Sewer Water Harvesting to Support Urban Green Spaces

The potential of 'waste' water as a resource to support urban green spaces during dry periods through integrated local water treatment

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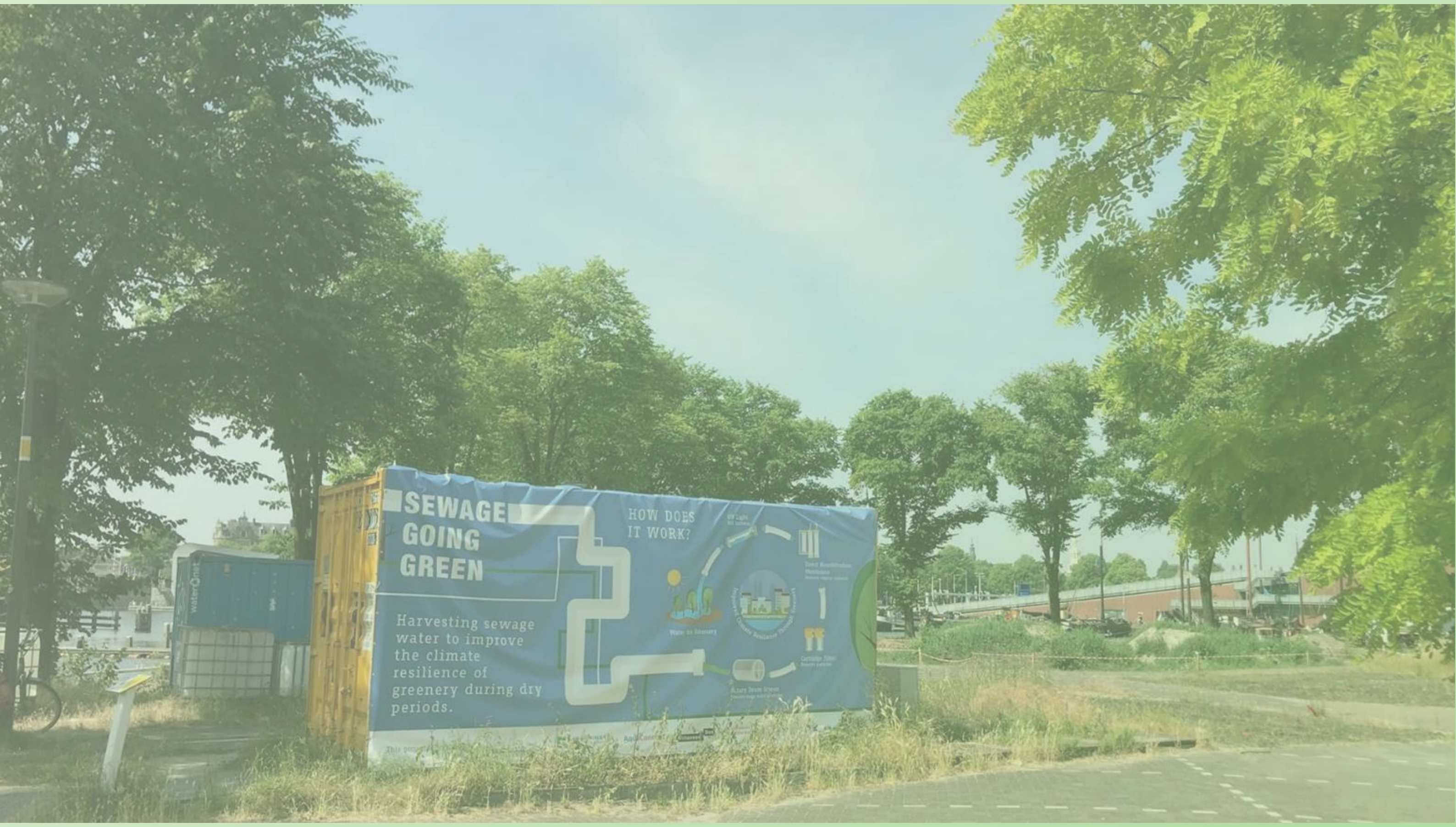

Sewer Water Harvesting for Urban Green Spaces in Amsterdam

Master Thesis

By

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Acknowledgements

In front of you is my Master Thesis about the potential impact of Sewer Water Harvesting (SWH) to support Urban Green Spaces (UGS), focussing on its application in Amsterdam. This thesis is written in fulfilment of my master Metropolitan Analysis, Design and Engineering, a joint degree from the Delft University of Technology and Wageningen University & Research. I can proudly say this thesis covers all aspects of this diverse master programme. I was able to focus on an interdisciplinary urban challenge, which I thoroughly analysed to come up with a fitting solution in the form of a conceptual design of a SWH-unit, for which I had to apply my engineering knowledge and skill. Also building further on knowledge from my bachelor Civil Engineering. In all, I am proud of this tangible end-result of my academic growth and journey. Before presenting my research, I would like to thanks everyone that helped me throughout this project.

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To whoever that reads this report, I hope that you enjoy it!

Jan-Joris van der Plas

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Abstract

This research has investigated how Sewer Water Harvesting (SWH) can be applied to provide a climate-proof fresh water source to support Urban Green Spaces (UGS) in Amsterdam. SWH is the process of extracting raw municipal sewage from the sewer and locally treating this to provide fit-for-purpose water in a dense urban environment while treatment residuals are discharged back into the sewer. SWH can help to meet the increasing water demand of UGS in Amsterdam, which experience exacerbated dry periods as a result of climate change, while conventional water sources are unlikely to meet this demand.

The overall aim was to provide a conceptual design example of how SWH could be applied in the Amsterdam context to uncover what kind of impact can be achieved and advise on how SWH can be implemented From an analysis of potential applications, irrigation of UGS during dry periods was selected for the focus of the study. Suitable locations were identified, from which the Vondelpark was selected as study area for this research. Quality requirements for irrigation water and discharge of treatment residuals were determined. The water demand of the study area was determined by modelling the soil moisture balance using transformed weather data, taking into account climate change. Based on these requirements, a conceptual design of an SWH-unit comprised of fine screening, MF, NF and UV steps. To evaluate this potential impact for Amsterdam as a whole, the findings from the study area were extrapolated. The cost of SWH were compared to alternative water sources and the potential direct economic benefits. This demonstrated that costs of SWH are acceptable and can be further decreased. Furthermore, the potential impact on plant and soil health was evaluated. Interviews with stakeholders identified barriers and opportunities of SWH and resulted in some recommendations for larger scale implementation.

The results of this research indicate that SWH can provide a new and reliable water source during dry periods to support UGS. SWH-units can be designed as mobile and modular units that can for a large part be operated and monitored remotely. The results further demonstrate that potential negative environmental effects can be prevented or mitigated and SWH can even improve the plant and soil health of UGS. From an engineering perspective, challenges related to the water quality are unlikely to be insurmountable. However, three aspects still require a significant amount of time and investment before SWH can be implemented on a larger scale. These are: (1) the lack of regulatory framework, (2) the unresolved responsibility for operation and (3) extensive water quality testing and environmental impact assessment. To accelerate innovation it is recommended to start as soon as possible with addressing these remaining issues. Commercial operation of SWH can provide an interesting opportunity, all the more so because SWH can also be used for household or industrial applications. The involvement of a wider variety of stakeholders can further help to overcome the remaining barriers.

Key Words: Sewer Water Harvesting; Urban Sewer Mining; Water Reuse; Water Shortage; Urban Green Spaces; Climate Adaptation

List of Abbreviations

SWH: Sewer Water Harvesting

UGS: Urban Green Spaces

WWTP: Waste Water Treatment Plant

(I)UWM: (Integrated) Urban Water Management

N: Nitrogen (Concentration)

BOD$_{(5)}$: Biological Oxygen Demand (measured over 5 days) (Concentration)

COD: Chemical Oxygen Demand (Concentration)

TOD: Total Oxygen Demand (Concentration)

TSS: Total Suspended Solids (Concentration)

P: Phosphorus (Concentration)

MBR: Membrane BioReactor

MF: Microfiltration

UF: Ultrafiltration

NF: Nanofiltration

RO: Reversed Osmosis

UV: UltraViolet (Disinfection)

NOM: Natural Organic Matter (Concentration)

TOC: Total Organic Carbon (Concentration)

CAPEX: CAPital EXpenditure

OPEX: OPerational EXpenditure

Table of Contents

1. Introduction

This Chapter introduces the research. First the relevance of this research is explained in section 1.1. After which the aim of the research is outlined in section 1.2. Here, the main research questions and sub-questions are presented. Lastly, the structure of this report is displayed.

1.1 Grounds for Research

The municipality of Amsterdam has shown full commitment to increase Urban Green Spaces (UGS) over the recent years and in the future (Gemeente Amsterdam, 2020b). This process of 'greening the city' is undertaken for its many social, economic, biodiversity and ecology benefits (Fam, et al., 2008; Gemeente Amsterdam, 2020b; WHO, 2017). Besides, increasing UGS is one of the most important tools that the municipality advocates as part of their climate adaptation strategy (Gemeente Amsterdam, 2020a). For instance, it is becoming common practice throughout Amsterdam to use UGS to reduce heat stress caused by the urban heat island effect and to mitigate nuisance due to extreme precipitation which will increase due to climate change. UGS are thus becoming increasingly important and present in Amsterdam.

However, in (extremely) dry periods the additional UGS will irrefutably lead to a higher water demand, which is further increased due to the increase in likelihood, length and severity of drought events as a result of climate change (Veraart & Voskamp, 2022; Heuvelink, Jensen, Hulsman, & Stapel, 2021; NKWK, 2021). When UGS experience water shortage social, economic, biodiversity and ecology benefits start to diminish and plants could even permanently wilt, an example of which can be seen in Figure 1 (Fam, et al., 2008).

Figure 1 A wilted tree in the Vondelpark in Amsterdam as a result of the long dry period in 2018 (Khaddari, 2018).

In 2018, water shortages resulted in approximately €1.400.000 restoration cost for UGS despite spending an additional €475.000 on prevention measures throughout the municipality of Amsterdam (Gemeente Amsterdam, 2020a). Moreover, the cooling effect of UGS will be reduced significantly if plants occur water shortages, which of course often coincides with heat (Gräf, Immitzer, Hietz, & Stangl, 2021). Furthermore, plants with large root depths (i.e. trees and shrub varieties) rely on groundwater during dry periods which can actually cause a local drop in ground water level (Tolk & Kuiper, 2020), which has caused subsidence that resulted in damages to surrounding buildings and infrastructure (Zoelen, 2020). Additionally, extensive use of groundwater could lead to subsidence, resulting in the ground compaction that decreases the infiltration capacity of the soil permanently. Moreover, the infiltration capacity of dried out soil is way lower and thus water nuisance can still occur after a sudden heavy shower in the summer. On top of that, plants can also sustain indirect damages because they become more susceptible to diseases or infestations. An additional negative impact of water shortages for UGS is that less CO_2 can be absorbed by plants (Peters, et al., 2018).

Concurrently, conventional water sources are likely not able to meet the increased water demand of UGS. During dry periods the water level of surface water and its quality will drop and in the western part of the Netherlands the quality is further deteriorated due to salinization (Veraart & Voskamp, 2022; Atelier Groenblauw, n.d.; Hoogvliet, et al., 2012). Due to seepage the groundwater becomes increasingly brackish, which forms a direct threat to most bushes and trees (Brolsma, Buma, Meerten, Dionisio, & Elbers, 2012; Twynstra Gudde & HydroLogic, 2019). Furthermore, Amsterdam's drinking water company, Waternet, (and all others in the Netherlands) has stressed that from 2030 the supply of drinking water cannot be guaranteed due to, among others, population growth (Waternet, 2021; Meershoek, 2019). In that case, UGS will be first in line to not receive any (drinking) water if a water shortage is imminent according to the national 'verdringingsreeks' (distribution priority sequence) (Rijkswaterstaat, n.d.). Within policy documents of the municipality of Amsterdam (e.g. (Gemeente Amsterdam, 2020a; Gemeente Amsterdam, 2020b)) there is barely any attention for how the increased water demand of UGS can be met in the future. Only rain water storage is offered as an alternative water source. However, rain water storage would take up a lot of valuable space in the already dense urban environment of Amsterdam, especially for larger UGS such as the Vondelpark and Rembrandtpark. As a result, several Dutch research projects are currently focussing on new ways to ensure a sustainable fresh water supply (for UGS) in the future, such as the WiCE (Water in the Circular Economy) research programme and the NWO-programme AquaConnect. New innovative solutions to meet the water demand of UGS during dry periods are a must to ensure all the intended benefits of 'greening the city'.

One of the only steady and reliable supplies of fresh water in long-lasting dry periods can be provided by the sewage system, because of the relatively predictable water use of households. Besides, pipelines are nearly always nearby to locally provide water. If the water that can be extracted from the sewer system can be treated locally in order to provide enough water with a sufficient quality for UGS and public health, this will be a good solution to prevent water shortages and ensure all the intended

Figure 2 Example of a SWH-unit fitted into the dense urban environment of Athens, Greece (Frijns & Makropoulos, 2022).

benefits of UGS. This process of water extraction and local treatment for a specific use in the city is referred to as Sewer Water Harvesting (SWH) or Urban Sewer Mining which is a form of decentralized water reuse or recycling (Butler & MacCormick, 1996; Sydney Water, n.d.). In Australia and the Mediterranean (pilot) projects have showed that SWH technology can be connected to the sewer system and compactly fitted in dense urban environments, as can be seen in Figure 2 (Makropoulos, et al., 2018; Sydney Water, n.d.; Rahman, Hagare, & Maheshwari, Use of Recycled Water for Irrigation of Open Spaces: Benefits and Risks, 2016).

In the Netherlands there has been some research focussing on water reuse. However, the research has mostly focussed on agricultural irrigation with water directly from centralised Waste Water Treatment Plants (WWTP) or large scale decentralised units in rural areas (van Hooijdonk, 2020; Cirkel, van den Eertwegh, Stofberg, & Bartholomeus, 2017). Smaller scale decentralised applications in a dense urban environment and their potential impact have not yet been investigated properly.

Within the AquaConnect research programme, the Amsterdam Metropolitan Area is one of the study cases, as requested by the municipality, with a focus on providing new climate proof water sources (Al & Stolp, 2022). Amsterdam thus has an expressed need for innovations such as SWH. Furthermore, water reuse aligns with the circularity goals of the municipality (Delgado, Rodriguez, Amadei, & Makino, 2021; Cirkel, van den Eertwegh, Stofberg, & Bartholomeus, 2017; Makropoulos, et al., 2018) Another important stakeholder for SWH in Amsterdam is Waternet, which manages the full urban hydrological cycle and is a collaboration of the municipality and the water board (Amstel, Gooi and Vecht). In the ‘Omgevingsprogramma Riolering 2022 – 2027’ (Environmental Programme Sewage), drafted by the municipality and Waternet, they outlined the exploration and implementation of local decentralized water treatment and supply as one of their sustainability goals (Waternet, n.d.). SWH thus and aligns with goals of the most important stakeholders and can help meet the increased water demand of UGS in Amsterdam. Hence, the scope of this research will focus on Amsterdam.

The semantics of SWH
Originally, at the start of this research, the concept of SWH was called (Urban) Sewer Mining, which is more commonly used in (scientific) literature. However, during conversations with multiple people as part of this research it became clear that the term did not resonate and can have a negative connotation (as mining itself is perceived as unsustainable). Moreover, there were some mix ups since people assumed it had to do with the recovery of resources from the water and not about the reclamation of water itself. Based on the more positive sounding term rainwater harvesting, the term Sewer Water Harvesting was adopted for this research.

1.2 Aim of the Research

In short, this research will investigate how SWH can be applied to provide a reliable fresh water source to support UGS in Amsterdam. The aim is to provide a conceptual design example of how SWH could be applied in the Amsterdam context to uncover what kind of impact can be achieved and advise on how SWH can be implemented. The main research question that will be addressed is:

Main research question: *How can the concept of Sewer Water Harvesting be deployed to support sustainable and climate-proof water supply for Urban Green Spaces in the city of Amsterdam to have positive impact on the urban environment?*

In order to provide a comprehensive answer to this question four sub-questions have been established:

Sub-question 1: *For what kind of applications could Sewer Water Harvesting be beneficial in Amsterdam?*

Sub-question 2: *How could a Sewer Water Harvesting unit be designed to meet water demand and quality requirements?*

Sub-question 3: *What would be the potential impact if Sewer Water Harvesting is deployed in Amsterdam on a larger scale in terms of plant and soil health and costs and direct economic benefits?*

Sub-question 4: *What are opportunities and barriers from a stakeholders perspective?*

The report is structured such that every chapter will be steadily working towards answering the research question by formulating answers to sub-questions. First, the theoretical framework will be discussed in Chapter 2 to see how this research relates to existing theories and concepts and how it fits into the broader context. The perspective from which this research is conducted is hereby described to clarify underlying assumptions. In Chapter 3 the research structure and methodology of the research is discussed. Chapter 4 will study the applications of SWH for UGS worldwide and translate these findings to potential applications in Amsterdam, after which is study area is selected for the next stages of the research. In Chapter 5 the water quality and quantity requirements for the study area are established. This then results in a conceptual design (i.e. systems specifications) of a SWH-unit which is able to meet the requirements, suitable for its application and can fit into the dense urban context of Amsterdam. The impact of this conceptual design in terms of the potential to reduce damages to UGS in comparison with the anticipated costs and the effect on plant and soil health are evaluated in Chapter 6. In Chapter 7 the stakeholder perspective on SWH in terms of barriers and opportunities is investigated to be able to figure out the (larger scale) implementation potential. Hereafter, the conclusions and answer to the main research question is provided in Chapter 8. Limitations to the research and recommendations for future research are presented in the discussion Chapter 9. Lastly, this report contains a reference list and multiple appendices.

2. Theoretical Framework

The theoretical framework provides an overview of the key concepts relevant to this research and how they relate to each other. Since Urban Water Management (UWM) can be understood and reviewed in many different ways, the perspective from which this research is conducted is described to clarify underlying assumptions in section 2.1 and 2.2. Hereafter, in section 2.3, an overview of SWH projects globally is provided, focussing on the general characteristics, the use of different treatment technologies and different applications that support UGS.

2.1 Towards a Water Sensitive City

Over the recent years, the global and Dutch UWM sector has seen significant changes in its goals reflected in policy and vision documents of key stakeholders (e.g. waterboards, water companies and municipalities). Traditionally, the sector is characterized by its conservative, risk-averse and technocratic way of thinking (van der Brugge, Rotmans, & Loorbach, 2005; de Graaf, 2009). This has resulted in a sub-optimal compartmentalised grey system that relies on centralised end-of-pipe technologies and large energy demanding transport infrastructure (i.e. network of pipes and pumps) (Wong & Brown, 2009; van der Brugge, Rotmans, & Loorbach, 2005; Brears, 2018). This has led to the development of new concepts and approaches for UWM. This includes Water Sensitive Cities and Integrated Urban Water Management which will be discussed further in this chapter. The overarching thought behind these concepts is that due to the growing pressures of predominantly population growth and climate change, the need for a more resilient, sustainable and circular water system has increased (Wong & Brown, 2009). However, while policy and vision documents from key stakeholders in the Dutch urban water management sector (i.e. waterboards and companies) reflect major changes over the past decade(s), changes to the physical infrastructure and implementation of innovative technologies remain limited (de Graaf, 2009; de Graaf, et al., 2009). An explanation for this can be provided by the fact that there is not as much innovation as in other sectors and the long time it takes for innovation to be adopted (Wehn & Montalvo, 2018; O'Callaghan, 2020; Kiparsky, Sedlak, Thompson, & Truffer, 2013). This can be linked to the slowly changing institutional culture in the Dutch water sector (de Graaf, 2009; de Graaf, et al., 2009). Experiments and pilots with new technologies and modes of governance are necessary instrument (Ehnert, 2023; Bos & Brown, 2012; de Haan, Rogers, Frantzeskaki, & Brown, 2015). In the end, this should lead to a new form of UWM.

The goal of the ongoing transition in UWM is best captured by the concept of a Water Sensitive City. The concept was established in Australia by Brown, Keath and Wong (2009) based on their studies of the historical, current and future regimes of UWM. Based on their research they identified 6 states of the Urban Water Management, which can be seen in Figure 3 with their corresponding socio-political drivers and characterising service delivery functions. The first three states were identified based on historical research of UWM and reflect the aforementioned compartmentalisation of the current system. The states Waterways City and (a small) part of the Water Cycle City were established based on the current state of (Australian) UWM. Lastly, the concept of a Water Sensitive City and for the most part Water Cycle City were derived from their research focussing on "anticipating and projecting the future institutionalisation of sustainable UWM" (Brown, Keath, & Wong, 2009). SWH can be easily linked to the Water Cycle City as this would create fit-for-purpose water and a diversification of resources. Besides, as previously mentioned, socio-political drivers for intergenerational equity and resilience to climate change are currently in place to pave the way towards a Water Sensitive City. This can be achieved by reusing water, which will reduce the depletion of other sources for future generations, and, since this research focusses on UGS, SWH can contribute to climate adaptation. Furthermore, SWH has the potential to be used for multiple purposes besides for UGS. It could also be applied for industrial applications or non-potable household reuse such as toilet flushing, although this requires separate household connections and piping (Kohn, Duong, Hoang, & Nghiem, 2022).

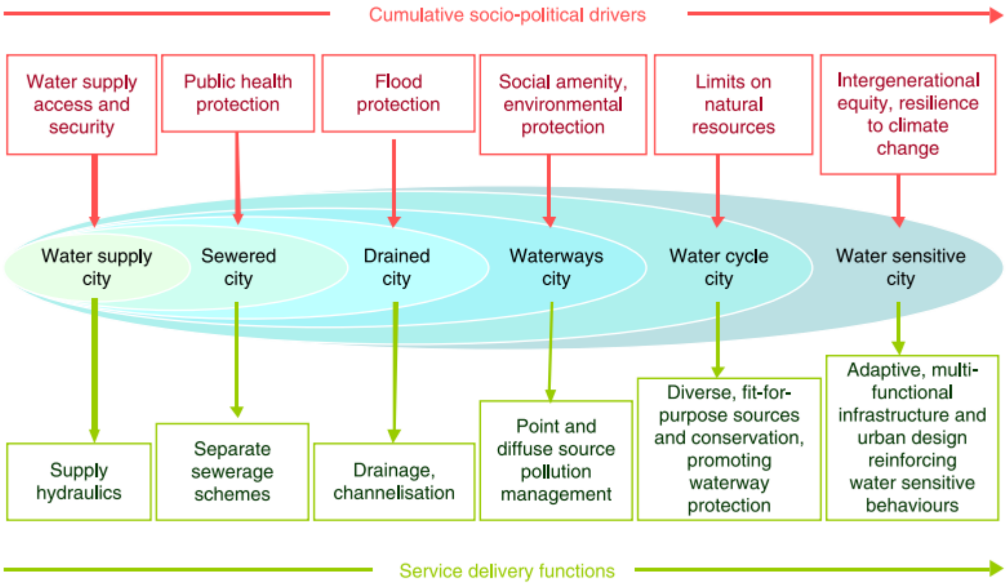

Figure 3 States of Urban Water Management transition with their socio-political drivers and characterising functions (Brown, Keath, & Wong, 2009).

Besides, by applying compact and advanced treatment technologies opportunities arise to create portable SWH-units which would make the deployment adaptive (Plevri, et al., 2020). The adaptiveness can also be achieved by using modular treatment components (Kohn, Duong, Hoang, & Nghiem, 2022). In addition, for the concept of a Water Sensitive City, three key principles should be considered (Wong & Brown, 2009; Howe & Mitchell, 2011):

1. Water should be provided by multiple sources within the city to create resilience by means of a variety of centralised and decentralised technologies.
2. Cities should support eco-system services that make up urban environments.
3. Institutional and public support and awareness for sustainability and water sensitive behaviour

SWH for irrigation of UGS relates to these principles as it is a way to provide a new source of water by decentralised treatment technologies. Besides, SWH could be used as a showcase to create public awareness of the importance of water in a sustainable and liveable city, with the potential of increasing public support. Furthermore, the intention is to support the eco-system services of UGS. Eco-system services can be subdivided in four categories: provision services (e.g. food produced by urban farms or wood production), regulating services (e.g. cooling effect or uptake of CO_2), cultural services (e.g. aesthetics and recreation) and supporting services (e.g. nutrient cycling or habitat provision for biodiversity), which support one of the first three services (Pataki, et al., 2011; Gómez-Baggethun, et al., 2013). The examples given for each form of eco-system service are either directly or indirectly impacted by a water shortage. Therefore, provision of these services is highly reliant on water and thus can be supported by SWH (Voskamp & Ven, 2015).

This relation between greenery and water is captured well by the concept of Blue-Green Infrastructure. The term is used regularly when discussing the Water Sensitive City or climate adaptation and liveability of cities in general. The term encompasses integrated multi-functional networks or measures consisting of natural and engineered blue and green components that provide resilience to extremes as a result of climate change (e.g. urban heat islands and pluvial floodings) but also increase the liveability of cities (e.g. well-being and biodiversity) (Voskamp & Ven, 2015; Climate-KIC, n.d.; Kaur & Gupta, 2022; Probst, Bach, Cook, Maurer, & Leitão, 2022). SWH can be an engineered component that supports UGS to be able to achieve resilience to climate extremes and increase liveability during dry periods. Hence, we can conclude that SWH could in theory contribute to progress the transition of UWM towards a Water Sensitive City. However, as previously mentioned, lack of institutional support could form a serious barrier for the implementation of innovative technologies and solutions such as SWH. Since this is a key principle for the realisation of a Water

Sensitive City, it should be investigated if there is enough institutional support for SWH during this research. Therefore, this research aims to apply (a) similar approach(es) to UWM and urban planning as adopted by the key (institutional) stakeholders, the municipality of Amsterdam and water company Waternet, to fulfil the transition of UWM.

2.2 Integrated Urban Water Management

The relevant approaches and strategies of the municipality of Amsterdam and Waternet to UWM and urban planning can be best characterized as an integrated approach (Gemeente Amsterdam, 2020a; Gemeente Amsterdam, 2020b; van den Berg, Riccetti, van Schijndel, & Pixley, 2020; Waternet, 2022; Claassen, 2020; Gemeente Amsterdam Ruimte en Duurzaamheid, 2021). Likewise, SWH for the support of UGS can be characterised as integrated for two main reasons:

1. It links the water system to UGS and urban planning and thus integrates insights from several disciplines.
2. It is decentralised technology integrated into the centralised waste water network.

Integrated Urban Water Management (IUWM) is an approach that has been widely adopted to further the transition of the urban water system in relation to achieve Water Sensitive Cities (Bach, Rauch, Mikkelsen, McCarthy, & Deletic, 2014; de Haan, Rogers, Frantzeskaki, & Brown, 2015). This is illustrated by the fact that IUWM also focusses on integration of both centralised and decentralised technologies for the provision of fit-for-purpose water from a variety of sources (Bach, Rauch, Mikkelsen, McCarthy, & Deletic, 2014; Bahri, 2012). This can only be achieved if links are made with other disciplines (e.g. urban planning or energy) and all components of urban hydrology are considered as a continuous cycle instead of linear and discrete processes. A balance is sought after between economic efficiency and environmental and societal benefits, based on the current and future situation (Bahri, 2012; Mitchell, 2004). It should be noted that this bears similarity to the three pillars of sustainable development: People, Planet, Profit (3P's). As a result of the similarity in triple bottom line approach, IUWM and Sustainable Urban Water Management are often used interchangeably. The IUWM approach often has recourse recovery as a guiding principle for sewage water (Daigger, Sharvelle, Arabi, & Love, 2019). In addition to the recovery of useable water, the opportunities for the recovery of energy, nutrients and materials such as cellulose or bioplastics should be considered. In the Netherlands, this principle has shaped the 'Energie- en Grondstoffenfabriek' (Energy and Resources Plant) initiative from the Dutch water boards (Energie- en Grondstoffenfabriek, n.d.). An important pillar for success of an IUWM approach depends on the engagement of stakeholders (Bahri, 2012; Mitchell, 2004). This can vary from co-creation to just informing stakeholders on the decisions made and from engagement from an early stage or right before the end. However, in general, the earlier stakeholder are involved, the more insights and thus benefits can be gained (Conallin, Dickens, Hearne, & Allan, 2017). Furthermore, an IUWM approach requires a variety of quantitative indicators to measure the sustainability of the components of the urban water system in order to rationalise decision making (Behzadian & Kapelan, 2015; Aydin, Mays, & Schmitt, 2014; Lee & Kim, 2020). These are relevant when designing new components of the urban water system and during the assessment of its impact (Bach, Rauch, Mikkelsen, McCarthy, & Deletic, 2014; Makropoulos, Natsis, Liu, Mittas, & Butler, 2008). To come to a balanced decision, a distinction between economic, environmental, social and technical criteria can be made (Ashley, Blackwood, Butler, & Jowitt, 2004; Makropoulos, Natsis, Liu, Mittas, & Butler, 2008). However, not all criteria can be assessed quantitatively. For instance, stakeholder perceptions of barriers and opportunities depend on (subjective) expert opinions and should thus be investigated qualitatively. In summary, this research aims to apply a methodology that fits within the IUWM approach to explore the potential of SWH to support UGS to further the ongoing transition of the urban water system of Amsterdam to become water sensitive.

2.3 Global Sewer Water Harvesting Reference Projects

Globally, there are several reference projects of successful SWH applications that prove the viability and endorse the potential of the innovation as part of a sustainable water system and circular economy. These provide important insights into the possibilities in terms of applications, capacity, energy use, costs and treatment steps. Table 1 provides an overview of several SWH applications from Greece and Australia. Australia is the country where SWH was pioneered and broadly implemented for the first time driven by local water scarcity (Makropoulos, et al., 2018; Jimenez & Asano, 2008). Greece is one of frontrunners in Europe that has picked up this innovation to combat the increasingly dry summer period of the Mediterranean climate. It has successfully experimented with different pilots as part of the EU-funded DESSIN project ('Demonstrate Ecosystem Services Enabling Innovation in the Water') and continues to operate SWH-units (Makropoulos, et al., 2018). While dry periods such as in Greece seem far removed from the situation in the Netherlands, it is expected that the climate in the Netherlands could also be classified as Mediterranean before the end of the century (Snoek, 2020).

Table 1 Overview of SWH applications from Greece and Australia.

Location	Use	Capacity	Treatment Steps	Energy	Cost	Source
KEREFYT, Athens, Greece	Irrigation of urban green space	10 m^3/d	Floating and settling tank; coarse filter; Membrane Bioreactor (MBR); Reversed Osmosis (RO)	N/A	Capital: 225.000 € (Liakou, 2020)	(Makropoulos, et al., 2018)
Athens Plant Nursery, Athens, Greece	Irrigation of plant nursery	25 m^3/d (max. 100 m^3/d)	Prescreen; MBR; Ultraviolet Disinfection (UV)	N/A	Capital: 0,36 €/m^3 Operational: 0,50 €/m^3 (2021 prices)	(Plevri, et al., 2020)
Flemington Racecourse, Melbourne, Australia	Irrigation of grass field	100 m^3/d	(200 Micron) Prescreen; (0.2 Micron) Pressured Microfiltration & RO (Dual membrane); Chlorination	2.5 kWh/m3 (estimate based on 50 m3/d)	Capital: 350.000 A$ Operational: 0,6 A$/$m^3$ (2006 prices)	(Waste Technologies of Australia Pty Ltd, 2006)
Darling Quarter, Sydney, Australia	Toilet flushing, cooling towers, irrigation	170 m^3/d	Moving Bed Biofilm Reactor (MBBR); MBR; RO; UV; Chlorination (to storage tank)	4.5 kWh/m3	Capital: 4,70 A$/$m^3$ Operational: 4,80 A$/$m^3$ (2011 prices)	(Institute for Sustainable Futures, 2013)

Riverside Rocks Park, Sydney, Australia	Irrigation of public park	360 m^3/d	Reed Beds, UV	N/A	Capital: 0,49 A\$/m^3 (2006 prices) (Makropoulos, et al., 2018)	(Farrelly, 2009; McFallan & Logan, 2007)
Pennant Hills Golf Club, Sydney, Australia	Irrigation of sports field (golf)	650 m^3/d (max. 1000 m^3/d)	MBR, UV, Chlorination	N/A	Capital: 3.500.000 A\$ (2008 prices)	(Dahl, 2008)

As can be seen in Table 1 SWH-units can vary greatly in terms of capacity (i.e. scale) and treatment steps (and thus also in energy use and costs). The notable difference between the capacity of the SWH applications in Greece and Australia has to do with the fact that the Greek examples were pilot projects and meant to serve as a proof of concept before developing larger scale installations or increasing the capacity. Prices proved to be competitive with potable water (Makropoulos, et al., 2018). Only exception was the SWH-unit at Darling Quarter. This has to do with the fact that the SWH is located in the basement of a building, several new risks were identified after the contracting process and adaptations had to be made after implementation. In addition, the water was used for household applications as well. This required additional piping to distribute the non-potable water throughout the building. Moreover, during the first year, several investments were made to reduce the energy consumption from 7.8 kWh/m^3 down to 4.5 kWh/m^3 (Institute for Sustainable Futures, 2013). At the Flemmington Racecourse, there was an experiment with a submerged microfilter instead of a pressurized one to reduce the energy use. However, due to problems such as irreversible fouling, submerged microfiltration was deemed to be unsuitable (Waste Technologies of Australia Pty Ltd, 2006).

Especially for the treatment steps there remain nearly endless possibilities of combinations to achieve water that could comply with water quality requirements. However, despite the wide range of options the MBR (3 times), RO (3 times) and UV (4 times) treatment steps were commonly used to achieve fresh water that complied with quality standards. UV was mostly used as a final disinfection step to prevent (re)growth of microbes. An alternative or addition to UV is chlorination, which was used 3 times. However, in the Netherlands chlorination is an uncommon and less preferred practice. RO is also able to remove pathogens, as well as suspended solids, minerals and can even effectively remove micropollutants (e.g. drugs residues and pesticides), which is important to ensure safe use of water in (public) UGS (Mulder, 2021). RO is the most advanced form pressure-driven membrane filtration, which separate pollutants from the water by size. Other forms of membrane filtration are micro-, ultra- and nano-filtration (MF, UF and NF). RO is able to remove smaller pollutants because of the smaller membrane pores which consequently require more pressure than MF (pores 10-0.1 mircon), UF (pores in the range of 2-500 nm) and NF (pores smaller than 5-1 nm) (Van der Bruggen, 2018; Sewerin, et al., 2021; Ostarcevic, Jacangelo, Gray, & Cran, 2018). For high saline (sewage) water RO is typically necessary to comply with environmental standards (Plevri, et al., 2017). However, this comes with the downsides of higher energy use resulting in higher costs and increased fouling resulting in more maintenance compared to other pressure driven membrane filtration methods. Moreover, RO nearly completely removes all nutrients (i.e. total nitrogen and phosphorus) from the water. These nutrients are beneficial for the plants and are thus a valuable addition to the irrigation water. Therefore, the RO was replaced by UV in the second Greek pilot project, as valuable nutrients remained in the water while still achieving the desired reduction of pathogens (Plevri, et al., 2017). A MBR was often used to achieve removal of biodegradable organic matter and suspended solids as well as nutrients. It was mostly selected for its reliability despite the varying water quality of the sewage water and limited human intervention. A residual product of the MBR is highly concentrated excess (activated) sludge which should be deposited (back in the sewer) (KEREFYT and Pennant Hills Golf Club) or can be used as a resource, for instance by being composted to create fertilizer (Athens Plant Nursery). Alternative biological treatment processes are SBR or MBBR (Darling Quarter). At the Flemmington Racecourse, it was intentionally avoided to use biological treatment, such as MBR, and to solely rely on membrane filtration as secondary treatment to achieve a more compact SWH-unit, as it does not need a large bioreactor tank (Waste Technologies of Australia Pty Ltd, 2006). In addition, biological processes are sensitive, since they rely on life micro-organisms. Therefore, operation requires more effort than filtration steps. Moreover, the internal blowers and pumps of the MBR and MBBR treatment steps proved to be the largest energy users at the Darling Quarter (Institute for Sustainable Futures, 2013). At Riverside Rock Park, it was chosen to deploy a nature based solution by construction a subsurface horizontal flow filter (i.e. constructed wetland).

Based on the reference projects a typical SWH scheme consists of at least 3 steps in order to fulfil its function:

1. Extraction of raw sewage from the sewer to a treatment unit.
2. Treatment unit that produces recycled fresh water and residual products.
3. A system to distribute the recycled fresh water for its intended use.

Before and after each steps there is generally monitoring required to ensure smooth operation and to verify if the fresh water and residual products comply with the (quality) requirements. The Greek projects have shown that currently it is possible to fully automate the monitoring process and allow remote control of the unit and regular maintenance processes such as backwashing using smart ICT systems (Makropoulos, et al., 2018; Plevri, et al., 2020). Hereby, limiting the deployment of personnel which reduces costs.

Furthermore, nearly all selected reference projects aimed to design their SWH-units such that they had a minimal footprint. For reference see Figure 4, which shows the SWH-unit at the Flemmington Racecourse that fitted in a 6 meter (i.e. 20 ft) standard shipping container (left photo) and at KEREFYT which consisted of two 2.16x 3.00x2.87 m^3 boxes (right photo). However, at both locations buffer tanks were also placed outside of the main structure which adds to the eventual space that is needed. In between the steps (also in between the different treatment steps within the treatment unit) buffer tanks can be used to temporarily store water and manage flow rates. Hereby, also increasing the robustness of the system and allowing for flexibility of the design (Plevri, et al., 2020).

Figure 4 Photos of the SWH-units at the Flemmington Racecourse (left) and KEREFYT (right) (Waste Technologies of Australia Pty Ltd, 2006; Makropoulos, et al., 2018).

The reference projects selected also provide some insight in different, more specific UGS irrigation applications. For instance at the Athens Plant Nursery plants are grown and supplied to UGS around Athens (temporarily, since the site will be transformed into a large public park after renovation of the area) (Makropoulos, et al., 2018). This is interesting as plant nurseries can be commercially deployed. Ensuring a reliable water supply during dry periods is especially important for young plants since they are more susceptible to water shortages. For instance, unmature trees and bushes (younger than 3 years) will directly start to limit evapotranspiration and start the wilting process as opposed to mature plants (Smith, Dearborn, & Hutyra, 2019; NKWK, 2021; Brolsma, Buma, Meerten, Dionisio, & Elbers, 2012). By ensuring the supply of these young plants, even during dry periods, the plants can become more tolerant and be later moved and used for new construction or renovation of UGS. Besides, the SWH-unit at the Athens Plant Nursery was made such that it was mobile in order to potentially move it after the pilot project (Plevri, et al., 2020). Hereby making the unit deployable at multiple locations. Other SWH-units have been permanently constructed, such as at Riverside Rocks Park or Darling Quarter. Since a mobile SWH-unit can also serve areas permanently and even multiple smaller mobile SWH-units could potentially be used to serve larger UGS. The current research will focus on designing a SWH-unit which could be mobile as this would maximise the potential of the designed SWH-unit

Another notable application is the irrigation of the golf course at the Pennant Hills Golf Club. Adequate water supply of sports fields is important, as they provide important and unique societal benefits (Fam, et al., 2008). Other more specific UGS irrigation applications that have been encountered during this research for waste water reuse applications in general are UGS for food production and support of UGS through ground water infiltration. Food production in urban areas provides next to societal and ecological benefits also a means of sustainable food production which also provides an economic incentive (Specht, et al., 2014). Groundwater infiltration can help restore ground water levels at UGS caused by plants with large root depths that can take up ground water during dry periods. Additionally, it can provide pressure against creeping brackish water, which could pose an important threat to nearly all bushes and trees (Brolsma, Buma, Meerten, Dionisio, & Elbers, 2012).

3. Methodology

This chapter will describe how the established research questions will be answered over the course of the project. Firstly, the rationale behind the research strategy is discussed in sub-section 3.1. Secondly, an overview of the activities and their corresponding methods is presented in sub-section 3.2.

3.1 Research Structure and Rationale

This research aims to provide a conceptual design example of how SWH could be applied to support UGS in Amsterdam to uncover what kind of impact can be achieved and advise on how SWH can be implemented. Hence, the research has a strong design and validation focus. Based on the four sub-questions and the main research question, this research can be divided in five phases respectively:

1. Explicate the problem and refine objective(s)
2. Establish design requirements and generate suitable conceptual design
3. Simulate potential impact based on conceptual design
4. Investigate stakeholder perspective into SWH
5. Evaluation of phases 1, 2, 3 and 4 to answer main research question

In Figure 5 a visualisation of the research structure is shown. As we can see some sub-questions, such a sub-question 2, will require more steps than others. The approach is outlined in more detail in section 3.2.

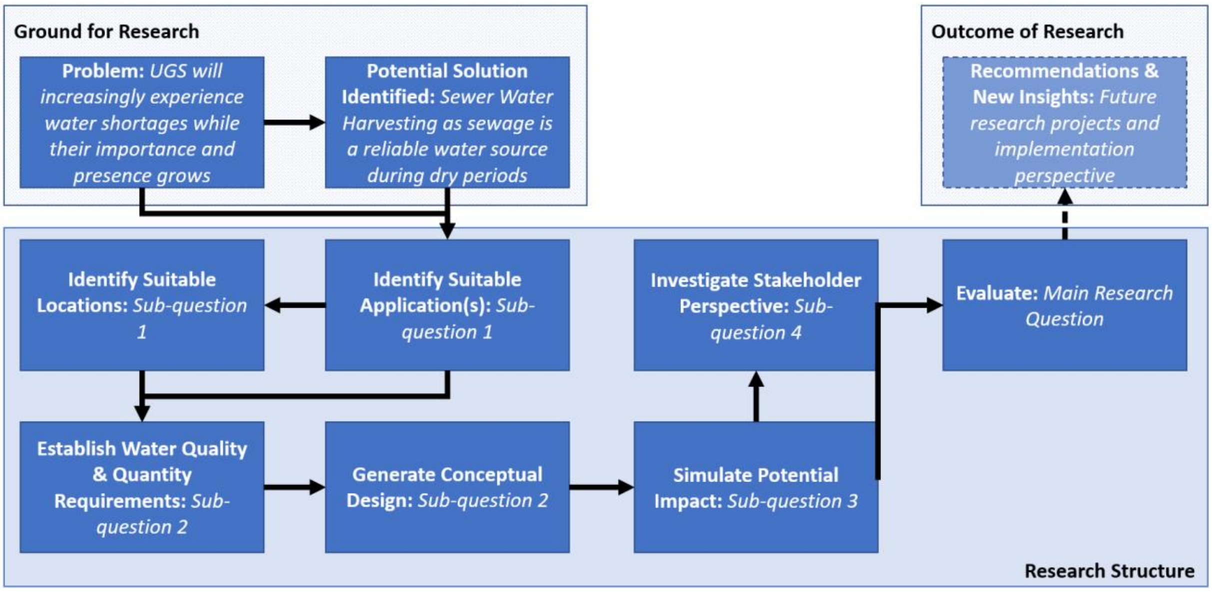

Figure 5 Structure of this research.

Based on Figure 5 and the description of the four phases (i.e. sub-questions) the research strongly focusses on the innovation of SWH itself (in the Amsterdam context). It focusses on the characteristics and features of SWH, evaluation of its impact (e.g. on the environment) and (sustained) implementation perspective. Additionally, many similarities can be seen with product design as the research has aspects that could be described as research for design (i.e. research informs design decisions) and research through design (i.e. design decisions generate new knowledge) (Sauerwein & Beek, 2023). The research phases also correspond with the four design activities set out in the Delft Design Guide (Boeijen & Daalhuizen, 2010): Creating a Design Goal (phase 1 and 2), Creating Product Idea and Concept (phase 2), Generate Design (phase 2) and Evaluation of Features (phase 3, 4 and 5). This study has both a stronger theoretical and practical focus. Based on this research a decision can be made if it is worth to invest in a prototype or a pilot project and the conceptual design developed can be a starting point for the realisation of such. Furthermore, other recommendations and more general insights regarding SWH are generated. The research has a strong emphasis on the functional and technical requirements. This is in line with the need for quantitative indicators for the decision making process that is an important part of an IUWM approach.

3.2 Methods

Now the rationale behind the methodology has been established, suitable methods can be selected. Every research question can be subdivided in several activities. Tables 2, 3, 4 and 5 provide an overview of all these activities per sub-question with the selected methods that will be conducted and sources or persons that are relevant. Besides, for every activity it is indicated in which (sub-)section of the report the results can be found.

Table 2 Overview of activities, selected methods, sources of information and corresponding section in the report were the results can be found for sub-question 1.

Sub-question 1: For what kind of applications could Sewer Water Harvesting be beneficial in Amsterdam?			
Activity	*Selected Method(s)*	*Sources and/or Persons of Interest*	*Section of report*
Review global applications of SWH that could benefit UGS.	Literature review	(Makropoulos, et al., 2018; Plevri, et al., 2020)	2.3
Investigate problems UGS face in Amsterdam and select useful application(s) to focus on	Literature Review & Inquiry at Stakeholders	Policy documents; Scientific literature; Niels Al (Municipality); (Waternet) ; News articles	4.1
Identify Problem Areas / Potential Problem Areas	Literature Review & Inquiry at Stakeholders	Policy documents; Scientific literature; News articles Niels Al (Municipality); Torben Tijms, Mark Nijman, Alice Fremont (Waternet)	4.2
Find suitable location(s) / Study Area	Literature Review & Inquiry at Stakeholders	-	4.2.1

Table 3 Overview of activities, selected methods, sources of information and corresponding section in the report were the results can be found for sub-question 2.

Sub-question 2: How could a Sewer Water Harvesting unit be designed to meet water demand and quality requirements?			
Activity	*Selected Method(s)*	*Sources and/or Persons of Interest*	*Section of report*
Determine water quality and quantity requirements	Sewage data analysis; Literature research; Demand modelling based on evapotranspiration in Python	Regulatory Frameworks; Weather Data (KNMI); Sewage Quality and Quantity Data (Waternet)	5.1
Discuss Proposed Conceptual Design	Scientific Literature Study; Technical Information Analysis; Information from Aquaconnect Stakeholders	Sources from 1.1; Technology Providers; Aqua NL conference; Informal talks with Aquaconnect Stakeholders	5.2
Review if conceptual design fits with requirements	Based on requirements from 2.1	Scientific Literature; Informal talks with Aquaconnect Stakeholders	5.2
Visualize conceptual design	Not applicable	Not applicable	5.2

Table 4 Overview of activities, selected methods, sources of information and corresponding section in the report were the results can be found for sub-question 3.

Sub-question 3: What would be the potential impact if Sewer Water Harvesting is deployed in Amsterdam on a larger scale in terms of plant and soil health and costs and direct economic benefits?			
Activity	*Selected Method(s)*	*Sources and/or Persons of Interest*	*Section of report*
Estimation of the prevented damages to UGS and cost of additional preventive measures	Literature research and potentially Klimaatschadeschatter.nl calculation methods	Damages 2018: (Gemeente Amsterdam, 2020a) and (Klimaatschadeschatter, 2020)	6.1
Check the effect on soil quality and plant health of certain residual nutrients in the water	Literature review	(Maikhuri & Rao, 2012)	6.2

Table 5 Overview of activities, selected methods, sources of information and corresponding section in the report were the results can be found for sub-question 4.

Sub-question 4: What are opportunities and barriers from a stakeholders perspective?			
Activity	*Selected Method(s)*	*Sources and/or Persons of Interest*	*Section of report*
Test knowledge about SWH	Interviews	Municipality of Amsterdam (Niels Al), Waternet (Marcel van Uitert)	7
Investigate perceived barriers	Interviews		7
Investigate potential opportunities	Interviews		7

In subsections 3.2.1, 3.2.2 and 3.2.3 the methodology for the literature reviews, development of the water shortage model and interviews are discussed more in depth.

3.2.1 Literature Review Approach

For many parts of this research a literature review was conducted to (partially) provide answers to the research questions. The studied literature included scientific articles, news (and opinion) articles, policy documents, legal documents and specific technical information (regarding treatment technologies for activities 2.2 and 2.3). The scientific databases that were used included, among others, Google Scholar, ScienceDirect, Scopus, ResearchGate, SpringerLink and the TU Delft Library. Besides the articles found through searches in the databases, cited works from articles and works that cited the articles are studied when deemed relevant. News articles were provided by national or regional news outlets, informational websites about parks and greenery in Amsterdam or research institutes such as KWR. Policy documents were mostly collected from sources of the municipality and Waternet, but also from the Dutch government or EU. Legal documents were obtained from national government sources (i.e. Dutch, Greek or Australian) or European rules and regulations. Technology providers, such as Van Remmen, NX Filtration or Nijhuis Industries, were a source of technical information. For the different searches a wide variety of key words was used, which often were enriched with new key words (or themes) based on the first findings. For specific information regarding the Amsterdam context, such as for activities 1.2, 1.3, 1.4, 2.1 and 3.1, mostly Dutch searches were conducted. This literature mostly included policy documents, legal documents and news articles, but also more scientific advisory reports, for instance from Dutch knowledge and innovation programmes. Findings from the literature were often checked and complemented by (email) inquiries to stakeholders (i.e. the municipality of Amsterdam and Waternet), for activities 1.2, 1.3, 1.4 and 2.1, or experts, for activities 2.1, 2.2 and 2.3.

3.2.2 Water Shortage Modelling

In order to quantitatively asses the future water demand of UGS a Water Shortage Model is constructed. Based on data from the KNMI the water demand for 2030, 2050 and 2085 can be determined. Firstly, the theoretical basis of the model is shortly explained. Secondly, the methodology of developing the model is clarified step by step.

Theoretical Basis of the Model

When UGS are faced with a drought the plants could wilt permanently. But, even before that happens, the plants will experience water stress and the wilting process starts. As a result the plant is possibly not able to (fully) fulfil its functions and social, economic and environmental benefits are diminished (Fam, et al., 2008). For instance, the cooling effect of plants to mitigate the urban heat island effect is reduced or even lost if the vegetation becomes water-stressed (Gräf, Immitzer, Hietz, & Stangl, 2021). Therefore, the soil moisture content (θ) preferably should not drop below a certain threshold in the rootzone of the vegetation. The amount of water that a plant can extract from the soil without suffering water stress is called the Readily Available Water (RAW). The RAW is a fraction of the Total Available Water (TAW), namely the depletion factor (p; $p < 1$). The TAW is the difference between the moisture content that can be held against the gravitational force in the rootzone, which is called the field capacity (FC), and the moisture content which can no longer be extracted by the roots of the plant, at which point the plant permanently wilts and thus is called the wilting point (WP) (Allen, Pereira, Raes, & Smith, 1998). The following formulas can be used to calculate the threshold moisture content (θ_a) (Schoups, 2021):

$$\theta_a = (1-p) * \theta_{FC} + p * \theta_{WP}$$

$$\theta_{FC} = \theta_r + (n - \theta_r) * \left(\frac{\psi_b}{10^2}\right)^{\lambda}$$

$$\theta_{WP} = \theta_r + (n - \theta_r) * \left(\frac{\psi_b}{10^{4.2}}\right)^{\lambda}$$

Where:
$\theta_r = Irreducible\ moisture\ content$
$n = porosity$

$\psi_b = displacement\ pressure$
$\lambda = pore\ size\ distribution\ index$
$p = depletion\ factor$

Now that the threshold of the soil moisture content has been established, the soil water balance (SWB) can be used to see if the soil moisture content will fall below this threshold at a certain point. After this point there is a water shortage for the urban green and this can be quantified using the SWB. The soil water balance (per day) results in the following equation (Pereira & Alves, 2005; Schoups, 2021):

$$\theta_i = \theta_{i-1} + \frac{1}{Z_r} * (P_i + I_i + CR_i + RO_i - DP_i - C_{adj} * ET_i)$$

Where:
$Z_r = Rooting\ Depth\ (mm)$
$\theta_i = moisture\ content\ at\ the\ end\ of\ day\ i$
$\theta_{i-1} = moisture\ content\ at\ the\ start\ of\ day\ i$
$P_i = rainfall\ depth\ at\ day\ i\ (mm)$
$I_i = irrigation\ at\ day\ i\ (mm)$
$CR_i = capillary\ rise\ or\ groundwater\ contribution\ at\ day\ i\ (mm)$
$RO_i = Run - on\ (+)\ or\ Runoff\ (-)\ at\ day\ i\ (mm)$
$DP_i = deep\ percolation\ at\ day\ i\ (mm) = 0\ if\ \theta_i \leq \theta_{FC}\ otherwise\ DP_i = (\theta_i - \theta_{FC}) *\ Z_r$
$C_{adj} = adjustment\ factor\ from\ reference\ evapotraspiration$
$ET_i = reference\ evapotranspiration\ at\ day\ i\ (mm)$

In order to prevent UGS from experiencing water shortages as a result of dry periods, the soil water balance should be increased by adding irrigation such that $\theta_i \geq \theta_a$.

Methodology
First step is the collection of the data needed to do the calculations. Transformed metrological data can be obtained from the KNMI's transformation programme. Historical weather data has been transformed taken into account changes in averages, day to day variation and likelihood of extremes (such as droughts), among others, based on the 2014 climate scenario's. A further justification for this specific data and the other parameter choices will be provided in section 5.1.1. For clarity the data and parameters that need to be collected in order to develop the water shortage model have been displayed in Table 6 and categorised by data dependent on the meteorological, soil or plant conditions.

Table 6 Overview of the to be collected parameters for the development of the water shortage model per category.

Category	Data
Meteorological Data	Evapotranspiration (ET_0) Rainfall Depth (P_i) Run-on/Runoff (RO_i)
Soil Data	Porosity (n) Capillary Rise (CR_i) Displacement Pressure (ψ_b) Pore Size Distribution Index (λ) Irreducible moisture content (θ_r) Ground Water Level
Plant Data	Rooting Depth (Z_r) Adjustment Factor (K) Depletion factor (p)

After the collection of the data, the data should be cleaned and prepared so it can be used in the model. This includes calculating averages of historical data, transforming units and creating data for 365-day years (i.e. removing leap days). Besides, the data should be restructured in order to run the calculation in a loop, because calculations for the water shortage model are done for 3 different years (2030, 2050 & 2085). After that the model can be constructed to calculate the water shortage of UGS, which will be used to determine the water quantity requirements for the conceptual design of an SWH-unit. During the construction of the model, it will be taken into account that the water demand for UGS should be converted from mm to a flow rate (e.g. l/s or m^3/day) to be able to compare that with the supply quantity that can be provided by raw sewage. However, this highly depends on for instance the method for water distribution (continuous or with a certain frequency) and the size of the study area. By calculating the water demand in mm it remains flexible to test several possibilities for the water distribution and service area (e.g. irrigate during a certain period water parts of the study area instead of irrigating an entire UGS in one day). The Python scripts can be found in Appendix A.

3.2.3 Approach to semi-structured interviews to investigate the perception of stakeholders

In order to uncover the opportunities and barriers perceived by stakeholders in regards to SWH, two semi-structured interviews have been conducted. Semi-structured interviews were chosen since they allow the participants to express their opinion in their own words and facilitate two-way communication which can be needed to clarify certain topics (Keller & Conradin, n.d.). Moreover, semi-structured interviews were considered appropriate to allow for flexibility in questioning while maintaining a level of consistency across participants. Furthermore it enables the researcher to explore emerging or unanticipated topics that may arise during the interview process. As new ideas, perspectives, or issues emerge, the questioning can be adjusted and followed up on, enabling a more comprehensive exploration of these perspectives. This adaptability is particularly valuable since SWH is a complex, innovative and evolving subject. This makes semi-structured interviews a suitable tool to involve stakeholders and provide useful qualitative data (Brouwer, Woodhill, Hemmati, Verhoosel, & Vugt, 2015).

The aim was to involve participants from the two most important stakeholders: Waternet and the municipality of Amsterdam. The participants were selected based on their relevant knowledge and experience in urban infrastructure, water management, climate adaptation, UGS and policy-making in Amsterdam. Several potential participants were contacted via email with an explanation of the purpose and significance of this research and the specific goal of the interviews. Moreover, the voluntary nature of participation, the form of data collection and the confidentiality of the collected data were made clear beforehand. Interested individuals were invited to participate in the interviews. This resulted in interviews with Marcel van Uitert (advisor asset management and analysis at Waternet) and Niels Al (coordinator water and climate adaptation at the municipality of Amsterdam).

At the start of the interviews a short introduction of the topic of SWH was given and some main take-aways of the current progress of the research were presented. An interview guide was developed, consisting of open-ended questions and prompts to guide the discussion, which can be found in Appendix D. The guide consisted of some general questions and questions related to barriers and opportunities for SWH or decentralised water treatment (for irrigation of UGS) in general found in scientific literature. These were complimented with other topics that were uncovered during the previously conducted parts of this research. Further inspiration for prompts was drawn from criteria used in decision making tools or frameworks that promote sustainable or integrated UWM (e.g. UWOT and SWARD) (Makropoulos, Natsis, Liu, Mittas, & Butler, 2008; Ashley, Blackwood, Butler, & Jowitt, 2004). The interviews were audio-recorded with participants' consent and transcribed verbatim. Thematic analysis was used to identify key themes and patterns within the data. The analysis involved coding the transcripts, categorizing the codes into themes, and exploring relationships and connections between them using the method developed by Braun & Clarke (2012). Moreover, remarks related to the themes were marked with a plus (+) or minus (-) sign to indicate if the remark was positive (i.e. opportunity, stimulator or advantage) or negative (i.e. barrier, disadvantage or critical question) regarding SWH. This process aimed to identify common perspectives, recurring challenges, and potential opportunities related to SWH. The coded transcriptions can be found in Appendix E. As the interviews were in Dutch so is the transcription, but these are therefore complemented with a short synopsis.

4. Application of Sewer Water Harvesting in Amsterdam

Firstly, this chapter will discuss the selection of a suitable application to support UGS in Amsterdam in section 4.1, based on the problem posed by dry periods. Thereafter, potential locations for the selected application are discussed in sub-section 4.2.1 and a motivation and brief description of the selected study are for this research is presented in section 4.2.2. All this is done to be able to establish suitable water quality and quantity requirements for a SWH-unit in Chapter 5.

4.1 The Potential Applications of SWH

Based on the threats posed by dry periods, the effects of climate change and studied reference projects four potential applications of SWH to support UGS have been identified:

- Irrigation of public UGS for recreation (e.g. parks and sports fields)
- Irrigation of (temporary) plant nursery (to support drought susceptible young plants)
- Ground water infiltration (to increase ground water level or provide pressure against creeping brackish ground water)
- Irrigation of UGS for food production (e.g. urban farming)

Based on the aforementioned applications of SWH globally it seems that irrigation of public UGS, such as parks or sporting fields, is the most obvious application to support UGS during dry periods. Moreover, surface area data to study the potential impact is available and shows significant scale, as can be seen in Figure 7 in subsection 4.2. Besides, there are already some concrete examples of the negative impact of drought for these applications in the past UGS (Zoelen, 2020; Vrienden van het Vondelpark, 2020; Kropveld, 2018; Khaddari, 2018).

In contrast, for the application of (temporary) plant nurseries there is no available data on surface areas or any other way to quantify the water demand. Besides, there seems to be a lack of scale for this application, although some commercial nurseries are located at (the outskirts of) the municipality of Amsterdam. Only two (small) examples of a (temporary) plant nursery were found, located at the Amsterdamse Bos and the Zuidas (Hoek Groen, n.d.; Antonisse, 2021). Therefore, this application is not further investigated.

The application of ground water infiltration in Amsterdam does not seem viable at this point or in the near future for several reasons. In Amsterdam ground water levels are relatively high and problems are often much less severe than in the Eastern part of the Netherlands due to the polders and composition of the soil (i.e. peat which is able to hold on to the water better compared to the sand in the Eastern parts). Although the creep of brackish ground water could pose an important threat to nearly all plants, local preventive measures such as groundwater infiltration to provide pressure against creeping brackish water is most likely a last resort measure (Brolsma, Buma, Meerten, Dionisio, & Elbers, 2012; Twynstra Gudde & HydroLogic, 2019; Informatiepunt Leefomgeving, n.d.). Prevention of the advancement of increased salty water near the source (e.g. the bubble screen at the Amsterdam-Rijncanal) would be preferred (Informatiepunt Leefomgeving, n.d.). Besides, most problems due to salinization are caused outside of the city in the surrounding polders (Zoelen, 2020). Ground water infiltration also requires and extensive and expensive drainage system, which will significantly increase the cost of the SWH-unit. In addition, to increase the ground water table, the SWH-unit should produce a relatively large amount of fresh water (Wimmers, Sweijen, Brugman, Meinhardt, & Maljaars, 2020). Moreover, currently there is a lack of information on the extent of the creep of brackish groundwater in Amsterdam (in the future) and identified locations with vulnerable UGS (Ferrarese & Koevoet, 2019). This should therefore be investigated first before ground water infiltration (by SWH) can be considered as an option to protect UGS from the effects of salinization

Available data about a wide variety of UGS for food production show plenty of locations around Amsterdam, as can be seen in Figure 6. Unfortunately, the crucial information needed to study the potential impact of SWH as a result of irrigation of the UGS, such as the surface area of urban farms in Amsterdam, is not included in the dataset. Hence, the application cannot be studied further.

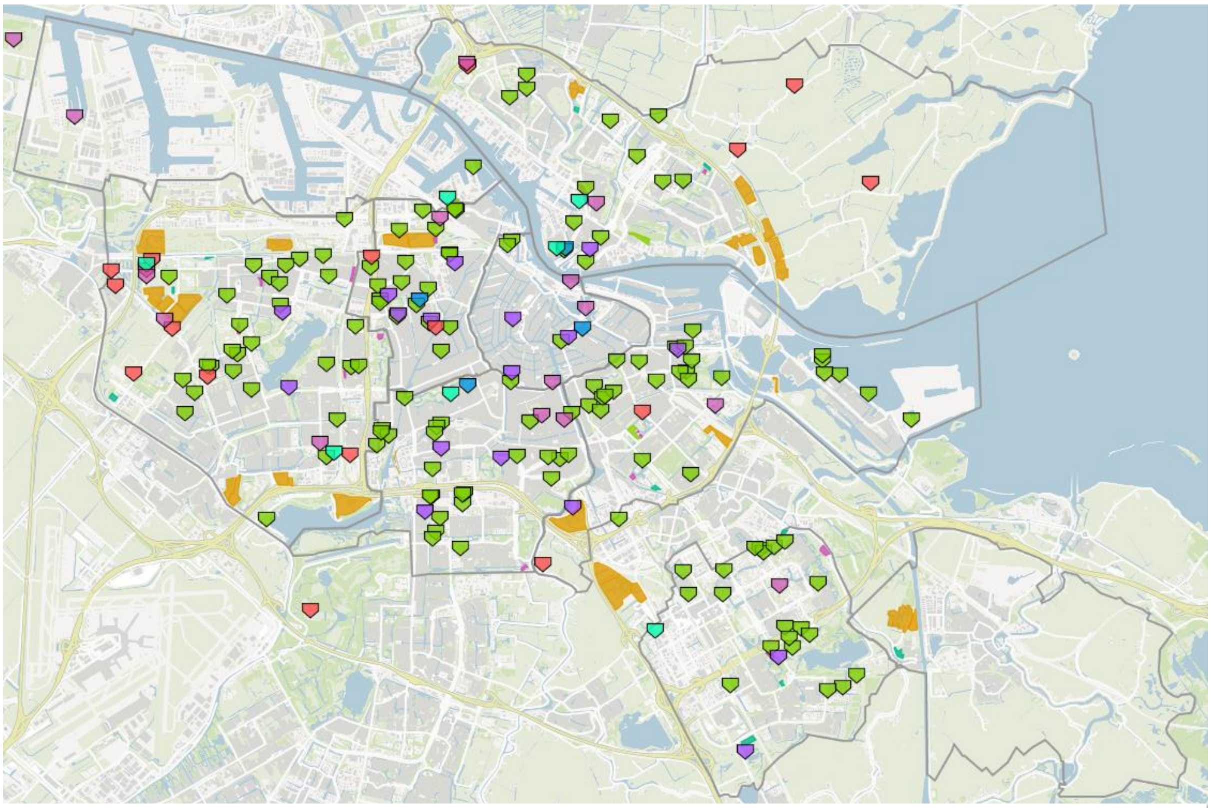

Figure 6 Overview of a wide variety of UGS for food production such as urban farms, allotment gardens and even vertical farming, the different colours represent different kinds of UGS for food production (Gemeente Amsterdam, n.d. A).

From the evaluation of the four potential applications of SWH to support UGS in the Amsterdam context irrigation of public UGS for recreation was selected as the most suitable for this study. This is because for this application the largest amount of necessary information is available and the most concrete examples exist for the need of this application.

4.2 The Potential Locations

To identify potential locations and eventually a study location for this research the first starting point is to identify UGS that are large enough to make SWH a viable option. After all, it is evident that the investment in an SWH-unit is not viable for several individual trees alongside a canal and a larger UGS is needed. Figures 7 and 8 display these potential locations with overviews of respectively the city parks and green areas for recreation and the sports fields.

Parks and Green Areas for Recreation

In total the area of the parks and green areas for recreation is approximately 25.5 km^2 (Gemeente Amsterdam, n.d. B). As can be seen in Figure 7 these UGS differ in size. Further, these UGS largely differ in vegetation types. These and other local factors highly influence the vulnerability to drought. As aforementioned, older trees and some bushes with large root depths are very resilient since they have roots that can reach until the groundwater table. Despite the fact that grass does not have these larger roots and thus will become yellow or brown during longer periods of drought, grass is very resilient and will recover again after a few rain showers. However, this will mean a deterioration of its recreative function and its appearance. Hereby temporarily diminishing its positive social, economic, biodiversity and ecology benefits (Fam, et al., 2008; Gemeente Amsterdam, 2020b; WHO, 2017). Most of the damage occurs to young plants (i.e. young trees and large shrub varieties), understorey vegetation (e.g. flowers and other plants lower than 2 m (Ecopedia, n.d.)) and bushes such as shrubs, yews and Rhododendrons (Zoelen, 2020; Vrienden van het Vondelpark, 2020; Kropveld, 2018). Therefore, it is important to especially irrigate these types of vegetation during dry periods. In 2018, the wilting of these plants resulted in €1.400.000 replacement costs over Amsterdam. On top fo that, nearly €500.000 was spend on additional irrigation efforts that year (Gemeente Amsterdam, 2020a). However, more detailed information about the most vulnerable parks and where most of these damages occurred is relatively scarce. Based on news articles the Vondelpark has experienced longer periods of drought that severely affected the UGS (Zoelen, 2020; Vrienden van het Vondelpark, 2020; Kropveld, 2018). Moreover, during the introduction of the Amsterdam Metropolitan Area case of the NWO-programme AquaConnect, the drought problems of the Vondelpark and the Oosterpark were highlighted by Niels Al & Sascha Stolp (2022) from the municipality of Amsterdam. Parks can be irrigated with drinking water, but larger parks are often watered by surface water (e.g. from canals or ditches), either directly but most often by a water tank truck (Vermeulen, 2021; Metropoolregio Amsterdam, 2021; Amsterdam Rainproof, n.d.). The municipality of Amsterdam provides an overview of 36 locations of larger scale greening projects such as park renovations or expansions to increase UGS in Amsterdam (Gemeente Amsterdam, n.d. C). However, no data was available to determine the exact scale of these projects.

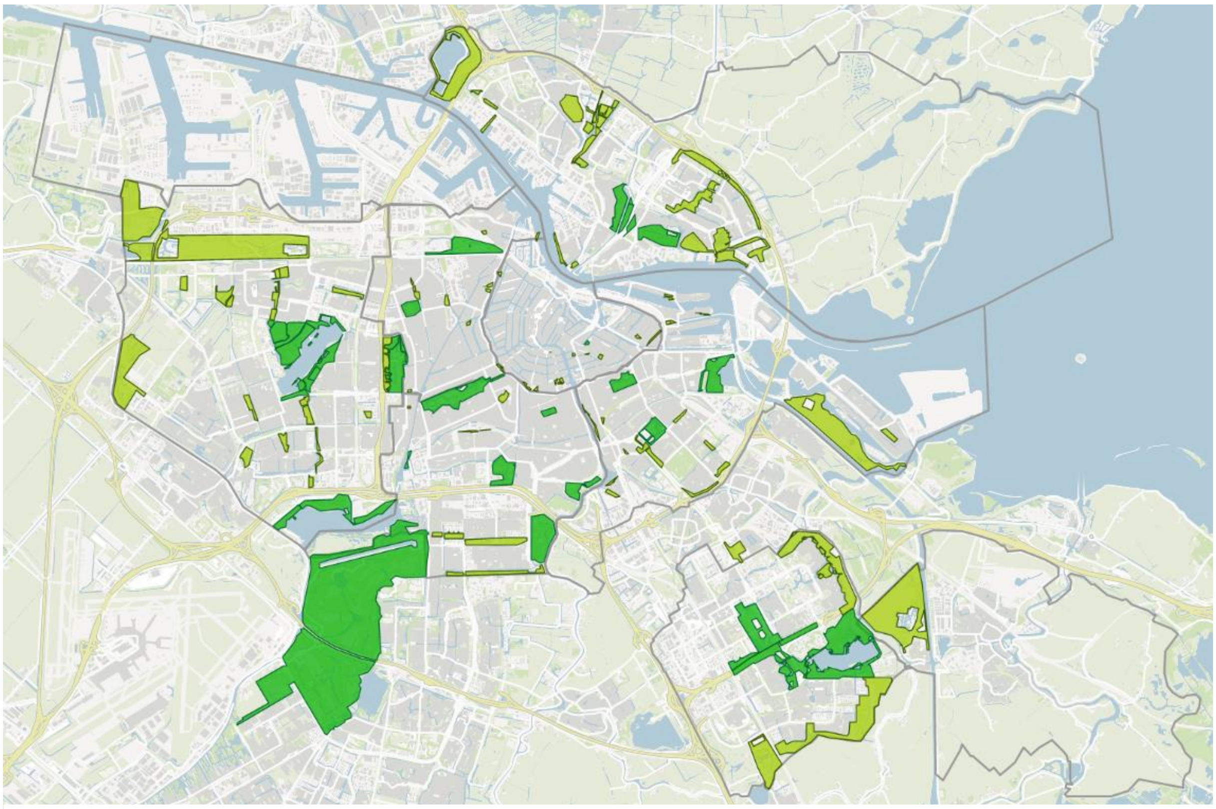

Figure 7 Overview of city parks (dark green) and other green areas for recreation (light green) (Gemeente Amsterdam, n.d. D).

Sports Fields

In Figure 8 a map with the sport fields in Amsterdam is displayed. Of the 170 sports field in Amsterdam, 98 are made of natural grass (Khaddari, 2018). The sports fields with natural grass that are managed by the municipality make up a total area of 795652 m^2 (approximately 0.8 km^2) (Gemeente Amsterdam, n.d. B). While grass in parks can be considered relatively resilient to water shortages and will receive less priority for irrigation, irrigation of the grass of sports fields is more important. The grass should be well watered in order to be able to play sports such as football. Namely, because during the summer break, new grass is sown and the field has time to recover from the previous season. As a result of long dry periods the natural sports fields will not have the time to adequately recover and regrow the grass. Consequently, the fields will be damaged early on during the new season and become unplayable while the time to sow again and regrow the grass has passed, resulting in unusable or poor quality fields. Due to the long dry spell in 2018 the municipality had to prohibit the use of dozens of natural sports fields, especially in the western city districts which has several large sport complexes such as De Eendracht and Ookmeer (Khaddari, 2018). Often, sports fields are irrigated by pumping water from nearby ditches (Khaddari, 2018; Gemeente Amsterdam, 2021).

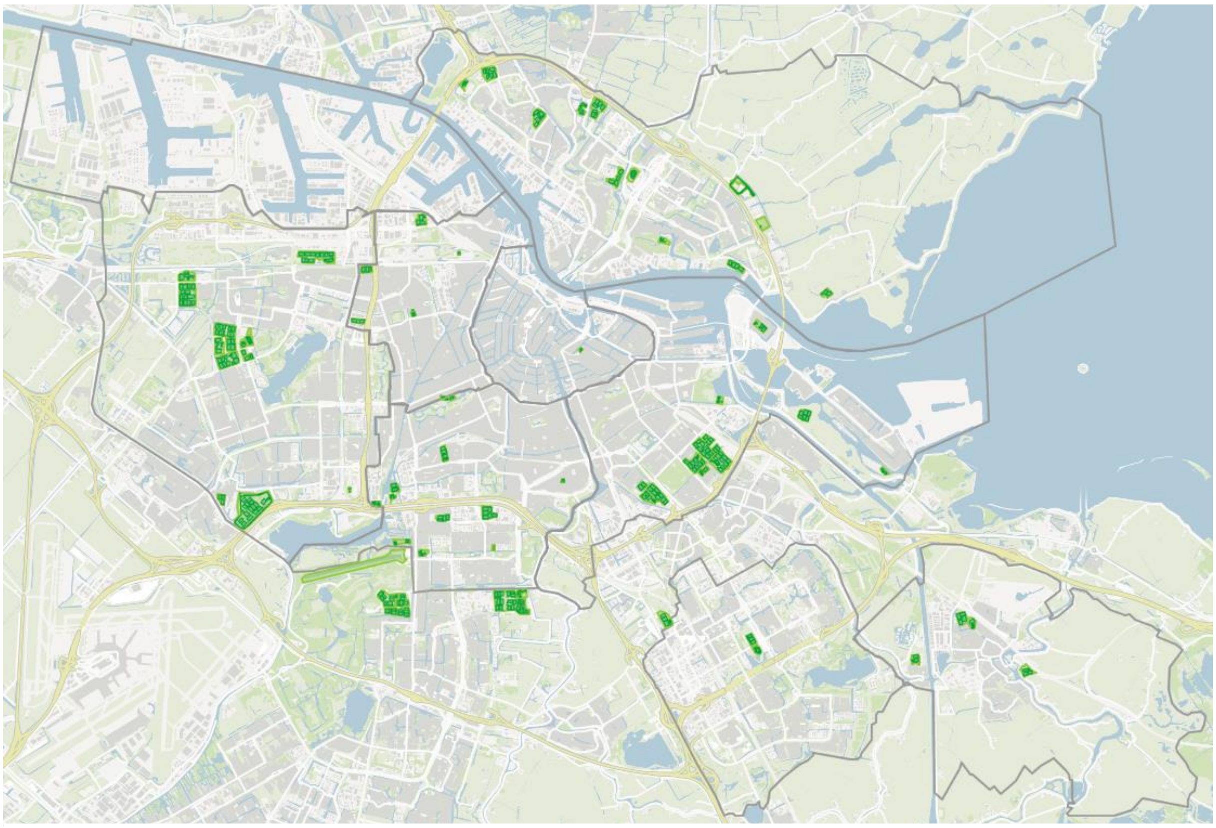

Figure 8 Overview of the sports fields (Gemeente Amsterdam, n.d. E).

4.2.1 Selected Study Area

The Vondelpark is chosen as the study area for this research. The park is located at the outskirts of the city centre, as can be seen on Figure 9. Based on the findings in subsection 4.2.1 it becomes clear that due the large surface area of UGS for recreation, there is plenty of potential and scale to test the potential impact of SWH. The Vondelpark has been confronted several times with the negative effects of water shortage in the recent past (Zoelen, 2020; Vrienden van het Vondelpark, 2020; Kropveld, 2018). Moreover, there is an expressed need for innovative solutions to address the water shortages caused by long dry periods in the Vondelpark by the municipality (Al & Stolp, 2022). The Vondelpark (Gemeente Amsterdam, n.d. E) has a surface area of approximately 0.46 km^2 and is the largest park in the crowded city centre of Amsterdam (Gemeente Amsterdam, n.d. B). The park has a total green area (i.e. total area minus paved area and surface water) of approximately 0.28 km^2 (van Eijkeren, 2021). The monumental park is one the most well-known and busiest parks of Amsterdam. Besides recreation, the park is often used by runners and for other sports activities, while also hosting several cultural activities (Gemeente Amsterdam, n.d. F). Therefore, the park serves an extremely important social function in the city and the park is one of the cooler places in the neighbourhood during hot periods (Sevil, 2010). SWH could help to ensure these benefits in the future.

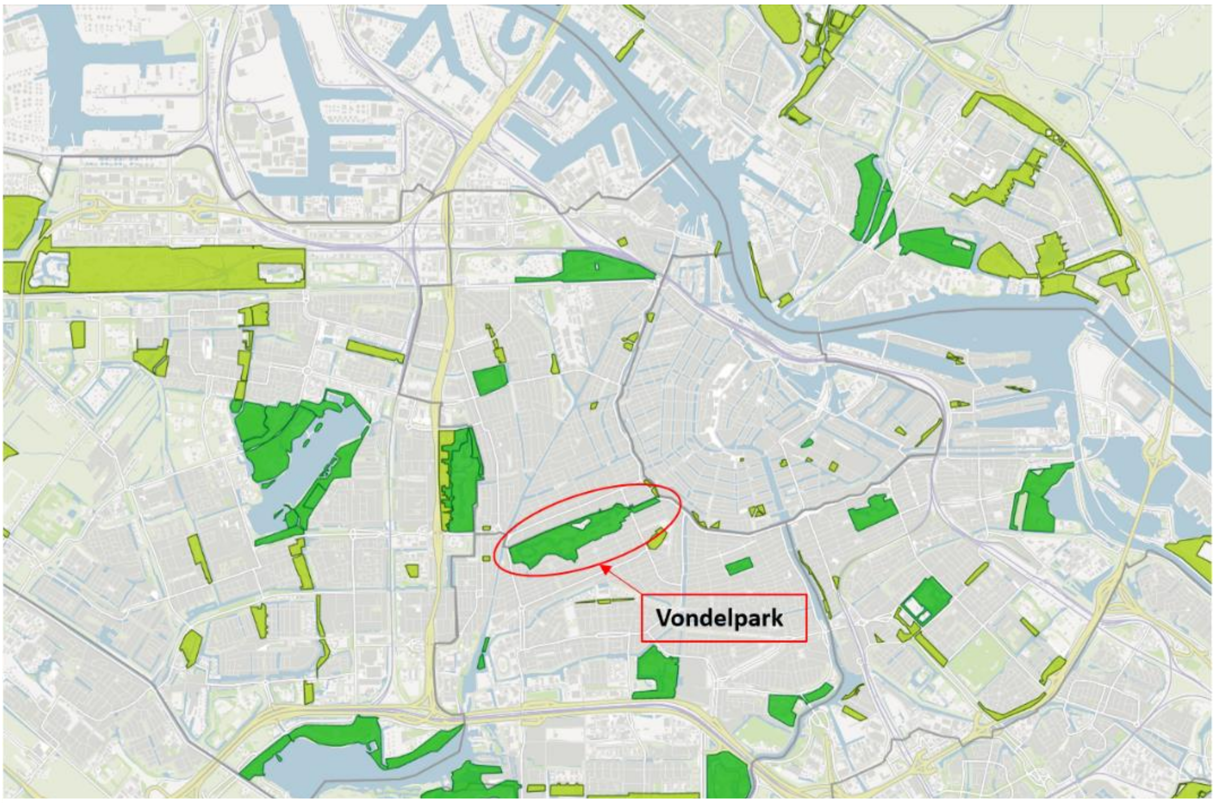

Figure 9 Location of the Vondelpark (Gemeente Amsterdam, n.d. D).

5. Conceptual Design of SWH-unit

In Chapter 5 a conceptual design for a SWH-unit is devised based on the selected applications and study area from Chapter 4. First the water quality and quantity and requirements are established in section 5.1. After that the a reasonable conceptual design of the SWH-unit is presented and motivated in section 5.2.

5.1 Design Requirements

The conceptual design of the SWH-unit has to meet the water quality and water quantity requirements to be able to be suitable for irrigation of public UGS. These requirements will be discussed in sub-section 5.1.1 and 5.1.2 respectively. First the output requirements are established after which th

5.1.1 Water Quality Requirements

Raw sewage will contain a wide range of pollutants that need to be removed before the water can be used for irrigation. In Appendix A, a description of the most important pollutants discussed during this research and their potential (negative) impact is given for the reader as theoretical background.

Water quality of SWH-unit output
To determine the water quality requirements for a SWH-unit the first step is to comply with the set rules and regulations. However, specific standards for irrigation of public UGS with treated sewer water do not exist. Moreover, the scarce regulations that apply have not yet been properly reviewed and seem to be inadequate for larger scale implementation of municipal waste water reuse (Outhuijse, Melchers, & Gilissen, 2022). Therefore a suitable regulatory framework is still under development by, for instance the EU, which often draws comparison with the more well-established water reuse regulatory framework in Australia (European Comission, 2020; European Comission, 2022; Alcalde-Sanz & Gawlik, 2017; Cirkel, van den Eertwegh, Stofberg, & Bartholomeus, 2017). Therefore, Table 7 on the next page provides an overview of the standards that could apply to the reuse of sewage water for irrigation in the public space. Standards for the reuse of sewage water from Greece and Australia are also displayed. This has been supplemented with (averages of) the pollution level for alternative water sources (i.e. surface water and rainwater). For the surface water a measurement location relatively close to the study area was chosen, at the Valschermkade. In addition, standards for the effluent of WWTP's are included. The EU classes for agricultural irrigation with reclaimed municipal sewer water can be considered a good proxy for irrigation of public UGS as the standard are related to the level of exposure (for both humans, animals and plants). Class A is for crops that are eaten raw and are in direct contact with the irrigation water, Class B and C is for crops that are eaten raw but where the eatable part is not in direct contact with irrigation water or that are further processed during food production or crops that are used for animal food and Class D is for industrial use such as seed production (Energie- en Grondstoffenfabriek, 2019). Class A, B and D apply to all irrigation method while Class C is only for drip-irrigation, where water is less in contact with the crop and humans.

However, these set of standards often seem to lack standards for various pollutants, including micro-pollutants (Energie- en Grondstoffenfabriek, 2019). Therefore, there is no hard requirements incorporated in the quality standards of the SWH-unit but they are considered during the design of the SWH-unit. Especially, since the Ministry of Infrastructure and Water Management will obligate the removal of 70% of at least 7 out of 11 guiding micro-pollutant substances for WWTP (STOWA, 2021). It remains to be determined whether this will also apply to decentralised and small scale treatment installations (H. K. Gilissen, personal communication, 12 May 2023). However, it is desirable to monitor the micropollutant concentrations occasionally, for instance monthly as is done with the WWTP in Amsterdam.

Table 7 Overview of the standards that could apply to the reuse of sewage water for irrigation in the public space.

Parameter	Unit	EU Class A Irrigation	EU Class B Irrigation	EU Class C Irrigation	EU Class D Irrigation	Greek Legislation	Australian legislation	WWTP Effluent Standards	Surface water Amsterdam	Rainwater Quality
Source	-	(European Comission, 2020)	(European Comission, 2020)	(European Comission, 2020)	(European Comission, 2020)	(CMD (Common Ministerial Decision), 2011; CMD, 2013)	(Radcliffe & Page, 2020)	(InfoMil, n.d.)	(Meulen, et al., 2018; Informatiehuis Water, 2022)	(Liefting, Boogaard, & Langeveld, 2020)
TSS	mg/l	10	35	35	35	2	5	30	-	38
BOD_5	mg/l	10	25	25	25	10	10	20	10.2	-
COD	mg/l	-	-	-	-	-	-	125	-	-
E. coli	kve/ 100ml	10	100	1000	10000	5	10	-	1362	24000
Legionella spp	kve/ 100ml	1000	-	-	-	2	-	-	-	-
Turbidity	NTU	5	-	-	-	2	2	-	-	-
Total N	mg/l	-	-	-	-	15	-	15 (75% removal of influent)	2.7	3.6
NH_4	mg/l	-	-	-	-	2	-	-	-	-
Total P	mg/l	-	-	-	-	-	-	2 (75% removal of influent)	0.08	0.3
pH	-	-	-	-	-	-	6-9	-	8.4	-

However, these set of standards often seem to lack standards for various pollutants, including micro-pollutants (Energie- en Grondstoffenfabriek, 2019). Therefore, there is no hard requirements incorporated in the quality standards of the SWH-unit but they are considered during the design of the SWH-unit. Especially, since the Ministry of Infrastructure and Water Management will obligate the removal of 70% of at least 7 out of 11 guiding micro-pollutant substances for WWTP (STOWA, 2021). It remains to be determined whether this will also apply to decentralised and small scale treatment installations (H. K. Gilissen, personal communication, 12 May 2023). However, it is desirable to monitor the micropollutant concentrations occasionally, for instance monthly as is done with the WWTP in Amsterdam.

Moreover, since the SWH-unit will produce fit-for-purpose water for irrigation for public UGS, some parameters could deviate from standard of food production or effluent of WWTP. For instance, there is less risk of nutrients and BOD concentrations that could lead to eutrophication of receiving (or in this case run-off into) water bodies, as is with WWTP effluent, and BOD and nutrients could even benefit plant and soil health, as can be found in section 6.2. As a result the most lenient standards for the BOD concentration is chosen from the analysed standards. For the nutrient concentrations (i.e. total N and P) the analysed standards provide just one standard concentration which is therefore selected as the requirement. Based on the studied global applications of SWH from section 2.3, the removal of TSS can easily meet the strictest standards by means of a simple screening and filtration step (i.e. MF). As TSS can only damage or clog downstream components and is of no added benefit, the strictest standard from the Greek legislation is applied. Since, contact with humans of (reclaimed) waste water can pose serious health risks and is likely to occur at public UGS, the E. coli concentration is set to the strictest standard. Moreover, this was pointed out as one of the main concerns of stakeholders, as will be later presented in Chapter 7. This results in the water quality standards for the irrigation water from the SWH-unit depicted in Table 8.

Table 8 Overview of the selected water quality standards for SWH for the irrigation of public UGS.

Parameter	Standard
TSS	2 mg/l
BOD_5	25 mg/l
E. Coli	10 kve/100ml
Total N	15 mg/l
Total P	2 mg/l

Discharge of Treatment Residuals

Besides the quality of the reusable water, the residual stream with pollutants (and water) from the treatment steps has to comply with regulations to be allowed to be discharged into the sewer again. Among others, the ‘Wet Milieubeheer’ (Law Environmental Management), ‘Wet Algemene Bepalingen Omgevingsrecht (Wabo)’ (General Provisions Act) and the ‘Waterwet’ (Water Law) will apply to this situation (H. K. Gilissen, personal communication, 12 May 2023). The discharge of water into the municipal sewage system has been regulated by three orders in council (‘Algemene Maatregelen van Bestuur (AMvB)’): ‘Activiteitenbesluit’, ‘Besluit lozing afvalwater huishoudens’ and ‘Besluit lozen buiten inrichtingen’ (Rijkswaterstaat, n.d. a). The most important part of these orders in council is the duty of care (‘Zorgplicht’). It follows from this that the discharge of the treatment residuals cannot have a (negative) influence on the effective operation of provisions for the transport and treatment of sewage water (Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, 2007a). The municipality, as the sewage system caretaker, is able to either grant permission for a certain discharge or prohibit it, hereby also considering the interest of the water board (Informatiepunt Leefomgeving, personal communication, 6 April 2023). There are no exact and concrete guidelines as the compliance with the duty of care highly depends on the characteristics of the sewage system and the end of pipe treatment capabilities. However, several thresholds and rules of thumb are devised over the different orders of council that could indicate noncompliance with the duty of care. Exceedance would, in most cases, require additional justification in order to receive a permit from the municipality to discharge these residuals (Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, 2007a):

- If the discharge has a temperature higher than 30 ˚C.
- If the discharge has and a pH above 10 or below 6.5.
- If the discharge has a SO_4-concentration of 300 mg/l or higher. Because under anaerobic condition SO_4 can become sulphuric acid which could damage concrete sewer pipes.
- If the discharge could cause fire or an explosion.
- If the discharge has been through a cesspit or sceptic tank.

Specifically the prevention of build-up of sulphuric acid in the sewer system was besides the water demand of UGS the main determining factor for a suitable location in one of the Greek reference projects from section 2.3 (Makropoulos, et al., 2018).

Especially since the residual discharge of SWH will (mostly) consist of pollution that originated from the sewer it could be debated if strict standards for this discharge are neccessary (H. K. Gilissen, personal communication, 12 May 2023). Moreover, if the flow through the sewer pipe is much larger than the extracted water for SWH, the concentration of pollutants will effectively become much lower after mixing. Besides, the pollutant concentrations in the residual discharge will be dependent on the actual water recovery rate of the SWH-unit. A lower recovery rate would result in lower pollutant concentrations. However, this means more raw sewage water is needed to produce the same amount of fresh irrigation water.

Overall, the rules and regulations, which include the 'Wet Milieubeheer', the 'Waterwet' and the three order of council, do not provide a clear answer to the maximum allowable standards of the residual discharge. Therefore, a permit should be granted by the municipality, which will also consider the interest of Waternet. For the authorization of this permit, experts will be consulted to eventually determine under which conditions the discharge of treatment residuals back into the sewer can be allowed, as this is juridically highly complex and case specific (H. K. Gilissen, personal communication, 12 May 2023). At least this will require a well-monitored pilot project to demonstrate the expected concentration of pollutants in the discharged residual first and continuous monitoring to assure compliance with the set standards in the permit will be necessary (H. K. Gilissen, personal communication, 12 May 2023). As a result of the quality regulations monitoring of at least the following parameters is deemed necessary for the discharge of treatment residuals:

- Temperature
- pH
- SO_4-concentration
- Flow rate
- TSS

In addition, this list should be extended in case of chemical dosing as part of the treatment steps of the SWH-unit since this could lead to the discharge of substances of very high concern ('Zeer Zorgwekkende Stoffen (ZZS)') or very harmful substances (Rijkswaterstaat, n.d. b). Since, for this research, it is important to at least asses if the concentration of treatment residuals is reasonable, inspiration is drawn from the standard set by Sydney Water (n.d.). A concentration of maximum 600 mg/l of TSS needs to be achieved on average after the discharged treatment residuals are mixed with the receiving sewer system. Furthermore, screenings are only accepted back in the sewer after mixing with water. This could be water that is discharged back in the sewer as a result of other treatment steps.

Water quality of SWH-unit input

Although water quality in specific sewer pipes can deviate significantly over a day and between days a good approximation of the quality can be established from the influent quality of the WWTP Amsterdam West. As a courtesy of Waternet the data quality measurements for the years 2021 and 2022 was obtained (P. Piekema, personal communication, 13 April 2023). A summary of the data with the number of data points, weighted average, maximum, minimum, standard deviation and upper 95th-percentile (only for the flow rate the lower 95th-percentile is determinative) of the monitored concentrations of the organic substances and heavy metals and the flow rate is displayed in Table 9.

Table 9 A summary of the data from Waternet of the daily influent at the WWTP Amsterdam West from 2021 and 2022 (P. Piekema, personal communication, 13 April 2023).

Parameter	Data Points	Average (Weighted)	Maximum	Minimum	Standard Deviation
Flow Rate (m^3/d)	730	168308	511771	112431	49934
COD (mg/l)	220	534	850	230	88
BOD_5 (mg/l)	220	265	550	130	61
TOD (mg/l)	220	789	1174	340	121
N_{total} (mg/l)	220	55	73	24	9.0
P_{total} (mg/l)	220	6.9	10.0	3.1	1.2
TSS (mg/l)	220	316	1100	85	95
$C_{organic}$ (mg/l)	12	163	330	100	56
Cd (µg/l)	21	0.2	0.2	0.2	0
Cr (µg/l)	21	4	7	2	1.5
Cu (µg/l)	21	86	150	34	24
Pb (µg/l)	21	16	46	6	9.2
Ni (µg/l)	21	7	95	1	20
Zn (µg/l)	21	220	380	130	67
Hg (µg/l)	21	0.04	0.12	0.01	0.03
As (µg/l)	21	3	5	2	0.7

From this data it can be observed that, although we can see some outliers in the concentration during the dry period over which the SWH-unit will be active, overall the concentration of organic pollutants remains relatively stable over the year. Figure 10 shows the concentration of the organic pollutants over the year 2022 to illustrate this. Therefore, averages and maximum concentrations of the pollutants will be considered for the design of the SWH-unit and asses if the set water quality requirements are likely to be met. The same can be done for heavy metals because the limited data points cannot provide a valuable insight into the differences between dry and wet periods.

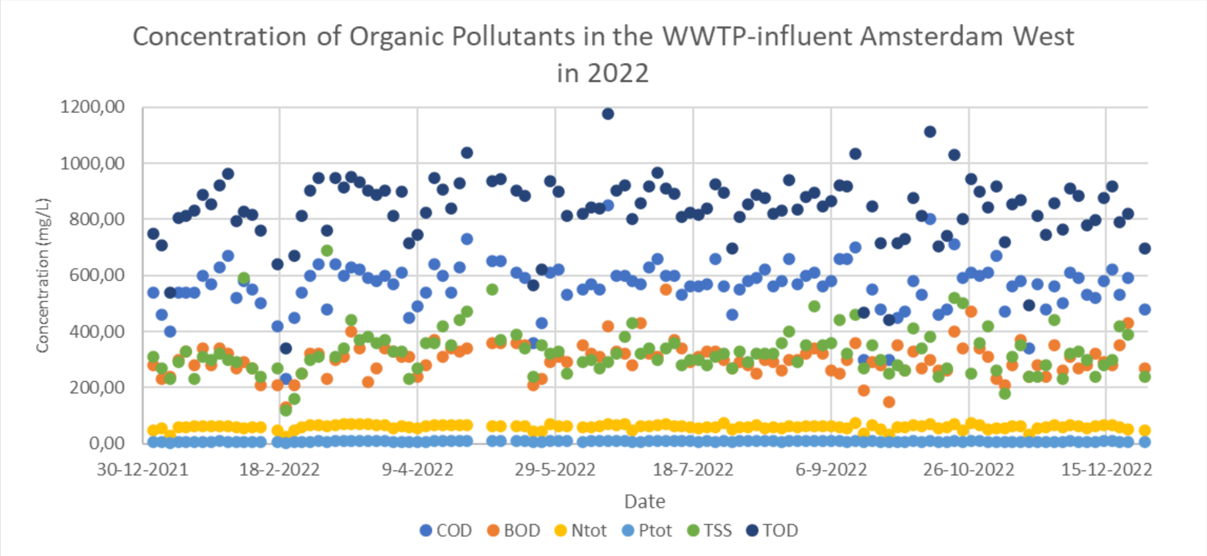

Figure 10 Concentrations of organic pollutants in the WWTP-influent Amsterdam West in 2022.

5.1.2 Water Quantity Requirements

Water Demand UGS and SWH-unit output
In order to determine the water demand of UGS a water shortage model is made using Python programming. This can be used to determine the water quantity requirements for the SWH-unit at the Vondelpark study area. In Table 10 an overview of the collected data for the parameters and their sources can be seen. Following Table 10 the selection of the data is justified and explained.

Table 10 Overview of the collected data for the parameters and their corresponding sources.

Data Type	Data	Source
Meteorological Data	Evapotranspiration (ET_0)	(KNMI, 2015)
	Rainfall Depth (P_i)	(KNMI, 2015)
	Run-on/Runoff (RO_i)	Based on spatial analysis and (Zhang, Xie, & Wang, 2015)
Soil Data	Porosity (n)	(Van Genuchten, Leij, & Yates, 1991)
	Capillary Rise (CR_i)	(-)
	Displacement Pressure (ψ_b)	(Van Genuchten, Leij, & Yates, 1991)
	Pore Size Distribution Index (λ)	(Van Genuchten, Leij, & Yates, 1991)
	Irreducible moisture content (θ_r)	(Van Genuchten, Leij, & Yates, 1991)
	Ground Water Level	(Waternet, 2023)
Plant Data	Rooting Depth (Z_r)	(Allen, Pereira, Raes, & Smith, 1998)
	Adjustment Factor (K)	(-)
	Depletion factor (p)	(Allen, Pereira, Raes, & Smith, 1998)

Transformed Meteorological Data
The first step of the model is to come up with reliable future weather data which takes into account the climate scenarios of the KNMI. Note that the weather data is not predictive but only accurately simulates the (increase in) severity of drought in the future.To this end, transformed daily weather data from 1 January 1981 up to 31 December 2010 (i.e. the base period) is used. The data includes the reference evapotranspiration (mm) and precipitation (mm). The weather data follows a similar pattern as in the base period and is transformed based on the four climate scenarios of the KNMI taking into account changes in means, year to year and day to day variations and chances of extreme events (KNMI, 2015). This has been done for the years 2030, 2050 and 2085. In simple terms this means that the data represent 30 years of possible weather data for the years 2030, 2050 and 2085. Based on the recent update by the KNMI on the new ICPP6 report which will lead to an update of the four climate scenarios medio 2023 the W_H scenario is chosen due to the expected rise in mean temperature (W-component) and change in air circulation (H-component) (KNMI, 2021). The precipitation data that is used was collected at the Hortus Botanicus weather station (number 441) in Amsterdam (nearest weather station to the Vondelpark with transformed precipitation depth) and the reference evapotranspiration originates from the Schiphol Airport weather station (number 240) (the one nearest to the study area that has transformed reference evapotranspiration).

Run-on
The run-on for a specific green area highly depends on its location and surrounding spatial characteristics. The run-on coefficient is determined based on the area size of the green area compared to the areas from which water could run-on and the runoff coefficients for each land cover type (e.g. paved, bare soil or grass) established during field studies by Zhang, Xie &Wang (2015). Based on this research the run-off coefficient of paved surface is determined to be 0.9 while the green areas have a run-off coefficient of 0.1. Combined with the ratio of unpaved and paved area, the new run-on coefficient (i.e. percentage of the precipitation that runs onto UGS from paved areas) can be determined for a green area. This results in the following formula for the run-on coefficient:

$$RO_i = \frac{A_{paved}}{A_{unpaved}} * 0.9 * 0.9$$

Assuming all rainwater from the paved areas (100000 m^2) will flow towards either the surrounding surface water or the UGS ($A_{unpaved}$ = 360000 m^2), the run-on coefficient is 0.225.

Adjustment Factor
The reference evapotranspiration can be adjusted to account for the difference in water use between the reference crop (grass) and the actual vegetation. For monotonous agricultural crops this ca easily done by applying a known specific crop factor. However, in the urban environment vegetation is mixed and the (micro) environmental conditions vary largely due to urban characteristics. Several practical approaches exist to take into account these effects, such as the LIMP coefficient, WUCOLS Landscape coefficient, Plant Factor (PF) and Irrigated Public Open Space (IPOS) factor (Shojaei, Gheysari, Nouri, Myers, & Esmaeili, 2018; Snyder, Pedras, Montazar, Henry, & Ackley, 2015; Nouri, Beecham, Hassanli, & Kazemi, 2013). However, all investigated adjustment factors relied on subjective assessment of several other factors that make up these adjustment factors, especially for micro-climate conditions (e.g. amount of shade, aggravation of winds, capacity of surrounding built environment to absorb heat). As a result of the subjective determination of these different factors, different studies resulted in both over and under estimation of the actual evapotranspiration using these different adjustment factors (Shojaei, Gheysari, Nouri, Myers, & Esmaeili, 2018; Snyder, Pedras, Montazar, Henry, & Ackley, 2015; Nouri, Beecham, Hassanli, & Kazemi, 2013). After deliberation with an expert, the use of the reference evapotranspiration was deemed more comprehensible, reliable and sufficiently accurate to model the water demand of UGS (M. M. Rutten, personal communication, 19 October 2022). Therefore, no adjustment factor is applied in the model.

Rooting Depth and Depletion Factor
The rooting depth and depletion factor are highly dependent on the specific vegetation. Therefore, a choice was made to only review the most critical vegetation based on the water shortage model. This turned out to be the young trees, grass and other understorey vegetation which have an average rooting depth of 500 mm and a depletion factor of 0.5 (Allen, Pereira, Raes, & Smith, 1998). Besides, trees which have a considerably larger rooting depth are able to reach the ground water table (0.6 to more than 1.0 meter below the surface). Therefore, trees will experience drought only after a severe drop in ground water level which is not realistic since the area is lower compared to its surrounding and thus ground water from the surrounding areas will flow towards the park (Wimmers, Sweijen, Brugman, Meinhardt, & Maljaars, 2020).

Soil Data
The porosity, displacement pressure, pore size distribution index and irreducible moisture content all depend on the composition of the ground and have been empirically determined by Van Genuchten, Leij & Yates (1991). At the Vondelpark, the soil is moderately fine silty sand for the first 0.5 meter (Venhuis & Bleumink, 2011). Therefore, it was determined that the porosity of the soil is 0.41, the irreducible water content becomes 0.07, the displacement pressure is 30 cm and the pore size distribution index will be 0.3. Based on measurements from Waternet in several monitoring wells (E051224, E051225 & E051226) the ground water level fluctuates in the dry period (from April-September) between 0.6 and more than 1.0 meters depending on the exact location (Waternet, 2023). Based on the available soil data, it is hard to accurately quantify the contribution of the capillary rise to the soil water balance, this would require soil testing which is beyond the scope of this research (Liu, Yasufuku, Miao, & Ren, 2014). Since the porosity of the soil is relatively high and to prevent an unfair contribution of the capillary rise to the RAW of the plants the capillary rise is set to 0 (Tuller & Or, 2005). This might lead to a slight overestimation of the water demand. However, since the goal is to irrigate UGS during severe drought this is preferred over an underestimation.

Result
Now having established the parameters, calculations can be made using the Python scripts from Appendix B. The irrigation amount per irrigation event was determined based on the maximum monthly deficit (i.e. evapotranspiration minus the rainfall depth), which occurred in June. This monthly deficit was divided by the amount of days in June (i.e. 30) to get a daily deficit which was used as the irrigation amount. Irrigation scheduling was done such that the soil moisture content would not drop below the threshold moisture content. By doing irrigation this way, water can be saved, since there is less irrigation needed than the daily deficit (which is 5.86 mm in 2030), and the needed

capacity of the SWH-unit can be lower. Irrigation models exist that are able to take into account soil moisture content (from soil moisture meters) and weather predictions to schedule irrigation events in order to save water in practice as well. The soil water balance calculation was performed for the 95th-percentile water shortage (i.e. if this shortage is resolved the vegetation in the Vondelpark that is irrigated will not experience any water stress 95% of the time). It is also good to note that in practice plants can handle some form of water stress as well, although this would limit their evapotranspiration. An overview of the yearly deficit, maximum monthly deficit, irrigation depth per event, the irrigation amount, the capacity of the SWH-unit and the yearly irrigation depth are displayed in Table 11.

Table 11 Result from the Water Shortage Model displayed in the yearly deficit, maximum monthly deficit, irrigation depth per event, the irrigation amount, the capacity of the SWH-unit and the yearly irrigation depth.

Year	Yearly Deficit (mm/year)	Maximum monthly deficit (mm/month)	Irrigation depth per event (mm/day)	Irrigation Amount (L/ha/s)	Maximum capacity SWH-unit (m^3/h/ha)	Yearly Irrigation depth (mm/year)
2030	240	76	2.5	0.29	1.05	94
2050	280	85	2.8	0.33	1.18	113
2085	309	90	3.0	0.35	1.25	124

In Figure 11 all 30 plots of the soil moisture content over time for the year 2030 without and with irrigation are shown. If the soil moisture content dips below the threshold moisture content this means that the plant will experience some water stress. It can be seen that this does not occur for the year 2030 when irrigated with water from the SWH-unit.

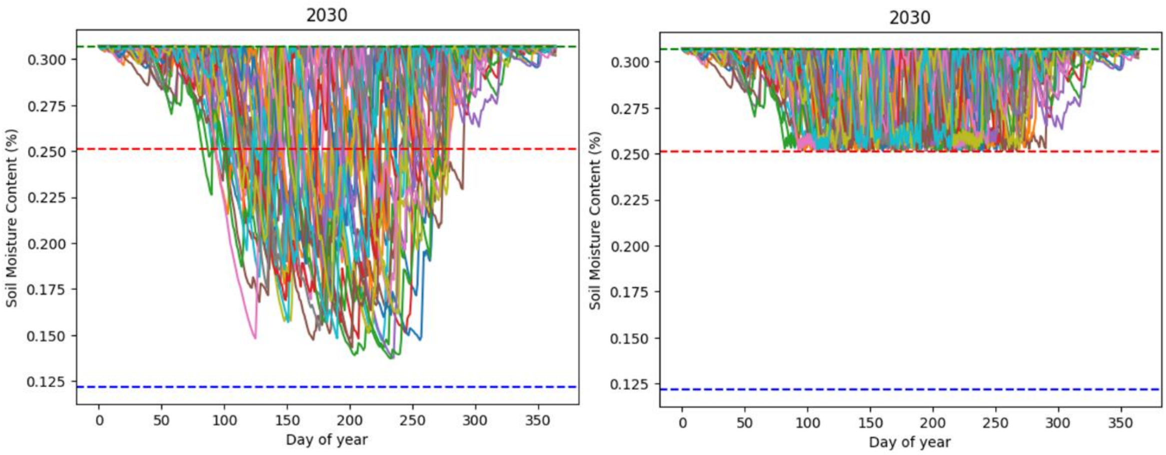

Figure 11 Plots of the soil moisture content for the year 2030 without (left) and with irrigation (right). The dashed green line represents the field capacity the dashed red line represents the threshold moisture content, at which plant will start to experience water stress, and the dashed blue line represents the wilting point.

Based on these results the irrigation of the entire area of 28 ha of UGS of the Vondelpark would require a SWH-unit with a capacity of nearly 30 m^3/h. This is similar to the capacity of one of the reference projects (i.e. Pennant Hill Golf Club), which required a permanent building with a relatively large footprint. Fitting this into the existing dense urban area of the Vondelpark seems unfeasible. To come to a more realistic and feasible capacity of the SWH-unit, it was decided that the most vulnerable plants must be preserved. Therefore, not all the existing UGS in the Vondelpark needs to be irrigated. The UGS in the Vondelpark can roughly be subdivided into 16 ha of grass, 0.2 ha ornamental shrubs and 11 ha of woodlands (van Eijkeren, 2021). Since grass is mostly resilient to drought (e.g. loses green colour but will not permanently wilt and regain green colour quickly after a rain event) irrigation is not necessary. In addition, mature trees (and larger shrubs) do not require irrigation as they can reach the groundwater in the Vondelpark with their roots. However, young trees and shrubs (i.e. woodland plants) as well as ornamental shrubs require sufficient irrigation to withstand long periods of drought. No data was available on the amount of young plants in the Vondelpark specifically. However, in the Beatrixpark, another park in the city district Zuid, 20% of the woodlands was deemed young, which is classified as a relatively high amount compared to similar parks (Gemeente Amsterdam, 2009). Therefore, it is assumed that the woodland area of the Vondelpark will also consist of 20% young and vulnerable plants. Based on this assumption the total area of the Vondelpark that requires irrigation is determined to be 2.4 ha, which comes down to a capacity of the SWH-unit of 2.5 m^3/h.

Water quantity of SWH-unit input

To determine how much raw sewage is available as input for the SWH-unit, the flow rates of sewer pipes of the Vondelpark are investigated. In and around the Vondelpark there are combined gravity sewers and pressure sewers. Since, extraction from pressurised sewer pipes is harder and can cause a drop in pressure, the raw sewage needs to be harvested from a gravity sewer pipe. Waternet has determined the average flow rate for several pipelines in Amsterdam (Waternet, 2023). Two of these sewer pipes were identified near the Vondelpark which can be seen on Figure 12. Since the sewer pipe on the top right of Figure 12 is located at the entrance at the Stadshouderskade and the average flow rate is higher, this pipe is deemed the most suitable for the extraction of raw sewage. This sewer pipe has an average flow rate of 84 l/s.

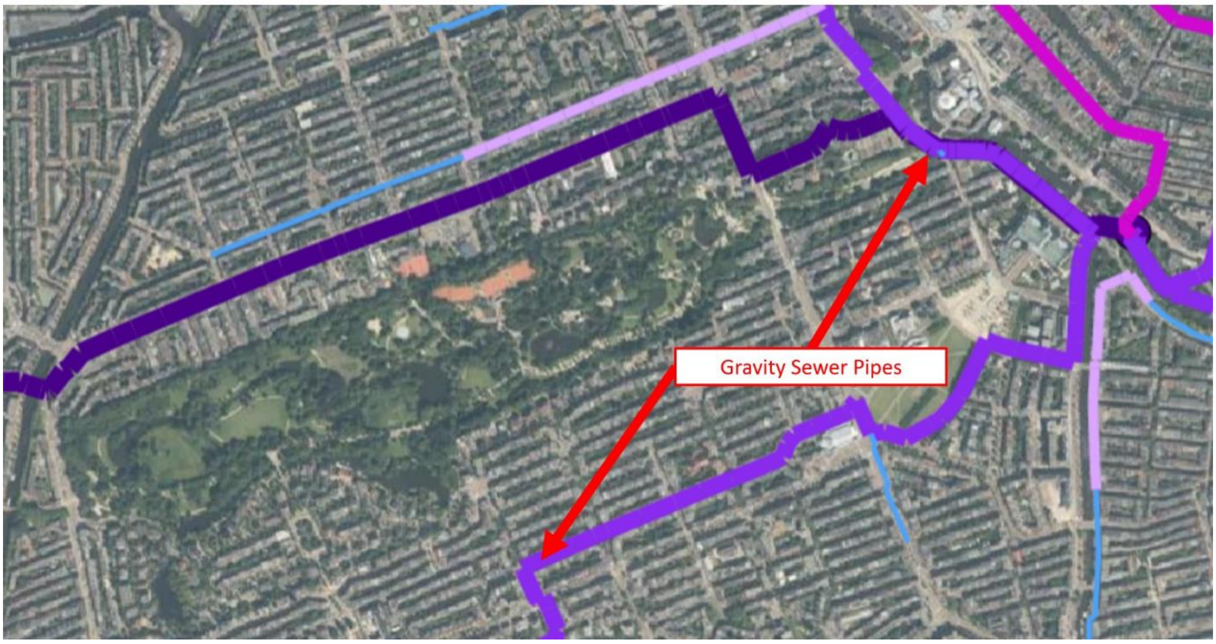

Figure 12 Potential sewer pipes for extraction of raw sewage (Waternet, 2023). With arrows directed to the point closest to the Vondelpark.

The minimum amount of water that can be reliably extracted depends on the water recovery rate of the SWH-unit, the minimum water flow in a sewer pipe and possibly on the discharge of treatment residual back into the sewer, as sewer pipes with higher flow rates can handle treatment residuals with higher concentrations before resulting in a negative impact downstream in the sewer system. The impact of the discharge of treatment residuals and the recovery rate will be considered in section 5.2. The minimum flow rate of the pipe depends on the difference between the average flow and the dry weather flow and on the daily dry weather flow pattern of municipal sewage. Based on the data provided by Waternet from the Amsterdam West WWTP, a factor that translates this average flow into the dry weather flow can be computed by dividing the average flow rate by the minimum flow rate. For the year 2022 and 2021, these factors are 1.48 and 1.39 respectively. For this reason, the average flow rate in the pipelines will be divided by a factor of 1.5 to determine the dry weather flow.

In Figure 13, we can see the daily dry weather flow pattern in the Netherlands.

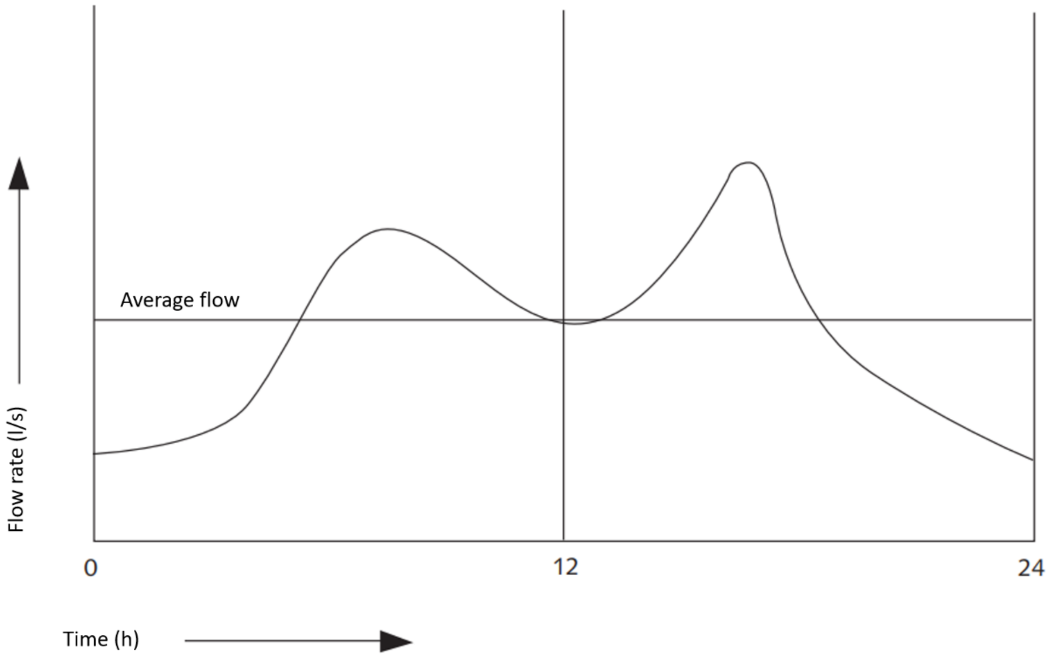

Figure 13 Daily dry weather flow pattern with a corresponding peak factor of 2.4 (ONRI-werkgroep riolering, 2009).

Sewer pipes in the Netherlands are designed for a peak dry weather flow of a factor 2.4 of the average daily flow. Hence, the same factor is assumed for the minimum dry weather flow, based on the pattern of the dry weather flow. The minimum flow rate in the selected sewer pipe which will feed the SWH-unit can therefore be determined with the following formula:

$$Q_{avg} = \frac{84}{2.4 * 1.5} \cong 23\ l/s$$

When considering the maximum water need of 0.29 l/s/ha for the UGS in the Vondelpark in 2030, 78 ha of UGS can be irrigated maximally during a dry period with water from the selected gravity sewer pipe. This is more than enough to irrigate the Vondelpark, which has 28 ha of UGS. However, it is not likely all this water can be used since a SWH-unit with a capacity of 23 l/s (or 83 m^3/h) would require such a large footprint that fitting this into the dense urban area of Amsterdam seems unreasonable. On the other hand, this flow rate provides a large margin to discharge treatment residuals which after mixing with the receiving water should not contain a TSS concentration exceeding 600 mg/l. Based on the average TSS concentration of the raw sewage nearly half of this flow, roughly 11 l/s (40 m^3/h), can effectively be used for irrigation before this standard for the discharge of treatment residuals will be exceeded. The amount of raw sewage in the selected sewer pipe is thus more than enough to supply the SWH-unit to meet the water demand of 2.5 m^3/h of UGS. This is the case even considering the losses as a result of the treatment steps and irrigation system which are later specified in sub-sections 5.2.2 and 5.2.3.

5.2 Components of a SWH-unit for the Study Area

In Figure 14 a schematic diagram of the SWH-unit is depicted.

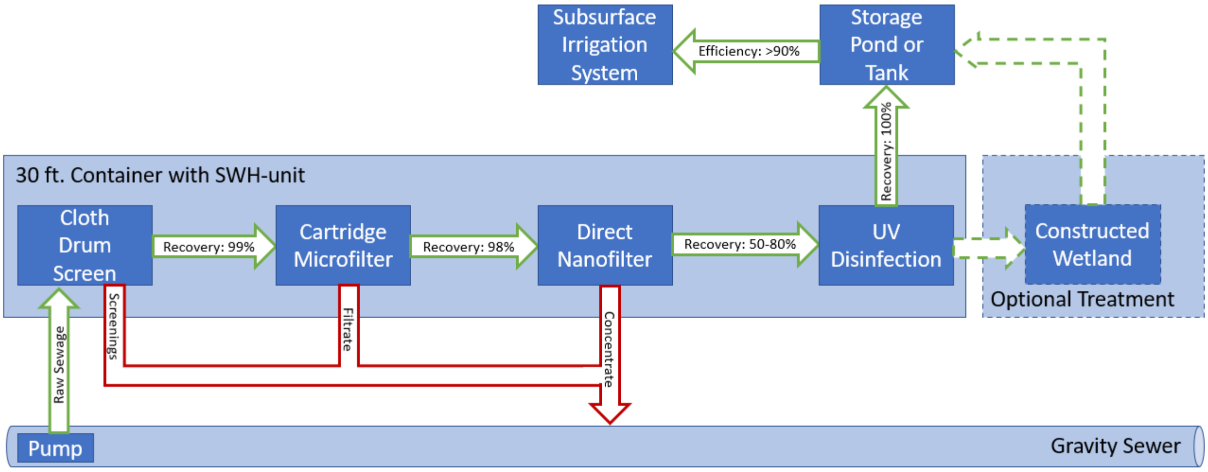

Figure 14 Schematic diagram of the SWH-unit.

As mentioned, the process of an SWH consists typically of three steps in order to fulfil its function:

1. Extraction of raw sewage from the sewer to a treatment unit.
2. Treatment unit that produces recycled fresh water and residual products.
3. A system to distribute the recycled fresh water for its intended use (in this case irrigation).

Each of these steps will be explained in a subsection (respectively 5.2.1, 5.2.2 and 5.2.3) and design choices will be motivated. Between these steps (or in between the different treatment steps of the set-up) buffer tanks can be used to temporarily store water and handle potential differences in flow rates. Besides there is need for monitoring of the water quality and operation parameters throughout the process. Monitoring is therefore discussed separately in subsection 5.2.4. Lastly, in subsection 5.2.5 an overview of the estimated cost, size and energy use of the SWH-unit is presented. Based on the size of the components required it will be determined if the SWH-unit can be fitted in a container and thus will be mobile.

Pilot Project Sewer Water Harvesting in Amsterdam
As part of the NWO research programme AquaConnect, a pilot project with a SWH-unit will be undertaken at the Marineterrein in Amsterdam. Among others, the municipality of Amsterdam, Nijhuis Saur Industries BV, NX Filtration, the AMS Institute and Witteveen+Bos, will be involved during this pilot. The goal is to find new sources to ensure a sustainable fresh water supply for UGS in the future. As also established during this research a pilot project is important to obtain permanent permits and gain further insight in the capabilities and impact of this innovation. A similar treatment set-up to the conceptual design from this research will be tested during the pilot. Therefore, this research is of added value to the pilot project and recommendations can be made to be applied to this real world setting to increase the impact of the research outcomes.

5.2.1 Step 1: Extraction of raw sewage to SWH-unit

The conceptual design of the SWH-unit begins with a cast iron pump that is responsible for continuously extracting the wastewater from a gravity sewer. The pump is installed with a coarse filter with pores of 5 mm to handle large debris which can be in the sewage. A pump is selected with a continuous self-cleaning system which allows for clog-free operation (Abelin & Karlén, 2015). This will protect downstream components as well as prevent clogging of the pump itself. In contrast to a grinder pump, this pump will not cut up the larger debris into smaller pieces to prevent clogging but filter them out. The pumped up water will thus contain less particles and in doing so reduce the need for maintenance of the downstream components. The pump is strategically located at a manhole or sewage drain to facilitate efficient access and possibility to transport the water to the SWH-unit. Municipal sewage can contain excessive amounts of oil and grease which can clog not only the sewer but also the components of the SWH-unit (Oesterholt, 2021). If this is the case in the selected sewer pipe, a block that biologically breaks down fats, such as developed by Macero, can be easily hung in the manhole to eliminate any negative effects (R. de Vreede, personal communication at the AquaNederland convention, 21 March 2023). If needed a weir can be installed in the sewer pipe to create sufficient water depth for the pump. It operates with robust sensors and controls to ensure proper pressure and flow rates, while also being able to detect any issues with the sewer. To reduce the amount of necessary piping the SWH-unit is located as close as possible to the extraction point (as there are two pipes, one for raw sewage and one for treatment residuals, going from and to the SWH-unit to the extraction point). Before entering the SWH-unit for treatment, the quality of the raw sewage needs to be monitored to provide valuable insight on the performance (i.e. removal efficiency) of the treatment process. Moreover, in the case of extremely high concentrations of critical parameters (e.g. BOD and N) in the raw sewage, which would result in the effluent not meeting the set standards, the water can be preventively drained back to the sewer and extraction can be temporarily stopped.

5.2.2 Step 2: Treatment Process SWH-unit

The treatment process of the SWH-unit will consist of three main steps: fine screening, MF and NF. In order to minimise the health risks a UV disinfection step is applied at the end. The use of (inorganic) coagulants, for instance for the removal of nutrients, is undesirable and thus avoided as this could result in a high concentration of chemicals in the treatment residuals stream that is drained back into the sewer (Ruigómez, González, Rodríguez-Gómez, & Vera, 2020). In addition, based on the specifications of the manufacturer of the NF membranes, coagulation pre-treatment is not necessary (NX Filtration, 2020). The treatment process of the SWH-unit will thus be purely physical and rely on membrane filtration. This is done for four main reasons:

1. Membrane filtration allows for simple operation (Mejía-Marchena, et al., 2023). Biological processes, such as MBR which is frequently used in SWH systems, are sensitive, since they rely on life micro-organisms. Therefore, operation requires more effort than filtration steps (Waste Technologies of Australia Pty Ltd, 2006). Moreover, this allows for the SWH-unit to be turned off and on easily compared to biological processes (Makropoulos, et al., 2018). A mobile SWH-unit could thus be swift in operation and potentially serve at different locations.
2. Less footprint required due to the absence of a relatively large biological reactor tank and sludge tanks and thus also no sludge treatment required (Mejía-Marchena, et al., 2023; Waste Technologies of Australia Pty Ltd, 2006).
3. Membrane filtration is built up of modules and thus is easily scalable to meet the required irrigation needs and flow rates of the treatment set-up, which reduces the need for buffer tanks and makes it possible to increase the capacity with increasing demand over the years (Mejía-Marchena, et al., 2023).
4. Membrane filtration systems have a high rate of automation, which reduces the need for human involvement and allows for remote control. (Plevri, et al., 2020).

The design of the SWH-unit is very similar to the reference project at the Flemington Racecourse, discussed in section 4.1. Additionally, the raw sewage characteristics (measured on 4 occasions) are very similar to the raw sewage at the Amsterdam West WWTP influent, with the exception of an up to approximately two times lower BOD concentration (Waste Technologies of Australia Pty Ltd, 2006). Hence, the results from that reference project can be used to give an indication of the to be expected effluent quality of the treatment steps of the conceptual design presented in this research, since specific quality calculations are outside the scope of this research. The effluent quality of each treatment step of the SWH-unit at the Flemington Racecourse are therefore provided in Appendix C. Figure 15 further illustrates the removal capabilities of the different membrane technologies.

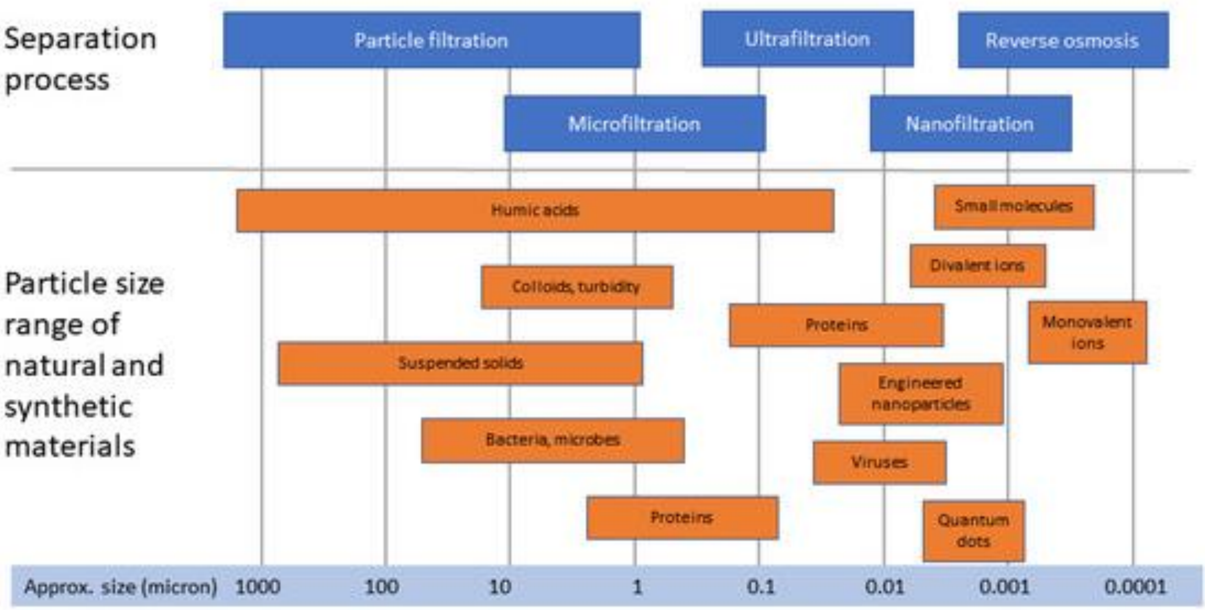

Figure 15 Overview of the removal capabilities of membrane filtration techniques (Ostarcevic, Jacangelo, Gray, & Cran, 2018).

Cloth Drum Screen

Once the wastewater is extracted, it enters the first stage of treatment, which involves a NDF200 cloth drum screen produced by Nijhuis Industries. The maximum capacity is 5 m^3/h. The inlet is designed such that it remains clog free despite the remaining solid particles in the waste water (Nijhuis Industries, 2017a). The NDF200 is a mechanical filtration device with a rotating cylindrical perforated drum screen covered with a an easily exchangeable inner cloth that effectively removes larger debris and solid particles from the wastewater (Nijhuis Industries, 2017b). The recommended pore size of the cloth is 80-160 micron (T. van den Einde, personal communication, 30 May 2023). Since the pore size of the stainless steel mesh screen used at the SWH-unit at the Flemington Racecourse was 200 micron, it is expected that the quality of the effluent of the cloth drum screen is similar (see Appendix C). With an internal screw, the screenings are transported to a waste container which will later be drained back to the sewer. This should be done after mixing with filtrate or concentrate from the MF or NF treatment step to comply with the set standard for the discharge of treatment residuals. This initial screening process helps protect downstream components from potential clogging and damage.

Cartridge Microfilter

From the rotary drum screen, the wastewater moves on to the next stage, which involves cartridge microfiltration. MF is a widely used treatment step and has proven its abilities as a pretreatment step for NF and RO. Cartridge microfiltration employs a series of filter cartridges with microscopic pores of 0.2 micron. The pore size was selected since the MF membranes with 0.2 micron pores of the SWH-unit at the Flemington Racecourse proved to be very effective as a pre-treatment for further membrane filtration. Moreover, such microfilters are widely available for this application and can be acquired directly from several suppliers (Naim, Sean, Nasir, Mokhtar, & Muhammad, 2021). By applying cartridges, the microfilters can be easily replaced, just like the cloth of the drum filter, to maintain optimal performance of the filter. After cleaning these cartridges can be reused. To limit the need for replacement of the cartridges due to fouling, a cross-flow is applied instead of dead-end filtration (Hakami, et al., 2020). The microfiltration cartridges effectively remove suspended solids, bacteria and other larger microorganisms from the wastewater, which can be seen in Figure 15. The to be expected water quality will be similar to the SWH-unit at the Flemington Racecourse (see Appendix C) due to the application of membranes with a similar pore size.

Direct Nanofiltration
The most notable difference with the SWH-unit at the Flemington Racecourse is that the RO treatment step is replaced with direct NF (dNF80) produced by NX Filtration. This is done for six main reasons:

1. Lower operating pressure and thus a lower energy use and costs (Yahya, Gökçekuş, & Ozsahin, 2020).
2. The recent development of commercially available hollow fibre NF membranes which, compared to spiral wound (and tubular) membranes, are easier to clean (with less chemicals), require less pre-treatment (i.e. only microfiltration or fine sieving), allow for surface modification (layering of different materials) and higher packing densities. Overall this significantly improves their performances and reduces the footprint, creating ideal circumstances to apply them for decentralised treatment (Arun, 2021; Jonkers, Cornelisse, & Vos, 2023).
3. RO drastically reduces the nutrient (N and P) concentrations in the water, which are beneficial to plant and soil health (Plevri, et al., 2017).
4. Water treated by RO will be depleted of nearly all salts and important minerals, compared to NF, which makes it unsuitable for irrigation water. As a result certain minerals need be reintroduced. Moreover, the retention of salt on the RO membranes causes scaling and diminishes water recovery rates and increases maintenance compared to NF (Nativ, Leifman, Lahav, & Epsztein, 2021). Besides, there is no indication or reason to assume that municipal sewage in Amsterdam is highly saline which would make RO a more appropriate option.
5. Recent research and (pilot) projects have shown that dNF is able to successfully remove micropollutants from the water (Brinke, Reurink, Achterhuis, Grooth, & Vos, 2020; Krajenbrink, Stofberg, Bartholomeus, & Disselhoff, 2021; van der Poel, 2020; Visser, et al., 2023).
6. NF is able to produce odourless and clear water (i.e. not turbid or with very low turbidity).

The hollow fibre NF used has a 800 Dalton Molecular Weight Cut Off (MWCO), which can be seen as substitute parameter for the pore size of the membranes (Kovacs & Samhaber, 2008). The membranes are made out of different layers of PES (polyether-sulfone) and PEM (polyelectrolyte) which significantly reduces fouling and need for backflushing (Sewerin, et al., 2021; Jonkers, Cornelisse, & Vos, 2023). This surface modification technique also allows for control over the membranes surface charge which allows for the rejection of solutes and ions with pore sizes smaller than the membrane due to electrostatic repulsion (van der Poel, 2020; Arun, 2021). Fouling is further reduced by applying a cross-flow. Due to a maximum of 6 bar of transmembrane pressure the influent water is pushed out of the hollow fibre membranes. As a result dissolved solids, organic matter, micropollutant, certain salts from the water and multivalent ions will be (partly) removed. The operation of the dNF modules is fully automated and can be controlled remotely using SEMCA software (T. van den Einde, personal communication, 30 May 2023). The water recovery of the NF can vary from 50-80% based on existing applications (Arun, 2021; Visser, et al., 2023) A lower water recovery means less fresh water produced to irrigate. However, a lower recovery allows for a lower pressure, which is beneficial in terms of membrane fouling and energy use (Mkilima, et al., 2022; T. van den Einde, personal communication, 21 April 2023). In subsection 5.2.3, in which the irrigation efficiency is determined, the minimal desired recovery of the NF step is explained based on a flow diagram (see Figure 16). This results in a minimal recovery of 57% to be able to fulfil the water demand. After mixing the treatment residuals of the cloths drum screen, MF and NF are discharged back into the sewer downstream of the extraction point.

The dNF80 membranes are backwashed to maintain flow and the transmembrane pressure, which is affected because of membrane fouling (NX Filtration, 2020). In addition air can be injected to increase turbulence which will help remove material attached to the membranes (Visser, et al., 2023). Thereby, some chemicals need to be added to support the cleaning process and prevent scaling. The optimal chemical dosing depends on the hardness of the water and consists of NaOH, H_2SO_4 and NaOCl which should be dosed approximately every 40 m^3 of treated water (i.e. every 8 hours) (Visser, et al., 2023).

Furthermore, the membranes should be cleaned with citric acid approximately 2 times a month to remove persistent fouling.

After the NF step, the quality standards for TSS and total P will be met. The TSS concentration could already be below the standard after MF, but NF further reduce the concentration to an undetectable amount. Based on research from Mkilima et al. (2022) the removal of P from the water by NF is extremely efficient (up to 98%), especially in combination with pre-treatment, and it can be assumed that therefore the set standard for P of 2 mg/l is met (Kovacs & Samhaber, 2008). In addition, pathogen concentrations will be significantly reduced.

However, due to the novelty of the NF membranes and their application as part of SWH, it cannot be set with absolute certainty that the BOD and total N standards are met.

To the knowledge of the author, no studies have focussed on the BOD removal efficiency of hollow fibre NF membranes. A study into the BOD removal capacity of flat sheet nano-porous membranes indicated an efficiency of nearly 77%. Furthermore, research and applications of similar dNF40 membranes (400 instead of 800 Dalton MWCO) proved to be very effective in the removal of Natural Organic Matter (NOM) and Total Organic Carbon (TOC) (85%-97%) (Arun, 2021; NX Filtration, n.d.; General Electric, 2015). These parameters relate to the BOD concentration such that a lower concentration of TOC or NOM indicates a lower BOD concentration, while it is hard precisely quantify this relation. Based on the removal of NOM and TOC it is suggested that the BOD concentration would also be significantly reduced. Moreover, most of the BOD is bound to particles ranging from 63 to 5 micron in size, which is significantly higher than the pore size of NF (Ravi, 2018). Based on this it can be assumed that the BOD concentration will be significantly reduced due to the aforementioned reasons. However, it cannot be said with absolute certainty that the set standard for the BOD concentration of 25 mg/l is not exceeded slightly at times when the raw sewage contains extremely high BOD concentrations.

Also for the removal of N by the hollow fibre NF membranes limited scientific studies were conducted. Based on empirical research by Mkilima et al. (2022), the removal efficiency of N can be expected to be around 50-90%. Especially the removal of ammonia (approximately 55%) turned out to be less efficient compared to nitrate and nitrites (above 80%) (Mkilima, et al., 2022). Based on the maximum concentration of N of raw sewage from 2021 and 2022, a N-removal efficiency of around 79% would be needed to ensure reaching the set standard of 15 mg/l. Experts from the technology provider (i.e. NX Filtration) also acknowledged, based on their own testing, that it is uncertain if the N concentration can be lowered if the raw sewage concentration are high (J. de Grooth, personal communication, 21 April 2023).

The BOD and N standards were mostly set to prevent (re)growth of microorganisms and bacteria. This could consequently lead to biofouling in downstream piping or growth of algae in storage tanks or ponds. The risk of regrowth could be reduced by limiting the storage time of the treated water before irrigation, which will be taken into consideration during the selection of an irrigation system in subsection 5.2.3. Exceedance of the standards could further have a negative environmental impact, on plant and soil health as well as deterioration of nearby surface water and groundwater due to runoff. This potential impact on plant and soil health is further discussed in section 6.2. Furthermore, the addition of a constructed wetland to the treatment set-up can be opted for to further reduce the N and BOD concentration if necessary, which is briefly discussed later on in this sub-section. The effluent water from the NF will be collected in a buffer tank. In this tank the effluent water quality can monitored to check if the standards are met. If N and BOD standards are (far) exceeded, the water in the buffer tank can be drained back to the sewer.

UV-disinfection

UV-disinfection is added to the treatment process in order to further reduce the pathogens and risk of regrowth. This is necessary to ensure compliance with the strict standard for E. coli and limit any human health risks. Stakeholders also expressed the need to eliminate any health risks, as discussed further in Chapter 7. The application of UV has proved to be very effective during many of the reference projects that were studied and will assure the desired reduction of pathogens. Based on information from the supplier of the UV-technology, maintenance is only needed once a year (Van

Remmen, n.d.). This means that during the operation of the SWH-unit, no maintenance should be necessary.

Optional Treatment: Constructed Wetland
If quality standards are not sufficiently met, a constructed wetland can be added at the end of the treatment train. Constructed wetlands have proven to further remove N and BOD concentrations (Zhang, et al., 2010; Abou-Elela, Golinielli, Abou-Taleb, & Hellal, 2013; Abou-Elela, Golinielli, Abou-Taleb, & Hellal, 2013; Li, et al., 2021). It also further reduces the concentration of micropollutants and pathogens. The main disadvantage of a constructed wetland is the large area that is needed, especially when applied in a dense urban area. Therefore, it is currently not deemed a reasonable regular component of the treatment set-up. Recent developments, such as the addition of aeration to the constructed wetlands, have already helped to reduce the surface area from 3 to 0.75 m^2 per residential equivalent (150 l/d) (Zhang, et al., 2010; M. Martens, personal communication at the AquaNederland convention, 21 March 2023). Moreover, constructed wetlands can add to urban greenery, as it is a nature based solution or they can be integrated in parking spaces or walkways (Rietland, n.d.). In addition, they could also be used to enhance the water quality of ponds or (stored) rainwater (during times when they are not used for SWH). Advantages of constructed wetlands are among others the low energy use, robustness of the system and low maintenance. The application and effects of constructed wetlands as a final treatment step after NF is currently studied by Philip Meijer. The result of this study will be shared as part of the AquaConnect research programme. Results from this study and the pilot project should be used to decide if constructed wetlands should be applied.

5.2.3 Step 3: Irrigation System

After treatment, the water needs to be distributed to the demanding UGS. Three different methods have been selected for evaluation: sprinkler, drip and subsurface drip irrigation. Several criteria are considered, which are cost, irrigation efficiency, health safety, clogging potential and required water storage. Furthermore, some practical considerations are taken into consideration.

First of all sprinkler irrigation is the most convenient form of irrigation of UGS as it does not require an extensive network of driplines for the distribution of water. Subsequently, the mobile SWH-unit can be operational at any location without investing in a local irrigation system, as the sprinklers can be relocated with the unit. Besides, moving the sprinkler can help to cover a larger area without the need for additional equipment. Therefore, sprinkler irrigation is also by far the cheapest irrigation alternative. With subsurface drip irrigation being more expensive than regular drip irrigation due to the need to bury the system underground (Payero, Yonts, Imrak, & Tarkalson, 2005; Suárez-Rey, Choi, Waller, & Kopec, 2000). Also clogging of the irrigation system, due to biofouling or salt built up, is much more of a concern for the drip irrigation systems, which in general have smaller emitters (Capra & Scicolone, 2007; Suárez-Rey, Choi, Waller, & Kopec, 2000). Although it should be noted that a study by Oliver, Hewa and Pezzaniti (2014) into the biofouling of a subsurface drip irrigation system which distributed reclaimed waste water, showed that the structural backbone of biofilms consists of particles with a size of less than 20 micron. This is considerably larger than the pore sizes of the applied NF and thus should limit severe clogging issues. Sprinkler irrigation has an efficiency of just 75% due to evaporation and less precise distribution of the water. The efficiency can be slightly improved by irrigating at night as evaporation decreases. Drip irrigation has an efficiency of 90% with subsurface drip irrigation being even slightly more efficient (Brouwer, Prins, & Heibloem, 1989; Payero, Yonts, Imrak, & Tarkalson, 2005; Martínez & Reca, 2014). Lower irrigation efficiency effectively lowers the capacity of the SWH operation. Besides, these losses are in light of the water scarcity issue which SWH addresses undesirable. Another downside of sprinkler irrigation compared to both drip irrigation systems are the health risks, as pathogens can come into contact with humans through aerosols or water which ends up on plants (Hashem & Qi, 2021; Capra & Scicolone, 2007). Although UV-disinfection will lead to the removal of nearly all pathogens, regrowth as a result of higher BOD and N concentrations can still pose some risks (Singh, et al., 2020). One of the main advantages of drip irrigation systems is that it allows for continuous irrigation. This also reduces the need for (large) storage of the treated water, which is needed for sprinkler irrigation, as the flow rate of that system is much higher. Hereby, regrowth of microorganisms in the treated water can also be limited. With subsurface drip irrigation, irrigation is even unrestricted by the usage of the UGS (e.g. recreation) (Suárez-Rey, Choi, Waller, & Kopec, 2000). Regular drip irrigation cannot be applied at publicly accessible UGS but is better suited to irrigate shrubs, trees or flower beds which are not directly accessible to humans to prevent potential damages. Another advantage of subsurface drip irrigation compared to regular drip irrigation is the fact that the soil can act as a buffer or filter (Bartholomeus, 2020). Hereby, human health risk are further minimised as contact with humans is not possible at all. Moreover, the soil can act as a filter for, for instance, remaining micropollutants as soil processes are able to further filter and even break down some substances.

In conclusion, overall the preferred irrigation system is subsurface drip irrigation. If the irrigation system would be part of the mobile SWH-unit however, sprinkler irrigation is most convenient as it can be transported to multiple locations. However, health and safety risks, which also turned out to be a big concern for stakeholders (see Chapter 7 and Appendix E), drastically increase with sprinkler irrigation. Despite the fact that drip irrigation systems require higher investments, they are therefore better suited to distribute the reclaimed waste water. Besides, they assure more efficient water use and effectively increase the capacity of the SWH operation by 20% or more. Moreover, they are able to continuously irrigate which reduces the need for large water storage ponds or tanks and thus the needed space. Subsurface drip irrigation, although this is slightly more costly than regular drip irrigation, can be applied in areas which are publicly accessible as its application is totally unrestricted by the use of the area. Moreover, the systems is less susceptible to vandalism or damages and can provide an additional buffer that further decreases health risks and filters pollutants which remain in the water. Subsurface drip irrigation is therefore selected as the most preferred irrigation system for SWH. However, in order to maximise the use of the SWH-unit, this should be designed such that it is able to make use of different irrigation systems when needed. Based on the use of sub-surface drip irrigation and the recovery rates of the established treatment set-up, the flow diagram in Figure 16 on the next page is made. Based on this, an area of 2.1 to 3.3 ha can be irrigated. Based on this, the recovery rate of the NF step should be at least 57% to be able to produce enough water to irrigate the 2.4 ha of UGS as established in subsection 5.1.2.

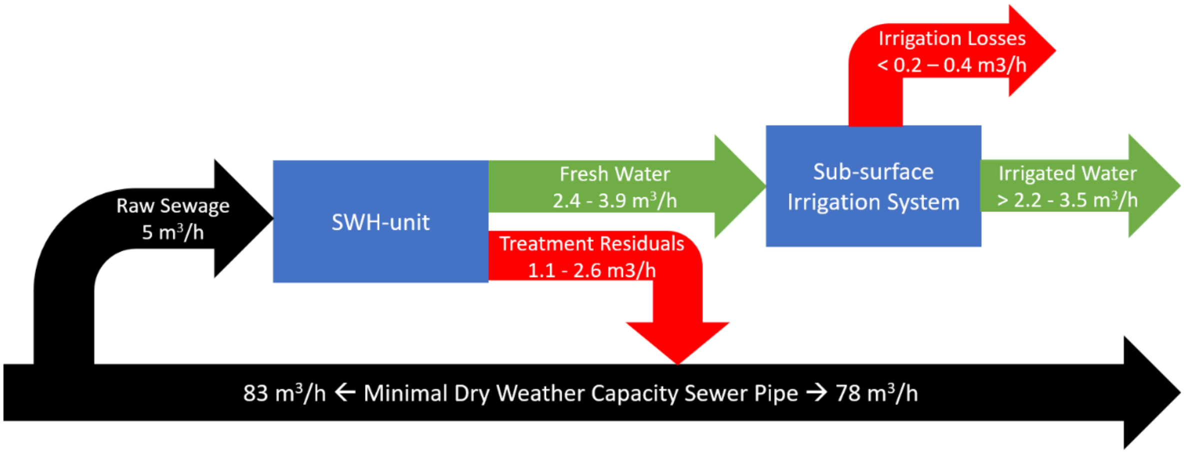

Figure 16 Flow diagram of the conceptual design of the SWH-unit. The eventual output of the SWH depends mostly on the recovery rate of the NF step. Black arrows indicate raw sewage, green arrows indicate effluent and red arrows indicate losses due to the discharge of treatment residuals or irrigation efficiency.

5.2.4 Monitoring Scheme

The monitoring scheme is important to be able to assess the performance of the treatment steps and check compliance with the set standards. Based on the set standards discussed for the water quality, treatment residuals and operational parameters of the treatment set-up, the monitoring scheme depicted in Figure 17 is established. The operational parameters are continuously monitored in order to ensure smooth operation. Deviating measurement can help indicate damages or need for regular maintenance. The water quality parameters help to provide insight in the treatment efficiency of the different treatment steps and are used to see if the water meets the set standards. Moreover, monitoring of parameters such as temperature, pH, conductivity and hardness is needed, since they can influence the performance of the subsequent treatment steps. Most parameters can and should, especially during the first phase of operation, be monitored continuously. After which, some measurement could be proven redundant. Since an accurate measurement of BOD will take 5 days of laboratory testing, measurements should only be done periodically. TOC & COD are measured to give an indication of the BOD content in real time to be able to act fast when too high BOD concentrations are measured and prevent the water from being used for irrigation. At a later stage, it could be possible to predict the exceedance of standards based on the raw sewage quality. The relation between BOD and COD and TOC should be derived based on tests. As part of the monitoring of the irrigation system, soil moisture meters have been added in order to be able to accurately predict the water demand of UGS in real time and provide the necessary amount of irrigation. Besides, they can be used to measure the performance of the irrigation system (Martínez & Reca, 2014).

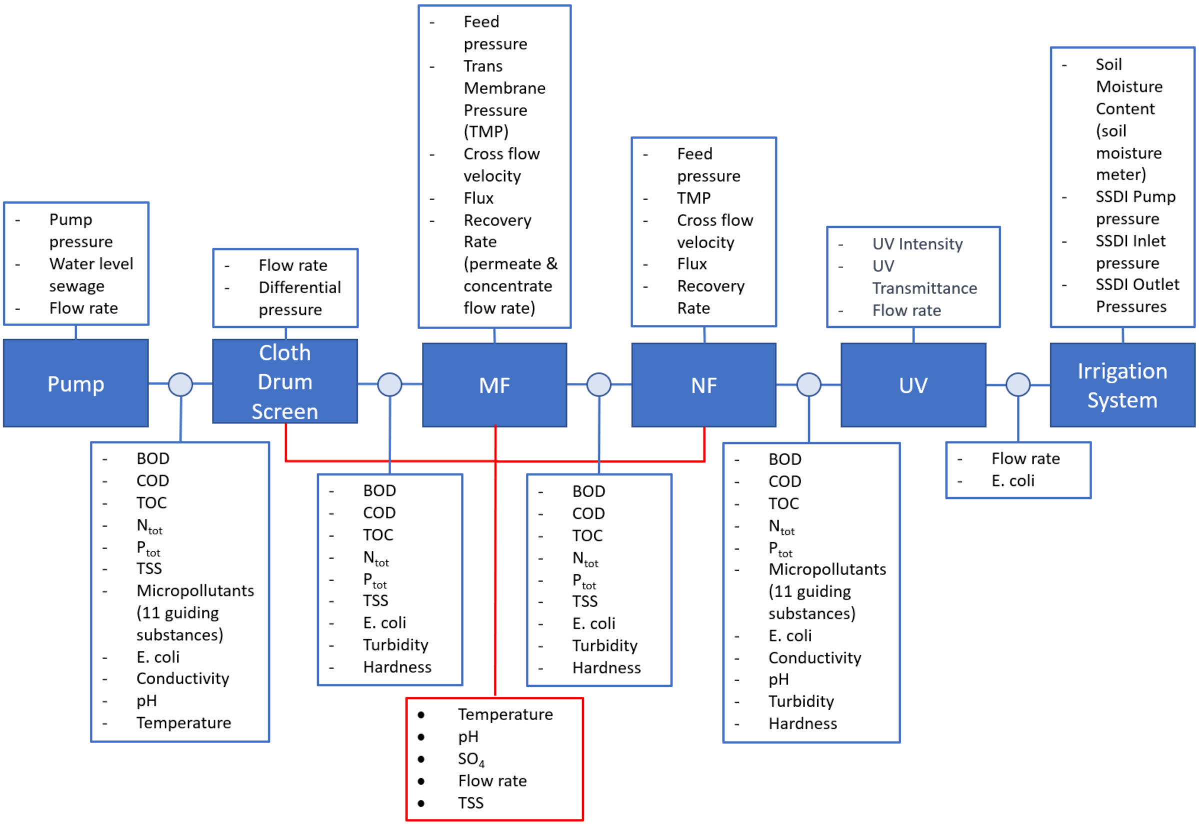

Figure 17 Monitoring scheme of the SWH-unit including both operational and water quality parameter. Operational parameters are placed above the process steps, water quality parameters are placed below. The blue boxes indicate measurements of the effluent water while the red box indicates the treatment residuals.

5.2.5 Cost, Size and Energy Considerations

Estimation of the investment costs

Based on a database from Witteveen+Bos a first estimation of the investment cost for a SWH-unit with a capacity of 2 m^3/h of effluent (based on a recovery of the NF of 50%) has been made. The results are converted to the needed capacity of 2.5 m^3/h and depicted in Table 12 on the next page. This information is supplemented with the available information about the size of the component and an estimation for its energy use. Since the SWH-unit is an innovative concept a short depreciation time of 10 years is assumed. The interest rate is set to 4% and inflation is not considered. Straight-line depreciation results in an annual CAPEX of about €10200 which is roughly €4,50 per m^3 irrigation water. Assuming the yearly water demand of the Vondelpark based on the calculations in sub-section 5.1.2 of 2256 m^3.

The investment cost are relatively low compared to the studied reference projects when comparing the capacity of the conceptual design (60 m^3/d). However, the annual CAPEX (in €/m^3) is considerably higher than the studied reference projects. This can be explained by the fact that the yearly water demand is (much) lower in the Netherlands than in Greece or Australia. The SWH-unit at the Vondelpark will not operate at full capacity over the entire operation period from April-September. If the SWH-unit would produce irrigation water constantly at full capacity and with a maximum recovery (23 hours a day at 3.5 m^3/h) over the entire operation period this would result in nearly 14700 m^3 of produced water. Hereby lowering the CAPEX to just around €0,70 per m^3.

Further reduction of the CAPEX can be achieved if the operating life of the SWH-unit could be extended to 15 years. Again applying a straight-line depreciation (with 4% interest rate) over this period an annual CAPEX of €8250 can be attained. This equates to a cost of roughly €3,60-3,70 per m^3 for the Vondelpark water demand (2256 m^3). If the maximum yearly production of the SWH-unit (14700 m^3) is considered, the CAPEX is reduced to approximately €0,50-0,60 per m^3.

Total Energy Use and Solar Energy Potential

Based on the estimation of the energy use of the SWH-unit displayed in Table 12, 1.5 kWh per m^3 of produced irrigation water is deemed to be a reliable assumption of the energy use. Compared to the reference projects, the energy use is relatively low. This is in part due to the fact that neither RO or an MBR is applied, which both have high energy use (Singh, 2015). Based on the yearly irrigation demand from Table XXX is subsection 6.1.2, the total yearly energy need would be approximately 3400 kWh. Next to a connection to the energy grid it is conceivable that the SWH-unit can be equipped with solar panels. Hereby green energy can be provided and an energy connection should not have to be considered for the location of the unit. This also would further contribute to the sustainability of the SWH-unit, which was pointed out by one of the stakeholders as an important aspect for implementation (see Chapter 8). The average energy yield of solar panels (with a capacity of 360 wp) during the dry period from April-September is approximately 230 kWh (Regionaal Energieloket, 2023). 15 solar panels would thus be required to fully meet the energy demand of the SWH-unit. Based on their size of 1776x1052x35 mm (standard for 360 wp), just 8 solar panels could realistically be fitted on top of the container meaning that an energy connection remains necessary. Furthermore, it should be noted that the actual energy yield would be dependent on the orientation of the solar panels with regards to the sun, potential obstructions (for instance due to greenery) and the slope on which they are installed. Moreover, this would require additional electrical components and to ensure operation even when solar energy is not generated, battery packs are required which would also require a considerable amount of space in the container. The installation of solar panels could also have implications for the transportability of the SWH-unit, since the height is increased and lifting of the container might be obstructed. These implication and the potential of using solar based on costs is not further investigated as part of this research.

Table 12 A first estimation of the investment cost, size and energy use of the conceptual design of the SWH-unit.

Component (Supplier)	Costs	Remarks	Size (LxWxH) (mm)	Estimation Energy Use per m^3 Output	Additional Sources
Coarse filter feed pump (Nijhuis)	€ 1.000	Estimates based on several pumps	291x291x393	0.22 kWh/m^3	(Duijvelaar Pompen, 2023)
Cloth drum screen NDF200 (Nijhuis)	€ 3.500	Pore size: 80-160 micron; Capacity: 5 m^3h	2600x1000x 1800	0.22 kWh/m^3	(T. van den Einde, personal communication, 30 May 2023; Nijhuis Industries, 2017b)
Cartridge filters (Jotem)	€ 2.000	Pore size: 0.2 micron; Modular; Size estimate based on several models	800x400x300	0.2 kWh/m^3	(Singh, 2015; Fluytec, n.d.)
4 800 Dalton dNF modules skid mounted (NX Filtration)	€ 17.500	Modular	1678x163x 163 (1 module)	0.5 kWh/m^3	(Sewerin, et al., 2021; Visser, et al., 2023; NX Filtration, 2020)
Optional UV-unit 254 nm lamp (double unit) (Van Remmen Technologies)	€ 1.500	Additional information Based on the Waste-series UV-lights; Modular	68x68x1250 (light) 280x150x90 (control box)	0.05 kWh/m^3	(Van Remmen, 2022)
4 IBC Storage Tanks (Huchem)	€ 400	Pricing based on used containers	1200x1000x 1160	-	(Huchem, n.d.)
Container 30 ft (Jotem)	€ 9.750	Equipped with ventilation, cooling and heating; Ready for transport	Outside: 9110x 2440x2590 Inside: 8980x 2330x2380	-	(Pieterse, n.d.)
Electrical Components and Processors for operating and monitoring systems	€ 3.200	Estimate 12.5% of subtotal; rounded to the nearest hundred)	-	Estimate 20% of subtotal of the energy use: 0.24 kWh/m^3	-
Piping and Appendages	€ 1.300	Estimate 5% of subtotal; rounded to the nearest hundred	-	-	-
Subtotal	€ 40.200	rounded to the nearest hundred	Excluding Container size: 7 m^3	1.43 kWh/m^3	
Project Support, Engineering, Permits and Overhead	€ 20.100	Estimate 50% of subtotal; rounded to the nearest hundred			
Tax	€ 8.400	21%; rounded to the nearest hundred			
Total	€ 68.700	rounded to the nearest hundred			

Size and Space Considerations
The inside volume of a 30 ft. container is nearly 50 m^3. The total volume of the components is approximately 7 m^3. This does not yet include spacing, electrical components and monitoring systems, piping and clear (walking) space which is needed for maintenance. However, considering the significant difference it can be concluded that a 30 ft. container is spacious enough and could even leave room. This allows for the modular filtration treatment components to be added to increase the capacity of the SWH-unit (over time). However, the selected cloth drum filter currently has a maximum capacity of 5 m^3/h and thus would require replacement by another model if the demand exceeds 3.5 m^3/h. Potentially the footprint of the SWH-unit could be reduced by applying a 20 ft. container, which has a volume of about 33 m^3.

Estimation of the operational costs
The operational costs are determined by four main components: labour, energy, chemical use and maintenance (and replacement) costs. General key figures for the operational costs of the different applied treatment technologies do not provide a valid estimation of the operational costs as they are based on conventional WWTP for which significant scaling advantages apply. Therefore, the operational costs are determined based on the four main components.

Energy costs are based on the price level of January 2023 which is €0,40 (Regionaal Energieloket, 2023). With an energy use of 1.5 kWh/m^3 the energy costs will be €0,60/m^3. This comes down to €1360 per year

The labour costs are derived from a yearly salary of €50.000 which is considered in conformity with the market for specialised personnel (Visser, et al., 2023). Based on the Flemmington Racecourse reference project, 5 hours a week on average was deemed to be a conservative estimate of the labour needs. This results in a total of 130 hours of labour over the operation time of 6 months. 1 FTE is equivalent to 1720 hours a year (Ministerie van Sociale Zaken en Werkgelegenheid , n.d.). Therefore the labour costs are estimated to around €3800 per year.

The chemical costs can be determined based on the report by Visser et al. (2023) for which the chemical use is determined based on a capacity of 7.700.000 m^3 treated waste water per year compared to the 4533 m^3/year of the SWH-unit. Based on the chemicals used for the maintenance of the NF the total chemical costs are roughly €362. Table 13 displays the costs per chemical.

Table 13 Breakdown of the chemical costs as a result of maintenance of the SWH-unit.

Chemicals	Yearly Use	Cost/kg	Total Costs
NaOCl	63 kg	€ 3,27	€ 206
NaOH	45 kg	€ 0,46	€ 21
H_2SO_4	137 kg	€ 0,24	€ 33
Citric Acid	11 kg	€ 9,20	€ 103

General maintenance and replacement costs for conventional large scale WWTP are commonly assumed to be 3% of the investment costs each year (Visser, et al., 2023). Since this treatment set-up is more experimental and maintenance of certain components (especially NF) will have a larger impact on the costs this percentage will probably be higher for the SWH-unit. However, since the SWH-unit will only be in operation half of the year, 3% is still seen as a fair assumption. This results in approximately €2.100 of maintenance costs each year.

By adding all individual components of the operational cost the annual OPEX is determined to be about €7600 which results in €3,40 per m^3 of irrigation water based on the yearly water demand of the Vondelpark. This is significantly higher than the studied reference projects. This can partially be explained due to the steep increase in energy prices and overall inflation over the past years. While the

OPEX is thus quite considerable, it should be noted that all parts of the OPEX were based on conservative estimates.

Moreover, the maintenance costs (25%) and the labour costs (roughly 50%) currently make up more than 75% of the total OPEX while these estimates do not necessarily increase if more water is produced. Increasing the capacity of the SWH-unit and a further reduction of labour needs can therefore reduce the OPEX significantly. For example, if the SWH-unit would produce irrigation water constantly at full capacity and with a maximum recovery (23 hours a day at 3.5 m^3/h) over the period from April-September this would result in nearly 14700 m^3 irrigation water. The total OPEX would then be about €17800 and thus just €1,20 per m^3.

6. Potential Impact of SWH

Based on the case study of the Vondelpark the potential impact of SWH can be extrapolated to the city of Amsterdam. This is done based on two aspects. First a comparison of the potential direct economic benefits and costs as a result of scaling-up the SWH efforts is done. Secondly, the potential implication on plant and soil health are discussed.

6.1 Direct Economic Benefits and Cost Comparison

To compare the cost to the direct potential economic benefits of SWH, the year 2018 has been used as a benchmark. It was otherwise hard to estimate the direct economic benefits based on the available information as precise locations of damages and specific restoration costs are not well documented. The direct economic benefits consist of the damages and additional cost to protect UGS during dry periods. In 2018 water shortages resulted in approximately €1.400.000 restoration cost for UGS despite spending an additional €475.000 on prevention measures (Gemeente Amsterdam, 2020a). Therefore, €1.8750.000 are considered the potential benefits of the implementation of SWH. As determined in subsection 6.2.5 the total cost of SWH will be roughly €7,90/m^3 for the irrigation of the Vondelpark.

The cost of the most commonly used alternative in Amsterdam, irrigation with surface water distributed using watertankers (i.e. trucks with large water storage), is determined by the National Knowledge and Innovation Programme Water and Climate (NKWK) to be €860 - €1060 for 6 m^3 of irrigation water (Vermeulen, 2021; Noome, et al., 2023). The exact cost depend on the distance between the surface water and the location of the UGS to be irrigated. Since Amsterdam in general has surface water nearby the lowest estimate is applied which comes down to €143/m^3.

Drinking water is another alternative source. In 2023 drinking water will be priced at €1,03/m^3 (Waternet, 2023). This price is excluding the fixed costs that have to be paid for the maintenance of the piping which depend on the consumed volume. These cost are around € 873 for 1.000 - 10.000 m^3 per year (corresponding to the situation in the Vondelpark), €7.071 for 10.000 - 100.000 m^3 per year and consumption over 100.000 m^3 per year will cost €57.300. It is assumed that the total water use for UGS in Amsterdam will determine the amount of fixed cost that have to be paid for the calculation. However, based on the forecasted drinking water shortages by Waternet from 2030 and beyond and the 'verdringinsreeks' (distribution priority sequence), it should be noted that this alternative will probably not be available in the near future (Rijkswaterstaat, n.d.; Waternet, 2021).

The total water need of Amsterdam is extrapolated based on the water quantity requirement of the Vondelpark study area and the proportion of the park's area (460.533 m^2) and the total area of UGS in Amsterdam (25.455.655 m^2). This results in a water need of approximately 124.700 m^3 for a year whereby nearly 133 ha of vulnerable UGS can be protected. If this is possible of course depends on local characteristics, such as the availability of sewer pipes with sufficient flow nearby each UGS. However, since the minimal daily flow over the year 2021 and 2022 at the WWTP Amsterdam West was 112.000 m^3/day, it can be assumed that there is sufficient raw sewage available for SWH on a large scale. For the different water sources we can now compute the costs to prevent the damages and additional spending on preventive measures of €1.875.000. In Table 14 an overview of the total annual costs and net benefits (i.e. direct economic benefits minus the costs) is displayed.

Table 14 Overview of the total annual costs and net benefits (i.e. direct economic benefits minus the costs) rounded to the nearest thousand for the irrigation of public UGS in Amsterdam with SWH, surface water or drinking water.

Alternative	Cost per m^3	Total Cost	Net Benefits
SWH	€7,90	€985.000	+€890.000
Surface Water (Watertankers)	€143	€17.832.000	-€15.957.000
Drinking Water	€1,03 (+ €57.300 fixed cost)	€186.000	+€1.689.000

Based on these results we can conclude that SWH can be considered a cost-effective water source. Based on these findings more than €700.000 could potentially have been saved in the year 2018 by implementing SWH on a large scale. Moreover, benefits of well-irrigated UGS, such as the cooling effect and health benefits, can further increase the economic gains, although quantification of these gains was outside the scope of this research. SWH can be considered a significantly less costly alternative for the irrigation of UGS than the use of watertankers that distribute surface water. The same amount of irrigation supplied by SWH with watertankers would result in additional cost of nearly 16.000.000 compared to the direct economic benefits. Besides, the quality of the surface water and potential restriction of its use make it a less reliable alternative. However, it should be noted that a watertanker is also able to irrigate single trees alongside canals in the city whereas SWH only provides a solution for larger UGS. Further improvements to the SWH operation could be made by increasing the recovery rate and the addition of larger water storage, which would allow for constant production at full capacity. This could even lower the cost to nearly €2,10 per m^3 in the future (a reduction of 77%) and resulting in net benefits of over €1.600.000. Drinking water remains the most cost-effective alternative with net benefits of up to €1.700.000. However, for the aforementioned reasons, it can be considered less reliable as a source, especially in the future.

6.2 Effects on Plant and Soil Health

The use of reclaimed water irrigation can have both a positive and negative impact on plant and soil health. The potential negative environmental impacts are one of the main concerns of stakeholders regarding SWH, as is further discussed in Chapter 7. This section discusses several positive and negative effects on plant and soil health in relation to the proposed conceptual design in this research. Hereby, special attention is given to the effects of a BOD and N concentration in the water from the SWH-unit which exceeds the selected standards.

Impact of Nutrients (N & BOD)

Studies of both agricultural and UGS irrigation with reclaimed waste water in China, indicate the positive impact of water with relatively high BOD and N concentrations on both plant and soil health, when compared to tap water irrigation (Chen, Lu, Pan, Wang, & Wu, 2015; Lyu, Wu, Wen, Wang, & Chen, 2022; Wang, Li, & Li, 2017). N is a necessary nutrient for plant growth and health. BOD provides energy for important soil microbes and can increase the organic matter content of soil, which for instance increases its water holding capacity and overall soil quality (Lyu, Wu, Wen, Wang, & Chen, 2022; Zalacáin, Bienes, Sastre-Merlín, Martínez-Pérez, & García-Díaz, 2019). The concentrations of N from the studies exceeded the set standard for the current research nearly 2-5 times (26-70 mg/l), which is more than to be expected from the SWH-unit. The BOD concentration from the studies was up to 2 times the set standard (50 mg/l), which is a reasonable maximum concentration for effluent of the SWH-unit.

Under these conditions, nutrient conditions improved as a result of a slight increase in available nitrogen and organic matter (as a result of BOD). Additionally, biological activity in the soil was positively impacted. Over a period of 9 years soil conditions were improving, indicating a positive effect even under long term irrigation with reclaimed water (Chen, Lu, Pan, Wang, & Wu, 2015). Furthermore, no noticeable negative effects were observed over the years as a result of the slight increase in N and BOD in the soil.

However, no excessive nutrient (i.e. BOD and N) built up was found as a result of short and long term (up to 9 years) irrigation of UGS (Chen, Lu, Pan, Wang, & Wu, 2015). This can be explained by the fact that N and organic matter are present in reclaimed water in a form which can be easily taken up by plants and soil microbes. As a result of excessive build-up, nutrients could leach into ground and surface waters, which was specifically pointed out as a main concern of stakeholders in Chapter 7. This risk can be further diminished by using drip irrigation systems as their gradual irrigation results in less leaching compared to for instance sprinkler irrigation (Chen, Lu, Pan, Wang, & Wu, 2015). Moreover, organic matter will increase the retention of N in the soil.

The addition of N to the irrigation water can potentially limit the use of fertilizers as well (Chojnacka, et al., 2020; Wang, Li, & Li, 2017). Hereby, it is important that the amount of N (but also

P and K) provided by the reclaimed water is at least deducted from the use of conventional fertilizer (Serra, et al., 2023). Especially for agricultural applications of SWH, these nutrients are a valuable addition and could provide great benefits in terms of yield as well (Lyu, Wu, Wen, Wang, & Chen, 2022; Serra, et al., 2023). A specific load of N for UGS is not established. Based on the critical N deposition value of Natura 2000 and agricultural land the N load should be in between 10-20 kg/ha/year and 170 kg/ha/year (Wageningen University & Research, n.d.; RVO, 2019). For perspective, based on the Vondelpark situation (2256 m^3 irrigation over an area of 2.4 ha) and the conservative assumption of an average load of the 15 mg/l N (which is the set standard), the N load as result of SWH will be roughly 14 kg/ha/year. Hence, it is expected that the impact of N in the SWH effluent is manageable. Moreover, research by Nashikkar & Shende (1988) found that there is no direct negative impact of irrigation with reclaimed water with concentrations of up to 400 mg/l BOD.

Impact of Salt Accumulation

Besides the potential effects of nutrient build-up, salt accumulation is named in scientific literature as the other main negative effect of reclaimed water irrigation. Accumulated salts can harm plants and also lead to a reduced infiltration capacity of the soil or salinization of ground and surface waters due to leaching (Chen, Lu, Pan, Wang, & Wu, 2015; Zalacáin, Bienes, Sastre-Merlín, Martínez-Pérez, & García-Díaz, 2019).

An increase of the salt content of the soil and plants was evident based on a research which studied the impact of reclaimed water compared to drinking water irrigation of UGS in Madrid, Spain (Zalacáin, Martínez-Pérez, Bienes, García-Díaz, & Sastre-Merlín, 2019). However, even after 15 years the increase in salts was far from posing a risk to plant and soil health (Zalacáin, Martínez-Pérez, Bienes, García-Díaz, & Sastre-Merlín, 2019; Lyu, Wu, Wen, Wang, & Chen, 2022). . Furthermore, another study showed that the negative effects of soil salinity were found to decrease over time (Lyu & Chen, 2016). Nonetheless, it is advised that salt sensitive plants should receive extra attention to prevent adverse effects (Zalacáin, Martínez-Pérez, Bienes, García-Díaz, & Sastre-Merlín, 2019). For instance, this can be done by applying additional irrigation water, up to around 9%, that flushes out salt from the rootzone. The same effect can be achieved by a rain event or irrigation from another water source (Rahman, Shahrivar, Hagare, & Maheshwari, 2022). Another way to prevent salt accumulation would be the apply RO as a treatment step in the SWH-unit. Since, no information was available that would indicate excessive salinity of the treated Amsterdam sewage, it was opted to apply NF instead of RO, which is also able to reduce the salinity somewhat.

As a result of leaching, salts might end up in ground or surface water. This is especially important for Amsterdam as salination of ground and surface waters already occurs as a result of seawater and brackish groundwater intrusion. Unfortunately, to the best knowledge of the author, no studies exist that report on the risks of salt leaching from soils to ground or surface water. Based on this and the fact that the amount of irrigation water is very small compared to the amount of surface but especially groundwater, salination of these waters is not expected as a result of SWH. However, since salination of ground an surface water can harm the entire urban hydrological cycle, periodical monitoring could be useful to rule out any negative effects.

Impact of Micropollutants

Another important impact on soil and plant health can be caused by the micropollutants that remain in the water after treatment. A differentiation can be made between heavy metals and contaminants such as drug residues, plastics and pesticides. Excessive amounts of heavy metals can redcue plant growth and activity of soil organisms (Lyu & Chen, 2016). Other emerging micropollutants can have a wid range of negative effects as they vary greatly. Most notably,

Heavy metal accumulation was not significant over a short-term irrigation, but only after a significant period of time (approximately 30 years) (Lyu & Chen, 2016; Wang, Li, & Li, 2017). Even under long-term irrigation the increase in heavy metals in the soil was only small and did only lead to negative in extreme cases (for instance with direct raw sewage irrigation) (Wang, Li, & Li, 2017; Chen, Lu, Pan, Wang, & Wu, 2015). Moreover, often the input of heavy metals as a result of the use of reclaimed water is relatively small compared to the atmospheric deposition and other external sources (Chen, Lu, Pan, Wang, & Wu, 2015). Therefore, heavy metals will presumably not pose a serious risk.

Most emerging contaminants can be rapidly transformed or removed as a result of chemical, biological and photodegradation (Lyu, Wu, Wen, Wang, & Chen, 2022). The same processes which give the ability to constructed wetlands to remove micropollutants. An example are PAH's (polycyclic aromatic hydrocarbons), which are highly biodegradable and therefore form no risk to plant or soil health. However, in other cases the continuous input as a result of irrigation could exceed the removal capacity. Especially, pharmaceutical and personal care products tend to accumulate in soils, which could negatively impact microorganism in the soil. However, the understanding of the effect and degradation of such contaminants is limited and can therefore not be predicted with certainty (Lyu, Wu, Wen, Wang, & Chen, 2022). Soil testing could provide more insights into these processes and is needed to ensure no negative environmental impact as a result of micropollutants.

All in all, studies show that short term irrigation with reclaimed water will not lead to any negative effects. However, long-term irrigation (continuous over multiple years) can lead to build-up of nutrients, minerals, heavy metal or micro-pollutants over time. All can result in a negative impact on plant and soil health or even ground or surface water. Salts (i.e. minerals) and N form the main risks (Chen, Lu, Jiao, Wang, & Chang, 2013). However, for all negative effects it is likely that they can be mitigated or prevented. One of the most important factors for this is the irrigation amount which is applied to the UGS (Wang, Li, & Li, 2017; Chen, Lu, Jiao, Wang, & Chang, 2013). Considering the fact that the water need in the Netherlands is in general significantly less than for the studies discussed in this sub-section (e.g. from China and Spain), it can be expected that irrigation with reclaimed water will not lead to an insurmountable negative impact. Moreover, the irrigation amount will vary over the years and thus the pollutant load will often be less during less dry years. Therefore, in years which are less dry the soil (and plants) have time to recover from the additional loads of reclaimed water. Moreover, studies focussing specifically on UGS irrigation have reported less negative effects of irrigation with reclaimed water than for agricultural irrigation, presumably due to less intensive irrigation practices (Chen, Lu, Pan, Wang, & Wu, 2015; Zalacáin, Bienes, Sastre-Merlín, Martínez-Pérez, & García-Díaz, 2019). However, as the severity of the effects of using reclaimed water for irrigation of UGS heavily relies on site specific characteristics such as soil characteristics, plant diversity and effective quality of the reclaimed water, risks cannot be eliminated with absolute certainty. Therefore, periodical soil testing is highly recommended to mitigate potential build-up risks of nutrient, minerals, heavy metals or micropollutants over a longer period as a result of SWH. As an additional benefit, this could provide more insights into the actual risks.

7. Perceptions of Stakeholders

As part of this research semi-structured interviews have been conducted to gain insight into the perception of the two (most important) stakeholders: Waternet and the municipality of Amsterdam. Two interviews have been conducted with Marcel van Uitert (advisor asset management and analysis at Waternet) and Niels Al (coordinator water and climate adaptation at the municipality of Amsterdam). Based on the analysis of these interviews, of which coded transcription can be found in Appendix E, this chapter will discuss the barriers, stimulators and opportunities perceived by stakeholders. Hereby, the large scale implementation perspective (i.e. feasibility and viability) of SWH in Amsterdam can be explored which will help in determining the potential impact.

The management and responsibilities for the operation of the units is not something that both stakeholders are eager to take on and they refer to each other. Currently the operation of such systems does not fall under the responsibilities of Waternet, as irrigation of UGS is the responsibility of the municipality. While, at the municipality there is no expertise on the operation of such units. However, the municipality could potentially assign this as a new responsibility to Waternet. However, a public private partnership were the municipality hires a private party, for instance the technology provider(s), to operate the units is deemed a more suitable and feasible alternative, accepted by both stakeholders. This would also allow the municipality to make use of such a service only when needed.

Other potential applications should be investigated further to increase the potential of SWH. One can think of industrial or household applications. Especially since this increases the profitability of the units as they could provide water all year round and not only during dry periods, which makes the operation of SWH-units by a third party more realistic. Besides, involving commercial parties, such as developers, could accelerate the innovation process.

Next to the management and responsibility for the operation of the SWH-unit, cost are seen as the most important decision making criteria for larger scale implementation. For the municipality it is important to have an estimate of the cost of water production compared to the prevented damages, as is done globally in section 6.1. For a more accurate and in depth analysis, more information is needed regarding the location of vulnerable UGS and specific damages that are expected to occur or have already occurred in the past. Currently, the municipality is working on a heat and drought plan for their UGS, for which this will be mapped (J. Hermans, personal communication, 26 June 2023). Besides, within the decision-making process, a further comparison with alternatives for SWH (e.g. rainwater harvesting) is necessary for each location to ultimately decide on the implementation. Moreover, this should consider potential combinations of measures, for instance where SWH can be used to supplement rainwater storage. Public-private partnerships could also help limit the investment costs for the stakeholder(s). On the other hand, operational costs will increase since the third party operator will aim to make a profit.

For the operation of the SWH-unit most concerns are related to the quality of the effluent. Main concerns that need to be addressed before large scale implementation are the risk to human health and the environment. Human health risks can be minimised by applying (subsurface) drip irrigation and adequate treatment with UV, as discussed in this thesis and should therefore not form a major barrier. However, the impact on soil and plant health as well as potential contamination of ground and surface water should be tested extensively during (a) pilot project(s). Preferably over a longer period of time. Besides, the potential risks are highly dependent on the locational characteristics. The fact that such technology is already applied in the Mediterranean and Australia provides endorsement for SWH and makes implementation more realistic. However, negative environmental impact should be further ruled out.

The use of SWH on a larger scale is seen as a last resort measure and is less preferred than using larger scale centralised treatment systems and reuse. However, it is considered as a good opportunity when other sources are unavailable or use is restricted. Besides, it does fit with the circular economy goals of the stakeholders. To ensure that it fits within the sustainability goals, low energy use or the use of green energy and a small CO_2-footprint is important and should be further addressed.

However, both acknowledge the potential need for new climate-proof due to an increasing water demand (of UGS). Also considering the intention of the municipality to increase the amount of greenery. This is further stimulated by the increasing (fresh) water scarcity and the need for new water sources. Rules and regulations that prevent the use of other water sources, for instance as part of the Water Framework Directive (Kaderrichtlijn Water in Dutch), can stimulate the implementation of SWH in the future.

Nevertheless, stakeholders still perceive the challenges posed by drought as less of a priority than nuisance posed by the excess of water in Amsterdam. It was pointed out that drought problems in Amsterdam are less severe than in the Eastern part of the Netherlands and there are doubts if SWH is necessary every year. Moreover, other alternatives, such as rainwater harvesting and storage currently receive more priority. SWH is seen as a more last resort measure which will maybe become more interesting int the future (i.e. 10 years). Especially if Amsterdam goes through several dry years.

Finding space for such a container remains a challenge in the existing dense urban environment of Amsterdam. Therefore, both stakeholders mentioned that the implementation perspective is more positive when applied during new development or renovation projects. In that case SWH can be fitted into new buildings or a strategic location can be thought of up front. In case of the use of SWH-units in the existing urban environment, an aesthetic appearance of the SWH-units, with the help of art or additional greenery, can help increase the willingness to implement them. Besides, it can be an opportunity to spread awareness for the water need of UGS and educate the public on the possibilities of waste water reuse, which will also facilitate a positive public perception.

Furthermore there were some questions raised about the capacity of SWH-units. Irrigating a whole park, such as the Vondelpark, including all grass, would require large and therefore less desirable SWH-units. It was also pointed out however that SWH was a more suitable solution when the focus is on irrigating more vulnerable and young plants. As this fits better with the capacity of the unit and is the most important factor in reducing the damages to UGS caused by droughts.

Concluding, an overview of the 6 most important discussed opportunities and barriers presented in this chapter are displayed in Table 15.

Table 15 Overview of the 6 most important barriers and opportunities as discussed during the stakeholder interviews.

Barriers	Opportunities
Operational Responsibility	Public-private partnerships
Testing of potential environmental impact	Household and industrial applications
Cost	Locations: newly developed/renovated areas
Uncertainty about the need for SWH	Fits with circular Economy
Integration in existing urban area	Additional climate-proof water source
Human health risk (and public perception)	Locations: part of Netherlands with sandy soils

8. Discussion

In this Chapter the results of this research are discussed and interpreted in relation to the main research question and overall objective of the research in section 8.1. In section 8.2 the limitations of this research are presented.

8.1 General Discussion of the Results

This research has investigated how SWH can be applied to provide a reliable fresh water source to support UGS in Amsterdam. The overall aim was to provide a conceptual design example of how SWH could be applied in the Amsterdam context to uncover what kind of impact can be achieved and advise on how SWH can be implemented.

This research demonstrates that SWH can help to tap into a new reliable and climate-proof water source for UGS. In the introduction of this research it was outlined how conventional water sources are unlikely to meet the (future) water demand of UGS during dry periods. This means that every drop of water counts for the protection of UGS, even more so in light of the exacerbation of dry periods as a result of climate change. Especially, for a city such as Amsterdam, where additional effort and investment is made to increase UGS and capitalise on its many social, economic, biodiversity, ecology and climate adaptive benefits (Gemeente Amsterdam, 2020a; Gemeente Amsterdam, 2020b).

On top of that, this water source can be utilised outside of dry periods. As came forward during the stakeholder interviews, SWH can be used for household and industrial applications as well. This can help to increase the commercial value of SWH, lower the cost per m^3 and attract more and more varied stakeholders.

The value of SWH is not limited to economic benefits or benefits as a result of well-irrigated UGS. Besides providing a new reliable and climate-proof water source, SWH can help to reduce the use of drinking water, which availability will be under serious pressure from 2030 (Waternet, 2021; Meershoek, 2019). Furthermore, water reuse through SWH contributes to a circular economy. It fits with the IUWM approach, which is applied by the most important stakeholders (i.e. Waternet and the municipality of Amsterdam), and the ideal of a Water Sensitive City as discussed in the theoretical framework. The results from section 6.2 indicate that nutrients in the irrigation water from SWH can be used as a resource and help to reduce the use of fertilizer.

The results of this research indicate that the technology exists for SWH to be able to meet the water demand and likely comply with selected standards. The choice to incorporate innovative NF membranes in the conceptual design of the SWH-unit has created some uncertainty about the water quality of the effluent when the raw sewage has relatively high N and BOD loads. However, despite the fact that standards for BOD and N are sometimes exceeded it is unlikely that this will cause any insurmountable negative effects, based on the findings presented in section 6.2. Moreover, besides the treatment steps incorporated in the presented conceptual design, many other treatment steps are used to provide fit-for-purpose water that complies with strict water quality standards (e.g. MBR or RO), as can be seen in section 2.3. Additionally, local characteristics can highly influence the optimal design of a SWH-unit. Applying the same methodology to another case or application could thus lead to a different (conceptual) design. However, the general steps that were taken to come up with the conceptual design presented in this research can be applied to any location or application to come up with an equally fitting solution. Technological advancements can help to further improve the potential for SWH, but it is unlikely that treatment technology will be a significant limiting factor. The fact that (most) membrane filtration techniques are made modular contributes to their suitability for SWH as the desired capacity can be more easily achieved. Furthermore, development of ICT-systems that help with remote monitoring and operation, have further enhanced the potential of smaller scale decentralised water treatment in general (Makropoulos, et al., 2018).

The engineering challenges that remain, go beyond the scope of this research. They are related to actually fitting the SWH-unit into the existing urban environment and integrating it with the centralised sewer and energy network (Makropoulos, et al., 2018). To enhance the deployability of the

SWH-unit this researched aimed to design a mobile unit and minimise its footprint by making use of compact membrane filtration modules. Furthermore, stakeholders identified newly developed or renovated areas as a place where SWH could be more easily fitted in, as the requirements for a SWH-unit can be taken into account during the design of the area. Additionally, newly developed areas are likely to have a larger amount of more drought susceptible young greenery, making them a suitable location for SWH.

Another important aspect is the determination of the most suitable locations for SWH. This research has picked a location for a study area based on irrigation need, whereafter the availability of sufficient raw sewage was checked. However, studies, such as the one by Makropoulos et al (2018) and Psarrou, Tsoukalas, & Makropoulos (2018), have adopted modelling tools which take into account multiple criteria to optimise the location of SWH in a city. For instance water demand of UGS, availability of raw sewage and potential H_2S build-up in the sewer caused by the discharge of treatment residuals are considered. Such decision making tools can assist in optimising the potential impact of SWH and ensure the effectiveness, robustness and safety of the operation.

Based on the results of this research three main barriers for larger scale implementation can be identified: (1) the lack of a regulatory framework, (2) extensive water quality and environmental testing and (3) operational responsibility. While these barriers are significant and require a significant amount of time and investment, current leading countries, such as Australia, show they can be overcome.

Firstly, the lack of a regulatory standards for SWH, or any other form of water reuse, for the irrigation of public UGS causes difficulties in securing a permit and discourages further research and implementation (H. K. Gilissen, personal communication, 12 May 2023). For this research, water quality standards were therefor approximated. Legally binding standards would provide clarity and guidance for selecting proper treatment steps. The establishment of specific standards for different applications (for the support of UGS and household or industrial applications) based on the associated risks would be optimal (Outhuijse, Melchers, & Gilissen, 2022). Standards should not only be drafted for the water quality but also for the discharge of treatment residuals, to able to better identify suitable streams (i.e. pipes) for the extraction of raw sewage. Furthermore, a clear regulatory framework can be supported by clear guidelines and compilation of overall best practices, as is for instance done in Australia (Sydney Water, n.d.). This can be done on a national or European level. With water reuse receiving more attention in the Netherlands as well as in the EU, currently the first basis of an adequate regulatory framework is under development (Outhuijse, Melchers, & Gilissen, 2022).

Secondly, to comply with potential quality standards and to minimise potential environmental risk, SWH will require extensive testing. The planned pilot project of SWH in Amsterdam as part of the AquaConnect research programme can be considered an example of this. New treatment set-ups, such as the one from the conceptual design, should be monitored to gain better insight in their treatment efficiency and to improve overall operation. Especially, the potential negative environmental impact would require testing over a couple of years before they can be ruled out, as the impact of irrigation with reclaimed most likely only emerges after a longer period. From a stakeholder perspective, ruling out the potential negative effects on soil and plant health or on ground and surface water quality is absolutely necessary before a larger scale implementation can be envisaged. Therefore, action should be taken as soon as possible to set-up long term environmental testing, for instance as part of the planned pilot project to be able to develop and demonstrate the potential of SWH. As discussed in the theoretical framework, the (urban) water sector is slow in adopting innovations, and thus it will take some time and perseverance to build a convincing case

Thirdly, the investigation into the perspectives of the most important stakeholders, Waternet and the municipality of Amsterdam, showed reluctancy to take on the responsibility of operating SWH-units. This is despite the fact that their mutual goals expressed in policy documents such as the 'Omgevingsprogramma Riolering 2022 – 2027' (Environmental Programme Sewage) endorse experimentation and implementation of local decentralized water treatment and supply in general (Waternet, 2022). To overcome this barrier, public-private partnerships were identified as a potential solution. Private companies, for instance treatment technology providers, would take on the operation of the units on behalf of the governmental organisation. In order to make this attractive for private parties, such arrangements must be economically profitable for the private parties (Makropoulos, et al., 2018). As mentioned before, exploring the opportunities for household, industrial or other commercial applications of SWH can help to achieve this goal. To increase the chance of successful implementation of SWH, a network of a (wide) variety of involved stakeholders should therefore be established (Goodwin, Raffin, Jeffrey, & Smith, 2019). This can also assist in establishing a more comprehensive regulatory framework and the ability and willingness to properly test (different) SWH operations.

In many other scientific papers mentioned throughout this paper, public perception was mentioned as one of the main barriers of water reuse in general. Although briefly mentioned by one of the interviewed stakeholders, public perception did not come forward as a large barrier during this study. This can be supported by recent studies which have shown that the Dutch public perception to water reuse is actually quite positive (Barendse, Brouwer, Dijk, & Schriks, 2023; Frijns, Aanvaarding hergebruik water en voedingsstoffen groter dan verwacht, 2021). The studies even considered sewage water as a source for drinking water instead of irrigation. A global comparative study actually showed that this is the least favourable intended use globally, while irrigation was seen as the most favourable (88% compared to 28% for drinking) (Hurlimann & Dolnicar, 2016). Hence, it is likely to assume that the Dutch public perception towards water reclamation for irrigation of UGS is primarily positive.

Overall, SWH shows some significant potential to provide a new reliable and climate-proof water source. The technology exists to create SWH-units that can meet the water demand and potential regulatory water quality standards. Barriers regarding the regulatory framework, extensive water quality and environmental testing and operational responsibility remain and need to be addressed going further. Exploring household and industrial applications and expanding the stakeholder network and involvement can help overcome these barriers and improve the larger scale implementation perspective.

8.2 Limitations of the Research

Although this research was carried out with great diligence, there remain some limitations. To provide an accurate picture of the outcomes of this research the most important limitations are listed and briefly explained.

Firstly, there are some limitations due to the stipulated scope and structure of the research:

- Since there was a focus on the Amsterdam context several applications, such as urban farming and (temporary) plant nurseries, have not been further investigated due to a lack of useful available data or scale. Especially, since these applications can also be exploited commercially there is ground for a future study which focusses on exploring new opportunities that can be created within the Amsterdam context or which already exist outside of Amsterdam.
- Because of the delineation to focus on SWH for the support of UGS there is a wide variety of other (commercial) applications which have not been considered, such as industrial (e.g. food, and beverage, textile and mining) and household applications (drinking water and toilet flushing) (Sewerin, et al., 2021; Ahmad, Ang, Teow, Mohammad, & Hilal, 2022).
- Because of the broad scope of this research, which required a great variety of research tasks not all potential design considerations could be optimised. For instance the placement of the SWH-unit has not been optimised. Studies, such as the one by Makropoulos et al (2018) and Psarrou, Tsoukalas, & Makropoulos (2018), have adopted modelling tools to optimise the location based on for instance water demand of UGS and potential H_2S build-up in the sewer caused by the discharge of treatment residuals.
- The assessment of overall life-cycle sustainability of SWH was only considered in terms of energy use. Further assessment of the sustainability of SWH is important as sustainability is seen as an important decision criterion for the stakeholders.
- The research was structured such that interviews with stakeholders were near the end of the research. However, discussions with them about the implementation perspective also provided several interesting insights for the design. Some of those aspects were already addressed

during the design part or could be taken into accounts afterwards. However, earlier stakeholder involvement could have strengthened the conceptual design further.

Secondly, some limitations can be identified as a result of the execution of the research steps:

- Accuracy of the water shortage model: The calculations for the water demand still make use of transformed weather data based on the 2014 climate scenario's established by the KNMI. However, since then a new IPCC report (Assessment Report 6) has been published which the KNMI currently uses to develop new scenarios. Making use of these updated scenarios could provide different results for the water demand of UGS. Because extensive soil testing was outside the scope of this research, soil characteristics such as the porosity, capillary rise, displacement pressure, pore size distribution index and irreducible moisture content have been determined based on available information about the soil type and certain assumptions. As a result the actual water demand of UGS could differ from the calculations in this research. In practice, the water demand can be more accurately determined using soil moisture meters as part of the irrigation system.
- Assessment of SWH-unit effluent quality: Since direct hollow fibre NF is a relatively new development there was a lack of scientific research into the removal capabilities of several of the set parameters. Moreover, existing information often did not focus on the treatment of waste water or concerned different types of dNF membranes than the dNF80 membranes of NX Filtration applied in the designed SWH-unit. Therefore, there still remains some uncertainty whether the conceptual design can meet the set water quality standards.
- Extrapolation of potential impact: The direct economic benefits were estimated roughly based on the damages and additional cost as a result of the dry period(s) in 2018. Other assessment methods such as developed as part of the National Knowledge and Innovation Programme Water and Climate (NKWK), which was also pointed out as a potential method by one of the stakeholders, were considered. However, the method used to predict the damages to UGS was deemed not accurate by the developers of the tool itself (Klimaatschadeschatter, 2020). Additionally, the cost of surface water irrigation, although retrieved from a credible source, seems disproportionately high. As a result, it does not over a strong comparison with SWH. The analysis of the potential impact for this research was done by extrapolation of one study area while design requirements (e.g. water demand) and other practical considerations are highly site specific. This means that in practice outcomes could be very different, and the economic assessment only provides a rough first estimate. It could for instance be possible that near some UGS, a sufficient raw sewage stream is unavailable. Furthermore, because extensive soil testing was outside the scope of this research and no information about the specific soil composition of (a) UGS in Amsterdam was available. Hence, the analysis of the potential impact on plant and soil health was done more generally. Therefore, no statements about the specific potential impact for UGS in Amsterdam could be made with certainty.
- Reliability of stakeholder perceptions: To uncover the perception of stakeholders only two interviews were conducted. As a result it is harder to generalise the outcome of the interviews as the outcome of the research is more susceptible to the personal interpretations. Despite the best efforts of the researcher it was hard to involve more participants since the contacted stakeholders often did not respond. Especially, the lack of a participant (from the municipality of Amsterdam) with extensive knowledge of UGS (e.g. plant and soil health) can be considered as a limitation to the results describing the stakeholder perceptions.

9. Conclusions

To conclude this research a brief summary of the work done is presented in section 9.1. Hereafter, the key research findings are discussed per research question in section 9.2. The answer to the main research question forms the main take-away of this research. Lastly, in order to build further on this research, several recommendations for future studies are made in section 9.3

9.1 Brief Summary of Work Done

This research has investigated how SWH can be applied to provide a reliable fresh water source to support UGS in Amsterdam. The overall aim was to provide a conceptual design example of how SWH could be applied in the Amsterdam context to uncover what kind of impact can be achieved and advise on how SWH can be implemented. First of all, global reference projects were studied to gain insight into the state of the art of SWH around the world and to uncover its challenges. As a first step towards achieving the research objective, the problem posed by dry periods for UGS in Amsterdam was analysed. Based on this analysis, the irrigation of public UGS was selected as the application of SWH covered in this study. Next, suitable locations were identified, from which the Vondelpark was selected as study area for this research. After that, quality requirements for irrigation water and discharge of treatment residuals were determined. The water demand of the study area was determined by using transformed weather data, taking into account climate change, to model the soil moisture balance. Based on these requirements, a conceptual design of an SWH-unit was developed. To evaluate this potential impact for Amsterdam as a whole, the findings from the study area were extrapolated. The cost of the designed SWH-unit were, for perspective, compared to alternative water sources and the potential direct economic benefits, consisting of prevented damages and additional prevention measures. Furthermore, the potential impact on plant and soil health was evaluated in general. To gain insight into the perspective of stakeholders, interviews were conducted to identify barriers and opportunities of SWH and to be able to make some recommendations for larger scale implementation.

9.2 Key Findings

At the start of this research, the following main research questions was established:

How can the concept of Sewer Water Harvesting be deployed to support sustainable and climate-proof water supply for Urban Green Spaces in the city of Amsterdam to have positive impact on the urban environment?

Subsequently, the research was subdivided into four sub-questions to work towards answering this question:

1. *For what kind of applications could Sewer Water Harvesting be beneficial in Amsterdam?*
2. *How could a Sewer Water Harvesting unit be designed to meet water demand and quality requirements?*
3. *What would be the potential impact if Sewer Water Harvesting is deployed in Amsterdam on a larger scale in terms of plant and soil health and costs and direct economic benefits?*
4. *What are opportunities and barriers from a stakeholders perspective?*

Firstly, four applications were identified to support UGS: irrigation of public UGS for recreation, irrigation of plant nurseries, ground water infiltration and irrigation of UGS for food production. Based on the available data and global applications irrigation of public UGS for recreation was deemed the most suitable to further study. To this end, the Vondelpark was selected as the study area for this research. Especially the protection of drought susceptible and vulnerable young plants is important to minimise damages.

Secondly, a conceptual design of a SWH-unit was made with a treatment set-up consisting of four main steps: fine screening, MF, NF, UV (see Figure 14 on page 33 for a schematization). The design is both modular and can for a large part be automated and monitored remotely. This SWH-unit is mobile, as it fits in a container, and has a maximum capacity of 5 m^3/h and is able to irrigate around 2.4 ha of UGS. The advantage of a mobile SWH-unit is the potential to serve multiple different UGS. Despite the lack of a legal framework for the water quality of a SWH operation, this unit can most of the time comply with a selected set of standards based on relevant regulations for Greece, Australia, the EU and the Netherlands, considering all input and output streams. The reclaimed water for irrigation is best distributed by subsurface drip irrigation to minimise both health and environmental risks and be able to continuously irrigate even when the UGS is used. It should be noted that the design of a unit is highly dependent on local characteristics that influence the water demand but which also pose potential practical challenges. Moreover, several other treatment steps can be applied or added if necessary. However, the approach that was taken to develop the conceptual design presented in this research can be applied to any location or application to come up with a fitting solution.

Thirdly, the net benefits of SWH are positive when the Vondelpark case study is extrapolated to the whole of Amsterdam and compared to the cost of the damages and additional preventive measures of the dry period in 2018. It should be noted that this extrapolation only provides a rough first assessment, as a SWH operation and its effectiveness relies for a large part on local characteristics. Opportunities even exist to further lower the cost per m^3 of produced irrigation water. Short term irrigation with reclaimed water from a SWH-unit is not likely to pose any immediate risks to plant and soil health. Especially the addition of nutrient such as N and BOD (which consist of organic matter) can even help to improve overall soil quality and plant growth, potentially limiting the need for fertilizers. Longer term irrigation (continuous over multiple years) can lead to build-up of nutrients, salts (minerals), heavy metals and emerging contaminants which all have different potential negative effects. However, with good water quality monitoring and periodical soil tests it is probable that these negative effects can be prevented or adequately mitigated.

Fourthly, stakeholders were moderately positive towards the potential of SWH. Especially, the fact that a new and reliable water source during dry periods can be tapped into to capture a considerable amount of water of sufficient quality is seen as its main advantage. One of the most important barriers perceived is the potential environmental impact on plants, soil and surrounding ground and surface water. Therefore extensive testing is required (through (a) pilot project(s)) to indeed ensure no negative environmental effects. Furthermore, neither the municipality nor Waternet was keen to take on the responsibility of operating the SWH-units. On the other hand, the possibility of a public-private partnership, with for instance technology providers that are responsible for operation, is seen as an opportunity to overcome that barrier. Other opportunities that arose where the potential for household and industrial applications and the application of SWH in newly constructed or renovated areas where a SWH-unit could be more easily fitted in. For both of the aforementioned opportunities it is of importance to increase the amount of stakeholders involved and start cooperation as soon as possible. However, larger scale implementation will become more interesting in the future (e.g. 10 years) and is seen as a last resort measure for the Amsterdam case. Overall the technical barriers are likely surmountable. But to gain further trust and a stronger engagement from the stakeholders, an adequately instrumented pilot project is necessary.

Finally, the main research question can be answered. The results of this research indicate that SWH can help to secure a new and reliable water source during dry periods. Hereby, damages to UGS can be prevented even though due to climate change dry periods become more severe and conventional water sources are under pressure. This will ensure all the socio-economic and climate adaptive benefits of UGS. Based on a specific study area a conceptual design was presented that is able to meet the water demand and mostly complies with selected quality standards. The design shows that SWH-units can be designed as mobile and modular units. Remote control and monitoring can simplify operation of these units and increase their overall potential. Based on the conceptual design, costs are deemed acceptable in comparison to the direct economic benefits. The results further demonstrate that potential negative environmental effects can be prevented or mitigated, while remaining nutrients in the reclaimed water can even improve the plant and soil health of UGS. It can be concluded that from an engineering perspective, challenges related to the water quality are unlikely to be insurmountable.

However, three aspects still require a significant amount of time and investment before SWH can be implemented on a larger scale. These are: (1) the lack of regulatory framework, (2) the unresolved responsibility for operation and (3) extensive water quality testing and environmental impact assessment. To accelerate innovation it is recommended to start as soon as possible with addressing these remaining issues. The involvement of a wide variety of stakeholders can help to overcome the remaining barriers. All the more so because SWH can also be used for household or industrial applications and the reuse of water can contribute to a reduction in the use of valuable drinking water. Although this study focussed on Amsterdam, the results and undertaken research steps can be translated and applied to other (more suitable) areas in the Netherlands or even globally.

9.3 Recommendations for Future Research

Based on the conclusions and discussion of the results several recommendations can be done for further practical or scientific oriented research. The most important recommendations are discussed in this section.

First of all, the following future scientific research is recommended:

- As mentioned, not all potential applications of SWH have been considered for this study. Especially, more research into the use of SWH for industrial and households applications is recommended as this would allow for the use of SWH outside of just dry periods. This could help to bring down the costs per m^3. Furthermore, it provides more commercial opportunities which can attract more stakeholders and accelerate the innovation process.
- Modelling tools can optimise placement of SWH-units. This can be based on various criteria such as water demand, raw sewage quality and quantity, availability of an energy connection and space and capacity of the sewer to discharge treatment residuals. The development of such models can help to increase the effectiveness, robustness and safety of the operation.
- It is widely acknowledged that SWH and the reuse of municipal waste water in general can contribute to a circular economy and combat (fresh) water scarcity by providing a new water source. However, legal frameworks, especially concerning quality standards of the effluent and treatment residuals, are often absent or not yet adequately reviewed. This could hamper the use of this valuable and significant alternative source. Therefore, more research into the interplay of technical and legal aspects (with respect to different applications and thus risks) is necessary to be able to fully maximise its potential.
- During this research SWH has been studied as a stand-alone solution. However, it is possible to combine for instance SWH with other water sources or drought interventions. SWH could for instance supplement harvested rainwater during extensive dry periods. Research in combinations of interventions and water sources to irrigate UGS could increase the potential. Besides, a thorough comparison of the costs and impact (for different drought scenario's) of alternatives for SWH could provide a fair assessment and aid in the decision-making process.

Moreover, based on the results and deliberations of this research there are some recommendations for practical research that can be conducted, for instance as part of the AquaConnect pilot with SWH:

- Monitoring of both the effluent water and treatment residuals is of great importance for the viability of the designed SWH-unit. Therefore, extensive testing of these streams is important to ensure compliance with the regulatory frameworks. To determine the effect of the discharge of treatment residuals it is also advised to test for instance odour nuisance and hydrogen sulphide built up further downstream of the extraction and discharge point (Marleni, Gray, Sharma, Burn, & Muttil, 2013). This can help in setting up guidelines and best practices.
- Testing of environmental impact is needed to provide insight into the most important concern of the stakeholders in regards to the effluent quality. Impact on soil and plant health should be monitored, preferably over a longer period (i.e. multiple years). Moreover, runoff of irrigation water could deteriorate the quality of the local surface and ground water and therefore runoff of irrigation water should also be monitored.

- Setting up an network of a wide variety of involved stakeholders can contribute to accelerate the innovation of SWH. Next to regulating and governing bodies, technology providers, developers, research institutions, (municipal) organisations responsible for UGS maintenance or crop cultivators can be brought together. This can also help in more broadly exploring the (commercial) implementation perspective of SWH.
- A proper cost-benefits analysis that considers sustainability, economic and social benefits (3P's) should be conducted to be able to fairly compare SWH and other drought mitigation strategies for UGS (e.g. planting more drought susceptible greenery, rainwater storage and surface water irrigation) and test potential combinations of measures.

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Appendix A: Short Description of Pollutants in Raw Sewage

Organic Matter
Most Important Parameters: BOD, Turbidity
Organic matter is a common pollutant in sewage. It can adversely affect water quality, for instance by reducing clarity and depleting oxygen levels. Organic matter refers to the carbon-based compounds present in water or soil that originated from living organisms or their by-products. It includes a wide range of substances, including human waste and food waste. Bacteria and other microorganisms in the water can decompose organic matter. This decomposition process consumes dissolved oxygen in the water, leading to oxygen depletion. Besides, organic matter in water serves as a nutrient source and adhesive surface for microorganisms. It provides a favourable environment for the attachment and growth of biofilm-forming bacteria, leading to increased biofouling, which hampers operation of a treatment unit and can clog pipes. Organic matter in sewage can also lead to an unpleasant odour and colour of the water. Processes such as screening, sedimentation and filtration can help reduce organic matter. Moreover, biological processes such as MBR can remove organic matter through microbial decomposition.

Suspended Solids
Most Important Parameters: TSS, Turbidity
Suspended solids are solid particles, both organic and inorganic, that remain suspended in water rather than settling to the bottom. In sewage, suspended solids can originate from various sources, including human waste, food scraps, toilet paper, debris, and other particulate matter. Suspended solids can significantly reduce the quality of sewage water as they cause turbidity and make the water visually unappealing. Excessive suspended solids in sewage can overwhelm and clog wastewater treatment systems. They can settle in pumps, tanks, pipes, and other treatment equipment, leading to reduced efficiency, increased maintenance requirements, and higher operational costs. Effectively removing or reducing suspended solids in sewage can be done by means of (coarse) screening, filtration, sedimentation or even biological treatment.

Nutrients
Most Important Parameters: Total N (NH_3, NH_4, NO_x), Total P
Nutrients, particularly nitrogen and phosphorus, are essential for plant growth. However, excessive nutrient levels in sewage can result in eutrophication, which stimulate the rapid growth of algae. This leads to oxygen depletion and ecological imbalances. Furthermore, similar to organic matter, provides a favourable environment (i.e. nutrients) for the growth of biofilm-forming bacteria, leading to increased biofouling, which hamper operation of a treatment unit and can clog pipes. Excessive nutrients from irrigation can cause soil degradation. Moreover, nutrients can lead to rapid vegetative growth which could lead to more park maintenance and an increased water demand of UGS. Nutrients are commonly removed through biological process that utilizes specific bacteria to remove nutrients under both anoxic and aerobic conditions. For phosphorus removal chemical dosing (e.g. with $FeCl_3$) can be applied to bind phosphorus to solid particles which will precipitate and hereby can be removed. Also membrane filtration techniques can be effective, especially for removing dissolved nutrients.

Pathogens
Most Important Parameters: E. Coli or Total Coliforms (Bacteria), Coliphages (Virusses), Cryptosporidium or Giardia (protozoa)
Pathogens refer to disease-causing microorganisms, including bacteria, viruses and protozoa, that are present in wastewater. These pathogens can pose significant risks to human and environmental health. Pathogens can cause various waterborne diseases if the water comes into contact with humans or animals, for instance as a result of sprinkler irrigation. The environmental impact of pathogens can be caused by disrupting the natural balance of aquatic or soil ecosystems. Additionally, in combination with (excessive) nutrients and organic matter it can promote algal blooms, leading to oxygen depletion and further impacting the ecosystem, but also potentially damaging components of the treatment set-

up. Excess pathogens can be removed through applying a final disinfection step through UV or chlorine dosing.

Micro-pollutants

Most Important Parameters: heavy metals, guide substances of Ministry of Infrastructure and Water Management

Micro-pollutants are a wide range of synthetic or naturally occurring chemical substances that can have adverse effects on human health and the environment. These include but are not limited to pharmaceuticals, pesticides, hormones, plastics, heavy metals and per- and polyfluoroalkyl substances (PFAS). Because of the wide range of different micro-pollutants the effects are extensive. They may disrupt natural biological processes, interfere with hormone systems of humans and animals and cause toxic effects in organisms. Negative impact on plants can be reduced plant growth and photosynthesis. Additionally, certain compounds, such as heavy metals or organic pollutants, can accumulate in plant tissues, potentially leading to reduced vigour, nutrient uptake, or overall plant productivity. Effective treatment technologies for micro-pollutant removal include advanced oxidation processes, activated carbon filtration, and membrane technologies. Soil health can be affected by disruption of the beneficial microbial communities in the soil, affecting nutrient cycling, organic matter decomposition and soil structure.

Appendix B: Python Script Water Shortage Model

```
%matplotlib inline
import numpy as np
import matplotlib.pyplot as plt
from pandas import read_csv
from IPython.display import display
import pandas as pd
import scipy.optimize as opt

#Cleaning transformed KNMI Data (1981-2010)
#2030
    #Rain
knmi2030 = read_csv('KNMI14_2030_neerslag.txt', sep = ' ', skiprows = [0,1,2,3,4,5,6,8,9,10,11], index_col = 0, skipinitialspace = True, parse_dates= [0])
keep_col = ['441']
rain2030 = knmi2030[keep_col]
WD2030 = rain2030.rename(columns={'441': 'Rain'})

    #Temp
temp2030 = read_csv('KNMI14_2030_temp.txt', sep = ' ', skiprows = [0,1,2,3,4,5,7,8,9,10], index_col = 0, skipinitialspace = True, parse_dates= [0])
keep_col_tr = ['240']
temp2030 = temp2030[keep_col_tr]
WD2030['Temp'] = temp2030['240']

    #Rad
rad2030 = read_csv('KNMI14_2030_rad.txt', sep = ' ', skiprows = [0,1,2,3,4,5,7,8,9,10], index_col = 0, skipinitialspace = True, parse_dates= [0])
keep_col_tr = ['240']
rad2030 = rad2030[keep_col_tr]
WD2030['Rad'] = rad2030['240'] / 86400 * 1000 / 10

  #EVAP
evap2030 = read_csv('KNMI14_2030_Evap.txt', sep = ' ', skiprows = [0,1,2,3,4,5,6,8,9,10,11], index_col = 0, skipinitialspace = True, parse_dates= [0])
keep_col_tr = ['240']
evap2030 = evap2030[keep_col_tr]
WD2030['Evap'] = evap2030['240']

    #YEARMONTHDAY
WD2030['YEAR'] = WD2030.index.year - 1980
WD2030['MONTH'] = WD2030.index.month
WD2030['DAY'] = WD2030.index.day


#2050
    #Rain
knmi2050 = read_csv('KNMI14_2050_neerslag.txt', sep = ' ', skiprows = [0,1,2,3,4,5,6, 7,9,10,11,12], index_col = 0, skipinitialspace = True, parse_dates= [0])
rain2050 = knmi2050[keep_col]
WD2050 = rain2050.rename(columns={'441': 'Rain'})

    #Temp
temp2050 = read_csv('KNMI14_2050_temp.txt', sep = ' ', skiprows = [0,1,2,3,4,5,6,8,9,10,11], index_col = 0, skipinitialspace = True, parse_dates= [0])
temp2050 = temp2050[keep_col_tr]
WD2050['Temp'] = temp2050['240']

    #Rad
rad2050 = read_csv('KNMI14_2050_rad.txt', sep = ' ', skiprows = [0,1,2,3,4,5,6,8,9,10,11], index_col = 0, skipinitialspace = True, parse_dates= [0])
rad2050 = rad2050[keep_col_tr]
WD2050['Rad'] = rad2050['240'] / 86400 * 1000 / 10

  #EVAP
evap2050 = read_csv('KNMI14_2050_Evap.txt', sep = ' ', skiprows = [0,1,2,3,4,5,6,7,9,10,11,12], index_col = 0, skipinitialspace = True, parse_dates= [0])
keep_col_tr = ['240']
evap2050 = evap2050[keep_col_tr]
WD2050['Evap'] = evap2050['240']

    #YEARMONTHDAY
WD2050['YEAR'] = WD2050.index.year - 1980
WD2050['MONTH'] = WD2050.index.month
WD2050['DAY'] = WD2050.index.day


#2085
    #Rain
knmi2085 = read_csv('KNMI14_2085_neerslag.txt', sep = ' ', skiprows = [0,1,2,3,4,5,6, 7,9,10,11,12], index_col = 0, skipinitialspace = True, parse_dates= [0])
rain2085 = knmi2085[keep_col]
WD2085 = rain2085.rename(columns={'441': 'Rain'})

    #Temp
temp2085 = read_csv('KNMI14_2085_temp.txt', sep = ' ', skiprows = [0,1,2,3,4,5,6,8,9,10,11], index_col = 0, skipinitialspace = True, parse_dates= [0])
temp2085 = temp2085[keep_col_tr]
WD2085['Temp'] = temp2085['240']

    #Rad
rad2085 = read_csv('KNMI14_2085_rad.txt', sep = ' ', skiprows = [0,1,2,3,4,5,6,8,9,10,11], index_col = 0, skipinitialspace = True, parse_dates= [0])
rad2085 = rad2085[keep_col_tr]
WD2085['Rad'] = rad2085['240'] / 86400 * 1000 / 10

  #EVAP
evap2085 = read_csv('KNMI14_2085_Evap.txt', sep = ' ', skiprows = [0,1,2,3,4,5,6,7,9,10,11,12], index_col = 0, skipinitialspace = True, parse_dates= [0])
keep_col_tr = ['240']
evap2085 = evap2085[keep_col_tr]
WD2085['Evap'] = evap2085['240']
```

```
    #YEARMONTHDAY
WD2085['YEAR'] = WD2085.index.year - 1980
WD2085['MONTH'] = WD2085.index.month
WD2085['DAY'] = WD2085.index.day

#DROP LEAPDAYS
WD2030 = WD2030[~((WD2030['MONTH'] == 2)  &  (WD2030['DAY'] == 29))]
WD2050 = WD2050[~((WD2050['MONTH'] == 2)  &  (WD2050['DAY'] == 29))]
WD2085 = WD2085[~((WD2085['MONTH'] == 2)  &  (WD2085['DAY'] == 29))]

#Create day of year; 365-days
WD2030['DAY'] = WD2030.index.strftime('%j').astype(int)
WD2050['DAY'] = WD2050.index.strftime('%j').astype(int)
WD2085['DAY'] = WD2085.index.strftime('%j').astype(int)

WD2030.DAY[(1460-306):1460] = WD2030.DAY[(1460-306):1460] -1
WD2030.DAY[(2*1460-306):2*1460] = WD2030.DAY[(2*1460-306):2*1460] -1
WD2030.DAY[(3*1460-306):3*1460] = WD2030.DAY[(3*1460-306):3*1460] -1
WD2030.DAY[(4*1460-306):4*1460] = WD2030.DAY[(4*1460-306):4*1460] -1
WD2030.DAY[(5*1460-306):5*1460] = WD2030.DAY[(5*1460-306):5*1460] -1
WD2030.DAY[(6*1460-306):6*1460] = WD2030.DAY[(6*1460-306):6*1460] -1
WD2030.DAY[(7*1460-306):7*1460] = WD2030.DAY[(7*1460-306):7*1460] -1

WD2050.DAY[(1460-306):1460] = WD2050.DAY[(1460-306):1460] -1
WD2050.DAY[(2*1460-306):2*1460] = WD2050.DAY[(2*1460-306):2*1460] -1
WD2050.DAY[(3*1460-306):3*1460] = WD2050.DAY[(3*1460-306):3*1460] -1
WD2050.DAY[(4*1460-306):4*1460] = WD2050.DAY[(4*1460-306):4*1460] -1
WD2050.DAY[(5*1460-306):5*1460] = WD2050.DAY[(5*1460-306):5*1460] -1
WD2050.DAY[(6*1460-306):6*1460] = WD2050.DAY[(6*1460-306):6*1460] -1
WD2050.DAY[(7*1460-306):7*1460] = WD2050.DAY[(7*1460-306):7*1460] -1

WD2085.DAY[(1460-306):1460] = WD2085.DAY[(1460-306):1460] -1
WD2085.DAY[(2*1460-306):2*1460] = WD2085.DAY[(2*1460-306):2*1460] -1
WD2085.DAY[(3*1460-306):3*1460] = WD2085.DAY[(3*1460-306):3*1460] -1
WD2085.DAY[(4*1460-306):4*1460] = WD2085.DAY[(4*1460-306):4*1460] -1
WD2085.DAY[(5*1460-306):5*1460] = WD2085.DAY[(5*1460-306):5*1460] -1
WD2085.DAY[(6*1460-306):6*1460] = WD2085.DAY[(6*1460-306):6*1460] -1
WD2085.DAY[(7*1460-306):7*1460] = WD2085.DAY[(7*1460-306):7*1460] -1

DECADE_NAMES = ['2030', '2050', '2085']
decades = [WD2030, WD2050, WD2085]
COLUMN_NAMES = ['Rain', 'Temp', 'Rad', 'Evap', 'YEAR', 'MONTH', 'DAY']

for decade in decades:
    decade.columns = COLUMN_NAMES
```

```
#Soil Moisture Content Calculation
p = 0.3
porosity = 0.41
thetar = 0.07
psib = 30
lam = 0.3
pFFC = 2
pFWP = 4.2
ROp = 0.225
Kl = 1

thetaFC = thetar + (porosity-thetar)*((psib/(10**pFFC))**lam)
thetaWP = thetar + (porosity-thetar)*((psib/(10**pFWP))**lam)
thetaa = (1-p)*thetaFC + p*thetaWP
irrigation_threshold = thetaa

irr_interval = 1
Zr = 500

for decade in decades:
    print('Computing...')
    decade['MC'] = 0
    decade['EvapNoIrr'] = 0
    decade['EvapDiff'] = 0
    decade['Irrigation'] = 0

    for gen_idx in range(30):
        year = gen_idx + 1
        gen = decade[decade['YEAR'] == year]
        theta_prev = None
        prev_irr = -irr_interval

        for day_idx, day in gen.iterrows():
            jday = int(day.DAY)

            if jday == 1:
                decade.loc[day_idx, 'MC'] = thetaFC
            else:
                evap_rate = 1.0 if theta_prev > thetaa else \
                    max((theta_prev - thetaWP) / (thetaa - thetaWP), 0.0)

                MC_delta = (1 / Zr) * ((1 + ROp) * day.Rain - evap_rate * Kl * day.Evap)
                new_MC = min(theta_prev + MC_delta, thetaFC)

                decade.loc[day_idx, 'EvapNoIrr'] = evap_rate * day.Evap
```

```python
                decade.loc[day_idx, 'EvapDiff'] = evap_rate * day.Evap - day.Evap

                if ((new_MC < irrigation_threshold) and (prev_irr <= jday - irr_interval )):
                    irrigation =  max(deficit_by_month) / 30  / Zr
                    prev_irr = jday
                    decade.loc[day_idx, 'Irrigation'] = irrigation * Zr
                    new_MC = theta_prev + irrigation


                decade.loc[day_idx, 'MC'] = new_MC

            theta_prev = decade.loc[day_idx, 'MC']
```

```python
for decade, name in zip(decades, DECADE_NAMES):
    for gen_idx in range(30):
        year = gen_idx + 1

        MC = decade.loc[decade.YEAR == year] \
                    .sort_values(by='DAY') \
                    .MC
        MC = list(MC)

        irr = decade.loc[decade.YEAR == year] \
                    .sort_values(by='DAY') \
                    .Irrigation
        irr = list(irr)

        plt.xlabel('Day of year')
        plt.ylabel('Soil Moisture Content (%)')
        plt.title(name)
        plt.plot(MC)

        #plt.plot(irr)

    plt.axhline(thetaa, color='red', linestyle='--')
    plt.axhline(thetaWP, color='blue', linestyle='--')
    plt.axhline(thetaFC, color='green', linestyle='--')
    plt.show()
```

```python
for decade, name in zip(decades, DECADE_NAMES):
    Irri = decade.groupby(by='YEAR').Irrigation.sum()
    per95Irr = np.percentile(Irri, 95)
    print(per95Irr)
```

```python
for decade in decades:
    print('Computing...')
    decade['Deficit'] = decade['Evap'] - decade['Rain']

    deficit_gen_period = np.zeros((30,))
    deficit_gen_month_matrix = np.zeros((30, 6))

    for gen_idx in range(30):
        year = gen_idx + 1

        deficit_by_month = decade.loc[decade.YEAR == year] \
          .groupby(by='MONTH') \
          .Deficit.sum() \
          .iloc[3:9]

        deficit_gen_month_matrix[gen_idx] = deficit_by_month
        deficit_gen_period[gen_idx] = deficit_by_month.sum()

    top_generation_deficit = np.percentile(deficit_gen_period, 95, method='closest_observation')
    top_generation = list(deficit_gen_period).index(top_generation_deficit)
    print(top_generation)
    print(top_generation_deficit)
    print(deficit_gen_month_matrix[top_generation])
```

Appendix C: Effluent Quality per Treatment Step at the Flemmington Racecourse, Melbourne, Australia

Table 16 Overview of the average effluent quality of each treatment step over a two year period of the SWH-unit deployed at the Flemmington Racecourse (Waste Technologies of Australia Pty Ltd, 2006).

Parameter	Screened Sewage (200 micron)	Microfiltration Filtrate (0.2 micron)	Reverse Osmosis Permeate
BOD (mg/l)	230	89	<2
TOC (mg/l)	103	46	0.6
TSS (mg/l)	144	<2	Undetectable
TDS (mg/l)	Not measured	403	12
Total N (mg/l)	50	51	3.9
Total P (mg/l)	11.2	9	0.03
E. Coli (cfu/100ml)	5.1×10^6	1.3	<0.1

Appendix D: Interview Guide

General Questions:
What does your current position entail on a daily basis?
How do you see the impact of climate change and other development (e.g. population growth, salination, etc.) on the availability of fresh water?
How do you consider the availability of fresh water to impact UGS/water available for irrigation?
How important is good irrigation of UGS to you/your organisation?
What do you think of sewage as a (new) water source and how do you compare it to other potential water sources (for irrigation)?
What are the main criteria that you consider when deciding on the implementation of new innovations or assets for the provision of fresh water (or related to water management)?
Now you have heard about the concept of SWH are there any questions that come to mind?
How do you perceive the concept of SWH? Is it viable? Does it fit within the existing water system of Amsterdam?

Barriers:
Now you have heard about the concept of SWH are there any concerns you directly think of?
Now you have heard about the concept of SWH are there any disadvantages you directly think of?
Odour (Makropoulos, et al., 2018)
Space (i.e. footprint) (Makropoulos, et al., 2018) (Makropoulos, Natsis, Liu, Mittas, & Butler, 2008; Ashley, Blackwood, Butler, & Jowitt, 2004)
Operation
Management & Responsibilities
Who should be responsible for the operation of SWH-units?
Costs (Makropoulos, Natsis, Liu, Mittas, & Butler, 2008; Ashley, Blackwood, Butler, & Jowitt, 2004):
How do you determine if an innovation is cost effective?
Is there a set budget for irrigation/water supply?
Is it feasible to apply sub-surface irrigation over time at more UGS?
Public perception (Makropoulos, et al., 2018) (Makropoulos, Natsis, Liu, Mittas, & Butler, 2008; Ashley, Blackwood, Butler, & Jowitt, 2004): (McFallan & Logan, 2007)
Human health risk (Makropoulos, Natsis, Liu, Mittas, & Butler, 2008; Ashley, Blackwood, Butler, & Jowitt, 2004)
Plant health risks
Soil degradation
Location selection (Makropoulos, et al., 2018)
Unclear/lack of or limiting laws and regulations (McFallan & Logan, 2007)
Damage to sewers or odour problem downstream of treatment residual discharge point
Engineering challenges related to meeting water quality requirements (Makropoulos, Natsis, Liu, Mittas, & Butler, 2008; Ashley, Blackwood, Butler, & Jowitt, 2004): (McFallan & Logan, 2007)
Governance framework
Operation and maintenance (Makropoulos, et al., 2018)

Opportunities:
Now you have heard about the concept of SWH are there any opportunities you directly think of?
Now you have heard about the concept of SWH are there any suitable applications or cases you directly think of?
Water can be made fit-for-purpose (McFallan & Logan, 2007)
Reduced demand for (waste) water infrasctructure: (McFallan & Logan, 2007)
New business model (SME & PPP's) (Makropoulos, et al., 2018) (McFallan & Logan, 2007)
Is it realistic and do you consider it desirable that SWH-unit will be operated by third parties?
realisation of (formerly non-viable) projects (e.g. urban farming, tree nursery) (Makropoulos, et al., 2018)
Have there been instances where water was a limiting factor for the feasibility of a project?

Are there any concerns that water can be a limiting factor for the feasibility of a project?
Guarantee water demanding projects with a sustainable water supply (e.g. golf courses)
Increase soil and plant health:
Higher quality UGS
Facilitate 'greening the city'
Is there any policy in place that assures sufficient water supply of greenery?
Urban Heat Island reduction (Makropoulos, et al., 2018)
Ensure ecosystem services of UGS (Makropoulos, et al., 2018) (Makropoulos, Natsis, Liu, Mittas, & Butler, 2008; Ashley, Blackwood, Butler, & Jowitt, 2004)
Ensure socio-economic benefits of UGS (Makropoulos, et al., 2018):
Diversification water sources
Has municipal waste water been considered as a source for fresh water and in what way (e.g. centralised vs. decentralised)?
Water conservation (i.e. water used twice)
Reliability of water supply for irrigation
Resource recovery or nutrient recycling
Soil enrichment
Mobile SWH-unit (McFallan & Logan, 2007)
Automation of SWH-unit and remote control
Modularity (Makropoulos, Natsis, Liu, Mittas, & Butler, 2008; Ashley, Blackwood, Butler, & Jowitt, 2004) (McFallan & Logan, 2007)
In line with circular economy goals (Makropoulos, et al., 2018)
Create awareness for water scarcity and importance of water for health UGS (Makropoulos, et al., 2018) (Makropoulos, Natsis, Liu, Mittas, & Butler, 2008; Ashley, Blackwood, Butler, & Jowitt, 2004)

Final Questions:
Do you see SWH as a feasible option in combatting water stress of UGS?
What do you see as the main barriers for (larger scale) implementation of SWH and why?
What do you see as the main disadvantages for (larger scale) implementation of SWH and why?
What do you see as the main advantages for (larger scale) implementation of SWH and why?
What do you see as the main opportunities for (larger scale) implementation of SWH and why?
What are the main questions or concerns that need to addressed during a pilot project in order for SWH to become (more) promising as an alternative for the irrigation of UGS or fresh water supply as a whole?
Are there any other applications of SWH that come to mind (e.g. industrial, households use) for which you see more potential?
After this conversation how do you perceive the concept of SWH?

Appendix E: Interview Transcriptions

Interview Marcel van Uitert (Waternet) Synopsis English
Based on the interview with Marcel van Uitert it became clear that the management of SWH-units is one of the main concerns that should be addressed. He pointed out Waternet will most likely not see this as its responsibility. However, an opportunity was identified to work with technology developers or other businesses in the form of a public-private partnership (PPP). The municipality (as irrigation of UGS is their responsibility) would in that case be the responsible party to set up contracts with the service providers of SWH-unit that would be responsible for the operation. If this is feasible would off course depend on the cost of these units and the prevented damages. The management (and responsibility) and cost are always the main factors for the implementation of new innovations. Another main concern (i.e. potential barriers) that was raised, that needed to be addressed with testing (in the form a pilot) were the quality of the effluent and its resulting effect on the quality of surrounding surface and ground water as well as plant and soil health. Moreover, van Uitert pointed out the potential of SWH-units in areas that are under development or being renovated, where they can be fitted more easily compared to the already existing urban environment due to lack of space. In addition the need for such (smaller scale) decentralised innovation was questioned since Amsterdam has relatively high ground water levels and water stress as a result of dry periods are often not the main priority. Although it was acknowledged that the water demand is rising while conventional sources are becoming less available. Furthermore, the problem with a lack of (clear) regulation and standards was pointed out. The appearance of the container could be improved with art or educational information about water scarcity or the importance of properly irrigated UGS in the city. SWH fits within the goals of Waternet for sustainability and a circular economy. Lastly the interviewee was positive towards the application for sports fields and also pointed out the potential for urban farming (or more commercial applications in general). Overall, the conversation was very open and positive but several practical issues still need to be adequately addressed before SWH can be implemented and have a positive impact.

The following themes were discussed and used for coding:
- Management & Responsibility
- Cost
- Location
- Application
- Quality effluent
- Quantity effluent
- Need & Necessity
- Rules & Regulations
- Soil & Plant Health
- Space & Appearance
- Vandalism
- Discharge of treatment residuals
- Impact Surface & Ground water
- Circular Economy & Reuse
- Innovation & Decentralised Systems
- Education & Awareness

Transcription Interview Marcel van Uitert (Waternet) 20 juni
(Kennismaking en korte inleidende presentatie weggelaten)

Plas, Jan-Joris van der 8:13
Het doel van vandaag eigenlijk, zoals ik al aangaf is om eigenlijk een open gesprek te voeren en inzicht te krijgen in hoe u vanuit uw rol binnen Waternet aankijkt tegen.

Uitert, Marcel van 8:23
Je mag jij zeggen, je mag jij zeggen.

Plas, Jan-Joris van der 8:25
Sorry, zal ik dat doen Tegen dit soort innovatie, wat voor implementatie mogelijkheden zijn hier op de langere termijn en wat zou dan de potentiële impact kunnen zijn voor Amsterdam of misschien wel algemener voor Nederland? De focus probeer ik hierbij te leggen op onderscheid maken tussen barrières en kansen of belemmeringen en stimulansen, nadelen en voordelen, zodat het wat makkelijker wordt om die gesprekken ook te analyseren. En die inzichten zal ik dan verwerken om uiteindelijk tot een soort antwoord te komen over de mogelijke impact die sewer water harvesting kan hebben.

Uitert, Marcel van 8:53 DISCHARGE OF TREATMENT RESIDUALS (-)
Ja, ik snap dat. Nou ja, je hebt het over een constante water stroom of nou ja… Ja, Het is een constante waterstroom van zwart water. Ik begrijp dat Als je zeg maar in dat systeem dat ze wat water reinigt, dan blijft er een residu over dat residu zal weinig vloeibaar zijn neem ik aan, want je wil juist het vloeibare gedeelte eruit halen, zodat er het vaste gedeelte wat je niet kunt gebruiken overblijft dus in die in die zin werkt het eigenlijk hetzelfde als bijvoorbeeld een septic tank met biologische zuivering, want daar geldt ook alleen het water gedeelte wordt gezuiverd en gaat naar de volgende fase en alle vaste deeltjes zinken af naar de bodem dus in die zin is dit systeem wel vergelijkbaar.

Plas, Jan-Joris van der 9:35
Ja.

Uitert, Marcel van 9:55
Maar je geeft aan dat je daarna terug geeft aan het riool.

Plas, Jan-Joris van der 10:00
Ja.

Uitert, Marcel van 10:02
Hoe wou je dat doen? Want als daar geen vloeibaar middel in zit, gaat dat ook niet stromen.

Plas, Jan-Joris van der   10:10
Nee, ik zal het even verklaren de eerste twee stappen, dus het dus een eigenlijk de grove zeefing en de microfiltratie die bevat eigenlijk voornamelijk vaste deeltjes. Inderdaad, de nanofiltratie stap die werkt met een recovery van 50 tot 80%.

Uitert, Marcel van   10:21
Aha

Plas, Jan-Joris van der   10:30
Dus dan blijft er eigenlijk 50% tot 20% van het water over dat dan weer mee terug gaat in het riool. Ik denk dat Misschien trouwens goed is om te zeggen wat u hier op de achtergrond ziet. Is het opzetje van een pilot.

Uitert, Marcel van   10:35
Ja Nou, ik zie op dit moment niet. Ik zie op dit moment Alleen jouw gezicht. Ik zie verder niks anders.

Plas, Jan-Joris van der   10:47
Oh, hij wordt niet meer gedeeld. Nee, sorry.

Plas, Jan-Joris van der   10:51
Ik zal hem even. Ja, dan zie ik hier ook weer beter. Zo nee, er komt ook een pilot project mee.

Uitert, Marcel van   10:58
Er wordt nog steeds niet gedeeld, hoor.

Plas, Jan-Joris van der   11:00
Sorry even kijken ja.

Uitert, Marcel van   11:01
Ik zie nog helemaal niks, ik zie Alleen jouw gezicht. Ja nu wel nu wel, ja, nu zie ik hem wel.

Plas, Jan-Joris van der   11:07
Zo weer wel ja.Kijk, Dit is een duidelijker plaatje. Dit is zo'n container. En hiermee komt ook een pilot project op het op het Marineterrein, dus Dat is Misschien goed om te vermelden en daarbij wordt dan dus ook gekeken naar dit soort vraagstukken van wat is nou een goede recovery om te hanteren

Uitert, Marcel van   11:14 SOIL & PLANT HEALTH (-)
Ja. Je hebt Natuurlijk, je probeert de cirkel zoveel mogelijk te sluiten en ik zet letterlijk erbij zoveel mogelijk, want je zult nooit helemaal 100% circulair kunnen zijn, want er zitten stoffen in die je niet terug wil brengen in het milieu, niet In de bodem, niet In het grondwater en niet In het oppervlaktewater. Dus dat moet allemaal naar de zuivering, de echte rioolwaterzuivering? Ja sorry, echte… de grote rioolwaterzuivering toesturen.

Plas, Jan-Joris van der   11:47
Nee zeker.

Uitert, Marcel van   12:01
Kijk, en dan gaat het wel. Biologische zuivering met bacteriën Natuurlijk, want oh, daar ga je weer.

Plas, Jan-Joris van der   12:01
Ja, Exact.

Uitert, Marcel van   12:09 QUANTITY EFFLUENT (-)
Dus in die zin wel. Ik snap het concept. Ik vraag me Alleen af als je tussen de wat was, het tussen de 20 en 50% van het van het debiet overhoudt voor planten.Of het dan op termijn?

Plas, Jan-Joris van der   12:34
50 tot 80 procent dan ja.

Uitert, Marcel van   12:36
Ahhh 50 tot 80% van het afvalwater kan nog hergebruikt worden.

Plas, Jan-Joris van der   12:40
Ja.

Uitert, Marcel van   12:41 QUANTITY EFFLUENT (+)
OK nee, dan haal ik het aan de andere kant uit dat 80%. Nou dan, dan heb je het wel over serieuze hoeveelheden.

Plas, Jan-Joris van der   12:43
Ja.

Uitert, Marcel van   12:53 QUANTITY EFFLUENT (+) SPACE & APPEARANCE(-)
Oké, het zou kunnen werken, dan zie ik wel kansen dat je inderdaad dit gebruikt. Een paar bedreigingen, zo'n container vraagt natuurlijk ruimte. Die kun je niet overal In de openbare ruimte neerzetten. Hoewel een container redelijk hufterproof is. En als alles in de container staat hoef je niet bang te zijn dat deze locatie zeg maar kapot gemaakt wordt, want daar moet je tegenwoordig ook allemaal rekening mee houden.

Plas, Jan-Joris van der   13:30

Ja klopt

Uitert, Marcel van 13:31 VANDALISM (-) QUANTITY EFFLUENT (-) SPACE & APPEARANCE (-)
Hoe dan ook, er zijn altijd van die gasten die denken, Oh, Dat is leuk, die boel vernielen wel. Maar dat is wel een dingetje ruimtevraag van hoeveel van die containers heb je nodig om een substantieel? Nou ja, even kijken bijvoorbeeld naar het Vondelpark, het Vondelpark is echt geen klein park.

Plas, Jan-Joris van der 13:49
Nee, zeker niet

Uitert, Marcel van 13:55 QUANTITY EFFLUENT (-) SPACE & APPEARANCE (-) NEED & NECESSITY (-)
Als je het Vondelpark, zeg maar dit in dat Vondelpark zou willen benutten. Hoeveel van die containers heb je dan nodig om een substantiële hoeveelheid te krijgen? En even specifiek voor Vondelpark zou ik eerder iets gaan bedenken over hoe je met het grondwater om kunt gaan, want dat is daar misschien een grote probleem dan de droogte.

Plas, Jan-Joris van der 14:20
Ja.

Uitert, Marcel van 14:23 NEED & NECESSITY (-)
Dus in het Vondelpark droog, echt heel droog zal het nooit worden, want al het grondwater stroomt er naartoe, dus dat.

Plas, Jan-Joris van der 14:33
Dat klopt ja, maar ook daar dreigt droogte

Uitert, Marcel van 14:36 EFFLUENT QUALITY (-) SOIL & PLANT HEALTH (-)
Nou dat. Ik ben ook wel op een benieuwd of er in de methodiek nagedacht wordt over het meten en monitoren van het water wat eruit vrijkomt, want jij zegt, er komen nutriënten die die blijven erin.

Plas, Jan-Joris van der 14:56
Ja, voor een deel, ja

Uitert, Marcel van 14:58 IMPACT SURFACE & GROUND WATER (-)
Ja voor een deel, maar ja, juist in West Nederland is het oppervlaktewater al redelijk nutriënten rijk en dus je voegt, je voegt dan wel weer nutriënten aan het grondwatersysteem toe, dus Ik weet niet of dat. Of dat vanuit het doelstellingen van de kaderrichtlijn water. Of dat nou wel handig is? Ik heb, Maar dat zou je dan dus mee moeten nemen in je aanbeveling en dat er met die proefopstelling goed meten en monitoren en getoetst wordt op hoeveel dat daadwerkelijk uitkomt en of het naar het grondwater gaat en dat soort zaken.

Plas, Jan-Joris van der 15:31
Ja.

Uitert, Marcel van 15:45
Nou, ja, ik even voor jou informatie, waarom ben ik op jouw traject gekoppeld. Omdat ik op dit moment namens Waternet ook betrokken ben bij de Mannoury blokken van AMS in West Amsterdam, waar ook een systeem is waar met een cascadesysteem

Plas, Jan-Joris van der 16:03
Ik heb daar toevallig met een eerder project, niet met Mannoury zelf, maar toevallig heb ik daar toen van gehoord over het project.

Uitert, Marcel van 16:10
Ja nou dat project, maar met dat soort projecten hebben we dezelfde vragen van. Hoe zit dat nou? We hebben daar meetresultaten uit gekregen waar we waar we echt wel hele grote vraagtekens bij hebben, want we zien in plaats van dat het systeem de nutriënten eruit haalt, dat nutriënten hoeveelheid alleen maar toeneemt. Ja, Dat is niet de bedoeling dat we, dat wil je niet de natuur hebben.

Plas, Jan-Joris van der 16:35
En, dat gaat om de nutriënten die dan In de grond of planten achterblijven. Of hoe? Hoe moet ik me dat voorstellen?

Uitert, Marcel van 16:40 SOIL & PLANT HEALT (-)
Nou, in dat systeem wordt grijs water opgevangen. Niet zwart water. Zwart water gaat daar gewoon rechtstreeks naar het riool, daar wordt douche water opgevangen en water uit de wasbakken en d daar wordt de eerste, zeg maar grote smerige flush, wordt gelijk afgevoerd en de rest wordt in een systeem naar het dak gepompt waar het op een groen dak wordt, zeg maar uitgespoten. Dat heeft het voordeel één het groene dak zuivert het water op een natuurlijke wijze en twee die het water kan op het groendak dan de zonnepanelen koelen. Dat is het idee en als het water op gegeven moment zeg maar over een bepaalde rand heen gaat, gaat via de zijkant via een cascadesysteem met heel veel groen ook weer naar beneden en dan wordt het opgevangen in het groen onderaan het woonblok. En, We hebben daar twee woonblokken staan, één met het systeem en één zonder het systeem. Dus om die vergelijking met elkaar te kunnen maken, dus dat. En ja., nou en AMS is daar heel erg heel erg trots op. Ja, wij hebben daar toch echt wel wat bedenkingen bij. Maar met zal ik maar zeggen dit soort systeem, ja, lokale zuiveringen.

Plas, Jan-Joris van der 18:06
Is dat iets wat veel aandacht krijgt bij Waternet? (Doelend op lokale zuiveringssystemen)

Uitert, Marcel van 18:07 INNOVATION & DECENTRALISED SYSTEM (-)
Kijk nou, we hebben Buiksloterham natuurlijk het lokale zuiveringssystemen gehad. Nu met die Mannoury blokken. Nee, nog niet echt super. We weten dat dat natuurlijk wel een trend is om daar naar te kijken en we doen daar ook wel aan mee, maar het blijft toch altijd het meest doelmatig en efficiënt om gewoon alle gebouwen aan te sluiten op de riolering. Het blijft gewoon nog steeds efficiënter als allerlei lokale zuiveringssystemen In de lucht te houden en te beheren.

Plas, Jan-Joris van der 18:43

En, hoe ziet u dat dan in deze toepassing. Als het gaat om het meer hergebruiken van water? Dus eigenlijk dat je het zelfde water In de stad twee keer gebruikt voordat je het zuivert en eigenlijk afvoert naar de zee.

Uitert, Marcel van 18:44 CIRCULAR ECONOMY & REUSE (+) NEED & NECESSITY (+)
Nou ja dat, dat is natuurlijk wel, kijk als je afvalwater zodanig kunt zuiveren dat je het inderdaad kunt gebruiken als hergebruik voor planten en groen. Plantsoenen, ja, ik zou er geen tegenstander van zijn. Als dat mogelijk is, dan moet je dat altijd proberen. Want de watervraag gaat alleen maar toenemen. Dus en de watervraag neemt toe, maar de bronnen niet.

Plas, Jan-Joris van der 19:22
Nee precies.

Uitert, Marcel van 19:23
Dus je moet wel even heel goed nadenken waar je het kunt hergebruiken en ik weet niet of je bekend bent met ook met de hemel waterverordening van Amsterdam?

Plas, Jan-Joris van der 19:35
Ja, dat is de opslag van die 60 mm. Denk ik dan, hè?

Uitert, Marcel van 19:39 SPACE & APPEARANCE (- & +)
Tijdelijke opslag hè tijdelijk. Tijdelijke opslag dus. Dus percelen moeten inderdaad ook wel zorgen dat ze een beetje hun eigen broek op gaan houden. Dus maar ja, voor openbare groen geldt dat natuurlijk, voor de gemeente, geldt die je hemelwater verordening natuurlijk zelf ook, dus als zij inderdaad in groenvoorzieningen ook de ruimte kan zoeken om bijvoorbeeld wadi's of dat soort dingen aan te leggen, dan heb je heb je gelijk een mooie ruimtelijke component en ik moet eerlijk zeggen, ik vind een wadi in de omgeving iets mooier staan als een container. Een container is nou niet echt. kunt zo'n container natuurlijk wel met een of andere kunstuiting, ook wel mooi maken dat je een soort aparte ja. Je kunt er zelfs een toeristische route maken als je wil. Als je ze ziet overal nu.

Plas, Jan-Joris van der 20:29
Of zelfs een, hoe zeg je dat iets educatiefs van maken?

Uitert, Marcel van 20:32 EDUCATION & AWARENESS (+)
Ja precies, datje educatie panelen erop zet, dat je de bewustwording daarmee vergroot. Dat is allemaal mogelijk. Dat zou ik ook zeker aanbevelen.

Plas, Jan-Joris van der 20:34
Demonstratieproject ja.

Uitert, Marcel van 20:47 MANAGEMENT & RESPONSIBILITY (-)
Waar ik benieuwd naar ben in dit geheel is, en daar komt Waternet weer dat Waternet DNA, wie doet dat beheer van die dingen. Hoe wordt daar over gedacht?

Plas, Jan-Joris van der 20:59
Ja dat, Dat is ook iets wat ik ook natuurlijk naar gekeken heb. Dat is ook iets wat naar voren kwam in eerdere projecten in bijvoorbeeld Griekenland of Australië. Dat is ook iets waar ik waar vragen heb voor heb voor u. Er zijn meerdere mogelijkheden. Ik denk dat dat uiteindelijk in Amsterdam, de gemeente Amsterdam en Waternet in die zin de belangrijkste stakeholders zijn en ook eigenaren van de infrastructuur, zoals het riool. Wat ook ja echt wel nodig is voor deze toepassing.

Uitert, Marcel van 21:16
Ja oke, maar ho even, even voor jou Waternet is geen eigenaar, hè?

Plas, Jan-Joris van der 21:37
Beheerder.

Uitert, Marcel van 21:38 MANAGEMENT & RESPONSIBILITY (-)
Waternet is beheerder, eigenaar van dit soort riolering en drinkwater infrastructuur is altijd de gemeente Amsterdam. Ja, dus als de gemeente vindt dat het moet beheerd worden. De gemeente, het gemeentebestuur vindt dat dat bij de taak hoort van Waternet. Dan zal Waternet het beheren, maarja.

Plas, Jan-Joris van der 21:59
Nee precies, maar het heeft Natuurlijk wel impact voor het beheer van het systeem als er dingen terugeloost worden en er vervuilende residuen terug geleverd worden.

Uitert, Marcel van 22:11 MANAGEMENT & RESPONSIBILITY (-)
Ja Daarom. Het is eigenlijk een. Als ik er even over nadenk. Kijk, de input komt uit de riolering dat beheert Waternet namens de gemeente vanuit de zorgplicht stedelijk afvalwater het residu gaat weer terug In het systeem, wat Waternet beheert. En die container die container is een installatie die met name bedoeld is om cd groenvoorzieningen, het water, de watervraag van groenvoorzieningen. En dan kom je weer, dan kom je op het grijze vlak van, ja groenvoorzieningen beheerd Waternet niet.

Plas, Jan-Joris van der 22:56
Nee.

Uitert, Marcel van 22:56
Dus dan zou je de container in beheer moeten geven bij…

Plas, Jan-Joris van der 23:04
Ja de gemeentelijke tak voor de groenbeheer?

Uitert, Marcel van   23:07 MANAGEMENT & RESPONSIBILITY (+)
Ja, Dat is een goeie. Dan zit ja groenbeheer valt volgens mij, is de opdrachtgever V&OR, verkeer en openbare ruimte en die geeft dat dan weer in opdracht aan stadsbeheer.

Plas, Jan-Joris van der   23:15
Ja.

Uitert, Marcel van   23:23
En nou is stadsbeheer degene die de facto de beheerder zou worden. Nou?

Plas, Jan-Joris van der   23:29
Ja, ja dat is ook een optie.

Uitert, Marcel van   23:31 MANAGEMENT & RESPONSIBILITY (-)
Ik kan je nu al vertellen dat ze bij stadsbeheer hier totaal geen kennis van hebben en dus ook direct zullen roepen dat ze dit die niet gaan beheren.

Plas, Jan-Joris van der   23:35
Nee en dan kom je bij de andere tussenoplossing. Dat is dan dat het beheer gedaan wordt via een public private partnership of op een manier dat de degene die de technologie levert van de container ook eigenaars zijn van de container en ja, op basis daarvan de gemeente gebruik laat maken van die voorziening of dat de gemeente dat inhuurt.

Uitert, Marcel van   23:48 MANAGEMENT & RESPONSIBILITY (+)
Dat zou een oplossing kunnen zijn. Ja ja. Nou, toevallig heb ik daar ervaring mee, want we hebben, Ik heb in mijn vorige functie was ik opdrachtgever voor renovatie van onder andere de defosfatisering installaties. En een hele grote staat, er vlakbij het Naardermeer en het waterschap moest. Of Waternet moest namens het waterschap die installatie helemaal renoveren, want dat ding was gewoon aan groot onderhoud en renovatie toe. En er zaten we met het probleem dat de bestaande tanks, Met God, hoe heet het spul Nou? Ja een of ander chemisch goedje, laten we even zeggen

Plas, Jan-Joris van der   24:55
OK.

Uitert, Marcel van   24:58
Is goedje wat nodig was voor het proces die bestaande tanks waren zo groot dat zelfs dak van de hele schuur eraf gehaald moest worden om die dingen te ontmantelen. Nou, toen zijn we naar een oplossing gaan zoeken van kan dat niet anders? En toen kwamen we bij een leverancier van tanks tegen die dat soort installaties in een soort compacte vorm aanlevert. En die installatie is, die wordt ongeveer nou, Ik denk wel 1/3 kleiner dan wat daarvoor stond. En, daar hebben we ja, een proef mee gedraaid en uiteindelijk heeft het waterschap dat gewoon overgekocht en die op die plek laten staan. En nu hebben we dat. Dat soort bedrijven zijn er wel. Ja, en Als je daar inderdaad een beheer of huurovereenkomst mee kunt afsluiten.

Plas, Jan-Joris van der   25:41
Ja zoiets inderdaad

Uitert, Marcel van   25:51
Het is Natuurlijk niet handig om ze ook zulke constructies voor de lange termijn aan te gaan, want Dat is. Dat is voor een ja.

Plas, Jan-Joris van der   26:01
Minder aantrekkelijk voor gemeente en Waternet?

Uitert, Marcel van   26:03 MANAGEMENT & RESPONSIBILITY (- & +)
Ja ja dat is minder aantrekkelijk voor een overheidspartij. Ja, dat is voor de gemeente, want de gemeente zal dan de huurovereenkomst of de beheerovereenkomsten aan moeten gaan. Ja, Ik weet niet of dat handig is je aan de andere kant, ja, Waarom ook niet. Sommige beheer activiteiten huren wij ook marktpartijen voorin. Omdat we het gewoon zelf niet meer kunnen, dus dat misschien wel een constructie waar je vaker aan moet gaan denken.

Plas, Jan-Joris van der   26:32
Oké interessant.

Uitert, Marcel van   26:33 SPACE & APPEARANCE (-) QUALITY EFFLUENT (-) SOIL & PLANT HEALTH (-)
Nou ja, ik ben benieuw naar nog een paar onderwerpen. De inpasbaarheid ben ik wel benieuwd naar ruimtelijke inpasbaarheid, want. Overal containers neerzetten zal, zal het beeld van het straatbeeld niet ten goede komen. Ik, ook wel benieuwd naar het residu van wat er blijft of wat er nu echt overblijft en wat de kwaliteit daarvan is en het effect van het van dat water, zeg maar. Effluent op de groene omgeving, want alleen water toevoegen. Ja, dat is makkelijk, maar er zitten stofjes in. Die zullen ook wel een effect op de bodem en het bodemleven en dat soort dingen hebben.

Plas, Jan-Joris van der   27:17
Zeker.

Uitert, Marcel van   27:18
Dusja.

Plas, Jan-Joris van der   27:21
En zijn dat dan ook de 3 belangrijkste criteria waar vanuit Waternet naar gekeken wordt Als het gaat om het ontwikkelen van dit soort innovatievere nieuwe ja, hoe zal ik het noemen, assets of technologieën?

Uitert, Marcel van   27:32 MANAGEMENT & RESPONSIBILITY (-) COST (-)

Haha nee de belangrijkste vraag is diegene die we het laatst behandelen, wie gaat beheren en wat gaat het kosten? Dat is altijd de vraag. Dat is met alle oplossingen is dat de vraag, wie gaat dit beheren en wat kost het dan en wie wordt dan kostendrager? Kijk, Dit is.

Plas, Jan-Joris van der 27:37
Ja haha exact.

Uitert, Marcel van 27:54 MANAGEMENT & RESPONSIBILITY (-)
Ik zal heel eerlijk zijn, ik zie de rol van Waternet In het beheer van deze installaties zie ik, zie ik somber in. Ik geloof niet dat Waternet deze installaties het beheer van deze installaties gaat doen, ook al zijn ze gekoppeld aan de riolering. Ja tenzij het gemeentebestuur vindt dat het wel zo is, Maar ik denk dat op voorhand Waternet niet happig zal zijn om dit om het beheer van deze installatie naar zich toe te trekken. Mede ook omdat ik mijn twijfels heb of het onder een van de zorgplichten valt. Want het valt niet onder de zorgplicht stedelijk afvalwater, groenvoorzieningen op peil houden, dat valt daar niet onder. Zorgplicht hemelwater is het ook niet, want je gebruikt geen hemelwater en zorgplicht grondwater. Heeft het wel relaties mee, omdat je het water natuurlijk wel naar de grond brengt, maar, dan ook weer.

Plas, Jan-Joris van der 28:52
Het kan natuurlijk ook onttrekking van grondwater door grote bomen tegengaan. Maar ja, Dat is ook weer de dan, dan ben je net aan het echt aan het opzoeken.

Uitert, Marcel van 28:57 MANAGEMENT & RESPONSIBILITY (-)
Ja, maar ja, dat is het effect. Dat is het effect ervan dus. Het is in die zin zal het ook wel een moeilijk verhaal worden om het beheer bij Waternet onder te brengen. Want Waternet de gemeentelijke zorgplichten worden bijna allemaal worden allemaal uit de rioolheffing betaald en dit valt als activiteit. Maar mijn weten niet onder de rioolheffing daar zal een fiscaal jurist zal dat, zal daar zijn bedenkingen bij hebben.

Plas, Jan-Joris van der 29:30
En hoe, hoe wordt daar vanuit Waternet gekeken naar meer algemeen hun taak In het tegengaan van waterschaarste? Is, dat, is dat dan nog iets dat meespeelt, en de transitie naar een circulaire economie die binnen de gemeente Amsterdam leest, maar die ik ook kon terugvinden in beleidsdocumenten van Waternet.

Uitert, Marcel van 29:53 CIRCULAR ECONOMY & REUSE (+) MANAGEMENT & RESPONSIBILITY (-)
Ja circulaire economie is wel iets waar we aandacht aan besteden. Absoluut! Duurzaamheid ook. We hebben duurzaamheidsdoelstelling, Maar de duurzaamheidsdoelstellingen die wij volgen zijn de duurzaamheidsdoelstellingen van of Amsterdam of het Waterschap Amstel Gooi en vecht. We hebben geen eigen duurzaamheidsdoelstelling als de organisatie. In die zin zijn we echt een uitvoerende dienst. Van de beide bestuurlijke organisaties. Dus ja kijk als Amsterdam vindt dat dit onder circulaire economie valt ja dan. En daarom ligt dit belangrijkste beslispunt hierover ligt bij Amsterdam zelf. Amsterdam moet aangeven of dat zij vinden dat dit belangrijk is. En als ze dat belangrijk vinden, dat ze dan het gesprek met Waternet, de directie van Waternet gaat. Van oké, wij vinden dat dit om jullie taak hoort, takenpakket hoort en zus en zo en dan en dan zal. Dan zal er een gesprek op gang komen. Van oké, hoe gaan we dat dan regelen? Hoe gaan we dat organiseren? Ik zie vooralsnog. Zeg maar In het beheer van deze installaties. Geen taak van Waternet, Omdat ik niet. Ik heb daar een hard hoofd in. Ook eerlijk bekennen.

Plas, Jan-Joris van der 31:09
Duidelijk. Nee, Dat is duidelijk.
Uitert, Marcel van 31:14
Dat. Want het is.

Plas, Jan-Joris van der 31:16
Hoe kijkt u wat breder aan? Oh, sorry, gaat uw gang.
(Hier is een stuk verwijderd dat ging over het gebruik van u of je)

Uitert, Marcel van 31:41 MANAGEMENT & RESPONSIBILITY (-)
Ja dat. Want laat ik het zo zeggen, het zit, het zit een beetje op het wisselvlak tussen wat Waternet ambieert en aan de riolering doet en wat de stad eigenlijk nodig heeft om hittestress en droogte tegen te gaan. En ja, die verdeling is, nu Waternet is van de riolering en alle andere zaken is gewoon echt voor de stad zelf.

Plas, Jan-Joris van der 31:57
Ja. Duidelijk. Ziet u wel kansen voor dit soort technologieën, en bijvoorbeeld heeft u een idee van waar dit soort dingen goed kunnen toegepast worden binnen de stad of binnen het huidige waterbeheer?

Uitert, Marcel van 32:23 INNOVATION & DECEMTRALISED SYSTEMS (+)
Ja, kijk, dit soort nieuwe technologie moet je altijd eerst uitproberen, dus je zult je zult ergens een proeflocatie moeten gaan zoeken waar waarmee je hiermee een paar jaar minimaal een paar jaar mee proefdraait, want.

Plas, Jan-Joris van der 32:40
Ik weet niet hoe lang de pilot duurt, maar op het Marineterrein zal binnenkort. Ik denk dat het wel volgende zomer wordt, aangezien het niet echt van toepassing is om het In de winter te testen, een pilot komen. Ik weet niet of dat een paar jaar is, of dat dat een zomer zal duren, maar die komt er dus wel nu.

Uitert, Marcel van 32:40 NEED & NECESSITY (-)
Je zult. Ja nou een zomer, een zomer zal nooit genoeg zijn, want je zult je zult in verschillende situaties moeten gaan ijken tenminste, dat is mijn idee. Kijk, een droog jaar wil nog niks zeggen, want wat gebeurt er bijvoorbeeld met de installatie? Dat is wel een hele goede. Wat gebeurt er eigenlijk als bijvoorbeeld wel voldoende regen valt, want dan heb je dat water bijna niet nodig. Gaat dan de aansluiting van het zwarte water gewoon rechtstreeks door naar de riolering. Of zet je dan de aansluiting op de installatie dicht en gaat het gewoon via de normale rioleringswerk weg.

Plas, Jan-Joris van der 33:39
Ja, Als het niet uit het riool gewonnen wordt door middel van een van het oppompen van het water als het ware, dan gaat het gewoon via de normale weg. Ja, naar de centrale zuivering. De container kan verplaats worden naar bijvoorbeeld een andere locatie.

Uitert, Marcel van 33:50
Oh ja, dat moet Natuurlijk opgepompt worden.

Plas, Jan-Joris van der 33:53
Ja.

Uitert, Marcel van 33:53 MANAGEMENT & RESPONSIBILITY (-)
Dus je zult ook wel een pompinstallatie. Oh, nou, nou zit, maar Waternet gaat dit niet meer doen. We zijn namelijk juist alle pompen aan het afstoten haha.

Plas, Jan-Joris van der 34:01
Duidelijk.

Uitert, Marcel van 34:09 LOCATION (+)
Ja het, je zult een locatie moeten zoeken, waar, met een groot bemalingsgebied achter zit. En tegelijkertijd groenvoorzieningen in de buurt zit die voor hitte en droogte gevoelig is. Dan even dat kaart van Amsterdam in mijn hoofd nemend.

Plas, Jan-Joris van der 34:34
Het Vondelpark kwam in mijn analyse wel naar voren als een van de plekken die veel genoemd wordt als het gaat om verdroging van het groen. Je noemde al dat er , ja dat het lager ligt en dus de grondwaterstand relatief hoog is. Maar het is vooral ook van belang voor jong groen. Gewoon volwassen bomen kunnen altijd wel bij het grondwater, maar vooral ook jong groen lijdt daar heel erg onder of wat kleiner groen om het zo maar te zeggen. En daarbij kwam wel in mijn analyse naar voren. Er was, moet ik eerlijk toegeven, niet bijzonder veel informatie te vinden over specifieke locaties en specifieke droogteproblemen in Amsterdam, behalve het algemene plaatje uiteindelijk. Maar daar kwam Vondelpark wel in naar voren als een waterbehoevend park, zeker in tijden van lange droogte.

Uitert, Marcel van 35:28
Ja, want je hebt je hebt, je hebt je informatie uit maps.amsterdamen.nl gehaald, neem ik aan.

Plas, Jan-Joris van der 35:33
Ook ja, zeker. Ja en nieuwsartikelen en andere literatuur die ja indicatie gaf van droogteproblematiek in Amsterdam.

Uitert, Marcel van 35:43 NEED & NECESSITY (-) LOCATION (+)
Ja, ja, dat kijk de droogteproblematiek zoals ik die nu in Amsterdam ervaar, is dat vooral zeg maar dat grasvelden, heel gauw vergelen en uitdrogen bomen inderdaad kunnen wat beter tegen droog, maar ook niet al te lang kijk zoals nu, zonder regen, dat zullen heel veel bomen ook niet fijn vinden. Bomen kunnen beter tegen klets natte voeten. Als in lange tijd natte voeten als lange tijd droge voeten dus in die zin. Ja. Kijk, en je hebt natuurlijk. Ja in je analyse zul je moeten kijken in hoeverre je Natuurlijk vanaf oppervlaktewater zit, want Als je bijvoorbeeld het centrum kijkt, ja, het centrum is bijna sowieso al heel veel versteend en dat soort dingen. Daar zit niet zoveel groen meer. En al het groen wat er is, ligt relatief dichtbij oppervlaktewater en dus ook al relatief dicht bij grondwater dus verwacht dat de droogteproblematiek, met name het groen, in het stadscentrum niet zo heel groot probleem zal opleveren. Het gaat meer om de zones die eromheen liggen en zoals het Vondelpark, Sarphatipark en Oosterpark.

Plas, Jan-Joris van der 37:02
Aha oke.

Uitert, Marcel van 37:02 LOCATION (-)
Hoewel Oosterpark ook weer zo'n typisch voorbeeld is, grondwaterproblemen een hele veel grotere rol spelen als droogte. Ook daar wordt al die parken liggen allemaal lager dus.

Plas, Jan-Joris van der 37:15
Mmm

Uitert, Marcel van 37:21 NEED & NECCESITY (-)
Ja, Dat is goeie, waar zou je dat waar zouden dit soort problemen nou echt serieus in Amsterdam?

Plas, Jan-Joris van der 37:30
Ja Misschien zegt u wel, Dat is helemaal niet zo'n groot probleem als dat het soms voor doet komen.

Uitert, Marcel van 37:36 NEED & NECCESITY (-)
Nou, ik zou in Amsterdam nou niet echt zo keihard heel grote problemen kunnen benoemen, maar dan moet ik eerlijk zeggen dat ik de droogte kaart op dit moment ook niet heel goed in mijn hoofd heb zitten. Ik heb wel inmiddels, vorig jaar, de cursus klimaatadaptatie voor ambtenaren gedaan en daar kwam die wel voorbij.

Plas, Jan-Joris van der 37:57
Haha oke.

Uitert, Marcel van 37:59 LOCATION (+)
Maar daar deden we onderzoek naar de Zuidas. En de Zuidas wordt Natuurlijk net aan versteend, dus daar is juist probleem dat je te weinig groen hebt in plaats van dat je droog groen hebt. Maar moet ik ook eerlijk zeggen, daar zie je ook wel weer voorbeelden van. Dat het vallend regenwater wat daar komt ook niet bij het groen komt, dus dat is ook.

Plas, Jan-Joris van der 38:20
Nou ja, goed, het wordt Natuurlijk steeds belangrijker, ook als ondersteunende rol voor het vergroenen van de stad zelf, wat Natuurlijk ook een ambitie is van Amsterdam. Natuurlijk met verhevigende droogte is dat ook belangrijk.

Uitert, Marcel van 38:37 LOCATION (+)

Ja je zou je zou eens moeten kijken of je ergens in ergens In de buurt gewoon van een park nieuwbouwproject hebt. Waar je voor die zo'n container zeg maar In het In het nieuwe gebouw zou kunnen incorporeren als een soort opvang van zwart water uit het gebouw.

Plas, Jan-Joris van der 39:03
Aha Ja.

Uitert, Marcel van 39:04 LOCATION (-)
En dan zuiveren en dan in de groene omgeving zou kunnen lozen dat je dat je op die manier zeg, maar iets kunt creëren bijna zoiets als Mannoury, maar dan bijvoorbeeld rondom het Vondelpark.. Nou ja, rondom het Vondelpark wordt niet zoveel gebouwd, dus misschien niet?

Plas, Jan-Joris van der 39:23
Nee. Maar ik snap het idee. Ook dat je dan de combinatie maakt met het nieuw aangelegde jonge groen en de nieuwbouwproject waar er ruimte is om van tevoren over na te denken hoe je zoiets In het stedelijke omgeving in past.

Uitert, Marcel van 39:24 LOCATION (+) SPACE & APPEARANCE (+)
Ja precies. En misschien zou je het zelfs in een. Ik weet niet hoe groot die, of het altijd in zo'n grote container moet zijn? Misschien kun je er ook nog wel een kleinere versie van maken die je in een mooi hoog flatgebouw zou kunnen incorporeren als een soort voorziening die voordat het water het gebouw verlaat je daarna kan teruggeven aan de omgeving en de rest naar de riolering.

Plas, Jan-Joris van der 40:00
De container is nu, hoe het vanuit mijn analyse en onderzoek is ontwikkeld. Er zijn Natuurlijk ook mogelijkheden om dit soort installaties permanent in gebouwen te verwerken. In Australië zijn veel voorbeelden van dit soort ideeën dat het dan In de kelder van een gebouw is ingepast.

Uitert, Marcel van 40:15 SPACE & APPEARANCE (+) LOCATION (+)
Kijk. Ja, kijk, als je het op die manier zou kunnen gebruiken en daar zijn al meerdere voorbeelden van dat je dat je inderdaad water in je eigen huis hergebruikt. En Als je dan bijvoorbeeld in een groot publiek gebouw zou kunnen opnemen. Ja dan ga ik dan kun je, dan zou je er inderdaad zo een soort opschaling van kunnen maken door het inderdaad in grotere gebouwen op te nemen en dan ga je overal Natuurlijk dit soort installaties creëren die langzamerhand het groen In de omgeving gaan voorzien. Op die manier zie ik er wel kansen voor, dat je het op die manier innovatief in nieuwe gebouwen gaat opnemen als een soort systeem om een deel van je zwart water te hergebruiken.

Plas, Jan-Joris van der 40:56
Goeie. Ja, nee, dat is een hele interessante om over na te denken. Die zal ik zeker meenemen. Ziet u misschien nog mogelijkheden voor? Sorry, zie je misschien nog mogelijkheden voor het ontwikkelen van bijvoorbeeld projecten zoals stedelijke landbouw of, in Athene was er een voorbeeld dat Ik ben tegengekomen van een ja een tree nursey, dus een soort kwekerij voor jong groen om die daarmee te ondersteunen. En dat nog projecten die hiervoor niet uitkonden, mogelijk gemaakt kunnen worden.

Uitert, Marcel van 41:39 APPLICATION (+)
Dan ga ik je even verwijzen naar de tuinen van West. Want daar zijn ideeën om inderdaad een soort boerderijen te maken die voor een groot deel zelfvoorzienend zijn. Ik weet niet hoe ver de ontwikkeling daarvan is, want Het is wel een paar jaar geleden dat ik daar als planadviseur op aangehaakt ben, maar In de tuinen van West weet ik dat dat dit soort ideeën zijn. Dus je zou even even daar. Dan moet je denk ik even contact zoeken met iemand binnen stadsdeel Nieuw West.
Plas, Jan-Joris van der 42:14
Oké. Ik heb namelijk heel, heel grondig gekeken. Inderdaad, ook naar de tuinen van West. Daar ben ik ook weer voor een ander. Ja, van een ander project ben ik daar ook geweest. En ja, Er zijn wel gesprekken over geweest, maar ik kon niks uiteindelijk niet erover vinden dat zulke ideeën echt in gang gezet zijn. Of daar is nu in ieder geval niet publiekelijk beschikbare informatie over.

Uitert, Marcel van 42:35 APPLICATION (+)
Nou nee, ,maar ik ben daar. Daar lopen Natuurlijk verschillende particuliere projecten die die hier wel misschien interesse in hebben, In de zin dat ze op die manier water kunnen besparen en hun afvalwater kunnen hergebruiken. Dat scheelt Natuurlijk enorm. Ja en op dit moment zijn twee sportparken in herontwikkeling. Dat is een bij Sloterdijk Spieringhorn. En twee aan de zuidkant, sportpark Sloten. Nou, daar worden wel natuurlijk ook gebouwen neergezet. Sportgebouwen waar je misschien ook iets mee zou kunnen doen door in zo'n voorziening ergens op het sportterrein te zetten die ervoor zorgt dat het afvalwater wat daarvan vrij komt, niet vanuit het terrein wordt afgespoeld. Maar dat je daar ook iets gaat doen met hergebruik.

Plas, Jan-Joris van der 43:36
Ja.

Uitert, Marcel van 43:37 APPLICATION (+)
Omdat je dat je daar inderdaad het water eventueel zou kunnen hergebruiken om de grasvelden te besproeien in tijd van droogte.

Plas, Jan-Joris van der 43:46
Ja precies. Want dat is ook een probleem dat die sloten dan niet meer mogen gebruiken, vaak voor irrigatie dat die niet meer gebruikt mogen worden.

Uitert, Marcel van 43:55 NEED & NECESSITY (+)
Wij, ik wou zeggen, dat mag al helemaal niet meer

Plas, Jan-Joris van der 43:57
Mag dat helemaal niet meer, oké?

Uitert, Marcel van 43:59
Nee, nee, want dat trek je zeker wel rondom het sportpark Sloten, dan trek je de sloten helemaal droog.

Plas, Jan-Joris van der 44:08
Ja, Het gaat ook meer om de kleinere slootjes die eromheen liggen, dan hoor. Het zijn niet de grote sloten, geloof ik.

Uitert, Marcel van 44:12
Nou sportpark Sloten ligt om, één grote sloot omheen om het hele sportpark. Een van de dingen die je zou kunnen oplossen is door het sportpark wat meer kleinere slootjes te trekken, Maar dat doen ze dan weer niet, want dat kost te veel ruimte.

Plas, Jan-Joris van der 44:18
Ja haha precies

Uitert, Marcel van 44:27
Ja ja dan houdt het op.

Plas, Jan-Joris van der 44:30
Ook altijd een probleem, toch weer, ruimte.

Uitert, Marcel van 44:32 SPACE & APPEARANCE (-)
Ja nee, met het ruimtegebruik in Amsterdam is elke vierkante centimeter belangrijk, dus Dat is heel moeilijk, zelfs ondergronds. Dus het is niet alleen bovengronds, het is ook ondergronds een knelpunt.

Plas, Jan-Joris van der 44:43
Oke.

Uitert, Marcel van 44:47 LOCATION (+)
Maar daar zou je eventueel. Hoewel sportpark Spieringhorn is al een wel een poosje in ontwikkeling is, dus Ik weet niet hoe ver ze daarmee zijn met ontwerpfase. Sloten zijn ze ook wel een poosje opgang met de ontwerpfase dus. Maar je zou je zou In het kader van sport een bos eens kunnen navragen, bij de directie Sport en Bos kunnen navragen of ze nog met andere sportparken bezig zijn waar, waar of die nog in ontwikkeling komen om daar eens te kijken of je daar een pilot kunt gaan doen met dit soort daken.

Plas, Jan-Joris van der 45:16
Ja. dat is zeker een interessante.

Uitert, Marcel van 45:26 LOCATION (-) APPLICATION (-)
De stadsparken, daar zie ik hier niet zo gauw dat ze daar iets mee gaan doen (doelend op SWH)

Plas, Jan-Joris van der 45:36
En, Dat is vooral vanuit een operationeel of hoe zeg je dat een beheer oogpunt of meer vanuit er is niet genoeg droogteproblematiek en er is niet genoeg ruimte om het in te passen in de bestaande omgeving.

Uitert, Marcel van 45:49 MANAGEMENT & RESPONSIBILITY (-) SPACE & APPEARANCE (+) NEED & NECESSITY (-)
Ja, een combinatie daarvan. Nou ja, het Vondelpark is een groot park, dus daar zou er altijd wel een plek gevonden kunnen worden. Maar ik vraag me af of de urgentie voor het Vondelpark zo groot is dat, want ik weet, ik weet niet wat het verschil is op dit moment tussen de watervraag en het water aanbod.

Plas, Jan-Joris van der 45:51
OK. Nee precies.

Uitert, Marcel van 46:12 NEED & NECESSITY (-) COST (-)
Dus, maar ik verwacht eigenlijk voor het Vondelpark dat het niet zo groot is, dat daar niet zo'n groot verschil tussen zit, dus ik weet niet of zo'n systeem dan het echt zoden aan de dijk zet. Maar ja, als alle kleine beetjes helpen, dan zou je het kunnen overwegen, maar dan is het een kosten afweging. Dan is het afweging van wat het kost. Wat kost het beheer en het onderhoud van zo'n installatie ten opzichte van de schade die wordt voorkomen, want dat is natuurlijk wat je wel in beeld moet brengen.

Plas, Jan-Joris van der 46:38
Ja, ja, daar ben ik op dit moment mee bezig, daar kan ik nog niet al te veel over zeggen. Dat is ook erg lastig omdat.

Uitert, Marcel van 46:45
Geen makkelijke vraag hoor, dat kan ik je nu al vertellen haha.

Plas, Jan-Joris van der 46:47
Nee, de enige informatie wat ik kan vinden is de schade eigenlijk over heel Amsterdam voor 2018 en dat wordt ook niet verder gespecificeerd. Waar dat dan is en wat dan de grootste veroorzaker is van die schade, dus dat is altijd nog heel lastig om daar goed.

Uitert, Marcel van 47:01
Ja. Een tip, een tip voor je. Kijk even op de website van even kijken is, dat is dat het ministerie van Infrastructuur en Milieu, of is dat Rijkswaterstaat? Er is, Er is een tool die heet klimaatschatter en, daar kun je eventueel zeg maar, als je wat data hebt kun je daarmee een soort schatting maken.

Plas, Jan-Joris van der 47:26
Ja, die ben ik tegengekomen. Inderdaad, klimaatschadeschatter ja.

Uitert, Marcel van 47:28
Nou, want dat is zo'n beetje de enige tool die op dit vlak nu op dit moment beschikbaar is, dus daar zou je dan mee kunnen gaan spelen, zou ik zeggen.

Plas, Jan-Joris van der 47:39
Klopt ja dat was ik inderdaad wat ik op het oog om te gaan gebruiken. Maar de berekeningen moeten daar nog even mee gedaan worden.

Uitert, Marcel van   47:47
Ja.

Plas, Jan-Joris van der   47:48
He super, Ik denk dat ik veel gehoord heb veel geleerd heb en duidelijk aanknopingspunten om te kunnen verwerken in mijn onderzoek, dus dat is heel mooi. Heeft u nog vragen voordat we het straks afsluiten?

Uitert, Marcel van   48:03
Nee, nou een vraag.

Plas, Jan-Joris van der   48:05
Ja tuurlijk.

Uitert, Marcel van   48:05
Deed je dit vanuit de Hogeschool Amsterdam.

Plas, Jan-Joris van der   48:08
Nee, ik studeer aan het AMS instituut. De master, Metropolitan Analysis, design en engineering. Altijd een hele mond vol, Maar het komt neer op duurzame stedelijke ontwikkeling.

Uitert, Marcel van   48:11
Oh oke. Oké, want ik wist niet eens dat AMS een eigen opleiding had.

Plas, Jan-Joris van der   48:24
Het is ja, het zit aan het AMS Instituut. Het is eigenlijk een opleiding van Wageningen en Delft gecombineerd.

Uitert, Marcel van   48:32
OK.

Plas, Jan-Joris van der   48:33
En, dat zit dan Alleen deze master zit, dan zit dan hier op locatie Omdat ja, het gaat toch over stedelijke ontwikkeling en dan moet je toch vaak voor de grote stedelijke ontwikkelingen. Moet je toch in Amsterdam zijn.

Uitert, Marcel van   48:45
Ja, ja, Wij zijn dé voorbeeldstad voor Nederland natuurlijk op heel ja. Nou, Rotterdam heeft ook goede voorbeelden, maar. Dat willen we niet erkennen in Amsterdam dat niet.

Plas, Jan-Joris van der   48:52
Hahaha dit is iets wat je vaak hoort, degene die niet genoemd mag worden.

Uitert, Marcel van   49:02
Hahaha Ja precies haha
Plas, Jan-Joris van der   49:02
Mag ik u nog? Mag ik je nog vragen of er nog iets is dat je meeneemt van dit gesprek? Of dat je denkt dit is me het meest bijgebleven of belangrijkste punten neem ik mee?

Uitert, Marcel van   49:11 INNOVATION & DECENTRALISED SYSTEM (+)
Nou in ieder geval kennis dat er een dergelijk systeem nu is. En ja, ik kom vaak genoeg projecten in de stad tegen waar dit soort dit soort zaken wel een rol gaan spelen, dus ik kan eventueel collega's van mij wel attenderen op dit soort zaken. Ik doe zelf niet zoveel gebiedsprojecten meer, ik zit ik zit nu meer op het niveau van adviezen en maken plannen, dus ik maak meer de kaders.

Plas, Jan-Joris van der   49:49
Ja goed, daar is ook nog veel onduidelijk over die kaders, dus Dat is ook iets wat meegenomen moet worden voor het onderzoek.

Uitert, Marcel van   49:54 RULES & REGULATION (-)
Nou ja, en een van de dingen waar ik nu ook mee bezig ben, of waar ik in ieder geval binnenkort mee aan de slag ga, is van wat hergebruik van water. Ja, we krijgen regelmatig de vraag, ook van projectontwikkelaar, aan welke water kwaliteitseisen moet bijvoorbeeld het water het restwater voldoen? Ja.

Plas, Jan-Joris van der   50:11
Ja.

Uitert, Marcel van   50:15 RULES & REGULATION (-)
Goeie vraag, daar zijn eigenlijk geen normen voor en de vraag is.

Plas, Jan-Joris van der   50:18
Ik heb me inderdaad suf gezocht naar die normen haha

Uitert, Marcel van   50:21 RULES & REGULATION (-)
Haha Nee, die bestaat, stop maar met zoeken, want die bestaan gewoon niet.

Plas, Jan-Joris van der   50:23
Daar ben ik al tijdje mee gestopt. Gelukkig maar, ja haha

Uitert, Marcel van   50:27
Nou ze bestaan niet is ook weer niet helemaal waar er zit, even kijken is dat hier?

Plas, Jan-Joris van der   50:33
Agrarisch hergebruik heb ik wel gevonden.

Uitert, Marcel van   50:36 RULES & REGULATION (+)
Nee In het besluit lozingen.

Plas, Jan-Joris van der   50:43
Aha

Uitert, Marcel van   50:44
Ja, die nieuwe namen die ik ken die niet die

Plas, Jan-Joris van der   50:45
Ik weet het ook niet meer hoe die heet, maar die ben ik ook tegengekomen

Uitert, Marcel van   50:58 RULES & REGULATION (+)
Daar staan wat richtlijnen of richtsnoeren. Maar dat zijn geen vaste normen. Dus Er zijn wel wat richtlijnen en richtgetallen richtwaarden. Dat woord zocht ik richtwaarden waar waarmee je aan de slag kan. Maar ja, echt hard zijn ze niet. Dus we kunnen dus een overheid kan ze ook niet opleggen of afdwingen dus dan greef je het mee. Ja, en dan kan een ontwikkelaar zeggen, ja, doei. Dat gaat me veel te veel geld kosten en dat doen we niet dus, maar er zijn wel richtwaarden voor effluent vanuit riolering die zijn.

Plas, Jan-Joris van der   51:26
Aha

Uitert, Marcel van   51:28
Mocht je die nog nodig hebben, dan zoek ik die eventueel wel voor je op. En dan mail ik die wel aan je toen.

Plas, Jan-Joris van der   51:28
Oké nou. Dat zou erg fijn zijn. Het kan zeker geen kwaad om dat nog even dubbel te checken.

Uitert, Marcel van   51:40
Dan ga ik die nog even voor je opzoeken en dat wordt alleen wel aan het einde van de week, want Ik ben nu heel druk bezig met directievoorstellen

Plas, Jan-Joris van der   51:49
Geen probleem, geen probleem ik, ik wacht het gerust af. Mijn allerlaatste vraag dan nog, dit alles in ogenschouw nemend, hoe ziet u het perspectief van een innovatie als sewer water harvesting? Kijkt u daar vooral nog met veel vragen tegenaan, of bent u gematigd positief? Hoe, hoe zou ik dat mogen omschrijven.

Uitert, Marcel van   52:16 IN GENERAL (+ & -)
Ik ben positief, maar wel met een heleboel vragen.
Plas, Jan-Joris van der   52:20
Oké.

Uitert, Marcel van   52:23 INNOVATION & DECENTRALISED SYSTEM (- & +)
Er zitten heel wat in, maar dat is altijd met innovatie. Er zitten altijd een heleboel praktische vragen aan en je moet, je moet nooit zeggen, het kan niet, het kan niet. Want je moet het gewoon uitproberen. Daarom heet het in innovatie, dus Als je ergens proef kan draaien, moet je het zeker doen. En dan, dan zijn wij zeker benieuwd naar de resultaten.

Plas, Jan-Joris van der   52:47
Als het goed is, wordt dat vanuit het NWO programma AquaConnect ook met in ieder geval de gemeente is erbij betrokken, Maar ik denk dat ook Waternet daar vast bij betrokken zal worden.

Uitert, Marcel van   52:57
Dat geloof ik ook vast wel.

Plas, Jan-Joris van der   52:59
Dus dat komt helemaal goed, denk ik dan. Oké dan hartstikke, bedankt voor je tijd.

Uitert, Marcel van   53:06
Graag gedaan. Succes met je thesis.

Plas, Jan-Joris van der   53:07
Gaat helemaal lukken, gaat helemaal lukken.

EINDE INTERVIEW (verdere afsluiting weggelaten)

Interview Niels Al (municipality of Amsterdam) Synopsis English
Similar to Marcel van Uitert, Niels All mentioned the management of SWH-units as one of the main concerns that should be addressed. The municipality does not have the needed knowledge to operate SWH-units. He acknowledged that operation of SWH by a private party is a suitable and feasible option to address this concern. While SWH is seen as an interesting option in light of increasing drought and the decrease in usability of other sources, which can be further hampered by laws prohibiting the use of surface water, SWH is seen as a last resort measure. Another main concern (i.e. potential barriers) that was raised, that needs to be addressed before large scale implementation were the quality of the effluent and its resulting effect on the quality of surrounding surface and ground water, biodiversity and plant and soil health. Moreover, human health risks should be minimised and public perception towards the use of sewage can make it as less preferred

option compared to for instance rainwater harvesting. However, when fitted with an explanation on the necessity he feels that people would be understanding to the fact that a container is temporarily placed in the UGS. While he acknowledges that SWH fits with circularity goals of the municipality, the environmental impact (i.e. CO_2-footprint and energy use) should be minimised in order to also fit with the sustainability goals. Overall the attitude towards SWH was positive but barriers remain especially concerning the need and necessity (i.e. last resort measure) and the potential environmental impact. A pilot should provide more insights into this. If the outcomes turn out to be positive it is conceivable that in 10 years SWH might be used on a larger scale.

The following themes were discussed and used for coding:

- Management & Responsibility
- Energy & Sustainability
- Cost
- Location
- Application
- Quality effluent
- Quantity effluent
- Need & Necessity
- Rules & Regulations
- Soil & Plant Health
- Space & Appearance
- Human Health
- Biodiversity
- Impact Surface & Ground water
- Circular Economy & Reuse
- Innovation & Decentralised Systems
- Education & Awareness
- Public perception
- Benefits & Increase of Greenery

Transciption Interview Niels Al (municipality of Amsterdam) 22 juni
(Kennismaking en korte inleidende presentatie weggelaten)

Plas, Jan-Joris van der   0:04
Dankjewel. Ja dan even kijken, dan laad hij hem nu. Ja, super kijk, dan wordt de automatische transcriptie gemaakt. Ik ben wel benieuwd. Nu je een beetje hebt gehoord over het concept van sewer water harvesting en de eerste resultaten van het onderzoek waar denk je dan als eerste aan, je eerste reactie. Of vragen die te binnen schieten.

Al, Niels   0:07 NEED & NECISSITY (+)
Ja. Nou, het is wel bijzonder hè dat dit soort ontwikkelingen nou ja, nu steeds meer zichtbaar worden dat geeft gewoon aan dat die klimaatverandering ook gewoon daar is, hè? Dus het is geen nou ja, geen verhaal van oh in de toekomst krijgen we daarmee te maken, maar je ziet gewoon dat er allerlei initiatieven oppoppen om te kijken van, hoe gaan we dat zoete water organiseren. Nou dat artikel wat ik jou doorstuurde is natuurlijk al een voorbeeld van, ze kampen in het zuiden, al met ja gewoon intensieve periode van droogte en zien dit als een mogelijkheid. Nou, als je mij 10 jaar geleden had gevraagd, is dit realistisch in Nederland? Amsterdam? Ja ik was toen ook al met klimaatadaptatie bezig, maar toen begon het beetje toen dat hele domein. En dan had ik gezegd, Nou, nou zie ik niet zo zitten. We zitten toch wel met het teveel aan water en nou droogte is niet echt een probleem, Maar de afgelopen jaren is gewoon wel duidelijk geworden dat droogte ons ook gewoon kan raken. Ja en dat we kennelijk ook dit soort innovaties misschien straks nodig hebben om ons groen overeind te houden.

Plas, Jan-Joris van der   1:12
Oké.

Al, Niels   1:14 LOCATION (- & +) APPLICATION (- & +)
En, Ik denk dat in West Nederland ja met het IJsselmeer en de regen en de buffer die we daar straks ook nou ja gaan vergroten hebben we natuurlijk een enorm ja buffervat aan zoet water. Ja, waar we voor de delen die we goed kunnen doorspoelen, best wel op kunnen teren. Maar dan zullen er ook delen zijn waar we die verzilting niet gaan tegenhouden met dat. Nou in dat soort van gebieden kan dit interessant zijn. En ik denk zeker ook op de hogere zandgronden. Ja deels wordt daar natuurlijk geput uit het grondwater. Maar ja, dat is nu eindelijk wat ik al heb begrepen, een beetje teruggekomen op de niveaus waarop het was. Maar ja, dat zakt natuurlijk nu weer heel hard uit en er is een enorme irrigatie vraag vanuit de landbouw, hè, dus. Dat is heel veel dus ja, dit gaat wel iets worden waarvan ik denk dat het dan wel in het stedelijk gebied dan wel in het landelijk gebied, ja ook in Nederland een serieuze optie gaat worden.

Plas, Jan-Joris van der   2:21
Oke, duidelijk. Is, is dat ook iets waar. Ik denk misschien vanuit jouw rol als klimaatadaptatie en water, iets waarop gefocust wordt op de irrigatie van stedelijk groen. Omdat dat ook zijn klimaatadaptieve voordelen heeft, het koelende effect, etcetera, maar ook gewoon sociaal economische voordelen. Is dat iets waar jullie mee bezig zijn?

Al, Niels   2:41 INCREASE GREENERY (+) BENEFITS OF GREENERY (+)
Nou, we zijn vooral bezig met het vraagstuk van we moeten vergroenen. We moeten die verkoelende werking van de stad verbeteren regenwater opvangen en de droogte maar droogte, met name in relatie tot de assets in de stad. Ik moet heel eerlijk zeggen dat het, maar dat zou je dan ook denk ik aan zo'n Hans Kaljee moeten vragen, dat het bevloeien van groen met name in hele droge periode gericht, is op jonge aanplant en dat dat zeg maar de focus nu is hè? Van zorgen dat die jongen aanplant, het overleeft en niet zozeer op het geven van de rest van het groen van water nou.

Plas, Jan-Joris van der   3:13
Ja.

Al, Niels   3:28 NEED & NECESSITY (+) RULES & REGULATIONS (+)

En de bron daarvan, voordat water rijdt er dan zo'n tankwagen. Die haalt dat altijd op uit de gracht of op een andere plek. Nou ja, dit zou natuurlijk iets kunnen zijn waarvan je op een gegeven moment zegt, nou, we gaan deze bron daarvoor gebruiken of omdat het grachtenwater zout is of omdat er een verbod komt, hè, dat zou ook een situatie kunnen zijn. Nou, dan kan je als gemeente natuurlijk niet het slechte voorbeeld geven, hè. Dus als er dan als er vanuit ons waterschap, of in het grootste gedeelte in Amsterdam een verbod komt om oppervlaktewater te gebruiken, ja, dan zul je als gemeente, als je die bomen wil behouden die jonge, dan zul je dit soort van opties moeten gaan doen en drinkwater zal dan ook geen optie zijn.

Plas, Jan-Joris van der 3:55
Nee zeker ook niet nee.

Al, Niels 4:14
Want daar zal een zelfde verbod voor zijn. En dan zijn we zelf eigenaar van een drinkwaterbedrijf, dan kunnen we die optie eigenlijk ook niet doen dus. Nou ja, Ik denk dat je het in die hoek moet zoeken.

Plas, Jan-Joris van der 4:26
Oke, en zijn er wel. Nou laat ik anders beginnen als jullie naar dit soort ontwikkelingen kijken, wat zijn dan de voornaamste criteria waar jullie naar kijken? Als jullie zouden zeggen, stel, dit is interessant.

Al, Niels 4:41 ENERGY & SUSTAINABILITY (-) MANAGEMENT & RESPOSIBILITY (-) QUALITY EFFLUENT (-)
Nou ja, wat dan natuurlijk belangrijk is, is het zonder risico's te gebruiken in een in een stedelijke omgeving zijn daar al voorbeeldprojecten van in omringende landen. Hè, dus is het een bewezen technologie? Past het bij onze andere ambities, hè, dus ik weet niet wat het aan energie kost, hè? Ja, is dat dan strijdig met? Nou ja, met onze energietransitie of is dat wel te matchen. Het beheer van dit soort van installaties zijn, wie gaat dat dan doen hè, is dat dan het? Dan is dat dan Waternet voor ons, hè? Dus daar allemaal van dat soort vragen krijg je dan op een gegeven moment. Als je een nieuwe technologie of een innovatie een plekje wil geven, dus van zowel nou ja, het gebruik als het hele beheer en onderhoudsgedeelte.

Plas, Jan-Joris van der 5:41
Zou de gemeente openstaan voor het beheer van zoiets, of zou die dat liever niet zelf op zich nemen?

Al, Niels 5:49 MANAGEMENT & RESPOSIBILITY (+)
Nou even hardop filosoferend. Ik denk dat stel, we zouden dus dit echt nodig hebben dat de gemeente daarvoor naar Waternet kijkt en vanuit de Amsterdamse watertaken, riolering ligt daar, dat dat zij een dergelijke installatie zouden beheren en dat de gemeente dan vervolgens kan aftappen. Want kennis over dit soort systemen zit meer aan die kant dan aan onze kant.

Plas, Jan-Joris van der 6:13
Ja precies.

Al, Niels 6:16 MANAGEMENT & RESPOSIBILITY (+)
En dan hebben wij het voordeel dat we in een watercyclus bedrijf onze taak hebben ondergebracht. De kennis over zuivering dat is natuurlijk formeel een taak van het waterschap. Ja, die kunnen we dan via zo een gezamenlijke constructie met Waternet ook gebruiken.

Plas, Jan-Joris van der 6:31
Ja en ik heb dan natuurlijk ook al met Marcel (van Uitert) gesproken van Waternet, die zei zelf dat hij het in eerste instantie niet schaalt onder de verantwoordelijkheden van Waternet.

Al, Niels 6:43
Nee dus toch niet?

Plas, Jan-Joris van der 6:46
Maar dat zou dus wel. Ja een verantwoordelijkheid kunnen worden, zeg jij.

Al, Niels 6:51
Ja, nou ja, dat is met kijk. Dat zijn ook innovaties rondom aquathermie warmte uit het riool te halen. Sorry, riothermie eigenlijk.

Plas, Jan-Joris van der 6:52
Oké.

Al, Niels 7:00 MANAGEMENT & RESPOSIBILITY (+ & -) RULES & REGULATIONS (-) COST (-)
Ja, dat zijn ook nieuwe ontwikkelingen, daar hebben we ook eigenlijk geen afspraken over. Ja, daar moet dan wel bedacht worden op gegeven moment wie gaat, wie is daar dan verantwoordelijke van. En ja, als je heel eventjes de lijn volgend van, in het geval van riothermie heb je het over iets wat in een riool geplaatst wordt. Ja, dan is het gek dat een andere partij dat zou doen dan degene die daar eigenlijk over gaat, hè, dus dat zou mijn lijn zijn dus maar ja, dat zou ook kunnen betekenen dat er een taak bijkomt die je dan neerlegt bij Waternet. Dus zo gaat het met alle innovaties op een gegeven moment moet er een eigenaar zijn en soms is die heel logisch en soms zal dat met meer zoeken zijn, maar dan moet op een gegeven moment een eigenaar van zijn die de verantwoordelijkheid draagt over het hele ja beheer en onderhoud. En dan moet natuurlijk ook financieel juridisch alles geborgd zijn.

Plas, Jan-Joris van der 7:33
Ja. Er kwam ook ter sprake, als andere optie, dat er eventueel een publiek privaat partnerschap zou kunnen zijn als Waternet het niet is. Is dat ook iets wat tot de mogelijkheden behoort dat jullie als het ware dan zo'n unit inhuren en de operatie aan iemand anders uitbesteden.

Al, Niels 8:01 MANAGEMENT & RESPOSIBILITY (+)
Ja zou kunnen. Je kan natuurlijk in eigendom dat gaan doen of je zegt, nou ja, inderdaad, dat zie je ook dat soort constructies dat die er zijn. Dat je dat het gewoon inhuurt, dat je zegt, net als een, hoe heet het nou? Ja, in een droge periode kun je die dan huren en dan komt er dan een bedrijf en die plaatst hem op één locatie en dan heb je de afspraak waar die het water uit kan vandaan halen en hoe dat kan natuurlijk ook. En misschien dat je als je het elk jaar gebruikt dat je zegt, nou ja, dat gaan we het in eigen beheer doen. Ja.

Plas, Jan-Joris van der 8:37
Ja, en even voor mijn informatie. Ik heb veel opgezocht over de droogteproblematiek ook. Ik heb het een en ander kunnen vinden, bijvoorbeeld wat de schade was van droogte aan het stedelijk groen in 2018 dan voornamelijk. Dat gaat dan om de hele stad zijn er echt probleemgebieden of ja, plekken waar dat echt helemaal aan de orde is dat je zegt hier hebben we echt elk jaar of veel meer last van droogte.

Al, Niels 8:57
Ja het is vooral op de plekken waar de ondergrond niet heel robuust is. Ik zal nu jij dit zo zegt, we hebben vooral last van de assets, hè? Ons eigendommen die dan schade oplopen hè? Dus ons asfalt wat breekt en zetting. Maar we hebben een collega die daarmee bezig is om een droogteplan te maken. Als je daar geïnteresseerd in bent, dan kan ik wel even zijn naam ook doorspelen, zodat ik je daar eventjes kan polsen waar het er nou precies zit in de stad.

Plas, Jan-Joris van der 9:31
Ja zou fijn zijn.

Al, Niels 9:53
Mijn gevoel is dat het met name in de lagere delen zit met de veen ondergrond, maar dat weet ik niet helemaal zeker.

Plas, Jan-Joris van der 10:02
En waarom is dat dan? Want ik hoorde ook weer dat juist in de lagere delen stroomt meer grondwater naartoe. Dus juist ook weer extra aanvoer van water.

Al, Niels 10:10 LOCATION (- & +)
Nou, dan krijg je die verdroging van die veenlaag en kijk in de binnenstad is best wel goed opgehoogd met zand, redelijk robuust, dus daar kan het groen op zegt ook wel wat te maken krijgen met wegzakkende grond water, maar in die lagere delen heb je wat minder stabiele grondlagen. Als het droog wordt krijg je daar sneller verzakkingen, die wijken zijn niet integraal opgehoogd, maar ja vaak alleen waar de woning staat of half half en dan heb je wat meer te maken met met zettingen Als het grondwaterpeil wat eigenlijk zakt, want dan zakt het wel gewoon uit. En dan als dat veen gaat inklinken, dan krijg je die nou ja, bodemdaling met als gevolg zetting.

Plas, Jan-Joris van der 10:57
En past zoiets als dit dan goed binnen de strategie die de gemeente Amsterdam nu hanteert, zijn dit dingen waar echt naar gekeken wordt naar dit soort losse innovaties, decentraal water zuiveren? Of vanuit de circulaire doelstellingen bijvoorbeeld, het hergebruik van water. Of zijn dit dingen waar ja jullie toch altijd een beetje terughoudend mee zijn?

Al, Niels 11:20 NEED & NECESSITY (-) INNOVATION & DECENTRALISED SYSTEM (+)
Nou kijk, ik zie dit nog niet 1 2 3 gebeuren in de stad. Maar we hebben bijvoorbeeld ook voor nieuwe sanitatie in de buiksloterham. Ja, daar heeft het waterschap nu een kleine zuivering aangelegd en wil men ja zo een nieuw sanitatiesysteem gaan inrichten, waarbij de grondstoffen vanaf het het huis eigenlijk gescheiden worden en dan in die kleine zuivering gaan. En dan tot energie of tot de andere nieuwe grondstoffen worden omgezet en daar lijkt het eigenlijk wel een beetje op, hè? Dat is ook een kleiner, want we hebben natuurlijk de grote zuiveringen maar daar komt alles in een binnen. En dan, ja, dan kun je het niet meer scheiden van elkaar. Maar bij nieuwbouw kun je ook zo'n, want dat heeft dan te maken met vacuüm riolering. Nou, daar gaan we nu een pilot mee doen in de stad. Ik geloof iets van 160 woningen, krijgen zo een vacuüm rioleringssysteem en er is een hele kleine zuivering bij. Nou ja, Misschien dat dat de concepten zijn voor de toekomst, hè? Waarbij je dan zuiniger om kan gaan met je met je drinkwater en energieterugwinning uit die stoffen. Dus daar moest ik wel aan denken toen ik dit voorbeeld zag, hè, dus? Nou ja, enerzijds is de opschaling, maar je ziet ook klein initiatieven in de stad. We hebben ook bij Mannoury, dat is een appartement complex.

Plas, Jan-Joris van der 12:29
Ja daar heb ik toevallig ook over gesproken met Marcel ja.

Al, Niels 12:42
Nou ja, Dat is ook zo'n voorbeeld van nou een andere manier omgaan met je, in dit geval douchewater, hè. Of is het grijswater volgens mij?

Plas, Jan-Joris van der 12:51
Ja. Klopt.

Al, Niels 12:54
Wat dan een zijdelings slag krijgt van zuivering doormaakt en dan gebruikt kan worden voor ja voor het groen wat daar op het dak onder andere zit. Maar ja.

Plas, Jan-Joris van der 13:06
En, hoe zou je er tegenaan kijken als zo een container zoals dit? Want je hebt het nu over nieuwbouw, maar als dit gebruikt wordt in ik zeg, Vondelpark bijvoorbeeld, dan heeft zo een container ook een plekje nodig. Is dat iets waar je waarvan je denkt dat dat? Levert misschien problemen op, of misschien biedt het juist kansen om daar iets educatief van te maken om mensen daarover te informeren.

Al, Niels 13:29 NEED & NECISSITY (+) PUBLIC PERCEPTION (+) EDUCATION & AWARENESS (+)
Ja, nou ja, ik zou zeggen dat kijk als de droogte er is en het risico voor zo een parkomgeving wordt groter, dat mensen zullen begrijpen dat daar dan tijdelijk een container staat met informatie erbij. En dat die dan natuurlijk. Ja, dat gaat daar geen jaar staan. Die zal na twee drie vier maanden wel weer weg zijn, hè? Dus dan als de droogte voorbij is, dus dat het een tijdelijke maatregel kan zijn, net zoals ja erin drukke periodes in de stad, ook toilet voorzieningen soms staan ja.

Plas, Jan-Joris van der 13:50
Ja.

Al, Niels 14:00 EDUCATION & AWARENESS (+)

Dat je dat doet met een goed verhaal daarbij natuurlijk. Voor het behoud van het park hebben we dit nodig, laat ik het zo zeggen, behoud van het groen

Plas, Jan-Joris van der   14:08
Ja ja. Is er dan ook vanuit de gemeente een soort kostenplaatje waar jullie aan denken bij dit soort innovaties zijn daar harde eisen aan. Of hebben jullie daar richtlijnen voor richtsnoeren voor?

Al, Niels   14:26
Ik heb geen idee. Ja, ik zou zeggen van als je, want we gaan even uit van in ieder geval het bevloeien van jonge aanwas hè ja dat je dat doet.

Plas, Jan-Joris van der   14:35
Ja ja, daar heb ik ook voornamelijk op gefocust bij mijn onderzoek of tenminste de kwetsbare aanwas, ja.

Al, Niels   14:38 QUANTITY EFFLUENT (-)
En, en ik weet niet, en ik weet niet wat zo een container oplevert aan productie?

Plas, Jan-Joris van der   14:46
Ik heb nu als soort concept gefocust op de watervraag van de ja kwetsbare groen in het Vondelpark en toen zijn we uitgekomen op winning van water dat uit riool wordt gewonnen is 5 kuub per uur.

Al, Niels   15:03
Nou ja.

Plas, Jan-Joris van der   15:03
En de productie ligt dan tussen de 2,5 kuub en afgerond 4 kuub per uur.

Al, Niels   15:10 QUANTITY EFFLUENT (-) COST (-) NEED & NECESSITY (+) BENEFITS OF GREENERY (+) INCREASE GREENERY (+)
Nee, nou ja, Dat is best wat! Da zul je op een gegeven soort model moeten maken, hè? Van wat Als we geen water uit de gracht kunnen halen, geen drinkwater kunnen gebruiken en die jonge aanwas gaat eraan. Ja wat, wat is het ons waard dan, hè? Of alles dood Laten gaan, het risico lopen op alles, dood laten gaan, of nou ja, of deze techniek omarmen? Ja, en dan is dit vind ik eigenlijk best mooi aantal kuubs wat dan per uur… We rijden, ze rijden dan met van die wagens rond met van die dingen er ook op die kun je dan vullen, daar op zo een punt en dan vervolgens rijden ze door de stad heen. Ja en dan is natuurlijk de vraag, wat kost dat? Zeg maar hè per kuub en hoe verhoudt zich dat tot? Nou ja, tot wat je daarmee mee wint, nog even los van de emotionele schade, want als alle jonge aanplant doodgaat ja, kan je ook gewoon wel een op een vervangen. Maar dat is natuurlijk ook. Ja, heb je weer minder groen. Nou ja, je groen heb je minder snel groot dan je had gehoopt en dat is dan weer slecht voor de hitte.

Plas, Jan-Joris van der   16:10
Ja en het blijft langer kwetsbaar, ook nog dan.

Al, Niels   16:17
Ja.

Plas, Jan-Joris van der   16:18
Nee duidelijk.

Al, Niels   16:18 NEED & NECESSITY (-)
Dus, Ik kan me voorstellen dat zo een soort van redenering dan in zit, maar wat ik zeg ja, ik zie het niet 1 2, 3 gebeuren zoals het nu is.

Plas, Jan-Joris van der   16:24
Oke, en wat is dan de voornaamste reden dat je het nog niet ziet gebeuren?

Al, Niels   16:33 NEED & NECESSITY (- & +) RULES & REGULATIONS (+)
Ik denk nu dat we nog niet zo ver zijn, maar als je nog dat we een paar keer zo'n droge periode hebben, dat we op gegeven moment denk ik ja en dat er van die verboden gaan komen hè van het gebruik. Dat we er dan tegenaan lopen. Kijk, nu vinden we nog de normaaste zaak van de wereld dat we gewoon eventjes een slang in de grachten hangen of in het water en.

Plas, Jan-Joris van der   16:58
(hoest erdoorheen) Excuus.

Al, Niels   16:59
En dan ben je voor een kuub heel weinig kwijt. Maar ja, net zoals in die zuidelijke landen, daar is het gewoon al praktijk, daar hebben ze ook een periode gehad van dat er een iemand begon en dat andere dachten nou… Water uit het riool gebruiken om mijn druif groot dat verzin je toch niet? Ja en nu zie je dat dat dan ook een vlucht neemt.

Plas, Jan-Joris van der   17:13
Zie je dit ook als een mogelijkheid voor andere toepassingen? Ik heb nu gefocust op de irrigeren van stedelijk groen, maar zou je zeggen, Dit is ook iets wat voor het hele watersysteem een kans heeft of juist niet. Dat je zegt, er zijn meer betere alternatieven, bijvoorbeeld het opvangen van regenwater.

Al, Niels   17:46 SPACE & APPEARANCE (+)
Nou ruimte in de stad is natuurlijk altijd een ding. Dus dat, je hebt nu ook met groene daken. Die hebben dan vaak ook. Ja, op een gegeven moment is dat wel weg. Dus je hebt opslaan van water in de stad, hè? Vanuit de hemel Waterverordening zetten we daar wel op in en ook dat je een deel van dat water weer hergebruikt. Maar ja, na 6 weken, kun je droogte zoals het nu is, is alles wel een beetje op schat ik zo in. En In de stad gaan we niet van die grote reservoirs aanleggen. Je zou misschien nog aan de randen van de stad dat soort dingen kunnen gaan doen of op bepaalde daken die een hele goede constructie hebben. Dat je water opslaat. Dat is ook een van die ideeën in dat AquaConnect project,

dat je daar misschien een beetje mee kan spelen. Maar dit is natuurlijk wel een oplossing die weinig ruimte vraagt in verhouding en nou ja, een constante stroom of gebruik kan maken van een constante stroom in je stad. Dus, dat is wel het voordeel van deze methode.

Plas, Jan-Joris van der 18:47
Oké. Zijn er nog dingen waar je aan denkt Als het gaat om ja, het is gezuiverd afvalwater. Dat brengt natuurlijk risico's met zich mee dat zij nou zoals we al even kort hadden benoemd, risico's voor mensen, maar ook bijvoorbeeld voor de natuur zelf zijn er vanuit Amsterdam dingen waar of vanuit jouw kijk erop zeg maar. Daar zou ik het meest op focussen of bijvoorbeeld daar heb ik nog de meeste vragen bij, of dat zou kunnen voldoen.

Al, Niels 18:57 SURFACE & GROUND WATER (-) HUMAN HEALTH (-) BIODIVESITY (-)
Nou ja, die gezondheidsrisico's, wat doet het met de mens, stink dat of zo, hè, krijg je dat? En wat betekent dat ook voor de biodiversiteit, hè? We hebben natuurlijk de kaderrichtlijn water in ons beheersgebied betekent dat dat water wat uitstroomt en uiteindelijk in de watergangen terecht komt, kan dat een negatieve invloed hebben hè? Dus daar hebben we ook nog wel rekening mee te houden. Dat zat eigenlijk ook volgens mij in het artikel wat ik hier doorstuurde. Dus ja, daar moet je op al die aspecten moet je Natuurlijk een goed verhaal hebben.

Plas, Jan-Joris van der 19:54
Ja zeker.

Al, Niels 19:54 SOIL & PLANT HEALTH (-) SURFACE & GROUND WATER (-) RULES & REGULATIONS (-)
Het kan niet zo zijn dat we dan dat groen wel overeind houden, maar vervolgens al dat bodemleven daar schade door oploopt omdat er allerlei reststoffen in achter blijven en die hopen zich dan langzaam op in dat bodemprofiel of die komen terecht in de watergangen en dat we dan vervolgens daar weer tegenaan lopen. Kijk in de KRW gaat straks natuurlijk ook gewoon zeggen, je mag de waterkwaliteit niet zo slecht maken. Dus dat ja dit en dat wordt ook juridisch straks wel afdwingbaar ben ik bang dus daar nou ja.

Plas, Jan-Joris van der 20:30
Ja, dat zijn nog belangrijke dingen die echt goed getest moeten worden ook. Nee, duidelijk, even kijken. Misschien als het gaat om kansen voor de applicatie, dus zou jij zeggen, dit heeft meerdere mogelijkheden. Ik noemde al natuurlijk stedelijk groen irrigatie, maar je kan ook kijken naar bijvoorbeeld sportvelden, voetbalvelden die opnieuw ingezaaid zijn in de zomer of.

Al, Niels 20:45
Oh ja.

Plas, Jan-Joris van der 21:06
Golfcourses die natuurlijk vaak veel water vragen. Stedelijke landbouw. Zeg je dat zijn kansen of zie jij zelf andere kansen, bijvoorbeeld waar nog extra aandacht aan besteed moet worden of.

Al, Niels 21:22 APPLICATIONS (+)
Nou ja, die opties die je hebt benoemd zijn wel, ja, ja. En kijk in die met die sportvelden heb je bijvoorbeeld, ik weet in Rotterdam, ook in Den Haag heb je een urban waterbuffer.

Plas, Jan-Joris van der 21:37
Aha

Al, Niels 21:38
Dat is eigenlijk ook wel een vorm van. Ik ben trouwens er zelf bij betrokken geweest bij die in Den Haag. Dus het opslaan van regenwater ondergronds in een soort van zoetwaterbel die je dan weer kan gebruiken in tijden van droogte. En dat is Natuurlijk een vorm van waterbuffer die ook minder ruimte vraagt. Althans wat minder ruimte bovengronds en dus in stedelijk gebied toepasbaar is.

Plas, Jan-Joris van der 22:01
Ja.

Al, Niels 22:07 NEED & NECESSITY (+) COST (- & +)
Dus die dat zijn methodes die ze daar nou ja gebruiken voor sportvelden. Ja, Ik weet niet. Ja, kijk, als die als Als de sec voor ook golf clubs, als er dit soort van dingen gaan gebeuren dat het watersysteem nou ja, dat je gewoon niet dat je geen water meer uit de sloot mocht halen. Ja, dat worden dit soort systemen opeens hot en net zoals een urban waterbuffer. Ja, dat zijn enorm dure projecten, maar dan ga je wel zien dat dat dit soort dingen waarschijnlijk omarmd gaan worden.

Plas, Jan-Joris van der 22:41
Ja.

Al, Niels 22:43 PUBLIC PERCEPTION (-)
En dan is een urban waterbuffer misschien dan nog iets veiliger voor partijen. Omdat je dan nou ja, het gaat gewoon regenwater en daarvoor de ondergrond in. Het kan natuurlijk zijn dat er vervuiling in zit die je dan vervolgens weer omhoog pompt. Maar dat is dan meer een gevoelskwestie net iets veiliger om te sproeien. Zeg maar.

Plas, Jan-Joris van der 22:59
Ja ja. Qua perceptie is dat dan?

Al, Niels 23:04 PUBLIC PERCEPTION (-)
Dat ja. Misschien is dat helemaal niet zo, hè? Dat je het gewoon op kan drinken als je het zou willen, Maar dat is even het beeld.

Plas, Jan-Joris van der 23:14
Nou ja, het doel is wel nu inderdaad irrigatie, dan is het zonde om het zo ver te reinigen dat het ook drinkwater is natuurlijk

Al, Niels 23:18 HUMAN HEALTH (-)
Ja. Ja, maar als je het gaat sproeien, op een veld en er zijn ook kinderen of zo. Welke risico's loop je loop je dan?

Plas, Jan-Joris van der   23:22
Nee zeker. Zeker.

Al, Niels   23:31
Maar in Rotterdam doen ze dat bij het Sparta stadion.

Plas, Jan-Joris van der   23:35
Dat klopt Dat is inderdaad ja, Dat is net nieuw. Hebben ze dat toegepast, geloof ik.

Al, Niels   23:39
Nou ja het Ik denk 4, 5 jaar geleden of zo.

Plas, Jan-Joris van der   23:41
Ja, Ik heb het. Ik heb er nog een vak inderdaad over gehad in Delft inderdaad. Toen kwam dat als voorbeeld voorbij. Ja, dat was ik helemaal vergeten, Maar dat is zo ja.

Al, Niels   23:51
Ja.

Plas, Jan-Joris van der   23:52
Even kijken nou, ik denk dat we ook bijna aan het einde zijn van onze tijd. Mag ik jou vragen na dit gesprek zijn er dingen waarvan je denkt dat dat neem ik mee of hier? Dit blijft me het meest blij van dit gesprek.

Al, Niels   24:06 INNOVATION & DECENTRALISED SYSTEMS (+) NEED & NECESSITY (+)
Nou ja, in ieder geval wat ik zeg, het is voor mij ook een relatief nieuw onderwerp. En nu ik zo met jou in gesprek ben, denk ik, oh ja, We hebben dit, We hebben dat en dus het zet mij gewoon ook aan het denken. Ik had hier gewoon nooit bij stilgestaan bij dit soort dingen, maar nu valt opeens mij ook zo een krantenberichten op en dus het helpt mij ook gewoon een beetje dit veld wat meer in het vizier te krijgen en ook het besef dat ja dat dit soort dingen er ook gewoon aankomen als gevolg van klimaat verandering.

Plas, Jan-Joris van der   24:21
Oké.

Al, Niels   24:34
Dus dat dat ja.

Plas, Jan-Joris van der   24:37
En stel we zijn een paar jaar verder. Wat zijn voor jou dan de belangrijkste stappen die gezet moeten worden voor grootschalige implementatie van deze innovatie?

Al, Niels   24:52 NEED & NECESSITY (- & +)
Nou, kijk, ik zou hopen dat het niet nodig is. Dat we ja erin slagen om ons watersysteem robuuster te maken. Ook de zoetwater aanvoer beter op orde te krijgen. Dat we ja, dit zit net toch wel het laatste redmiddel hè, vind ik. Er komt echt wel een categorie van ja, dat speelt ook in Zuid-Europa. Misschien moeten we in bepaalde gebieden gaan voor woestijnen. Nou ja, in Nederland kun je misschien ook de discussie krijgen, ja, moeten we niet andere dingen gaan aanplanten? Ja, kunnen we dan Misschien wel zo groen in de stad? Moeten we dat niet? Dus ja, je komt ook wel in dan een heel ander. Maar ja, willen we ons groen hebben houden en ja, dan dit zou dit wel een oplossing kunnen zijn.

Plas, Jan-Joris van der   25:56
En hoe kijk je er dan tegenaan? Want je zegt, Dit is een soort laatste redmiddel, maar het is natuurlijk ook een mogelijkheid om het water dat in de stad is een tweede keer eigenlijk te gebruiken voordat het eigenlijk de zee in wordt gepompt. Nadat het gezuiverd is zoals dat nu gaat.

Al, Niels   26:06 CIRCULAR ECONOMY & REUSE (+)
Ja nee vanuit dat je vanuit de circulaire gedachte en ook de watercyclus is dit ook helemaal geen gek idee. Het idee wat dat betreft vind ik ligt voor de hand. Het is Alleen jammer dat we dat we gewoon zover hebben Laten komen, hè? Dus Dat is maar ja.

Plas, Jan-Joris van der   26:31
Ja nee, dat ben ik met je eens.

Al, Niels   26:34
Dus, maar ja, dat geldt op heel veel terreinen dus. Maar dan wijken we een beetje af. Ik zag gisteren een programma over hommels.
We hebben 60 tot 70% van onze gewassen moeten bestoven worden door hommels. Nou gebruiken we zoveel gifstoffen en ja zijn er weinig te hommels. Gaan we die hommels kweken, maar die hommels die zijn allemaal is een soort, die gaan we ook naar Zuid-Amerika sturen. Nou, dan verdwijnen nu al die inheemse soorten hommels. En denk ik altijd, ja, we hebben dan weer een oplossing. Maar ja, de kern is natuurlijk dat we ja ons systeem gewoon niet duurzaam voor elkaar hebben, waardoor we elke keer weer in de reflex schieten om allerlei ja hebben we een innovaties nodig.

Plas, Jan-Joris van der   26:51
Ja ja. Je zou liever aan preventie doen dan aan de adaptatie eigenlijk haha.

Al, Niels   27:21
Haha. Ja, eigenlijk hebben we gewoon een heel mooi systeem in ons land. Nou ja. Maar ik bedoel ik ben wel gecharmeerd van dit voorbeeld hoor, dus daar niet van. 10 jaar geleden had ik hier dan nooit over nagedacht, maar misschien over 10 jaar dat we nou dat elke stad dit wel heeft. Ja, ik weet het niet.

Plas, Jan-Joris van der   27:45

Nee nee OK.

Al, Niels 27:47
En weet jij of dit al op deze manier gebruikt wordt in andere steden in Europa?

Plas, Jan-Joris van der 27:53
In Athene zijn er meerdere pilot projecten mee geweest maar die hebben ook een aantal water prijzen gewonnen. Innovatieprijzen. En daar zijn ze daarna ook aan de slag gegaan met het verder uitbreiden. Het gebeurt ook op grotere schaal. Kijk, Dit is natuurlijk wat kleinere schaal voor de stad. Echt gericht gebeurt op grotere schaal, veel in de landbouw, het Midden-Oosten, heel veel, ook in mediterrane gebied en het in Australië gebeurt het op hele grote schaal. Daar is natuurlijk hele erge droogte. En ja, ik zou eigenlijk willen zeggen, zoals ik het heb begrepen, is het daar ontstaan het concept en daar heb je het voor golfcourses, stedelijk groen, sportvelden, landbouw, echt van alles en nog wat. Daar wordt dat heel breed toegepast.

Al, Niels 28:23
Ja oke.

Plas, Jan-Joris van der 28:41
Er zijn daar ook veel meer richtlijnen die in Nederland gewoon nog wel echt ook ontbreken. Dus ja, nee, het is zeker iets wat in het buitenland al gebeurt.

Al, Niels 28:46 INNOVATION & DECENTRALISED SYSTEMS (+)
Ja oké dit dus dit is eigenlijk gewoon een bewezen technologie.

Plas, Jan-Joris van der 28:54
Ja de technologie zoals het nu in de ontworpen container zit met directe nanomembraanfiltratie, om het modulair te maken en om het wat kleinere footprint te geven, maar met biologische behandeling van het water of met RO wat dan weer net iets meer energie vraagt, is zeker bewezen technologie.

Al, Niels 29:17
OK.

Plas, Jan-Joris van der 29:18
Nou.

Al, Niels 29:19
Nou, nou ja, zo zie je maar dat is dus al best wel uitgerold in de wereld.

Plas, Jan-Joris van der 29:23
Ja.

Al, Niels 29:25
En ook voor verschillende functies. Je hebt ook partijen die natuurlijk uit zeewater dit soort dingen halen.

Plas, Jan-Joris van der 29:33
Ja. Dat is dan echt met reversed osmosis. Dat is echt puur, dan moeten er zoveel zout uit gehaald worden, dat je dat je dat echt nodig hebt. Maar inderdaad dat dat zou ook nog kunnen in een in een container. Nou ja, als jij zegt inderdaad verzilting van het grachtenwater of oppervlaktewater, dan zou je ook nog op die manier toch weer gebruik eventueel kunnen maken van oppervlaktewater. Dat zijn ook dingen waar je aan kan denken.

Al, Niels 29:36
Ja, dan heb je de vraagt wat meer of minder energie kost?

Plas, Jan-Joris van der 29:56
Reversed Osmosis vraagt het meeste energie en dan nanofiltratie van de membraanfiltratie stappen. In ieder geval zit dat daar dan onder. Maar, dat scheelt nogal wat druk, dus ook wat energie.

Al, Niels 30:08 APPLICATION (+)
Oke oke. Die techniek passen ze natuurlijk vaak toe op eilanden, hè, dus? Curaçao en ook Kaapverdische Eilanden hebben we al dit soort van technieken om zoet water te winnen (vanuit zout water).

Plas, Jan-Joris van der 30:24
Ja.

Al, Niels 30:25
Dus nou, ik vond het leuk ook een beetje hier meer over te horen.

Plas, Jan-Joris van der 30:31
Mooi om te horen.

Al, Niels 30:32
Ik wens je succes met je, uitwerking. En kan je nog even die naam sturen van die collega.

Plas, Jan-Joris van der 30:35
Dankjewel.Ja zou fijn zijn hartstikke bedankt voor je tijd nogmaals en, wederzijds vond het een erg leuk gesprek en goeie bruikbare input, dus dat zal ik zeker kunnen verwerken.

Al, Niels   30:44
Ja. Ik heb mijn best gedaan. He succes, hoi.

Plas, Jan-Joris van der   30:49
Dankjewel doei doei.

EINDE INTERVIEW