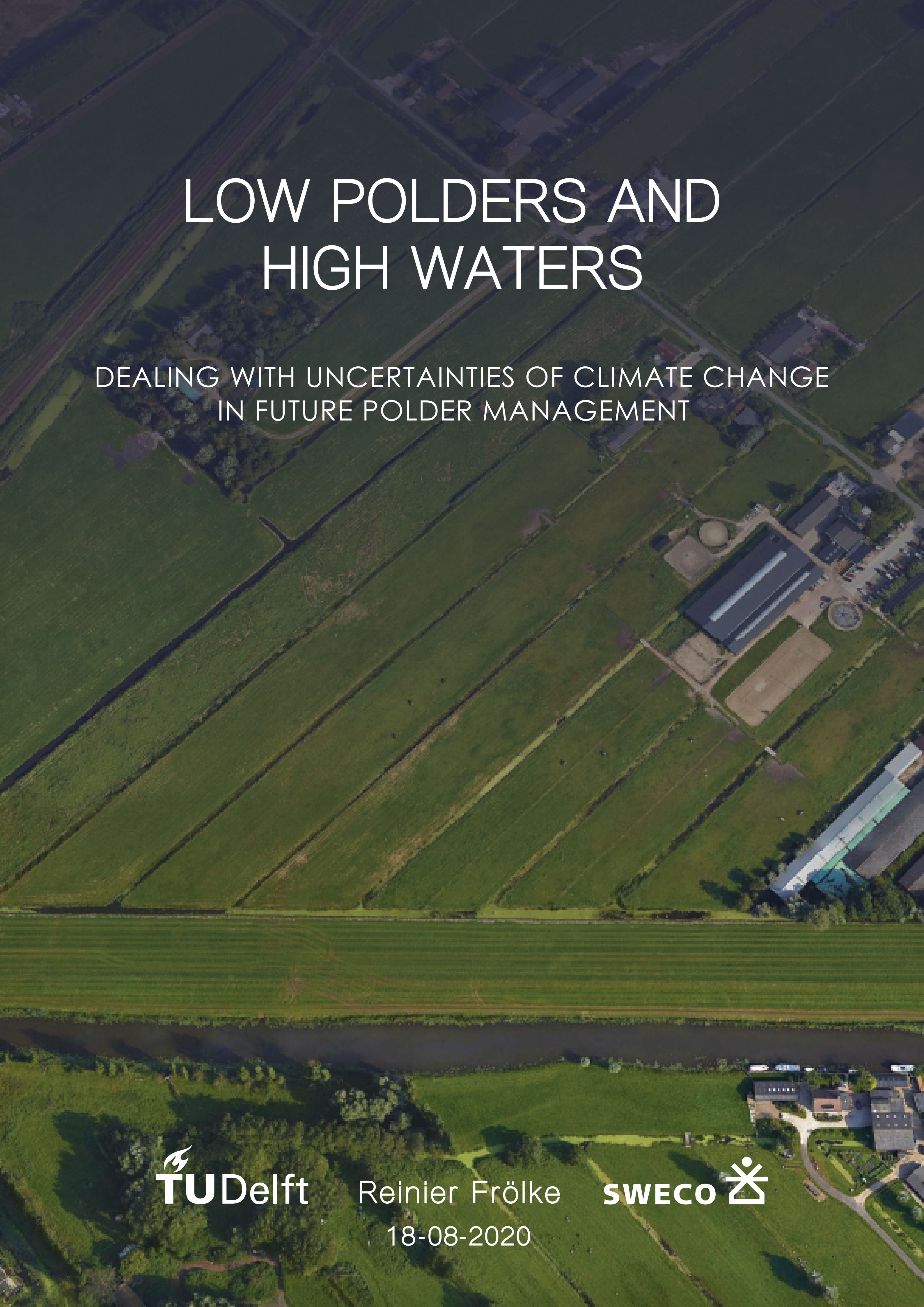

LOW POLDERS AND HIGH WATERS

DEALING WITH UNCERTAINTIES OF CLIMATE CHANGE IN FUTURE POLDER MANAGEMENT

TU Delft

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SWECO

18-08-2020

Low polders and high waters:

Dealing with uncertainties of climate change in future polder management

by

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to obtain the degree of Master of Science
at the Delft University of Technology,
to be defended publicly on Tuesday August 18, 2020 at 11:00 AM.

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TU Delft

Preface

This thesis could not be finished without the help and guidance of others. Therefore, I would like to take the opportunity to express my gratitude and deepest appreciation to everyone who have helped me during this research project.

At first, I would like to express my gratitude to the members of my committee at Delft University of Technology. To Erik Mostert, for his time for frequent progress meetings which provided useful and practical feedback. To Olivier Hoes, for his help in unravelling the puzzle my hydrological model proved to be. To Jos Timmermans, for his clear feedback, especially on the methodology part of this research.

Secondly, I would like to thank Sweco and its employees for providing a pleasant place to perform my research. Here, a special thanks goes out to Nikeh Booister, being my in-company supervisor. Due to her helpful, understanding and friendly supervision I was able to lift the quality of my research in an amiable way.

Besides, I would like to thank my roommates. Not only for helping with my thesis, but for providing a loving, caring and *gezellige* place to live during my years of studying as well. In the same line, I want to express my gratitude to my friends who helped out in varying parts of my research. Additionally, I owe a big thanks to the roommates of my former house (read: my parents) for their care and support, especially during the final months of my thesis. Last but not least, a special thanks to my girlfriend Kim for her encouragement, suggestions, and constructive criticism.

Reinier Frölke
Delft, August 2020

Abstract

It is no secret that the climate is changing, however, the severity and speed of this process is under debate. This leads to the question if and when we need to take action to protect the Netherlands against the effects of climate change. In order to deal with the uncertainties in policy- and decision-making, an adaptive approach is desirable. An option is to apply the Dynamic Adaptive Policy Pathways (DAPP) approach.

The DAPP approach has been applied successfully in several large scale projects. However, less attention is given to the application on small scale areas, and no applications on (small-scaled) polder areas are present.

The aim of this report is to answer the following research question: *"Is the Dynamic Adaptive Policy Pathways approach suited for improving the adaptivity of polder management, given the uncertainty in climate change effects?"* The Zuidplaspolder is used as a case area for application of the DAPP approach. This deep-lying polder is interesting due to its diverse land use, the low elevation levels and already present issues in water management.

Through assessing the potential effects of climate change, conducting interviews, creating a hydrological model and following the steps of the DAPP procedure, a pathway map for the Zuidplaspolder is created. This pathway map is evaluated during focus groups with stakeholders from the Zuidplaspolder case area, as well as actors from a different polder area, being the Schermerpolder. Besides evaluating the applicability of the pathway map, the DAPP approach itself was assessed as well.

The pathway map provided several insights, one being the requirement to start considering actions at present in order to timely cope with issues in the future.

Moreover, it was found that the DAPP approach is suited for improving the adaptivity in polder management, given the uncertainty in climate change effects. The pathway map is a helpful tool for authorities and affected stakeholders within polder areas to explicate upcoming issues. However, a cost-benefit analysis is required for actual, well-informed policy- and decision-making based on the pathway map. Nonetheless, it assists in making decisions more strategically and to explain certain choices in decision-making, which helps in creating support and understanding. Even though there are difficulties in translating large-scale actions and their effects to a smaller scale, the scale of the case area proved not to be a major issue. At last, the DAPP approach is found useful for other polder areas as well. However, a general pathway map cannot be created, since each polder has its unique set of characteristics and stakeholders with mindset on urgency.

When the pathway map is utilised for actual policy- and decision making, the use of an extended model is recommended. Here, probabilistic simulations are suggested, as well as the incorporation of several components that were excluded in this research. For identifying an integral pathway map for Dutch polder areas, it is recommended to research the clustering of polder characteristics on their constraints and related measures. By selecting the clusters that fit a designated case polder, a tailored pathway map can be created.

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Abbreviations

KNMI Koninklijk Nederlands Meteorologisch Instituut (Royal Netherlands Meteorological Institute)

HHSK Hoogheemraadschap van Schieland en de Krimpenerwaard

IPCC Intergovernmental Panel on Climate Change

DAPP Dynamic Adaptive Policy Pathways

LTO Land- en Tuinbouw Organisatie (Agricultural and Horticultural Organisation)

GOM Gebiedsontwikkelingsmaatschappij Zuidplas (Consortium of several companies, assigned for the construction of housing in the Zuidplaspolder)

1 Introduction

The history of the Netherlands holds a large amount of stories where the terms *water* and *fighting against* are combined. Tales on battles in which water is the enemy are widely present. Currently, with nearly 18.000 km of levees protecting its inhabitants and assets [90] and nearly 1900 pumps working to keep lands dry [65], the Dutch are in a continuous brawl to prevent their land from falling into wetness. Especially since large parts of the country are used intensively, and require both constant flood protection and artificial drainage.

Figure 1.1: Drawing of one of the numerous floods in Dutch history, at Gorinchem in 1820. (Roelof van der Meulen, 1820)

The most recent and memorable incident where water overran the Dutch water defences, is the flood of 1953. This event sparked the launch of the Delta Plan, which forms the core of the current water protection infrastructure and policies in the Netherlands. Ever since, no actual flooding of Dutch regions has occurred. However, the last decades have shown signs that larger resistance from the waterfront is to be expected.

This is due to a new component within the playing field between man and water: climate change. This phenomenon is expected to increase the number of *fighting against water*-stories in the future, as it negatively affects several aspects of the water system, both on a global and a local scale. Especially for the Netherlands, where around one-third of the total surface area is located below sea level [4]. Amongst the areas that will face challenges are the famous, but also sensitive Dutch polder systems.

1.1. Consequences of a changing climate

The world as we currently know is changing in many aspects due to climate change; the temperatures increase, the sea level rises and precipitation becomes more extreme [41].

One of the mayor concerns is the rise in sea level. This phenomenon is mainly caused by the increase of global temperature, as this induces the melting of land ice and the expansion of seawater. Besides the shift in temperature, human activities are bolstering the rise in sea level; by making use of groundwater and fresh water from inland reservoirs, excluded volumes of water are becoming included in the global water system [22].

In 2018, a review of one-hundred years of scientific, political and media records by Baart et al. showed that "the attention to sea-level rise rose faster than the sea level itself". Despite a possible disproportional growth in awareness, there is a valid reason for it: world wide, over 625 million people are currently living in coastal areas, defined as areas with an elevation of less than 10 meter above mean sea level. Furthermore, the population within these regions is expected to increase in the future [66].

Besides causing a rise in sea level, the shift in temperature will have an effect on Dutch water management. In the upcoming century, climatic warming is expected to force changes in the global hydrological cycle that will have an impact on regional water resources [40].

Associated with these changes in temperature, is a shift in global atmospheric circulation. This shift in *circulation pattern*, that is driven by large-scale wind and pressure systems, will impact the hydrological conditions on a local scale. In essence, as the wind behaviour within the Netherlands is expected to change, precipitation and evaporation values will become more extreme and severe [38].

1.2. Uncertainty...

Based on historical data, a shift in the aforementioned consequences of climate change are undisputed [41]. However, the severity and speed of this process are prone to discussion. The Intergovernmental Panel on Climate Change (IPCC) presents projections of climate change in their Assessment- or Special Reports, containing predictive values for climatic parameters that are shifting due to climate change. The IPCC uses scenarios based on different projections for the emission of greenhouse gasses.

The fifth, and latest Assessment Report (AR5) was delivered in 2014, stating that the global mean sea level would rise with 0.5 to 1m in the worst scenario [41]. Subsequently, in 2019, a *Special Report on the Ocean and Cryosphere in a Changing Climate* was delivered, containing a more concentrated view on future values of sea level rise [74]. It presented a comparable vision on the future sea level rise as the AR5. Since 2014, there has been discussion about these values. It is ought that influential mechanisms that enhance sea level rise have been left out, causing the rise in sea level to be underestimated [54]. Since the AR5 was published, research has provided new projections which include several mechanisms of the melting of arctic ice.

For example, DeConto and Pollard (2016) found that with incorporating *hydrofracturing* (separation of relatively large ice sheets) and *Marine Ice Sheet Instability* (increasing contact area of ice sheets with ocean water), the melting of Arctic ice sheets alone are capable of contributing 1.14 meter to the rise in global mean sea level in 2100. This is an significant increase, since the the expected sea level rise for the Dutch situation (based on the AR5) in 2100 lies between 0.35 and 1 meter [38]. When the Arctic contributions, as found by DeConto and Pollard, are used in the original AR5 calculations, predictions of high-end values for the Dutch situation are varying from 2 to more than 3 meter at the start of the 22th century [55]. A visualisation of the bandwidth in uncertainty is presented in Figure 1.2. Moreover, the sea level will continue to rise after 2100, possible some 5 to 8 meter in 2200 [26].

Besides, the predictions for precipitation and evaporation values, driven by changes in circulation pattern and temperature rise, have a range of uncertainty as well (see Figure 1.3). Where the methods for concluding these projections are not as much under debate compared to sea level rise, projections for the far future (around 2100) always bring uncertainties.

Uncertainty is found in both the methods to determine the effects of climate change, as well as in the provided values by these methods since they present likely ranges. In predicting precipitation and evaporation values, driven by changes in circulation pattern and temperature rise, there is a smaller range of uncertainty. This is due to the fact that there is negligible ambivalence in the methods of retrieving the results, like there is for sea level rise.

Even though, all aspects of climate change hold uncertainty, albeit on a varying level. Since all of the predictions are constructed using self-created scenarios on the severity of the climatic interference of mankind, they may hold ambiguity.

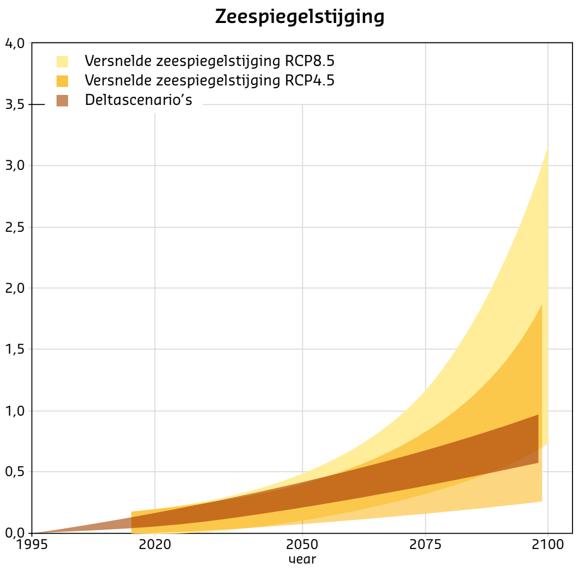

Figure 1.2: Predictions of sea level rise in meter until 2100 for three scenarios, indicating the bandwidth of uncertainty [26]

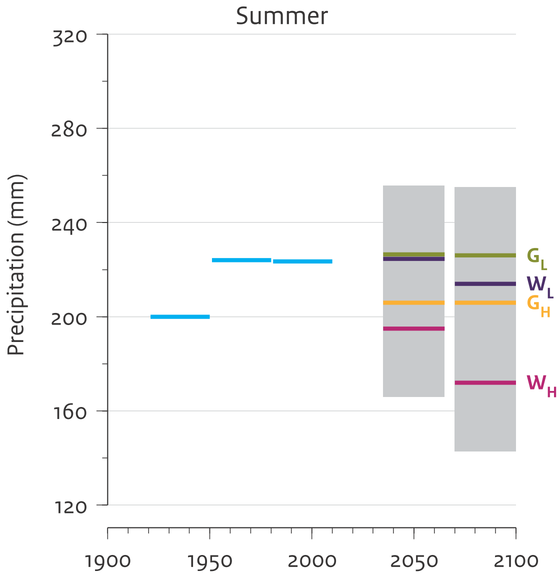

Figure 1.3: Forecasts of summer precipitation values until 2100 for four KNMI scenarios. The range of uncertainty is shown in grey [46]

The answer to the question how severe and fast climate changes leads to an even more crucial question; do we, and when do we need to take action in order to protect the Netherlands against the effects of climate change?

Multiple aspects of the Dutch water system are sensitive to the consequences of climate change: the protection of coastal areas, the supply of drinking water, salt water intrusion in rivers and the failure rates of flood barriers [17]. On a smaller scale, climate change will induce more pressure on the intensive management of polder areas [30]. This applies especially to low-lying polders, due to their sensitivity to changes in the hydrological system [52]. For the sustainable management of water systems, a method to deal with the uncertainties in climate change is required.

1.3. ... and how to deal with it

The uncertainty in climate change poses challenges for long-term water management, especially the management of polder areas. Besides, non-environmental aspects entail uncertainties as well, such as population growth and economic developments [25]. Hence, policy- and decision-makers need to be confident that the measures they take at present are able to cope with the changing conditions in the future. In order to do so, decision-makers need approaches that consider the uncertainties and help them with decision- and policy-making on the long term.

Broadly, a distinction can be made into *static* and *dynamic* approaches. The static approach is considered the most traditional, and assumes that the future is predictable. It uses a single most likely future, or focuses on acceptable outcomes in most future pathways, to create a plan or strategy [29]. This method is somewhat treacherous, as there is a tendency to be over-confident in the ability to predict the future [85]. Furthermore, when one of the unexpected futures unfolds, the adopted plan or strategy is highly likely to fail [60].

Therefore, more policymakers start to adopt a dynamic approach. With handling an adaptive approach, the ability to change plans based on new experiences and insights is embedded in the planning process [56]. Flexible, dynamic approaches to planning can enhance the timeliness, efficiency and effectiveness of policy decisions under uncertainty, especially since historical data becomes an increasingly unreliable guide to future conditions [68]. With this, policy- and decision-making is becoming a part of the narrative, instead of playing an overarching role [25]. Over the last decades, the research on adaptive approaches rose and gained attention worldwide.

The *Dynamic Adaptive Policy Pathways* (DAPP) approach is one of the applicable methods for integrating flexibility in decision- and policy-making [58]. As presented by Haasnoot et al. (2013), the DAPP approach supports the development of adaptive policies and plans based on an analysis of possible alternatives over time, under a range of possible future scenarios. In short, application of the DAPP approach results in a map of pathways that lead to a desired future situation. Here, pathways are sequences of actions that ought to be taken on the right time.

There are multiple positive aspects of the DAPP approach. First of all, it is found to be an effective method to inform and mobilise decision-makers [7]. This is partly due to the clear visual representation, which makes it easy to understand and use. Besides, Maru and Smith (2014) found that adaptation pathways have the ability to combine vulnerability-reducing and resilience-building responses into (potentially) better outcomes in the future. Furthermore, application of the DAPP approach in New Zealand learned that it enables a full range of plausible futures to be explored, even the futures with a very small chance of becoming reality [58]. Considering a wide range of possible futures, this provides a clear view on the extreme scenarios.

An example of the use of DAPP is provided in Figure 1.4, regarding the management of a proper freshwater system in the Dutch basin of the river Rhine. Here, actions are listed on the y-axis and two scenarios, with their respective timelines, shape the x-axis. Choosing different sets of actions lead to different pathways. More information on using a pathway map is provided in Section 7.1.1.

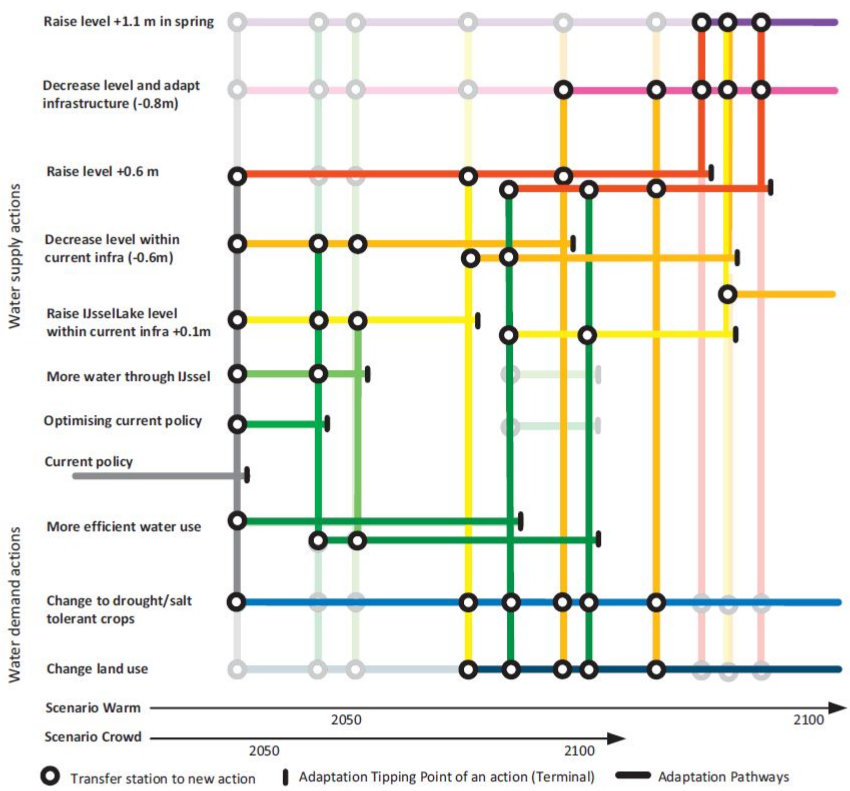

Figure 1.4: Adaptation pathway map for the provision of fresh water in the Dutch Rhine basin [25]

1.4. Knowledge gaps

It is found that uncertainties in the consequences of climate change are potentially troubling the management of Dutch water systems, such as polder areas. Research shows that Dutch polder areas are prone to changes in the future, such as shifts in water quality and quantity [13] [30] [39] [71] [82] and land subsidence [19] [93]. Currently, scenarios created by the Koninklijk Nederlands Meteorologisch Instituut (KNMI) provide the basis for most of the policies regarding climate adaptation in the Netherlands [38]. Hence, these scenarios are used in the water management of polder areas as well, for example in the design of water storage capacity [32]. However, being a static approach, as mentioned in Subsection 1.3, this method leaves no space for changes after a strategy is implemented. When an unexpected scenario unfolds, which is likely due to the many uncertainties in climate change, the inability to adapt to these circumstances causes complications [25].

And so, the use of a dynamic adaptive approach, such as DAPP, may help to increase the adaptivity in policy- and decision making in polder areas. The DAPP approach already proved to be a useful method for increasing adaptivity in numerous large scale projects. As Haasnoot et al. (2019) argue, much of the work related to DAPP has been carried out for large, well-resourced, regional or national-scale planning studies (e.g. the example of the Dutch Rhine basin in Figure 1.4, the Dutch Delta Programme and the Bangladesh Delta Plan [26]). Practice has shown that the approach is appropriate for tailoring to context-specific conditions. However, they state that further application of the approach to local, and possibly more resource-constrained, planning challenges is necessary to evaluate its general usability [28].

Therefore, this study will go beyond the level of large scale applications of the approach and will provide more insight in the use of DAPP in the context-specific conditions of polder areas. Additionally, the application of the approach to polder systems could potentially improve the adaptivity in polder management as well. At present, no research has been conducted on the effectiveness of DAPP on polder systems, which differ from large scale projects due to different stakeholder dynamics and institutional settings. By addressing this knowledge gap, the present study will enhance our understanding of the DAPP approach.

The knowledge gap mentioned above consists of two components; a difference in (1) dynamics between stakeholders and (2) the institutional setting within a polder setting, compared to large scale projects.

To begin with, future changes in the physical system of polder areas may induce issues for stakeholders, as their objectives may be endangered. Here, decision- and policy-makers are expected to provide a strategy to cope with these issues. However, within a polder area, a wide and diverse set of affected stakeholders is found. With a wide range of stakeholders, each with their own objectives and measures to meet these objectives, a complicated context setting emerges [58]. Consequently, a greater community consensus is required for implementing adaptive approaches, compared to larger scale case areas [53]. Haasnoot et al. (2019) state that in previous studies, little attention has been given to these issues, when applying the DAPP approach. They argue that it is a challenge to support the design of adaptation pathways in complex multi-stakeholder contexts effectively. Different stakeholders are responsible for different actions and have different preferences. What is desirable for one stakeholder might be conflicting for another, giving rise to conflicts [10]. Besides, due the small scale of the case area, decisions may potentially affect the current livelihood or family-owned assets of stakeholders, which is likely to induce a certain degree of conflict [99]. The emergence of these conflicts might be conditional on specific actions, driven by changing conditions, or be defined by individual preferences. The overarching challenge is to bring the societal robustness of pathways into focus, in addition to robustness with respect to the future.

Next to the stakeholders dynamics, another distinction found between the national- and polder scale is the institutional setting. The institutional setting can be described as a system of rules that guide the actions of actors [81]. Examples of this system's function are structuring local responses and mediate between the different stakeholders [2]. On a polder scale, a different system of rules is found compared to large scale cases. Whether this affects the effectiveness of the DAPP approach is not fully tested yet [53].

In particular, this study will focus on the complex multi-stakeholder setting within polders and will therefore enhance our understanding of the DAPP approach given the interests of multiple stakeholders. Besides, useful insights for long-term polder management could be obtained when applying the DAPP approach to polder areas.

Furthermore, when creating scenarios for the DAPP approach, the use of high-end projections for sea level rise could provide new insights in long-term planning. Currently, many reports and policy documents use fairly moderate projections of sea level rise for creating future adaptation strategies. One example is the governmental Deltaprogramme 2019, being one of the highest overarching policy programmes in Dutch water management, where a maximum sea level rise of 1 meter is considered in 2100 [17]. So far, within the Netherlands, a limited number of studies use extreme high-end values for their analysis or research. The ones that did were conducted mostly for exploratory reasons [27] [69] [88]. Embedding high-end values for sea level rise explicates a wider range of possible futures within polder areas. With that, further understanding of possible futures is enabled within polder areas.

1.5. Research questions and methodology

The aim of this report is to assess whether the Dynamic Adaptive Policy Pathways approach can enhance the adaptivity of policy- and decision-making in polder areas. Since polder areas are small-scale water systems, they create a relevant case for testing the usability of DAPP on this level of scale. Besides, due to their vulnerability to hydrological changes and wide presence in the Dutch landscape, the application of DAPP might create valuable insights for the management of polders in the future. Therefore, the main question is as follows;

Is the Dynamic Adaptive Policy Pathways approach suited for improving the adaptivity of polder management, given the uncertainty in climate change effects?

In order to answer the main question, a case area is needed to test the DAPP method on. For this, the Zuidplaspolder is used, located between Rotterdam and Gouda in the province of South-Holland. This deep-lying polder makes an interesting case due to its low elevation, compressible soil types and diverse land use. Besides, several issues regarding water management are present already. These characteristics create a complex system, on which climate changes are expected to have a significant effect. Therefore, the DAPP approach can be evaluated for its effectiveness in improving the adaptivity of policy- and decision making within this polder area.

Hereafter, the general applicability of the DAPP approach is tested using on a second case polder. To provide an answer to the main question, the following sub questions are formulated;

1. What does the hydrological system of the Zuidplaspolder look like?
2. How is the Zuidplaspolder influenced the effects of climate change?
3. How can a quantitative model of the Zuidplaspolder's hydrological system be constructed?
    3.1. How can the polder be schematised?
    3.2. What components of the polder system need to be embedded?
4. What scenarios should be used for future projections?
5. How can a pathway map be constructed for the Zuidplaspolder?
    5.1. What are the objectives and crucial aspects of different actors within the polder area?
    5.2. What actions can actors take to maintain a desired situation?
    5.3. When do these actions need to take place?
6. To what extent is adaptive management incorporated in the current policy- and decision-making of the Zuidplaspolder?
7. Can the used methodology and the outcomes for the Zuidplaspolder be applied in other polder areas?

The interlinked use of (1) a hydrological model of the Zuidplaspolder, (2) the DAPP approach and (3) gathered qualitative data through interviews and focus groups is required to answer both the main- and sub questions. More details about the methodology are presented in Chapter 3.

1.6. Report outline

At first, the relevant consequences of climate change in polder systems will be presented in Chapter 2. Secondly, Chapter 3 will elaborate on the methodology. More specifically, each of the methodological components, and the way there are interlinked is presented. Thirdly, a description of the Zuidplaspolder is presented in Chapter 4. Here, information is presented which provide a base for the creation of the hydrological model. Fourthly, Chapter 5 will elaborate on the hydrological model of the Zuidplaspolder, along with its design choices, input parameters and scenarios. At fifth, Chapter 6 shows the outcomes of the Dynamic Adaptive Policy Pathways approach. Chapter 7 presents the results of this research. Here, the pathway map of the Zuidplaspolder is presented, developed with the findings in Chapter 5 and 6. Besides, results from the focus group sessions are elaborated. In Chapter 8, the results and methodology will be discussed. The final chapter, Chapter 9 will provide a conclusion to this report and present recommendations.

2

Future changes in polder systems

This chapter will present several changes that may occur in Dutch polders in the future. Since every polder has its unique features and characteristics, the impact and severeness of climate-driven shifts will differ per polder. Below, several aspects of a polder system that are prone to changes are elaborated. In Subsection 4.7, the current and future issues within the Zuidplaspolder case area are identified.

The changes in polder areas can be distinguished in two types. Firstly, there are shifts which are inflicted by local human intervention in the polder system, having both a direct and relatively short-term impact. Secondly, there are changes caused by climate change, which are part of a global, long-term process that can not be influenced by anthropogenic actions on the scale of a polder.

First, a clear definition of a polder area is provided. In 1982, Segeren defined a polder as follows:

> *An area which has originally been subject, permanently or seasonally, to a high water level (groundwater or surface water) and is separated from the surrounding hydrological regime, to be able to control the water levels in the polder (groundwater and surface water) independently of the surrounding regime.*

A visualisation of a polder catchment area is presented in Figure 2.1.

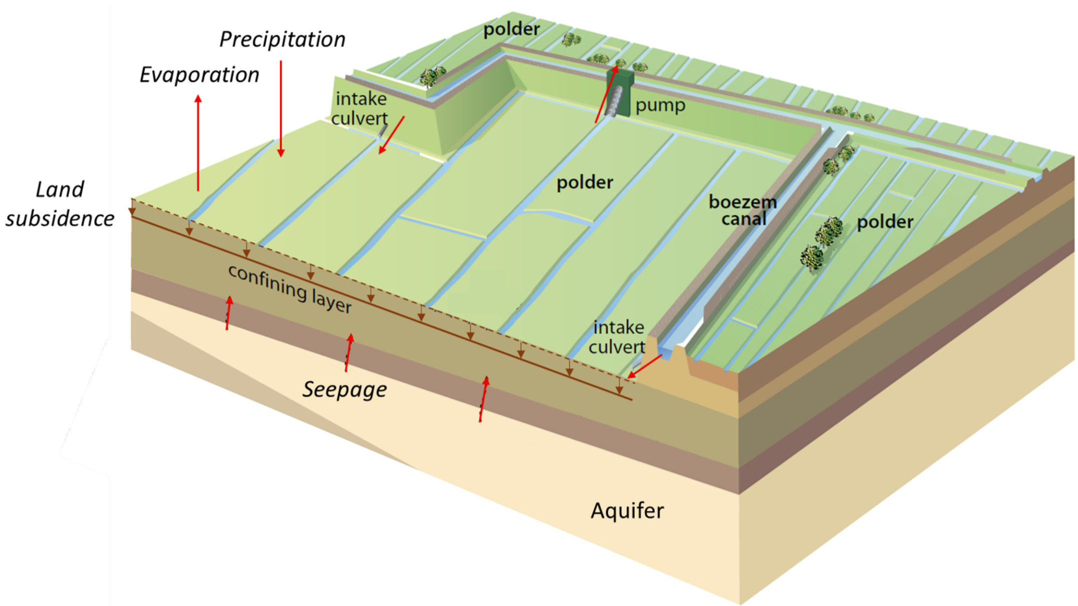

Figure 2.1: Visualisation of a polder system. Water fluxes are represented with red arrows. The process of land subsidence is visualised with brown arrows.

In the Netherlands, around 30% of the total surface area lies beneath sea level [4]. Through isolation of a local water system from the water system on a higher scale, thus creating a polder, it is possible to use these areas despite the low altitude. The following sections will present the transitions polder areas have to endure in the future. At first, land subsidence will be clarified. Secondly, the effects of sea level rise are elaborated. As third, a clarification on seepage flows is presented. Finally, changes in precipitation and evaporation are explained.

2.1. Land subsidence

The process in which the soil elevation level is lowering, caused by both anthropogenic and autonomous processes, is called land subsidence. It occurs mainly at regions with clay and/or peat soil types, as these are susceptible for *compaction*. Compaction means the continuous compression of soil layers by its own weight, the weight of higher-elevated soil layers or structural loading (i.e. roads and buildings). Furthermore, peat soils are subject to *oxidation*. Oxidation occurs when organic matter is exposed to oxygen due to drainage, resulting in a reaction in which the organic matter is decomposed [19].

The subsidence mechanisms of oxidation and compaction are enhanced by anthropogenic actions, however, they occur naturally as well. The autonomous component of land subsidence cause certain areas in the Netherlands to lower by several millimetres per year [86].

However, most of the soil subsidence is human-induced. This anthropogenic component has the potential of causing several centimetres of subsidence per year. The main drivers are the extraction of groundwater, drainage for land reclamation and structural loading [91]. Furthermore, local water authorities contribute to land subsidence by lowering water levels for the benefit of users within the low-lying areas. This leads to extended oxidation of peat layers, causing a further lowering in elevation [76]. Figure 2.2 visualises the varying mechanisms for land subsidence.

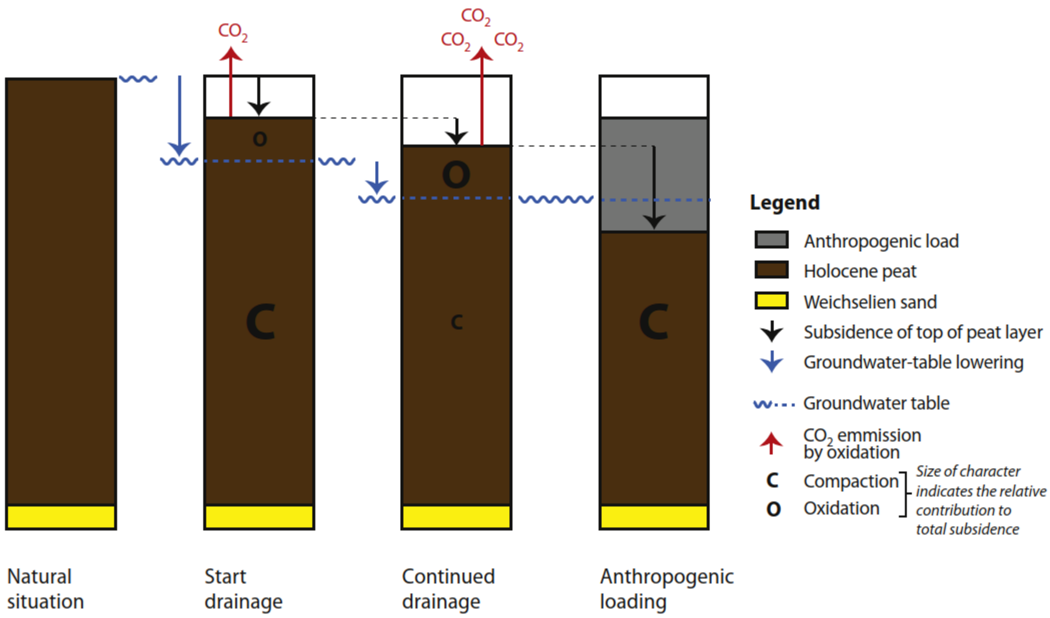

Figure 2.2: Schematic representation of land subsidence due to peat compaction, oxidation and anthropogenic loading [91]

Land subsidence causes several issues. At first, it may cause damage to buildings and infrastructure, both below and at the surface level [91]. Especially when there are local differences in subsidence rates, this may become a significant burden. Secondly, the process of peat oxidation leads to the emission of CO_2 gasses. Being a greenhouse gas whose emission is to be reduced to zero in 2050 ([63]), this is of national political importance. The emission of CO_2 gasses from peat areas contributes approximately 5% to the national CO_2 emissions [31]. Thirdly, lower elevation levels cause a increase in flood risk. Certainly in combination with sea level rise, an increase in flood frequency, inundation depth and flood duration is expected [24]. Lastly, a lowered elevation increases the water level difference between the polder and both its surrounding water bodies and the sea. This may increase the incoming water fluxes from adjacent water bodies and deeper soil layers (see Section 2.3).

As presented above, land subsidence may affect several aspects in polders of the future. For decent management, it is important to recognise the severity and rate of this process to prevent its negative effects within the system.

2.2. Sea level rise

The increase in global temperature causes land ice to melt and sea water to expand, inducing a rise in sea level. Furthermore, the anthropogenic use of inland water reservoirs adds previously excluded volumes of water to the global water system, which adds to the rise in sea level as well [22].

Sea level rise induces two influential changes to a polder's water system. Firstly, the hydraulic head of aquifers underlying the confining soil layer will rise, inducing an increase in seepage flows. Secondly, water levels in adjacent water bodies will rise, causing several issues to occur. Below, the two shifts are elaborated, including the issues they may induce.

2.2.1. Increase in hydraulic head aquifers

Most aquifers (i.e. water carrying sand layers underneath a confining top layer) in the western part of the Netherlands are in contact with the North Sea. When the sea level rises, the groundwater pressure in these aquifers increases as well. This groundwater pressure, named *hydraulic head*, can be described as the height that the water will reach when a tube is placed in the aquifer, in contact with the atmosphere. A large hydraulic head, compared to a reference level, indicates a high upward water pressure originating from aquifers.

High values for the hydraulic head lead to larger upward flux of deep and saline groundwater. Both the water quantity and quality of this flow may cause issues in a polder system. In Section 2.3, an elaboration on this mechanism is presented.

In areas close to the North Sea, the rise in hydraulic head due to sea level rise is larger compared to regions further inland. Figure 2.3 shows the increase in hydraulic head as the percentage of the absolute sea level rise, as presented by Oude Essink et al. (2010). In this figure, an open connection between the sea and inland rivers is assumed, thus neglecting water barriers. This causes the effect of sea level rise to reach further inland than presumably will.

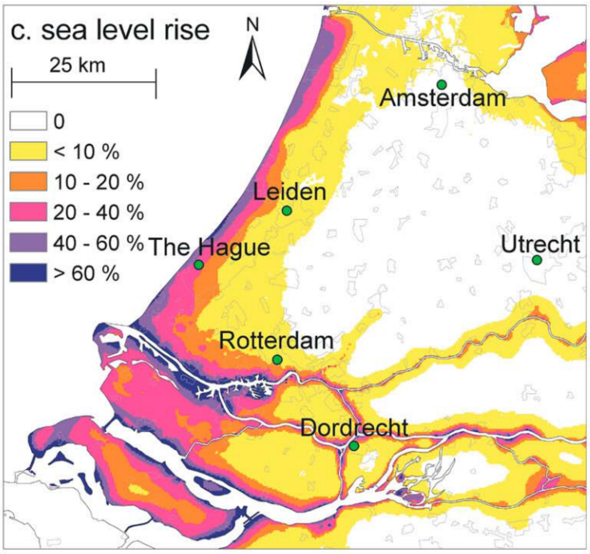

Figure 2.3: Percentual increase in hydraulic head in the first aquifer, compared to the absolute rise in sea level within the province of South-Holland [71]

As visualised in Figure 2.3, the severity of rising hydraulic heads shows a strong spatial distribution. For polders near the sea, the effect is significant and will potentially have a large contribution to increasing seepage flows. Knowing the potential increase in seepage flow, and its related issues, may affect the choices in policy- and decision-making.

2.2.2. Rise in adjacent surface water levels

Along with the sea level, the surface water level in connected rivers and other water bodies will rise as well. This affects several components of a polder system. First, it increases the risk of floods. As surface water levels rise, levees become more vulnerable and the probability of failure increases [69].

Secondly, high water levels in adjacent water bodies reduce the capability of discharging water from a polders water system. When a maximum surface water level is reached, and with that the maximum storage capacity of the receiving river, further discharge from the polder is stopped. This decision relieves further pressure on downstream flood protection works in situations where the threat of high waters is significant already. This phenomenon is called a pump stop (NL: *maalstop*). A pump stop leads to an accumulation of water within the polder area, causing water nuisance.

Generally, the management of surface water levels of (large) adjacent water bodies lies beyond the stakeholders in a local polder area. However, these water levels are important as they increase the risk of levee failures and water nuisance within polders. Therefore, possible changes in the higher level management of these water bodies should be observed.

2.3. Seepage

Seepage can be described as the process where (saline) groundwater reaches the surface by upward groundwater flow [13]. This flux is the largest at deep-lying polder areas and originates from higher elevated nearby areas and deep aquifers. As the opposite of seepage, *infiltration* may occur. Here, a flux leaves a water system, heading towards locations with a lower elevation or hydraulic head.

2.3.1. Seepage types

Seepage can be divided into three types, based on their water and salinity flux; *diffuse*-, *paleochannel*- and *boil* seepage [14]. Figure 2.4 presents a visualisation of the seepage mechanisms.

Diffuse seepage This type of seepage considers an upward flow through ground layers with low permeability and is present over the majority of a polder area. Examples of soil types with low permeability are peat, loam and clay. The quantity flux of this seepage mechanism is relatively small, as well as its salinity since the flow originates from shallower, less saline ground layers. However, since it is widely present, the flow over the polder surface is a significant component of the polder's water balance. Equations for calculating the diffuse seepage flux is found in Appendix B.4.3.

Paleochannel seepage As a result of the deposition from ancient water flows, *paleochannel* belts are meandering through the underground landscape. In these belts, a more sandy and permeable soil is found compared to the rest of the polder. This induces a larger seepage flux compared to diffuse seepage. Furthermore, this flow typically contains a higher grade of salinity as it originates from deeper aquifers. Clearly, this kind of seepage only occurs in areas where paleochannel belts are present. Mainly in the western part of the Netherlands, multiple locations with paleochannels are found [33].

Boil seepage Due to the groundwater pressure, cover layers with a low permeability may burst. At these locations, named *boils*, a highly saline seepage flow will start to move upward with high velocities. This is most likely to occur at locations where the cover layer is thin. Typically, this is found in ditches or areas where parts of the cover layer are excavated, for example at newly created water bodies [45]. Furthermore, boils are to be expected at locations with steep hydraulic head gradients, typically at the edges of polder areas [35]. In the Noordplaspolder, a deep-lying polder in the province of South-Holland, de Louw et al. (2010) found that 85% of the boils are found in ditches or at ditch banks.

2.3.2. Increase in salinisation

Seepage contributes to both the incoming water and salinity flux in a polder's water system. Where the water flux is relatively moderate compared to other incoming fluxes, the salt load has a larger impact and is a growing concern [21].

Salinisation in a polder system may interfere with the fresh water demand of different land uses, like industries, drinking water production, agriculture, nature areas, but also the liveability of urban areas [64]. For agricultural activities, a certain demand on fresh water has to be met to maintain desired circumstances for crop growth, since excessive salt concentrations will cause a reduced crop yield.

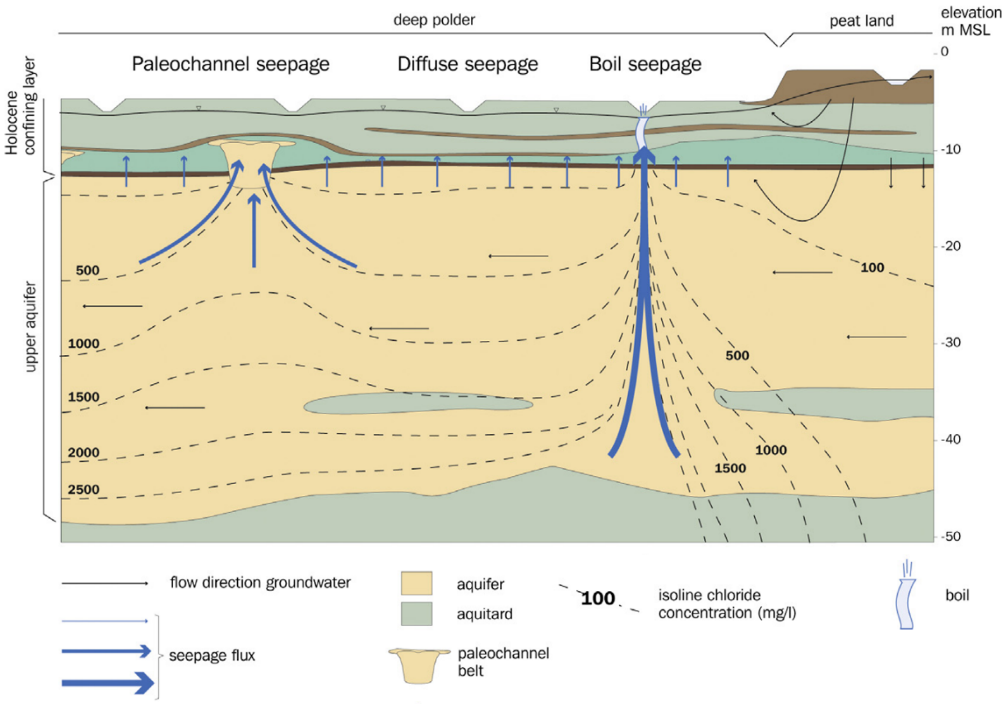

Figure 2.4: Visual representation of three seepage mechanisms in polder areas [14]

Similar to the effect on farmlands, an increased salt load will disturb the environment for species in nature areas. With this, the current ecosystem within a polder could be threatened.

Due to the combination of sea level rise and land subsidence, the upward seepage pressure from (deep) aquifers will increase. Consequently, the increase in saline and water fluxes will impact the water management in polder areas, especially in deep-lying polders. Here, salinisation is expected to be the main issue, due to its negative effects on agricultural activities.

2.4. Precipitation and evaporation

In the majority of polder areas, precipitation and evaporation are the largest in- and outgoing fluxes respectively [96]. This makes them crucial components in the polder's water balance.

Over the last century, an increase in values for precipitation and evaporation is found [11]. Furthermore, the intensity of extreme rain events in the summer increased [38]. Due to an increase in global temperature, and its subsequent shift in global atmospheric circulation, the precipitation and evaporation regime will experience further change. Specifically, a additional increase in severity and extremity of precipitation and evaporation values is expected [38].

Changes in the precipitation and evaporation regime, mainly the increasing extremity, may induce multiple issues. Firstly, a surplus of water is to be excepted in autumn and winter season, leading to water nuisance or even floods when the storage capacity does not suffice. Besides, when the pumping capacity within a polder system is insufficient, excess water can not be discharged from the area adequately. Furthermore, with higher river discharges, the flood protection against adjacent water bodies might be in jeopardy.

Secondly, drought will become an increasingly bigger issue in warmer months. Longer periods between rainfall events, together with an increase in evaporation rates will negatively affect the water availability. This causes issues for agriculture, as harvests may shrink. Besides, the strength of levees may decrease [57]. Thirdly, drought issues are narrowly related with salinisation as well; when drought occurs, insufficient water present to flush the saline input out of a polder area.

With precipitation and evaporation being the largest fluxes in a polder's water system, and their capability of causing a wide range of issues, they are crucial aspects within polder management. Therefore, potential changes in these fluxes should be considered in decision- and policy-making for future polders.

3

Methodology

This chapter presents the methodology used in this report. In essence, all methods to provide an answer to the research question will be elaborated. The research question states: *"Is the Dynamic Adaptive Policy Pathways approach suited for improving the adaptivity of polder management, given the uncertainty in climate change effects?"*.

With the use of a case area, being the Zuidplaspolder, and performing both qualitative and quantitative research, an answer to the research question was found. More specifically, through the application of the following methods; using a hydrological model of the Zuidplaspolder, conducting both interviews and focus groups and applying the DAPP approach. A schematic overview is presented in Figure 3.1, and will be elaborated below.

At first, a hydrological model was created for the Zuidplaspolder case area, in which scenarios for a changing polder system were simulated to obtain a set of future projections. As fundamental input, information on the polder system and stakeholder objectives is required, which was collected from actors (interviews) and through a review of literature and policy documents. In turn, the findings from the hydrological model (more specifically; the *sell-by dates*, which will be explained in Section 3.3) were used in the DAPP procedure. Along with the input from the hydrological model, the gathered information from interviews was used in this procedure as well. The DAPP approach resulted in a pathway map for the Zuidplaspolder case area.

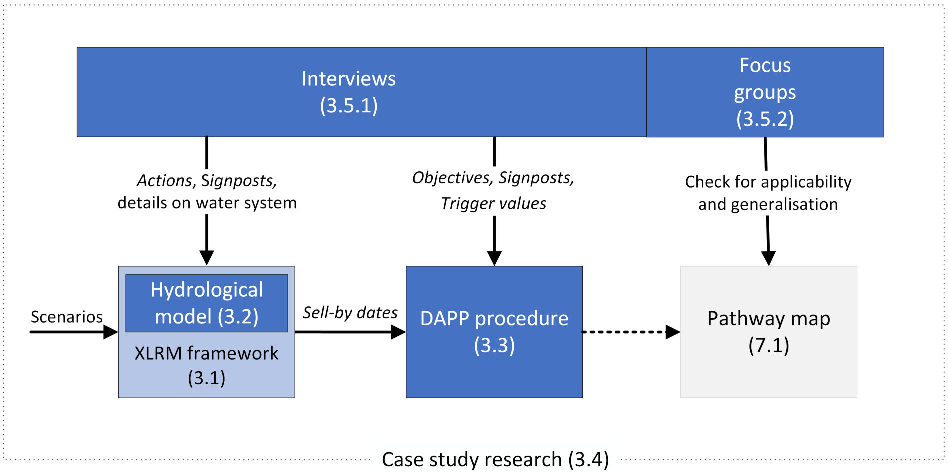

Figure 3.1: Visual representation of the coherence between methods

To check whether the pathway map is valuable for stakeholders in the Zuidplaspolder, a focus group was organised. Here, the resulted pathway map was checked and the stakeholders' opinions were obtained. Besides, to determine the possibility of generalisation to other polder areas, a qualitative validation was performed. During a focus group session with actors from a different polder, the Zuidplaspolder's pathway map and the DAPP approach were explained and discussed. For this second case area, the Schermerpolder was selected.

The findings of this second focus group provides an answer on the general applicability of the created pathway map. The insights gathered during the Zuidplaspolder's and Schermerpolder's focus groups are used to formulate an answer to the research question.

The link between the methods mentioned above can be schematised with the aid of the *XLRM framework*. First, the XLRM framework is introduced. After this, the three respective methods will be elaborated. At last, details and information on the case areas will be presented.

3.1. XLRM framework

The XLRM framework is used to show the relation between the interviews, the hydrological model and the DAPP procedure. It is a method to organise and extract relevant information for decision-making under deep uncertainty. By grouping the elements within the analysis into four categories, it can be used as a "formal intellectual bookkeeping mechanism" [56]. The four components of the framework are listed below, and the relation between them is shown in Figure 3.2.

External factors or exogenous uncertainties (X) For the polder area, this will be the effects of climate change and other potential uncertainties in the polder area which may affect the water system. These will be translated into scenarios. The scenarios used in this report are presented in Section 5.4.

Policy levers (L) Policy levers are actions, or possibly a combination of actions, that may lead to desired outcomes. Within the polder area, these are actions that stakeholders can take to meet their objectives. These actions and objectives are found during interviews with different actors. Section 6.4 elaborates the actions that are obtained.

Relationships in the system (R) This part of the framework describes the way in which factors within the system are related, under influence of the external factors (X) and policy levers (L). In this report, Relationships (R) will consist of the water system with all relevant components, forged into a hydrological model. The construction and components of the hydrological model are explained in Chapter 5.

Performance metrics or measures of performance (M) The performance metrics are parameters within the system that are of specific importance to stakeholders. These parameters can be used as *signposts* in the DAPP approach. Together with the threshold values of each parameter, named *trigger values*, they are used to determine the desirability of the circumstances in the polder. A description of the *signposts* used is presented in Section 6.3.

The outcomes of the performance metrics, together with their *trigger values* (values where the state of success is not met anymore), are used in the DAPP approach for the creation of an adaptive pathway map. More specifically, the *sell-by dates* (moment when a trigger value is reached) are required, as they will define the moment of change in actions. In Section 3.3, a further elaboration is given.

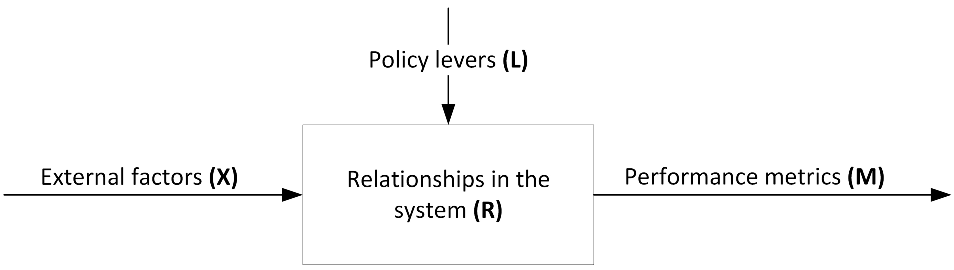

Figure 3.2: Visual representation of the XLRM framework, adapted from Lempert et al.(2003)

3.2. Hydrological model

The hydrological model functions as *Relationships in the system (R)* in the XLRM framework. With the use of a hydrological model, the quantitative effects of both climate change and anthropogenic processes were determined for the Zuidplaspolder in the future. The general hydrological system of polder areas is comprehensively described in literature [49] [13] [34]. However, since every polder has unique features, knowing the specifics of the Zuidplaspolder is essential. Therefore, information on the characteristics and processes within the polder was gathered by researching local policy documents and conducting interviews with responsible authorities. These findings are presented in Chapter 4.

The model provided explicit values for parameters of interest, which could be used for multiple purposes.

Firstly, the effects of the implemented actions for predetermined sequences of actions could be observed. With this, strategies could be rated on their effects regarding relevant values such as the effects on the ecosystem, water management, costs, etc. However, in this research, the hydrological model will serve this purpose.

Secondly, the model could be used to determine the *sell-by dates* of actions. Sell-by dates are points in time when a threshold value of a crucial parameter is surpassed. Both the crucial parameters and threshold values are obtained through interviewing stakeholders. Sell-by dates are crucial within the DAPP approach, as it initiates the selection of a new action and hence shapes potential pathways for the future. Hence, the purpose of the hydrological model in this research is to serve as a monitoring system for detecting sell-by dates in multiple scenarios.

3.2.1. Choice of modelling technique

For modelling the polder system, the *System Dynamics* approach is used. System Dynamics is “a method to describe, model, simulate and analyse dynamically complex issues and/or systems in terms of the processes, information, organizational boundaries and strategies” [75]. Kelly et al. (2013) found that System Dynamics can be used for a broad range of applications, amongst others for interlinking multiple factors within case study areas. Within a polder area, several interlinking aspects are relevant, such as processes regarding water quantity, water salinity and land subsidence. Since the System Dynamics method is suited to integrate these factors, this method is used for modelling the polder area. Besides, the scenario-based character of this method suits the exploration of changes in multiple future projections [43].

An appropriate model for exploring adaptation pathways is expected to embed dominant processes, natural variability, outcome indicators and the effect of policy actions, but without unnecessary detail [8]. To exclude unnecessary detail, the hydrological system of the Zuidplaspolder is modelled with a *bucket* approach. Here, by simplifying main hydrological components to interlinked reservoirs, a coarse estimation of future projections can be made. Considering the exploratory nature of the DAPP approach, this coarse determination of sell-by dates is expected to provide satisfactory input for the DAPP procedure. Moreover, the method of System Dynamics is well-fit for applying a bucket approach, as it is based around *stocks* (which serve as the reservoirs) and *flows* (the reservoirs’ in- and outflows) [12].

Multiple software programmes exist in the field of System Dynamics, e.g. *I Think*, *Stella*, *Vensim*, and more [83]. Since Pruyt (2013) published a detailed guide for the use of *Vensim* software, and this is the general software for modelling System Dynamics at the TU Delft, this software is used for modelling the polder area.

3.2.2. Scenarios

Scenarios function as *External factors (X)* within the XLRM framework (see Figure 3.2). In order to create relevant projections for the future, a set of well-thought scenarios is required. They are based on changes in sea level, evaporation/precipitation regime and built environment, being influential aspects in current and future polder systems.

3.3. Dynamic Adaptive Policy Pathways approach

The DAPP approach utilises the Performance metrics (M) from the XLRM framework. The metrics contribute to the design of adaptive strategies as they determine the moments in time where actions are required.

By applying the DAPP approach, different sequences of actions are explored for multiple possible futures. Since its introduction by Haasnoot et al. in 2013, the DAPP approach received positive feedback and has been applied in multiple practical cases around the world. Examples are the Bangladesh Delta Plan [26], the Australian coastal flood risk programme [77] and the Thames Estuary 2100 project [78].

The main input for the approach is the gathered information from interviews with stakeholders; their objectives, constraints, possible actions to take, the implementation time of these actions and the effects they have on other aspects in the system. Furthermore, the *sell-by dates*, which are found using the hydrological model, are contributing to the goal of this method. A sell-by date indicates the moment where a predefined indicator variable surpasses a certain threshold value.

3.3.1. Combining earlier approaches

The origin of the DAPP approach lies with two other approaches that deal with uncertainty in policy- and decision-making; *Adaptive policy-making* and *Adaptation pathways*.

Adaptive policy-making aims at designing a basic plan through a step-wise approach. Along this basic plan, contingency planning is developed to adapt the basic plan to a flow of new information over time. A well-designed monitoring system that observes essential parameters and compares them to well defined trigger values (i.e. threshold values for parameters) is essential for the effective implementation of adaptive policies.

Closely related to Adaptive policy-making is the *Adaptation pathways* approach. Adaptation pathways present a view into possible sequences of actions over time, along with the potential lock-ins and path dependencies. This method results in a pathway map. An analysis through Adaptation pathways is used in numeral practical cases, for example in the Dutch Delta Programme [17].

3.3.2. Sequence of steps

In order to apply the DAPP approach, a series of steps is prescribed. When following all seven steps of the DAPP procedure, a strategic and adaptive plan will be delivered. Since this thesis will not focus on making policies and decisions, but aims at supporting policy- and decision making and fuel the public discussion, several steps will be left out. More specifically; step 5 (*Design adaptive plan*), 6 (*Implement the plan*) and 7 (*Monitor the plan*) will be neglected. Figure 3.3 shows a visual representation of the steps in the DAPP procedure.

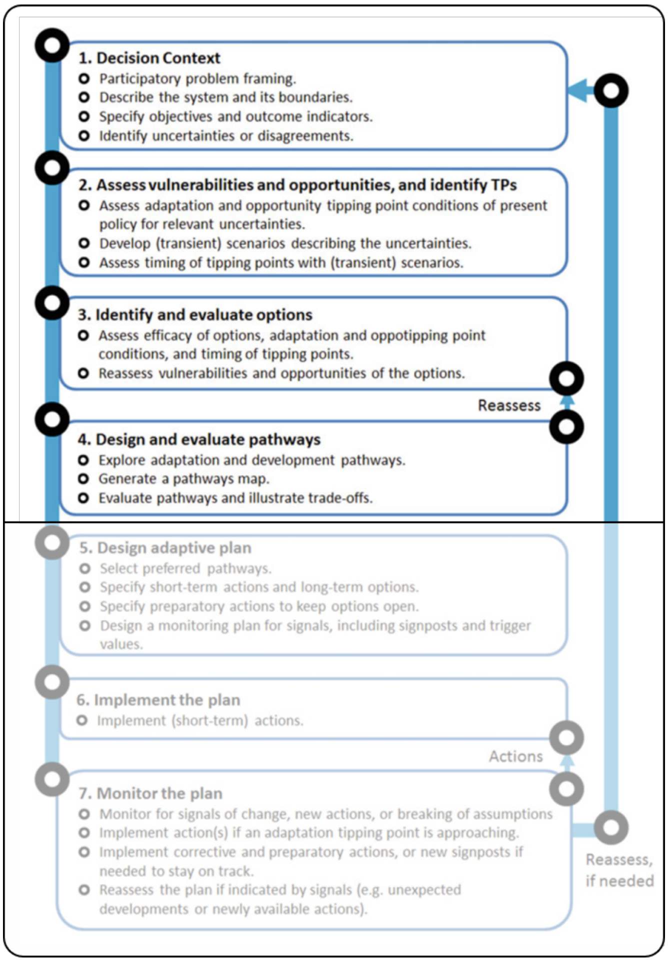

Figure 3.3: Schematisation of the steps within the DAPP procedure [58]. The top segment contain the steps that are followed in this report. The bottom segment, slightly blurred, contain steps that are neglected.

Below, the set of steps that are taken in this research are elaborated.

1. **Decision context -** The first step aims at framing the current system, its problems and its boundaries. Both the hydrological and stakeholder-related setting are defined. For all significant stakeholders, their respective objectives and constraints are identified. Regarding the constraints, the focus lies on the expected issues in the future. Indicators are defined for important components of the system, as well as their threshold value. Furthermore, uncertainties are specified which will provide the basis of the scenarios used (*External factors (X)* within the XLRM framework). This information is gathered through interviews and literature review.

2. **Assess system vulnerabilities and opportunities, and identify adaptation tipping points -** In the first step, stakeholders identified indicators and targets for their important parameters. With the use of the hydrological model (*Relationships in the system (R)* in the XLRM framework), *sell-by dates* can be determined for every scenario. A sell-by date marks the moment where a predefined indicator variable surpasses a certain threshold value. At this point, the system does not perform acceptably anymore and action is required.

3. **Identify actions and evaluate options -** In the third step, possible actions to restore a desired situation within the polder area are defined. When a wide range of parameters is dubbed crucial, a large set of actions is expected. Ineffective, and overlapping actions should be filtered out. The remaining actions will form the building blocks for the pathways.

4. **Design and evaluate pathways -** At last, a pathway map presenting all possible pathways will be constructed. The map provides an overview of the total set of policy actions and the logical pathways in which a desired situation is achieved under changing conditions. Per pathway, an evaluation can be made to check for affected interests.

3.3.3. Objectivity in pathway map

During the process of DAPP, a wide set of stakeholders with varying objectives is considered. It is possible that interests are conflicting, which may lead to disagreement on whether certain actions should be implemented or not [10]. One of the aims of the resulting pathway map in this report is to explicate the potential trade-offs between actions and pathways. Therefore, a neutral point of view is maintained during the construction of pathways in order to prevent a biased pathway map. An important assumption involving this objectivity is that within a pathway, the implementation of an action at a certain time has no grade of uncertainty, which could otherwise have been induced by disagreement.

Eventually, preferred pathways are chosen from the pathway map. In this phase, the actual policy- and decision-making takes place, which is not included in this report. It is up to the governing actors, in cooperation with the other stakeholders, which pathways are favoured and what responsibilities they may bring.

3.4. Case study research

As mentioned before, this research will examine if a DAPP approach can be applied in a polder setting, with specific institutional settings and stakeholder dynamics. Therefore, a small-scale case area is used to apply the DAPP method to.

Yin (2009) defines a case study research as "an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context". The aim of case study research is to gain understanding of a phenomenon, and through this understanding extend or test theory [20]. Within this research, a polder area under changing conditions is assessed, on which the DAPP approach is tested. This research will use interviews and focus groups to collect data upon the case areas, which will be explained in Section 3.5.

To check the applicability of the DAPP approach in polder management, two case areas are required. A main case area is used to apply the DAPP approach to, in order to assess its capability in enhancing the adaptivity in policy- and decision making. A second case area is utilised to check the general applicability of the pathway map and the DAPP approach on other polder areas.

In the selection of case areas, a certain distinction between the two case polders is necessary to adequately check the general applicability of the DAPP approach. Therefore, a typology of Dutch polders by Nijhuis and Pouderoijen is considered. This map, presented in Figure 3.4 introduces polder formations based on differences in substrate, soil and aspects of water management. Anthropogenic influences, such as land cultivation or peat extraction, play a role in the distinction as well.

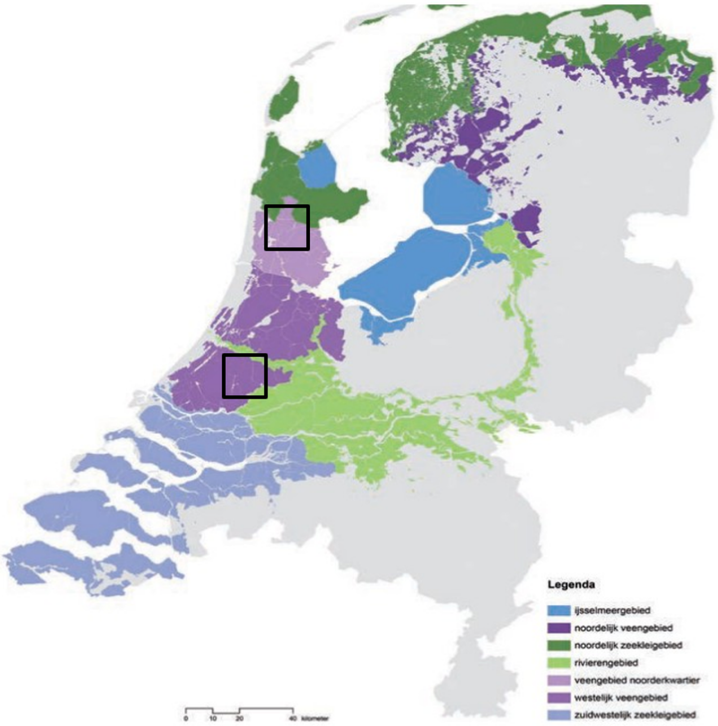

Figure 3.4: Polder formations within the Netherlands with the Schermerpolder marked north of the Zuidplaspolder [67]

In this research the Zuidplaspolder is adopted as the main case area. This polder is classified as a *Western peat polder*. For the second and smaller case study area, the Schermerpolder is selected. This polder, located in the North-Holland province, is classified as a *peat polder in the Noorderkwartier area*, adjacent to the *Northern sea clay area*. By comparing the results from the Zuidplaspolder to the Schermerpolder with its different characteristics, the general applicability of the pathway map can be checked. The following subsections will briefly present the main characteristics of these case areas and an elaboration on the differences.

Figure 3.5: Zuidplaspolder location. Obtained from Google Maps.

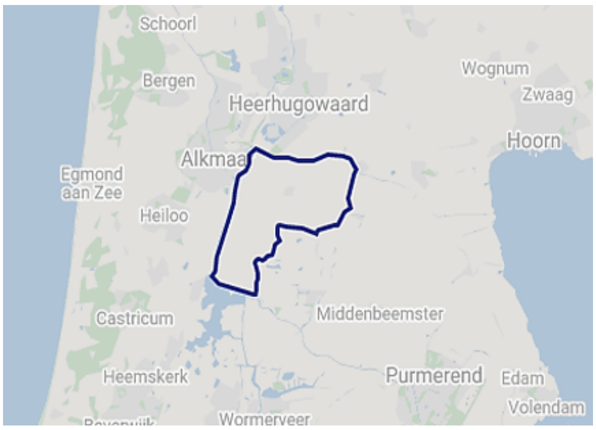

Figure 3.6: Schermerpolder location. Obtained from Google Maps.

3.4.1. Zuidplaspolder

The main case area for this study will be the Zuidplaspolder. This deep-lying polder, located between Rotterdam and Gouda is interesting due to its low elevation, soil composition and diverse land use. To answer the main question of this research, the hydrological model will be based upon this polder system. Therefore, a detailed analysis on this area is essential. An elaborate description of this polder is presented in Chapter 4.

3.4.2. Schermerpolder

The Schermerpolder is located directly east of the city of Alkmaar, in the North-Holland province. The reclamation of the Schermerpolder was finalsed in 1635, providing a usable area of approximately 6500 hectares. Ever since, the largest part of the polder is used for agricultural purposes, not the least due to its fertile clay soils. At the moment, nearly 90% used for farmlands [98]. Furthermore, several small town centres are located within the perimeter.

3.4.3. Differences between case polders

The Zuidplaspolder and Schermerpolder differ on several aspects, which can broadly be divided into physical and stakeholder-related differences.

Regarding the physical aspect, multiple differences are found. A first distinction lies in the dominant soil types. Where the Zuidplaspolder has several areas with peat as the main soil type, this is not the case in the Schermerpolder. Here, sea clay deposits are found throughout the entire polder area. This indicates a lower sensitivity to land subsidence, no emission of CO_2 gasses and a higher drought tolerance (see Appendix D.2). Secondly, there is a large difference in soil elevation. In the Zuidplaspolder, elevation levels vary from -4.5 to nearly -7m NAP. In the Schermerpolder, a relatively consistent elevation level of -3.5m NAP is found [36]. Lower elevations indicate a more intensive system of water management, as higher seepage fluxes are found. Besides, a higher risk of floods is present. Thirdly, both polders contain different types of land usage. Within the Zuidplaspolder, a wide range of relevant land uses is found: agriculture (both arable- and grassland farming), horticulture, built environment and large infrastructural components [87]. In the Schermerpolder, arable- and grassland farming are the only types of land use, apart from small residential areas [36]. This brings a different set of potential issues for stakeholders within the polder system.

Secondly, the differences in land use provides a different group of relevant stakeholders in the respective polders. Within the Zuidplaspolder, nearly 10% of the surface area is used by horticultural businesses [87]. Therefore, the representative organisation *LTO Glaskracht* plays a relevant role in the polder's stakeholder setting. Due to the absence of horticultural businesses in the Schermerpolder, *LTO Glaskracht* and its objectives are not considered. Furthermore, the Zuidplaspolder contains several important motorways and rail tracks which are managed by *Rijkswaterstaat*. Again, in the Schermerpolder these aspects are not present. On the other hand, significant actors like waterboards, municipalities, provinces and *LTO Noord* (representing arable and grassland farmers) are present in both polders. However, there is a difference in the actual organisations present and people involved in the area.

Given the different physical characteristics, stakeholders and interests, the Schermerpolder is considered a useful case area to assess the general applicability of the DAPP results from the Zuidplaspolder. Somewhat contrarily, the degree of overlap in the set of stakeholders is expected to provide an adequate evaluation of the DAPP approach in polder areas as well.

3.5. Gathering of qualitative data

Through conducting interviews and focus groups, essential qualitative information was collected from stakeholders of the case areas mentioned above. With interviews, information was gathered on the objectives, constraints and possible actions for each stakeholder in the Zuidplaspolder. Besides, details regarding the hydrological system of the Zuidplaspolder were acquired. The insights from interviews served as input for both the hydrological model and the DAPP procedure. Next to that, focus groups were organised to extract information on the value of the DAPP approach in enhancing the adaptivity of polder management. This was evaluated for the two case areas as described in Section 3.4. The following subsections present an elaboration on the two qualitative research methods.

3.5.1. Interviews

The interviews mainly contributed to finding both *Policy levers (L)* and *Performance metrics (M)* in the XLRM framework. The former concerns the set of actions that are implementable to maintain a desired situation, per stakeholder. The latter considers the constraints and the related threshold values for each individual stakeholder. Furthermore, details on the Zuidplaspolder system were discussed in several interviews, providing valuable data on the *Relationships in the system (R)* which was used in the hydrological model.

The selection of interviewees was based on a brief stakeholder analysis in the Zuidplaspolder, presented in Subsection 4.6. From each of the eight relevant stakeholder organisations, employees with a vision on the future of the polder area were invited. Since a vision on the far future is required, the interviews started with a exploratory introduction to set the scope of the conversation. After this, more in-depth questions were asked.

The interviews were held in a semi-structured way, in essence with a blend of closed- and open-ended questions, often followed by questioning "how?" or "why?" [1]. As the interviewer wanted to address fairly specific topics, this was a good way to guide the conversation into a useful direction. Also, it provided the possibility to confirm expected answers. On the other hand, the free part of the semi-structured interview gave room for experimental thoughts and out-of-the-box answers from the interviewee's part.

The list of questions is presented in Appendix A.1. In general, the questions are not followed exactly as outlined and questions that are not included in the setup may have been used.

All interviews were conducted in Dutch. In that way, interviewees could express themselves better. The duration of the interviews varied from one to one-and-a-half hour.

3.5.2. Focus groups

The Zuidplaspolder's pathway map was presented to stakeholders of both case areas in two focus groups. Focus groups are a method in which qualitative data is acquired through facilitating a group discussion, mostly with a small number of people [104]. Due to circumstances, the focus groups were held online.

At first, a focus group was organised with actors from the Zuidplaspolder. The aim is to determine whether the DAPP approach is useful and suited for improving the adaptivity of decision- and policy-making within the polder.

After this, a second focus group was organised with similar stakeholders from a different polder; the Schermerpolder. This polder, located in the North-Holland province, has different polder characteristics. By proposing the results from the Zuidplaspolder to users of a different polder, with different interests and other polder characteristics, the general applicability of the pathway map was checked.

To prepare the attendees of a focus group, a stakeholder specific pathway map was sent beforehand, along with an introduction on pathway maps. With this, the introduction to the method during the sessions itself could be shortened, leaving more time for an open discussion. Similar to the interviews, the focus groups are held in Dutch. The duration of both focus groups was one-and-a-half hour.

4

Case area: the Zuidplaspolder

In order to examine whether the DAPP approach can improve the adaptivity of management in polder areas, a case area is required. This report will use the Zuidplaspolder as the a main case area. The Zuidplaspolder proves an interesting case polder due to its diverse land use, plans for constructing of new housing areas and the lowest elevation levels in the Netherlands [87].

This chapter will present an introduction to the Zuidplaspolder. First, the demographic characteristics will be shown. Secondly, the history of the polder is elaborated. As third, the (current) land use will be elaborated, as this is important for both the water system and other aspects in the polder. Fourthly, details on the soil composition are presented. As fifth, an elaboration of the water system is given. Here, both the surface- and groundwater system is considered. After this, relevant stakeholders within the polder are identified. Finally, the consequences of climate change to the polder's water system will be presented, including both new and enforced existing vulnerabilities.

4.1. Demography

The Zuidplaspolder is located in the province of South-Holland, roughly in the triangle between Rotterdam (Nieuwerkerk a/d IJssel), Zoetermeer and Gouda (see Figure 4.1). It holds a population of around 24 thousand inhabitants, divided over several residential areas of different cities; Moordrecht, Nieuwerkerk a/d IJssel, Zevenhuizen, Moerkapelle, Waddinxveen and Gouda. None of these settlements are located entirely in the Zuidplaspolder, but have neighbourhoods lying within the polder boundaries. The total surface area is around 4600 hectares [87].

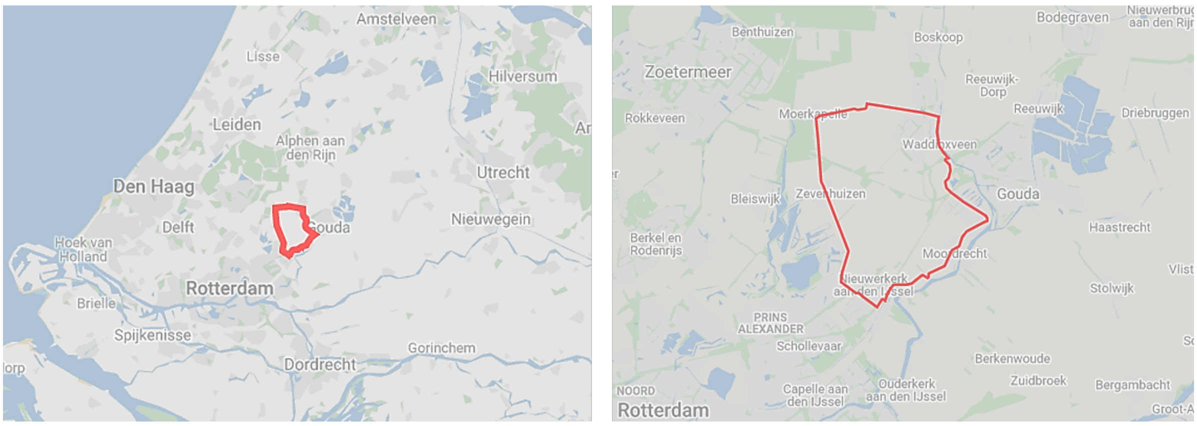

Figure 4.1: Geographical positioning of the Zuidplaspolder in the western part of the Netherlands (left) and within the Rotterdam-Gouda-Zoetermeer triangle (right). Obtained from Google Maps.

4.2. History

The origin of the polder lies in the 17th and 18th century, when large peat areas in the western part of the Netherlands were *peated* (= extracted for peat, which served as fuel). This excavation process could reach peat located several meters below the groundwater level [51]. Because of the high demand for fuel and insufficient supervision, the large-scale activities led to the creation of lakes. This occurred in the area between Gouda and Rotterdam as well, where several *plassen* (English: lakes) occurred, one being the Zuidplas (see Figure 4.2).

In the 19th century, the reclamation of these lakes started, as they threatened the adjacent cities with erosion. Besides, the demand for agricultural lands grew. In the South Holland province alone, around forty lakes were reclaimed [51]. For the Zuidplas, being the largest and deepest lake in the area, the project of reclamation required the construction of 30 windmills and four years of pumping [48]. The later phases of the process made use of steam driven pumps as well. In 1839, the Zuidplaspolder was finished and used as an area for agriculture.

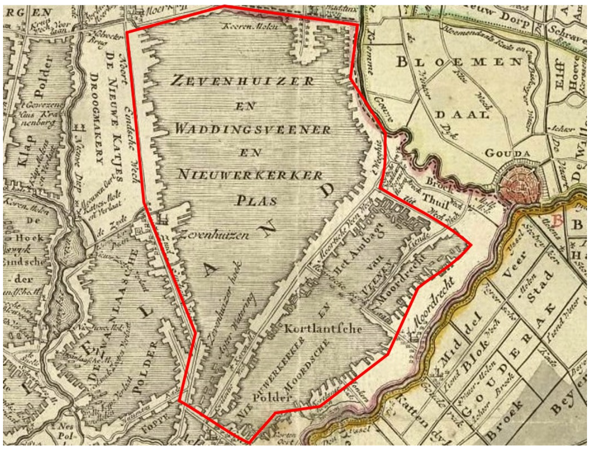

Figure 4.2: The lakes before reclamation, around 1750. The red line indicates the current polder outline [48].

Figure 4.3: Allotment plan for the Zuidplaspolder, 1815. Obtained from Nederlands Architectuurinstituut.

During the seventies, greenhouses were introduced to the polder. Farmers from greenhouse cores such as Westland and Rotterdam settled, mostly in the northern areas. Furthermore, multiple agricultural lands became part of plans for the construction of housing, business areas or infrastructural works.

In 2004, the Zuidplaspolder was designated as a location for the development of new residential areas to meet the demand for housing in the western part of the Netherlands [89].

4.3. Land use

After the reclamation of the Zuidplaspolder, the main land use was agriculture; both grasslands (used for livestock) and arable farming were the main activities. Over the years, several other uses followed. Currently, the main types of land use are peat meadows used for livestock (42.5%), arable agriculture (21%), built environment (12.5%) and greenhouses (9%) [87].

Additionally, important infrastructure is found. There are three main components; the A12 and A20 highways and railway tracks. Both highways have an end in Gouda, where the A20 moves towards Rotterdam, and the A12 heads in the direction of Zoetermeer. They serve a vital role in connecting the Randstad region with Utrecht and outer areas. The railway tracks enter the polder at Gouda and, similar to the highways, diverge towards both Zoetermeer and Rotterdam.

With the Zuidplaspolder being a designated area for providing residential areas, an increase in built environment is expected in the future. Currently, plans for the construction of the *Vijfde Dorp* are in an advanced stage. In this project, nearly 150 hectares of residential areas are constructed in the centre of the polder area [9].

4.4. Soil composition

The quantity and quality of groundwater play an important part in the overall water system. Since the composition of the soil is significant for these groundwater flows, it is important to be familiar with it. A map showing the different main soil types is presented in Figure 4.4.

An area with peat cover layer is located in the south-eastern part of the polder, bordering the Hollandsche IJssel. The rest of the polder has a clay top layer, with a distinction between clay that is *zavelig/kalkrijk* (i.e. containing a higher fraction of sand) or *potentieel katteklei/moerig* (i.e. with a changing pH value when in contact with oxygen). Each type of clay has different hydraulic characteristics, with hydraulic conductivity being the most influential. This defines the ability of a fluid to pass through the medium, influencing the velocity of groundwater flows.

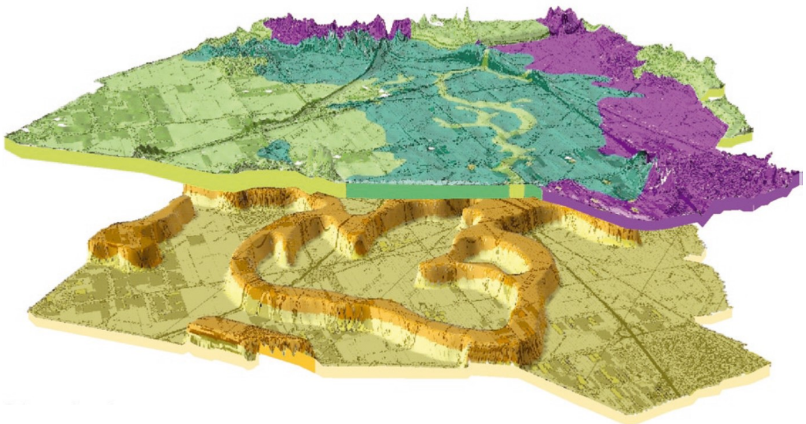

Figure 4.4: Soil types in the cover layer and the underlying aquifer. Purple: peat, tints of green: two types of clay, brown: paleochannels. The northern side of the polder is directed to the left. [105]

Underneath the cover layer, an aquifer is located, consisting of sand and gravel. In this aquifer, a meandering path of firm sand bodies can be found. These *paleochannels* are a result of the deposition from ancient rivers. The aquifer layer with paleochannels is thicker, compared to the rest of the aquifer, resulting in higher elevation levels. The added strength of this layer causes the paleochannel grounds to withstand land subsidence better compared to the soil containing more peat and/or clay. Another aspect of paleochannels, is the presence of paleochannel seepage: the high fraction of sand leads to higher permeability rate, which induces an increased seepage flux. This seepage type is clarified in Section 2.3.1.

4.5. Water system

The water system in the polder can be separated into two main components, the surface- and the groundwater system.

4.5.1. Surface water

A dense system of canals and ditches is used for the allocation of surface water. The main canals are called *tochten*, of which six are present. Smaller ditches flow into these waters. Figure 4.8 shows a map of the surface water bodies.

Typically, the surface water levels within the polder are managed by designated decree areas (NL: *peilvakken*). Decree water levels (NL: *waterpeilen*) are set per decree area within the polder, depending on the land usage and local preferences. Most of the decree areas are small and sometimes even specific for one plot of land. This causes the Zuidplaspolder to hold over three-hundred areas with different decree water levels (see Figure 4.7).

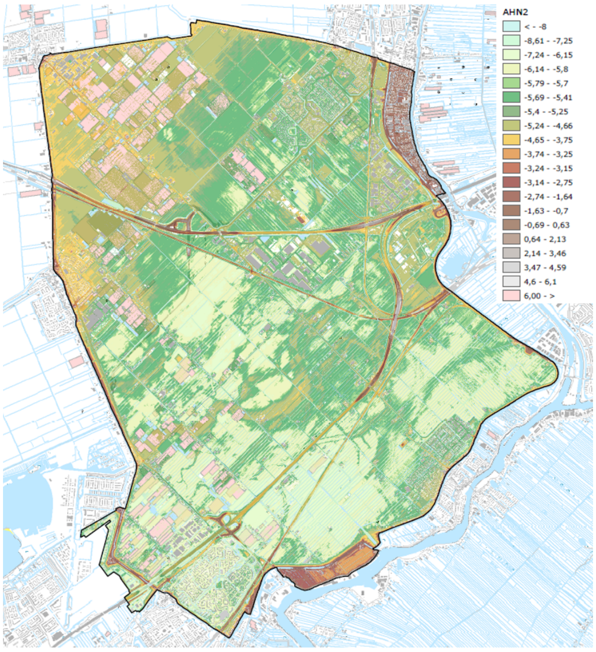

Figure 4.5: Elevation map of the Zuidplaspolder, in m [87]

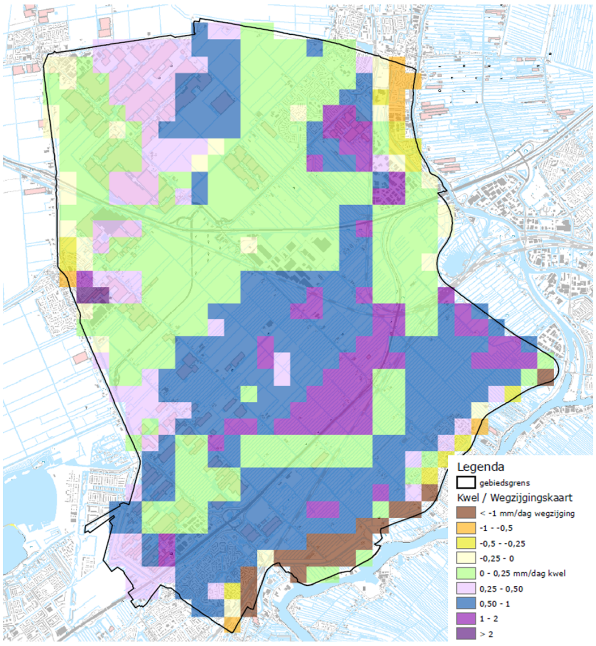

Figure 4.6: Map indicating areas with seepage (in blue, purple, green) and percolation (in orange, brown) within the Zuidplaspolder. [87]

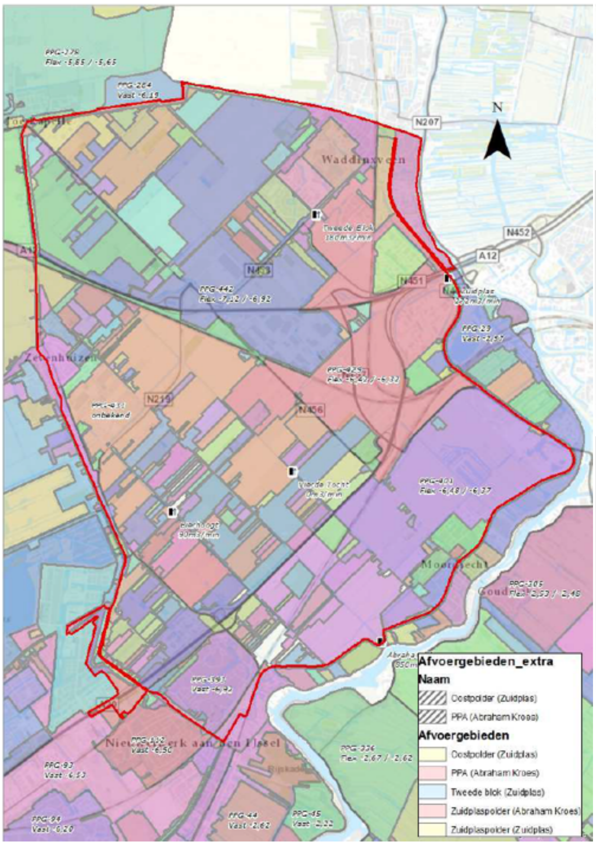

Figure 4.7: Decree areas within the Zuidplaspolder.
Every coloured area has its own target water level. Obtained from HHSK.

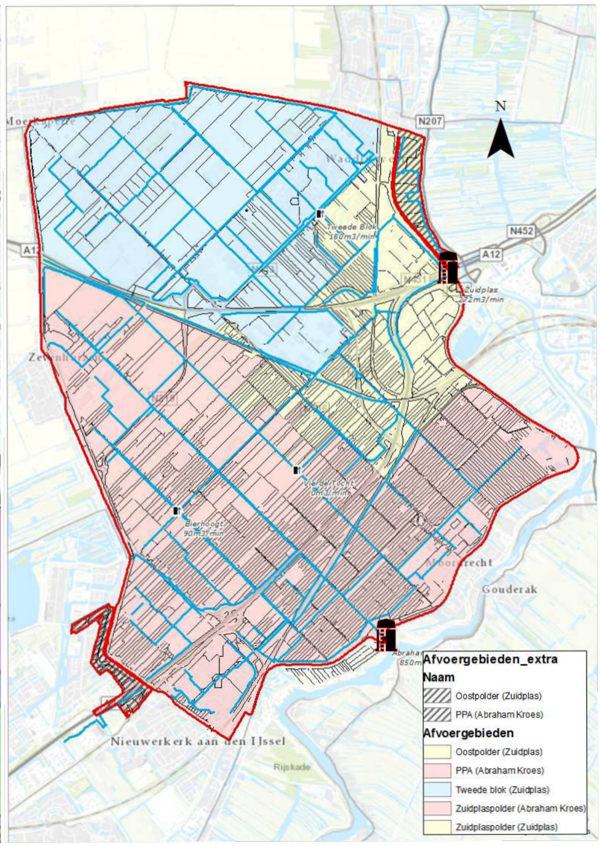

Figure 4.8: Service areas of pumping stations Zuidplas (black figure, north-east) and Abraham Kroes (black figure, south).
The blue and yellow zones flow towards Zuidplas, the red area flows towards Abraham Kroes. Obtained from HHSK.

The surface water system is fed by multiple inlets from the *Ringvaart*, a canal flowing right outside the eastern and southern boundaries of the Zuidplaspolder. Besides, several inlets are found at the western boundaries of the polders as well [87].

In order to discharge excess water, two pumping stations are discharging into the Ringvaart. The *Zuidplas* pumping station, located in the north-eastern part of the polder is able to pump at a rate of 275 m3/min. At the south- eastern edge of the area, pumping station *Abraham Kroes* is located, able to discharge 410 m3/min. Each station has its service area, presented in Figure 4.8. The blue and yellow zones represent the area for *Zuidplas*, the red zone flows towards the Abraham Kroes pumping station. Pumping station *Abraham Kroes* contains a part that pumps water from the Ringvaart to the Hollandsche IJssel as well.

4.5.2. Groundwater

Due to its low elevation, the Zuidplaspolder is prone to large seepage loads (see Section 2.3). The majority of the incoming seepage enters the groundwater system, influencing both the quantity and quality of the groundwater [15].

Besides seepage, groundwater fluxes enter the polder from surrounding areas with a higher elevation. One of them is a fresh groundwater flux coming from the Krimpenerwaard, south-east of the Zuidplaspolder. Since this adjacent polder, fed by the Rhine system, has a higher elevation its groundwater naturally flows into the Zuidplaspolder. Additionally, the Hollandsche IJssel, the river that separates the Zuidplaspolder from the Krimpenerwaard, has a small influence on the groundwater system.

Through communication with HHSK (2020), it was found that the incoming fluxes from adjacent areas have a small effect on the groundwater system, when compared to the seepage from (deep) aquifers. This is due to the absence of salinity within these fluxes and a relatively small water flux.

4.6. Stakeholders and roles

Within the polder, a wide range of stakeholders is present. First, multiple (non-governmental) users of the polders are identified. Secondly, the government authorities within the polder are elaborated. Thirdly, a power-interest grid is presented, providing insight in the significance of each stakeholder.

4.6.1. (Semi-)private organisations

The largest non-governmental party involved in the polder is the agricultural sector. This sector is present in several shapes; arable farmland, grasslands and greenhouses. Both the outdoor and greenhouse agriculture are represented by an overarching organisation. For the arable and grassland farming this is Land- en Tuinbouw Organisatie (LTO) Noord, whereas the horticultural businesses is represented by a similar organisation, named LTO Glaskracht.

Besides, Staatsbosbeheer is involved in the polder with a focus on nature. Staatsbosbeheer is commissioned by the Dutch government to strengthen the position of nature in the Netherlands. As a national public body and as land owner and manager of a sizeable amount of nature reserves, they aim to develop and conserve green areas.

Lastly, the Gebiedsontwikkelingsmaatschappij Zuidplas (GOM) is active in the Zuidplaspolder. The GOM is a collaboration between five companies: *AM*, *Amvest*, *ASR*, *Heijmans* and *Woonbron*. They collectively own lands within the Zuidplaspolder for the development of residential areas.

4.6.2. Governmental organisations

As in every other polder in the Netherlands, the regional waterboard (here: Hoogheemraadschap Schieland en Krimpenerwaard) is the main authority responsible for water management within the polder. However, the water-related objectives of the waterboard do not stand on their own, as they support the spatial planning objectives from other governmental organisations.

On a provincial scale, tasks on spatial planning, environmental- and nature management are assigned to the provinces. In the Zuidplaspolder, this is the province of South-Holland.

Municipalities convert the plans from provinces to match the local situation, and have their own instruments for policy making within their area. The Zuidplaspolder contains lands within the boundaries of three municipalities; Zuidplas, Waddinxveen and Gouda. Since the largest part lies within the municipality of Zuidplas, this municipality is considered in the remainder of this research.

As last, Rijkswaterstaat is active in this area. Rijkswaterstaat is the executive agency of the Ministry of Infrastructure and Water Management and responsible for the design, construction, management and maintenance of the main infrastructure facilities in the Netherlands. Within the Zuidplaspolder, their focus lies on the management of the A12 and A20 motorways.

4.6.3. Power-Interest grid

Stakeholder groups can be distinguished or analysed based on *Power* (the ability to influence the organisation strategy or project resources) and *Interest* (how interested they are in the organisation or project succeeding) [61]. A power-interest matrix helps in understanding the stakeholder community and the respective influences of stakeholders within the Zuidplaspolder. The benefit of using this stakeholder-based approach is to identify the most significant stakeholders in order to shape the research at an early stage.

The stakeholders mentioned above can be prioritised according to those who have power and influence in the Zuidplaspolder, and therefore this research. Information regarding the respective *Power* and *Interest* of the stakeholders is obtained during interviews. Figure 4.9 presents the levels of power and interest for each stakeholder.

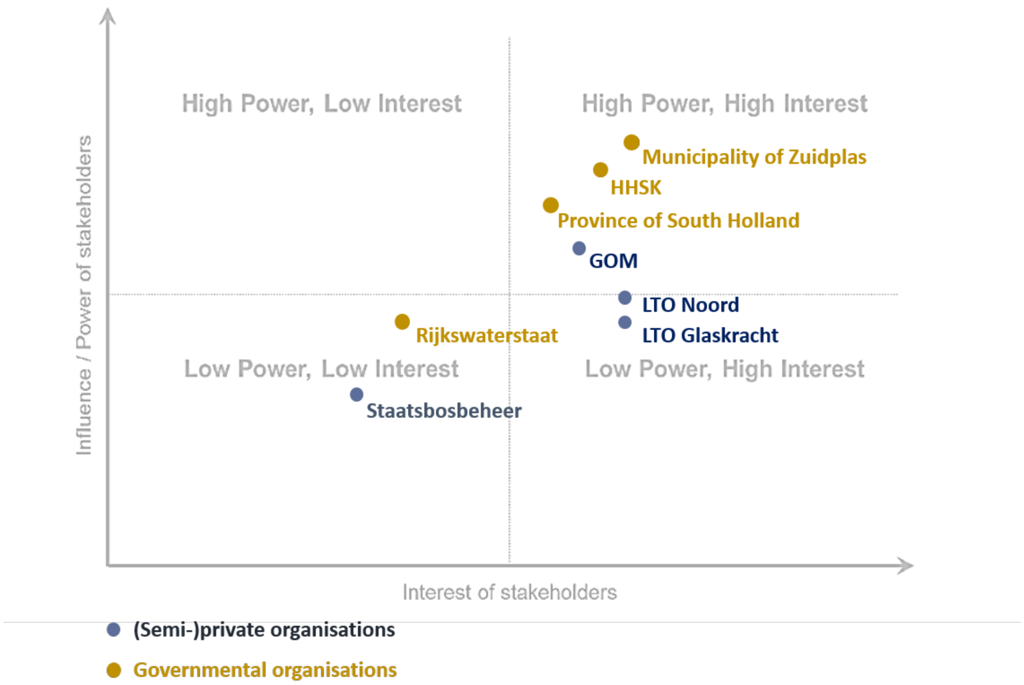

Figure 4.9: Power-Interest grid with Zuidplaspolder stakeholders.

From the set of stakeholders, two stakeholders are situated in the bottom-left part of the figure, indicating a moderate interest and/or power. These two stakeholders are *Rijkswaterstaat* and *Staatsbosbeheer*. This implies that both parties should be considered in the remainder of this research, but will not play a significant role. This is expressed during the creation of the pathway map for the Zuidplaspolder. Here, the objectives, constraints and actions of the two stakeholders are not embedded in the pathway map. However, whilst not explicated, they should be considered when preferred pathways are chosen in actual policy- and decision making.

4.7. Present and future issues

By reviewing the potential changes in polder areas (defined in Chapter 2), combined with the characteristics of the Zuidplaspolder (elaborated in the sections above), potential issues for the case area are identified. Specifically, issues related to land subsidence, sea level rise, salinity, water nuisance and drought are mentioned.

4.7.1. Land subsidence

The present soil types in the top layer make the Zuidplaspolder sensitive to land subsidence. Mainly the peat soils in the southern part are vulnerable, as compacting and oxidation may occur. The areas with clay as the main soil type will not experience oxidation, but are prone to compaction as well albeit on a lower magnitude.

Over the last decades, the decree water levels have been lowered to serve user functions within the polder area [87]. With this, the soil elevation lowered severely. When maintaining the same policy of lowering the water levels, land subsidence will become an issue in the polder, where it already causes problems in the southern part near the city of Moordrecht. As the elevation is low, the Abraham Kroes pumping station encounters problems with discharging water when the water levels are low.

Land subsidence in the Zuidplaspolder is to a large extend due to human activity. The effect of autonomous land subsidence is considered insignificant relative to the anthropogenic subsidence rates in this part of the Netherlands [50].

4.7.2. Sea level rise

Sea level rise may force a significant increase in hydraulic head in deeper ground layers, inducing a rise in (saline) fluxes in certain areas. For the Zuidplaspolder, this is not an issue, as the area lies too far inland to be affected. Oude Essink et al. published maps for the effect of 1 meter of sea level rise in the western part of the Netherlands. Here, the hydraulic head in the Zuidplaspolder is found to be out of reach. For a high-end rise in sea level of +3 meter, Figure 4.10 presents the effect on the hydraulic head. An increase of less than 0.1% or 0.1 to 0.5% of the rise in sea level is expected in the Zuidplaspolder.

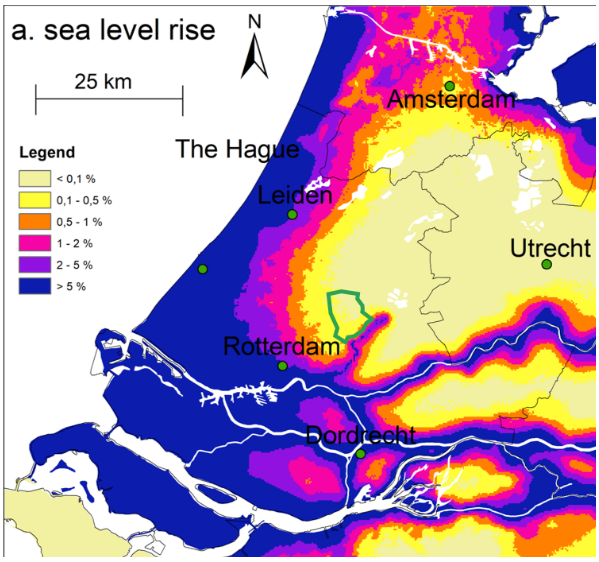

Figure 4.10: Percentual increase in hydraulic head in the first aquifer, induced by sea level rise of +3 meter. The outline of the Zuidplaspolder is found in green. Obtained through personal communication with Oude Essink.

Additionally, sea level rise affects the water levels in the Hollandsche IJssel. Specifically, high sea water levels, for example during storm surges, will cause the Hollandsche IJssel storm barrier to be closed. This induces a water level rise in the Hollandsche IJssel, as it becomes impossible to discharge towards the sea due to the closed barrier downstream. As this river is used for the discharge of excess water from the Zuidplaspolder, this water level is of importance. When the water level exceeds a certain level, the pumping stations can no longer discharge into the Hollandsche IJssel. This situation is called a *pump stop*, and has a severe effect on the water levels within the polder area as water starts to accumulate. Currently, the frequency of pump stops is 1 in 20,000 year but is expected to increase significantly with a rising sea level [80].

4.7.3. Salinity

Issues regarding salinisation are induced by seepage fluxes. Due to the low elevation of the Zuidplaspolder, substantial seepage fluxes enter the water system. In the polder, three types of seepage are present, as identified in Subsection 2.3.1; diffuse-, paleochannel- and boil seepage. Diffuse seepage is found throughout the entire polder area. Paleochannel seepage occurs on locations where the paleochannel belt is present, which is visualised in Figure 4.4. Boil seepage occurs at locations with a thin clay layer, however, the exact locations of these boils in the Zuidplaspolder are unknown [105]. Therefore, it is difficult to assess effect of this seepage mechanism on the overall polder level. On a local scale, boils are strongly affecting the water quality [13].

Due to land subsidence, the seepage pressure will increase. This indicates an increase in the incoming fluxes of water and salt. As the Zuidplaspolder is sensitive to land subsidence, this flux is assumed to increase in the future.

4.7.4. Water nuisance and drought

Currently, water nuisance is occasionally experienced in the southern, low lying, part of the Zuidplaspolder. Since a large part of the polder area discharges through the Abraham Kroes pumping station, large quantities of water is present in this (southern) part of the polder. With future projections of increasing extremity in precipitation, along with the growing probability on pump stops, water nuisance is expected to become an issue on several parts within the polder [23].

Due to its location in the Dutch western delta region, drought is currently not a main concern for the users within the Zuidplaspolder. However, with increasing periods without precipitation and rising evaporation rates, this might change in the future. To deal with potential drought issues, the region is connected to the *Kleinschalige Wateraanvoervoorzieningen*, a system of small-scale water bodies providing fresh water in case of emergency. All together, drought is not expected to become an issue with high severity in the Zuidplaspolder.

5

Hydrological model

This chapter will elaborate on the hydrological model. The aim of this model is to determine *sell-by dates* for the Zuidplaspolder system: the moments in time where a change in policy is required. Besides, the effect of the implemented actions can be evaluated.

At first, the schematisation of the polder area is presented. In essence, several simplifications are shown which are required to create a simplified representation of the actual polder system. Secondly, the most influential assumptions are mentioned. After this, the input parameters will be elaborated. Fourthly, the used scenarios will be shown. At last, the model outputs will be presented.

5.1. Schematisation

In order to create a suited model of the Zuidplaspolder's water system, choices are made on how to create a fitted representation. In this process, the aforementioned aim of the model is kept in mind. In general, two steps of schematisation are made. Furthermore, the polder area is divided into several zones.

5.1.1. Reservoir approach

The first step of schematising is the simplification of main hydrological components to interlinked reservoirs. Here, two main reservoirs are created, along with two minor reservoirs. The main *buckets* are the surface- and groundwater within the polder. They are modelled as a reservoir, with fluxes moving in- and outward, to create a simplified representation of the actual surface- and groundwater system in the polder. Next to the two main components, there are two types of land use which have a significant effect on the polders water system: horticulture and paved environment. Due to their impact on the hydrological system, they are embedded in the model individually. Therefore, they are modelled as a reservoir, similar to the surface- and groundwater systems. Figure 5.1 presents a visualisation of this division and their corresponding fluxes. Below, an elaboration is given on the influences of both horticulture and paved environment on the polder system.

Firstly, horticultural business play a role by storing precipitation for watering their crops. Since each business is legally required to have a water storage of 500 m^3 per hectare [97], and are free to expand this reservoir if desired, they add a notable part to the polders buffer capacity. The stored water is used for watering their crops, and is discharged into the surface water when the maximum storage capacity is (expected to be) reached. Since the horticultural sector covers nearly 10% of the polder area, its effect on the overall land use is embedded in the hydrological model [87].

Secondly, paved environment such as residential areas and distribution centres affect the water system in several ways. During the process of fast run-off, water that otherwise would have infiltrated into the soil flows towards the sewage system or surface water bodies, possibly leading to water nuisance [92]. Besides, the sewage discharges a part of the precipitation towards treatment plants, removing it from the polders' water system. Furthermore, a part of the urban water will infiltrate, which adds to the rise in the groundwater level. Since 17% of the Zuidplaspolder surface area is paved, this component is incorporated in the model.

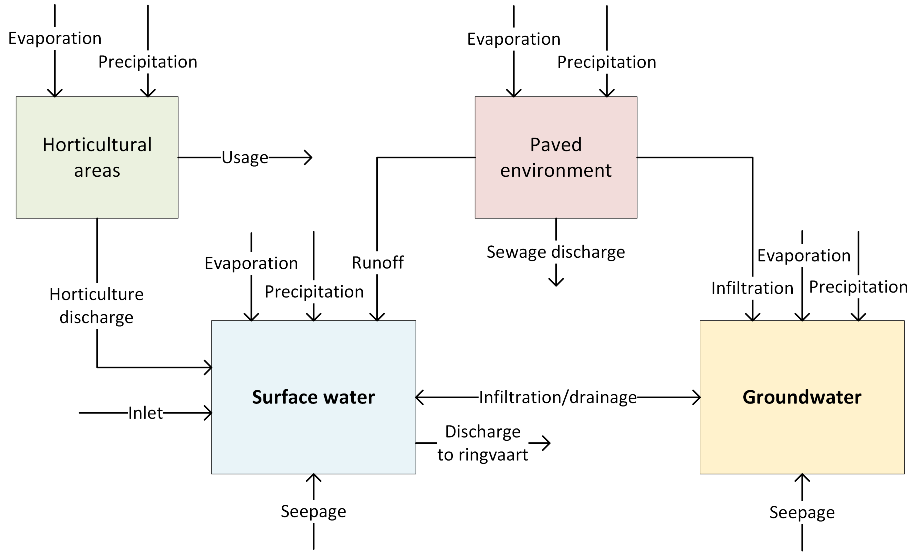

Figure 5.1: The water system modelled as two main reservoirs (surface- and groundwater) and two smaller reservoirs for horticultural- and paved areas.

5.1.2. Water quantity and quality

After simplifying the water system into reservoirs, a following step of schematisation is performed. Here, the aspects of water quantity and quality are introduced. By separating these two components, their behaviour in the system can be observed independently. With this, undesired situations regarding both the water quantity and quality can be identified. Water quality will address the salinity within the polder, as this is recognised as one of the main threats in deep-lying polders [82].

As polder management focuses on the surface- and groundwater aspects, the horticultural and paved reservoirs are neglected in observing water quantity and quality. However, their fluxes entering either the surface- or groundwater reservoir are embedded.

The water quantity and quality fluxes are interlinked since the water flows carry a salt load. Each flow contains a different value for salinity. By multiplying the quantity fluxes with the salt concentration of the respective flows, saline fluxes are determined. Similarly, the salinity of the two reservoirs can be determined.

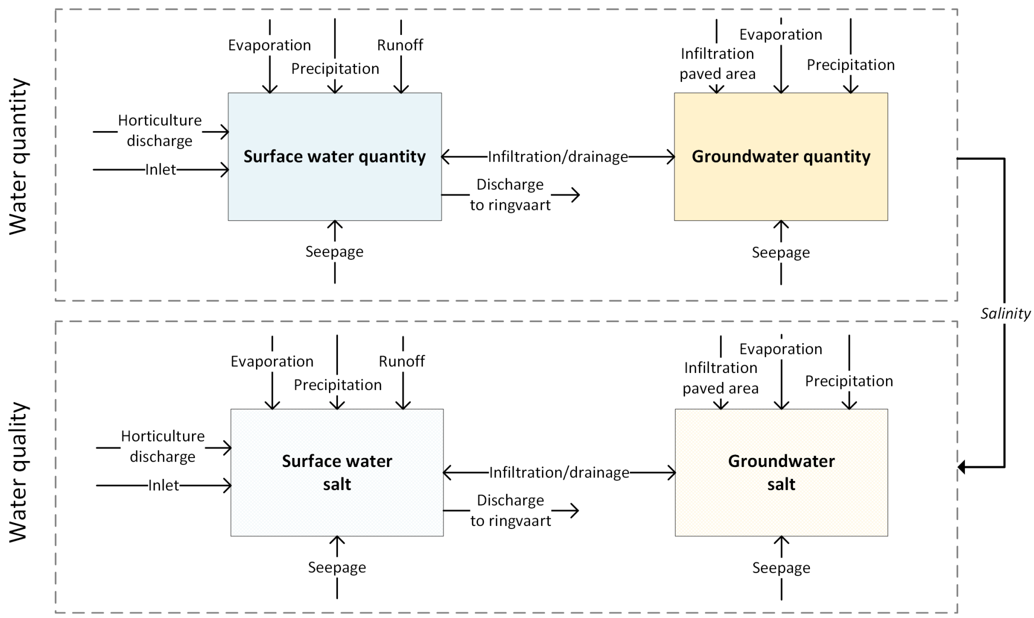

Figure 5.2: The water system divided into two sub-models; water quality and quantity

5.1.3. Polder division into zones

In order to embed the spatial variety within the Zuidplaspolder, the area is divided into multiple zones. With this, the different hydrological- and hydraulic characteristics can be distinguished, as well as different types of land uses. As different land uses have a different set of constraints, certain sell-by dates are only reached in certain zones.

The division into zones will mainly focus on the decree areas (NL: *peilvakken*), which are further explained in Subsection 4.5.1. However, since over three-hundred different decree areas are present, areas are bundled to maintain a comprehensible model and limit the computational time. In deciding what segments to merge, adjacent decree areas with similar decree water levels are bundled as far reasonable.

Besides the decree water levels, other aspects are taken into account as well. Firstly, the land use is considered. As different land uses bring different objectives and constraints, it is useful to cluster land uses into the same zone. Secondly, the service area of each pumping station is regarded. The surface water flows to either one of the pumping stations (see Figure 4.8), and do not interfere with the other station's working area.

Considering the aspects mentioned above, nine zones are created. These zones, along with their respective direction of surface water discharge, are presented in Figure 5.3. The zones have a varying set of values for the following characteristics: surface area, fraction wet surface, fraction paved environment, fraction horticulture, fraction with paleochannel soil, initial elevation, decree water level, groundwater level, number of inlets, ground layer thickness and values for hydraulic conductivity.

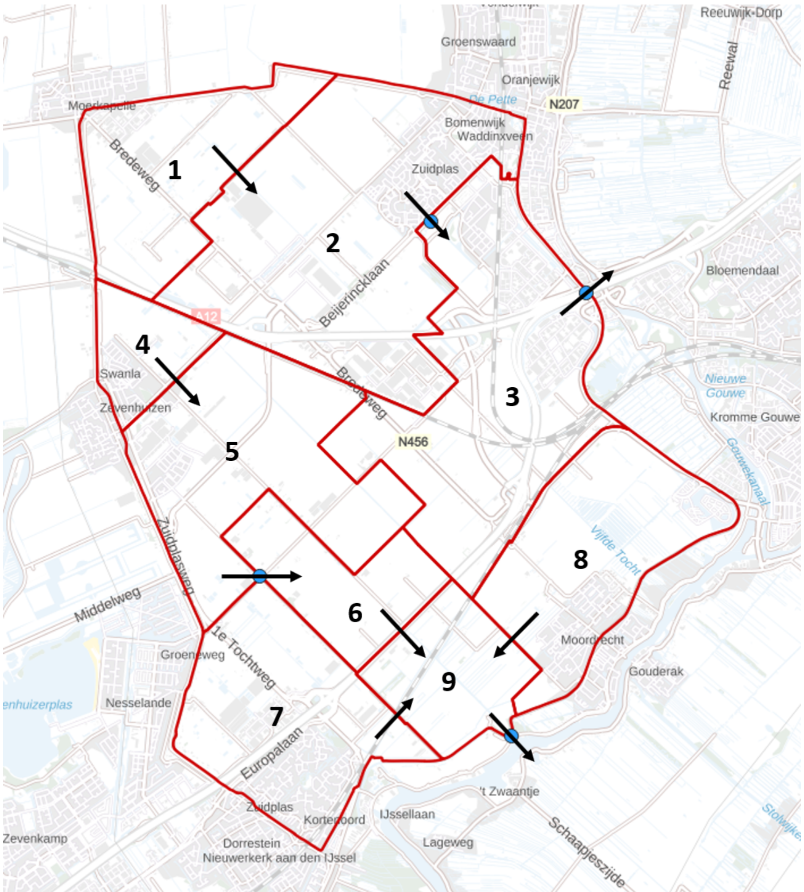

Figure 5.3: The Zuidplaspolder divided into nine zones with interlinking water quality and quantity fluxes. The blue dots indicate pumps, either for discharge between zones or out of the polder. Arrows represent the direction of water discharge.

5.1.4. Model layout

In Appendix B.2, the layout of the hydrological model of the Zuidplaspolder is presented. Here, Figure B.1 presents the water sub-model, while B.2 visualises the salt sub-model.

5.2. Assumptions and simplifications

In the development of the hydrological model, several assumptions and simplification are made. The most significant are listed below, while additional assumptions can be found in Appendix B.3.

- The exact water level of the adjacent water bodies such as the Hollandse IJssel, Gouwe and the Ringvaart are not included in the model, as this would require modelling of the full river water system, including two storm barriers (the *Maeslant barrier* and the *Hollandsche IJssel barrier*). Due to this simplification, the threat of levee breaches is not incorporated.
- The water system is fed by multiple inlets from the Ringvaart. Besides, several inlets are found at the western boundaries of the polder as well. The water supply for the inlets into the Zuidplaspolder is considered to be sufficient throughout all scenarios, disregarding the chance on lower water provision by drought.
- Groundwater is incorporated as the water within the top soil layers, from the surface to the first aquifer (approximately 8 meters below the surface level). This is chosen as this part of the groundwater system has a direct relation to other components within the polder system, such as the surface water level (through drainage or infiltration) and soil elevation levels (affecting the oxidation of peat layers [42]). Incorporating the aquifers water system would embed a different set of processes and mechanisms [72] which are considered outside the scope of this research.
- Additional land subsidence due to structural loading (by infrastructure, buildings, etc.) is not embedded. A base minimum of land subsidence per year is used, which could be enhanced by certain values for freeboard (NL: *drooglegging*, height between elevation- and surface water level) and sensitive soil types, such as peat (see Appendix B.4.4).
- Residual settlement (the compaction after finishing a construction) is measured by regular land subsidence rates. Regularly, the residual subsidence differs from regular subsidence rates as the soil is reinforced to cope with a lowering soil elevation.
- When a *trigger value* is reached in a certain zone, the associated action to deal with the emerged issue will be implemented in all zones. More information on this topic is provided in Section 5.5.2.
- The decree water level follows the land subsidence, as is practised in the current situation (*decree indexation*). This maintains until an action is implemented which affects the decree. In practise, the decree is lowered once in every few years. However, during model runs, the decree water level will follow the land subsidence rate in every time step, being one hour.

5.3. Input parameters

In Chapter 2, several changes to the polder system are identified. Based on these findings, four parameters that will affect changes in the polder system are selected. These parameters are implemented in the hydrological model, and are elaborated below. Appendix B presents more details on input- and system parameters.

5.3.1. Precipitation

In order to support decision making in water management, Beersma et al. (2019) published future projections for precipitation values. Here, different time series were created for different KNMI scenarios and varying temporal scopes. Future changes, such as the increase in extreme precipitation, are embedded in these values. The time series are free to use, and found on the Meteobase.nl web page.

To cope with regional variation in precipitation regimes, several regions are identified. Besides, a distinction is made in seasonality as well, resulting in both all-year and winter specific values. A map, indicating the different all-year regime areas, is presented in Figure 5.4. In both the winter and all-year maps, the Zuidplaspolder is located in area *H*. This means that this precipitation regime is used as the input time series for the hydrological model.

Within the projection of different precipitation regimes, an extra option is provided to account for uncertainty of the projections: *lower*, *center* and *upper*. This indicates the severeness of change on the bandwidth of uncertainty. *Lower* indicates the relatively lower projections, *upper* indicates the worst projection of a certain scenario in a given year. *Center* values lie in between the aforementioned. As input value for the hydrological model, the *center* precipitation values are used.

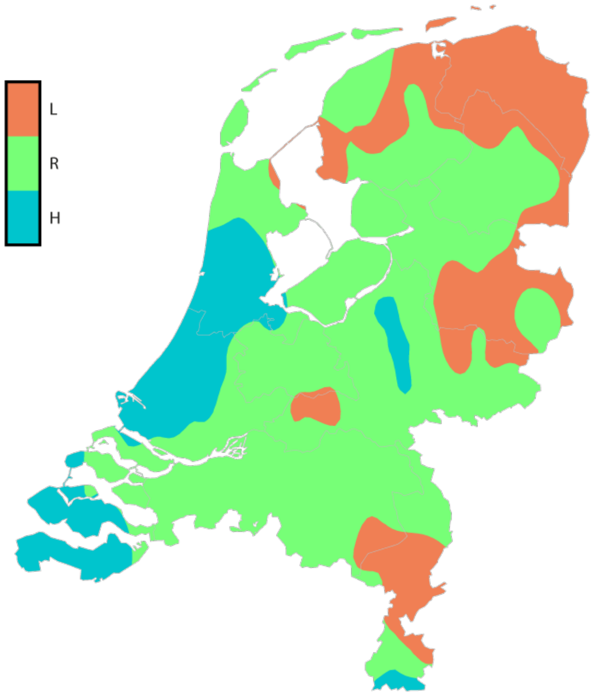

Figure 5.4: Three all-year precipitation regimes within the Netherlands, each with their own future precipitation statistics [6]

5.3.2. Evaporation

Similar to the precipitation input values, evaporation projections are gathered from Meteobase.nl. The increase in extremity of evaporation is incorporated in time series for daily evaporation rates. The unit is millimetre per day. Unlike the precipitation, the evaporation regimes show no differences in regions.

KNMI's evaporation values are based on Makkink's potential evaporation. In essence, this means the values are calculated for grass land areas in certain conditions with sufficient water available. To incorporate these values into the hydrological model, transformation coefficients are added to achieve the appropriate evaporation rates. This transformation coefficient varies for open water- and soil evaporation respectively.

5.3.3. Sea level rise

A rise in sea level increases the hydraulic head of aquifers, inducing an increase in seepage fluxes. Besides, it increases the probability of pump stops: as the Hollandsche IJssel will have high water levels more frequently, more situations will occur in which there is no possibility to discharge water out of the polder system [80].

For the current hydraulic head, data is obtained from Hoogheemraadschap van Schieland en de Krimpenerwaard (HHSK) and is presented in Figure 5.5. As elaborated in Section 4.7, the sea level rise does not have a significant impact on the hydraulic head in the Zuidplaspolder due its distance from the sea. Nonetheless, this aspect is embedded as an input, as the model may be used for other polder areas where this factor has a greater influence.

The probability of a pump stop is 1 to 20,000 per year in the current circumstances [80], and substantially rises with an increased sea level. The increased probability of pump stops is not incorporated in the hydrological model. However, pump stops are embedded in model runs to check the effect on the polder system.

5.3.4. Paved environment

Paved environment affects the hydrological system in multiple ways. First, it increases direct run-off of precipitation events into the surface water, potentially causing high water levels over a short period. Secondly, a part of the incoming precipitation is discharged through the sewage system. As third, a relatively small part infiltrates to the groundwater reservoir.

With every polder zone having a different fraction of paved area, the current paved environment is mapped per zone. This examination is performed using data from *OpenStreetMaps* in QGIS. Within this open-source platform for analysing spatial data, the surface area of paved environment was estimated.

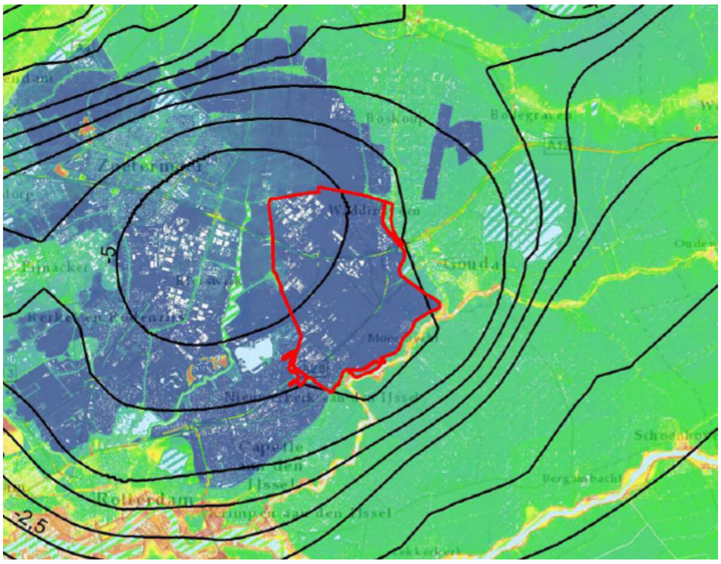

Figure 5.5: Map with isohypsen of the hydraulic head in the first aquifer with the outline of the Zuidplaspolder framed in red. Obtained from HHSK.

5.4. Scenarios

Scenarios are used as input to project possible futures within the Zuidplaspolder area. The temporal scope of the scenarios will be until the year 2100, as this time span gives a fair view on the long-term future.

The scenarios are mainly based on two uncertainties; the changes in sea level and circulation pattern & temperature. Circulation pattern & temperature are the drivers for changes in both precipitation and evaporation values. With these two uncertainties, having a low- and high impact value projection, four scenarios can be forged.

Additionally, uncertainty on the increase of housing areas is embedded in the scenarios. Currently, only one residential area is expected to be built, being the *Vijfde Dorp*. Since this housing project has a large probability of realisation (see Section 4.3), the *Vijfde Dorp* residential area is expected in all scenarios. Additionally, scenario V and VI will assume a larger part of the Zuidplaspolder to be transformed to built environment. Using the found values for sea level rise and circulation pattern & temperature, the following scenarios are created for, and towards, 2100. A visualisation of the six different scenarios is presented in Figure 5.6.

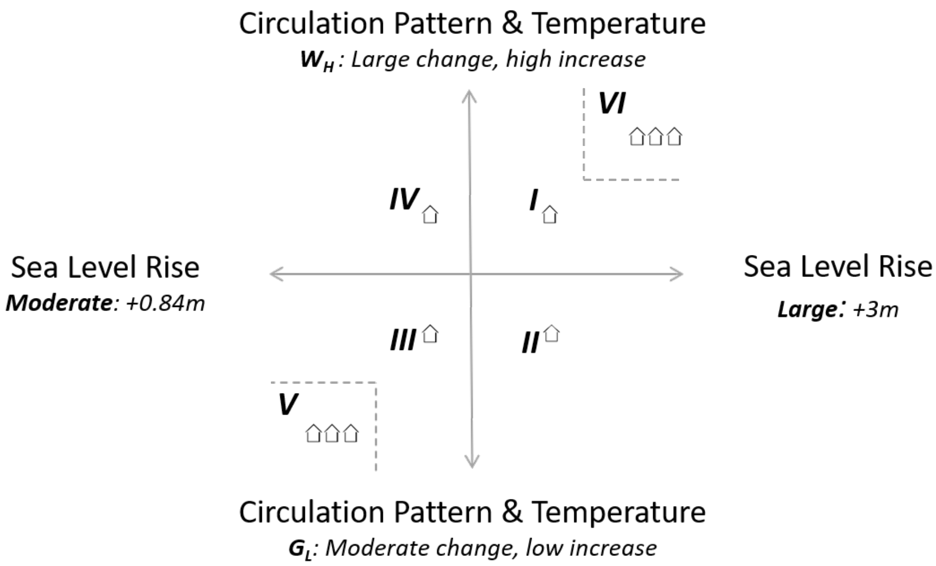

Figure 5.6: Two axes of uncertainty and varying built environment (house icons) creating six scenarios

Furthermore, Table 5.1 presents an overview of the varying values for sea level rise, circulation pattern & temperature and increase of paved environment for, or towards, the year 2100. In the sections below, the terms and values used in the respective scenarios are elaborated.

	Sea level rise	*Prob. of pumpstop*	*Circulation pattern & temperature*	*Paved env.*
Scenario I	+3m [55]	Every high tide	W_H scenario prec./evap. (mm/hr) [38]	+150 ha [9]
Scenario II	+3m [55]	Every high tide	G_L scenario prec./evap. (mm/hr) [38]	+150 ha [9]
Scenario III	+0.84m [70]	1/600 per year [80]	G_L scenario prec./evap. (mm/hr) [38]	+150 ha [9]
Scenario IV	+0.84m [70]	1/600 per year [80]	W_H scenario prec./evap. (mm/hr) [38]	+150 ha [9]
Scenario V	+0.84m [70]	1/600 per year [80]	G_L scenario prec./evap. (mm/hr) [38]	+450 ha
Scenario VI	+3m [55]	Every high tide	W_H scenario prec./evap. (mm/hr) [38]	+450 ha

Table 5.1: Six scenarios with their respective values for 2100.

5.4.1. Sea level rise

The latest IPCC projection for sea level rise predict a global sea level rise of 0.84m (0.61 - 1.10) in 2100 within *RCP8.5*, being the most severe of all pathways [74]. This value consists of AR5 projections from 2013, complemented with sea level rise due to the melting of arctic ice. This value of sea level rise is used in scenario III, IV and V (see Table 5.1).

Several groups and scientists consider this value to be conservative. When certain additional mechanisms of melting ice caps are taken into consideration, the numbers of maximum sea level rise significantly. Le Bars et al. found that the melting of Arctic ice sheets alone is capable of contributing 1.14 meter to the rise in global mean sea level in 2100. When translated to the Dutch situation, the predictions of high-end values are varying from 2 to more than 3 meters of sea level rise in 2100 [55]. Considering these numbers, Deltares published a report on (strategies to cope with) sea level rise uses projections of severe sea level rise between +2 and +4 meter in the coming 100 to 200 years [27]. This underlines the relevance of using extreme sea level rises in scenarios. Therefore, the value of 3 meter sea level rise, being an extreme value, is used in scenario I, II and VI (see Table 5.1).

Varying increases in sea level rise bring a different probability of pumpstops. Rongen and Maaskant (2019) found that for a sea level rise of approximately 1 meter, the frequency of pumpstops will increase from 1 in 20,000 per year to 1 in 600 per year. For a sea level rise of 3 meter, the water level in the Hollandsche IJssel potentially surpasses the threshold water level during every high tide, inducing a pumpstop twice a day (personal communication with HKV).

5.4.2. Circulation pattern & temperature

In 2014, the KNMI presented four climate scenarios, varying in temperature rise and changes in circulation pattern. The scenarios are based on the 5th assessment report of the IPCC, but translated to specific values for the Netherlands. The scenario with a small temperature increase combined with a small change in circulation pattern is named scenario G_L (which is used in scenario II, III and V in Table 5.1), while a high rise temperature and a large change in circulation pattern is labelled W_H (which is used in scenario I, IV and V1 in Table 5.1). Time series are available for each scenarios, as mentioned in Subsections 5.3.1 and 5.3.2.

The circulation pattern (mostly focused on wind) is of importance for sea-bordered countries, such as the Netherlands. Wind coming from the sea often creates a flux of moist, while inland wind carries dry air. Large changes in circulation pattern result in warmer and dryer weather compared to a more moderate change of circulation [47].

Besides, the changes of temperature are considered. Temperature has a direct influence on precipitation and evaporation [73]. The KNMI uses a small temperature increase of +1.5°C and a large increase of +3.5°C in their scenarios for 2100.

5.4.3. Construction of housing

With the Zuidplaspolder being a designated area for providing residential areas, it is important to incorporate the effect of additional paved environment on the polder system. Currently, plans for building 4000 houses in the centre of the polder are in progress. This project, named the *Vijfde Dorp* will cover approximately 150 hectares [9]. This value is used in scenario I, II, III and IV.

During interviews, the municipality and GOM stated that more residential areas are expected in the future (see Appendix A.6 and A.7). With that, an increase in paved environment is anticipated. Municipal targets are to realise 4000 houses in 2030, with a possible extension to 12000 houses in the future.

To explicate this to an increase in paved environment, and determine a date in which the additional housing is realised, assumptions are made. The *Vijfde Dorp* project is assumed to be realised in 2030, as stated in the original municipality plans. For further additions in housing areas, two more similar projects of the same scale are expected. To use the same scale as the *Vijfde Dorp*, an additional built environment of twice 150 ha is assumed. For each newly built residential area, it is assumed that 50% of the surface is either paved or built. This is based on literature that embeds 55% paved- and built environment [44] and research that uses urban case areas where 35 to 69% paved- and built environment is found [37]. The remaining half of the new residential areas is expected to remain of unpaved soil, i.e. unpaved gardens, parks, etc.

The new residential areas are assumed to be finished in 2050 and 2070. The chosen locations are based on maps of future spatial planning found in *Ontwikkelingsvisie middengebied Zuidplaspolder* [9]. One residential area will be located in zone 7, adjacent to the urban area of Nieuwerkerk a/d IJssel. The second will be planned in zone 3, near Waddinxveen.

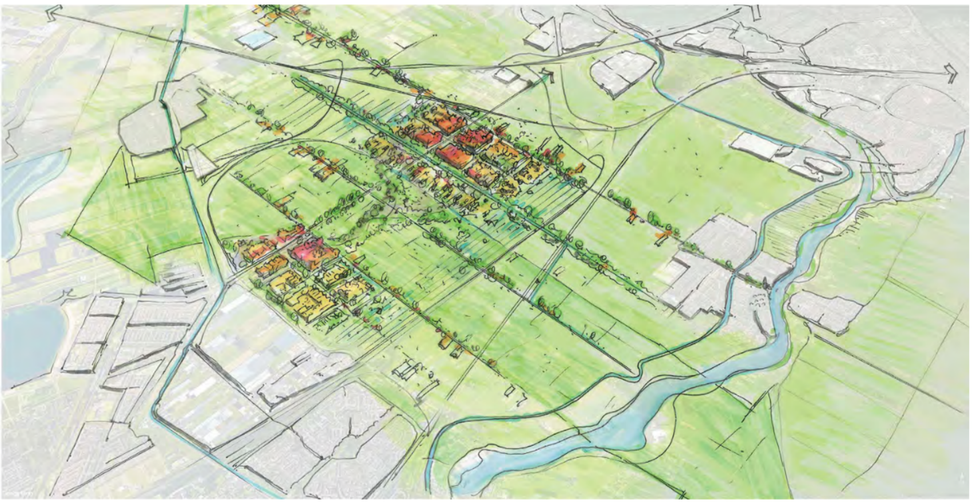

Figure 5.7: Impression of the *Vijfde Dorp* project, based in the center of the Zuidplaspolder [9]

5.5. Determining sell-by dates

The hydrological model helps in the creation of the pathway map by detecting trigger values for crucial parameters (*signposts*) within the Zuidplaspolder system. When a trigger value is detected, the sell-by date of the current course of action is met. This demands the implementation of an action that deals with the emerged issue. First, the signposts and trigger values are presented.

5.5.1. Detecting trigger values

Within the polder system, several variables are significant for the respective stakeholders' objectives, called signposts. These parameters, along with their trigger values (values where the state of success is not met anymore), were found during interviews with stakeholders. In Section 6.3, an elaboration on these signposts and trigger values is presented.

5.5.2. Activating actions

When a trigger value is detected, the sell-by date of the current course of action is reached. This requires the implementation of an action that deals with the emerged issue. The hydrological model detects the moment when a trigger value is reached. Depending on the sequence of actions that is simulated, a new action is activated in the system. Different sequences of actions shape the pathways that collectively create a pathway map.

The signposts are evaluated for every zone separately. However, when a trigger value is met, the implementation of the subsequent action is performed over the entire polder area. This simplification is made to prevent different zones requiring their own pathway maps; when the hydrological system is altered solely in a certain area, the pathways in the remainder of the simulation become zone specific. By incorporating a polder-wide implementation of actions, this is prevented.

An example of the activation of a measure is presented below. Here, the *Increase private storage horticulture* action is regarded.

In Figure 5.8, the detection of trigger values is shown. The implementation of this action is required when either the groundwater salinity or the freeboard (NL: *drooglegging*, height between elevation- and surface water level) reaches its trigger value, in order to protect the objectives of stakeholder LTO Glaskracht. Since the greenhouses are present in specific areas, the signposts are evaluated in these areas only. When one of the trigger values is reached, the *Switch A1* is activated.

The effect of this activation in the polder system is visualised in Figure 5.9. When this action is activated, the storage capacity of the horticultural business will increase. The exact effects of actions on the polder system are presented in Appendix B.5. In the case of *Increase private storage horticulture*, the storage capacity is assumed to be doubled from 1000 m^3 per hectare to 2000 m^3 per hectare. As more precipitation can be stored, the surface water system receives less inflow from the horticultural areas.

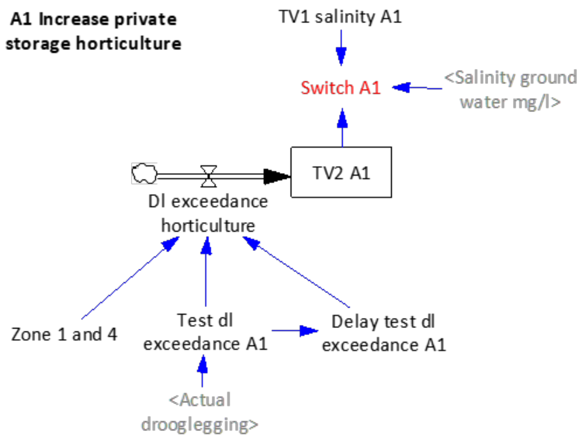

Figure 5.8: Detecting trigger values (labeled *TV*'s) for the *Increase private storage horticulture* action (labeled *A1*) in the hydrological model.

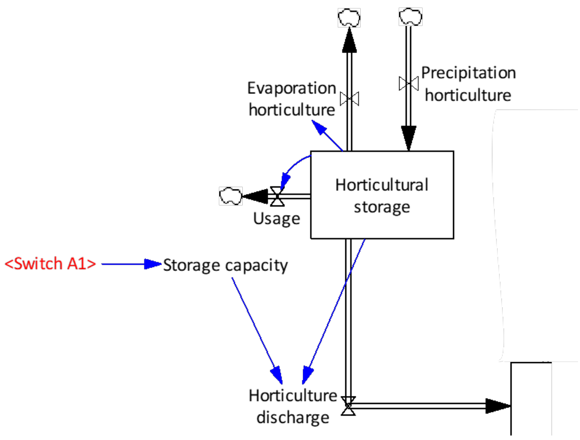

Figure 5.9: Activating the *Increase private storage horticulture* action, affecting the horticulture discharge towards surface water.

6

Dynamic Adaptive Policy Pathways

This chapter will present the outcomes of the DAPP procedure. Through following the steps presented by Haasnoot et al. (2013), a pathway map containing possible futures is forged. Where the actual map is presented in Chapter 7, the development process is described below.

Most of the information provided in this Chapter is gathered through interviews with the respective stakeholders. Here, the results from interviews are filtered for specific details, where full summaries of the interviews are found in Appendix A.

At first, a brief review of the current circumstances in the Zuidplaspolder is given. Secondly, the objectives of stakeholders are presented, along with their constraints. As third, the outcome indicators and their trigger values are shown. Here, the sell-by dates will be given as well. At last, the actions that can be taken are presented.

6.1. Decision context

The Zuidplaspolder holds a complex system, both for the hydrological and social component. At first, the hydrological and demographic circumstances (mainly the low elevation) within the polder induce the need for robust water management. In this way, the area can be secured from water nuisance, salinisation of ground- and surface water and land subsidence. Besides, the future conditions are threatening to worsen due to climate change, as mentioned in Subsection 4.7. Furthermore, the social dynamics are of importance as well. With four governmental parties, and four (semi-)private actors, a wide range of means and objectives are present. Subsection 4.6 provides an elaboration on other stakeholders.

6.1.1. Simplification in stakeholders

In the remainder of the DAPP approach, two stakeholders are not taken into consideration; Rijkswaterstaat and Staatsbosbeheer. The main impact of this assumption is the absence of these actors in the pathway map.

For Rijkswaterstaat, the actions to meet their goals have only a small effect on the overall polder system. Since they mainly affect the motorway system, and a fairly small area around it, the actions are neglected from the pathway map. However, it is important to consider their objectives when a decision moment is present.

Staatsbosbeheer does not have a direct influence on meeting their objective within the polder area (interview, see Appendix A.5). As there is no active acquisition for grounds to transform to green zones, a lack of impact is present. Therefore, similar to Rijkswaterstaat, their objectives and constraints are to be considered at decision moments, but not embedded in the pathway map.

To conclude, the objectives of six remaining stakeholders are embedded in the creation of pathways; the province of South Holland, the municipality of Zuidplas, LTO Glaskracht, LTO Noord, GOM and HHSK.

6.2. Objectives and constraints

Through interviews, an insight was given on the situation of each stakeholder. One of the main results from the interviews are the objectives; what are the respective goals of each actor? Furthermore, it is of importance to identify the possible threats for reaching these goals. Table 6.1 displays the different objectives within the group of stakeholders, along with the constraints that may prevent them from reaching it.

Stakeholder	Objective	Constraints
Province	Have a future proof and stabilised area with a positive revenue model	Economic degradation of the area Emission due to oxidation of peat Loss of scenic value
RWS	Improve the flow and traffic safety of the A20 motorway	Land subsidence Negative influence on water system Water nuisance on road surface
Municipality	Create a liveable and futureproof environment and realise the construction of housing	Water nuisance in built areas Loss of scenic value Land subsidence
Staatsbosbeheer	Facilitate green and recreational areas through creating wetland landscapes	Absence of transition jumps Construction of housing Emission of fosphate when wetting former agricultural grounds
LTO Glaskracht	Protect, and increase the circularity of horticultural businesses	Demand for area Disturbance of fresh water lens Water nuisance Changing government policies
GOM	Develop a future proof, and sustainable living environment	Land subsidence Water nuisance Sentiment of current inhabitants Disagreement in local government
HHSK	Support user functions within the polder by providing dry feet and clean water	Unable to discharge polder water Salinisation Water nuisance Drought
LTO Noord	Ensure viable agricultural circumstances, or otherwise a fair relocation procedure	Water nuisance Salinisation Drought Unclear future plans of government

Table 6.1: Objectives and constraints for stakeholders in the Zuidplaspolder

Given the presence of eight relevant stakeholders, the set of objectives shows both overlapping and conflicting aspects. These corresponding and conflicting objectives are elaborated below.

6.2.1. Corresponding objectives

By identifying the overlap in stakeholder objectives, the process of finding a suited strategy for the future could be simplified. When one action is able to serve the purpose of multiple actors, it could be preferred over other types of measures.

At first, reducing land subsidence has a positive contribution to several objectives. For the province, this is beneficial as this inherently leads to lower CO_2 emissions from peat oxidation. This helps in reaching the national targets for reducing emissions. Additionally, the decrease in land subsidence rates induces an increase in soil stability which is beneficial for GOM and Rijkswaterstaat. For both stakeholders, their built environment and infrastructure becomes less affected or damaged by land subsidence. In the same manner as GOM and Rijkswaterstaat, a stable soil benefits the built environment for the municipality as well, although this constraint was not mentioned explicitly during the interview. For Staatsbosbeheer, the measure of adapting high water levels provides a desired "transition jump"; by changing the system, a shift in mindset within the area is explicated. In this case specifically, higher water levels may function as a stepping stone to the facilitation of wetland nature, as larger quantities of water are accepted already.

Secondly, a shared objective is found in the desire of low salinity grades within the polders water system. Here, LTO Noord has a focus on the salinity of surface water as this is used for watering crops. LTO Glaskracht is dependent on groundwater salinity, as a share of their fresh water provision originates from groundwater bells. Here, fresh water is pumped into the ground, to be withdrawn when required at a later moment.

This storage can be disturbed by groundwater with a high salinity. Since HHSK aims at providing suitable circumstances for the users within the polder, this actor is involved in this matter as well.

6.2.2. Conflicting objectives

Besides corresponding intentions, objectives may expose conflicts as well. Recognising opposition in goals is important in order to identify possible friction or issues. Several conflicting goals can be determined, and are elaborated below.

Firstly, the surface water levels are prone to discussion. As mentioned in Subsection 6.2.1, land subsidence is important to several stakeholders. The process of land subsidence can be reduced by maintaining high surface water levels. However, this opposes the requirements of agricultural businesses, where high surface water levels cause lower crop yields and a reduced strength for carrying machinery and livestock.

Secondly, there are several stakeholders with a demand for space within the polder, for different reasons. This pressure on land use causes choices to be made in favour of specific stakeholders. For the construction of new residential areas, GOM requires large plots of land. Despite the fact that GOM already possesses grounds in the Zuidplaspolder (see Appendix A.6), more plots might be necessary for the realisation of housing areas. Besides, agricultural businesses require space. Especially for the objectives of LTO Glaskracht, since expanding the surface area is often crucial for the continuity of horticultural businesses. Regarding the objectives of Staatsbosbeheer, the pressure on land use reduces the opportunity for wet nature areas. Since green areas are currently not valued highly compared to the aforementioned types of land use (see Appendix A.5), the chances of implementation are lowered.

6.2.3. Non-quantifiable constraints

Most of the constraints, and the actions to cope with them are quantifiable and therefore simple to embed in the hydrological model. However, several of them are not possible to quantify at all, or are too far out of scope to use in the hydrological model of the Zuidplaspolder. Four non-quantifiable constraints are enumerated below.

At first, the *economic degradation of the area*, as mentioned by the Province. Since there is no clear definition of a positive revenue model on the scale of a polder area, it is impossible to tell when the revenue model is worsened as such that economic degradation has taken place. Besides, economic aspects are not considered in the hydrological model. Therefore, it is not known when action is required.

A second non-quantifiable aspect is the *loss of scenic value*, as mentioned by the municipality, province and GOM. The concept of scenic value (NL: *landschapskwaliteit*) has no clear definition, but it aims to value the quality of a landscape within an area [94]. For this, multiple types of landscapes are identified, each with their own characteristics. To what type of landscape an area relates, is not clear. Besides, each type of landscape might receive a different rating for scenic value per individual. Therefore, embedding scenic value in the DAPP approach is not feasible.

Thirdly, constraints regarding politics are mentioned by LTO Glaskracht, LTO Noord and GOM. These constraints mainly concern the *lack of certainty in future government policies*. An example is found with LTO Noord, to which governmental statements were made on the sustainability of agriculture in the Zuidplaspolder, but no changes were encountered (see Appendix A.3). For GOM, reaching their objective is strongly reliant on approval from the municipality council (see Appendix A.6). With many influences within the polder area, a clear vision on future planning of housing areas is required but often not experienced. As issues regarding the political context hold a large grade of subjectivity, are not physically related to the hydrological system and are not quantifiable, this aspect is neglected.

At last, the *availability of space*, and the competition to it are not quantifiable. In the case of LTO Glaskracht, space is required for horticultural business to maintain positive revenues. A specific demand for space is highly case dependent. Besides, for Staatsbosbeheer, high pressure on the land use indicates a small chance for green areas to be developed. Other types of land use, such as residential areas or farmlands, will be preferred at least until green areas are valued higher than they currently are.

The constraints mentioned above are not embedded when creating the pathway map. However, the non-quantifiable nature of these constraints does not mean they can be neglected in policy- and decision-making. When pathways are chosen, they need to be regarded, possibly based on qualitative judgement.

6.3. When to act?

With the non-quantifiable constraints neglected, a list of constraints remain that is used in the remainder of the DAPP procedure. When incorporated in the model, the related signposts that are related to these constraints can be assessed quantitatively. In turn, this is used for detecting sell-by dates. The signposts used for the creation of the pathway map are presented in Table 6.2. Besides, the trigger values of the signposts are given, varying per stakeholder. A trigger value is the threshold after which mark the moment when a sell-by date is reached.

Signpost	Province	Municipality	LTO-G	GOM	HHSK	LTO-N
Land subsidence (mm/year)	0 by 2050			8.3		
Water nuisance (per year)		1/100			*Standards*	
Salinity groundwater (mg/l)			1500			
Salinity surface water (mg/l)					900, 1800	900, 1800
Freeboard, minimum (m)			0.8	1.2		0.8, 0.4

Table 6.2: Relevant signposts with their respective trigger values, varying per stakeholder.

Land subsidence The province aims to reduce the emission of CO2 gasses from peat oxidation to zero in 2050. Additionally, lowered emissions are desired in 2030. One centimetre of land subsidence in peat soils causes approximately 22 ton CO2 per hectare [93], hence the desire to minimise this process.

For GOM, land subsidence is capable of damaging buildings and infrastructure. The trigger value of 8.3 mm/year is valid for residual subsidence; the subsidence in the period after the finalisation of construction. For GOM, this value should not exceed 0.25 meter over 30 years, which averages to 8.3 millimetre per year over this period of time.

Water nuisance Regarding water nuisance, the Dutch Water law provides standards prescribing a frequency of floods from surface water, which varies per land use. Water authorities and governments should design its system to meet these demands. For built environment, the standard is set to 1 in 100 per year. For other types of land use, other standards are prescribed, and act as trigger values. When the occurrence of water nuisance exceeds this standard, the trigger value is met. Below, the standards per type of land use are enumerated:

- Built environment: 1 in 100 year
- Horticultural areas: 1 in 50 year
- Arable farmlands: 1 in 25 year
- Grasslands: 1 in 10 year

Salinity of groundwater The horticultural sector utilises the first aquifer for storing fresh groundwater. If required, this water can be retrieved by pumping. When the aquifer becomes too saline, the created fresh water lens is difficult to maintain. Therefore, the signpost to measure the water provision for horticultural businesses is the salinity of groundwater (in mS/cm). According to LTO Glaskracht, the guideline for salinity of groundwater is 4 mS/cm, which will be 1500 mg/l when conversed tot mg/l (see Appendix B).

As mentioned in Section 5.2, the model solely incorporates the shallow groundwater system, hence excluding the salinity within the first aquifer. Therefore, the shallow groundwater is used for detecting trigger values on groundwater salinity in the creation of pathways.

For both the **salinity in surface water** and **freeboard**, multiple values are presented as a trigger value. Here, each value is applicable to either arable farming or grassland areas, where arable farming is the most sensitive. This holds that both the lowest salinity and freeboard value is applied to arable farmlands.

6.3.1. Start with implementation

When a trigger value is reached, a shift in policy is demanded. However, the implementation of actions requires preparation. This may vary from 1 year for small-scale actions or actions considering a change in policy, to 20 years when large physical changes are needed. For each action, the *implementation time* is based on findings from interviews (see Appendix A). These respective implementation times are presented along with the elaboration on the actions, in Section 6.4.

6.4. How to act?

To maintain a desired situation in the Zuidplaspolder, actions are required to counter the occurring constraints. Through interviews, each stakeholder listed a set of actions that ensures the state in which their objective is met.

In order to create a clear and comprehensible pathway map, actions that are similar, or have a significant overlap in their effect on the polder system, are bundled. In this process, the overall list of forty two actions is reduced to ten bundled actions. Appendix C presents a further elaboration on the combined actions.

In general, the set of actions can be divided in two categories; actions with a focus on water management or a focus on land use. The former category mainly aims at adjusting the hydrological system to cope with changing circumstances, while the latter primarily focuses on adapting the land use to match the changing circumstances. The adopted implementation time of actions are noted in brackets.

6.4.1. Actions regarding water management

By implementing the following actions, the water system of the Zuidplaspolder can be adjusted to a (more) preferred state. The actions are ranked on the effort for implementation, both in expected costs and implementation time.

Decree fixation (1 year) Over the last decades, the decree water levels were lowered frequently to sustain preferred conditions for agriculture. Unfortunately, this process induces land subsidence in peat soil areas. Fixation of the decree water level will help in decreasing the land subsidence rate.

Additionally, incentives or requirements could be set for farmers to maintain high water levels on their farmlands.

Increase private storage horticulture (2 years) Horticultural business have reservoirs for storing rainwater, which is used for watering crops. The reservoirs are also able to cope with water nuisance, as drainage systems will discharge excess water to these ponds. Every company is obliged to have a certain storage capacity within their perimeter. On top of that, farmers may choose to realise additional storage. Increasing the storage capacity may happen on land or underneath the greenhouses. Besides better circumstances for the horticultural businesses, an increase in storage will improve the storage capacity of the water system as well.

Increase public buffer capacity (small-scale) (3 years) By increasing the buffer capacity in the public domain, water nuisance and drought can be prevented. Examples are the construction of small water storages (e.g. wadi's), increase infiltration rates in urban areas, maintain flexible decree water levels and slightly lower freeboard values (within the acceptable boundaries of present land usage).

Increase public buffer capacity (large-scale) (10 years) Similar to the small-scale increase in buffer capacity, this action aims to prevent water nuisance and droughts. On a large scale, calamity areas can be created, where excess water is directed in case of emergency. An example is the *Eendragtspolder*, located east of the Zuidplaspolder, where large quantities of water from the adjacent *Rotte* water system can be stored. Another option is to create more, and slightly smaller reservoirs where water can be discharged.

The constructed buffer capacity is assumed to help in storing water for preventing drought as well. In months with high precipitation values, water is stored to use in drier periods.

Tweak regional/national water provision system (10 years) When drought becomes a serious issue, changes to the regional or national water provision system can be made. Options are to increase the supply of water to the Zuidplaspolder specifically, or construct barrages in the Nieuwe Waterweg river near Rotterdam, preventing fresh water to leave the inland water system.

6.4.2. Actions regarding land use

The following actions induce changes in the land usage within the Zuidplaspolder, in order to cope with the changes that occur. A distinction is recognised between actions considering agricultural and residential areas.

Adjust current way of agriculture (20 years) Due to increasing salt and water loads, the current way of agricultural practice might become unfeasible. By making small adjustments, it is possible to cope with undesired changes. Examples are the implementation of an enhanced drainage system (both for infiltration and drainage), improve the salt resistance of the current crop types or rescale the plot size of businesses.

Shift to future proof land use (20 years) In a situation where salinity and water levels exceed threshold values (too often), farmers may choose to adapt to a new land use. Options are to shift to saline and waterproof crops, use plots for solar meadows (fields with solar panels) or change from cultivating crops towards a consumer-based business (selling entrance tickets for farm experiences, renting houses, etc.).

Leave the polder (agriculture) (20 years) The most extreme, and undesired, action for the agricultural sector is to leave the polder area. As most farmers have a long family history in the polder, and their residences are located next to their plot, they reject the idea of relocation. When this action is unavoidable, the agricultural sector request a notification in an early stage, as it influences the type and sort of new investments. Furthermore, some sort of compensation is expected.

Adapt building principles (5 years) Land subsidence may become a serious concern for the built environment. To prevent land subsidence from becoming a significant expense, alternative techniques in the construction of housing could be applied. Options are to build with timber frames or other light materials, or to build on *terps* (small plots with a heightened elevation).

Present residences could be adapted to new building principles, however, this will be a time and funds-consuming operation. It is recommended to embed this action in the planning and construction phase of new housing areas.

Shift to wet housing and wetlands (5 years) When water nuisance become a significant issue in built environments, water could be embedded in the spatial planning. In practice, this means there will be more space for water; water residences could be realised, with large areas for surface water. Implementation of this action makes room for creating wetland nature.

Present built areas could be adapted to wet housing, however, this will be a time and funds-consuming operation. It is preferred to embed this action in the planning and construction phase of new housing areas.

6.5. Creating pathways

In Section 5.5.2, an example of the detection of trigger values and the subsequent activation of an action is presented. In order to create pathways, different sequences of actions are simulated in the hydrological model.

The implementation of an action leads to changing circumstances within the system. For example, the implementation of *Increase public buffer capacity (small-scale)* leads to a larger buffer capacity of the whole system, reducing the probability of water nuisance. Hence, by choosing an action, the course for the remainder of the future projection is altered. This also implies a different sell-by date for respective signposts in different pathways. To cope with this, every pathway is simulated separately for different scenarios.

Different pathways can be simulated by allowing the activation of certain actions during a simulation. When a trigger value is met, a *switch* variable is activated (i.e. set to 1) which implements the desired action. As actions may be induced by multiple trigger values, the trigger value is identified as well. Figure 6.1 presents the determination of sell-by dates for a pathway in scenario *V*, sequencing the following actions: *Increase public buffer capacity (large-scale)*, labelled *A4* → *Adjust current way of agriculture*, labelled *A5* → *Shift to future proof land use*, labelled *A6* → *Increase private storage horticulture*, labelled *A1*.

The moment an action is activated, a sell-by date is due. Therefore, with the information from Figure 6.1, the pathway as mentioned above can be constructed. The resulting pathway is presented in Figure 6.2. Combined with all other relevant pathways, a pathway map is created. This pathway map, along with an explanation on how to use it, is presented in Sections 7.1. A further explanation on how to read the pathways is presented in Subsection 7.1.1.

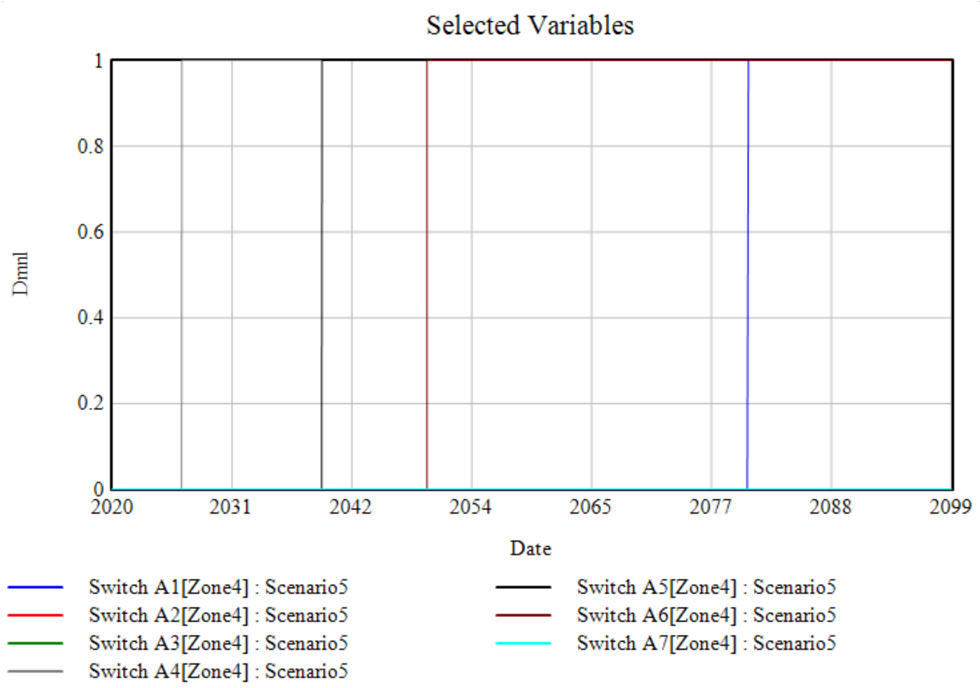

Figure 6.1: An example of the activation sequence of actions, creating a pathway.

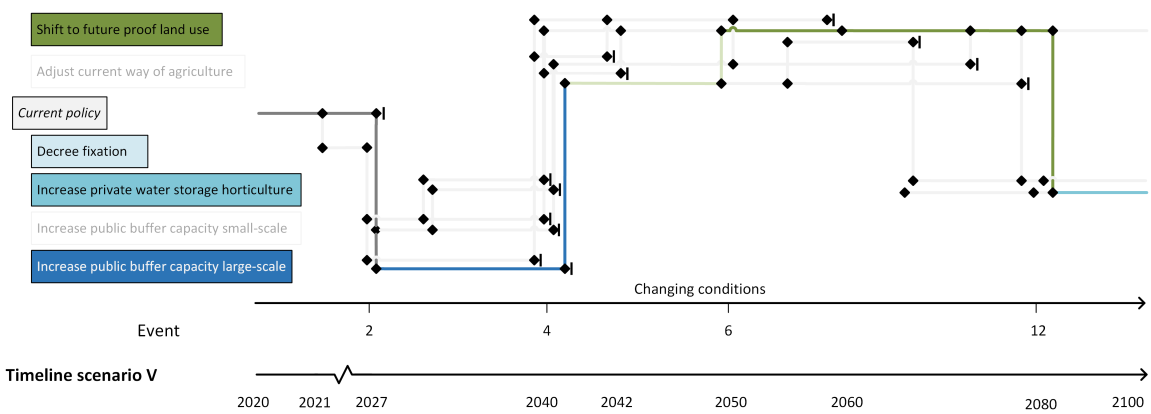

Figure 6.2: The pathway resulting from the sell-by dates found in Figure 6.1.

7

Results

This chapter presents the results from the multiple methods that are applied in this research. Firstly, the created pathway map will be presented, along with a description on how to read it. Additionally, several findings are elaborated. Secondly, the results of the two focus groups will be elaborated. These groups were organised to check whether the DAPP approach is suited to improve the adaptivity of policy- and decision making in Dutch polder areas. At last, a review on the current adaptivity within polder management is presented. Having a view on the current adaptivity is essential to assess the potential increase of adaptivity by handling the DAPP approach.

7.1. Zuidplaspolder pathway map

In the developed pathway map, both the results of the hydrological model and the DAPP approach are merged. This results in potential pathways into the future of the Zuidplaspolder case area. Figure 7.1 presents the actual pathway map. In order to read and use the pathway map, an explanation is provided first. Secondly, several choices in the design of the pathway map are elaborated. Thirdly, after the presentation of the pathway map in7.1, difficulties in decision making are identified. Fourthly, multiple other findings are presented. Finally, several excluded components are mentioned, which are to be considered in policy- and decision making.

7.1.1. Reading the pathway map

In order to provide a clear view on the contents of the pathway map in Figure 7.1, a description of its components is presented. After this, the pathway map can be interpreted correctly. Broadly, the pathway map consist of the following components:

- **Actions** On the left hand side, the actions or policies are found. The set of actions can be divided into actions regarding *Watermanagement* and *Land use*. Within land use, a distinction is visible between actions on *Housing* and *Agriculture* specifically. An elaboration on the set of actions is given in Section 6.4. For an example of trigger value detection and the subsequent action implementation, see Section 5.5.2.

- **Pathways** Pathways are of sequences of actions, aiming to maintain desired circumstances in the polder area. At every black node in the pathway map (labelled *transfer station*), a change in action is possible and/or demanded. The overall set of pathways create a wide range of possible futures. An explanation on the process of creating of pathways with use of the hydrological model is elaborated in Section 6.5.

- **Events** Right below the actions and pathways, an axis labelled *Changing conditions* is found. Numbers are attached to this axis, which indicate events. Here, events mark the sell-by date of a specific signpost, which is mentioned in a list in the bottom right of the figure. The list of signposts and their trigger values is presented in Section 5.5. On the *Changing conditions* axis, a continuously changing set of circumstances is represented, and no temporal scale is used. The temporal aspect is assigned in the *Timelines* below.

- **Timelines** In the timelines, the temporal aspect is embedded in the pathway map. The timelines provide the moments in time where actions should be considered, if they are to be implemented further in the future. Since each action has a respective implementation time, an action should be considered earlier in time. On two timelines, triangles indicate the signal to consider a specific action at that point in time. The colour of the triangle visualises the action that is to be considered. The number indicates the event that induces the need for this action, while the year in which this action should be finalised is presented in brackets.

  Two timelines are found, representing two sets of scenarios. The grouping of scenarios into two sets is elaborated in Subsection 7.1.2. As each set of scenarios require different actions, or at a different time, distinctive timelines are found.

Typically, when actions are not substituting each other, thus combined, a pathway shows a dashed line with the colours of the combined actions. In the pathway map of the Zuidplaspolder, it is chosen not to implement this feature for comprehensibility reasons. Instead, an important side note is provided:

- For *water management* actions (blue tinted), subsequent actions are combined with the previous action. The actions related to water management are complementary, and do not interfere with the others. As they serve (slightly) different purposes, a combination of these actions is required in all pathways.
- For *agricultural* actions (green tinted), subsequent actions substitute the previous action. Since the actions related to agriculture are concerning changes in land use for agricultural business, they can not be combined. The pathway map leaves no possibility for partial implementation of multiple types of agricultural land use, as could occur in reality. Therefore, if the step towards another land use is implemented, the previous action is discarded.
- For *housing* related actions (red tinted), subsequent actions substitute the previous action. Similar to the agricultural areas, the actions regarding housing areas substitute each other as the actions are not feasible to be practised simultaneously.
- However, when a *housing* related action follows an *agricultural* action, subsequent actions are combined with the previous action. Since there is no conflict between these two land uses in the pathway map, the related action can be combined.

7.1.2. Design choices

In designing the pathway map and its pathways, three decisions were made that require elaboration. At first, it is chosen to simplify the set of scenarios. Furthermore, actions considering land use in the early phase of the projection are neglected. Thirdly, the decision moment for the implementation of *Decree fixation* is assumed directly at the start of the future projection. The rationale behind these decisions will be explained below.

Firstly, a simplification is made in the set of scenarios. While running the hydrological model, it became clear that between certain scenarios, high similarities were found in sell-by dates and the created pathways. Specifically, two groups of scenarios could be distinguished, each containing three scenarios. Considering the similarities within the sets of scenarios, they share one timeline in the pathway map in Figure 7.1. The grouping of scenarios into two sets was performed with the following considerations.

It was found that the projection of *Circulation pattern & temperature rise* has the largest influence on the polder system. In fact, the effect of sea level rise has a minimal effect on the polders water system, due to the distance between the North Sea and the Zuidplaspolder and neglecting potential levee failures. Within this study, only the increase of pump stop frequencies causes a significant difference between the two projections of sea level rise. However, pump stop frequencies are not embedded in the pathway map, but are to be considered when choosing pathways.

Furthermore, only a small difference was found between the scenarios with additional housing and the ones without. The only difference is found in the requirement of the *Adapt building principles* action. Additionally, the effect of the added paved environment is found in slightly higher surface water levels and higher peaks during heavy rainfall, as the paved runoff increases. However, the influence of these changes were not influential enough to induce different sell-by dates.

As a result, timelines are constructed for two sets of scenarios; one containing pathways for scenario *I, IV* and *VI*, and one for scenarios *II, III* and *V*.

Secondly, in designing pathways, it is chosen to neglect actions considering land use in the early phase of the projection. For example, a pathway that uses the *Adjust current way of agriculture* action to deal with issues regarding water nuisance in events *2* and *3* is not created. This is due to the long implementation time that is accounted for; for each agricultural action, 20 years are assumed for providing the transition into new types of agriculture or land use. Besides, actions with a smaller impact are chosen first. The actions regarding water management create little to no conflict and are considered easier to implement.

Thirdly, the decision moment for the implementation of *Decree fixation* is assumed directly at the start of the future projection. Considering the provincial objective of reducing CO_2 emissions (induced by land subsidence) by 2030, this actions is demanded as soon as possible. Additionally, the implementation of decree fixation on the short term is becoming more realistic, as suggested by the Minister of the Interior and Kingdom Relations (2020) [62]. Here, in a letter towards the parliament, it is stated that governmental parties will start to apply this measure more frequently. This suits the early possibility of implementing this action.

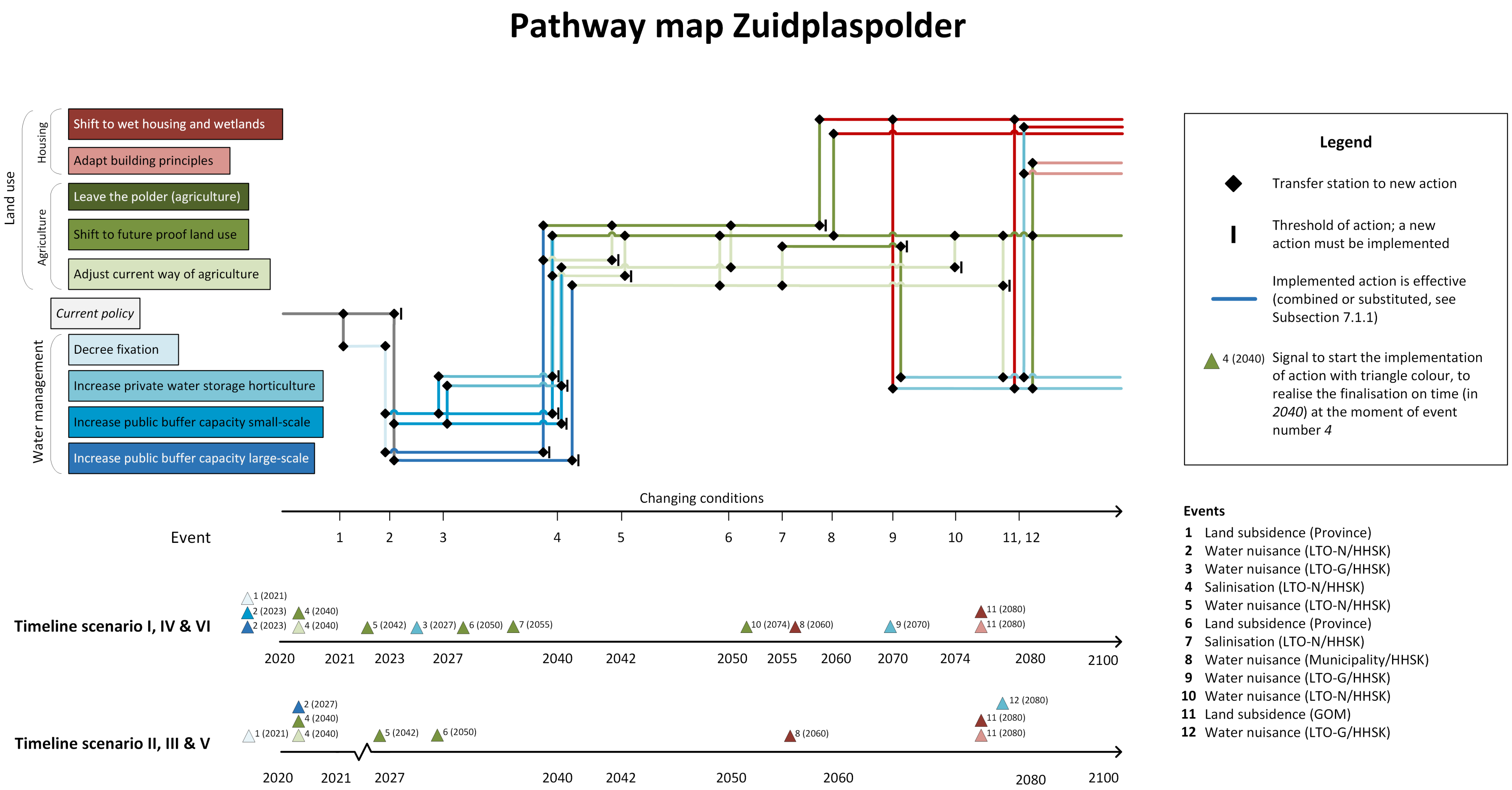

Figure 7.1: Pathway map for the Zuidplaspolder

7.1.3. Difficulties for policy- and decision makers

The pathway maps provides insight in the possible futures, and with that in the complications these futures may hold. Below, three difficulties are elaborated.

Firstly, the pathway map shows that many decisions need to be made on the short term, effectively in 2020. This is indicated by the large number of signals for preparing actions (visualised as triangles in Figure 7.1) early on both timelines. Decisions have to be made on ways to deal with water nuisance in the period until 2030, and on the changes in agricultural land use around 2040. Unfortunately, the decisions on these aspects are to be made while there is no opportunity for the policy- and decision-makers to obtain new information on the rate of changes within the uncertainties of climate change. This creates an even harder decision context.

Secondly, related to the complication mention above, the shifts to other types of agricultural land use hold an extra degree of uncertainty. For both the *Adjust current way of agriculture* and *Shift to future proof land use* actions, there is no clear view on the future revenue models of these types of land use. If there is no positive revenue model around 2040, when a change to one of these actions is required, the farmers will be troubled and might be forced to leave the polder. Additionally, it is uncertain whether the profitability of these types of land use becomes sufficient at all (see Appendix A.3).

Thirdly, a decision has to be made on the *Decree fixation* action, being one of the conflicting objectives as mentioned in Section 6.2.2. This action is required to meet the provincial targets of a reduced CO_2 emission in 2030. However, this negatively influences the circumstances for agriculture. The first moment where this conflict is found is immediately in 2021, where a pathway is created with a fixed decree. Additionally, the provincial target on minimising the subsidence rates to zero by 2050 proposes a *Shift to future proof land use*. This rises an even larger conflict with agricultural businesses, as this has a large impact on their situation.

7.1.4. Findings from pathway map

Besides exposing difficulties in decision making, the pathway map in Figure 7.1 presents other findings as well, of which several are presented below.

The first finding is an observation of the causes for adapting new actions. As spotted in the *Event* list, the larger part of the actions are implemented to counter water nuisance, while only a few shifts to new actions are induced by salinisation. This implies that water nuisance is a larger threat to the objectives within the polder area compared to salinisation, at least when the temporal scope is set to 2100.

A second finding considers the implementation of either the *Adjust current way of agriculture* or *Shift to future proof land use* action in multiple pathways within the pathway map for scenario *I, IV* and *VI*. In 2040, salinisation causes the need for a different type of land usage. Here, the options are the two actions mentioned above. However, when *Adjust current way of agriculture* is chosen, the need for a *Shift to future proof land use* is demanded two years later. As the implementation time of both actions is set to 20 years, it seems sensible to immediately implement the *Shift to future proof land use* in 2040.

Thirdly, the pathway map may influence the design choices in the new residential areas that are planned in 2050 and 2070 scenario *V* and *VI*. Several pathways in both pathway maps indicate that the *Shift to wet housing and wetlands* or *Adapt building principles* actions are required in the second half of the century. Given these findings, the choice for wet housing or a different set of building principles can be implemented before the issue of land subsidence becomes a burden.

7.1.5. Excluded components

Several aspects are not incorporated in the hydrological model, and therefore excluded in the pathway maps. The two most significant aspects are the frequency of pump stops and drought events. Both these aspects could have a significant impact on the polder system.

Pump stops cause water to accumulate within the polder boundaries, causing water nuisance and/or floods. For pump stops, values are present for the increase in occurrence forced by a rise in sea level; with a rise of 0.84 meter (scenario *II, III* and *V*) the frequency increases from 1 in 20,000 per year to 1 in 600 per year in 2100 [80]. In scenario *I, IV* and *VI*, with a sea level rise of 3 meter, a pump stop is expected twice every day. When choosing pathways in the policy- and decision making process, the potential increase in water nuisance should be considered. Actions on different land usage could be chosen to minimise the costs of frequent flooding, for example by implementing a *Shift to wet housing and wetlands* in an earlier stage. Additional, pathways could be *reinforced* by implementing other measures to support the current pathways. Options are to increase pump capacity or to aim at an adjustment the Hollandsche IJssel river system on a large scale.

Equally, drought has the potential of becoming an issue in the future. For this constraint, no clear parameters could be found to detect drought, partly due to the absence of a clear definition [103]. However, the potential effects of water deficits in the future should not be neglected in choosing pathways. For example, when the effects of drought become more severe, the action to *Tweak regional/national water provision system* could be implemented. This action is currently not embedded in the pathway map.

Besides, as presented in Subsection 6.2.3, several constraints were found to be non-quantifiable. Therefore, it was not able to model these aspects in the hydrological model. This caused constraints such as the *economic degradation of the area*, *loss of scenic value* and *demand for space* not to be embedded in the creation of pathways. Nonetheless, aspects should not be neglected in the actual decision making.

An example is found with the implementation of the *Increase private storage horticulture*, either around 2070 (in scenario *I, IV, VI*) or around 2080 (in scenario *II, III, V*). This implicates that horticultural business are expected stay until 2100, given that certain actions are implemented to cope with the constraints of water nuisance. However, the pathway map does not consider the demand for space, which is another potential constraint for horticultural businesses. In certain situations, the water related circumstances may be satisfactory but the competition for space might prevent the sustainability of certain land uses.

At last, two stakeholders are left out of the pathway map due to the relatively limited impact of their objectives and actions on the rest of the polder system. However, even though their interest may not trigger actions, their objectives and constraints should not be neglected within the policy- and decision-making process. For example, Rijkswaterstaat's action of renewing parts of one of the motorways could be performed alongside an increase in public water storage. Since the new constructions around motorways require additional measures to cope with the changes to the water system, joint solution could be found potentially.

7.2. Results focus group 1: Zuidplaspolder

The objective of this focus group was to determine whether the DAPP approach, i.e. the use of a pathway map, is suited to improve the adaptivity of decision- and policy making in the Zuidplaspolder. During an online session, of approximately one and a half hour, the results of the DAPP approach and the method itself were discussed with four key stakeholders. Being interviewed in an earlier stage of this research, the attendees were already familiar with the principle of a pathway map. The attended stakeholders and the function of its representative are presented below.

- *HHSK*, policy advisor on water systems.
- *Province of South-Holland*: policy advisor on water and land subsidence.
- *Municipality of Zuidplas*: policy advisor on the public domain.
- *LTO Noord*: policy advisor.

The session was held in Dutch. However, due to its direct importance to main components of this research, the results are translated to English. The main findings of the first focus group are presented in the following subsections. A complete review on this focus group session is found in Appendix D.1.

7.2.1. Use of the DAPP approach

In general, the DAPP approach left a positive and promising impression, leading to several affirmative comments which are presented below.

Firstly, a pathway map provides more clarity on the future. Especially for users within the polder, the long-term approach gives an indication of how their interests might be affected by the future and possible actions. This can be considered when investments are made.

> *Province: "This method provides transparency and tangibility in future projections. It could justify why certain actions are implemented, or are to be implemented."*

Secondly, the approach allows decisions to be made more strategically. Different paths, with different sequences of actions, may lead to the same situation at one point in time. As it might turn out that an action is unavoidable, a choice can be made to implement this action in an earlier stage and avoid actions in the meantime: "choose to replace the tire, instead of frequently repair (small) punctures".

Thirdly, the severeness of the (future) situation is explicated. This is often a returning issue within large societal subjects. A pathway map can present the physical boundaries of the polder system, after which can be decided what actions should be taken. It helps to confront society and administrators, and helps to put their focus on the far future.

Fourthly, the pathway map is a useful communication tool. Internally, it can help with starting a conversation and address future challenges with managers and administrators. Externally, it can be used to show the perspective of governments and provide clarity about decisions to users in the polder.

Municipality: "The pathway map helps in making the situation comprehensible, add the issues on the agenda and think of possible solutions. Besides, a positive aspect is that the uncertainty is visualised."

Furthermore, a few points of improvement and drawbacks were provided.

Firstly, in order to properly use the DAPP approach in decision making, a cost-benefit analysis is essential. As the pathway map provided in this report does not include a rating for different pathways, no clear preference can be stated. Adding a cost-benefit analysis helps in making well-reasoned choices between different pathways. Additionally, it helps in simplifying the pathway map by neglecting certain pathways.

Additionally, the waterboard and municipality stated that the pathway map would mainly be used to address future issues within the organisations, internally. Due to a lack of understanding about possible threats in the future and only having a vision on the short-term at policy makers and politicians, the pathway map could not directly be used for adaptivity in polder management. While still being useful, the main goal of the approach is not met.

At last, politics might hinder the actual usage of the DAPP approach, especially within municipalities. Councillors have many other subjects to look after, and would not want to burn their fingers on decisions for the benefit of a future far ahead.

Municipality: "The pathway map contains high-impact decisions, for instance on land use with the relocation of agriculture. There are no council members that are willing to make these choices, especially for the far future."

7.2.2. Usability on a (small-scale) polder level

Specifically on the use of DAPP on the small scale of the Zuidplaspolder, two statements are presented.

At first, the small scale of the case area makes it difficult to value actions that have results on a wider scale. For example, the action *Tweak regional/national water provision system* may have high costs, but also has a positive effect on the fresh water provision for other areas. In these areas, other stakeholders (e.g. drinking water companies and industries) are affected as well. This could lead to adoption of this action in an earlier stage, as the costs and effort are divided over all affected areas.

Province: "Certain futures are imaginable where the policies and decisions are made on a national scale. For example, a possible withdrawal from the western part of the Netherlands. Policies like that are difficult to embed in a pathway map of a small-scale area, as these decisions are made when the overall system is unviable."

Secondly, it is difficult to embed overarching national (or regional) decisions or policies in a local pathway map. For example, the possible option of withdrawing our society from the western part of the Netherlands. The rationale behind such enormous decisions on a large scale are based on a wide range of aspects, and not on the sustainability of one specific polder area. Many other aspects and areas within the region would be considered.

7.3. Result focus group 2: Schermerpolder

The aim of the second focus group was to determine whether the DAPP approach is suited to improve the adaptivity of decision- and policy making in polder areas other than the Zuidplaspolder. For this session, the Schermerpolder was selected as a case. During an online session, of approximately one and a half hour, the usability of the Zuidplaspolder's pathway map was checked for the case of the Schermerpolder, with three key stakeholders. Besides, the overall DAPP approach was discussed. The attended stakeholders and the function of its representative are presented below.

- *HHNK*, programme manager spatial adaptation.
- *Alkmaar region & municipality of Alkmaar*: regional programme director climate adaptation and regional coordinator housing.
- *LTO Noord*: policy advisor. Member of LTO Land van Leeghwater (local division of LTO Noord).

The session was held in Dutch. However, due to its direct importance to main components of this research, the results are translated to English. The main findings are presented below. A complete review on this focus group session is found in Appendix D.2.

7.3.1. Use of the DAPP approach

On the DAPP approach in general, i.e. the use of a pathway map, multiple positive aspects were mentioned.

At first, it assists in committing politicians and administrators. Whether it is for the Schermerpolder or even the entire Alkmaar region, the model prepares planners for the future and commit both politicians and other stakeholders in it. It is an instrument to stimulate administrators to think about the future, which is found especially useful for spatial planning.

Secondly, it helps in avoiding ad-hoc decision making. The pathway map can be used to find target situations in the future, and the paths that lead towards this situation. With this, no ad-hoc actions will be implemented that might not be necessary.

Thirdly, the method provides an examination on what actions to take. Often, large-scale actions are avoided due to the major impact or high costs. A pathway map may show that certain actions are unavoidable, possibly making it more useful to implement this actions at an earlier stage. When a lot of time is bought with an early adaptation, the trade-off might be worth it.

HHNK: "Often, large-scale actions are avoided due to the major impact they have or the high costs. However, if you buy a lot of time with that action, it can be a good trade-off. Hence, the approach can help in decision-making and with examining what type of actions are preffered to use."

On the other hand, it should be considered that policy makers have to cope with a political reality of thinking four years ahead, especially within the municipality. Government employees and stakeholders might want to look further ahead, but unfortunately this is often not possible. This decreases the potential effectiveness of the DAPP approach.

7.3.2. General applicability of pathway map

The pathway map constructed for the Zuidplaspolder was presented to the attendees from the Schermerpolder. On the use of these results in their own policy- and decision making, multiple statements were mentioned.

At first, due to the clear differences in polder characteristics, the potential issues and required actions do not overlap. The Schermerpolder has no peat soils (clay soils only), no horticulture and there are no plans for the construction of housing areas.

Secondly, the lack of plans for new housing also mismatches the scenarios used, as scenario *V* and *IV* will embed the realisation of new urban areas (elaborated in Section 5.4). Additional housing areas in the Alkmaar region are aimed to be built within the existing built environment.

LTO Noord: "The polders in the province of North-Holland are in good condition. The water management within these polders is on point, and is expected to be for a long period of time"

Thirdly, there are no significant issues within the Schermer at this moment. Therefore, one does not feel a considerable amount of urgency yet, nor the need to change. As the water management is of good quality in the polder, and it is expected to be for a long time, no problems are expected. When no issues are present, there is no need for a method that will help in dealing with future issues.

At last, the scope of this lie too far ahead in the future. Most policy documents and public assignments have set their targets on 2050, hence, using this time frame would make the pathway map more helpful at present.

In order to make an integral pathway map for polder areas, the variations in polder characteristics must be considered. It is recommended to create different clusters of polder characteristics, like soil type, land usage, etc. Actions related to a certain type of cluster can simply be taken out or visually made less important (grey) in the pathway map, if they are not applicable for a specific polder.

7.4. Current adaptivity in policy- and decision making

To provide an answer on whether the DAPP approach is suited to improve the adaptivity of polder management, a view on the current adaptivity is required. During interviews, focus groups and conversations with experts, a view on the adaptivity is found. The focus lies on the three main governmental stakeholders in the Zuidplaspolder, being HHSK, the municipality of Zuidplas and the province of South-Holland.

Each of the three aforementioned stakeholders are governed by politics, while the operational side of the organisation is not involved with the political aspect. As politicians tend to focus on the short term, and in someway even on their own political objectives, putting the focus on the far future might harm their current political status. Therefore, some stated that the largest form of adaptivity is gained from the renewal of policy makers every term of election, which is 4 years.

Furthermore, many other topics are to be dealt with, especially for the municipality with its wide range of societal tasks. Often, multiple of these are found to be of a larger societal interest, or hold a higher degree of urgency. Therefore, plans on dealing with climate change are frequently dubbed as no main concern and are shelved.

8 Discussion

After obtaining the results, it is important to describe their validity and identify limitations. This chapter will reflect on the methods and the results from the hydrological model, DAPP approach and focus group sessions.

At first, different aspects of the hydrological model and their limitations will be discussed. Secondly, a review on the DAPP approach is presented. Lastly, the check on the usability of the pathway map is discussed. Specifically, this presents a discussion on the results from the focus groups.

8.1. Hydrological model

In the development of the hydrological model, several assumptions and simplifications were made (see Section 5.2 and Appendix B.3). These were used to create a simplified representation of the actual polder system, while still gathering usable and relevant results. Nonetheless, the assumptions and simplifications result in limitations within the hydrological model. Since the results from the hydrological model are essential in the creation of pathways, these limitations may impact the legitimacy of the pathway map.

8.1.1. Embedded variables

At first, several components within the polder system were not embedded in the model, possibly leading to an under- or overestimation of these issues when no further understanding is gained. This concerns the issues related to drought, pump stops and levee breaches. Since these aspects are not incorporated in the model, and only to be considered by policy makers when choosing pathways, misinformed choices could be made. Especially for pump stops, which have the potential to induce significant water nuisance on a daily basis in 2100, this might be a problem. Likewise, the effect of levee failures could have a significant impact, as high damages are expected during these events.

Besides, the salinisation of aquifers is not incorporated in the model. As the first aquifer is used by horticultural businesses for storing fresh water, this is a relevant parameter. Currently, only an indirect evaluation of this parameter can be performed by assessing the groundwater salinity in the confining top layer. Therefore, as this is no adequate parameter for detecting trigger values, the issue of groundwater salinisation is not embedded in the pathway map.

Additionally, several non-quantifiable constraints of different stakeholders were not implemented in the hydrological model. Examples are the *economic degradation of the area, loss of scenic value* and the *competition for space*. Therefore, the related actions to cope with changes to these constraints are not embedded in the pathway map. Furthermore, more non-water related components could be embedded when a broader research is conducted. The *Vensim* software is usable for a wide range of practices, thus not specifically for water-related models. When these aspects incorporated in the polder's model, the relevance of the pathway map will increase.

8.1.2. Scenarios

Considering the scenarios, the following two topics can be discussed. Firstly, the embedding of additional construction of housing into scenarios is mentioned. By enclosing the creation of additional residential areas into scenarios, it is assumed that this process is determined by external factors, such as nation-wide policies on housing. To a certain extend this is true, however, stakeholders (i.e. the municipality and the province) do have an influence on this. Nonetheless, in the current scenarios, the present governmental stakeholders still can be involved in the decision of adding new residential areas. By choosing a scenario in which extra housing is realised, administrators can incorporate the planning for extra residential areas into their policy- and decision-making.

Secondly, in the process of creating pathway maps, strong similarities were found in the model outcomes of different scenarios. The sole difference in system behaviour was induced by the different climate scenarios, even though different values were used for sea level rise and construction of additional housing. For sea level rise, this is no surprise, as the effect on the hydraulic head is found to be negligible [71] and pump frequencies are not embedded. However, for the construction of housing, a larger impact on the water system was expected within the designated areas. An explanation could be that no additional effects, such as structural loading, are embedded, which may affect the surrounding groundwater system. Furthermore, larger surface areas of newly built residential areas may have been used. Besides, the estimation that 50% of a newly built residential area remains unpaved may have been a false assumption.

8.1.3. Trigger values and sell-by dates

On the detection of trigger values, thus identifying sell-by dates, there are several points of discussion.

At first, due to the zonal configuration of the hydrological model, local differences are not incorporated in the model. For example, locations with lower elevations compared to the rest of a zone are not identified. These locations are potential *hotspots* for the occurrence of issues such as water nuisance or increased seepage fluxes.

Secondly, it was found that trigger values were mostly reached in peak circumstances. As peaks may occur early within a run, this may imply that a sell-by date is reached earlier than necessary. This may overestimate the severity of issues, and call for actions too early within the time frame.

At last, considering the number of sell-by dates due to water nuisance, it seems that salinisation is only a minor issue within the polder area. However, this does not have to be true. First of all, the salinisation of the first aquifer is not incorporated, which may hinder the storage of fresh water by horticultural businesses. As the salinity of the shallow and less saline ground water is used for observing this issue, the potential threat of this issue is underestimated. Besides, several actions to deal with water nuisance increase the threshold for salinity levels as well, leaving the trigger values for salinity out of reach. For example, by adapting the actions *Adjust current way of agriculture* and *Shift to future proof land use*, not only the tolerance for water increases, but for salinity as well.

8.1.4. Validation

No detailed test on the validity of the hydrological model was performed. In this report, validation was performed through adjusting parameters and observing the expected behaviour. For example, an increase in groundwater levels is found after intense precipitation, which gradually lowers as drainage towards the surface water takes place. Also, the expected yearly variations were observed, for example the lower water levels in dryer summer months. Furthermore, the results from the model are realistic and logical, for all scenarios. However, until a full validation is performed, all outcomes should be used and examined critically.

Specifically, the results of the hydrological model are well-fit for the main purpose of this research as it provides input for the created pathway map. Since this pathway map helps in understanding the value of the DAPP approach in polder management, they are valuable for this evaluation. However, for actual policy- and decision making, a more in-depth model is required where the aforementioned limitations are incorporated.

8.2. DAPP approach

Regarding the DAPP approach and the resulting pathway map, several topics may be discussed. First, the neglected steps from the DAPP procedure are mentioned. Secondly, the contents of the pathway map are elaborated.

8.2.1. Steps within DAPP procedure

In this research, the DAPP approach is assumed a valid method for integrating flexibility in decision- and policy-making. However, the final steps of the DAPP procedure are excluded. To check whether the DAPP approach is applicable within a polder more accurately, it is preferred to conduct all steps of the approach.

The neglected steps involve choosing preferred pathways (based on an evaluation of individual pathways), designing an adaptive plan, implementing this plan and the monitoring of important changes in the polder area.

The excluded steps may prove to be problematic in some way, which is not detected in the current research setup. For example, the correct monitoring of signposts, thus determining sell-by dates, is proved to be a difficult task [79]. However, the larger part of the approach is proceeded and the conclusions are considered valuable to the stakeholders involved.

8.2.2. Content of pathway map

Some pathways are not modelled, but could provide useful insights. For example, in the current pathway (see Figure 7.1), the decision moment for the implementation of *Decree fixation* is set at the beginning of the timeline. However, this measure could be implemented at a later stage, for example to meet the objectives of GOM regarding land subsidence. Besides, due to the conflicting nature of this action (see Subsection 6.2.2), the action might be postponed to meet the objectives of agricultural businesses.

Another topic of discussion regarding the pathway map, is the postponing of actions on changing the agricultural land use. As these actions have a long implementation time, they are postponed until 2040. This is due to assumed implementation time of 20 years, which is obtained during interviews. The 20 years are mainly used to create a smooth transition for agricultural businesses, as this matches the investment cycle of current agriculture. When an earlier step to a different land use is taken, this will create costs for the business, but is practically feasible.

8.3. Usability check of pathway map

The usability of the pathway map is checked in two focus groups, with attendees of two different polder areas. During these sessions, the usability of the pathway map on a polder level was tested. More specifically, the DAPP approach was tested on its ability to improve adaptivity in policy- and decision-making within polder areas. Two points of discussion on the outcomes of the focus groups are presented below.

At first, the final version of the pathway map was not presentable yet during the sessions. A nearly finished version was shown, without the definite sell-by dates from the hydrological model. Instead of the exact sell-by dates, realistic literature-based estimations were used. As the final pathway map shows differences compared to the presented version, the opinions from attending stakeholders might differ as well. Nonetheless, the main principles behind the approach were clearly explained during the focus groups. Besides, an elaboration on the (possible) uses of the method was given. Even though the pathway map was not complete yet, the outcomes of the focus groups are considered to be of significant validity.

Secondly, there is a slight difference regarding the participants of the first and second focus group. The attendees of the focus group regarding the Schermerpolder were less familiar with the method compared to the Zuidplaspolder stakeholders. The latter were interviewed in an earlier stage of this research, as a part of the DAPP approach. Even though the method was explained extensively, this could have created a slight lack in familiarity with the approach between the two focus groups. Possibly, a different set of statements was received from the Schermerpolder actors when they were more acquainted with the DAPP approach.

9

Conclusion and recommendations

A rise in sea level, more extremities in precipitation and evaporation, land subsidence and salinisation; the Dutch polders face several challenges in the future. Due to the uncertainties in the severity of change regarding these threats, policy- and decision-makers face a difficult task. This report aims at assisting in this matter by examining a promising approach to deal with uncertainties: the DAPP approach. Therefore, the aim of this report is to provide an answer to the following research question:

Is the Dynamic Adaptive Policy Pathways approach suited for improving the adaptivity of polder management, given the uncertainty in climate change effects?

Based on the sub questions mentioned in Section 1.5, this research built towards an answer to the research question. Through assessing the potential effects of climate change, conducting interviews, creating a hydrological model and following the steps of the DAPP procedure, a pathway map for the Zuidplaspolder is created. This pathway map is evaluated with stakeholders from the Zuidplaspolder case area, as well as actors from a different polder area, being the Schermerpolder.

With the creation of a simplified model of the Zuidplaspolder system, insights are obtained on when and what issues are significant. The model in this report is capable of detecting threshold values of crucial parameters. With that, the moments in time where actions are no longer adequate are identified objectively. Despite potential over- and underestimations of issues due to simplifications, a pathway map is provided. However, when the pathway map is utilised for actual policy- and decision making, the use of an extended and enhanced model is required. In Section 9.1, specific points of improvement will be mentioned.

On the resulting pathway map, and the DAPP approach as a whole, several conclusions can be drawn.

Firstly, a conclusion on the actual usefulness of the DAPP approach in polder management is presented. In both focus groups, it was found that the pathway map is useful in several ways. A pathway map is capable of explicating upcoming issues and providing clarity on possible futures, for all stakeholders involved. Through the insights of possible pathways, decision making can be done more strategically. Even with the sell-by dates being of moderate accuracy, the insights provided by the pathway map are valuable.

However, to have a direct impact on the policy- and decision-making process, a cost-benefit analysis is essential. By attaching a set of values to each pathway, insights are gathered on the distinctions between pathways. Examples of effects to evaluate are the consequences on the ecosystem, agricultural businesses, livability and costs. Having a clear image on the varying outcomes of different pathways helps in making a well-reasoned selection of preferred pathways.

Even without a cost-benefit analyses, the DAPP approach is considered to be helpful. As governmental organisations currently have a low level of adaptivity in their policy- and decision-making, there is plenty of room for the DAPP approach to be effective. Besides an instrument for actual decision making, the pathway map is found useful in other roles as well. It can be used to trigger policy- and decision-makers into thinking about the (far) future and stimulate them to consider options for the long run.

Besides, as a communication tool, the pathway map can be used to explain certain choices to both administrators and affected stakeholders. The latter helps in creating support and understanding from the set of stakeholders. Hence, the DAPP approach is found to be useful, in varying forms.

A second conclusion is drawn on the effectiveness of applying the DAPP approach on polder areas, being small-scale areas.

The topographical scale of the pathway map was proved not to be an issue by the attendees of the focus groups. During the Zuidplaspolder focus group, a question was asked whether it is possible to apply the method on an even smaller scale, considering the local issues within this area.

However, it was found difficult to embed larger-scale actions on a smaller scale, as a polder area. As an example, the construction of a barrier in the Nieuwe Waterweg river was mentioned. In a proposed pathway map, this action was ranked as the most undesired, and only to be used as a last resort due to its high costs. However, as the benefits would be for many other small-scale areas and users, the costs and effort should be spread as well. This adds an extra difficulty to a cost-benefit analysis.

Furthermore, issues such as drought and high water levels on adjacent water bodies are managed on a larger scale than the Zuidplaspolder, making it difficult to translate them to the small-scale setting of the polder area. Besides, it is found more difficult to identify proper trigger values. During interviews, it was found that due to the small scale of the polder, it was difficult to find detailed information occasionally. In large scale projects, the stakes and interests are higher. This results in the presence of more information, or otherwise more willingness to obtain required data.

To conclude, there are certain difficulties in the use of the DAPP approach on a (small-scale) polder area, mainly in translating large scale actions and policies to the polder setting. Nonetheless, the value of the method on a small scale is recognised and thereby proving its worth.

Thirdly, a conclusion on the general applicability of pathway maps to Dutch polder areas is given.

Within this research, the Zuidplaspolder was selected as the case area for creating a pathway map. As the research question aims at improvement of polder management in general, it is important to check the general applicability of the DAPP procedure. The focus group with the Schermerpolder stakeholders provided insight in this matter. Here, two main findings were gathered. Firstly, the general applicability of the Zuidplaspolder's pathway map is hindered by the unique features of this polder area. With every polder having a different set of characteristics (soil type, land use, water management, etc.), the use of one general pathway map is not possible as a different set of constraints and actions is present.

Secondly, the stakeholders within different polders have a different mindset on the urgency of adaptive policy- and decision making. In the Zuidplaspolder, several issues regarding water management are present already. Consequently, there is more focus on developing solutions and preventing them from becoming worse in the future. The lack of urgency in a polder area is found to reduce the effective use of the DAPP approach.

Unfortunately, it was found difficult to create a general pathway map for Dutch polder areas. Additionally, a smaller sense of urgency on future issues reduces the necessity for the DAPP approach.

To come to a final conclusion, the DAPP approach is found to be suited for improving the adaptivity in polder management, given the uncertainty in climate change effects. The pathway map, based on the results of the hydrological model, is a helpful tool for authorities and affected stakeholders within polder areas to explicate upcoming issues. However, a cost-benefit analysis is required for actual, well-informed policy and decision making based on the pathway map. Nonetheless, it assists in making decisions more strategically and to explain certain choices in decision-making, which helps in creating support and understanding. Furthermore, the DAPP approach proved its effectiveness on smaller scales. Even though it can be difficult to translate large-scale actions and their effects to a smaller scale, the topographical scale of the pathway map was proved to be a minor issue for its applicability. Besides, the DAPP approach can be used and is applicable for other polder areas as well. However, a general pathway map cannot be created for different polders because each polder area had its unique set of characteristics and mindset on urgency.

9.1. Recommendations

Considering the conclusions mentioned above, and a review on the research process, several recommendations are provided.

Firstly, a recommendation to policy- and decision makers is presented.

When selecting actions to cope with future issues, it could be valuable to embed flexibility within these actions. Besides choosing actions solely to counter potential problems, actions can be implemented for increasing flexibility as well. When certain flexibility-increasing actions are used in the current policy- and decision-making process, the circumstances will be easier for planners and water managers in the future.

An example is found in the creation of the Flevoland polders, where a sand foundation was created to facilitate a four-lane motorway that was expected to be necessary. During the process of creating the polder, the construction of this foundation is easier compared to its construction when the polder is finished already [100]. Years later, only a two-lane motorway was built as this sufficed the required traffic capacity. However, when the future had unfold differently, a four-lane motorway could have been required. Even though the sand foundation turned out to be over-dimensioned, this action incorporated flexibility. In a similar fashion, actions could be designed for polder areas.

Secondly, two recommendation are presented considering further research on the use of DAPP within polder areas.

To identify an integral pathway map for Dutch polder areas, a recommendation was made in the second focus group. By creating clusters with actions for specific polder characteristics, such as elevation, land usage or soil types, a tailored pathway map can be created by selecting the clusters that fit the designated polder area. For example, a specific pathway map for a polder with peat soils, no greenhouses but a high pressure on providing residential areas could be forged. Here, the required set of actions that cope with the problems regarding this characteristics should be embedded. This concept of an integral pathway map could contribute to embedding adaptivity in Dutch polders as a whole. Therefore, it is recommended to conduct further research in this approach.

Besides, it is recommended to further investigate the interaction between the local and national levels of scale. Here, mainly the effects of large-scale measures and policies, and their effects on the polder level are of importance. Finding a way to translate the larger scale impacts into a smaller area when using the DAPP approach could be valuable when pathways are chosen.

Thirdly, a recommendation on the use of a hydrological model for the identification of sell-by dates is presented.

When a pathway map is utilised in actual policy- and decision making, the creation of an extended and enhanced model is recommended. This model preferably contains probabilistic (Monte Carlo) simulations to deal with probabilities in the occurrence of trigger events, such as pump stops and droughts. Moreover, such a probabilistic approach prevents the use of time series for precipitation and evaporation, ensuring more realistic projections of the future. Furthermore, embedding the probability of levee failure adds to a more complete model.

Additionally, to create an even broader image of a polder system, several other aspects could be considered in the hydrological model. By adding more non-water related components, the results will become more multidisciplinary hence significant. Examples are adding a component on issues such as *economic degradation*, *availability of space* and the *valuation of green areas*. The Vensim software, which is used in this research, has the ability to model more than solely the water system and could be useful for broadening the multidisciplinary scope of the model.

A

Interviews

This appendix will present summaries of the interviews held with Zuidplaspolder's stakeholders. Before conducting the interviews, each interviewee gave informed consent on their participation. Besides, after checking the summaries' content with the respective interviewees, approval for publishing the results was given by each individual stakeholder.

At first, the interview setup is presented. In general, the questions are not followed exactly as outlined and questions that are not included in the setup may have been used. After this, the individual interviews are elaborated. Since the interviews were held in Dutch, this is language they are documented in. The interview set-up is presented in Dutch as well.

A.1. Interview setup

Doel: achterhalen van objectives, constraints, signposts en bijbehorende trigger values. Daarnaast welke actions de actor (of andere actoren) kunnen ondernemen om de objectives van de geïnterviewde actor te bereiken.

Toelichting: In dit afstudeeronderzoek bekijk ik hoe effecten van zeespiegelstijging, en andere gevolgen van klimaatverandering, doorwerken in poldergebieden. Daarbij wil ik een methode toepassen om uiteindelijk uit te komen op een grote set aan opties om om te gaan met de veranderingen in het systeem. Om tot deze set aan opties, zowel lange- als korte termijn, te komen is het van belang goed inzicht te hebben in de belangen van betrokkenen. Door in kaart te brengen wat de doelen zijn van betrokkenen in de polder, wat de beperkende factoren zijn, wat er gedaan kan worden etc. kan hier een plan voor worden bedacht.

Nu richt mijn onderzoek zich niet op het maken van beleid, maar op het ondersteunen van een maatschappelijke discussie. Mijn doel is om alles op een rijtje te zetten en een beeld te schetsen over wat de toekomst kan brengen en hoe hier mogelijk op in kan worden gespeeld.

Vragen

- Hoe denkt u dat de Zuidplaspolder eruit ziet in de verre toekomst, aan de hand van klimaatverandering (omtrent 2100)? → Vooruitdenken stimuleren
- Hoe zou u willen dat de Zuidplaspolder eruit ziet in 2100? → voorproefje objectives
  Waarom? Wat is daar aantrekkelijk aan? → objectives
- Wat zouden potentiele bedreigingen kunnen zijn voor [objective]?
- Welke parameters zijn hierbij van belang voor u? → signposts
- Bij welke waarden zou voor deze aspecten zou er actie moeten worden ondernomen? → trigger values

Stel, de [trigger value] van [signpost] wordt overschreden.

- Hoe zou dit kunnen worden voorkomen? Of hoe zou hier passend op gereageerd kunnen worden? → actions
  Zijn er eventueel reële vergrotende/verkleinende trappen bij deze actie? → actions
- Hoe lang duurt het ongeveer voordat deze actie is doorgevoerd? (Ordegrootte jaren) → implementation time
- Hebben deze acties verder nog positieve effecten, op andere onderdelen binnen het poldergebied?
  En misschien ook negatieve effecten?

A.2. Interview Hoogheemraadschap Schieland & Krimpenerwaard

De geïnterviewde werkt als beleidsadviseur Watersystemen bij het Hoogheemraadschap Schieland & Krimpenerwaard. Dit interview is afgenomen op 28 april 2020 om 14 uur, met een duur van één uur en drie kwartier.

HHSK is bezig met beeldvorming van het beheergebied rond 2100. Dit proces is gaande en er is nog geen uitgesproken beeld vastgesteld. Op persoonlijke titel denkt de geïnterviewde dat de polder er vergelijkbaar uit zal zien als nu. Dat wil zeggen dat de uitdagingen op deze termijn niet van dien aard zijn dat de polder wordt 'opgegeven'. Wel zullen er verschuivingen plaatsvinden in functiegebruik. Functies die erg afhankelijk zijn van bepaalde drooglegginngen, voornamelijk akkerbouw en graslanden, zullen langzaamaan uit de polder verdwijnen. Hiervoor in de plaats wordt moerasachtige, natte natuur verwacht.

HHSK heeft zelf geen directe bevoegdheid om transities binnen de polder in gang te zetten. Ruimtelijke ordening is een taak die bij de rijksoverheid, provincies en gemeenten belegd is. Door het waterschap kan er wel (bij)gestuurd worden met het veranderen van de peilen, al is dit een indirecte manier. Ook kan er gespeeld worden met het bereik van toegestane/afgesproken drooglegginngen. Er zullen echter vanuit het waterschap geen ad-hoc veranderingen plaatsvinden met ingrijpende gevolgen voor de gebruikers. Het waterschap heeft wel een signaleren en adviserende rol. Zo wordt gesignaleerd dat sommige landbouwfuncties eindig zijn op bepaalde plekken binnen deze polder. Hierover worden gesprekken over gevoerd met andere overheden en particuliere partijen.

Het Hoogheemraadschap heeft als taken **te zorgen voor droge voeten, schoon water en veilige dijken**. Daarbij streeft het naar doelmatig en duurzaam waterbeheer om het watersysteem en **het gebied zo goed mogelijk geschikt houden voor de verschillende functies**. Dit gebeurt door de verschillende wateropgaven - waterkwantiteit, waterkwaliteit en grondwater - gebiedsgericht aan te pakken, in samenwerking met andere belanghebbenden.

Mogelijke belemmeringen die het doelmatig en duurzaam waterbeheer van HHSK in de toekomst kunnen tegenwerken zijn als volgt:

1. Niet kunnen afvoeren van boezemwater (maalstop van gemaal Abraham Kroes)

Bij een maalstop kan er geen water op de Hollandsche IJssel worden gezet, zowel vanuit de polder als vanaf de Ringvaart. Ten tijde van een maalstop zal het water in het poldersysteem accumuleren, wat daar tot problemen kan leiden. De Hollandsche IJsselkering sluit bij een verwachte waterstand van 3,0 +NAP bij Hoek van Holland. Wanneer de waterstand op de Hollandsche IJssel een bepaald niveau bereikt (2,6 m+NAP bij Krimpen a/d IJssel en 2,8 m+NAP bij Gouda) zal er een maalstop optreden. Bij een dichte kering treedt er niet direct een maalstop op, er is nog enige tijd en speelruimte om het bakje te kunnen opvullen. Zo kan er bij de eerstvolgende eb-cyclus meestal alweer iets worden afgevoerd.

(Signposts) De maatstaaf die aangeeft wanneer er geen boezemwater kan worden afgevoerd is de waterstand in de Hollandsche IJssel. Ook kan de sluiting van de Hollandsche IJsselkering worden genomen als indicator, aangezien deze (met een bepaalde vertraging) tot het optreden van de maalstop leidt.

(Trigger value) Er kan worden aangenomen dat bij één op de drie sluitingen ook daadwerkelijk een maalstop zal volgen. In de Waterwet worden normeringen voor wateroverlast voorgeschreven, verschillend per type landgebruik. Bebouwd gebied heeft de strengste normering, dit type landgebruik mag 1/100 jaar wateroverlast ondervinden. Als er wordt aangenomen dat een maalstop direct tot wateroverlast leidt mag deze dus maar eens in de 100 jaar voorkomen.

(Actions) Als oplossing kan de berging worden vergroot, op verschillende niveaus. Zo kan binnen de polder het bergend vermogen worden vergroot door aanpassingen te maken in het watersysteem. Een voorbeeld is het inpassen van meer flexibele peilen binnen de polder. Hiermee kan zo'n 20-30 cm aan berging worden verwezenlijkt, waarmee de voeding van de boezem kan worden vermindert.

Daarnaast kan er op grotere schaal worden gekeken naar calamiteitenbergingen, vergelijkbaar met de Eendragtspolder. Hiermee zou het wateroverschot in noodgevallen kunnen worden opgevangen.

(Impl. time) De kleinschaligere aanpassingen binnen het water systeem kunnen op korte termijn worden geïmplementeerd, hiervoor kan 1 jaar worden aangenomen. Voor het opzetten van grote calamiteiten polders kan 10 jaar worden gerekend. Echter, wanneer grootschalig boeren moeten worden uitgekocht kan dit langer duren.

2. Niet kunnen afvoeren van polderwater

Vanuit de polder wordt water geloosd op de ringvaart. Deze heeft een kleine bergingscapaciteit, dus wanneer dit water niet kan worden afgevoerd op de Hollandsche IJssel zal hij snel gevuld zijn. Daardoor hangt het niet kunnen afvoeren op de Ringvaart nauw samen met de mogelijkheid tot afvoer van het boezemwater (zie belemmering 1).

(Signposts) Wanneer er een maalstop van Abraham Kroes optreedt zal er geen polderwater kunnen worden afgevoerd.

(Trigger value) *Vraag wordt samengenomen met de vraag bij belemmering 1.*

(Actions) De acties die kunnen worden ondernomen, en hun implementatie tijd, zijn hetzelfde als bij belemmering 1.

3. Te hoge zoutgraad voor akkerbouw

Een te hoge zoutgraad zorgt voor problemen bij agrariërs. In de winter is de zoutgraad geen groot probleem, aangezien er dan weinig water op het land hoeft worden aangebracht. Alleen in droge periodes wordt het een probleem, in het groeiseizoen. Dan is de akkerbouwer het meest afhankelijk van het slootwater.

(Signposts) De parameter die hiervoor wordt gebruikt is de zoutgraad van het oppervlaktewater.

(Trigger value) De zouttolerantie verschilt per gewas. Op grotere schaal zijn er wel afspraken over maximale saliniteit, maar niet op slootniveau.

(Actions) Mogelijkheden om een te hoge zoutgraad te voorkomen is doorspoelen: het verdunnen van de zoute kwel door meer water in te laten vanuit de Ringvaart, indien mogelijk. Dit vormt echter wel een uitdaging tijdens droge perioden. Op dat moment is de doorspoelbehoefte hoog, maar is de waterbeschikbaarheid vanuit de Hollandsche IJssel zeer beperkt.

Doorspoelen/verdunnen is een oplossing voor de korte termijn. Op langere termijn zal het landgebruik moeten veranderen naar functies die minder afhankelijk zijn van bepaalde waterkwaliteit. Voorbeelden zijn natte natuurgebieden, of overstappen op gewassen als de natte lisdodde. Het is wel van belang om op de watervraag van deze gewassen te letten in de zomer weer veel water nodig wat er niet is.

(Impl. time) Het aanpassen van het landgebruik is een politieke keuze van de provincie of het rijk, HHSK heeft hier een adviserende rol in.

4. Overvloedige hoeveelheid water binnen de polder

Met name in het restveengebied is de drooglegging in combinatie met de gebruiksfunctie nu al precair. Het slootpeil staat eigenlijk te hoog staat om goede drooglegging de bieden. De gemaalcapaciteit is groot genoeg, dus het peil kan gewoon worden verlaagd. Wanneer het waterpeil verlaagd wordt zal de bodemdaling weer toenemen. Vanuit veiligheidsoogpunt is het niet wenselijk dat de verschillen tussen binnen- en buitenwater nog veel groter worden dan de huidige 7-8 m, dat is iets wat je zoveel mogelijk wil beperken.

(Signposts) HHSK meet de peilen, en stuurt hierop. Echter is niet het volledig duidelijk bij welke waterstanden er daadwerkelijk op perceel niveau problemen optreden. Wel worden er geluiden opgevangen vanuit het gebied. Peilbeheerders en andere mensen in de polder krijgen snel te horen als er iets niet klopt, waarna er wordt ingegrepen.

(Trigger value) Wanneer de peilbesluiten niet gehandhaafd kunnen worden is er sprake van een teveel aan water.

(Actions) Normaliter zou een het peil worden verlaagd om wateroverlast tegen te gaan. Dit kan nog in bepaalde gebieden van de Zuidplaspolder, maar in de meeste niet meer.

Een oplossing tegen wateroverlast op landbouwgrond is om de opbolling van het grondwater tegen gaan. Dit kan door de slootdichtheid te verhogen of door drainage buizen te plaatsen.

(Impl. time) Het aanpassen van het peil neemt ongeveer een jaar in beslag. Ditzelfde geldt voor de oplossingen die de opbolling tegengaan.

5. Aanwezigheid van droogte

Dit is een grote uitdaging voor het gebied, aangezien er geen zoetwater aanvoer mogelijk in droge periodes. De Hollandsche-IJssel heeft ten tijde van een beperkte rivierafvoer beperkte inlaatvensters. Als de Hollandsche-IJssel verzilt is kan er überhaupt niet worden ingelaten. Hierdoor zal de verzilting binnen de polder heftiger optreden.

Zoetwatertekorten zijn problemen die landelijk spelen. De verdeling van zoetwater wordt ook landelijk geregeld. De 'toegewezen' beschikbare hoeveelheid zoetwater wordt ten tijde van een droogtecalamiteit verdeeld op basis van prioritering. De verdringingsreeks is hier de leidraad voor het crisisteam droogte. Binnen zo'n reeks is ook nog speelruimte te vinden. Per droogte, en stadia hiervan, wordt bepaald hoe er gereageerd gaat worden.

(Signposts) Als er aan bepaalde criteria wordt voldaan gaat een crisisteam in werking. De afvoer bij Lobith is hier een van. Daarnaast wordt een lange termijn prognose van de neerslag bekeken.

(Trigger value) Bij een afvoer van 1200 m^3/s bij Lobith wordt er nauwlettend op de droogte gelet. Er zijn geen criteria over hoe vaak dit mag voorkomen voordat er actie moet worden ondernomen.

(Actions) Ad hoc kan er met tankwagens water aangevoerd worden door de gebruikers. Ook kan er kraanwater worden gebruikt. Dit zijn beide dure oplossingen. Een beter oplossing zou zijn om de watervraag naar beneden te halen.

Daarnaast kan het ook hier helpen om meer speelruimte in het systeem aanbrengen, echter zijn het wel beperkte hoeveelheden die hiermee gewonnen kunnen worden, en is meer waardevol voor het overbruggen van korte periodes van droogte. Ook kan het aanleggen van grote spaarbekkens een oplossing bieden. Ook

hier is het de vraag of dit de investeringen waard zijn, dit is echter een afweging voor de politiek

Tot slot is een verandering naar activiteiten met minder afhankelijkheid van zoetwater een mogelijkheid

(Impl. time) Grote gebieden, of zelfs hele polders opgeven en inrichten als spaarbekken heeft een duurtijd van ongeveer 10 jaar. Het vergroten van de speelruimte kan binnen 1 jaar.

A.3. Interview LTO Noord

De geïnterviewden werken respectievelijk als senior beleidsadviseur en provinciaal voorzitter Zuid-Holland (tevens portefeuillehouder water en bodem) bij LTO Noord. Dit interview is afgenomen op 1 mei 2020 om 9 uur, met een duur van één uur en een kwartier. Er is duidelijk gemaakt dat de Zuidplaspolder een van de meest complexe poldergebieden is, en daarom de uitspraken in dit interview enkel gelden voor de situatie binnen de Zuidplaspolder en niet toepasbaar zijn op andere polders.

Toen 60 jaar geleden werd nagedacht over de verre toekomst van de polder had niemand verwacht dat de situatie zo zou zijn als deze nu is. Op dit moment is nog maar ongeveer 30% van de oorspronkelijke landbouw over. Het is daarom ook niet ondenkbaar dat nu de laatste generatie agrariërs actief is in de polder, op uitzondering van wat kleinschalige landbouw. In de toekomst wordt een *rood* en *groen* gebied verwacht in de polder, zijnde bebouwd gebied en natuur.

Het ideaalbeeld voor LTO, zijnde een polder met een structuur die op landbouw is gecreëerd, is al een lange tijd niet meer haalbaar. Gezien de ontwikkelingen binnen de polder wordt er niet direct en actief ingestoken op het blijven van agrariërs, gezien de ontwikkelingen binnen de polder. Echter, zolang er agrariërs in de polder zijn moeten de omstandigheden wel geschikt zijn om landbouw te bedrijven. Mocht de situatie uiteindelijk onwerkbaar zijn of worden, dan kunnen de agrariërs uitwijken naar een andere locatie. Benadrukt wordt dat dit uitwijk proces wel op een nette manier dient te gebeuren, en niet met een zogeheten *uitrookbeleid*; eerst de omstandigheden onwerkbaar maken en dan kijken wat er gebeurt.

Het doel van LTO voor de Zuidplaspolder is daarom: **het waarborgen van werkbare landbouwgrond en anders een gepaste uitwijkstrategie verwezenlijken**. Enkele aspecten die dit doel kunnen belemmeren worden hieronder benoemd, waarvan één beleidsgerichte en drie technische belemmeringen:

1. Onduidelijkheid over toekomst van landbouw

Er is al geruime tijd onduidelijkheid over het voortbestaan van de landbouw in de Zuidplaspolder. Dit geldt met name voor het gebied rond Moordrecht. Ongeveer 10 jaar geleden is gemeld dat de boeren waarschijnlijk niet lang meer konden blijven. Echter kwamen er geen concrete ideeën voor het verhuizen van de ondernemingen. Sindsdien zijn er weer nieuwe investeringen gemaakt, zodat de bedrijfsvoeringen verder konden. Momenteel loopt er een tweede golf van meldingen over onhoudbaarheid.

Met technische oplossingen kan de houdbaarheid van de landbouw worden gerekt, maar steeds weer komt het investeringsvraagstuk naar boven. Als de omstandigheden niet meer geschikt zijn voor landbouw (zoals in de hieronder beschreven belemmeringen), dient een planologische stap te worden gezet. Dit dient te gebeuren in samenwerking met de boeren, i.e. de mogelijkheid tot uitkopen om ergens anders aan de slag kunnen. Het uitkopen dient via een polderbreed plan te gebeuren, zodat elke boer eerlijk wordt betaald en er geen onderscheid tussen de gebiedsplannen wordt gemaakt. Zo zal een boer wiens grond wordt verkocht voor woningbouw evenveel verdienen aan de verkoop als een boer wiens grond tot groen gebied wordt ontwikkeld.

(Actions) Er is behoefte aan een helder beslismoment over de toekomst van landbouw in de Zuidplaspolder. De overheden dienen op tijd aan te geven wanneer er geen plaats meer is, zodat de ondernemingen hierop kunnen inspelen met hun bedrijfsvoering en investeringen.

2. Vernatting

Vernatting in de polder is op dit moment al éen van de aandachtspunten. Vernatting belemmert de draagkracht, nodig voor machines of vee, en de groei van gewassen.

(signposts) Een indicator voor vernatting is de drooglegging (in meter)

(Trigger value) De drempelwaarde voor een ongewenste drooglegging hangt af van de functie en het jaargetijde. Voor de veehouderij (graslanden) kan deze idealiter worden vastgesteld op 0,60m, maar is ook nog werkbaar met 0,40m.

De akkerbouw heeft een grotere drooglegging nodig: tussen 0,60 en 1 meter. Deze percelen zijn bijna allemaal al voorzien van drainagebuizen.

(Actions) Een mogelijkheid kan zijn om onderwater drainage aan te leggen, hiermee kan een drooglegging van 0,20m worden aangehouden voor grasland.

Daarnaast kan een ondernemer overstappen van productie (zijnde liters melk, kilos gewas) naar de consument (bijvoorbeeld dagverblijf, verhuur van huisjes, entreebewijzen etc).

Ook het verplaatsen naar een andere landbouwlocatie, gepaard met uitkopen, is een mogelijkheid.

Het uitwijken naar andere locatie kan snel gebeuren, maar dan moet men veel afbetalen. Deze kosten kunnen gedrukt worden door op tijd aan te geven dat er veranderingen gaan plaatsvinden. Hierbij kan worden gekeken naar de investeringscycli van onderdelen van de bedrijfsvoering, dus 10 tot 30 jaar. Bij duidelijke communicatie zal de ondernemer andere investeringen doen.

3. Verzilting

Verzilting van het oppervlaktewater zorgt voor schade aan gewassen. In de Zuidplaspolder zijn er niet veel gebruikers van zoet water, behalve de glas- en akkerbouwers. Hierdoor moet er ruimte zijn in de waterhuishouding om te voorzien in de behoefte van de agrariërs.

(signposts) De parameter die hiervoor wordt getoetst is de zoutgraad van het oppervlaktewater.

(Trigger value) De maximale zoutgraad verschilt per gewas. Koolgewassen, uien en aardappelen kunnen niet veel hebben, terwijl granen en bieten beter bestand zijn tegen verzilting. In de zomer zijn de gewassen kwetsbaarder. Daarnaast is er ook sprake van een opbouwend effect; wanneer er vaak met chloride-rijk water wordt gesproeid stapelt dit op in de bovenste laag van de grond.

(Actions) Een oplossing kan zijn om over te stappen naar andere gewassen. Zo is de natte lisdodde te gebruiken in veengebieden, welke momenteel worden gebruikt als grasland. Echter zijn daar minder zorgen over verzilting. Op goede kleigrond is de lisdodde geen optie, aangezien er een drassige situatie nodig is.

Een andere optie is proberen om bestaande teelten meer zouttolerant te maken. Dit gebeurt nu ook op enkele locaties in Zeeland en op Texel. De opbrengsten vallen hierdoor wel lager uit. Ook zijn er grenzen de rekbaarheid van zouttolerantie, dus is deze actie werkbaar tot op zeker hoogte.

Het overschakelen op andere teelten is niet zo makkelijk, zeker qua verdienmodel. Dit is vooral een stuk wensdenken van de overheid. Over het algemeen wordt zoute teelt niet als een toekomstbestendige richting bestempeld, tenzij de markt een flinke verandering ondergaat. De gewassen die zout kunnen weerstaan brengen over het algemeen minder op, dus de boer streeft naar zoete gewassen. Zo gaat ook de voorsprong die Nederland heeft door de goede ligging en zoetwatervoorziening verloren.

(Impl. time) Voor het overschakelen naar een ander gewas zijn nieuwe investeringen nodig: wagenpark, machines etc. Voor de terugverdientijd kan ongeveer 10 tot 30 jaar gerekend worden.

Het zouttolerant maken van een gewas kan al snel 10 tot 20 jaar duren.

4. Droogte

Minder kunnen beregenen zorgt voor verminderde groei van de gewassen. Over het algemeen heeft West-Nederland voldoende water om alle gebruikers van water te voorzien. En mocht het zo ver komen; in principe is droogteproblematiek in West-Nederland altijd technisch op te lossen.

(Actions) Op lokale schaal kan het aanleggen van infiltratiedrainage zorgen voor beter bewaterde percelen.

Op grotere schaal zou een stuw in de Nieuwe Waterweg kunnen bijdragen aan een betere watervoorziening. Deze oplossing voorkomt het onnodig afvoeren van 70 á 80% van de zoete rivierstroom voor het terugdringen van de zouttong. Als een stuw het zout tegen kan houden is het mogelijk het zoete water te gebruiken voor andere doeleinden.

(Values for criteria) Infiltratiedrainage helpt ook tegen bodemdaling. Bodemdaling is geen probleem voor de individuele landbouwer, maar wel voor de streek. Minder bodemdaling zorgt voor een betere drooglegging, doordat dit makkelijker te waarborgen is.

De stuw in waterweg maakt scheepvaart moeilijker voor de Rotterdamse haven. Er wordt wel meer zeewaarts bewogen door de haven (zie het gebruik van de Maasvlaktes), wat de ernst van deze maatregel minder ingrijpend kan laten worden.

A.4. Interview province of South-Holland

De geïnterviewde werkt als beleidsadviseur Water en Bodemdaling bij de Provincie Zuid-Holland. Hij is actief in het nationale kennisprogramma bodemdaling en heeft jaren gewerkt omtrent het restveengebied nabij Moordrecht. Dit interview werd uitgevoerd op 22 november 2019 om 14:00 uur.

Naar verwachting zal de Zuidplaspolder 0.5m lager liggen vanwege bodemdaling, wat gepaard gaat met een zeespiegelstijging van 0.5m. Naar verwachting wordt het nat, al zal dit afhangen van de keuzes die we maken. Nat wordt hier bedoeld in de vorm van een moerassig landschap. Het zal een uitdaging worden om een geschikt gebruik te vinden voor het gebied.

Bij voorkeur zal de polder lijken op een gestabiliseerd parklandschap met waterlichamen, zonneweiden, rietvelden en misschien wat koeien die op hoogland lopen. Gestabiliseerd betekent dat de bodemdaling tot stilstand is gekomen. Het doel van de provincie is als volgt: **zorgen voor een toekomstbestendig en gestabiliseerd gebied met een positief verdienmodel.** Er zijn vier mogelijke beperkingen die het behalen van dit doel kunnen verhinderen;

1. Economische achteruitgang van het gebied

Alle delen van het land in het gebied dienen een doel te hebben, waar inkomsten uit worden gegenereerd. Dit kan elke vorm van landgebruik zijn, echter gaat de voorkeur uit naar behoud van landbouw in de polder. Andere vormen van landgebruik zijn bijvoorbeeld huisvesting, zonneweiden etc. Het is onmogelijk om het gebied nat en natter te laten worden, zonder gebruik en goed beheer.

(Signposts) Er zijn geen duidelijke parameters om te controleren of een verdienmodel positief is. Het is erg moeilijk om de huidige situatie te meten, en zelfs nog moeilijker om dat voor de toekomst te doen. Het is ingewikkeld om de winstgevendheid van toekomstige markten en de onderliggende ketens te voorzien.

Vanuit agrarisch oogpunt bekeken, kunnen de achteruitgang van het gebied in termen van landwaarde (€/m^2) of de productiviteit van de grond in €/ha de parameters zijn. In vergelijking tot stadscentra met lege winkelpanden kan de leegstand van landbouwgrond (%) of het aantal faillissementen (#/jr) een optie zijn.

(Trigger values) Aangezien er geen duidelijke signposts zijn, zijn ook de trigger values moeilijk te vinden.

(Actions) Om degradatie van het verdienmodel te voorkomen, zijn een aantal opties gevonden. Eén daarvan is de stimuleren van natte landbouw of andere soorten landgebruik zoals zonneweiden. Bovendien is het uitkopen van boeren een optie, samen met de extensivering van de resterende landbouw.

Natte landbouw wordt momenteel onderzocht, vooral gericht op de natte lisdodde en cranberries. Met name de teelt van deze gewassen op de lange termijn en de bijbehorende marktketens worden bestudeerd. De provincie kan dit soort onderzoek faciliteren en financiële ondersteuning bieden. Momenteel is het Veenweide Innovatie Centrum één van de experimentele projecten die door de provincie worden ondersteund. Dit om de huidige landbouw te verschuiven naar natte landbouw.

Zonneweiden hebben een hogere winstgevendheid in vergelijking met de meeste soorten landbouw. Als het aan projectontwikkelaars ligt, zou het hele Groene Hart volgebouwd worden met zonnepanelen. De gedeelde afkeer van ingrijpende veranderingen in het huidige landschap voorkomt dit echter. Zonneweiden kunnen in de toekomst nog interessanter worden als de vraag naar duurzame energie toeneemt.

Door het kopen van land van financieel noodlijdende boeren, en relatief goedkoop aan andere boeren door te verkopen, wordt de landbouw geëxtensiveerd. Zij zullen meer ruimte hebben voor hun activiteiten, wat opweegt tegen het verlies aan efficiëntie dat men ervaart door veranderingen in de omgeving. Dit ontlast de resterende landbouw. Ook biedt het de mogelijkheid voor de provincie om eisen te stellen aan het gebruik van stukken grond. Omdat het uitkopen van boeren duur is, wordt deze actie liever vermeden.

(Impl. time) De verschuiving naar ander landgebruik, zowel naar natte landbouw of zonneweiden, kan tot 20-30 jaar duren. Dit is namelijk de tijdsduur van de investeringscyclus in de huidige landbouw. Bovendien is tijd nodig om de langetermijneffecten van nieuw landgebruik te onderzoeken. Als de uitgaven en kosten voor het onderbreken van de investeringscyclus echter door de provincie worden gedekt, kan dit worden versneld tot ongeveer 5 jaar.

Het vaststellen van eisen voor nieuw uitgegeven gebieden werkt direct. Echter, als er rekening moet worden gehouden met de opkoop van landbouwgronden, kan dit ook meer tijd vergen.

2. Emissie door veenoxidatie (bodemdaling)

In landelijke gebieden (het grootste deel van het Groene Hart, evenals de Zuidplaspolder) is bodemdaling geen bedreiging op zich, maar de hierdoor veroorzaakte uitstoot van CO_2 wel. Voordat deze emissie een probleem werd, was er niet al te veel aandacht voor de stabiliteit van veengronden. Wanneer stabiliteit van de verticale beweging van de bodem wordt bereikt, zal CO_2-uitstoot worden voorkomen. Er zijn doelen om de uitstoot vanuit veenoxidatie te verminderen, of te stoppen.

(Signpost) Een maatstaaf om te controleren of de doelen worden bereikt, is door de bodemdaling (in mm/jaar) te meten, aangezien dit in directe relatie staat met de uitstoot van CO_2. Helaas is er weinig kennis over de exacte relatie tussen bodemdaling en emissie door oxiderend veen. Er zijn wel een aantal modellen te vinden, maar deze zijn gebaseerd op veel aannames. Momenteel wordt de relatie onderzocht op zes locaties met verschillende kenmerken, maar er zijn nog geen resultaten.

(Trigger values) De drempelwaarde voor emissie is afhankelijk van politieke en juridische keuzes, die in de loop van de jaren kunnen veranderen. Een gevoel van urgentie is vereist voordat er dingen in gang worden gezet. De huidige visie van de regering stelt dat in 2030 de landelijke CO_2-uitstoot door veenoxidatie met 1 Mt zou moeten dalen, wat waarschijnlijk een reductie van 1/3 betekent ten opzichte van de huidige situatie. In 2050 moet de uitstoot worden teruggebracht tot nul.

(Actions) De bodemdaling wordt bestreden door de grondwaterstanden hoog te houden, dat wil zeggen met peilfixatie. Op deze manier heeft het veen geen kans om te oxideren. Dit valt binnen de mogelijkheden van het waterschap.

Andere opties zijn het stellen van eisen, of het geven van incentives aan landeigenaren om hoge grondwaterstanden te stimuleren. Dit is een beleidsmaatregel die soms samenwerking met andere partijen vereist. Een voorbeeld hiervan was het besluit om, via een deal die werd gesloten met Campina, melkboeren extra eurocenten per liter melk te geven wanneer zij hoge grondwaterstanden hadden bereikt.

(Impl. time) Het fixeren van de peilen kan op korte termijn plaatsvinden. Het creëren van stimulansen heeft een implementatieperiode van ongeveer 2 jaar.

Belangrijk om te weten is dat veenoxidatie geen grote negatieve invloed heeft op het bodem- en watersysteem. Een studie van Deltares creëerde een toekomstbeeld waarbij alle veengronden geoxideerd/verdwenen zijn om te kijken waar er problemen zouden optreden. Hieruit bleek dat de gevolgen op het systeem niet al te ingrijpend zijn, ook niet voor het voorkomen van opbarstingen.

3. Verlies van landschappelijke kwaliteit

Landschappelijke kwaliteit kan worden geïnterpreteerd op verschillende manieren. Onder andere de biodiversiteit, natuur en waterkwaliteit dragen bij aan de landschappelijke kwaliteit.

(Signposts) Er zijn geen expliciete richtlijnen om landschappelijke waarden te meten. Wel zijn er beschrijvingen van verschillende soorten landschappen en de kwaliteiten die deze bezitten. Dit zijn echter beschrijvingen zonder karakteristieke parameters.

(Trigger values) Zonder duidelijke maatstaven is het erg moeilijk om te achterhalen wanneer de landschappelijke kwaliteit onvoldoende is. Meestal bepalen maatschappelijke keuzes wanneer actie moet worden ondernomen.

(Actions) Een optie om verlies van landschappelijke waarde te voorkomen, is het bieden van stimulansen voor het verbeteren van de biodiversiteit, de natuur of de waterkwaliteit. Een positieve stimulans is het gebruik van "pakketten", die door landgebruikers kunnen worden gekozen. Een voorbeeld; boeren nemen een pakket voor de weidevogels. De boeren zullen dan in hun bedrijfsvoering rekening houden met deze vogels en ontvangen subsidie voor de extra inspanningen die ze moeten leveren. Deze actie wordt al toegepast, maar kan nog meer worden gestimuleerd. Een andere stimulans zou de invoering van milieubelastingen kunnen zijn.

(Impl. time) De pakketten zijn al in gebruik en het kost niet veel tijd om deze te upgraden (maximaal 1 jaar). *Voor het invoeren van milieubelastingen is geen tijdsindicatie gegeven.*

4. Onvoldoende zoetwatervoorziening

Deze verantwoordelijkheid ligt vooral bij de waterschappen en zal slechts kort worden vermeld Bij onvoldoende zoetwatervoorziening wordt het huidige landgebruik (waaronder de landbouw) en het handhaven van het peil belemmerd.

(Signpost) Dit wordt waarschijnlijk gemeten in mm zoet water per ha.

(Trigger value) Het waterschap heeft waarschijnlijk richtlijnen voor de minimumwaarden voor zoetwatervoorziening in het poldergebied.

(Actions) Het is mogelijk om de regionale en/of nationale waterverdeling aan te passen. Daarnaast is de provincie een van de partijen die aan het nationale Deltaprogramma werkt en zorgt voor meer invloed op het grotere watersysteem.

(Impl. time) Het aanpassen van de nationale zoetwaterdistributie duurt ongeveer 5 tot 10 jaar.

Voor zowel de landschappelijke waarde als mogelijk het verdienmodel in de toekomst is de optie om groene gebieden te creëren zeer onwaarschijnlijk. Dit omdat er al een *Nationaal Natuurnetwerk (NNN)* bestaat met aangewezen natuurgebieden. Ook is het aanleggen van extra natuur lastig omdat er geen geld beschikbaar is. Daarnaast is er momenteel geen financiële waarde voor groen gebieden, en worden deze als een kostenpost beschouwd. Dit begint echter langzaam te veranderen, zeker wanneer de voordelen van natuurgebieden relevanter worden.

A.5. Interview Staatsbosbeheer

De geïnterviewde werkt als ecohydroloog bij Staatsbosbeheer (SBB). Het interview is afgenomen op 29 januari 2020, om 13.30 met een duur van een uur en een kwartier.

Voor de verre toekomst wordt een beeld geschetst waarin de veengebieden (met weinig weerstand in de ondergrond) een peil hebben dat ongeveer 2 meter hoger ligt dan nu. Daarnaast zal de functie veranderd zijn naar wetland natuur met recreatie. Hierin kan wel gebouwd worden, maar dat zal zich moeten vormen naar de nieuwe gebiedsontwikkeling. Technisch gezien is er veel mogelijk, maar dat zal situatie specifiek ingevuld moeten worden.

Dit toekomstbeeld komt grotendeels overeen met de gewenste situatie voor SBB. In de ontwikkelde wetlands is veel ruimte voor natuur en recreatie. Dit komt gelegen, aangezien er in de regio van de Zuidplaspolder veel gebieden zijn met een tekort aan openbaar groen. Daarnaast zijn het de restveengebieden waarvan uit nu nog veel CO_2 de lucht in gaat, en waar ook de meeste zakking optreedt. Bij het omzetten naar wetlands kan er worden gestopt met het intensieve onderhoud van deze gebieden. Voor de rest van de polder kan een verdere groene dooradering worden gerealiseerd, met bossen of iets dergelijks.

Als doelstelling voor de SBB binnen de Zuidplaspolder kan het volgende worden aangenomen: **het bevorderen van natuur en recreatie, in de vorm van wetlands.** De voorkeur voor wetlands komt voort uit het feit dat dit een veen producerende natuurvorm is. Ook is natuur die zal passen bij gebiedseigen karakteristieken. Een voorbeeld is de Groene Jonker, waar een deel van de droogmakerij is overgelaten aan natuurlijke processen. Hierbij is een mooi natuurgebied ontstaan, met betere waterkwaliteit dan de rest van de polder. Daarnaast is het ook een vrij robuust ecosysteem waarmee ook wordt ingespeeld op mogelijke veranderingen in de toekomst. Zo zijn wetland gebieden vrij resistent voor veranderingen in de zoutgraad. De natuur kan ermee dealen, maar dat moet worden meegenomen in de inrichting van een gebied.

Een goede bijkomstigheid van wetlands is dat het watermanagement in de polder zal vereenvoudigen. Het vernatten zorgt ervoor dat er minder water bij de gemalen terecht komt. Als ook de waterbergingsopgave wordt bekeken kan dit positief bijdragen. Daarnaast kan een goede ecologische staat doorwerken naar de omliggende zones.

Het is relevant op te merken dat SBB geen direct belang heeft in te polder. Vanuit het natuurbeleid van LNV & de provincies wordt er alleen natuur ontwikkeld op vrijwillige basis, als er ruimte beschikbaar wordt gesteld vanuit grondeigenaren. Er wordt niet actief gezocht naar nieuwe gronden. De huidige natuurontwikkelingsopgave is benoemd in de plannen van het Natuurnetwerk Nederland (NNN). Hierin staan gebieden aangewezen voor het ontwikkelen van groene gebieden, met enige schuifruimte. Binnen de Zuidplaspolder zijn momenteel nieuwe gebieden aangewezen voor groenontwikkeling.

Mogelijke belemmeringen bij het verwezenlijken van dit doel zijn als volgt:

1. Het uitblijven van een systeemsprong

Ideeën die goed zijn voor natuurgebieden leveren vaak problemen op voor (een van de) belanghebbenden. Hierdoor stranden projecten vaak, omdat er actie moet worden ondernomen vanuit een van de overheden. Iedereen moet over zijn schaduw heen springen om dit voor elkaar te krijgen. Er zijn acties nodig die een systeemsprong teweeg kunnen brengen.

(Actions) Het vastzetten van de peilen kan aanzetten tot een systeemsprong. Dit is ook gebeurd in de polder Groot-Mijdrecht. Hiermee werd een signaal afgegeven naar bouwers, boeren en andere gebruikers van de polder. De bodemprijs kan afnemen waardoor de grond makkelijker kan worden aangekocht voor het creëren van (wetland)natuur. Ook al is dit versnipperd, het is opschaalbaar en een goed begin voor uitbreiding in de toekomst.

Een andere mogelijke aanjager van verandering in de polder is het verbouwen van natte lisdoddes, eventueel op de grond van SBB. Dit kan fungeren als een overgangsfase naar (natte) natuurontwikkeling. Dit wordt toegepast in dezelfde polder Groot-Mijdrecht en in een proefgebied van landschap Noord-Holland.

Het vastzetten, of zelfs verhogen van de peilen zal zorgen voor minder verzilting; er ontstaat een hogere weerstand door de tegendruk van water en de verdikking van de bodemlaag door mogelijke aanwas van veen. Een mooie locatie om de peilen te verhogen zouden dan ook de locaties met de meeste wellen zijn.

2. Hinder van woningbouwopgave

De Zuidplaspolder is aangewezen als locatie voor nieuwe woningbouw. Woningbouw is mogelijk in wetland gebieden, mits er duidelijke plannen worden gemaakt over hoe dit eruit moet komen te zien. Het overleg met stakeholders is dan van belang.

(Actions) Hier kan mee worden omgegaan door bebouwing te realiseren in "plukjes". Hiermee wordt meteen een aantrekkelijke groen/blauwe omgeving gecreëerd.

Bij het wonen in dit soort woningen zou overlast kunnen optreden door muggen.

3. Vrijkomen van fosfaat

Bij het vernatten van voormalige landbouwbodem komt er in schokken fosfaat in het water terecht.

(Actions) De lisdodde kan hier optreden als acclimatisator. Deze plant wordt niet bemest, maar neemt juist de opgestapelde voedingsstoffen op uit de grond. Hiermee kan de geleidelijk laten overgaan tot natuur. Een positieve bijkomstigheid is dat er ook ervaring kan worden opgedaan naar het verbouwen van dit gewas.

4. Nadeel voor weidevogels

Vanwege het verdwijnen van veenweide gebieden zal er minder areaal zijn voor weidevogels. Echter op verreweg de meeste plekken zijn deze weidevogels al een tijdje niet meer natuurlijk aanwezig; de veengebieden zijn vanaf de randen volgebouwd en er wordt vaak per jaar gemaaid, vanwege bedrijfstechnische redenen. Alleen enkele gesubsidieerde boeren houden rekening met weidevogels. Het behoud van weides voor de vogels wordt daarom niet als argument gezien. Er kan beter op andere (nabije) locaties worden ingespeeld op de behoeftes van weidevogels.

Groene stukken land zijn geen verspilling van geld! Natuurgebieden hebben gemiddeld lagere subsidiekosten per hectare dan landbouwgrond. De subsidies die nu naar landbouw gaan zouden ook aan groengebieden kunnen worden besteed. Daarnaast zouden *carbon credits* (wanneer deze wel serieus geld gaan opleveren) de situatie voor SBB een stuk makkelijker maken. Er zijn een hoop aannames bij deze stelling waarbij er een hoop te weerleggen zijn.

Wanneer bestaande groengebieden als het Haagse bos of het Malieveld worden aangepakt, zal hier verontwaardigd op gereageerd worden. Ook zijn er bespiegelingen over de waarde van vastgoed dat naast natuurgebieden ligt. En hoe beroerd mensen zich voelen als er geen groen in hun leefomgeving is. Het monetariseren van deze gebieden is lastig, maar deze gebieden zijn erg waardevol.

Tot slot kan er gekeken worden naar de rol van de overheid binnen de polder. Het is enigszins vanzelfsprekend dat de overheid verantwoordelijk is voor hoogwaterbescherming, maar inmiddels zijn ze ook verantwoordelijk voor optimale productieomstandigheden. We zouden kunnen nadenken of dit een overheidsdoelstelling moet zijn. Wanneer hier minder nadruk op wordt gelegd in beleid zal dit meer ruimte bieden aan andere landgebruiken, zoals natuurgebieden.

A.6. Interview GOM

De geïnterviewden (twee personen) werken respectievelijk als projectontwikkelaar en landschapsarchitect bij AM. Momenteel hebben zij een actieve rol binnen de Gebiedsontwikkelings Maatschappij (GOM) Zuidplas. Vanuit deze rol wordt dit interview afgenomen. Het interview nam plaats op 10-2-2020 om 13.00 uur, met een duur van één uur.

De GOM is een samenwerking van AM, Amvest, Heijmans, ASR en Woonbron voor de ontwikkeling van woningen binnen de Zuidplaspolder. Ten behoeve hiervan bezitten ze gezamenlijk gronden binnen dit gebied. Heijmans en AM zijn momenteel de trekkers van deze ontwikkeling, wat bestaat uit meerdere delen. Het eerste deel, nabij Zevenhuizen, wordt inmiddels gerealiseerd. Voor het tweede deel, rond Nieuwerkerk Noord, is het bestemmingsplan reeds gewijzigd en wordt nu een haalbaar plan gemaakt. Daarnaast wordt er gewerkt aan het Vijfde Dorp. Hier wordt momenteel gewerkt aan het stedenbouwkundige concept van de ontwikkeling van 4000 woningen in het Middengebied. Gezien de positie (grondbezit) verwacht dat de GOM ook betrokken zou zijn bij deze volgende ontwikkeling binnen de polder.

Een toekomstbeeld voor de Zuidplaspolder wordt geschetst met veel ruimte voor woningen. Hier is veel behoefte aan, vooral in de Randstad. De Zuidplaspolder is hiervoor aangewezen. Door middel van de woningbouw kan worden bijgedragen aan de kwaliteit van de polder, zowel landschappelijk als qua bodemgesteldheid. De nieuwe inrichting van de polder zal er ook voor zorgen dat het enigszins rommelige karakter wordt aangepakt. Daarnaast kan de activiteit binnen de polder als impuls dienen voor andere projecten.

Voor de toekomst heeft de GOM de wens om zo snel mogelijk te voorzien in de woningvraag. Dit komt vanuit de behoefte in de markt en vanuit het eigendom van de gronden, waardoor er snel kan worden begonnen. Daarbij wordt de maatschappelijke verantwoordelijkheid niet vergeten. Het is van belang om te duurzaam te bouwen met het oog op de toekomst, zowel voor de woning zelf als voor de omgeving. Zo kan de woningbouw bijdragen aan een betere waterkwaliteit en het omgaan met klimaatverandering. Het doel van de GOM binnen de polder kan worden omschreven als het **ontwikkelen van een duurzaam woonmilieu dat houdbaar is voor de toekomst**. Er zijn enkele belemmeringen die het behalen van dit doel kunnen tegenwerken.

1. Bodemstabiliteit

Bodemdaling en lokale verzakkingen zorgen dat er inmiddels veel onderzoek is verricht en mogelijk veel maatregelen moeten worden genomen. Er wordt gekeken naar bouwen op de meest draagkrachtige grond, zoals op de oude kreekrug. Echter past niet alles op dit deel van de polder, met sterke zandbodem, vandaar dat er wordt gekeken naar manieren van ophogen van het gebied wordt bekeken. Vroeger werd er vaak een berg zand op de bodem gegooid, en werd alles gladgestreken. Dit is nu niet gewenst. Ten eerste is het erg duur, ten tweede is dit op dit terrein geen duurzame oplossing met het oog op de waterproblematiek.

Op basis van boringen voor kennis van de grondopbouw, ophoging en voorbelasting is er een beeld waar de zetting gaat eindigen, de zogenoemde restzetting. Zodoende is er weinig angst voor het verzakken van de woningen.

(Signpost) De parameter die hiervoor wordt gebruikt is de restzetting. Deze geeft aan hoeveel de bodem mag zakken in de komende 30 jaar.

(Trigger value) De Leidraad Inrichting Openbare Ruimte (LIOR) van de gemeente Zuidplas schrijft een maximale restzetting voor van 0,2 - 0,25m in 30 jaar.

(Actions) Er kunnen lichte materialen worden gebruikt in de bodem, zoals piepschuim of bims (bouwsteen met lage dichtheid) om de daling tegen te gaan. Daarnaast zou drijvend wonen een oplossing kunnen zijn, maar dit is voor de Zuidplaspolder nog niet aan de orde gekomen. Wonen op terpen zou een andere mogelijkheid kunnen zijn.

Tot slot zou het ophogen van het grondwaterpeil helpen tegen het verzakken. Middels een onderzoek van Witteveen+Bos wordt gekeken naar het optimale grondwaterpeil om zakking tegen te gaan. Bij voorkeur is dit één peil, echter is niet mogelijk gezien de bestaande lintbebouwing.

Dit vraagt ook veranderingen in de manier waarop mensen wonen, men moet hier welwillend tegenover staan. Het behouden van de traditionele vorm van wonen zal moeilijker worden.

2. Wateroverlast

Alhoewel de (toekomstige) hoeveelheid water binnen de polder kansen biedt voor gebiedskarakteristiek wonen, en dus voorzichtig als voordeel kan worden gezien, brengt het ook het gevaar van wateroverlast met zich mee. Er is een reële kans op natte voeten. Er wordt momenteel vanuit gegaan dat het waterschap dit allemaal onder controle heeft.

Aangezien wateroverlast op dit moment niet als ernstig wordt beschouwd zullen er niet snel ingrijpende veranderingen plaats vinden. Wanneer er wel urgentie is zal er waarschijnlijk wel snel en daadkrachtig worden gehandeld door de overheden.

Het probleem moet heel erg urgent zijn voordat er iets zal gebeuren. De discussie over mogelijk vollopen staat niet op de agenda. Dit zou eerder een probleem zijn voor de eigenaren van de woningen op dat moment.

(Signpost) De drooglegging tegenover vloerpeil wordt gebruikt om wateroverlast voor woningen te bepalen.

(Trigger value) Een minimale drooglegging van 1.20m (waterpeil – bovenzijde vloer BG) wordt gehanteerd. De woningen worden aangelegd met deze minimale drooglegging.

(Actions) Gezien dit binnen de verantwoordelijkheid van het hoogheemraadschap valt, zal de eerste reactie zijn om deze zo snel mogelijk te bellen met de vraag of de pompen hoger kunnen.

Een oplossing binnen eigen macht is het aanleggen van een bufferzone voor wateropslag in noodsituaties. Dit valt ook samen te nemen met de opgave tot watercompensatie; een bepaald percentage van aangelegd verhard oppervlak moet weer op in een watervorm worden teruggebracht. Vanuit HHSK staat dit percentage op 15%.

Wanneer in de toekomst blijkt dat de beoogde minimale drooglegging voor nieuwe woningen niet kan worden gegarandeerd, kan er worden overgestapt op het bouwen van kruipruimte-loze woningen of woningen met een hoger vloerniveau op de begane grond.

Als dit ook niet voldoende blijkt kan er worden overgestapt naar drijvende woningen.

3. Sentiment van inwoners huidige kernen

Het project van woning ontwikkelen is een flinke opgave voor de gemeente Zuidplas. Gemeente Zuidplas bestaat uit vier dorpen, en elk dorp binnen de polder staat hier anders tegenover. Er wordt vanuit de bestaande dorpen wantrouwend gekeken naar nieuwe bebouwing. Dit kan invloed hebben op hun bestaande, en vertrouwde leefomgeving. Dit zorgt voor weerstand bij het bouwen van nieuwe woongebieden tegen bestaande kernen aan. De oplossing voor nu is om een heel nieuw dorp, het Vijfde Dorp, te bouwen. Een nieuwe woonkern heeft echter wel een bepaalde omvang nodig om de voorzieningen levensvatbaar de laten zijn. Dit kan invloed hebben op de haalbaarheid van bepaalde plannen in de toekomst.

Wanneer er een sterk concept wordt neergelegd, heeft het plan een hogere kans van slagen dan wanneer er steeds wordt gereageerd op de kritische reacties op het plan. Dit leidt ertoe dat er constant naar compromissen moet worden gezocht. Het uitgangspunt zou moeten zijn om vanuit de behoefte, bodem en financiën een goed plan neer te leggen.

4. Politiek/ Ruimtelijke Ordening

Het uitvoeren van de plannen is afhankelijk van de instemming vanuit de gemeenteraad. Er zijn veel (lokale) belangen binnen de polder. Zo zijn er voor elke potentiele bouwlocatie voor- en tegenstanders te vinden. Zo speelt er onder andere de mobiliteitskwestie; er zal meer druk op de N219 komen te liggen. Theoretisch is er nog capaciteit, zeker wanneer enkele kleine ingrepen worden gedaan. Echter zal dit bij de gerealiseerde ontwikkeling niet genoeg zijn, en is het volgens de beleving van gebruikers nu al te druk op de weg.

Als de gemeente een duidelijke stelling durft aan te nemen kan dit probleem, en andere drempels, worden opgelost. Echter maakt de lokaal gewortelde politiek het niet makkelijk.

De GOM ontwikkelt binnen de kaders die worden meegegeven door belanghebbenden, zoals het waterschap (peilbesluit) en de gemeente (LIOR), en andere adviseurs. Als dit wordt meegenomen in het ontwikkelen van een plan, wordt er aangenomen dat er een goed plan ligt. De verantwoordelijkheid ligt na het afleveren niet meer bij de GOM. In het geval dat het water stijgt na de verkoop, is de GOM niet meer aansprakelijk, aangezien ze zich wel aan de vooraf gestelde afspraken hebben gehouden. De opstellers van de kaders zijn dan de verantwoordelijken. Echter staat ook de naam van het bedrijf op het spel. Zo het zal slecht afstralen als de woningen niet toekomstbestendig blijken te zijn. Vandaar dat het duurzaam functioneren van de polder als woongebied in al zijn facetten ook voor AM van belang is.

A.7. Interview gemeente Zuidplas

De geïnterviewde werkt als programmamanager Duurzaamheid & Klimaatadaptatie bij de gemeente Zuidplas. Het grootste deel van de Zuidplaspolder, en haar kleine 24.000 inwoners, valt binnen deze gemeente. Het interview is afgenomen op 16-1-2020 om 8.30, met een duur van 1 uur. Herziening van het document is gedaan in samenspraak met de geïnterviewde en een beleidsadviseur Openbare Ruimte.

Vanuit het Rijk is er een bovenregionale woningbouw opgave opgelegd, door het grote tekort aan woningen in de regio. Twintig jaar geleden is de Zuidplaspolder aangewezen als locatie voor nieuwbouw. Hierbinnen valt het plan om het *Vijfde Dorp* te bouwen, zijnde 4000 woningen in het midden van de polder. Dit plan is al ver in de voorbereiding, ook al is het nog niet opgenomen in bestemmingsplannen. Als een verwacht toekomstbeeld voor het jaar 2100 moet worden gegeven, wordt een volledig volgebouwde Zuidplaspolder voorspeld.

Door de Nederlandse kennis over water en techniek wordt het haalbaar geacht om in deze polder, zijnde de diepste polder van Nederland, te bouwen. Wel moeten er *bodemleidend* gebouwd worden, waarbij de belasting wordt verdeeld naar de sterkte van de bodem. De slapheid van de bodem, en de daarbij horende verzakkingen, wordt zodoende niet als een probleem gezien. Dit is overkomelijk, ook al kan dat veel geld en moeite kosten. Echter, als de woningnood daadwerkelijk zo hoog is, kunnen deze kosten worden opgenomen in de huizenprijzen.

Woningbouw

Problemen tijdens de bouw van nieuwe woningen, die kunnen optreden door de lage draagkracht van de bodem, wordt niet als een probleem gezien. Hier wordt al goed naar gekeken en rekening mee gehouden.

Voordelen van woningbouw zijn dat er nieuwe peilvakken worden gevormd. Dit zorgt voor eenvoudiger, en dus efficiënter, waterbeheer. Daarnaast kan het als vliegwiel fungeren voor een nieuwe inrichting van de rest van het gebied; de haalbaarheid van andere projecten wordt hoger doordat er ook andere veranderingen plaats vinden. Momenteel heeft de Zuidplaspolder een vrij rommelig landschap, met redelijk weinig regie omtrent biodiversiteit en watermanagement (inlaten/dammetjes door boeren gemaakt). Dit kan worden aangepakt door middel van woningbouw. Daarnaast wordt er met de bouw van woningen aandacht geschonken aan natuur en recreatie ten behoeven van de nieuwe woonkernen.

De gemeente heeft enkele doelen binnen de Zuidplaspolder, die kunnen worden samengenomen tot: **het verwezenlijken van een leefbare en toekomstbestendige omgeving en het realiseren van woningbouw**. Onder de noemer toekomstbestendig schaart de gemeente onder andere water robuust, energieneutraal (of energieleverend), betaalbaar, bereikbaar en circulair. Er moet worden gezorgd dat mensen over honderd jaar ook nog steeds goed en veilig kunnen wonen.

Enkele aspecten die problemen kunnen opleveren in het behalen van deze doelstelling zijn:

1. Wateroverlast

De polder wordt niet geacht zomaar te overstromen door dijkdoorbraken, daarvoor is er genoeg vertrouwen in de Deltawerken. Echter zal de gemeente zich wel moeten voorbereiden op meer en extremer hemelwater. Ook aangezien de Zuidplaspolder door zijn lage ligging enigszins fungeert als een afvoerput voor omliggende gebieden. Er is altijd veel aandacht geweest voor de inrichting, gezien de lage ligging van de polder.

(Signposts) Straten die blank staan voor langer dan ongeveer een half uur; wanneer het water leidt tot materiele schade bij publieke of private bezittingen. De neerslagintensiteit in mm/uur kan hiervoor worden gebruikt.

(Trigger value) Er wordt vanuit gegaan dat *bui 10* uit de Leidraad Riolering geen overlast zal geven in de huidige situatie. In de verdiepende stresstesten die staan gepland in 2020 zal dieper worden gekeken naar de daadwerkelijke schade op bepaalde momenten. Een duidelijke neerslag waarbij er te veel schade optreedt is niet aan te wijzen.

(Actions) Wateroverlast kan worden tegengegaan door de waterberging en/of -afvoer te verbeteren. Hier zijn veel mogelijkheden voor, zoals het uitbreiden van de rioolcapaciteit, het aanleggen van parkeerplaatsen met open verharding, het aanleggen van wadi's, waterbergende verharding, een hoger percentage groene omgeving realiseren of een grotere drooglegging aanhouden. Een beleidsmatige oplossing zou kunnen zijn om een maximum aan percentage bestrating voor tuinen in te stellen, of groene daken.

(Impl. time) Voor veranderingen aan het riool wordt in principe de vervangingscyclus aangehouden, deze ligt op gemiddeld 60 jaar. Voor wegen ligt dit op gemiddeld 40 jaar.

(Values for criteria) Positieve bijkomstigheden bij het aanleggen van waterbergingen of verbeterde afvoer: ruimte voor water zorgt ook voor ruimte voor de natuur, zo zou de biodiversiteit kunnen worden vergroot.

Een nieuwe rioolstructuur brengt kansen voor riothermie; het halen van warmte uit het riool. Ook ontstaan er kansen voor waterzuivering in terwijl het afvalwater zich nog in de rioolbuis bevindt.

Bodemkwaliteit gaat omhoog met het inlaten van water in de bodem.

Een negatieve bijkomstigheid is het gebruik van ruimte. Het aanleggen van meer openbare ruimte brengt meer kosten voor de gemeente voor zich mee. Zowel de aanleg als het onderhoud maar vooral minder verkoopbare kavels.

2. Afname landschappelijke kwaliteit

Ook de landschappelijke kwaliteit van het bebouwde gebied is van belang; als mensen in het Vijfde Dorp komen wonen voor het landschap, en er worden in een later stadium nog duizenden woningen bijgebouwd, kan dit afdoen aan het ideaal waarmee de mensen er zijn gaan wonen. Wanneer de landschappelijke kwaliteit afneemt heeft dit invloed op de leefbaarheid en de aantrekkelijkheid van (nieuwe) woningen.

(Signposts) Landschappelijke kwaliteit laat zich moeilijk kwantificeren. Daarnaast veranderen de meningen hierover elke vier jaar (per bestuursperiode).

(Trigger value) Gezien het moeilijk is landschappelijke kwaliteit te kwantificeren is er ook geen duidelijk punt aan te wijzen waarop actie moet worden ondernomen.

(Values for criteria) Positieve bijkomstigheden van het behouden van landschapskwaliteit: het biedt kansen voor biodiversiteit en recreatie.

Negatieve bijkomstigheid: de doelstellingen voor woningbouw kunnen in gevaar komen als het behouden van de landschappelijke kwaliteit de overhand krijgt boven het bouwen van woningen.

3. Grondverzakking/bodemdaling

Momenteel zijn er geen problemen met scheuren of verzakkingen in bestaande woningen en infrastructuur. Wel is er sprake van zakkende tuinen in het gebied tussen de A20 en de Hollandsche IJssel. Door afkalving verdwijnen de randen van tuinen in sloten. Het verzakken van de grond in het restveengebied zorgt ook voor overlast voor koeien. Hoe noordelijker, hoe minder last van verzakking. Wel resulteert dit in natte kelders na lange regenbuien. Zoals eerder genoemd, wordt niet verwacht dat het verzakken van de grond tot grote problemen leidt voor de toekomstige ontwikkelingen.

Wanneer de bodemdaling tot schade gaat leiden, kan er naar betaalbare manieren worden gezocht om bodemdaling tegen te gaan binnen het bouwproces. De makkelijkste manier zou zijn om er zand op te gooien. Het is echter de vraag of dit haalbaar is qua prijs. Er zijn ook andere opties, zoals waterwoningen of houtskeletbouw. Echter brengen deze mogelijkheden ook een groot prijskaartje met zich mee, ook al zijn de exacte kosten nog niet bekend.

De gemeente heeft dan ook geen verplichtingen wat betreft (de maximale) bodemdaling.

4. Politieke weerstand tegen woningbouw

Tot 2030 is de doelstelling om 4.000 woningen bouwen, met een mogelijke uitbreiding tot 12.000. De gemeentelijke politiek zouden deze huidige en toekomstige plannen nog tegen kunnen houden. De gemeenteraad moet de plannen nog goedkeuren. Zo zijn de huidige plannen ook nog niet definitief door de gemeenteraad. Daarnaast is ook het doorfaseren tot 12.000 woningen is nog niet bestuurlijk besloten.

Als de gemeenteraad tegen de voorgestelde plannen blijft stemmen kan dit vrij lang worden uitgesteld. Echter kan de provincie of het Rijk ervoor kiezen een aanwijzing te doen, hiermee word het heft uit handen van de gemeente genomen. Als dit gebeurt verliest de gemeente de regie, en besluiten andere partijen over hun grond. Uiteraard is dit niet gewenst.

Agrariërs

Onder de term *leefbaar en toekomstbestendig*, zoals beschreven in de doelstelling, kan ook het economisch welzijn van agrariërs worden gevat. De kwaliteit van het grootste deel van de grond is slecht, daarnaast staan de koeien momenteel al op een natte bodem. Er is de verantwoordelijkheid om bestaande bedrijvigheid mogelijk de maken, wellicht hoort het aanbieden van alternatieven of andere locaties tot de oplossing. De boeren hebben zelf echter ook in de gaten dat landbouw in dit gebied niet te toekomst heeft.

Huidige adaptiviteit van gemeentelijk beleid

In de planvorming worden dingen zo snel mogelijk aangepast wanneer er nieuwe kennis aanwezig is. De gemeente is zich ervan bewust dat er een ander systeem van inkopen en andere zaken nodig is. Maar het blijft een overheid, waarin alles traag verloopt. Een voorbeeld; de aanbesteding van een nieuwe wijk die nu in aanbouw is, is 4 jaar geleden gedaan. Inmiddels weten we al dat sommige aspecten hiervan achterhaald zijn, maar dit kan niet meer gewijzigd worden vanwege de afgesloten contracten. Zo worden er nog steeds huizen gebouwd die op gas zijn aangesloten terwijl dat niet meer gewenst is.

Op dit moment worden er besluiten genomen over het Vijfde Dorp. Daarbij is het de vraag of hier nog in kan worden gestuurd, indien gewenst. In de aspecten waar mogelijk nog in gestuurd dient te worden wordt zoveel mogelijk vrijheid ingebouwd. Echter dienen soms knopen te worden doorgehakt met de kennis die er nu is.

A.8. Interview LTO Glaskracht

De geïnterviewden (twee personen) werken als respectievelijk regio coördinator Zuid-Holland & Noord-Holland en landelijk beleidsspecialist Water & Omgeving. Het interview is afgenomen op 10 februari 2020, om 10.15 met een duur van één uur en drie kwartier.

Een toekomstbeeld schetsen voor de verre toekomst is erg lastig voor de glastuinbouw, gezien de ontwikkeling er snel gaan binnen de sector. *Vertical farming* (gestapelde kweeklagen, bijvoorbeeld in hoogbouw of oude panden) zou veel voor kunnen komen. Dit biedt kansen voor bepaalde gewassen, maar lang niet voor alle. Nieuwe technieken gaan vooral de kas in, en zijn niet kas-vervangend. Ook staat er veel druk op het grondgebruik, dit zou kunnen leiden tot een volgebouwde polder. Daarnaast is de planvorming met betrekking tot de houdbaarheid van de polder onzeker, en daarmee ook de aanwezigheid van glastuinbouw. Er zal rond 2100 volledig circulair worden gewerkt, in ieder geval op het gebied van water. Ook zullen de kassen van het gas afgesloten zijn.

De doelstelling van LTO Glaskracht luidt: **het beschermen en circulair maken van de glastuinbouw**. Een gewenst beeld voor de toekomst is circulariteit binnen de glastuinbouw-sector, op het gebied van water en energie. Het centraliseren van glastuinbouw locaties draagt bij aan dit doel; door gebundelde kassen zijn er meer mogelijkheden tot collectieve voorzieningen wat zowel de circulariteit als het bedrijfsresultaat van individuele tuinders kan verbeteren. De term beschermen duidt in de eerste instantie op het behoud van locatie, zeker gezien tuinders over het algemeen honkvast zijn. Echter, wanneer dit echt niet meer haalbaar is, zou het verplaatsen van de ondernemingen een mogelijkheid zijn mits er een goede exit strategie is. Enkele aspecten die dit doel kunnen belemmeren zijn:

1. Druk op het areaal

De uiteenlopende belangen binnen de polder, waaronder de woningbouwopgave, zorgen ervoor dat er veel aan de grond wordt getrokken. Hierdoor bestaat de kans dat grond wordt opgekocht en de glastuinbouw moet vertrekken. Dit terwijl het westen van Nederland, waaronder de Zuidplaspolder, een gunstige regio is voor glastuinbouw; er is relatief meer licht en een gematigder klimaat dan andere delen van Nederland.

Daarnaast is er (meer en nieuw) oppervlak nodig voor bedrijven om levensvatbaar te blijven. Soms krijgen tuinders een limiet op het oppervlak van hun onderneming. Op deze manier wordt een bedrijf impliciet naar zijn faillissement geduwd aangezien schaalvergroting op termijn noodzakelijk is. In sommige gebieden is er een max van twee hectare per onderneming vastgesteld, dat is niet vol te houden. Investeringen die worden gedaan moeten worden uitgesmeerd over het totale oppervlak en de producten die een bedrijf heeft.

Als verspreid liggende kasgronden worden opgekocht is er meer geld vrij tot centraliseren, en kan er bovendien een nieuwe, modernere kas worden neergezet. Ook betekent het uitkopen vaak dat er geen ruimte was tot schaalvergroting op deze locatie, gezien de druk op de grond. Er wordt zodoende een rendabele mogelijkheid geboden om naar een gebied te verhuizen met meer ruimte.

De overgangsperiode kan wel lastig zijn, aangezien de aanzet tot planologische veranderingen (zoals woningbouw) soms een periode van 10 tot 20 jaar overbrugt. De vraag of, en hoe, er dan nog geïnvesteerd moet worden is gecompliceerd.

(Actions) Mogelijkheden om hier mee om te gaan is het switchen naar andere teelt. Een andere optie is het verplaatsen van het bedrijf naar andere gebieden, mits er een goede exit strategie is.

(Impl. time) Het switchen naar een andere teelt kan erg lastig zijn. Dit hangt af van de technische eisen van de teelt aan een kas. Vooral investerings-technisch is het complex. Technisch gezien kan het in een paar maanden, financieel gezien in 10-15 jaar. Alhoewel een afgeschreven kas niet perse betekent dat hij niet meer bruikbaar is, soms zelfs het tegendeel; er kan eindelijk geld worden verdiend.

2. Verhindering zoetwaterbel

Regenwater is de voornaamste bron voor het gietwater binnen de kas, gezien de gunstige kwaliteit. De jaarlijkse hoeveelheid regen is in principe voldoende om het hele jaar te voorzien in gietwater. Echter zorgt de onbalans tussen perioden dat er behoefte is aan een secundaire voorziening. Hiervoor wordt meestal gebruik gemaakt van ontzout grondwater. Daarnaast maken binnen de sector alleen grondtelers (ongeveer 20% van de kassen) wel eens gebruikt oppervlaktewater.

Door tuinders binnen de Zuidplaspolder wordt veel gebruik gemaakt van een zoetwaterbel; het bergen van water in het eerste watervoerende pakket. Indien nodig kan dit water weer omhoog worden gepompt. Wanneer het grondwater te zout wordt is het lastig de bel in orde te houden. Het kan wel, maar het rendement van de opslag neemt af en je hebt meer techniek nodig om het water terug te winnen. Los van de zoutgraad zou ook een harde stroming van grondwater het benutten van de bel kunnen verhinderen.

(Signposts) De zoutgraad van het grondwater (in mS/cm) is hier een maatstaaf voor.

(Trigger value) De richtlijn is 4 mS/cm.

(Actions) bij verzilting van het grondwater kan worden gegrepen naar andere manieren om water op te slaan. Een voorbeeld is het installeren van een (groter, of extra) water bassin op het land.

Een andere optie is een betonnen kelder onder de kassen. Dit is op dit moment een erg dure oplossing, maar kan rendabel worden als de behoefte naar water groter wordt.

3. Wateroverlast

Momenteel kunnen tuinders kunnen zelf de grondwaterstand onder hun gebied beheren door eigen drainage aanleggen. Echter, als de sloten geen capaciteit hebben om dit pompwater af te voeren ontstaan er wel problemen. Een toename van buigrootte is hierdoor een zorgpuntje.

In de toekomst zou het kunnen dat er geen droge voeten kunnen worden gegarandeerd. Glastuinbouw heeft momenteel een norm van wateroverlast van 1 op 50. Stel, de sector krijgt eenzelfde normering als de akkerbouw (1 op 10) zal dat leiden tot grote schades bij de ondernemers. Waarschijnlijk zal dit leiden tot vertrek uit het gebied.

De stand van het grondwaterstand is hierin minder belangrijk. Substraatteelten (telen op kunstmatige bodem) kunnen met hoge drooglegging wel overweg. Bijna alle tuinders binnen de Zuidplaspolder telen op substraat. Grondteelten hebben hier meer moeite mee vanwege het directe contact van de gewassen met de bodem.

(Signposts) Drooglegging is een van de parameters die bepaalt of er wateroverlast plaatsvindt.

(Trigger value) De optimale drooglegging ligt rond de 0,80-0,90m. Mag dieper, ondieper levert grote problemen op. Met een lage drooglegging beperk je ook de opvangcapaciteit van de bodem. Voor substraatteelt is een drooglegging van 0,25 haalbaar als uiterste redmiddel. Dit brengt namelijk ook extra kosten mee voor de ondernemer.

(Actions) Het aanbrengen van bassins helpt tegen de wateroverlast. Zo zou het weg te pompen water hierin worden gestort.

4. Veranderend beleid vanuit overheden

Wisselingen in beleid hebben grote invloed op de beleidsvoering, deze kunnen van het een op het andere moment plaatsvinden. Zo is recentelijk de ODE (opslag duurzame energie) ingevoerd. Dit zijn extra kosten per kWh om verduurzaming te versnellen. Echter worden de duurzame aardwarmte installaties, die lopen op elektriciteit, nu een stuk duurder dan stoken op gas.

De grilligheid van het beleid zorgt ervoor dat voorlopers op het gebied van (duurzame) innovaties soms worden benadeeld. Dit is ook terug te vinden in het aansluiten van het Westland op het warmtenet; de wet- en regelgeving loopt achter de sector aan, en is omtrent dit systeem nog niet opgesteld. De randvoorwaarden, zijnde het beleid van de overheid en het consumentengedrag bepalen de lijnen van de sector.

Dit valt deels te wijten aan een gebrek aan kennis vanuit de overheid. Wanneer er meer kennis en inzicht aanwezig is, kan de overheid veel beter beleid uitzetten dan nu gebeurt. Op alle niveaus, van gemeentelijk tot nationaal. Op niveau van de Zuidplaspolder kan gemeentelijk gebrek aan kennis leiden tot bepaalde keuzes omtrent de glastuinbouw die nadelig uitpakken.

Naast de bovengenoemde beperkingen zou bodemstabiliteit voor sommige teelten problemen kunnen opleveren. Er wordt niet direct gedacht aan het verzakken van de bebouwing, maar eerder aan hoge karren op rails die scheef kunnen komen te staan.

Vanuit de waterschappen loopt het *Rainlevel project*. Dit omvat het benutten van de bergruimte in de bassins van tuinders heftige neerslag op te vangen. Hiermee wordt het oppervlaktewater minder belast. Bij een aankomende bui wordt, indien nodig, gevraagd of tuinders een deel van hun bassin willen laten leeglopen. Het voordeel voor tuinders zit hier in het feit dat waterschappen geen extra ruimte hoeven te maken voor wateropslag. Daarnaast is er minder kans op wateroverlast en -schade. Momenteel wordt dit nog niet toegepast binnen de Zuidplaspolder.

A.9. Interview Rijkswaterstaat

De geïnterviewde werkt als omgevingsmanager bij Rijkswaterstaat. Momenteel werkt hij aan het project A20 Nieuwekerk aan den IJssel – Gouda. Dit tracé loopt door de Zuidplaspolder. Het interview is afgenomen op 11-12-2019 om 10.30, met een duur van één uur.

In de toekomst ziet hij een bredere A20; van 2x2 naar 2x3 banen, een sterkere waterstructuur, bredere waterschakels (ook onder de wegen door) en heel veel meer woningbouw. Dit is al gebeurd in de afgelopen tijd, maar zal met de realisatie van het Vijfde Dorp in de nabije toekomst nog meer worden. En rond 2100 nog veel meer.

Woonachtig in Nesselande, zou hij het zelf mooi vinden als er meer ruimte wordt gemaakt voor groen/recreatie. Er is ten slotte genoeg potentie in de polder.

Na het opstellen van drie mogelijke opties is er besloten voor een verbreding naar 2x3 banen, tegenover de 2x2 banen in de huidige situatie. Momenteel is het project in de fase van de Planuitwerking en wordt de uitvraag voor een ingenieursbureau opgesteld. Dit bureau gaat tot eind 2023 onderzoek doen naar maatregelen voor de uitvoering en bijbehorende onderbouwing, waaronder effecten op de omgeving. Formeel leidt dit eerst tot een Ontwerptracébesluit en vervolgens een Tracébesluit, waarna de realisatiefase kan starten. De verbreding van het wegdek, dus meer verharding, moet worden gecompenseerd met nat oppervlak. In samenwerking met HHSK wordt gekeken of ook kan bijdragen aan het verbeteren van het algehele watersysteem.

RWS heeft het streven om de economische kernen van Rotterdam, Gouda en Utrecht beter te verbinden. Daarnaast wordt er ingezet op veilig weggebruik. Op dit moment gebeuren er op het traject ongeveer 300 ongelukken per jaar, wat ver boven het gemiddelde ligt. De meeste ongelukken gebeuren rond het Gouwe aquaduct, Moordrecht en de aansluiting Nieuwerkerk aan den IJssel. Samengevat is het projectdoel: **het verbeteren van de doorstroming en de verkeersveiligheid op de A20.** Daarbij moet worden gelet op de eisen vanuit wet- en regelgeving. Er zijn enkele mogelijke belemmeringen geïdentificeerd:

1. Instabiele bodemgesteldheid

De grond in het gebied is slap en bevat veel water. De weg kan verzakken, vervormen of er kan scheurvorming ontstaan. De weg is nu licht hobbelend. Dat is nu nog niet heel erg, maar als de watersituatie zou veranderen zou dit erger kunnen worden. Beheer en onderhoud van de infrastructuur kan problemen opleveren. Er wordt een maximale verzakkingsgraad geëist van aannemer. Bij de realisatiefase worden technieken gebruikt die zakking tegen gaan, bijvoorbeeld door het gebruik van bepaalde typen piepschuim. Het blijft echter moeilijk te voorspellen met hoeveel daling rekening moet worden gehouden.

(Signposts) De parameter die hiervoor wordt bijgehouden is de restzetting over zowel de langs- als de dwarsrichting. Dit wordt gemeten in mm.

(Trigger values) Voor de langs-richting mag er maximaal 50mm zetting optreden over 50m wegdek. In de dwarsrichting mag er maximaal 36mm zetting optreden over 3.6 meter wegdek.

(Actions) Wanneer de maximale verzakkingsgraad wordt overschreden, en er treden problemen op, moet er worden ingegrepen. Dan wordt (een deel van) de weg vernieuwd. Er kan dan worden opgehoogd en er kunnen nieuwe methoden voor stabiliteit worden toegepast.

(Impl. time) De benodigde tijd voor deze actie is erg afhankelijk van de urgentie. Als er niet op de verzakking geanticipeerd kon worden en er daarmee sprake is van een calamiteit, is er niet direct budget beschikbaar voor deze reparaties. Dit moet bij het ministerie van Infrastructuur en Waterstaat worden vrijgemaakt. Dit kan erg lang duren. Bij structurele en hevige problemen kunnen er preventief al eerder maatregelen worden getroffen. Dan komt er echter wel een discussie of het wel echt nodig is. Als de urgentie niet wordt erkent, of er zijn andere zaken belangrijker, kan dit grof geschat tot 5 jaar duren. RWS is erg afhankelijk van de politiek.

(Values for criteria) Mogelijke positieve neveneffecten: Een verzakkende weg heeft invloed op de rest van het systeem. Een stabiele weg zorgt ook voor stabiliteit in de rest van de omgeving. Er is dan beter te voorspellen wat er gebeurt. Ook voor de onderliggende kabels en leidingen is dit van belang.

Negatieve neveneffecten: Eventuele vervuiling van de grond, maar hier wordt goed op gelet. Echter bestaat de mogelijkheid dat de stofjes die we nu gebruiken over 10 jaar ineens gevaarlijk blijken te zijn, vergelijkbaar met PFAS.

2. Aanpassingen in grondwatersysteem.

Met het aanleggen van asfalt word de bodem ingedrukt, met veranderingen in het grondwatersysteem tot gevolg. Grondwater wordt weg gestuwd, wat moet worden opgevangen voordat het negatieve effecten oplevert voor de omgeving. Deze afvoer kan gerealiseerd worden met buizen waarmee het weggeduwde grondwater omhoog wordt geleid en vervolgens wordt opgevangen in waterlichamen. Door de natuurlijke bodemfiltratie kan dit water dan naar de rest van het watersysteem worden gevoerd.

Voor de realisatie van een wegverbreding of aanpassing wordt de situatie in kaart gebracht. Deze onderzoeken vormen de basis voor eisen richting de aannemer. Er wordt een monitoringsysteem opgesteld waarmee de veranderingen in de gaten worden gehouden. Andere grondgebruiken, zoals woningbouw, hebben ook effecten op het grondwatersysteem. Dit kan leiden tot het heen- en weer duwen van water.

(Signposts) De informatie uit het grondwater monitoringssysteem is case-specifiek. Er wordt minstens een jaar gemonitord op locatie om te kijken wat de seizoensgebonden effecten zijn. Per locatie komen er verschillende waarden uit deze monitoring (bijvoorbeeld voor stijghoogtes, zoutgehaltes), en de afwijkingen ten opzichte van de gevonden normale situatie.

(Trigger value) Ook al is er informatie vanuit de monitoring, het is niet eenduidig om te weten wanneer er actie moet worden ondernomen gezien de specificiteit van situaties.

(Actions) Er kan meer capaciteit voor waterberging worden gerealiseerd, of bredere/extra onderdoorgangen. In de eerste instantie worden opties gezocht langs de wegen, dit is minder ingrijpend en goedkoper.

(Impl. time) De implementatie tijd van deze oplossing is afhankelijk van wie er verantwoordelijk is, hoe groot de verbetering moet zijn en (wederom) de urgentie. Op zijn langst kan het grof geschat 15 jaar duren. Dit is de projectielengte van uitgaven in infrastructuur. Maar daarnaast wordt er ieder jaar gekeken wat er in het jaar daarna wordt uitgegeven aan infrastructuur. Dit zou er voor zorgen dat er binnen 5 jaar actie is ondernomen.

(Values for criteria) Mogelijke positieve neveneffecten: het aanleggen van natte zones biedt een mogelijkheid voor groen/blauwe gebieden. Waar watercompensatie wordt gerealiseerd kan dit toekomst vast worden gedaan. Er is een wettelijke verplichting aan deze compensatie. Echter kan hier in samenwerking met HHSK goed over worden samengewerkt. Het wettelijk te compenseren wateroppervlak staat vast, maar de locatie van de compensatie kan in samenspraak met een hoogheemraadschap worden bepaald.

Negatieve neveneffecten: Er wordt ruimte gebruikt die misschien voor andere doeleinden zou kunnen worden benut. Hierdoor zou het negatief kunnen zijn voor de ruimtelijke ontwikkelingswensen van regionale partners.

3. Wateroverlast

Extreme neerslag creëert onveilige situaties in het verkeer. Een snelweg kan in het ergste geval worden afgesloten, maar vaker wordt geadviseerd de weg te vermijden. Het gouweaquaduct kan overstromen en wordt dan afgesloten. Om dit tegen te gaan heeft dit kunstwerk een pomp met een capaciteit die nog 30 jaar mee kan.

(Signposts) Een parameter om te bepalen of de (hinder van) neerslag te extreem wordt is een combinatie van praktijkervaring met een toekomstverwachting wat neerslag betreft. Hier zijn geen concrete en/of algemene maatstaven voor.

(Trigger value) Als zowel uit de praktijk als de toekomstverwachting blijkt dat de beschikbare pomp- en afvoercapaciteit ontoereikend zijn, dient er actie te worden ondernomen.

(Actions) Als deze waarden wordt overschreden kan er worden overgestapt op enkele acties, voornamelijk het herontwerpen van de afvoercapaciteit. Bij het Gouweaquaduct kan de pompcapaciteit worden verbeterd. Op het maaiveld-niveau kan de afvoercapaciteit worden vergroot door een nieuwe laag asfalt neer te leggen.

(Impl. time) De levensduur van asfalt is ongeveer 10 jaar. Na het verstrijken van deze tijd kan er eenvoudig worden geschakeld naar een asfalttype met een grotere afvoercapaciteit. Het vernieuwen van asfalt kost niet veel tijd. De tijd die het kost om een pomp te vervangen is ook weinig.

(Values for criteria) Mogelijke positieve neveneffecten: aparte watergang waar dit wordt opgevangen creëer je de mogelijkheid om hiermee de biodiversiteit/ natuur/ recreatie te vergroten.

B

Details on hydrological model

In this appendix, further explanations on several components of the hydrological model will be given. This will complement the information provided in Chapter 5.

B.1. Vensim settings

Within the Vensim software, several choices were made on model settings.

Firstly, the unit of time was set to *hour*. With this decision, the peak events in the hourly values for precipitation and evaporation are modelled accurately. Hence, the effects of the increase of extreme values on the long term are embedded realistically.

Secondly, the integration method was set to *Euler*. Compared to other integration methods, the Euler method is suited for models where discrete functions are present [75]. In the hydrological model within this research, this characteristic suits the activation of actions, where discrete steps from value 0 to 1 are used.

Thirdly, a decision is made on the time step. A drawback of using Euler's integration method is the potential to be insufficiently precise unless a small time step is chosen [75]. A time step of 0.125 hour proved to be small enough for an accurate representation of the polder system, as the model behaviour proved to be identical to the smaller time step of 0.0625 hour. Additionally, using 0.125 hour provided acceptable computational times, even when eighty years (equalling 700800 hours) were simulated per run. Therefore, a time step of 0.125 hour was chosen.

B.2. Model layout

Split into two figures, the general layout of the hydrological model will be explained briefly. For the sake of comprehensibility, several parameters were left out. Figure B.1 represents the water sub-model, while Figure B.2 visualises the salt sub-model. Several parameters are coloured, indicating a different role compared to the regular, black-coloured parameters. The four types of parameters are elaborated below.

- Signposts: these variables are essential for (one of the) stakeholders within the Zuidplaspolder. They are observed to check whether trigger values are reached.
- Scenario driven variable: these variables are driven by future changes, which differ per scenario.
- Zone characteristic: each zone has its specific characteristics, which influence the water- and salinity sub-model within their boundaries.
- Action switch: as elaborated in Subsection 5.5.2, actions may be activated when they are part of the pathway that is simulated during this run. The changes to the hydrological model that are induced by these actions, are incorporated with *Action switch* variables.

Several variables are coloured gray, and are embedded in angle brackets. This indicates a *shadow variable*. These variables are present in another part of the model, either in the water or salt sub-model. For example, in Figure B.2, many shadow variables are found which represent the water flows that are determined in the water sub-model in Figure B.1. For comprehensibility, they are embedded as a shadow variable. The shadow variables present an indication of the interlink between the two sub-models.

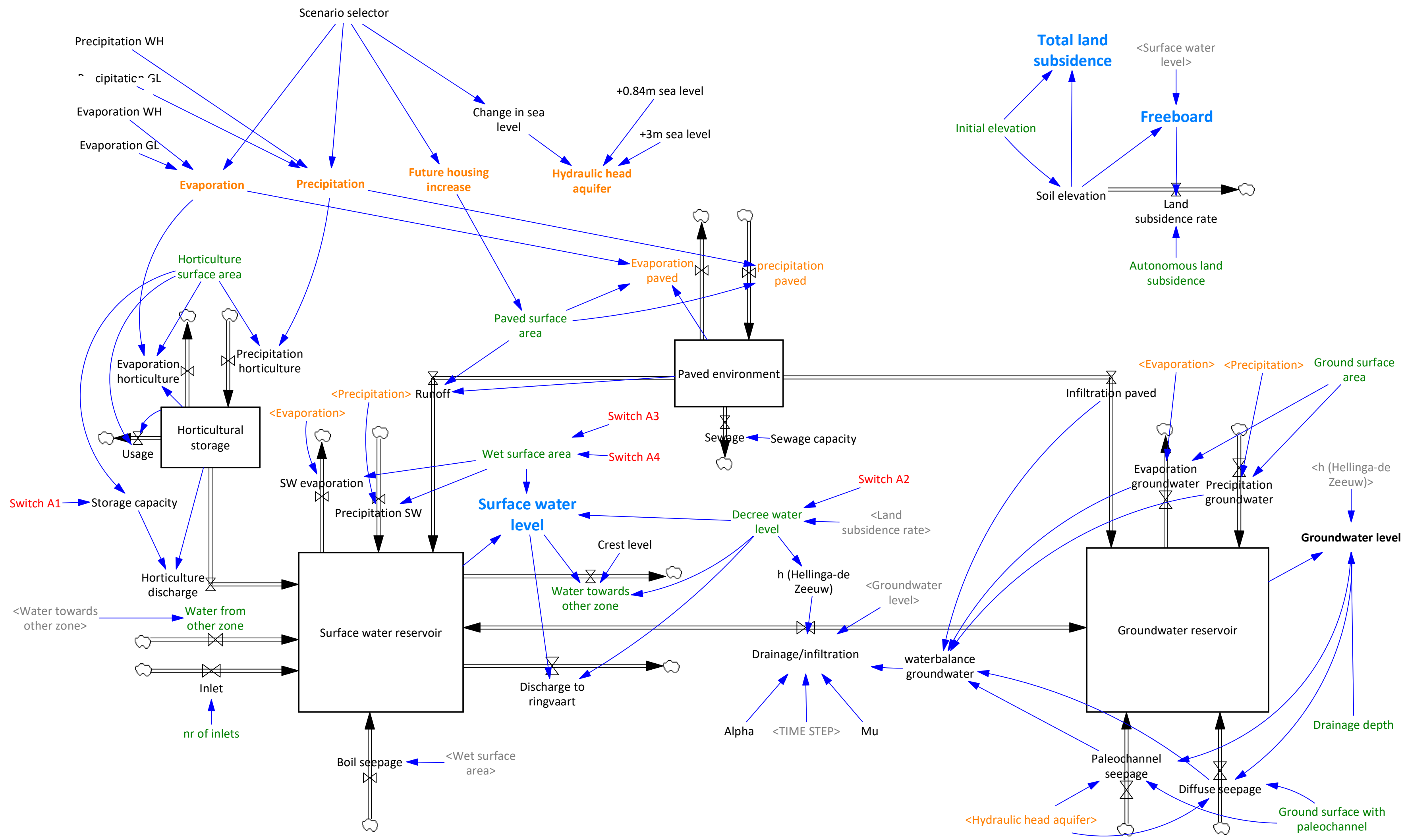

Figure B.1: Water sub-model of the Zuidplaspolder system (slightly simplified)

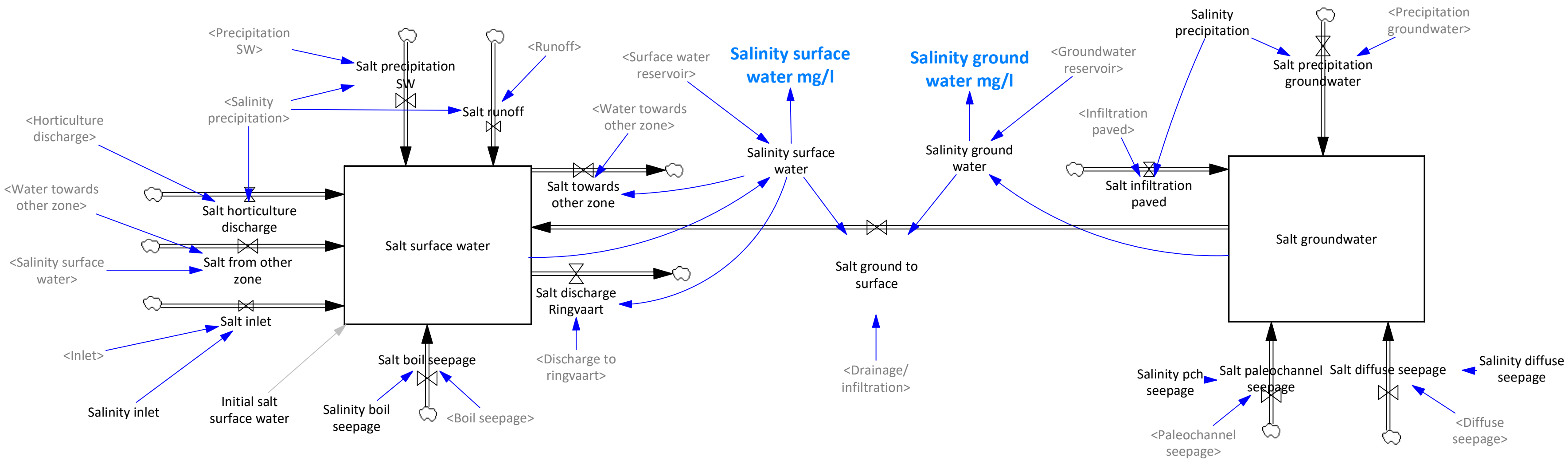

Figure B.2: Salt sub-model of the Zuidplaspolder system (slightly simplified)

B.3. Further assumptions and simplifications

In Section 5.2, the main assumptions and simplification are mentioned. Below, other simplifications are listed.

- The unsaturated zone within the groundwater system is not modelled within the groundwater system. Instead, relatively less precipitation will enter the groundwater reservoir, simulating the capture of rainfall by evaporation from the unsaturated zone. Each precipitation event is reduced to 80% of its original value. Besides, the inflow of a rainfall event is "spread" over a longer period of time (three time steps). This simulates the slower process of percolation from the unsaturated zone towards the groundwater.
- Discharge from the *Abraham Kroes* and *Zuidplas* pumping stations initiate when the water level in its zone is +5 cm to the decree water level. It will continue to pump on full capacity until the decree water level is reached.
- Evaporation rates for surface water are transformed from Makkink's potential evaporation to open water evaporation through Penman's reduction factor of 0.7 [73].
- In paved environment, 30% of the precipitation is discharged by sewage [92].
- In the initial polder conditions, horticultural business are assumed to have a water storage capacity of 1000 m^3 per hectare. This is based on the fact that 500 m3 per hectare is obligated, and businesses often choose to further expand this storage for a adequate provision of fresh water [97].
- Horticultural businesses are assumed to be present in Zone 1 and 4. Greenhouses are found in other areas, but to a smaller extent and are therefore neglected.
- Salinity of diffuse, paleochannel and boil seepage are assumed equal to de Louw's findings in the Noordplas polder.
- Accumulation of salinity in the top layer of agricultural grounds due to sprinkling with saline water is not embedded in the model, while this does have an effect on the potential crop damage.
- The conversion factor from salinity in mS/cm to mg/l chloride is 1 to 375, as used in a salinity research in the Koegraspolder [95]. In practice, a simple conversion to mg/l is not possible as it depends on several other aquatic parameters.

B.4. Equations

Several equations within the hydrological model require elaboration, which are presented below.

B.4.1. Groundwater-surface water interaction

For simulation of the water flow between surface- and groundwater, the *Hellinga-De Zeeuw* formula is used. This approach has a non-stationary characteristic [101], which makes it useful in the context of a continuously changing flux between ground- and surface water.

The approach is based on a simple equation for describing the discharge:

$$q = \alpha \cdot \mu \cdot h \tag{B.1}$$

With q the discharge intensity [m/hour], α the drainage factor [1/hour], μ the storage coefficient [-] and h the groundwater level above the drainage depth [m]. Within the hydrological model, the surface water level is considered the drainage depth.

For the Zuidplaspolder, α is assumed 0.3 which can be used for "Drainage discharge from well-drained agricultural soil" [102]. For μ, a value of 0.0664 is used. This value is applicable for clay and peat soils with a initial drainage basis (i.e. the distance between the surface level and the initial groundwater level) of 1m [18]. This is the case in multiple areas within the polder, and assumed for the other areas as well.

When the flow is directed towards the groundwater reservoir, i.e. when the surface water level is higher than the groundwater table, the drainage factor α is divided by one-hundred. With this reduced value, a smaller rate of infiltration is incorporated, when compared to drainage. This creates a more realistic representation of the actual flux, as the infiltration rates will be smaller compared to the drainage rate with an equal but reversed head difference.

For every time step within the simulations, h is determined as follows:

$$h_{(t)} = h_{(t-1)} \cdot e^{-\alpha\Delta t} + \frac{(P_{grw} + Inf_{grw} + q_{s,diff} + q_{s,pch} - E_{grw})}{\alpha\mu} \cdot (1 - e^{-\alpha\Delta t})) \tag{B.2}$$

With $h_{(t-1)}$ the difference between groundwater- and surface water level at the previous time step [m], Δt the time step [hour], P_{grw} the precipitation flux into the groundwater reservoir [m/hour], Inf_{grw} the infiltration flux from the paved environment into the groundwater reservoir [m/hour], $q_{s,diff}$ the diffuse seepage flux into the groundwater reservoir [m/hour], $q_{s,pch}$ the paleochannel seepage flux into the groundwater reservoir and E_{grw} the evaporation flux from the groundwater reservoir [m/hour].

When combining Equation B.1 and B.2, an equation is found for modelling the discharge intensity between the ground and surface water reservoir. To calculate the discharge in m^3 per hour, the discharge intensity q [m/hour] is multiplied with area A [m^2].

$$Q_{(t)} = Q_{(t-1)} \cdot e^{-\alpha \Delta t} + (P_{grw} + Inf_{grw} + S_{diff} + S_{pch} - E_{grw}) \cdot (1 - e^{-\alpha \Delta t}) * A) \tag{B.3}$$

B.4.2. Flow between zones

For the water flux between zones without a pumping station, a flow over a standard weir with free flow is assumed. Therefore, the following equation is used:

$$Q = 1.7 * m * B * h^{\frac{3}{2}} \tag{B.4}$$

With Q the discharge between two zones [m^3/hour], m the crest shape coefficient [-], B the width of the weir [m], h the water level upstream of the weir, with respect to the crest [m].

For crest shape coefficient m, the shape of a broad crested weir is assumed. For crest width B, a rule of thumb is used. This rule states that for every hectare of surface area, 1 cm of weir width can be assumed. With this, the overall set of flows through small ditches and canals are bundled to one value. For example, in calculating $Q_{a,b}$, where zone A has a surface area of 500 hectares, B is assumed 5 meter.

Between two pair of zones, a pumping station is used for discharging surface water. Between zone 2 and 3, a pump with a capacity of 180 m^3 per minute is present. Between zone 5 and 6, a pump with a capacity of 90 m^3 per minute is found.

B.4.3. Seepage fluxes

For diffuse and paleochannel seepage, the fluxes are derived from Darcy's law, and are adapted from de Louw et al. (2011).

$$Q_{s,i} = \frac{H_{aq} - h_{grw}}{r_i} * A_i \tag{B.5}$$

With $Q_{s,i}$ the seepage flux for seepage type i [m^3/hour], h_{grw} the groundwater level [m], r_i the resistance of the confining soil layer [hour] and A_i the area there seepage type i is present [m^2]. For diffuse seepage i = *diff*, while for paleochannel seepage i = *pch* is used.

The resistance of the confining layer for different seepage types i is determined with Equation B.6.

$$r_i = \sum_n \frac{d_n}{k_{v,n}} \tag{B.6}$$

With n the different soil layers within the confining layer, d_n the thickness of layer n [m] and $k_{v,n}$ vertical saturated hydraulic conductivity of layer n.

B.4.4. Land subsidence

A relation is found between freeboard (NL: *drooglegging*), the distance from soil elevation to the surface water level) and land subsidence in peat areas [42]. For different peat soils, an equation prescribes the subsidence per year, as presented in Figure B.3. For zone 7 to 9, with the majority of the soil column consisting of peat, the light blue graph is assumed to determine the land subsidence. This corresponds with meso- or eutrophic peat soils.

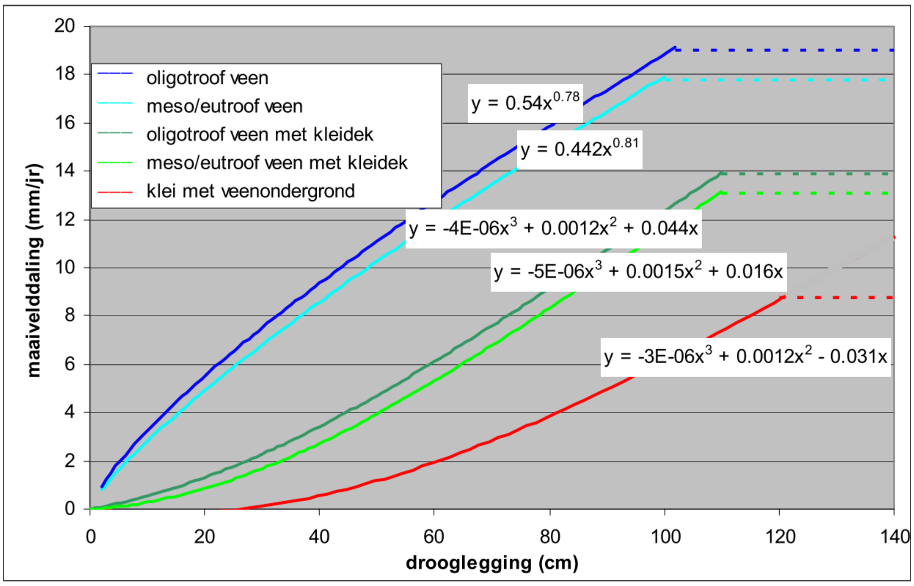

Figure B.3: The relation between freeboard (on x-axis) in cm and land subsidence in mm/year (on y-axis). These are applicable with certain soil types [42]

Within certain areas, specifically found in zones 1 to 6, the larger part of the soil consists of clay. For these zones, the equations in Figure B.3 are not valid. Here, the current land subsidence rate is assumed for the remainder of the simulation run. Values for current land subsidence are found on Bodemdalingskaart.nl.

B.5. Effect of implemented actions

Implemented actions have an effect on the polder system. Below, the effect of each action is elaborated. Considering the actions related to water management, the following choices are made.

Decree fixation After the fixation of decree, the current decree water level will stop following the soil elevation. The value will be fixed to the decree level in the time step before for the remainder of the simulation.

Increase private storage horticulture When the storage capacity is increased, horticultural business are assumed to have a storage reservoir of 2000 m^3/ha. Initially set on 1000 m^3/ha, this means the value is doubled.

Increase public buffer capacity (small-scale) The small scale increase in public buffer capacity is expected to add 33% extra surface water area to each zone, related to the respective initial surface water areas.

Increase public buffer capacity (large-scale) The large scale addition of public buffer capacity is modelled as a doubling of the surface water area at the moment of implementation. When the small-scale increase of buffer capacity is implemented in an earlier stage, an increase in surface water area of 266% is realised.

Tweak regional/national water provision system By tweaking the regional and national surface water provision system, drought is prevented. This is implemented by adding two inlets to every zone bordering the polder outline (all except zone 6) and increasing the inlet flows from 25 m^3/hour to 50m^3/hr, given the water levels are below decree water level.

For the land use related actions, the following implementations are made when activated.

Adjust current way of agriculture When the current way of agriculture is adapted to cope with higher water and salinity levels, the trigger values for the agricultural sectors is changed. After implementing this action, the trigger values for both water nuisance and salinity will change.

For the freeboard trigger value, a drop from 0.8 meter to 0.2 meter is assumed for both arable farming and grasslands, as 0.2 meter is the mentioned as the potential freeboard with an underwater drainage system in place. For salinity, the threshold is assumed to increase with 300 mg/l. For arable farming this means a step from 900 mg/l to 1200 mg/l, which implies the switch from a *light* to *medium brackish* threshold value [5]. For grassland farming, an increase from 1800 mg/l to 2100 mg/l is assumed.

Shift to future proof land use Similar to the *Adjust current way of agriculture* action, the shift to a future proof land use provides other trigger values for water nuisance and salinity values. It is assumed that the freeboard is allowed to be equal to zero. This means that only the occurrence of a flood is causing water nuisance. The trigger value for salinity is set to 1500 mg/l for arable farming and 2400 mg/l for grasslands.

Leave the polder (agriculture) All trigger values for the agricultural sector are released.

Adapt building principles By adapting other building principles, a lower structural load is realised. With this, the rate of land subsidence is assumed to be halved.

Shift to wet housing and wetlands With the shift to wet land usage, no more land subsidence or events of water nuisance are assumed. Therefore, the trigger values for these constraints are dismissed.

C Actions elaborated

In this appendix, an elaboration is presented on the process of bundling actions. In eight interviews, a total set of forty two actions is identified. To create a comprehensible pathway map, the overall set of actions is reduced to ten main actions. Below, the sub-actions are presented for every action used in the DAPP approach. Here, the related stakeholders are mentioned, together with the respective constraint that is countered.

Shift to future proof land use	***How?***	***Why?***
Province	Stimulate shift to solar meadows	Maintain revenue model despite wetness
Province	Stimulate shift to wet agriculture	Maintain revenue model despite wetness
HHSK (indirect)	Change function (or crop type)	Salinity/water nuisance
Staatsbosbeheer	Implementation of *natte lisdodde*	Initiates switch to wet nature
LTO-N	Change to salt resistent crops	Salinity
LTO-N	Change to consumer market	Water nuisance

Table C.1: Sub-actions for *Shift to futureproof land use*

Adjust the current way of agriculture	***How?***	***Why?***
Province	Extensivate agricultural land use (+ set requirements)	Maintain revenue model with less space
LTO-G	Switch crops (horticulture), more dense/capital intensive	Continuation of company with less space
HHSK	Increase drainage capacity (implement drainage tubes)	Prevent water nuisance for agriculture
LTO-N	Install underwater drainage	Water nuisance
LTO-N	Improve salt resistance of crops	Salinity
LTO-N	Install infiltration drainage	Drought

Table C.2: Sub-actions for *Adjusting the current way of agriculture*

Increase public buffer capacity large-scale	***How?***	***Why?***
HHSK	Create large (calamity) storage reservoirs	Discharge excess water
HHSK	Create large storage reservoirs	Save water, prevent drought

Table C.3: Sub-actions for *Increase public buffer capacity large-scale*

Decree fixation	***How?***	***Why?***
Province	Maintain wet soil; decree fixation	Prevent land subsidence = emission of CO2
Province	Set requirements/incentives for high water levels	Prevent land subsidence = emission of CO2
Sbb	Fixation of decree	Stepping stone to wetland
GOM	Fixation of decree	Prevent land subsidence
HHSK	Fixation of decree	Prevent salinisation

Table C.4: Sub-actions for *Decree fixation*

Tweak regional/national water provision system	***How?***	***Why?***
Province	Tweak regional/national water provision system	Prevent drought
LTO-N (province as caretaker)	Implementation stuw in NW *(Plan Sluizen)*	Prevent drought

Table C.5: Sub-actions for *Tweaking regional/national water provision system*

Increase public buffer capacity small-scale	***How?***	***Why?***
RWS	Create larger water storage capacity	-
Municipality	Increase sewage capacity	Water nuisance
Municipality	Increase (open) water storage (wadi's, etc.)	Water nuisance
Municipality	Increase infiltration rates	Water nuisance
GOM	Create bufferzones	Water nuisance
HHSK	Tweak water system (small-scale)	Prevent drought (create water storage)
HHSK	Tweak water system (small-scale)	Store water to discharge later

Table C.6: Sub-actions for *Increase public buffer capacity (small-scale)*

Shift to wet housing and wetlands	***How?***	***Why?***
Staatsbosbeheer	Adapt housing pattern to wet nature	Allows for wetland nature
GOM	Build water residences (floating houses)	Water nuisance
GOM	Build houses with elevated ground floor levels	Water nuisance
Municipality	Facilitate water residences	Prevent subsidence

Table C.7: Sub-actions for *Shift to wet housing and wetlands*

Adapt building principles	***How?***	***Why?***
Municipality	Construction with timber frame	Prevent subsidence
GOM	Insert light-weight materials	Prevent subsidence
GOM	Build houses on 'terps'	Prevent subsidence

Table C.8: Sub-actions for *Adapt building principles*

Leave the polder (agriculture)	***How?***	***Why?***
LTO-G	Move to other location	No space left
LTO-N	Move to other location	No workable circumstances (water nuisance, salinity)
GOM	Build houses on 'terps'	Prevent subsidence

Table C.9: Sub-actions for *Leave the polder (agriculture)*

Increase private storage horticulture	***How?***	***Why?***
LTO-G	Create/increase storage on land	-
LTO-G	Create concrete storage under greenhouses	-

Table C.10: Sub-actions for *Increase private storage horticulture*

D
Focus groups

This appendix will present reviews on the focus groups that are organised. Appendix D.1 presents the outcomes of the focus group with stakeholders from the Zuidplaspolder. In Appendix D.2, the second focus group is elaborated, involving stakeholders from the Schermerpolder area.

D.1. Documentation focus group Zuidplaspolder

The objective of this focus group is to determine whether the DAPP approach, i.e. the use of a pathway map, is suited to improve the adaptivity of decision- and policy making in the Zuidplaspolder. During this session, the results of the DAPP approach and the method itself are discussed with four key stakeholders. This focus group took place on the 28th of May, with a duration of one and a half hour.

This session was held in Dutch. However, due to its direct importance to main components of this research, it is translated to English. The contents of the following document were checked and approved by the attendees.

Out of the eight stakeholders considered in this research, four of them were attending this session. Due to a large overlap in overall objectives and constraints, *LTO Noord* and *LTO Glaskracht* were combined. Likewise, *municipality Zuidplas* and *GOM* were bundled. For both *Staatsbosbeheer* and *Rijkswaterstaat*, the direct influence and impact on the polder system were considered limited and were therefore excluded from this focus group.

The attending stakeholders and the function of its representative are presented below. For privacy reasons, no names will be mentioned.

- HHSK: Policy advisor on water systems, to be named **HHSK**.
- Province of South-Holland: policy advisor on water and land subsidence, to named **Province**.
- Municipality of Zuidplas: policy advisor on the public domain, to be named **Municipality**.
- LTO Noord: policy advisor, to be named **LTO**.
- Sweco Netherlands: consultant water safety and climate adaptation, to be named **Sweco**.

D.1.1. Review

First, a recap on the research methodology was presented, with a focus on the DAPP approach. Secondly, the steps towards an overall pathway map were explained. In essence, first a pathway map for HHSK was elaborated, after which the pathway maps for the province and the municipality were added.

With this map being easy to read, as the conflicting actions for LTO are not involved yet, two example pathways were presented. Furthermore, the possible outcomes of these pathways were mentioned. At this point, the first comments were given.

LTO notices that nearly all actions are within the polder apart from *Tweak regional/national water provision system*. This is one of the last actions to be considered in the map because of the high costs and effort. **LTO** also mentioned that the results of this action will affect more areas than the Zuidplaspolder only, therefore the costs and effort should be split over the entire affected area. By doing so, the bar for taking this action would be lowered. By doing so, the action would be positioned “lower” in the pathway map and chosen earlier.

Now, a pathway map was presented where the actions and interests of all stakeholders are considered. Due to its complexity, the map is split into two parts; one presenting the pathways between 2020-2055, and one for the period from 2055-2100. In the second half of the century, only one pathway was displayed to be used as an example.

LTO questioned if it is possible to reason backwards from a desired situation on a certain point in time, to know which paths could be chosen to reach it. This is confirmed by **Sweco**. Preferred paths can be chosen to reach this target. If it turns out that a (undesired) action is unavoidable, it could be chosen in an earlier stage to prevent implementing many small actions in the meantime:

"Choosing to replace the tire, instead of frequently repairing (small) punctures"

This emphasises the essence of a cost/benefit-analysis on all pathways to determine which pathway is to be preferred (**Sweco**). However, apart from the costs and benefits of actions, the impact (i.e. speed and severeness) of external changes to the system also plays a large part in the actual outcome rating of pathways.

LTO adds that a cost/benefit-analysis could lead to neglecting a part of the pathways, as there will be pathways that may be unfavourable in any circumstance. This will improve the readability and clarity of the pathway map.

D.1.2. Overall discussion

In general, the reactions the pathway map and the method were positive.

LTO states that when the two aforementioned aspects are embedded, this method would definitely be useful. Firstly, a cost/benefit analysis on the different pathways is required to make actual decisions. Additionally, the investments of actions on a larger scale should be divided on all affected areas, thus lowering the threshold to initiate this action.

The **Province** agrees with **LTO**. The **Province** has seen this method being applied before, and it proved to be useful. In particular the part of observing certain situations in the future, and to look back on how this could be realised through pathways. Especially with this complex and large type of transition processes.

Some of the moments where actions are required, are determined by governments and policies. On the other hand there are moments in time where the system becomes physically unsustainable, which is a solid incentive to adapt. Even though these moments are very hard to predict, it is important to do so. With these results, society and managers can be confronted to put their focus on the far future.

Another point that the **Province** specifies is that certain futures are imaginable where the policies and decisions are made on a national scale. An example is given with possible withdrawal from the western part of the Netherlands. Policies like that are difficult to embed in a pathway map of a small scale area, as these decisions are made when the total system is unviable.

Province recalls an old saying, jokingly used by waterboards: "Provide us our daily bread, and a flood from time to time". It indicates the need for a disaster in order to get things done for proper water management. This saying originates from a situation where there is no vision on possible futures, hence the opposite of decision- and policy-making with a pathway map.

In response, **HHSK** states that the pathway map is indeed useful. It is a powerful communication tool, both for internal and external use. Internally, it helps to start a conversation and address future challenges with managers. Externally, it can be used to show HHSK's perspective and provide clarity on their decisions to, for example, farmers.

Municipality addresses that earlier in this session, it was mentioned that the larger-scale issues and actions should not be forgotten. This is agreed, however, in certain parts of the polder (between Moordrecht and Nieuwerkerk a/d IJssel) the thresholds for salinity are already in plain sight. This makes the small-scale focus of this method extra appreciated. Especially in the Zuidplaspolder, where other issues besides salinisation are already experienced as well. In fact, the applicability on even smaller scales is requested, specifically on smaller zones within the polder. This is answered positively, although it might require more specific knowledge on the area and will probably be more labour-intensive.

On the current decision-making in local government, **Municipality** states that the time scale used in the pathway map is rarely explored. The vision of the municipality lies on the short term, mostly on the coming four years (being one election cycle). There might be an individual enthusiast within the organisation what looks into the coming twenty years at most. Furthermore, sometimes the most obvious issues are not recognised by local decision makers, and are to be explained first.

There are two reasons a technical document (like this one) might not have the effect it aims to achieve. First of all, the short term vision of the local council may cause technical reports to get lost in the appendix of another report, and not to be taken into consideration.

Besides, the pathway map contains high-impact decisions, for instance on land use with the relocation of agriculture. There are no council members that are willing to make these choices, especially for the far future. This technical document will not change this, as it is predominantly a political game.

LTO confirms that a long-term vision is lacking within municipalities. Within provinces and waterboards, there is more focus on the longer future.

HHSK notices that, when talking about political dimension in the municipality, political discussions are present at **HHSK** as well. The **Municipality** replies that water systems are the main subject for waterboards, while there is a much broader spectrum of issues to be considered in local politics. Subjects within spatial planning, and considering the far future, get insignificant attention compared to urgent and current issues.

Municipality says that the DAPP approach is useful in making decisions that are difficult regarding the costs, interests, and its direct impact on inhabitants. However, commitment from an entire organisation is required to adopt this method as their main approach in policy- and decision-making for the future.

A few prescribed advantages on the DAPP approach and the pathway maps are displayed. This sparked the following findings:

Province states that this method provides transparency and tangibility in future projections. It could justify why certain actions are implemented, or are to be implemented.

At HHSK, there is no clear vision of how the future will unfold. Additionally, half of the organisation is not convinced of the potential issues that lie ahead of them. Before a pathway can be chosen from the pathway map, some things need to change at HHSK. To start with, the pathway map can serve as an instrument to start an internal discussion. Here, a view on what lies ahead and how to deal with it can be forged.

Municipality agrees with this; the pathway map helps in making the situation comprehensible, add the issues on the agenda and think of possible solutions. Besides, a positive aspect is that the uncertainty is visualised. There are high- and low-end scenarios, but despite these uncertainties it is possible to make the right decisions over time.

LTO mentions that transparency has to do with the comprehensibility as well. This pathway map and the related matter is understandable for technical educated people, but others might struggle with understanding it. Using easy language may help in resolving this. Besides, the final pathway map should include a small summary with quick conclusions and the main story line. The ones who will read and use it, namely managers and politicians, are often short in time.

D.2. Documentation focus group Schermerpolder

The objective of the second focus group is to determine whether the DAPP approach, i.e. use of a pathway map, is suited to improve the adaptivity of decision- and policy making in other polders. For this session, the Schermer polder was used as a case. During this focus group, the usability of the Zuidplaspolder's pathway map is checked for the case of the Schermer. Besides, the overall DAPP approach is discussed with three key stakeholders. This focus group took place on the 11th of June, with a duration of one and a half hour.

This session was held in Dutch. However, due to its direct importance to main components of this research, it is translated to English. The contents of the following document were checked and approved by the attendees.

Unfortunately, a representative of the province of North-Holland was not able to attend the session. The attending stakeholders and the function of its representative are presented below. For privacy reasons, no names are mentioned.

- HHNK: programme manager spatial adaptation, to be named **HHNK**.
- Alkmaar region & municipality of Alkmaar: regional programme director climate adaptation and regional coordinator housing, to be named **Municipality**.
- LTO Noord: member of LTO Land van Leeghwater (local division of LTO Noord), to be named **LTO**.
- Sweco Netherlands: consultant water safety and climate adaptation, to be named **Sweco**.

D.2.1. Review

First, a recap on the research methodology was presented, with a special interest on the DAPP approach. A list of all implementable actions is elaborated.

HHNK notices that all of the actions considering water management are fairly common and standard in polder management. Nowadays, the focus lies more on other types of solutions, like incorporating flexibility, controlling the streams between different zones in a polder and designating areas that are allowed to flood more frequently than others. This latter action is to be implemented in accordance with other stakeholders.

As a reply, it is mentioned that those actions might suffice for small changes in a polder system, but probably not for the long term.

Now, a joint pathway map for HHNK, the province and the municipality is presented. With this map being easy to read, as the conflicting actions for LTO are not involved yet, two example pathways were presented. Furthermore, the possible outcomes of these pathways were mentioned. **HHNK** states that the map is based on a rather conservative strategy, if the current situation is constantly used as a starting point. In other words, continuing with one scenario as long as possible until it is no longer tenable. Only when the scenario is not tenable anymore, actions should be taken. This strategy is in contrast to other parties that will take instant action, in terms of the future. They will argue that actions that have been taken may be too soon, although they will be prepared for a future-proof area.

The **Municipality** reacts with a statement that public opinions are still divided regarding future-proof areas and climate adaptive decision and policymaking. "What does climate adaptive decision and policymaking enhance and what is our vision?"

Now, a pathway map is shown where the actions and interest of all stakeholders are considered. Due to the complexity, the map is split into two parts; one presenting the pathways between 2020-2055, and one for the period from 2055 to 2100. In the second half of the century, only one pathway is displayed to be used as an example. At this point, a general discussion is started to check whether the map is useful in the Schermer polder case area. If not, it is questioned what alterations are to be made to generalise the pathway map.

LTO addresses that the Schermer is a completely different area. There are no peat meadows within the Schermer polder, in consequence decree fixation to prevent CO_2 emissions is not necessary. Furthermore, all agriculture is land-based and there are no greenhouses. Besides, the Schermer polder has an abundance of sea clay. That is why cultivating crops in the Schermer consistently continues, even when it is dry season.

Additionally, the area is less affected by drought. On the other hand, this year, farmers have had more difficulties due to the wet winter and severe drought afterwards. In general, **LTO** finds it difficult to compare the entire Zuidplaspolder to the Schermer polder.

As a response, **Sweco** mentions that on one hand there is the exact, site-specific context of a pathway map, which may be various for different places in the Netherlands, in particular for polder areas in the western part of the Netherlands. Therefore, for this meeting, a different type of polder area is selected as a case. On the other hand, a methodological discussion can be conducted apart from the substantive context.

The **Municipality** confirms that this model is very interesting as a planning tool for planners. Whether it is for the Schermer or even for the entire Alkmaar region, the model prepares planners for the future and commit both politicians and other stakeholders in it. Hence, it is valuable to have a full picture of when and if actions should be taken. Furthermore, you can break down one action in the pathway map to various actions. Nonetheless, it is important to acknowledge that these actions and decisions include policies that are subjective. The policies are not objectively the truth and can simply be adjusted. The **Municipality** also finds it interesting that, based on the pathway map, one can examine what a target situation would be. With this, no ad hoc actions will be implemented that might not be necessary. By using the map, the municipality can show what goal they are aiming for and how the world of 2100 would look like, in their point of view. In this way, policy makers can never be surprised by events that happen in, for instance, 2050. On the contrary, if the municipality is using the pathway map it will make its decisions based on a clear final vision and end goal of 2100 and all actions and choices are adjusted according to that. In conclusion, as a tool it is interesting. However, one should have someone with it to explain the model.

The **Municipality** notices that the temporal scope of the method might be too far in the future. Considering the fact that policy makers of the municipality always has to cope with a political reality of four years ahead. Both government employees and stakeholders prefer to plan and look further ahead (up to 40 years), however that is often not the case.

HHNK agrees, and states that the year 2100 lies far ahead. For many people this specific point in time feels far away, particularly for businesses it is difficult to look that far into the future. Hence, **HHNK** mentions that because of that, it is difficult to examine if this method works well or is appropriate. For HHNK it would be better to move the scope of the map to 2050. That is the point in time that many policy programs and assignments are now working with. Putting the spot on the horizon too far ahead makes no sense.

When there are certain assignments that have to be realised before a certain point in time, this is a pleasant tool to examine when you have to take action. **HHNK** finds this tool particularly interesting for spatial adaptation. The year 2050 may sound far away to many people, however realising plans, in terms of spatial planning, also take a lot of time. For administrators and managers, the pathway map will be a good instrument to realise they should not start with making the city climate-proof in about 20 years. A pathway map could help administrators with making decisions, being an instrument to stimulate thinking about the future.

Furthermore, **HHNK** states that in terms of areas the Schermer is not the most appealing and suitable area. At the Schermer one does not feel a considerable amount of urgency yet, nor the need to change.

The following question is asked regarding the applied scenarios, including housing construction: "Are these scenarios also applicable for the Schermer polder?"

The **Municipality** replies that this is not the case at the moment. The addition to housing for 2050, policy-wise, will be carried out within the currently present built environment. The Schermer will not be designated for housing, confirmed by the **Province** and the state as well.

Sweco states that one can discuss the usability of the pathway map. Ergo, the conclusion of the discussion so far would be: when no issues are present, there is no need for a method that will help in dealing with future issues. Only when the first signs of problems arise, enough urgency is felt to do something about it. This is a valuable conclusion, however the question remains to what extent it is possible to make an integral pathway map for the West of the Netherlands.

Sweco mentions that for making an integral pathway map, different clusters can be created. A number of clusters, approximately 3 or 4, in which actions that are potentially applicable can be indicated. The soil type would be the main aspect, besides land use. Actions can simply be taken out or visually made less important (grey) in the pathway map, if they are not applicable for a specific polder. These are the actions a stakeholder will not take or use.

LTO states that the polders in the province of North-Holland are in good condition. For instance, the large polders in North Holland. These are well-drained areas with excellent water management. In that respect, the Beemster and the Schermer are good examples of areas where the water management is on point. A problem merely occurs due to heavy rainfall. For now the polders work pretty well, and **LTO** has the feeling that this will be the case for a long time.

Sweco addresses that, regarding the contents of the pathway map, the conclusion would be that this specific polder is too different compared to the Zuidplaspolder. This polder might have its own issues. However, it is possible that in the far future, the same issues as found in the Zuidplaspolder may occur. This may shift the pathway map's structure to the far future (beyond 2100) and make the pathway map not applicable for that polder yet. For polders in other parts of the Nederland, for instance in the southwest of the Netherlands, these challenges may already be present, making the pathway map useful at present.

LTO agrees with **Sweco**. For instance, the Eilandspolder, is completely different regarding peat meadows and natural interests.

Sweco replies that in that case, it means that one can actually work towards a number of concept pathway maps. Where one map may already be supportive for an interesting discussion now and the other might be in 20 years. Hence, you actually have to examine some basic principles. If there are some basic principles that make the foundation of pathway map in terms of water management, you could make 3 or 4 types of pathway maps to support decisions and discussion in specific polders. In the Beemster you would have a completely different discussion compared to the Zuidplaspolder.

The previous discussion mainly concerned the applicability of the map to the Schermer polder. Now, a follow-up question is asked regarding the DAPP approach: "Is the DAPP approach useful for making decisions and policy in the future? Besides, is it useful on the scale of a polder?"

The **Municipality** agrees. At the beginning of this meeting the **Municipality** already indicated what they think of the approach: the tool is useful, especially for the long term. The tool can also provide insights for administrators. Besides, it is an advantage that one can tailor the map. However, as said before, you should be transparent about what policy is underlying it. As a planning tool, it is a good and an interesting vision. The representative of the municipality would have to delve into it more to get to the bottom of it, nevertheless the municipality definitely thinks it could be an appealing tool.

HHNK agrees with the **Municipality**. At the same time, **HHNK** thinks it is especially interesting to examine what actions to take at which moments. Often, large-scale actions are avoided due to the major impact it has or the high costs. However, if you buy a lot of time with that action, it can be a good trade-off. Hence, the approach can help in decision-making and with examining what type of actions are preffered to use. HHNK finds it interesting to use it for that purpose.

LTO states that a choice have to be made: rely on technical solutions or use this type of decision-making tools. **LTO** expects that technical solutions for water management will improve over the coming years.

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