


**Deltares**  
Enabling Delta Life

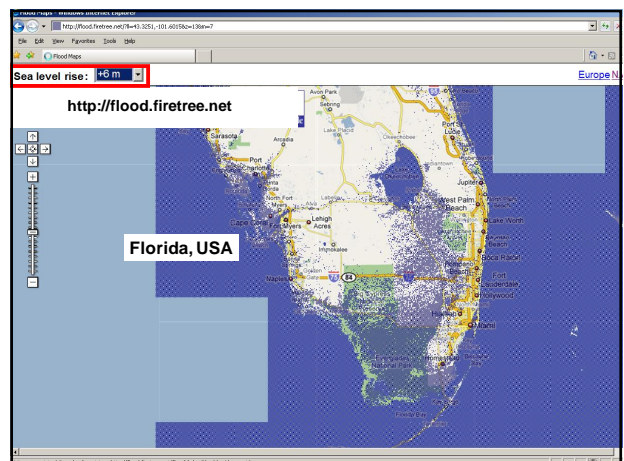
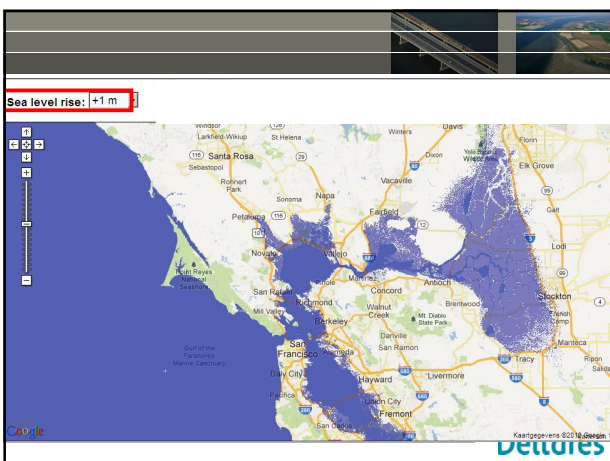
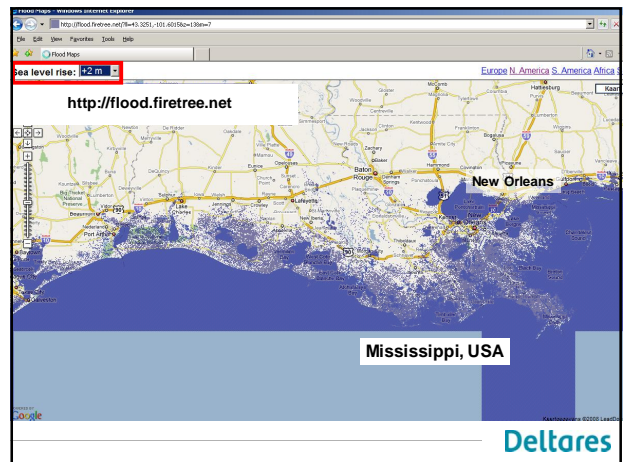
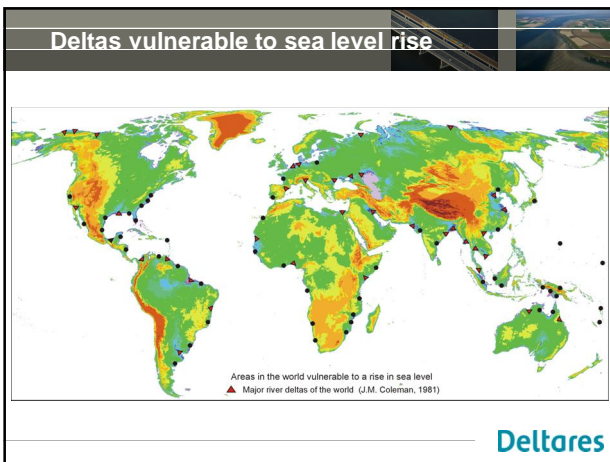
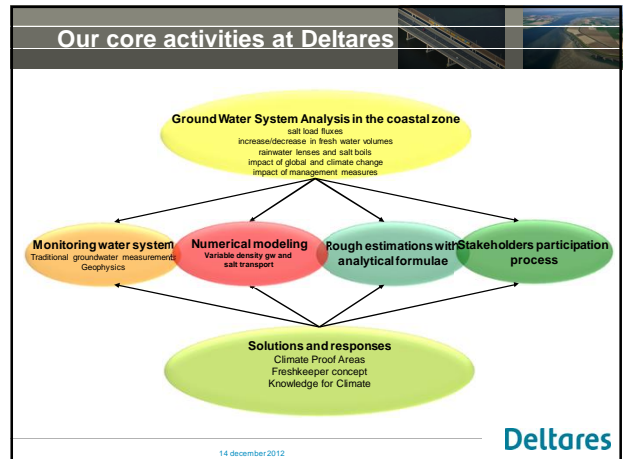
## Fresh-saline groundwater in the coastal zone

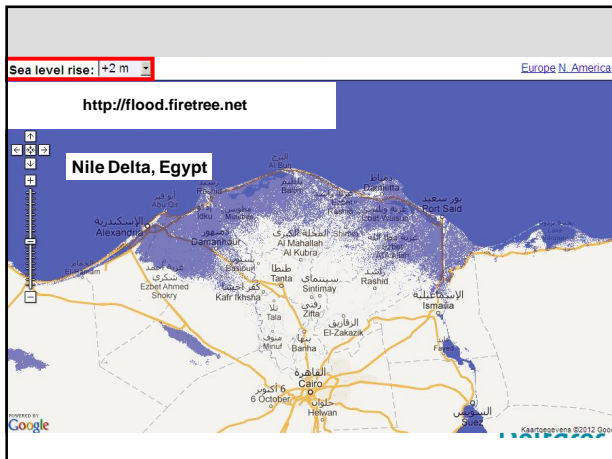
**Gualbert Oude Essink**  
P. de Louw, E. van Baaren, Marta Faneca, J. Delsman, P. Pauw  
Deltares, The Netherlands

[freshsalt.deltares.nl](http://freshsalt.deltares.nl)  
[zoetzout.deltares.nl](http://zoetzout.deltares.nl)



*Pery Esther Marta Joost Pieter*





### Learn from other areas

Want to get an idea about the effects of climate change in your delta?

*Evaluate past and present water management in the Dutch delta*



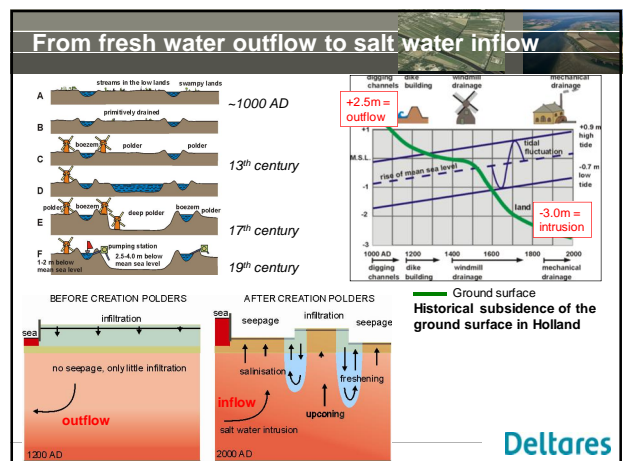
### Groundwater in the future

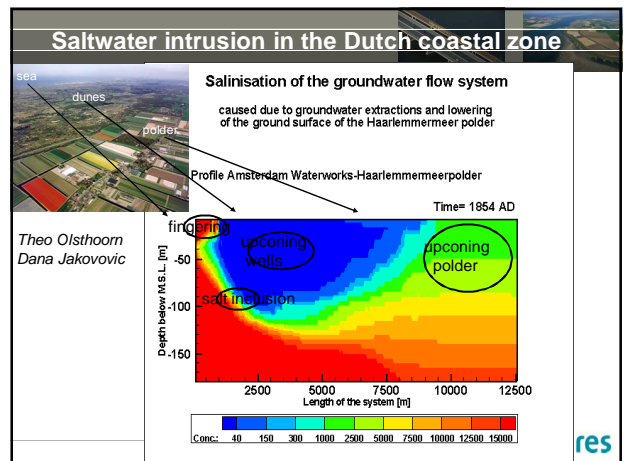
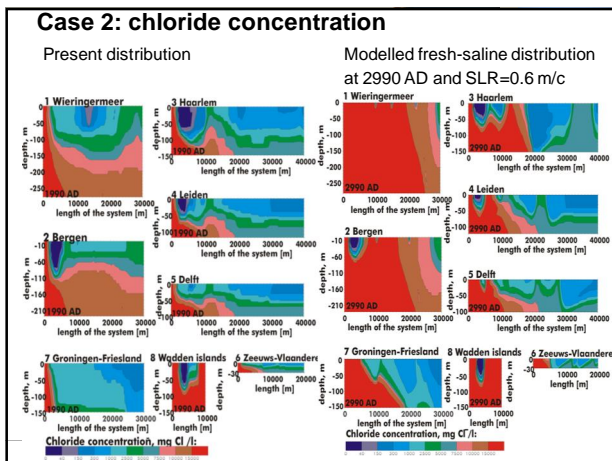
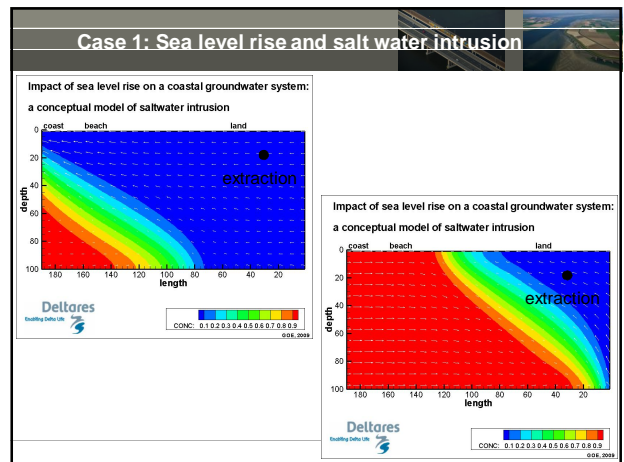
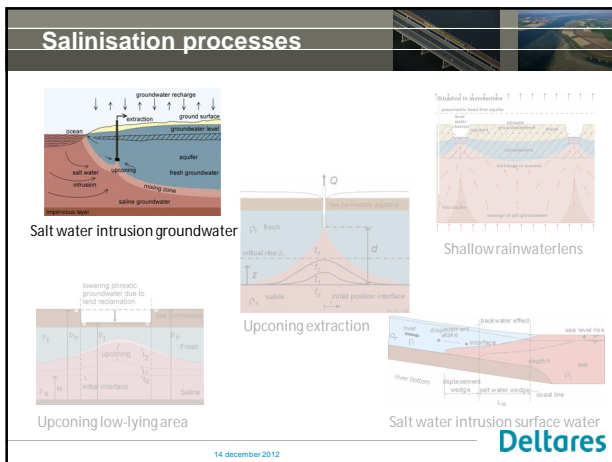
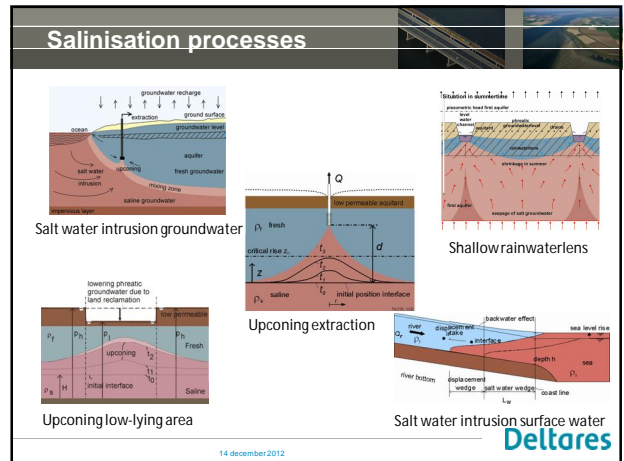
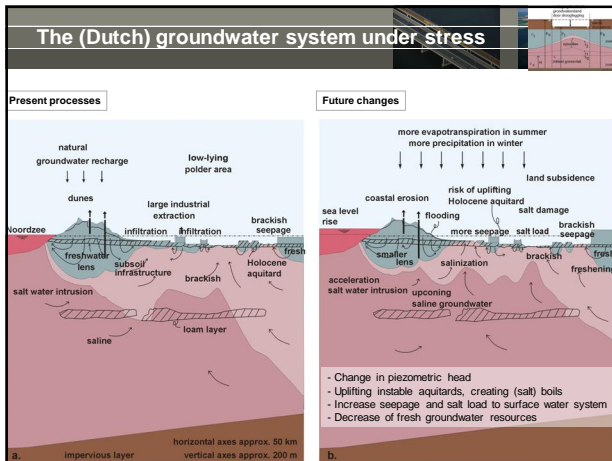
We have to cope with...

- Groundwater extractions
- Development energy use/production (heat-cold)
- Climate change
- Land subsidence
- Development spatial land use
- Politics, Policy & Watermanagement

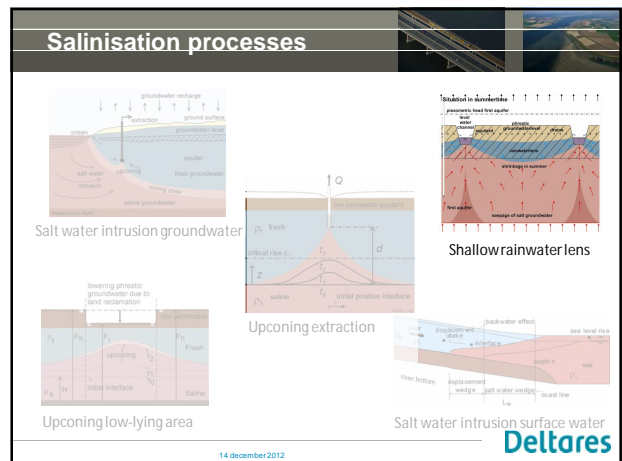
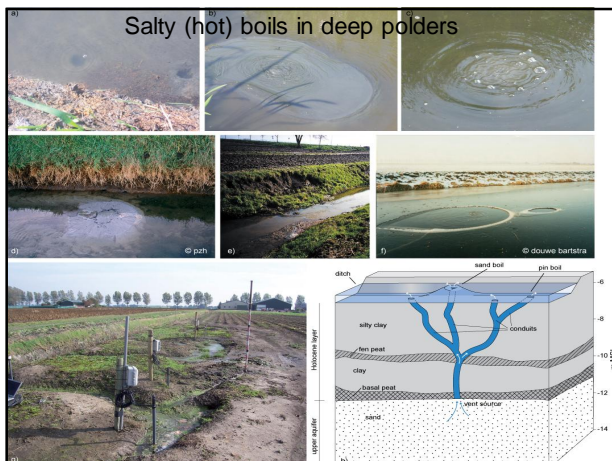
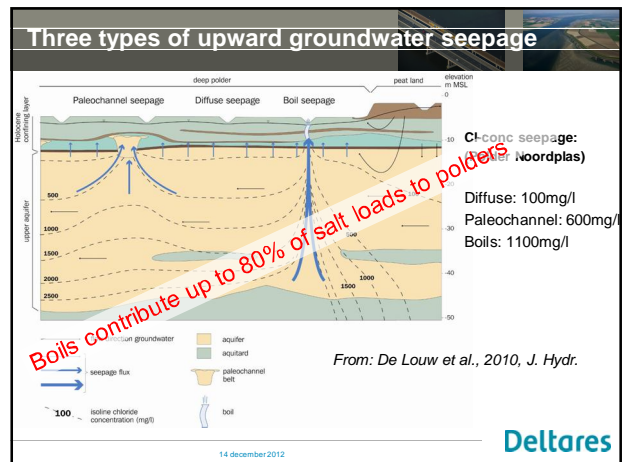
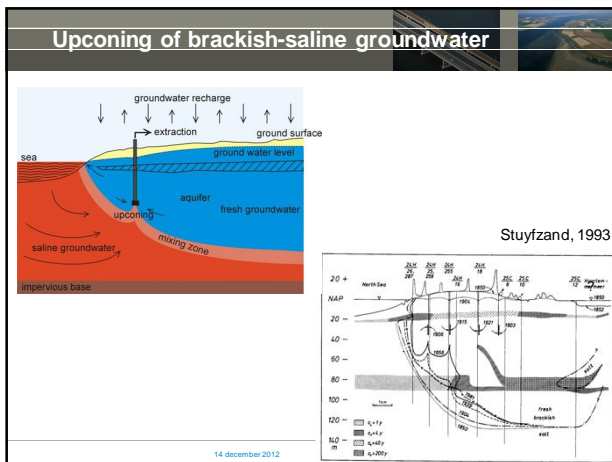
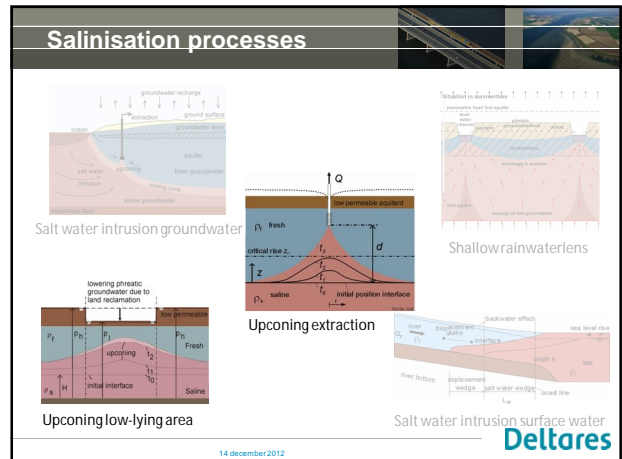
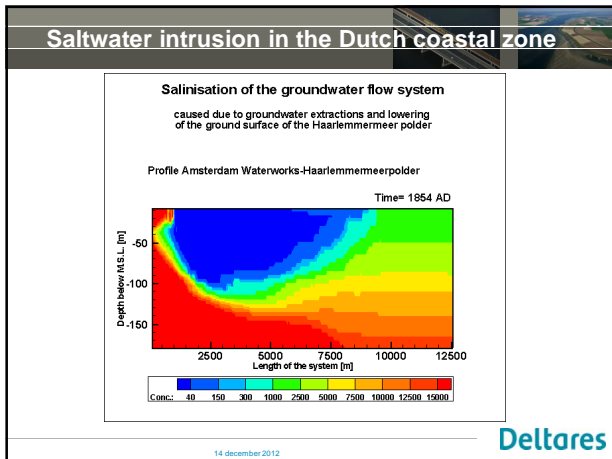
*Direct anthropogenic influence on groundwater is more important than climate effect*

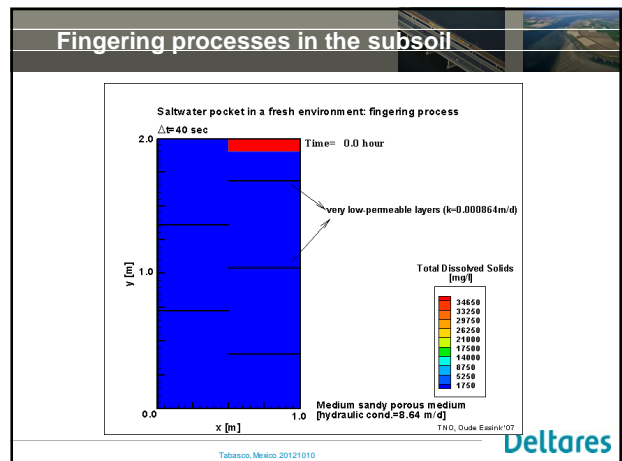
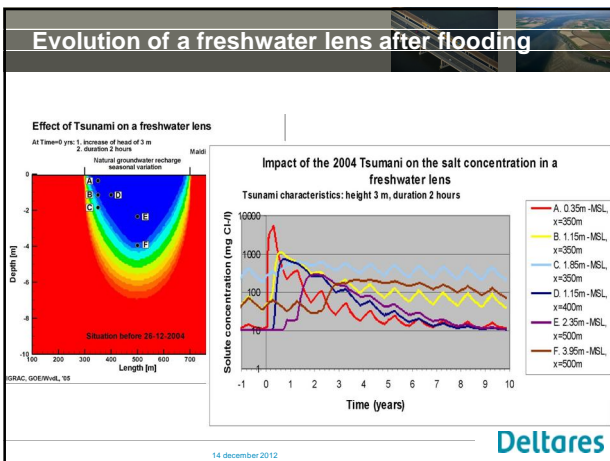
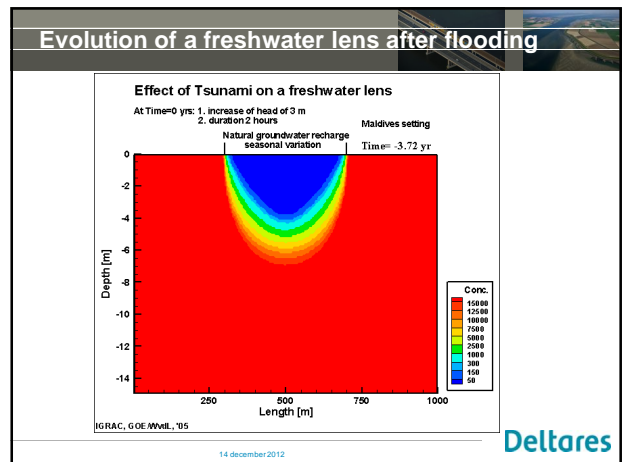
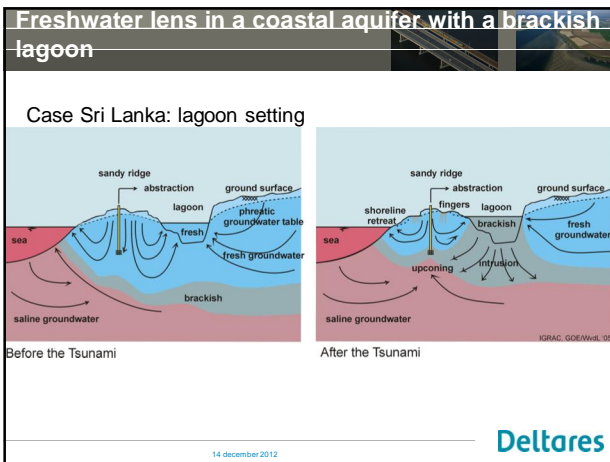
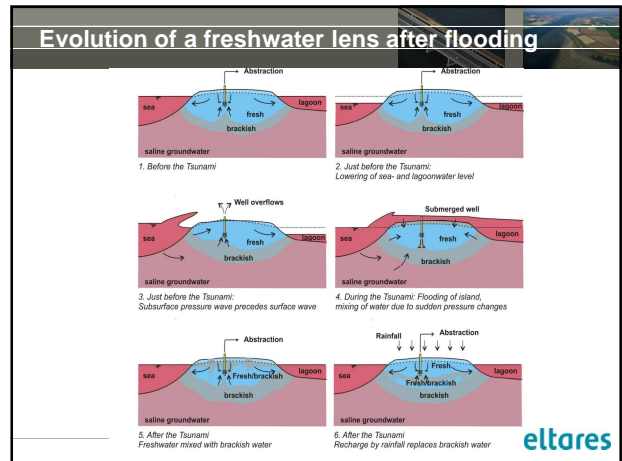
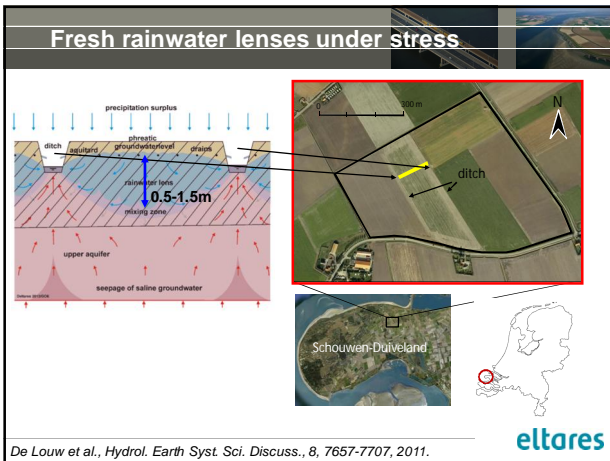
**Deltares**

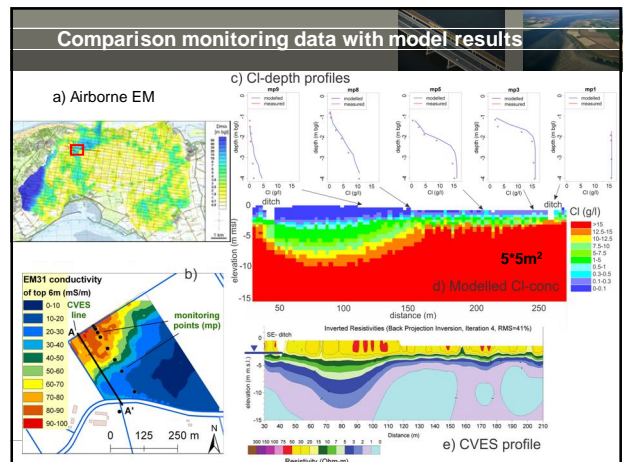
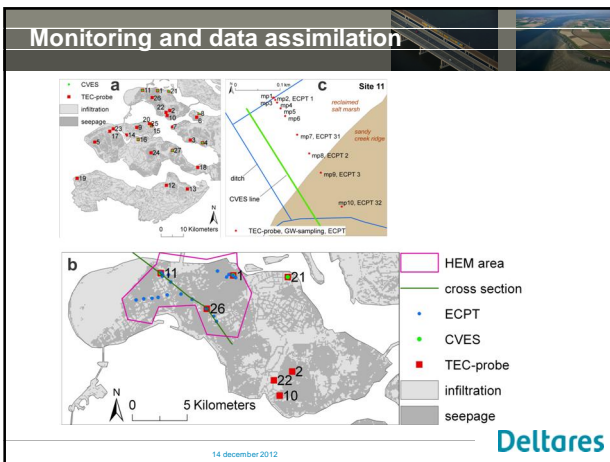
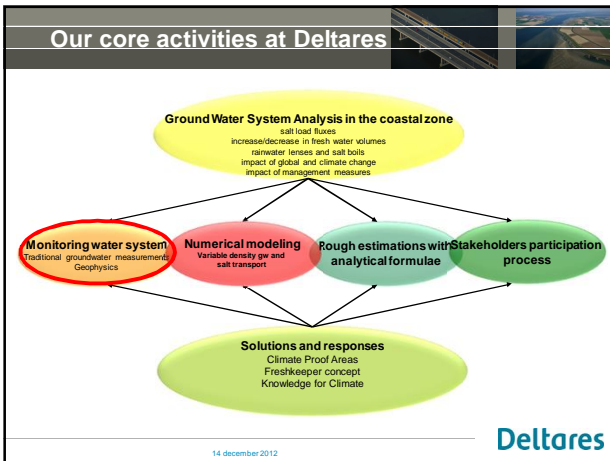








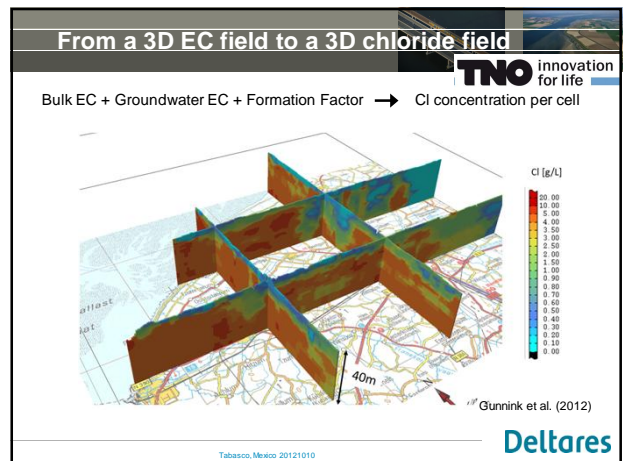




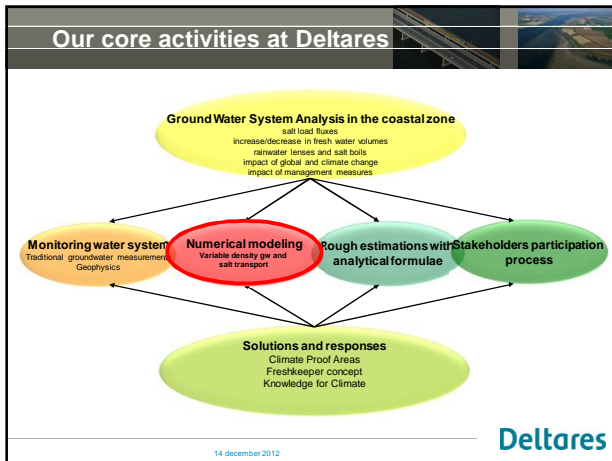
### Combination monitoring and modelling

- Airbone Electromagnetic geophysics
- Modeling
- Assessing climate change impacts

14 december 2012 **Deltares**







### Numerical modelling of salt water intrusion

**Characteristics:**

- variable-density groundwater
- fresh, brackish and saline
- 3D, non-steady
- coupled solute transport
- heat transport

**Assess combined effects:**

- past land subsidence polders
- sea level rise
- changing recharge pattern
- land subsidence
- changing extraction rates
- adaption measures

**Software (MODFLOW family):**  
SEAWAT, MOCDENS3D  
MT3D, iMOD, link NHI, etc.

0 25 50 75 100 km

Name project  
Number of cells  
Size of cell  
Date of release

14 december 2012

### Different model cell sizes to consider several phenomena

**Sub-local:** fingering, salty sand boils  
Sri Lanka (Tsunami 2004), Zandmotor  
**cell size=1cm-1m**

**Local:** rainwater lenses, heat-cold  
Tholen, Schouwen-Duiveland  
**cell size=5-25m**

**Regional:**  
Zeeland, Gujarat/India, Philippines  
**cell size=100m**

**National:** salt load  
Zuid-Holland, NHI  
**cell size=250m-1km**

**Goal:**  
To take largest cell size possible to accurately model relevant salinisation processes

14 december 2012 **Deltares**

### Modelstudy Zuid-Holland

- 100km \* 92.5km \* 300m depth
- ~4 million active cells
- Land subsidence
- Sea level rise
- Change in natural groundwater recharge

**Detailed fresh-saline distribution**

**Digital Elevation Model**

14 december 2012

### Modelstudy Zuid-Holland

- 100km \* 92.5km \* 300m depth
- ~4 million active cells, MOCDENS3D
- Land subsidence
- Sea level rise
- Change in natural groundwater recharge

**Land subsidence**

**4 recharge scenarios**  
Present 2010 → e.g. KNMI'06 W+2100  
Summer: -38%  
Winter: +28%

**GW recharge mm/day**

- 0 - 0.4
- 0.4 - 0.5
- 0.5 - 0.6
- 0.6 - 0.7
- 0.7 - 0.8
- 0.8 - 0.9
- 0.9 - 1
- > 1

14 december 2012 **Deltares**

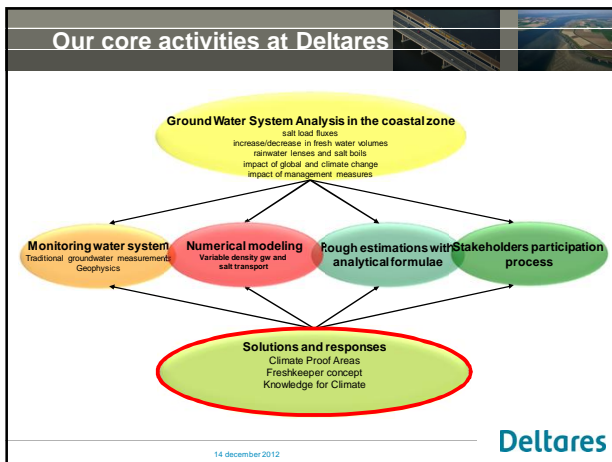
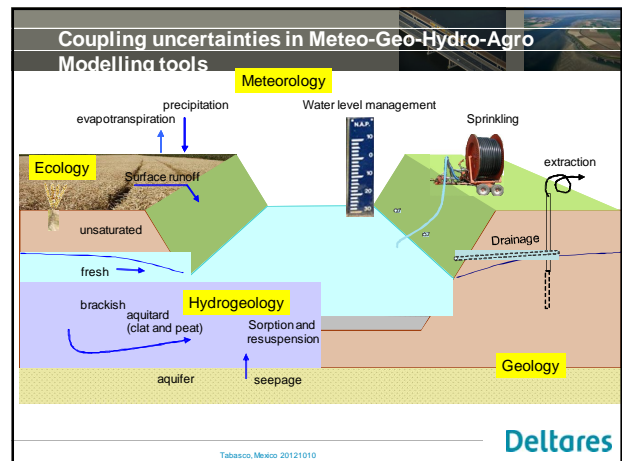
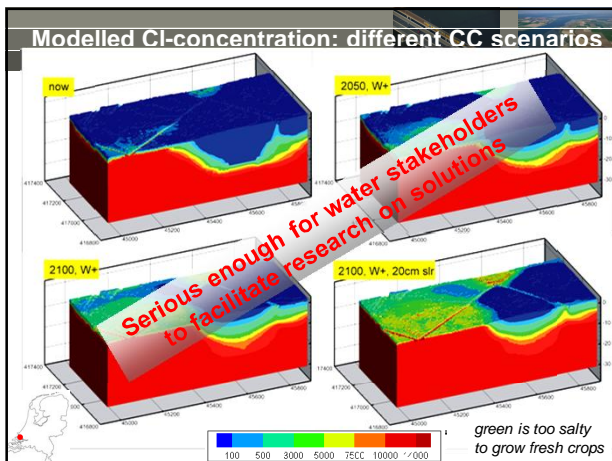
### Zone of influence of sea level rise

**Zone of influence is limited!**

backwater effect surface water

Ude Essink et al. (2010): WRR

**Deltares**



### Delta Program and National Water Plan

Two main goals for water management of our national government:

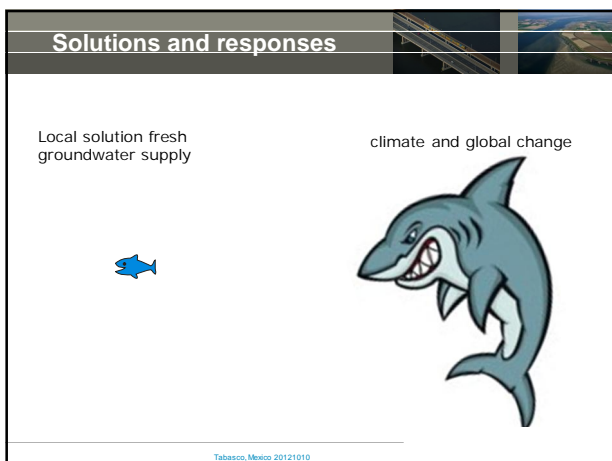
- To protect The Netherlands from flooding
- To make Fresh Water Supply Climate Change Proof (2015-2050):

Assessing the effects of:

- Changing water management (lake same again, lake higher water level)
- Droughts
- Land subsidence
- Sea level rise and change precipitation pattern
- Coming year, nutrient emissions and pesticide leaching, etc.
- Adaptation and mitigation strategies

Tools: Deltamodel and Netherlands Hydrological modeling Instrument

*To implement Delta Program (2015-2050): 7,10 billion euro per year*



### What should be the response?

Deltares



Many local solutions fresh groundwater supply climate and global change

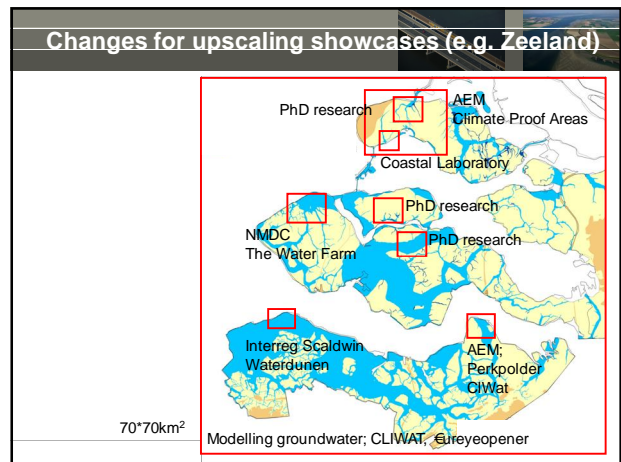
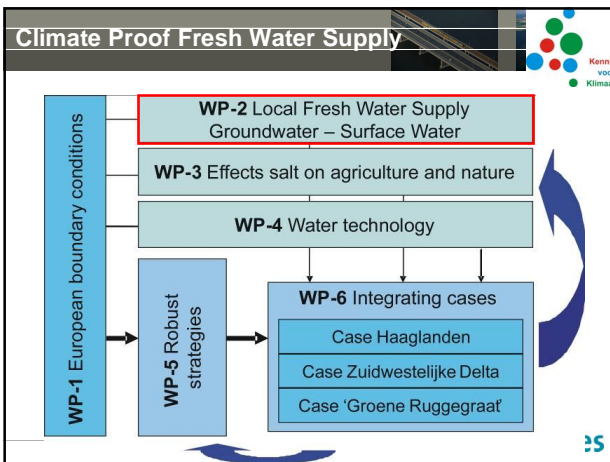
Many local solutions for fresh groundwater supply can have regional impact!

Tabasco, Mexico 20121010

**Key activities**

- upscaling local cases to regional strategy
- assess economical feasibility
- increase impact: communicate our showcases
- working together

Tabasco, Mexico 20121010



**Combining groundwater projects, e.g. in Proeftuin Zeeland**

Initial situation

beek

ruches

Deltares

**Deltares**  
Enabling Delta Life

Mission: *Enabling Delta Life*

To provide areas with fresh-salt issues enough and clean water in a sustainable way and at the right moment of time

Can we make a difference?

Deltares

