An institutional analysis framework to close the regional water cycle

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by

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Preface

This document presents the final report for the master thesis of Systems Engineering, Policy Analysis & Management (SEPAM) at the TU Delft. From December 2016 onwards, I have worked both on the master thesis for SEPAM and the master thesis for Civil Engineering, Watermanagement, specialization Sanitary Engineering, at water authority Delfland (HH Delfland).

I would like to thank water authority Delfland (HH Delfland) and more specifically Oscar Helsen for the opportunity to write my master thesis at HH Delfland. I have appreciated the supervision of Oscar during my year at HH Delfland and our conversations on our shared interest in cycling. In the final weeks of my research, I have greatly appreciated the opportunity to present the research to the board of HH Delfland and the support of Oscar during the preparations of the final presentations.

I am grateful to so many employees and all board members of HH Delfland for supporting my research. I would especially like to thank Bas Nanninga for providing me the opportunity to join his interviews with two board members of HH Delfland. My research has become so much more in-depth because of this opportunity. Also, I would like to thank Jouke Boorsma and Marije Paardekooper for the constructive meetings and their introduction to many relevant stakeholders in the water system for the interviews. Finally, I would like to thank the board of HH Delfland for the opportunity to present the main findings of my research. It has been a very interesting conclusion of my research and above all a great learning experience.

Of course, I would also like to thank my graduation committee from the TU Delft: prof. Bartel van de Walle, Bert Enserink and Aad Correljé. I would like to thank prof. Bartel van de Walle, as chair of my graduation committee, for his comments during the official meetings. Furthermore, I would like to thank my first supervisor Bert Enserink for his positive support during our meetings in The Hague. I have experienced our collaboration as very pleasant and straight-forward. I would like to thank Aad Correljé for the substantive meetings we have had, mostly regarding the theoretical framework of my research. His extensive knowledge on institutional analysis and critical comments have made my research much more profound.

Finally, I would like to thanks my family and friends for their support and interest during the past year and for making all the hours in the library so much more fun.

Ward van Es – October 2017

Summary

Part I - Introduction

Climate change is expected to put increasing stress on urban water management. Expected water shortages due to intensified periods of drought are a great threat in the near future. Water authorities in The Netherlands are facing the challenge how to close the water cycle by wastewater reuse, to guarantee good water quantity and quality. In the complex policy making process of the multi-actor water system, water authorities would benefit from a comprehensive and sufficiently guiding framework. Currently, scientific research only provides either too general or too specific frameworks for urban water management. This research aims to provide such a framework, with the main research question:

How to specify and operationalize an institutional analysis framework to guide actors in closing the regional water cycle?

Part II - Conceptualization

The Technological, Institutional and Process (TIP) framework of Koppenjan and Groenewegen (2005) has the potential to be both comprehensive and sufficiently guiding. The framework is specified with other frameworks and tools to provide guidance in closing regional water cycles. Functional diagrams are used to provide insight into the required technological changes for a closed water system. The institutional analysis is specified with the four-layer model of Williamson (1998) and the Institutional Analysis and Development (IAD) framework of Ostrom (2011). Concepts of process management that can help in the process towards a closed water cycle, are introduced.

This research focuses on the institutional analysis framework. The IAD framework of Ostrom (2011) allows more detailed institutional analysis than the four-layer model of Williamson (1998), by specifying the input and interaction of action situations. An action situation is 'a conceptual space in which actors inform themselves, consider alternative courses of action, make decisions and take action' (Polski and Ostrom, 1999). Ostrom acknowledges that it can be hard to identify relevant action situations in large, complex policy systems (Polski and Ostrom, 1999). To resolve this, this research proposes to use the four-layer model of Williamson (1998) to find the critical action arenas in institutional redesign. The four-layer model conceptualizes social analysis by categorizing institutions in four different layers (1) cultures & norms, 2) institutional environment, 3) governance and 4) marginal analysis).

Figure 1 provides an overview of the proposed Williamson (1998) – Ostrom (2011) institutional analysis framework. The first step is to find critical issues with Williamson's (1998) framework. Critical issues must be addressed in action situations. The critical action situations are those situations that will be critical to the success of redesigning the urban water cycle towards a closed system. These critical action situations require coordination by the system designer to guide interaction towards desired outcomes. The IAD framework of Ostrom (2011) is well suited to specify key features of the critical action situations to predict interactions and outcomes.

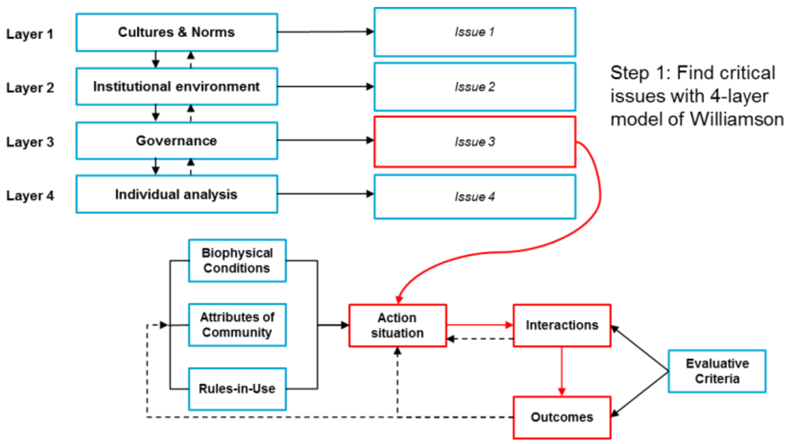


Figure 1 – The Williamson (1998) – Ostrom (2011) institutional analysis framework

To operationalized the proposed institutional analysis framework, a case study of closing the water cycle at HH Delfland is conducted. The first step (finding critical issues) is executed in five parts: 1) technological design, 2) first scan of issues, 3) interviews, 4) analysis of interviews and 5) conclusion on critical action situations. The second step (specifying critical action situations) consists of a description of the 1) external variables, 2) action situation, 3) interaction & outcomes and 4) coordination of the two most critical action situations.

Part III - Operationalization

Step 1 – Identifying the critical issues

The required **technological changes** for a closed water system are found by constructing function diagrams of the current and desired water system. The main changes to the technological system are 1) addition of advanced wastewater treatment to conventional treatment plants and 2) new infrastructure to transport wastewater treatment effluent to the location of reuse. A wide range of potential issues is found in a **first scan of issues,** based on four projects of wastewater reuse (Belgium, USA, Singapore and Namibia) and a Green Deal. Examples of issues are: public acceptation, adjustment of rules and regulations and the business case of wastewater reuse.

To find the most critical issues for the case of HH Delfland, **twenty-two interviews** have been conducted with relevant actors in the water system (e.g. HH Delfland, Dunea, ministry, province, municipalities and universities). The four-layer model of Williamson (1998) is used to structure empirical information from the interviews. In layer 1 (cultures & norms), social acceptability of wastewater reuse and a lack of urgency have been mentioned as issues in closing the water cycle. The issues of difficulty to meet water quality standards and legislation that proves to be conflicting during implementation are mentioned in layer 2 (institutional environment). The wide variety of actors involved in the regional water system and the political nature of the system are issues mentioned in the third layer of governance. The economic feasibility of wastewater reuse is the main issue mentioned in the lowest layer of marginal analysis.

Analysis of the interviews shows that the values and drivers of board members of HH Delfland, regarding wastewater reuse, are located at three different levels of the four-layer model of Williamson (see Figure 2). The first group is driven by the values of sustainability and circularity, located at the highest institutional level. The position of the second group corresponds to the third layer of governance, focusing on relations and interactions. The driver of the third group can be found at the forth level of the individual analysis. In their eyes, projects in closing the water cycle should have a positive business case. The difference in institutional levels from which board members reason, are a source of disagreement within the board of HH Delfland.

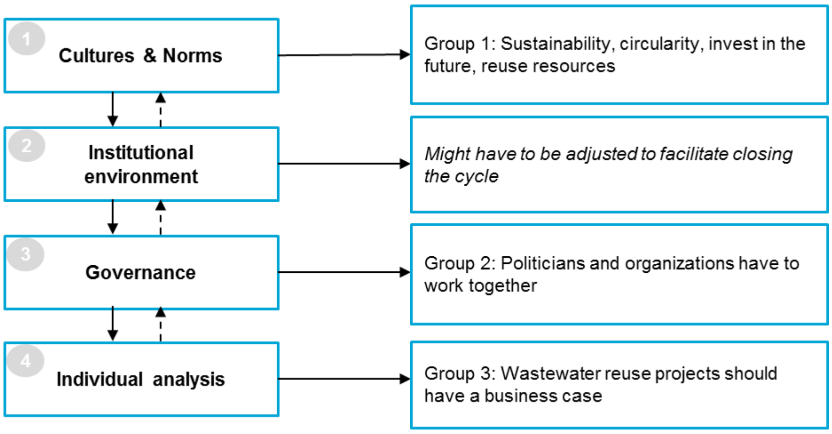


Figure 2 - Overview of levels on which board member argue

An action situation is regarded as critical when the most critical issues are addressed within this action situation. The interviews conducted for this research allowed to find the most critical issues. This research finds these issues are addressed in **two critical action situations:** 1) HH Delfland having to obtain a permit to discharge treated wastewater and 2) new arrangements between HH Delfland and Dunea. The first action situation address the critical issue of obtaining a discharge permit. The second action situation addresses the critical issues of technological changes, social acceptation and economic feasibility (see Figure 3).

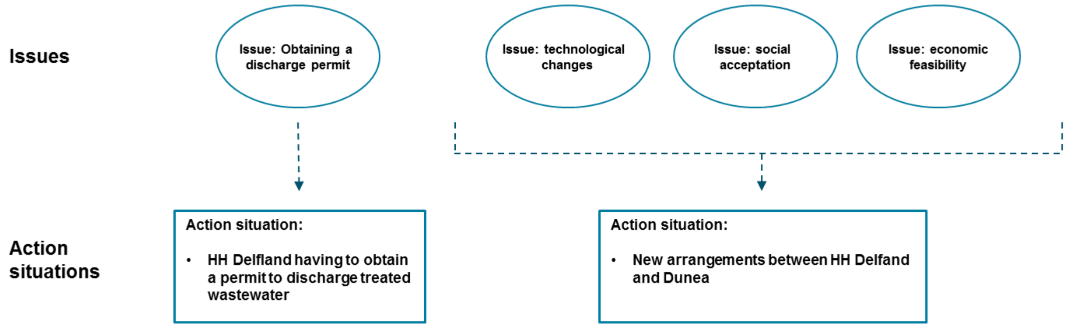


Figure 3 - Overview of issues and action situations

Step 2 – Specifying the critical action situations

Action situation 1 – Obtaining a permit to discharge treated wastewater
The 'Freshwater Factory' (FF) pilot project at the wastewater treatment plant 'De Groote Lucht' in Vlaardingen, which tests advanced treated wastewater for recreational reuse, is used to specify the first action situation. Figure 4 shows the nestedness of the action situation. Interactions and outcomes of an action situation influences the external variables of other action situations.

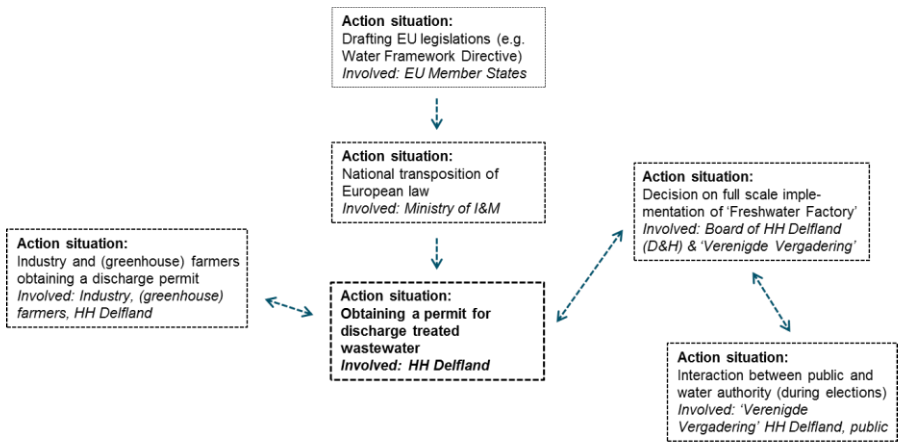


Figure 4 - Overview of nested action situations

HH Delfland is both the applicant and the provider of the discharge permit. Figure 5 shows that three different departments of HH Delfland are involved. The tension in this action situation is between preventing risks for public health (by preventing pollutants to be discharged into surface water) and imposing such strict standards that reuse projects become financially unviable. The three departments together must find a balance between both. With a lenient interpretation of the 'stand-still' principle, the FF will obtain a permit with the currently proposed treatment scheme of ozonation and biofiltration. When the 'stand-still' principle is strictly interpreted, additional advanced treatment is required (e.g. reverse osmosis), which increases costs and energy requirements. With insight into the positions of the board members of HH Delfland (see Figure 2), it is clear that the project will not find support in that case. The licensed FF treatment scheme is part of the *rules-in-use* of the action situation, in which the board of HH Delfland decides on full-scale implementation (see Figure 4).

HH Delfland should stimulate the interaction between the three departments. The department of Process, contract and wastewater chain management (PCW) observes a knowledge gap on what water quality standards must be met. Water system quality (WSQ) has the feeling they have been involved too late in the project. HH Delfland should keep pace in the process of finding a balance between water quality and costs and should dare to move forward. Finding the right balance between water quality and treatment costs can in the end only be achieved by executing the project.

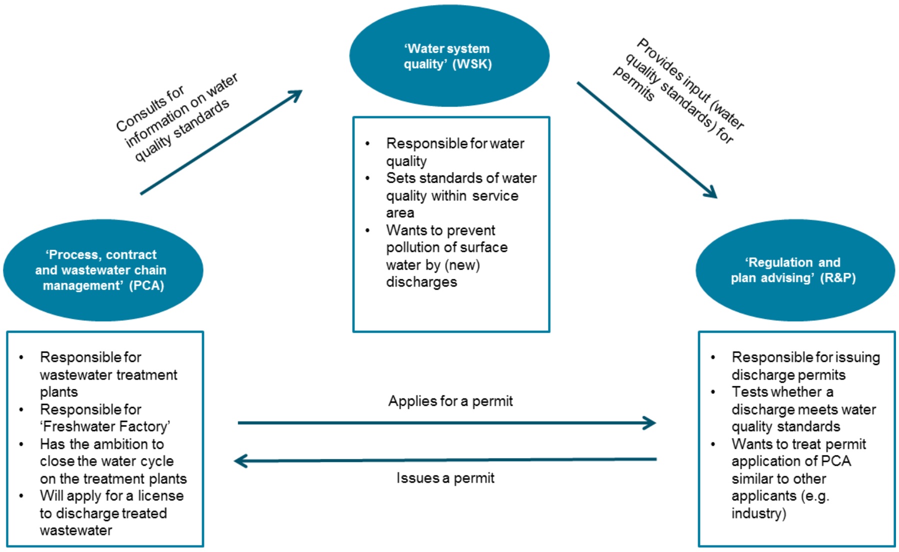


Figure 5 - Overview of actors, relations and responsibilities

Action situation 2 – New arrangements between HH Delfland and Dunea

The second critical action situation, new arrangements between HH Delfland and Dunea for a potable wastewater reuse project, addresses three critical issues in closing the water cycle: technology, social acceptability and financials. HH Delfland and Dunea hardly communicate with each other at the moment. A long road is ahead before both organizations can work together in a water reuse project. Especially Dunea doubts whether a **technology** is available that can meet all requirements, with acceptable costs. Installing a pilot project together, can help to exchange information and learn from each other's way of working. Obtaining **social acceptance** of potable wastewater reuse will be a 'huge' challenge. Moral, pragmatic and cognitive legitimacy must be acquired for a project to be accepted. HH Delfland can help to obtain the first, by actively communicating the sustainability and circularity of the project, for instance in a visitors center and guided tours through the plant. For the **financial** issue, the actors need to rise above their own interest. Extra investments in advanced treatment and transport have to be allocated to both organizations. The willingness of Dunea to pay for a reliable and high quality water source, is a great opportunity for this project. When all issues have been successfully addressed, the actors must find the optimal form of collaboration. This research proposed two options: Dunea to act as a customer of treated wastewater or both actors to merge into a water cycle company.

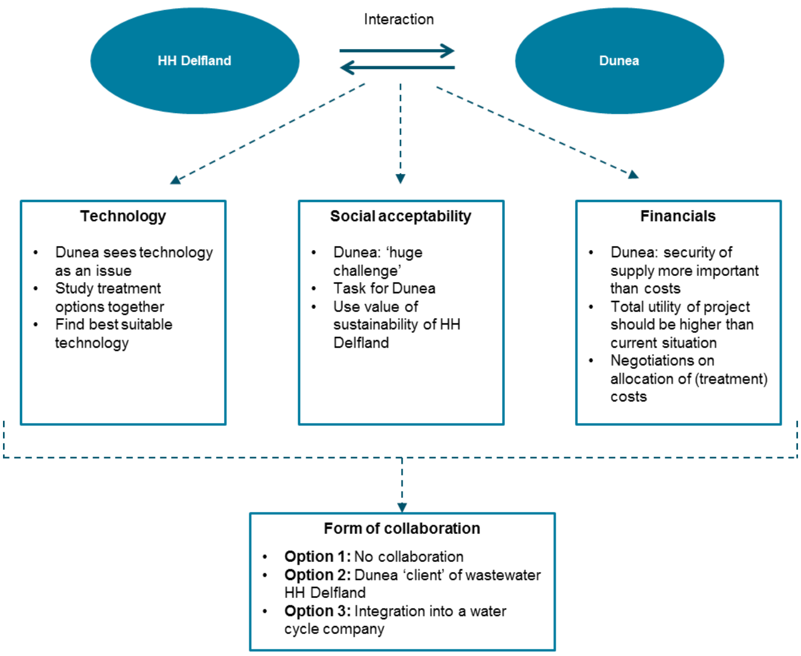


Figure 6 – Overview of critical issues in new arrangements between HH Delfland and Dunea

Part IV – Evaluation & recommendation

The institutional analysis has provided a comprehensive framework (TIP framework of Koppenjan and Groenewegen (2005)) to start the analysis of the regional water system. The proposed Williamson-Ostrom framework offers the opportunity to further specify and operationalize the institutional analysis. The four-layer model of Williamson (1998) provided clarity in attitudes and positions of actors, and structured critical issues and action situations in closing the water cycle. The IAD framework of Ostrom (2010) has provided further insight into the interaction on the critical issues in the two critical action situations. Table 1 provides an overview of the (dis)advantages of the frameworks used.

Table 1 - Evaluation of frameworks used

	Advantages	Disadvantages
TIP framework	• Useful starting point for analysis, by providing provide a good idea on what aspects of closed water system have to be analyzed (technology, institutions, process management)	• Scope is too wide for a SEPAM MSc. Thesis • 'Empty shell' in the sense that the institutional analysis has been conducted with the Williamson-Ostrom framework
Four-layer model	• Helped to structure empirical information on expected issues • Useful in analyzing drivers, attitudes and values of relevant actors • Provides input for the analysis of the critical action situations	• Critical issues and action situations not one-on-one related • Translating the critical issues into critical action situations remains the job of the institutional analyst
IAD framework	• Description of external variables provides insight into the action situation (e.g. water as different types of good) • The framework provides insight into nestedness of action situations and how outcomes of one action situation influences other action situations	• The framework can be conceptual and hard to apply in practice • The most important question in the action situation must be known beforehand, to meaningfully apply the IAD framework • Other frameworks (e.g. social legitimacy framework of Harris-Lovett (2015)) can be more helpful in analyzing the interaction than the description of the external variables

In future institutional analysis, the TIP framework can be omitted, since the proposed Williamson-Ostrom framework covers all three aspects of the TIP framework. The technological system can be described as the external variables (biophysical conditions) of the IAD framework. Process management can be included in the analysis of the interaction of the action situation. Further research can contribute to the field of institutional analysis by conducting more case studies with the proposed Williamson-Ostrom framework and execute the case study in a theoretical way instead of an empirical way.

Contents

Abbreviations

DGL	De Groote Lucht
DOC	Dissolved Organic Carbon
IAD	Institutional Development and Analysis
HH	Water Authority (Hoogheemraadschap)
OMP	Organic Micro-Pollutant
PCW	Process, contract and wastewater chain management (department of HH Delfland)
p.e.	People Equivalent
RIVM	National Institute for Public Health and the Environment
RO	Reverse Osmosis
R&P	Regulation and plan advising (department of HH Delfland)
STOWA	Dutch Foundation of Applied Water Research
Vewin	Association of Drinking Water Companies
UF	Utrafiltration
UV	Ultraviolet
UvW	Union of Water Authorities
UWM	Urban Water Management
WFD	Water Framework Directive
WSQ	Water System Quality (department of HH Delfland)
WWTP	Wastewater Treatment Plant
FF	Freshwater Factory (at WWTP DGL)

Part I – Introduction

1. Research problem

1.1 Introduction

This final report will provide an introduction of the research in Part I. The second part (conceptualization) contains the theoretical framework and methodology. Part III discusses the operationalization of the proposed framework by a case study at HH Delfland. Finally, Part IV provides the evaluation and recommendations.

1.2 Context

1.2.1 The issue of water scarcity

Climate change and urbanization put increasing stress on urban water management. Climate change will lead to intensified and prolonged periods of both drought and precipitation. Meanwhile urbanization is creating areas with extraordinary high population density, prone to a wide variety of water management challenges (Sun, 2008). Long and intense periods of drought in a specific area with a high population density can easily lead to water scarcity which causes severe economic and societal damage. Sufficient fresh water supply is essential for drinking and industrial water use and for agricultural purposes. The urban water cycle runs from fresh water supply to water treatment and use (by a variety of users and purposes) to wastewater treatment and discharge into the environment. Local water crises are increasingly viewed as the greatest social risks of coming years by business (World Economic Forum, 2012) and national security communities (Clapper, 2012). Sustainable urban water management (UWM) has the potential to alleviate these problems by guaranteeing a safe and reliable water system for all inhabitants of urban areas (Kiparsky, 2013). Closing the urban water cycle by means of (waste)water, energy and nutrient reuse can contribute significantly to a sustainable water system (Grundmann, 2017). The governance and management of a sustainable water system is difficult, given the complex institutional settings involving many parties with different perspectives (Schuwirth, 2012). Decisions need to take existing infrastructure and economic, financial, environmental and institutional conditions into account (Wilcox, 2016). This research proposal focuses on urban water management in developed, urban areas. These areas face a complex multi-level institutional landscape, for instance embracing both EU, national and sub-national level for countries in the EU (Söderberg, 2016). The system of concern is demarcated to the (waste)water cycle, which excludes the energy and resources cycles.

1.2.2 Water reuse as potential solution to water scarcity

A solution for sustainable Urban Water Management with high potential, is the reuse of wastewater. In the Netherlands, wastewater currently is a limitedly used source of fresh water. After advanced treatment, wastewater can be reused for a variety of purposes, which will close the water cycle of the urban water system. These projects are illustrative for the complexity that UWM deals with. Technological solutions might be available but the economic, financial, environmental and institutional aspects are just as important for a successful implementation of a water reuse system. Integrated frameworks can guide decision makers and all other relevant stakeholders in implementing improvements to the socio-technical water system.

The 'socio-technical water system' can be regarded as the small water cycle. This cycle is part of the global hydrological cycle (Correljé and Schuetze, 2012). The small water cycle includes extraction or abstraction, treatment, use and the return of water to the hydrological cycle (Correljé and Schuetze, 2012). Drinking water companies in the Netherlands are owned by local governments. They use surface water or groundwater as sources for drinking water production. Water authorities are responsible for water safety and water quality. The next section introduces water authority Delfland.

1.2.3 Introduction of water authority Delfland

Water authorities in the Netherlands are crucial actors in the regional water systems. They are the oldest governance bodies in the country, with history back to the 13th century (Havekes, 2008). The 22 water authorities are responsible for a good water quantity and quality in their service areas. Treatment of municipal and industrial wastewater is part of these responsibilities. Water authorities have to prevent both high and low (ground)water levels in their surface areas.

Water authority Delfland (HH Delfland) expressed its ambition to close the regional water cycle through wastewater reuse in the coalition agreement 2015-2019. HH Delfland has the ambition to be self-sufficient in fresh water needs. Their wastewater treatment plants will have to be used as fresh water source in order to achieve this goal (HH Delfland, 2015). The wastewater could be reused for water level management and potentially even for drinking water.

HH Delfland is covering the densely-populated area spreading from The Hague in the north to Schiedam in the south and from Berkel en Rodenrijs in the east to the North Sea coast in the west (see Figure 7). The service area is characterized by intensive greenhouse agriculture, especially around wastewater treatment plant (WWTP) Nieuwe Waterweg.

Figure 7 - Service area of HH Delfland

1.3 Problem statement

In the socio-technical water system many different social actors are active that hold conflicting interests, objectives and perceptions of a problem situation and act strategically to get the best out of that situation (Enserink et al., 2010). The presence of these actors makes closing the water cycle a complex problem. Problem definitions are unclear and often contested. Even knowledge can be contested in the field of urban water management. How severe is the threat of droughts caused by climate change in the Netherlands? What are acceptable concentrations of emerging pollutants in our water bodies?

Van de Graag and Hoppe (1989) categorize problems as tamed or untamed by the degree of technological uncertainty and the degree of social consensus. There is no consensus on the degree of technological uncertainty in closing the water cycle. On the one hand, recent scientific research has resulted in technological solutions being available for advanced wastewater treatment to enable reuse (Mulder et al., 2015). Technological uncertainty has been reduced by proven full scale applications in Singapore, Germany and Switzerland. In this view, technological complexity has been reduced to a trade-off for policy makers regarding effectiveness of treatment and costs. Achieving lower pollution levels will increase the costs of treatment. On the other hand, later in this report (Chapter 4) it is found that actors highly question the availability and applicability of advanced technologies that are required for a closed water system. The degree of social consensus is small: different actors have different views on the what the actual problem is that the socio-technical water system is facing. Even within organizations (e.g. board of HH Delfland) the problem situation is contested (see section 4.4.1). Social consensus should be created to turn the future of the water system into a tamed problem.

Problem formulation is a very important activity in policy making since a badly or wrongly formulated problem can leave the situation unsolved or it can even worsen a problem (Enserink et al., 2010). A lot of activities can be observed in urban water management, for instance the advanced wastewater treatment pilot of HH Delfland to enable water reuse. But what is the problem that HH Delfland is trying to solve with this activity? Hoogerwerf (1987) speaks of a policy problem when two conditions are apparent: a gap between an existing or expected situation and a criterion and a dilemma on what can be done about the gap.

The formulation of the problem statement in this chapter is substantiated by a system and actor analysis as proposed by Enserink et al. (2010). A system analysis is used to structure complex and untamed problems and to find the system boundaries. The actor analysis provides information on the interests, objects and power of relevant actors in the multi-actor setting that HH Delfland operates in. The means/ends and objectives tree constructed in the system analysis (see Appendix I – System and actor analysis), shows that the main goal of HH Delfland is to guarantee a good water quantity and quality in its service area (see Figure 7).

Water quantity and quality are closely related (see causal diagram in Appendix I). In times of drought, HH Delfland has to use freshwater sources outside its service area. Currently, the Brielse Meer is used for this purpose. The Brielse Meer is a reliable source with 'almost always' good water quality (van Woerden, HH Delfland). Such alternative freshwater sources can sustain the desired water quantity in a water system. The quality of the fresh water sources used in periods of drought are of vital importance to the water quality of the water system. In the delta area of south west Holland water quantity alone is not expected to be a problem. The Rhine and Meuse will always have a minimal discharge – and the sea is an endless source of water. However, it is the *quality* of the freshwater sources that determines the usability in times of drought. To guarantee sufficient water quantity (with a good quality) in periods of drought, HH Delfland can close the regional water cycle and make use of wastewater as freshwater source. This alleviates pressure on the currently used source of freshwater supply, the Brielse Meer. This gives the following problem formulation:

How can HH Delfland close the regional water cycle to guarantee good water quantity and quality?

HH Delfland has substantial means to achieve this goal (see means/ends diagram in Appendix I). However, the implementation of these measures is complex in the multi-actor setting of the water system. The actors behave in a network in which they are interdependent and in which both formal and informal relations play a role. The formal chart in Appendix I shows which actors are relevant in the water system and how they are formally related. The chart shows that HH Delfland is situated in the very middle of the playing field. Actors around HH Delfland have different interests and their power positions vary. Appendix I shows the problem formulations of relevant actors.

Water is of such vital importance for economic activity that many actors have a high interest in the water system. Closing the water cycle while maintaining a good water quality is a goal that could be shared by all governmental institutions (mentioned in Appendix I) and can benefit both farmers and industry. However, when efforts towards a closed water cycle will be contrary to economic interests (e.g. stricter water effluent standards for farmers and industry), implementation is guaranteed to meet resistance.

The question rises what the best strategy would be to work towards a closed water cycle. HH Delfland is operating in a strong and dynamic field of actors. In the complex policy making process of the multi-actor water system HH Delfland would benefit from scientific research to (re)designing socio-technical systems. Frameworks on sustainable Urban Water Management have the potential to provide guidance to actors in closing the regional water cycle. The next section discusses a knowledge gap found in a literature review on such frameworks.

1.4 Knowledge gap

1.4.1 Literature review on UWM frameworks

Over the past years, multiple frameworks for urban water management have been constructed. These frameworks ought to be helpful for all actors involved to shape processes in urban water management. In the scientific field of urban water management, a wide variety of frameworks are presented to work towards a sustainable water system. Frameworks are considered to provide guidelines for structure and direction towards a preferred state of the system concerned. Frameworks are less detailed and predefined than methodologies, but should still provide sufficient guidance. The question in this section is whether scientific literature provides comprehensive frameworks that offer guidance to actors in their attempts to close the regional water cycle.

For this purpose, eleven frameworks proposed by scientific research have been studied (see Table 2). The frameworks range from more general frameworks (e.g. Hellstroms 'Framework for sustainable UWM) to more focused on a specific aspect of UWM (e.g. Harris-Lovett 'Societal legitimacy framework'). Also, the larger scope frameworks of Koppenjan and Groenewegen (2005), Chappin et al. (2014) and Seijger et al. (2016) are included. This type of framework takes a larger view on socio-technical systems, but are applicable to urban water management.

Table 2 - Frameworks reviewed in literature study

Author	Year	Focus of research
Biswas	2004	Reassessment of integrated water resources management framework
Chappin	2014	Adaptation of infrastructure systems
Gleick	2003	Soft path solutions for water management
Harris-Lovett	2015	Societal legitimacy framework for water reuse system California
Hellström	2000	Framework for sustainable UWM
Hering	2013	A changing framework for UWM
Kiparsky	2013	Framework for innovation in water systems
Koppenjan	2005	Technology, Institutional and Process framework for socio-technical systems
Lafforgue	2015	Framework for closing water loop, case study Singapore & Windhoek
Seijger	2016	Analytical framework for strategic planning
Wilcox	2016	Three aspects of UWM framework

All authors mention a sense of urgency to address future water challenges. That climate change and urbanization will aggravate these challenges is put forward by all. Hering (2013) mentions the first industrialized countries that have already made major technological and institutional improvements in their water systems to face severe water shortages. All authors agree that current water management practices will not be adequate to face these challenges.

Many researchers address the importance of an integrated approach in sustainable UWM. Lafforgue and Lenouvel (2015) stress the importance of closing the urban water cycle "within a framework that is broader than a strictly technical approach." Wilcox (2016) uses an economic, social and environmental framework to assess issues to implementing water reuse networks in cities. The author argues that all three aspects are important for a successful implementation. Kiparsky (2013) emphasizes the importance of the institutional context (actors, networks and institutions) as key hindrance or potential drivers of innovation in urban water systems. Gleick (2003) is also agitating against mere technological solutions to confront water problems. He proposes 'soft-path' solutions to address the challenges of the 21st century. Koppenjan and Groenewegen (2005) argue that 'technological aspects [of socio-technical systems] matter, but so does behavior of actors'. Finally, Hellström (2000) emphasizes the importance of both technical factors and the social and cultural institutions in the evaluation of a well-functioning framework. In the proposed framework, only one of the five most important criteria for sustainable development addresses the technological aspect.

1.4.2 Knowledge gap: general *or* specific frameworks

Most frameworks proposed by researchers remain rather general and are not directly applicable for actors in the field of UWM. In the frameworks, guidelines of actions and collaborations are proposed for a sustainable practice. For instance, Hering (2013) argues that “collaborations between teams of engineers, city planners, and social scientists also will be needed to develop new forms of water governance and management.” Although this is a widely-acknowledged aspect of a well-functioning framework, the author remains unspecific about *how* these collaborations should take place. A detailed process or methodology does not have to be part of a framework – but some sort of handle for the addressed actors on *how* to collaborate would be highly useful. Same goes for the research of Lafforgue and Lenouvel (2015): emphasizing the importance of a broad framework but remaining general regarding social and economic factors. While the technological framework is rather detailed and full of examples, the evaluation of the social side of the framework does not provide more information than “that regulations [should] be compatible with needs” (Lafforgue and Lenouvel, 2015). Wilcox (2016) also emphasizes the importance of economic, social and environmental aspects in UWM in his research but does not provide any specific examples that are useful to actors in the field. The research remains general in providing a high-level overview of all three aspects in urban water management. These scientific articles leave a gap for academia to further analyze what aspects a framework should entail and what their implications are for urban water management.

The frameworks that *are* usable for actors in the water system only capture a specific aspect of sustainable UWM, for instance the social legitimacy framework of Harris-Lovett (2015). Her research would be highly valuable within a broader framework that also includes technological, economic and environmental aspects. The level of detail is very useful and could serve as an example for the currently missing frameworks for the above-mentioned aspects of UWM.

So, although a wide variety of frameworks is found during the literature review, the frameworks remain either general or focused on a specific aspect of UWM. The main research gap identified, is a comprehensive framework acknowledging the importance of different aspects (technological, social, economic, and environmental) while providing a sufficient level of detail to be applicable for actors in the field of UWM.

The Technological, Institutional and Process (TIP) framework of Koppenjan and Groenewegen (2005) has the potential to be both comprehensive and sufficiently guiding. For this reason, it is chosen as the ‘umbrella framework’ for this research. According to the authors, the conceptual framework can be applied to a wide variety of complex technological systems, such as energy networks, transport systems, industrial networks and water management services (Koppenjan and Groenewegen, 2005). In its attempt to be widely applicable, the conceptual framework cannot become specific on what steps should be made in institutional (re)design. Specifying and adapting the framework can provide the guidance needed for actors in regional water systems, while preserving the comprehensive character of the framework. Chapter 2 on the theoretical framework will present the frameworks and tools to specify the TIP framework. That chapter will introduce two well-known frameworks for institutional analysis: the four-layer model of Williamson (1998) and the Institutional Analysis and Development (IAD) framework of Ostrom (2011).

1.5 Research questions

To fill the research gap identified in the previous section, the main research question to be answered in the proposed research is:

How to specify and operationalize an institutional analysis framework to guide actors in closing the regional water cycle?

The sub questions that can be raised concern the three aspects of the TIP design, with a strong focus on the institutional design. The final three sub questions concern the evaluation of the frameworks used.

Technological design:

1. What is the current technological system of the regional water cycle?
2. What adjustments to the current technological system are required for a closed water cycle?
3. What are the main issues that will be encountered in technological redesign?

Institutional design:

4. What theoretical frameworks can be used to analyze the current institutional system?
5. Why is institutional (re)design complex?
6. What are the critical issues that will arise in redesigning the institutional system to facilitate closing of the water cycle?
7. What are the critical action situations in which the critical issues are addressed?
8. What recommendations on coordination of the action situations can be provided?

Process design:

9. What concepts of Process management could be used to resolve the critical issues in institutional redesign?

Evaluation of theoretical framework

10. What is the added value of using the various frameworks to operationalize the TIP framework?
11. Can frameworks be combined within the Institutional design framework (most importantly Koppenjan and Groenewegen (2005), Williamson (1998) and Ostrom (2010))? If yes, how?
12. How are the T-I-P pillars related in redesigning the system?

1.6 Scientific and societal relevance

Specifying and adapting the TIP framework to provide guidance in closing the regional water cycle, is highly relevant for the scientific field of complex socio-technical systems analysis and improvement. These large-scale systems are highly complex, due to a huge number of elements and their connections (Chappin, 2014). The proposed research addresses a currently existing research gap: the lack of a comprehensive and at the same time applicable framework. The specified TIP framework will address all relevant aspects required for UWM, while also having the potential to offer guidance for all stakeholders involved. Societal relevance can be found in preparing the Netherlands for future water challenges – in first instance the service area of HH Delfland specifically. Successful change to the socio-technical water system, guided by a clear framework, will contribute to making the Dutch water system resilient to future periods of water scarcity. This is exactly what HH Delfland is trying to achieve, with plans for wastewater reuse for its treatment plants. The specified and operationalized TIP framework will guide HH Delfland in closing the regional water cycle. In the near future, other water authorities can also use the proposed framework and benefit from the experience of HH Delfland.

1.7 Theoretical framework

This research will build upon existing scientific frameworks and theories to construct a framework to guide actors in closing the water cycle. The Technology, Institution & Process management (TIP) framework of Koppenjan & Groenewegen (2005) will be used as an 'umbrella framework' to analyze the socio-technical water system. This framework captures the most important aspects of system design by discussing the three pillars of Technology, Institutions and Process management.

1.7.1 Technological design

The basis of these systems, technology, is analyzed in the first pillar of this framework. According to Koppenjan & Groenewegen (2005), technology is an important aspect but it does not solely determine the functioning of the system. Functional diagrams will be used to obtain insight into the current technological system, and how this system will need to change to be a closed cycle.

1.7.2 Institutional design

The second pillar of the TIP framework, institutions, are regarded as systems of social rules that structure behavior and social interaction (Ostrom, 2010). Complex socio-technical systems require this institutional structure to coordinate the positions, relations and behavior of the actors involved (Koppenjan & Groenewegen, 2005). In designing a new system, these relations will change. The Institutional Analysis and Development (IAD) framework of Ostrom (2010) can provide specific starting points for institutional analysis. The IAD framework provides insight into external variables (biophysical conditions, attributes of community and rules-in-use) causing tension within the various action arenas. These tensions can be analyzed with the 'four-layer model' of Williamson (Williamson, 1998). The frameworks of Ostrom (2010) and Williamson (1998) are both widely used in institutional research.

1.7.3 Process design

The third pillar of the TIP framework is the Process management design to guide actors in implementing the required changes to the system. A process design can be used to resolve the issues that have surfaced in institutional design. It does so by conscious efforts to structure the process more adequately - it is *designing the design process* (Koppenjan & Groenewegen, 2005). In scientific literature, theories on Process management are numerous. Section 2.5 on the Process Design will discuss some of these theories.

1.8 Research design

Figure 8 shows a flow chart of the research design. The research proposal is the deliverable of the first preliminary research phase. The next step has been the conceptualization with the theoretical framework as output. The analysis has resulted in a specified and operationalized TIP framework. Synthesis of the research activities is presented in this final report.

The main deliverable is the specified and operationalized TIP framework to guide actors in closing the regional water cycle by wastewater reuse. The TIP framework will be tested in a case study on the service area of HH Delfland and will be applicable to other water systems in developed countries. HH Delfland has started its efforts to close the urban water cycle and it is expected that other areas in the Netherlands will have to follow. The lessons learned with the TIP framework for the case of HH Delfland will be highly useful for other water authorities in the Netherlands.

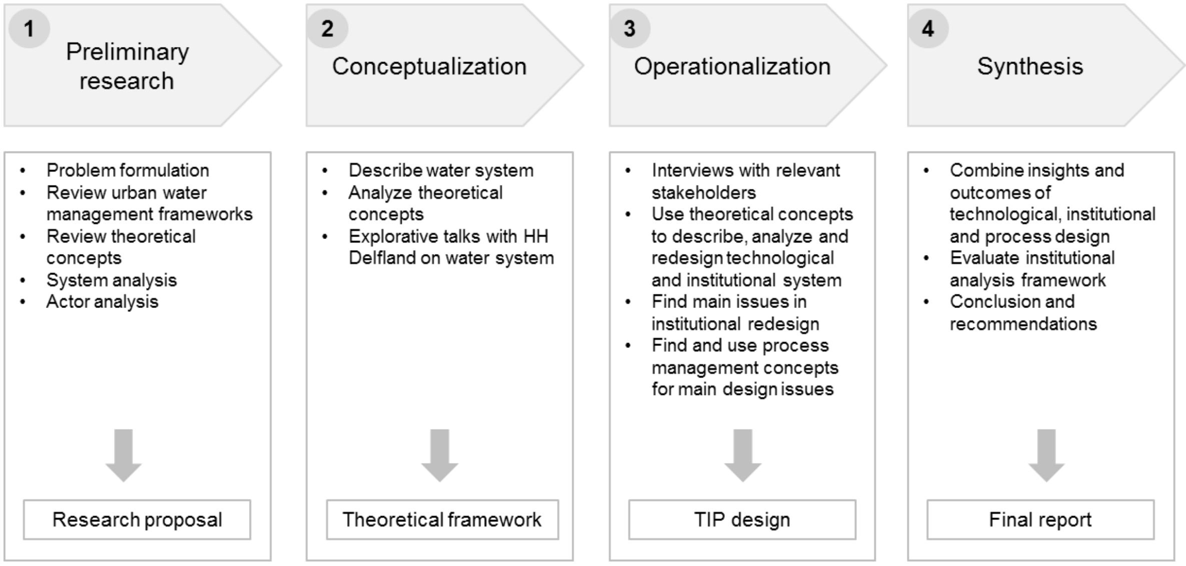


Figure 8 - Schematic overview of research design, with four phases

1.9 Research methods

The research will be conducted in collaboration with HH Delfland. The main research methods will be literature research and expert and stakeholder interviews. Literature review will contribute to a well embedded research in most recent scientific papers. To come to a technological and institutional redesign of the current system, the research must be well founded by views and expertise of all relevant experts and stakeholders. By means of interviews, the main issues in institutional (re)design can be found. The technological design will build on research conducted for the master Watermanagment (Citg) to advanced wastewater treatment. In this research advance wastewater treatment is modelled and data from the advanced treatment pilot, currently operated by HH Delfland at WWTP De Groote Lucht in Vlaardingen, is analyzed (Van Es, 2017b).

1.10 Reading guide

This section concludes the first part of this report (Introduction). Part II discusses the conceptualization of this research, with the chapters on the theoretical framework (Chapter 2) and methodology (Chapter 3). The third part (operationalization) presents the findings of the case study performed at HH Delfland. The chapter layout of the third part follows the two steps (Chapter 4 - Step 1: Identifying the critical action situations and Chapter 5 - Step 2: Specifying the critical action situations) as presented in the methodology. The final chapters present the evaluation of the operationalization (Chapter 6) and the recommendations for HH Delfland (Chapter 7).

Part II – Conceptualization

2 Theoretical framework

This chapter will discuss the theoretical framework of this research. Based on an earlier conducted literature review (Van Es, 2017a), the first chapter concluded that current frameworks for sustainable urban water management are either too general or solely focused on a very specific aspect of water management. The identified research gap is the lack of a framework that is both comprehensive and applicable to guide actors in closing the regional water cycle. The Technological, Institutional and Process design framework of Koppenjan and Groenewegen (2005) has the potential to be a comprehensive framework. Operationalization for the case of closing the regional water cycle is required to be sufficiently specific and thus applicable. This chapter will first provide a section (2.1) with relevant definitions of the concepts used in this research. Section 2.2 discusses the TIP framework in more detail and section 2.3-2.5 provide frameworks and theories with which the three pillars of the TIP framework can be further specified. As previously mentioned, this research will focus on the Institutional pillar of the framework.

2.1 Relevant definitions

Before diving into the theoretical framework of this research, the reader might need some general definitions of concepts used in this research. The distinction between the concepts of 'framework, theories and models' will be explained and the first definition of institutions is provided, as central concept in this research.

E. Ostrom (2011) acknowledges that understanding the difference between frameworks, theories and models can be a puzzle. All three are nested concepts that attempt to explain human behavior (Ostrom, 2011). Theoretical work on institutions has been undertaken at all three levels to provide different degrees of specificity. *Frameworks* are the most general forms of theoretical analysis. They are used to identify universal elements and general relationships which should be considered for institutional analysis. *Theories* specify which elements of a framework are particularly relevant. Theories diagnose phenomena, explain processes and predict outcomes. Multiple theories can be compatible with one framework. Economic theory, game theory, transaction cost theory and theory of common-pool resources are for instance all compatible with the Institutional Analysis and Development (IAD) framework (Ostrom, 2011). Finally, *models* make precise assumptions about a limited set of variables and parameters to derive precise predictions about the results. Examples of models are agent based models, game theory models, experimentation and simulation. This research will operationalize a framework by filling it in with other frameworks and theories.

Institutions are most simply explained as *rules that guide and coordinate the behavior of actors* (Koppenjan and Groenewegen, 2005). Institutions are a broad concept: language, money, law, covenants, systems of weights and measures, table manners can all be seen as institutions (Hodgson, 2006). Since institutions are a very central concept in this research, section 2.4.1 (institutional design) provides a more detailed discussion on how institutions are defined in this context.

2.2 TIP framework

Scientific literature widely acknowledges that designing a water system requires more than just a technological approach. As mentioned in Chapter 1, Lafforgue and Lenouvel (2015) stress the importance of closing the urban water cycle "within a framework that is broader than a strictly technical approach." Wilcox (2016) uses an economic, social and environmental framework to assess issues in implementing water reuse networks in cities. Also, Koppenjan and Groenewegen (2005) argue that designing and redesigning complex technological systems, of which water management systems are an example, is not just a technological challenge. In fact, three types of design are interrelated and should all be considered when (re)designing a complex technological system: technological design, institutional design and process design. The terms 'technological, institutional and process' should capture the most relevant aspects, which other authors for instance call economic or social aspects (Wilcox, 2016). Especially 'institutional design' is broad in coordinating 'the positions relations and behavior of the parties that own and operate the system' (Koppenjan and Groenewegen, 2005) and includes a variety of theories such as economic and transaction costs theories (Ostrom, 2011).

Koppenjan and Groenewegen (2005) propose the TIP framework to position the institutional design in relation to the technological and process design (see Figure 9). In complex technological systems, the technological component can be characterized as 'unruly'. Technology is important, but only determines the functioning of the system *together* with behavior of actors. Institutional factors can place demands upon the technological design (Koppenjan and Groenewegen, 2005). The process design in a complex technological system is important given the multi-actor setting in which decision making and behavior in these systems take place. Technological and institutional design can never be a 'blueprint' created by a single designer, but rather has to emerge from continuous interaction between stakeholders during decision and implementation processes (Koppenjan and Groenewegen, 2005). Process design attempts to improve this process by conscious efforts to structure it more adequately (Koppenjan and Groenewegen, 2005). It does so by determining who should be involved in the process, which rules are relevant and which subjects should be considered. A process design is *designing the design process* (Koppenjan and Groenewegen, 2005). It consists of all the agreements and provisions aimed at the organization and course of the design process (De Bruijn et al., 2002). The process design should precede the technological and institutional design. It shapes the processes in which eventually the technological and institutional design have to be created.

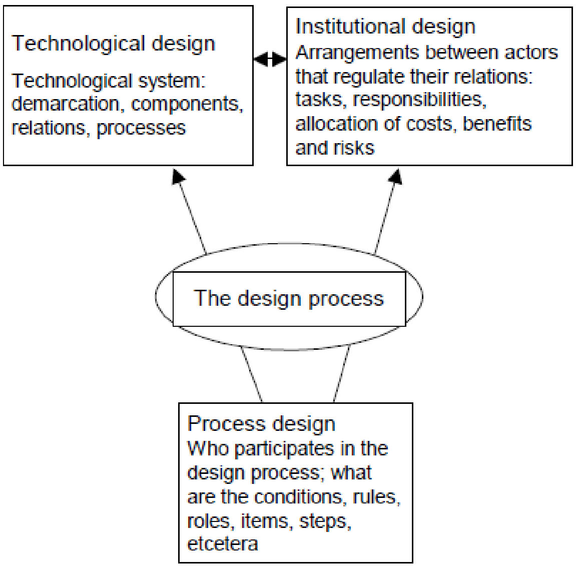


Figure 9 - Position of institutional design in relation to technological and process design (Koppenjan and Groenewegen, 2005)

Within the TIP framework, Koppenjan and Groenewegen (2005) place the institutional design at the center of the system design (in their analysis, not visually). The authors position the institutional design within the context of the technological design but do not further elaborate on the technological design.

The next sections will discuss the three pillars of the TIP framework in more detail, focusing on institutional design. The three pillars will be operationalized with other frameworks and theories in order to develop a framework that is both comprehensive and sufficiently specified for application to the redesign of the water cycle.

2.3 Technological design

Koppenjan and Groenewegen (2005) use the technological design to determine the context of the institutional design. As mentioned, in their eyes the 'technology is important but does not determine the functioning of the system' (Koppenjan and Groenewegen, 2005). This research will focus on the institutional design of closing the regional water cycle. This section, on the technological design, serves as context. In Figure 9, Koppenjan and Groenewegen distinguish four factors of interest in the technological design: demarcation, components, relations and processes. This section will discuss these aspects of the technological design and introduces the functional diagram to support the analysis.

Demarcation

Demarcation is the creation of boundaries around the system of concern. Research is benefited by a right demarcation to keep the scope of research doable. Demarcation can be geographically oriented by existing of drawn-up geographical boundaries. Another option is to demarcate the system to the area of influence of the respective problem owner. For each socio-technological system, boundaries can be drawn in a system-specific manner. For a water system, the boundaries could be the catchment area of a river. The Rhine, for instance has a catchment area spreading across country borders from Switzerland to the Netherlands.

Components

Technological systems can be composed of a wide variety of separate components. What are the main components of a system? Insight into these components form the basis of the analysis of relations between them and the processes they make up.

Relations

Technological components can individually work well but the interaction between them often causes problems in complex socio-technical systems. It is at the interfaces of technological components that complexity rises. Analysis to the relations between the system components can provide the needed insight into these complexities. How do the components relate to each other and what input and output do they exchange?

Processes

The functioning of a complex technological system can become more clear due to analysis of the processes that take place within the system. A useful tool for this analysis is the functional diagram, see Figure 10 (DAU, 2001). The functional analysis can be used to guide the (re)design phase of the technological system. One must have a clear insight into the processes that take place before technological redesign can start. Figure 10 shows that the function as conducted by a certain entity, has a central position in the functional diagram. The function converts input into output, while receiving support from the enablers, e.g. equipment, personnel and/or software (DAU, 2001). The control variables that can be used to steer and evaluate the process, are positioned at the top of the diagram.

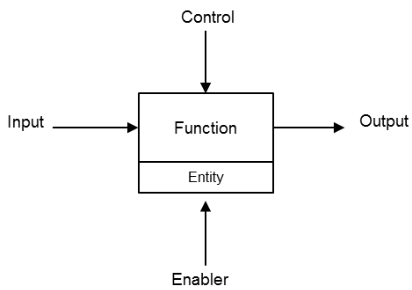


Figure 10 - Functional diagram (DAU, 2001)

The analyst can start from an aggregate process level and subsequently zoom in on relevant processes with multiple sub-functions. Figure 11 shows an example of a functional diagram on an aggregate, top level and zoomed in on the second function on the second level.

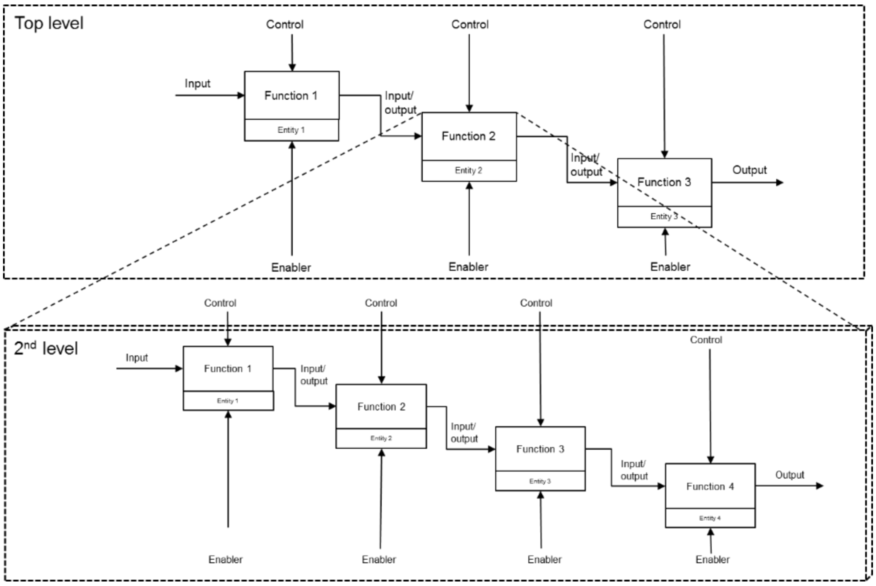


Figure 11 - Functional diagram with multiple layers

The functional diagram provides insight into the sequences and relationships of separate processes (DAU, 2001). Complexities may rise when, for instance, two subsequent processes are conducted by two different entities, or when one or multiple processes have to provide input for a subsequent process. When insight into the processes has been obtained, it can become clear which processes have to be added or changed in order to redesign the technological system as desired. It provides a clue on what technological issues require coordination in institutional analysis. When the analyst has obtained a clear view on the required technological (re)design, the focus of the analyst can shift towards the institutional design.

2.4 Institutional design

The importance of institutional design is widely acknowledged in scientific literature, as crucial aspect of system (re)design. Kiparsky (2013) for instance emphasizes the importance of the institutional context as key hindrance or potential drivers of innovation in urban water systems. But what exactly is meant with the term institutions? This section will first provide a definition and explanation of the term institutions before two frameworks for institutional analysis (by Williamson (1998) and Ostrom (2011)) are introduced.

2.4.1 What are institutions?

The term 'institutions' has become widespread in social sciences and in other disciplines. The term has a long history in social sciences, even dating back to Giambattista Vico in *Scienza Nuova* of 1725. However, there is still no unanimity in the definition of this concept (Hodgson, 2006). This can be regarded as a problem since adequate conception of what institutions are, is required before empirical or theoretical analysis can be conducted. For this reason, Hodgson devotes a complete paper to answer the question what institutions are (Hodgson, 2006).

Scientific literature offers a myriad of definitions and explanations of the term 'institutions'. This section discusses the definitions from some of the most relevant sources for this research.

- Hodgson (2006) defines institutions as 'systems of established and prevalent social rules that structure social interactions'. In general, institutions enable ordered thought, expectation and action by imposing form and consistency on human activities. This usefully creates stable expectations of the behavior of others.
- Koppenjan and Groenewegen (2005) use the words of Scharpf (1997) to describe institutions as a 'system of rules that structure the course of actions that a set of actors may choose'. However, the authors add that rules can only be regarded as institutions when they are accepted by those involved, used in practice and have a degree of durability (Koppenjan and Groenewegen, 2005).

- Ostrom et al. (1994) define institutions as 'the set of rules actually used by a set of individuals to organize repetitive activities that produce outcomes affecting those individuals and potentially affecting others'.
- Ostrom reformulates the concept of institutions in her paper with Polski (1999): 'an institution [is defined] as a widely-understood rule, norm, or strategy that creates incentives for behavior in repetitive situations'.
- Williamson (1998) brings in North (1991) to provide a definition of institutions as being 'the humanly devised constraints that structure political, economic, and social interactions. They consist of both informal constraints (sanctions, taboos, customs, traditions, and codes of conduct), and formal rules (constitutions, laws, property rights)'.
- Ghorbani (2010) presents the most practical definition: institutions influence, guide and limit the behavior of actors.

The above description of five definitions proves the point of Hodgson (2006) that there is no unanimity in the definition of 'institutions'. Definitions range from more complex (North, 1991), or even philosophical (in the paper of Hodgson, 2006), to a more practical definition as provided by Ghorbani (2010). For this research, the definitions of Ghorbani (2010) and North (1991) are combined: *institutions influence, guide and limit the behavior of actors and structure political, economic and social interaction*. The first part explains well how institutions are an 'invisible hand' in influencing the behavior of actors. The second part is relevant since *interaction* between stakeholders is crucial in the institutional analysis of this research. Also, in its attempt to be comprehensive, the proposed framework will include political, economic and social interaction. Institutions exert major influence on the interaction between actors.

With a better explained view on what institutions are, the next sections will discuss two frameworks for institutional analysis: the four-layer model of Williamson (1998) and the Institutional Analysis and Development (IAD) framework of Ostrom (2011). The Nobel Prize in Economics was jointly awarded to Elinor Ostrom and Oliver Williamson for their work on nonmarket economic arrangements (Toonen, 2010). E. Ostrom was the first woman to receive the Nobel Prize in Economics, for 'her analysis of economic governance, especially the commons' (Toonen, 2010).

2.4.2 Four-layer model by Williamson (1998)

This section discusses the four-layer model as developed by Williamson (1998). After a short history on the New Institutional Economics, the four-layer model is discussed.

Development of the four-layer model came from the research field of the New Institutional Economics (NIE) (Williamson, 1998). The NIE is an attempt to incorporate a theory of institutions into economics. It builds on neo-classical theories to permit addressing issues that were previously impossible to analyze (North, 1993). NIE comes in two parts: the institutional environment (rules of the game) and institutions of governance (play the game) (Williamson, 1998). The first has its origins in Coase's 1960 paper on 'The problem of social cost' and the second in Coase's 1937 paper on 'The nature of the firm' (Williamson, 2010). Both fields of research have hence long been studied, with an acceleration in attention in the 1970s and 1980s.

The four-layer model of Williamson (1998) conceptualizes social analysis by categorizing institutions in four different layers (see Figure 12). The higher and lower levels are connected: a higher level impose constraints on the level immediately below (solid arrow in Figure 12) and a lower level signals feedback to a higher level (dashed arrow) (Williamson, 1998). The latter interaction is largely neglected in the work of Williamson (1998). NIE mainly concentrates on level 2 (institutional environment) and level 3 (governance) (Williamson, 1998).

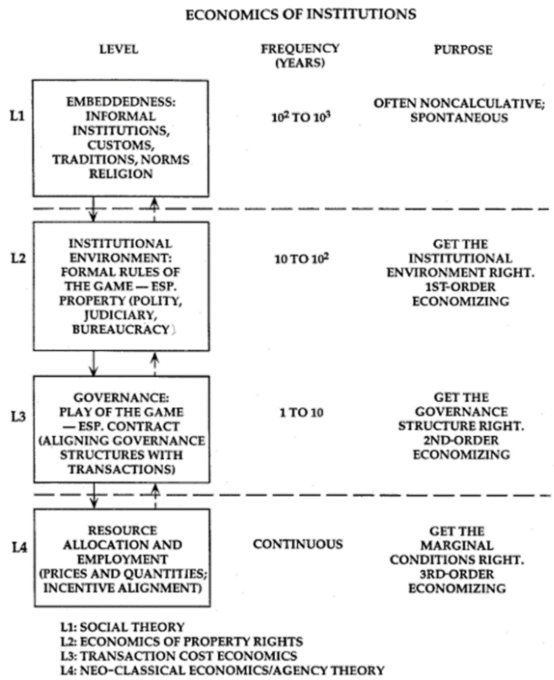


Figure 12 - Four-layer model of Williamson (1998)

The four layers

The **top level** of the model is the social embeddedness level, in which norms, customs, traditions, mores etc. are located. The *informal constraints* as defined by North (1991) (see section 2.4.1), are located at this level. At times of Williamson's research, religion played a central role at this level. Institutions at this level are regarded as given for most economists, since they change very slowly – over centuries or even millennia. These institutions mainly have a spontaneous origin and have a lasting grip on the way society behaves (Williamson, 1998).

The **second level** is the institutional environment in which institutions are the product of politics. These institutions provide the rules of the game within which economic activities are organized (Williamson, 1998). Polity, judiciary and bureaucracy of governments are located at this level. The formal rules as defined by North (1991) (see section 2.4.1) are located at this level. The definition and enforcement of property right laws have a central place within the institutional environment. In (re)designing socio-technical systems, this level is important to, as Williamson (1998) states it, 'get the institutional environment right'. Major changes in institutions at this layer mainly occur at rare windows of opportunity. Changes in rules of the game are mostly effected at 'defining moments' such as civil wars or economic breakdowns (Williamson, 1998). The financial crisis of 2007-2008, for instance, has been a window of opportunity for nations to change the rules of the game of the financial sector.

The institutions of governance are located at the **third level** of the model. Transaction costs economics operates at this level to deal with the 'play of the game'. With the constraints of the *rules* of the game from the level above, the *play* of the game can be determined at this level. Redesigning this level is 'getting the governance structures right' (Williamson, 1998). The time horizon of change in these institutions is of the order of one year to a decade.

The **lowest level** of institutions concerns marginal analysis; the examination of costs and benefits of individual actions. Neo-classical economics and agency theory play a role in this institutional layer (Williamson, 1998). Agents take price and output into account in their decision making. Altering this level of institutions is about 'getting the marginal conditions right'. Price and output continuously change in response to market conditions and this is hence the fastest changing institutional level.

2.4.3 Institutional Analysis and Development (IAD) framework by Ostrom (1994)

Another well-known framework for institutional analysis is the Institutional Analysis and Development (IAD) framework by Elinor Ostrom. Elinor Ostrom has devoted a lifelong career to the field of common pool resources (CPR) in an intellectual partnership with her husband and colleague Vincent Ostrom (Toonen, 2010). The systems she studied stress the need for institutional variety, layers within layers and a multi-scale society (Toonen, 2010). E. Ostrom embraced this variety and tried to understand institutional diversity ('no panaceas'). These efforts amounted to the formulation of the Institutional Analysis and Development (AID) framework (Ostrom, 2011). The current day regional water system is heavily institutionalized and thus not a classical CPR system (such as a shared pasture). However, the IAD framework can be very useful in institutional analysis of this socio-technological system. This section will discuss this IAD framework in detail.

The IAD framework

According to Ostrom (2011), a framework should identify the major types of structural variables that are present in all institutional arrangements, but whose values differ. These variables are the elements and relationships to be considered in institutional analysis. The IAD framework helps analysts to understand complex social situations and to break these situations down into manageable sets of practical activities (Polski and Ostrom, 1999). The framework can also help in organizing knowledge from empirical studies (Ostrom, 2011). Without the capacity to undertake systematic, comparative institutional assessments, recommendations on institutional redesign may be based on naïve ideas about which kinds of institutions are 'good' or 'bad' and not on an analysis of performance (Ostrom, 2011). A common framework and a family of theories is needed to address questions of redesign and transition.

Ostrom provides this common framework in the Institutional Analysis and Development (IAD) framework, as depicted in Figure 13. The core of the IAD framework is the 'action situation'; a conceptual unit that can be utilized to describe, analyze, predict and explain behavior within institutional arrangements (Ostrom, 2011). External variables (left in Figure 13) affect the action situation (Ostrom, 2010). Action situations are the social spaces where individuals interact and exchange goods. In the action situations, regularities in human behavior and results of the interaction can be explained. Ostrom (2011) mentions that these action situations potentially allow redesign. The IAD framework is foremost developed for institutional analysis and less for redesign, given by the careful notion of Ostrom (2011) that redesign is 'potentially' possible.

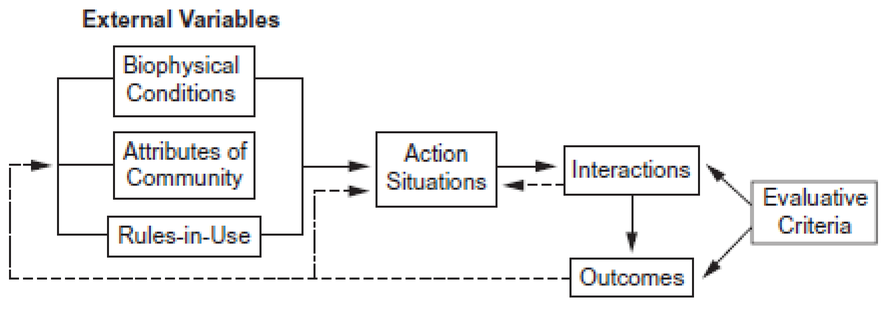


Figure 13 - IAD framework (Ostrom, 2011)

Figure 13 shows that Ostrom identifies three categories of external variables affecting an action situation at a particular time (Ostrom, 2010).

I. *Biophysical conditions* include the physical and material conditions influencing action situations (Polski and Ostrom, 1999). These conditions are the physical and human resources and capabilities related to providing and producing goods and services. Resources include capital, labor, technology, sources of finance, storage and distribution channels (Polski and Ostrom, 1999). The biophysical conditions also provide information on the type of goods of concern in the action situations.

Research of Ostrom is often focused on *common-pool resources* type of goods, but goods can also be private, public or toll goods (Ostom, 2010).

II. *Attributes of community* describe the cultural context of policy activity. It includes demographic features of the community, accepted norms about policy activities, common understanding of activities and homogeneity of values, beliefs and preferences about strategies and outcomes (Polski and Ostrom, 1999). It can also include history of prior interactions and the information position of participants in the action situation, for instance their knowledge on relation between strategies, actions and outcomes (Polski and Ostrom, 1999; Ostrom, 2010).

III. *Rules-in-use* are the set of rules that are needed to explain actions, interactions and outcomes (Polski and Ostrom, 1999). They specify shared understanding among the participants concerning who may or may not take which actions in the interaction. The rules-in-use might evolve over time due to interaction or conscious change by those actors involved (Ostrom, 2010). Seven types of rules are identified which influence the internal working parts of the action situation (see next section).

After describing the external variables and the action situation, the core question is what the resulting patterns of interactions and the outcomes of the action arenas are and how they are evaluated by the participants of the action situation. The interactions and outcomes provide feedback on both the external variables and the action situation.

The action situation

The section above has described the action situation as the arena in which participants interact. Polski and Ostrom (1999) describe the action arena as 'a conceptual space in which actors inform themselves, consider alternative courses of action, make decisions, take action, and experience the consequences of these actions'. The interactions are affected by external variables and result in outcomes, which in turn provide feedback on the external variables and the action situation. This section will discuss the action situation in more detail.

Ostrom uses seven sets of variables to describe the structure of an action situation, also called the internal working parts of an action situation (see Figure 14). Their relation and a description of the variables is given below, based on Ostrom (2011).

I. Characteristics of the *actors* involved (e.g. who withdraws resources?)
II. *Positions* that the participants hold (e.g. members of farming association)
III. Set of *actions* that actors can (potentially) take (e.g. groundwater extraction)
IV. The amount and nature of *information* available to actors at certain moments (e.g. information on condition of resources)
V. The *outcomes* of the interaction (e.g. will groundwater extraction result in salt intrusion?)
VI. The level of *control* participants have over their choices (e.g. do greenhouse farmers act on their own or do they confer with others?)
VII. *Costs and benefits* of actions and outcomes (e.g. what is the cost of overexploiting a resource?)

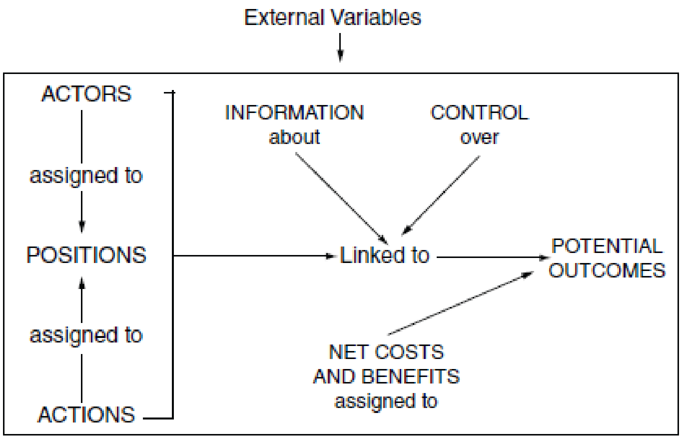


Figure 14 - Internal structure of the action situation (Ostrom, 2010)

All these working parts are influenced by rules as external variables (see Figure 15). These rules can be numerous and analysis of these rules certainly does not simplify the interaction between actors (Ostrom, 2010). However, analyzing these rules helps to conceptualize what (working) part of an action situation is influenced by which rule(s). The seven types of rules affecting the seven working parts of an action situation are (Ostrom, 2010):

I. Boundary rules specifying how actors were to be chosen
II. Position rules specifying the set of positions that actors hold
III. Choice rules specifying which actions actors can take in certain positions
IV. Information rules specifying channels of communication and what information should (not) be shared
V. Scope rules specifying the outcomes that could be affected
VI. Aggregation rules specifying how decisions of actors were to be mapped
VII. Payoff rules specifying how benefits and costs were to be distributed

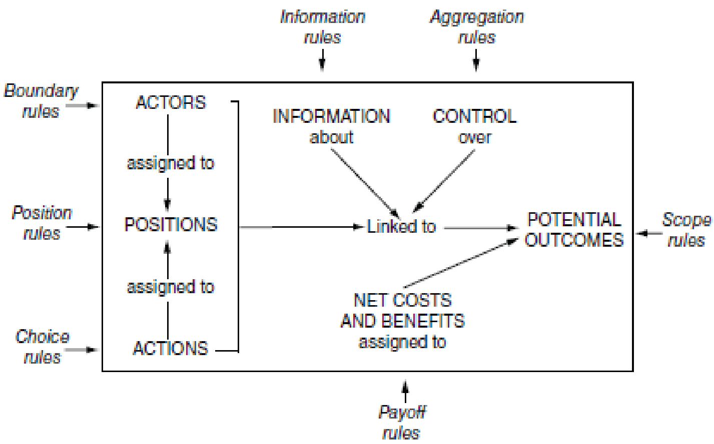


Figure 15 - Rules affecting the working parts of an action situation as external variables

Patterns of interaction and outcomes

When the behavior of actors in the action arena is thoroughly analyzed, the patterns of interaction follow logically from the analysis (Polski and Ostrom, 1999). Patterns of interaction show the structural characteristics of an action situation and how the participants behave in this structure. It differs whether participants have a limited or a broader range of strategies (Ostrom, 2011). In the first case, the policy analyst can make specific predictions on likely patterns of behavior. However, the latter case of a broad range of strategies is more likely in complex socio-technical systems. Actors can meet with other stakeholders in other situations, design new institutions along the way or learn from the outcomes of previous interaction (Polski and Ostrom, 1999). Policy analysts can only make weak inferences and 'more-or-less' likely predictions on patterns of interaction (Ostrom, 2011).

In turn, outcomes flow logically from well-founded observations about patterns of interaction (Polski and Ostrom, 1999). Outcomes can be seen as the performance of a policy system. Evaluative criteria have to be specified to analyze the outcomes in an objective way. For companies, the outcome is technically efficient when the marginal cost of a unit is equal to the price. In socio-technical systems the market price of a good or service is often hard to determine. For these situations, we can evaluate the allocative efficiency, which is achieved when the marginal social benefits equal or outweigh the marginal social costs (Polski and Ostrom, 1999). The sustainability criteria evaluate whether institutional arrangements are able to respond to changing environments. Natural disasters are examples of changing conditions under which institutional arrangements are unlikely to prosper (Ostrom, 2011). Precisely under conditions of great pressure, the institutional arrangements should remain firm.

Design principles

In analyzing an institutional system with the IAD framework, Ostrom aims to formulate 'design principles' that appear to be core factors of the well-functioning of a (common-pool resource) system. Systems characterized by most of these design principles are generally successful systems. To find the rules associated with successful systems, Ostrom and her team have analyzed numerous cases of successful and failed systems. It proved to be impossible to find *specific* rules associated with success (Ostrom, 2010). For this reason, Ostrom moved to a more generalized level to understand the broader institutional regularities among successful systems (Ostrom, 2010). These regularities are captured by the term 'design principles'. Several design principles have been identified, for instance that rules should be congruent with local social and environmental conditions (Ostrom, 2010).

2.4.4 Why are institutions hard to change?

The four-layer model of Williamson and the IAD framework of Ostrom, both described above, could evoke an image of institutional redesign as a task that can straightforwardly be performed. When the frameworks are applied to institutional environments, the policy area becomes clear and structured. With this basis, conscious redesign can be performed. However, scholars specialized in institutions and institutional (re)design address the difficulty of institutional (re)design. This starts with the notion that even institutional *analysis* (let alone *redesign*) is difficult, since institutions are highly abstract and frequently invisible (Polski and Ostrom, 1999). Changing institutions is even harder and attempts to do so are not always successful. What makes an institution, is the embeddedness of these 'nested rules' (Goodin, 1996) and the durability of institutions (Koppenjan and Groenewegen, 2005). In this, institutions provide stability and predictability, but at the same time makes them hard to change (Koppenjan and Groenewegen, 2005). Pierson (2000) argues that the *effects* of institutions have been studied intensively, but that the *origins* of institutions and *sources* of institutional change remain opaque. This section discusses why institutions are hard to change. The first part discusses why institutional redesign is often attempted and the second part discusses four scholars who have studied the difficulty of institutional (re)design.

Why institutional redesign?

Although institutions can be regarded as relatively robust and hard to influence, attempts to redesign them are numerous. Koppenjan and Groenewegen (2005) present several reasons why institutional (re)design may be desired, for instance when new systems need new institutional arrangements, when systems have to be integrated, or when systems do not have the right scale. Another reason why institutions are often subject to redesign is the fact that actors want to change the rules of the game to their own advantage (Koppenjan and Groenewegen, 2005). Institutions can provide distributional advantage to powerful actors (Blom-Hansen, 1997). Different actors with different positions and interests want to influence institutional (re)design to their own advantage. Institutional redesign is hence likely to result in conflict and negotiation between multiple parties. If the rules of the game have eventually been determined, they are often consciously designed to prevent adaptation. For example, it is said that the US Constitution is not designed to facilitate changes, but to prevent them (Koppenjan and Groenewegen, 2005).

Why is institutional redesign hard?

This section answers the fifth research question (see section 1.5): *Why is institutional (re)design complex?* Explanations why institutional redesign is complex, are numerous. This section discusses eight explanations as presented by Hodgson (2006), Blom-Hansen (1997), Koppenjan and Groenewegen (2005) and Pierson (2000) (see Table 3) before the findings are summarized in the final part.

Hodgson (2006) sees habits as the bases of customs, which in turn are the constitutive material of institutions. These habits provide customs with enhanced durability, power and normative authority. Redesigning institutions should be based on changing habits. However, citing William James (1892), Hodgson (2006) recalls that habits are the most precious conservative agent of society. This fact will highly complicate institutional redesign.

Table 3 - Overview of explanations on difficulty of institutional redesign

Author	Why institutions are hard to change
Hodgson (2006)	• Habits are basis of institutions and are the most conservative agents of society
Blom-Hansen (1997)	• Transaction costs of institutional redesign might be higher than expected benefits • Long term compliance makes institutions persistent
Koppenjan and Groenewegen (2005)	• Institutions are created in informal and incremental processes • Not all institutional levels are equally accessible to all relevant actors • Wide variety of actors involved in institutional design
Pierson (2000)	• Institutional stickiness: institutions are designed to be change resistant • Path dependency: social adaptation to existing agreements

Blom-Hansen (1997) provides two potential explanations why institutions are hard to change. Firstly, transaction costs may be involved in changing institutions, for instance in negotiations and communication. No change in the institutional environment will occur when the transaction costs are higher than the expected benefits of institutional change. Transaction costs hence serve as a 'cushion' to provide stability to an institution (Blom-Hansen, 1997). The second explanation why institutions are hard to change, is because they can be rather persistent. The persistence comes from long term benefits of complying with institutions in a network of continuous interaction with the same actors. Even if short term incentives to desert an institution exist, the long term rational strategy might still be compliance to the institution due to retaliatory responses from other actors. The time horizon of actors, whether long term or short term focused, is an important factor in this.

Interestingly, Pierson (2000) also addressed the time horizon of actors involved in the institutional environment. He focuses more on the actor as policy maker instead of an agent behaving in the institutional environment (as is the focus of Blom-Hansen (2006)). Pierson (2000) argues that actors often have short time horizons, which limits the rationality of institutional design. Policy makers lack incentives to think about the long term or believe they cannot reliably influence it. From this perspective, long term institutional consequences may be merely by-products of actions based on short term political reasons (Pierson, 2000).

Koppenjan and Groenewegen (2005) provide three possible explanations why it is hard to change institutions. Firstly, institutions have been created along informal and incremental processes during interaction over a longer period of time. The resulting institutions are unique and embedded in the larger institutional environment. Attempts to change institutions could revolt and destruct existing institutions, which can have uncertain consequences. Conscious redesign can destroy institutional capital (Koppenjan and Groenewegen, 2005).

Secondly, institutional levels are not equally accessible to all relevant actors in institutional redesign. To function well, the institutional environment of all four layers of Williamson's framework must be aligned (see section 2.4.2). On every institutional level, other 'action situations' (see section 2.4.3) determine the institutional environment. For a successful institutional redesign, the outcomes of different action situations must be aligned. Often, the required involvement of different action situations is consciously designed to prevent institutions from being easily changed (Koppenjan and Groenewegen, 2005).

The third explanation of Koppenjan and Groenewegen (2005) why institutions are hard to change, is the wide variety of actors involved in institutional redesign. Actors push and pull and negotiate about the institutional design. Thus, institutions are often accidentally established, unintended compromises (Koppenjan and Groenewegen, 2005). Pierson (2000) also addresses the issue of unanticipated consequences in institutional design. In our present-day complex socio-technical systems, with a wide variety of actors and a myriad of interactions, unanticipated consequences are likely to be significant in institutional redesign (Pierson, 2000).

Finally, Pierson (2000) claims that institutions do not follow in a straightforward way from the intentions of far-sighted, goal-oriented actors. Some notions of Pierson (2000) have already been discussed above. He summarizes his findings by presenting two fundamental obstacles to institutional redesign: *institutional stickiness* and *path dependence*. The first obstacles originate in the fact that institutions are actually *designed* to be change resistant. Actors involved in the establishment of institutions want to bind their successors by making preexisting arrangements hard to reverse (Pierson, 2000). Their successors will often face considerable obstacles to redesign the institutional environment. Secondly, not only the institutional arrangements are *difficult* to change, but the adaptations of actors to previous arrangements makes redesign *unattractive.* Social adaptation drastically increases the cost of changing an existing agreement. The 'lock in' of existing institutions result in path dependency in the institutional environment. Implementing new institutions often entails high costs and could prevent institutional redesign at all, as also argued by Blom-Hansen (1997) (described above).

This section discussed eight potential explanations why institutional redesign is difficult. The methodology as presented in the next chapter tries to include the notions of complexity in institutional redesign. All authors discussed in this section, present relevant explanations for the closing the urban water cycle. People have developed their own habits in dealing with water for centuries (Hodgson, 2006). Redesigning the urban water cycle will definitely come with transaction costs (Blom-Hansen, 1997). Since uncertain future water scarcity consequences are hard to monetize, it will be interesting to see what level of investment (in transaction costs) actors accept to prevent these future issues. Institutions in urban water management have indeed been established through informal and incremental processes in which a wide variety of actors have been involved (Koppenjan and Groenewegen, 2005). The methodology in the next chapter will further address the notion that not all institutional levels are accessible to all relevant actors. Finally, institutions are sticky. For instance, the legitimacy and function of the water boards well established in national legislation. Being the oldest institutional body in the Netherlands, the functioning of the water boards will also be highly susceptible to path dependency.

2.5 Process design

The third pillar of the TIP framework is the Process Management design to guide actors in implementing the required changes to the system. A process design can be used to resolve issues that have arisen in institutional design. It does so by conscious efforts to structure the process more adequately - it is *designing the design process* (Koppenjan and Groenewegen, 2005). This research will restrict the process design to providing some directions of analysis. Literature on Process Management shortly presented below, gives a first idea of the scientific field of Process Management (see Table 4).

Table 4 - Overview of relevant literature on Process Management

Author	Year	Focus of research
Susskind	1987	Mutual Gains Approach
Kirk	2008	Mutual Gains Approach
Bekkering	2007	Four element structure
De Bruijn	2002; 2008	Rules of Process Management
Harris-Lovett	2015	Societal legitimacy framework

In scientific literature, theories on Process Management are numerous. The Mutual Gains Approach (MGA) (Susskind, 1987; Kirk, 2008), the four-element structure of Bekkering et al. (2007) and/or the rules of Process Management of De Bruijn et al. (2002; 2008) could be used to *design the design process.* The theoretical framework of the Process aspect will depend on the main issues found in institutional (re)design. When for instance one of the main issues proves to be public acceptance of wastewater reuse, the societal legitimacy framework (Harris-Lovett, 2015) can be used.

An interesting link between the Institutional design and the Process design could be the action arenas of Ostrom's IAD framework. The conceptual space in which actors interact might well use an effort to structure the interaction (i.e. Process Management). However, as discussed before, this research will only mention what Process Management literature could be used and what the contribution of Process Management could be in resolving the issues found in the Institutional design.

This chapter has discussed the theoretical framework of this research. After a description of the TIP framework of Koppenjan and Groenewegen (2005) the chapter has zoomed in on all three pillars of the framework, focusing on the institutional design. With this theoretical basis, the next section on the methodology will discuss how these theories will be used in this research.

3 Methodology

This research will further specify the TIP framework with other frameworks and theories to provide guidance for actors in closing the regional water cycles. This framework should both be both comprehensive *and* sufficiently specific to guide actors. The previous chapter has provided the theoretical basis of this research, focusing on the TIP design of Koppenjan and Groenewegen (2005), the four-layer model of Williamson (1998) and the IAD framework of Ostrom (2011) for the institutional design. This chapter discusses the methodology that will be used to answer the main research questions.

Figure 16 shows a high-level visualization of the methodology based on the TIP framework. The pillar of the process design is omitted to pragmatically limit the scope of this research. The technological and institutional design pillars are operationalized for the case of a closed water system. By discussing both the technological and institutional design, the framework remains comprehensive, while still providing sufficient guidance to actors in the system. Section 3.1 and 3.2 will provide a conceptual discussion of the methodology of the technological and institutional design pillars. Section 3.3 provides the roadmap for the Operationalization in Part III of this research. The methodology of the technological and institutional design is the basis of this roadmap.

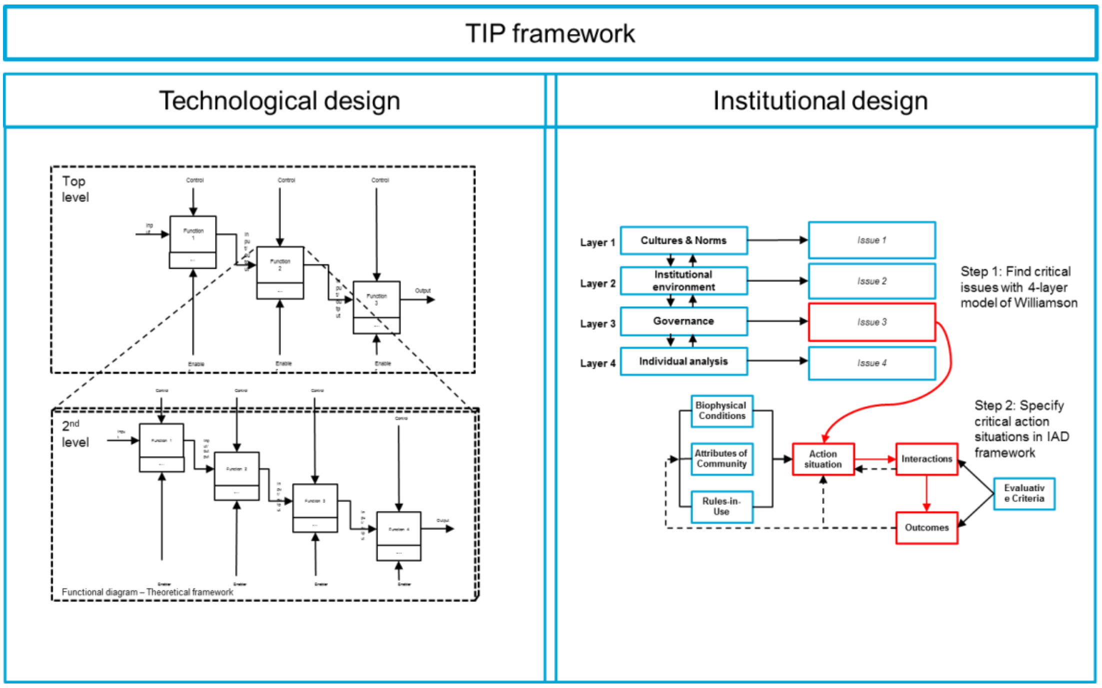


Figure 16 - Overview of operationalization of TIP framework

3.1 Technological design

Changing a conventional urban water system to a closed water cycle will require adjustments to the technological system. To provide insight into the current technological system, a functional diagram of the current situation is constructed. Subsequently, to find what components need to be changed to achieve a closed water cycle, a functional diagram of the desired future system is constructed (see Figure 17). Complexity will rise at the complex interfaces of the system, where ownership of the system is transferred from one actor to the other or where different system components need to connect. The functional diagram will provide insight into these complexities by offering a clear, visualized conceptualization of the technological system. This analysis will also contribute to finding the main issues that will rise in the institutional design (see the next section). The research conducted for the master Watermanagement (Van Es, 2017b) will be used as a basis for the technological design analysis.

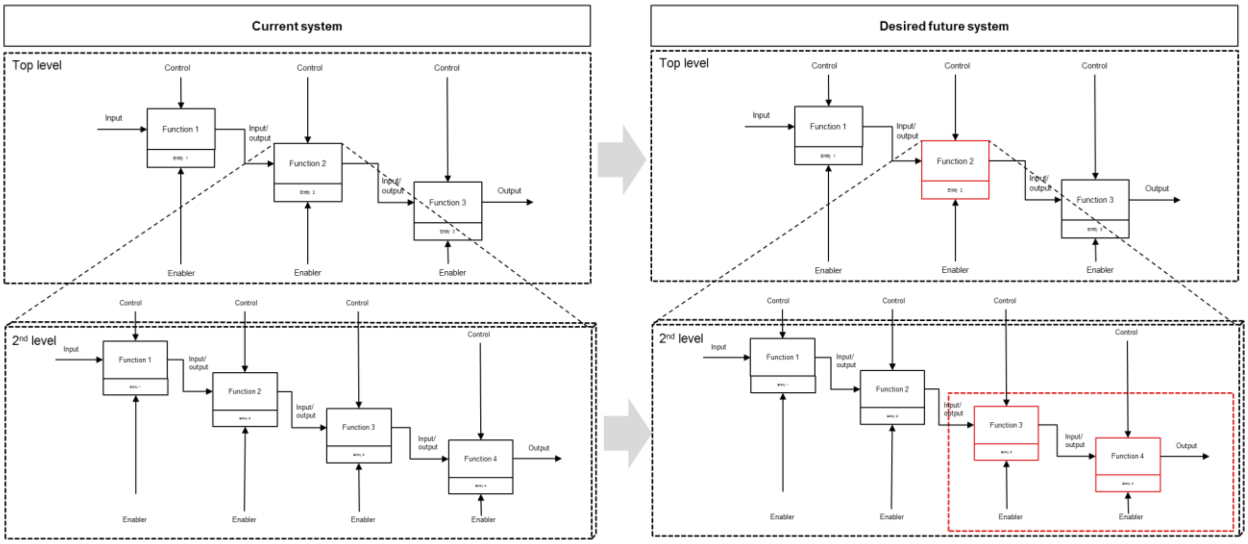


Figure 17 – Schematization of methodology of technological design

3.2 Institutional design

Chapter 2 on the theoretical framework has discussed two frameworks for institutional analysis, the four-layer model of Williamson (1998) and the Institutional Analysis and Development framework of Ostrom (2011). This section discusses how these two frameworks can be used to operationalize the institutional design pillar.

To date, the two frameworks have not been combined for institutional analysis and/or institutional (re)design. Ghorbani (2010) used both frameworks independently to conceptualize agent-based models of socio-technical systems. She concludes that both frameworks can be used to give structure to agent-based models. However, she does not elaborate on whether both frameworks can be combined in any way to improve institutional analysis of socio-technical systems. To the best of my knowledge, no other scholar has attempted to do so either. This research aims to operationalize the institutional design framework by combining the frameworks of Williamson (1998) and Ostrom (2010).

The IAD framework of Ostrom (2011) allows more detailed institutional analysis than the four-layer model of Williamson (1998), specifying the input and interaction of the action arenas. However, Ostrom acknowledges it can be hard to identify relevant action arenas in large, complex policy systems (Polski and Ostrom, 1999). Ostrom claims that 'the most relevant arenas readily emerge from a rigorous application of the IAD framework'. I argue that this solution of just starting to apply the IAD framework, will not suffice. Rather, the four-layer model of Williamson (1998) can be used to find the critical action arenas in institutional redesign. The four-layer model is a high-level conceptualization which gives liberty in analysis (Ghorbani, 2010). The distinction of four different levels of institutions provides structure in analysis to find the critical issues. Figure 18 shows the first step of the methodology is finding the critical issues using Williamson's (1998) framework. As discussed in the previous section, drafting a functional diagram of the desired technological system will also contribute to finding the critical issues in institutional redesign.

The critical issues found with Williamson's (1998) framework can be addressed in one or multiple action situations. For example, the social acceptability of wastewater could prove to be an issue in institutional design. This issue can be addressed in the action situation of the interaction of the drinking water company with its customers. The critical action situations are those arenas that will be critical to the success of redesigning the urban water cycle towards a closed system. These arenas are complex due to for instance involvement of multiple actors with different views and goals or interfaces between technological system components. These critical action situations require coordination by the system designer to guide interaction towards desired outcomes. To use the same example, the interaction between the drinking water company and the customers requires coordination to attain social acceptation of wastewater reuse. It can also be possible that an action situation deals with multiple issues in institutional redesign. For instance, the interaction between the water authority and a municipality address issues both with technology and with costs. Thus, issues and action arena's do not automatically fit one-on-one. With information on the critical issues, the critical action situations to be analyzed will be chosen in the final part of step 1 (in section 4.5 - Conclusion on critical action situations).

The IAD framework of Ostrom (2011) is well suited to specify key features of the action situations that have proven to be critical (step 2 in Figure 18). With physical conditions, community attributes, rules-in-use and the action arena specified for each critical situation, the patterns of interaction and outcomes can be predicted. It is expected that the critical action situations will involve multiple actors, who will have a broad range of strategies. This will make adequate predictions on the pattern of interactions and subsequent outcomes difficult. To address this issue, the institutional analysist can draft different scenarios of interaction and corresponding outcomes. Different actions within the range of strategies available to actors, will result in different patterns of interaction.

An action situation can be nested in other action situations, potentially located at different institutional layers of the four-layer model of Williamson (1998). The *outcomes* of one action situation can affect the *interaction* within another action situation. Especially when affected action situations are located at different institutional levels, the actors involved in one action situation might not have any influence in another action situation. However, for a successful redesign of a specific aspect, the redesigned institutions must be aligned on all four layers of Williamson's framework. The alignment of institutions on different layers will have to take place in different action situations, in which other actors are involved. Institutional analysis could provide insight into the nestedness of action situations.

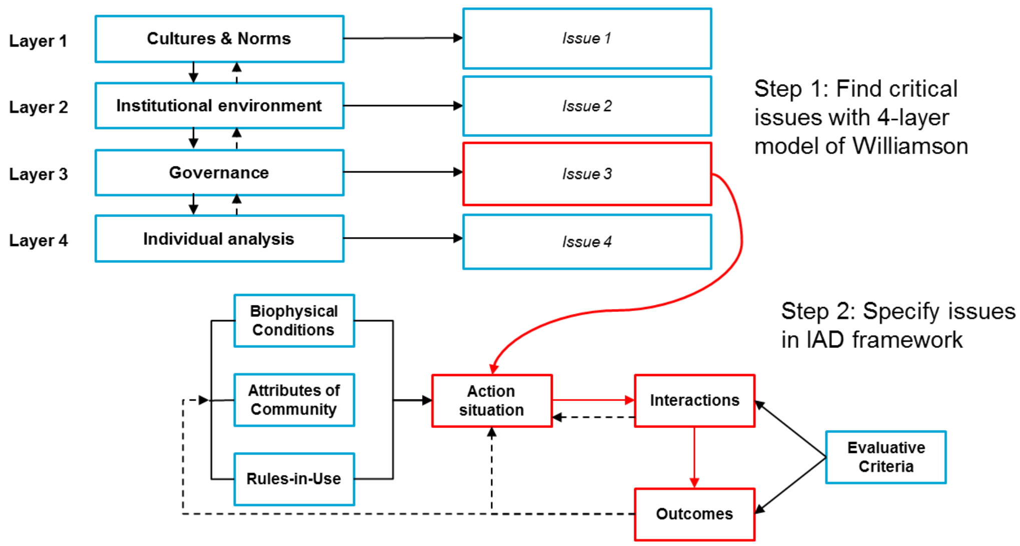


Figure 18 - Schematization of methodology of institutional design

To summarize, the four-layer model of Williamson (1998) will be used in the first step to identify the critical action situations in institutional redesign. The Institutional Analysis and Development framework of Ostrom (2011) will be used in the second step to specify the critical action situations and to predict interactions and outcomes based on the external variables.

3.3 Research method & roadmap

As a research method for the operationalization of the TIP design, a case study will be performed of redesigning the water system in the service area of HH Delfland. The case is analyzed from an empirical perspective, rather than a theoretical one. Theories, such as transaction costs economics, are not leading in the analysis but the perspectives of actors are leading. Information is gathered through interviews with relevant stakeholders, both within and outside HH Delfland. Within HH Delfland, multiple policy advisors will be interviewed, together with the board of HH Delfland (Dijkgraaf & Hoogheemraden). Other relevant actors in the water system include water companies Dunea and Waternet, Province South-Holland, municipalities and universities.

The research will follow the two steps identified in the institutional methodology in the next two chapters (4-5).

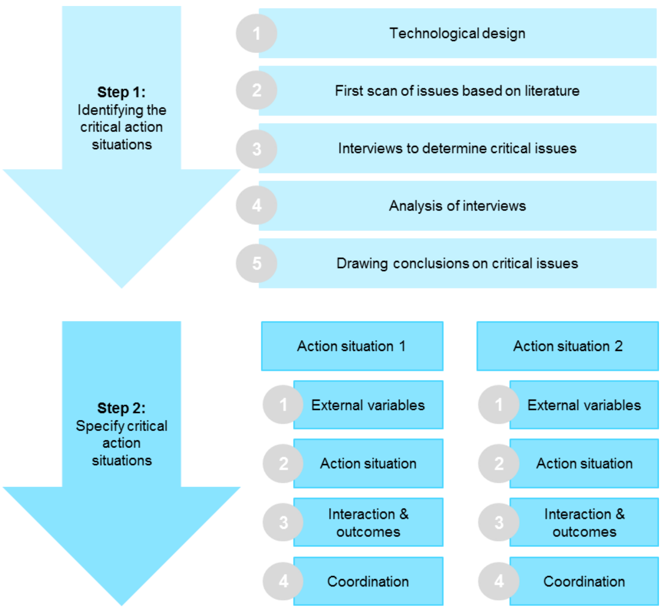
1. **Step 1: Identifying the critical action situations**

4.1 Technological design
4.2 First scan of institutions and issues with model of Williamson
4.3 Interviews to determined critical issues
4.4 Analysis of interviews
4.5 Conclusion on critical issues

2. **Step 2: Specify critical action situations**

5.1 Action situation I
5.1.1 External variables
5.1.2 Action situation
5.1.3 Interaction and outcomes
5.1.4 Coordination
5.2 Similar for action situation II

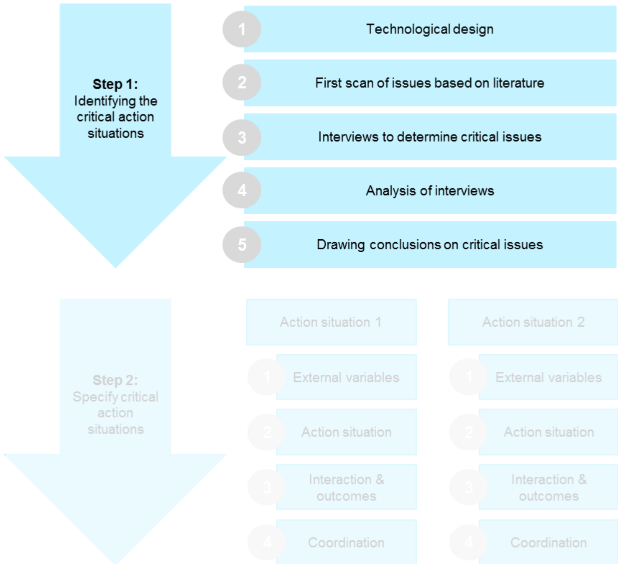
After having followed these two steps, the research meets the goal of offering scientific and societal relevance by both providing an evaluation on the combination of frameworks of Koppenjan and Groenewegen, Williamson and Ostrom and a recommendation for HH Delfland. The first will reflect on the scientific novelty of combining the two frameworks in institutional analysis. The latter will be more of practical use by advising HH Delfland on coordination of critical action situations for a successful closure of the water cycle.



Part III - Operationalization

4 Step 1: Identifying the critical action situations

This chapter will discuss the first step of the methodology: identifying the critical action situations in the case of closing the urban water cycle in the service area of HH Delfland. To find technological issues, the current and desired technological system will be analyzed in section 4.1. Based on literature research, a first scan of issues is performed in section 4.2. Subsequently, the issues mentioned by relevant stakeholders in the interviews are presented in section 4.3. Section 4.4 provides an analysis of the interviews. Finally, a conclusion on the most critical issues is drawn in section 4.5.



4.1 Technological design

As previously mentioned, the urban water system evaluated in this research, can be regarded as the 'small water cycle', which is part of the global hydrological cycle (Correljé and Schuetze, 2012). This small water cycle includes extraction or abstraction, treatment, use and the return of water to the hydrological cycle (Correljé and Schuetze, 2012). Section 4.1.1 answers the first research question *(What is the current technological system of the regional water cycle?)* by discussing the current technological design. Section 4.1.2 answers the second research question *(What adjustments to the current technological system are required for a closed water cycle?)* by presenting a technological design of the desired closed cycle. Section 4.1.3 evaluates the main complexities in technological redesigning to a closed water system and thus answers the third research question *(What are the main issues that will be encountered in technological redesign?)*

4.1.1 Current technological design

Figure 19 shows the urban water cycle in its current form, in which water enters the system as raw water and leaves the system after use and treatment as discharged water. Water is treated twice in the system: from raw water to drinking water and from wastewater to discharged water (treated wastewater). Four actors are responsible for the eight main processes on level 0 in Figure 19. Drinking water companies are responsible for the raw water intake, drinking water treatment and transport of raw water and drinking water. Dunea and Evides are the two drinking water companies active in the service area of HH Delfland. Intake of raw water for Dunea is situated at the Afgedamde Maas, from where water is transported (+/- 60 km) to the Dunes north of The Hague for drinking water treatment. Dunea is also responsible for the transport of drinking water to the consumers in its service area. Subsequently, water consumers use the water provided by the drinking water companies. Water consumers can take a wide variety of forms, ranging from households to industry. Only part of the water is actually consumed, either by drinking or by processing into products. The largest share of water is disposed as wastewater into the sewer system. The municipality is responsible for collection of wastewater and maintenance of the sewer system. During transport of wastewater to the treatment facilities, the responsibility of transport is passed from the municipality to the water authority Delfland. Municipalities conclude contracts with HH Delfland on the location of the transfer of responsibility, often at a pumping station where wastewater from a certain area confluences. HH Delfland is responsible for the final part of the transport towards the wastewater treatment plants. HH Delfland operates four wastewater treatment plants in its service area. After treatment, water is disposed into the river Nieuwe Waterweg or directly into the North Sea. Figure 19 shows the main processes and flows of the urban water system, but many (minor) exceptions and extra processes and flows could have been added. An example is sewage overflows, which by-pass wastewater treatment plants and are hence directly discharged after wastewater collection. Another exception could be small-scale individual solutions for water supply and sanitation (Correljé and Schuetze, 2012). Figure 19 is limited to the main processes and flows.

The final step of the process, wastewater treatment, is composed of several steps. Figure 20 zooms in on wastewater treatment at level 1 of the functional diagram. Current wastewater treatment at the four treatment plants of HH Delfland can be regarded as conventional treatment. Wastewater is passing three stages: primary, secondary and tertiary treatment. The first phase includes grids and/or screens and pre-settling tanks to remove larger particles, such as plastics, sand and debris. Solid waste is discharged while wastewater flows towards the secondary treatment. In this phase the water is biologically treated to remove organic matter. The organic matter is converted into sludge, which is partly recycled in the system and partly removed. The final phase of conventional treatment is nutrient (nitrogen and phosphorous) removal. Nutrients can be removed during sand filtration or they can be (partly) integrated in the biological treatment of the second phase. The current wastewater treatment process is discussed in more detail in Van Es (2017b).

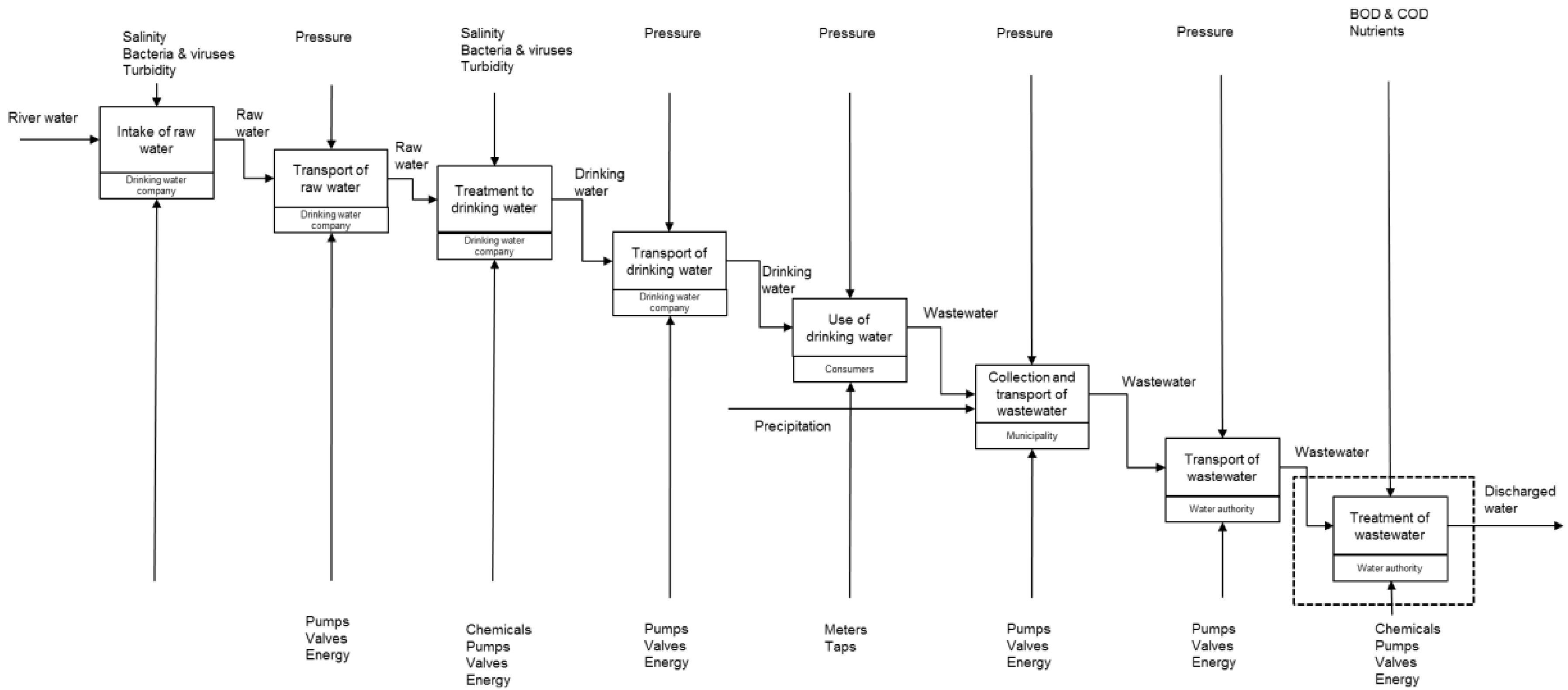


Figure 19 - Functional diagram - level 0 - current situation

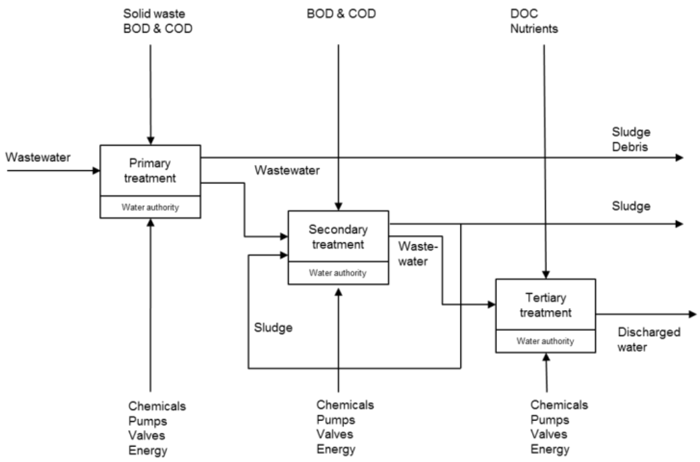


Figure 20 - Functional diagram - level 1 - current situation

Figure 19 and Figure 20 have shown that the current urban water system is a linear system in which water enters at the beginning of the chain and is disposed after the final process. As previously discussed, HH Delfland aims to close the urban water cycle to cope with expected future droughts. The next section will discuss the technological design of a closed urban water cycle.

4.1.2 Desired technological design

Figure 21 shows two major adjustments to the current technological design of the urban water system: 1) the raw water intake and transport to the drinking water treatment plant has become obsolete and 2) wastewater treatment effluent is no longer discharged to the hydrological water cycle, but it is transported to the drinking water treatment plant. The first change makes water companies no longer dependent on river water with varying quality – which is expected to deteriorate over time (Sjerps et al., 2016). The quality of wastewater treatment effluent is closely monitored during treatment, which allows the operation of the drinking water treatment plant to be adjusted accordingly. However, a complete new transportation system needs to be constructed, from the wastewater treatment plant towards the drinking water treatment plant (second adjustment). Responsibility and ownership of wastewater and drinking water are separated in the service area of HH Delfland and current infrastructure (plants and transport pipelines) are separately constructed. These factors make the construction of one integrated water treatment plant – from wastewater directly to drinking water – unrealistic for the near future. The new transport pipeline to the drinking water treatment plant will require a huge investment. The trajectory of the pipeline will have to run through the densely populated and built environment of the Randstad. Also, questions on responsibility and finance will rise with the construction of the new pipeline. Section 4.1.3 will further elaborate on this complexity.

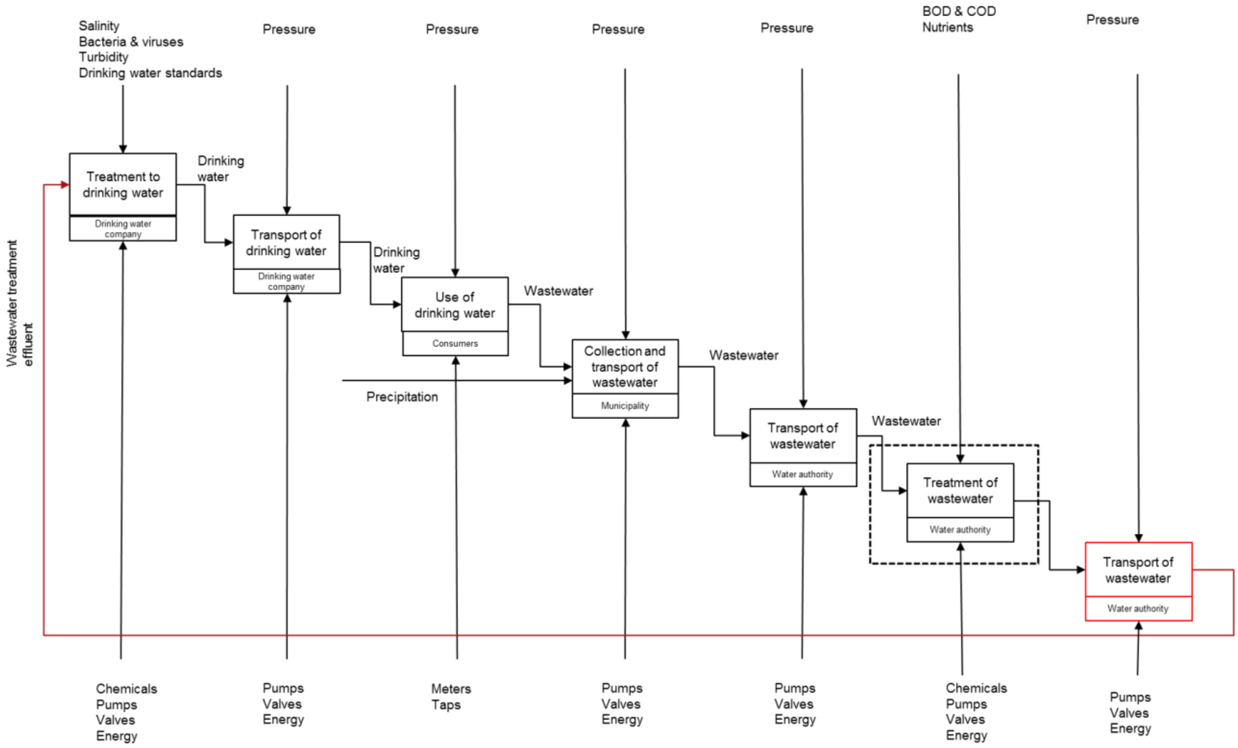


Figure 21 - Functional diagram - level 0 - desired situation

The third main adjustment to the technological design can be found within wastewater treatment. Figure 22 of level 1 shows that the conventional treatment of the current system is extended with advanced wastewater treatment. Advanced wastewater treatment is mainly targeted at removing organic micro-pollutants such as pharmaceuticals, pesticides and endocrine disruptors. Three options for advanced wastewater treatment are currently regarded as both effective and economically feasible: reverse osmosis, activated carbon adsorption and ozonation (Margot, 2013). The latter treatment option is currently studied by HH Delfland in the 'Freshwater Factory' (FF) pilot at wastewater treatment plant De Groote Lucht in Vlaardingen. Ozonation is a promising technique for advanced wastewater treatment. It effectively removes most of the organic micro-pollutants without causing negative side effects (Van Es, 2017b). The main trade-off in advanced wastewater treatment is between energy use, costs and water quality. It is technologically possible to treat wastewater towards feed water for drinking water treatment. The main question remains whether the responsible actors want to invest energy and costs that come with this technological design.

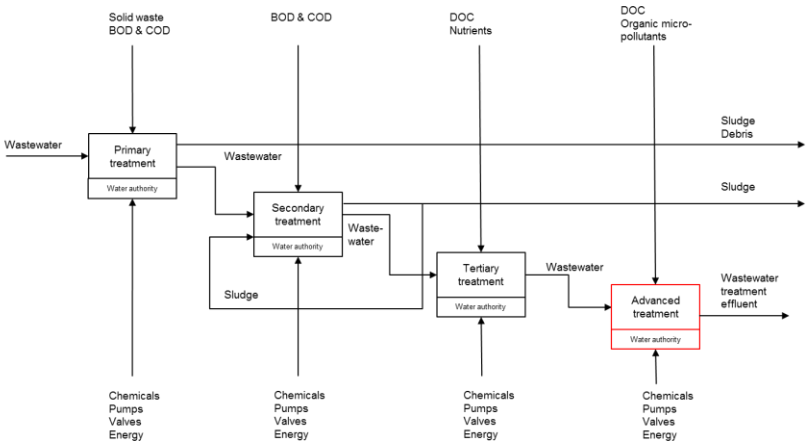


Figure 22 - Functional diagram - level 1 - desired situation

The above described technological design presents a circular water system in its height. It closes the gap from the lowest water quality (wastewater) towards the highest water quality (drinking water). A closed system does not have to upgrade wastewater all the way to drinking water, but it can also be used for other, lower quality purposes. An example would be to reuse wastewater to enhance the water quality of recreational water bodies. In that case, there is no current transport infrastructure to the drinking water treatment facility that becomes obsolete. However, advanced wastewater treatment and transport of the treated wastewater towards the location of reuse is still required.

4.1.3 Main technological issues

The previous section has identified three major adjustments to the technological design that are needed to closed the urban water cycle. The first adjustment, the raw water intake and transport to the drinking water treatment plant becoming obsolete, could be a positive outcome for drinking water companies. Water intake and especially transport requires a large infrastructure. The moment when this infrastructure requires major maintenance or even complete replacement, could be a window of opportunity to switch to wastewater treatment plant effluent as raw water source. The 'old' infrastructure can be dismantled while the once-required investment on replacement can be spent on the new infrastructure. If the current water intake and transport infrastructure is still required as a back-up system, this does not hold.

Two required changes to the technological system that *will be* an issue are the construction of the infrastructure to transport treated wastewater to new destination and the addition of advanced wastewater treatment. The first issue has been encountered with a project to reuse water for irrigation of greenhouse farms in the service area of HH Delfland. The project did not commence since it was not financially feasible. Transport of water from the treatment plants of HH Delfland was found to be too expensive to be an attractive option for greenhouse farmers. The second issue is the advanced wastewater treatment that needs to be added. Advanced wastewater treatment must be able to meet the desired water quality standards, for drinking water, recreational water or to protect the ecology of the water body.

4.2 First scan of issues

With a better idea of the required technological changes, this section explores potential issues from (scientific) sources on wastewater reuse. Wastewater reuse projects have been executed worldwide, especially in countries coping with droughts. This section shortly evaluates four projects of wastewater reuse to find their issues in implementation: Koksijde in Belgium, Orange County in the USA, Singapore and Windhoek in Namibia. Potential issues can also be found in attempts to close other regional cycles, such as the energy and resources cycles. For this reason, the Green Deal between, among others, the Union of Water Authorities (UvW) and the Ministries of Infrastructure & Environment (I&M) on 'Energy Factories' is studied.

Koksijde (Belgium)

Flemish water company IWVA runs a project of indirect potable wastewater reuse via dune recharge in the coastal region of Veurne since 2002. The region had a lack of alternative sources and experienced water shortages during the summer. The reuse project had to prevent saline intrusion in the dunes and had to meet increased drinking water demand, especially during tourist season (Kok and Peters, 2008). After ten years of research, including four years of pilot testing, the installation treats 6.000 m^3/day since 2002. After conventional wastewater treatment, ultrafiltration (UF), reverse osmosis (RO) and ultraviolet (UV) disinfection are applied (Onyango et al., 2014). The concentrate of the RO treatment is discharged into the sea. After a residence time of 35-55 days in the dunes, post treatment produces drinking water for 60.000-200.000 people. No issue with obtaining an environmental permit for the infiltration of treated wastewater has been reported.

The main issues that had to be addressed in this project are **public acceptation**, **health risks**, **legislation**, **costs** and **technology** for advanced treatment (Kok and Peters, 2008). The project evoked very few negative responses from the public (Kok and Peters, 2008). It was publicly accepted, since it solved issues of drinking water quality and water shortage. Water company IWVA actively informed the public through a website, a visitors center and guided tours through the plant (Onyango et al., 2014). The health risks mainly concerned pharmaceuticals and pathogenic micro-organisms (bacteria and viruses). Standards on water quality are set in national legislation. IWVA consciously chose a very extensive treatment of UF, RO and UV disinfection. Costs for advanced wastewater treatment are 0.50 euro/m^3 (Kok and Peters, 2008). Research has been conducted on advanced treatment options.

The potable wastewater reuse project in Koksijde can be regarded as a success. The question rises whether this project can be directly translated to the case of HH Delfland in the Netherlands. Two important differences can be observed: less sense of urgency in the Netherlands and larger scale of wastewater reuse. Firstly, the service area of HH Delfland has not experienced water scarcity in periods of drought, as the Veurne area in Belgium has. The public might be hence less willing to accept potable wastewater reuse and associated costs. Secondly, the scale of wastewater reuse is expected to be larger in the densely populated area of the western part of the Netherlands. Water company Dunea for instance produces drinking water for 1.3 million people, which is significantly more than the 60.000-200.000 people drinking reused wastewater in Koksijde. With a larger scale, it is questionable whether the advanced treatment is still an option. Treating large volumes for instance requires more energy and produces more concentrate streams from the RO treatment.

Orange County (USA)
In Orange County in California (USA), wastewater that was previously discharged into the Pacific Ocean, is now reused as drinking water. Microfiltration, RO and UV disinfection is applied after conventional wastewater treatment. The facility treats 379.000 m^3/day to supply drinking water to 875.000 residents in Orange County (Orange County Water District, 2017). California has experienced severe droughts in recent years, which provided a window of opportunity for this potable wastewater reuse project. Orange County had very limited options for drinking water sources. In the past, raw water was transported all the way from north California to Orange County in the south. Even though very energy intensive treatment steps are applied, the wastewater reuse project uses only half of the energy that was previously required for water transport. No issues with public acceptation or legislation have been reported.

The regional water system of Orange County has large differences with the regional water system of HH Delfland. The main differences are the experienced droughts and the long distance of water transportation from source to treatment facility. In the past, residents of Orange County were already used to paying a relatively high price for their drinking water, since it had to be transported from the other side of California. The high water price had a positive effect on the business case of potable wastewater reuse.

Singapore and Windhoek (Namibia)
Lafforgue and Lenouvel (2015) present an evaluation of the attempts of Singapore and Windhoek (Namibia) to close the urban water loop. Both in Singapore and Windhoek, around one quarter of the water used, is derived from recycled wastewater. In Singapore, the reclaimed water is mainly used for industrial use and in Windhoek for drinking water purposes (Lafforgue and Lenouvel, 2015). Reclaimed wastewater is called NEWater in Singapore and is produced by a combination of microfiltration, reverse osmosis and UV treatment. In 2012, the total NEWater production was 300.000 m^3/day, which is around 18% of the total water demand (Lafforgue and Lenouvel, 2015). Windhoek has to cope with a continually escalating water demand, with very few fresh water sources available. Since 2002, Windhoek has an advanced treatment plant with a capacity of 21.000 m^3/day. An extensive treatment is applied, consisting of coagulation/flocculation, dissolved air flotation, ozonation, activated carbon filtration and ultrafiltration. Reclaimed wastewater accounts for 26% of total volume of water produced. In both cities, the water authority is responsible for the complete water cycle, i.e. (drinking) water supply, wastewater collection and treatment, and rainwater and resource management (Lafforgue and Lenouvel, 2015). The integrated organizational structure of the water authorities helped to facilitate a closed water cycle.

From the research of Lafforgue and Lenouvel (2015), four potential issues in closing the water cycle can be observed. Firstly, energy consumption for advanced wastewater treatment can be high. Secondly, affordability of reused wastewater for the people is especially an issue in poor countries. In the Netherlands, the issue will not be that people cannot afford more expensive drinking water. Rather, the issue will be whether the higher price is accepted, both by politicians and by the consumers. Thirdly, closing the urban water cycle in Singapore and Windhoek has been facilitated by one water authority being responsible for whole water cycle. In the Netherlands, the responsibility of drinking water and wastewater are completely separated. This organizational structure of the water system could be an issue in closing the water cycle. Finally, both cities had to adjust their regulations and standards to enable wastewater reuse. For the heavily institutionalized Dutch water system, this might also prove to be an issue.

Green Deal 'Energy Factories'

The Dutch government has the ambition to stimulate sustainable growth and invented the Green Deal to facilitate societal initiatives. The Union of Water Authorities (UvW), all 23 Dutch water authorities and the Ministries of Infrastructure & Environment and Economic Affairs have closed a Green Deal on turning wastewater treatment plants into 'Energy Factories' in 2011 (Dutch Government, 2011). The government promised to adjust rules and regulation and to provide subsidies for innovative projects. Apparently, both aspects are required for the water authorities to realize 'Energy Factories'. The actors together found that the most important issue is not technology but rather uncertainty about and ambiguity of rules and regulation (Dutch Government, 2011).

Potential issues

This section has explored the potential issues in closing the regional water cycle, based on four projects of wastewater reuse and the Green Deal regarding the energy cycle. Table 5 summarizes the potential issues for the case of HH Delfland, based on lessons learned from the cases analyzed in this section. In the analyzed cases, the issues have often been effectively addressed. This has resulted in successful wastewater reuse projects in Koksijde, Orange County, Singapore and Windhoek. However, the situation of the Netherlands is different, and it is questionable whether these issues can also be resolved here. The next section (4.3) will present the information obtained in interviews with relevant stakeholders in the case of HH Delfland. The interviews have been conducted to find the critical issues in closing the water cycle in the service area of HH Delfland.

Table 5 - Lessons learned from the analyzed cases on potetial issues for the case of HH Delfland

Case	Lessons learned on potential issues for the case of HH Delfland
Koksijde (Belgium)	• Public acceptation • Health risks • Legislation • Costs • Technology for advanced wastewater treatment
Orange County (USA)	• Business case of wastewater reuse project • No sense of urgency
Singapore and Namibia	• High energy consumption of advanced wastewater treatment • Affordability of reclaimed wastewater • Drinking water and wastewater separated in Dutch organization structure • Adjustment of rules and regulations
Green Deal 'Energy Factories'	• Uncertainty about and ambiguity of rules and regulations • Business case of wastewater reuse project

4.3 Interviews to determine critical issues

In March-June 2017, twenty-two interviews have taken place with employees and board members of HH Delfland and other relevant actors in the regional water system (Ministry of Infrastructure & Environment, Province of South Holland, municipalities, universities and drinking water companies[1]). Semi-structured interviews have been conducted to allow diversion from previously defined questions, when interesting topics are addressed by the interviewee. Table 6 shows an overview of the respondents, including their organization and function. To guarantee anonymity of the respondents, most information and quotes obtained from the interviews are not directly linked to the source. Instead of a name, the type of respondent (e.g. employee HHD) is mentioned as source. Both the board members and the chair of the board of HH Delfland are mentioned as 'board member HHD'. All interviews with board members of HH Delfland and with Dunea are verified for this report. When respondents *are* explicitly mentioned, the information or quote is verified with the respondent before publication of this report.

Table 6 - Overview of interviews conducted

Organization	Person	Function	Field
HH Delfland	Fred Nederpel	Policy advisor	Wastewater
HH Delfland	Oscar Helsen	Policy advisor	Wastewater
HH Delfland	Marije Paardekooper	Policy advisor	Wastewater
HH Delfland	Carl Paauwe	Policy advisor	Climate adaptation
HH Delfland	Bas Nanninga	Policy advisor	Wastewater
HH Delfland	Fincent van Woerden	Policy advisor	Water management
HH Delfland	Helen Hangelbroek	Policy advisor	Water quality & ecology
HH Delfland	Han van Olphen	Hoogheemraad	Wastewater treatment
HH Delfland	Ingrid ter Woorst	Hoogheemraad	Nature, water quality
HH Delfland	Ries Smits	Hoogheemraad	Finance
HH Delfland	Marcel Houtzager	Hoogheemraad	Water safety
HH Delfland	Hans Middendorp	Hoogheemraad	Water quantity
HH Delfland	Michiel van Haersma Buma	Dijkgraaf	
Bureau Brussel UvW-Vewin	Dieter Staat	Lobbyist	
TU Delft	Erik Mostert	Lecturer	Water law
TU Delft / Waternet	Jan Peter van der Hoek	Professor / head of strategic centre	Drinking water
University of Ghent	Wim Audenaert	Lecturer	Advance wastewater treatment
Province of South-Holland	Erik de Haan	Environmental economist	Climate adaptation
Ministry of Infrastructure & Environment	Barry van de Glind	Advisor International Coordination	Water Framework Directive
Municipality of The Hague	Arthur Hagen	Policy advisor	Water
Municipality of Pijnacker-Nootdorp	Kees van Schieveen	Team leader	Public space
Dunea	Wim Drossaert	CEO	
Dunea	Gertjan Zwolsman	Project manager	Drinking water sources

[1] The interview with Hoogheemraad Middendorp has been conducted by policy advisor Bas Nanninga. The interview is used as secondary source for this research. The information in this report is verified with the board member before publication.

This section will discuss and structure the information obtained in the interviews. The main question is what issues the respondents expect with attempts to close the regional water cycle by wastewater reuse. Section 3.2, on the institutional design methodology, explained that the four-layer model of Williamson (1998) might be helpful in finding the most critical issues and their corresponding action situations. This section uses the four-layer model of Williamson (1998) to structure the information provided in the interviews. In this way, the sixth research question is answered: *What are the critical issues that will arise in redesigning the institutional system to facilitate closing of the water cycle?* Chapter 6 evaluates the use of this framework within the proposed methodology. We will see that not all issues stated by the respondents can be structured within the four-layer model. For this reason, this section has been divided in two parts: institutional issues structured by the four-layer model (section 4.3.1) and non-institutional issues (section 4.3.2).

4.3.1 Institutional issues

Respondents have addressed issues on every layer of the institutional framework of Williamson (1998) (see section 2.4.2 for a detailed description of the framework). This section discusses the issues that can be structured along the four layer of the institutional model. The description starts at the highest institutional level (1) of culture & norms and ends with the lowest institutional level (4) of individual analysis.

Layer 1 – Embeddedness; culture & norms

To recap, the highest institutional level model is the social embeddedness level, in which norms, customs, traditions, mores etc. are located. At this institutional level, three themes have frequently been addressed by respondents: **social acceptability of wastewater reuse**, the **sense of urgency of freshwater scarcity** and water being part of **energy and resources cycles**.

Firstly, many respondents have addressed the need for **social acceptability** of wastewater reuse projects as one of the main issues in closing the water cycle, both from governmental bodies and drinking water companies. Opinions differ on the degree to which the public perception is negative. Opinions range from 'social acceptation of wastewater reuse is unknown' (employee HHD) to 'a first small survey shows social acceptability of wastewater as a single source for drinking water treatment is low' (Dunea). An employee of a governmental body thinks wastewater reuse projects for drinking water production will 'undoubtedly lead to parliamentary questions and angry citizens'. According to another respondent it will be a challenge to win the trust of both the intermediary (greenhouse farmers, Dunea) and the consumers (the public) in wastewater reuse projects. HH Delfland is less certain that the negative perception of the public to wastewater reuse is one of the main issues. Many respondents from HH Delfland do not even mention the social acceptability as an issue in closing the water cycle. If they do, they restrict to mentioning that the public perception is unknown or that the issue is the responsibility of Dunea. The latter notion is indeed felt by Dunea, which sees the social acceptability of wastewater reuse (for drinking water production) as one of the main issues. The CEO of Dunea explained that plans for wastewater reuse can be promising, but a wastewater reuse project will not commence if the public does not accept it. He considers selling drinking water from wastewater reuse as 'a huge challenge' (Drossaert – Dunea). Dunea has held a first survey among employees of Dunea (including supporting staff), which showed that up to 25% of the respondents do not favor wastewater as sole source of drinking water. Since the respondents have significant more knowledge on drinking water production than the public at large, Dunea expects that approval rates of the public for (indirect) wastewater reuse will be even lower.

Secondly, the **lack of urgency** of freshwater scarcity is addressed by many respondents of governmental bodies. The availability of alternative freshwater sources for water level management, irrigation and drinking water production creates a lack of urgency of freshwater scarcity according to two respondents. The Brielse Meer is a reliable source for water level management in the service area of HH Delfland, greenhouse farmers use rainwater for irrigation and the Meuse river serves as source for infiltration water in the dunes of Dunea. Countries in which wastewater reuse has already been implemented at a large scale (e.g. Australia, Namibia and Singapore) had a significantly higher sense of urgency. Australia and Namibia have coped with severe droughts in recent years and Singapore has additional geopolitical reasons to be self-sufficient in freshwater supply (Lafforgue and Lenouvel, 2015). The lack of alternative freshwater sources created a high sense of urgency in these countries (employee of drinking water company). In the Netherlands, the sense of urgency is not felt at all by some actors. A board member of HHD argues that disconnecting rainwater from the sewage system and reusing the rainwater, is far more urgent than wastewater reuse at the treatment plants. If this has been accomplished, he argues that the water scarcity issue might be so unurgent that wastewater reuse from treatment plants is not even desired anymore. Interestingly, water company Dunea thinks that freshwater scarcity *is* urgent. Dunea sees its current freshwater sources (Afgedamde Maas and Lek) threatened by pollution and low discharges (Dunea). Other sources are not readily available, which could create a sense of urgency for reliable and high quality freshwater sources. Section 1.3 (problem statement) has addressed the difference in sense of urgency felt as 'contested knowledge'. Actors in the water system do not agree on whether fresh water is scarce or not. This contributes to the complexity of the problem, as defined in section 1.3.

The *sense* of urgency of freshwater scarcity is regarded as a layer 1 issue in this issue. However, the freshwater *scarcity* is also typically a layer 4 (marginal analysis) issue. Freshwater is (or isn't) a scarce product, subject to economic considerations of price and output. This research categorizes this issue primarily as a layer 1 issue since the issue addresses the *perception* that the actors have (sense of urgency) on freshwater availability rather than the *economic activity* (price and output) regarding the scarcity of fresh water.

The social acceptability and sense of urgency are closely related aspects of the water system. A high sense of urgency of freshwater scarcity can significantly increase the social acceptability of wastewater reuse. At the institutional level of embeddedness, norms on what is acceptable and how urgent a problem is, changes occur slowly. However, a severe drought could also cause a sudden change in these institutions in the coming years.

Thirdly, attempts to close the water cycle needs to be seen in wider context of the **energy and resources cycles** (two respondents from governmental bodies). This category touches upon the above discussed issue that water scarcity is too unurgent to close the water cycle. Some respondents see the energy and resources cycles in the wastewater system as more important than the water cycle (board members HHD, employee governmental body). Closing the energy and resources cycles is regarded to have a better business case (board member HHD). Attempts to close the water cycle can even have negative effects on the energy cycle, since more energy will be required for advanced wastewater treatment. The energy cycle is currently a hot topic in politics and might have a greater momentum than the water cycle at the moment.

Layer 2 – Institutional environment

The second layer in the framework of Williamson (1998) is the institutional environment providing the rules of the game within which the economic activity is organized. Major changes in institutions at this layer mainly occur at rare windows of opportunity. Many respondents of HH Delfland have mentioned issues at this institutional level. Issues mentioned are closely to each other and can be divided into two categories: the **difficulty to meet water quality standards** and **legislation that proves to be conflicting** during implementation. Issues regarding the **formal financial rules** are mentioned as third issue at this institutional level.

Firstly, many respondents foresee that reuse projects will have difficulties in obtaining required permits due to strict regulation and standards (three employees HHD). Legislation works down from European level to the licensing entity. Respondents varied in addressing the issue at higher levels (new expected EU standards on pharmaceuticals and the EU 'standstill' principle to lower levels (obtaining a permit from the licensing entity. These levels are highly connected, since permits must comply with national and European legislation. An interesting aspect of water quality standards that wastewater reuse projects must meet, is the knowledge gap on which standards should be met (employee HHD). Monitoring pollutants and setting standards in legislation is in continuous development at both national and EU level. For instance, there are currently no standards set in Directive 2013/39/EU on pharmaceuticals (in surface water). However, several pharmaceuticals have been put on the 'Watchlist' which means they are currently monitored (academic researcher). Substances on the Watchlist might be included as priority substance with an official water quality standard.

A practical example is the permit that HH Delfland has to obtain to discharge water from the 'Freshwater Factory' (FF) on the Krabbeplas water body. This discharge is regarded as 'new' since treated wastewater is currently discharged on the Nieuwe Waterweg. A new discharge needs to comply to water quality standards and the 'standstill principle' as laid down in the Water Framework Directive (2000) to be able to acquire a permit. It is highly questionable whether the proposed advanced wastewater treatment can fulfill these requirements. This discussion assumes it is technologically possible to meet the water quality standards, but that the crux is to achieve this quality with reasonable costs. The entire project will not be implemented when a permit cannot be obtained at acceptable (investment and operational) costs.

The second part of the lack of 'facilitating' legislation is about conflicting legislation. Respondents have come up with several stories in which conflicting legislation has frustrated efforts to close the urban water cycle. One example is the company Pharmafilter that attempts to remove pharmaceuticals from wastewater (which can enable wastewater reuse). Due to existing regulation, the company was seen as a waste processor which obliged them to follow an extensive set of rules and regulations. One board member of HH Delfland summarizes this issue by stating that 'the spirit and the letter of current legislation does not coincide in closing the water cycle'. Changing legislation could better align legislation, but this process is 'difficult and time consuming' according to another board member of HH Delfland.

A third group of issues regard the formal financial rules in the water system. Firstly, water authorities are **obliged to pay VAT** while municipalities are not. This is relevant when tasks and responsibilities of municipalities and water authorities are integrated in the implementation of wastewater reuse projects. Another financial issue is the different ways in which municipalities currently **finance their sewage system** (employee municipality). Integrating these different approaches would be an issue in a closer cooperation between municipalities, water authorities and drinking water companies.

The level of the institutional environment sets the 'rules of the game'. According to many respondents within HH Delfland it is currently questionable whether the institutional environment can facilitate wastewater reuse projects. Interesting to notice is that only employees and board members of HH Delfland see the institutional environment as a potential issue in closing the water cycle. A potential explanation could be that HH Delfland is already actively exploring the possibilities of wastewater reuse projects (e.g. Pharmafilter, Freshwater Factory). In these projects, they have encountered problems with the formal institutional environment. It could well be that other actors have not experienced these issues yet and hence do not mention them in the interviews.

Layer 3 – Governance

The third institutional layer provides the institutions of governance, dealing with the 'play of the game'. With the constraints of the *rules* of the game from the second level, the *play* of the game can be determined at the third level. The main issues presented by respondents concern the **variety of actors involved**, the **political nature** of the regional water system and **decentralized solutions**. Both within and outside of HH Delfland, actors see both aspects as potential issues in closing the water cycle.

Firstly, respondents see the **variety of actors involved** in the water system as a potential issue in closing the water cycle. Tasks, responsibilities and financial costs and benefits are divided between actors. There is not one single problem owner of threatening water scarcity, but instead the responsibility is divided between water authorities, provinces and municipalities. With shared responsibility comes differences in strategies and approaches. Responsibilities can also be unclear, for example the removal of pharmaceuticals from the water system. Are point sources (e.g. hospitals), water authorities or drinking water companies responsible for the removal of micro-pollutants (such as pharmaceuticals) from the water system? Wastewater reuse projects will always have to take a variety of stakeholders into account, within and even outside the service area of HH Delfland (two employees governmental bodies). Notable is that involving municipalities into attempts to close the water cycle is mentioned twice. Convincing municipalities to invest in the water system (board member HHD) and involving the municipality in obtaining a permit (employee HHD) is both mentioned once as potential issue.

Secondly, a variety of aspects regarding the **political nature** of the regional water system is mentioned by respondents. Firstly, the short-term focus of politicians is seen as an obstacle for wastewater reuse projects (board member and employee HHD). These projects usually transcend political terms of four or five years and benefits of these projects might only be observed during future terms. The process towards a closed water cycle will be long and the decision-making process is seen as complex and time consuming by two board members of HH Delfland. Secondly, changing political colors of coalitions after elections at national or regional level or at the water authorities threatens consistent policy (board member HHD, Drossaert – Dunea). Similar to the first point, reuse projects require long time, continuous political support in order to be implemented. A sudden change in political color of a coalition, for instance from 'green' to 'grey', could lead to a sudden end of a project. Thirdly, the political 'play of the game' can be one of the daily issues instead of focusing on long term interests (employee governmental body). Politicians can overreact on incidents, which could again suddenly end a project. Next, politicians must be willing to share credits & acknowledgments among each other (board member HHD). Apparently, politicians allowing each other their successes cannot be taken for granted. Finally, the fiercest statement of politics as an issue comes from the CEO of Dunea. He sees the 'political inability' to solve problems as a major issue in attempting to close the water cycle.

Thirdly, one respondent mentions that the trend in sustainability goes more towards **decentralized solutions** (e.g. at household level) than towards centralized solutions (i.e. at centralized wastewater treatment plants (employee governmental body). Closing the water cycle might happen at a smaller scale, at household or neighborhood level. This is a third layer issue since it concerns where 'the game is played'. Closing the water cycle could be achieved with arrangements between provinces, municipalities and water authorities (i.e. among governmental bodies). However, it could also happen on a smaller scale. Neighborhoods can make use of different water streams, for instance directly reusing rainwater for gardening and separating urine to produce struvite in small scale treatment plants. Large scale reuse projects are no longer required in such a scenario. This research has shortly addressed this issue in the demarcation of regional water system in section 4.1.1 on the current technological system. The functional diagrams in this section omit small-scale individual solutions for water supply and sanitation, since these are currently minor water flows. Correljé and Schuetze (2012) do mention these decentralized solutions as part of the small water cycle. One respondent argues that these decentralized solutions can become so widely adopted that they do have impact on the regional water system.

Layer 4 – Marginal analysis

The lowest institutional level concerns marginal analysis: the examination of costs and benefits of individual actions. Agents take price and output into account in their decision making, at the fastest changing institutional level. The main issue raised at this level is whether wastewater reuse projects are **economically feasible.**

In answering the question on what would be the main issues in closing the water cycle, many respondents mention financial aspects of wastewater reuse. Some actors stress the importance of financial viability by stating they only want to commence a reuse project if it has a positive business case (board member HHD). One board member of HH Delfland states that 'closing the water cycle is mainly a financial challenge'. The financial viability of reuse projects is also mentioned by the Ministry of I&M and municipalities. Dunea also states that the financial aspects of wastewater reuse are important. However, they do see financial implications as inferior to security of (drinking) water supply (Drossaert – Dunea). HH Delfland has the right to levy taxes to fulfill its obligation to ensure a good water quantity and quality in its service area. When costs would rise because of a water reuse project, it is a political choice to execute the project and thus increasing wastewater tariffs. Respondents state that it is questionable whether HH Delfland can politically sell higher wastewater tariffs, since it already has the highest tariff of all water authorities in the Netherlands. A complicating factor is that the price of freshwater is currently very low, making it hard for reuse projects to be at least cost neutral. Respondents mention that new sources of financing should be sought, for instance better apply the 'polluter pays' principle.

At the lowest institutional level, all respondents agree there are financial limits to closing the water cycle. The main difference between respondents is the importance that they assign to the economic feasibility of reuse projects. For some it is the single most important aspect (and hence issue), for others it is inferior to values such as sustainability or security of water supply.

4.3.2 Non-institutional issues

Not all issues addressed by respondents can be structured with the institutional analysis framework of Williamson (1998). This section discusses two issues: **technology** and **core tasks** of the water authority.

The first category is that of the **technological system** required for a closed water system. Section 4.1 has analyzed the current and technological system. Technological issues are hardly mentioned by respondents from HH Delfland. One board member mentions a technological issue by stating that the construction of new pipelines in densely populated areas will be a challenge. Respondents from other organizations however do mention technological issues. In general, the required technological system needs to fit the current, not yet depreciated, infrastructure. More specific issues are divided along different requirements to a new technological system, as observed in section 4.1. The first issue is advanced wastewater treatment that needs to be added before wastewater can be reused. Respondents question whether advanced wastewater treatment can meet all demands (e.g. low pharmaceutical concentration, high water recovery, low toxicity etc.). Secondly, the construction of new pipelines to the location of wastewater reuse is mentioned as potential issue by many respondents. Especially when these pipelines will go through populated areas the construction will be expensive and will evoke public resistance. Zooming in even further on the technological system, it is questionable whether wastewater can provide sufficient security of supply with its daily and seasonal fluctuations (Dunea, employee governmental body). Drinking water demand is highest in times in the summer months (July and August). Will the dry weather flow through wastewater treatment plants provide sufficient water for drinking water production?

Secondly, closing the water cycle is **not seen as one of the core tasks** of the water authority (employee HHD). Water authorities do not have to feel obliged to close the water cycle, as opposed to for instance their task to ensure safe dikes.

Also, three respondents have partly taken up the role of the institutional analysist by providing considerations between different issues. These respondents have tried to find the crux in closing the water cycle. The first ‘summary issue’ provided is that **technology, financials and legislation** should be aligned. Another respondent provided a somewhat more detailed consideration by stating that the main issue is the tension between risks for public health (e.g. pollutants in wastewater) and imposing such strict standards that reuse projects become financially unviable.

4.4 Analysis of interviews

The previous section (4.3) has described the issues as presented by respondents in the twenty-two interviews conducted for this research. This section will further analyze the issues to find similarities and differences in attitudes and expected issues within and between organizations and actors. Four relations will be closely analyzed in this section: within the board of HH Delfland, between the board and public servants of HH Delfland, between HH Delfland and other government bodies and finally between HH Delfland and Dunea.

4.4.1 Within the board of HH Delfland

Four board members (Hoogheemraden) and the chair of the board (Dijkgraaf) of HH Delfland have been interviewed for this research. This section will first discuss the attitudes of the board members towards closing the water cycle, before the expected issues as presented by the respondents are discussed. The final part of this section uses the four-layer model of Williamson to structure the attitudes and expected issues.

Attitude towards closing the water cycle

Figure 23 shows an overview of the attitude of the board members towards closing the water cycle. The figure shows that roughly three groups can be observed within the board. The group on the left side is driven by the values of sustainability, investing in the future and circularity. One of the board members is a strong advocate for a closed water cycle. The board member tries to see 'problems' in closing the water cycle as 'opportunities'. The (underlying) values are explicit arguments for the board member to close the water cycle. Other board members in this group argue that circularity is a given and that politics should be at the forefront of developments. One board member argues that innovation is important and should be stimulated. Another board member thinks that the opportunities and developments towards closed cycles are unstoppable. The board member thinks the time has come to invest in water reuse projects. However, this board member does stress that investments in circularity must have a positive return in the long term.

On the right side of the figure the attitudes of the third group of board members can be found. These board members are generally skeptical about closing the water cycle. They belief that wastewater reuse projects should always have a business case. In fact, they argue that there is currently no urgency in freshwater scarcity, which makes closing the water cycle not even necessary. One board member agreed that there might be situations in which re-use of wastewater is prudent or necessary. However, in his/her eyes, neither are the case in the Delfland region. There is generally no scarcity of freshwater and the emergency supply from the Brielse meer has been generally sufficient over the years. Other projects such as recovering energy and/or resources in wastewater and disconnecting rainwater from the sewage system have a higher priority according to this group. One board member sees the latter as 'solving problems in a smart way', instead of focusing on wastewater reuse projects. Board members in this group argue that circularity and self-sufficiency (of freshwater supply) should not be goals as such.

Group 2 can be found in between these two camps. The views on closing the water cycle of this group have not been outspoken during the interviews. One board member argued that the water authority should dare to experiment and that opportunities must be utilized. The board members at the left side of Figure 23 share this view, which is why the words are depicted in between these two groups.

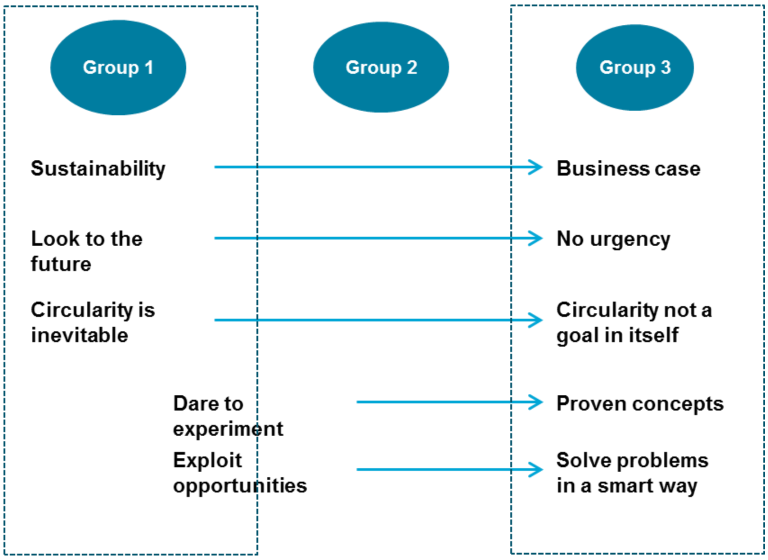


Figure 23 - Overview of attitude towards closing the wastewater cycle

Expected issues in closing the water cycle

Figure 24 shows an overview of the expected issues as brought forward by the board members. The attitude of the board members can be found in their perception of issues in closing the water cycle, most clearly on the right side of the figure. Group 3 sees the lack of urgency as a potential issue in implementing wastewater reuse projects. In their eyes, it is not needed at the moment and it should hence not be pursued. Also, they see the potentially negative business case of wastewater reuse projects as an issue. Projects of the water authority should be at least costs neutral in their eyes. The energy and resources cycles have a better potential for a positive business case. One board member in this group further argued that the energy and resources cycles appear to have a much higher potential for a positive business case. For this reason, the focus should be on these cycles instead of the water cycle. These board members stress that any wastewater reuse project must have a positive business case in order to take off independently and without subsidies.

On the left side of Figure 24, the issues expected by the first group are different. These board members have a positive attitude towards closing the water cycle and address issues that will rise along the road towards a closed cycle. Obtaining a permit and dealing with contradicting legislation is mentioned two board members. Interesting to notice is that board members often reason from their background and/or policy areas. For instance, the board member responsible for the finances of the water authority, sees closing the water cycle mainly as a financial challenge. The board member mentions that HH Delfland has little financial room to maneuver, since it already has the highest tariffs of all water authorities in the Netherlands. Two board members mention that closing the water cycle will be a long process. Changing legislation will be difficult and time consuming. One board member sees the short-term focus of politicians as an issue in implementing long term wastewater reuse projects.

The board members in group 2 are clearly taking a position at a higher level than expected issues in closing the water cycle. One board member argues that failing to see efforts to close the water cycle as an innovative and creative process is a threat to wastewater reuse projects. The second problem this board member mentions, is closely related to the criticism on the political play of the game within the board of HH Delfland. The board member states that ‘politicians have to be willing to share credits and acknowledgments’ in successful projects. The board member acknowledges that conflicts *within* the board of HH Delfland take place at a smaller stage than closing the water cycle requires. However, disagreement within the board can form a risk for projects that aim to close the water cycle.

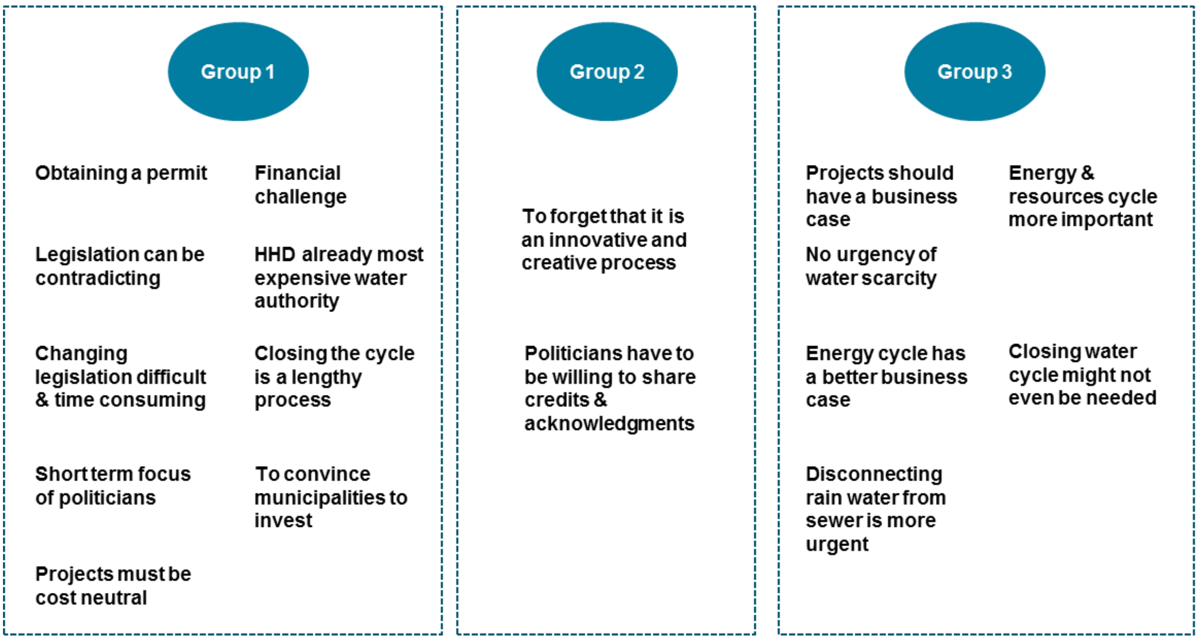


Figure 24 - Overview of expected issues brought forward by board members

Analysis with four-layer model of Williamson (1998)

The reasoning of the board members of HH Delfland on closing the water cycle and expected issues can be attributed to different levels of the 4-layer model of Williamson. Figure 25 shows the four layers of the institutional framework of Williamson (as discussed in section 2.4.2). Reasoning of the first group can be located at the highest level of the framework. In their eyes, HH Delfland should stimulate sustainability by closing the water cycle. They are driven by the values of sustainability and stewardship. The second level of the institutional environment is mentioned by three board members. The formal institutional environment might not be suitable to facilitate wastewater reuse projects, but legislation can be changed. The position and reasoning of the second group corresponds to the third layer of governance. These board members are concerned with the personal relations in the 'play of the game'. A board member mentions both the relations and interaction between members of the board of HH Delfland and between HH Delfland and Dunea as organizations. The reasoning and drivers of the third group can be found at the forth level of the individual analysis. In their eyes, projects in closing the water cycle should have a positive business case in order to be implemented.

Figure 25 structures the positions of the board members of HH Delfland. It shows that board members reason from different institutional levels with different values. An interesting consequence of the difference in institutional level and values, is that both groups of board members see the opposite institutional level as issue. To clarify, board members reasoning at the first institutional level (cultures & norms) see the forth level (marginal analysis) as an issue to achieve their goals. The first group argues that investments in a circular water system should be made now, and that (potential) economic benefits will follow later. Focusing too much on the business case at this moment will hinder the implementation of wastewater reuse projects in their eyes. One board member argues that investments should be made now, to meet the goal of a circular economy in the future. In turn, the third group reasons at the forth institutional level (marginal analysis) and sees the values of the first institutional level (culture & norms) as an issue. What some call 'driven by or reasoning from values' is called 'dogmatism' by a board member from group 3. As discussed before, group 3 feels that circularity and self-sufficiency (in freshwater supply) should not be a goal in itself. Rather, they reason from an economic analysis of reuse projects, in which only projects with a positive business case should be implemented. The difference in institutional level of reasoning and values by which the board members are driven, are a source of disagreement within the board of HH Delfland.

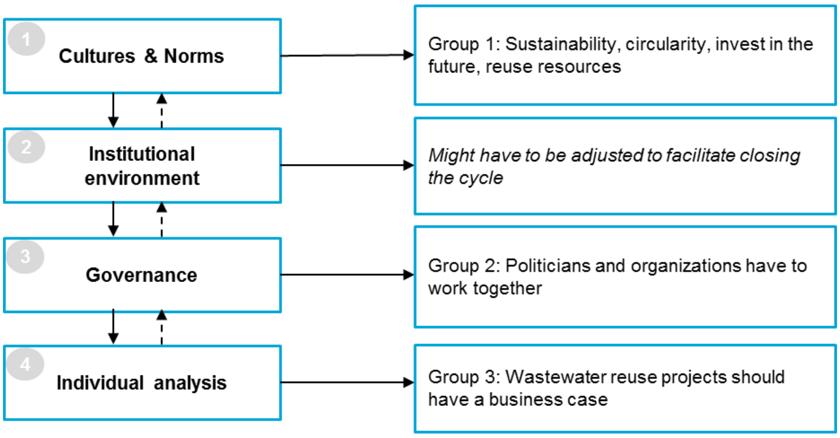


Figure 25 - Overview of level on which board member argue

The board of HH Delfland is internally divided on whether wastewater reuse projects should be pursued, based on differences in values driving board members (value of sustainability vs economic efficiency). Projects in which the drivers of all board members are aligned have most chance finding unanimous approval from the board. See Chapter 7 for more elaborate recommendations for HH Delfland.

4.4.2 Between the board and public servants of HH Delfland

For this research, both members of the board and public servants of HH Delfland have been interviewed. This section analyzes any differences and similarities in attitudes and issue perception of both groups.

In general, the attitudes on closing of the water cycle and the views on potential issues of the board of HH Delfland and the public servants coincide. In both groups, the attitude ranges from seeing 'circularity as inevitable' to water scarcity as an unurgent problem. Board members and public servants often bring the same expected issues forward. For instance, the issue of obtaining a permit for reusing treated wastewater is mentioned by both groups.

A difference noticed in the interviews is that board members more strongly express their vision on the subject. Some examples from board members: 'the time is ripe' to close the water cycle, 'government should be at the forefront of the developments'. The responses of civil servants are more often focused on facts or own experiences instead of personal visions on the future. This difference can of course be explained by the different roles of both groups. As politicians, board members have to express their views, beliefs and opinions to the public or their interest groups. Civil servants are responsible for transposing the ideas of the board members into effective policies.

4.4.3 Between HH Delfland and other governmental bodies

In the previous sections (4.4.1 and 4.4.2) the similarities and differences within the board of HH Delfland and within the organization (board members and public servants) have been analyzed. This section will analyze the positions and mentioned issues of HH Delfland compared to other governmental bodies. The governmental bodies interviewed for this research are the ministry of Infrastructure & Environment (I&M), province of South Holland and the municipalities of The Hague and Pijnacker-Nootdorp. The interests, attitudes and expected issues are presented in Table 5 and are discussed and compared in this section.

Interest

The province and municipalities are actively involved in the process of closing the water cycle. The province has joined the Costar project to investigate the possibilities of underground (aquifer) storage of surplus rainwater in winter. The municipalities have co-founded the 'Network Wastewater chain Delfland' (NAD) in which twelve municipalities, two drinking water companies (Dunea & Evides) and water authority Delfland work together in the wastewater chain. These activities correspond to the third layer (governance) of the institutional model of Williamson (1998). The ministry of I&M has less interest in the regional water cycle and does not see closing the regional water cycle as one on their own responsibilities.

The role of HH Delfland as pioneer in exploring wastewater reuse plans has been noticed by the governmental bodies. One respondent sees and appreciates the role that HH Delfland has taken up in recent years, with projects such as the 'Freshwater Factory' in Vlaardingen. HH Delfland can count on involvement from other governmental bodies. It is unlikely that the pioneering role of HH Delfland will be taken over by another governmental body.

Attitude

All three governmental bodies discussed above have a positive attitude towards closing the water cycle. They see the potential benefits for the long term and encourage drinking water companies to thoroughly investigate the future availability of drinking water sources. However, the sense of urgency is lacking at all respondents. The ministry, province and municipalities all do not see direct threats of water scarcity and thus doubt the current necessity of wastewater reuse. This attitude does not match the attitude of scientific researchers who are studied in the literature review on UWM frameworks (section 1.4.1). All researchers mention a sense of urgency of future water challenges and find argue that current water management practices will not be adequate to face these challenges. However, the ministry has adopted a 'wait-and-see' strategy in this process. They do have a positive attitude towards closing the water cycle, but they do not actively explore or encourage wastewater reuse projects. The ministry is open for talks with water authorities and drinking water companies to potentially facilitate their efforts to close the water cycle.

The positions and values of different board members of HH Delfland can be found in the attitude of the other governmental bodies. The ministry, province and municipality share the value of sustainability with the first group of board members. On the other hand, the doubt on the urgency and even the necessity corresponds to the views of the third group of board members.

Expected issues

The expected issues mentioned by the governmental bodies show two interesting deviations from the issues mentioned by HH Delfland. These issues concern social acceptation of wastewater reuse and (conflicting) legislation. The third difference discussed in this section is the ‘out-of-the-box’ issue as mentioned by the municipality of The Hague.

Firstly, the ministry of I&M and the province see **social acceptation** of wastewater reuse as an important issue in closing the water cycle. As mentioned in section 4.3.1, one respondent reckons wastewater reuse projects will lead to parliamentary questions and angry citizens. Another respondent argues that trust of both intermediaries (Dunea) and consumers (the public) has to be won to successfully implement a wastewater reuse project. Interestingly, the interviewed municipalities do not think social acceptation will be one of the main issues. One respondent argues that the public will appreciate the sustainability aspect of such a project and that they might find it ‘weird’ to reuse their own wastewater. However, the financial aspect is far more important in the eyes of the respondent. HH Delfland also hardly mentions social acceptation as main issue in closing the water cycle. The water authority has more distance to the consumer of reused drinking water, which might explain their position on social acceptation as issue in wastewater reuse projects.

A second interesting difference between HH Delfland and other governmental bodies, is that only HH Delfland mentions **legislation** as potential issue in closing the water cycle. The legislative issue ranges from ‘conflicting legislation’ to difficulty to meet water quality standards. Not one respondent within the ministry, province or municipality mentions legislation as an issue. Two reasons might explain the difference: the practical experience of HH Delfland with wastewater reuse projects and the legislative abilities of governmental bodies. Firstly, HH Delfland is one of the few actors that has actually started to implement wastewater reuse pilot projects, such as the Freshwater Factory. In executing these pilot projects, HH Delfland apparently finds conflicting legislation and strict water quality standards. Other actors do not have the practical experience of implementing a wastewater reuse project, and might hence not see issues with legislation (yet). Secondly, governmental bodies are responsible for legislation on water. Especially the ministry of I&M is an important actor in transposing European law (e.g. Water Framework Directive) into national legislation. Being (one of) the legislative authorities, the governmental bodies might not see legislation as an issue. They might rather see legislation as an institution that can be changed as desired.

The third difference is more an addition to the long list of expected issues. The issue of **decentralization,** as mentioned by one respondent has been discussed in section 4.3.2. Decentralization means that closing the water cycle might happen at a smaller scale, at household or neighborhood level. HH Delfland is also involved in small scale reuse projects and thinks this trend will not pick up sufficient speed to truly impact large scale wastewater reuse projects (employee HHD). However, it remains valuable for HH Delfland to hear from other actors what issues they expect in closing the water cycle.

4.4.4 Between HH Delfland and Dunea

This section discusses the similarities and difference between HH Delfland and Dunea according to the same structure as the previous section. Table 5 also provides an overview of the interest, attitude and expected issues of and by Dunea.

Interest

Dunea has a high interest in efforts to close the regional water cycle. The drinking water company is actively exploring possibilities to use treated wastewater as (partial) source for drinking water production. Together with HH Delfland, HH Rijnland and Evides, a scan of reusing wastewater as infiltration water has been executed (Zwolsman et al., 2017). Treated wastewater will be infiltrated in the dunes and subsequently used as source for drinking water production. Potable reuse of wastewater proves to be a serious option for the coming years. As intermediary of wastewater reuse – eventually supplying water to the consumer, Dunea is an important actor in wastewater reuse projects. Their involvement is crucial if potable wastewater reuse wants to be seen as a serious option.

Attitude

The attitude of Dunea towards potable wastewater reuse is positive. The two current (river water) sources of Dunea’s drinking water production are severely threatened by pollution. In the search of a ‘third source’, wastewater reuse is a serious option. Interesting to notice is that Dunea expresses the highest sense of urgency of freshwater scarcity of all actors in the water system. In their efforts to provide reliable drinking water with the highest security of supply, Dunea finds a threatening situation for the near future. Pressure on current sources visibly increases by pollution (e.g. traces of chemicals, pesticides and pharmaceuticals) and periodic low water discharges due to irregular rainfall caused by climate change. In the area of Dunea, no obvious alternative sources of drinking water production are present. All currently explored alternatives have their disadvantages. Desalinizing sea water for instance has the disadvantage of high energy requirements.

Process technologists of Dunea have a predominantly positive attitude towards wastewater reuse. They feel it would be a serious option, if advanced wastewater treatment can meet water quality standards as determined in the Infiltration Decision (Infiltratiebesluit)[2]. Water must meet the standards of the Infiltration Decision to be allowed to be infiltrated in the dunes between Katwijk and Monster. The infiltrated water serves as source of production water for Dunea.

Expected issues

Three differences in expected issues have been observed between HH Delfland and Dunea. These issues are social acceptation, technology and political nature of governmental bodies.

Firstly, similar to the ministry of I&M and the province, Dunea expects **social acceptation** to be a major issue in closing the regional water cycle. The CEO of Dunea calls convincing the public of wastewater reuse a 'huge challenge'. Zwolsman, project manager of the search for a 'third source', mentions the results of a small survey among employees of Dunea as a cause of concern. An implication of the (expected) negative public attitude towards (indirect) potable wastewater reuse, is that Dunea has already decided wastewater is only an option as partial source of drinking water. Social acceptance is expected to be higher when wastewater is mixed with other water sources (e.g. surface water, groundwater, rain water). Zwolsman expects Dunea to choose for a 'range of sources' for its future drinking water production. A combination of surface water (Valkenburgse meer) and wastewater is in his eyes the most promising option as sources for infiltration water.

Secondly, **technology** is seen more as an issue by Dunea than other actors do. Policy advisors, without a technological background, often state that technologically, everything is possible. However, Dunea truly questions whether advanced wastewater treatment can meet all demands associated with drinking water production (e.g. quality, quantity, continuity). An explanation for this view could be that Dunea has a lot of experience with emerging pollutants (e.g. chemicals, pesticides, pharmaceuticals) in drinking water treatment. They know how difficult it can be to meet water quality standards for *all* substances and they are aware of the disadvantages of treatment options. Dunea questions whether a promising treatment option, ozonation, can truly remove emerging pollutants, without producing toxic by-products (i.e. bromate). The second master thesis of this author concerns ozonation as advanced wastewater treatment option, see Van Es (2017b). The reason that Dunea is mentioning these issues, could be similar to HH Delfland mentioning issues with legislation (see section 4.4.3). HH Delfland has come across legislative issues during the implementation of wastewater reuse pilot projects. Similarly, Dunea observes issues in drinking water techniques such as reverse osmosis and ozonation, required for advance wastewater treatment.

The third main difference in expected issues is fierce criticism of Dunea on the political nature of governmental bodies. The short-term focus and changing coalitions are seen as an issue in implementing long term wastewater reuse projects. Dunea sees itself as more stable and less politically motivated, as a 'government Ltd.' As mentioned, the CEO of Dunea sees the 'political inability' to solve problems as a major issue in attempt to close the water cycle. The negative attention for the political play of the game should be a point of attention for HH Delfland. See Chapter 7 on recommendations for HH Delfland.

[2] Process technologists consulted at ozone workshop of PWNT on June 26, 2017

Table 7 - Involvement, attitude and expected issues of other governmental bodies and Dunea

	Involvement	Attitude	Expected issues
Ministry of I&M	• Hardly involved, not seen as their responsibility, few employees working on wastewater reuse	• In general: positive • Wait-and-see	• Public resistance to reuse projects • No urgency of fresh water scarcity problem • Financially viability of reuse projects • Projects always need to take other actors into account, also in other catchment areas
Province of Z-H	• Involved in networks/collaborations	• Positive towards wastewater reuse • Urgency doubted	• To win the trust of intermediary (greenhouse farmers, Dunea) and the public • The availability of alternative water sources creates a lack of urgency • Politicians overreact on incidents which could suddenly end a project • There is not one single problem owner of water scarcity – 'bevoegdheden' divided between water authorities, provinces and municipalities • Closing the water cycle does not always have the same priority as closing the energy and resources cycle • Tension between risks for public health (pollutants) and imposing such strict standards that reuse projects become financially unviable
Municipalities	• Involved in networks/collaborations	• For the long term: positive • Short term: necessity doubted	• The availability of alternative water sources creates a lack of urgency • Financially viability of reuse projects • Closing energy and resources cycles more important than closing the water cycle • Closing the water cycle can have negative effects to other cycles (mainly energy) • Questionable whether pharmaceuticals will be effectively removed in advanced treatment • Transport of water to the location of reuse • Questionable whether wastewater reuse can provide sufficient security of supply with its daily & seasonal fluctuations • Does the required technological system fit with the current (not yet depreciated) infrastructure? • The trend in sustainability is more towards decentralized solutions
Dunea	• Highly involved • Actively exploring possibilities	• Wastewater reuse is a serious option as 'third source'	• 'Selling' drinking water from wastewater reuse is a huge challenge • Social acceptability of wastewater as a single source for drinking water treatment is low • Changes in political 'color' after elections and political 'inability' • Questionable whether advanced treatment technology can fulfill all demands (e.g. low pharmaceutical concentration, high recovery, low toxicity etc.) • Transport of water to the location of reuse: construction of new pipelines required in densely populated areas • Questionable whether wastewater reuse can provide sufficient security of supply with its daily & seasonal fluctuations • Financial aspects of wastewater reuse

4.5 Conclusion on critical action situations

The previous sections have provided a lot of information on the attitudes of relevant actors on closing the water cycle and on the issues they expect in attempting to do so. To conclude this chapter, this section (4.5) draws conclusions on the most critical issues found. This section also determines the critical action situations (Ostrom, 2011) in which these critical issues are addressed. The seventh research question *(What are the critical action situations in which the critical issues are addressed?)* is answered in this way. The critical action situations will be subject of analysis in the next chapter, with the use of the IAD framework of Ostrom (2010). The structure of this section follows the technological design and subsequently the four layers of Williamson's model.

Technological changes

As discussed, technological challenges are mostly mentioned by Dunea. Pilot scale research, as conducted by HH Delfland at the Freshwater Factory, has to provide more information on the feasibility of advanced wastewater treatment. It should also be remembered that the construction of new pipelines is expensive and complex, especially in densely populated areas. For a detailed study on advanced wastewater treatment with ozonation, the master thesis of this author for Sanitary Engineering can be consulted (Van Es, 2017b).

Implications of these technological challenges can have an effect in other, institutional issues. For instance, with new infrastructure to transport wastewater to its reuse consumer, the question rises who will be responsible for the required investments. This issue will be an important aspect of required new arrangements between HH Delfland and Dunea. Analyzing the technological (re)design has provided a lot more insight into required changes to the system.

Layer 1 - Social acceptation of wastewater reuse

From literature research, social acceptation of wastewater reuse was expected to be an issue, especially for potable wastewater reuse. This issue has rarely been mentioned by HH Delfland, but it has been mentioned as a critical issue by the ministry of I&M, province of Z-H and especially Dunea. HH Delfland is aware Dunea is fearing the reaction of the public when announcing wastewater will be used as source for drinking water. However, one board member expects that a reuse project would consist of many steps to slowly get the public used to the idea of potable wastewater reuse. Respondents often mention that other (potable) wastewater reuse projects, for instance in Koksijde (Belgium) and Singapore, have been implemented without much resistance from the public. Others doubt the success of potable wastewater reuse in Singapore though and argue that the situation in the Netherlands is different from those countries.

Both the interaction between Dunea and HH Delfland and between Dunea and its customers will (have to) address the issue of social acceptance. HH Delfland should be aware this aspect is more important than currently felt and expressed within the organization. Public acceptation is one of the main issues is a potable wastewater reuse project and hence a very important aspect of the new relation between HH Delfland and Dunea in a closed water cycle.

Layer 2 – Rules and regulation

Within HH Delfland, the complexity that current legislation imposes on efforts to close the urban water cycle, is often mentioned. Literature research (section 4.2) found that rules and regulations can be an issue in closing the water cycle. This issue can be further specified with the information obtained from the interviews. Based on the interviews, it can be concluded that the issue entails both the difficulty to meet water quality standards and legislation that proves to be conflicting during implementation. Firstly, many respondents within HH Delfland foresee that reuse projects will have difficulties in obtaining required permits due to strict regulation and standards. Legislation works from European level down to the licensing entity (HH Delfland). Respondents varied in addressing the issue at higher (new expected EU standards on pharmaceuticals and the EU 'standstill' principle) to lower levels (obtaining a permit from the licensing entity). Secondly, legislation can be conflicting. Respondents have come up with several stories in which conflicting legislation has frustrated efforts to close the urban water cycle. One example is the company Pharmafilter that attempts to remove pharmaceuticals from wastewater (which can enable wastewater reuse). Due to existing regulation, the company was seen as a waste processor which obliged them to follow an extensive set of rules and regulations (employee HHD).

In the interviews, the difficulty to meet water quality standards in water reuse projects has been stressed most. The issue is in full development with new standards on pharmaceuticals expected from the EU. These standards, written down in Directives, have to be transposed in national legislation. The application procedure for a discharge permit could be impacted by these new standards. The issue is nested in different action arenas at different levels in the four-layer model of Williamson (1998). The action arena in which EU legislation is drafted and the arena in which EU law is transposed in national legislation are examples of related action arenas. Obtaining a permit for wastewater reuse is regarded as critical in closing the urban water cycle. In the next chapter, the action situation of HH Delfland having to obtain a discharge permit (and hence meeting the water quality standards) for wastewater reuse, will be specified with the IAD model. See Figure 26 for a visualization of the issue and action situation. This action situation is suitable for analysis in this research, since the stakeholders involved at this level are accessible for interviews. As mentioned, respondents from HH Delfland see this issue as critical in closing the water cycle. Institutional analysis and resulting recommendations will be highly relevant for HH Delfland.

Layer 3 – 'Play of the game'

The main issues mentioned in the third institutional layer, concern the variety of actors involved and the political nature of the regional water system. One of the main relations in a closed water system, in which wastewater is reused for drinking water production, is between the water authority and the drinking water company. In the cases of Singapore and Windhoek (Namibia), the regional water authority is responsible for the whole water cycle. Thus, new arrangements between the water authority and drinking water companies were not required in closing the water cycle. For the case of HH Delfland, new arrangements between HH Delfland and Dunea are crucial in institutional redesign of the water system.

The action situation of new arrangements between HH Delfland and drinking water company Dunea involves a lot of critical issues. First of all, the actors have to find together whether advanced wastewater treatment (see technological changes in this section) can meet the drinking water quality demands. Secondly, the customers of Dunea must be willing to consume drinking water produced from wastewater (social acceptation - see layer 1 in this section). Thirdly, the contractual arrangements need to capture the allocation of costs for required investment in advanced wastewater treatment and new infrastructure (economic feasibility - see below). See Figure 26 for a visualization how the three issues are addressed in the action situation of new arrangements between HH Delfland and Dunea.

Given the wide range of issues coming together in the action arena of negotiating new arrangements between HH Delfland and Dunea, this research will specify this action arena with the IAD model in the next chapter. Actors in this action situation are open for consultation for this research, which makes it a suitable action situation to analyze.

Layer 4 – Economic feasibility of wastewater reuse

Financial aspects of closing the water cycle are often mentioned by respondents. Part of the board of HH Delfland wants water reuse projects to have a business case. Also mentioned often, is the fact that HH Delfland already has high tariffs due to high capital costs. It is questionable whether it is politically accepted to increase tariffs for inhabitants, farmers and companies to implement a water reuse project with a negative business case. This gives the business case of water reuses projects even more relevance. The importance of financial viability of reuse projects is also mentioned by two other governmental bodies and Dunea.

The economic feasibility of wastewater reuse projects is a critical issue. The issue is highly relevant in the critical action situation of new arrangements between HH Delfland and Dunea, discussed above. The costs associated with wastewater reuse is a determining factor for the outcome of this action arena.

Conclusion

This section has concluded Chapter 4 by choosing the critical action arenas that will be specified in the next chapter. See Figure 26 for a visualization of the critical issues and action situations in which these issues are addressed. The action arenas of meeting legislation to require a permit for wastewater reuse and new arrangements between HH Delfland and Dunea have proven to be the most critical arenas. These action situations address the issues of obtaining a discharge permit, required technological changes, social acceptation and economic feasibility.

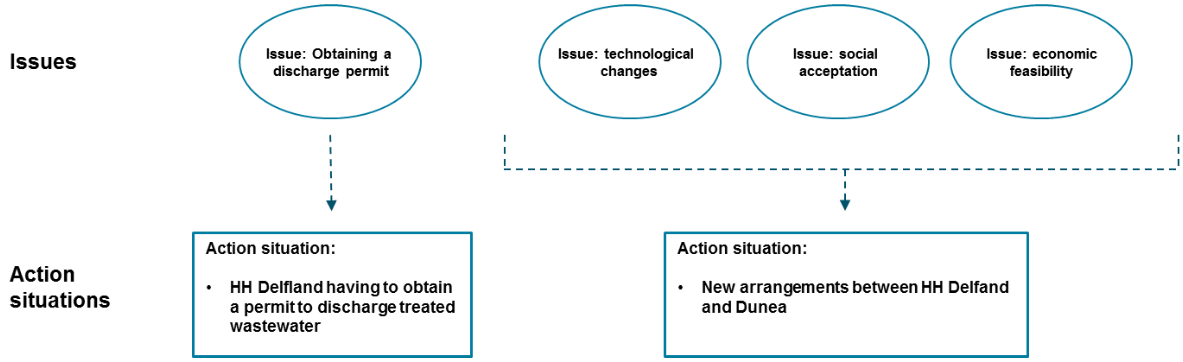
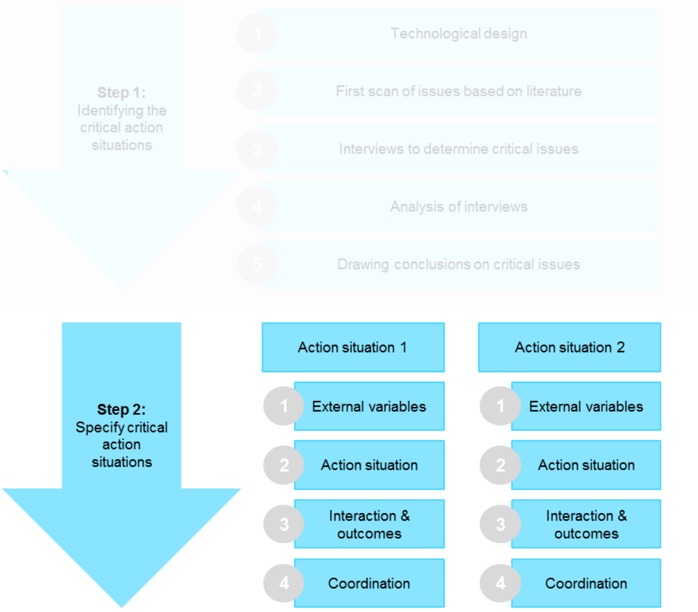


Figure 26 - Overview of issues and action situations in which they are addressed

HH Delfland is currently working on multiple wastewater reuse projects to close the regional water cycle. The 'Freshwater Factory' (FF) project at the wastewater treatment plant 'De Groote Lucht' in Vlaardingen will be used to specify the first action situation. In the FF project, HH Delfland want to reuse wastewater for recreational purposes in the Krabbeplas near Vlaardingen. Another project is the early staged idea of reusing wastewater from the Harnaschpolder and Houtrust treatment plants in Delft and The Hague as infiltration water for the drinking water dunes of Dunea. This project will be used to specify the second action situation. A short description of the projects will be provided in the introduction of the action situations. The next chapter will specify the critical action situations with the IAD framework of Ostrom (2011). An evaluation of the use of the four-layer model of Williamson (1998) in this chapter, can be found in Chapter 6.

5 Step 2: Specifying the critical action situations



The two most critical issues found in the first step require coordination to come to desirable outcomes. The Institutional Analysis and Development (IAD) framework of Ostrom (2010) is well suited to further specify these critical action situations (see section 2.4.3 on the theoretical description of the IAD framework and section 3.2 for the reasoning behind the methodology). With the IAD framework of Ostrom (2010), the key features of the critical action situations can be specified. With physical conditions, community attributes, rules-in-use and the action arena specified for each critical situation, the patterns of interaction and outcomes can be predicted (see Figure 27, which is a copy of Figure 13).

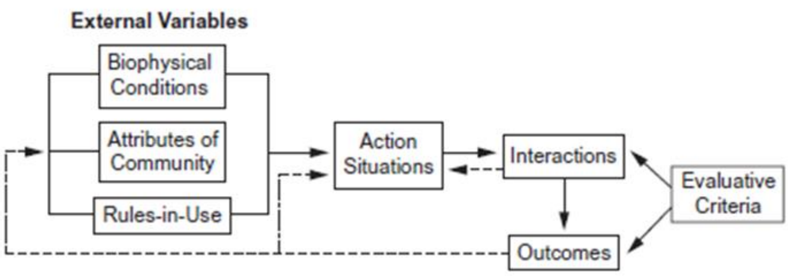


Figure 27 - Schematic representation of the IAD framework (Ostrom, 2011)

Empirical research, structured by the four-layer model of Williamson (1998) has provided insight into the most critical action situations (see the previous chapter). These action situations are:

1. Obtaining a permit for discharging treated wastewater
2. New arrangements between HH Delfland and drinking water company Dunea

Section 5.1 specifies the first action situation and section 5.2 the second action situation.

5.1 Obtaining a permit for discharging treated wastewater

The issue of obtaining a permit for discharging treated wastewater will be analyzed with the 'Freshwater Factory' project of HH Delfland. This section will provide more information on the reuse project and introduces the critical question in this action situation, before a short reading guide for this section is presented.

The Freshwater Factory

The water authority started a wastewater reuse pilot at treatment plant 'De Groote Lucht' in Vlaardigen. 'De Groote Lucht' is one of four large wastewater treatment plants of HH Delfland. The facility has a design capacity of 260.000 people equivalent and treated 219.000 people equivalent in 2015. Treated wastewater is currently discharged into the Nieuwe Waterweg, which quickly flows into the North Sea. The plan of HH Delfland is to transform the current treatment plant into a 'Freshwater Factory' (FF). Treated wastewater will flow to constructed wetlands (the 'Water harmonica') and subsequently into the polders north of the treatment site. The fresh water can support (ground)water levels and enables recreational use of the water body by avoiding algae growth in currently (semi) stagnant waters. A pilot of ozonation and biologically active filtration is installed in summer 2016 to gain experience with advanced wastewater treatment on location. See Appendix II, based on Van Es (2017b), for a more detailed description of the advanced treatment facility. Discharging to the constructed wetlands (instead of the Nieuwe Waterweg) is regarded as a 'new discharge' and hence requires a new permit.

Critical question

The central question in this action situation is whether HH Delfland can obtain a permit for discharging treated wastewater at the location of reuse. The crux of this action situation is well summarized by one respondent, who argued that the tension in this action situation is between preventing risks for public health (by preventing pollutants to be discharged into surface water) and imposing such strict standards that reuse projects become financially unviable. For the first goal one would want to impose the strictest water quality standards. The second goal however shows the downside of doings so. Too strict water quality standards will require such extensive wastewater treatment that the FF project becomes financially unviable. At the moment, the FF project is actively exploring the requirements and procedure of obtaining a permit to discharge treated wastewater.

As mentioned, HH Delfland requires a permit for this new discharge. Interestingly, HH Delfland is both the applicant and the licensor for the discharge permit. Three sections of HH Delfland are involved in this action situation. The three departments of HH Delfland advise the board of the water authority on their respective policy area. In the end, the board makes the decisions and is eventually responsible for the policies of HH Delfland. Firstly, 'Process, contract and wastewater chain management' (PCW) advises the board on the 'Freshwater Factory' and hence on the application for a permit. Secondly, the 'Water system quality' (WSQ) department advises the board on water quality standards in the service area of HH Delfland. Thirdly, the 'Regulation and plan advising' (R&P) department issues permits for discharges under the authority of the board of HH Delfland. R&P tests whether a new discharge will meet the water quality standards as laid down by WSQ. Both R&P and WSQ have to comply to legislation from 'higher' levels, mainly national and European levels. As one of the 22 water authorities in the Netherlands, HH Delfland has limited impact on legislation at higher levels. Thus, these laws and standards can be regarded as exogenously given. Legislation at higher levels shows the nestedness of this action situation within other action situation. When the Member States of the European Union agree on new water quality standards, HH Delfland will have to adjust their standards and permits.

Reading guide

This section will first discuss the external variables of the action situation in section 5.1.1. The next section discusses the action situation along the seven internal working parts (5.1.2). Section 5.1.3 evaluates potential interaction within and outcomes of the action situation. The final part (5.1.4) presents recommendations to HH Delfland in possible ways of coordination of the action situation.

5.1.1 External variables

The external variables of the action arena consist of biophysical conditions, attributes of community and rules-in-use. See section 2.4.3 for a description of the external variable and Figure 21 for a visualization of the IAD framework.

Biophysical conditions

As discussed, the *biophysical conditions* include the physical and material conditions influencing action situations (Polski and Ostrom, 1999). An important aspect is what **type of good** is concerned. In this action situation, wastewater will be reused as surface water for recreational purposes. For this purpose, water can be regarded as a public good since it is non-rival and non-excludable. Recreational water is non-rival since a person's use does not reduce the value to others. It is also non-excludable, since the recreational water is open to anyone, without an admission fee.

The **physical system** is also part of the biophysical conditions of the action situation. The physical system has been sketched in section 4.1. Two technological aspects are required for the wastewater reuse project: advanced wastewater treatment needs to be added to the treatment plant and transport to the 'Water harmonica' and subsequently to the Krabbeplas. Since only part of the wastewater will be reused, the discharge into the Nieuwe Waterweg remains. Advanced wastewater treatment is currently studied in the pilot (Van Es, 2017b). Transport from the treatment plant to the 'Water harmonica' requires new infrastructure. The route of the water will go through uninhabited area. Although constructing new infrastructure always requires a significant investment, the construction is not expected to cause major problems.

The physical and material conditions mentioned above are the physical and human resources and capabilities related to providing and producing goods and services. This section will discuss capital, labor, technology, sources of finance, storage and distribution channels (based on Polski and Ostrom, 1999). The financial position **(capital)** of HH Delfland is relatively unfavorable with a high debt, due to large investments in the recent past (i.e. WWTP Harnaschpolder). Water authorities are allowed to determine their own taxes **(sources of finance)**. The main question with determination of the taxes is whether they are accepted by politicians and in the end by the public, who can vote every four years for the members of the 'Verenigde Vergadering'. HH Delfland has high taxes ('waterschapslasten'), compared to other water authorities. This gives HH Delfland little financial room to meet water quality standards to obtain a permit. This increases the described tension in this action situation. Various actors have mentioned the unfavorable capital position and relatively high taxes as major issues in wastewater reuse projects during the interviews conducted for this research (see section 4.3).

HH Delfland has the availability of policy advisors and process technologists **(labor)** who can implement the proposed technology. Process technologists need to have very specific knowledge on the advanced treatment process. Knowledge on one of the potential advanced treatment processes (ozonation) is gained with the current pilot project. The **technology** that can enable wastewater reuse is available. Multiple technologies might be suitable to reach the desired effluent quality. The techniques are widely applied in drinking water treatment and relatively new, but proven, in wastewater treatment. **Storage** of water is only limitedly possible, given the large volume of wastewater that is continuously treated. Treated wastewater is transported through a new-to-construct pipeline from the treatment plant to the 'Water harmonica' **(distribution channels)**. From here it flows to the recreational waters of the Krabbeplas.

Attributes of community

Attributes of community describe the cultural context of the action situation. This section discusses demographic features of the community, accepted norms about policy activities, common understanding of activities and homogeneity of values, beliefs and preferences about strategies and outcomes, history of prior interactions and the information position of participants in the action situation (Polski and Ostrom, 1999; Ostrom, 2010).

Wastewater is reused for recreational purposes at the Krabbeplas. The **demographic features of the community** are characterized by a high population density. The recreational lake is in the southwest of the Netherlands, surrounded by the city of Vlaardingen, infrastructure (A20 highway) and polders. Inhabitants of Vlaardingen and surrounding cities make use of the Krabbeplas for recreational purposes. The **norms about policy activities** are well known and widely accepted. The PCW department advises the board of HH Delfland on the wastewater treatment plant and the WSQ department advises the board on the quality of the surface water. PCW has the possibility to adapt new treatment facilities as the board and 'Verenigde Vergadering' of HH Delfland desires. As mentioned, WSQ sets the water quality standards in the service area of HH Delfland. R&P grants discharge licenses, for instance to industrial activities, under authority of the board of HH Delfland. The policy activities of HH Delfland are well mandated and clearly assigned to the different departments.

The three departments of HH Delfland have a good **understanding of each other's activities**. The departments are part of the same organization and some of the employees know each other personally. WSQ has joined a consultation group of the FF, which stimulates sharing information and increases understanding of each other's activities. With all three departments being part of the same organization, there is a great **homogeneity of values and beliefs.** Among them are the beliefs of the core tasks of the water authority: 'clean water, dry feet' and the values of good governance and sustainability. The **preferences about strategies** could be less homogeneous. The board of HH Delfland has the ambition to close the water cycle at the treatment plant and at the same time improve water quality of the Krabbeplas by wastewater reuse. PCW is responsible for the implementation of this ambition. On the other hand, the board of HH Delfland also wants the best water quality possible, on which WSQ has to advise the board. Wastewater reuse might not lead to the desired water quality. R&P wants to allow only discharges with a high water quality to protect the water system. At the same time, the board of HH Delfland wants R&P to treat all applicants of discharge permits equally, to prevent accusations of unfair practices. In general, the three departments share the same **preferences about outcomes**. All actors want to ensure sufficient water with a good quality. However, depending on the impact of wastewater reuse on the surface water, the preference of the outcome might be different. For PCW the goal of closing the water cycle in itself might also play a role.

The three departments do not have a **history of prior interactions** regarding permits for discharging wastewater. All treatment plants of HH Delfland are currently discharging on water bodies for which Rijkswaterstaat is responsible. Hence PCW was required to obtain a discharge permit from Rijkswaterstaat up to this moment.

The final aspect of the attributes of the community is the **information position of participants in the action situation**. An example is the knowledge that participants have on the relation between strategies, actions and outcomes. Two interesting things can be noticed on the information position of the three departments of HH Delfland. Firstly, process technologists and technological managers of PCW find it hard to know which standards must be met to obtain a discharge permit for the FF. There is a knowledge gap on which standards for which substances must be met. When one zooms in on the substances and their standards, it appears to be quite complex. Some examples: substances can be reported with a different name in laboratory analysis, or a permit requires information on a group of substances while laboratory analysis only provides concentrations of individual substances. The process technologist must have detailed knowledge of the substances to find out whether the current treatment meets the standards. Another difficulty is whether substances must meet yearly average loads, maximum concentrations or average concentrations. Measuring and analyzing (micro)pollutants in wastewater is a very money and time consuming effort. All these complexities make it hard for PCW to determine whether the FF will be able to meet the water quality standards as set by WSQ.

Secondly, the WSQ and R&P departments are aware that the actions of WSQ can be crucial in the question whether the FF can be implemented or not. The technique that is currently tested in the pilot project is ozonation in combination with biofiltration (see Van Es, 2017b for detailed information on the pilot). This technique effectively removes a wide range of organic micro pollutants, such as pharmaceuticals and pesticides. However, it does not remove heavy metals from the wastewater. R&P could decide that the FF is not allowed to discharge water in which heavy metal concentrations are above the standards. This would mean PCW needs to advise the board of HH Delfland to add an additional advanced treatment step that does remove heavy metals, such as reverse osmosis. Costs for wastewater treatment (investment and operational costs) will in that case become almost certainly too high for the project to be accepted by the board of HH Delfland. At the moment, WSQ and R&P are aware that their action (demanding heavy metals to be removed below water quality standards) will certainly mean the end of the FF project. WSQ has the feeling that they have been involved too late in the pilot project. With the pilot project long on its way, the gravity of the decision to not allow the new discharge of the planned full-scale installation on the water body, increases significantly. WSQ questions whether employees of the WSQ department still dare to decide not to allow the water discharge with the proposed advanced treatment facility (ozonation plus biofiltration).

Rules in use

Rules-in-use are the set of rules needed to explain actions, interactions and outcomes (Polski and Ostrom, 1999). As previously discussed, they specify shared understanding among the participants concerning who may or may not take which actions in the interaction (Ostrom, 2010). Seven types of rules are identified which influence the internal working parts of the action situation (see next section). This section discusses the rules and the next section, on the action situation, discusses the internal working parts.

- Boundary rules specifying how actors were to be chosen

Actors are involved based on the responsibilities formally assigned to them by the Water Authority law ('Waterschapswet') (1991).

- Position rules specifying the set of positions that actors hold

PCW is concerned with advising on the wastewater treatment plants of HH Delfland. The position of WSQ and R&P regards advising on the quality of the water within the service area of HH Delfland.

- Choice rules specifying which actions actors can take in certain positions

The actions actors can take in the action situation are mandated in the 'Waterschapswet' (1991). The choice for certain actions will be determined by the board of HH Delfland and European and national law.

- Information rules specifying channels of communication and what information should (not) be shared

PCW has to share information on the water quality of the treated wastewater with R&P. Communication will be formal, especially to avoid the suspicion of preferential treatment.

- Scope rules specifying the outcomes that could be affected

The scope of this action situation is determined by the responsibilities and authorities of the actors involved.

- Aggregation rules specifying how decisions of actors were to be mapped

R&P decides on whether to grant a permit with the treatment facility. PCW advises on the expected effects on water quality. A study with multiple treatment options is eventually proposed to the board of HH Delfland.

- Payoff rules specifying how benefits and costs were to be distributed

The execution of the 'Freshwater Factory' will be done by PCW, that will bear all costs involved.

5.1.2 Action situation

As discussed in section 2.4.3 on the IAD framework, the action arena is described as 'a conceptual space in which actors inform themselves, consider alternative courses of action, make decisions, take action, and experience the consequences of these actions' (Polski and Ostrom, 1999). The rules affecting the seven internal working parts have been discussed in the previous section. This section discusses the seven sets of variables (the internal working parts) to describe the structure of an action situation.

I. Characteristics of the *actors* involved

Since the 'Freshwater Factory' will discharge its treated wastewater on a water body under the responsibility of HH Delfland itself, both the applicant and the licensor is HH Delfland. As mentioned in the introduction, three departments of HH Delfland are involved. See Figure 29 for an overview of the actors, their responsibility and relations among each other. Of course, many other actors are (indirectly) involved in this action situation. Within the board of HH Delfland, board members have different opinions on wastewater reuse projects (see section 4.4.1). The public is affected since the 'Freshwater Factory' will increase spending of HH Delfland and hence taxes. Industry and (greenhouse) farmers will watch the application procedure to see whether it will affect their (future) applications. European and national legislators are involved since their laws and water quality standards have an impact on the permit requirements. However, the three departments of HH Delfland depicted in Figure 29 are the ones directly involved in the analyzed action situation. Other actors mentioned are involved in other action situations, in which the analyzed action situation is nested. Figure 28 shows the nestedness of the analyzed action situation.

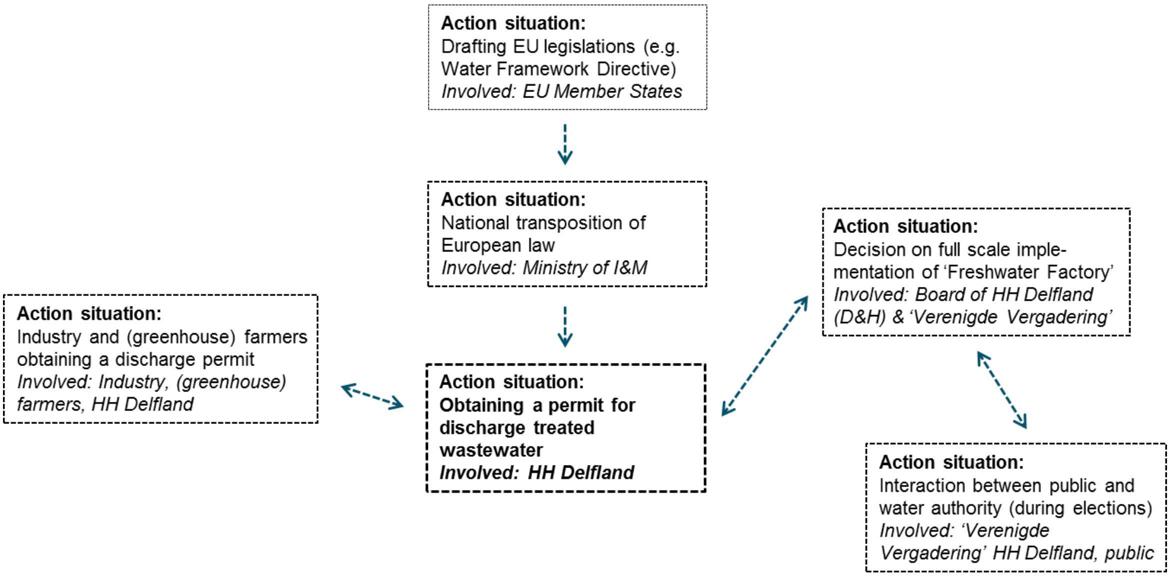


Figure 28 - Overview of nestedness of action situations

II. *Positions* that the participants hold

All three departments are part of HH Delfland and none of them have special connections with other associations, such as farmers or industry. HH Delfland is part of the Union of Water Authorities (UvW).

III. Set of *actions* that actors can (potentially) take (e.g. groundwater extraction)

HH Delfland could well continue with the current process of discharging wastewater into the Nieuwe Waterweg after conventional wastewater treatment. However, they would rather proceed with the 'Freshwater Factory' project. The board of HH Delfland will eventually decide whether to implement a full-scale 'Freshwater Factory'. PCW can advise on multiple advanced wastewater treatment options, as required by WSQ and R&P and as desired by the board of HH Delfland. WSQ can adopt strict standards for surface water quality, when desired by the board of HH Delfland. To a large extent however, the laws and standards have to follow European and national legislation. This limits the set of actions available to WSQ. R&P also has a very limited set of actions available. This department basically has to check whether the planned discharge of the 'Freshwater Factory' meets the standards imposed by WSQ. However, the reality is more ambiguous. It will depend on the interpretation of the different (conflicting) legislation and standards, whether R&P will decide to grant a permit or not.

IV. The amount and nature of *information* available to actors at certain moments (e.g. information on condition of resources)

The previous section (5.1.1) has described the information position of the three departments of HH Delfland. PCW experiences a knowledge gap on what water quality standards must be met for what substances. WSQ, on the other hand, has the feeling they have been involved too late in the FF pilot project. Miscommunication or the lack of communication can have a significant impact on the information available to the actors. WSQ can in turn lack information from European and national levels on what water quality standards are expected in the near future. However, permits are granted based on the legislation and quality standards that are currently in place. When new legislation is adopted at higher levels, these changes will be communicated to the Member States or the water authorities.

V. The *outcomes* of the interaction (e.g. will groundwater extraction result in salt intrusion?)

The outcomes of the interaction will not be limited to the physical system of this action situation. The outcome of the interaction between the three departments of HH Delfland is a balance between obtaining a permit and the costs to meet the required water quality standards. It is for the board of HH Delfland to decide whether the FF will be implemented at full-scale. This process takes place in another action situation (see Figure 28) in which the outcome of the analyzed action situation serves as input. The outcome of the analyzed action situation will be of great influence on other wastewater reuse projects. If the 'stand-still' principle will be deemed more important than reusing wastewater, this will be a signal to future wastewater reuse projects in other parts of the Netherlands. It provides guidelines for other projects on the water quality versus treatment costs trade-off.

VI. The level of *control* participants have over their choices (e.g. do greenhouse farmers act on their own or do they confer with others?)

The three departments of HH Delfland have limited control over their own choices. PCW executes the pilot project, but the decision on constructing a full-scale installation will be made by the board of HH Delfland. PCW delivers information to the board of HH Delfland. The trade-off between costs and water quality will eventually be determined by the board. To a large extend, WSQ has to follow European and national legislation on water quality standards. R&P has to follow the guidelines as drafted by WSQ.

VII. *Costs and benefits* of actions and outcomes (e.g. what is the cost of overexploiting a resource?)

PCW already has a good idea on the costs involved in the FF project. The costs consist of the investment costs and the operational costs of advance wastewater treatment. The operational costs depend on the applied ozone dosage. With an ozone dosage of 1.0 $gO_3/gDOC$[3], as chosen by HH Delfland, the operational costs will be around €120.000 per year (Van Es, 2017b). The energy requirements to apply this ozone dosage is around 600.000 kWh, which is 10.4% of the current total energy consumption by WWTP De Groote Lucht (Van Es, 2017b). Stricter water quality standards will require increasing treatment effort and hence increasing costs (i.e. extra energy costs for a higher ozone dosage applied).

One of the difficulties of the 'Freshwater Factory' is that the project does not have a paying customer for the treated wastewater (board member HHD). The water will eventually be used for recreational purposes in the Krabbeplas. It is not planned to ask an admission fee to the Krabbeplas. Therefore, the benefits of the project are not easy to monetize. The benefits of the project have to be seen in the context of improved landscape and more recreational possibilities for the inhabitants of Vlaardingen and surroundings.

With significant costs and no directly monetizable benefits, the project is deemed to have a negative business case. As discussed in section 4.4.1 (analysis of interviews within the board of HH Delfland), the views on whether a project with a negative business case should be executed, differ within the board. Some board members have drivers on the highest institutional layer (culture & norms) and reason from the values of sustainability and circularity. These board members will hence have a positive attitude towards this wastewater reuse projects. Other board members operate on the lowest institutional level of individual analysis and are driven by the economic costs and benefits. With a negative business case of the 'Freshwater Factory', this project cannot count on support from these board members.

[3] DOC stands for Dissolved Organic Carbon. See van Es 2017b for a detailed description on the application of ozone, including a comparison of operational costs and effectiveness at different ozone dosage.

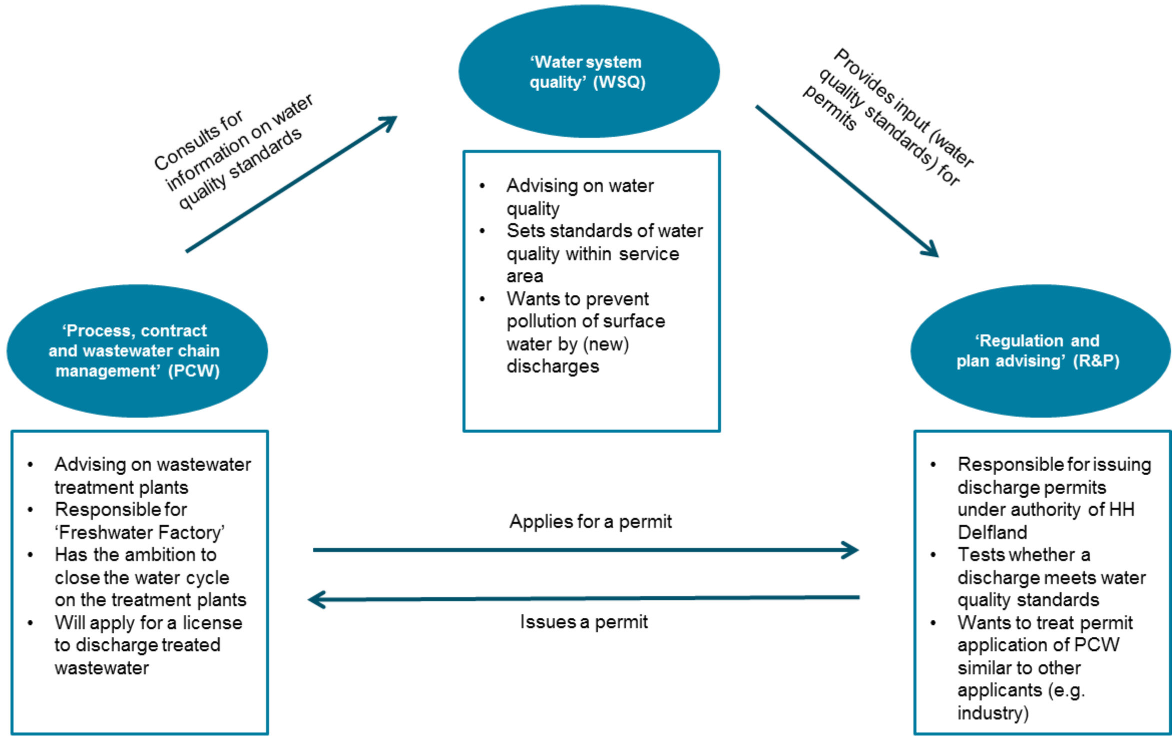


Figure 29 - Overview of actors, relations and responsibilities

5.1.3 Interaction and outcomes

Figure 29 has shown the interaction between the three departments of HH Delfland. As previously discussed, the main question is whether PCW can obtain a permit for discharging treated wastewater at the location of reuse, with the currently proposed treatment. Important to mention is that in this stage of the project, the application for a permit will not be officially filed. The decision to implement the FF at full-scale, will first have to be taken by the board of HH Delfland. However, in order to make a decision, the board needs to have information on whether a permit will be granted with the proposed technological installation. To prepare the political decision on a full-scale implementation, PCW will have to find whether a permit will be granted or not.

The core of the interaction in the action situation is sharing information on standards, principles and considerations. WSQ has joined a consultation group with PCW on the FF to exchange information and learn about each other's principles and considerations. It is highly important that PCW obtains clarity on what standards the FF need to comply to. In turn, WSQ must be clear on the water quality standards and the interpretation of the Water Framework Directive and the 'stand-still' principle. The latter European principle dictates that no water body can have any deterioration due to new actions. Exemptions can be made on grounds of disproportionate cost and/or socio-economic need. It will eventually be a political choice how to balance deterioration of the water quality due to the addition of 'foreign' substances such as heavy metals, and improvement of water quality due to water flow preventing algae growth. WSQ is an extension of HH Delfland politics to give an interpretation of this trade-off.

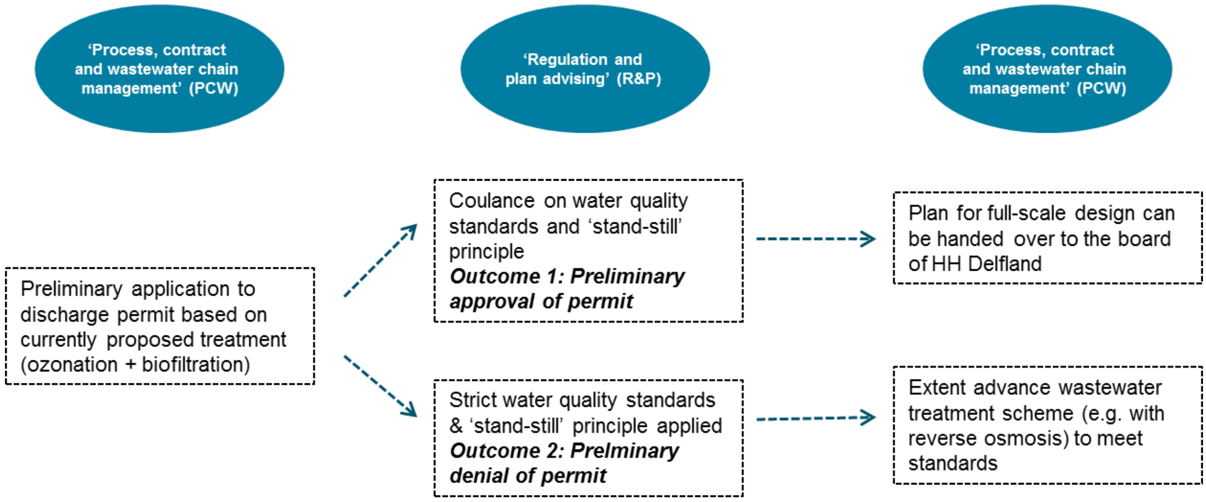


Figure 30 - Overview of potential outcomes

Figure 30 shows two potential outcomes of PCW applying for a preliminary permit to discharge wastewater at the location of reuse. R&P can see the 'Freshwater Factory' as positive for the water body, since the water flow will prevent algae growth in the currently semi-stagnant water. R&P can give an exemption for the 'foreign' substances discharged on the water body on the grounds of disproportionate costs to remove them. When R&P reasons in such manner, a preliminary approval can be given to PCW. With this information, the board of HH Delfland can decide (in another action situation) whether the full-scale 'Freshwater Factory' will be implemented with the currently proposed technological design.

However, another outcome of the preliminary application of a discharge permit is also possible. If R&P strictly applies the water quality standards and the 'stand-still' principle, the discharge of 'foreign' substances on the water body will be deemed unacceptable. The nested action situation of industry and (greenhouse) farmers obtaining a discharge permit could play a role in the rejection of a permit. R&P certainly does not want to generate the image of treating the application of PCW (i.e. of the same organization) differently. Industry and farmers are not allowed to violate water quality standards and the 'stand-still' principle and hence PCW should not be either. In case R&P reasons in such manner, PCW will have to advise the board of HH Delfland to extend the 'Freshwater Factory' treatment scheme, for instance with ion exchange or reverse osmosis. The addition of these advanced treatment technologies will significantly increase investment and operational costs and energy requirements of the 'Freshwater Factory'.

The outcome of this action situation has a great influence on the action situation in which the eventual decision on full-scale implementation of the 'Freshwater Factory' will be made. It is highly questionable whether the board of HH Delfland will decide to implement the 'Freshwater Factory' when a more extensive treatment scheme than currently proposed, is required to obtain a permit (outcome 2). With the great difference in views of the board members (as described in section 4.4.1) it is already questionable whether the project will continue with a preliminary permit with the proposed water treatment (outcome 1). Section 4.4.1 and section 5.1.2 have showed that board members of HH Delfland are either driven by the values of sustainability and circularity or by economic arguments on the business case. A more extensive treatment than proposed will be negatively received by both sides, for different reasons. The first group will find that the higher energy requirements negatively impacts the energy cycle. As discussed in section 4.3 on the issues mentioned during the interviews, many respondents are aware that closing the water cycle should be seen in a broader context of closing the energy and resources cycles. If a wastewater reuse project would only be possible with a disproportionately negative impact on the energy cycle, the board members driven by the values of sustainability and circularity might no longer support the project. On the other side, increased treatment requirements will lead to higher costs and hence to an even more negative business case. Board members driven by economic reasoning will oppose the project even more.

Figure 28 has shown the nestedness of the analyzed action situation within other action situations. Figure 31 shows how the outcome of this action situation influences the closely connected action situation in which the board of HH Delfland decides on full scale implementation of the FF.

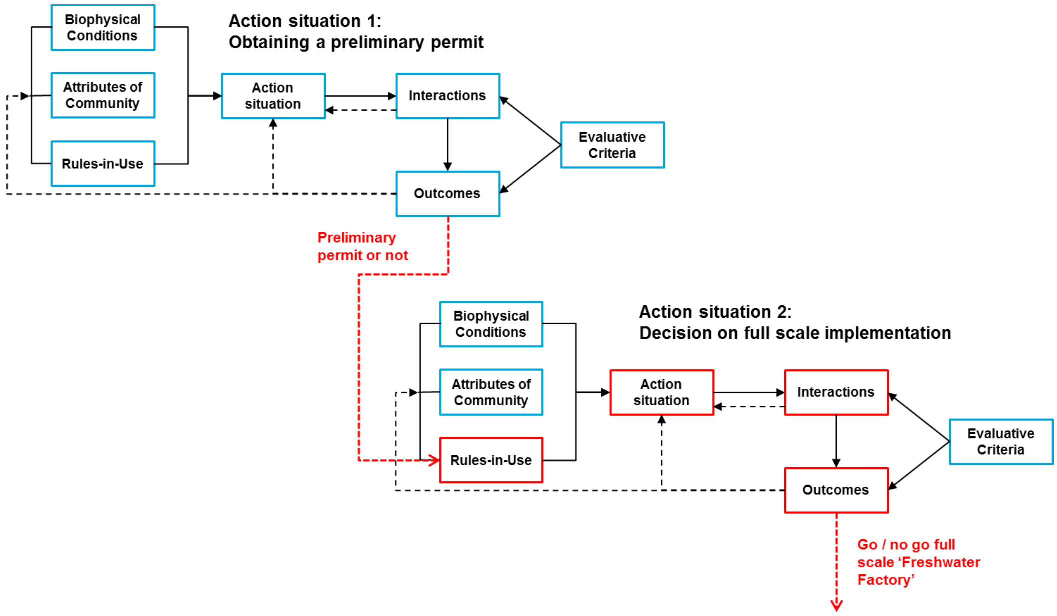


Figure 31 - Influence of outcome on the 'next' action situation

5.1.4 Coordination of the action situation

Obtaining a permit for discharging treated wastewater to the location of reuse, has been found to be one of the critical issues in closing the water cycle. The previous sections have further specified this issue with the use of the IAD framework of Ostrom (2011). The analysis showed that the outcome of the action situation depends on the interaction within the action situation, influenced by the external variables. The outcome of the action situation has a great impact on the action situation in which the decision is made whether to implement a full-scale FF.

From the institutional analysis, two recommendations on coordination of the action situation can be given. Firstly, the **interaction** between the three departments of HH Delfland should be **stimulated**. The three departments tend to focus on their own area of responsibility. Employees of PCW responsible for the FF observed a knowledge gap on what water quality standards have to be met. WSQ has the feeling they have been involved at a late stage of the pilot project. Interaction between the departments will increase the understanding of each other's considerations and trade-offs. For example, PCW can periodically include WSQ in meetings on the experiments conducted in the pilot experiments. In this way, WSQ can get an understanding of the challenges PCW is facing to meet all water quality standards. The crux of this action situation (tension between preventing pollutants to be discharged into surface water and imposing such strict standards that reuse projects become financially unviable) should be addressed by all three departments. The action situation should not be seen as a conflict between PCW on one side and WSQ and R&P on the other side. Together, the departments should find a balance in the trade-off between water quality and costs. This balance can be presented to the board of HH Delfland, that is eventually responsible for making a decision whether the pilot will be upgraded to full-scale.

The second recommendation is to **keep pace in the process** of finding the balance in the trade-off and to **dare to move forward**. The pioneering role HH Delfland has adopted in this wastewater reuse project is recognized and appreciated by other stakeholders. HH Delfland has entered unknown grounds with the FF project. It naturally follows that HH Delfland finds knowledge gaps on the way towards a full-scale wastewater reuse project. Finding the balance between water quality of reused wastewater and the costs required, can in the end only be achieved by actually executing the project. The board of HH Delfland will have to show political courage in deciding to continue the pilot project towards a full-scale installation. To make such a decision, the three departments should at some point present their mutual view on the optimal balance between water quality and costs. After presenting the full-scale design of the FF, the road towards implementation will still be long. Other stakeholders, such as the industry, farmers, recreational users and other governments must be involved in the decision-making process in order to create support for the project and to limit resistance. This process will take place at a different action situation (see Figure 28 on the nestedness of action situations) and will hence not be further specified in this research.

5.2 New arrangements between HH Delfland and Dunea

This section will discuss the issue of new arrangements between the water authority and the drinking water company, required for a potable wastewater reuse project. This issue will be analyzed with the project (in exploration phase) of reusing wastewater from WWTPs Houtrust and Harnaschpolder as infiltration water for the dunes of Dunea. This section will provide more information on the reuse project and introduces the critical questions in this action situation, before a short reading guide for this section is presented.

Potable wastewater reuse

Dunea provides drinking water to 1.3 million people in the western part of the Province of South Holland, including the cities of The Hague, Leiden and Zoetermeer. The source of drinking water production is the 'Afgedamde Maas', which is a side branch of the river Meuse. An alternative source is the river Lek, which can be used when the water quality of the Afgedamde Maas does not suffice. After intake near Andel (at the border of the Provinces of North Brabant and Gelderland) and pre-treatment at Bergambacht, water is transported through pipelines to the dunes between Monster and Katwijk. In the dunes, the river water is infiltrated through infiltration ponds and naturally purified by the dunes. After around two months of residence time, the 'dune water' is pumped up for post treatment. Post treatment consists of softening, activated carbon, cascades and rapid and slow sand filters (see Figure 32).

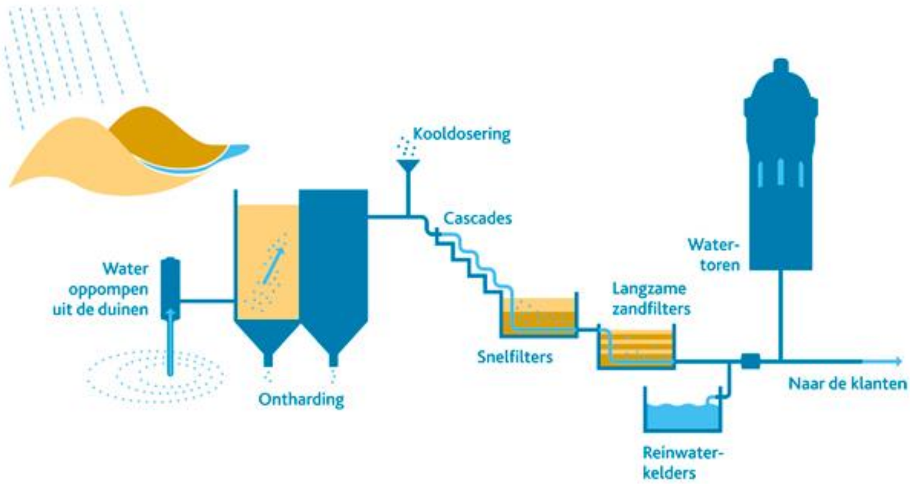


Figure 32 - Water treatment scheme of Dunea (Dunea, 2017)

In recent years, Dunea has found its current (river water) sources threatened by polluting substances such as chemicals, pharmaceuticals and pesticides. The impact of the emission is aggravated by periodic low river water discharges. Periods of low water discharges are expected to occur more often due to climate change. Dunea feels a sense of urgency about freshwater shortages. The current water sources are not found to be sufficiently reliable for drinking water production and hence Dunea is looking for alternative sources.

In 2015, Wim Drossaert is appointed as CEO of Dunea, succeeding the previous CEO who served 22 years. Wim Drossaert focuses both on protecting the current sources and finding new sources for the near future (Drossaert – Dunea). He installed a project team to explore six alternative water sources for the production of drinking water (see section 5.2.2). One of the potential sources is reused wastewater from HH Delfland's wastewater treatment plants Harnaschpolder and Houtrust. The Harnaschpolder treatment plant is located in Delft and has 1.2 million people equivalent (p.e.) design capacity (0.96 million p.e. treated in 2015). Houtrust is located in The Hague and has 390.000 p.e. design capacity (320.000 p.e. treated in 2015). Advanced treatment would be required before wastewater from the two facilities can be transported and infiltrated into the dunes (see section 4.1 on the technological design). Infiltration water has to meet the water quantity and quality standards of the 'Infiltration Decision' as determined by the Province of South Holland.

Critical questions

For wastewater reuse to become an option for drinking water treatment, a whole new arrangement between HH Delfland and Dunea have to be installed. Now, the two actors and their technological system operate completely separated. Based on the interviews conducted (see Chapter 4), this research finds that the most critical issues to be addressed are **technology**, **social acceptation** and **financial arrangements**. The critical question for the technological aspect is whether a treatment option is available that can meet all the water quantity and quality demands. For the issue of social acceptation, it is critical whether the public will accept wastewater as (partial) source of drinking water. Finally, the costs and benefits of the project must be allocated to both actors. This section addresses these three issues, after which a first discussion on the form of collaboration between the two actors is started. This issue is not yet on the agenda of the policy makers, but it will be an important aspect in the process towards a closed water cycle, if the first three aspects have been effectively addressed.

Reading guide

Similar to section 5.1, this section will first discuss the external variables of the action situation in section 5.2.1. The next section discusses the action situation along the seven internal working parts (section 5.2.2). Section 5.2.3 evaluates potential interaction within and outcomes of the action situation. The final part (5.2.4) presents recommendations to HH Delfland in possible ways of coordination of the action situation.

5.2.1 External variables

The external variables of the action arena consist of biophysical conditions, attributes of community and rules-in-use. See section 2.4.3 for a description of the external variable and Figure 13 for a visualization of the IAD framework.

Biophysical conditions

As discussed, the *biophysical conditions* include the physical and material conditions influencing action situations (Polski and Ostrom, 1999). The **type of good** is an interesting aspect of the biophysical conditions. While surface water (the end product of the FF) has more characteristics of a public good, drinking water can be seen as a private good. The use of drinking water is rivalrous and excludable since there is competition between individuals and consumption of a glass of water by one prevents consumption by another. However, access to safe drinking water has been declared a 'human right' by the United Nations (UN) in 2010 (UN, 2010). People require 50-100 liters of fresh water each day to meet their basic needs. Water as a basic need and a 'human right' cannot be regarded as a pure private good. This research however focuses on water consumption in the Netherlands, where everyone has access to drinking water. Water consumed above the requirements for basic needs *can* be regarded as a private good, based on rivalry and excludability. Wastewater delivered by HH Delfland to Dunea can be seen as the raw product of the drinking water production process. Thus, the product of concern in this action arena is a private good.

The **physical system** of this action situation has been described in section 4.1. The technological systems of the drinking water system and the wastewater system are currently completely separated. Closing the water cycle by wastewater reuse will require that the two systems become connected. To integrate these systems, three major changes are required: 1) the raw water intake and transport to the drinking water treatment plant has become obsolete, 2) a new transport system is required to transport wastewater treatment effluent to the drinking water treatment plant and 3) advanced wastewater treatment has to be added to conventional treatment plants. The second and third changes must be addressed in the interaction between HH Delfland and Dunea. Section 5.2.2 further analyzed the interaction regarding this issue.

Based on Polski and Ostrom (1999), this section discusses the resources capital, labor, technology, sources of finance, storage and distribution channels. The financial position (**capital**) of HH Delfland is relatively unfavorable with a high debt, due to large investments in the recent past (i.e. WWTP Harnaschpolder). The financial position of Dunea is more sound with an equity : total balance ratio of 0.886 and a profit of 9.2€M in 2015 and 8.8€M in 2016 (Dunea, 2016). The **sources of finance** of both actors is comparable, in the way that their budget is solely meant for their wastewater and drinking water responsibilities. As discussed in section 5.1, HH Delfland can determine its own taxes. Dunea is allowed to set the tariff for its water. The increase in tariff is limited by law to the Weighted Average Cost of Capital (WACC) (4.2% in 2016) (Dunea, 2016). The drinking water benchmark compares the (financial) performance of Dutch drinking water companies. Water companies are eager to perform well and a low tariff is a major part of their performance. However, the CEO of Dunea has expressed his opinion that he would not mind a tariff increase if needed to guarantee a reliable drinking water supply (Drossaert – Dunea). This notion will be highly important in the interaction on the financial issue (see section 5.2.3). HH Delfland and Dunea have in-house expertise (**labor**) on respectively wastewater and drinking water treatment and transport. Wastewater treatment requires a lot of biological expertise, since it makes use of bacteria to treat the water. Drinking water treatment is more chemical/physical of nature and requires a different field of expertise. Both HH Delfland and Dunea currently make use of rather conventional treatment steps (**technology**). HH Delfland operates conventional activated sludge treatment plants according to the University of Cape Town Process. Nitrogen and phosphorous removal is included in the treatment (Van Es, 2017b). Research on advanced technologies (advanced oxidation, Nereda) is currently conducted by HH Delfland in collaboration with, among others, TU Delft. Although drinking water treatment is common to make use of more advanced technologies (e.g. reverse osmosis, advanced oxidation), Dunea has a rather conventional treatment scheme after natural purification by the dunes (see Figure 32).

Whereas **storage** is hardly possible for HH Delfland, Dunea can make use of storage in dunes. A volume of water equal to two weeks of drinking water production is stored in the dunes. However, fluctuations of groundwater levels in the dunes is undesirable for the ecology and purifying ability of the dunes. The lack of storage is crucial in the sense of urgency about water scarcity of Dunea. When water intake must be stopped due to pollution of the river, the drinking water supply is threatened within weeks. The technological system, and hence the **distribution channels**, of both organizations are completely separated. HH Delfland and Dunea are responsible for the transport of treated wastewater to the location of discharge (North Sea) and the transport of drinking water to the consumer respectively.

Attributes of community

Attributes of community describe the cultural context of the action situation. This section describes demographic features of the community, accepted norms about policy activities, common understanding of activities and homogeneity of values, beliefs and preferences about strategies and outcomes, history of prior interactions and the information position of participants in the action situation (Polski and Ostrom, 1999; Ostrom, 2010).

The **demographic features of the community** have similarities and differences for both organizations. Both HH Delfland and Dunea operate in a densely-populated area in the (south) west of the Netherlands. The service area of both organizations differs. The service area of HH Delfland is party supplied with drinking water by Evides. Dunea also supplies water in the service are of HH Rijnland. Dunea has to deal more directly with customers, in the sense that the company is delivering them a product (drinking water). HH Delfland operates at a further distance from the clients, by processing their wastewater (and keeping their feet dry). The wastewater is (currently) not coming back to the customers, so HH Delfland has less direct contact with its customers. The interviews conducted for this research show that the difference in distance to the customers results in a different perception of the social acceptation issue (see section 4.4.4). HH Delfland does not see social acceptation of potable wastewater as an issue, while Dunea does.

The **norms about policy activities** are well known and widely accepted. Both organizations are responsible for their own tasks and do not interfere with each other's activities. In general, there is a **common understanding of activities,** in the sense that both are treating water and dealing with 'water through pipes'. However, the purpose and water quality parameters differ to a great extent (see the discussion on labor above). The organizations do not speak the same language. The respondent from Waternet, in which wastewater and drinking water are integrated in one organization, gave an example of the difference in language. 'Safety' means no risks in water quality for drinking water company, while it means 'no accidents with employees' for water authorities.

The underlying **values and beliefs are homogeneous**. Both organizations care for high quality water to consume (Dunea) and to discharge into the environment (HH Delfland). They both try to minimize the use of energy and resources and to limit costs for the consumers/inhabitant. Both organizations are part of the Dutch government, although HH Delfland is a democratic institution and Dunea is a ‘government Ltd.’ (‘overheids N.V.’). Both organizations want the same **outcome**: a safe and reliable water system. In this, Dunea is more focused on security of supply of drinking water and public health and HH Delfland is more focused on water quality of surface and groundwater.

HH Delfland and Dunea have a very limited **history of prior interactions.** Until recently, Dunea was a relatively closed organization, hardly interacting with other actors in the water system. HH Delfland still does not have an account manager for Dunea, whereas they have for many other actors (e.g. municipalities). The new CEO of Dunea wants the organization to be more open towards other stakeholders. He has appointed ‘strategic managers’ to connect with stakeholders in the water system (Drossaert – Dunea). Dunea has recently joined the, already existing, ‘Network Wastewater chain Delfland’ (NAD) (Netwerk Afvalwaterketen Delfland) in which HH Delfland and municipalities work together in the regional water system. Section 5.2.3 will further discuss the implication of the very limited history of prior interactions between both organizations. With limited interaction, it is questionable whether both actors are aware of their **information position in the action situation.** Dunea is exploring five more sources of drinking water, in which HH Delfland is not involved. In turn, HH Delfland mentions they can also look at other options for wastewater reuse from Harnaschpolder and Houtrust (employee HHD). However, both actors are aware of the impact of their decisions on the action arena. Both actors can cause a sudden end of the potable wastewater reuse project, based on other actions (e.g. selection of another source for drinking water production than wastewater).

Rules in use
As mentioned in section 5.1, *rules-in-use* are the set of rules needed to explain actions, interactions and outcomes (Polski and Ostrom, 1999). Seven types of rules are identified, which influence the internal working parts of the action situation (see section 5.2.2 on the internal working parts). This section discusses the rules and the section on the action situation (5.2.2) discusses the internal working parts.

I. Boundary rules specifying how actors were to be chosen

The actors in this action situation are geographically chosen. The Harnaschpolder and Houtrust treatment plants of HH Delfland are close to the dunes of Dunea. Rijnland is also active in the surrounding area, for instance with their wastewater treatment plant in Leiden. To limit the scope of this research, Rijnland is not involved in this action arena.

II. Position rules specifying the set of positions that actors hold

HH Delfland is responsible for treatment and disposal of wastewater. The Drinking Water Law (2009) assigns the responsibility for production and supply of drinking water to Dunea.

III. Choice rules specifying which actions actors can take in certain positions

To execute their responsibilities, HH Delfland and Dunea can determine their own strategies. Within HH Delfland the most important decisions are made by the board members (Dijkgraaf & Hoogheemraden). A coalition is formed after elections that are held every four years. Decisions of HH Delfland are made by an elected coalition. Decisions of Dunea are made by unelected board members and are hence further removed from politics. The board of Dunea consists of three members that are appointed by the shareholders. All shareholders are municipalities in the service area of Dunea. The influence of politics within Dunea is limited to shareholder meetings and the decisions are made by the appointed board members.

IV. Information rules specifying channels of communication and what information should (not) be shared

HH Delfland and Dunea have shared information in a preliminary feasibility scan of the potable wastewater reuse project (Zwolsman et al., 2017). Account managers of HH Delfland and ‘strategic managers’ of Dunea are the main channels of communication between the actors. The chairmen of both organizations (Dijkgraaf of HH Delfland and CEO of Dunea) know each other and communicate on this project.

V. Scope rules specifying the outcomes that could be affected

The scope of this action situation is determined by the responsibilities and authorities of the actors involved.

VI. Aggregation rules specifying how decisions of actors were to be mapped

Since the interaction between a water authority and a drinking water company on potable wastewater reuse is a novelty in the Netherlands, there are no aggregation rules determined. The process in the coming years will show how decisions of actors were to be mapped.

VII. Payoff rules specifying how benefits and costs were to be distributed

There are no specific rules that determine how benefits and costs should be distributed. HH Delfland is responsible for wastewater treatment and hence must bear the costs for the treatment. When extra treatment (and hence extra costs) is required to allow potable wastewater reuse, there are no rules on whether HH Delfland or Dunea should bear these extra costs. The interaction of the actors will have to result in an agreement on the distribution of costs and benefits. The fact that there are no rules on this matter makes it an interesting action situation to analyze (see section 5.2.2 on the interaction).

5.2.2 Action situation

As discussed in section 2.4.3 on the IAD framework, the action arena is described as 'a conceptual space in which actors inform themselves, consider alternative courses of action, make decisions, take action, and experience the consequences of these actions' (Polski and Ostrom, 1999). The rules that affect the seven internal working parts have been discussed in the previous section. This section discusses the seven sets of variables (the internal working parts) to describe the structure of an action situation.

I. Characteristics of the *actors* involved

The main actors in this action situation are water authority Delfland and drinking water company Dunea. HH Delfland is responsible for wastewater treatment and disposal and Dunea for drinking water treatment and transport to the consumer (see Figure 33). The board of HH Delfland is internally divided within this action arena (see section 4.4.1). In this action arena, HH Delfland is regarded as one actor speaking with one voice. HH Delfland has to solve internal debate, so that a clear position can be taken in this action situation. Dunea has already addressed the political nature as an issue for the success of this project in the interviews (i.e. short term vision of politicians, changing color of coalitions). The project of potable wastewater reuse will require large, long-term investments and hence requires clear and consistent support of the actors involved. The coalition of HH Delfland has expressed its ambition to close the regional water cycle. The interviews conducted for this research show that finding a business case for wastewater reuse projects is an important requisite to obtain support from some of the board members (see section 4.4.1 on analysis of the interviews within the board of HH Delfland).

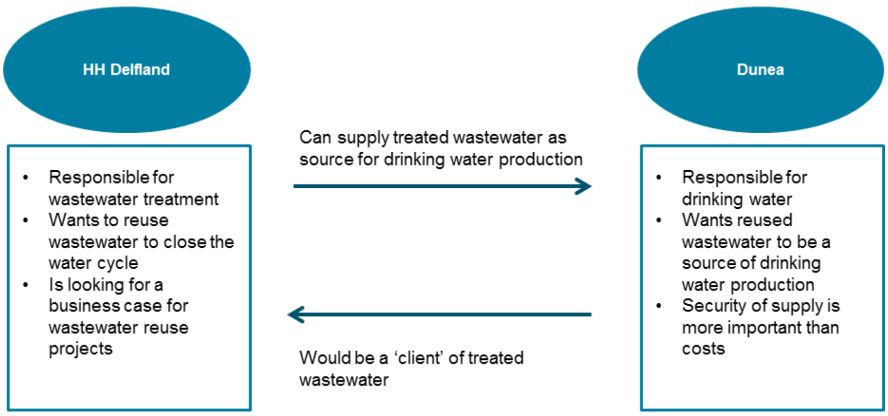


Figure 33 - Responsibilities and relations HH Delfland and Dunea

II. *Positions* that the participants hold (e.g. members of farming association)

HH Delfland is part of the Union of Water Authorities (UvW) and Dunea is part of the Association of Drinking Water Companies (Vewin).

III. Set of *actions* that actors can (potentially) take (e.g. groundwater extraction)

Both actors can choose from a wide set of actions, which complicates this action situation. Only when all aspects (see section 5.2.3 on the interaction) in this action situation turn out positively, the potable wastewater reuse project will commence. Figure 34 shows that HH Delfland has three alternatives. They can continue their operation as usual, i.e. conventional treatment of wastewater and subsequently discharging into the North Sea. The second option is to reuse wastewater from Harnaschpolder and Houtrust for their own purposes. This own purpose could, for instance, be water level management or enhancing the water quality of recreational water bodies (which is the purpose of wastewater from De Groote Lucht). The third option is the one in which wastewater would be infiltrated in the water dunes of Dunea, after advanced treatment at the plants.

Dunea is evaluating an even wider range of options in their quest for a new source of drinking water production. The only constraint that has been imposed by the CEO of Dunea is that the new source should not be river water (since that is the current source) (Drossaert – Dunea). A project team is currently examining six potential sources, including groundwater, surface water, sea water, rain and wastewater (Zwolsman – Dunea). The first option (see Figure 34 below) is to continue using the river Meuse as source, potentially with extra upstream discharge. This could alleviate problems with periodic low discharges in the river Meuse. This option is considered as a short-term option, before other sources are available. The second option is to catch brackish groundwater ('kwel' in Dutch) in the polders. Surface water (e.g. Valkenburgsemeer) is another option under investigation. Fourth option is desalination of sea water from the North Sea, abundantly available but very energy intensive to produce drinking water from. Fifth option is catching and storing precipitation. The sixth option is that of the collaboration with HH Delfland by reusing wastewater from the Harnaschpolder and Houtrust treatment plants. For the interaction in the action situation it is important to realize that both actors have multiple alternatives for the wastewater reuse project.

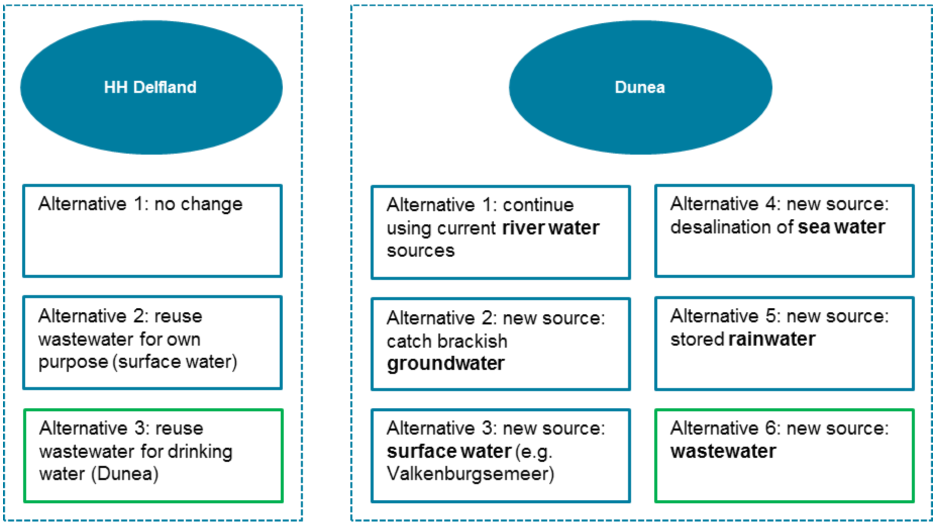


Figure 34 - Set of actions for HH Delfland and Dunea (no preferred order)

IV. The amount and nature of *information* available to actors at certain moments (e.g. information on condition of resources)

As described in section 5.2.1 on history of prior interactions, Dunea is now more open towards other stakeholders in the water system. With more interaction comes sharing of information, for instance on the search for new sources of drinking water production. Dunea has a lot of information available on the condition of their current source, since they are closely monitoring the water quantity and quality. However, they have little information on pollution discharges from upstream industry. Changes in water quality can come as a surprise for Dunea, which results in sudden intake stops.

The amount of information available to both actors is a crucial point within this action situation. Information needs to be shared on a wide range of subjects, such as water quality standards, treatment efficiencies and by-products of treatment. The actors need to trust each other and need to understand each other's way of working.

Also, information on the set of actions (discussed in internal working part II above) is crucial for this project. Both actors can make decisions that would highly impact the action situation.

V. The *outcomes* of the interaction (e.g. will groundwater extraction result in salt intrusion?)

The outcomes of the interaction on technology, social acceptability and financials (see section 5.2.3) will determine whether a collaboration between the two organizations can take place. The wide range of strategies available to both actors (see internal working part II) implies that a collaboration will only be the outcome of the interaction if all issues can be addressed. Section 5.2.3 discusses the three main issues in this action situation.

VI. The level of *control* participants have over their choices (e.g. do greenhouse farmers act on their own or do they confer with others?)

As previously mentioned, both actors have a high level of control over their choices. It is their responsibility to achieve a good and reliable wastewater and drinking water management. Both actors have a high degree of liberty in determining the way to achieve these goals.

VII. *Costs and benefits* of actions and outcomes (e.g. what is the cost of overexploiting a resource?)

The costs and benefits of actions and outcomes are a very important issue in this action situation. Investment and operational costs of a wastewater reuse project will be substantial. Both actors want to limit their costs to limit their taxes or tariffs. The benefits of the project can be found in security of supply of drinking water. This is hard to monetize, but it is highly important for Dunea. A shortage of drinking water in the densely-populated service area of Dunea can cause millions of euro's economical damage within a short time.

5.2.3 Interaction and outcomes

The main interaction in this action situation will concern three issues of the wastewater reuse project: technology, social acceptability and financial arrangements. When outcomes of the interaction on these issues have been obtained, the form of collaboration between HH Delfland and Dunea can be a next point of discussion. This section hence first discusses the three main issues of this action situation, before the form of collaboration between the two actors is shortly addressed.

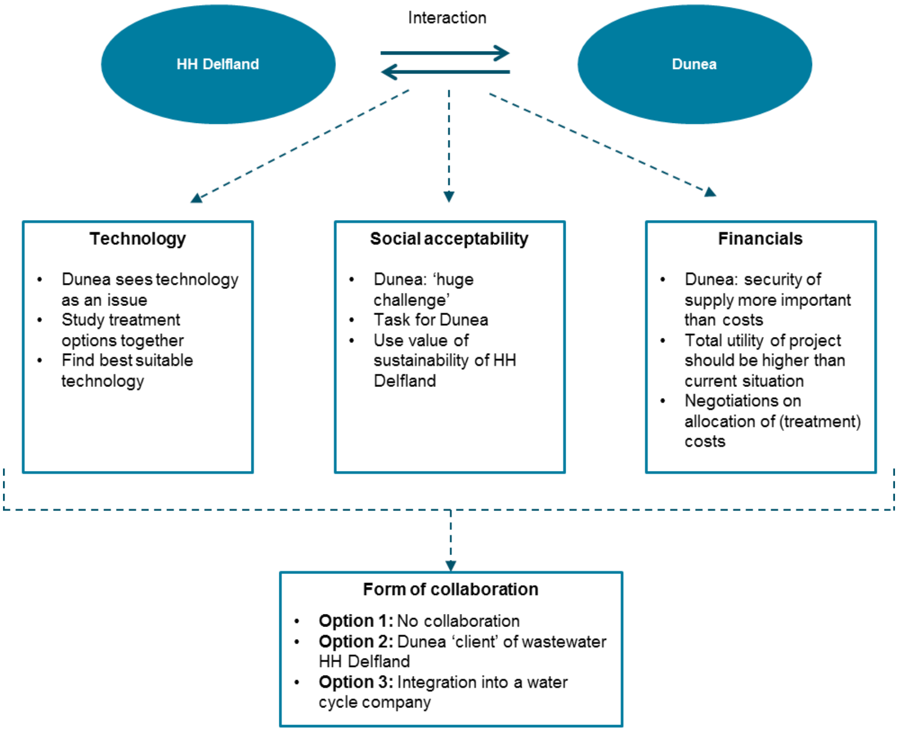


Figure 35 - Overview of form of action situation of arrangements between HH Delfland and Dunea

Technology

As discussed in section 4.3 on the issues as presented in the interviews, technology is not part of the institutional analysis. However, Dunea has clearly mentioned technology as an important issue in wastewater reuse projects. Respondents of HH Delfland often argue that technology is not a big issue, since they believe that advanced treatment technology is available and applicable. The pilot at WWTP De Groote Lucht with ozonation and biofiltration shows however that many questions rise during the testing phase.

Important in the interaction of the two actors on the required technology, is that they do not talk the same 'technological language', i.e. not using the same water quality parameters. Exchanging information and knowledge on water quality parameters and standards used is crucial in the interaction. Currently, both reverse osmosis and ozonation are under investigation as advanced treatment option. Both treatment options have their advantages and disadvantages. Reverse osmosis for instance produces a waste stream of brine water and ozonation can form the carcinogenic by-product bromate. Dunea highly questions whether there is a treatment option that can fulfill all requirements. HH Delfland and Dunea together must investigate the options for advanced treatment, in order to decide whether the project is technologically feasible. If so, the most suitable technology can be determined.

In a new technological design, the actors must be careful where the interfaces of the technological components are designed. Sections 2.3 (theoretical framework – technological design) and 3.1 (methodology – technological design) explained that complexity rises at the interfaces of the system, where ownership of the system is transferred from one actor to the other or where different system components need to connect. When HH Delfland will supply treated wastewater to Dunea, this will yield a new technological interface. A question to be answered, is where the transfer of ownership and responsibility from HH Delfland to Dunea will be placed. The first option is directly after advanced wastewater treatment at the facilities of HH Delfland (interface I in Figure 36). The second option is to transfer ownership and responsibility at the location where new-to-construct pipelines connect with existing infrastructure that currently transports river water to the dunes (interface II in Figure 36). The final option is less likely; that HH Delfland is responsible for the transport of water through new and currently existing pipelines and that the transfer of ownership is located at the infiltration sites of Dunea.

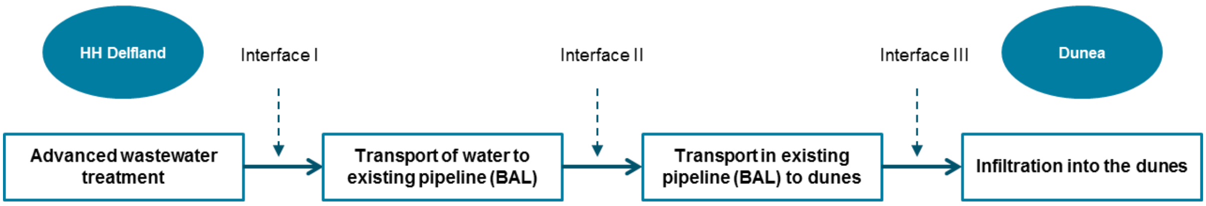


Figure 36 - Options for transfer of ownership and responsibility from HH Delfland to Dunea

Dunea has already decided that the dunes will remain an essential part of the treatment scheme. Even though it might not be technologically required, the public perception of drinking water from the dunes is so positive that Dunea wants to keep the dunes in the treatment scheme (see the next aspect of the interaction).

Social acceptability

The second important issue of the new collaboration between HH Delfland and Dunea for potable wastewater reuse is the social acceptability. HH Delfland does not see social acceptability as a major issue while Dunea sees it as a 'huge challenge'. One of the consequences of the expected issue is that Dunea does not want wastewater to be the sole source of infiltration water. Dunea argues that it will be easier to sell the story that wastewater is only part of the source of drinking water.

The previously used four-layer model of Williamson (1998) provides an interesting view on the interaction regarding this issue. Figure 37 shows the interaction at the highest institutional level of cultures and norms. Both the value of sustainability and issue of social acceptation of wastewater reuse projects are located at this level (see Chapter 4). Firstly, part of the board of HH Delfland operates from the values of sustainability and circularity. Secondly, social acceptation of wastewater reuse project is mentioned as a 'huge' challenge by Dunea. In the interaction between HH Delfland and Dunea, both aspects can be linked to each other. This link can be an opportunity to 'sell' the project as a sustainable and circular project. The public is more and more driven by these values and might be more willing to accept potable wastewater reuse when these values emphasized. HH Delfland can support Dunea by actively communicating the project through all sort of channels (open days, website, news, information at treatment plants), as is done by Flemish water company IWVA in the Koksijde reuse project (see section 4.2).

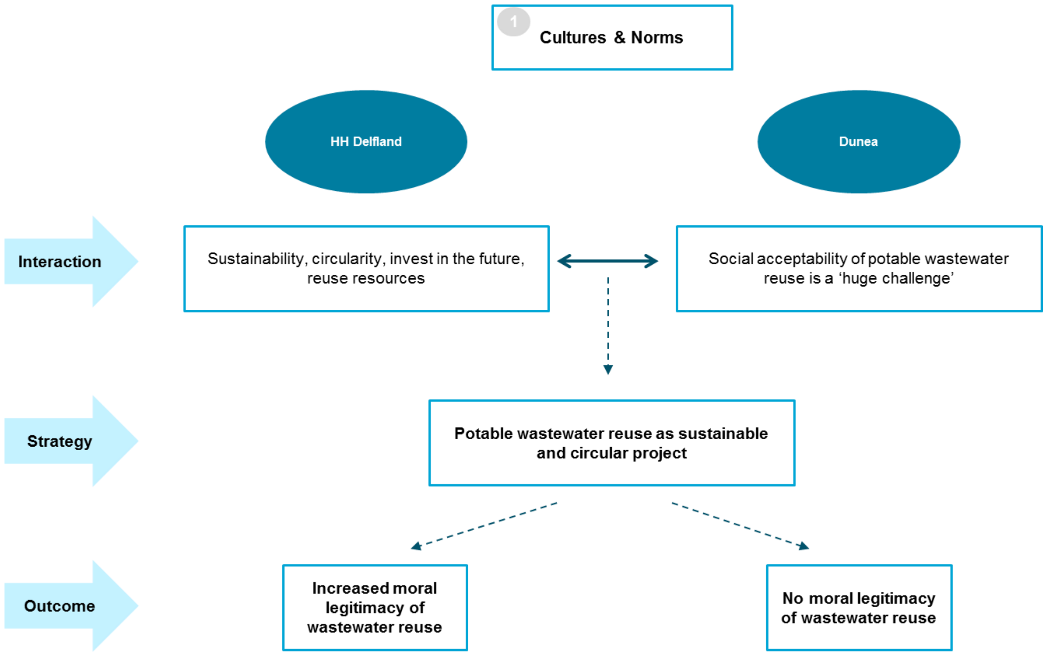


Figure 37 - Interaction, strategy and outcome regarding the issue of social acceptability

In addressing the issue of social acceptability, this action situation is closely linked with the action situation of Dunea interacting with its customers to 'sell' wastewater as source of drinking water production. Dunea is more directly involved with the customers than HH Delfland (see section 5.2.1 on the demographic features of the community).

In obtaining social acceptance of the potable wastewater reuse project, Dunea can use research conducted by Harris-Lovett (2015) on the social acceptability of potable wastewater reuse projects in California, USA. She finds that successful potable wastewater reuse projects engage in a portfolio of strategies to address three main dimensions of legitimacy. These three dimensions of legitimacy are 1) pragmatic legitimacy, 2) moral legitimacy and 3) cognitive legitimacy. Pragmatic legitimacy is based on the end user's self-interest calculations about the direct benefits of a reuse project. The second, moral legitimacy, is established when a project corresponds to societal values. Cognitive legitimacy is based on compliance with taken-for granted routines ('the way we do things') (Harris-Lovett, 2015).

The interaction of between HH Delfland and Dunea, as depicted in Figure 37, can contribute to obtaining moral legitimacy for the potable wastewater reuse project. The values of sustainability and circularity of closing the water cycle can match the social values of Dunea's customers. However, not all customers of Dunea will share the importance assigned to the value of sustainability. The belief that drinking treated wastewater is 'dirty' might be a stronger driver for a large part of the population. Expecting that all customers will welcome the wastewater reuse as a sustainable project, is regarded as a naïve perspective by Dunea (Drossaert – Dunea). Nevertheless, this strategy will help to sell the project to customers that share the values of sustainability and circularity. The other two dimensions of legitimacy (pragmatic and cognitive legitimacy) will be crucial in obtaining acceptation from customers that are not driven by these values. Figure 38 shows that the interaction between Dunea and the customers will be important in obtaining pragmatic and cognitive legitimacy. The arrangement between HH Delfland and Dunea can contribute to obtaining moral legitimacy.

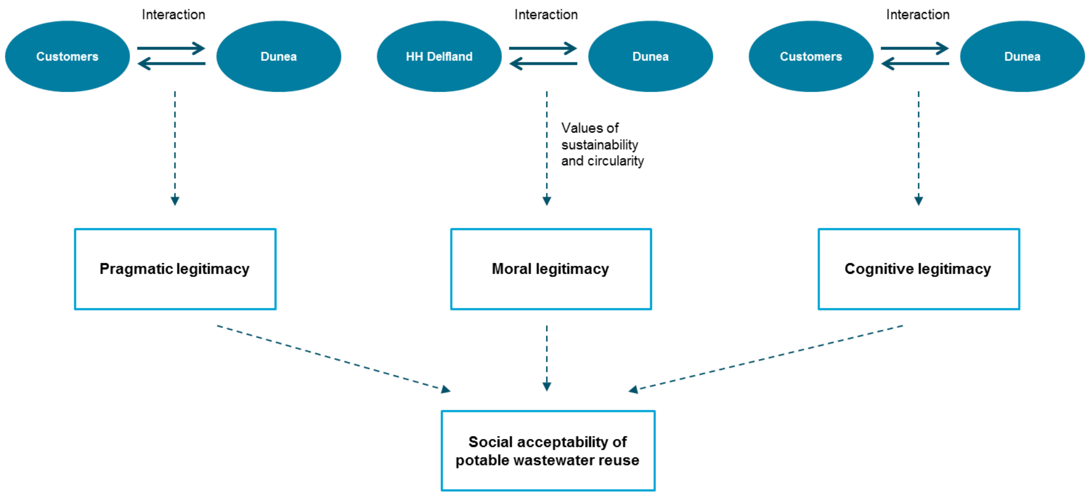


Figure 38 - Obtaining three dimensions of social legitimacy, based on Harris-Lovett (2015)

Dunea is the actor that sets the pace for this part of the project. Dunea has clearly indicated the project will not be executed when the public acceptance is found to be too low. Dunea should clearly communicate the process of obtaining social acceptability to HH Delfland. The eventual outcome of these action situations is either social acceptance of potable wastewater reuse or no social acceptance.

Financial arrangements

As emphasized by virtually all respondents, the financial aspects are an important aspect of a wastewater reuse project. The economic feasibility of wastewater reuse projects has a great impact on the financial arrangements between HH Delfland and Dunea. The issue of economic feasibility is located at the lowest institutional level of the four-layer model of Williamson (1998) of individual analysis. Section 5.1 on the wastewater reuse project at WWTP De Groote Lucht for recreational purposes has explained the difficulty of a positive business case of this project, due to the public nature of the water. The potable wastewater reuse project has more potential for a positive business case, since treated wastewater can be regarded as a private good (see section 5.2.1 on the type of good). As opposed to the reuse project at De Groote Lucht, the potable reuse project *does* have a 'customer' for the treated wastewater: drinking water company Dunea (and eventually the customers of Dunea). The question is however whether this customer is indeed willing to pay for the treated wastewater.

As section 4.4.1 on the positions within the board of HH Delfland has explained, part of the board is mainly driven by the business case of wastewater reuse projects. An opportunity can be found in the willingness of Dunea to pay for a reliable and high quality water source. HH Delfland is currently struggling with its financial position. However, the CEO of Dunea is not scared of raising the water tariff if this is required for a reliable source of drinking water production (Drossaert – Dunea). The current sources are not regarded to be reliable and hence Dunea is willing to pay for a new source.

An interesting aspect of this issue is whether the EU or national government will make removal of organic micro-pollutants from the water system obligatory. If they decide to do so, the question is to whom the responsibility of removing organic micro-pollutants (pharmaceuticals, pesticides etc.) will be assigned. When water authorities will become responsible, HH Delfland must add advanced treatment steps to remove these pollutants, even if the wastewater is not reused by Dunea. The 'standard' treatment in this scenario would produce high-quality water. Reusing the high-quality wastewater would make a lot more sense than disposing it into the sea (which is the current practice). When the water authorities are responsible for the removal of organic micro-pollutants, the costs of advanced treatment will likely be borne by HH Delfland. However, currently there are no standards for organic micro-pollutants for wastewater discharges. HH Delfland can continue to discharge wastewater with these pollutants into the North Sea (alternative 1 in Figure 34). If Dunea wants to reuse the wastewater for drinking water production, the organic micro-pollutants do have to be removed to achieve the desired drinking water quality. HH Delfland will in that case argue that they are not responsible for the removal and hence should not be the ones having to pay for the advanced treatment.

A lot of financial aspects must be negotiated by HH Delfland and Dunea in a new arrangement. Required technological changes are an important aspect of the costs. The willingness of both parties to invest and to bear operational costs will be crucial for this reuse project to commence. Figure 39 shows that the importance that Dunea assigns to security of supply offers an opportunity for this issue. Dunea would be willing to increase the drinking water tariff to finance advanced wastewater treatment. Board members of HH Delfland that are drive by the business case of reuse projects, will give their support if this project can become at least cost neutral.

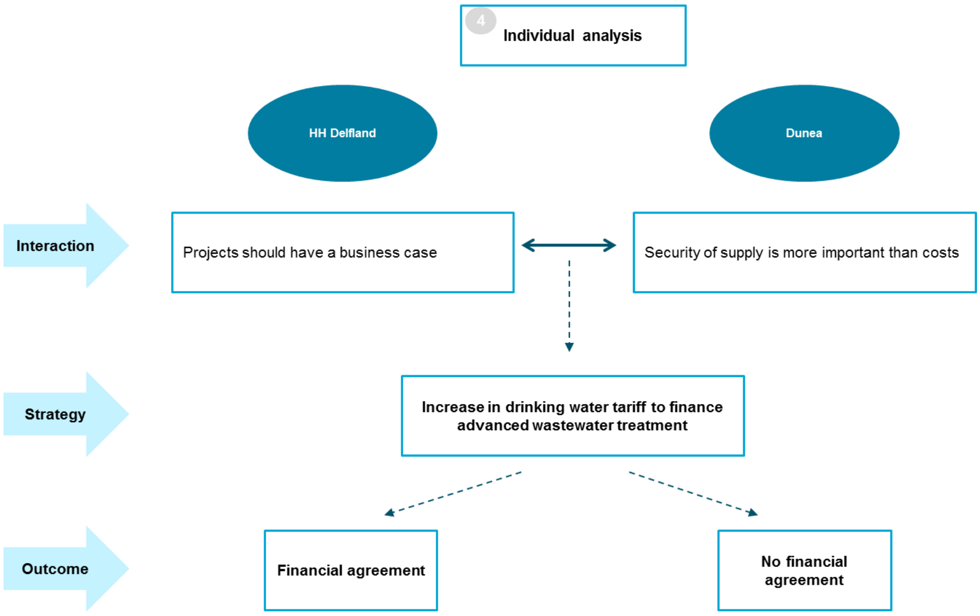


Figure 39 - Overview of interaction, strategy and outcome of the financial issue

Summary of social acceptability and financials

Figure 40 shows how the two issues of social acceptability and financials can be aligned between HH Delfland and Dunea. The project offers opportunities to address the two main driving values (sustainability and business case) of the board members of HH Delfland. During the exploration and negotiations, the process is likely to find issues in the formal institutional environment of level 2. At the moment, no specific issues for the potable wastewater reuse project have been mentioned at this institutional layer. The experience from the Freshwater Factory project is that formal institutional issues will rise during the pilot project and towards implementation of a full-scale design. The negotiations will take place at the institutional level of governance (layer 3). The chairman (Dijkgraaf) of HH Delfland is open to a collaboration with Dunea. The new CEO of Dunea focusses his attention on relation building and communication with other stakeholders. The appointment of a new CEO of Dunea in September 2015 offers a window of opportunity for such collaboration. The question on the form of collaboration between HH Delfland and Dunea, is not yet on the agenda of the two actors. Dunea stated they have not yet thought about the form of collaboration. It will be an important question for later stages of the potable wastewater reuse project though. The next section discusses the interaction on the form of collaboration between HH Delfland and Dunea.

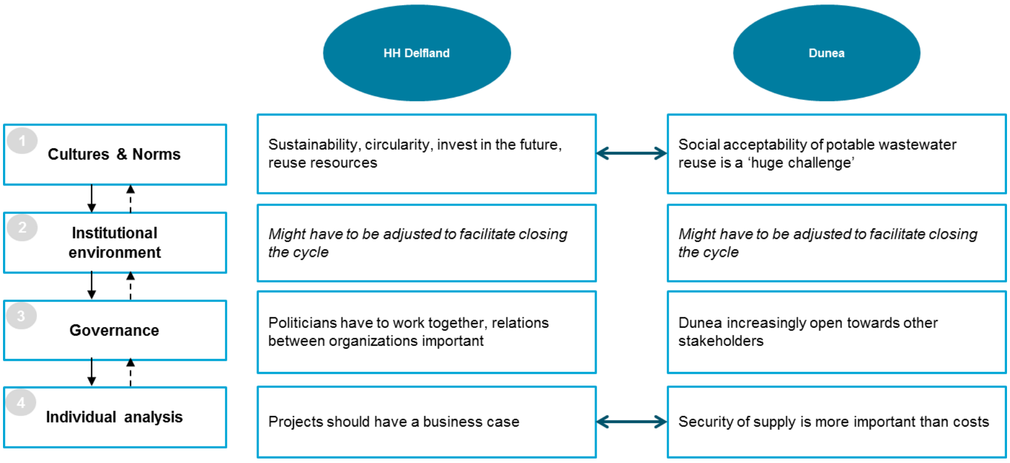


Figure 40 - Overview of four-layer model of Williamson (1998) for both HH Delfland and Dunea

Form of collaboration

The previous sections have discussed the issues that have to be explored (technology), thought out (social acceptability) or negotiated (financials) for a successful implementation of the potable wastewater reuse project. During this process, it could become more clear what the optimal form of cooperation can be between HH Delfland and Dunea. Figure 35 shows how the outcomes of the interaction on the three main issues influence the form of collaboration between HH Delfland and Dunea. This research finds that there are roughly three options of collaboration. There can be 1) no collaboration, 2) Dunea can become 'customer' of the treated wastewater or 3) the organizations can move towards a 'water cycle company'.

Firstly, the two actors must find whether advanced treatment can meet the required water quality standards to infiltrate treated wastewater into the dunes. If not, the project will not commence and hence there will be no collaboration (option 1 in Figure 41). If an advanced treatment technology is found to be applicable, then the required technological changes provide input for another issue: the financial arrangements. Secondly, the potable wastewater reuse project must be accepted by the public. If Dunea finds that there is no support, the project will not commence either (option 1). Thirdly, HH Delfland and Dunea have to negotiate the distribution of costs (and benefits) of the project. This issue can be of great importance for the form of collaboration. If the two actors can reach an agreement on the allocation of costs (e.g. Dunea increases the water tariff to finance advance wastewater treatment), Dunea can become a 'customer' of treated wastewater. HH Delfland will be the owner of and responsible for advanced wastewater treatment, while Dunea monitors water quality as measure of control. Dunea expressed its trust in HH Delfland to construct and operate the advanced wastewater treatment. This option is the preferred form of collaboration of the CEO of Dunea (Drossaert – Dunea). It could also be that the two actors cannot agree on the allocation of costs in the potable reuse project. This could trigger a movement towards a 'water cycle company', if two important conditions are met. First, the overall utility of the potable reuse project should be positive. This implies that the disagreement on the financial arrangements is a matter of the *allocation* of the costs. As separate organizations, the two actors might not agree on who should bear the costs and who profits from the benefits. In case both actors are part of the same organization, the allocation of costs might be less relevant (if the overall benefits are bigger than the costs). The second condition is that alternative water sources are not readily available for Dunea. Section 5.2.1 showed that Dunea is currently exploring six alternative options for the source of drinking water. If other options prove to be (more) attractive, then it is questionable whether Dunea will start the endeavor of emerging into a 'water cycle company' with HH Delfland.

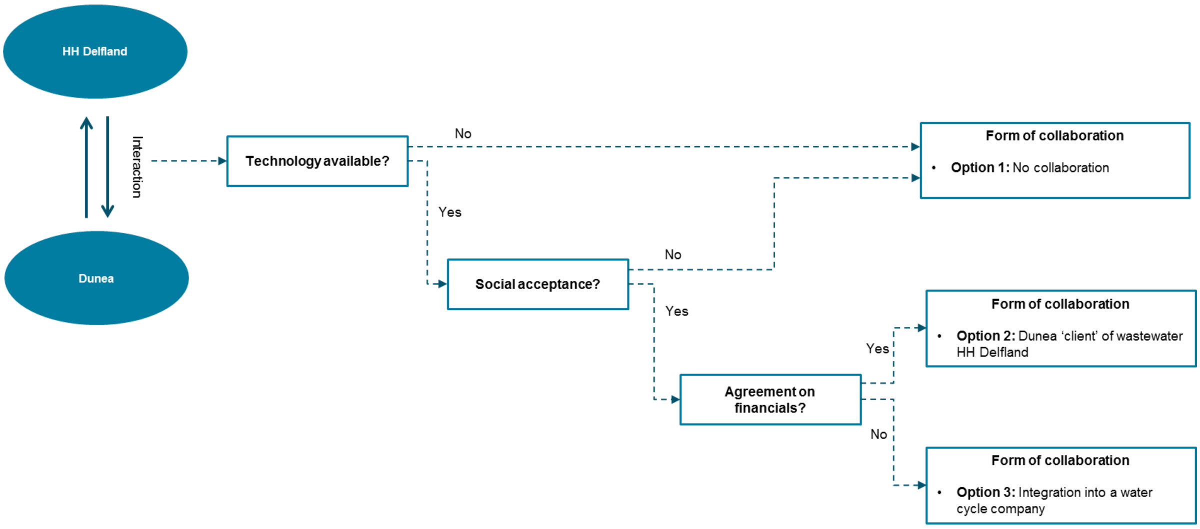


Figure 41 - Schematic overview of how outcomes of the three main issues influence the form of collaboration

The option of a 'water cycle company' opens a whole new discussion on a wide variety of issues. The question rises for instance whether a water cycle company can charge one 'water cycle tariff' to consumers. Furthermore, other actors will be involved. Municipalities are currently responsible for collection of wastewater in the sewer system, and will logically be involved in a water cycle company. This process takes place in a new action situation and is hence not elaborated on in this research. It will be a very interesting subject for further research.

5.2.4 Coordination of the action situation

The previous section on the interaction and outcomes of the addressed issues in the action situation, has already provided clues on coordination of the action situation. This section will summarize and conclude on coordination of the three main issues addressed in the action situation: **technology**, **social acceptability** and **financial arrangements**.

The interaction on the **technology** must go further than just exchanging information. The actors have to experience the way in which both two actors work. The scan of wastewater reuse, executed by HH Delfland and Dunea, is a good first step (Zwolsman et al., 2017). Further research is required to find whether a technology is applicable in this project. If this question is confirmed, the actors must decide on the most suitable technique. Experience with the Freshwater Factory shows that it is highly recommendable to execute a pilot project with the preferred treatment technology. During a pilot project, many technological and institutional issues are expected to surface. With a pilot project, both actors can obtain knowledge and experience with the advanced treatment and the required institutional changes.

To obtain **social acceptability** for the potable wastewater reuse project, all three dimensions of legitimacy should be addressed. HH Delfland can help Dunea to create moral legitimacy by emphasizing the values of sustainability and circularity. The action situation of Dunea with its customers will have to address the other dimensions of legitimacy. To achieve pragmatic legitimacy, Dunea should increase the sense of urgency of freshwater scarcity with other actors. The public is a main actor in this, but also HH Delfland, ministry, province, municipality and other water companies. Dunea should actively communicate that the current sources of drinking water production are threatened by pollution and low discharges. A sense of urgency will increase support and decrease resistance from other actors. If it is the best option for the source of drinking water production, then the customers must realize that it is in their self-interest to accept the potable reuse project (pragmatic legitimacy). Cognitive legitimacy can be obtained by limiting the impact on customers ('the way we do things'). Changes in taste, color and smell of water are quickly noticed by domestic and industrial consumers. Limiting changes in these parameters will reduce the likelihood that customers start to complain (employee HHD).

For the **financial** issue, both actors need to rise above their own interests. The central question in the financial issue is who will pay for the required advanced treatment and new infrastructure to transport treated wastewater to the dunes of Dunea. It is expected that the potable wastewater reuse project will involve more costs than the current situation of river water as source of drinking water and discharging conventionally treated wastewater into the sea (Drossaert – Dunea). However, the main benefit is a reliable and robust source of drinking water production. If the total utility of a closed water cycle is greater than the current situation, the project should be executed. Disagreement on the allocation of the costs and benefits between the two organizations should not be the reason that the reuse project will not commence. To avoid this from happening, both actors should rise above their own interest to achieve the maximal utility.

In general, a lot of aspects still need to be addressed, before an idea can be obtained on whether the potable wastewater reuse project is desirable. HH Delfland and Dunea hardly communicate with each other at the moment. A lot is to learn and discover from and about each other before a clear picture of urgency, technological feasibility, social acceptability and costs and benefits can be obtained. Along the way, the stakeholder should start to think about the form of collaboration.

To further structure the interaction between HH Delfland and Dunea, concepts of **Process Management** can be used. In section 1.5, research question 9 has been formulated as: *What concepts of Process Management could be used to resolve the critical issues in institutional redesign?* Section 2.5 on the process design (theoretical framework) named four concepts of Process Management. The societal legitimacy framework of Harris-Lovett (2015) has been used for the issue of realizing social acceptation for potable wastewater reuse. The action arenas of Ostrom's IAD framework can benefit from efforts to structure the design process towards new arrangements between HH Delfland and Dunea. HH Delfland is working with the Mutual Gains Approach (MGA) (Susskind, 1987; Kirk, 2008), which provides four steps in the process of negotiation (preparation, value creation, value distribution and follow through). Understanding each other's interests, values and alternatives are crucial in the MGA. Interested employees of HH Delfland are encouraged to follow a course in MGA. HH Delfland could include Dunea in the concept of MGA in the process of negotiation. The rules of Process Management of De Bruijn (2002; 2008) could also be highly useful in *designing the design process.* For example, the rule of ensuring progress in the process of negotiation can be useful in keeping pace in the coming negotiations. This is, among other things, achieved by heavily staffing the negotiations (include Dijkgraaf of HH Delfland and CEO of Dunea) and to find quick wins in the process. Since the main focus of this research has been on institutional analysis, the role of Process Management in attempts to close the regional water cycle would be an interesting topic for further research.

Part IV – Evaluation & recommendation

6 Evaluation of operationalization

Chapters 4 and 5 have presented the execution of the two steps of the proposed Williamson-Ostrom framework. Chapter 4 identified the critical action issues and action situations, which were further specified in Chapter 5. This section evaluates the operationalization of the proposed institutional analysis framework. Firstly, the job of the institutional analyst is discussed in section 6.1. The use of the TIP framework is evaluated in section 6.2. The focus of the evaluation is on the use of the Williamson-Ostrom framework (see section 6.3 and 6.4), which was also the focus of this research. The final section (6.5) presents recommendations for further research in institutional analysis.

6.1 The job of the policy analyst

Imperial and Yandle (2005) provide an accurate description of the job of the policy analyst. In their eyes, *"the job of the policy analyst is to clarify and define problems and then help decision makers identify appropriate goals, objectives, and values to achieve. This requires understanding how a program works, who benefits and loses, how it changes incentives, whether the program likely to accomplish what was intended, and how it can be improved or discontinued".*

This research has aimed to fulfill the job of the policy analyst, to clarify and define problems for the socio-technical system of regional water management in the Netherlands. The institutional analysis has provided a comprehensive framework (TIP framework of Koppenjan and Groenewegen (2005)) to start the analysis of the regional water system. The inclusion of technological, institutional and process management aspects can provide the policy analyst a thorough idea of the relevant aspects of the system of concern. The proposed Williamson-Ostrom framework offers the opportunity to further operationalize the institutional analysis. The four-layer model of Williamson (1998) provided clarity in attitudes and positions of actors in closing the water cycle. It has also helped to structure the search for critical issues and critical action situations in closing the water cycle. The IAD framework of Ostrom (2010) has provided further insight into the interaction on the critical issues in the two critical action situations. This insight allowed to provide recommendations for coordination of the action situation. Identification of goals, objectives and values are in the end the responsibility of decision makers, but the frameworks have helped in structuring these aspects. The institutional analysis framework helped to understand how interactions in critical action situations are likely to play out, who benefits and loses, what the trade-offs are (within and between organizations) and how incentives can be improved.

The next sections discuss the use of the TIP framework and subsequently the use of the Williamson-Ostrom framework. It provides answers to the research questions (see section 1.5) on the use of theoretical framework, see below.

Evaluation of theoretical framework

10. What is the added value of using the various frameworks to operationalize the TIP framework?
11. Can frameworks be combined within the Institutional design framework (most importantly Koppenjan and Groenewegen (2005), Williamson (1998) and Ostrom (2010))? If yes, how?
12. How are the T-I-P pillars related in redesigning the system?

The three frameworks that have been used (TIP framework, Williamson and Ostrom) all have their advantages and disadvantages. These aspects are described in detail in section 6.2 - 6.4. Table 8 provides an overview of the (dis)advantages of the frameworks used.

Table 8 - Advantages and disadvantages of the frameworks used

	Advantages	Disadvantages
TIP framework	• Useful starting point for analysis, by providing provide a good idea on what aspects of closed water system have to be analyzed (technology, institutions, process management)	• Scope is too wide for a SEPAM MSc. Thesis • 'Empty shell' in the sense that the institutional analysis has been conducted with the Williamson-Ostrom framework
Four-layer model	• Helped to structure empirical information on expected issues • Useful in analyzing drivers, attitudes and values of relevant actors • Provides input for the analysis of the critical action situations	• Critical issues and action situations not one-on-one related • Translating the critical issues into critical action situations remains the job of the institutional analyst
IAD framework	• Description of external variables provides insight into the action situation (e.g. water as different types of good) • The framework provides insight into nestedness of action situations and how outcomes of one action situation influences other action situations	• The framework can be conceptual and hard to apply in practice • The most important question in the action situation must be known beforehand, to meaningfully apply the IAD framework • Other frameworks (e.g. social legitimacy framework of Harris-Lovett (2015)) can be more helpful in analyzing the interaction than the description of the external variables

6.2 TIP framework

The theoretical framework (Chapter 2) explained that Koppenjan and Groenewegen (2005) propose the TIP framework to position the institutional design in relation to the technological and process design. After application of the TIP framework to the case of HH Delfland, it can be concluded that the scope of the TIP framework is too wide for a master of science graduation thesis. Especially the process management pillar of the could have been a graduation thesis in itself. In this research, the TIP framework is mainly used to include both technological design (as link with Msc. Thesis Watermanagment (Citg), van Es (2017b)) and institutional design.

Looking back, the TIP framework has turned out to be an 'empty shell' in this research. The institutional analysis has mainly been performed with the proposed Williamson-Ostrom framework, and not with the TIP framework. The institutional analyst will see that the IAD framework covers all aspects mentioned by TIP framework (see Figure 42). The technological system can be described as the external variables (physical system of the biophysical conditions). Process management can be included in the analysis of the interaction of the action situation (see Figure 42). However, at the start of the research, using the TIP framework did provide a good idea on what aspects of closed water system have to be analyzed (technology, institutions, process management). This research argues that the TIP framework is useful to start a policy analysis of a socio-technical system, especially for the non-experienced institutional analysist. However, institutional analysis is better served by the frameworks that *specify* the TIP framework (i.e. Williamson and Ostrom) than with the TIP framework itself. In further research, the TIP framework can be omitted in institutional analysis. The Williamson-Ostrom framework provides better guidance in institutional analysis, while including both technological and process management aspects. For this reason, the TIP framework has been left out in the scientific article on the combination of the frameworks of Williamson and Ostrom for institutional analysis. In the section below, a more detailed evaluation is provided on the three pillars (T-I-P) of the framework.

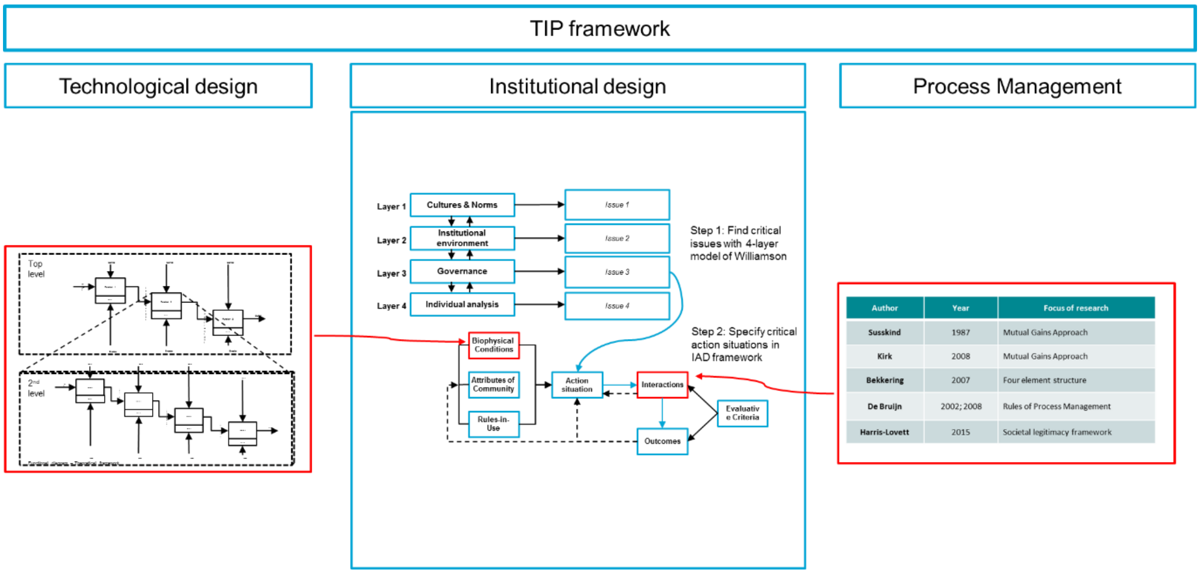


Figure 42 - The three pillars of the TIP framework are all covered by the IAD framework

Technology

The technological analysis is operationalized by functional diagrams. These diagrams have provided valuable insight into the required changes of the system, which supports the institutional analysis. The technological issues turned out to be one of the main issues in closing the water cycle. It provided insight into the technological issues that have to be addressed in one of the critical action situations. The technological (re)design is also useful in describing the 'physical system' of the IAD framework. The functional diagrams have visualized the required technological adjustments (step 1 in the Williamson-Ostrom framework), which can be used in the description of the action situations (step 2 in the Williamson-Ostrom framework). So, the technology pillar of the TIP framework turned out to be also part of the institutional analysis.

Institutions

The Institutional pillar of the TIP framework does not provide sufficient guidance for institutional analysis. It requires operationalization with more specialized frameworks. These frameworks have been found for this thesis in the four-layer model of Williamson (1998) and the Institutional Analysis and Development (IAD) framework of Ostrom (2010). See section 6.3 and 6.4 for an evaluation of the use of these two frameworks in institutional analysis.

Process management

Process management becomes relevant during the specification of the critical action situations. Process management can provide ways of *coordination* of the critical action situations. Process Management theories were expected to be helpful to resolve institutional issues. An example in this research of a Process Management concept that has proven to be helpful in resolving institutional issues, is the social legitimacy framework of Harris-Lovett. The framework did not only help in providing insight into social legitimacy, but also in showing the nestedness of action situations (see Figure 38). The figure shows that the three different aspects of social legitimacy are not all addressed in the same action situations. By shortly introducing other concepts of Process Management, it is clearly observable that these concepts can be of great help in designing the process of negotiations between HH Delfland and Dunea (e.g. protecting each other's core values, ensure progress).

6.3 Four-layer model of Williamson

The four-layer model of Williamson (1998) conceptualizes social analysis by categorizing institutions in four different institutional layers. The framework has proven to be highly useful in the different ways in the institutional analysis of this research. The framework helped 1) to **structure empirical information** on the expected issues in closing the water cycle, 2) to analyze the **drivers, attitudes and values** of relevant actors in the regional water cycle and 3) to provide **input for the analysis of the critical action situations** with the IAD framework.

Structure empirical information on expected issues

The twenty-two interviews conducted for this research, have resulted in a long list of issues mentioned. The four-layer model of Williamson (1998) has proven to be highly useful in structuring this extensive list of issues, along the four institutional layers. It also provided good insight in how institutions are embedded in different institutional levels (e.g. a discharge permit of HH Delfland is embedded in national and EU legislation). In structuring the issues, it was noticed that not all issues were institutional issues. For this reason, section 4.3 is divided in institutional issues (structured along the four institutional issues) and non-institutional issues (e.g. technology). The policy analyst should be aware that not all issues need to be 'forced' into the four-layer model. As long as most issues can be structured according to the four institutional layers, the four-layer model remains very useful in doing so. In this case, only two issues could not be structured along the four-layer model and hence the model proves to be highly useful in structuring the issues.

With a clear overview on what issues are most crucial in closing the water cycle, the issues can be translated into action arenas. However, the *translation* of critical issues into critical action situations to be analyzed, has to be done by the institutional analyst. Choice of the critical action situations can be subject of discussion in a scientific debate.

Analyze drivers, attitudes and values

The four layers of Williamson's framework provide insight into the differences in drivers, attitudes and values of relevant actors in the regional water system. It was especially interesting to structure these aspects for the board members of HH Delfland. It provided insight into the different institutional levels on which between board members act (layer 1, layer 3 and layer 4). The four layers are relatively simple to explain to non-institutional analysists, for which the framework is appreciated by policy advisors of HH Delfland.

Input for the critical action situations

The four-layer model of Williamson (1998) also provided valuable input for the analyzed action situations. The different positions as taken by the board of HH Delfland are important input for both action situations analyzed. For instance, when a preliminary permit cannot be obtained with the proposed treatment scheme, additional treatment is required (with extra costs). With insight into the different positions of the board members, it becomes clear that the need for additional treatment significantly reduces the support for the project within the board.

6.4 IAD framework of Ostrom

With the four-layer model of Williamson (1998), the most critical issues have been found and translated to critical action situations. The critical action situations address the critical issues. The IAD framework ought to help analysts to understand complex social situations and to break these situations down into manageable sets of practical activities (Polski and Ostrom, 1999). The framework can also help in organizing knowledge from empirical studies (Ostrom, 2011).

The IAD framework can be conceptual and hard to apply in practice. Simply filling in the framework soon leads to a static enumeration of variables. Instructions such as: '*Aggregation rules specifying how decisions of actors were to be mapped*' (Ostrom, 2010) are hard to meaningfully apply to a case study. The high level of conceptuality makes the framework unsuitable to be used by non-institutional analysists (i.e. policy advisors of HH Delfland), as opposed to the four-layer model of Williamson.

To meaningfully apply the IAD framework, the institutional analyst should work backwards from the most critical question of the action situation to the (external) variables, action situation and interaction. The analysist must keep in mind *why* the action situation must be described, to prevent the description to evolve into a very general discussion of the action situation. A point of reflection for this method is that the policy analyst cannot use the IAD framework to determine the most critical question in the action situation. The framework does not help to find the critical question within the action situation, but rather, the critical question must be formulated beforehand, in order to use the framework. This research has made use of interviews to determine the critical question in the action situation.

When the critical question in the action situation is formulated well, the analysis with the IAD framework can provide very useful insight into the interaction and possible outcomes. The external variables can help to structure empirical information in a systematic way. For instance, the discussion of biophysical conditions provides the insight that wastewater is reused as two different types of good in the two action situations analyzed: as a public good and as a private good. The IAD framework can also clearly show the nestedness of action situations (see Figure 28 and Figure 38). It shows how outcomes of one action situation affect another action situation. In the action situation of obtaining a permit, the IAD framework showed that the balance between water quality and costs (outcome of the action situation, see Figure 30) has a great influence on the rules-in-use of the action situation of the decision making process (see Figure 31).

In applying the IAD framework to the case of HH Delfland, the description of the external variables did not always prove to be helpful in analyzing interaction in an action situation. Rather, it was found that using other frameworks (i.e. four-layer model of Williamson (1998) and social legitimacy framework of Harris-Lovett (2015)) provided more insight into the interaction, by structuring empirical information. As mentioned in section 6.3 above, the four-layer model of Williamson can be used in the description of the rules-in-use. It helps to emphasize and visualize the different positions of actors in an action situation. These positions play an important role in predicting the interaction and corresponding outcomes. Also, the social legitimacy framework of Harris-Lovett (2015) provided a lot of insight into the interaction regarding social acceptation. Thus, it is not the (static) description of external variables that helps to explain and predict interaction in the action situation, but rather the other frameworks used (Williamson, 1998; Harris-Lovett, 2015).

The IAD framework is of itself very a-theoretical. The use of other, for instance economic or social theories can be helpful in the application of the IAD framework. As discussed in section 2.1 on the theoretical framework, Ostrom acknowledges this by explaining that theories can be used to specify which elements of a framework are particularly relevant. She mentions that multiple theories (e.g. economic theory, transaction cost theory) can be compatible with the IAD framework (Ostrom, 2011).

6.5 Recommendations for further research

Based on the evaluation provided in this chapter, three recommendations for further research can be given. Firstly, more case studies conducted with the Williamson-Ostrom framework would contribute to the applicability of the framework. The application to the case of HH Delfland has resulted in the reflections presented in this chapter. Other case studies could provide more information on the use of the framework and might propose adjustments. One of the aspects that can be formalized, is the translation of critical issues to critical action situations.

In the application of the proposed Williamson-Ostrom framework, two options for finding the critical issues and critical action situations are available: empirical and theoretical. In the empirical way, the actors determine what the most critical issues and action situations are. The institutional analyst can interview relevant stakeholders to obtain information. In the theoretical way, the analyst uses theories (e.g. transaction costs economics) to find the critical issues. This research is conducted in the first way. The second recommendation for further research would be to execute this case study in a theoretical way. It will be interesting to evaluate whether the same critical issues and action situations are found with a different method.

Thirdly, the first section of this reflection has mentioned that the scope of the TIP framework is too large for a MSc. Thesis. This research only touches slightly upon Process Management aspects for coordination of the critical action situations. A separate research on the Process Management aspect of closing the regional water cycle, could be a highly useful addition to this research.

This chapter has provided an evaluation of the use of the frameworks in this research, which is the scientific contribution of this research. A scientific paper on the combination and application of the frameworks for institutional analysis, can be found as attachment to this report. The next chapter provides a more practical reflection of the case study in the form of recommendations to HH Delfland.

7 Recommendations

This chapter provides a more practical reflection on the institutional analysis of closing the regional water cycle in the form of recommendations to HH Delfland (7.1) and Dunea (7.2). Table 9 provides an overview of the recommendations for HH Delfland and Dunea.

Table 9 - Overview of recommendations

General	• **Pioneering role** of HH Delfland is commendable and appreciated • The organization should have a stronger **sense of urgency** • The **internally divided board** should look for common ground • HH Delfland should be aware of its **heavily politicized nature**
Freshwater Factory	• The pilot project should be seen as a **learning project** in which (political) risks have to be taken to find a balance between quality and costs • HH Delfland should **keep pace** in the ZWF project • **Interaction** between the three involved departments should be stimulated
Potable reuse w/ Dunea	• The technological options should be studied with Dunea, e.g. in a **pilot project** • Emphasize **sustainability and circularity** to obtain social acceptability • Both actors need to **rise above their own interest** in a financial agreement • HH Delfland should approach the question of water reuse in a **less political fashion** • The road towards a implemented potable reuse project will be **long**
Dunea	• Dunea should **create a sense of urgency** of freshwater scarcity with other actors • **Moral, pragmatic and cognitive** legitimacy has to be obtained

7.1 Recommendations HH Delfland

The research for this report has been conducted at HH Delfland. This section provides recommendations for the water authority on three subjects: 1) general recommendations on the regional water system and specific recommendations on 2) the Freshwater Factory project and 3) the potable wastewater reuse project with Dunea.

General recommendations

The **pioneering role** that HH Delfland has adopted in exploring wastewater reuse projects is commendable. Instead of waiting for droughts to occur and take action when the damage has already been done, closing the regional water cycle now, can prevent water scarcity in the future. HH Delfland can be inspired by the Deltaprogram 2015, which has to protect the Netherlands from flooding. Delta commissioner Wim Kuijken: “We are not going to wait for a disaster before we take action. Instead, we take preventive action to increase safety. I hope that we are finished in time, but you never know what to expect with nature” (Bockma, 2014). Implementing projects of wastewater reuse will contribute to a closed water system, resilient to future periods of drought.

Although the ambition to close the regional water cycle has been expressed in the coalition agreement 2015-2019, a **sense of urgency** is lacking at HH Delfland and other governmental bodies. However, the organization that is closest to the use of water, drinking water company Dunea, *does* feel the urgency of freshwater scarcity. Dunea expressed a sense of urgency of the lack of high-quality fresh water. The drinking water company sees its water sources being threatened and finds alternatives not readily available. The awareness of the vulnerability of freshwater supply for (greenhouse) farmers, industry and drinking water production should increase.

The board of HH Delfland is **internally divided** on whether wastewater reuse projects should be pursued, based on differences in values that drive board members. The division can roughly be explained by values of sustainability versus economic efficiency. Providing insight into the different values, as this research has attempted to do, could help the board members to understand each other’s position. It might provide common ground to find agreement within the board. Projects in which the drivers of all board members are aligned have most chance finding approval from the board. An important aspect of the business case of a wastewater reuse project is finding (paying) customers for reused wastewater. These customers can be found in drinking water companies and (greenhouse) farmers. Analysis of the potable wastewater reuse project showed that Dunea is willing to increase its water tariff to guarantee security of supply. It will be harder to align all values on the Freshwater Factory project, since a paying customer of the reused wastewater is absent.

HH Delfland should be aware of the **heavily politicized nature** of the water authority. Other actors see the political nature not always as beneficial. Both inside and outside HH Delfland, the short-term vision of politicians and the changes in political color are addressed as issues. Dunea even sees the political 'inability' to implement projects as a major issue. HH Delfland should critically examine the political nature of the water authority, to find whether the decision-making process within the water authority has been too heavily politicized. Politics within HH Delfland can also have a positive effect: other stakeholders recognize and appreciate the pioneering role that HH Delfland has taken. Political vision can be a major driver to implement innovative and bold projects.

This research found that the **main issues** of wastewater reuse projects are technology and (structured according to the four-layer model of Williamson): social acceptation (level 1), obtaining permits by complying to (inter)national water quality standards (level 2), establishing a new relation between drinking water companies and water authorities (level 3) and economic feasibility of reuse projects (level 4).

Recommendations on the Freshwater Factory (FF)

Section 5.1 analyzed the action situation of HH Delfland having to obtain a discharge permit for the FF. Only respondents of HH Delfland have mentioned issues in the institutional environment (level 2). An explanation could be that HH Delfland is actively exploring wastewater reuse projects, foremost the pilot FF. In this process HH Delfland encounters problems and contradictions in the institutional environment. Other actors are not yet involved in the actual process of implementing wastewater reuse projects and might thus not see issues in the institutional environment.

Piloting and implementing a water reuse project such as the FF needs to be seen as a **learning process** to open new horizons. Politicians have to take (political) risks to find a balance between meeting legislation and limiting costs. A Dutch interpretation of the Water Framework Directive for wastewater reuse projects, is required to find the balance between preserving the 'stand-still principle' in working towards a closed water cycle. The process towards a fully implemented FF will be long, especially when legislation requires adjustments and/or interpretation. HH Delfland should take this into account and be prepared for a long process.

Interaction between the three departments of HH Delfland involved in obtaining a permit (PCW, WSQ, R&P), should be **stimulated**. The three departments tend to focus on their own area of responsibility. PCW observed a knowledge gap on what water quality standards have to be met. WSQ feels that they have been involved at a late stage of the pilot project. Interaction between the departments will increase the understanding of each other's considerations and trade-offs. The interaction should not be seen as a conflict between PCW on one side and WSQ and R&P on the other side. Together, the departments should find a balance in the trade-off between water quality and costs. This balance can be presented to the board of HH Delfland, that is eventually responsible for deciding whether the pilot will be upgraded to full-scale.

HH Delfland should **keep pace in the process** of finding the balance in the trade-off and should dare to move forward. The pioneering role that HH Delfland has adopted in this wastewater reuse project is recognized and appreciated by other stakeholders. HH Delfland has entered unknown grounds with the FF project. It naturally follows that HH Delfland finds knowledge gaps on the way towards a full-scale wastewater reuse project. Finding the balance between water quality of reused wastewater and the costs required can in the end only be achieved by executing the project. The board of HH Delfland will have to show political courage to decide to continue the pilot project towards a full-scale installation. HH Delfland can use the goodwill and momentum of the project (e.g. winning water innovation price) to keep on moving forward.

Recommendations on new arrangements with Dunea for potable reuse

A potable wastewater reuse project in collaboration with Dunea, will require new arrangements between HH Delfland and Dunea. Both actors, and their systems, act almost completely separated at the moment. Implementing a potable wastewater reuse project will be a long process and both actors have to rise above their own interest for a successful implementation. This research found the three main issues in new arrangements between the two actors to be: technology, social acceptability and financials.

Regarding the technology, both actors not only need to exchange information, they should experience the way in which both actors work. The scan of wastewater reuse, executed by HH Delfland and Dunea (Zwolsman et al., 2017) is a good first step. Further research is required to find whether a technology is applicable in this project. If this question is confirmed, the actors must decide on the most suitable technique. Experience with the Freshwater Factory learns that it is highly recommendable to first start a pilot project with the preferred treatment technology. During a pilot project, many technological and institutional issues are expected to surface. With a pilot project, both actors can obtain knowledge and experience with the advanced treatment and the required institutional changes.

To obtain **social acceptability** for the potable wastewater reuse project, HH Delfland can help Dunea to create moral legitimacy by emphasizing the values of sustainability and circularity. Part of the board of HH Delfland is driven by these values. Expressing these values in the project will encourage the board members of HH Delfland to execute the project. The public is more and more driven by these values and might be more willing to accept potable wastewater reuse when these values emphasized. HH Delfland can support Dunea by actively communicating the project through all sort of channels (open days, website, news, information at treatment plants).

For the **financial** issue, both actors need to rise above their own interests. The central question in this financial issue is who will pay for the required advanced treatment and new infrastructure to transport treated wastewater to the dunes of Dunea. Dunea is willing to increase its drinking water tariff, if this is required to guarantee security of supply. This offers an opportunity to obtain support for this project from the part of the board of HH Delfland that is driven by the business case of reuse projects.

In general, HH Delfland could be benefited by approaching the question of circularity in a **less political fashion**. In circular projects, such as potable wastewater reuse, other actors will always be involved. The discussion within the board of HH Delfland could change when other actors in the water system are consulted. For the potable reuse project, Dunea has a more pragmatic attitude. If wastewater is the most reliable and at the same time financially acceptable (partial) source of drinking water, a wastewater reuse project should be implemented in their eyes. This approach takes away the heavily politicized discussion on values of sustainability, circularity and the business case of wastewater reuse projects. The necessity of wastewater reuse for Dunea alters the discussion within the board of HH Delfland.

A lot of aspects still need to be addressed, before an idea can be obtained on the feasibility of the potable wastewater reuse project. HH Delfland and Dunea hardly communicate with each other at the moment. A lot has to be done before a sound idea of urgency, technological feasibility, social acceptability and costs and benefits can be obtained. Only when all issues can be resolved, the project will commence. The collaboration between the two actors can take multiple forms. Dunea could become a customer of advanced treated wastewater by HH Delfland or both actors can merge into a water cycle company.

For the latter form of collaboration, HH Delfland and Dunea could consult Waternet regarding their experiences as a water cycle company. One organization in which drinking water and wastewater transport and treatment are combined, could be economically more efficient and could better facilitate a closed water cycle. This organization would take over responsibilities of drinking water companies, water authorities and municipalities. Further research on warranty of the public function of the water system and economic efficiency, is required to find the optimal form of (democratic) organization of such new entity. The current form of drinking water companies as ‘government Ltd’ could well be the optimum of private execution of a public function.

7.2 Recommendations Dunea

This section presents recommendations for Dunea, one of the main actors in the potable wastewater reuse project. Firstly, Dunea should increase the **sense of urgency** of freshwater scarcity with other actors, such as HH Delfland, the Ministry of I&M, the Province of South-Holland, municipalities and even other water companies. Currently, these actors support the idea of wastewater reuse but none of them share the same sense of urgency. Being responsible for high-quality and highly reliable drinking water system, it is no surprise that Dunea is the first to experience deterioration in source water quality and availability. Dunea should actively communicate that their current sources of drinking water production are threatened by pollution and low discharges. Dunea must explain that alternative sources (e.g. surface water or sea water) have a lot of disadvantages and that wastewater reuse is thus a serious option. A sense of urgency will increase support from other actors and decrease resistance.

Secondly, it will be a challenge for Dunea to obtain **social acceptance** for potable wastewater reuse. The social legitimacy framework of Harris-Lovett (2015) can be helpful in creating this acceptance. Three dimensions of legitimacy should be addressed: moral, pragmatic and cognitive legitimacy. As explained in the recommendation for HH Delfland, moral legitimacy can be obtained by emphasizing the values of sustainability and circularity of the wastewater reuse project. Creating a sense of urgency with other actors (see recommendation above) will achieve pragmatic legitimacy. Cognitive legitimacy can be obtained by limiting the impact on customers. Changes in taste, color and smell of water are quickly noticed by domestic and industrial consumers. Limiting changes in these parameters will reduce the likelihood that customers start to complain.

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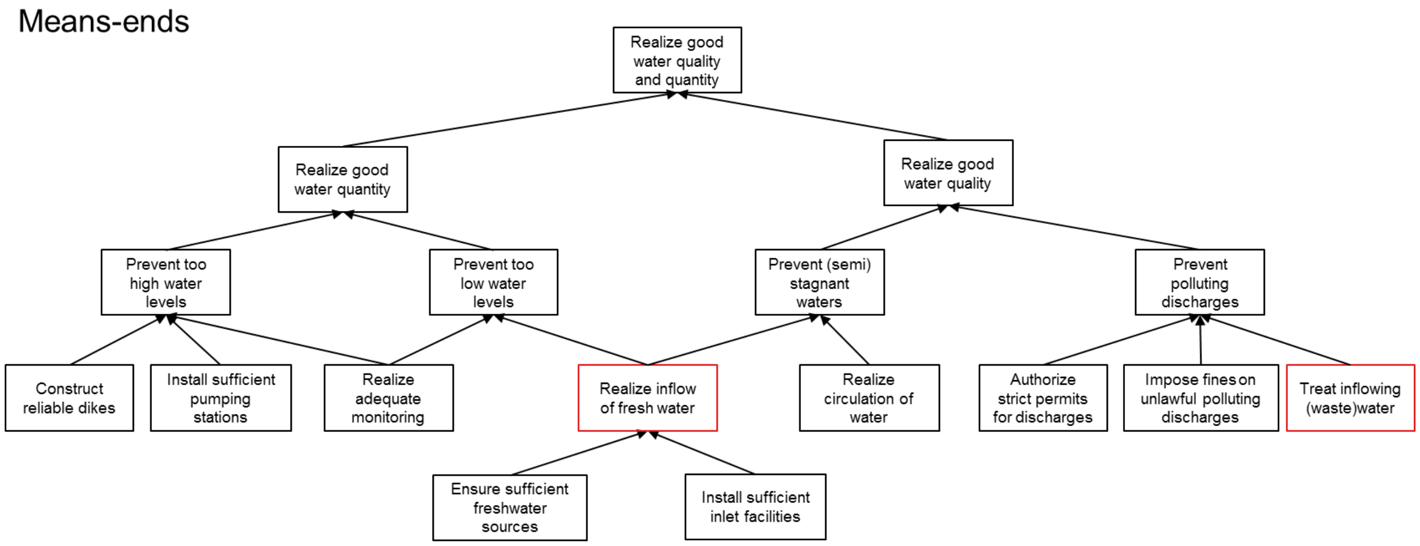
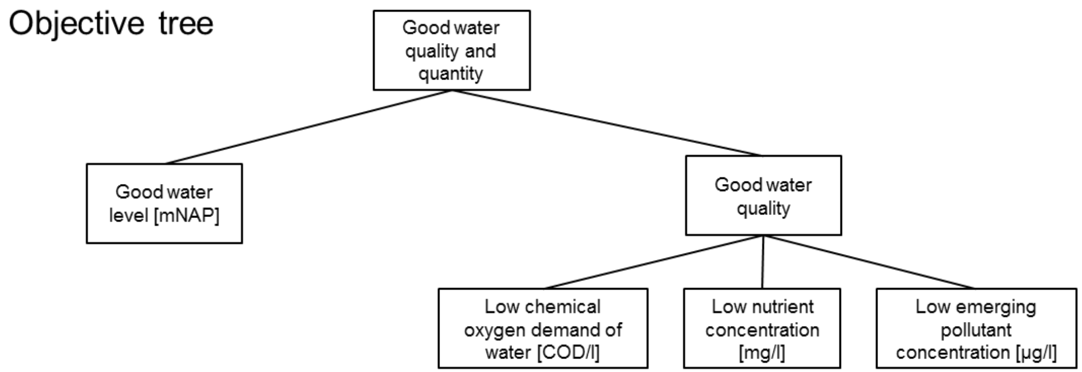
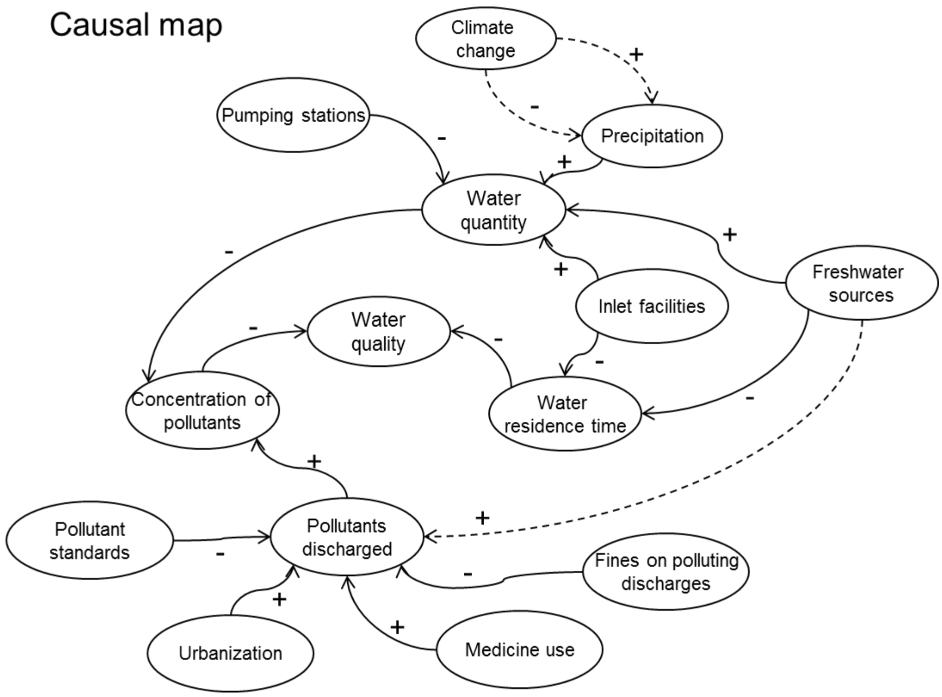
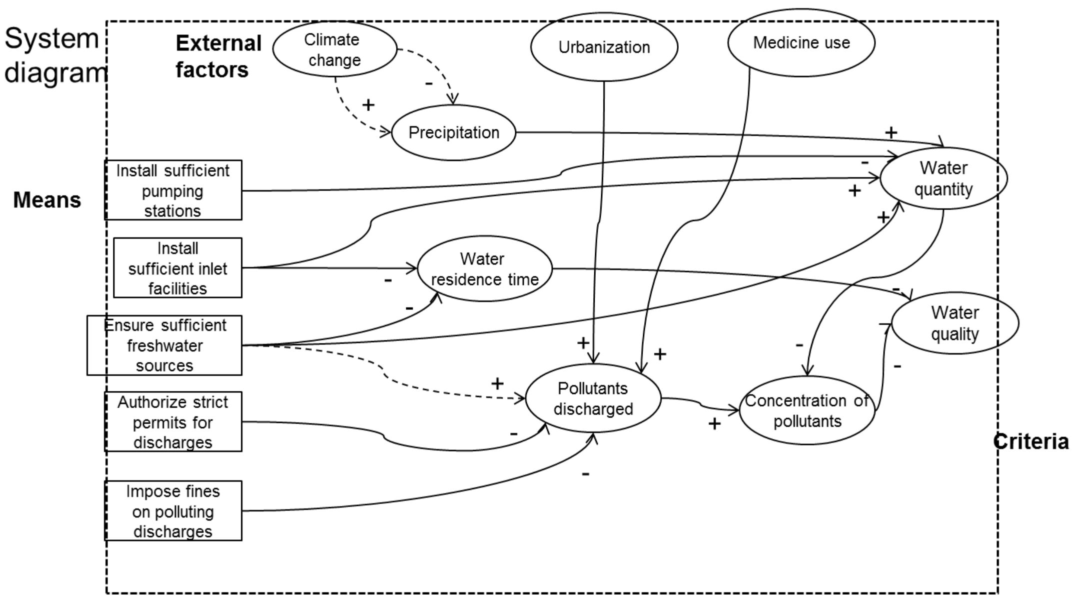
Appendix I – System and actor analysis





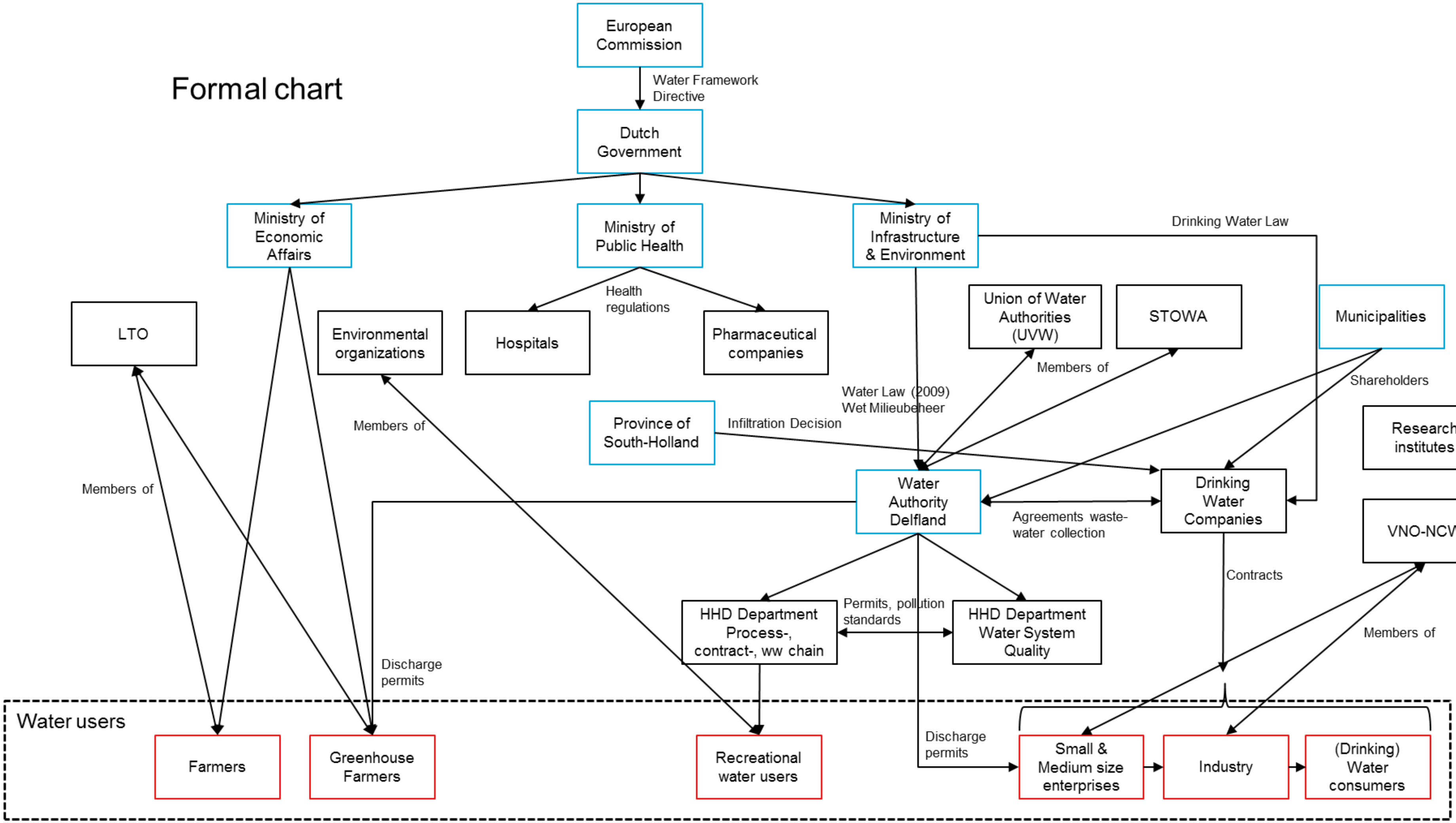


Causal map
Climate change
Precipitation
Pumping stations
Water quantity
Freshwater sources
Inlet facilities
Water quality
Concentration of pollutants
Water residence time
Pollutant standards
Pollutants discharged
Fines on polluting discharges
Urbanization
Medicine use



System diagram
External factors
Climate change
Precipitation
Urbanization
Medicine use
Means
Install sufficient pumping stations
Install sufficient inlet facilities
Ensure sufficient freshwater sources
Authorize strict permits for discharges
Impose fines on polluting discharges
Water quantity
Water residence time
Water quality
Pollutants discharged
Concentration of pollutants
Criteria

Formal chart



Agriculture

Actors	Interest	Power	Interests	Objectives	Existing or expected situation	Possible solutions
Farmers	++	-	Continuation of farming	Reliable fresh water supply for water level management and irrigation	- Shortage of fresh water and deterioration of quality can damage crops - Stricter discharging standards on pesticides can restrict current operation	Increase and improve fresh water sources, e.g. groundwater pumping
Greenhouse farmers	++	-	Continuation of farming	Reliable fresh water supply for irrigation	- Shortage of fresh water and deterioration of quality can damage crops - Stricter discharging standards on pesticides can restrict current operation	Increase and improve fresh water sources, e.g. groundwater pumping
LTO	+	+	Defend interests of farmers	Good farming conditions for its members	- Expected future, temporal, water scarcity threatens farmers - Stricter discharging standards can be a burden for farmers	- Increase availability and reliability of fresh water sources - Develop discharging standards in close cooperation with LTO/farmers
Ministry of Economic Affairs	+/-	+	Economic development in The Netherlands	Improve business environment	Competition between different sectors/businesses for water in times of scarcity	- Increase availability and reliability of fresh water sources

Water management

Actors	Interest	Power	Interests	Objectives	Existing or expected situation	Possible solutions
Water authority Delfland - Water system quality department	+	+	Water quality in service area	Good water quality in water system	Deterioration of water quality due to polluting discharges and accumulation in water system	Stricter water discharge standards and permits Higher fines on polluting discharges
- Process-, contract- and wastewater chain department	+	+	Water quantity and quality in service area	Good water quantity and quality in water system	- Expected future, temporal, water scarcity - Deterioration of water quality due to polluting discharges	Increase quantity and improve quality of fresh water sources
Drinking water companies - Dunea	+	-	Supply of drinking water	Reliable water supply of excellent quality	Freshwater source threatened by deterioration of water quality	Find alternative fresh water source
- Evides	+	-	Supply of drinking water	Reliable water supply of excellent quality	Challenges in protecting fresh water sources	Continuous efforts to improve water quality of sources
STOWA	+/-	-	Research in water management	Develop, gather and spread knowledge	Challenges due to climate change and urbanization	Increased knowledge and technological advancement to address water challenges
Union of Water Authorities (UvW)	+	+	Defend interests of Dutch water authorities	- Good conditions for water authorities - Knowledge building and sharing	Increasing importance of water authorities in providing good water quantity and quality due to climate change	More sharing of knowledge on best practices More collaboration between water authorities
Rijkswaterstaat	+/-	+/-	Water in The Netherlands	Safe, livable and accessible country	Increasing water challenges due to climate change and urbanization	Adaptive water management Collaboration on different governmental layers

Local economic development

Actors	Interest	Power	Interests	Objectives	Existing or expected situation	Possible solutions
Municipalities in southwest of The Netherlands	+	+/-	Urban development Traffic and transport	Good functioning cities	Increased challenges caused by climate change and urbanization: e.g. water and heat management	Integral approach of challenges with all actors involved
Province of South-Holland	+	-	Spatial development	Good social and economic development	Increased challenges caused by urbanization and climate change	Integrated spatial planning and increased space for urbanization and climate change adaptation measures
Industry	++	-	Economic activity, profit	High profits and continuation of business	Stricter regulation and permits for industry: carbon emission, pollution discharges etc.	Develop regulation in cooperation with industry representatives
Medium and small enterprises (MKB)	+	-	Economic activity, profit	High profits and continuation of business	Stricter regulation and permits for MKB: carbon emission, pollution discharges etc.	Develop regulation in cooperation with MKB representatives
Port of Rotterdam	-	-	Economic activity, port development	Remain attractive port for world trade	Stricter regulation and permits, Low water levels can hamper shipping	Develop regulation in cooperation with port representatives Cooperate in climate change mitigation measures

Healthcare

Actors	Interest	Power	Interests	Objectives	Existing or expected situation	Possible solutions
Hospitals (e.g. Reinier de Graaf)	-	-	Well being of patients	Effectively treating and curing patients	More patients due to ageing of population	Treatment at home, healthier lifestyle of population
Pharmaceutical companies	+	+/-	Pharmaceutical development, profit	High profit	More demand for medicines due to ageing of population	Developing the right medicines and producing sufficient amounts
Ministry of Public Health	-	+	Public health	Heathier population at lower healthcare costs	More pressure on healthcare costs due to ageing of the population	Cheaper treatment (e.g. at home, cheaper medicines), healthier lifestyle of population

Actors	Interest	Power	Interests	Objectives	Existing or expected situation	Possible solutions
Ministry of Infrastructure & Environment	+	++	Infrastructural and environmental development	Livable, accessible and safe Netherlands	Urbanization and economic development is increasing pressure on Dutch infrastructure and environment	Integral approach of challenges, e.g. investment in infrastructure, protection of environment
Environmental organizations (e.g. Natuurmonumenten)	+/-	+/-	Environmental protection and development	More nature, good protection	Population growth and economic development is threatening nature	Influencing policy making to achieve more focus on protection and development of nature
Recreational water users	+	--	Leisure	Enjoy leisure time to full satisfaction	Insufficient recreational water available with good water quality	Implementing measures to increase recreational value of water, e.g. circulation of water to prevent algae growth in summer
(Drinking) water consumers	+	-	Drinking water	Safe and reliable drinking water of excellent quality	Outstanding quality and reliability challenged by deterioration in quantity and quality of fresh water sources	Adequate monitoring of source quantity and quality, protection of fresh water sources, identifying alternative fresh water sources
Safety regions - Haaglanden	++	--	Fire fighting, disaster and crisis management of Haaglanden region	Effective management during times of disaster and crisis	Urbanization, the (inter)national security situation and climate change will put increasing stress on our society with great potential damage of a crisis/disaster	Prevention of crisis by preventive measures (e.g. reinforce infrastructure against super storms) Developing integral approaches to alleviate effects of crises
- Rotterdam-Rijnmond	++	--	Fire fighting, disaster and crisis management of Rotterdam-Rijnmond region	Effective management during times of disaster and crisis	Urbanization, the (inter)national security situation and climate change will put increasing stress on our society with great potential damage of a crisis/disaster	Prevention of crisis by preventive measures (e.g. reinforce infrastructure against super storms) Developing integral approaches to alleviate effects of crises
European Commission	+	+	Well being and prosperity of EU Member States	High economic development, more sustainable society	Urbanization, international security situation and climate change put increasing stress on our social and economic structure	Integral approach of challenges, e.g. investment in infrastructure, protection of environment
RIVM	+	--	Public health and environment	Healthy population and sustainable environment	More pressure on public health and environment in The Netherlands	Promote public health and consumer safety Protect environment Collect and collate knowledge
VNO-NCW	+	+	Business and investment climate of The Netherlands	Excellent business and investment climate	Sustainability targets must not negatively influence the business and investment climate	Influencing policy making to promote employers' interests
Research Institutes (e.g. TNO, Deltares, WUR, TUD)	+	+/-	Research and knowledge	Creating innovations to advance society	Climate change and urbanization require innovations for a sustainable society	Invest in research Include scientific findings in policy making

Appendix II – Interview guideline

22 interviews have been conducted for this research, both within and outside HH Delfland. The interviews were semi-structured to allow adjustments the questions during the interviews. Some of the interviews have been recorded, with permission of the respondent. For other interviews, it was expected that respondents would speak more freely when the interviews would not be recorded. In these cases, notes have been made during the conversations.

Below a standard interview guideline is provided, that has been used for the interviews. Question four, on the main issues in closing the water cycle, is seen as the central question in the interviews. Based on the response to this question, follow-up questions have been asked to go obtain more information on the mentioned issues.

Standard questions

1. What role does *[organization of the respondent]* play in the regional water cycle?
2. How does *[organization of the respondent]* relate to other stakeholders in the water system?
3. What is the attitude of the *[organization of the respondent]* towards the goal of HH Delfland to close the regional water cycle by wastewater reuse?
4. What are in the eyes of *[organization of the respondent]* the main issues in closing the water cycle?
    a. Why will the issues mentioned cause a problem?
    b. Who are involved in this issue?
    c. What legislation, technological components and/or financial arrangements play a role in this issue?

The interviews with Dunea were more focused on the potable wastewater reuse project. The questions below have been asked in addition to the standard questions above.

Additional questions for Dunea

1. For what time period are the current freshwater sources of Dunea deemed reliable?
2. What other alternative sources are explored, besides wastewater reuse?
3. If wastewater from HH Delfland would be a source of drinking water production, what would be the optimal form of collaboration between HH Delfland and Dunea?

Additional questions for Waternet

1. How did Waternet originated as water cycle organization?
2. Is the technological drinking water system connected with the wastewater system?
3. How is the communication between the different sections of Waternet (wastewater, drinking water, water management, sewage)?
4. Does Waternet have one tariff for all water services?
5. Did the merge of different Waternet lead to economic efficiency?
6. Do you see drinking water companies and water authorities moving towards a water cycle company? Should they?

Appendix III - The Freshwater Factory

Water Authority Delfland has installed a pilot at WWTP De Groote Lucht (DGL) to obtain knowledge on technological practices of ozonation and biofiltration and the costs associated with organic micro-pollutant (OMP) and toxicity removal. A second goal for the pilot is to find design parameters for the desired full scale installation. As explained, HH Delfland has chosen for ozonation but remains interested in pilot experiments with other advanced treatment steps. It has not been decided yet what treatment method the desired full scale installation will consist of. The other options for advanced wastewater treatment (reverse osmosis and activated carbon) are also an option still. This Appendix will discuss the treatment scheme of WWTP DGL including the pilot configuration, based on Van Es (2017b).

Treatment scheme

Figure 43 shows the treatment scheme of the conventional WWTP De Groote Lucht including the pilot of ozonation and biofiltration. The first step of treatment at WWTP DGL is the conventional step of activated sludge (CAS) treatment. Activated sludge (CAS) treatment is a common way of conventional biological wastewater treatment in Europe. The configuration of the CAS treatment is according to the University of Cape Town (UCT) Process which includes biological nitrogen and phosphorous removal.

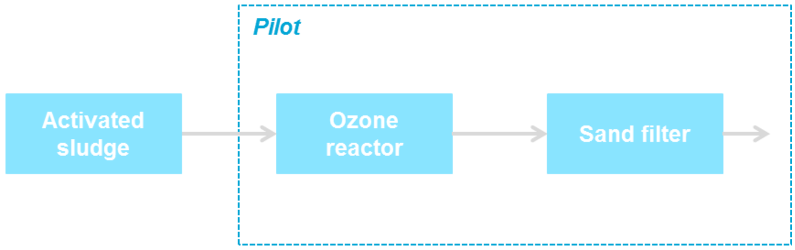


Figure 43 - Treatment scheme of WWTP DGL including the pilot

The pilot consists of an ozonation step and sand filter. The principle of treatment with ozone is oxidation of OMPs into smaller, biodegradable transformation products (Margot et al., 2013). In the biologically active sand filter the oxidation products are biologically degraded by the biomass. The sand filter also achieves further nitrogen and phosphorous removal. Table 10 shows the key figures of the FF pilot.

Table 10 - Key figures of the FF pilot

Key figures HHD pilot			
Water analyzed	WWTP DGL effluent	**Contact time**	14 min
Chemical analysis	129 OMPs	**Ozone generated**	From pure oxygen (corona generator)
Biological analysis	YES	**Ozone dosage range**	4,6-13,8 mg/l
OMPs present	Naturally occurring	**DOC**	10,5 mg/l
OMP concentrations	0 - 2,5 µg/l	**O3/DOC range**	0,44-1,31 O3/DOC (corrected for nitrite)
Set-up	Pilot scale	**NO2-N**	0,07-0,57 mg/l
Ozone contact	Continuous-flow	**Temperature**	21,5 °C
Flow analyzed	26 m^3/h	**Type of ozone injector**	Venturi injector (in main stream)

Ozonation

This section provides more information on the ozonation treatment step. Ozone is an unstable molecule and should hence be generated at the point of application. The reaction is endothermic and requires a considerable amount of energy (EPA, 1999).

$$3O_2 \rightleftarrows 2O_3$$

Operation

Ozone treatment systems typically consist of four components: gas feed system, ozone generator, ozone dosing, ozone contactor and off-gas destruction (see Figure 44) (EPA, 1999).

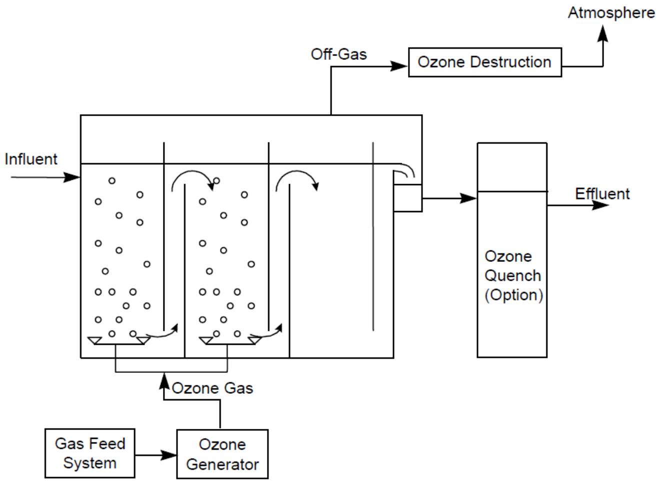


Figure 44 - Four components of an ozone treatment system (EPA, 1999)

The installation requires a **gas feed** flow which can be high purity oxygen or air. The operation of the first is relatively simple; liquid oxygen is stored in a tank and converted to a gas by an evaporator. The latter is fairly complicated as the air should be properly conditioned with all sorts of air compressors, filters and dryers. The gas feed flows into a generator in which, most commonly by corona discharge, **ozone is generated**. An oxygen-containing gas passes through two electrodes separated by a dielectric and a discharge gap. When voltage is applied to the electrodes, an electron flow across the discharge gap will occur. The oxygen molecules are disassociated by the energy of the electrons which leads to the formation of ozone (EPA, 1999). Generating ozone requires balancing between ozone yield and operational reliability and reduced maintenance (EPA, 1999).

The ozone gas is transferred (dosed) to the water by flowing into the **ozone contactors** to transfer to the water. Two configurations are widely used: bubble diffuser contactors or injectors. The final component of an ozone treatment system is the **off-gas destruction**. The off-gas from the installation can have dangerously high concentrations of ozone. For this reason, the gas is collected and ozone is converted back to oxygen by a catalyst before released into the atmosphere (EPA, 1999).

Reaction mechanisms

Ozone in water can react in two different ways with compounds present: direct oxidation by molecular ozone (O_3) or oxidation by hydroxyl radicals ($\cdot OH$) produced during the decomposition of ozone (see Figure 45). The decomposition of ozone happens spontaneously during water treatment by a complex mechanism involving the production of hydroxyl radicals (EPA, 1999). Ozone reacts selectively with compounds at a reaction rate from no reaction up to 10^{10} $M^{-1}s^{-1}$ (Hollender et al., 2009). Hydroxyl radicals react strongly and non-selectively with compounds at reaction rates of 10^{10} to 10^{13} $M^{-1}s^{-1}$ (EPA, 1999).

Reaction of ozone or hydroxyls does not fully mineralize organics (converting them into inorganic substances such as H_20 and CO_2) or physically removes organics but rather produces smaller organic compounds as product (Lee et al., 2012). These metabolites are typically more polar and biodegradable than their parent compounds (Lee et al., 2012). Biodegradable oxidation products can be (partially) removed during biological post-filtration (Margot et al, 2013). It remains largely unpredictable what oxidation products will be transformed during ozonation, but in general they are expected to have a lower toxic activity than their parent compounds (Hollender et al., 2009; Larcher et al., 2012). However, higher toxicity of the metabolites has also been reported (Larcher et al., 2012; Rosal et al., 2009).

Figure 45 - Two pathways of ozonation: direct and indirect

Process conditions

Ozone dosage and ozone contact time are the most important process conditions during the operation of an ozone installation (Lee and von Gunten, 2016). A higher ozone dosage increases the removal of OMPs but does so at higher energy requirements and can also increase concentrations of toxic by-products in the effluent. Determining the ozone dosage will have to be the optimum between effective removal and low side effects. The ozone contact time will be the other important process condition. Ozone is usually completely consumed in 5-20 minutes (Lee and von Gunten, 2016). Research of Hollender et al. (2009) indicates that most of the ozone reacts within four minutes of contact time.

Main complexities

- Ozone dosage applied
- Average removal efficiency
- Bromate formation
- Individual OMP removal
- Modelling OMP removal

References Appendix III

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Appendix IV – Scientific article