn't have monitoring in their municipality yet got question Q5.3, asking if they wanted to be responsible for the implementation. Of the 16 respondents, 9 wanted to be partly responsible and 3 wanted to be responsible, as shown in figure D.19. The answers to who (else) should be responsible were categorised and shown below. The full answers can be found in table D.24.

1. **People responsible for the field of expertise**
   Respondent R16 mentions that they work within specific teams, and everyone should use their expertise. This relates to the answers from R2 and R6, which mention that biodiversity should be handled by someone from team "Green" which could be an ecologist, and that the water quantity part could be someone who is responsible for drainage. Respondent R34 mentions a colleague from sustainability.
2. **People related to maintenance**
   Respondent R14 and R24 mention that it should be done together with the colleagues responsible for the maintenance. Respondent R19 mentions the work planner and data manager from their swales should by partly responsible as well, since they collect and analyse the data. Respondent R34 also mentions an external party that takes care of the mowing.
3. **Tactical managers**
   Respondent R18 mentions the tactical managers, which can be the layer in between the strategic managers and the personnel that goes out into the field.
4. **Volunteers, residents and users**
   Respondent R22 mentions that volunteers, residents or other users could help out.

The respondents who answered no regarding the responsibility for the implementation of monitoring refer to an ecologist (R1), personnel from maintenance and policy (R15), personnel from sewers (R27) and the water manager (R33).

Table D.24: Q5.4 - Who (else) should be responsible?

Response number	Dutch answer
Partly	
R2	Ecoloog voor biodiversiteit. Drainage nog een verantwoordelijke voor bepalen
R6	De beheerders (groen en drainage)
R14	operationele dienst
R16	Wij werken met vak teams, hierin zou ieder zijn eigen expertise moeten inzetten
R18	tactisch beheerders
R19	De werkvoorbereider/databeheerder van onze wadi's. Deze verzamelt en analyseert data.
R22	Directe omwonenden/gebruikers/vrijwilligers. Ipv 'moeten' > 'kunnen'.'
R24	Samen met de werf die onderhoud doet kan monitoring geregeld worden
R34	collega duurzaamheid/klimaat aannemer maaien volgens kleurkeur
No	
R1	ecoloog
R15	beheer en beleid
R27	riolering
R33	afhankelijk welke functie, maar de beheerder van het waternetwerk lijkt mij de eerste verantwoordelijke

D.6.3. How/what do they want to monitor?

Figure D.20 shows which functions the respondents would like to monitor swales. Most respondents would like to monitor water quantity. Next to that, part of the respondents would like to monitor water quality and/or biodiversity. Two respondents would like to monitor liveability, and two respondents would like to monitor wellbeing. Two respondents also would like to monitor something else. Six respondents mentioned that some monitoring is already in place at a previous question and don't want to add additional monitoring on the defined functions. In the paragraphs below, the mentioned variables for each function are mentioned, together with the answers.

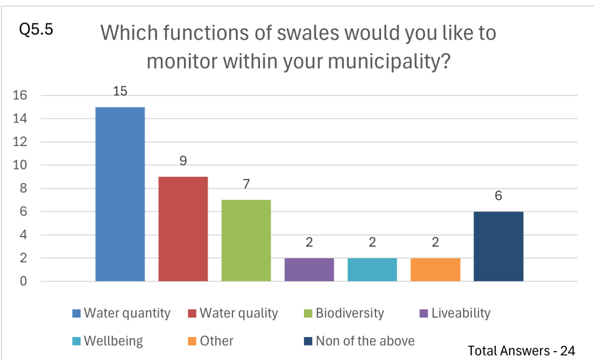


Figure D.20: Q5.5 - Which swale functions would you like to monitor within your municipality?

Water quantity

For the water quantity function, different variables are mentioned that the respondents would be interested in for monitoring. These are: water storage or the capacity, infiltration, discharge time, use over time in case of filling, flow rate, the groundwater level, and sediment. The frequency is most often yearly, but some want to measure them more frequently (e.g. monthly or weekly).

Table D.25: Q5.7 Q5.8 - Suggested variables and frequency for water quantity

Response number	Variable	Frequency	Frequency if other
R2	per wadi de waterberging vast leggen	Yearly	
R6	Capaciteit Afvoersnelheid	Yearly Yearly	
R7	Sediment Nutriënten Toxische stof	Monthly Monthly Monthly	
R10	Berging Capaciteit Infiltratie	Yearly Yearly Yearly	
R13	hoe frequent wordt de wadi gevuld Is de ledigingstijd acceptatbel hoe snel gaat de capactiteit achteruit a.g.v. dichtslibben	Other Other Other	5 Yearly 5 Yearly 5 Yearly
R14	vulling in de tijd	Other	doorlopend
R16	Infiltratie Vertraagd afvoer Opvang capaciteit	I don't know I don't know I don't know	
R18	berging afvoer doorlaatbaarheid	Yearly Yearly Yearly	
R19	Debiet Grondwaterstand in nabije omgeving Vul en leegtijd	Yearly Yearly Yearly	 Mogelijk vaker in het begin
R20	infiltratie snelheid (duur leegloop)	Other	3 a 5 Yearly
R21	Capaciteit Ledegingstijd	Yearly Other	 Ntb
R22	Volume Leeglooptijd Debiet dat naar riool/oppervlaktewater overstort	Other Other Other	Bij/na maatgevende regenbuien Na zware regenval (icm metingen neerslag) totdat leeg. Bij regenval
R24	infiltratiesnelheid/capaciteit	I don't know	Niet bekend wat een juiste herhalingstijd is van monitoren, is dit elk jaar elke 5 jaar?
R26	infiltratiesnelheid	Wekelijks	
R34	de wijze waarop de wadi binnen 48 uur weer droog staat	Yearly	

Water quality

For the water quality function, different variables are mentioned that the respondents would be interested in for monitoring. These are: General variables such as pH and Turbidity (NTU), E. coli, PAK, nutrients, organic substances like nitrogen and phosphorus, heavy metals, PFAS and polluting and toxic substances. The frequency is most often yearly, but some also quite some respondents marked 'I don't know' or Other.

Table D.26: Q5.7 Q5.8 - Suggested variables and frequency for water quality

Response number	Variable	Frequency	Frequency if other
R9	pH waarde NTU Verontreinigende stoffen (oa PFAS)	Yearly Yearly Yearly	
R10	Ecolie	Yearly	
R13	is de filterende laag onder de wadi nog voldoende om metalen te kunnen binden	Other	5 jaarlijks
R14	kan er geen bedenken	I don't know	
R18	specifiek verontreinigende stoffen fysisch chemische paramaters (organische belasting, N/P) zware metalen	Yearly I don't know I don't know	
R20	welke stoffen worden afgevangen in de "standaard" wadi die we toepassen	I don't know	
R21	Nutriënten Zware metalen Pak	Other Other Other	Om de paar jaar Zie vorige Idem
R32	-	Yearly	
R34	in de uitstroom bak niet te veel vuil blijft liggen	Yearly	

Biodiversity

For the biodiversity function, different variables are mentioned that the respondents would be interested in for monitoring. These are: the number of species, target species, variable species, insects, plants, effect on trees, strength of plants and the effect on soil permeability. The preferred frequency is most often yearly.

Table D.27: Q5.7 Q5.8 - Suggested variables and frequency for biodiversity

Response number	Variable	Frequency	Frequency if other
R2	werkt de bodemdoorlaatbaarheid	Yearly	
	welke dieren en insecten zijn er	Yearly	
R6	Aantal soorten	Yearly	
R18	doelsoorten	Yearly	
	variatie soorten	Yearly	
R19	Gidssoorten aanwezig	Yearly	
	Aantal soorten	Yearly	
R21	Nog geen idee	Yearly	
R22	Aantal en variatie aan bezoekers (insecten en dieren)	Other	Onregelmatig, projectmatig. Minimaal 1x per jaar
	Gevolgen voor bestaande bomen nabij de wadi en evt. overloopgebied	Yearly	Gelijk met vtm bomeninspecties
	Veerkacht beplanting na natte of juist droge periodes	Other	Ad hoc
R34	monitoring insecten	I don't know	
	monitoring beplanting	I don't know	

Liveability

Two respondents want to monitor something for the liveability function. These are: apparent temperatures, noise reduction, and air quality. The preferred frequency is yearly.

Table D.28: Q5.7 Q5.8 - Suggested variables and frequency for liveability

Response number	Variable	Frequency	Frequency if other
R19	Gevoelstemperatuur	Yearly	
	Mening omwonenden	Yearly	
R21	Nog geen idee	I don't know	

Wellbeing

Two respondents want to monitor something for the wellbeing function. These are: the experience and safety, the opinion from local residents, the use as a meeting place, and the use by children. The preferred frequency is yearly.

Table D.29: Q5.7 Q5.8 - Suggested variables and frequency for wellbeing

Response number	Variable	Frequency	Frequency if other
R9	Temperatuurregulatie	Yearly	
	Geluidsdemping en luchtkwaliteit	Yearly	
	Beleving en veiligheid	Yearly	
R19	Gebruiksmomenten als ontmoetingsplek	Yearly	
	Gebruiksmomenten door kinderen	Yearly	
	Mening van omwonenden	Yearly	

Other

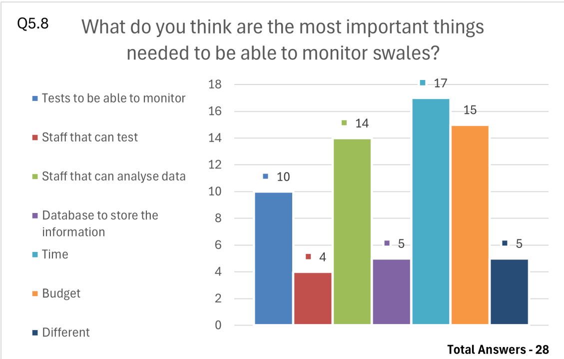
Two respondents marked that they want to monitor something else besides the five given functions. Respondent R4 mentions additional variables for water quantity, which have already been mentioned in the right paragraph. Respondent R22 wants to know how the water quality of the groundwater level is influenced by the swale or other types of infiltration objects. Variables are the quality of the infiltrating water of the swale and on the different levels under the ground and then comparing it with locations close by to see if there is a difference.

Table D.30: Q5.7 Q5.8 - Suggested variables and frequency for the other option

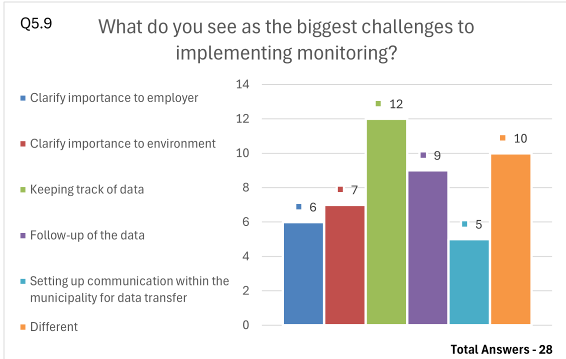
Response number	Other function	Variable	Frequency
R4	Hoe lang blijft het water in de Wadi staan na hevige regenval	Tijdsduur	I don't know
		mate van vulling (hoeveelheid water)	I don't know
R22	Waterkwaliteit invloed op grondwater, indien dit eenvoudig en goedkoop mogelijk zou zijn.	Kwantiteit en samenstelling infiltrerend water wadi (of ander soort object): bij de inlaat, op +0,05 m in de wadi, op -0,2 m onder de wadi,	Other: Indien subsidie hiervoor beschikbaar
		Vervolg: op -0,4 / -0,6 / -0,8 / -1,0 / -2,0 / -3 / -4 / -5 / -10 / -15 / -20	Other: Indien subsidie hiervoor beschikbaar
		In vergelijking met nabije locaties waar geen wadi of andere infiltratievoorziening ligt én in vergelijking tot andere infiltratiesystemen	Other: Indien subsidie hiervoor beschikbaar

Challenges and motivators

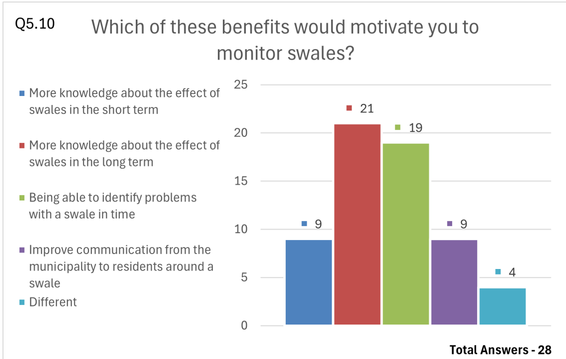
In the survey, three questions specifically asked questions related to the challenges and motivators for the implementation of monitoring. First, it was asked what the respondent thinks needed to be able to monitor swales (figure D.21a), then it was asked what they see as the biggest challenge to implement monitoring (figure D.21b) and then it was asked what would motivate them to monitor swales (figure D.21c). Table D.31 shows the answers when the respondents marked 'Different' for the three questions.



(a) Q5.8 - What do you think are the most important things that are needed to be able to monitor swales?



(b) Q5.9 - What do you see as the biggest challenges to being able to implement monitoring?



(c) Q5.10 - Which of these advantages would motivate you to monitor swales?

Figure D.21: Results Question Q5.8, Q5.9 and Q5.10

There are different things needed to be able to monitor swales. Most respondents have marked time, budget and staff that is able to analyse the data as the three most important things. Tests to be able to monitor are seen as important by ten respondents. Five respondents found the database needed to store the information important, and four respondents answered staff that is able to test. Five respondents have answered the option different. Answers that were given for this were field visits during or after rainfall, guidelines on how to monitor, the right knowledge, frequency and understanding of utility and necessity.

Keeping track of the data is answered most often as the biggest challenge for the implementation of monitoring. Second is the option different, here reasons as time, capacity, budget, feasibility and continuity were given. Nine respondents answered the follow-up of the data. Seven respondents answered clarifying the importance of monitoring to the environment and six respondents see clarifying the importance of monitoring to their employer as a challenge. Five respondents answered setting up communication within the municipality for the data transfer as a challege.

The third questions was related to the motivation of monitoring swales. Twenty one respondents answered that the knowledge about the effect of swales in the long term motivates them. Nineteen respondents answered being able to identify problems with a swale in time as motivation. Nine respondents answered that short term knowledge of the effect on swales would motivate them and nine respondents would be motivated for monitoring because it can improve the communication from the municipality to residents around the swale. Four respondents answered the option different. Answers that were given in this field were, more knowledge to motivate other disciplines for the implementation of swales, to get more insights for maintenance, to get input for future swale design and maintenance and to be able to maintain and improve the functioning of swales.

Table D.31: Answers to the different options for questions Q5.8, Q5.9 and Q5.10

Response number	Different option
Q5.8	
R13	veldbezoek tijdens en na een regenperiode om infiltrerende werking te kunnen bekijken
R18	handreiking hoe
R21	Juiste kennis, Begrip nut en noodzaak, Frequentie
Q5.9	
R2	uitvoerbaarheid bij aannemers
R3	Tijd i.s.h. met alle taken die we hebben
R6	Capaciteit
R8	continuïteit, tijd en geld
R13	gebrek aan voldoende tijd
R15	beschikbare middelen (personeel / geld) verkrijgen
R17	Werking van Wadi te controleren
R21	Capaciteit beschikbaar
R22	Budget
Q5.10	
R3	Meer kennis, waardoor andere disciplines ook meer wadi's willen.
R18	onderhoudsopgave beter in beeld
R22	Input voor toekomstige ontwerp en voor beheer
R24	functioneren van wadi's kunnen behouden en verbeteren

The final question asked if the respondents had any remaining remarks regarding the challenges for the monitoring of swales. The answer to this question are shown in table D.32.

Table D.32: Q5.11 - Do you have any other comments regarding challenges of monitoring swales?

Response number	Answer
R3	Eerst gewoon doen, vergroenen en inrichten voor gebruik, monitoren op het gebied van HWA is niet nodig om het belang aan te geven.
R4	Nee
R5	uitleg geven aan beheer waarom het onderhoudsregime moet worden gevolgd
R19	Als er in de buurt bijv. drainage ligt, hoe meet je dan welke invloed de wadi heeft t.o.v. de drainage.

E

Workshop tools

This appendix contains the materials that are necessary for the activities of the workshop.

E.1. Connection activity

Figure E.1 shows how the cards should look like. The function on the front responds to the group and the number is for the order in the pile. The function on the back is the 'other' function and the small number on the back responds to the number in the chain. Table E.1 to table E.5 show the overview of the cards information together with some information for the workshop facilitator of type of connections and explanations.

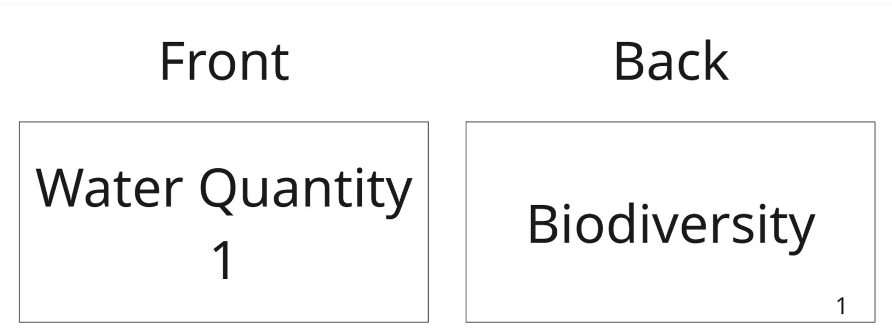


Figure E.1: Example of the card

Table E.1: Card information overview – Water Quantity

Number in group pile	Number in chain	Function on the back	Type of connection	Possible explanation
1	1	Biodiversity	Hydrological processes	The availability of water influences plant growth
2	7	Wellbeing	Temporary effects	Presence of open water has a positive influence on the aesthetics
3	13	Water Quality	Hydrological processes	Infiltration and HRT influences the ability to treat water
4	18	Liveability	Hydrological processes	The availability of water influences evaporation and transpiration processes which cool the environment

Table E.2: Card information overview – Biodiversity

Number in group pile	Number in chain	Function on the back	Type of connection	Possible explanation
1	2	Liveability	Potential via design	Presence of vegetation is necessary to provide service
2	6	Water Quantity	Ecological processes	Root growth affects permeability, plant height influences channel roughness
3	11	Wellbeing	Potential via design	Presence of vegetation is necessary to provide service
4	16	Water Quality	Ecological processes	Water treatment mechanisms are ecological processes

Table E.3: Card information overview – Water Quality

Number in group pile	Number in chain	Function on the back	Type of connection	Possible explanation
1	5	Biodiversity	Ecological processes	Distinct bacterial communities
2	10	Biodiversity	Effects of pollution	Pollution affects plant growth
3	14	Wellbeing	Effects of pollution	Soil pollution affects recreation
4	17	Water Quantity	Effects of pollution	The filtration of sediments can cause clogging of the swale

Table E.4: Card information overview – Liveability

Number in group pile	Number in chain	Function on the back	Type of connection	Possible explanation
1	3	Wellbeing	Potential via design	Perceived noise influences stress recovery and cognitive restoration
2	9	Water Quality	Effects of pollution	Atmospheric deposition is a source of pollution when the dust particles wash off the leaves
3	19	Wellbeing	Temporary effects	The swale can cause cooling during warm days, which residents could then use for recreational purposes

Table E.5: Card information overview – Wellbeing

Number in group pile	Number in chain	Function on the back	Type of connection	Possible explanation
1	4	Water Quality	Impacts of recreation	Additional source of pollution
2	8	Liveability	Potential via design	The aesthetics influence the perceived noise
3	12	Water Quantity	Impacts of recreation	Compaction of soil due to walking
4	15	Biodiversity	Potential via design	The choice in maintenance influences the aesthetics
5	20	Biodiversity	Impacts of recreation	Additional source of pollution

E.2. Make your monitoring story

There are two sheets needed for this activity. The first sheet is for the first three steps and is shown in figure E.2, the second sheet is for the story and is written down in figure E.3. The first sheet should be printed on an A3 sheet, and the second one on an A4.

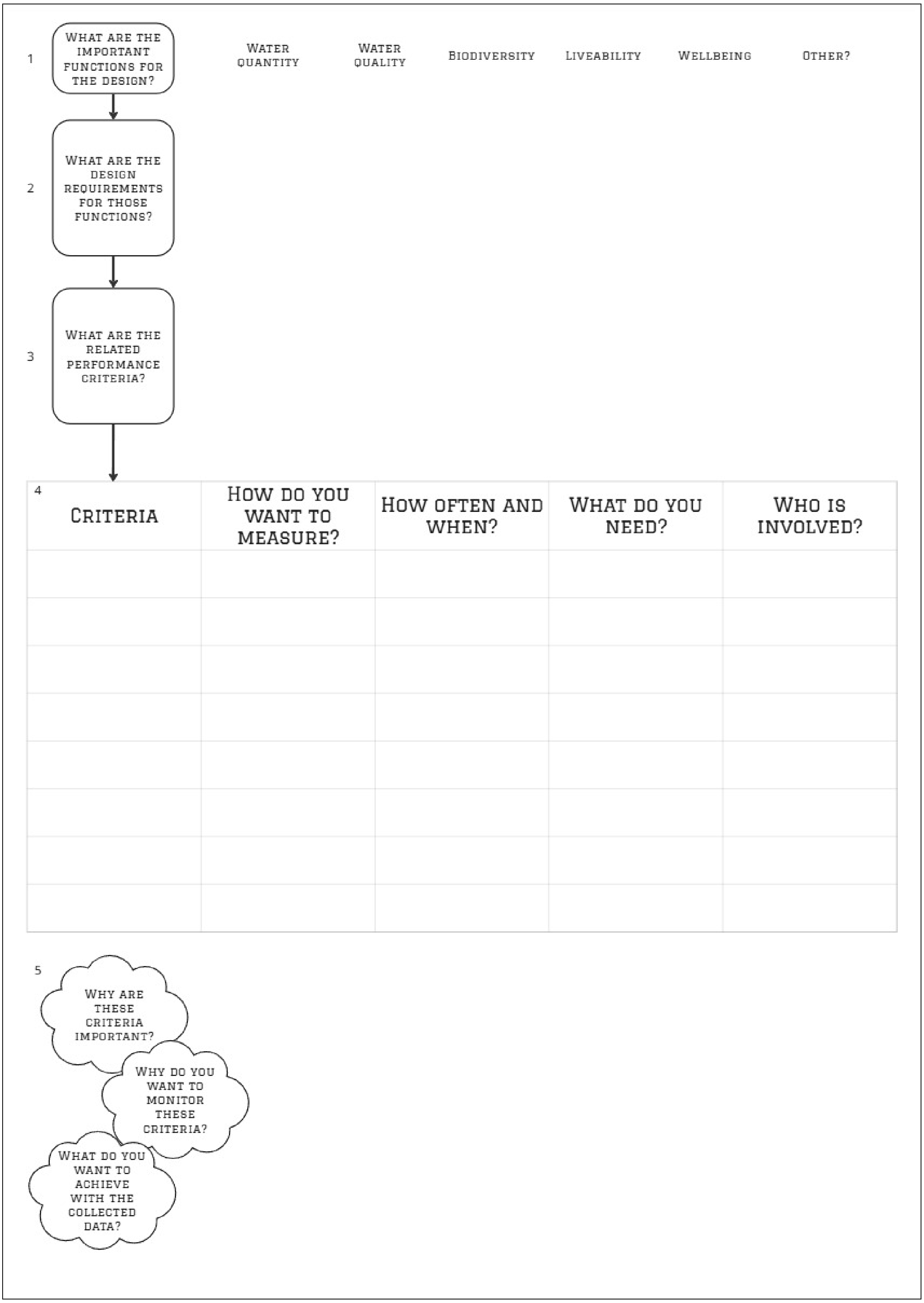


Figure E.2: Monitoring story sheet part 1

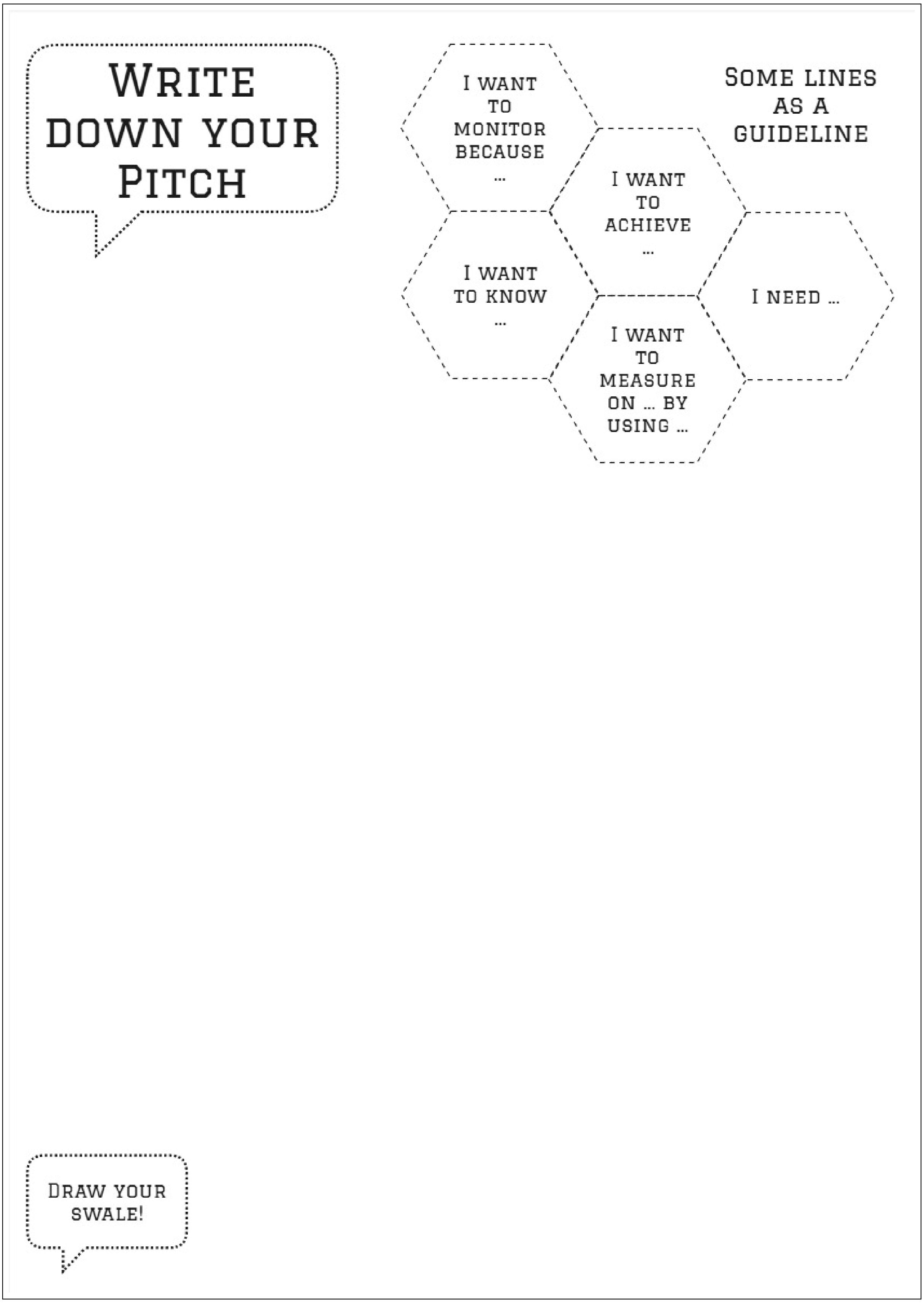


Figure E.3: Monitoring story sheet part 2