# 3D groundwater model: A tool to design schemes for infiltration and storage of fresh water in brackish aquifers

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Acacia Water
Solutions in Groundwater

Department of Geology
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unicef unite for children

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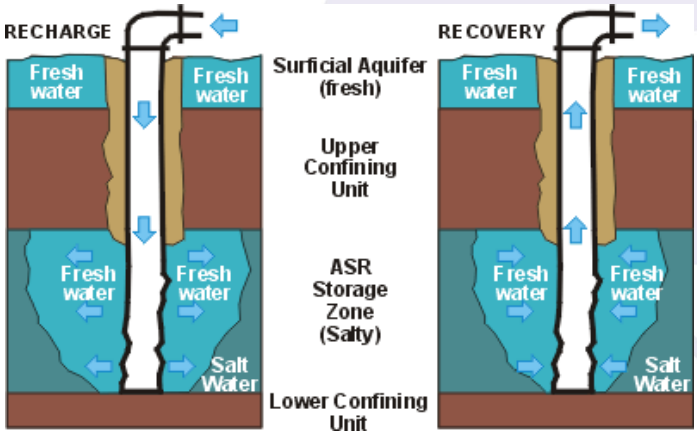
## Contents

- General concept
- What information is needed
- What type of model(code) meets the criteria

- Simulations to test the feasibility of ASR in brackish aquifers
  - Step 1 : Sensitivity study testing infiltration amounts
  - Step 2 : Simulation for test locations Assasuni and Batiaghati

- Conclusions

## Infiltration of fresh water in a brackish aquifer

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## What information do you need Why use a groundwater model

- Design and operation
- In other words answers needed for questions like:
  - Is the hydrogeology suited
  - How much water can be infiltrated
  - Where does the infiltrated water go to
  - What concentrations will develop
  - How much and during what period can we abstract
  - How much water can be recovered.
  - How does the waterquality develop over time.
- Groundwater flow in brackish aquifers is complicated. Therefor a need for a tool to help with design and operation of a ASR scheme.

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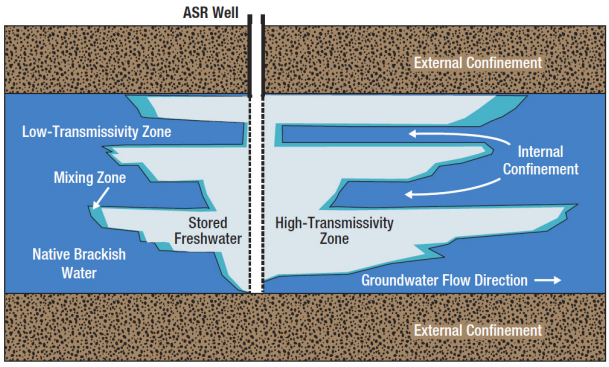
## Groundwater model

- Heterogeneous aquifer and aquitards

Acacia Water 6

# Heterogeneous aquifers

- Freshwater will preferentially enter high-transmissivity flow zones.
- Relatively low transmissivity strata will receive relatively little freshwater and act as internal confining units to the flow zones.
- Water in the flow zones will migrate at a more rapid rate under prevailing ambient hydraulic gradients.

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# Groundwater model

- Heterogeneous aquifer and aquitards
- Density dependant flow

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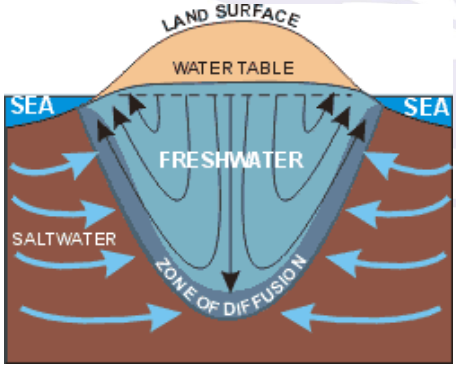
## Density difference

- Fresh water is lighter than salt water
- Fresh water floats on salt water

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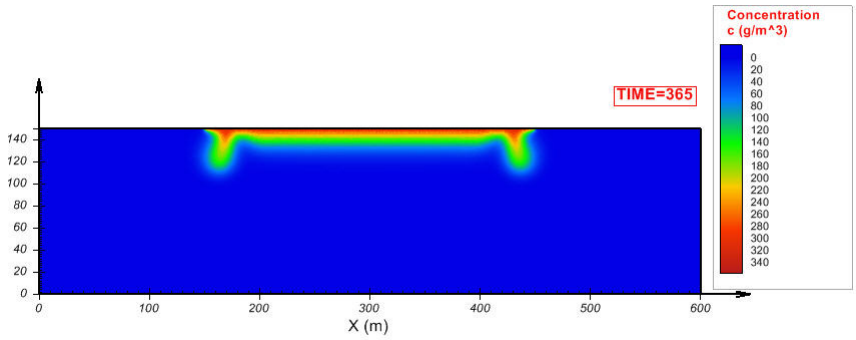
## Density difference

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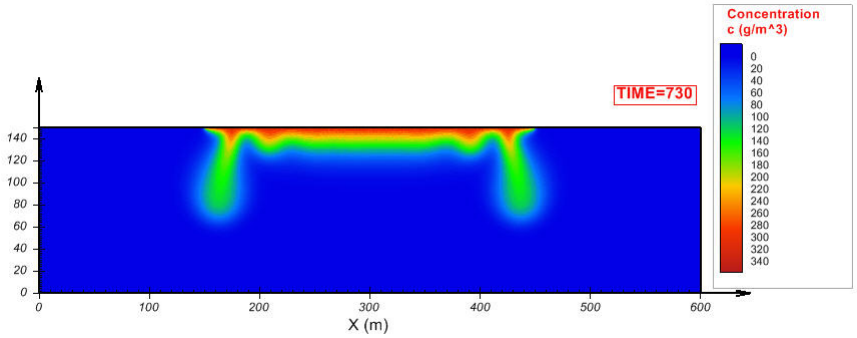
# Density difference

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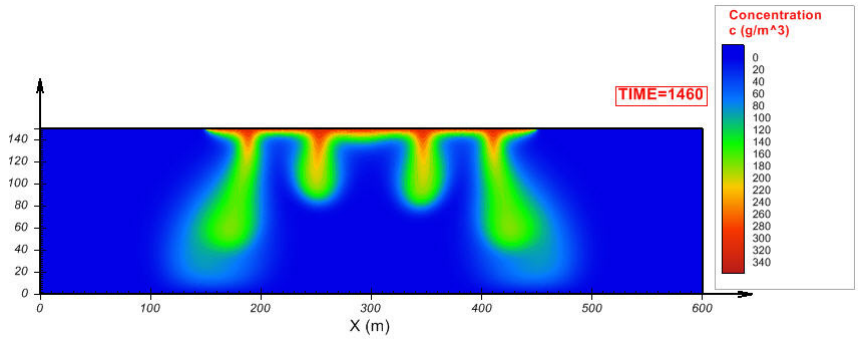
# Density difference

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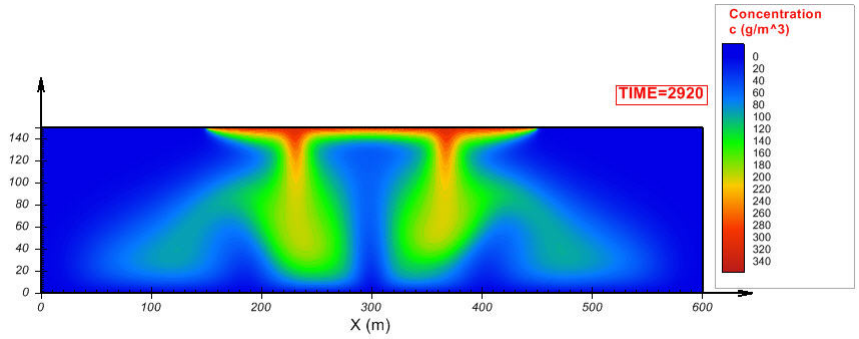
## Density difference

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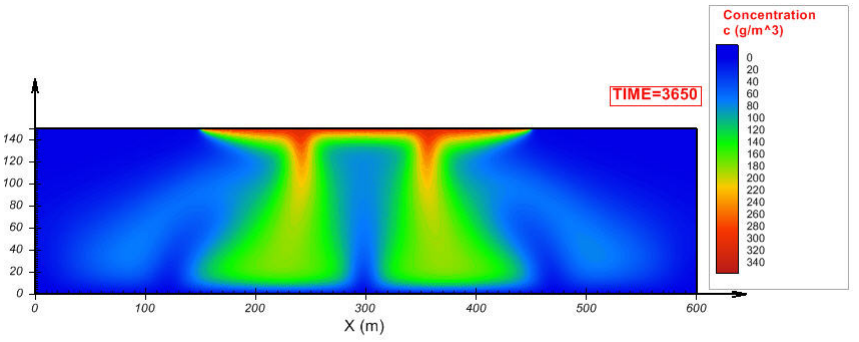
## Density difference

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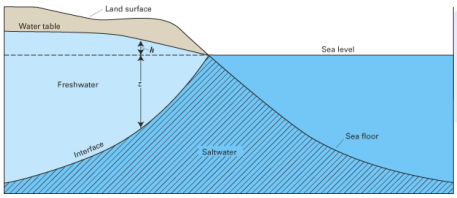
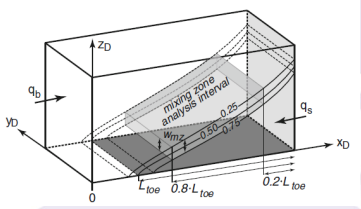
## Groundwater model

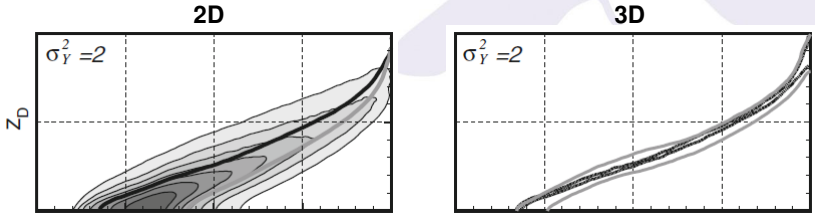
- Heterogeneous aquifer and aquitards
- Density dependant flow
- Three dimensional



## 2D vs 3D



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## Groundwater model

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- Changes in flow en concentration through time

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- Heterogeneous aquifer and aquitards
- Density dependant flow
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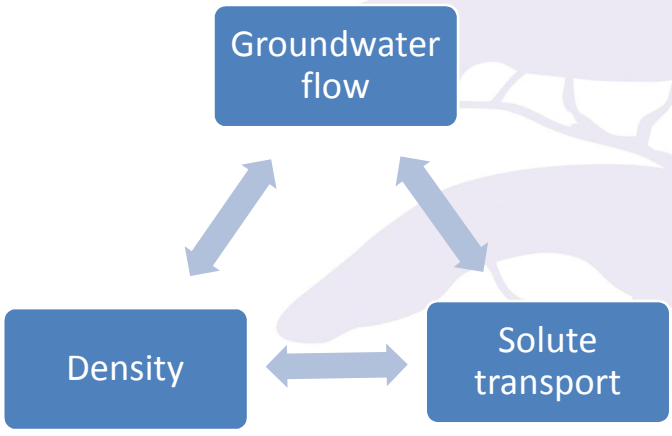
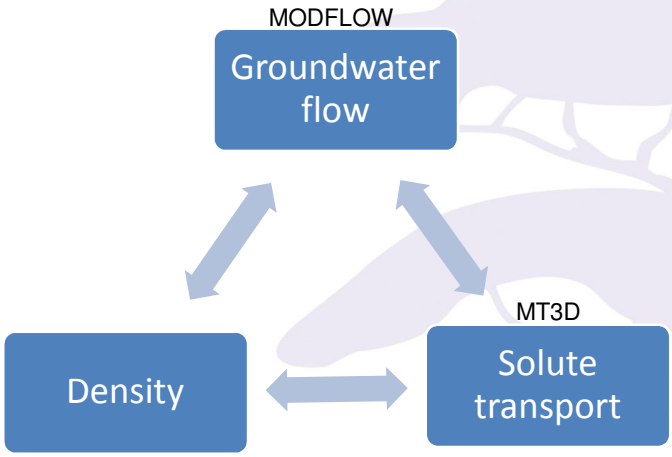
- Several codes available with pros and cons:
  - FEFLOW
  - FEMWATER
  - SEAWAT
  - SUTRA
  - …



## Modelcode



## Modelcode : SEAWAT



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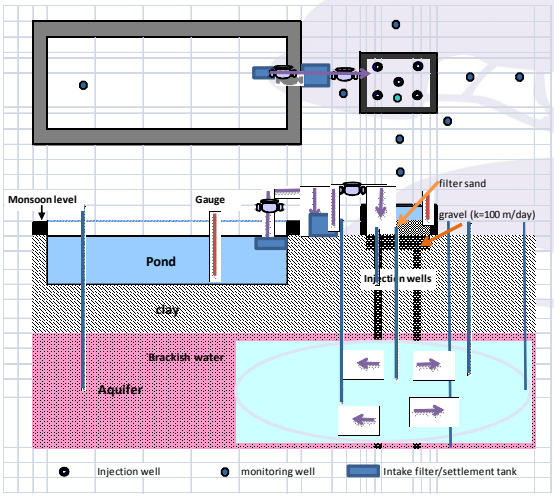
# From real life to schematized world of models

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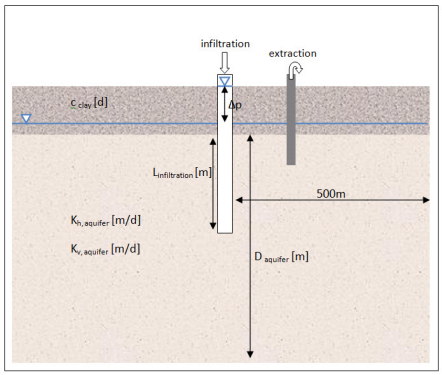
# From real life to schematized world of models

- $K_{h,\ aquifer}$ horizontal permeability aquifer [m/d]
- $K_{v,\ aquifer}$ vertical permeability aquifer [m/d]
- $D_{\ aquifer}$ thickness aquifer [m]
- $L_{infiltration}$ length infiltration well below clay layer [m]
- $c_{\ clay}$ resistivity upper layer [d]
- $\Delta p$ head infiltration well [m]

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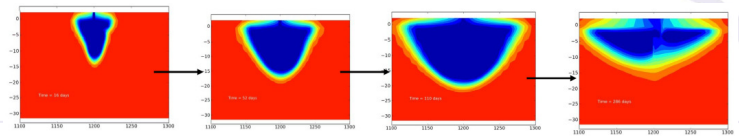
# Simulations to test the feasability

- A number of test runs are made to verify the design of the technology

| Aquifer thickness | Permeability | | Infiltration water head | length infiltration well below clay | Resistivity clay layer | Infiltration rate |
|---|---|---|---|---|---|---|
| | horizontal | vertical | | | | |
| D [m] | $K_h$ [m/d] | $K_v$ [m/d] | Δp [m] | L [m] | c [d] | [$m^3$/d] |
| 30 | 25 | 2.5 | 3 | -10 | 1000 | 37 |
| 10 | 5 | 2.5 | 3 | -3.33 | 1000 | 28 |
| 10 | 1 | 0.5 | 3 | -3.33 | 1000 | 14 |
| 10 | 1 | 0.5 | 2 | -3.33 | 1000 | 10 |
| 10 | 1 | 0.5 | 3 | -10 | 1000 | 17.5 |
| 10 | 0.5 | 0.25 | 2 | -10 | 1000 | 10 |
| 5 | 0.5 | 0.25 | 2 | -5 | 1000 | 8.3 |
| 10 | 0.5 -5 m | 0.25 | 2 | -10 | 1000 | |
| | 0.1 – 1m | 0.1 | | | | |
| | 0.5-4 m | 0.25 | | | | |



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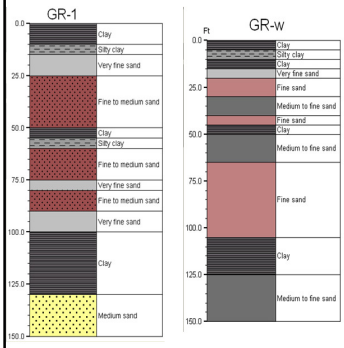
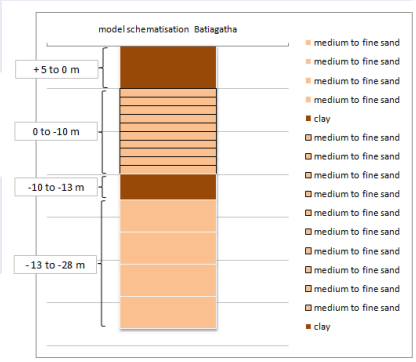
# Case Batiagatha

Borehole logs




Model schematization

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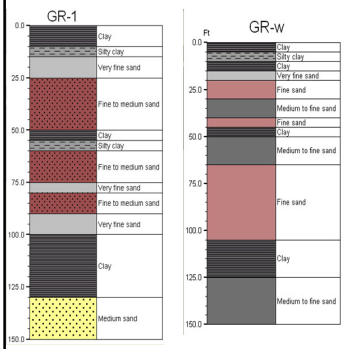


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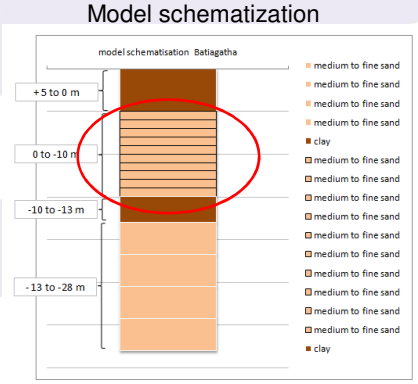


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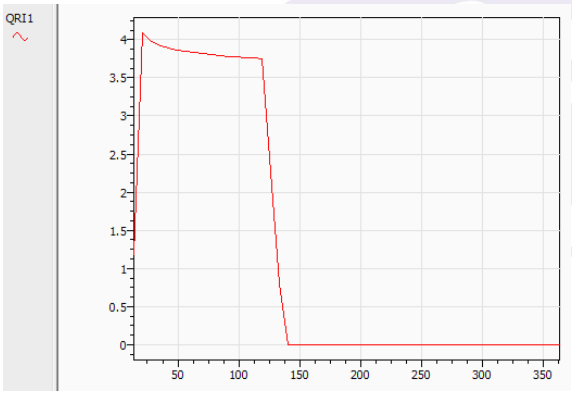
# Case Batiagatha

Infiltration reaches about 3.7 $m^3$/day

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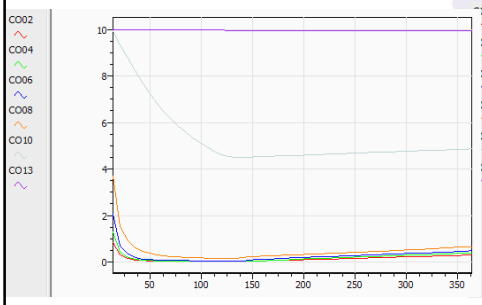
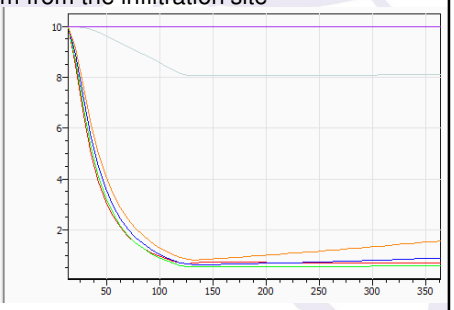
# Case Batiagatha

Chloride concentration in different layers at the location of the infiltration




Chloride concentration in different layers at 3 m from the infiltration site

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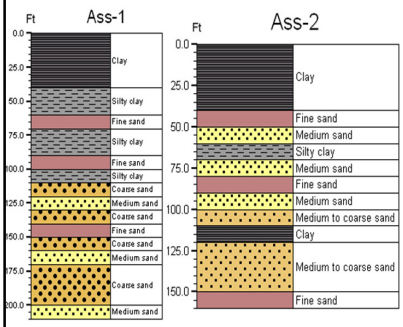
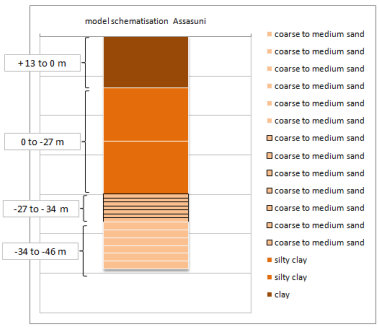
# Case Batiagatha

# Case Assasuni

Borehole logs




Model schematization

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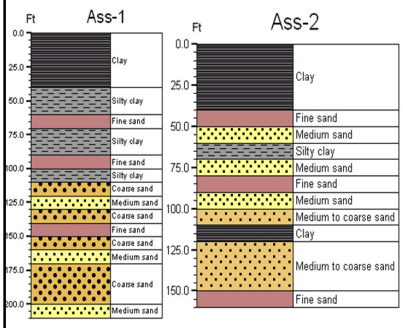
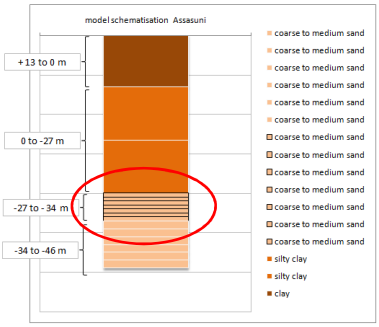
# Case Assasuni

Borehole logs




Model schematization

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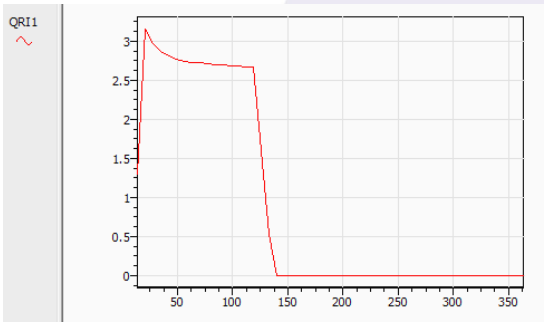


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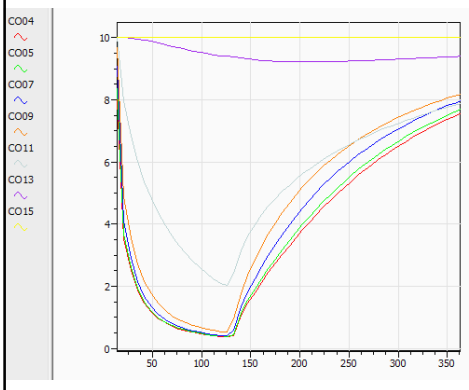
# Case Assasuni

Chloride concentration in different layers at the location of the infiltration

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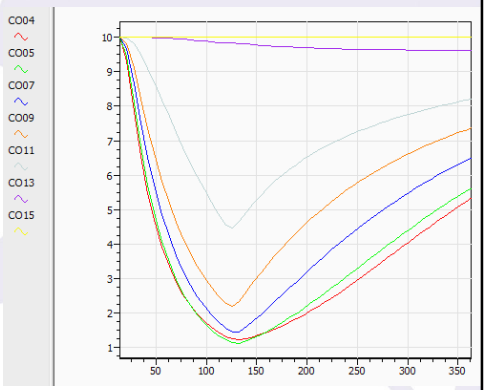


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## Conclusions

- In general a model can test the feasibility for several design options and circumstances.
- Site selection and design
  - Suitability of the hydrogeology
  - Dimensions of the scheme
  - What resulted infiltration and abstraction capacity is feasible
  - …
- Operation
  - What head is optimum for maximum infiltration
  - What maximum abstraction rate and amount per time unit is recommended



## Final remarks

- A model is simplified representation of the real world. So it is never perfect.
- However, since the processes are very complex,
  to better understand the governing processes of ASR in brackish aquifers the modeling tool is essential.
- Testresults and measurement data used to improve models

## Final remarks

- A model is simplified representation of the real world. So it is never perfect.
- However, since the processes are very complex, to better understand the governing processes of ASR in brackish aquifers the modeling tool is essential.
- Testresults and measurement data used to improve models
- Garbage in is garbage out
  - the model is as good as the available data and knowledge of the hydrological processes
  - The model is as good as the one who pushes the buttons



Thank you for your attention