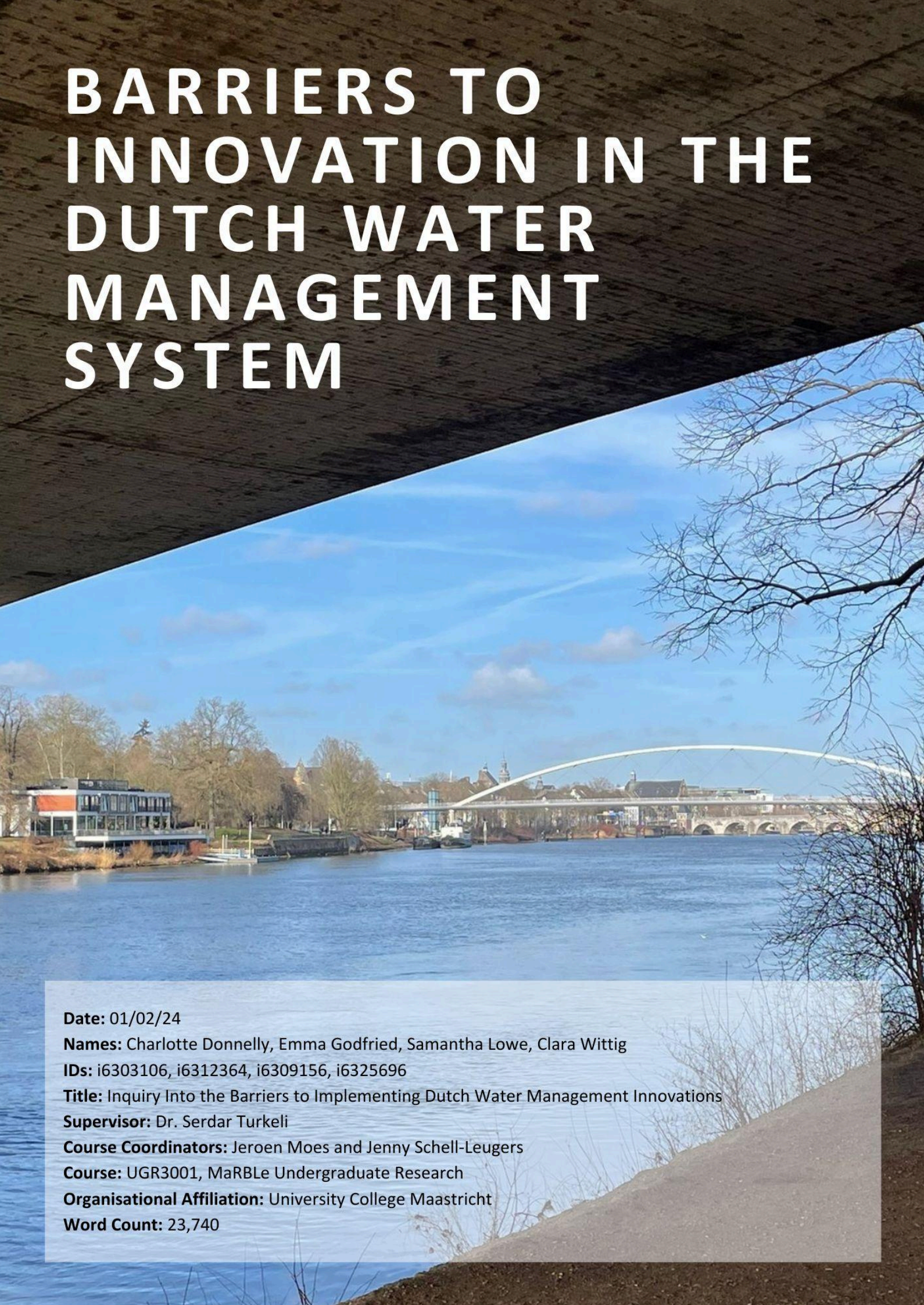
BARRIERS TO INNOVATION IN THE DUTCH WATER MANAGEMENT SYSTEM



Date: 01/02/24
Names: Charlotte Donnelly, Emma Godfried, Samantha Lowe, Clara Wittig
IDs: i6303106, i6312364, i6309156, i6325696
Title: Inquiry Into the Barriers to Implementing Dutch Water Management Innovations
Supervisor: Dr. Serdar Turkeli
Course Coordinators: Jeroen Moes and Jenny Schell-Leugers
Course: UGR3001, MaRBLe Undergraduate Research
Organisational Affiliation: University College Maastricht
Word Count: 23,740

Abstract

The Dutch water management sector has a reputation for innovation and good water quality. However, Dutch water fails to meet the standards set by the European Union Water Framework Directive. In this paper, we aim to identify barriers to innovation in the Dutch water management sector that prevent the Netherlands from meeting the WFD standards. We conducted qualitative research, interviewing 14 actors in the Dutch water management system across 5 different stakeholder groups. From these interviews, we identified various factors that influence innovation, and clustered them into four themes, and analysed them using the Multi-Level Perspective framework. Our results suggest that pressing barriers to implementing innovations in the Dutch water management system revolve around issues with effective inter– and intra stakeholder communication, public awareness and involvement, and integration of newer technologies in existing aged infrastructure. Based on these obstacles, our recommendations advise to clarify stakeholder responsibilities, encourage collaboration and dialogue between and within stakeholder groups, and encourage nature based solutions.

Key words: water management, innovation, barriers

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[1] Introduction and Research Question

The Netherlands has the worst water quality of all European Union Member States (MS). Of all Dutch surface and groundwater, only 1% fulfils the European Union's (EU) Water Framework Directive (WFD). This was found by Wageningen University and published in a report in 2022 (Didde). In 2022, it was predicted that only 5% of Dutch water bodies would meet the WFD standards (Aan De Brugh & Wassens, 2022). Seeing as the Netherlands is renowned for its water management strategies and good water quality, this statistic is remarkable (VEWIN, 2016). Water is an essential resource, for economic, ecological, and agricultural operations as well as a human right (Álvarez, 2023). The sixth Sustainable Development Goal (SDG) of the United Nations emphasises the need for clean water, especially for preserving human health. It is indisputable that the Dutch water management is under increasing pressure from climate change (Verweij et al., 2010). The increased temperatures both in the summer and the winter raise the temperatures of water bodies fostering the growth of pathogens, thus deteriorating the overall quality of the water by decreasing the potential for biodiversity to grow in these water bodies. This makes maintaining the water quality standard a more difficult task.

Globally, demand for water is steadily increasing. Climate change, population growth and increasing water scarcity will put pressure on food supply as most of the freshwater used, about 70% on average, is used for agriculture (Jiménez Cisneros et al., 2014). Farming is already the single biggest user of water and it is projected to almost double in 2050 relative to the industry's size in 2012 to meet the rising demand for food, fibre, and biofuels (Mekonnen & Gerbens-Leenes, 2020). The Netherlands is an export economy and a large part of its annual earnings come from the agricultural sector. It is Europe's largest meat exporter (Reiley, 2022). More than half of the land is used for agricultural purposes which requires a dramatic amount of water to bring good yields. This implies that the Netherlands already uses a large amount of its available water for agricultural practices, and with the aforementioned added pressures the Netherlands will have to significantly increase their water usage to satisfy all its water demands.

Organisations such as the United Nations (2022) predict that water will be the next major crisis and that global demand for clean drinking water will rise dramatically. Despite this, maintaining water quality has not always been of great concern for more developed countries, as other interests are prioritised. In addition, some of these countries' locations in shared water basins has caused blame for subpar water quality to be placed elsewhere (National Intelligence Council, 2021). Another challenge is the way in which water management is governed differently compared to other industries like agriculture and energy. Sectors don't always coordinate their usage of water; they

don't always acknowledge their connection to one another (National Intelligence Council, 2021). These all constitute examples that can impede maintenance and management of water quality.

Noting the importance of water as a resource and as a human right, the current dire quality of Dutch water, the imminence of climate change which will aggravate all contemporary conditions and the lack of steps to completion of the WFD produced the following research question: What barriers are hindering the effective implementation of innovations to improve water quality in the Netherlands according to the European WFD standards*?*

This research is relevant because it highlights how Dutch water quality ought to be improved on. Not only to fulfil the WFD standards but also because of the importance of clean water as a commodity and as a human right. Climate change puts additional pressure on the Netherlands to perform its developments to achieve better water quality. This research aims to investigate the factors as to why the renowned Dutch water management system is so far from meeting the WFD demands, as stated in a source .

Key terms and concepts will be elaborated on throughout the background section of the paper, previous literature will also be presented to identify gaps which this paper takes the beginning steps to fill. Furthermore, two theoretical frameworks were used to categorise and process our qualitative findings which are analysed below. A conclusion will ensue with recommendations based on the findings.

[2] Background

This section aims to provide the reader with the context that informed our research question as well as providing adequate background to understand the findings and results.

[2.1] EU Water Framework Directive and Water Quality

In order to better identify the obstacles and barriers that limit water management innovation and progress, we outline the EU's WFD, which serves as a framework to define water quality in all of the EU. Through this framework, we can better understand what exactly the goal is in collecting and presenting research for the paper. The WFD is a set of policies defined by the EU that outlines its standards for good water quality, and how it expects EU MS to achieve them (European Commission, 2023). The framework was established in October of 2000, and incorporates 'fitness checks' every few years wherein the progress of each country is visited. The fitness check that uncovered the Netherlands' slow progress to reaching the WFD standards likely took place in the most recent check of December 2019, though this has not been explicitly published. The determination of regional WFD water bodies is a competence of the provinces (Provincie Limburg, n.d.). The WFD is seen by many as

a positive move for river basins throughout the EU, and it is believed to set the stage for an ambitious, comprehensive, and contemporary water strategy for the Union (Josefsson, 2011). The WFD identifies 110,000 water bodies, which are surface and groundwaters, all across the EU which must meet and improve for the WFD standards (Blom, 2023).

Legally speaking, the WFD is set apart from the other water management frameworks in the EU because of its additional focus on both the biotic and abiotic components of ecosystem architecture and functioning based on Article 2(21)–(22). Previously, the major focus of water management has been on abiotic ecosystem components, notably chemical ones. A strategy that has frequently failed to restore or rehabilitate aquatic ecosystems. Thus, the defined ecological status within the WFD is the most in line with a sound ecological definition for status of water. This makes the WFD fundamentally progressive and adequately distinguishes it from other water directives (Josefsson, 2015).

Some principles of the WFD are that there can be no further deterioration of the chemical and ecological status of water after 2000. In addition to water quality, there is a focus on ecology. Both the polluters and the user of the water pay for any damage to the water quality. The overall goal of the WFD is to achieve a ‘good’ status for water. This entails that there is good ecological status or good ecological potential for biology which correspond with hydromorphology and ecologically relevant parameters. Good chemical conditions for the so-called Priority Substances were revised in 2022 to include a total pesticides standard, and 25 new additions (European Commission, n.d.). They include: PFAS (a huge gathering of "everlastingly synthetic compounds" utilised in cookware), clothing and furniture, fire-fighting foams and personal care products; a range of pesticides; bisphenol A, a plasticiser and a component of plastic packaging; a number of pharmaceuticals used as painkillers, anticonvulsants or antibiotics; and silver (European Commission, n.d.). These proposed substances have been shown to be harmful to human health and the environment

The Prague method, established in 2005 at a WFD Common Implementation Strategy (CIS) conference, is a ‘mitigation measure approach’ that is adopted by many MS (Eurelectric, 2020). The ‘mitigation measure approach’ is meant to prevent, decrease or control unfriendly ecological impacts of a venture (Levy & Patz, 2018). The overall score will be determined according to the Prague method which will result in MS achieving a ranking on the WFD scale, 0 is the worst and 1 the highest, with a ‘good water quality’ rank lying between the ratio 0.6 and 1. The measuring standards mean that if part of a body of water fails in one category, the whole river or lake is given an “unsatisfactory” rating, this has otherwise been referred to as the ‘one out, all out’ strategy (Didde, 2022).

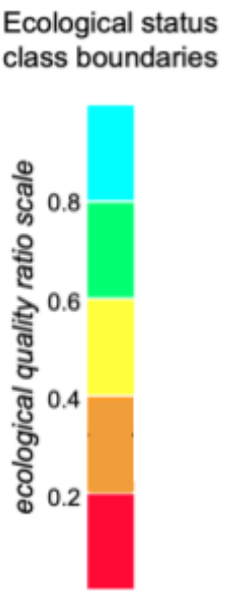

Fig. 1: Illustrates how the ecological quality represented by GEP in different water bodies can be compared using the biological assessment methods developed for the closest comparable water body types (European Commission, 2008).

The legal definition for good water quality is the source of much dispute. The ideal ecological definition of an ecosystem describes it as being robust and highly adaptable (Josefsson, 2015). Nevertheless, this idea is undermined by the WFD's formal requirements. The WFD's methodology is dependent on the idea that the structure and function of ecosystems may be precisely determined by measuring specific fixed biological constituents, such as the aforementioned compounds that must be absent from surface and groundwater. This strategy is debatable and makes achieving the goal of "good ecological status" less likely (Josefsson & Baaner, 2011). It is important that fulfilling the WFD's standards does not compromise the ecosystem's autonomy – a healthy ecosystem should exist and flourish without management. However, because of the WFDs innovative all-encompassing definition for ecological status of water, 'good quality water' is somewhat accepted as a requirement that may be fulfilled. Furthermore, it is valid to state that any legal directive outlines a goal that EU MS must achieve, and allows room for MS to interpret the regulation as they wish (Directorate-General for Communication, n.d.). This wiggle room offered by a directive might suggest that the ambiguity of the definition of good ecological water is forgiven for the fact that MS are not all bound by the same implementary guidelines.

By 2015, the Netherlands ought to have already accomplished the goals set by the WFD, but all the MS asked for an extension (Aan De Brugh & Wassens, 2022). Therefore, the deadline is now 2027. As of now, it appears to be probable that numerous Dutch water bodies can not meet the objectives by 2027. Neglecting to resolve this issue will bring about critical results, for example, imperilling drinking water supply (Blom, 2023; Aan De Brugh & Wassens, 2022).

Failing to meet the WFD has the concerning consequence of indicating that Dutch water quality is subpar. Potentially leading to deleterious effects to human and ecosystem health, as well as being potentially inadequate for industrial and sanitary use. Additionally, the WFD poses consequences in the form of an annual fine post-2027 posted by the Court of Justice of the EU, most likely calculated relative to the amount of pollution the Netherlands generates. This non-compliance with the WFD also implies that local authorities will not be able to concede permit applications for activities that include water use or could influence water quality (Aan De Brugh & Wassens, 2022; Didde, 2022).

As many water bodies such as lakes and rivers cross national boundaries, the WFD uses what it calls a 'river basin district approach' to share responsibility of water body management between countries. This river basin approach means that regions are divided by river basins, rather than by national borders, and all the countries that share the basin are expected to cooperate in management. The Netherlands is part of the Rhine basin, and has submitted its plan for overseeing all the water within it alongside Italy, Lichtenstein, Austria, Germany, France, Luxemburg, and Belgium (International Commission for the Protection of the Rhine, 2022). The Netherlands has also subdivided its water bodies into four smaller river basin regions, for which it created a National Water Management Plan. The first version was in effect between 2016 and 2021, followed by an updated plan in 2022 which would stay in effect until 2027 (The Government of the Netherlands, n.d).

The Netherlands' existing surface water quality issues are made worse by climate change; no new issues with water quality are anticipated. This is the finding of a literature search conducted by Dutch ministry for public health and environment (RIVM), which was centred on the anticipated consequences of climate change on water quality, taking into account effects on human health, environment, and certain economic sectors. Therefore, the RIVM advises authorities to consider the potential effects of climate change in existing policies rather than creating new ones. The added strain brought on by climate change may make the WFD objectives unachievable. Additionally, RIVM suggests greater coordination between authorities and more integration within policy domains (Verweij et al., 2010).

In summary, the WFD provides an overview of how countries are expected to improve their water quality, to which the Netherlands has responded by creating an international plan in cooperation with other states that lay in the Rhine river basin, as well as a national plan. With these plans, our group is able to better identify what the Netherlands aims to do to achieve the WFD which may bring us closer to understanding where and why the country falls short.

[2.2] Current Water Standards and Quality

In 2022 ‘Wageningen World’, a quarterly magazine created by the Wageningen Research University was published. The magazine aims to inform readers of recent updates related to nutrition, nature, climate, the circular economy, and the environment (Wageningen University & Research, 2023). When doing initial research for this project, Wageningen World was one of the most recent publications we found, which highlighted the importance of addressing the Netherland’s issue with water quality for the general public. Given that Wageningen University is a renowned university for environmental issues, their findings were summarised to commence and aid our own research.

As already mentioned and stated by the report, the Netherlands is grappling with a severe water quality crisis, showing continuous poor performance in the last 15 years. Groundwater and surface water, encompassing rivers, canals, and lakes, exhibit high levels of pollutants like nitrate, phosphate, PFAS, and microplastics. Despite historical efforts to reduce water pollution, since the introduction of the WFD, nitrate and phosphate from agriculture has increased, and new industrial substances continued to be detected. This has led to the Netherlands being referred to as the "cesspit of Western Europe," with polluted water flowing in from neighbouring regions, and domestic activities like agriculture and a high population density contributing to pollution.

The measurement criteria for the WFD is complex, and involves assessing over 700 designated water bodies, with the 'one out, all out' principle, causing only 1% of Dutch waters to score 'good' in all categories. The Netherlands, therefore, ranks the lowest of all European countries, with only 17% of water bodies achieving a good ecological status. Agriculture is a major contributor to WFD failures, with a third of quality issues blamed on the leaching of fertilisers and pesticides. Another third comes from substances in domestic wastewater and industrial discharges. External sources, like neighbouring countries and flooding add to these challenges.

In addition there are further inadequacies found in wastewater treatment plants, such as poor discharge licences for large industrial companies, and a lack of sensitive measurement methods for certain pollutants. Notably, pollutants not targeted by the WFD, such as those in ditches, can leach into major rivers, further contributing to poor water quality in the Netherlands. Despite these challenges, experts see some hope in new initiatives such as restoring meanders in streams and meeting nitrogen and phosphate targets in various water bodies.

According to the report, the Netherlands now faces a pivotal moment, demanding more stringent measures to enforce regulations, monitor industrial discharges, and address sewage treatment deficiencies. Spatial planning measures, including banning crops on vulnerable soils and designating wetlands as nature areas, are now being proposed. The ‘National Rural Area Programme’

also offers potential for an area-specific approach to reconcile conflicts between agriculture and nature, providing hope for achieving water quality targets and preserving biodiversity.

[2.3] Dutch Water Management System

The water management system in the Netherlands is considered the oldest Dutch public democratic institution (Mostert, 2020). The shared interest in water necessitates cooperation, therefore, the management of water in the Netherlands is split up into a number of bodies. At the national level there is the Rijksoverheid, or the national government, which issues national policies and national measures such as flood protection standards. Additionally at the national level there is the Rijkswaterstaat, which is part of the Dutch Ministry of Infrastructure and Water Management. They are responsible for the management of national water bodies, such as the sea and the four international rivers that flow through the country: the Eems, Schelde, Rijn, and Maas (Ministerie van Infrastructuur en Waterstaat, n.d.-b).

On a regional level there is a hierarchy topped by 12 provincial governments who are responsible for managing water quality (Ministerie van Infrastructuur en Waterstaat, n.d.-b). They are responsible for translating national water policy into regional measures, operational tasks and management of groundwater quality. Then follows the authority of the water boards which represent district authorities, such as Waterschap Limburg (Van Buggenum, 2023). They create management plans for regional waters, canals and polder canals. They are also responsible for regional flood defences, and monitor water quality of regional water bodies. In cooperation with NGOs, they manage the nature around regional water bodies. The water boards act as functional democracies and are considered as an autonomous government. To fund management, water boards collect taxes from citizens, land owners and industries. For example, the declared goals of Waterschap Limburg are flood protection, sufficient water and ensuring clean water for people and nature (Van Buggenum, 2023). Finally, on a regional level there are the municipalities. The municipalities are responsible for managing groundwater in urban areas and the disposal of wastewater and excess rainwater through sewage (Van Buggenum, 2023). At both the national and regional levels, the public sector relies on private drinking corporations to distribute clean drinking water to various users.

Additionally, research institutes form an integral part in the designing of water management innovations and solutions, as well as setting guidelines and requirements for water quality. For example, the KWR pushes to improve water quality and sustainability through research and innovation (KWR, n.d.). The institute works together closely with the national and regional public actors to ensure the practical application of their research. Research institutes in the Netherlands, like the KWR, are both publicly and privately funded.

The social sector is involved with water quality management in the Netherlands through cooperation with NGOs. Nature preservation organisations work together with the water boards to reintroduce, monitor, and sustain the wildlife around water bodies (Natuurorganisaties en Natura2000, n.d.). Cooperation with NGOs is commonly found in the sustainability sector, focussing on moving to greener agricultural practices. Additionally, civilians are included in the water management process through the municipalities and water boards (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2021). Every four years, elections are held for the 21 water boards.

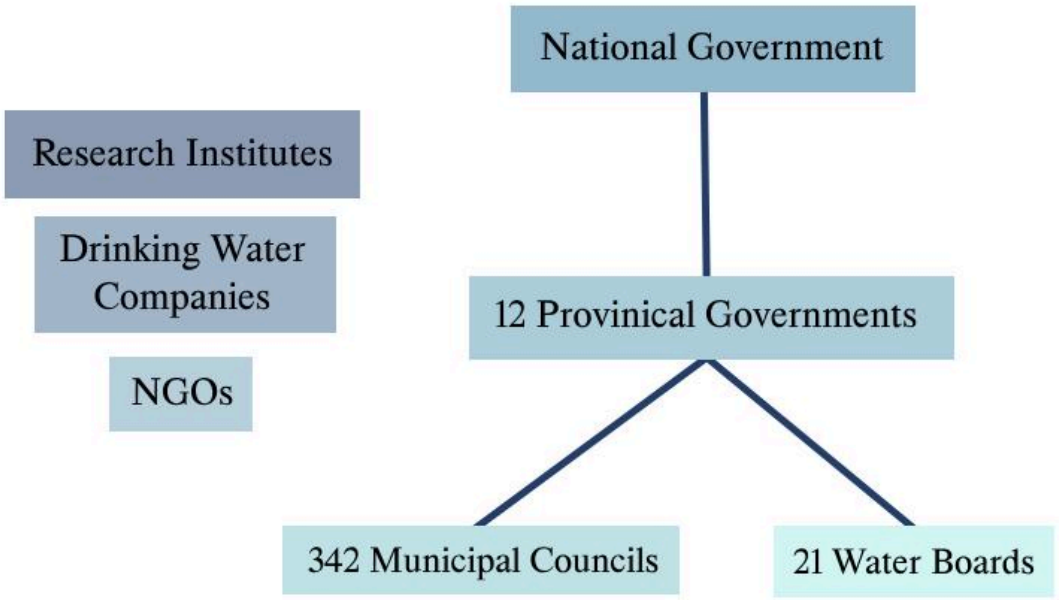

Fig. 2: Diagram illustrating members of the Dutch water management sector.

Every six years the Rijksoverheid composes a plan for national water governance and management, the latest edition being the National Water Program (NWP) in 2022 - 2027 (Ministerie van Infrastructuur en Waterstaat, 2021). With this plan the central government describes the main features of national water policy and its implementation in national waters to accommodate for changes brought about by climate change, environmental pollution and spacial pressure. The Netherlands and water are inextricably linked. Besides the fact that 26% of the Netherlands is below sea level, water influences where and how Dutch citizens live. Furthermore it also influences the ecology, the quality of drinking water, shipping, agriculture and industry (Ministerie van Infrastructuur en Waterstaat, 2020b).

The NWP is relevant to mention in this report because it provides an insight into what the executive Dutch water governance has produced and is planning to produce in order to meet the WFD's water quality goals. Whilst the NWP is aimed to be finished in 2027 it will not be sufficient for

meeting the WFD aims therefore it is not a satisfying solution for the demands of the EU WFD and for answering why the Dutch water quality is so low.

The Dutch water management outsourced some of their responsibility to private sectors, as they hire external companies like Boskalis. Boskalis is a dredging and heavy lifting firm that offers services for building and maintaining marine infrastructure across borders but also within the Netherlands (Boskalis, n.d.; Ministerie van Infrastructuur en Waterstaat, 2022). Furthermore, Dutch drinking water companies are formally categorised as part of the private sector. There are ten drinking water companies in all and they are responsible for making sure that the drinking water is clean (Vewin, 2014). They do this by taking either surface or groundwater, cleaning it, and distributing it through a network of water distribution systems to our tap.

In summary the Dutch water management sector lies mainly in the public sector with much governmental involvement with a few exceptions in the private sector. This public categorisation of the Dutch water management sector makes it so that there is opportunity for civilian input into the system because of its democratic basis.

[2.4] Defining Innovation

The term ‘innovation’ is used in our research question to describe any kind of change that might be made in order to modify the overall approach to the Dutch water management system to meet the WFD standards. Innovation, as defined in the Cambridge Dictionary (2019) describes “a new idea, design, product”. Innovation heavily relies on context, with the goal of creating significant changes to infrastructure by incorporating not just the innovative creations that drive efficiency and physical changes, but also the political, social and financial elements that affect such changes (Kiparsky et al., 2021).

Another type of innovation to keep in mind are socio-technical innovations. This is a popular term to assess sustainable transitions in general. Socio-technical innovations pertain to communication, influence, and other social aspects involved in the introduction of new technology. It has been found that if there is no support for technical developments, then they are fated to disappointment (De Vries, 2018; Marcel de Arruda Torresa, 2017). If a community does not fully understand the technical innovation being introduced or if it is not phrased in a satisfying way for the public, the innovation could see much opposition and might even be discontinued. Therefore, socio-technological innovations are vital for any type of physical or mechanical innovation to occur.

Socio-technological innovations are exemplary of the interdisciplinarity specific to the water sector. This interdisciplinarity also means that there is significant dependence on other industries for a change to be undertaken in the water sector. This is caused by the increasing societal pressure from

the rapidly growing population and further environmental pressures from climate change (Taka et al., 2022). The water sector is intricate because policy, infrastructure, and the economy are all affected by water (Arp, 2023). If long-lasting, resilient water systems are to be created, issues in the water sector ought to be tackled in a multifaceted manner.

It has been reported that the water industry is less innovative than other industries. The water industry invests significantly less in research and development (R&D) than other industries (Directorate-General for Research and Innovation, 2016). A few authors have brought up the chaos of the innovation process. This is due to the interaction between multi-actor systems and oscillating between stages of innovation development which is pertinent for advancement in management (Wehn & Montalvo, 2018; Kline & Rosenberg, 2009).

[3] Literature Review

[3.1] Existing General Research

Through a literature review, we can establish a stronger foundation for our project, familiarising ourselves with existing research. First, we looked at case studies outside the Netherlands to gain an understanding of more universal, overarching factors that contribute to the success of innovations. Then, we focused on Dutch research to find information more specific to our research question and objectives. We selected international case studies from developed countries, as these would have funding, technology, and educational institutions comparable to the Netherlands. The United States (US) and United Kingdom (UK) in particular make good case studies due to highly publicised research, and having a growing hydroinformatics / water research sector. Because the Netherlands is unique in its geography, finding a developed country with similar circumstances is difficult in this case, which is something that needs to be considered. Across these international literatures, common themes included role of policy, risk taking, collaboration, and infrastructure integrity in water management innovations.

Ajami et al. (2014) identified management and policy as pressing barriers in United States water management sectors. This concerns issues such as unnecessary or difficult to navigate regulatory restrictions, making it challenging for stakeholders in the water sector to be able to develop, test, and market innovations. The use of ‘unnecessary’ also denotes that some of these regulations are outdated or irrelevant and must be revised in order to incentivise and allow innovation. Similar findings were also reported by a UK study (O’Keeffe et al., 2016). Further studies, such as the California focused Kiparsky et al. (2016) found that policy and regulations not only constrain innovation, but in some cases also facilitate it. Rouillard et al. (2016) also reported similar consensus in their EU focused literature review, stating that regulations can facilitate innovation

uptake. A UK study by Spiller et al. (2015) also discusses how 'diffusion' and facilitation of innovation also requires specific and clear policies and regulations, as vague or flexible legislation such as the WFD may not be detailed enough to spur innovations, which are often context specific and specialised. Regardless, broad legislation such as the WFD is still important to help guide innovation in a new direction. Legislation and policy can thus play a role as both an obstacle and a facilitator to innovation.

Disproportionate concerns about health risks related to adopting new technology were also identified in the US as causing hesitation among multiple stakeholder groups when it came to funding, testing and adopting innovations (Ajami et al., 2014). End-users, such as the general public, may be hesitant about using innovations or water derived from such, impacting its distribution and funding. Kiparsky et al. (2016) also found that managers in California reported that risk averse decision-making, particularly the need for technologies to have 'close to 100% reliability' can lead to delays in adopting new innovations, a sentiment echoed by O'Keeffe et al. (2016) in a UK based study. Investors may then be hesitant to fund projects, something identified as another obstacle to innovation, as lack of funding makes innovation difficult to see through (Ajami et al., 2014). Responses gathered by Kiparsky et al. also found that while managers are optimistic about return on investment in technologies in the long term, in the short term they are much less sure, reflecting the hesitance around initial investment in new projects. Reddaway (2019) stated that the risk involved in investing in UK innovation may cause hesitation in providing funds, similar to the financial obstacles identified earlier on for the United States. An international study by El-Khattab (2019) also identified lack of private funding as a significant barrier, suggesting that many water management sectors across developed countries tend to struggle in this area.

Speight (2015) and Ajami et al. (2014) identify the fragmented structure of water management bodies in the United States as a factor that may make funding difficult. In the US, many small municipal bodies do independent water management work, leading to difficulties in finding funding, human capital, or materials. On the one hand, such fragmentation is a product of geographical barriers, requiring that different regions have geography specific water management approaches. However, a solution may be to consolidate municipalities into larger water authorities to pool resources (Speight, 2015). Kiparsky et al. (2016) similarly suggests that more collective action to pool intellectual and financial resources could help address underfunding issues. El-Khattabi (2019) finds similar results on an international scale, where lack of communication between different stakeholder groups, rather than just within, limits knowledge sharing. In Australia, this was identified to be one of the contributing factors to tensions between stakeholder groups such as water utilities, property developers, and end-users for example (Quezada et al., 2016). El-Khattabi advises

innovation ecosystems that allow innovators, research institutes, governments and utilities to form networks and share knowledge.

In a study on three EU countries, Germany, Spain, and Denmark, Rouillard et al. (2016) finds that social networks are also critical to the success of (urban) water management innovations. Innovation uptake generally occurs on the lowest social levels, defined as areas encompassing water companies, local authorities, households, and businesses. Here, it was observed that entrepreneurial individuals play an important role in innovation uptake, as they can form social networks to build support. Higher social levels, such as national, can then influence dynamics of innovation by providing opportunities or additional support to the aforementioned local actors.

Finally, ageing physical infrastructure was also identified as an issue in common within many developed countries, as the initial infrastructure was built to last, and implemented a long time ago (Ajami et al., 2014; Speight, 2015; Kiparsky et al., 2016). In both the US and UK a lot of physical infrastructure has stayed in use with minimal replacement or repair. While they generally still function, cases of malfunction or poor water quality need to be addressed, suggesting that the sewer systems need renovation. In the UK up to 25% of treated water was lost in 2015 due to leakage. In the US the estimate was 16%. Rouillard et al. (2016) found that barriers to similar challenges in the EU revolved around the characteristics of the existing infrastructure such as its large scale, capital-intensivity, durability, and centralisation. Other than updating and renovating this infrastructure, Spiller et al., (2015) suggests that importance should also be placed on non-technological innovations, such as sustainability, efficiency and reuse, as well as good environment management, resource protection, and more decentralised approaches. In summary, factors identified through literature studies across various developed countries identified four common factors that influenced innovations in the water management sector. These were policy, risk taking, collaboration, and infrastructure integrity.

[3.2] Existing Dutch Research

According to Van Der Brugge et al. (2005), in previous decades the Dutch water management system has undergone a transformation, due to increasing pressure from housing, industry, infrastructure and agriculture. This has caused water management in the Netherlands to transition from a technocratic model to a more integral and participatory approach, meaning the social, ecological and physical components of the water system are better integrated into water management. Disco (2002) agrees that there has been a shift in Dutch water management, moving towards ecological considerations, as a result of various political and cultural influences rather than technological ones. According to Woltjer and Al (2007) in a study of integrating Dutch water management with spatial

planning, they have also identified a noticeable shift towards new policy strategies. In both the Netherlands and EU the new policy acknowledges water as a more dynamic element within its overall landscape. They claim this is because of climate change and an increased awareness of the Netherland's interdependence with other European nations. As the Dutch water management system continues to evolve, understanding and addressing barriers and innovations within water management will continue to be important to improve water quality in the Netherlands.

De Graaf et al. (2009) claims that although a transition was observed in the Dutch water management system and newly made policy changes, the actual physical changes to urban water systems are small. To investigate this, the authors surveyed 89 urban water management professionals (working in water boards, consultancies, municipalities, etc.) on questions related to what problems they currently saw in the water management sector. The study found that Dutch water professionals prefer improving the current water system over adopting large-scale innovative solutions. According to most respondents, this optimization of the current system is sufficient to achieve both European and national objectives for sustainable urban water management. Collaboration with other sectors, especially linking water management with 'urban renewal', is seen as essential. Climate change was found to be their top concern, whilst issues like land subsidence and droughts were more overlooked. Financial incentives, citizen involvement, and cooperation among stakeholders were also considered crucial. Interestingly, the survey results suggest different priorities from the government's previous focus of 'awareness' whereas the professionals think it's more important to understand local water systems, build skills, build trust among different groups, and involve elected officials and citizens more. To conclude, this research from over a decade ago believed improving the current water system would be enough to meet water quality objectives from the EU and the Netherlands, despite collective worries over climate change. Today in 2024, the Netherlands is still not on track to meet the conditions outlined in the upcoming 2027 EU WFD, making it even more relevant for us to conduct further research to understand why.

Although the previous study found that urban water management professionals held adversity towards adopting large-scale innovative solutions, there has also been research on how water innovations can be encouraged in the Netherlands. For example, Krozer et al. (2010) outlines several strategies for encouraging innovations in water management specifically within the context of the Netherlands. Firstly, the authors delve into economic incentives, emphasising the significance of both the supply and demand sides of innovations. On the supply side, they advocate for increased investment in research and development, and the demonstration of new technologies. On the demand side, the adoption and use of these innovations through effective communication are crucial. Secondly, the paper describes the role of policy-making in fostering innovations. Using insights from a

regional case study, the authors explore how policy frameworks can be tailored to incentivize risk-taking and innovation within the water management sector. The emphasis is on creating an environment that supports and rewards transformative changes.

All of these previously reviewed literature sources were published between 2005 – 2009. After this period there seems to be a lack of relevant research conducted on Dutch water management. Although literature from post-2020 exists, there seems to be much less research conducted specifically in relation to both water quality and barriers. Given the current context in which the Netherlands is set to fail the upcoming 2027 EU WFD standards. Although much research was conducted on the previous perceived transition from technological to social in Dutch water management, we were unable to find more recent papers addressing this switch, meaning there appears to be a gap in research on the impact this has had today on the Netherland's water management sector.

[4] Framework

[4.1] Multi-Level Perspective Framework

The Multi-Level Perspective Framework (MLP) will serve as our analytical framework for this research, enabling us to explore the potential integration of innovations and long-term technological transitions within the Dutch water management system. MLP consists of three key levels, as seen in figure 1: Niche, Regime, and Landscape (Geels, 2002).

Firstly, regimes represent the established systems and practices governing a particular technology, including the rules, skills and processes that guide its development and incremental innovations (Nelson & Winter, 1977; Nelson & Winter, 1982). The six main elements of regimes are science, technology, industry, policy, market user preferences, and culture (Geels, 2004). Next, the landscape encompasses external factors, such as economic trends and cultural values, providing a context for technological trajectories e.g. oil prices, economic growth, wars or immigration (Rip & Kemp, 1998). Finally, niches act as a space for radical innovations protected from conventional market pressures, which eventually have the ability to influence the landscape and regime (Schot, 1998). Transitions in socio-technical regimes usually arise as a response to landscape pressures. These landscape pressures create a demand for alternatives, in which a niche may grow and eventually replace a previous technology.

In the context of water quality management in the Netherlands, we can apply the MLP framework to gain a deeper understanding of the complexities and challenges in the field. At a niche level, we can examine the emerging innovations and measures that have the potential to improve water quality. This may include science and technology innovations, social innovation, organisational

changes, and policy initiatives. The regime level represents the established systems and policies already governing water quality management in the Netherlands. This includes various actors such as the national government (Rijkswaterstaat), water boards, and institutes like the KWR Water Research Institute. Finally, the landscape level includes external factors such as climate change and the economic climate which can exert a significant impact on water quality.

The MLP framework can then be used to analyse systems innovation (SI), contributing to an holistic understanding of the dynamics at place in transitions. SI aims to look at 'systematic' interactions between the various components of inventions, research, technical change, learning, and innovation (Soete, et al., 2010). The application of the MLP framework to SI is especially interesting in the case of socio-technical innovation systems, wherein various actors interact to bring about technological change (Soete, et al., 2010). This is relevant in the case of water management in the Netherlands, which depends on close interaction and cooperation between regime elements such as policy and technology.

Therefore, the MLP framework will help us to identify niche innovations in water management, assess how various regimes interact with emerging innovations, help us understand the potential ways they could be implemented, and analyse how these landscape-level changes influence the dynamics occurring at the niche and regime levels. This analysis will help us formulate policy recommendations and strategies to improve water quality in the Netherlands and help achieve the WFD goals.

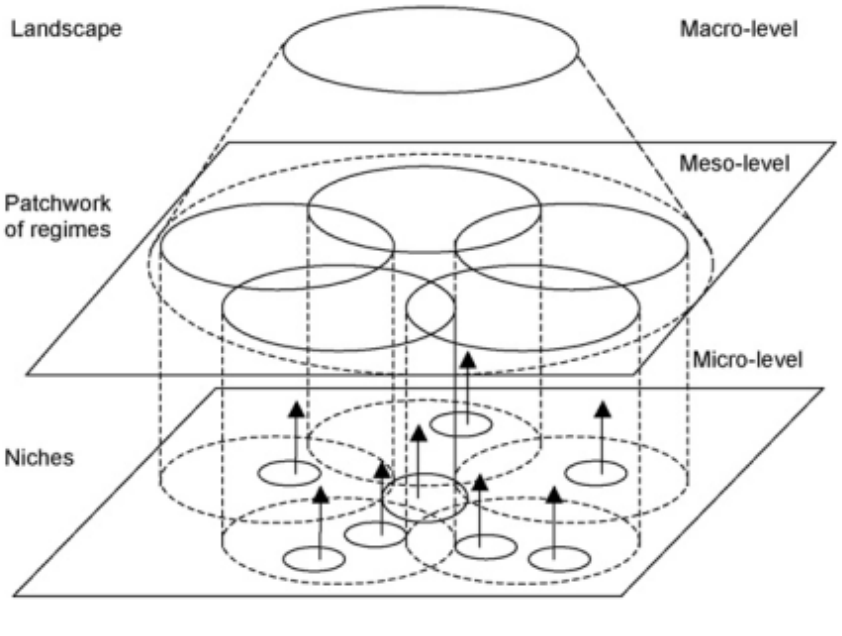

Fig. 3: Diagram showing MLP framework for socio-technological innovations

[4.2] Barrier framework

In addition to using the MLP framework, six main capital theories will be used to categorise the barriers we discover through our research: physical, financial, human, social, cultural, and policy capital. These theories are drawn from a variety of sources, including the human, cultural and social theories as described by Lin (1999), and the physical and financial capitals introduced by Coleman (1990). In addition, through the course of our research the framework was expanded by a sixth barrier to encompass policy and law.

The idea of capital comes from the theories of Karl Marx, who proposed the classical capital theory which refers to the various forms of resources that are invested to generate returns within society. Capital traditionally represents the 'surplus' value, which is the additional value obtained when selling something for more than it costs to produce. This surplus value is then vital for the exchange of goods and money in a capitalist society (Marx, 1935; Marx, 1857/2008). Later theories of human, social and cultural (referred to as neo-capital) shifted away from these traditional economic ideas, suggesting that capital could also include investments in skills, knowledge, education, cultural symbols and social relations (Becker, 1994; Bourdieu, 1986; Lin, 1999; Schultz, 1961). Finally we will also use the 'natural capital' theory first introduced by Schumacher (1973). Below, some potential barriers that may arise have already been identified in each of the five categories:

1. **Physical Barrier** - Includes limitations in or that may be caused by particular infrastructure (including digital), geographical features, or environmental qualities. According to Wageningen University and Research (2022), outdated spatial planning and draining practices in the Netherlands have a negative effect on water quality. In addition, poor land management practices (draining wetlands, cultivating crops in areas prone to leaching etc.) can contribute to water pollution. In addition, Ahmed et al. (2023) states that environmental changes, such as reduced rainfall and desertification due to climate change can lead to increased water demand and challenges for water quality. This may create more difficulties in developing long-term innovative solutions.
2. **Financial Barrier** - Includes financial constraints and the high costs associated with adopting innovative water treatment technologies. Such constraints may revolve around challenges with investment, funding, and socioeconomics. Kiparsky et al. (2016) says that one of the most significant institutional barriers to innovation is cost and financing, resulting in difficulties in securing funding.
3. **Human Capital Barrier** - Includes knowledge, skills, and human resources. Kiparsky et al. (2016) also claims that 'staff limitations' can have a negative impact on the ability to implement new innovations. This means that the skills of a workforce and their capacity in water management organisations may hinder implementation of desired technical or management solutions, as these innovations require

additional operational capacity. Similarly, Ahmed et al. (2023) claims that water management organisations often lack in-house research and development departments, causing an over reliance on external research institutions and slowing capability for innovation.

4. **Social Barrier** - Includes barriers related to trust, collaboration, and social networks. Issues such as deficits in trust among stakeholders can slow down innovation and the sharing of critical resources. According to Ahmed et al. (2023), stringent regulations and approval processes can slow down the adoption of new technologies, although they admit that regulations can also promote innovations. Additionally, the relationship between public sector organisations, regulators, civil society, and civilian users further complicates the adoption of new technologies. For example, Kiparsky et al. (2016) says that wastewater utility managers often have a skewed perception of innovativeness, meaning they believe they are more innovative than the evidence suggests, which can hinder actual innovation efforts between the various actors involved in the adoption of new technologies in water management. Although not a direct barrier, in a yearly report for the Netherlands, the European Commission (2022) claims that poor air quality due to nitrates and ammonia can affect water quality as they find their way into water bodies. Therefore it is important to also remember the influence other organisations have, such as air quality and agriculture, on the development of water management innovations.
5. **Cultural Barrier** - Includes barriers arising from cultural norms and perceptions among the public, within stakeholder groups, or any other relevant defined group. Ahmed et al. (2023) states that the water industry is often resistant to change, due to various cultural factors and institutional constraints. This is because existing water infrastructure systems such as treatment facilities or desalination plants are designed to have long lifespans, making it challenging to transition to new technologies. In addition, they say that public health and the provision of water services usually take precedence over innovation, as there is a civilian expectation for the current water management system to continue providing their services. Kiparsky et al. (2016) backs this up by claiming that customers and ratepayers may not always be open to change. As a result, there may be little interest in seeking innovative technologies if there is no external pressure to do so.
6. **Policy Barrier** - Includes barriers regarding legal challenges stakeholder groups may face, navigation of laws and policies, or even modification of them. O'Callaghan (2020) outlines the importance of policy innovation for improvements in water management, illustrating how poor involvement of policy in innovation could create barriers. Using the United States as a case study, Ajami et al. (2014) found that policy obstacles pose a significant barrier in water management innovation due to their entanglement in other barriers such as financial and physical. Similarly, studies such as Cipolletta et

al. (2021) also identify policy as a barrier to water management but only within the EU, suggesting a lack of research focusing on the role of policy in Dutch water management specifically.

[5] Methodology

[5.1] Paradigm and Methodological Approach

The research design of this study follows the epistemological approach of interpretivism and its qualitative methodological implications. This paradigm suggests that individuals socially construct the world through their social interactions and thereby acknowledges the complexity of reality (Della Porta & Keating, 2008). This study seeks to understand interactions between stakeholders and innovations in Dutch water management to identify barriers that hinder the improvement of water quality according to the WFD's standards. This research approach allows to account for different stakeholders in the water management-ecosystem and create a more holistic understanding of possible issues that characterise it.

The explorative, qualitative research approach that is tied to interpretivism implies an inductive design that uses non-numerical, textual data (Creswell & Creswell, 2018). This kind of data is especially suited to explore under-researched problems, as it gives room for more elaborate reflections from the participants and hence facilitates to develop a deeper understanding of the different barriers and their interaction with each other (Creswell & Creswell, 2018). Considering the lack of recent studies on Dutch water management the study uses individual, semi-structured interviews with the different key stakeholder groups as the main method of data collection. Thus, this primary data is used as the main source of data to analyse barriers and stakeholder interaction and secondary data from EU and Dutch governmental reports and past studies for its background research. The thematic analysis by Braun and Clarke (2006) constitutes the main method of analysis to identify relevant themes that emerge from the semi-structured interviews. In addition, it is complemented by the application of the Multi-Level Perspective framework by Rip and Kemp (1998) to further analyse the interactions of the different interviewed stakeholders and the identified barriers that hinder the effective integration of innovations to improve water quality. The key elements of the research design are described in more detail in the following.

[5.2] The Sample

The sample encompassed stakeholders from each key stakeholder group involved in the Dutch water management system. To identify which stakeholder categories should be included for a holistic

representation of the water management-ecosystem, the MLP framework was applied to the structure of the Dutch water management system.

In total, the sample consisted of 14 participants that were chosen by following a non-probability, purposive sampling approach with an additional quota approach. This means that the participants were specifically chosen based on their expertise in the field as well as their ability to sufficiently represent their respective stakeholder group. In that, the quota sampling served to ensure a balanced representation of the different stakeholder groups. The sample size is based on a study by Guest et al. (2006) who found that a minimum number of 12 participants is needed for non-probabilistic samples to reach a point of saturation for themes and enable generalisations based on qualitative data. The population from which the sample was drawn encompasses the water management guarantors for the whole of the Netherlands. In the end, we had three interviewees from Rijkswaterstaat, 4 interviewees representing the regional management level, two interviewees working in the private sector, two from NGOs as well as three researchers. All of them had a scientific academic background, for example as environmental scientists, engineers or biologists. Only one of our interviewees reported to work in a team consisting of several people with a social scientific training.

Creating the sample was more difficult than anticipated, as it was quite difficult to reach relevant interviewees that were willing to collaborate with us. We initially aimed to have three participants per category, meaning a sample size of 15 participants. With this, we were planning to include civilians for the social sector category as well as drinking water companies. Both could not be integrated, as there appears to be a lack of civil engagement regarding water management, and drinking water companies were difficult to contact. Nonetheless, based on our subsequent analysis this does not present a limitation to the findings we were able to gather. Overall, we reached out to around 80 people using official contact forms, email addresses found online, by calling them or via LinkedIn. Especially for interviewees working in hierarchically higher institutions such as Rijkswaterstaat unofficial networks like LinkedIn were most effective.

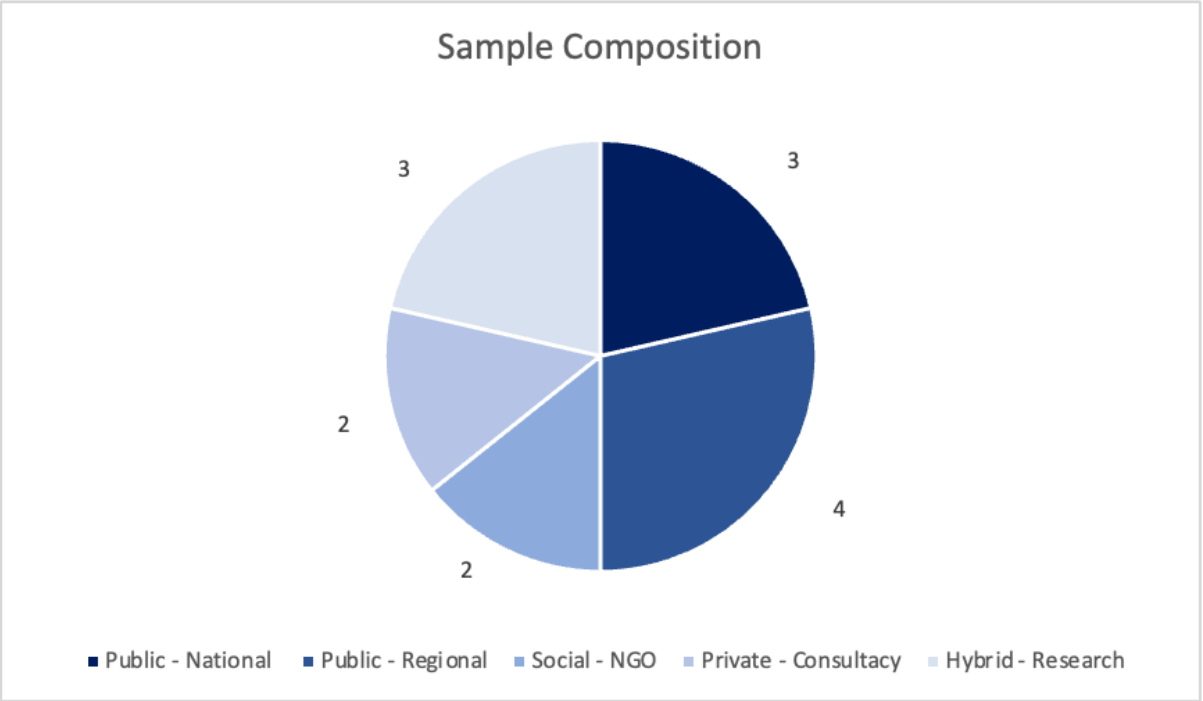

Fig. 4: Shows the sample composition regarding participants. It encompassed 3 from the national level (Rijkswaterstaat), 4 regional (water boards and municipalities), 2 NGOs for the social sector, 2 Consultancies for the private sector stakeholders and 3 researchers.

[5.3] Research Instruments - The Interview Guide

Since semi-structured in-depth interviews constituted the core data of analysis our interview guide represents the key research instrument of this study (Appendix I). Its semi-structured design allowed us to guide the conversations along key themes with open-ended questions facilitating elaborate answers and closed questions for obtaining more specific information. The main questions were based on the barrier framework established in the background section based on Lin's (1999) and Coleman's (1990) work on different forms of capital. Here the framework served as a starting point to identify which domains should be incorporated in the interview guide for a holistic understanding of possible barriers to innovations in the water management sector. The specific questions and supporting elaboration and clarification probes were refined through an additional literature review. Overall, the interview guide consisted of 18 questions that started with an icebreaker and were organised to support a natural flow of the conversation. Hence, the guide first addressed the physical domain where barriers were easiest to identify and ended with the questions that required more individual reflection. This flexible design enabled us to pursue issues brought up by our interviewees that we did not anticipate based on the literature review, which provided us with unexpected and crucial insights (Creswell & Creswell, 2018). As such, we added two additional questions after the first

two interviews as part of our emerging research design since they seemed to constitute crucial barriers. First, one about economic consideration for the financial domain and second a question relating to law and policies as potential barriers.

In addition to the interview guide, several technical instruments were used to support this study. First, most of the interviews were conducted online using Zoom. All interviews were recorded using the researchers' phones and first transcribed using the transcription software Whisper. For the subsequent thematic analysis the qualitative data analysis software Atlas.ti was used combined with extensive mind-maps. Finally, the researchers themselves represent a crucial instrument, as they collected the data, interviewed participants and analysed the interviews (Creswell & Creswell, 2018).

[5.4] Data Analysis: Thematic Analysis and MLP Framework

Thematic analysis was the main method used to analyse the qualitative data gathered through the semi-structured interviews. This analytical approach developed by Braun and Clarke (2006) is especially suitable for the analysis of textual data as part of an explorative research design, as it allows researchers to focus on the content of this data instead of trying to support presumed explanations for the research question.

Overall, our data set encompassed about 14 hours of audio material and 212 pages of transcripts, which are analysed by applying the 6 characteristic steps of the thematic analysis approach. These consist of familiarising yourselves with the data, coding, generating themes, reviewing the themes, defining- and naming the themes and subsequently writing the analysis (Braun & Clarke, 2006). In the first round of “open-coding” a variety of subjects, both general and focused, were established as codes. In total, 38 different codes were used in the analysis, which represented a mix of topics stated in the interview guide such as “cultural barrier” as well as new one’s such as “generational barrier”. The theoretical flexibility of this approach required in-depth reading and a critical reflection of presumptions, to include and code information that may have otherwise been overlooked, and reveal elements that were not predicted before the analysis process. We established four main themes by grouping the codes that appeared to be connected and identifying the conceptual link that binds them. Essentially, codes function as an argument concerning the “phenomenon that is being examined” (Braun & Clarke, 2006, p. 88). The themes were refined after their first deeper analysis, since several sub-themes turned out to be interdisciplinary with several codes having been applied to them, which indicates the complex nature of barriers in the Dutch water management system. Moreover, some initial barrier names were renamed after this analysis when the first name did not represent their core sufficiently. For example, barriers related to the initial name “financial barrier” were renamed “investment uncertainties” or “economic mindset”.

To ensure the reliability and validity of the thematic analysis's results, triangulation approaches were incorporated where possible. This serves to prevent and mitigate possible biases in the researchers' analysis of the data (Carter et al., 2014). For example, the interviews were rotated at each step of their analysis between the researchers. In addition, the answers from interviewees from different hierarchical levels were combined to validate the important themes and where possible, compared with elements from the literature review (Cresswell and Cresswell, 2018).

Subsequent to the thematic analysis, the Multi-Level Perspective framework was applied to the identified barriers that emerged from the thematic analysis. Through this, the identified barriers were located within the three levels outlined by the framework – regime, niche, and landscape. This served to further our analysis of their interaction and role in hindering the effective implementation of innovations within the water management system and their interaction with our identified barriers.

[5.5] Ethical Considerations

Several measures were taken throughout the study to prevent possible ethical issues. To prevent issues around informed consent the researchers ensured that the interviewees participation was voluntary and that they were sufficiently informed about the researcher's methods and aim (Ravelo, 2023). For example, before recording the interview each interviewee was specifically asked for their consent. For purposes of legal protection, the consent sheet was sent at least three days prior to the interview to the participants to inform them about these measures. Nonetheless, the interviewees kept their right to withdraw from the study at any point.

[6] Results and Discussion

Themes were created to provide a more manageable overview of the obtained results. The four themes being physical, governmental, cultural, and social. The usage of themes enables the clarification, origin and relationships between particular barriers. There was some overlap between themes but this was to be expected due to the general interdisciplinarity of the water sector between stakeholders and issues.

[6.1] Theme 1: Physical

[6.1.1] Geography

Within the theme of the physical barrier, the first cluster of codes shared common concerns for how the geography of the Netherlands could pose various obstacles to implementing physical innovations.

The first of three distinct geographic barriers identified was topography. Two interviewees explicitly noted that a large portion of the Netherlands is below sea level, with physical infrastructure being the only measure to prevent flooding. The implication of this is that new innovations have to be able to exist alongside this vital infrastructure without interfering with its functionality. Similarly, two other interviewees mentioned that innovations may not be generalisable to Dutch topography, as it is uniquely flat, as for example *"...when you don't have hills, you don't have opportunities to create surface reservoirs, you know, to put a dam and then have a storage reservoir where you can store water…"*. The common concern then appears to be that the flat topography of the Netherlands poses challenges with physically managing and controlling bodies of water. Conversely, another pair of interviewees felt that in general, these obstacles were not of enough concern to be considered legitimate 'barriers', and if anything, also posed some advantages to implementing physical innovation. This is because the flat topography makes for few obstacles in finding a physical foundation for many construction projects. The topography of the Netherlands could thus be said to pose both limitations and benefits to the implementation of physical innovations.

The second geographic barrier identified was related to a lack of space. Several interviewees agreed that there is little land available for use and development, as the Netherlands is relatively small and faces a lot of land use pressure. Most land has already been used, so the physical size of water management infrastructure can become a limitation in and of itself. Not only that, the little land that is available for use is highly sought after by different stakeholders. The agricultural sector in particular was identified as a group with interests that conflicted with that of the water management sector. Three interviewees explained that members of the water management sector often try to regulate land use close to water bodies, to monitor what substances might enter the waterway. On the other hand, with increased land use pressure, farmers want to use these areas as well to increase crop yield. Control over floodplains was mentioned as an example of where this conflict might occur:

> *"…for instance the flood plains, most flood plains in the Netherlands, they are owned… by Rijkswaterstaat, but we… leased them out to farmers and they have their own infrastructure on it which also prevents us from doing good things we would like to do for ecological water quality and other functions."*

In this instance, the Rijkswaterstaat has to balance the conflicting interests of the agricultural and water sectors, posing a physical barrier to water management projects (Rijkswaterstaat, n.d.).

The third geographic barrier identified concerned the Netherlands' location in a river basin. This means that the Netherlands receives water from various rivers that run through multiple different countries before arriving in the Dutch delta. To quote an interviewee, what the Netherlands has in terms of water quality "*depends largely on what our neighbouring countries do or don't do in*

the water system". In other words, the Netherlands is not only responsible for its own contamination, but also to the extent of other countries such as Germany, France, Switzerland, etc. As part of this added responsibility, the Netherlands has to take initiative to communicate with these other countries to be able to properly manage the incoming contamination. However, one interviewee posited that the WFD takes these geographic differences into account, meaning the Netherlands shouldn't be putting much more effort into maintaining good water quality compared to other countries, assuming the standards of the WFD have been properly implemented. In short, it was suggested that geographic location cannot be the main cause of poor Dutch water quality, as this difference is accounted for in the WFD (Didde, 2023; Cox, 2016).

[6.1.2] Ecology & Chemistry

The second cluster of codes to fall under the theme of physical barriers concerned challenges that could be posed due to the current chemical conditions and ecological context that the water management sector needs to work with. Beginning with chemistry, half of all interviewees voiced concerns about how challenging it is to try to innovate for better water quality when one of the overwhelming causes of pollution is the agricultural industry, which some interviewees worried had significant lobbying power. Agriculture is responsible for significant nitrogen and phosphate pollution by fertilisers, and glyphosate pollution by way of pesticides. These pollutants contaminate the soil and run off into aquifers and canals, contaminating the water as well. One interviewee phrased the consequences of such pollution as: *"We don't want to have fosfor [phosphorus] in our service waters, because… it's a nutrient…and then, uh, the rivers and the lakes, they will grow… with the–with the algae, and the—and the water will–will be dead".* Chemicals like nitrogen and phosphate are of concern because they cause eutrophication, wherein increased nutrient leads to algal blooms that block out sunlight on the water's surface and prevent oxygen circulation in the water, killing the remaining flora and fauna beneath the blooms (Yang et al., 2008). Eutrophicated water becomes still or 'dead', with no natural processes left to circulate or clean it, making it a risk to human and ecological health (De Vries, 2021). Based on innovation projects that interviewees spoke of, abundance of these fertiliser chemicals is extremely difficult to separate from sludge — what is removed from wastewater to purify it — making it unusable. The difficulty in recycling this non-renewable resource means that the agricultural sector will simply continue to add more of these chemicals to the soil, increasing the abundance of pollution that needs to be removed from the water. However, there is hope that projects such as Wageningen's magnetic phosphorus recovery could develop new techniques to help remove and reuse nutrient chemicals from wastewater to mitigate such an outcome (Kuipers, 2022).

Focusing on ecology, three interviewees spoke about how there is a responsibility to innovate in a way that does not contribute to further disruption or degradation of ecological health. Infrastructure has a carbon footprint that must be monitored for example, and physical structures must limit the disruption of river flows as to avoid disturbing the flora and fauna that contribute to good water quality. Monitoring the ecological changes a physical structure can cause is particularly important because the environment is not static. A few interviewees agreed that the dynamic and unpredictable nature of many variables in the environment can make innovation difficult. Improper implementations of innovations without accounting for the environmental changes it can lead to can result in physical degradation. A named example was the effects of weirs, a barrier used to control water levels in streams: *"So what we see all over the country is where you have river reaches that are … impacted by weirs, because we have altered morphology that these rivers, they continue to erode the zomerbed [the riverbed during the summer]".* This erosion can cause further disfiguration to streams, and interfere with the local ecology that contributes to good water quality. This example illustrates the importance of accounting for the dynamic nature of the environment, to minimise ecological damage. This principle is fortunately already in use in various projects, as one interviewee mentioned using native trees to strengthen river banks in place of typically plastic-based reinforcements, with similar pilots being tested throughout the Netherlands (Rijkswaterstaat & Deltares, 2013).

[6.1.3] Technology & Infrastructure

The third cluster of codes under the theme of physical barriers is concerned with obstacles posed by the current state of existing technology and infrastructure. A number of interviewees highlighted for example that a significant amount of infrastructure — having been built to last — is now over 50 years old:

> *"...there are some pipes which are now at the end of the lifetime. And that's, that's an issue because they are in the ground and there's a lot of, uh, there are roads over needed or railways or houses or whatever. So replacing those pipes is a big challenge".*

Much of this ageing infrastructure may have issues with functionality such as leakage, and may need to be repaired, renovated, or replaced altogether. As highlighted, this is not so simple, as much of it is difficult to access. Monitoring and replacing the physical water management infrastructure is thus challenging and time consuming. An interviewee involved with a water infrastructure stakeholder shared how there are teams that work to anticipate such challenges in the future through projects such as Verdygo, wherein more efficient and less resource intensive construction plans for water treatment facilities are being designed for easier construction and access.

Determining how this infrastructure should be replaced has also been pointed out as an obstacle. For example, to minimise the need for maintenance and further replacement, these new innovations must be able to function for a similarly long period of 50 to 60 years. Another interviewee said about infrastructure replacement: *"We can never stop our [wastewater treatment] installations. If we would do so, for example, a week, then we would have a catastrophic, a catastrophic situation. … I think all kinds of diseases, which we don't want to have".* This implies that the water management sector lacks redundant or backup components that could be used in the case the main system fails to operate or must be brought offline for maintenance. This means that not only can accessing ageing infrastructure be difficult, but renovating or replacing it without critically hindering the entire water management process is an added challenge, a sentiment that was found in Ahmed et al. (2023) as well.

[6.1.4] Climate Change

The fourth and last cluster of codes concerning physical barriers relate to the challenges associated with climate change. Nearly all interviewees brought forward climate change as an obstacle to innovation, particularly in the future. In particular, they felt that it would exacerbate existing problems:

> *"Climate change is increasing the whole pressure on the system. … We know this stage [without climate change]. We've been here before. Then, we see it [climate change] at the scale that's happening now, … you're dealing with the urban floods, you're dealing with the coastal floods. You're dealing with the agricultural drought."*

They feel that climate change will worsen problems such as flooding and drought. This could put stress on infrastructure, because while current infrastructure is occasionally able to deal with these issues, climate change will increase the magnitude and frequency of flood and drought occurrences. These changes could make innovation difficult as well, because as one interviewee pointed out, climate change in the Netherlands will exacerbate both extremes, drought and flood. Preventative flood measures can worsen drought and vice versa, posing an extra challenge in water management engineering. Many interviewees also agreed that in this case, innovation would have to be done in a way that anticipates these problems, to minimise damage after implementation as aforementioned.

In addition to more extreme climates, a few interviewees highlighted how increased temperatures associated with climate change could drive up demand for water in the future. Paired with phenomena like drought, population growth, and rising sea levels salinating fresh water sources, there is a fear that the Netherlands could face a future of serious water stress: *"... if the sea level rises, the salt water will intrude and we will lose some of the very important sources of water".* In

summary, climate change poses a physical challenge to water management innovation because it could cause more extreme weather phenomena that could damage infrastructure, worsen water quality, and lead to water scarcity. However, stakeholders cannot be certain exactly what or how these changes will take place, making adaptive and preventive innovations difficult and risky to implement.

[6.2] Theme 2: Government

The largest code generated from our research was under the label 'government and policy' which suggested that the interviewees felt especially affected by the Dutch water governance when discussing our interview guide about barriers to implementations of innovations in the water sector. This generated theme titled "Government and Policy" was split into four categories to provide a more robust analysis. The first of these categories is titled Unclear Responsibilities. This is followed by Public Expectations, Conflicts of Interests and Regulations.

[6.2.1] Unclear Responsibilities

When interviewing the variety of actors within the water management system it became clear that amongst different stakeholder levels there was confusion amongst who was responsible for specific policy. As aforementioned, there are many actors in the Dutch water management and therefore the execution and/or implementation of specific legislation became unclear as it trickled down the bureaucratic hierarchy. As outlined by a representative of a water board, *"We don't know if a certain measure should be done by the conservationist party, or the province of Limburg, or our water board."* Despite the responsibilities being outlined in the Dutch *Waterwet* (Water law) (Binnenlandse Zaken en Koninkrijksrelaties, 2021), there is still confusion amongst the actors regarding specifics. In this instance the interviewee mentioned that confusion arose when there was an overlap of responsibilities. For example, when approaching nature conservation in line with ecological demands outlined by the EU WFD. Nature conservation is also a component of the habitat directive which is another EU initiative and is tackled by the Dutch government (Ministerie van Algemene Zaken, 2014). With the habitats directive a European network of protected nature areas where certain species of animals and their natural habitats are protected in order to preserve biodiversity (European Commission, n.d.). Therefore, the interviewee said, there was inaction because of the confusion on who should act. What was most hindering about this, the interviewee mentioned, was that with an overlap in responsibilities came also an overlapping of finances and staff. If two parties have the

means to act one has to step forward and take the leap. This would let the other party have room, funds and staff to tackle another issue.

A further point that arose in relation to 'Unclear Responsibilities' was the ineffective handling of the EU WFD. The fact that the quality of the Dutch surface and groundwater is in such a bad state, and so far away from meeting the 2027 deadline, there is mounting pressure on water authorities to undertake action. One interviewee commented,

> *"95% of all the water bodies in the Netherlands are in a…bad condition. So it's a very complicated thing, the Water Directive. And we have complete orchestra of colleagues who are working each on his own field of speciality, fish…microfauna, hydromorphology, etcetera, etcetera to implement it, the ...Water Framework Directive in our province and our water board."*

The Dutch water system is quite bureaucratic and therefore the final executive on a number of decisions might be unclear when making decisions. This issue is also highlighted in the previous quote. Perhaps, because of the ineffective action taken by the Dutch government to meet the WFD standards there is confusion on who should act.

Another example of unclear responsibilities that arose from the interviewees was economic externalities:

> "*We know today that all in Europe you find a high level of Glyphosate [pesticide] in water.…and because after a distribution of that water there can be some of that pollutant in it that negatively impacts health, for example. And the barrier is that the actor, who are the drivers of those impacts, don't have incentive to stop doing what they're doing. Because the cost of that is on society and nature. It's not on the private actor. They just use it and they don't bear...the cost and that's all a problem within our economic system in general*."

Individual, household, and business decisions regarding consumption, production, and investment frequently have an impact on individuals who are not directly involved in the transactions. At times these circuitous impacts are little. However, when they grow in size, they can cause issues (Varian, 2014). This is problematic because water is such a universal commodity – everyone is affected by water and any changes concerning water – the water management sector has to invest funds into cleaning up run off from other industries such as the pesticide Glyphosate mentioned by the interviewee. The damage that agricultural runoff causes is of no direct consequence to the agricultural industry, so they have no incentive to correct this.

Another point in reference to economic externalities that can be elaborated on is the tragedy of the commons phenomenon. The tragedy of the commons is a situation in which people who have access to a public resource, also known as a common, act selfishly and ultimately deplete the

resource (Spiliakos, 2019). This concept tailored specifically to water as the common is that as the quantity of families and organisations increase and dump their waste into the water, the water loses its capacity to clean itself. This results in water that is poisonous to natural life and individuals that live around and depend on it (Robinson, 2021). This tragedy of the commons as well as other externalisation of costs makes government management of water difficult and ultimately forms a barrier to succinct governance.

[6.2.2] Public Expectations

Under this theme another category came together, one that dealt with the citizen's involvement, or lack thereof, in the water management system. What became apparent throughout the conduction of the interviews is that the Dutch public has a significant lack of knowledge concerning the Dutch water management system in place. There needs to be some type pressure to enact change. Essentially, the sentiment seems to be that there is a large knowledge gap between the average citizen and the experts. As one interviewee remarked:

> *"Because we outsource everything to [the] government….So, I trust the government. So, I don't care. And that makes me make a lot of wrong decisions. Yeah? You will not see this happening in Bangladesh. [In] Bangladesh people don't trust their government to this level. And so, they will know what kind of decisions they make and how their decisions will impact their life. That doesn't mean that they will make better decisions, but at least they take responsibility for that decision."*

The average citizen cares only for drinking water to come out of their tap when they turn it on and this remains an affordable resource for them. By 'outsourcing responsibility' the interviewee meant that the citizen entrusts the government to take care of this expectation for them. The interviewee who stated the aforementioned quote was an individual who worked for a consultancy company that also worked in Asian countries such as Bangladesh which gave them the expertise to remark on the significant differences observed by them.

Dutch citizens not exerting pressure onto the government to perform in terms of water management can be juxtaposed with other issues that the government faces. For example, due to the housing crisis, the Dutch public is actively demanding that the government provides housing. This pressure that the public exerts onto the government is useful in increasing the rate and the scale of change. In the water sector this is missing. The average citizen is not aware of the WFD and therefore does not expect the water sector to provide any measures to meet the deadline in 2027. This identified lack of knowledge amongst the public means that the Dutch water sector misses a 'pressure group' to exert change (Goedendorp & Struijk, 1978). So, what happens is that when

additional funds are allocated to water management there is discontent amongst the public in response to these funds because they don't understand how pressing the problem is and how close the WFD deadline is.

> *"So you have to have proper participation of the public to understand acceptance of change…For example, now we have water shortages. So we ask you, 'Please save your water… ' At the same time, we will not decrease your price for water. You consume less, but you still pay the same amount because most of the cost…in infrastructure, not in cleaning water. So if you don't tell the story to people why this is important, and if you don't have proper participation of the public in your campaigns for water conservation, people will not understand and will not do it. They will say, 'I use less water, I pay the same, I won't do this.'"*

This quote very clearly emphasises how important it is for the public to be aware of at least the basics of the water management system in the Netherlands so that they may support changes and regulations imposed by the government. What was emphasised by multiple interviewees was that the cost of water would increase. This concern has been corroborated by additional research which also outlines a reason for this expected rise in costs (Keijl, 2023; Niewold, 2023). Below is table from Nieuwold (2023) which predicts the rising cost of water between 2023 and 2024 in euros per cubic metre of water.

Leverancier	2023 per 1m3	2024 per 1m3	Stijging %
Brabant Water	1,21	1,25	3,31
Dunea	1,29	1,33	3,1
Evides	1,06	1,17	10,38
Oasen	1,05	1,15	9,52
PWN	1,73	1,77	2,31
Vitens	0,85	1,04	22,35
Waternet	1,03	1,13	9,71
Waterbedrijf Groningen	0,93	1,04	11,83
WMD Drinkwater	0,93	1,09	17,2
WML	0,91	0,99	8,79

Fig. 5: Shows the predicted rise in water costs per cubic metres between 2023 and 2024, along with the increasing annual percentage of the price.

Precisely because the public is not involved enough in the Dutch water management system this change, as mentioned by a higher representative from a Dutch prominent research institute for water innovations, will not be accepted peacefully.

To conclude this subtheme, public awareness is very important to generate change. If the public expects change and actively awaits for the water management sector to undertake change, either technical or social, this will more likely occur. Currently, without the presence of a pressure group the water management sector does not feel the need to undertake change. This might be considered as a reason for why the Dutch water sector is so far from meeting the WFD standards.

[6.2.3] Conflicting Interests

The sub-theme of conflicting interests was developed when analysing the comments about funds specifically. Originally, it was anticipated that there would be various complaints and or comments about the funds available to enact change but this was not the case. What was identified instead were the conflicting interests of all the stakeholders who could use the available funds. There are a multitude of issues to tackle within the water sector and thus there are conflicting interests as to what should be the first issue to be tackled. Interviewees highlighted that innovation does not come from funding but from "*a severe problem that we're facing and somebody has to start doing something about it. And if funding is available, that's good, but water management doesn't stop if there would be no innovation funding available.*"

Furthermore, governmental investments are either to fund something in the long term or in the short. As emphasised by another interviewee, "*There is always something more important in the now.*" This quote summarises the difficulty the water sector has to face when considering where to invest. Nature-based engineering is a popular way to improve infrastructure, but it is not as popular as it could be because of the generally significant time lag between implementing them and when they actually start to function as intended. In the long run this is a sound investment but in the short term it will not perform as it was intended to.

Another factor that represents this sub-theme is the conflict between the usage of water in the agricultural sector and in the drinking water sector. These conflicting interests create tensions between actors in the water industry and this creates inaction.

> *"That's a fight over interest…There's interest [the] of people who want to use fertiliser and pesticides in order to increase production…That pure objective is contradictory to what we all want: Better water quality…So, there's a conflict there…There's a conflict of interest. And that's only one of the conflicts of interest, but the whole field of water management is full of this kind of conflicts of interest."*

This quote showcases the existence of difficulty between conflicting actors in the water sector, because it is such an interdisciplinary sector. This has been found in investigations into the Dutch water system before, which emphasises the solidity of the issue (Wuijts et al., 2023). Furthermore, conflicting interests in general provide a barrier to undertaking effective action to create change.

[6.2.4] Regulations

Another idea arising from this theme encompasses barriers related to regulations. The following quote from a researcher at the KWR is exemplary of what this sub theme describes:

> *"So for innovations, you also need support from policy regulatory regulations. So support from policy could be a subsidy program, a subsidy program for any new technology development, or for research and development. So green subsidies can be crucial in new innovations. At the same time, you need also proper regulations. And regulations, for example, nowadays, many regulations are a barrier for innovations in the water sector."*

Researchers especially remarked on the barrier created by regulations, which in their descriptions could even be seen as red tape, an economic term that describes legal rulings as mere hurdles to overcome. Another researcher from a different Dutch research institute remarked, *"I think that's…the main thing which hinders innovation in general in Holland. It's just…the law which is super slow."* This further emphasises that legal processes and the creation of new legislation can be a hindrance for the implementation of innovations in the Dutch water sector. The time lag is especially highlighted to be an issue when discussing barriers. Amongst the interviewees it was often described as something that was a time consuming necessity.

Another point developed under this sub-theme was the critique that the Dutch government had high implementing standards. New innovations must be able to function the same–ideally better–than whatever system they are replacing. Some interviewees commented that the implementing standards are demanding, perhaps too demanding, to foster new innovations and their implementations.

> *"Standards for safety, strength and everything. That's limiting. I think mainly the regulations help us, because they force you to be climate neutral in 2030, to be working circular in 2050. That is a huge driver for innovation, because we need to meet these new standards. And now, of course, it's a good thing of being in the European Union. Now we probably have a new government that says, "Oh, we can lower these standards." And then the European Union will say, "No, no, no, Holland, you have to keep up with your promises and meet the European laws." So I think for innovation, the regulations mainly are necessary, but of course they are always running behind."*

The strict and high regulations for innovations are seen by interviewees both as 'red-tape' meaning that they are mere hoops to jump through and a nuisance. But their necessity in ensuring a high quality of operation was also noted and highlighted upon. Despite them creating a barrier to implementation of innovations.

[6.3] Theme 3: Culture

The third major theme is named 'cultural barriers', which encompasses barriers arising from cultural norms, beliefs, and traditions as established attitudes towards innovations in the water management sector, as well as its organisational structures, work and decision-making culture (Lin, 1999). it revolves around perceptions in the general public towards water management and the value of water, as well as the communication culture towards the stakeholder groups of water managers and the general public.

[6.3.1] Generational Barriers

A key concept arising from the theme 'cultural barriers' is the idea of a 'generational barrier' to implementing innovations within water management organisations. Most of our interviewees, regardless of their own age, reported that the water management sector is currently dominated by an older workforce. For example, one of the interviewees said: *"You know, the water sector is really old guys like me, 50 years, 60 years, and most of us are going forward with time."* It is important to point out that although interviewees agreed that this issue was most prominent in the provincial water boards it is a trend that was reported for all hierarchical levels of the Dutch water management system. The quote implies that the Dutch water management system is shaped by people that have been working in the sector for many years and rely on similar training and knowledge on how to manage water and possible arising difficulties. This has significant implications for water management institutions concerning their internal organisation, work priorities, and overall attitude toward innovations.

Different generations have different attitudes towards innovations and hence influences the importance their organisation attributes to investing in innovations. Several interviewees described this as a dynamic characterising the internal work culture they experienced. As one of the interviewees put it: *"… Often it's the young generation who wants to have change. The old generation is the guy that [like] me is saying "Oh, don't! Be careful. Don't forget this."* Accordingly, younger employees can be characterised to be keener on innovations but are only given very limited room to pursue these due to a lack of openness towards innovations that is shaped by the dominating older workforce. This is further supported by the following quote:

> *"… In our management, they say, they have written that they want to be innovative, they want to make changes in the organisation, but the way they work on it is not always in that manner. … But, so it's more the focus we have, how to divide the time of your people is more important than just hiring your people. So it's not a solution that we have not enough people to do the work, it's more that to prioritise where you have to spend your time on."*

Especially water boards appear to not sufficiently recognize the importance of innovation in their day-to-day work, creating a substantial barrier to progress as innovations are not adequately prioritised in the organisation's workflow and resource allocation. The same interviewee emphasised the importance to have people in leading positions of the organisation that are inclined to innovate. For example, he mentioned that his water board was one of the few that had an internal fund specifically dedicated to innovations, which enabled the water board to work much faster on innovations than others. This was only set up thanks to a former "Dijkgraaf" (chair of the water board) that considered innovations to be very important.

Another consequence reported regarding the prevalence of the older workforce was its influence on approaches chosen to innovate and tackle problems. One interviewee that had worked in different public organisations within the Dutch water management system described that there was a culture of "*continue with doing what we are good at, but it's not going to take us where we want to get."* This quote indicates that Dutch water management continues to rely on old strategies even when trying to mitigate new problems created through climate change, as outlined in the physical barriers section. This barrier is further illustrated by another quote in the context of river renaturations:

> *"So, when I started at the water boards, I thought: "What we're doing here is actually, in terms of interventions and measures, is quite old."... So, for work on river restoration or stream restoration… We'd just dig a new channel which has some nice bends in it and then we're done. Which obviously didn't tackle almost any of the underlying problems [which are] mostly ecological water quality but also other issues…"*

This quote illustrates the problem of continuing to think in more technical parameters instead of fully assessing problems regarding river ecosystems and floods through newer, more ecologically oriented innovations. Moreover, it points towards the barrier that employees who have been working in the water sector for a long time are still relying on more technological fixes and innovations they are familiar with. With water boards relying on such older expertise, this essentially shapes the knowledge transfer within the organisation and becomes a critical barrier to new approaches of innovating.

Several interviewees, that were specifically working in the innovation teams of their organisations, highlighted that the technical part was often the go-to approach, but not necessarily the main issue that needed to be addressed. This is exemplified by the following quote:

> *"… I think that most of the people who are working in water boards etc., they are normally more focused on technology innovation. And meanwhile … technology and innovation is only a quarter of it, a big part of it is social innovation. And most of the people [we have to] inform that the social innovation always is a part of the innovation as well."*

This quote illustrates the existence of more recent knowledge advocating for a more interdisciplinary and integrated approach to innovations aimed at improving water quality. For example, by complementing technology with social approaches and also regarding ecological innovations as mentioned above. However, such innovations often appear not effectively integrated due to the generational barriers within water management organisations. This is supported by other interviewees' observations that using new approaches does not come naturally in organisations dominated by older workforce. They reported that there was an internal disagreement on what kind of knowledge would be most effective in addressing recent challenges in water management.

However, it is important to realise that the barrier here is not only the attitude towards innovations; as water boards and other water management bodies refrain from testing new approaches, they miss a crucial opportunity to develop more hands-on knowledge about the complexity of how innovation processes actually work.

[6.3.2] Risk Aversion

Another central barrier revealed in the theme 'cultural barriers' is the idea of risk aversion. This was brought up by many of the interviewees that pointed out the generational barrier. They agreed that the tendency of risk aversion was directly connected to the older workforce in the Dutch water management sector, especially in the water boards and drinking water companies. The essence of this barrier is illustrated by the following quote:

> *"It's stopping innovation because water companies are very conservative, risk averse. They don't want to jeopardise your health or my health. And that's why anything new has to be almost 100% [fool] proof."*

Accordingly, this risk aversion appears to be most prominent regarding declines in water quality that may pose possible health issues. This is supported by studies such as Kiparsky et al. (2016) on wastewater utility managers' attitudes in California. The concern with health risks is understandable since one of the main objectives of drinking water companies and the water sector in general is to

provide safe and healthy water to the Dutch population. Furthermore, as the health concerns are based on high regulatory governmental standards that require the maintenance of high water quality at any time. Thus, if an innovation indicates the slightest possibility to increase a health risk it will not be considered and implemented, as reported by several interviewees.

Yet, although high water quality is crucial for a society, this often unquestioned rationale constitutes a serious barrier to implementing innovations in the water sector. To illustrate this, one of our interviewees gave the example of opposing new heating systems in the neighbourhood as it bore the risk of bacterial growth in the water with possibly negative health consequences for older people. The interviewee highlighted the problems arising from this mindset as follows:

> "*And I then have to tell them, now that's not the good angle to take this discussion. First of all, the energy transition will happen anyhow. They will not wait for the water sector. Secondly, our answer should be, we need a solution for this legionella problem. So, the answer should not be 'stop'. The answer should be, 'Oh, a challenge. Let's do research to solve this problem.'*"

This example depicts how risk adversity in water management organisations slows down the effective implementation of innovations that may be crucial for maintaining water quality in the long-term. Several younger interviewees agreed that innovations could only be realised, if organisations were willing to change their attitude towards risks inherent to trying out innovations. *"So, you can have your [freedom from] risk at 99% instead of you know 0% [risk]... So a bit more risk and it means much more speed"* one of the researchers told us. Thus, especially considering the importance of certain transitions due to increasing climate change pressures, it seems important for the water sector to reflect on its tendency to be averse to risks tied to promising innovations.

[6.3.3] Investment Uncertainties

Interviewees often noted that risk adversity also created financial barriers regarding investment uncertainties. Almost all interviewees reported that ultimately there was enough money available in the Dutch water management sector but that it was sometimes difficult to access this money for innovations. Accordingly, interviewees found it easier to get funding for projects that operated within established infrastructures and solutions but experienced a lack of financial support for newer approaches. One of the interviewees explained this by saying that *"… for water companies, it's difficult to make investment decisions based on these uncertain futures."*. This points out the barrier that although the WFD is in favour of unconventional innovations, like nature-based solutions, these often fail to be funded as they are less manageable and there is a lack of knowledge on how these will develop over time also regarding additional future costs.

Interviewees commented that a prevalent financial barrier for innovation projects were traditional budgeting and investment practices. Although the main objective of water management as a public institution was to serve the people by providing safe water, the sector is still controlled by a more traditional economic mindset. For example, an innovation project still must make a good business case that will create short-term revenue to be seriously pursued. This conflicts with the innate nature of innovations, as they often require higher investments in the beginning but will only become profitable in the long-term. Furthermore, interviewees noticed an aversion to innovations that may exceed initial budgeting in terms of money and time as this quote illustrates:

> *"You've got two kinds of risks here. The risk of performing your project within the standards, within the time limits, within your budget. That's also… one of the risks you don't want to take. And that's a barrier for innovation."*

Thus, the aversion towards investment uncertainties not only limits the possibilities to test innovations more in depth, but it also highlights a general culture of not wanting to take responsibility for projects that do not guarantee success, as no one wants to be held responsible for having wasted the organisation's money or time. This mindset that appears to prevail at all levels of Dutch water management is a critical barrier to implementing innovations in the water sector that aim to improve water quality especially regarding future climate change related challenges.

[6.3.4] Economic Values

This leads onto another broader idea of economic values linked to 'cultural barriers'. Interviewees from all stakeholder groups reflected prevalent economic priorities often hindered the implementation of innovations within the water management system. As already mentioned in the 'governmental barriers' section, other economic objectives, or governmental projects, such as housing, are often prioritised over water projects. In that, the interviewees reflected that this tendency extends to the general public. One interviewee elaborated on the source of this tendency as follows:

> *"So actually the municipality of Veenendaal was set up as a business to exploit the peat and this mindset of well maybe I shouldn't say exploiting nature, but the business mindset you can feel still in Veenendaal. And that also was a factor in… what Veenendaal looks like, and it's also a factor in the mindset of people. So, there are a lot of entrepreneurs in Veenendaal and usually the entrepreneurs want to make sure that … the spatial characteristics of the area but also nature serves humans instead of that human-served nature or adapt to nature. So, within the borders of the municipality of Veenendaal you can see that everything is, the whole spatial planning is directed at serving people and not serving nature."*

This example elucidates that the development of the Netherlands has been historically shaped by a lack of recognition of the innate value of nature and intact ecosystems, such as water and river basins, as well as their interdependence. Instead water in the traditional Dutch value system, seems to be conceptualised exclusively as natural capital that serves as an exploitable resource for economic ends, which continues to shape the attitude towards water and its management within the general public.

Some interviewees pointed out that the protection of water quality is often pitted against the goal to maximise economic productivity. This appears to be especially a problem when water quality interests compete against economic sectors that constitute major pillars of the Dutch economy, such as agriculture:

> *"There are still a lot of problems related to water quality. And it's also an economic [one]. On the other hand, the agricultural sector is quite important in the Netherlands and that's one of the main contributors to water pollution. So, they won't have the high productivity and that conflicts with the water quality problems. So that's I think the cost of the problem, that you have to make a choice. And at this moment the economic interest is larger than the water quality."*

This statement was reflected in many similar quotes across all interviewed stakeholder groups. Hence, the importance of the agricultural sector for the Dutch economy continues to be considered more relevant than the country's water quality interests. According to an interviewee specialised on river renaturation projects and ecological innovations, this rationale is also found regarding navigation on Dutch canals and rivers. Thus, efficient shipping traffic is often considered more important than changing canal designs to improve ecological water quality.

Besides, this prevalent Dutch economic mindset has significant implications for innovations in the water sector. Especially interviewees working for more regional and provincial water management facilities noted that the availability of funding for water management depends on the political party in power, since water boards are being elected. For example, regarding the nitrogen pollution issue one of our from a water board explained:

> *"And that decision has to be done by the new government, as you know, is a right wing. And for them nitrogen is not an issue. They don't care… about water quality or nature. So, when you have a right-wing government, yeah, they don't invest in water quality or nature and that means that we have four years … [in] which you can't do enough, or perhaps nothing for water quality and nature."*

This quote reflects the importance of the public's mindset towards the valuing of water quality versus desirable economic priorities. Since water management is organised through public institutions a

majority vote in favour of a political party that prioritises agricultural, economic productivity has direct implications for the water sector's ability to invest in maintaining water quality. Hence, if the political party does not recognize the importance of addressing water related challenges, this becomes a barrier to water innovations by slowing down relevant political decision processes and cutting down on available financial resources.

[6.3.5] Ineffective Communication to the General Public

The final barrier of this theme captures the issue of a culture of ineffective communication between the water management experts and the general public. This point was especially noted by stakeholders working on lower hierarchical levels of the water sector. The interviewees often identified this lack of communication as one of the main underlying reasons for the lack of awareness and interest within the general public regarding water management. Interestingly, one of the interviewees forms RWS reported that this was rooted in traditional work-culture among governmental employees that was difficult to overcome:

> *"… One of the things our government really wants us to do it so be as transparent as possible… So, yeah, but it's difficult, especially for not necessarily older people, [but] people who have been working for the government a long time in any capacity. It used to be quite normal to keep your information to yourself and not to share it."*

This depicts how deeply some of the communication practices are rooted that constitute this barrier. Overall, the collected data reveals that this problem encompasses different aspects. For example, several interviewees highlighted that the work of the water management sector suffered from a lack of visibility. One interviewee working on innovations for a water board reported: *"Water boards [are] not the kinds of organisations that are normally very, very known with innovations, innovation behaviour."* According to these interviewees this is linked to the fact that organisations like water boards often do not put a lot of effort into communicating the innovative work they are doing, which may also be attributed to their leadership approaches described in previous sections. Hence, the water sector misses important opportunities to promote their crucial contribution to societal wellbeing and spark societal enthusiasm and support for the work they are doing. As reported by an interviewee from a research institute this may be related to the fact that public institutions, conversely to the private sector, are not as familiar with promoting their work and lack specific knowledge and experience to do so more effectively.

Another identified issue in relation to this is the lack of effective science communication. Several interviewees reported that they experienced a tendency among water managers and experts

to only communicate among their peers, instead of communicating important data to laymen and explaining its implications. In this regards an interviewee from a consultancy said:

> *"...You will need to put the blame with us experts not communicating correctly to them. So, you cannot ask from [the] general public to understand what I mean by partial differential equations. That's just language that doesn't make sense to [the] general public. That means whatever you are saying, … whatever you're doing needs to be translated into language that makes sense with the focal group we are talking about."*

This quote elucidates one of the key issues related to scientific data and public understanding. Although there is much more detailed data available than ever before, only experts have the tools to understand them properly, making it crucial to actively reach out to the public, to facilitate the understanding of water challenges and their interconnectedness with other domains such as private lifestyle choices. Referring to this, an interviewee from the Rijkswaterstaat pointed out that public consultation events around water projects were already legally required. However, it remained questionable how effective their current set up was:

> *"Whether they are real cooperation events? Not necessarily. … I think we can do a lot better than what we do at the moment. We just do what's required, and we don't necessarily go above and beyond that. …For instance, in a process like this you will have like maybe three or four of these events where you invite everybody, and it's … almost like a transient contact, or connection you have with the local people, but I think what you need is… like a more continuous relationship with the local stakeholders."*

Hence, although there are some efforts regarding the communication of projects to local communities these appear to be of limited effectiveness. The quote suggests that Dutch water management institutions may fail to make this social part of their work a priority and thus only put limited effort into building a stronger dialogue with their local communities. Through the prevalence of these described practices the lack of effective science and water innovation communication enhances the lack of awareness among the general public and hinders its interest regarding water issues. Meanwhile, reports from other interviewees suggest that more proactive efforts to communicate the benefit of innovations and river restoration projects foster a better acceptance of them and increase collaboration with the general public as an important stakeholder group in water management. For example, an interviewee from a water board recalled how pilot projects like going to people's homes to discuss new river renaturation plans and holding workshops at primary schools had helped create public approval and support for a recent project. Taken together, this emphasises the importance of such social innovations and a stronger dialogue from water institutions with the public to facilitate the implementation of innovations and transitions. Moreover, it illustrates that a

bottom-up support for water matters does not arise naturally within the Dutch general public. Therefore, these must be promoted proactively by devoting more time, money and possibly even involving expertise from social scientific fields in efforts to overcome such social barriers to the implementation of innovations in the field of water management.

[6.4] Theme 4: Social Network

The fourth theme is labelled 'Social Networks'. This theme is built upon the 'social capital' theory described in our previous barrier framework, which includes ideas of trust, communication, interdisciplinary work, and the way different stakeholders interact with one another. As mentioned by Machalek and Martin (2015), examining social capital offers insights into how various preferences may hinder or enhance effective water management practices and is key to addressing barriers and innovations – in our case in the Dutch water management system. As already described, this is a vital theme to explore due to the different stakeholders and disciplines we have identified that are involved within water management. As summarised by one researcher:

> *"the days are gone that you can look at water by itself. It's part of the societal challenges and changes we need. So, that means that you have to collaborate…with other stakeholders… we all think from our own point of view. And it takes time to get to learn the others, to look for joint future perspectives"*.

[6.4.1] Silo Mentality

Interviewees often noted their disconnect from other stakeholders within the water management sector, mentioning the term 'silo' several times. This is a corporate term referring to a concept called 'silo mentality', which is where coworkers within different divisions are unwilling to share information with one another due to a narrow mindset or competition between barriers (Kenton, 2019). For example, one interviewee from a consultancy said

> *"And we as experts … seem to be focused on our own expertise and we are within our own silo … experts should be much more aware of that, much more trained in that, have much more tools for that.".*

Another interviewee from a different consultancy said *"we are pretty much working in silos … in the Netherlands there are already many actors and the communication, learning and cooperation with each other is not really happening".*

A researcher from the KWR says that the solution to overcoming this is to have *"joint future perspectives",* and active contribution from all stakeholders. The researcher illustrates this with an example involving the recovery of materials from waste water and subsequent development of

innovative technologies. Rather than presenting finished products to the market, the emphasis should be on adapting these technologies based on market feedback and the specific requirements of different sectors.

[6.4.2] Formal vs Informal Networks

It was revealed that at a national level, although there is recognition that formal networks do exist, they may not always be as effective as desired. One interviewee claims that more emphasis is placed on the significance of informal networks within the organisation: *"It's the informal network you have in the organisation where you can really learn from colleagues at other areas who are doing similar things."* Notably, these informal networks can be used to gain support for innovation: *"Not so much on the technical parts of delivering innovation, but much more about how you can get people that they allow you to do that, basically.".*

Examples of how these existing formal networks may be ineffective were suggested by many different interviewees. For example, one researcher said *“you have two things you could talk about it or you can do it, and then if you talk too much about it, you cannot do it."* This shows that there may be potential inefficiency in having an overemphasis on discussions within formal networks. The interviewee further highlighted the challenge, noting:

> *"Don't you have meetings and conferences? You don't do anything. It is also useful because you get in touch with people. It has to be relevant really when you do it and not go to any conference or any social network, it only eats your time, and if you have too much, it's just a waste."*

Therefore an abundance of formal network engagements that lack relevance, could potentially contribute to a barrier in the Dutch water management system's innovation process. The interviewee instead advocates for a more focused approach, suggesting that *"less is better, actually less, but with high quality".*

[6.4.3] Interdisciplinary Nature

Another barrier revealed by interviewees can be found in the interdisciplinary nature of water management. As well as different stakeholders involved directly in water management, one also has to consider other groups such as farmers, nature conservationists, the energy industry, citizens, other countries etc. An interviewee from a consultancy said *“we need to reach out to many other groups and the other groups needs to reach out to us and, yeah, step away from your own, let's say, your own small domain. Start seeing the integrated picture here”.* In particular there appeared to be a lot of uncertainty surrounding social networks with the agriculture industry in the Netherlands from

interviewees due to politics and policies, *"there is competition between drinking water and agriculture"*. One researcher from the KWR said:

> *"Don't forget that in the Netherlands, they have the lowest water quality in Europe. We are not on top. … politicians are telling us, 'Oh, but for the Netherlands this is difficult, because we are a populated country and we have all the water from Germany and Belgium'. We already have standards taking that into account. But still, we don't reach those standards at all. At all. And mainly, mainly it relates to agriculture. And that mainly relates to manure, so it relates to animals, animal farming."*

Although there is a barrier here involving politics, population density, and pollution, no clear way to address the issue was revealed, particularly as *"within the farmer group there will be conflicting interests".* One interviewee stated that farmers should stop using fertilisers and pesticides to help water quality, but admitted this isn't a realistic goal. Others simply hinted at the issue, *"You might know the Netherlands, have all the issues with the farmers, we can't build new houses, etc…".* The various challenges discussed in the interviews surrounding agriculture in the Netherlands, reveal a significant and politically sensitive issue. While the acknowledgment of the problem seems widespread, the lack of consensus on solutions reflects the intricate and touchy nature of navigating a political landscape within water management. This complexity also underscores the need for careful consideration and collaboration when addressing water quality concerns or implementing new innovations.

[6.4.4] Divided Responsibility and Lack of Integration

Another key concept and barrier arising in the theme 'Social Networks' is the idea of responsibility, i.e. the social dynamics involved with who has different responsibilities in the water management industry. One researcher in the KWR said:

> *"if drinking water is not good, drinking water companies will be to blame. Then you have municipalities who are in charge of the sewer network, but not sewer treatment. So water companies take water, clean it, deliver it to you. They have that responsibility. Municipalities have a responsibility to collect wastewater, but not to treat it. Then waterschappen, water boards, they take over treatment and water quality of the water boards. So you can see that the responsibility is a bit divided, and there is a lack of that integration of the entire cycle.*

This quote highlights the different roles each stakeholder must perform in the water management sector. However, as mentioned by the interviewee, responsibility is divided which may cause issues when deciding whose role it is to do certain tasks, particularly in the face of bigger landscape issues such as the agriculture industry or climate change. `An interviewee from the water board states that

to overcome this barrier and *"to really make a change in water systems and thinking, we have to cross those borders, working together with authorities, the public relations, in another way than just focusing on your own responsibility.".*

As mentioned in relation to the silo mentality, having a joint future perspective can help with the aforementioned division of responsibility. However, according to another interviewee from the Limburg water board,

> *"the real challenge is getting a really integral water chain vision in this case in Limburg… And I don't know who's taking that role… if you can open that door, we can open the door for a lot of innovation".*

A researcher from the KWR refers to this implied role as *"agents of change"*. These are the kinds of people working in organisations who are enthusiastic and willing to take risks, despite the struggles and barriers they may be faced with. The interviewee says that networks of people who are agents of change must be built into organisations, particularly between the young to old and experienced to inexperienced.

[6.4.5] Human Capital

This leads onto another important feature of social networks, 'human capital', which refers to the knowledge various people have. Many interviewees claim that *"a lot of organisations do have trouble finding good people"*. Other interviewees mention a current lack of technical expertise or raised some issues surrounding the perceived older average working age in the Dutch water management system. On the other hand, there were still some positives. For instance, at a national level, one interviewee said *"we have 50 to 100 people who've just finished Bachelor or Master… every year we can fill at least five or ten times more posts than we have".* Another interview from the water board Limburg believes that *"young people like you are much more with the mindset of, 'I want to work in a company that really is helping the world to get better'."* Therefore, although there may be some current difficulties in 'finding good people', it seems many are hopeful about the future of human capital.

Despite this, there are still barriers within companies in the water management industry to finding new labour. Several interviewees claim that technology is so evolved people are hesitant to get into it, or there is too much data and knowledge needed to become an expert in something. An interviewee from the water board Limburg said: *"There is a lot of data in our system… then we need other competence of people. We need data managers, and system architects, and system engineers, data engineers.".* One interviewee from a consultancy then said *"There's lack of expertise… it is a lack of understanding what this data means and where to find it and what it actually tells you.".* An advisor at the RWS says this is where the *"heart of the conflict"* sits. According to them, 'innovations' are

“moving away from the technical engineering solutions to much more nature-based solutions… which are by default, I think, less controllable than engineering solutions, controllable and less predictable than engineering solutions.”

In summary, there seems to be some sort of reluctance when it comes to innovation, perhaps due to perceptions of advanced technology requiring more extensive expertise, or due to vast amounts of data. Clearly ‘social networks’ are of utmost importance in lieu of this analysis, as an interconnected knowledge sharing network is necessary to overcome arising gaps in knowledge and interpret the growing amounts of complex data. The final quote shows that innovations have evolved into a social issue, meaning addressing barriers in water management not only requires technical proficiency but also a social understanding of evolving industry dynamics and solutions.

Within human capital, the role of agents of change as aforementioned becomes even more critical. They act as champions for attracting and retaining talent within organisations. Their enthusiasm and dedication can inspire the younger generation, as mentioned by an interviewee highlighting the mindset of young people who want to contribute to making the world a better place. Building networks of agents of change therefore becomes a strategic imperative for organisations to address the challenges related to finding and retaining skilled professionals in the water management industry. These networks can bridge the gap between generations and experience levels, ensuring a continuous flow of knowledge and expertise. In addition, agents of change create an environment that encourages learning, adaptability, and a willingness to embrace technological advancements.

In conclusion, the 'Social Networks' theme in Dutch water management emphasises the vital role of trust, communication, and collaboration. Barriers such as the silo mentality, formal vs. informal networks, interdisciplinary challenges, and issues of responsibility underscore the complexity of the sector. The concept of 'agents of change' emerges as crucial, requiring enthusiastic individuals to bridge generational and experiential gaps. Human capital, despite challenges in finding talent and evolving technology, remains hopeful, particularly with a younger generation eager to contribute. In conclusion, a balanced blend of technical proficiency and social understanding is essential, highlighting the interconnected nature of addressing barriers and fostering innovation in Dutch water management.

[7] Applying Multi-Level Perspective

Locating the elements arising from the thematic analysis within the MLP framework helps to clarify connections and interactions between the different structural levels that shape innovation processes. The subsequent analysis highlights which interactions constitute barriers that hinder the implementation of innovations to increase water quality.

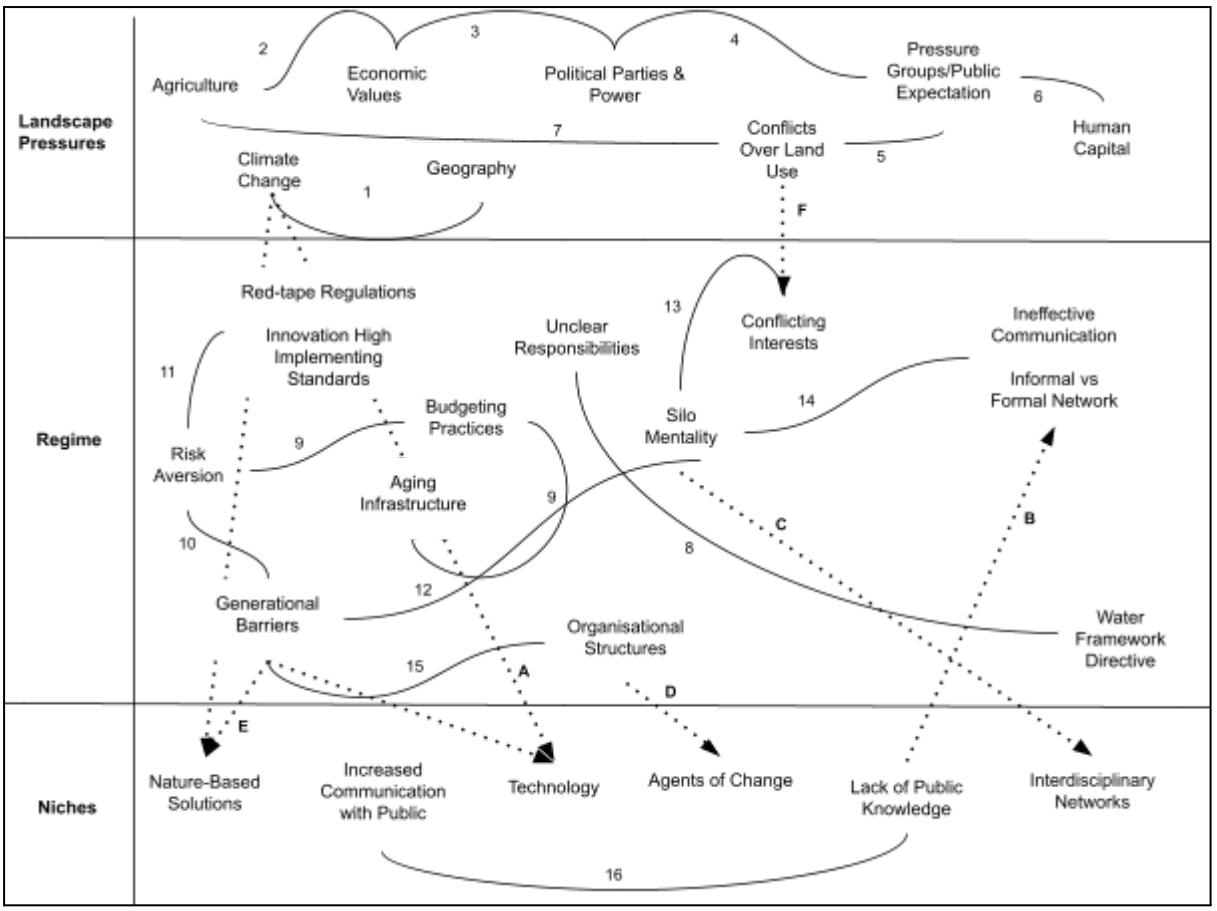

Fig. 6: Application of MLP framework to findings

Table 1

Applying the MLP framework to analyse different stakeholders from different levels

Links Between Levels	Explanation
A. Climate Change & Technology & Nature-Based Solutions	To mitigate and adapt to climate change, new technological solutions must account for the effects of climate change (e.g. changes in precipitation, sea level rise, temperature rise). Nature-based solutions are a good way to do so, but are not sufficiently established yet.
B. Lack of Public Knowledge & Ineffective Communication	Ineffective communication from water management institutions regarding water education and water innovation projects enhances the lack of public knowledge and interest for these issues. At the same time, a more informed public represents a crucial lever for more bottom-up innovations and support.

C.	Interdisciplinary Networks & Silo Mentality	Networks to encourage interdisciplinary information exchange is still not common practice in the water sector but can help break down the silo mentality and facilitate more efficient and holistic research and innovation.
D.	Agents of Change & Networks	The facilitation of informal networks can aid the fostering agents of change by creating more contacts and support for these individuals..
E.	Generational Barriers & Nature-Based Solutions	The generational barrier present senior staff members are less keen to go along with the newer technologies and nature based solutions may be less looked into.
F.	Conflicting Interests & Conflicts Over Land	Conflicts over land use can arise due to conflicting interests between stakeholder groups / sectors, which reduces the possibility for compromise.

Table 2

Applying the MLP framework to analyse different stakeholders from the same level

Links Inside Levels		**Explanation**
1.	Geography & Climate Change	How Dutch geography determines water availability, economics (exports), and vulnerability to climate change.
2.	Economic Values & Agriculture	The agricultural sector may be economically prioritised over sustainable innovative methods in the water sector which significantly slows the innovation process.
3.	Economic Values & Political Parties in Power	The economic climate influences the political parties in power which are elected. This influences the leadership strategy within the water sector as the water management sector is ultimately elected
4.	Pressure Groups/Public Expectation & Political Parties in Power	Public pressure influences and is influenced by political parties. Implications for decision making and innovation.

5. Pressure Groups/Public Expectation & Conflicts over Land	Public expectations can lead to conflicts over land use, with agricultural lobby as example again, how this affects decision making and innovation.
6. Pressure Groups/Public Expectation & Human Capital	How public expectations can impact the ability to find labour.
7. Conflicts Over Land & Agriculture	Majority of the Netherlands surface area has been allocated towards the agricultural sector but the water sector now also has rising demands for the land space which leads to conflicts over land use.
8. Unclear Responsibilities & WFD	The broad scope and formulation of the WFD creates performance gaps regarding certain innovation projects (i.e. for river renaturations) due to overlap with other directives and unclear responsibilities that hinder effective action.
9. Ageing Infrastructure & Budgeting Practices & Risk Aversion	There is a challenge of deciding how to distribute budgets to update or replace ageing infrastructure to make it fit for future water challenges. Risk aversion limits budgeting for innovations and moving on from old tried-and-true practices and can hinder effective long-term investments.
10. Generational Barriers & Risk Aversion	The prevalent risk aversion that characterises decision-making in water management is strongly influenced by the predominantly older workforce and its conservative attitude.
11. High Implementing Standards & Risk Aversion	Risk aversion tendencies in established water management instuîtutions are supported and informed by the high implementing standards that innovations must meet to be considered and integrated.
12. Generational Barriers & Silo Mentality	The distinct silo mentality among water management experts is sustained through the predominance of the older workforce. Older water management generations tend to rely on their existing knowledge and previous experience instead of drawing from new knowledge which may also come from different fields of expertise

13. Silo Mentality & Conflicts of Interest	The silo mentality expands to stakeholders outside of the direct water management system and limits progress and implementing innovations due to minimal communication and formation of common interests that facilitate establishing compromises.
14. Silo Mentality & Ineffective Communication	The silo mentality to communicate mainly within the own expert group represents a major source of ineffective communication. Both elements perpetuate each other.
15. Generational Barriers & Organisational Structures	Traditional organisational structures in the public water management sector maintain generational barriers and vice versa. Implementing newer managerial approaches and team structures may help build stronger inter-generational collaboration and overcome respective barriers.
16. Lack of Public Knowledge & Increased Communication with Public	To mitigate lack of public knowledge, better and clearer communication with the public can be implemented.

[8] Recommendations

Similar to previous studies, such as Rouillard et al. (2016) this report illustrates that a number of factors determine how successfully innovations are received and integrated. These are often independent of technology but more related to the social and managerial context. Thus, more action should be directed towards the domain of social innovations, since the Netherlands appears to already be well-equipped regarding technological innovations. The thematic analysis and subsequent application of the MLP Framework have led us to identify several key issues within the current Dutch water management system that need to be addressed to overcome crucial barriers that restrict the implementation of innovations to increase the Dutch water quality:

1. **Performance vs Responsibility:** Performance gaps due to unclear responsibilities, for example related to overlapping directives, must be identified, and translated into clearly allocated tasks down to an individual level.
2. **Multiple value creation via various stakeholders**: A stronger will between stakeholders to collaborate and find compromises must be fostered to create joint future perspectives and mitigate conflicting interests. This must encompass stakeholders that are not part of the water management

system but have a crucial influence on water quality, such as stakeholders from the agricultural sector. In that, the influence of different economic priorities that create possible tensions must be acknowledged and addressed.

3. **Integrating more interdisciplinarity:** Interdisciplinary teams and networks need to be actively built on all levels of organisation to create more holistic solutions for the increasingly interdisciplinary problems the water sector faces. This may facilitate a more natural integration of different kinds of knowledge and help building and valuing more informal networks.

4. **Supporting 'agents of change':** Water management utilities need to incorporate forms of innovation leadership that identify individuals that act as 'agents of change' and support them in their projects and build connections to 'agents of change' in other utilities. This is also supported by Rouillard et al.'s study (2016) on innovation uptake in the European context who found that individuals have a key role in the innovation uptake of urban water management.

5. **Fostering a trans-generational dialogue:** Organisation leaders should actively encourage a stronger trans-generational dialogue within their organisations to mitigate generational barriers, such as prioritising conventional solutions and hindering innovation projects due to risk aversion. Employees should be encouraged to collaborate more between different generations and work on an eye-to-eye base by appreciating their different perspectives and benefitting from each other's different kinds of expertise instead of maintaining a top-down knowledge transfer. For example, while older employees may be more familiar with the water systems characteristics, younger generations can contribute newer forms of knowledge to try more nature-oriented solutions.

6. **Encouraging nature-based solutions:** More sustainable innovations, such as nature-based or more resource effective solutions, must be strongly encouraged by decision-makers on lower organisational levels to overcome the tendency to rely on proven technological approaches, since the top-down WFD appears to be of limited effectiveness in this regard.

7. **Communication as key for success:** Effective communication and education on water projects, its relevance for societal well-being and interdisciplinary risks of water scarcity must be recognized as a core element of the water sector's work. Fostering public understanding may be essential to build societal acceptance and support for crucial innovations and could help facilitate a stronger bottom-up political support as well as spark young people's interest to work in the sector and increase the availability of human capital. Hence, more resources regarding money, time and specific communication expertise must be dedicated to developing effective communication strategies. Among others, these should encompass translating expert jargon into an accessible language and fostering transparency regarding governmental data and decision-making processes.

8. **Relationship building for collaboration:** Closely linked to this, more effort should be put into building stronger relationships and trust within the system of water management and periphery stakeholders as well as between water management representatives and local communities. Investing in more continuous relationships instead may be a key lever to create a more natural collaboration and exchange of knowledge. Water boards and municipalities seem to incorporate such relationship building and more innovative communication projects already more proactively, while higher up organisations like Rijkswaterstaat appear to be more disconnected.

The most relevant step to realise these recommendations appears to be the creation of a more interdisciplinary work culture and teams, as introduced under point three, and all levels of organisation. This appears to be especially relevant since Dutch water management is part of the public sector and hence shaped by its traditional managerial practices. While these are characterised by offering stability on the one hand, their rigidity and tendency to central management limit their ability to embrace complexity and interdisciplinarity which are crucial for the kinds of innovations currently needed in the Dutch water sector (Arundel et al., 2019 & Diel, 2023). Hence, the water management organisation appears to reach its limits and must not only focus on innovations for water quality, but also regarding its own internal management practices to improve its effectiveness regarding internal resources and in addressing new societal challenges tied to modernity and climate change (Arundel et al., 2019).

Several recent studies suggest that especially sustainability challenges, such as water management, can be dealt with most effectively through more holistic and interdisciplinary approaches and work units, which are already more prominent in private sectors (Cosens et al. 2011 & Rouillard et al., 2016). Hence, the public water sector may benefit from incorporating more entrepreneurial approaches to facilitate its uptake of innovations. This means, creating small groups to enhance effectiveness with a more diverse composition of knowledge and age to draw from (Taka et al., 2022). For example, combining civil and environmental engineers, with ecologists and specialists from urban studies and communication strategy departments. Through hybrid hierarchies and co-operation practice, these are found to enhance peer learning, creativity and effectiveness of solutions while encouraging individuals to take responsibilities and risks (Diel, 2023 & Taka et al., 2022). Meanwhile, the effectiveness of informal networks may be strengthened as each member contributes to different individual networks and the willingness to settle on compromises may be strengthened through engaging with different perspectives. In addition, it may naturally promote a stronger generational dialogue and thereby facilitate the acceptance and integration of more nature-based solutions.

[9] Evaluation & Limitations

Through our research, we came to the realisation that the scope of our study was quite broad, compared to how specialised our sources and interviewees were. However, we decided that this does not necessarily have poor implications for the relevance or legitimacy of our findings, as our goal was to be holistic in our analysis of barriers within the water management sector, as opposed to specific. In this section, we discuss other factors we encountered in our research that may have implications for the efficiency and quality of our methodology, and therefore our results as well.

[9.1] Time & Networking Constraints

A first obstacle we encountered that we would certainly like to improve upon in future methodologies is time management concerning reaching out to interviewees. Due to the fact that the majority of our research group had either never conducted research interviews before, or had never done so at such a large scale, our frame of reference for how long it might take to gather an appropriate sample size was limited. Originally, we had planned to contact, receive responses, and pinpoint dates for 15 interviewees within one week, and conduct interviews in three weeks. In the end, it took us eight weeks to contact and conduct 14 interviews.

Two other factors that may have made it more challenging to contact interviewees was the time of the project, and the personal lives of the student researchers. Firstly, the project took place between October and January, with interview searches scheduled to begin in November. This meant that most interviewees were extremely busy at the time, and also wanted to account for their Christmas or winter vacation. One interviewee even requested to postpone the interview by a month for this reason. We also noted that many interviewees were much easier to contact in January, further suggesting that it was unfortunate scheduling to wait until November to establish contact. Secondly, the academic and non-academic workload of university student life also posed some challenges to establishing contact with interviewees on time. In the future, to account for the time needed to contact interviewees, it would be a good idea to make time for this much earlier in the project. This way, dates can be set sooner, allowing more time for more interviews, allowing us to gather a larger sample size and represent more stakeholder perspectives.

Besides time, another obstacle we did not foresee was networking constraints. Originally, our research project was expected to align more with climate change resilience-related innovation and research. Thereby, because we shifted our scope to water quality management, we did not have the resources we might have had if we settled with the original theme of the project. By this we mean

that we were not acquainted with any students, researchers, or other persons involved in water management, leaving us with few interview candidates to begin with. While, as mentioned in the methodology, we were eventually able to find some ways to contact interview candidates, through mediums such as linkedin and governmental websites, some stakeholders were still especially challenging if not impossible to contact. One particular example is that of Dutch water companies. Of the Dutch water companies we contacted, a number was not possible to contact. Either because a customer number was required or because non-customer contact mediums (e-mail, text message, phone call) were temporarily down for an undisclosed time. Due to such challenges, certain stakeholder perspectives, specifically water companies and civilian points of view could not be included in the research project, the limitation of which will be further discussed.

[9.2] Emergent Methodology

Another factor that may have implications for the accuracy and generalisability of our results is the emergent nature of our qualitative methodology. As outlined earlier, we changed certain aspects of our methodology based on what we learned throughout our research and interviewing process. This means that our interview guide for example was changed marginally and may have affected interviewee responses. Additionally, due to our research being qualitative, the 'accuracy' of particular information is difficult to gauge, because we intentionally sought out the personal perspectives and opinions of different stakeholder groups on the same issue. Combined with the fact that our research was composed of 14 interviews, raises the possibility that our findings might not necessarily be very generalisable across the population of actors in the water management system. As mentioned earlier, Guest et al. (2006) suggests that 12 interviewees is enough to begin to make claims based on the findings, however, in our case due to the amount of individuals involved in the entire dutch water management system, it leads us to believe that our study could only benefit from having more interviewees.

Lastly, the qualitative nature of our findings, which makes it difficult to identify inaccuracies, means that our findings may be unintentionally interpreted through somewhat biassed or limited points of view. To help limit this flawed interpretation of data, we used triangulation, where each member of the research team was involved in the processing of a piece of data, whether it be interviewing, transcription, or analysis. This way, every research member was familiar with every interview, and we could all hold each other accountable and be involved in the reporting of the findings.

[9.3] Language Barrier

A last factor we found that may limit the quality of our data and created challenges in reaching out to interviewees was the language barrier, as our research was conducted in English by international students. Our area of research concerned Dutch water management, meaning that the vast majority of our interviewees conducted their work in Dutch. Thus, the interviewees found it difficult to translate jargon to English from their native Dutch. However, only two of our research members are able to speak Dutch with enough proficiency to understand this technical jargon. One solution would be to have our Dutch researchers responsible for Dutch interviewees, though this would result in unequal and challenging work distribution. Instead, we decided to conduct all interviews in Dutch since most Dutch people, especially those involved in academia and research, are able to speak English as well. Through this decision, it did mean that some interviewees struggled to articulate their thoughts in a foreign language. Both their ability to communicate, and our ability to understand may have been affected by this language barrier, raising the possibility that some ideas may have been lost or changed in translation. For the most part all transcriptions we generated were still comprehensible though. There were only a few cases where a Dutch accent made it difficult to infer what certain words were, particularly concerning jargon.

Another obstacle that we suspect may have emerged due to our decision to work in English is gathering interview candidates. Most of our attempts at reaching out were done in English, which were not very successful at getting responses. Messages composed in Dutch, while disclosing the English nature of the project generally had a somewhat higher response rate. In the future, this is something we can consider when choosing our language of communication.

[10] Conclusion

Our research sought to address the critical issue of water quality in the Netherlands, as the country appears to face significant challenges in meeting the standards set by the WFD. The overarching research question guiding our investigation was: What barriers are hindering the effective implementation of innovations to improve water quality in the Netherlands according to the European WFD standards?

Despite the country's global reputation for water management prowess, poor water quality persists, with only 1% meeting WFD standards. Our exploration extended to the background of the EU WFD Directive, emphasising its principles, challenges and the impending 2027 deadline for compliance. Further examination of water standards revealed persistent struggles with pollutants like nitrate, phosphate, PFAS, and microplastics, mainly driven by agricultural contributions. The study

also analysed the Dutch water management system, highlighting its complexity, democratic foundation, and the role of public-private collaborations. We also defined innovation within the context of our research as being broad in nature, ranging from technological advancements to socio-technical innovations. The interdisciplinary dynamics of the water sector were highlighted, acknowledging the societal and environmental dimensions that are crucial for effective water management innovation.

Employing the MLP and Barrier frameworks, our research then comprehensively explored barriers within Dutch water management through interviews. The MLP framework provided a structured analysis, unveiling some emerging innovations, established systems, and external factors affecting water quality. The Barrier framework helped to categorise key domains influencing innovation adoption, ranging from physical, financial, human, social, cultural, and policy capitals. The study's thematic analysis identified multifaceted challenges within physical factors, government and policy complexities, cultural impediments, and the critical role of social networks. In particular, themes such as generational differences, risk aversion, economic clashes, and ineffective communication, highlighted the need for a strategic shift towards addressing social and managerial aspects of the water management sector.

Consequently, our recommendations align with this imperative shift, emphasising the necessity for clear delineation of responsibilities, fostering collaboration among diverse stakeholders, and promoting interdisciplinary approaches. Additionally, recognizing and supporting Agents of Change is essential to drive innovation and overcome generational barriers. We propose fostering a trans-generational dialogue to facilitate knowledge transfers and cultivate a more dynamic mindset within the sector. Strategies such as embracing nature-based solutions, effective communication, and relationship-building are also crucial components of our recommendations. The highlighted significance of interdisciplinary work cultures and teams, extending across all organisational and stakeholder levels, stands out as central to realising these recommendations.

In conclusion, our research serves as a pivotal starting point for future investigations into water quality improvement in the Netherlands. Initially, we thought technological innovations would be potential solutions to water quality issues. However, our findings unveiled a more intricate reality, highlighting the dominance of social barriers over technological ones. We discovered that existing technological innovations are available, but their implementation is hindered by complex social dynamics within the Dutch water management system.

A promising avenue for future research lies in a deeper exploration of the relationship between agriculture and water management. Our study found that agriculture is a major contributor to water quality challenges, entangled in an intricate political landscape. Further research in this

domain could help unravel the complexities surrounding agricultural practices, addressing political dynamics that impede effective water management solutions. Our exploratory study lays the groundwork for these future research directions, advocating for a more holistic approach that considers the interplay between technological advancements and the sociocultural intricacies of the Dutch water management system. By addressing these complexities, future research has the potential to ultimately contribute to more effective and sustainable water quality solutions in the Netherlands.

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[12] Appendix

[12.1] Appendix I - Interview Guide

Introduction:

1. Can you briefly introduce yourself?
2. What is your experience in the field of water management?
3. Our project is centred around innovations in the water management sector: what water management innovations have you encountered or worked with?
    a. Clarification probe: Innovations here refers to any changes they may have noticed in their direct work surroundings in your direct field.
    b. Clarification probe *(if further clarification necessary)*: These innovations might include transformative or incremental changes in, for example, technical, technological, digital, social and organisational management strategies.

Section 1: Barriers to Implementation - Physical Domain

4. What physical infrastructures impede the implementation of water management innovations?
    a. Clarification probe *(if further clarification necessary)*: These infrastructures might include sensors, IoT, data infrastructures
5. What geographical factors impede the implementation of water management?
    a. Clarification probe: situational factors, location of country etc.
6. What environmental factors impede the implementation of water management?
    a. Clarification probe: dynamic environment such as ecosystems, water resources, animals, weather etc.

Section 2: Barriers to Implementation - Financial Domain

7. What financial challenges hinder the development and/or implementation of water management innovations?
    a. Elaboration probe: issues with investment: public funding/private funding?
    b. Elaboration probe: Which actor(s) financially support the water sector? Is this enough?
        i. Clarification probe: Water sector = sourcing, treatment, distribution sectors
    c. Elaboration probe: specifically in your domain of the water sector?
    d. Elaboration: to what extent are there certain economic considerations that hinder the implementation of innovations? Ie. financial or political considerations, short, medium and long term political and financial planning

Section 3: Barriers to Implementation - Human Domain

8. How does human capital affect the success of water management innovation implementation?
    a. Clarification probe: human capital = knowledge, skills, and abilities that individuals and organisations possess. It's basically what people know and can do.
9. Can you provide an example of how workforce skills, training, or expertise impact these innovations?

Section 4: Barriers to Implementation - Social Domain

10. How do social networks impact the implementation of water management innovations?
    a. Clarification probe: Networks between individuals within the field of expertise.
    b. Clarification probe: Networks between stakeholder groups around the field of expertise.
11. Could you share an example of how social networks, trust, or cooperation (or lack thereof) affect these innovations' implementation?
    a. Elaboration probe: How could trust be established between stakeholders (to implement innovation)? Why might cooperation be lacking? What initiative would they like to see from other stakeholders?

Section 5: Barriers to Implementation - Cultural Domain

12. What cultural barriers do you see that affect the implementation of water management innovations?
    a. Clarification probe: Social culture, general public perception of water quality and management.
    b. Clarification probe: Corporate / work culture, the culture within a stakeholder group.
13. Can you provide an example of how cultural barriers
    a. Elaboration probe: communication culture with other stakeholders and the decision making culture to implement innovations?
14. What barriers do you see regarding laws and the policy culture around water management?
    a. Elaboration probe: Example for a law that restricts water usage?

Section 6: Prioritising Barriers

15. From your perspective, which barriers, across the social, financial, cultural, physical, and human dimensions, are the most urgent or critical? Why?
    a. Elaboration probe: Are there any connections between these different dimensions of barriers?
    b. Elaboration probe: Are there any dependencies between these different dimensions of barriers?

16. How would you rank the different domains we discussed in this interview according to how pressingly they must be addressed to improve the water management in the Netherlands?
17. What are your expectations from other stakeholders in the ecosystem?

Conclusion:

18. Is there any additional information or insights you'd like to share regarding water management innovations and the multi-level barriers?

[12.2] Appendix II - Consent Form

DECLARATION OF CONSENT

For participation in the research study: Barriers to Innovations in the Dutch Water Management System

Executive investigators

Names: Charlotte Donelly, Emma Godfried, Samantha Lowe, Clara Wittig

Institution: University College Maastricht, The Netherlands

We are interested in understanding which barriers hinder the effective implementation of innovations in the Dutch water management system and how they do so. You will be presented with information relevant to our research study and asked to answer some questions about it. Please be assured that your responses will be kept completely confidential.

The study involves participating in an interview and should take you around 60 minutes to complete. Your participation in this research is voluntary. You have the right to withdraw at any point during the study, for any reason, and without any prejudice. If you would like to contact the executive researchers in the study to discuss this research, please e-mail c.wittig@student.maastrichtuniversity.nl

We will make an audio recording of the interview and write down all that has been said during the interview on the basis of the recording. In this written version of the interview and in our personal notes, we will use your name. These documents will not be shared with anyone else. If we share any of the interview material with someone else, the interview will be anonymized so that you are not personally identifiable.

There are no reasonable foreseeable risks of participating in the study. Your participation will help to attain the stated purposes of the study. Your participation will not be compensated financially.

You have the right to access all the information collected about you as part of the study. Upon request, we will send you the information collected about you. After the study is completed, the outcome of our research will be presented in a written report and at a conference that staff and students of University College Maastricht will attend. The information collected about you will have all been destroyed by 02/02/2024.

For research participants to sign:

☐ I have been informed of the study. I have read the written information. I have had the opportunity to ask questions about the study. I have been able to think about my participation in the study that is completely voluntary. I have the right to withdraw my consent and quit from the study at any time without needing to give a reason.

☐ I have agreed to participate in the study.

Name:

I am 18 years or older: □ YES □ NO

Signature: **Date**: