SWIBANGLA

Managing Salt Water Impacts in Bangladesh

Deltares Enabling Delta Life | UNESCO-IHE Institute for Water Education | Jahangirnagar University জাহাঙ্গীরনগর বিশ্ববিদ্যালয় | IRC Supporting water sanitation and hygiene services for life | brac | জনস্বাস্থ্য প্রকৌশল অধিদপ্তর Department of Public Health Engineering

Project duration May 2013 up to September 2014

PARTNERS AND STAKEHOLDERS

Partners

Deltares
Enabling Delta Life

UNESCO-IHE
Institute for Water Education

Jahangirnagar University → From April 2014

CEGIS → Until December 2013

Main Stakeholders

brac

IRC
Supporting water sanitation and hygiene services for life

Department of Public Health Engineering

Climate change hits Barisal agriculture sector

MURAD AHMED

BARISAL: Shortages in rainfall and changing weather pattern are greatly affecting the agricultural output in Barisal region. Farmers here have become highly frustrated facing the abnormality of the climate as they are facing difficulty in cultivating paddy, winter crops and vegetable.

Barisal met office recorded 700 mm rain fall here in the month of May last year. On the other hand, it was only 235mm this year and only 107mm in 2012. It is a record that only 235mm rain fall has been reported here in first five months of the current year compared to 769mm in same period last.

According to sources, abnormality of the rainfall has started to be felt here in last eight years.

Abdul Alim, working at

Scanty rain and rise in temperature worsen situation

Barisal Met office for last seven years said he never saw such abnormal pattern of weather. He said that temperature in the region is increasing at a rate of 0.05 degree Celsius every year. It climbed up to 39.2C in the month of May this year breaking all past records.

Climate Change in the region is not only affecting agricultural production, but also creating tornadoes like Sidr, Reshmi, Aila in this part of the country.

Agriculturalist Nitta Ranjan Biswas, training officer of AED Barisal said that over 28 varieties of local Aman and Aush paddy have become extinct from Barisal region facing the shortage of rain and rise in temperature in last 10 years.

The AED official said, Aman cultivation depends on weather mainly rain. But delay of monsoon rain caused Aman plantation started three weeks late all over the region again. At the same time abnormal rain fall makes situation out of control day by day here. AED Barisal source said that change of the climate said us to change the mode of agri season as soon as possible.

Increase of salinity is another big problem which has affected all the 53 upazilas of Barisal Agri region.

According their recent survey report of Barisal soil resource development institute, highly shortage of rainfall increased the salinity almost everywhere of Barisal region. Crop production must be decreased over 4,03570 tones by the affect of salinity according the report, source adds.

Md. Liaquat Ali, principal Scientific Officer of Barisal Soil Resource Development Institute (SRDI) said that shortage of rainfall and increasing salinity particularly in the thousands of acres of croplands in the southern Barisal region may cause the food production to decrease drastically.

A survey report of the department revealed that 53 upazilas of seven districts under Barisal Agri region salinity in the soil is increasing alarmingly. It said that over 5 lakh hectares of land here have been found to be saline affected.

Crop production may decrease by 5 lakh tones due to this reason.

OUR GOAL

To set up an approach to improve water safety plans in Bangladesh, based on salinity monitoring, modelling and stakeholder participation

- Introduction
- Salinisation processes
- Water Safety Plans
- Mitigation strategies
- Monitoring
- Modeling
- Deliverables
- Concl. & Recomm.

OUR OBJECTIVES

SWIBANGLA

1. Create a better understanding of the process of salinization of drinking water resources in Bangladesh
2. Provide recommendations for monitoring
3. Provide recommendations for mitigation strategies
4. Achieve an effective, tailored knowledge transfer between the Netherlands and Bangladesh
5. Advise on the integration of the salinization issue in Water Safety Planning

MAIN COMPONENTS OF OUR PROJECT

1. Literature review & Data acquisition
2. Monitoring
3. Contribution to Water Safety Plans
4. 3D density dependent groundwater model
5. Knowledge transfer: Training & Dissemination

SWIBANGLA

MAIN DELIVERABLES

1. Key components for WSP and mitigation strategies	2. 3D density dependent groundwater model	3. Water Quality Monitoring kit
4. Smart Phone App to measure Electrical Conductivity	5. Leaflet containing salinization processes information	6. Two Workshops one on Modelling and one on Monitoring

Deltares Enabling Delta Life
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Jahangirnagar University জাহাঙ্গীরনগর বিশ্ববিদ্যালয়
IRC Supporting water sanitation and hygiene services for life
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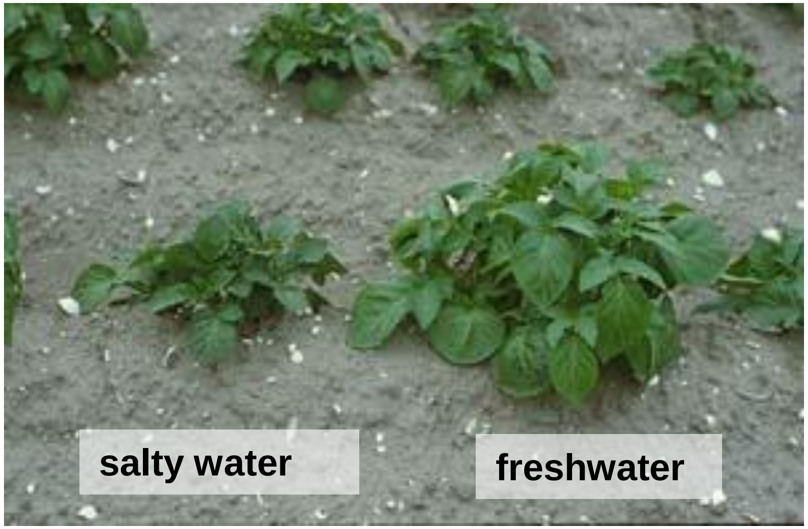
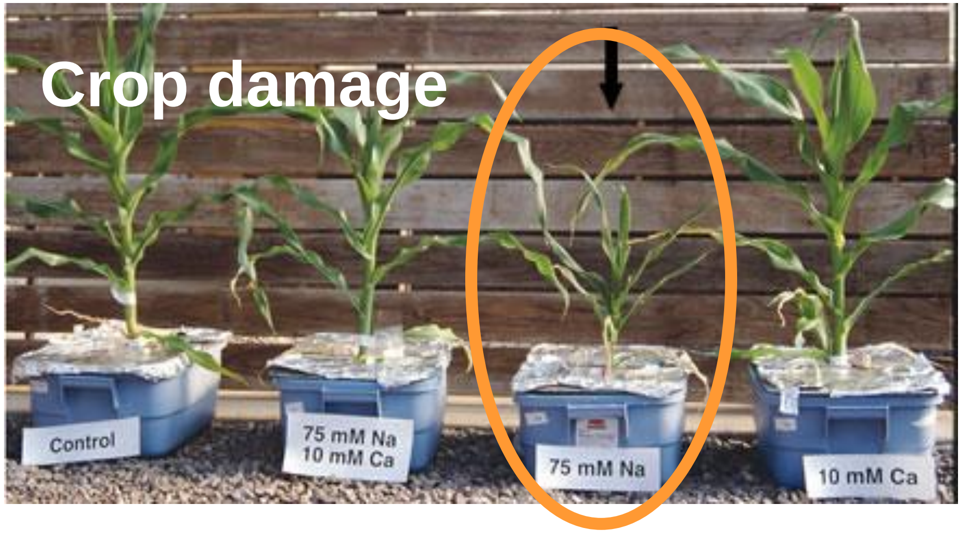
জনস্বাস্থ্য প্রকৌশল অধিদপ্তর Department of Public Health Engineering

INTRODUCTION

INTRODUCTION: SALT IN WATER IS A PROBLEM

- taste (100-300 mg Cl-/l)
- long term health effect



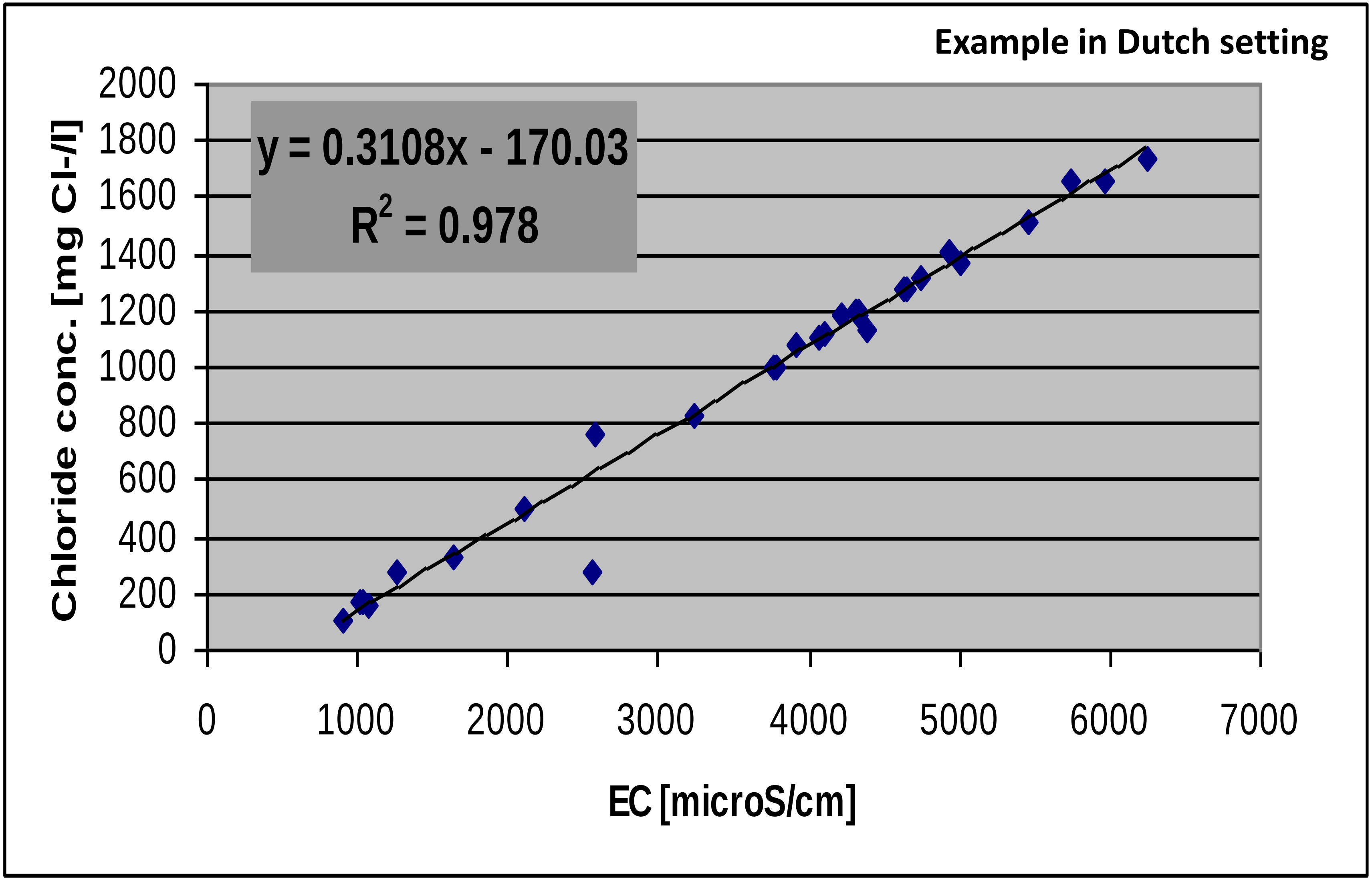


UNITS AND DEFINITION OF FRESH AND SALINE GROUNDWATER

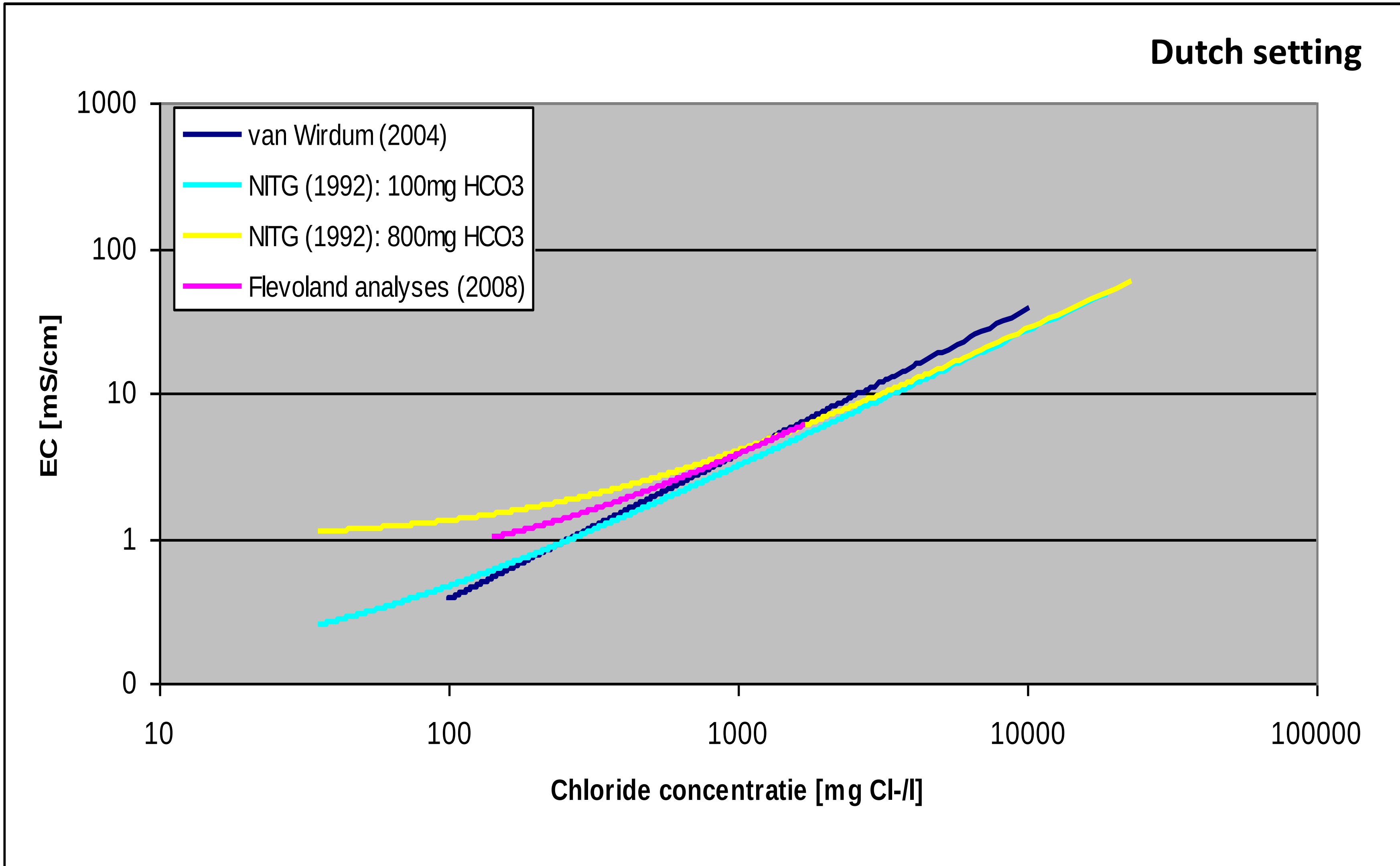
- milligrams Cl^- per liter; Cl^- is Chloride
- milligrams TDS per liter; TDS is Total Dissolved Solids
- Electrical Conductivity (EC) (in reference to 25^o Celcius):
  - in milliSiemens per centimeter (mS/cm), or
  - In microSiemens per centimeter (µS/cm).
- Sea water is ~19000 mg Cl-/l, or 35000 mg TDS/l, or 5S/m or 50mS/cm
- Relation Cl^-/TDS = ~0.55, stable relation for normal seawater environments
- 10^6 µS/cm = 10^3 mS/cm = 1 S/cm; 1 µS/cm = 100 µS/m

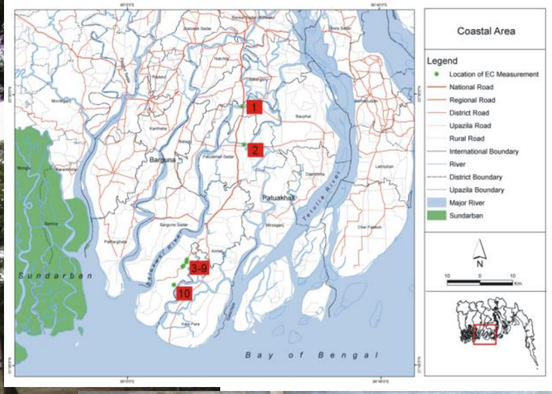
Type	mS/cm	mg TDS/l	Drinking- or irrigation water
Non-saline or fresh water	<0.8	<600 *	Drinking and irrigation water
Slightly saline	0.8 - 2	600-1.500	Irrigation water
Moderately saline	2-10	1.500-7.000	Primary drainage water and groundwater
Highly saline	10-25	7.000-15.000	Secondary drainage water and groundwater
Very highly saline	25 - 45	15.000-35.000	Seawater is 35000 TDS mg/l
Brine	>45	>45.000	

Close relation between chloride concentration and Electrical Conductivity



EC in mS/cm versus Chloride in mg Cl-/l





Focus on drinking water!

In 1 liter ocean: about 35 gr salt

In 1 liter ocean: about 35 gr salt

In 1 liter Dead Sea water (Jordan) : about 280 gr salt

In 1 liter drinking water: about 0.6 gr salt is allowed

Rice can grow well in water with a salt content less than about 2.0 gr salt in 1 liter water

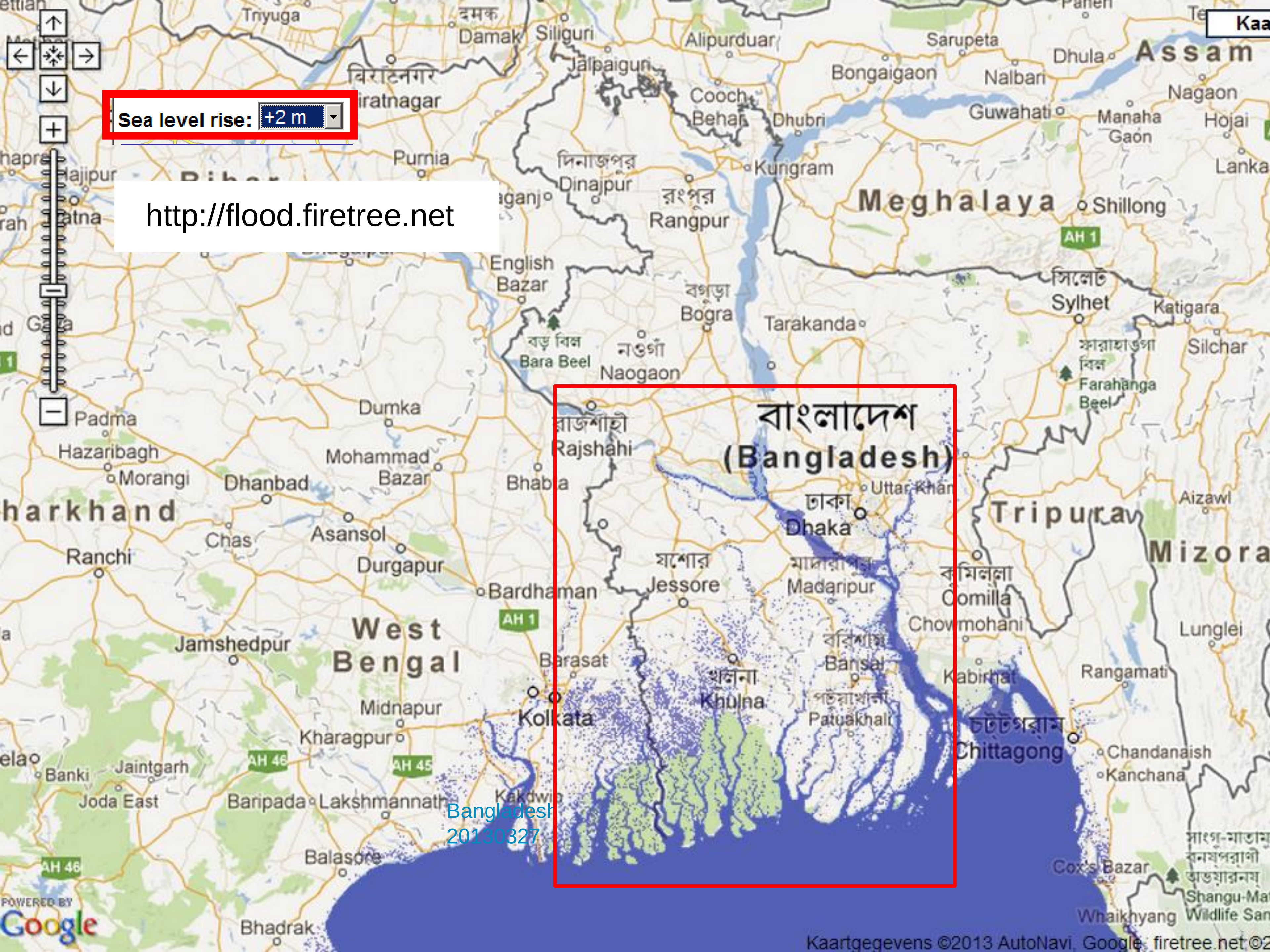

WATER USE:
2500 litres of water
for 1 cotton shirt


1500 litres of water
per kg refined sugar

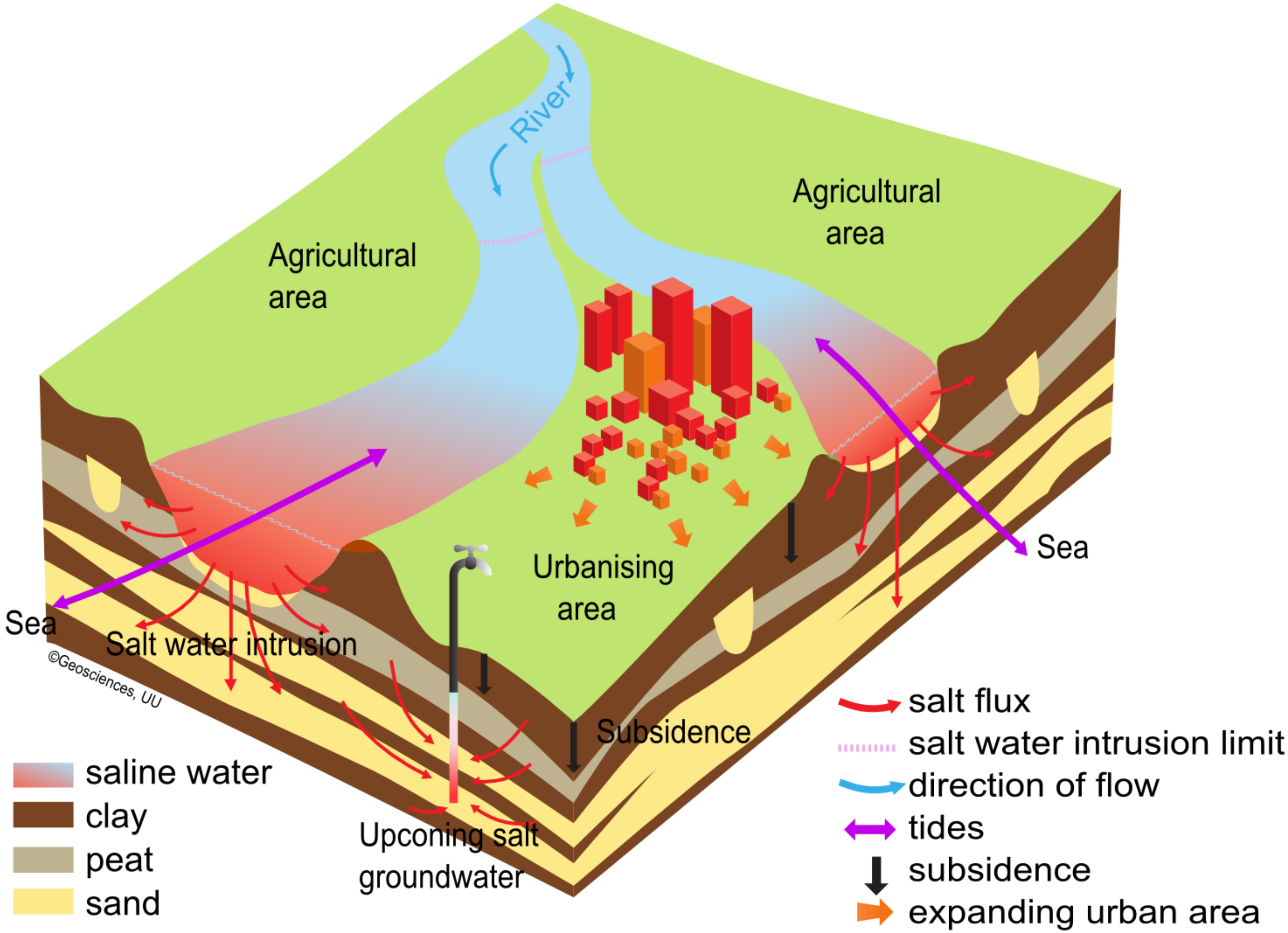

2400 litres of water
for 1 hamburger

= 140 litres of water

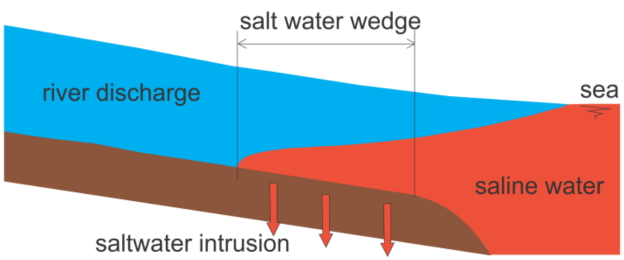
10 litres of water
for 1 sheet of A4-paper


Sea level rise: +2 m
http://flood.firetree.net
Bangladesh
20130327
বাংলাদেশ
(Bangladesh)
Dhaka
Rajshahi
Jessore
Madaripur
Khulna
Barisal
Patuakhali
Comilla
Chowmohani
Chittagong
Cox's Bazar
Kolkata
Barasat
West
Bengal
Jharkhand
Tripura
Meghalaya
Assam
Shillong
Sylhet
Silchar
Aizawl
Lunglei
Rangamati
Guwahati
Bongaigaon
Dhubri
Cooch Behar
Jalpaiguri
Siliguri
Purnia
Dinajpur
Rangpur
Bogra
Naogaon
Kurigram
English Bazar
Bara Beel
Tarakanda
Dumka
Hazaribagh
Ranchi
Dhanbad
Asansol
Durgapur
Bardhaman
Jamshedpur
Midnapur
Kharagpur
Baripada
Balasore
Bhadrak
Padma
Kaartgegevens ©2013 AutoNavi, Google, firetree.net

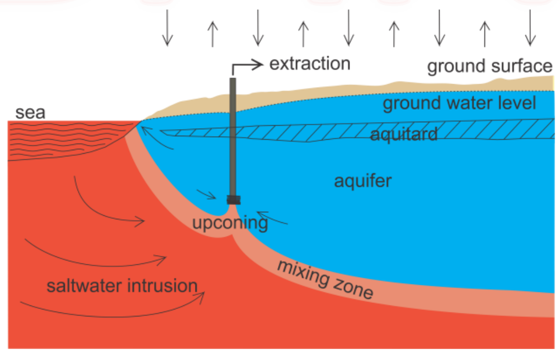
SALINIZATION PROCESSES IN THE COASTAL ZONE



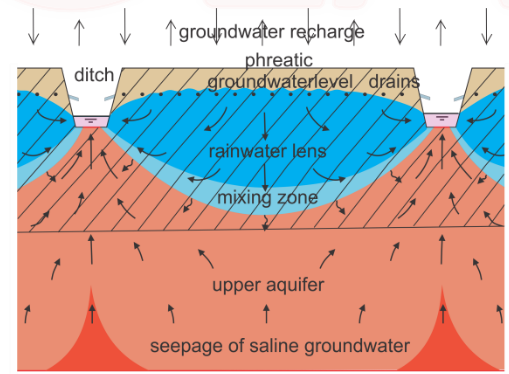
SALINIZATION PROCESSES



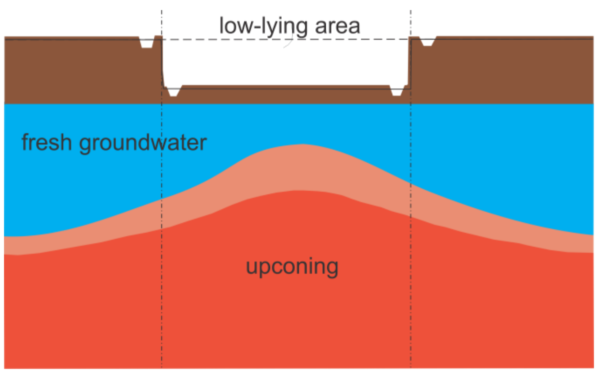
Salt water intrusion
surface water (and groundwater)



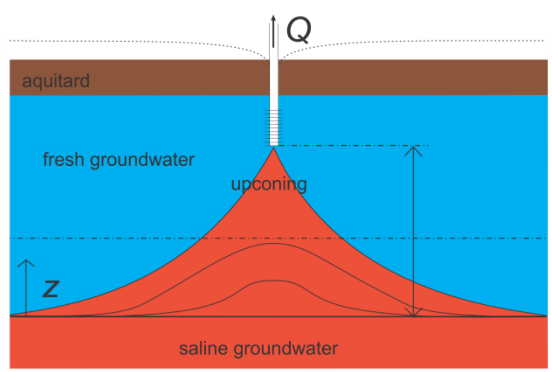
Salt water intrusion
groundwater



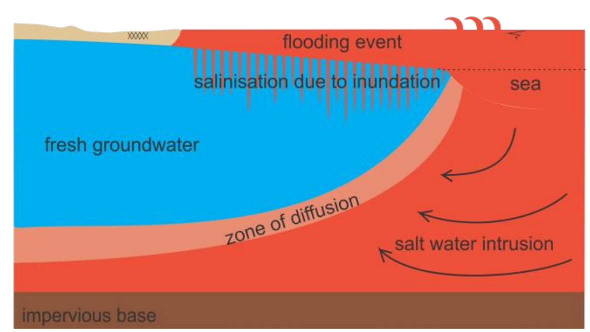
Shallow freshwater lenses
and saline seepage



Upconing low-lying area

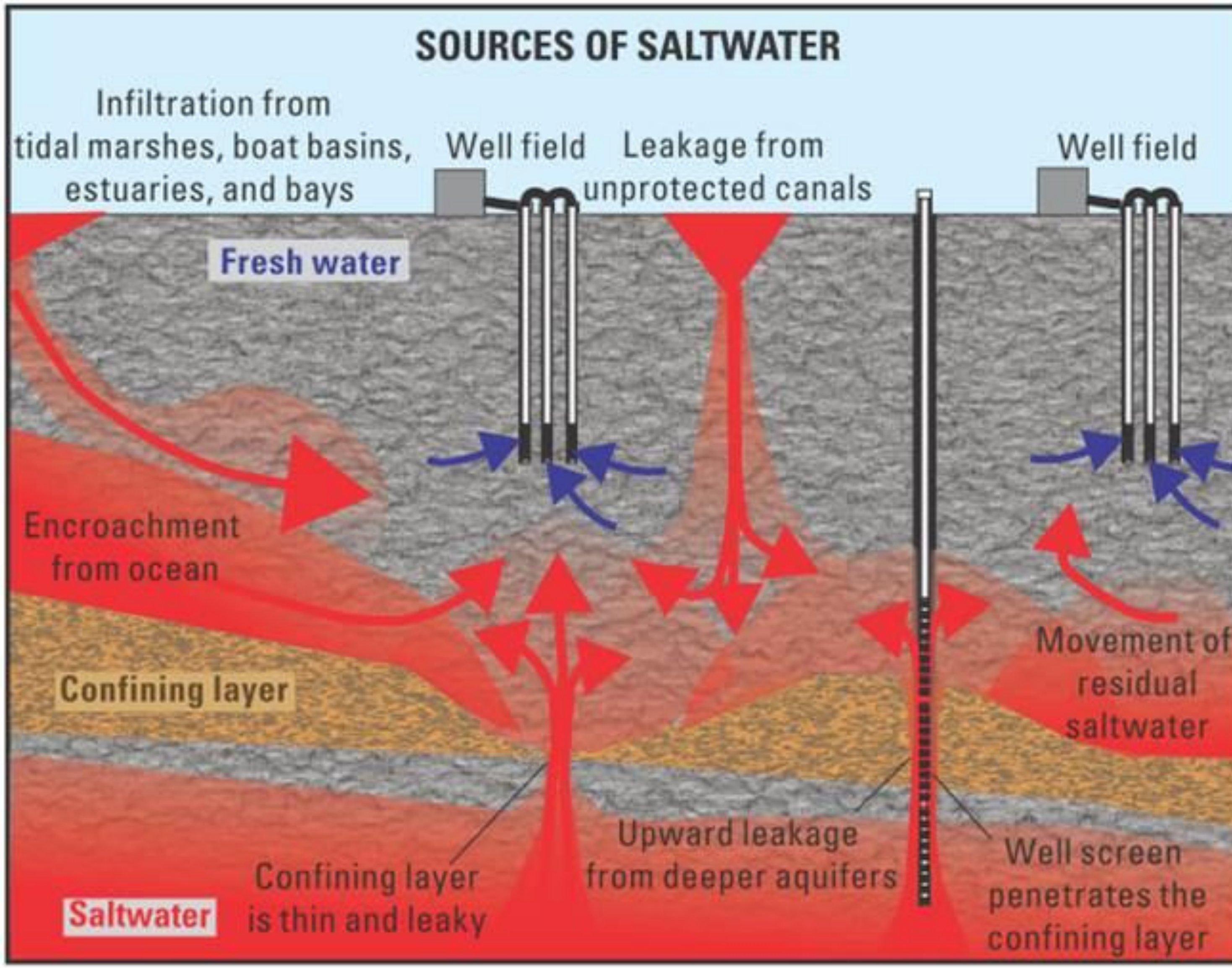


Upconing under
groundwater extraction

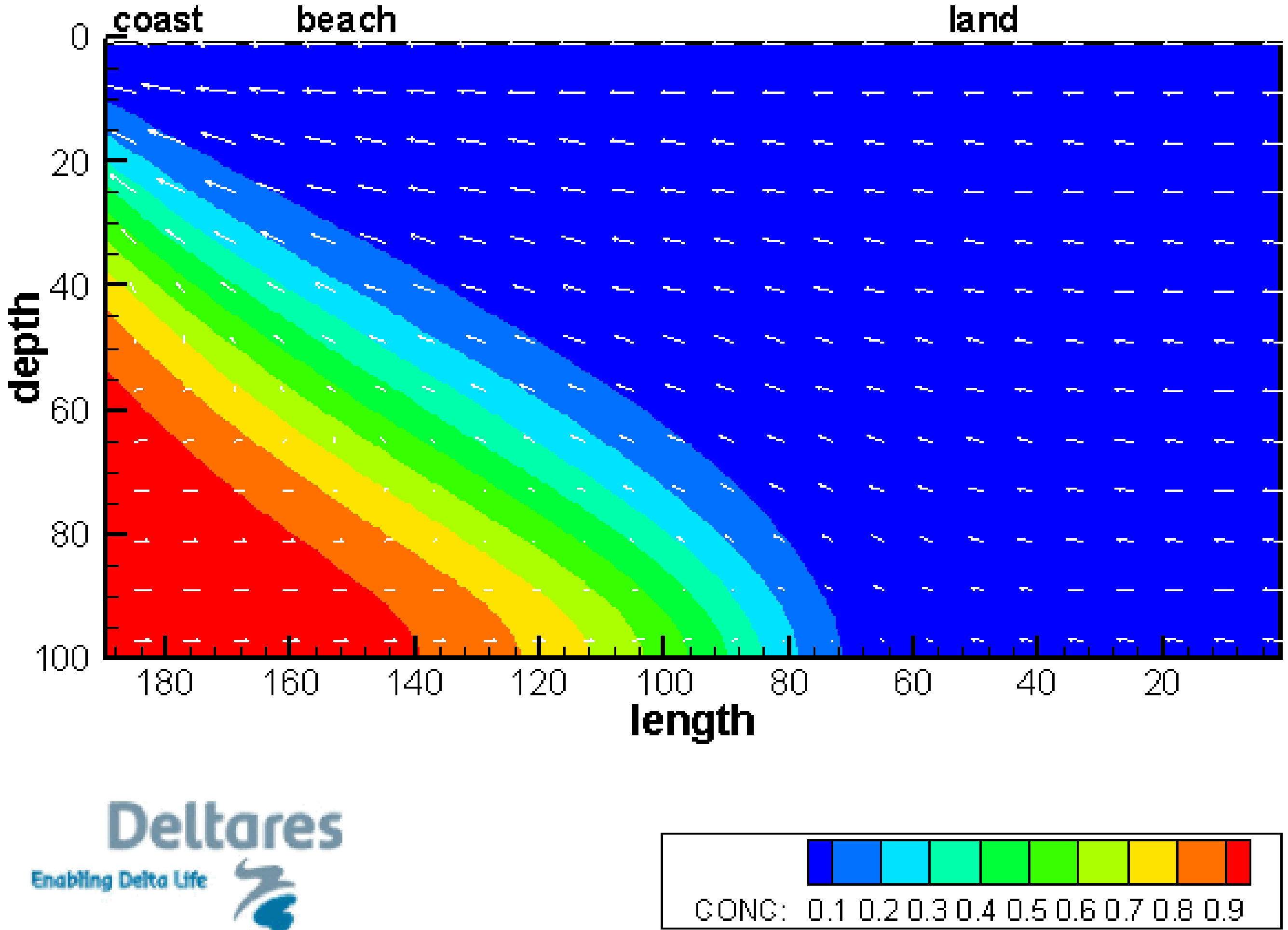


Shallow vertical salt water
intrusion after flooding
event (storm surge)

SALINIZATION PROCESSES IN THE COASTAL ZONE: COMBINATION

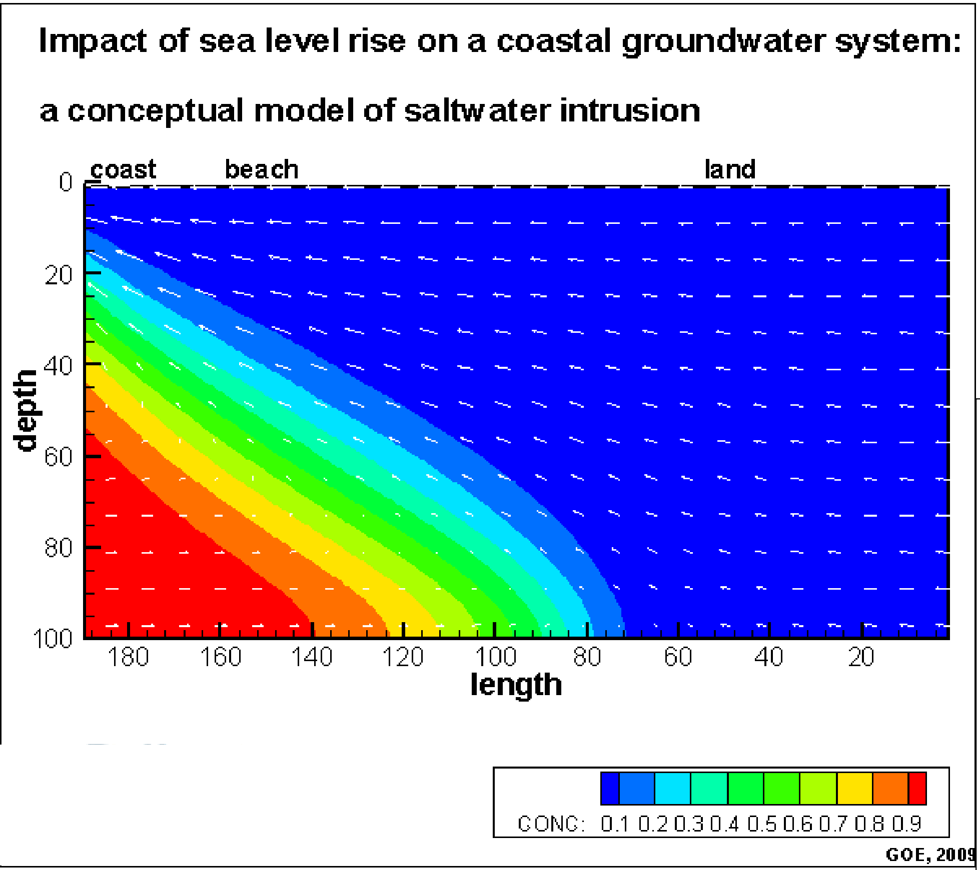


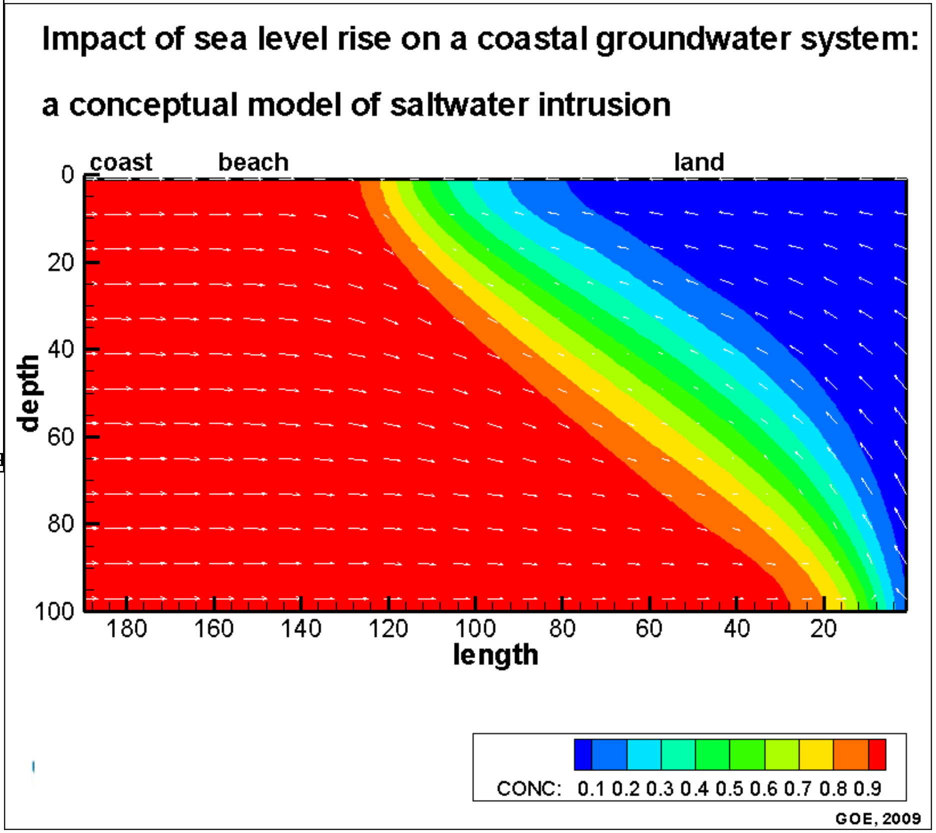
Impact of sea level rise on a coastal groundwater system: a conceptual model of saltwater intrusion



GOE, 2009

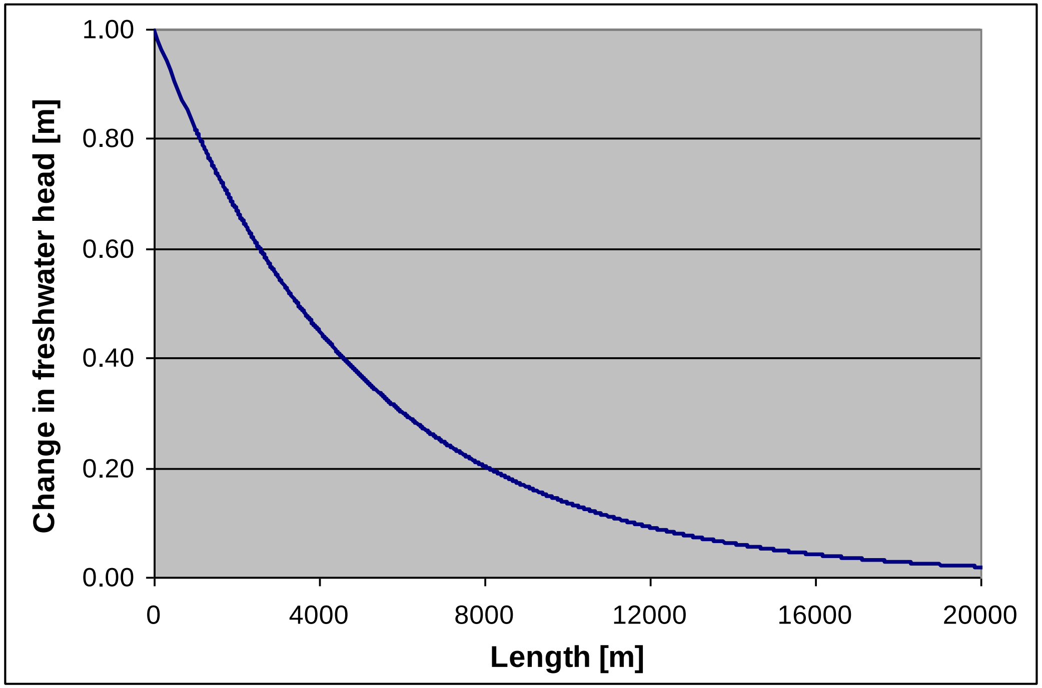
Sea level rise and salt water intrusion

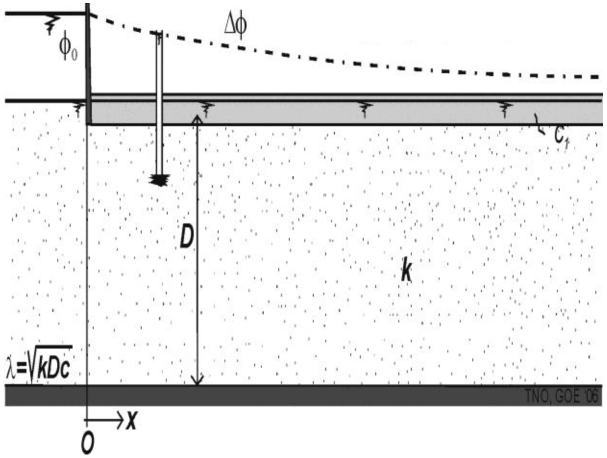


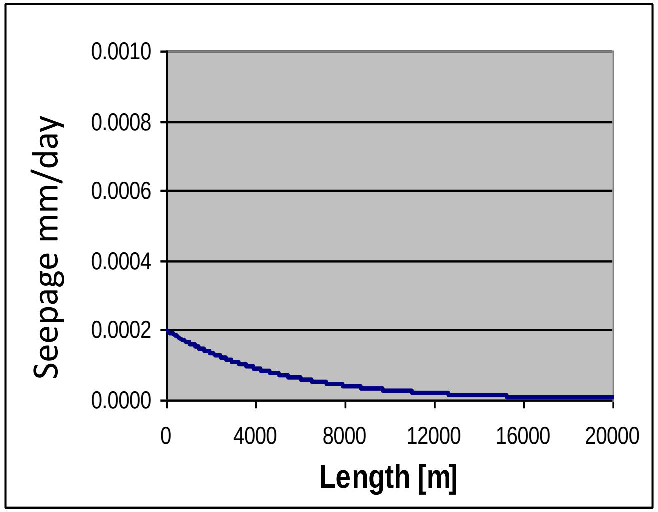


ZONE OF INFLUENCE OF SEA LEVEL RISE
Case 1 with subsoil parameters

kD = 5000 m2/day
c = 5000 day
λ = 5000 m





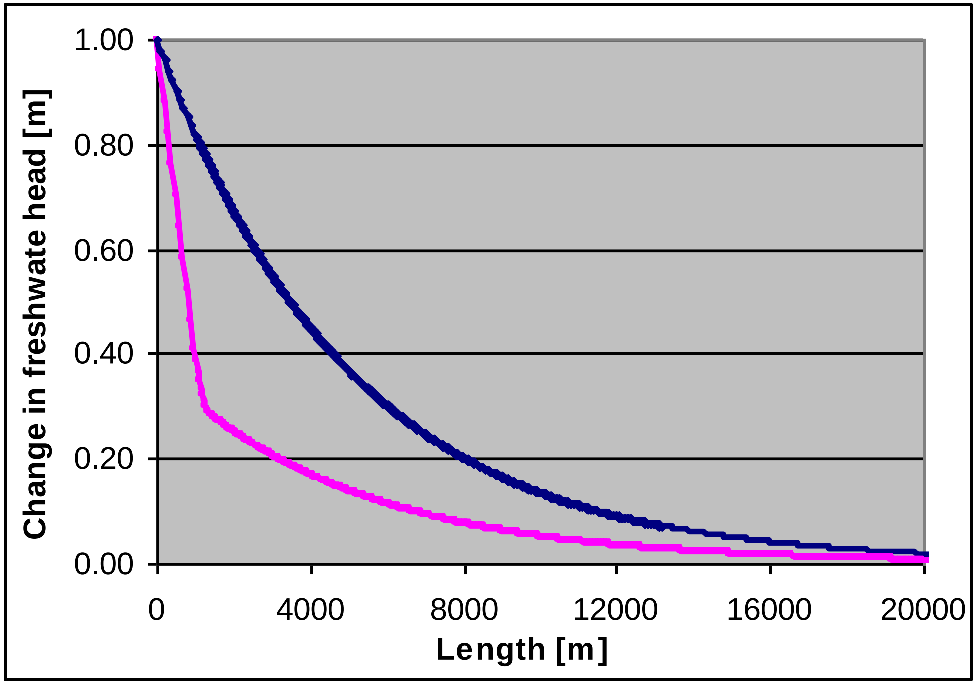


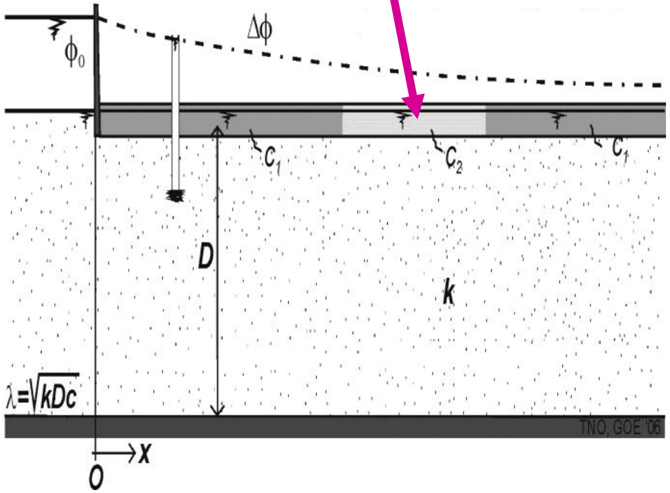
ZONE OF INFLUENCE OF SEA LEVEL RISE:

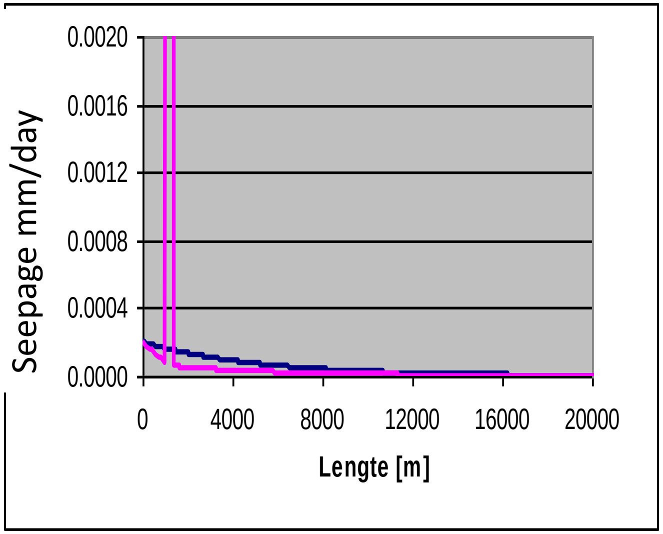
Case 2 with subsoil parameters

GOOD PERMEABLE AQUITARD

kD = 5000 m2/dag
c1 = 5000 dag c2 = 50 dag





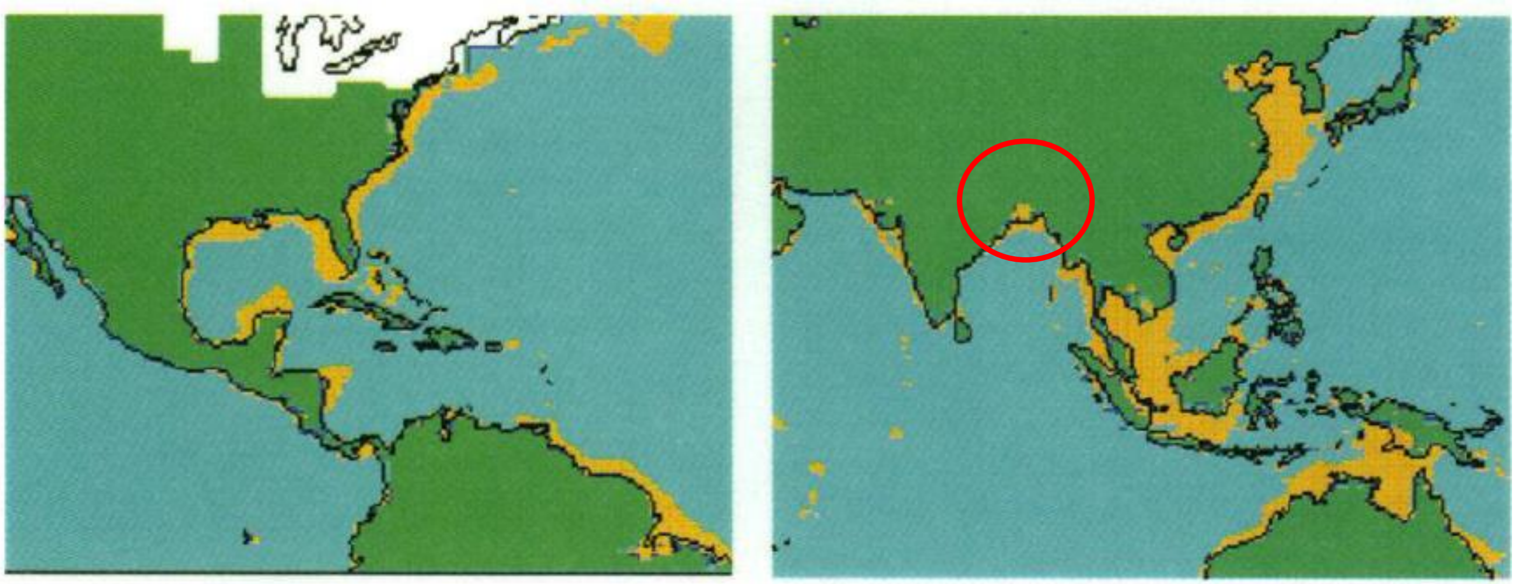


Hypothesis

Present 3D distribution of fresh-brackish-saline groundwater is not in equilibrium of present-day sea level.

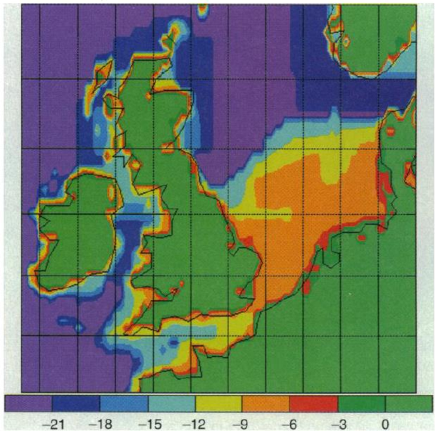
Bear in mind that groundwater is a slow process

COASTAL ZONE CASES AROUND THE WORLD
Occurrence related to dynamic sea-levels and coastlines

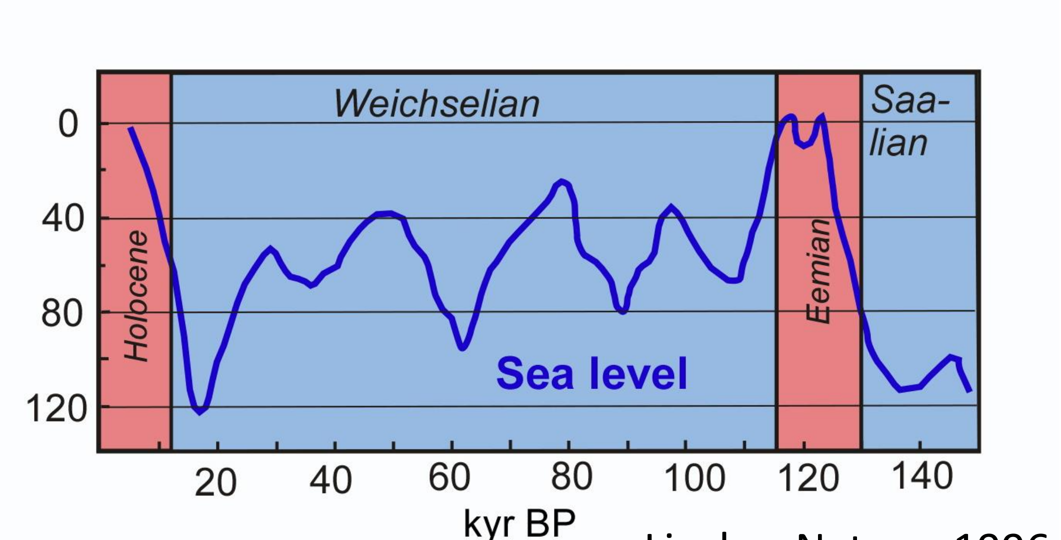


Exposed continental shelves

Peltier, *Science*, 1994

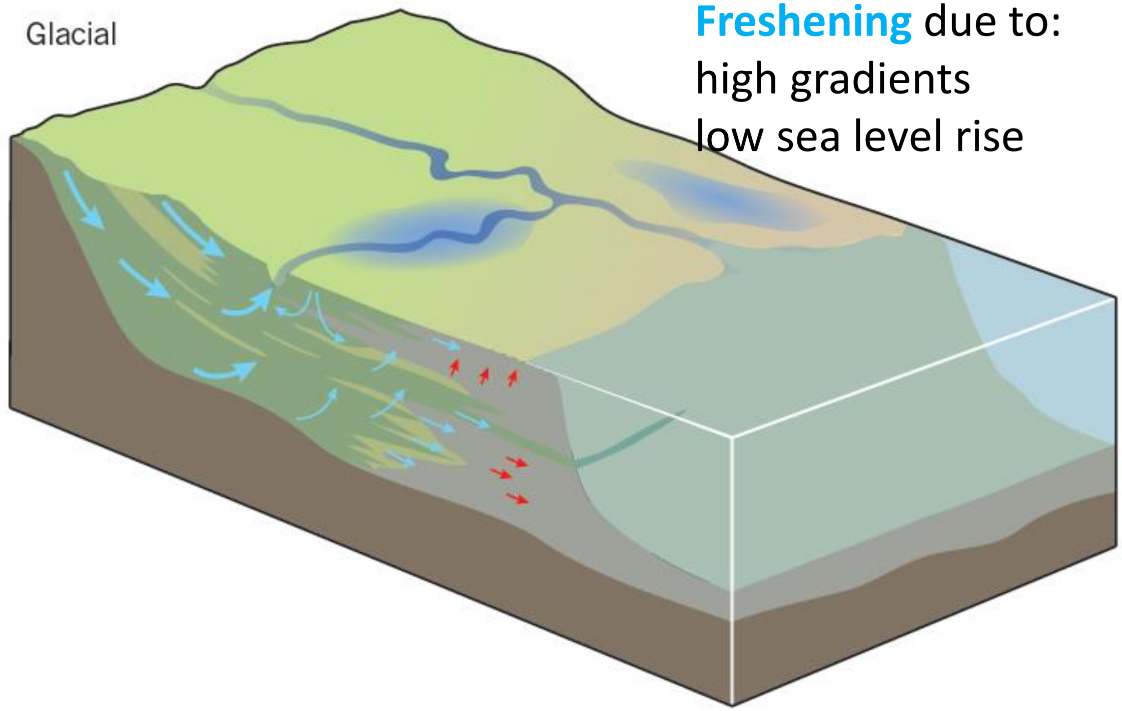


Inundated (kyr BP)

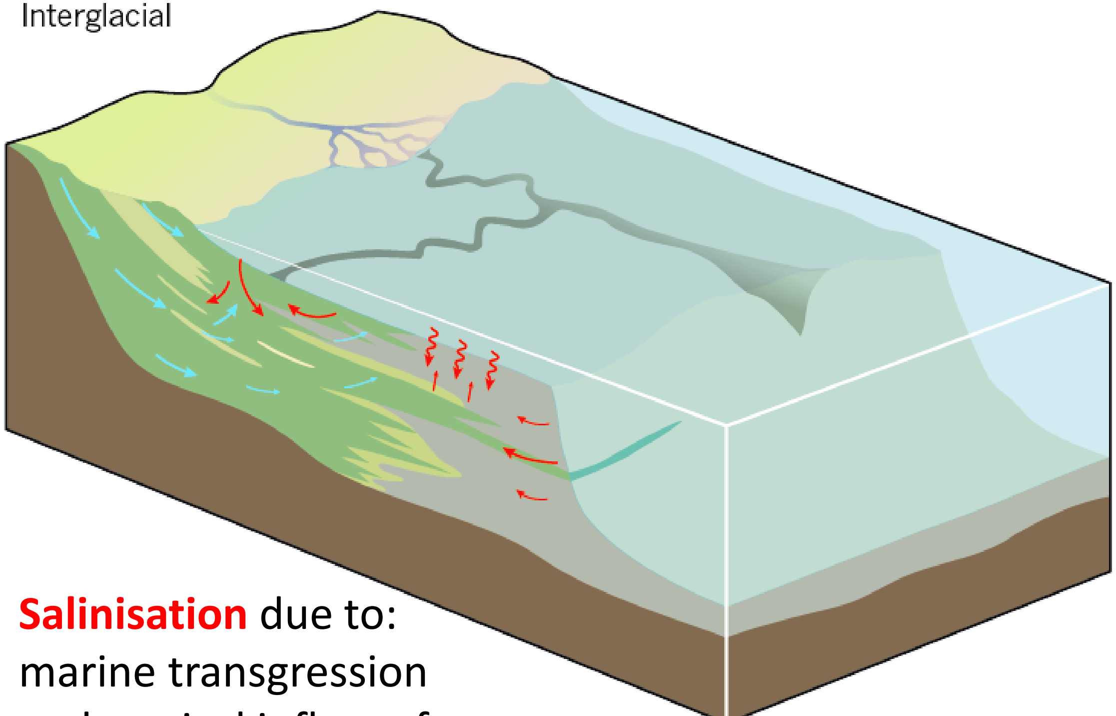


Linsley, Nature, 1996

Genesis and preservation



Freshening due to:
high gradients
low sea level rise



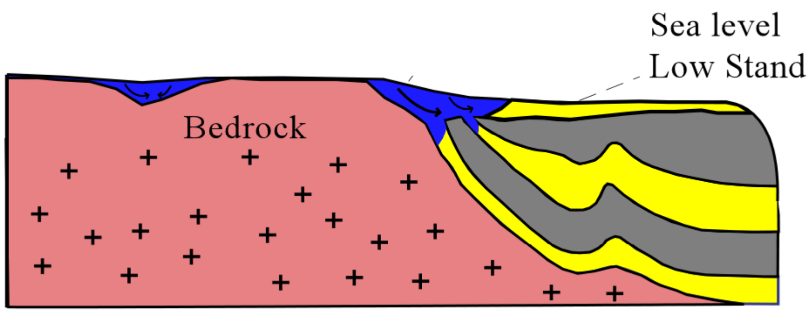
Salinisation due to:
marine transgression and vertical inflow of saline surface water

Source: Nature, 2013

GROUNDWATER IN THE COASTAL ZONE

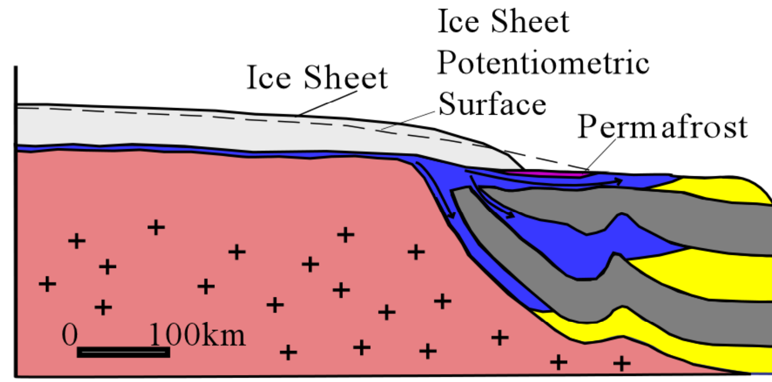
Possible mechanisms for continental shelf flushing

Sea Level Fluctuations



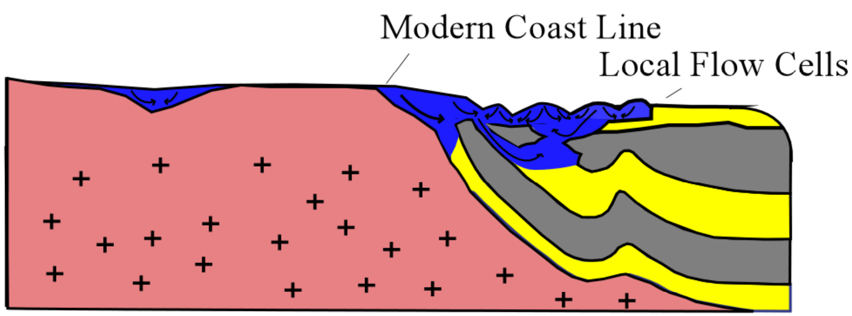
(Meisler et al., 1984)

Sub-Ice Sheet Recharge



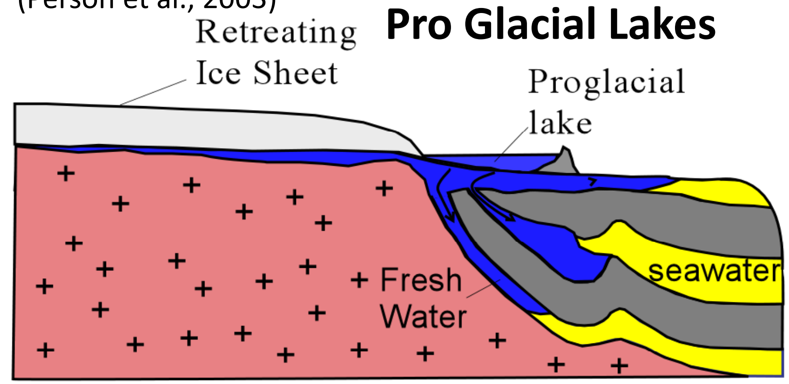
(Person et al., 2003)

Local Flow Cells



(Groen et al, 2000)

Pro Glacial Lakes



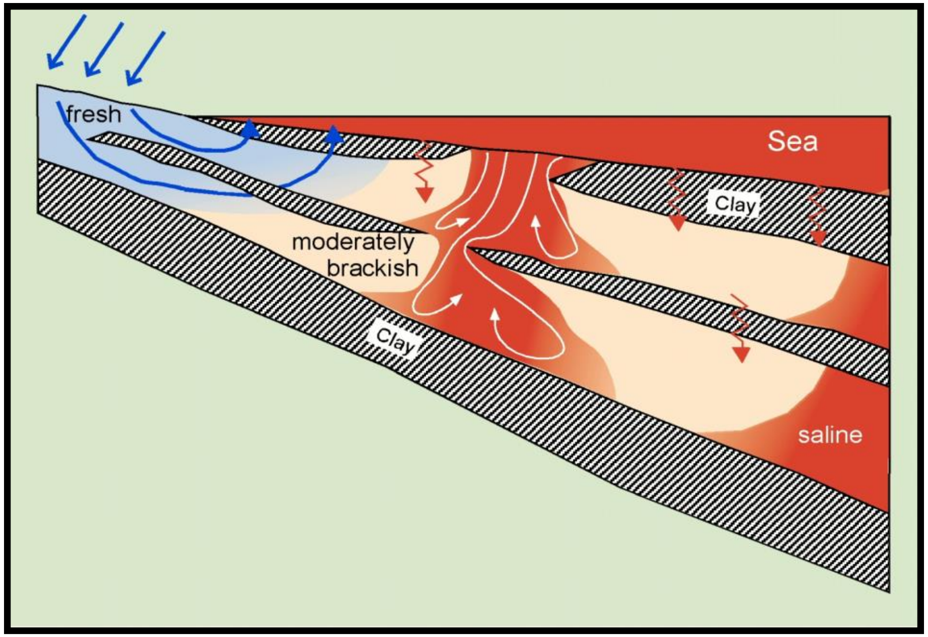
(Uchupi et al., 2001)

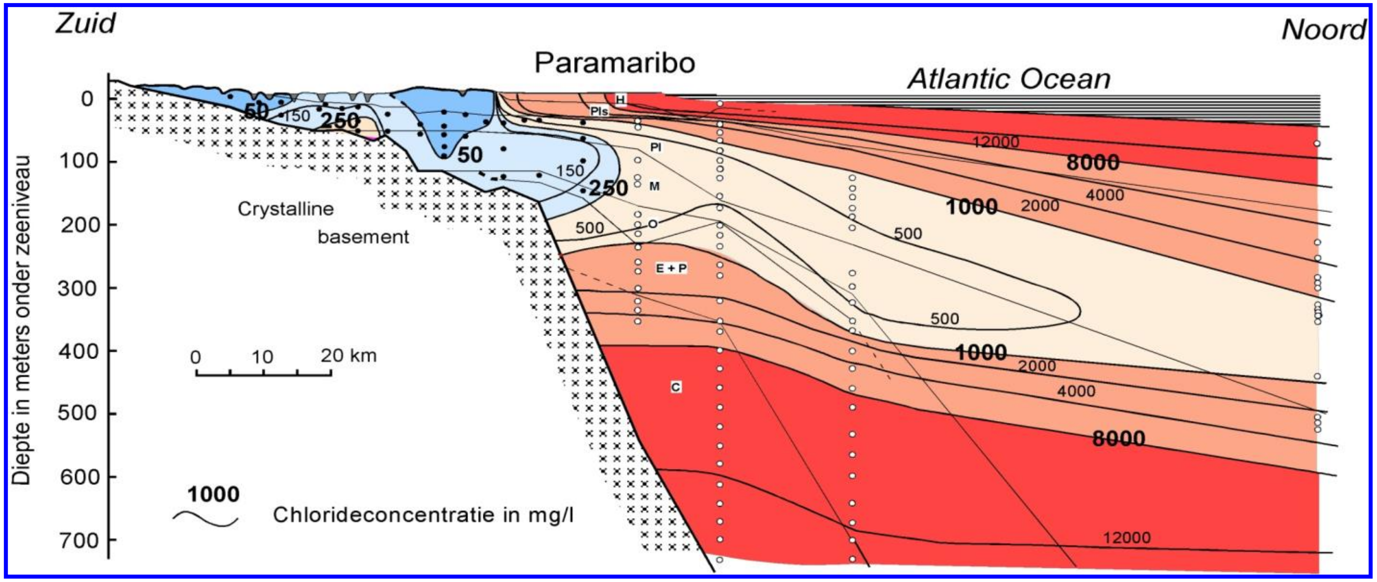
Freshwater

Seawater

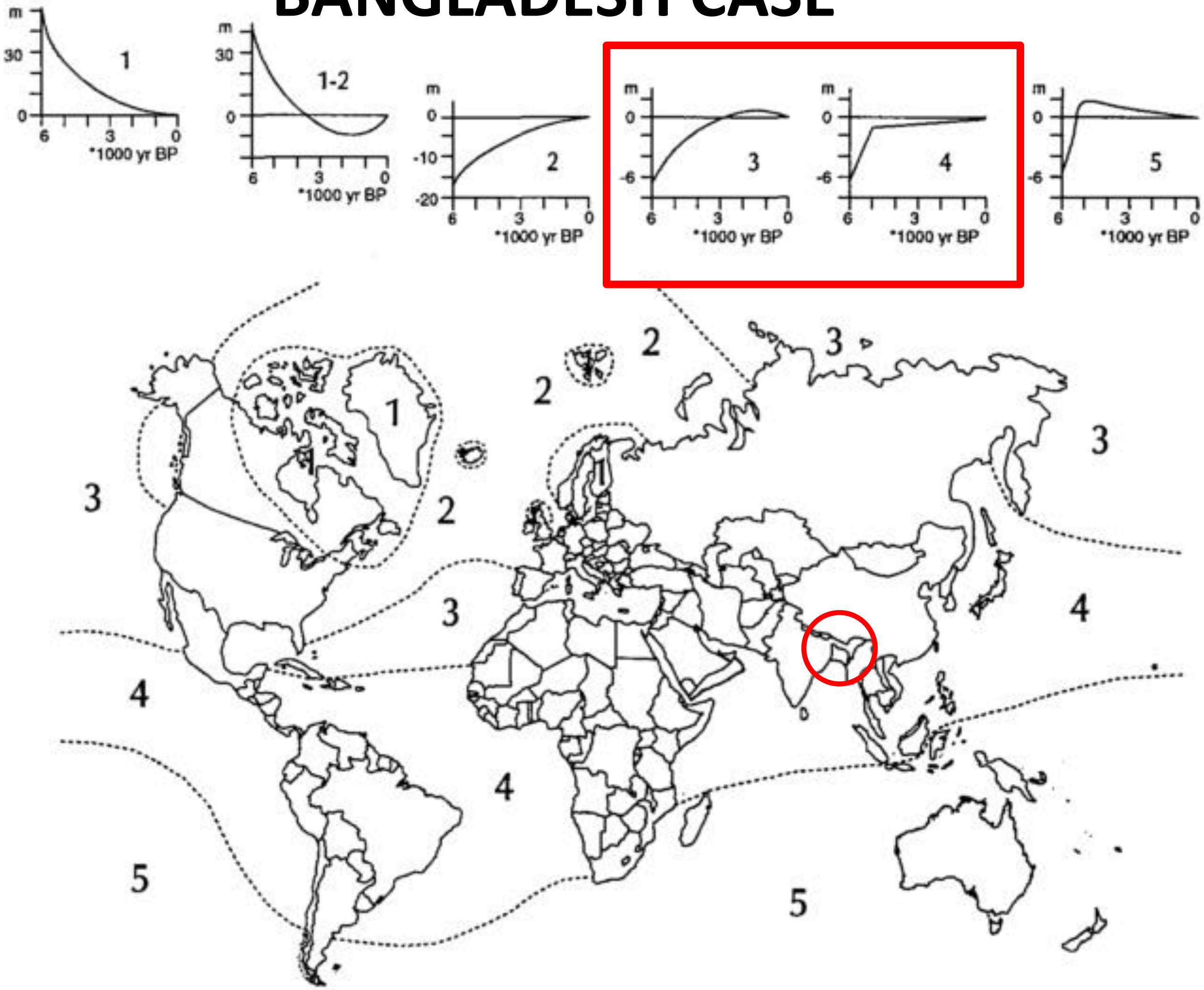
Nature, 2013

GROUNDWATER IN THE COASTAL ZONE



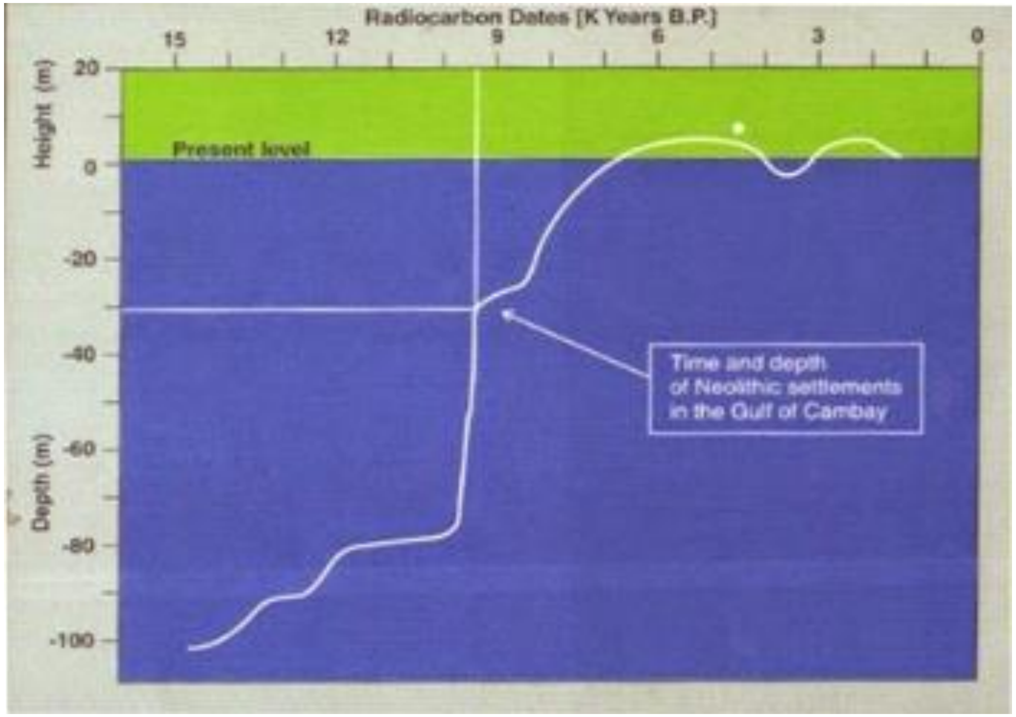


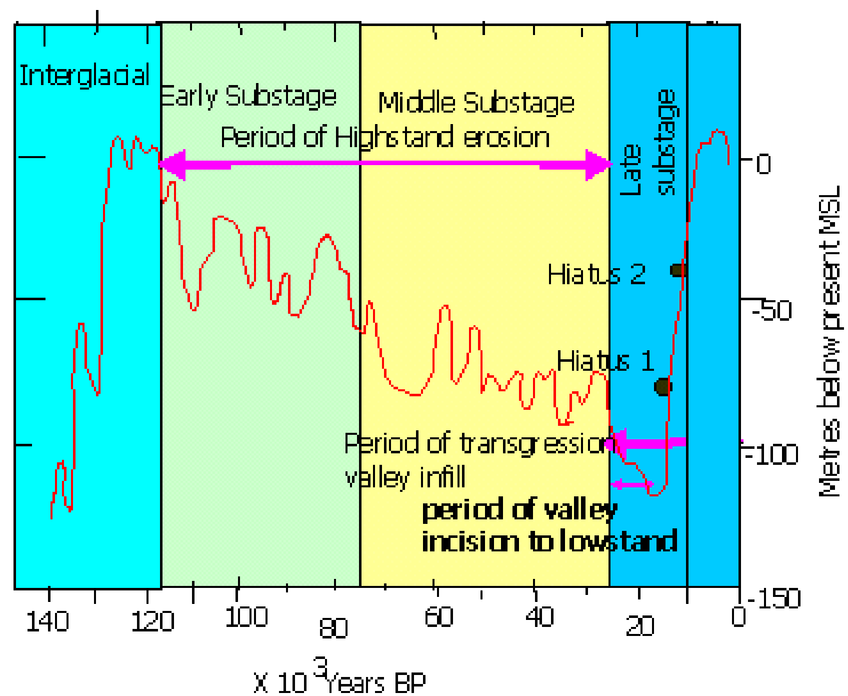
Regional distribution of Holocene Sea-level Changes
BANGLADESH CASE



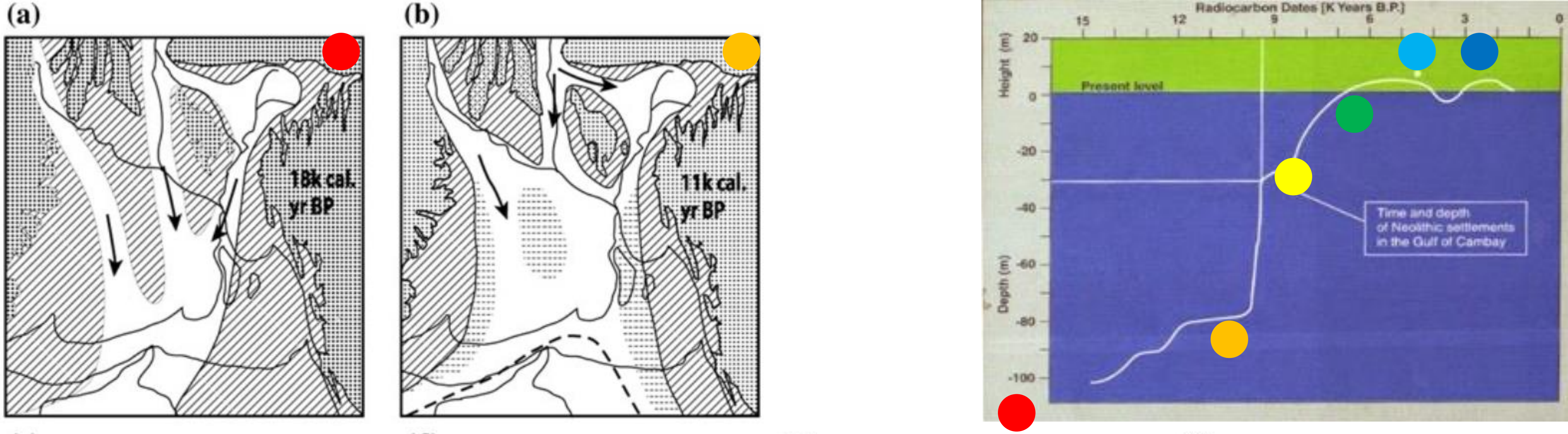
Source: Pirazzoli, P.A. & Pluet, J., 1991. World Atlas of Holocene Sea-level Changes. Elsevier Oceanography Series, Vol. 58

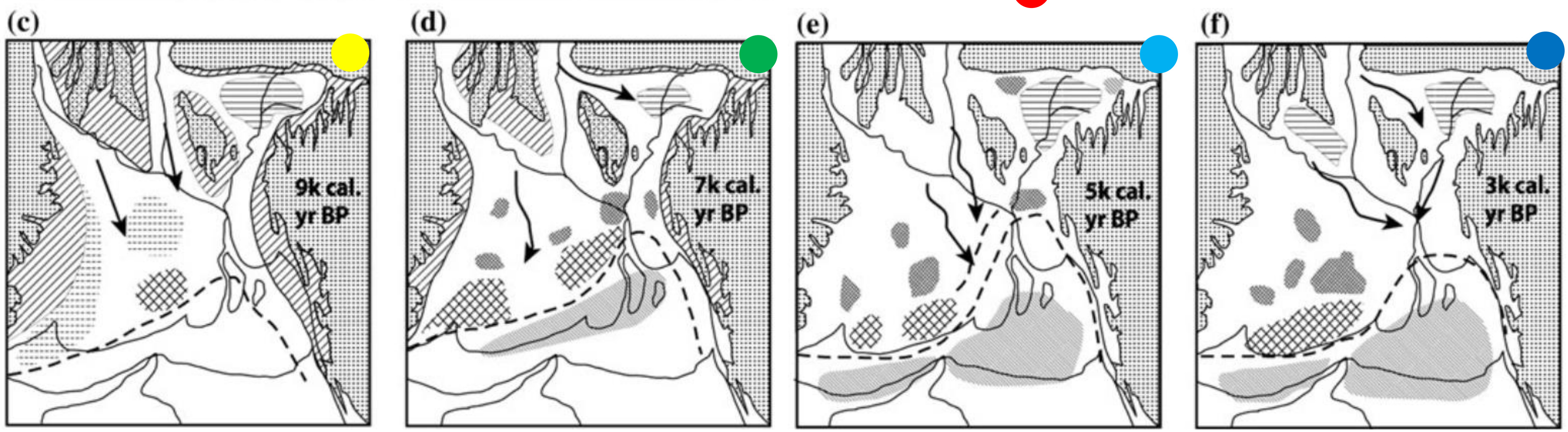
Holocene Sea-level Changes, in detail at the Bengal Bay





Source: Pirazzoli, P.A. & Pluet, 1991





onset sediment trapping and delta growth

upstream channel migration and widespread dispersal of sands

two rivers had migrated or changed course

large sediment supply, active tectonism, and eustasy

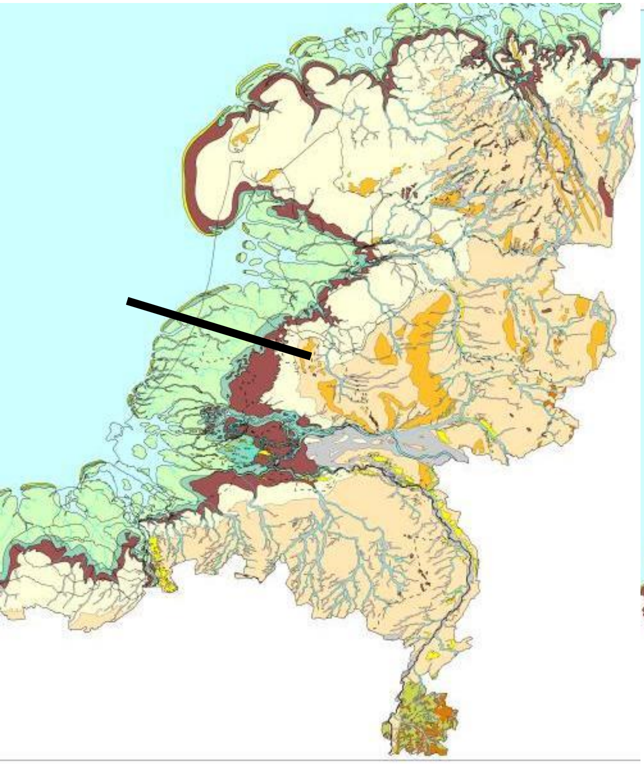
Source: Goodbred and Kuehl, 2000

Hypothesis

Present 3D distribution of fresh-brackish-saline groundwater is not in equilibrium of present-day sea level.

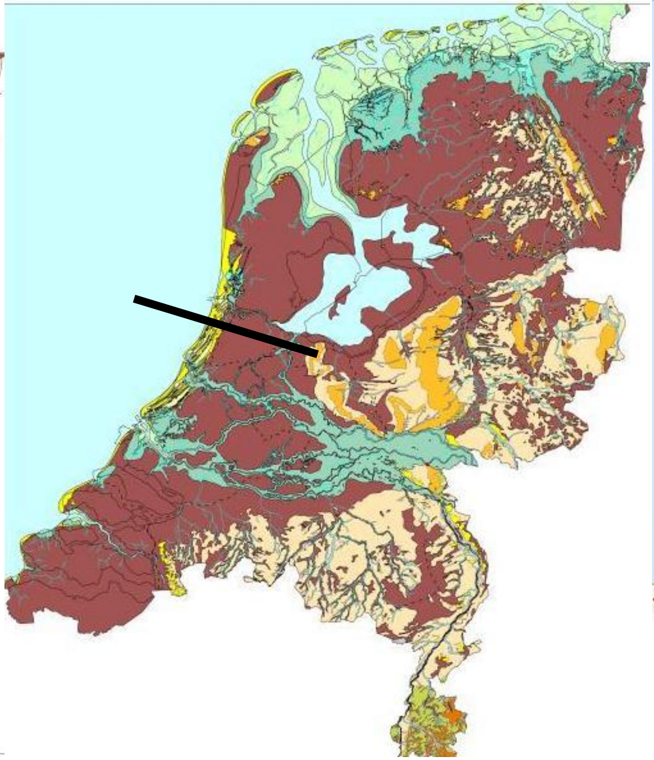
PALAEOGEOGRAPHICAL DEVELOPMENT

5500 BC



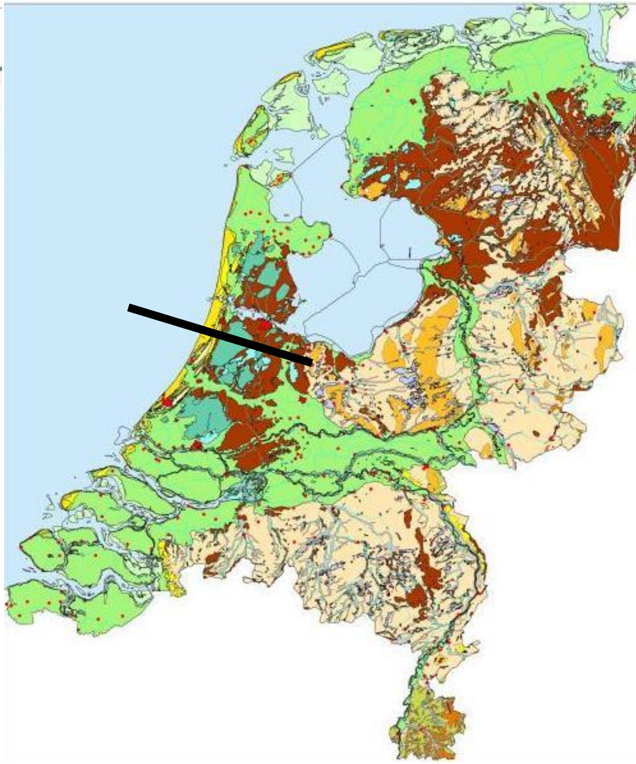
Maximal transgression

100 AD



Peat development

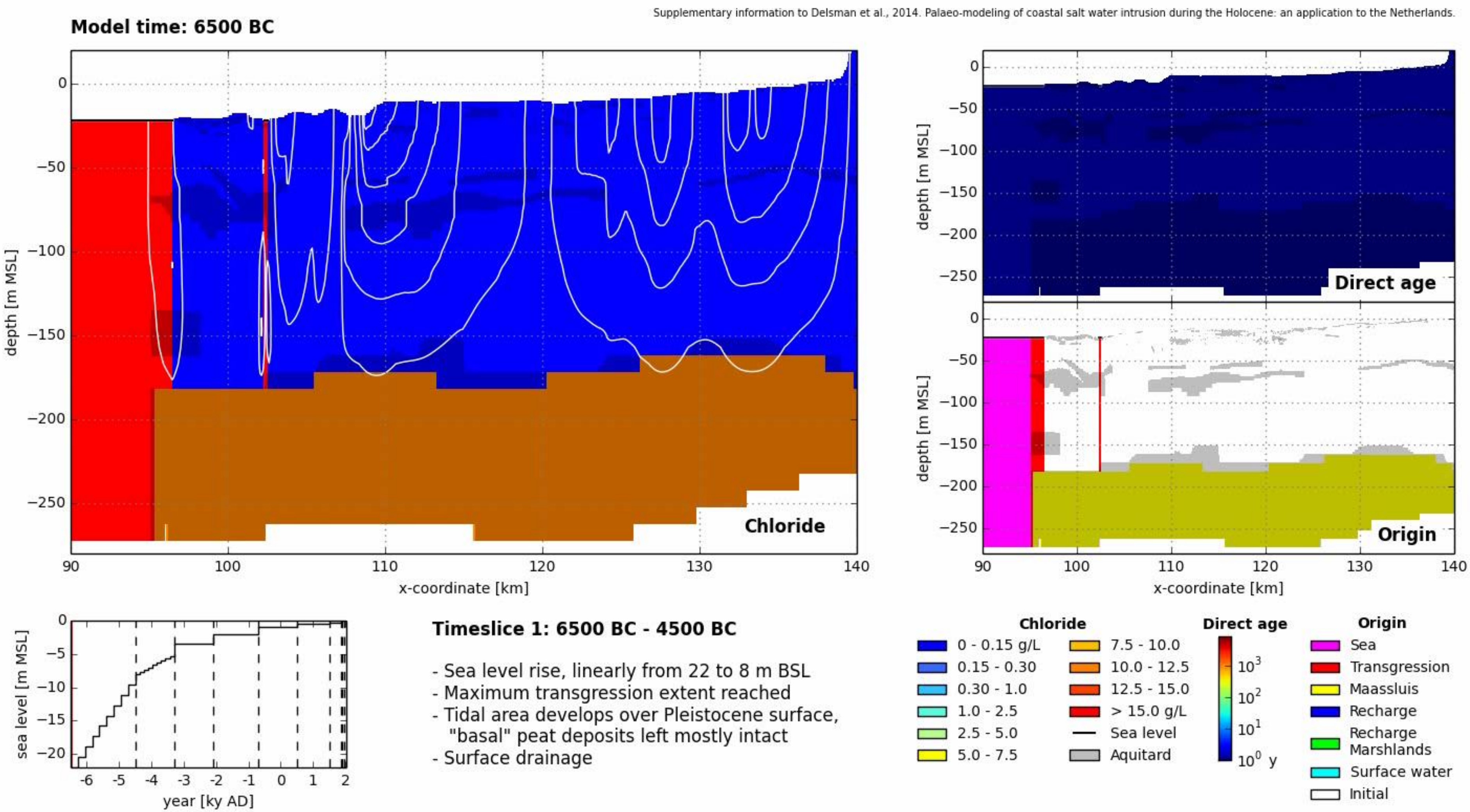
1850 AD



Reclaimed land, polder

Atlas NL in het Holoceen (Vos et al, 2011)

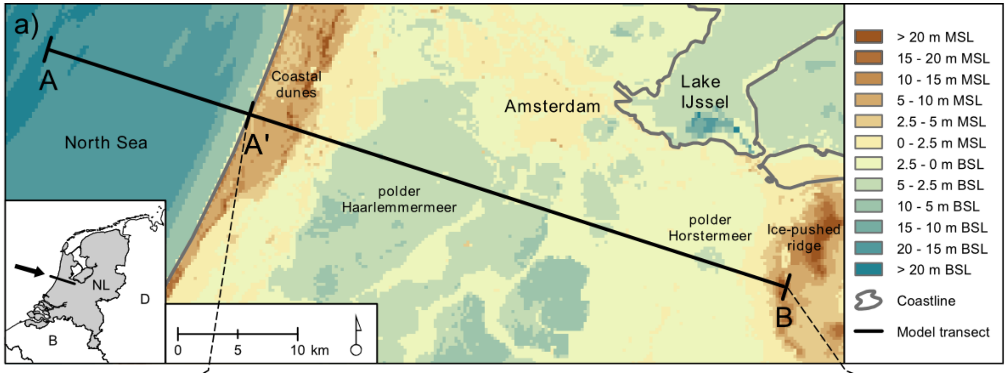
Development saline groundwater in

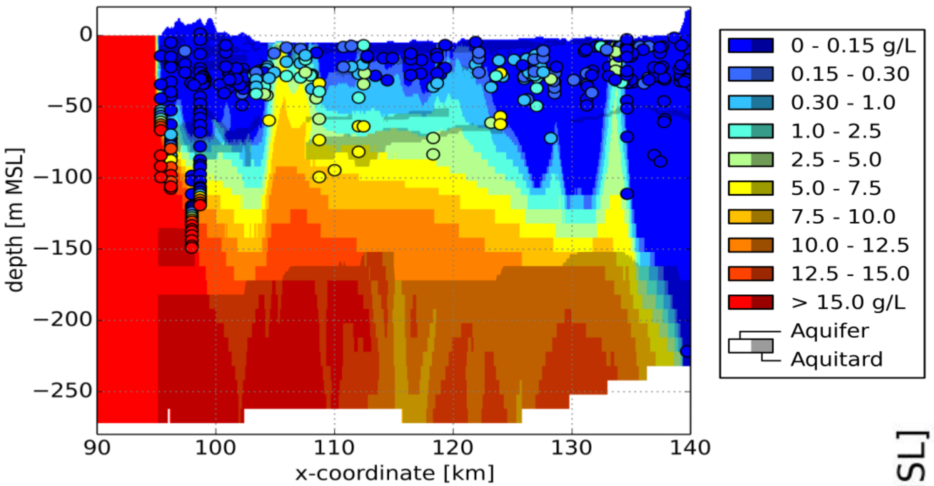


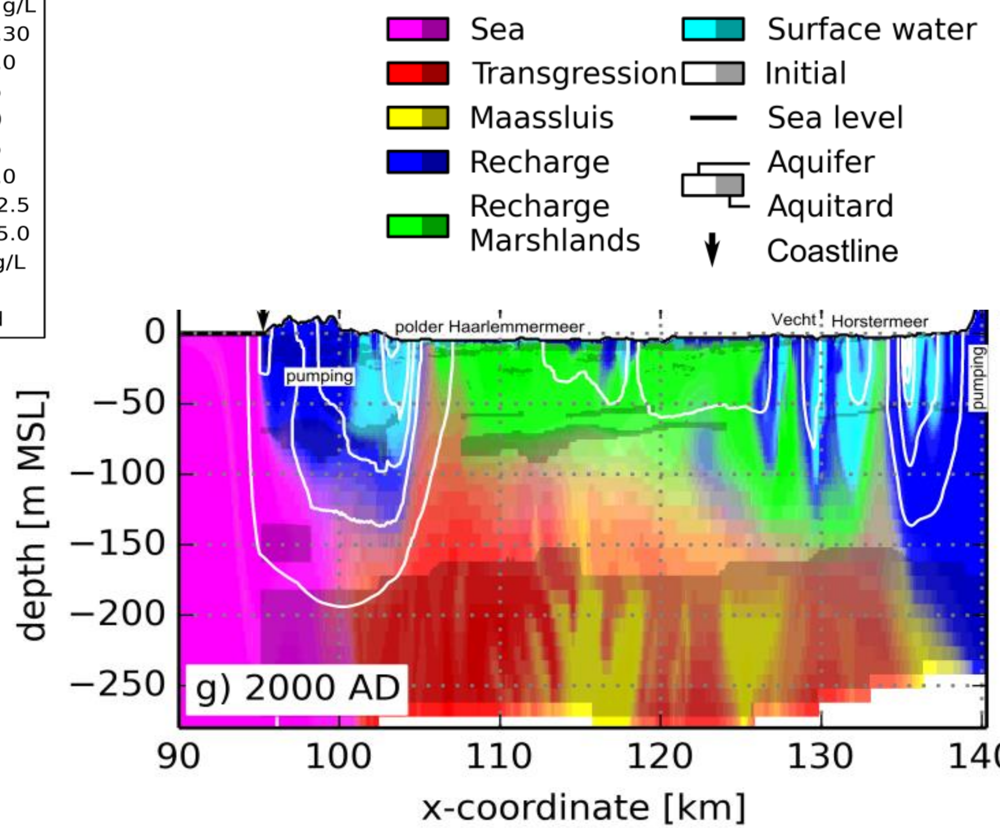
Delsman et al., HESSD, 2013

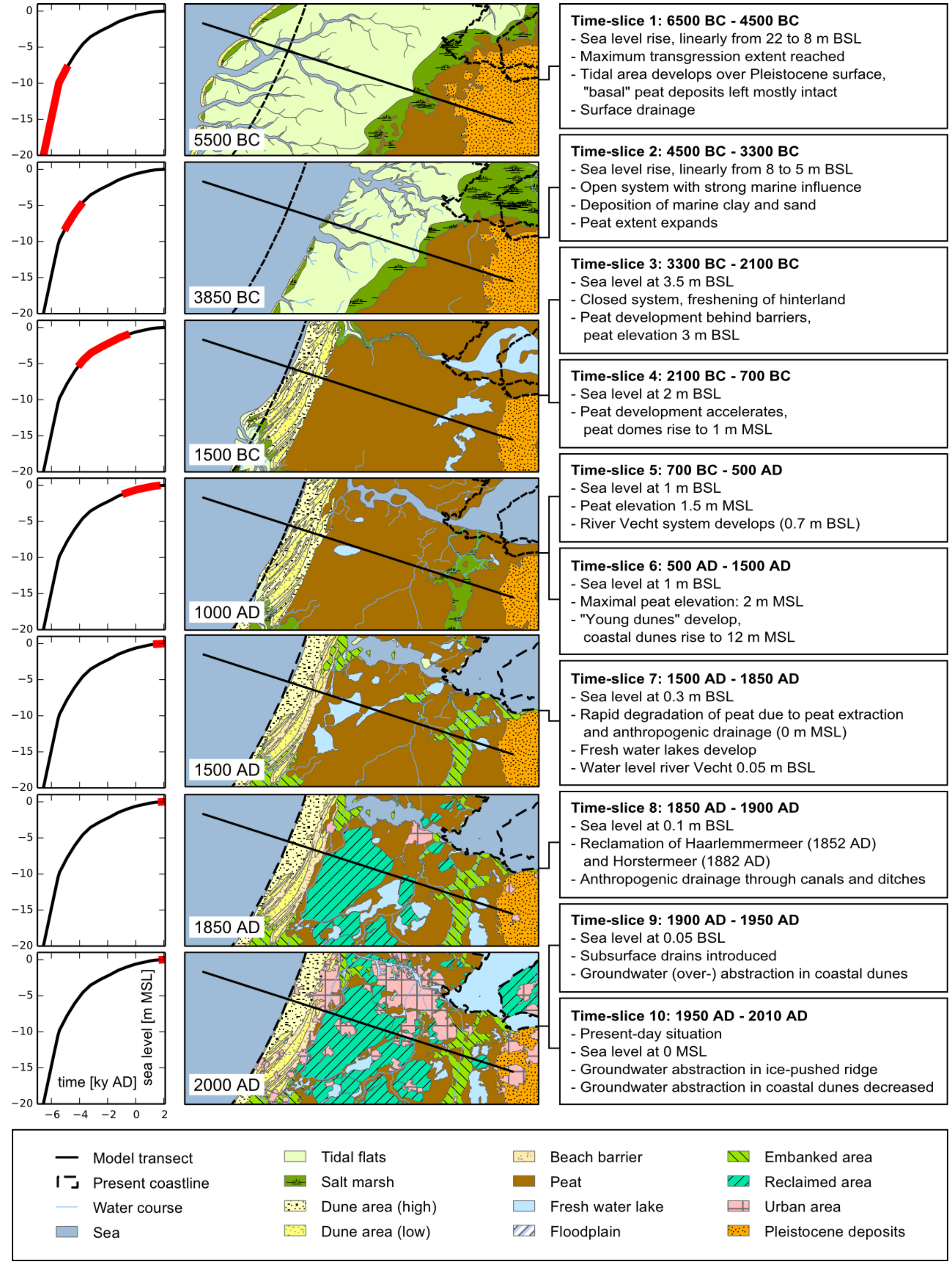
Sources of saline groundwater in the Dutch coastal zone

Delsman et al. HESSD, 2013



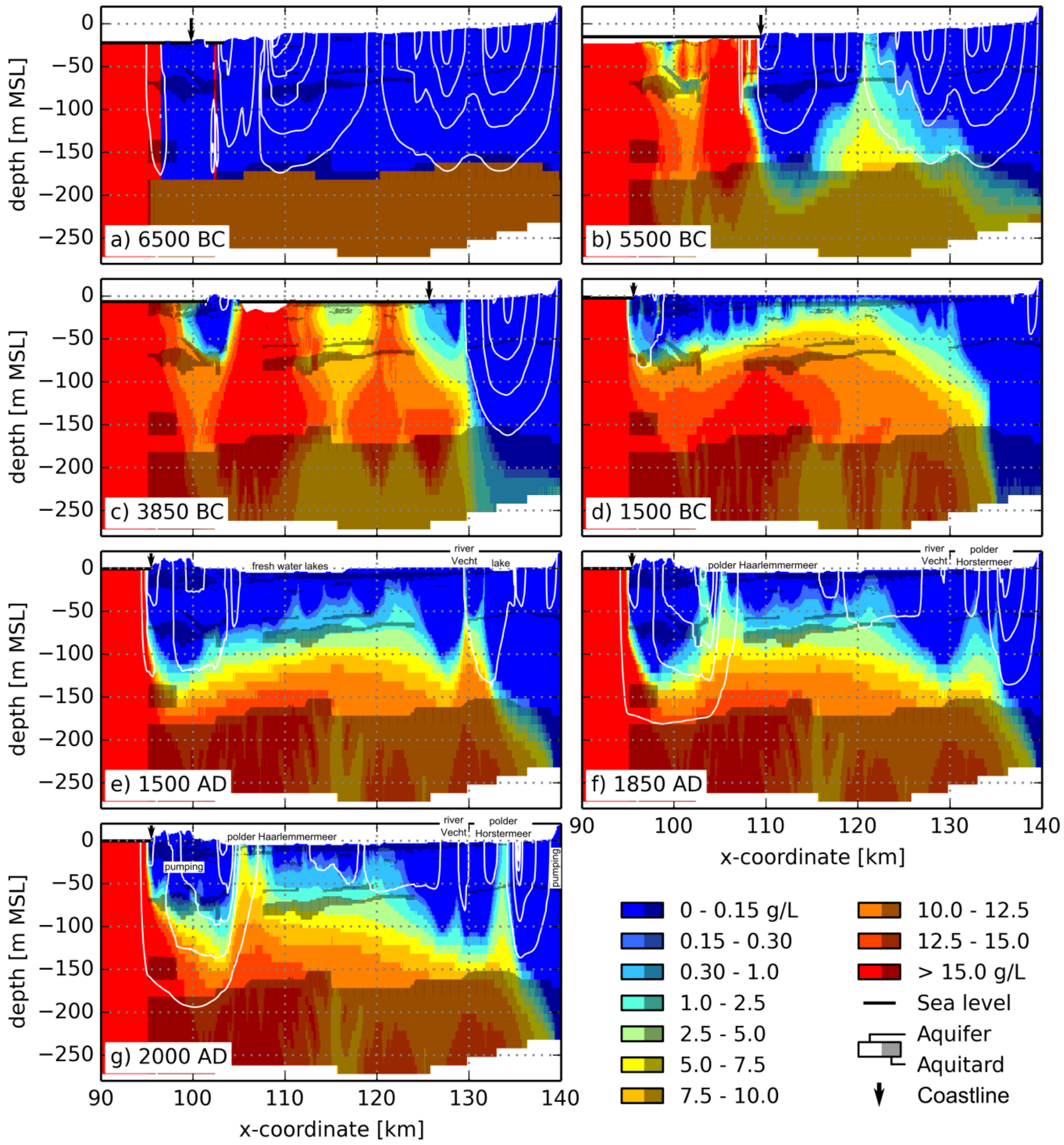




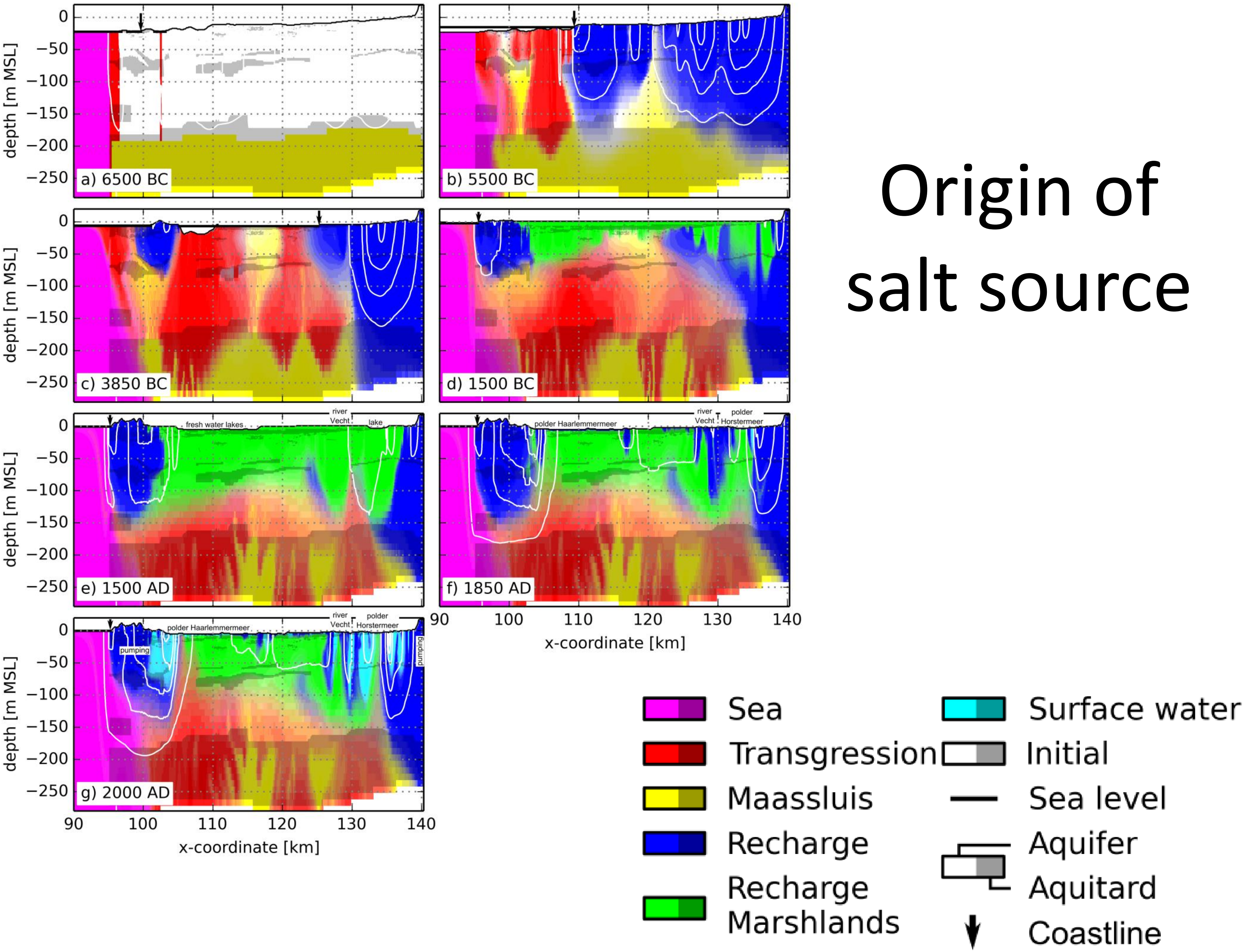


20140724 SFWMD

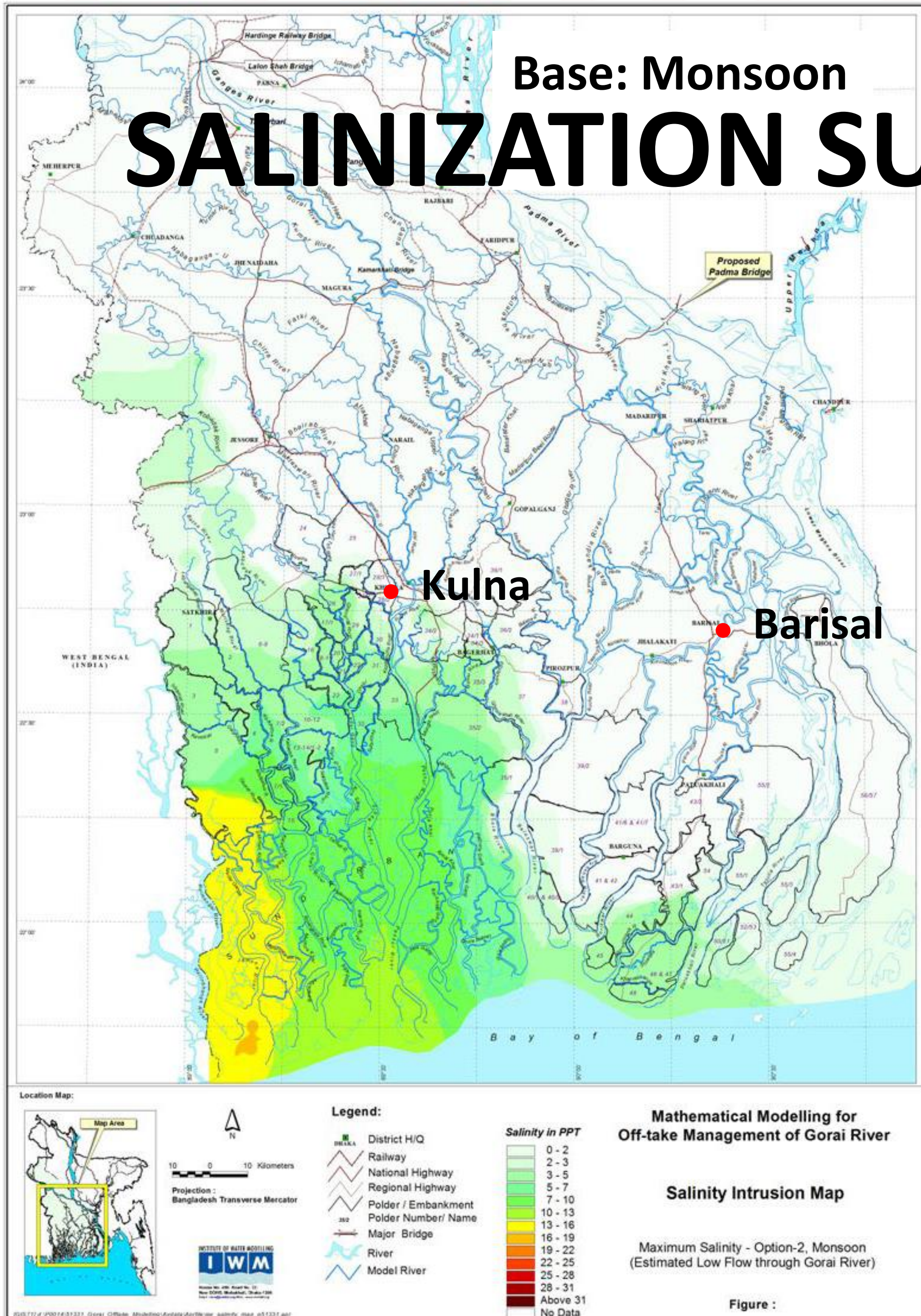
Chloride concentration Model versus measurements

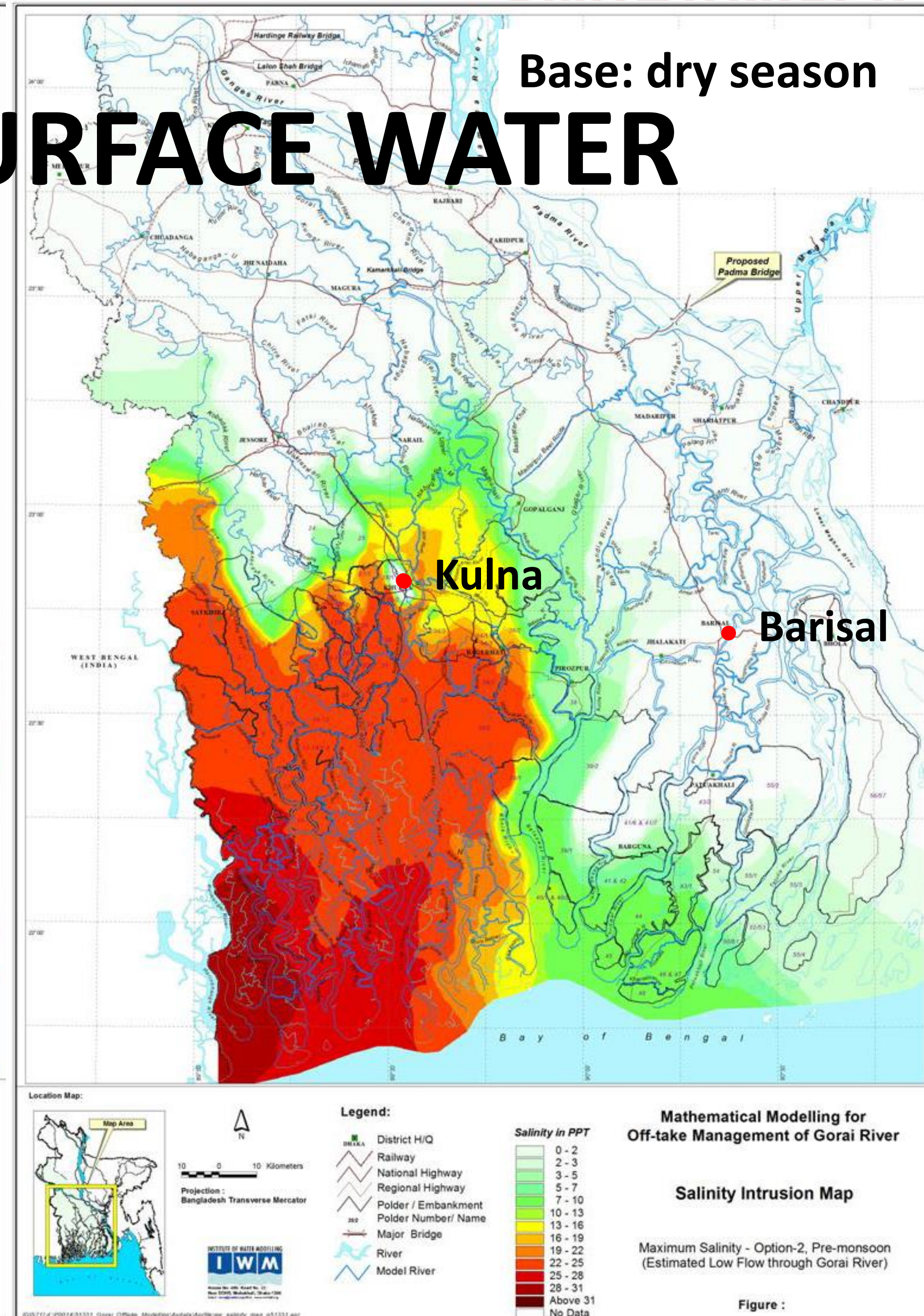


Origin of salt source



SALINIZATION SURFACE WATER

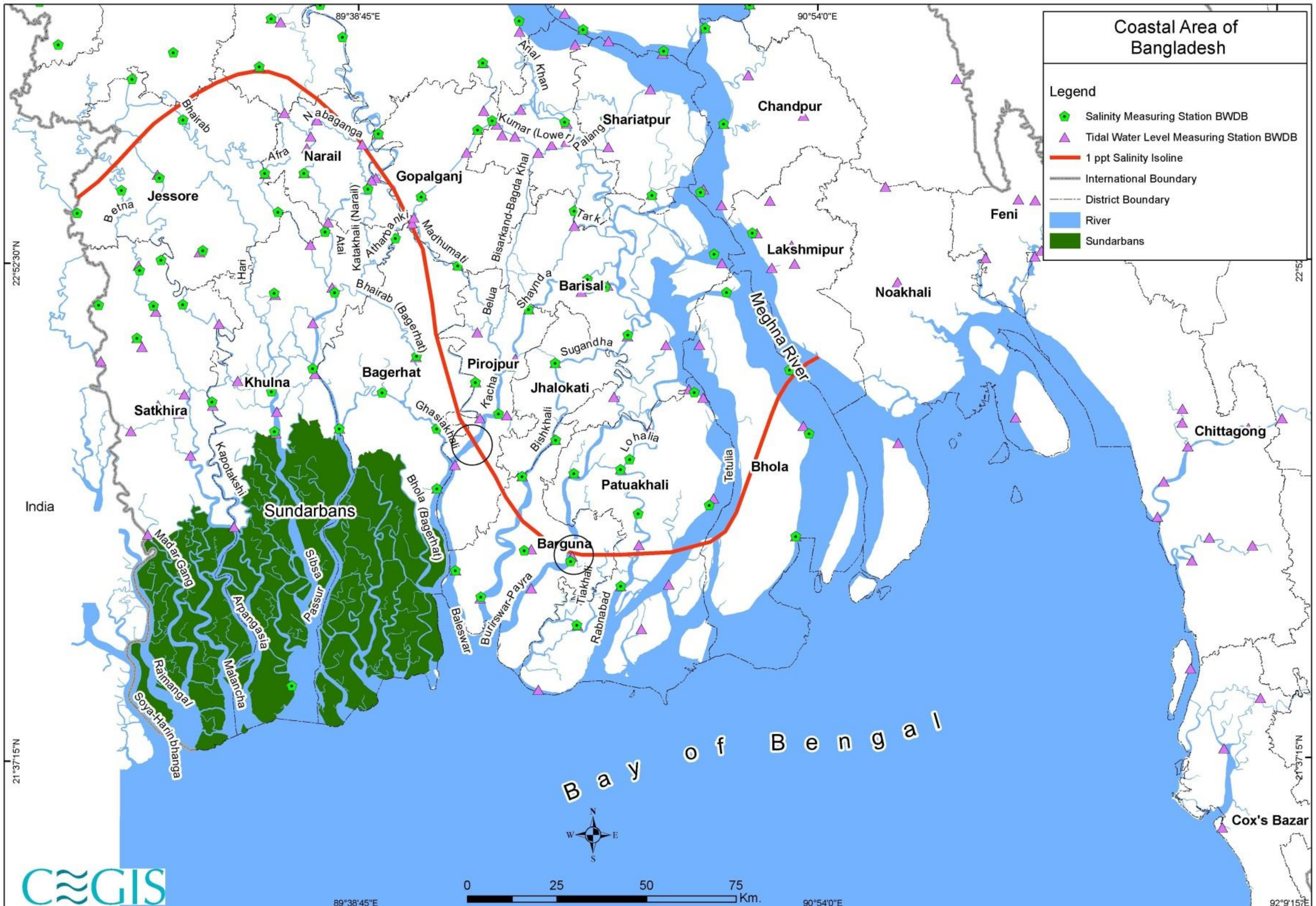




Base: Monsoon

Base: dry season

SALINIZATION SURFACE WATER

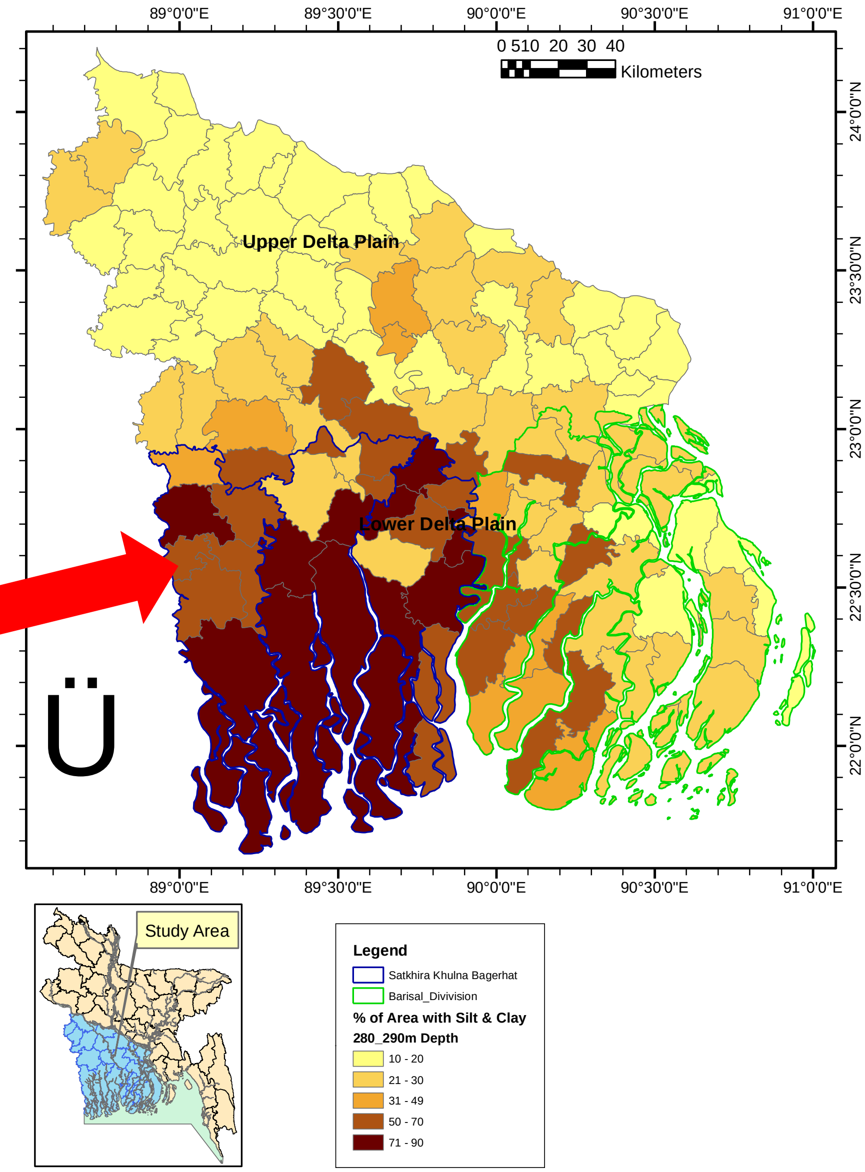


Geology: three fold classification of the study area

Three Classes:

1. **Upper Delta Plain**
2. **Western Lower Delta Plain**
3. **Eastern Lower Delta Plain**

! or ?



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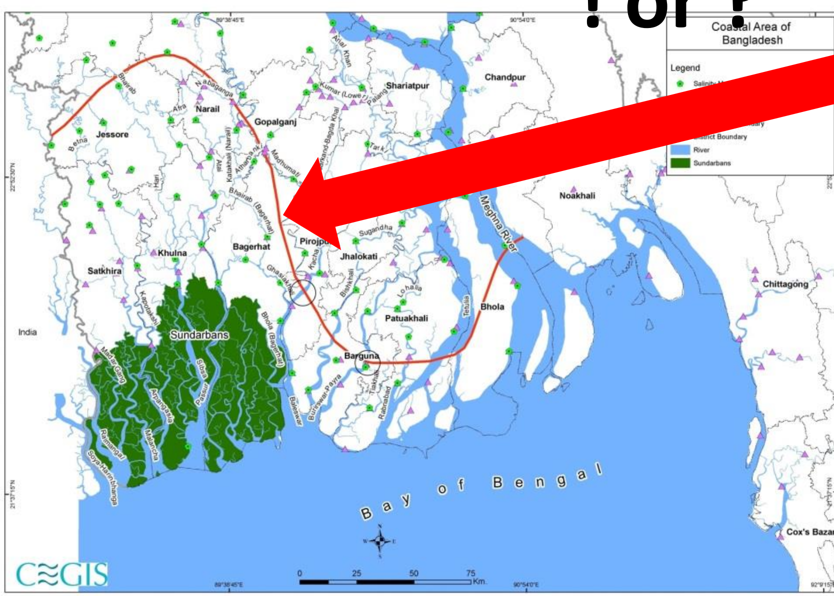
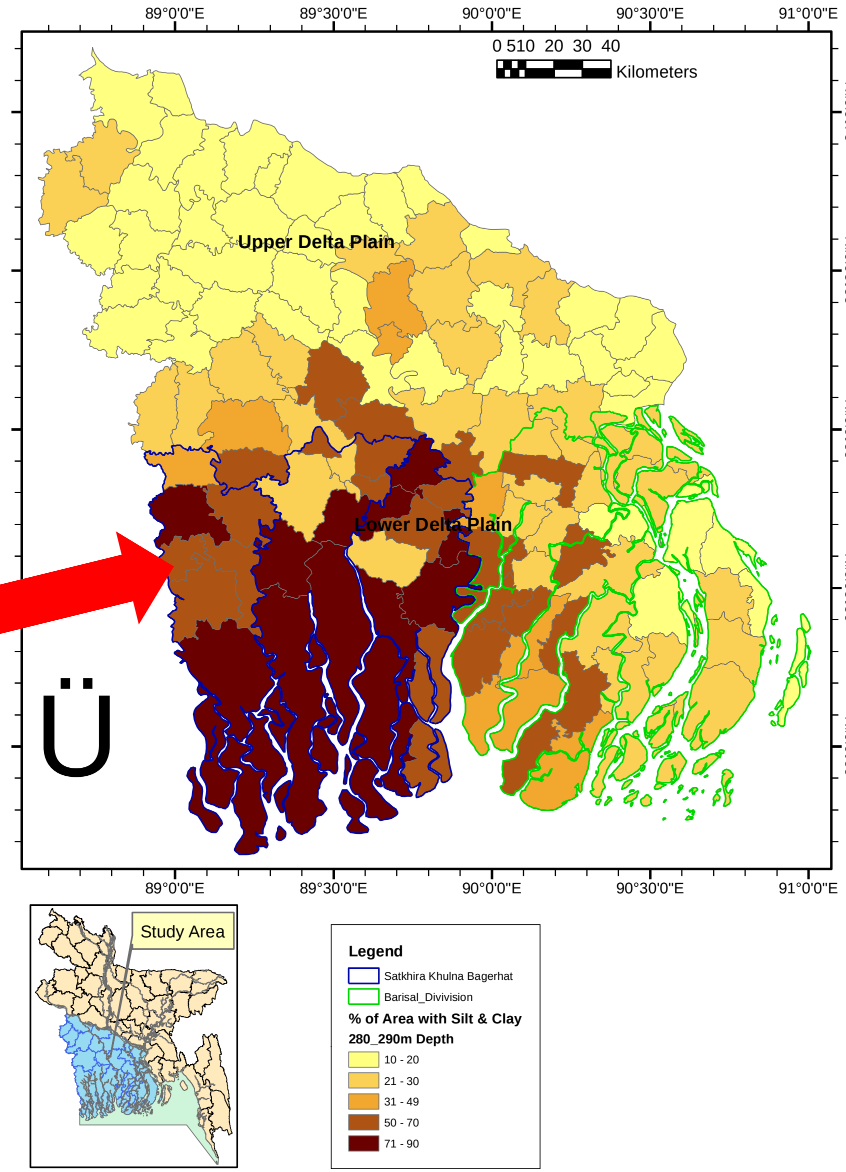
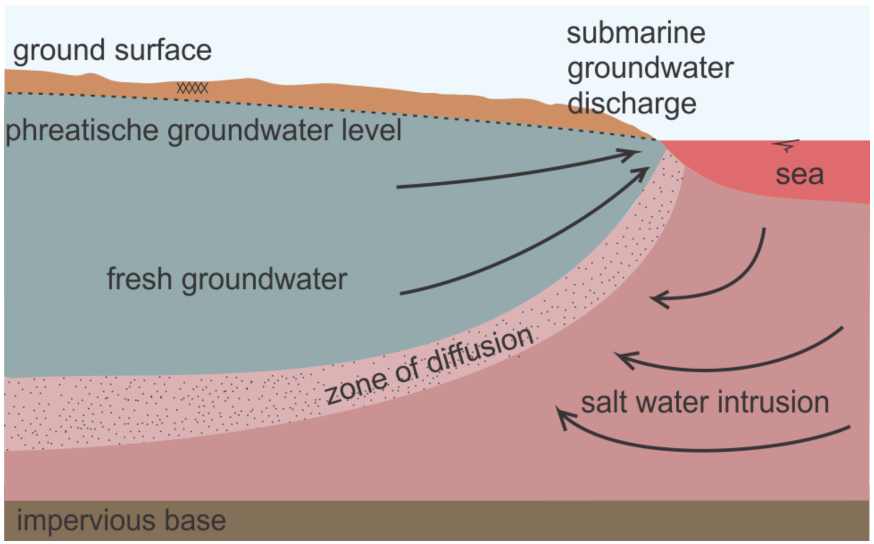


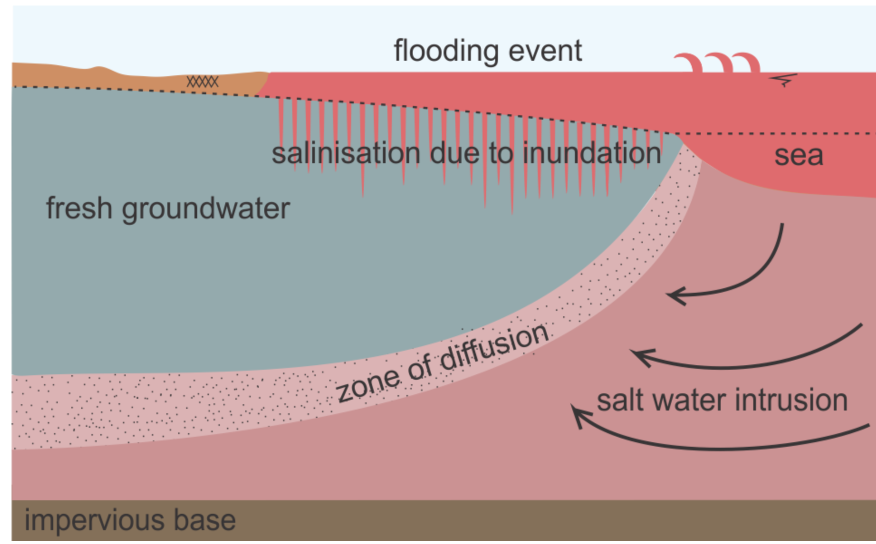


Vertical salt water intrusion under and after saline flooding events

http://svho-support.nl/index/images/new32.jpg

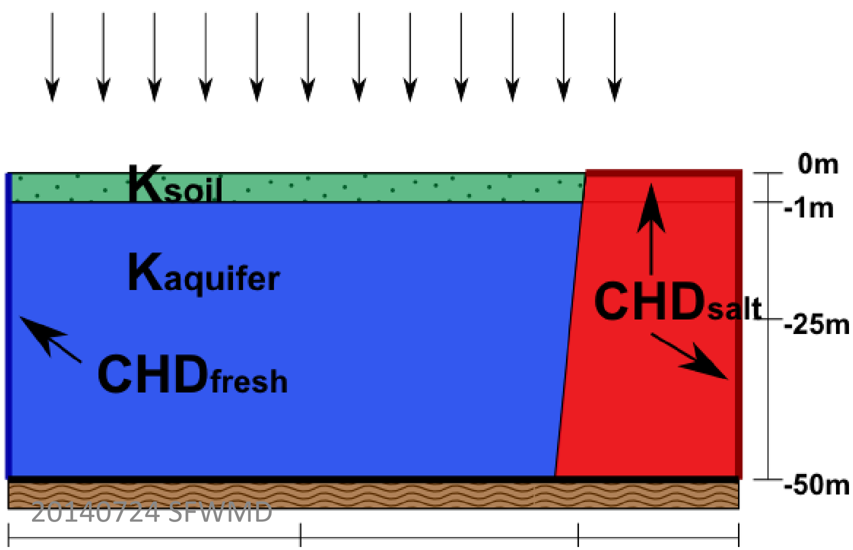
Quick scan salt water intrusion under flooding events

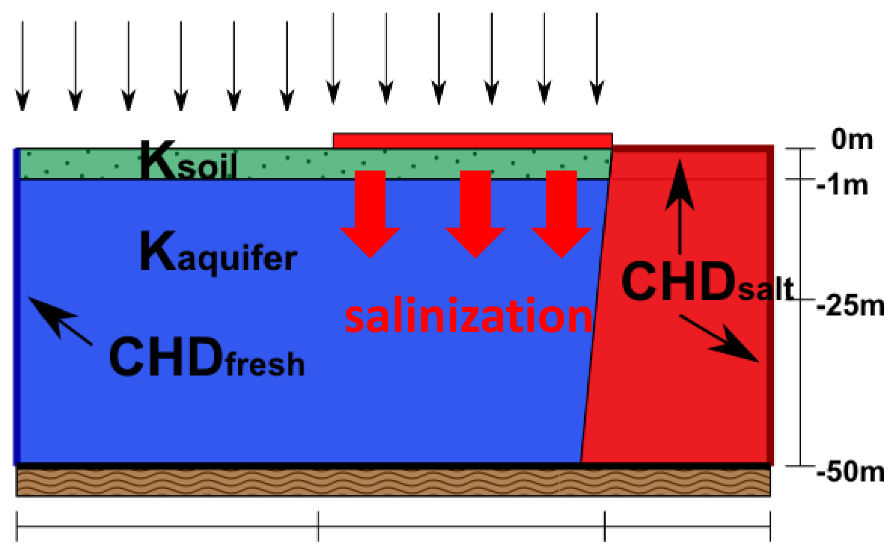




Normal situation

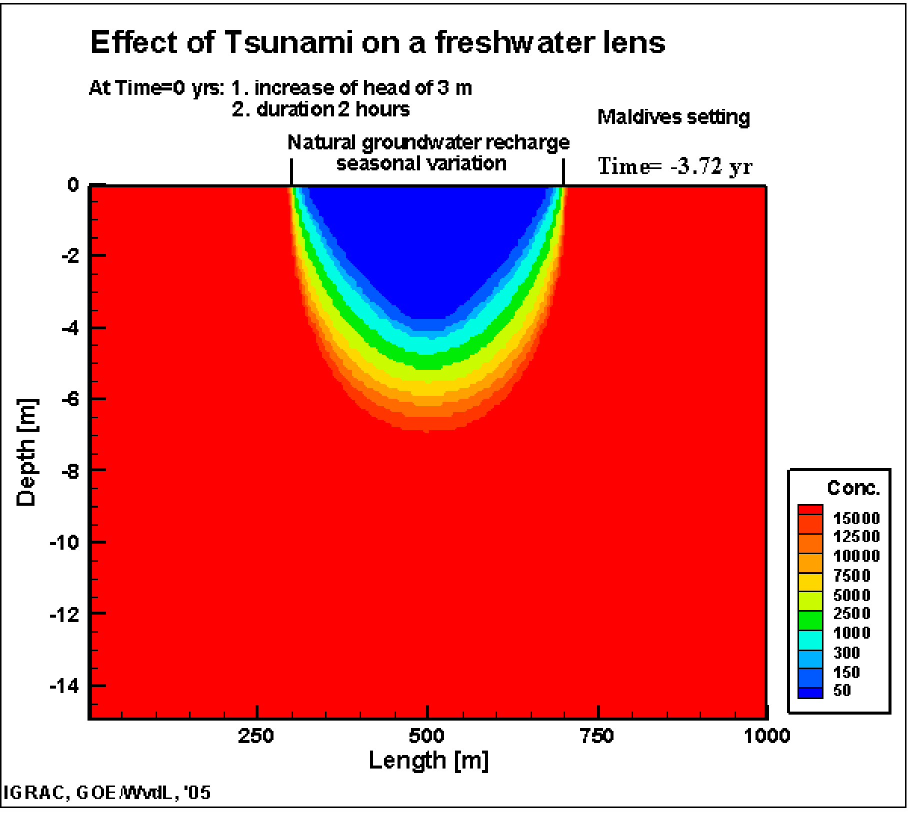
After flooding event

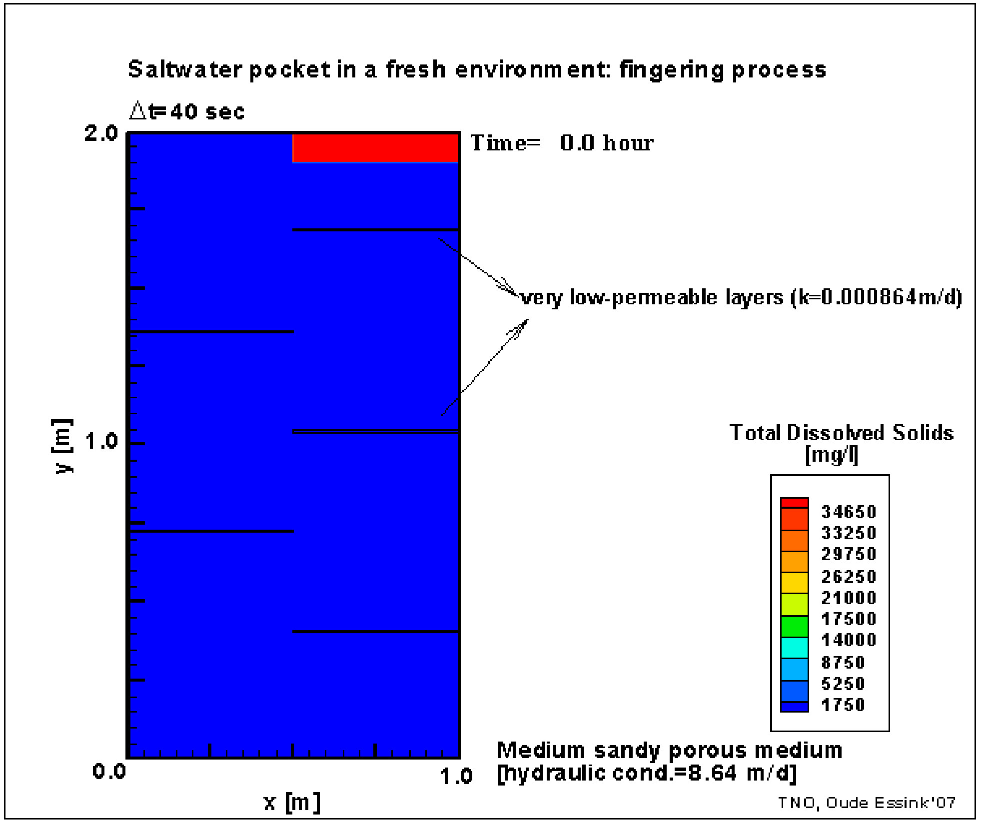




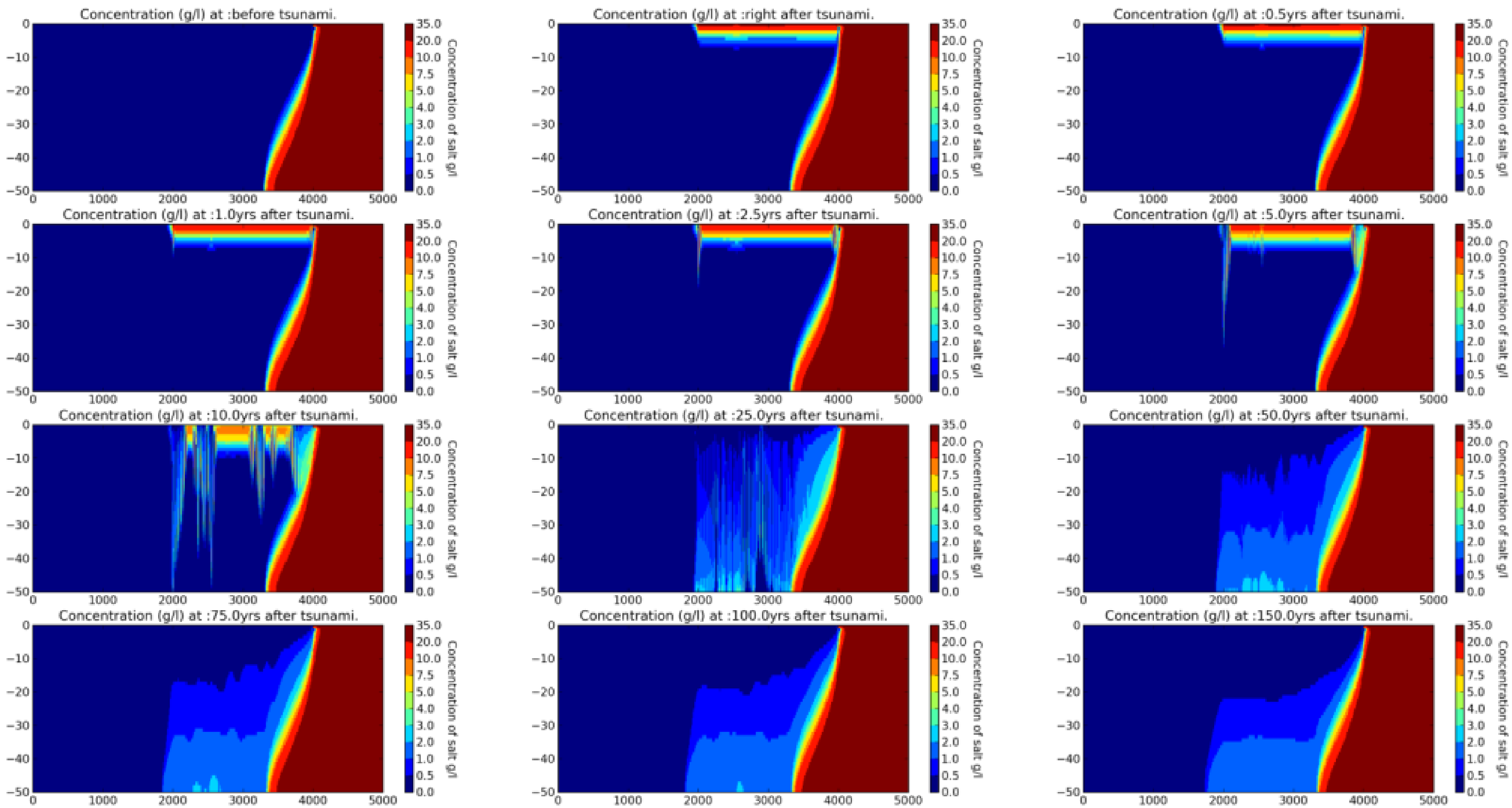
Salinisation processes of fresh groundwater reserves

- Impression of relevant salinisation processes in coastal aquifers:
- Contamination freshwater lens after sea water flooding
- Saline fingering processes in the subsoil

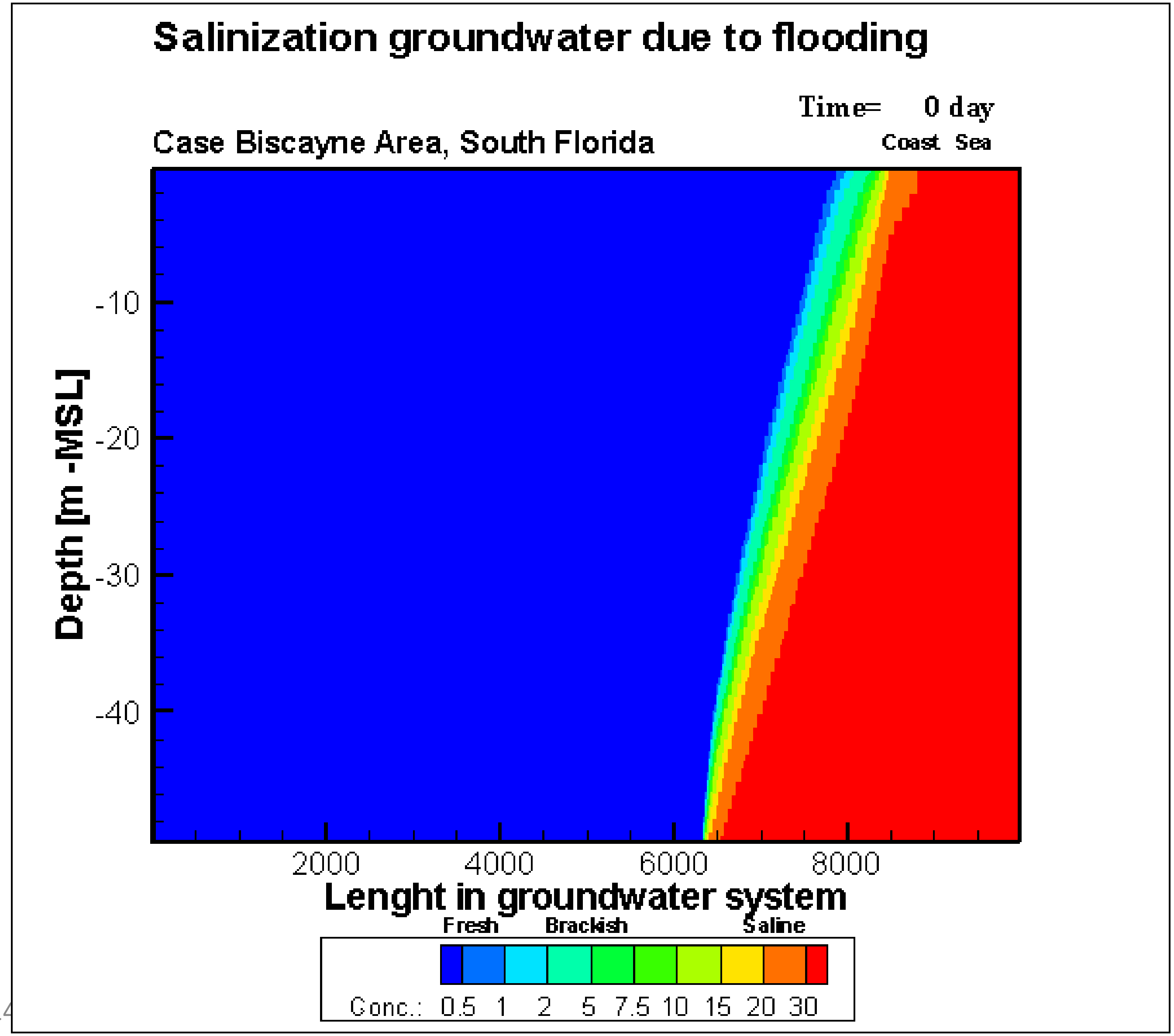


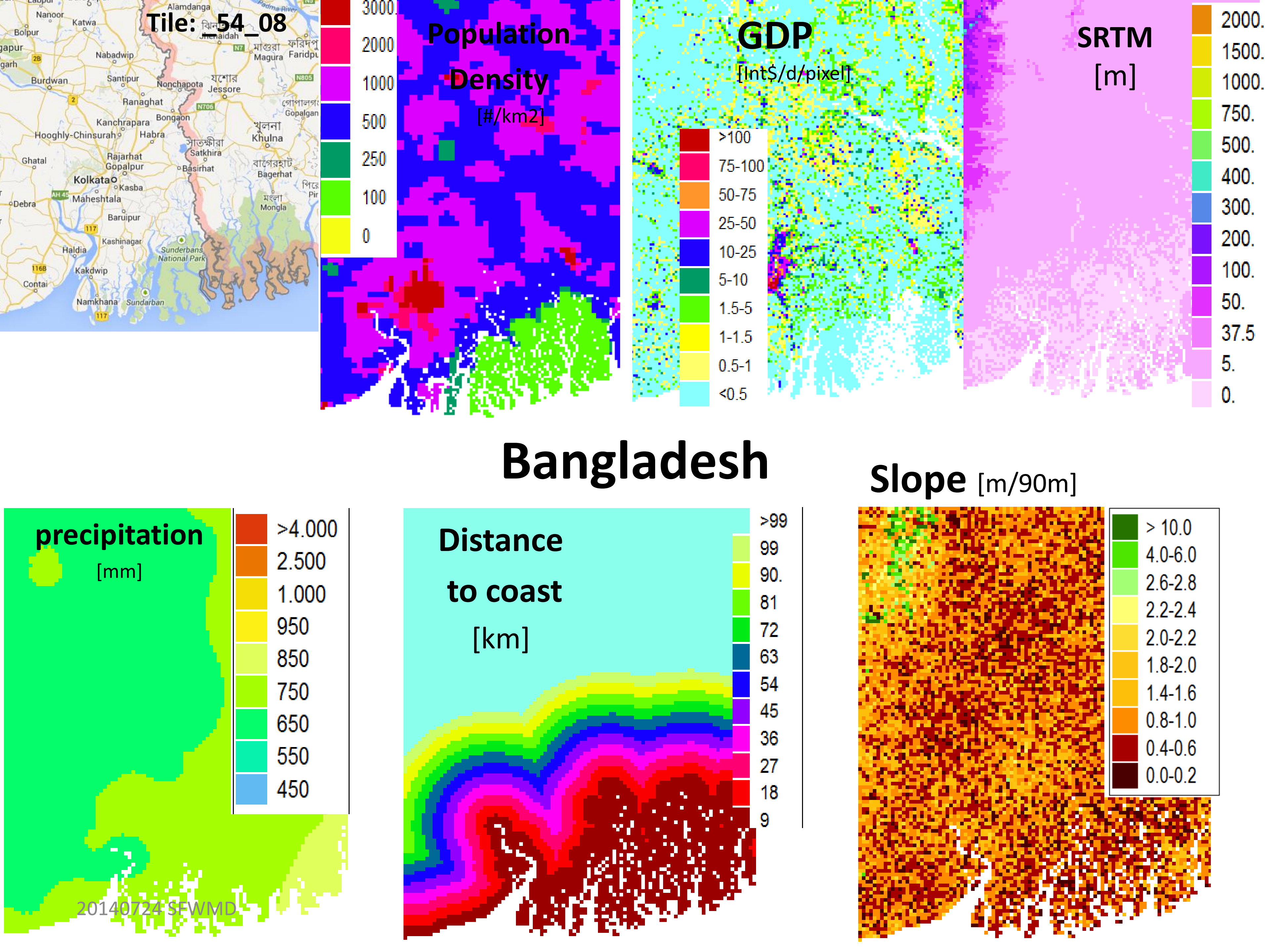


Example numerical model, different time steps, up to 150 years



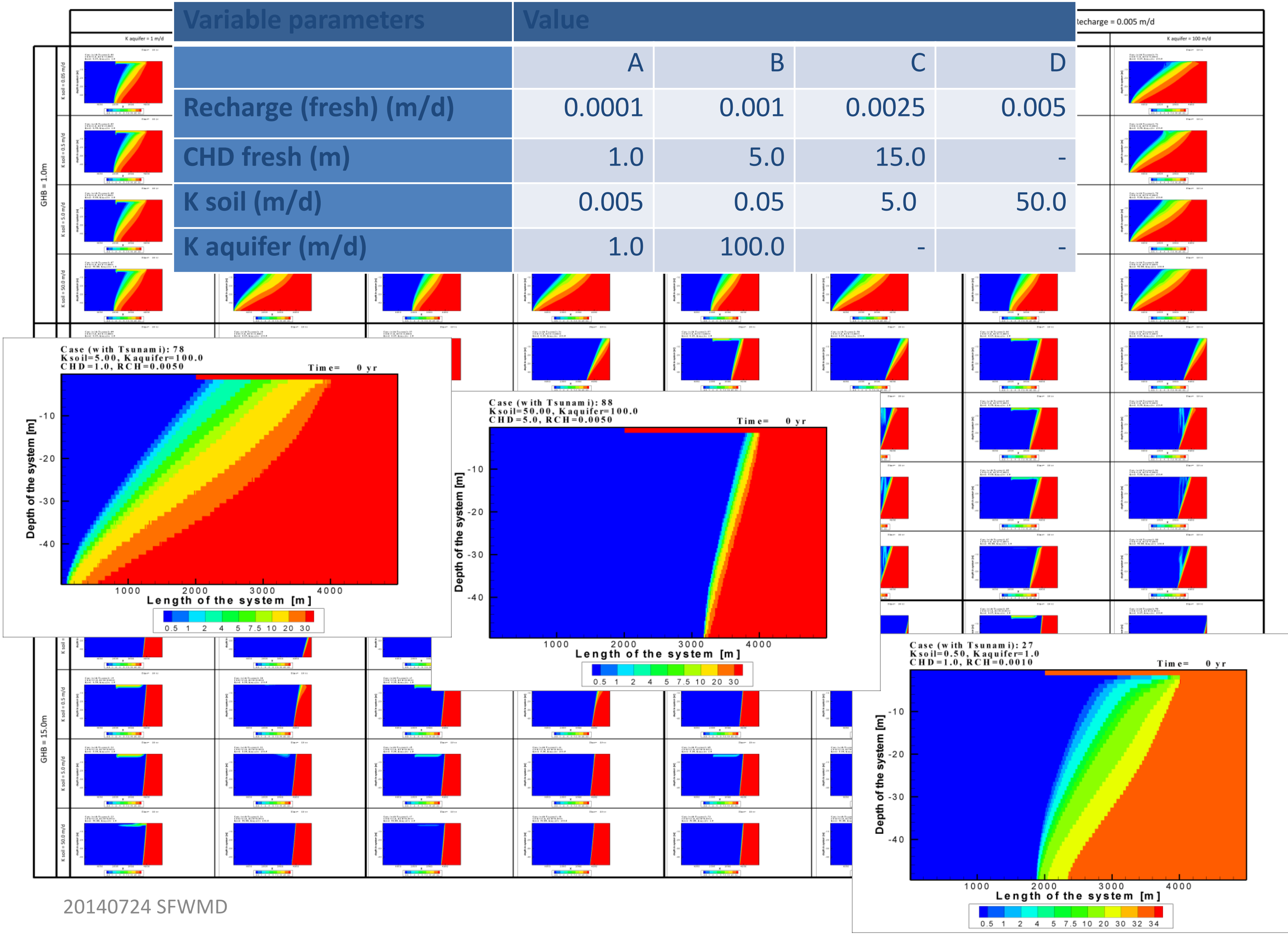
Salinisation due to salt water flooding in Florida, USA



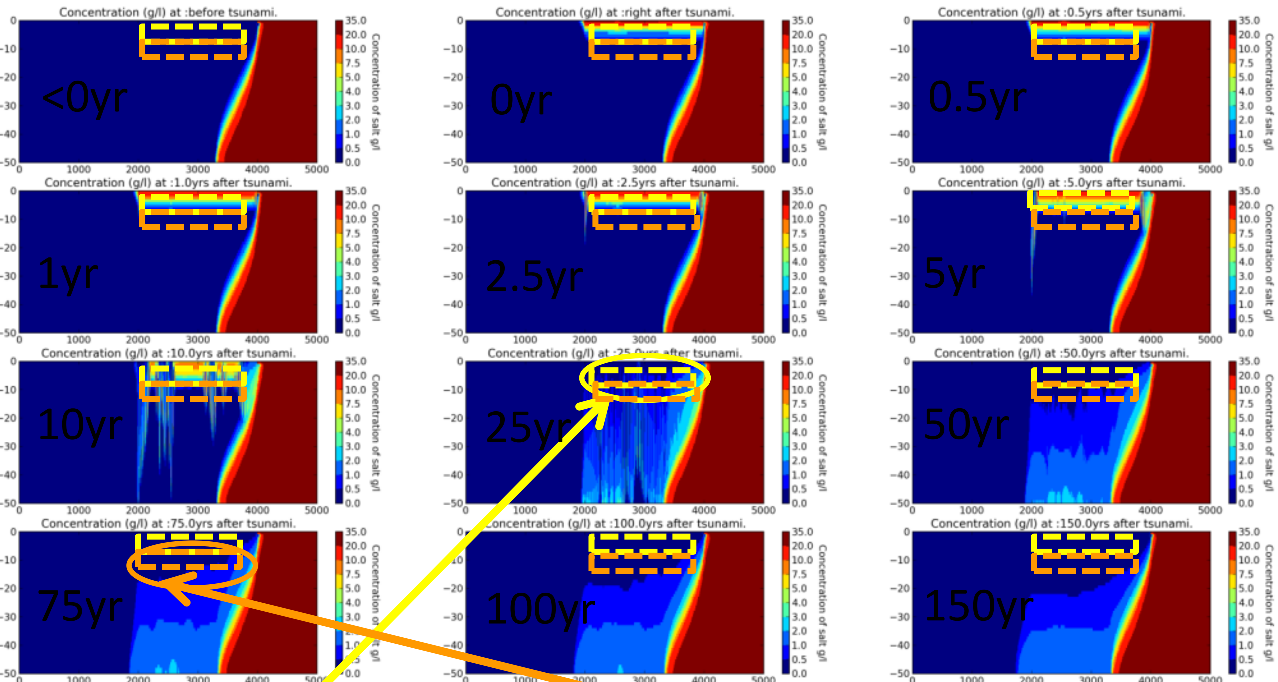


Tile: _54_08
Kolkata
Khulna
Jessore
Bagerhat
Satkhira
Mongla
Sunderbans National Park
Population Density
[#/km2]
3000
2000
1000
500
250
100
0
GDP
[Int$/d/pixel]
>100
75-100
50-75
25-50
10-25
5-10
1.5-5
1-1.5
0.5-1
<0.5
SRTM
[m]
2000.
1500.
1000.
750.
500.
400.
300.
200.
100.
50.
37.5
5.
0.
Bangladesh
Slope [m/90m]
> 10.0
4.0-6.0
2.6-2.8
2.2-2.4
2.0-2.2
1.8-2.0
1.4-1.6
0.8-1.0
0.4-0.6
0.0-0.2
precipitation
[mm]
>4.000
2.500
1.000
950
850
750
650
550
450
Distance
to coast
[km]
>99
99
90.
81
72
63
54
45
36
27
18
9
20140724 SFWMD

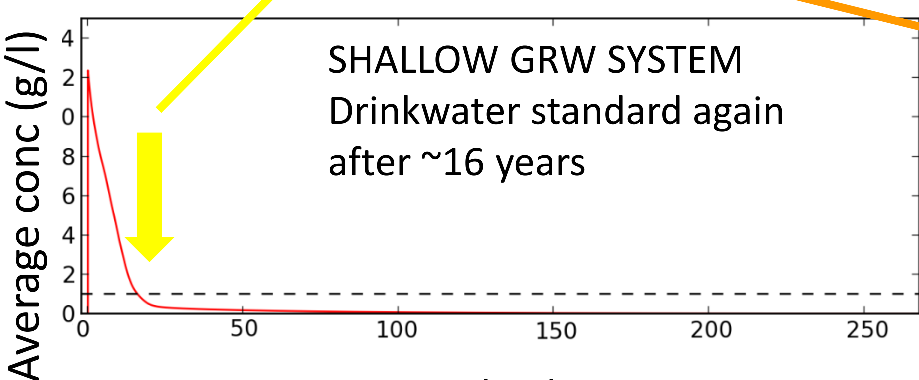
Variable parameters	Value			
	A	B	C	D
Recharge (fresh) (m/d)	0.0001	0.001	0.0025	0.005
CHD fresh (m)	1.0	5.0	15.0	-
K soil (m/d)	0.005	0.05	5.0	50.0
K aquifer (m/d)	1.0	100.0	-	-

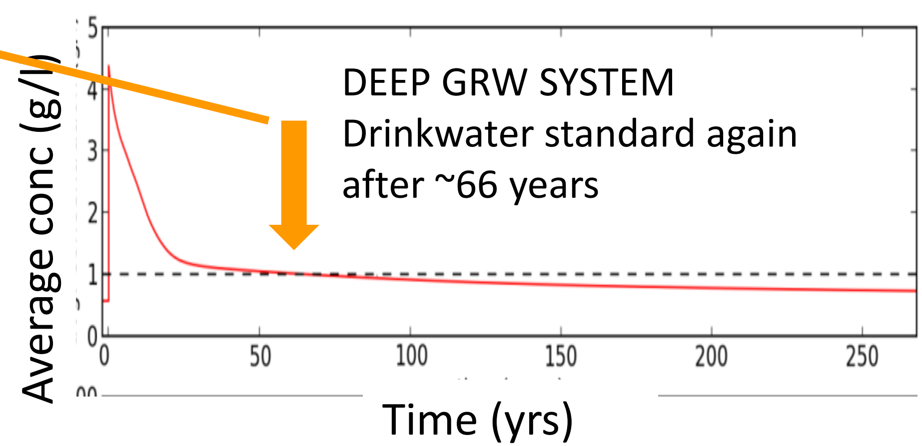


Results of one case



Salt water fingers intrude the groundwater system the coming tens of years





SWIBANGLA

MAIN DELIVERABLES

1. Key components for WSP and mitigation strategies	2. 3D density dependent groundwater model	3. Water Quality Monitoring kit
4. Smart Phone App to measure Electrical Conductivity	5. Leaflet containing salinization processes information	6. Two Workshops one on Modelling and one on Monitoring

SWIBANGLA

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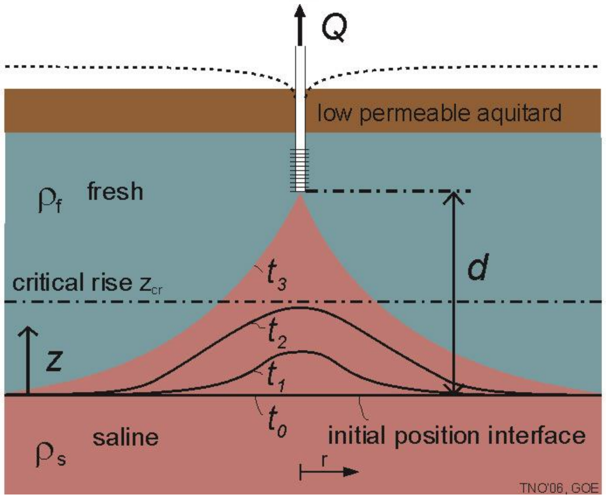
WHAT ARE WATER SAFETY PLANS?

- Describe all steps in water supply from catchment to consumer
- Meant to organize and systematise the water management practices applied to drinking-water
- Should be developed for each water and sanitation technology

GROUPING WATER AND SANITATION TECHNOLOGIES

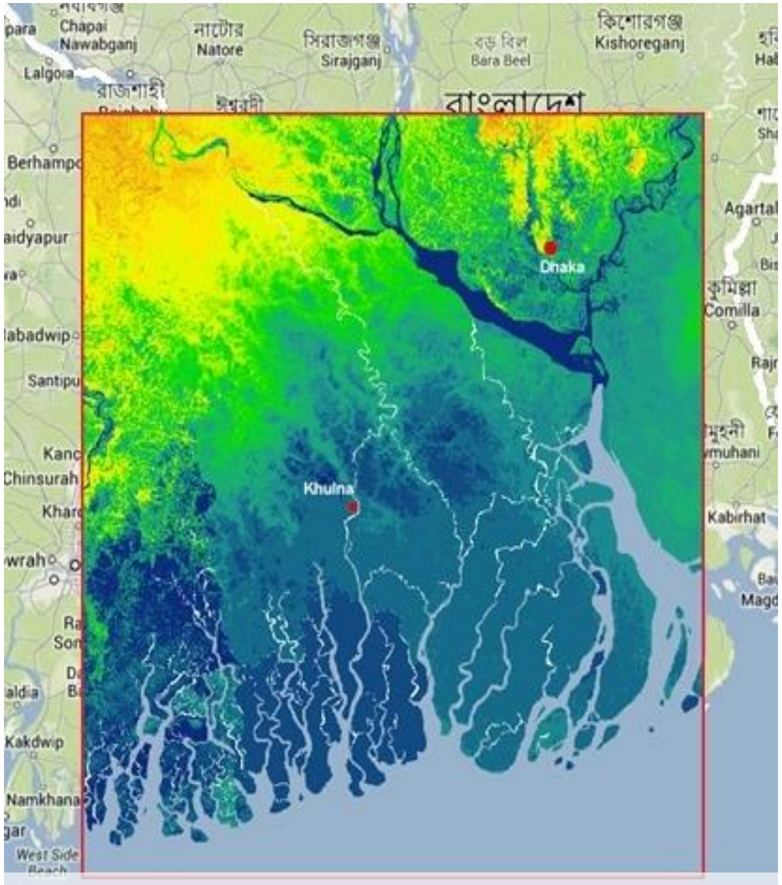
Shallow wells:
Shallow Tubewells
Tara Tubewells
Ring wells
Dug Well
Hand Pump Tubewells
Shrouded Tubewell (SST)
Very Shallow Schrouded Tubewell (VSST)

Deep wells (up to 300m):
Deep Tubewells
Tara Tubewells
Hand Pump Tubewells



Rain harvesting and artificial recharge:
Pond Sand Filters
Rainwater Harvesters
Infiltration galleries

LINKING THE WATER SAFETY PLANS TO SALINITY ASPECTS



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Supporting water sanitation
and hygiene services for life

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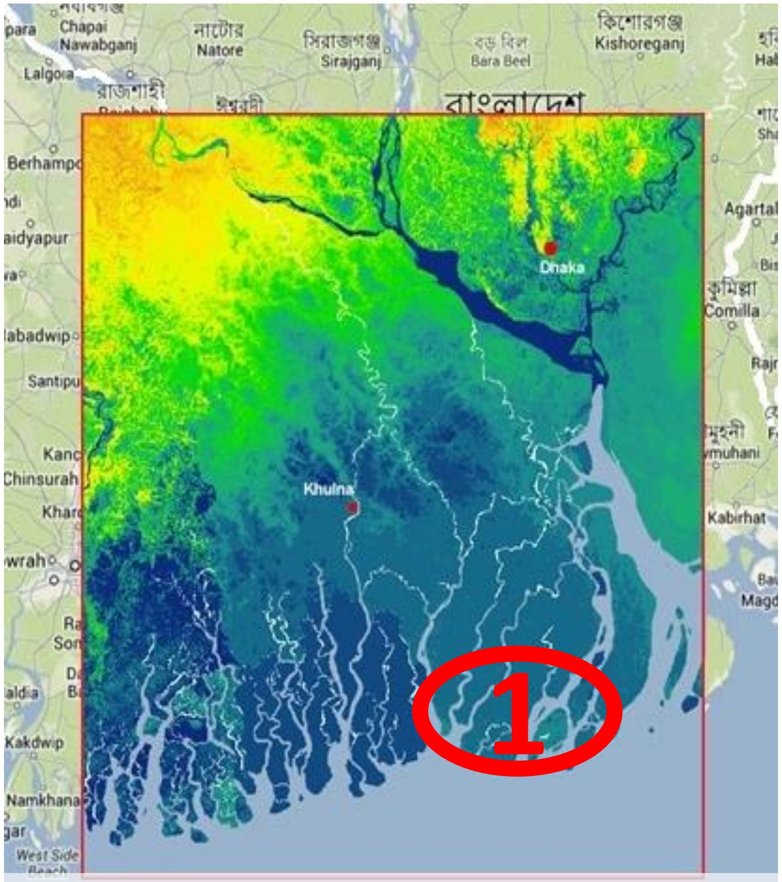
LINKING THE WATER SAFETY PLANS TO SALINITY ASPECTS



Region 1: Eastern coastal Belt

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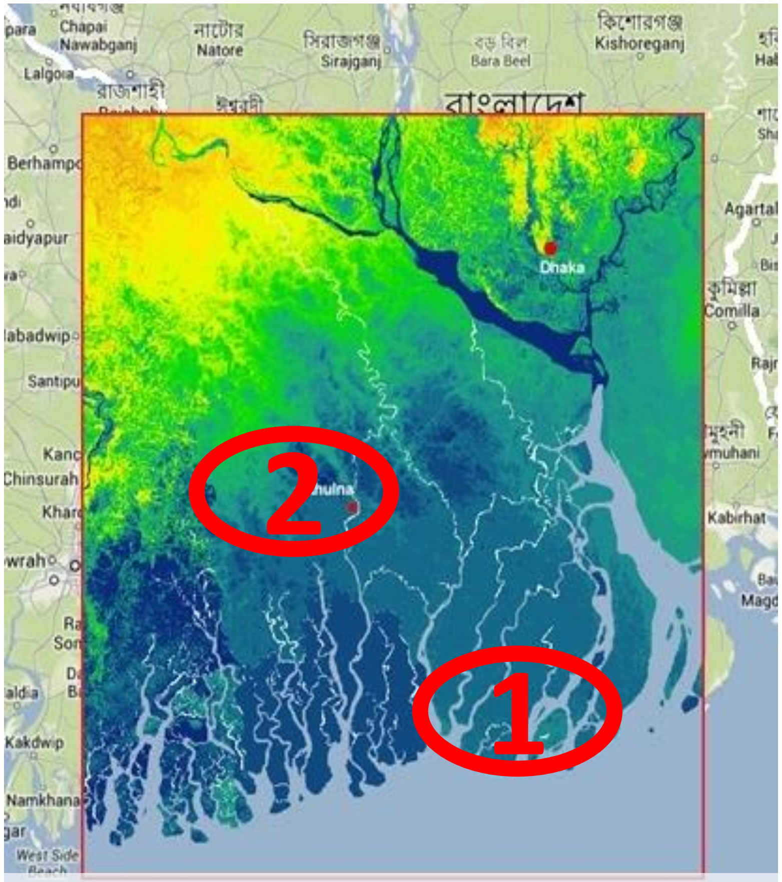
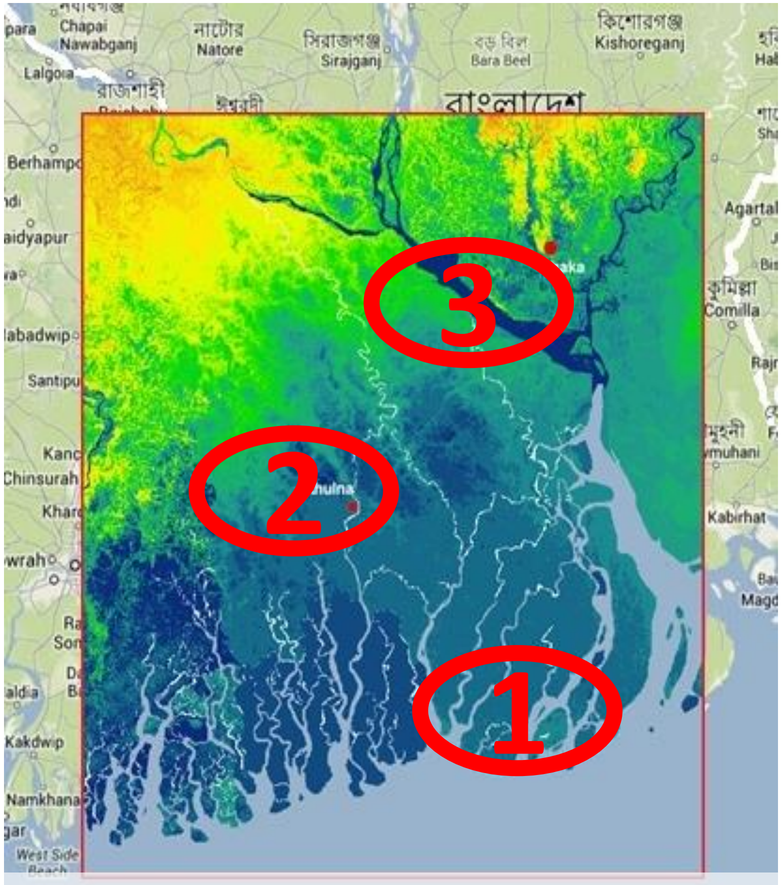
LINKING THE WATER SAFETY PLANS TO SALINITY ASPECTS



Region 1: Eastern coastal Belt

Region 2: Urban and rural areas far from big rivers

LINKING THE WATER SAFETY PLANS TO SALINITY ASPECTS

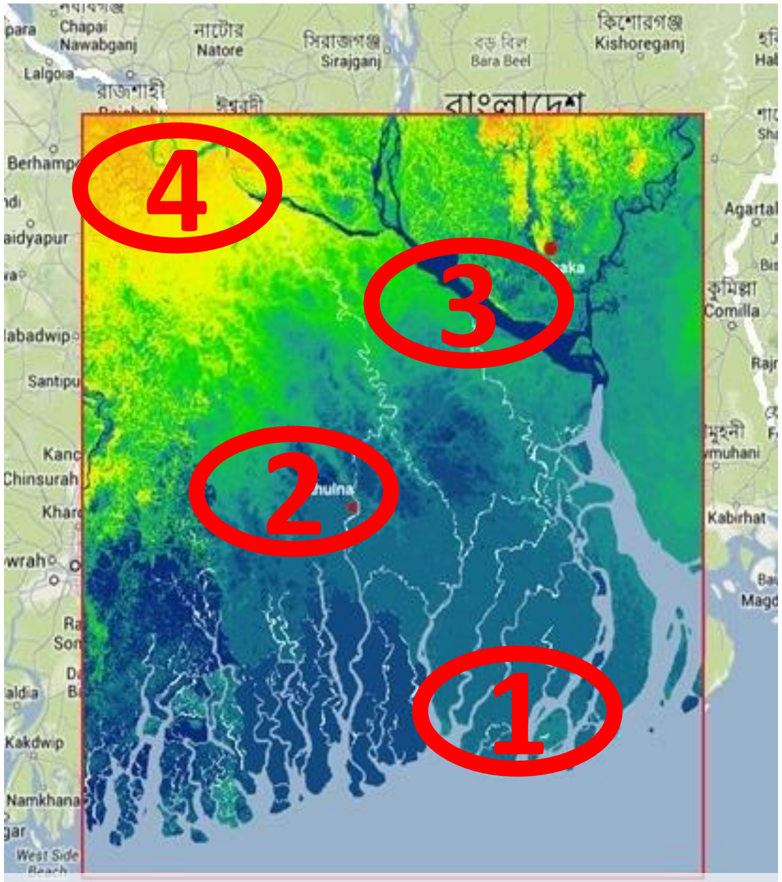


Region 1: Eastern coastal Belt

Region 2: Urban and rural areas far from big rivers

Region 3: Urban and rural areas close to big rivers

LINKING THE WATER SAFETY PLANS TO SALINITY ASPECTS



Region 1: Eastern coastal Belt

Region 2: Urban and rural areas far from big rivers

Region 3: Urban and rural areas close to big rivers

Region 4: High infiltration areas

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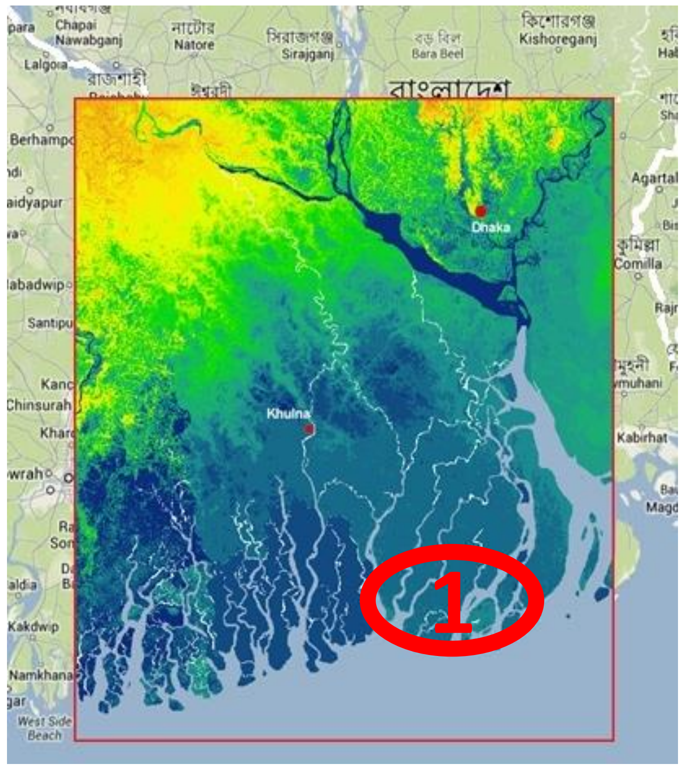
LINKING REGIONS WITH WATER AND SANITATION TECHNOLOGIES

Region	Group of technologies
Region 1: Coastal Belt	Deep wells, rain harvesting and artificial recharge
Region 2: Urban and rural areas far from big rivers	Deep wells (and shallow wells), rain harvesting and artificial recharge
Region 3: Urban and rural areas close to big rivers	Shallow wells (and deep wells), rain harvesting and artificial recharge
Region 4: High infiltration areas	Shallow wells (and deep wells), rain harvesting and artificial recharge

LINKING WSP COMPONENTS WITH REGIONS AND WITH WATER AND SANITATION TECHNOLOGIES

Technology group	Hazard
Deep wells	Up-coning Lateral seawater intrusion Vertical percolation at depth
Shallow wells	Up-coning Lateral seawater intrusion Seepage Lateral salt water intrusion from rivers Salt water intrusion caused by inundation
Rain harvesting and artificial recharge	salt water intrusion caused by inundation

EXAMPLE
REGION 1 – DEEP TUBE WELLS



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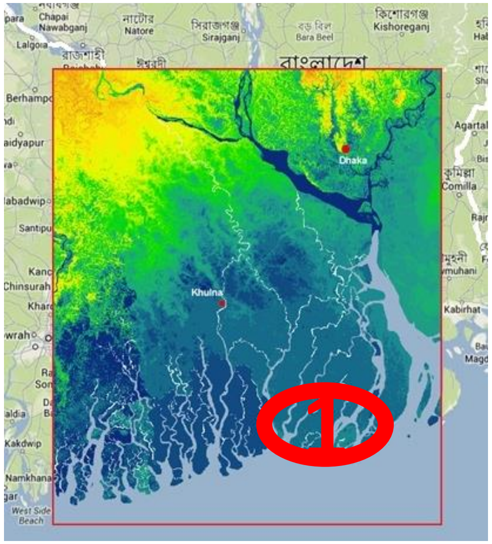
REGION 1 – DEEP TUBE WELLS – HAZARD ASSESSMENT AND RISK CHARACTERIZATION

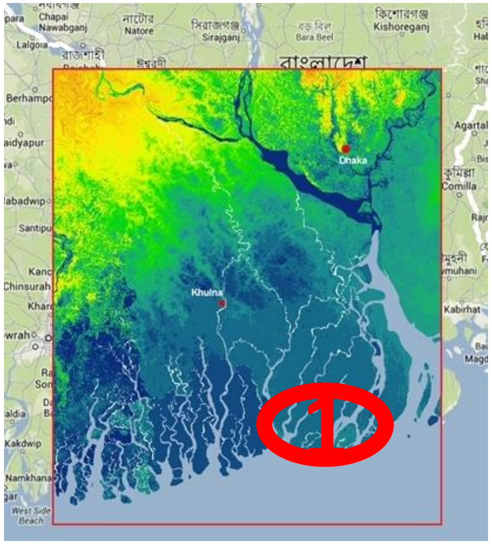


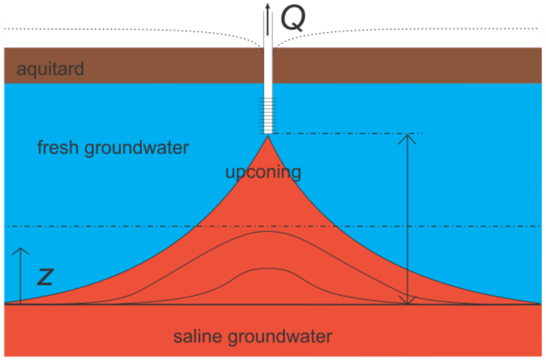
- Up-coning of saline groundwater from bigger depths
- Extraction of saline water due to location of the well, there were horizontal salt water intrusion takes place
- Soluble salts and ions in water as consequence of corrosion of the pipe due to high salt concentrations

REGION 1 – DEEP TUBE WELLS – HAZARD DESIGN OF THE WELL

Regarding avoiding salinization, the location of the depth of the well screen has to be a function of:

- Depth of the fresh water
- Stationary drawdown
- Distance to the interface of brackish or saline water
- The expected pumping rate (as a function of drawdown of the water head, up-coning of the fresh-brackish interface, water demand, and hydraulic properties of the aquifer).

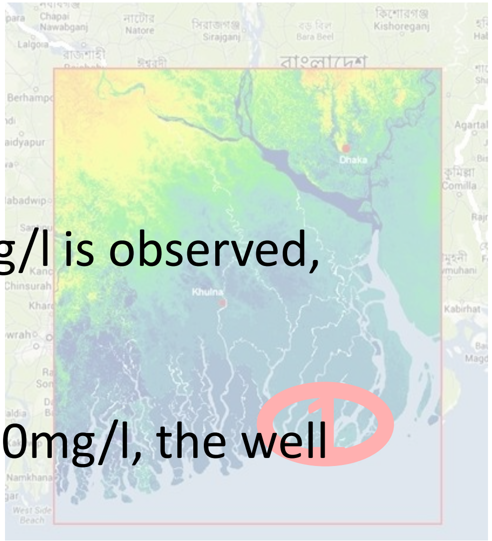




REGION 1 – DEEP TUBE WELLS – CONTROL MEASURES AND MONITORING

<table>
<tr><th></th><th>Salinity description</th><th>mS/cm</th><th>mg/l</th><th>Type of water</th><th>Symbol indication</th></tr>
<tr><td rowspan="8">Wells with arsenic in water are painted red. Wells with measured electrical conductivity (EC) should be marked depending on the EC.</td><td>Non-saline</td><td><0.8*</td><td><600</td><td>Drinking and irrigation water</td><td>blue filled circle</td></tr>
<tr><td>Slightly brackish</td><td>0.7 - 2</td><td>500-1500</td><td>Irrigation water</td><td>Light green filled circle</td></tr>
<tr><td>Moderately brackish</td><td>2 – 3</td><td>1500-2000</td><td>Irrigation water for vegetables</td><td>Dark green filled circle</td></tr>
<tr><td>Brackish</td><td>3-4</td><td>2000-3000</td><td>Irrigation water for wheat</td><td>Yellow filled circle</td></tr>
<tr><td>Moderately saline</td><td>4-10</td><td>3000-7000</td><td>Primary drainage water and groundwater</td><td>black/red cross</td></tr>
<tr><td>Highly saline</td><td>10-25</td><td>7000-15 000</td><td>Secondary drainage water and groundwater</td><td>black/red cross</td></tr>
<tr><td>Very highly saline</td><td>25 - 45</td><td>1 5 000-35 000</td><td>Very saline groundwater</td><td>black /red cross</td></tr>
<tr><td>Brine</td><td>>45</td><td>>45 000</td><td>(more than) Seawater</td><td>black/red cross</td></tr>
</table>

REGION 1 – DEEP TUBE WELLS – MANAGEMENT STRATEGIES



- Decrease the pumping rate:

If an increase of the chloride concentration above 400mg/l is observed, the pumping rate should be decreased.

If the salinity continues to increase and it reaches the 600mg/l, the well should not be used for drinking water anymore.

- All wells must be tested for chloride before they are handed in to community.

- Procedures or Records: use field tests kits and analyse sample for Chloride in the laboratory.

REGION 1 – DEEP TUBE WELLS – RECORDS FOR SALINITY MEASURES, EXAMPLE:

Date of sampling	Type of analysis (field test / laboratory)	Location of the well: Longitude	Location of the well: Latitude	Top of the screen (m below surface)	Bottom of the screen (m below surface)	Top of the screen (m below sea level)	Bottom of the screen (m below sea level)	Chloride concentration (mg/l)	Electrical conductivity (mS/cm)

STRATEGIES FOR MITIGATING SALINITY IMPACTS ON DRINKING WATER SUPPLY

COASTAL AREA

- **Strategy 1: Managed groundwater abstraction in the deep aquifer**
- **Strategy 2: Systematic monitoring of groundwater in the deep aquifer**
- **Strategy 3: Injection of harvested rainwater in the deep aquifer**
- **Strategy 4: Creation of fresh water lens in the shallow brackish aquifer**

INLAND AREA

- **Strategy 5 Conjunctive use of surface and groundwater**

  River Bank filtration

  Infiltration gallery

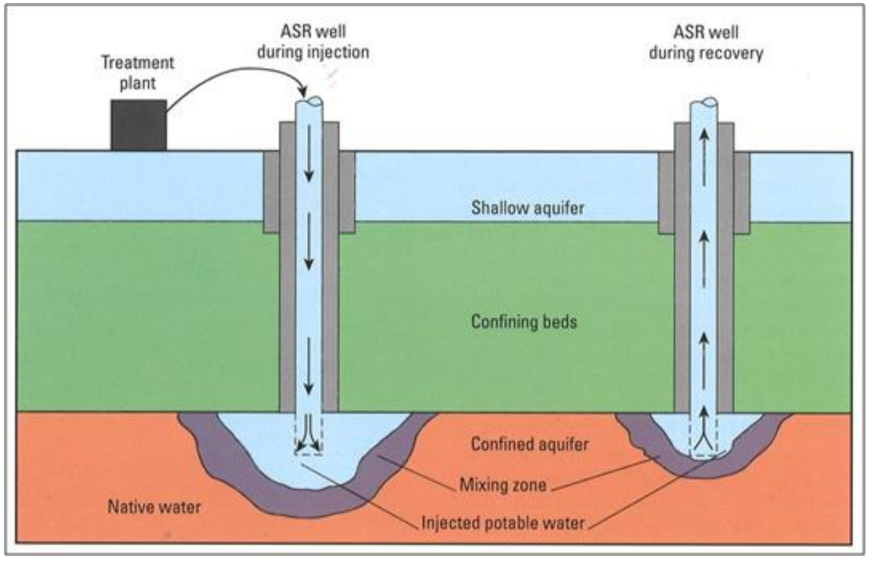
  Infiltration basin

MITIGATING SALINITY IMPACTS ON DRINKING WATER: 5 STRATEGIES

- Strategy 1: sustainability
  - Characterization of the groundwater system essential
  - Projection of drinking water demand
  - Optimization of well locations and production rates, using numerical models
  - Simulation the long-term response of the aquifer system to planned extractions
  - Implementation groundwater development plan
- Strategy 2: monitoring
  - National baseline monitoring
  - Early warning monitoring
  - Fresh/salt water interface monitoring

MITIGATING SALINITY IMPACTS ON DRINKING WATER: 5 STRATEGIES

- Strategy 3: deep well injection
  - ASR: Aquifer Storage and Recovery
  - Transmissivity of the aquifer should be sufficiently large
  - Water sources of good quality for injection must be available
  - Land availability and site accessibility
  - Technical capacities on well drilling, maintenance, and operation.
  - Proximity to electric power infrastructure and water distribution infrastructure.



MITIGATING SALINITY IMPACTS ON DRINKING WATER: 5 STRATEGIES

- Strategy 4: go-fresh

– Create fresh water lens in storing fresh water in shallow brackish water aquifer

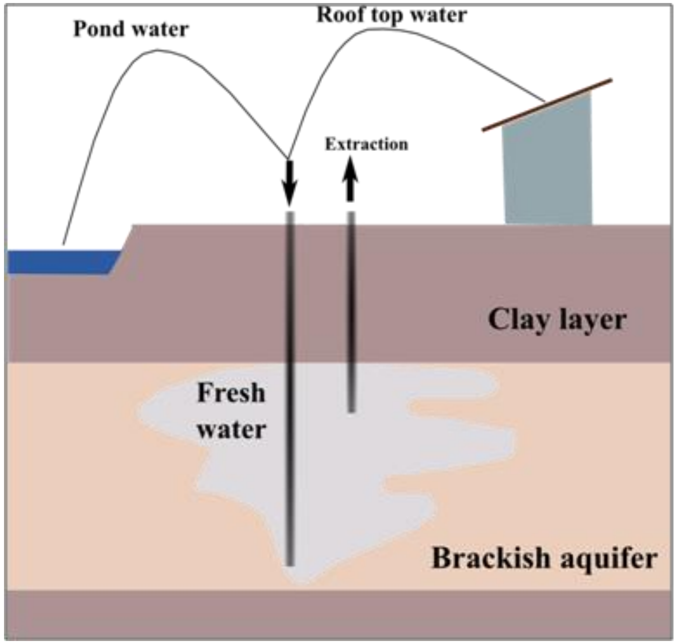
Advantages

– Water is stored in the subsurface, no evapotranspiration loss, less vulnerable to pollution and damage by storm surge/cyclones comparing to surface storage (such as ponds)

Limitations

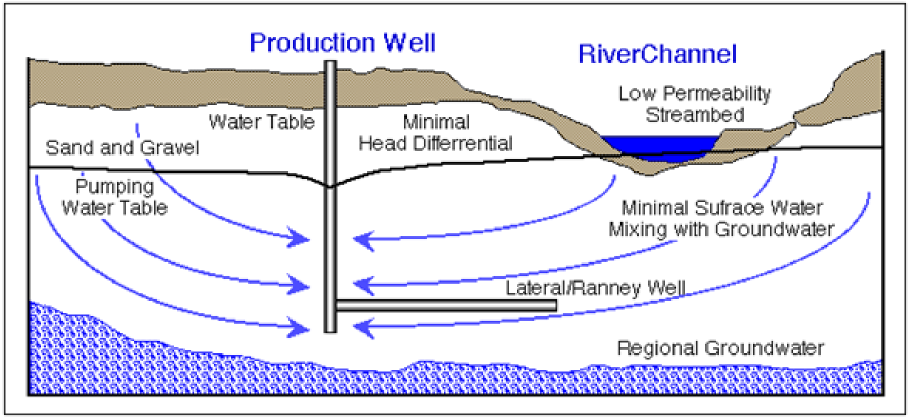
– Availability of good quality of source water (collection and pre-treatment of storm water)

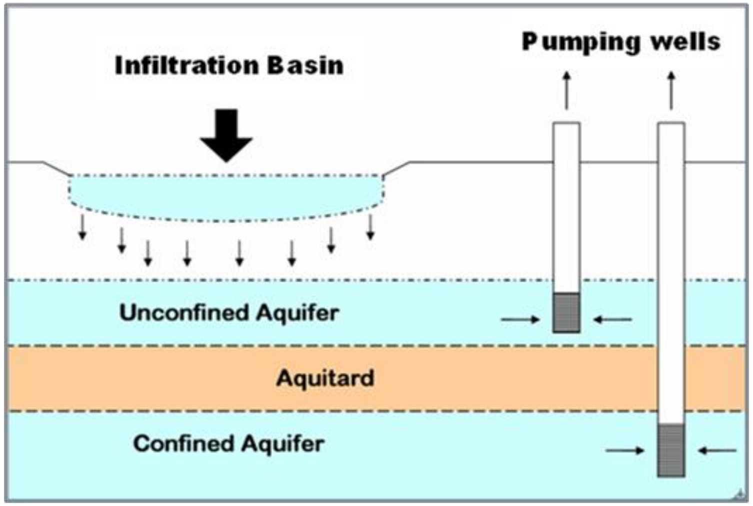
– Prevention of brackish water intrusion necessary



MITIGATING SALINITY IMPACTS ON DRINKING WATER: 5 STRATEGIES

- Strategy 5: conjunctive use (inland)
  - Objective is to increase the yield, reliability of supply and efficiency of a water system by diverting water from streams or surface reservoirs to storage in aquifers, for later use when surface water is not available.
  - Examples:
    - River bank infiltration
    - Infiltration gallery
    - Infiltration basin

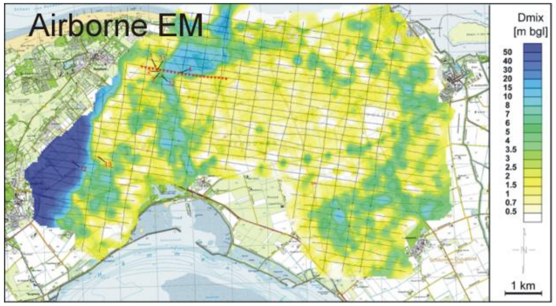


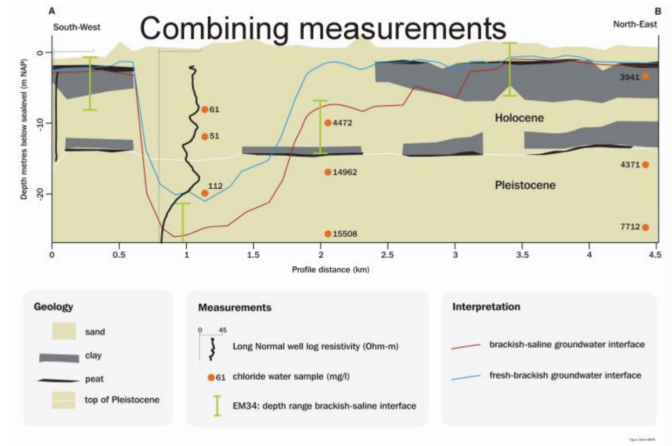


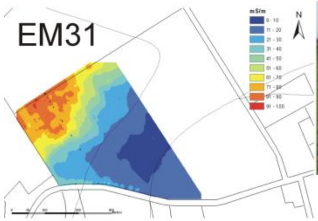
RECOMMENDATIONS BANGLADESH GROUNDWATER MONITORING

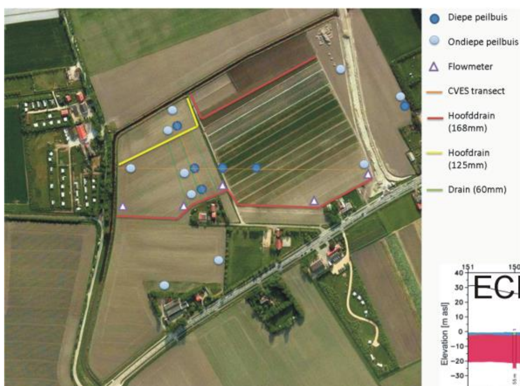
1. Determine clear monitoring objectives;
2. Determine what kind of results you want. Design the type of graphs etc. ("think backwards");
3. Every objective has his own design criteria, in space and in time;
   (Often different objective monitoring networks can be combined)
4. Collect and store all monitoring data in ONE central database;
5. Produce clear graphs, maps etc. to show the monitoring results on a public website;
6. Determine in advance what you decide to do with results, passing thresholds;
7. Evaluate existing monitoring networks;
8. Bring all monitoring stakeholders together in one network (at least one meeting/year)

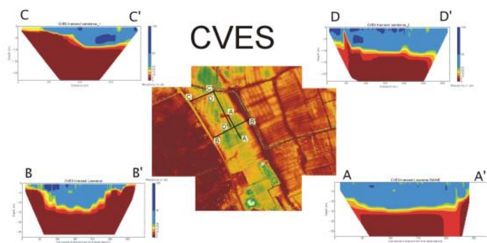
Combining different fresh-salt monitoring techniques

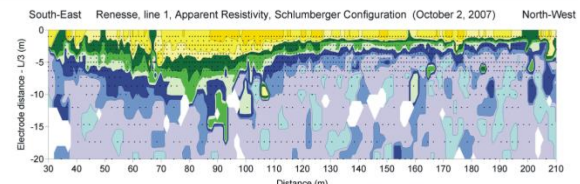


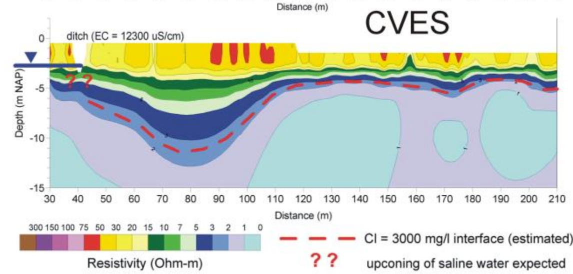


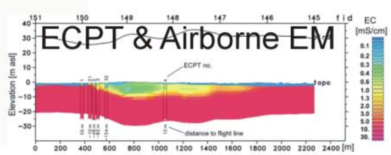


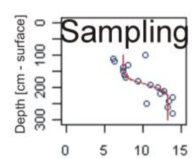


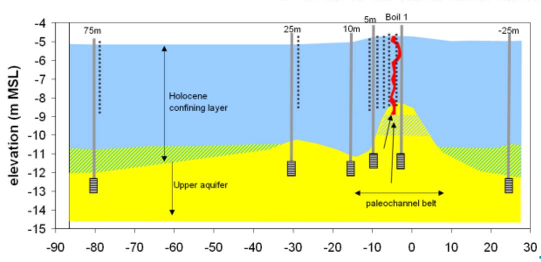


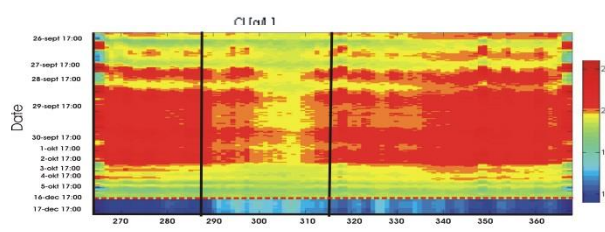




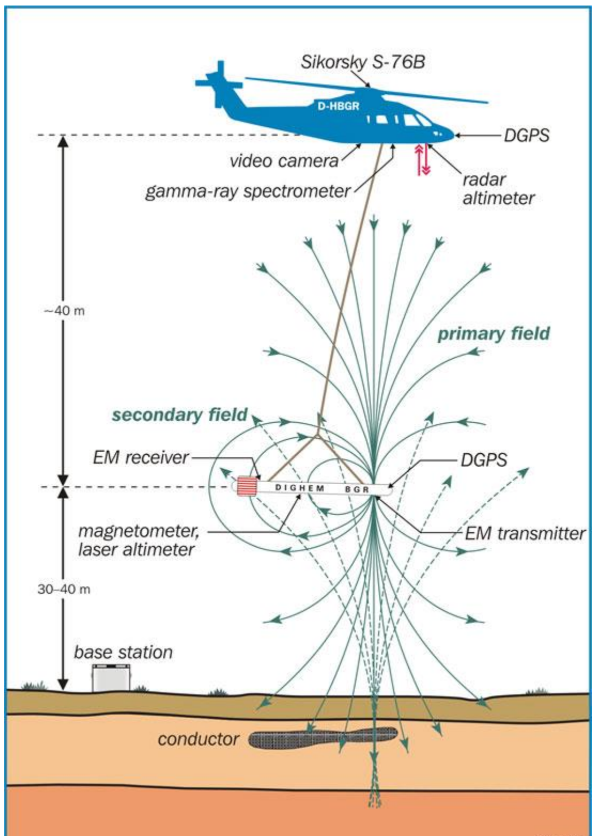


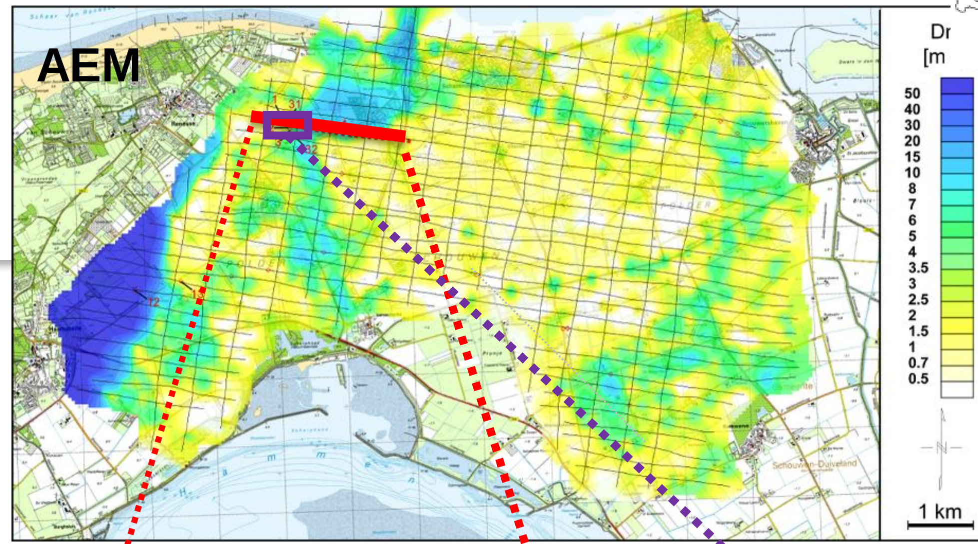


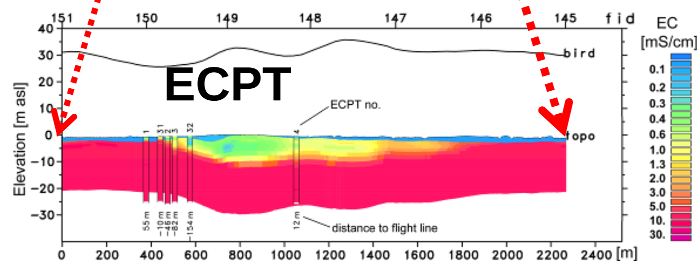


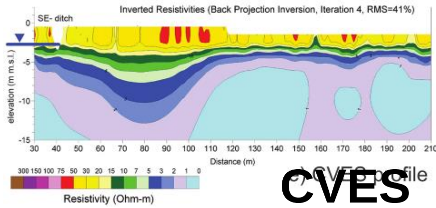


Example: Case AEM in Schouwen-Duiveland, NL

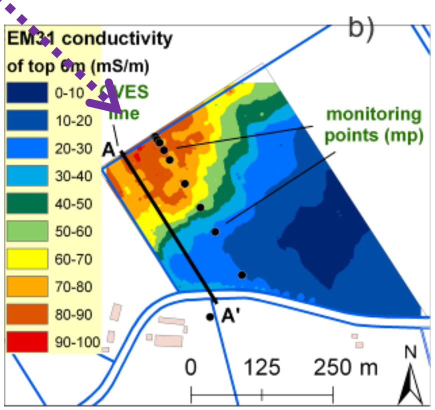








CVES



EM31

conventional monitoring techniques

DELIVERABLES

1. Key components for WSP and mitigation strategies	2. 3D density dependent groundwater model	3. Water Quality Monitoring kit
4. Smart Phone App to measure Electrical Conductivity	5. Leaflet containing salinization processes information	6. Two Workshops one on Modelling and one on Monitoring

3D VARIABLE-DENSITY GROUNDWATER MODEL: WHY?

- To understand and visualize the regional groundwater dynamics and the salinity processes

- To provide Bangladeshi water managers and universities with an instrument for their mandates

- To stimulate and assist further research (“seed model”)

- To fill the void: there is no regional groundwater model in Bangladesh that includes variable-density effects

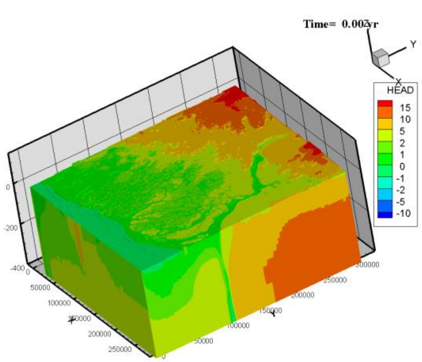
SWIBANGLA 3D variable-density groundwater Model

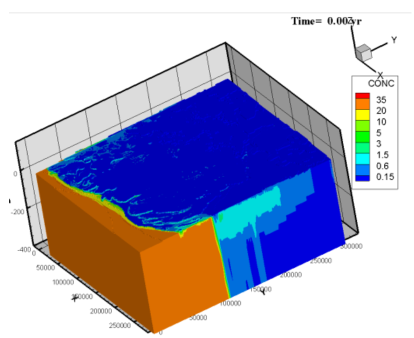
It is an iMOD-SEAWAT model of the central coast of Bangladesh.

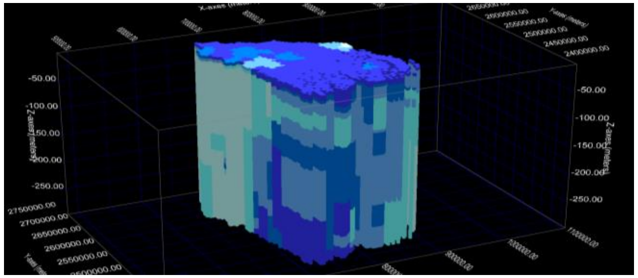
The questions that can be answered with the model are, for example:

- Where are the present fresh-saline interfaces?
- How will these interfaces evolve in the following years?
- What is the effect of the extractions in the vertical distribution of the salinity?
- Guiding the positioning of monitoring and data collection
- Guiding the positioning of (new) extraction wells

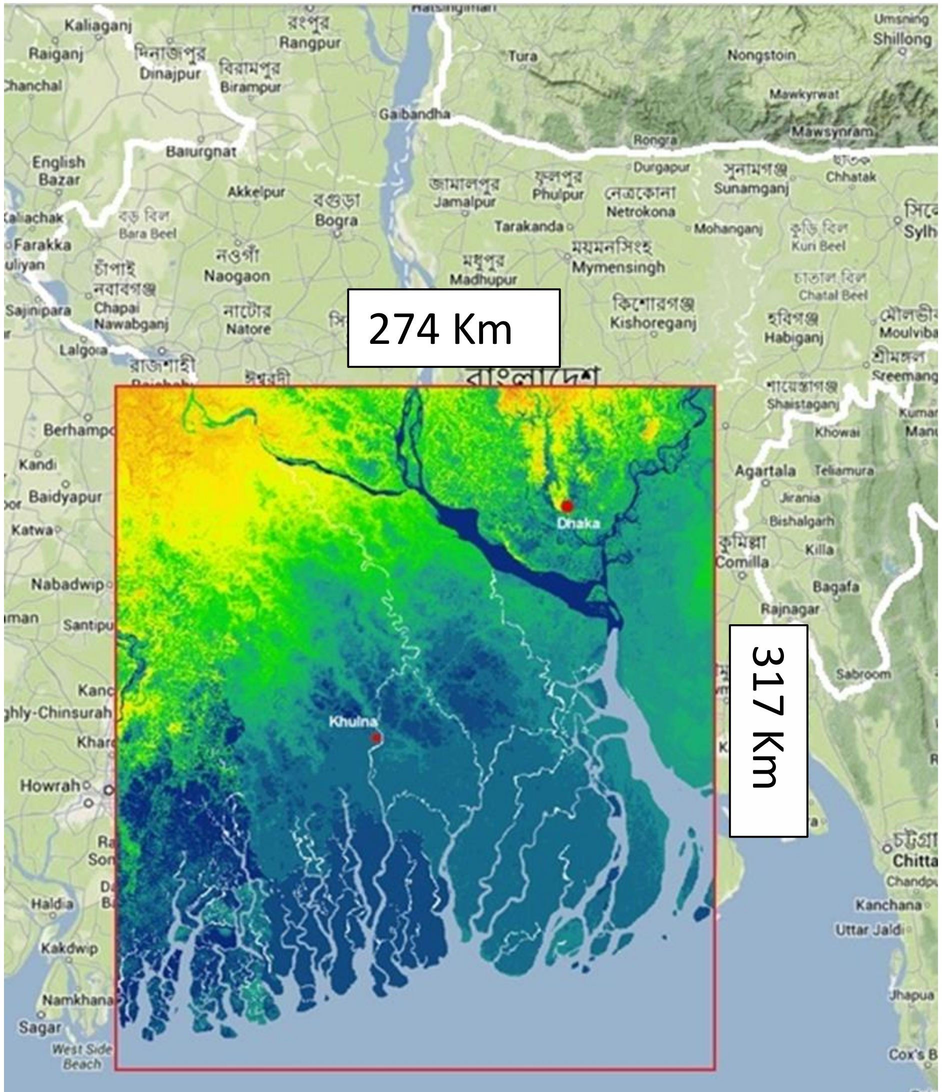
Moreover, the model is expected to be a very valuable tool in future research projects concerning groundwater salinization in Bangladesh



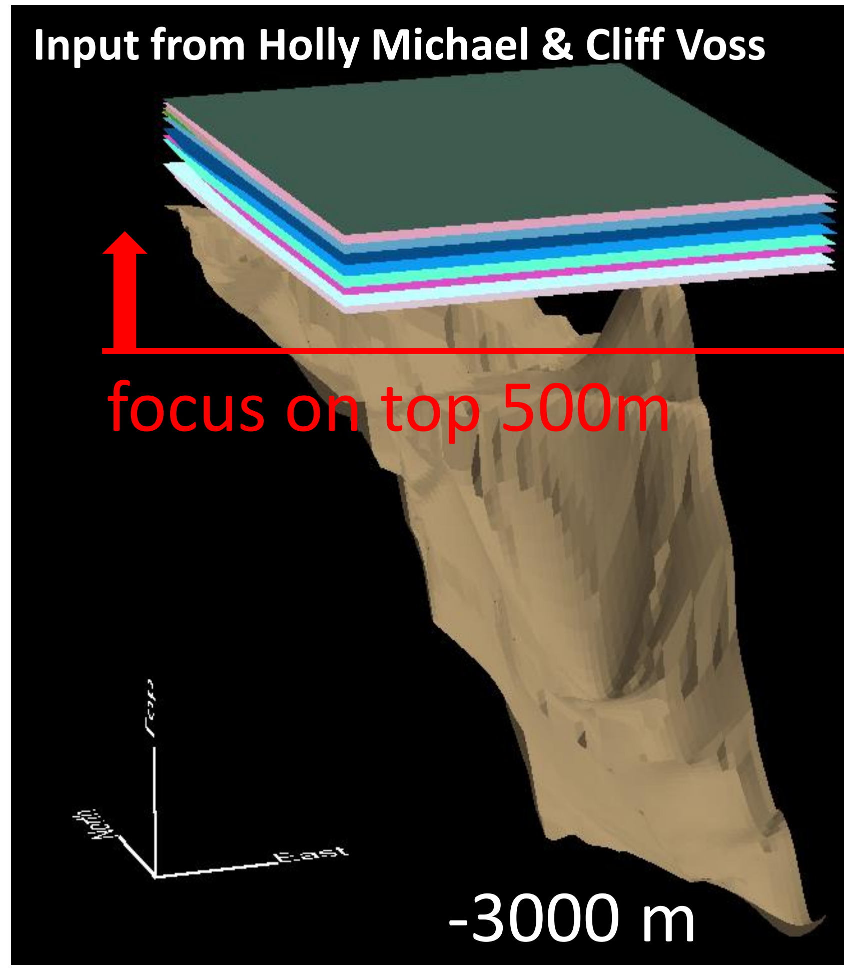




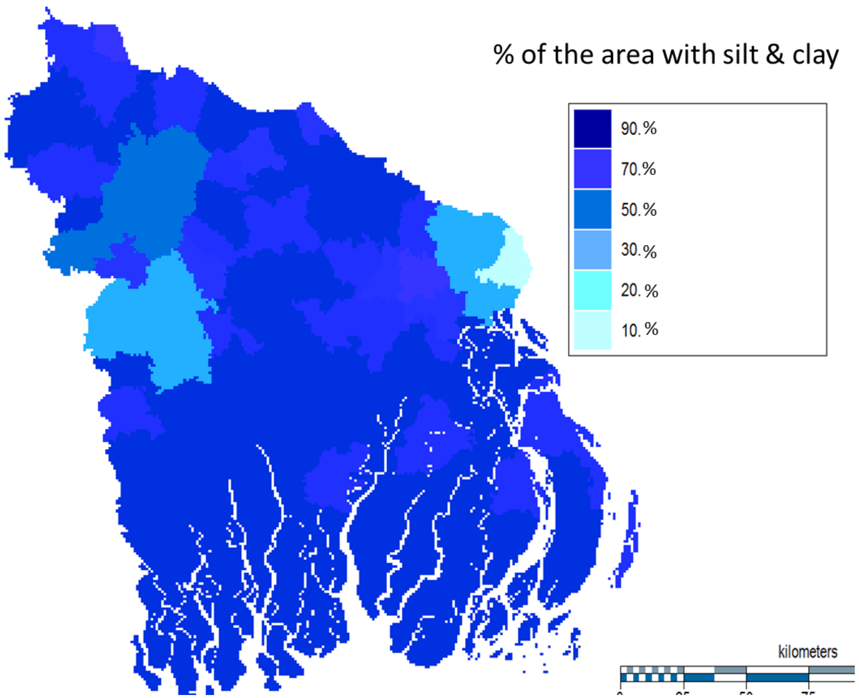
Model Geometry: model extent

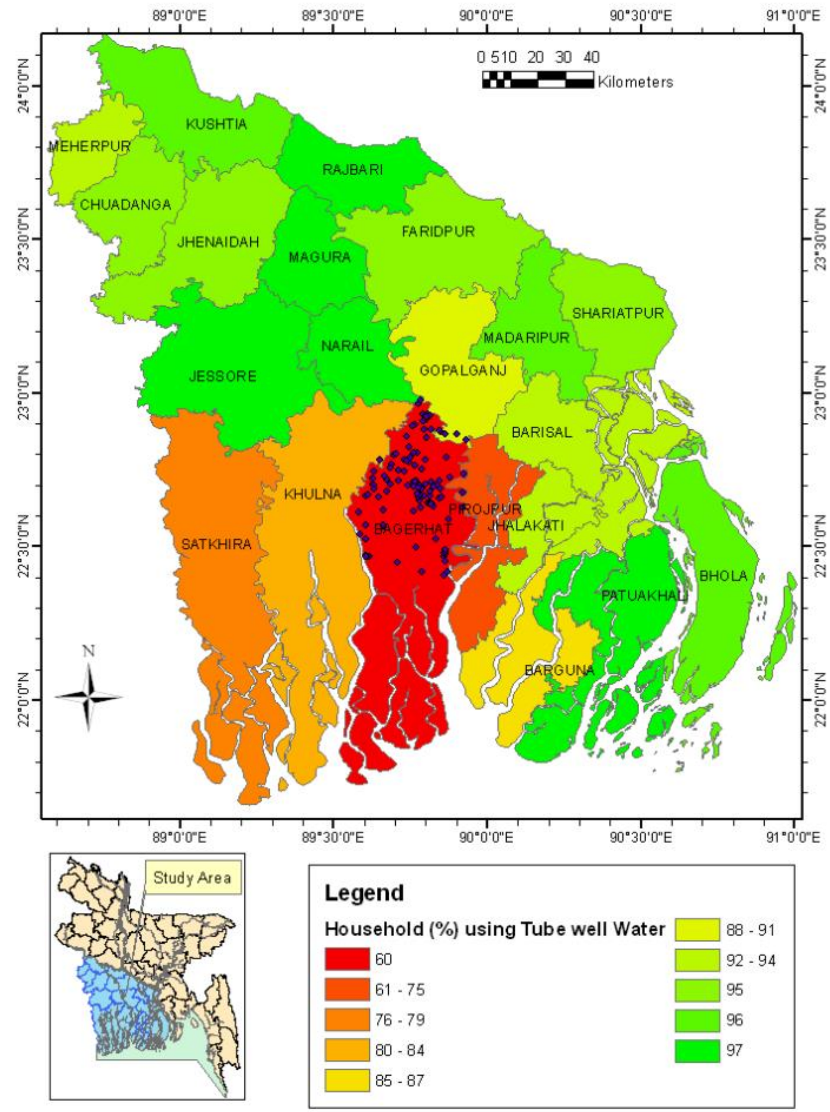


Bottom boundary: Boka Bil formation hydrological base (no flow)

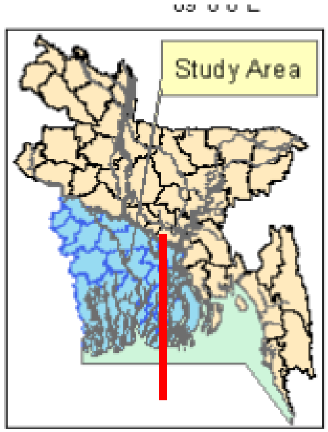


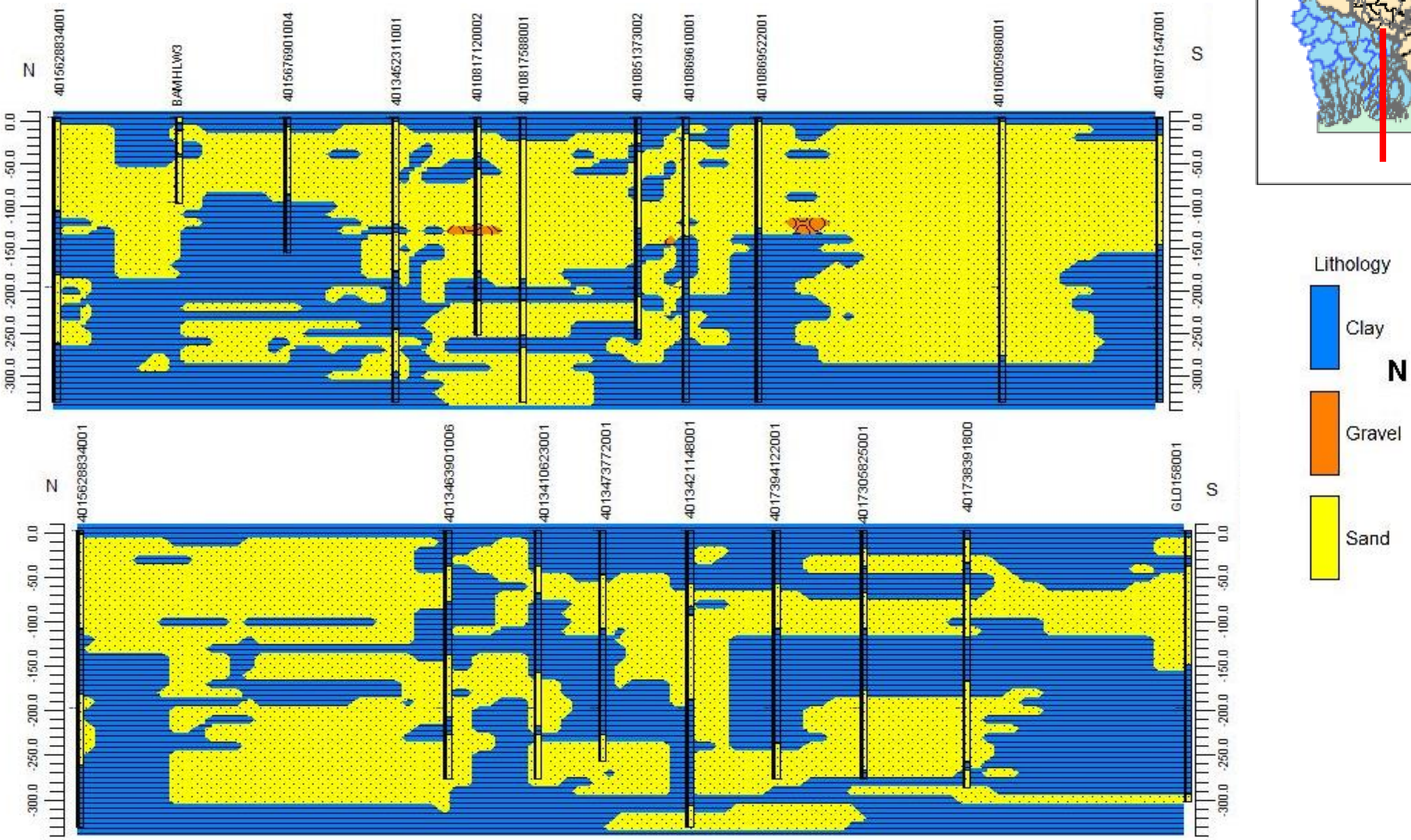
Geology: e.g. Case study Bagerhat District



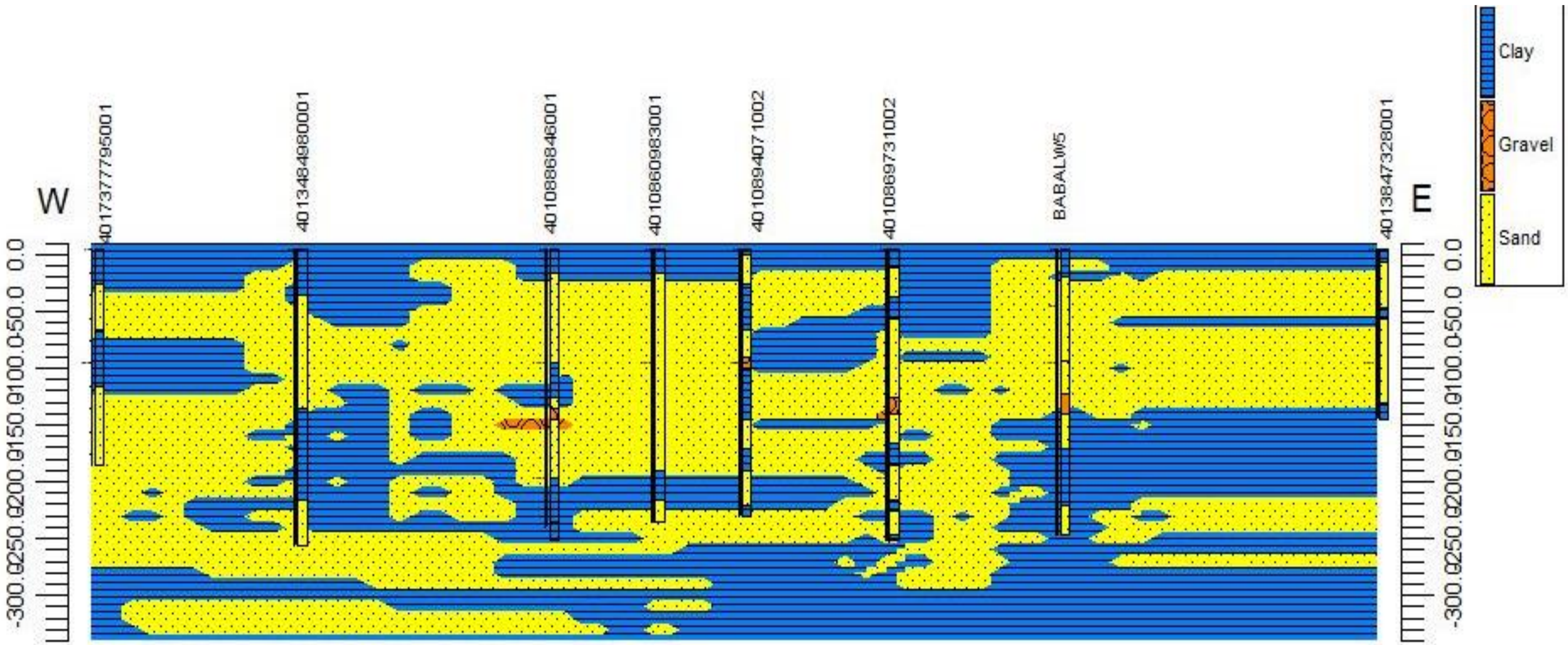


N-S Cross-sections of Bagerhat, it is a pathy complex geologic system

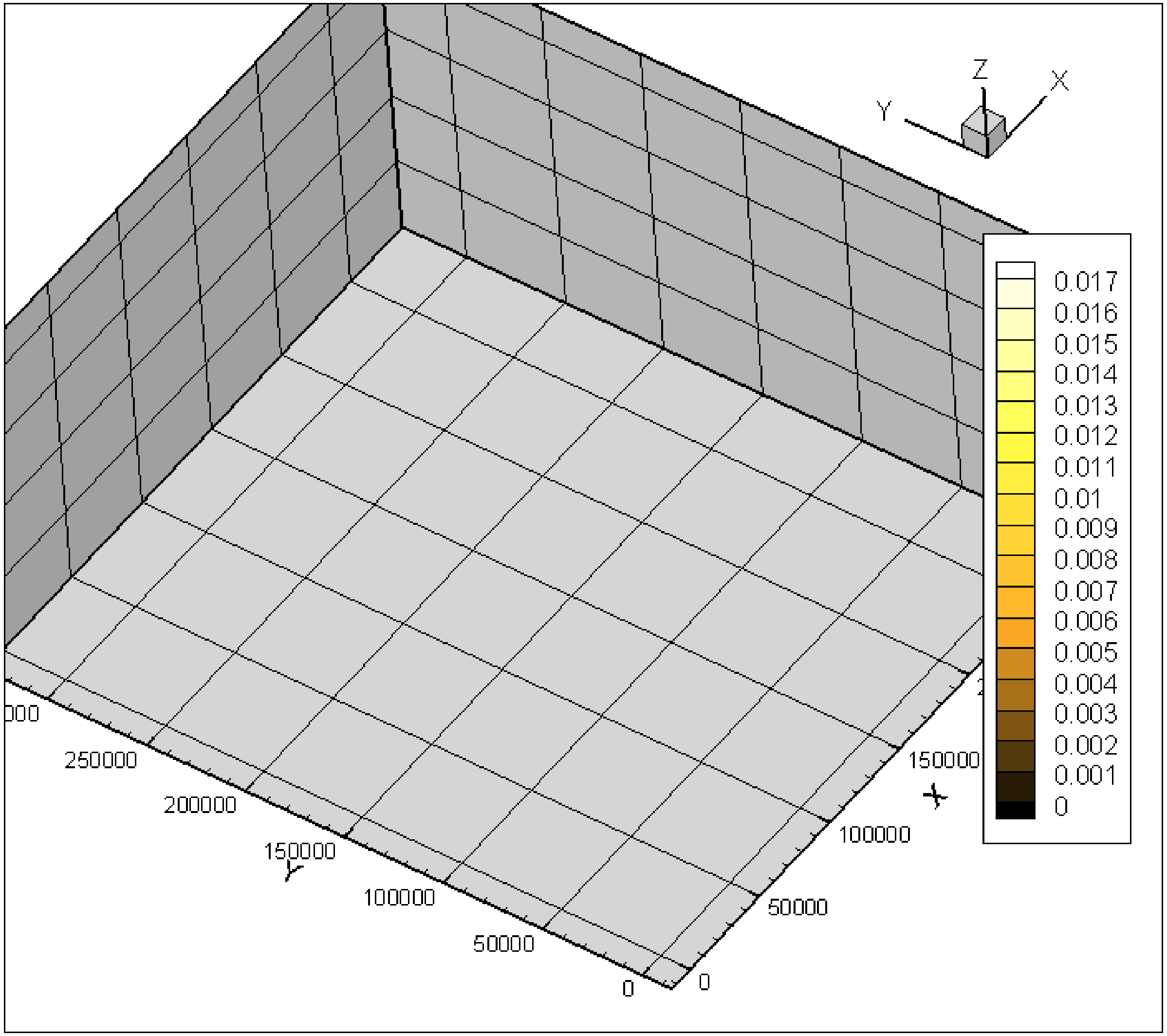


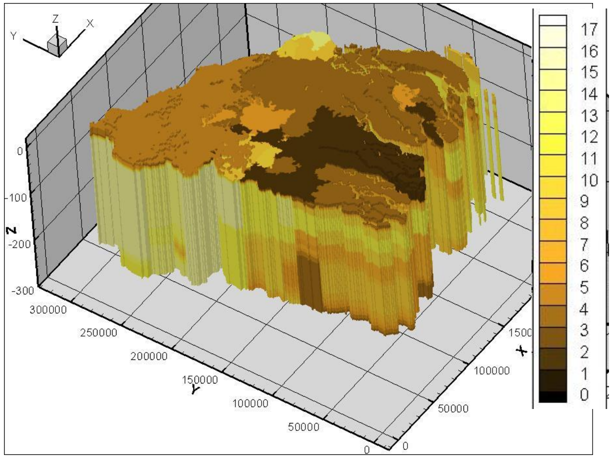


E-W Cross-sections of Bagerhat

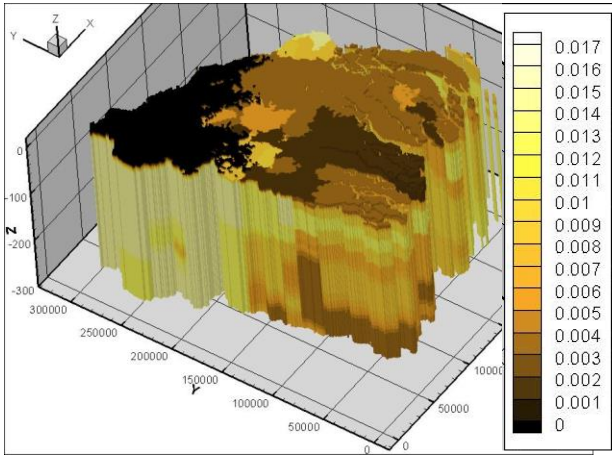


Geology





K_h=hor. cond. [m/d]

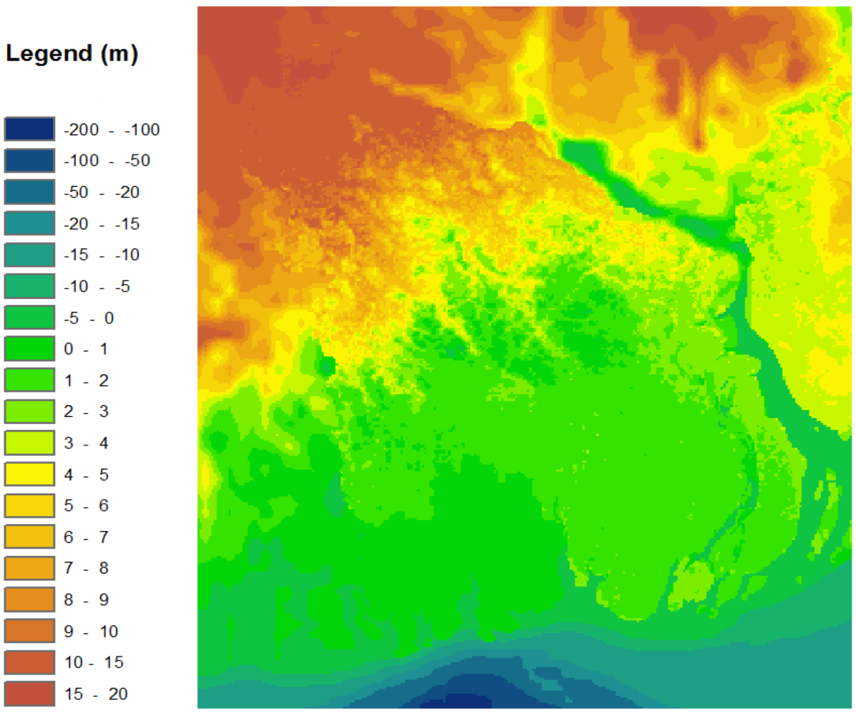


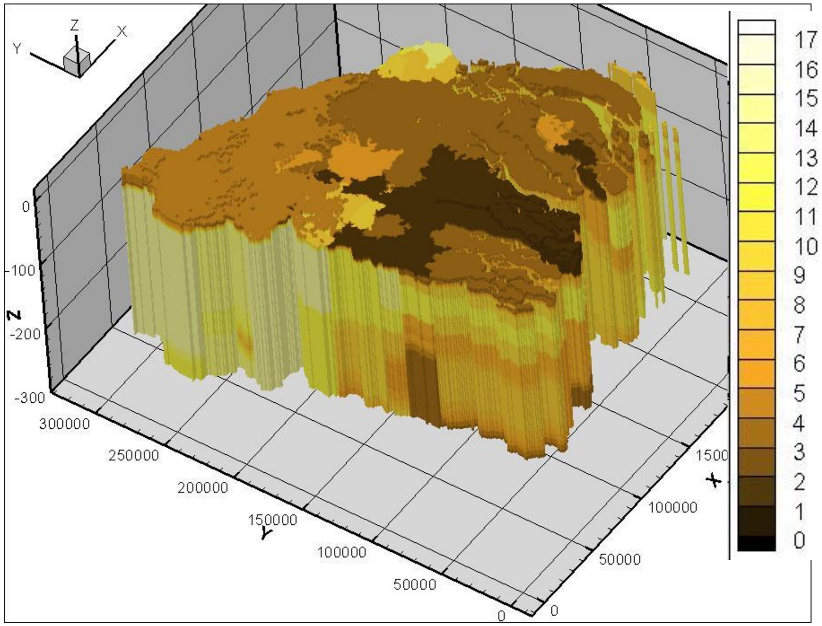
K_v=vert. cond. [m/d]

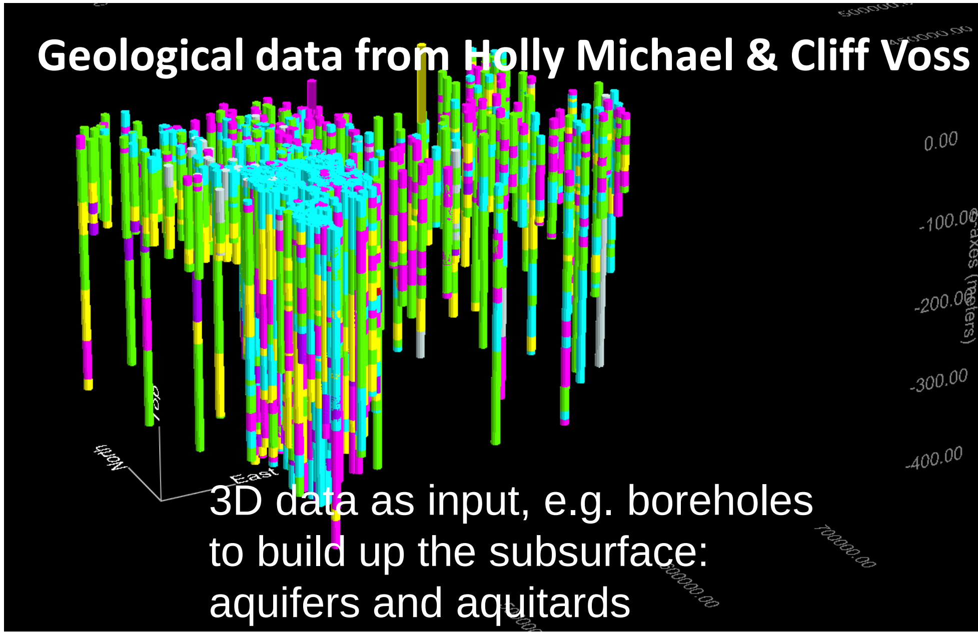
Source: Dr. Bashar

surface level (DEM)

subsurface model







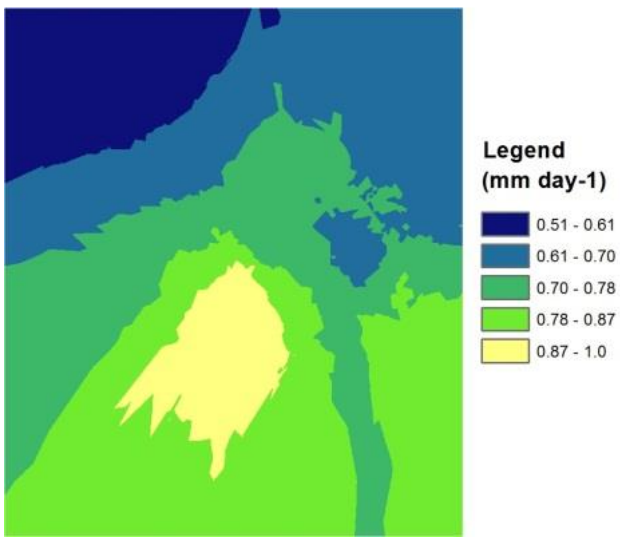
Sources:
CEGIS, BGS, DPHE, 2001

Net groundwater recharge

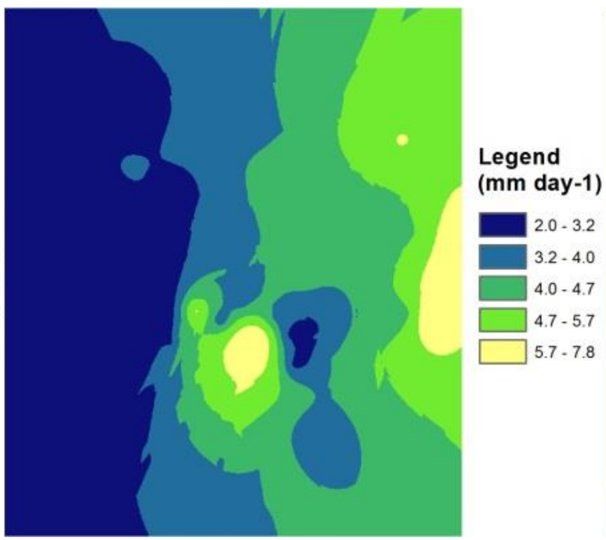
- Interpolation measured data (source CEGIS):
- 4 monitoring stations for evapotranspiration
- 96 monitoring stations for precipitation
- ±1990 – 2011

Data averaged per stress period:

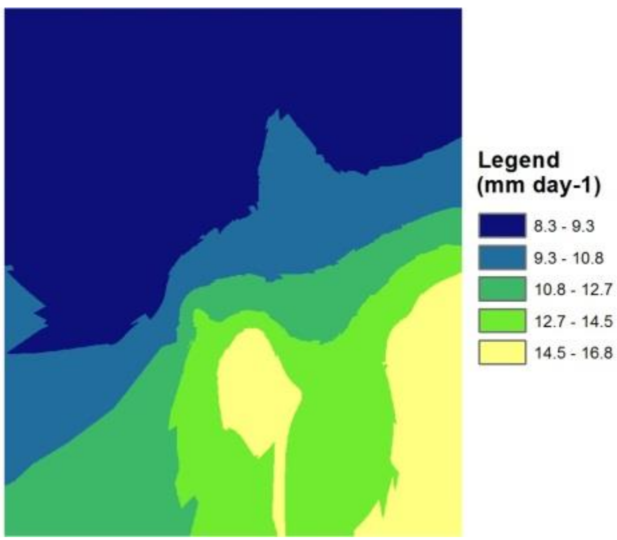
1. Cold and dry
Nov - Feb



2. Hot and humid
Mar - May



3. Monsoon season
June - October

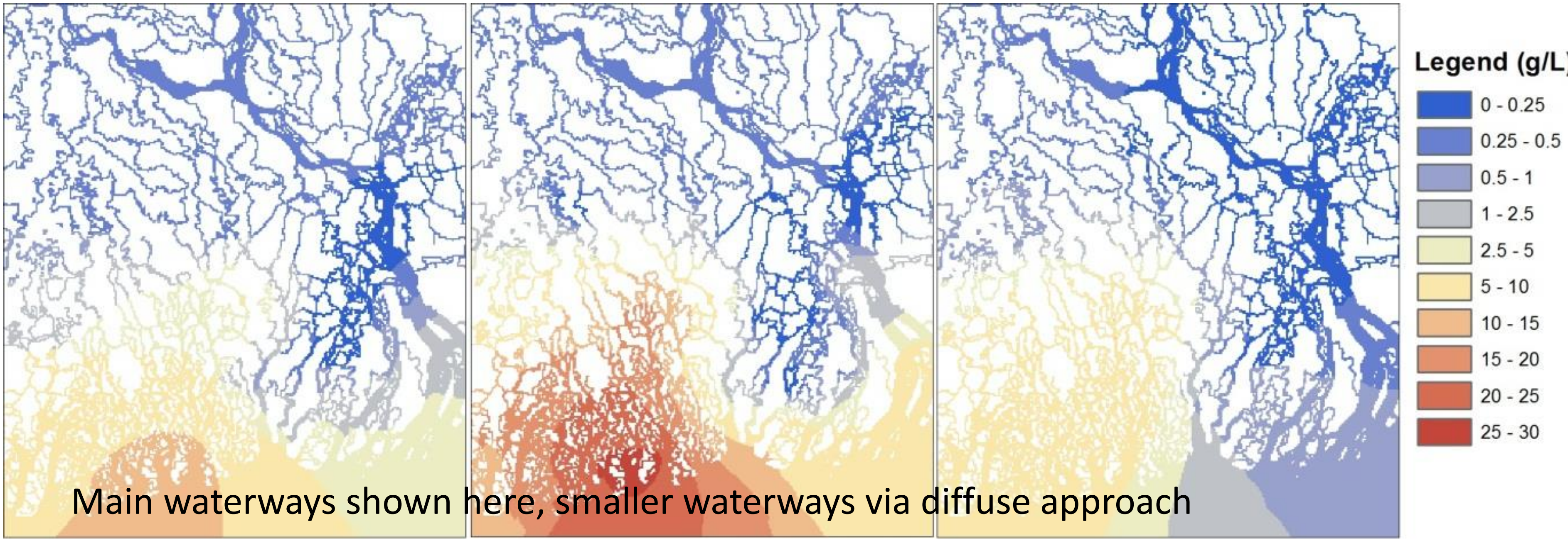


Surface water: Salinity levels in river package

1. Cold and dry
Nov - Feb

2. Hot and humid
Mar - May

3. Monsoon season
Jun - Oct

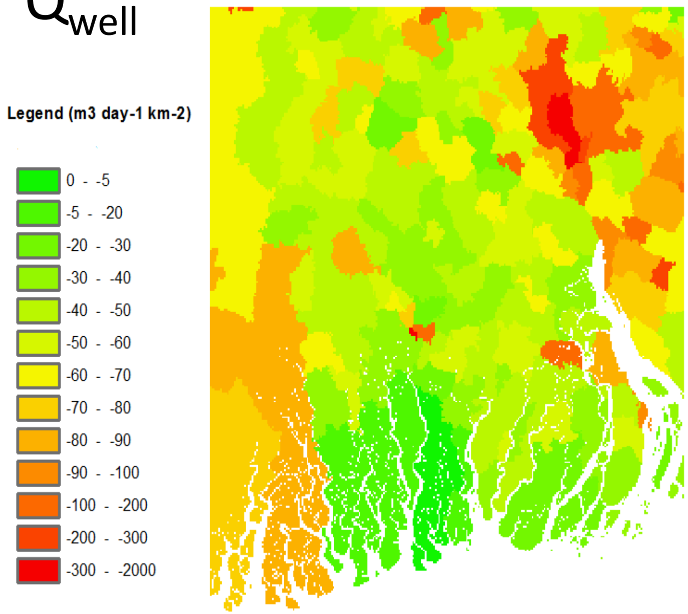


Main waterways shown here, smaller waterways via diffuse approach

Source:
Daily water level data from BWBD (126 locations on river levels)
CEGIS, completed by data from DIVA-GIS (84 monitoring stations on salinity values)

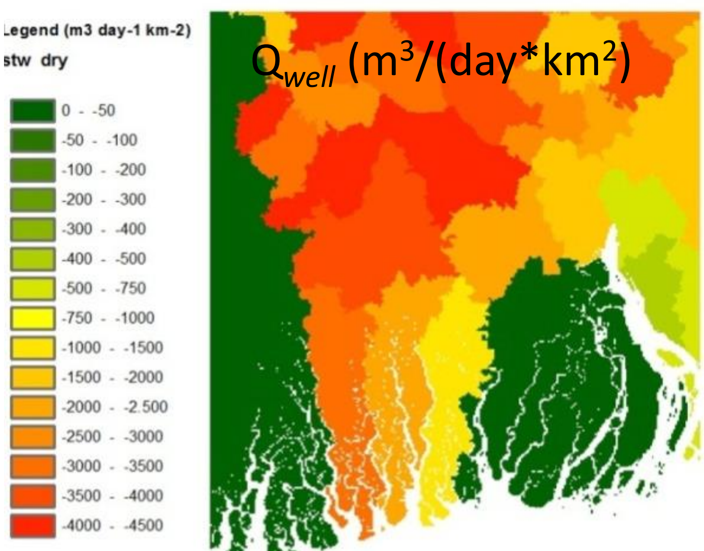
GROUNDWATER EXTRACTIONS

Q_{well}



Domestic&Industrial

- based on population size (cf Michael and Voss, 2009)
- total (domestic + industrial) demand 50 L/day per capita (WARPO, 2000)
- assumed constant throughout the year



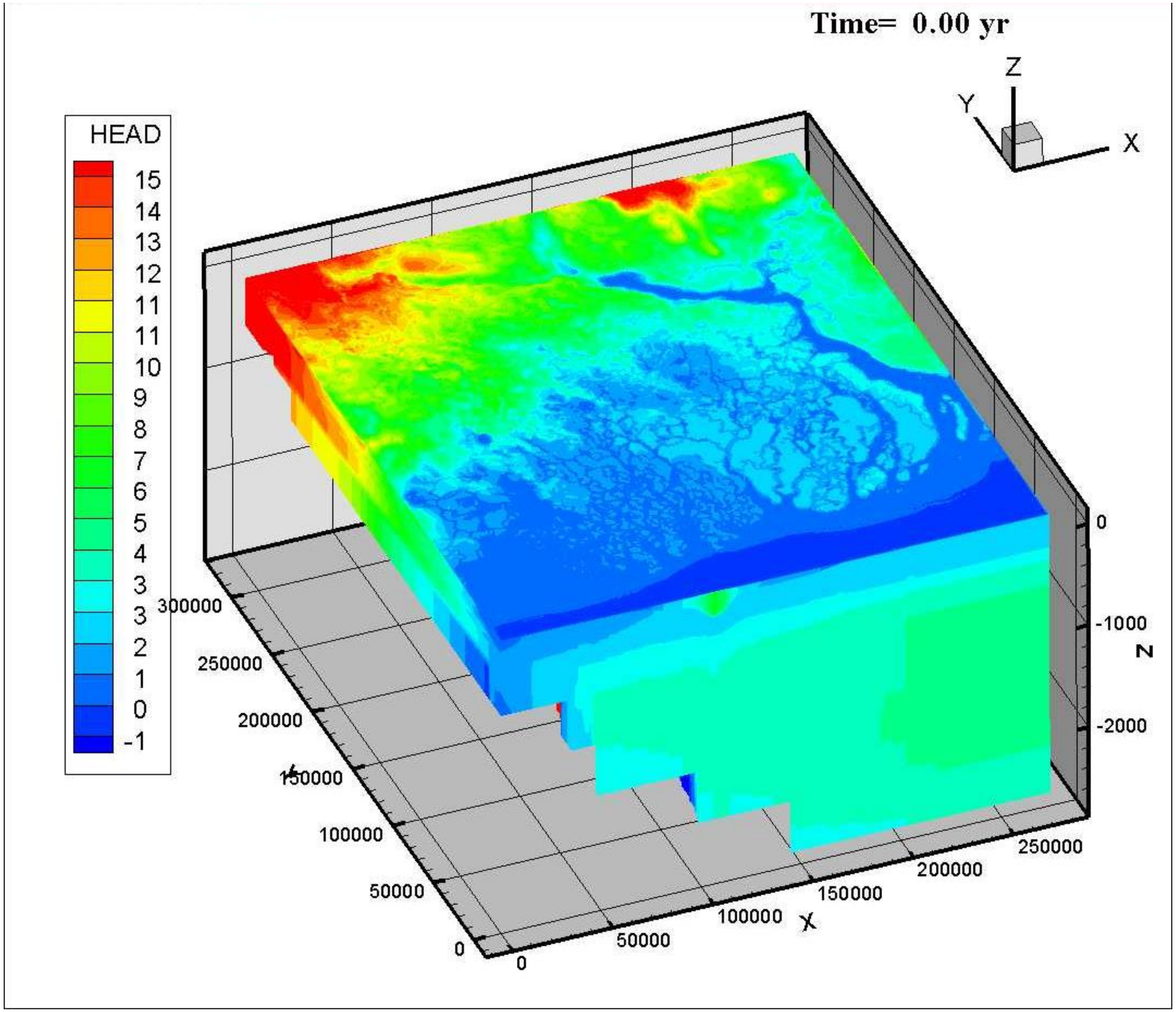
shallow, dry

Irrigation for agricultural purposes

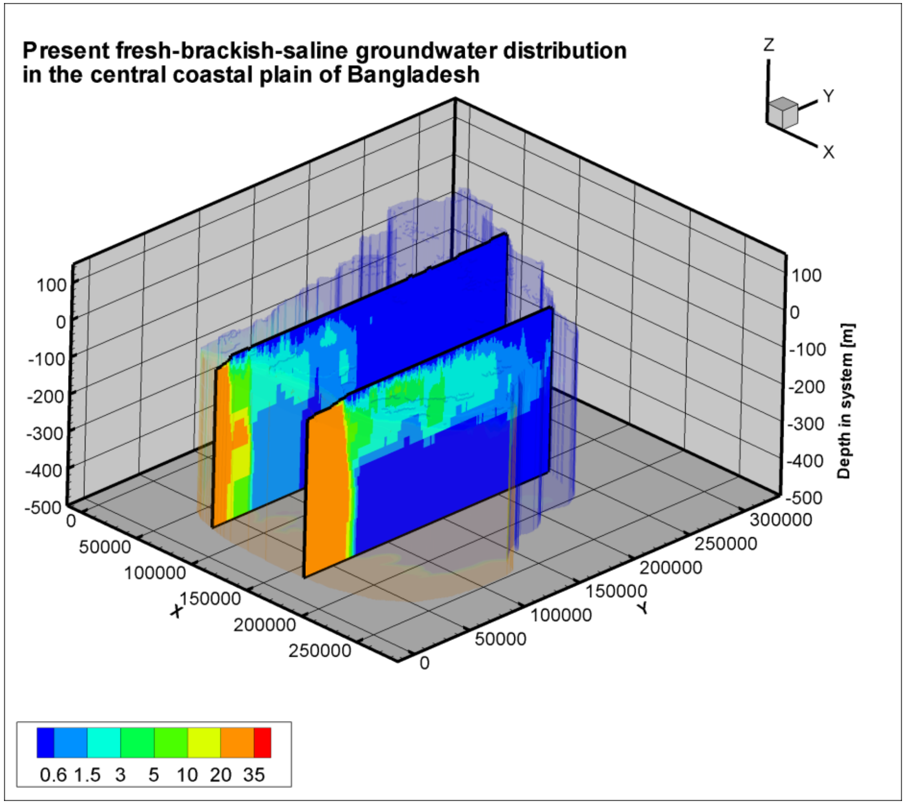
- known is area per irrigation type, on district level
- distinction between wet season and dry season
- irrigation Shallow Tube Well : 10-60m depth
- irrigation Deep Tube Well: 60-100m depth

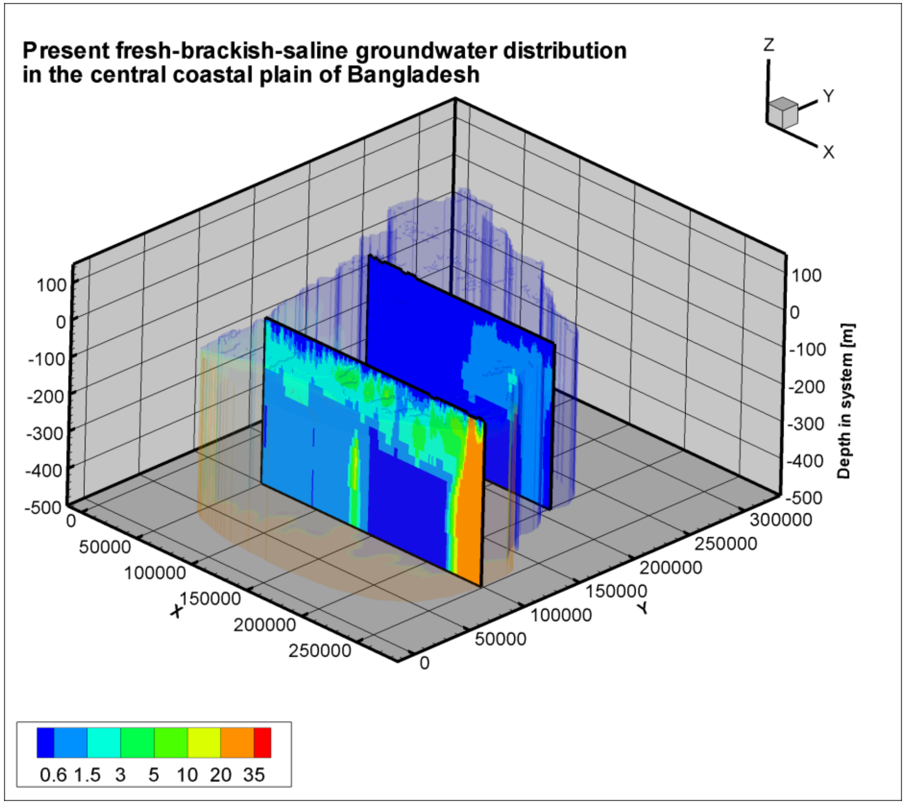
Source: depth based on the well data of DPHE

Model results: Heads

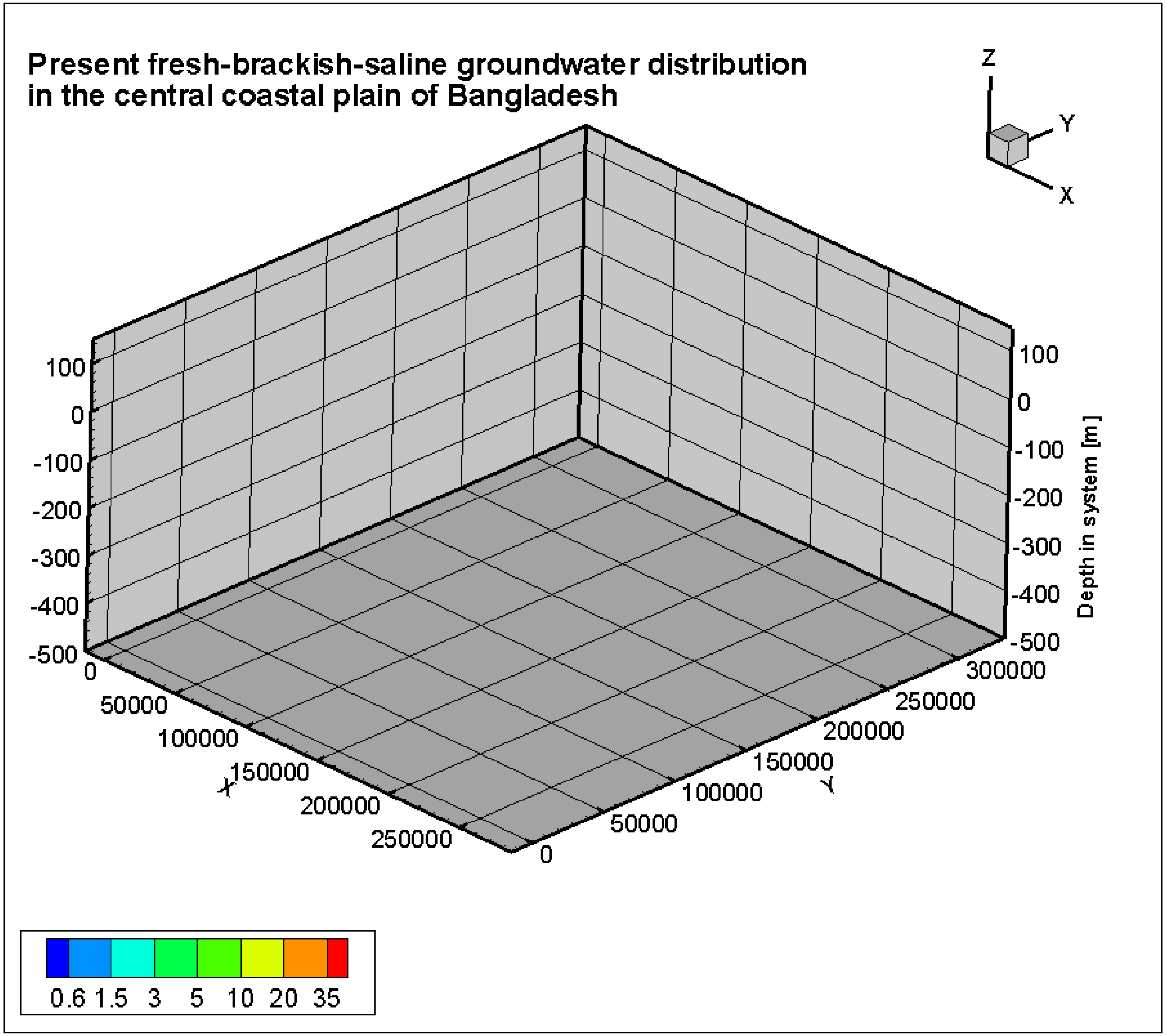


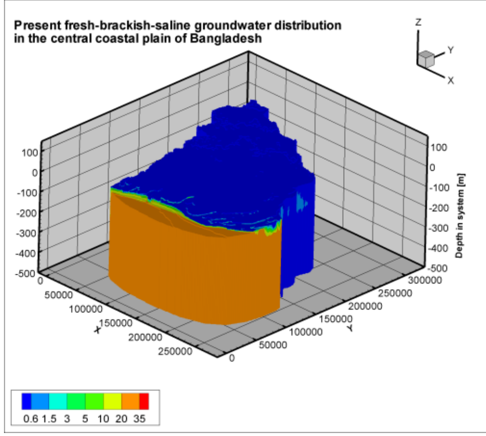
Model results: 3D-salinity





Model results: 3D-salinity





DELIVERABLES

1. Key components for WSP and mitigation strategies	2. 3D density dependent groundwater model	3. Water Quality Monitoring kit
4. Smart Phone App to measure Electrical Conductivity	5. Leaflet containing salinization processes information	6. Two Workshops one on Modelling and one on Monitoring

SWIBANGLA Water Quality Monitoring Kit

The Ruposhi Bangla Deep Groundwater Statement (UCL, 2013) calls for systematic monitoring of groundwater level and quality in all pumping boreholes and observation wells at different depths:

- To measure Electric Conductivity of groundwater regularly to detect possible salt water intrusion.
- To install targeted monitoring wells in the fresh-saline transition zone, to make it possible to detect an increase in salinity over time when on-going saltwater encroachment is taking place.

A toolkit are prepared with various cost-effective monitoring techniques to measure different parameters such as nitrate, pH, Electrical Conductivity, coliform bacteria, sulphate and bicarbonate.

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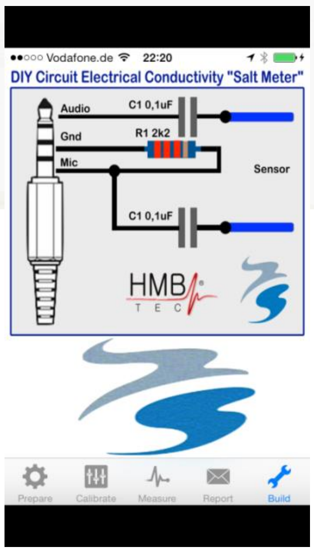
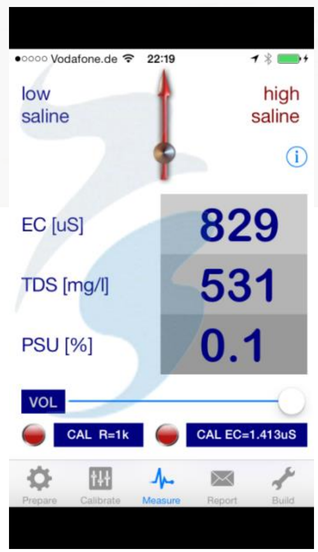
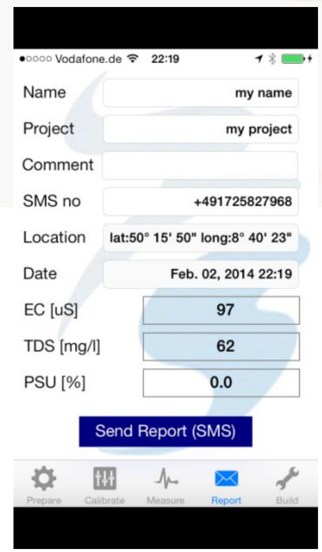
Prototype free Salt Water Smart Phone App

- to easily measure the Elec. Cond. (EC) of water → ECApp demo tomorrow!
- to provide guidance to the user on the usability of the water
- the sensor of the ECApp can easily be made by the user himself
- to set up of a on-line database to be used is fresh water management issues
- the possibility to measure Arsenic is investigated







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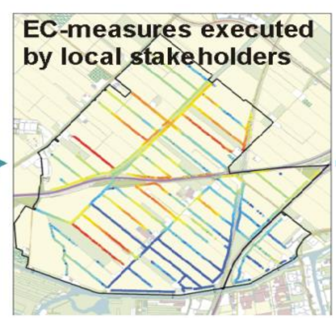

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Water system analysis

Solutions

DELIVERABLES

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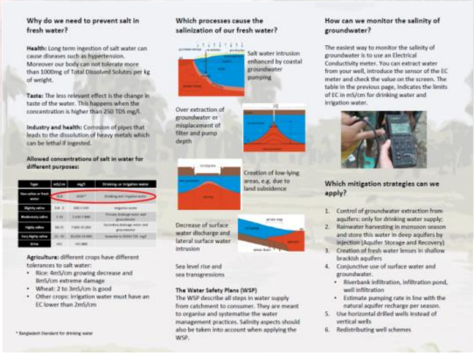
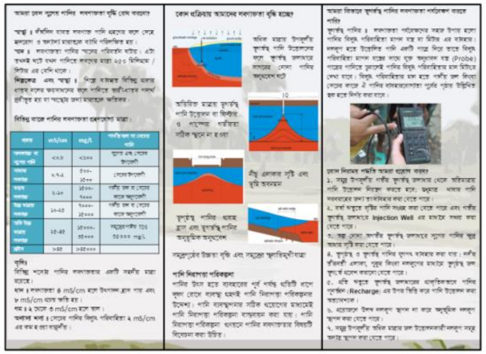
SWIBANGLA Leaflet salinization in English and Bangla

It is a compilation of information regarding the salinization of groundwater:

- relevant information about the effects of saline water for health and agriculture,
- the most relevant salinization processes in Bangladesh,
- the monitoring of saline groundwater, and mitigation strategies to reduce the impact of salinization.

The leaflet is meant for professionals that deal with monitoring and management of drinking water.





DELIVERABLES

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Modelling and Monitoring Workshops SWIBANGLA

Two workshops are give in the beginning of June 2014.

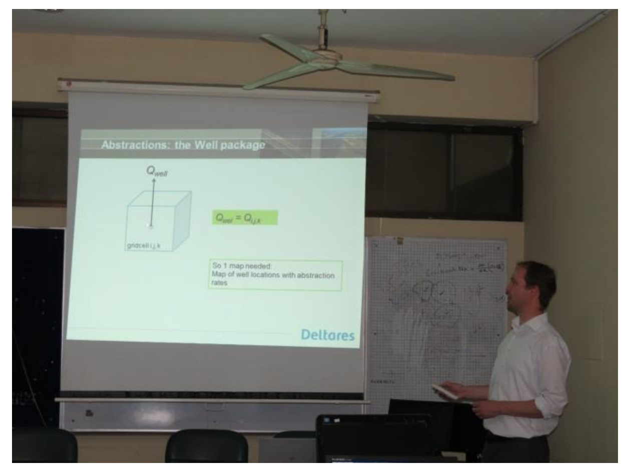
- A Modelling Workshop on 3D variable-density groundwater modelling, using the lastest fresh-saline groundwater modelling tool: iMOD-SEAWAT
- A Monitoring Workshop: Groundwater Quality Monitoring, using the Water Quality Monitoring kit

Monitoring being part as a public awareness

Desktop Knowledge Transfer

- Meetings

- Modelling Course



Conclusions and recommendations SWIBANGLA

- The geological and hydrogeological history of the coastal area of Bangladesh is not easy to understand.
- Sea regressions and transgressions, large sediment supply, active tectonism, eustasy, and the river dynamics of the past thousands of years created a system of heterogeneous sedimentary deposits, containing fresh and saline water.
- Anthropogenic actions through groundwater extractions have impacted the system, making it even more complicated.
- To add up to the complexity of the system, reliable hydro(geo)logical data is scarce.

Conclusions and recommendations SWIBANGLA

The complexity of the water system and the lack of data strongly frame the research conditions for any hydrogeological study done in the area. SWIBANGLA has not been an exception, and therefore the limitation to draw determinant conclusions is a fact.

However, the following conclusions and recommendations can still be made:

1. **Different types of salinization processes are currently taking place** in Bangladesh: lateral surface salt water intrusion, lateral salt groundwater intrusion, vertical up-coning under extractions and low-lying areas, infiltration of salt water due to inundations caused by storm surges.
2. **The awareness of population** regarding the existence, relevance and dynamics of these **salinisation processes** is **poor**. Awareness material can help spreading the knowledge on how to monitor this processes and how to mitigate their impacts.

Conclusions and recommendations SWIBANGLA

4. **Systematic monitoring** of groundwater in the coastal zone is of **key importance** to understand the functioning of the hydrogeological system and its velocity of the salinization processes. This systematic monitoring is **currently not taking place** in Bangladesh.
5. **Monitoring of groundwater** with the specific objective to monitor **salinization processes** has **particular characteristics** which are **not** clearly known **enough** by the monitoring institutions in Bangladesh.
6. **Numerical modeling** the impact of salt water intrusion processes under the pressure of global and climate change can **increase the sense of urgency** among water users, water managers and policy makers.
7. A **centrally organized and publicly available database** with hydrogeological data is needed. Currently such a database does not exist.
8. There are **several mitigation strategies** that could be applied in Bangladesh **to counteract the salinization impacts**. The proposed key components for the WSPs and mitigation strategies, proposed by SWIBANGLA, should be taken into the next generation of the WSP.

Thank you
for your attention!

Acknowledgements

IRC
Supporting water sanitation and hygiene services for life

brac

Department of Public Health Engineering

More information:
http://www.ircwash.org/news/introducing-swibangla-project

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September 2014