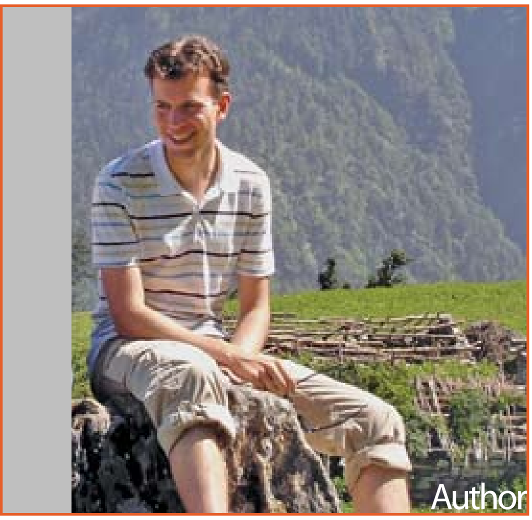
Water storage to protect our polders from flooding

Strategies for preventing water inconvenience resulting from intensive

Abstract

Without flood protection, two-thirds of the most intensively used part of the Netherlands would be flooded every day. In addition, climate changes are expected to cause sea levels to rise and rainfall patterns to intensify. These developments will in turn cause *polders* to flood more often. The Vlietpolder, a *polder* district located in the greenhouse area of the Netherlands, is one of the areas facing this problem. A hydrological model was used to simulate several flood protection measures in this *polder* during extreme rainfall events. Upstream measures and measures applying multifunctional land use were shown to be best suitable for the Vlietpolder.

by Erik Horstman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1 Introduction

The Netherlands is located in the delta of the Rhine, Meuse, and Scheldt river basins and is known for its everlasting struggle against floods. About 25 percent of the Netherlands lies below mean sea level. If there were no dykes and dunes along the rivers and coasts, about two-thirds of the most densely populated areas of the Netherlands would be flooded every day (Van Stokkum, Smits, & Leuven, 2005).

Two developments are pushing the need for increased flood protection levels. On the one hand, there is the ongoing economic development and population growth, both increasing the land use density and the social costs associated with floods in these highly developed areas. On the other hand, the expected global increase in temperature will lead to a sea level rise and increasing extremes in rainfall patterns. Rising sea levels and the discharge of increased amounts of precipitation through river basins will cause problems since not enough room remains to transport this water safely.

The lower part of the Netherlands consists of numerous *polders*. This study focuses on the Vlietpolder, which is located within the jurisdiction of the Delfland Water Board, one of the 27 water boards in the Netherlands. The Vlietpolder covers the triangular area between The Hague, Rotterdam, and Hook of Holland. Its land is used intensively, and includes the urban area of Naaldwijk.

Currently, the Vlietpolder already faces problems with discharging water in case of extreme rainfall. This problem will increase during the coming years due to the developments stated above. The initial solution identified by the water board in order to prevent flooding was to store water in the Wollebrand pond located in this *polder*. The goal of this study was to identify whether or not this measure would be effective and, if not, which other options are available to prevent water problems in the *polder.*

2 Water management in the Vlietpolder

Surrounded by dykes, *polders* form separated water systems that need pumping stations to drain rainwater from the *polder* water system to the *boezemwater* system[1]. From this *boezemwater* system, the water is subsequently pumped towards one of the large rivers or directly towards the sea. This *boezem* system has a higher water level than the *polders* and forms a transition zone between the *polder* water levels and the higher water levels of the rivers or the sea (Figure 1).

This system of pumping water from lower areas to the main water system faces limitations. Pumping capacities are limited and so are discharge capacities, defined by the bankfull discharge, in the *polder* and *boezemwater* systems. The discharge capacity may be too small when heavy storms occur. Either the pumping capacities may be insufficient or the *boezemwater* level may be too high to discharge water from the polder to the *boezem* and flooding will occur in the *polder.*

Land use in the Vlietpolder is very dense, including abundant cultivation of flowers and vegetables. Greenhouses occupy 42% of this *polder's* total surface area of 429 ha, and a total of 77% of the surface of the *polder* is hardened by greenhouses, businesses, houses and roads (Peijnenborgh, Van der Beek, & Van Bemmel, 2005). These areas discharge the rainwater rapidly to the *polder* water system.

The water system of the Vlietpolder consists of several main canals, all discharging into one pumping station, which drains to the surrounding *boezem* system. Furthermore, there are fourteen separate subsystems within the *polder*; all of them maintain a specific water level, varying from 1.90 m below sea level in the lowest part to 0.55 m below sea level near the pumping station.

3 Extreme events

Since flooding is a recurring event in the Netherlands, there are elaborate safety norms prescribing safety levels within certain areas. The National Policy Document on Water prescribes that urban areas should face inconvenience through rainfall not more than once in 100 years, equivalent to a maximum probability of flooding of 1:100 per annum. For greenhouses this maximum tolerated probability is 1:50 per annum and for pastures it is 1:10 per annum (Ministry of Transport, Public Works, & Water Management, 2003).

To develop safety measures for future extreme rainfall events, estimates of the maximum rainfall intensities in the year 2100 are available. These figures are based on expectations of the Dutch Commission on Water Management in the 21st Century (2000) concerning the increase in rainfall intensities and on current rainfall characteristics for this area (Meeuwissen, 2000, pp. 132–160). The figures, shown in Table 1, are modelled as separate design storms for every frequency of occurrence. Based on rainfall measurements, it is assumed that the design storms can be described by Gaussian curves representing normal distributions.

Storm frequency	24 hours	48 hours
1:10 per annum	63 mm	75 mm
1:50 per annum	82 mm	95 mm
1:100 per annum	92 mm	101 mm

Table 1. Design storms describing extreme rainfall in the year 2100, for which the water system should be designed. Compare the current annual average rainfall in the Netherlands, which is about 750 mm.

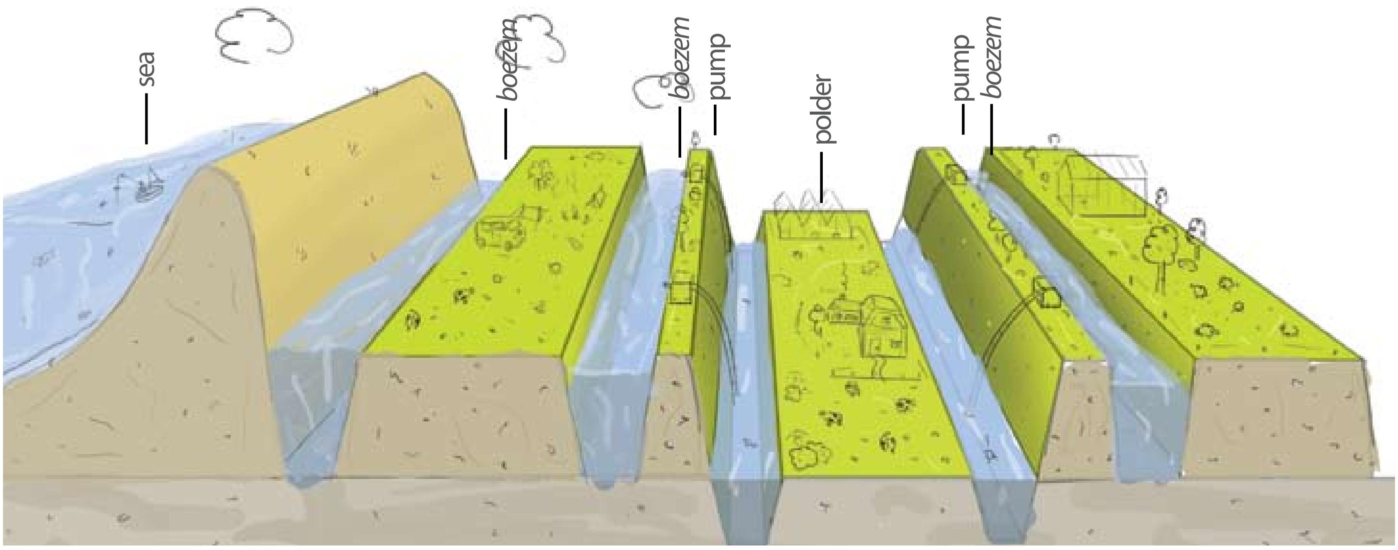


Figure 1: Water systems in the lower parts of the Netherlands consist of polders below sea level, from which water is pumped to the boezemwater. Boezem pumping stations drain into the rivers or the sea.

In the case of extreme rainfall, there is also a threat of overloading the *boezem* system due to increasing pumping discharges out of the *polders*. When the water level of the *boezem* system exceeds the maximum permitted level, pumping stations are closed down. This so-called 'pumping stop' may increase the water problems within the *polder*. Therefore, to model the worst-case scenario, the design storms were to be combined with a non-operating pumping station.

4 Modelling the water system

SOBEK One-Dimensional, a software package developed by WL|Delft Hydraulics for flood forecasting, modelling drainage systems, etc., was used to model the flow in the Vlietpolder. The hydraulic simulation only models the longitudinal flow behaviour in the separate channels, which is assumed to be a suitable level of detail to study the water flow balance in the entire polder. The SOBEK schematic representation of the Vlietpolder was already available at the Delfland Water Board.

'…urban areas should face inconvenience through rainfall not more than once in 100 years…'

In the SOBEK schematic representation (Figure 2), channels are represented as line elements with cross-sections, friction characteristics, and structures within the watercourse. Land use characteristics are compressed into point elements with a certain surface area and are linked to the water system to represent the ability to discharge rainwater.

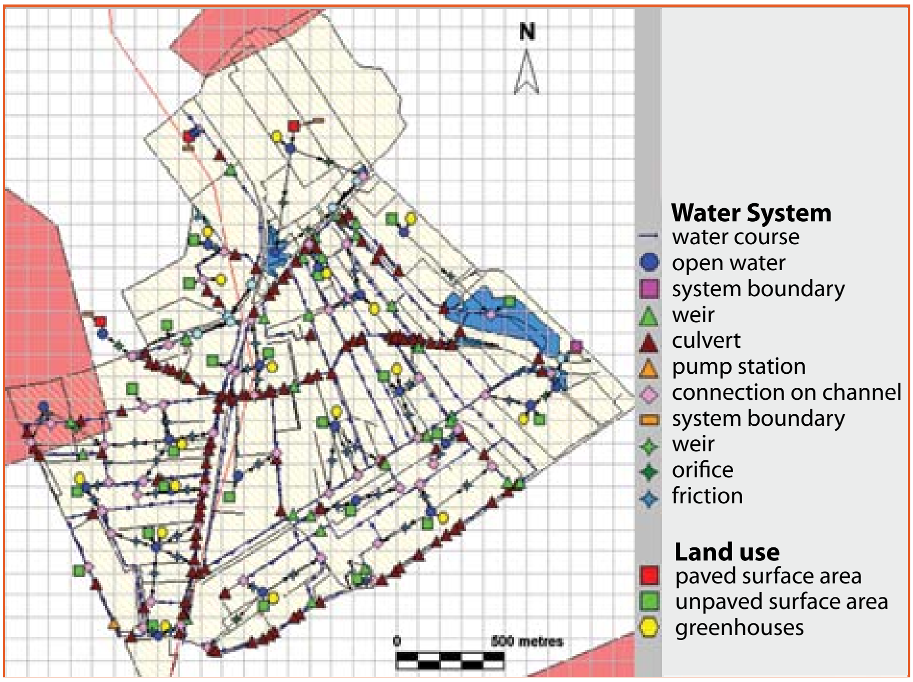


Figure 2. A screenshot of the representation of the Vlietpolder in SOBEK.

The model input consists of the following: rainfall; land use; ground characteristics; and the draining system consisting of ditches, canals, ponds, pumps, and other structures. Within the model, the rainfall comprises several runoff subsystems: surface discharge, groundwater flow, evaporation, and storage. Rainwater will only partially discharge to the open water system. This supply of rainwater causes a channel flow, influenced by the dimensions and characteristics of the channel and the operating structures within it like culverts, weirs, orifices, and pumping stations. The discharges of the water courses are calculated within the model and are converted into water levels. Next, the derivation of the differences in height between the water levels and the

[1] A *boezem* is part of the stepwise drainage system of the Dutch *polders*. Pumping stations drain the excess water from the *polders* into the *boezem* which forms a network of canals and sometimes small lakes, surrounding the *polders*. This *boezem* is also used to collect run-off from higher areas, named '*boezemland*'. The *boezem* system maintains an intermediate water level between the water levels in the *polders* and the sea level. Eventually, the water from the *boezem* system is drained into the rivers or the sea.

bottom levels of the areas adjacent to the water courses are calculated. The resulting values are called 'draining depth' or 'free-board' and a negative value indicates a flooding of the area adjacent to the watercourse.

The shortcomings of the model and the available schematic representation of the *polder* caused some important uncertainties. Some mistakes in the maintained water levels, levels of culverts, and locations of weirs in the *polder* representation had to be corrected; an entire canal was missing and had to be added to the model. In addition, an error in SOBEK was encountered in the input values for water storage capacities of watering basins receiving rainwater discharged from greenhouses.
It required the model input to be divided by a factor of 10^4. The modeller will correct this error in future editions of the program.

5 Assessing the current situation and the initial solution

Effects of the design storms on the current water infrastructure in the *polder* were evaluated, using the currently prescribed protocol. This protocol requires a general lowering of the water level in the *polder* when an extreme storm is expected and facilitates limited water storage in the Wollebrand pond, located next to the pumping station, during a pumping stop (Delfland Water Board, 2004).

The initial solution proposed by the water board necessitates extending the storage capacity of the Wollebrand pond and using this capacity for temporary storage in emergencies. This should be realised by separating the pond from the rest of the water system by closing the culverts connecting the pond to the entire *polder* water system and by activating an emergency pump. This solution was also simulated.

From the outcome of the simulations, it became clear that neither the current protocol for handling extreme rainstorms, nor the initial solution, was sufficiently effective to protect the Vlietpolder against flooding. In the worst-case situation of 101 mm rainfall combined with a pumping stop, large parts of the Vlietpolder flooded. Even less serious events caused flooding in areas that should stay dry.

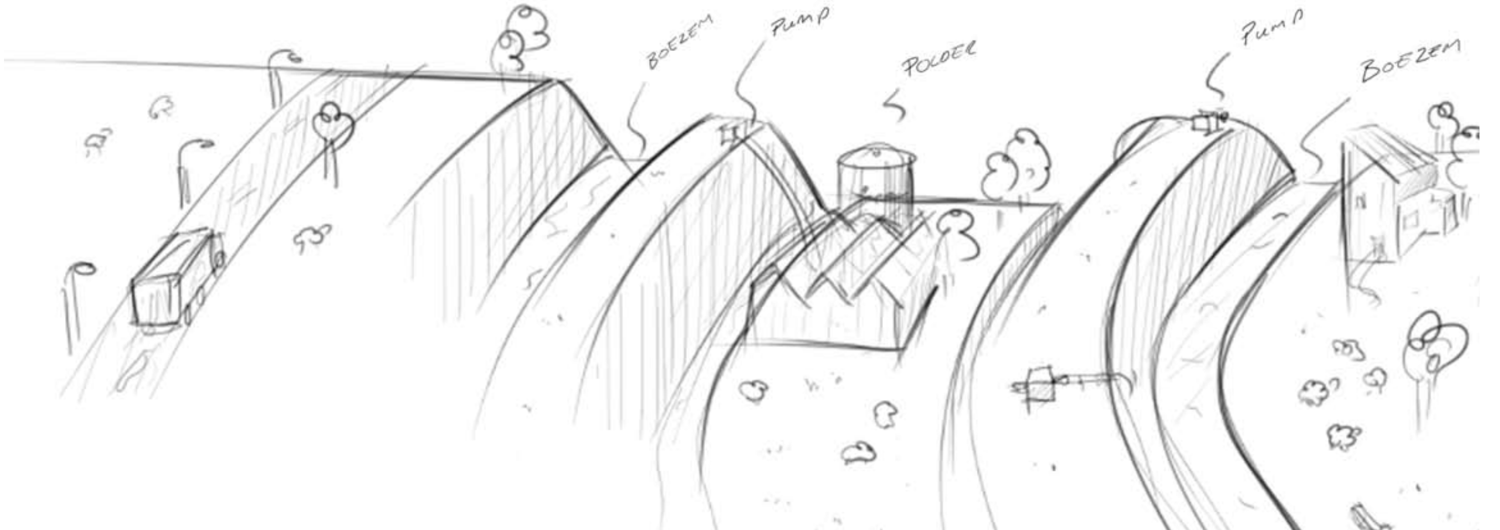
The conclusion from the simulation results is that there are three main causes of water problems in the Vlietpolder. Firstly, sufficient storage capacity within the *polder* is lacking, since the storage capacity of the Wollebrand is far too small. Secondly, the storage pond is located at the end of the water chain in the downstream part of the *polder*, which is not the best spot. Thirdly, the drainage capacity of the urban area of Naaldwijk is insufficient.

6 Innovative solutions for areas facing intensive land use patterns

The results and conclusions of the simulations of the current situation and the initial solution were translated into recommendations for improving the water system in the Vlietpolder. Twelve possible solutions emerged, and were included in the simulation. In the end, six effective alternatives were derived from these solutions and combinations thereof:

1. Storing rainwater in greenhouses' watering basins.
2. Storing water under greenhouses by building floating greenhouses (Figure 3) or greenhouses on piles
3. Storing water in greenhouses by creating special water-storing bassins.
4. Inundating pasture combined with local storage in greenhouses.
5. Creating a new storage pond in the undeveloped area of the *polder*, combined withlocal storage in greenhouses.
6. Increasing storage capacity of the *boezem* system to prevent pumping stops, combined with storing rainwater in watering basins.

A multi-criteria analysis was used to assess these six alternatives. Nine criteria were identified for each alternative: technical feasibility, effectivity, damage through inundation of unprotected parts of the *polder*, practical



feasibility, reliability, realisation costs, sustainability, possibilities for recreation, and ecological value. Each criterion was assigned a weight based on its ranking in a criteria analysis.

Figure 3. Artist's impression of floating greenhouses (Delfland Water Board, 2005).

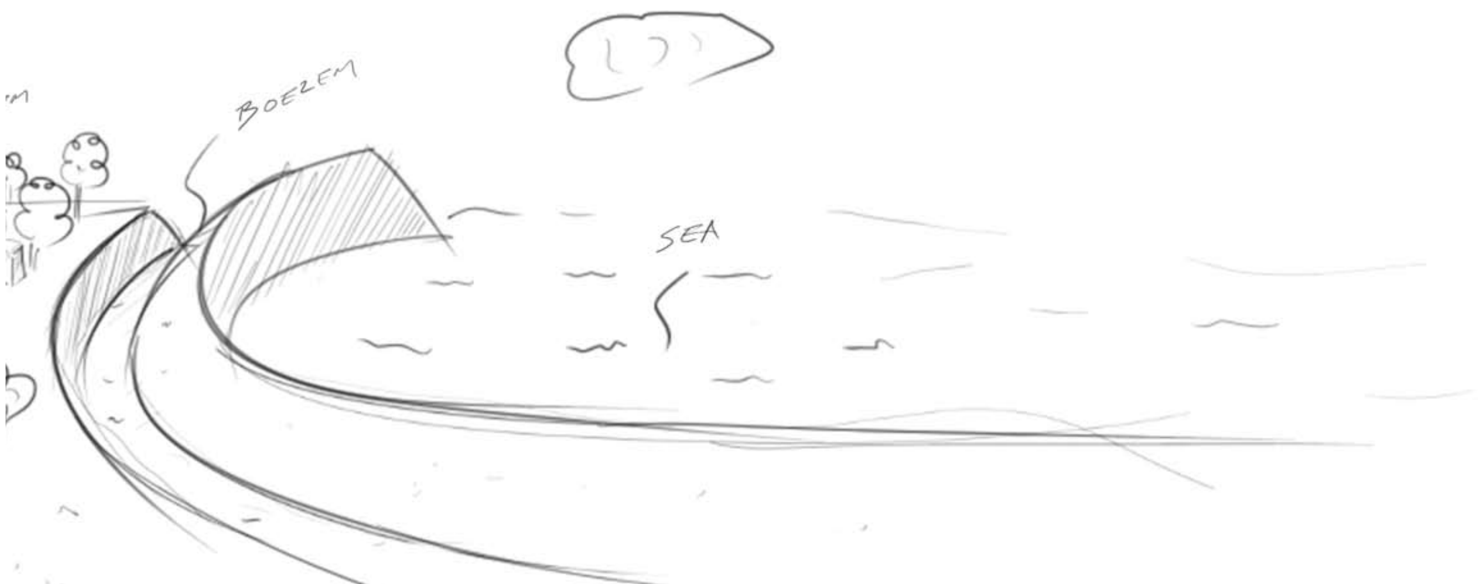
'Even the less serious events caused flooding in areas that should stay dry.'

7 Conclusions and outlook

Possible options for the prevention of flooding in the Vlietpolder due to extreme rainfall were evaluated using a one-dimensional hydrological model. It was found that neither the current water management protocol for storms nor the initial solution proposed by the water board can prevent flooding in the polder. According to the evaluation of newly developed alternatives, the storage of water below greenhouses and the creation of a new storage pond combined with locally storing water in greenhouses are the best possibilities for flood prevention in the Vlietpolder.

The selected alternatives identify a direction for preventing water problems in polders with intensive land use patterns. They show that planning preventive measures at the beginning of the water discharging chain is more efficient. Storage capacity is needed both in upstream and in downstream areas within the polder rather than only at downstream locations. Therefore, space for water-storing facilities should be made available throughout the system to prevent water problems.

Most of the alternatives incorporate some kind of multifunctional land use. Because of the intensity of land use in the Vlietpolder and in the polders of the western part of the Netherlands in general, there is little space left for water storage. This study showed that there are numerous opportunities to combine these forms of land use. Therefore, multifunctional land use should become another guiding principle for water management in intensively used areas. ■



Overview

- Neither the current water management protocol for storms nor the initial solution proposed by the water board can prevent flooding in the Vlietpolder.
- It is more efficient to plan preventive measures at the beginning of the water discharging chain. Storage capacity is necessary both in upstream and in downstream areas within the polders rather than only at downstream locations.
- Multifunctional land use should become a guiding principle for water management in intensively used areas.

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