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Focus Article

Using adaptation tipping points to prepare for climate change and sea level rise: a case study in the Netherlands

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Studies on the impact of climate change and sea level rise usually take climate scenarios as their starting point. To support long-term water management planning in the Netherlands, we carried out a study that started at the opposite end of the effect chain. In the study we refer to three aspects of water management, flood defense, drinking water supply, and protection of the Rotterdam Harbour. We examined whether, and for how long, current water management strategies will continue to be effective under different climate change scenarios. We did this by applying the concept of 'adaptation tipping points', and reached it if the magnitude of change is such that the current management strategy can no longer meet its objectives. Beyond the tipping points, an alternative adaptive strategy is needed. By applying this approach, the following basic questions of decision makers are answered: *what* are the first issues that we will face as a result of climate change and *when* can we expect this. The results show, for instance, that climate change and the rise in sea level are more likely to cause a threat to the fresh water supply in the west of the Netherlands than flooding. Expressing uncertainty in terms of the period that the existing strategy is effective (when will a critical point be reached) was found to be useful for the policy makers. © 2010 John Wiley & Sons, Ltd. *WIREs Clim Change* 2010 1 729–740

INTRODUCTION

The need for adaptation to climate change is recognized more and more. Even if we would succeed in mitigation of the emission of greenhouse gases, it will take several decades for the global warming trend to be stopped. In the Netherlands, adaptation of water management to climate change and accelerated sea level rise became a policy issue in the 1990 s with the publication of the Fourth National Policy Document on Water Management.[1] In 2000, the Committee Water management for the 21st century proposed three climate scenarios that could be used to design adaptation strategies: a lower, a central, and an upper estimate.[2,3] In a formal agreement,[4] the water management community agreed to adopt the central scenario to develop a series of adaptation measures. However, only 4 years later a new generation of scenarios was provided,[5] based on new insights from the IPCC fourth assessment.[6] These scenarios showed a much wider range of possible climate changes. The new scenarios resulted in two important issues for water managers, namely: (1) formalized agreements between different administrations and designed measures appeared to be insufficient already 4 years later and (2) a central scenario was lacking as there were four scenarios

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provided, making it difficult to select a scenario as norm for the design of strategies. This experience pointed out the need to shift to an alternative approach in support of the preparation of Dutch water management for climate change and sea level rise, given the associated uncertainties.

Currently, two basic approaches are used to support climate adaptation policy on a regional and local scale, the predictive top-down approach and the resilience bottom-up approach.[7,8] The top-down approach is the most widely applied and uses climate scenarios to assess impacts. The examples mentioned in chapter 17 of IPCC WGII[8,9] follow this approach. Climate scenarios play a key role in this approach as they form the starting point to analyze impacts and prepare adaptation strategies. A limitation is the strong reliance on climate projections, which may not be applicable for the scale of the problem or purpose of the decision maker. This was one of the difficulties the Dutch water managers had to deal with in the above example. Several other reviewers have also concluded that the results of this approach were not immediately useful for adaptation policy.

Bottom-up approaches focus on vulnerability and risk management by examining the adaptive capacity and adaptation measures required to improve the resilience and robustness of a system exposed to climate change.[8] This approach is more independent of climate projections and can even be done without them. A successful example is the Thames 2100 study in which a bottom-up approach was used to identify flood defense measures along the Thames and prepare a flood defense plan in order to delay the replacement of the Thames storm surge barrier as long as possible.[10] However, critique regarding the bottom-up approach is also encountered, specifically regarding its applicability. The critique encountered predominantly concerns the lengthy time to perform an assessment and the perception that the studied system is too complex for a proper comparison of all the drivers. It has been concluded, for example, that 'vulnerability assessment often promises more certainty, and more useful results, than it can deliver' (Ref 11, p. 411). Another disadvantage of the approach is the greater reliance on expert judgment and qualitative results.[12]

In order to enhance the transparency and reproducibility of the bottom-up approach and make it more applicable for decisions in water management adaptation, we developed the concept of 'adaptation tipping point (ATP)'. The objective of our study was to apply and test the concept for the Netherlands, and analyze the support of decision making on water management strategies. In the following sections, we elaborate on the approach and illustrate ATPs from a historical perspective. Then, ATPs in the Netherlands water management system that may be reached in the near future due to climate change are identified. The focus of the analysis is on flood defense, drinking water supply, and protection of the Rotterdam Harbour.

ADAPTATION TIPPING POINT APPROACH

In the context of climate change, adaptation refers to actions targeted at a specific vulnerable system, in response to actual or expected climate change, with the objective to either limit negative impacts or exploit positive impacts.[13] Adaptation involves dealing a.o. with the predictability of climate change (some aspects of climate change such as temperature rise can be predicted with reasonable confidence, whereas others are surrounded by more uncertainties); non-climatic conditions (it occurs against the background of current and future use of the specific system); timing (proactive or reactive); and time horizon (short- or long-term actions).[14,15] Adaptation planning focuses on the use of information about current and future climate and reviewing the suitability of current and planned management.[12]

The term tipping point is introduced in climate change research literature to indicate the point where a system change initiated by an external forcing no longer requires the external forcing to sustain the new pattern of change.[14,16,17] An example is the irreversible decay of the Greenland ice sheet.[18] In a slightly different sense, the concept also plays a role in greenhouse gas (GHG) emission policy when setting a standard for GHG reductions. The reductions should be such that global temperature rise at the end of this century should not exceed 2°C. Although many reviews in scientific literature[19–21] suggest that 2°C cannot be regarded as harm-free or 'safe', many believe that beyond this limit, the behavior of system earth will approach 'terra incognita' and might lead to dangerous impacts.[22] An additional 2°C as an ATP is also adopted in 1996 and recently (March 2005) reconfirmed by the European Council as a long-term EU climate target of limiting the global mean temperature. In climate change communication, the use of tipping points often illustrates 'points of no return'.[17,23]

We define ATPs as points where the magnitude of change due to climate change or sea level rise is such that the current management strategy will no longer be able to meet the objectives. This gives information on whether and when a water management strategy may fail and other strategies are needed.

An ATP analysis starts from the perspective that a water system provides the natural boundary

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conditions for living and working, i.e., for all socioeconomic activities. The system needs management to maintain the proper conditions and achieve objectives for living. In case of climate change and sea level rise these conditions change, resulting in a possible failure of the current water management strategy. At that moment an ATP is reached. Exceeding an ATP does not mean that water management is not possible anymore and that we might face catastrophic consequences. It simply means that alternative strategies are needed to manage the system. From this viewpoint, adaptation to climate change in itself has no value; it is aimed at sustaining human activities and preserving ecological values. Climate change only becomes interesting for policy makers if it would lead to alternative decisions about water management strategies. In other words, the driver for taking action is not climate change, but failing to meet the objectives.

Reaching ATPs might have physical, ecological, technical, economic, societal, or political causes.[24] An example of a physical boundary is the possible shift of aquatic habitats in case of sea level rise, limited by natural dunes or artificial barriers such as dikes. Technological economic ATPs may occur if the investments needed to adapt are larger than the economical benefits. Society may change its values and standards, resulting in different objectives, which may cause an ATP or may shift the timing of an ATP.[25,26] Political processes can make it unlikely to carry out a decision in time.[27] Because of these different boundaries, climate change should be considered as one of the issues (not necessarily *the* issue) to take into account the strategy development.[8,28–30] Other socioeconomic developments may, either in combination with climate change and sea level or on its selves, result in (earlier) ATPs.

The ATP approach differs from the classical top-down approach and contains elements from a vulnerable bottom-up approach. In the classical top-down approach to climate adaptation (see Figure 1; left panel), the underlying question is: 'What if climate changes or sea level rises according to a particular scenario?' This is followed by analyzing the cause-effect chain from pressures to impact (the PSIR concept[31]). If the impact is such that policy objectives are not achieved, adaptation measures are defined to overcome this problem. Then the chain is analyzed again, answering the question: 'What if this particular scenario becomes reality and we implement measure x, are the objectives achieved then?'

In the ATP (bottom-up) approach (see Figure 1; right panel) the underlying question is: 'How much climate change and sea level rise can the current strategy cope with?', and the analysis starts at the other end of the cause-effect chain. Policy objectives for

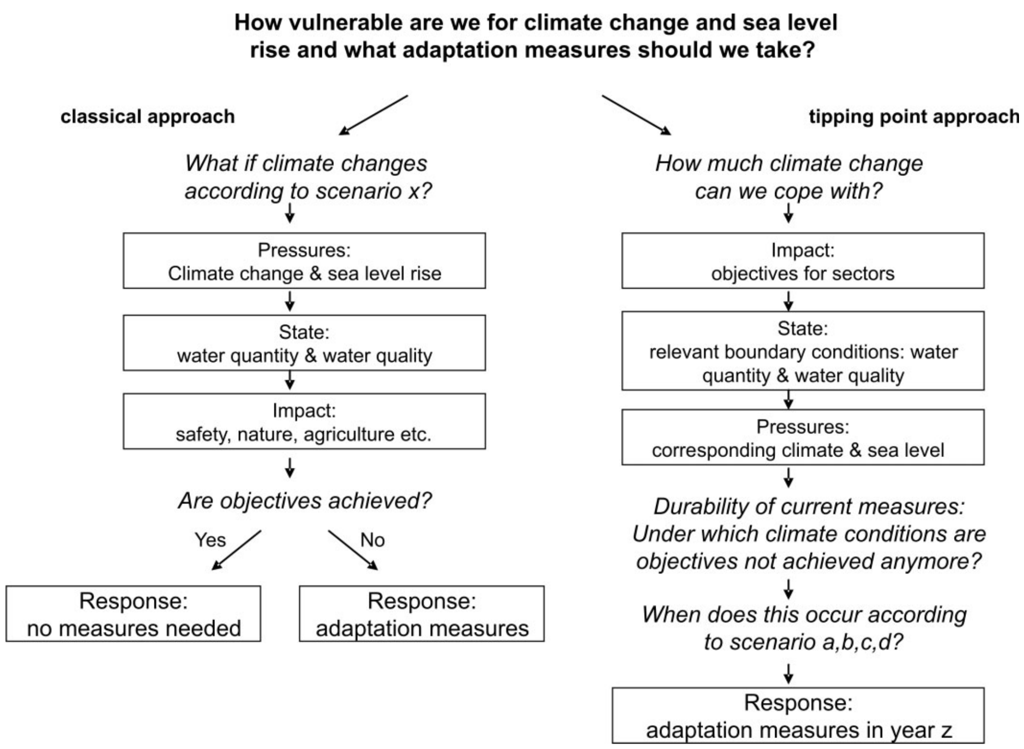

FIGURE 1 | Classical top-down approach and adaptation tipping point approach to develop adaptation measures.

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different sectors and areas are taken as a starting point. Then, the current measures to achieve these objectives are described. This is followed by a sensitivity analysis to determine the optimal and critical boundary conditions (state), e.g., for river navigation, water depth is an important boundary condition. A water depth larger than 4 m results in optimal conditions; at lower water levels, the suitability of the river for navigation gradually decreases to a critical minimum where no shipping is possible anymore. The state of the water system described in terms of relevant boundary conditions can be related to pressures in terms of climate and sea level. To do this, intermediate steps are sometimes needed. For example, in the case of river navigation, water depth needs to be related to river discharges.

The ATP approach focuses on defining if and when adaptation strategies are needed, thus enabling policy makers to plan the adaptation. The examples we give are ATPs from a physical and ecological point of view, considered as exogenous limitations. Identification of ATPs by no means guarantees successful adaptation. Adger et al.[25] identify four elements limiting the successful adaptive response of the society. These limitations are due to: (1) ethics, as diverse objectives within society imply that the interpretation of 'successful' is not uniform; (2) lack of knowledge about the future, resulting for instance in being too late; (3) perception of risk, resulting in a low sense of urgency; and (4) undervaluing of places and cultures, as valuing methods do not include cultural and symbolic values leading to a limiting range of actions.

DETERMINING THE NATURAL BOUNDARY CONDITIONS IN THE DUTCH CASE

In the case study for the Netherlands, we focus on physical and ecological ATPs driven by climate change and sea level rise. For this purpose, we used the results of various simulation studies (hydrological, hydraulic, morphodynamic, ecological, and impact models) to determine the sensitivity of different sectors and associated objectives to sea level rise and climate change.

To investigate morphological behavior of the coast on the large scale associated with climate change, a large-scale model of the Netherlands coastal system was available, based on a combination of different model concepts.[32–39] Sediment balance studies of the system were based on the national database for geological data and the geological mapping program of Deltares/Geological Survey of the Netherlands.[40] In addition, for the active subsystems of the coast, bathymetric data were used from the database on bed level monitoring of the Directorate General of Transport, Public Works, and Water Management dating back to beginning of the 20th century.[41]

For rivers and estuaries, the tools include a hydrological–hydraulic system to simulate river discharges in the Rhine and Meuse basins[42,43] as well as a weather generator to allow generating synthetic discharge series.[44] A hydraulic modeling system allows simulating water levels as well as water quality in the southwest estuary and tidal areas.[45,46] In the tidal area, the assessment of the water levels and salt intrusion was carried out by executing a Monte Carlo analysis using a one-dimensional hydrodynamic model with different sea levels and upstream boundary conditions. A national groundwater and water distribution model is used to estimate the effects on groundwater, agriculture, and water level management of lakes and small ditches.[47–49] An ecological model is used to assess the effects on the availability and quality of habitats.[50]

Climate change projections were used to time the ATPs. For the Netherlands, these projections were based on the IPCC 2007 fourth assessment[6] as published by KNMI.[5] High-end scenarios, beyond the range provided by IPCC, are published by Vellinga et al.[51] These projections were used in this study to establish linear temporal trends of temperature, rainfall, evaporation, and sea level rise (Table 1). Then these linear trends were used to force the various modeling systems; next, these results were used to determine the earliest and latest date that a strategy is no longer effective. Earlier studies[27] have investigated the sensitivity of the Rhine Meuse delta to even higher sea levels than in our study. However, more recent estimates of sea level rise[51] indicate that the rates of rise as assumed by Olsthoorn et al.[27] do not seem plausible.

HISTORICAL ADAPTATION TIPPING POINT IN THE NETHERLANDS

The long-term development of a low-lying deltaic area such as the Netherlands (Figure 2) is determined by a delicate balance between demand and supply of sediments.[52] This delicate balance may provide a system tipping point in deltaic formation.[53] Sediment demand is dependent on the change in hydraulic boundary conditions (e.g., a rise in sea level) and the initial topography of the coastal area, which together determine the (potential) accommodation space for sedimentation. Sediment supply is dependent on the availability of sediment resources and the

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TABLE 1 | Minimum and Maximum Climate Change and Sea Level Rise Scenarios for 2100

	Smallest		Largest	
	Winter	Summer	Winter	Summer
Temperature change	+1.8[1]	+1.8[1]	+4.6[2]	+5.6[2]
Rainfall change (%)	+8[1]	+6[1]	+28[2]	−38[2]
Evaporation change (%)	0[1,2]	+6[1]	0[1,2]	+30[2]
Sea level rise (cm)	30[1]	30[1]	105[3]	105[3]

[1]Based on the KNMI-G scenario (moderate change) for 2100.[5]
[2]Based on the KNMI-W+ scenario (large temperature and circulation change over Europe) for 2100.[5]
[3]Based on the high-end sea level rise scenarios for 2100.[51]

FIGURE 2 | The Rhine–Meuse delta.

transport capacity of the hydro- and aerodynamic forces within the system. The coastal evolution of the Netherlands during the Holocene illustrates the role of the sediment balance.[40,54,55] During periods with a negative sediment balance, the coastline retreats; when the balance is positive, the coastline extends. A lack of sediment supply is responsible for the retreating trend of the coastline during the last centuries.

Through time, man has applied different strategies to cope with the ever-changing physical conditions in the low-lying grounds of the Netherlands. The history of human occupation of the country has been previously shown in Refs 56–58.

From ca 2500 BP, artificial dwelling mounds have been built in the northern, 'swampy' part of the country, in response to a rising sea level causing more frequent flooding. In fact this might be considered the first major adaptation tipping point in occupation strategies: active interference with the physical conditions raising ground levels.

The era of water management started around 1200–1000 BP, when population increased and dwelling mounds became too small to accommodate the people. In parallel, agriculture became an increasingly important activity. Techniques were developed draining the extensive peat areas in order to create agricultural land. Around 800 BP another major ATP was passed, when the development started of dike systems and active drainage by pumping. During the following centuries, this system of water management has been optimized by successive technical, organizational, and financial innovations.

A more recent major ATP was reached toward the end of the last century. The Eastern Scheldt storm surge barrier, the final piece of the Delta Project protecting southwest Netherlands against flooding, originally designed as a pure flood defense structure, developed into an integrated design. An increased ecological awareness and social and political pressure resulted in the decision for an open barrier, not only serving safety against flooding but also ecological values and shell fisheries interests. The integrated approach that was developed to achieve this had to consider the entire estuarine system. During this process, the importance of the sediment balance for long-term morphodynamic boundary conditions gradually became apparent.[59,60]

In 1990 this resulted in a strategy change, when in the Netherlands a coastal policy was adopted based on the principle of dynamic preservation of the sediment balance.[61] Sand nourishments to an amount proportional to the yearly sediment deficit must be guaranteed to achieve the objective.[62] Since 2000 the yearly nourishment volume is 12 Mm^3.

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ADAPTATION TIPPING POINT IN CURRENT DUTCH WATER MANAGEMENT

As typical examples of the evaluation results of current water management in the Netherlands, we will focus on flood defense, the protection of Rotterdam Harbour, and fresh water supply.

Flood defense

To ensure safety against flooding, safety levels for all flood defenses in the Netherlands, including the dunes, have been established by law.[63] Coastal dunes must be able to withstand a storm event with a certain frequency of exceedance. The allowable frequency of exceedance is 1 in 10,000 years for the Holland coast, and between 1 in 4000 and 2000 years for the Delta coast and Wadden islands. For dikes along the tidal rivers in the western part of the country, it is between 1 in 2000 and 4000 years (Figure 3).

Additionally, for the coast the Water Act prescribes the preservation of the coast line at its 1990 position. This requirement ensures the maintenance of morphological boundary conditions for dune growth, and as such the sustainable preservation of safety levels. Preservation of the sand balance by sand nourishments started in 1990 and has shown to be effective at the present rate of sea level rise.[33,57]

For the coast, an increase in sea level rise might be compensated by a proportional growth of the yearly nourishment volume. An increase in rise from the present 2 mm/year to between 3.5 and 10.5 mm/year until 2100 would require a sand volume of 25 to 74 Mm^3/year (i.e., between two- and sixfold of the present yearly amount). Technically and financially this is regarded as feasible. Nourishments have been politically and socially accepted, and sand resources in the North Sea are abundant. Spatial reservations for future sand mining purposes must be able to safeguard ample availability. Optimization of both sand mining and nourishment must be able to meet ecological

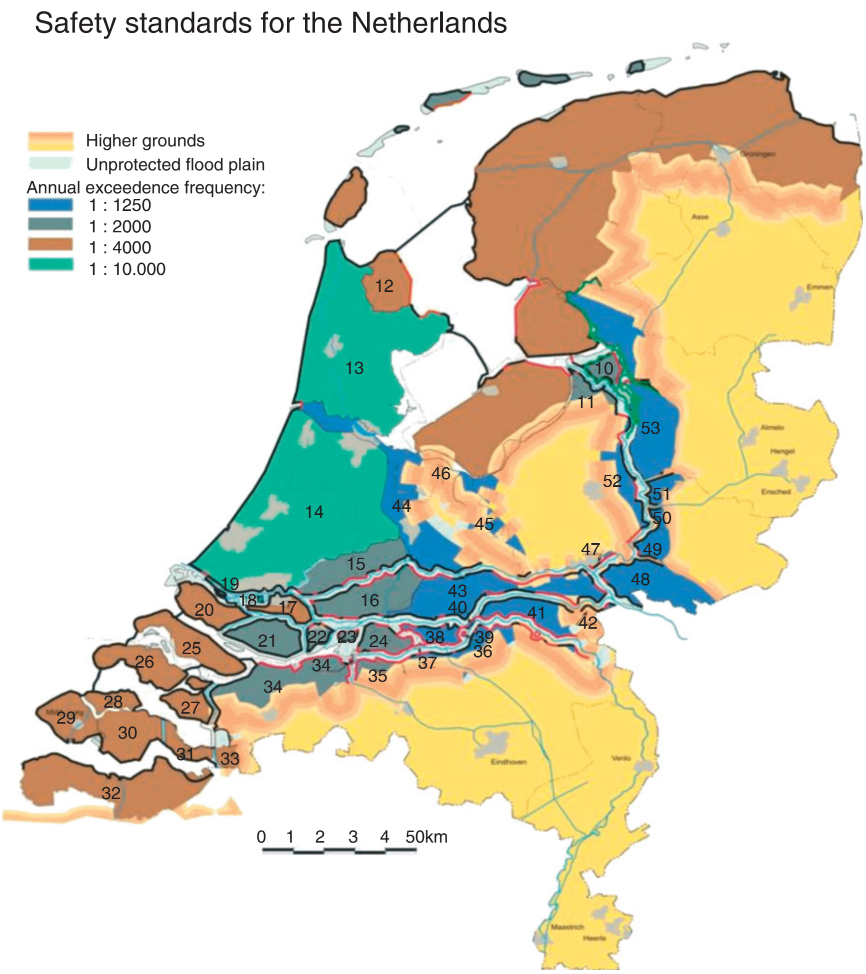

FIGURE 3 | Flood safety standards in the Netherlands.

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requirements. Thus even in the most extreme sea level rise scenario, the existing policy of protecting the sandy coast is not likely to encounter an ATP.

For dikes along the tidal river area in the western part of the country, technically and financially, no major ATPs are expected. Dike reinforcements and innovations must be able to cope with more severe hydraulic boundary conditions; expenses will grow, but remain feasible. Potential ATPs might arise on the social and political level. For example, the social acceptability of living behind giant dikes might decline, and increasing spatial claims of ever-larger dikes might invoke innovations in governance arrangements.

Protection of the Rotterdam Harbour

The Maeslant Barrier (Figure 4) is essential in the protection of the Rotterdam Harbour and tidal river area against flooding. In this region, the dikes are designed to withstand water levels that have a probability of occurrence between 1/10,000 and 1/4000 annually. To meet this safety level, the barrier closes if the water level at the outlet of the Waterway exceeds 3 m or exceeds 2.90 m upstream at Dordrecht. The return period of such an event is approximately 10 years. Rising sea level implies that the barrier will close more often. However, closing the Maeslant Barrier hinders navigation to and from the Rotterdam Harbour. According to the Rotterdam Port Authority a maximum closing frequency of one per year is acceptable. This is considered an ATP. The closing frequency of the Maeslant Barrier depends on the sea water level, the duration of storm events, and the discharge of the rivers. Once closed, the discharge of the rivers and the period the gate is closed determine the water level rise landward of the barrier, causing a back-water effect and forcing parts of the river flow to follow a route more south into the southwest estuary. Figure 4 shows that an 85-cm sea level rise would mean that the barrier would close approximately once every year. Another ATP is the maximum sea level rise the barrier has been designed for, which is 50 cm.

Fresh water supply

The tidal river area is crucial for freshwater provision (drinking water and agriculture) in the southwest of the Netherlands (Figure 5). A rising sea level and reduced river discharge during dry summers lead to extra salinization of the groundwater and surface water. An ATP for this sector would occur if sea level rise in combination with lower river drainage results in an inability to maintain salt concentrations at a level low enough to maintain key functions. Water allocation has been established in a series of water agreements between national and regional administrations. To meet the requirements, the maximum allowable chloride concentration in the inland water system is 250 mg/L. Under current conditions, the inlet of fresh water needs to be closed once between every 5 and 10 years[64] to protect against saltwater intrusion. However, the frequency and duration of necessary closure of fresh water inlets

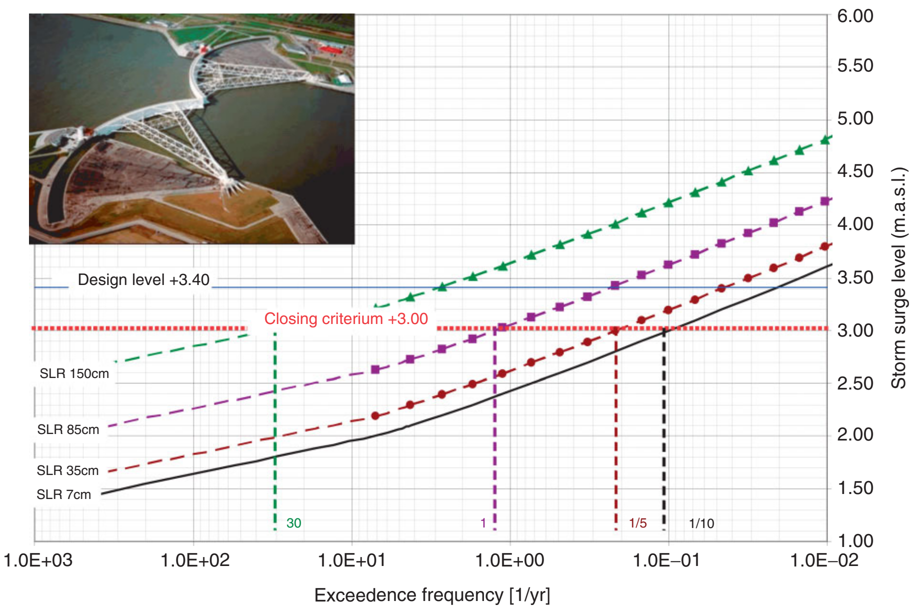

FIGURE 4 | The storm surge barrier (Maeslantkering) to protect the Rotterdam Harbour and exceedance frequencies (per year) of water levels in the Rotterdam Harbour assuming a sea level rise between 0 and 150 cm (Reprinted with permission from Ref 24 Copyright 2008).

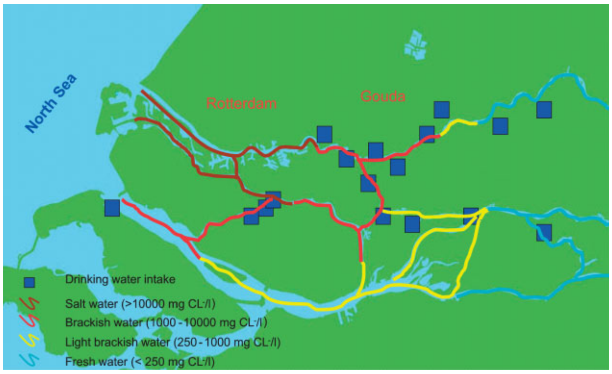

FIGURE 5 | Chloride concentrations and drinking water intake points along the tidal rivers in southwest Netherlands.

rapidly increase with rising sea levels and decreasing river discharges.

The present tolerable closure duration of a water inlet due to elevated chloride concentrations, varies between 12 and 48 h at the main inlet points within the region. Model results show that within the range of the current climate scenarios, elevated chloride concentrations can be expected for much longer periods at a sea level rise of 35 cm. For a strategic inlet such as Gouda, along the Hollandse IJssel river, the number of days inlets must be closed in an average meteorological year will increase from 0 to 76 days. Discussions with local water managers have indicated that this is such a dramatic change, that adaptive measures are considered insurmountable.

TIMING OF AN ATP: AVAILABLE TIME BEFORE ADAPTATION MEASURES NEEDS TO BE IMPLEMENTED

To estimate the maximum and minimum periods before decisions on adaptation measures in the Netherlands, we use the KNMI 2006 scenarios[5] as well as the high-end scenarios[51]: sea level rise until 2100 may vary between 30 and 105 cm (Table 1).

With respect to flood protection of the sandy coast and tidal river area, the current strategy can be continued within the evaluated range of sea level rise. This means that the current strategy is robust at least until the end of this century.

The Maeslant (storm surge) Barrier can be used to protect the Rotterdam Harbour up to a sea level rise of 50 cm. According to the upper limit of the considered range of sea level rise—a worst case of 105 cm in 2100 relative to 1990—this will be reached around 2050. Under the same worst case conditions, closing of the barrier would exceed a frequency of once a year only a few years later. Apparently, around 2050 sea level rise for the first time might present an ATP for the protection of Rotterdam Harbour. This ATP would lead to a reconsideration of the way the harbour needs to be protected.

Fresh water supply in the western part of the Netherlands will be hindered to an unacceptable level if the sea level would rise by 35 cm relative to 1990. In the worst case, this ATP would occur around 2030.

According to the lower limit of the considered range of future sea level rise (35 cm in 2100), the Maeslant storm surge barrier would remain effective and fresh water supply in the Netherlands would remain acceptable until 2100.

DISCUSSION

The classical approach for the development of adaptation strategies is to use one or more climate scenarios as a starting point for impact assessment and define adaptation strategies based on the impacts. This top-down approach is useful to explore possible adaptation strategies. However, the results of such studies strongly depend on the chosen scenario(s) and the assumptions concerning scientific and socioeconomic uncertainties related to these issues. Furthermore, each time new insights into climate change arise, physical boundary conditions alter and existing water management strategies are challenged. This poses an important pitfall to management. For example, in water management of the Netherlands one scenario as best estimate was taken as basis for the current strategy. Consequently, other scenarios and other possible futures which might have given useful information for the development of alternative adaptation strategies were ignored.

A bottom-up approach, i.e., a vulnerability assessment of the management system, has received remarkably little attention so far. The majority of studies starts top-down with one or more climate change scenarios and then tries to design strategies. In a vulnerability assessment using ATPs presented in this paper, we answer the basic questions of decision makers: *what* are the first issues we will face as a result of climate change and *when* can we expect this?

Relating climate change directly to the current water management strategy and expressing uncertainty in terms of the period that the existing strategy will be effective (when will a critical point be reached) in a practical way provides valuable information about ‘what’ and ‘when’ to decision makers. The result is a better dialogue between the scientific and water management world.

The ATP approach stimulates policy makers to look at sensitivity of sectors and durability of

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a strategy under different conditions. Critical limits may be exceeded at a particular condition of climate and sea level, resulting from either climate variability or climate change. In this way it may become clear that also in the current situation, due to climate variability there may be a reason to adapt the strategy. It also enables easier assessments to balance the risk of climate change with other risks.

Application of the ATP approach is relatively easy under the condition that management objectives are clear and quantified. Particularly for flood protection this is often the case. Application becomes more difficult if well-defined standards are lacking. In these cases we propose two approaches to determine ATPs: (1) by presenting fuzzy objectives and a period during which an ATP may occur; (2) by interviewing responsible authorities or stakeholders (e.g., this approach was followed for the fresh water intake assessment); and (3) by comparing expected climate—or sea level change with variations observed in history. The latter approach assumes that the current strategy is designed to cope with the current variation. As long as the change remains small relative to the observed variation, it implies that in near future climate change may not be the main reason to adapt the water management strategy, but that other (socioeconomic) drivers will be at least as important.

The concept of ATP strongly depends on the objectives defined. These objectives may, however, change in future as a result of different values and norms of future society, or maybe even within society. In this case the timing of an ATP may shift.

The method can be elaborated further to identify adaptation pathways in the future. For example, after an ATP has been reached, a new water management strategy is needed. In turn, this strategy will imply a new ATP. Analyzing different options and ATPs may result in adaptation pathways showing different water management options and possible dead ends once a water management strategy has been chosen.[65]

CONCLUSION

A bottom-up approach to assess vulnerability of the Netherlands water management system to climate change and sea level rise in terms of ATPs has been successful in answering the basic questions for decision makers: *what* are the most urgent effects and *when* will these occur?

The results are less dependent on climate projections, than a traditional top-down approach starting from climate scenarios. In addition, an analysis of ATPs provides a lot of information about the system and its weaknesses. This way it is easier to indicate potential consequences for planned measures in case new climate projections will occur in future.

The method has proven to be clear and practical, and more important, to support decision makers in dealing with future uncertainties. The best indication for this is the fact that the results of the approach have been approved by the Advisory Council for Transport, Public Works, and Water Management, in an advice to the Dutch Ministry concerned with water management issues.[66]

The results of the case study have contributed to the basis of long-term planning in the National Water Masterplan 2009–2015.[67] Findings of the research have also been input to the authoritative study on future adaptation options by the second governmental Delta Committee.[68,69] The analysis concluded that the first sector to be affected by an ATP due to increased sea level will not be flood protection, but rather fresh water supply in the western part of the Netherlands.

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