WATER NEXUS

Optimal flushing of a polder using Model Predictive Control

Boran Aydin en Gualbert Oude Essink
TUDelft en Deltares, The Netherlands

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Deltares
Enabling Delta Life

Meer informatie:
freshsalt.deltares.nl
zoetzout.deltares.nl

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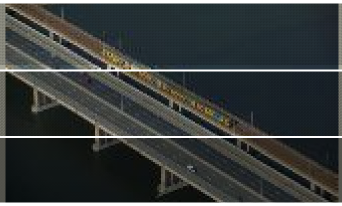
Hoogheemraadschap van Rijnland stowa Eijkelkamp Soil & Water STW connecting innovators

Introduction - Motivation



More than **35%** world's population live within 100 km of coast

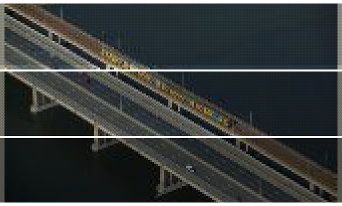
Groundwater resources in these areas are an important **source** for

- domestic
- industrial
- agricultural use

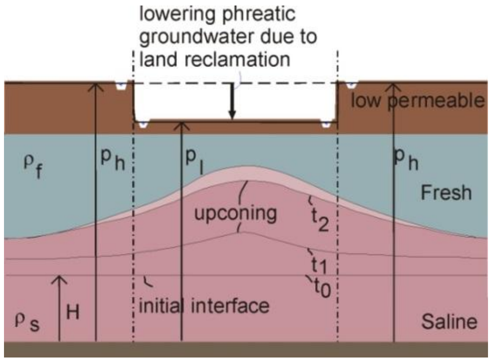
Deltaic areas are under stress due to

- climate change
- sea-level rise
- decrease in fresh water availability

Introduction - Motivation



In low-lying deltaic areas, saline groundwater **moves towards** ground surface and **exfiltrate** to surface water



Saline surface water affects:

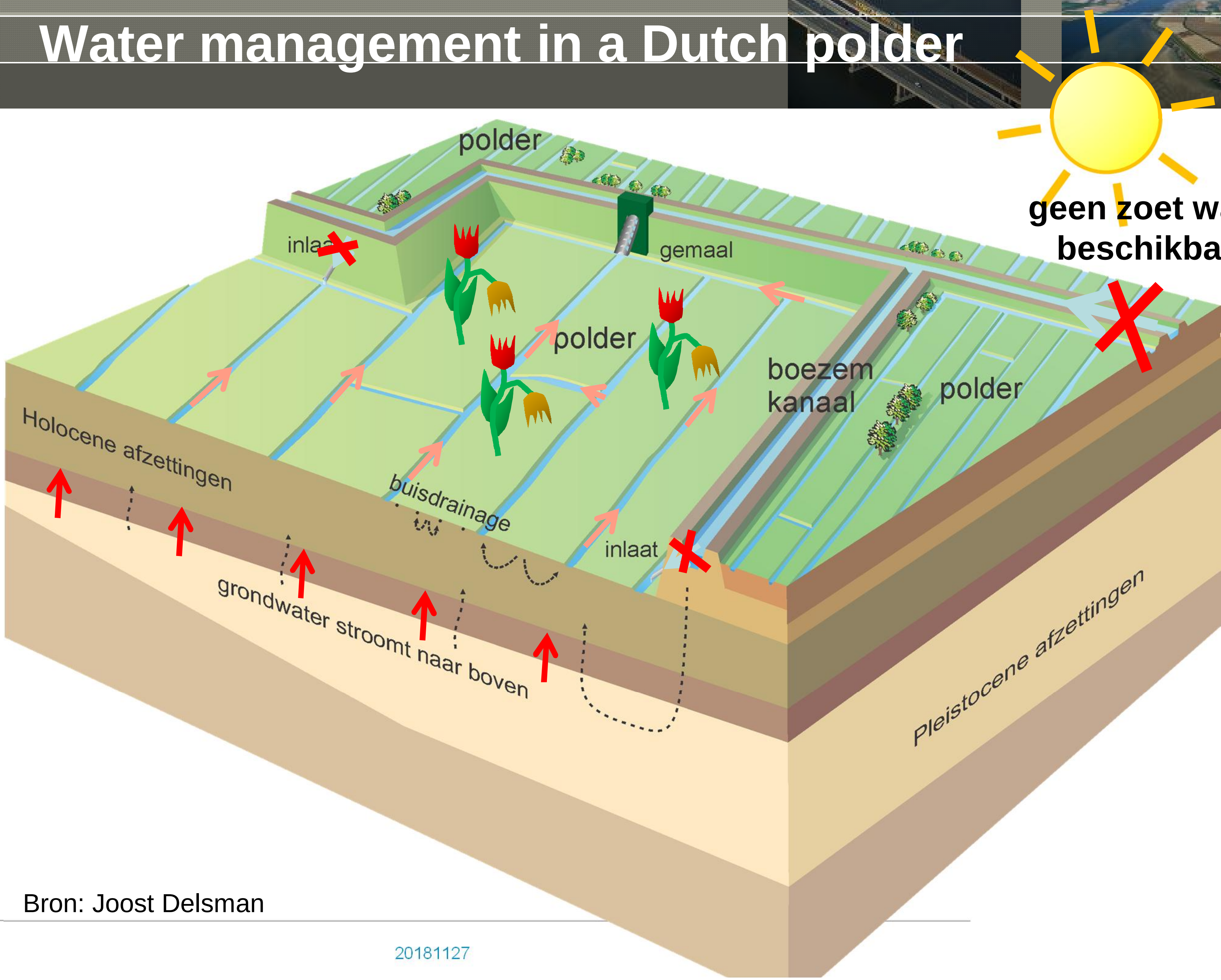
- agricultural and industrial use
- drinking water production

Flushing: using freshwater diverted from rivers to remove saline surface water

Current **saline-fresh water management strategies** have to be **reviewed**, and new **sustainable strategies** should be **developed**

- decreasing fresh water availability
- increasing surface water salinization

Water management in a Dutch polder

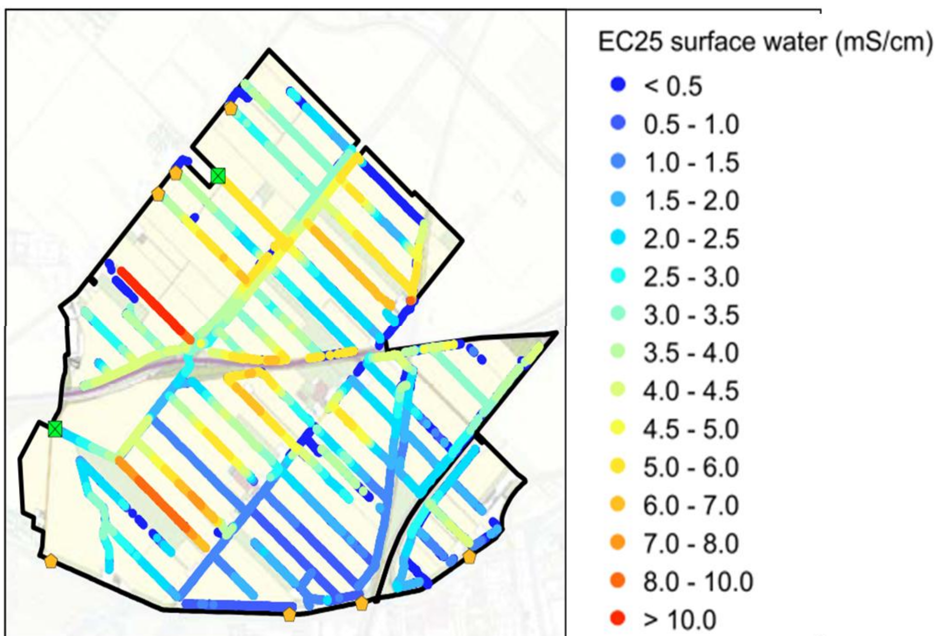


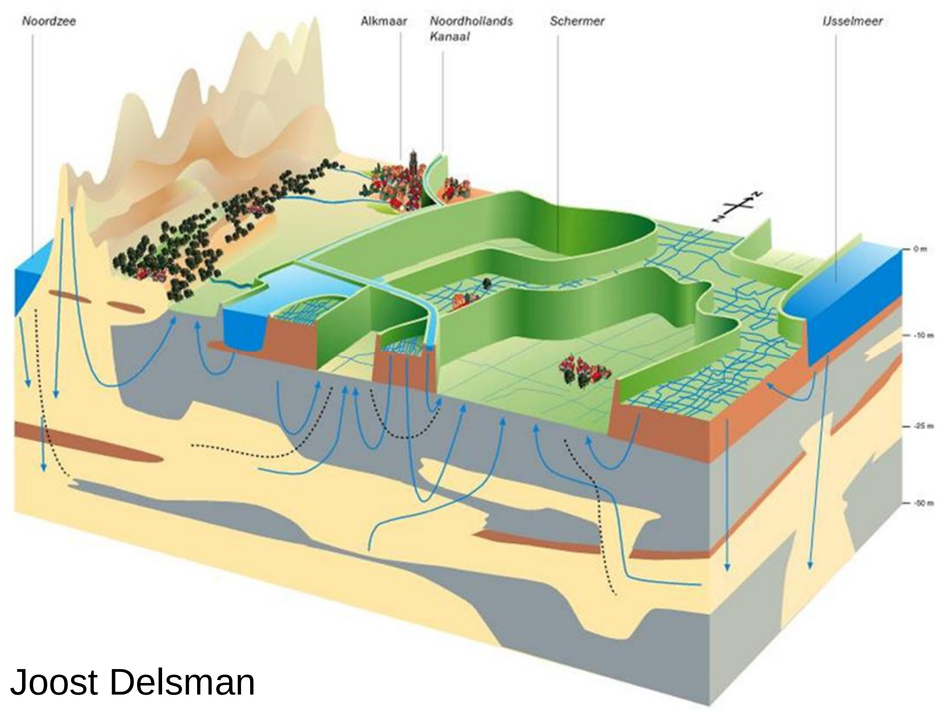
Bron: Joost Delsman

Polders

During dry periods: extra fresh water to polders
During wet periods: provide space for extra water from polders

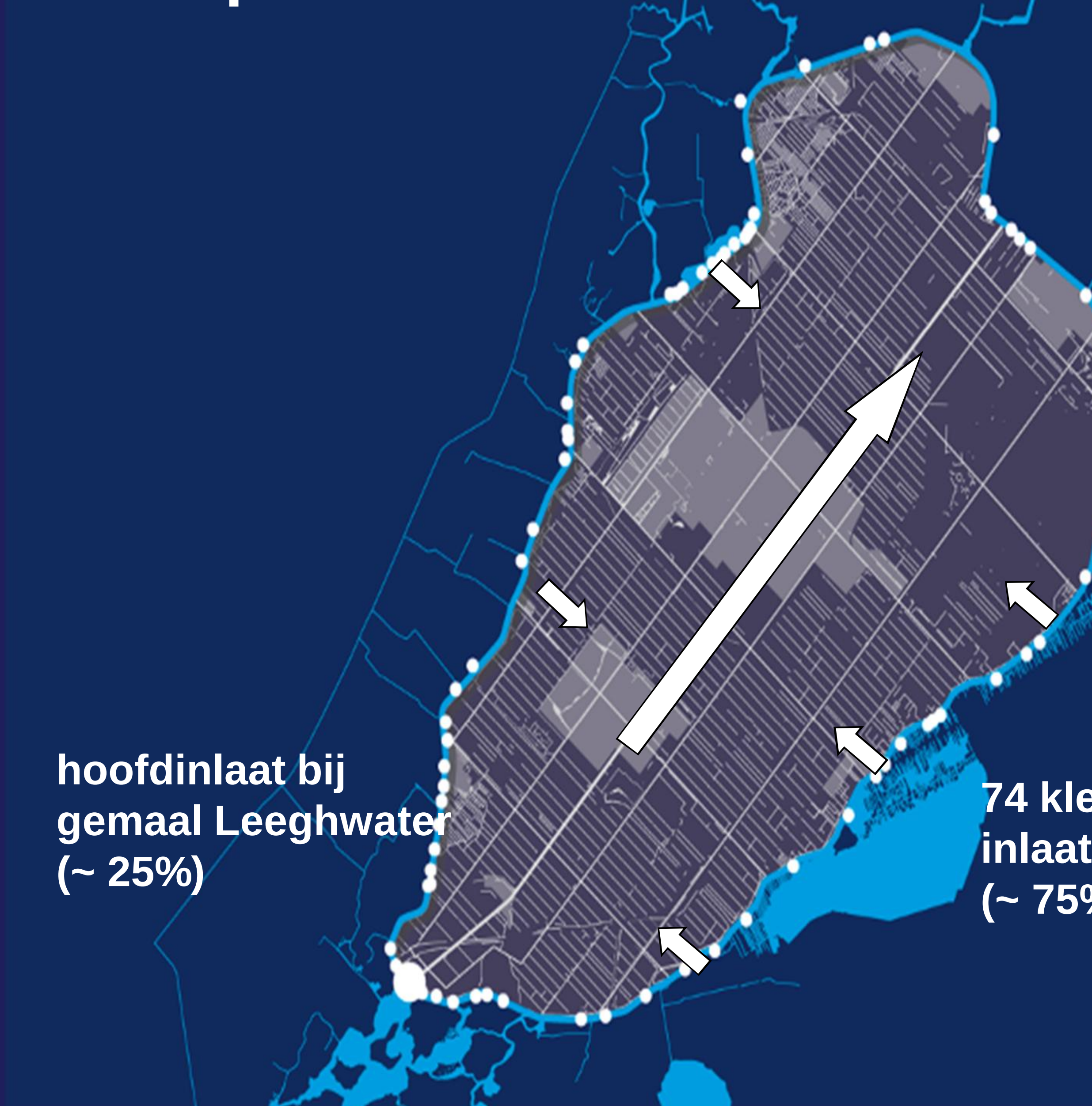
Water levels in polders are maintained within a given margin so that the groundwater levels in the polders are kept close to a target level





Bron: Joost Delsman

Doorspoelen in de Haarlemmermeer



hoofdinlaat bij gemaal Leeghwater (~ 25%)

74 kleine inlaatpunten (~ 75%)

With pressing Climate Change and SLR Scenarios

Salinization

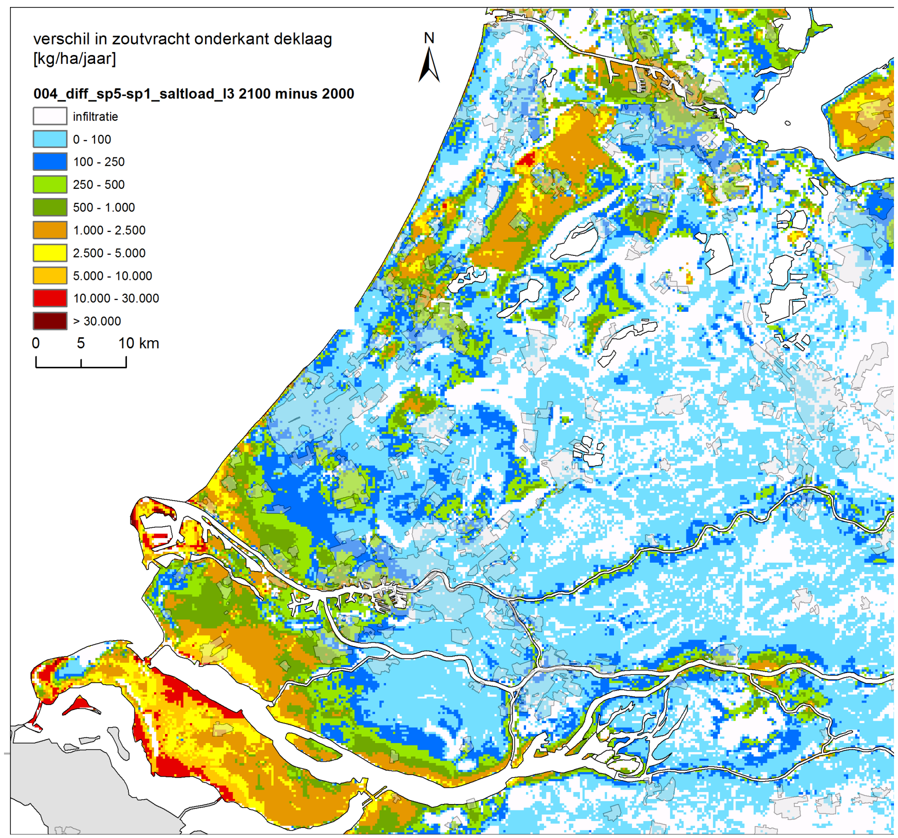
- expected to increase due to (extreme) sea-level rise

Freshwater Availability

- expected to decrease due to decreasing precipitation and increased consumption of upstream users

Problem becomes more severe.
Act efficiently when necessary.

Increase
salt load
under SLR




Objectives of the control

Water Level

- Always

Water Quality

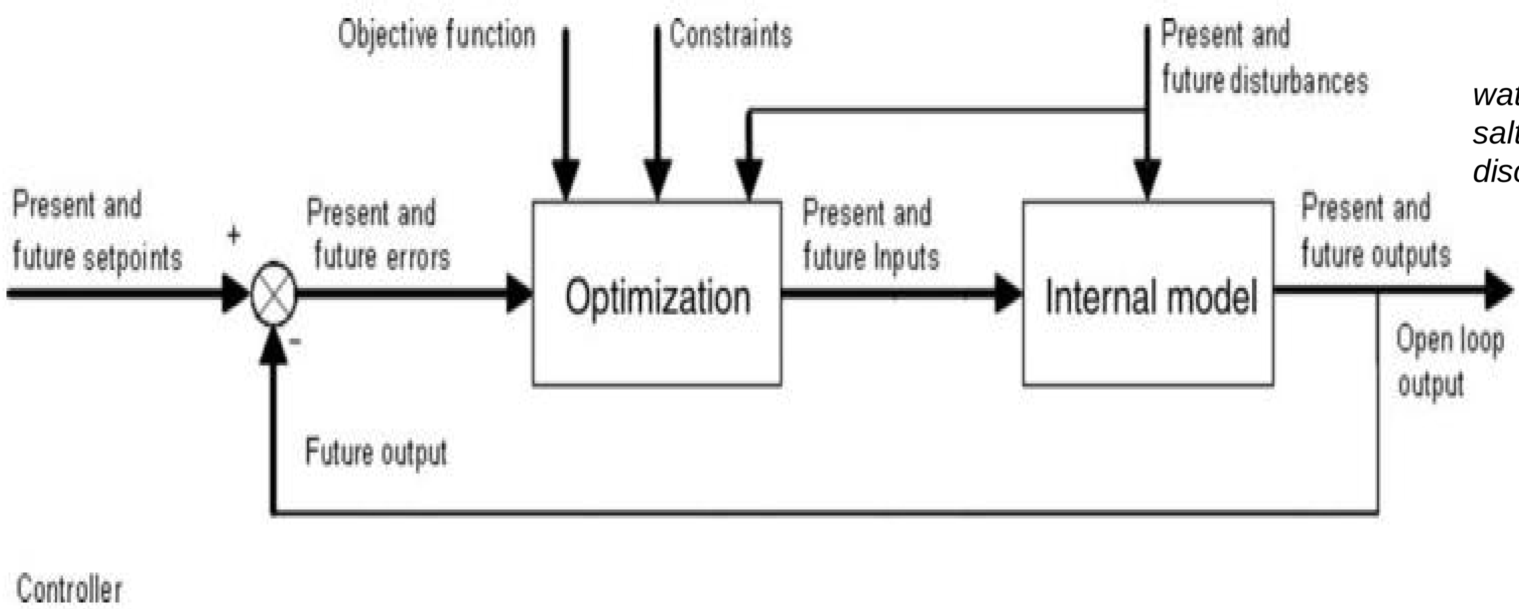
> When necessary

Use minimum freshwater

- Water is a scarce source / less pumping

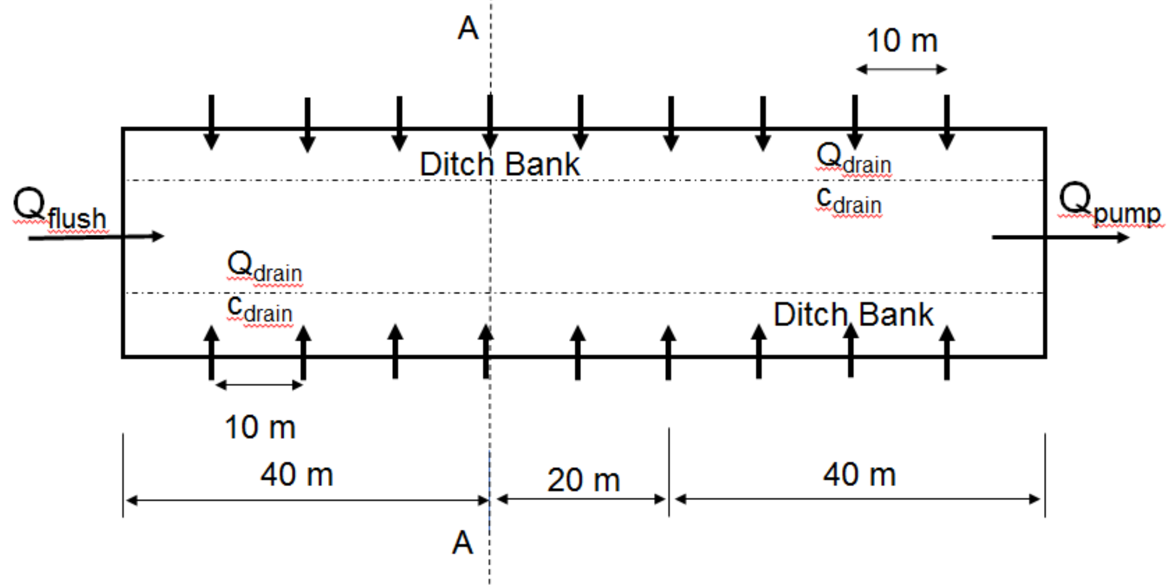
Model Predictive Control=optimization based control strategy

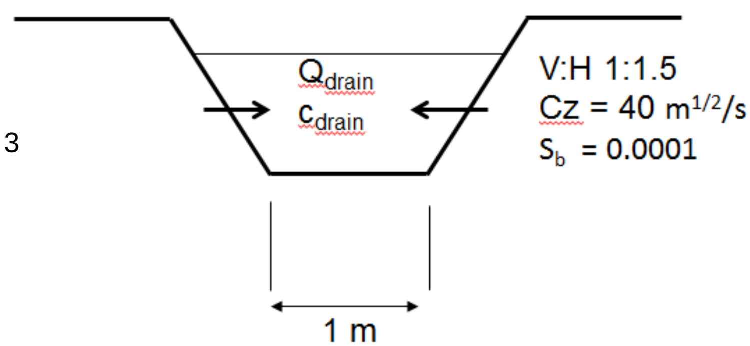
- Prediction of future process outputs
- Constraints of the system
- Optimization
- Keep the water level at target level
- Minimum effort and cost



water levels
salt concentrations
discharges

Understanding the problem - Test Case





Objective:

Downstream water level h_{out} = -0.41 m

Downstream concentration $C_{out} < 550$ g/m^3

Minimize the flushing discharge Q_{flush}

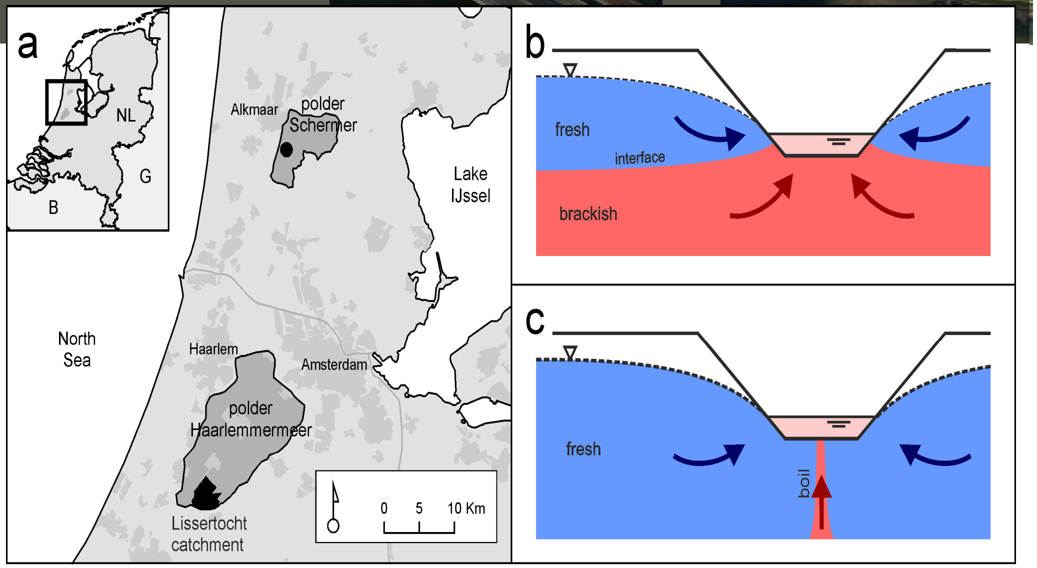
Disturbance:

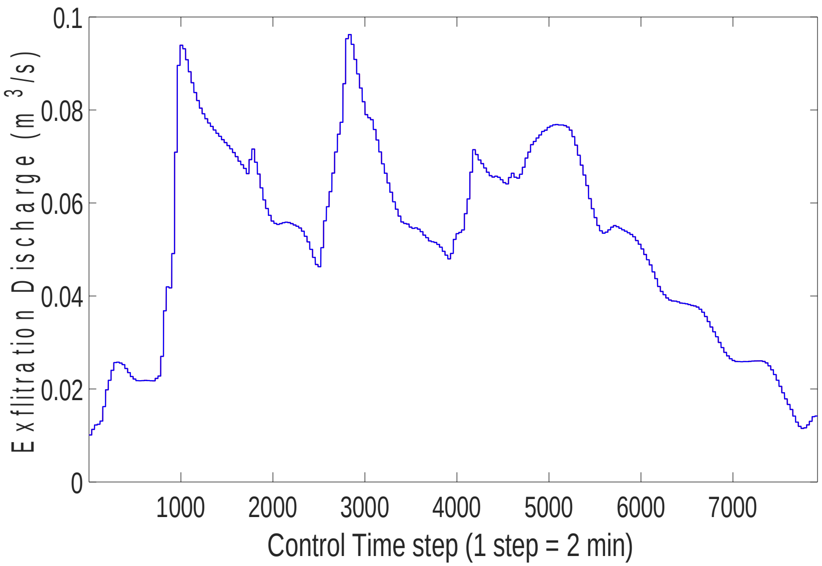
Saline Groundwater Exfiltration modelled

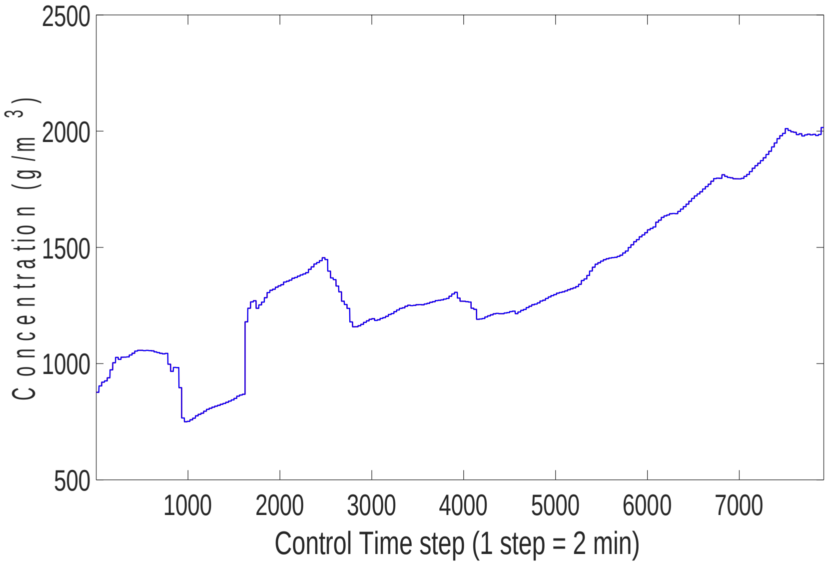
Control:

Manipulating the change of : Q_{pump} & Q_{flush}

Real data from Schermer Polder







Results

Objective:

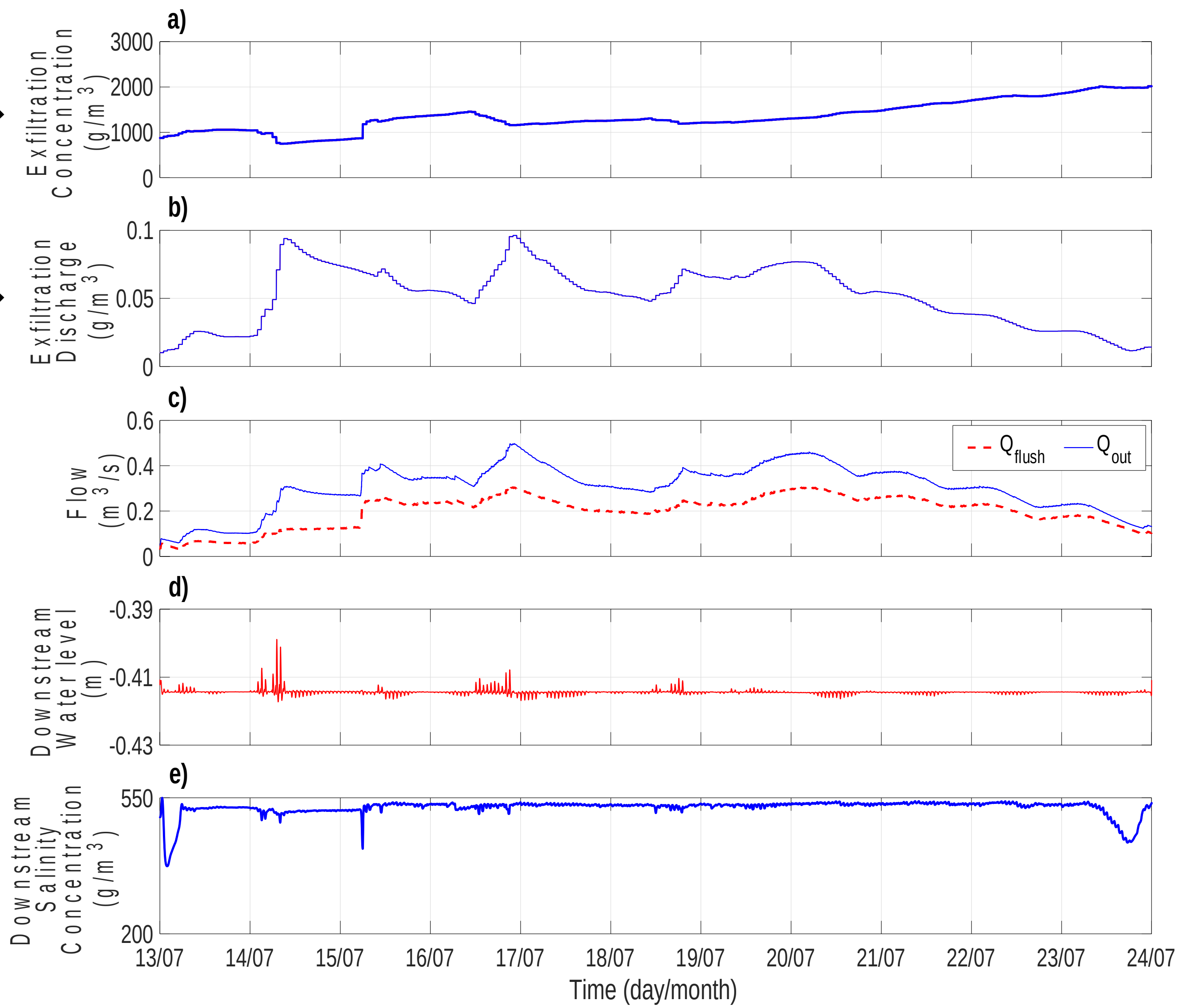
Downstream water level — h_{out} = -0.41 m

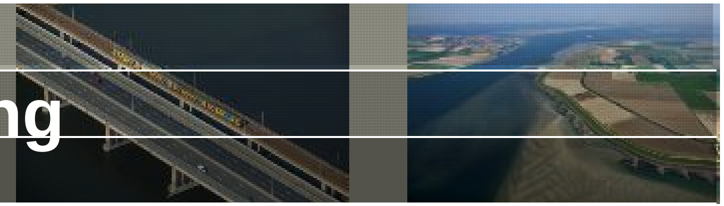
Downstream concentration — C_{out} < 550 g/m^3

Minimize the flushing discharge — Q_{flush}

input ➡

input ➡





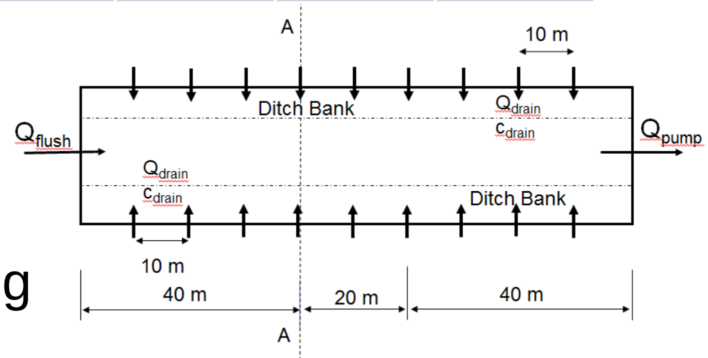
Comparison MPC vs Fixed Flushing

C_{ref} (g/m^3)	C_{av} (g/m^3)		Q_{max} (m^3/s)	ΣQ_{flush} (10^3 m^3)		ΣQ_{pump} (10^3 m^3)		% Saved	
	MPC	Fixed	MPC	MPC	Fixed	MPC	Fixed	Q_{flush}	Q_{pump}
550	512.8	374.2	0.384	198.1	365.2	296.8	463.9	45.7	**36.0**
750	684.9	555.2	0.172	105.6	163.4	204.3	262.0	35.3	22.0
900	810.8	664.8	0.115	67.7	109.2	166.4	207.9	38.0	19.9
1000	893.7	714.7	0.096	49.2	91.6	147.9	190.2	46.2	22.2

Conclusion:

MPC is effective tool for flushing operation

Up to 36% savings in freshwater use % pumping



(Next step: from this ditch to a network of a part of a polder)

(Other nutrients can alsobe controlled with the MPC scheme)

Questions?

B.E.Aydin@tudelft.nl

gualbert.oudeessink@deltares.nl

Aydin, B.E., Tian, X., Delsman, J., Oude Essink, G.H.P., Rutten, M., Abraham, E., 2018. Optimal Salinity and Water Level Control of Polder Ditches using Model Predictive Control. Environ. Model. Softw. doi:10.1016/j.envsoft.2018.11.010