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Alluvial aquifer modeling with MODFLOW in the case of a well-field facing global change (AUVERWATCH Project)

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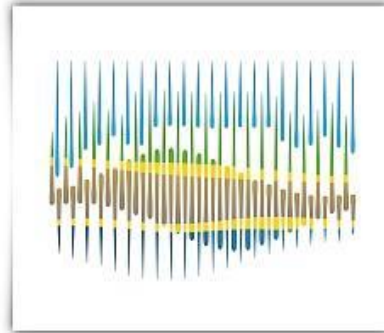
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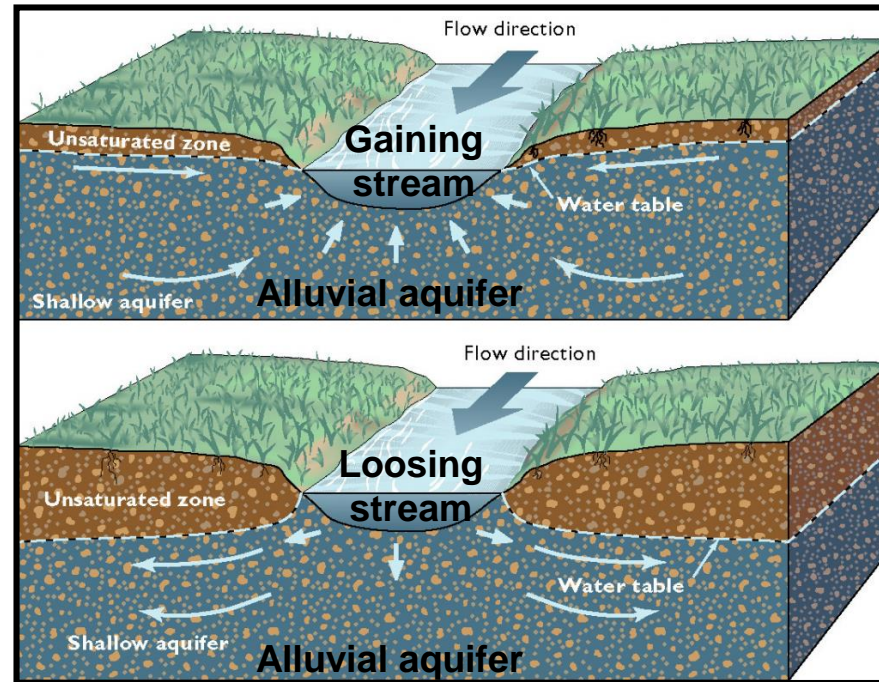


Alluvial aquifer modelling with MODFLOW in the case of a well-field facing global change (AUVERWATCH project)



1) Shallow groundwaters in relation to rivers/streams

2) Unconsolidated sediments



<https://waterknowledge.colostate.edu>

3) Important transmissivities
(provide high yields)

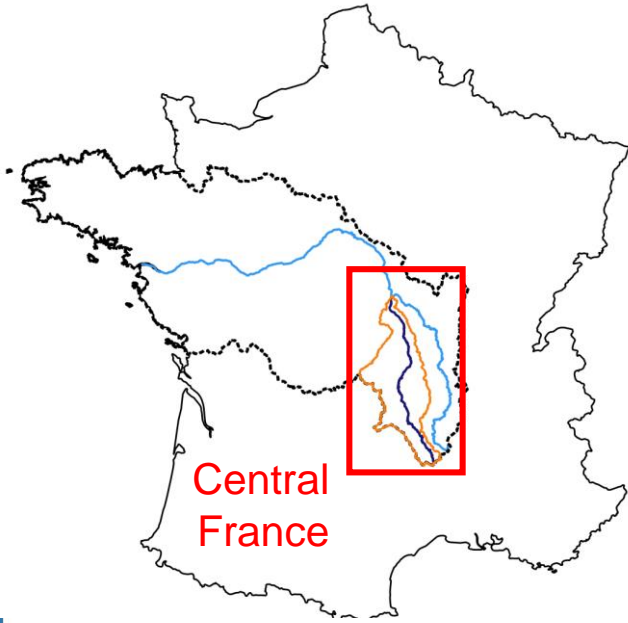
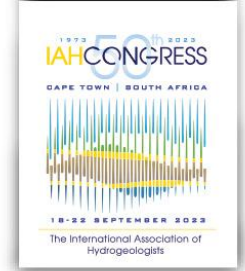
Groundwater abstractions worldwide:
67% Irrigation
22% Domestic
11% Industries

Smith et al., (2016)

In France:
45% of groundwater use
come from alluvial aquifers

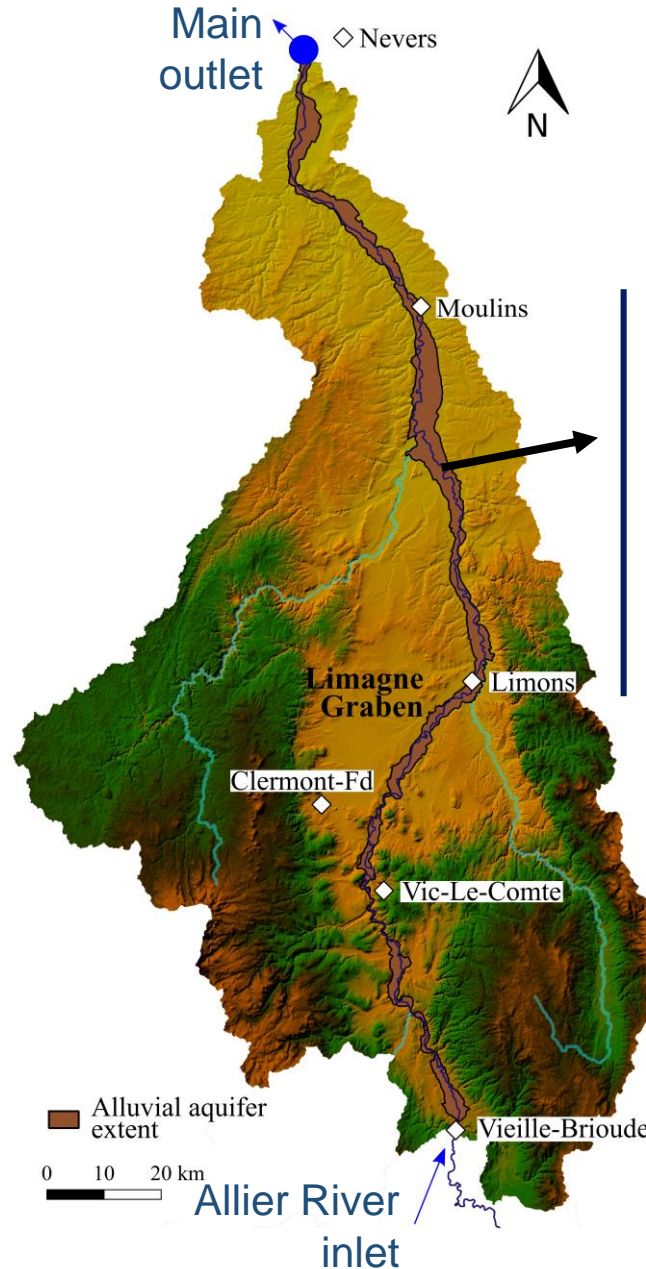
Maréchal et Rouillard, (2020)

CONTEXT: the case of the Allier River watershed (Central France)



Central France

Downstream part of the Allier River Watershed
11,100Km²



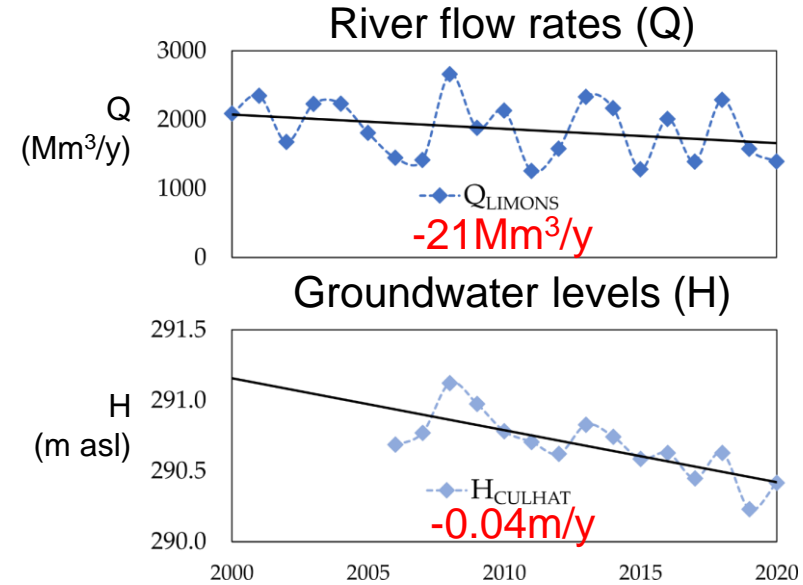
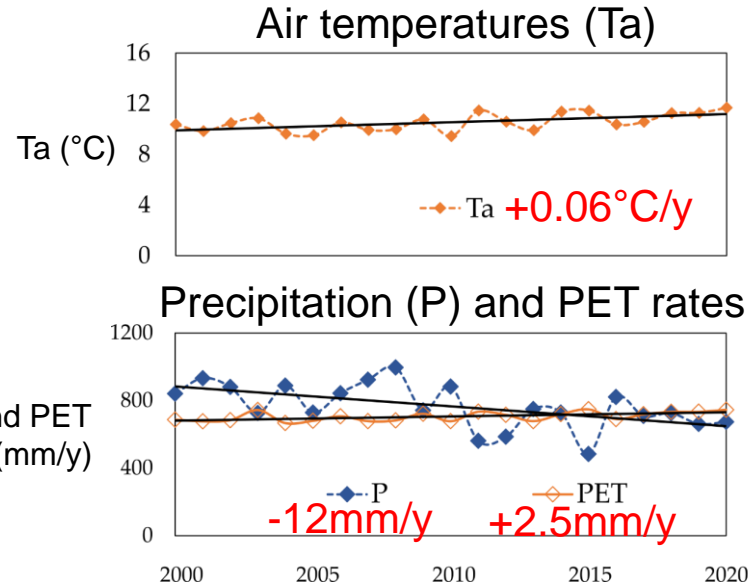
Allier River and its alluvial aquifer:
460km²

70% of the domestic water needs

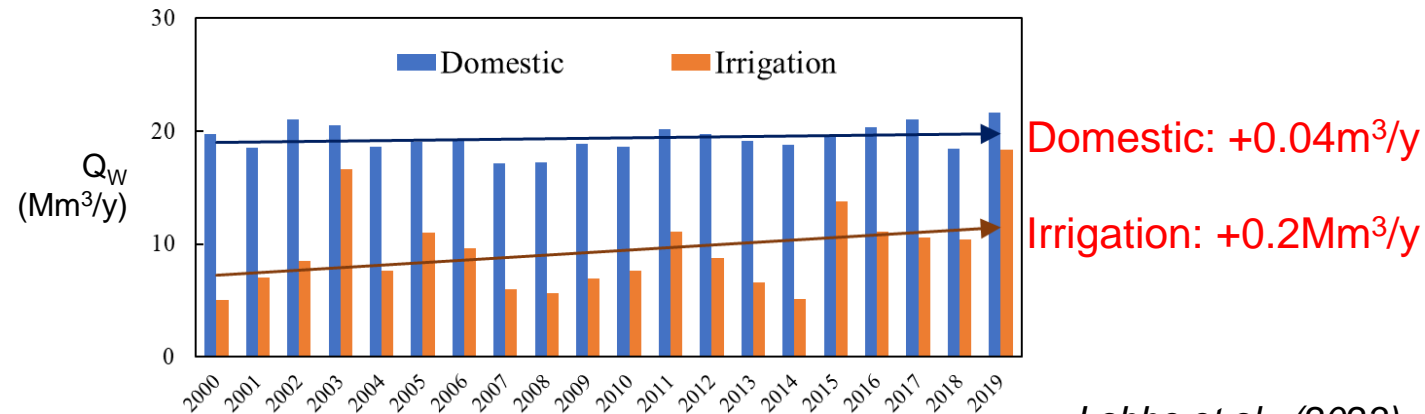
Elevations (m asl):

- 100
- 400
- 600
- 900
- 1200
- 1500
- 1700

Distinctive trends at the watershed scale



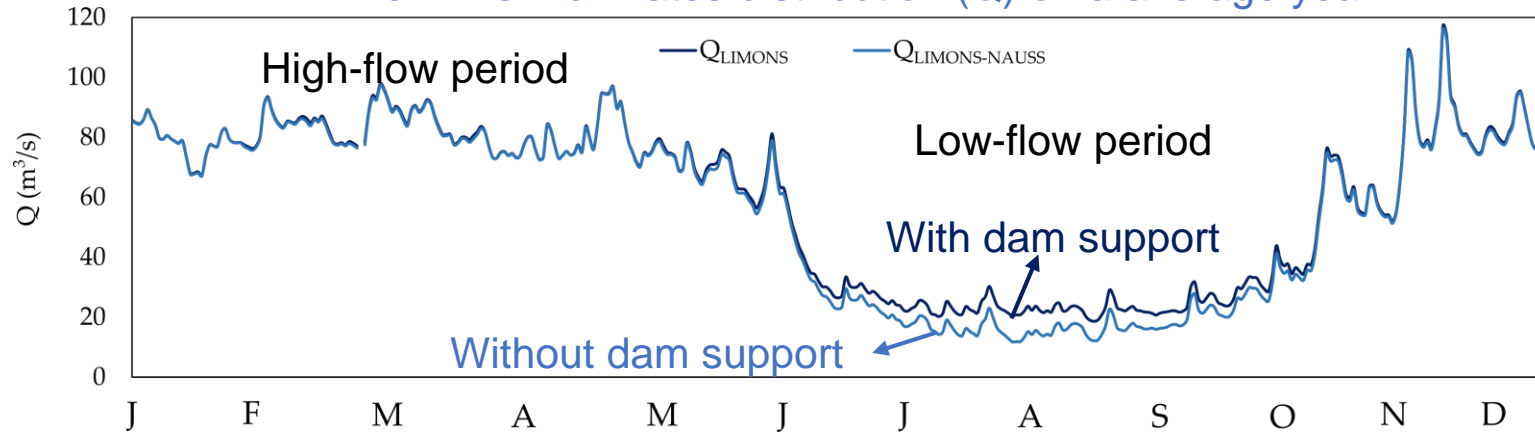
Water abstractions (Q_w) over the alluvial hydrosystem



Labbe et al., (2023)

The Allier River: known for its recurrent and intense summer droughts ($Q < 10 \text{ m}^3/\text{s}$)

Allier River flow rates distribution (Q) on a average year



Labbe et al., (2023)

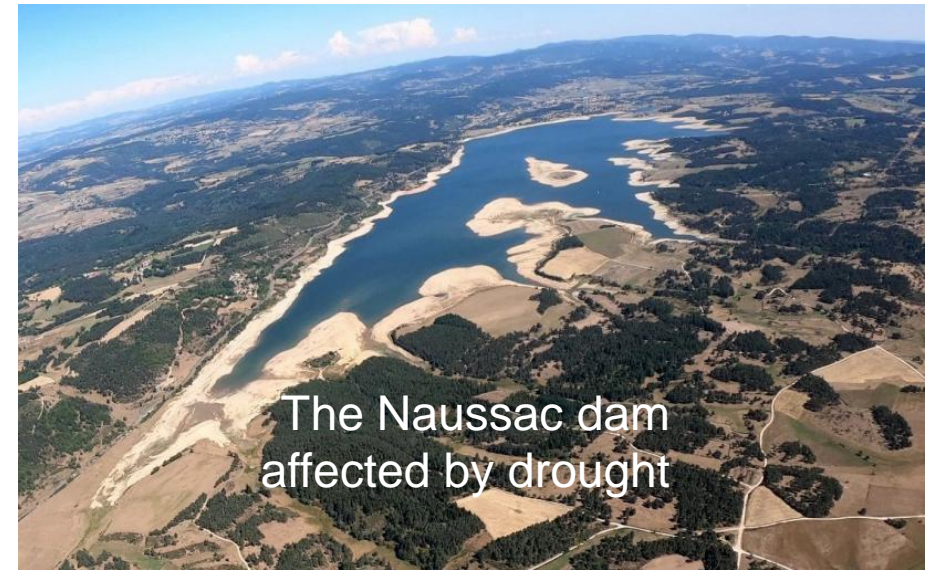
The dam of Naussac:

- Located in the upstream watershed
 - 185 Mm^3 of stored water
- Supports the Allier River low-flows (from June to October)



But the winter rainfall is less and less abundant and the dam is hardly refilled....

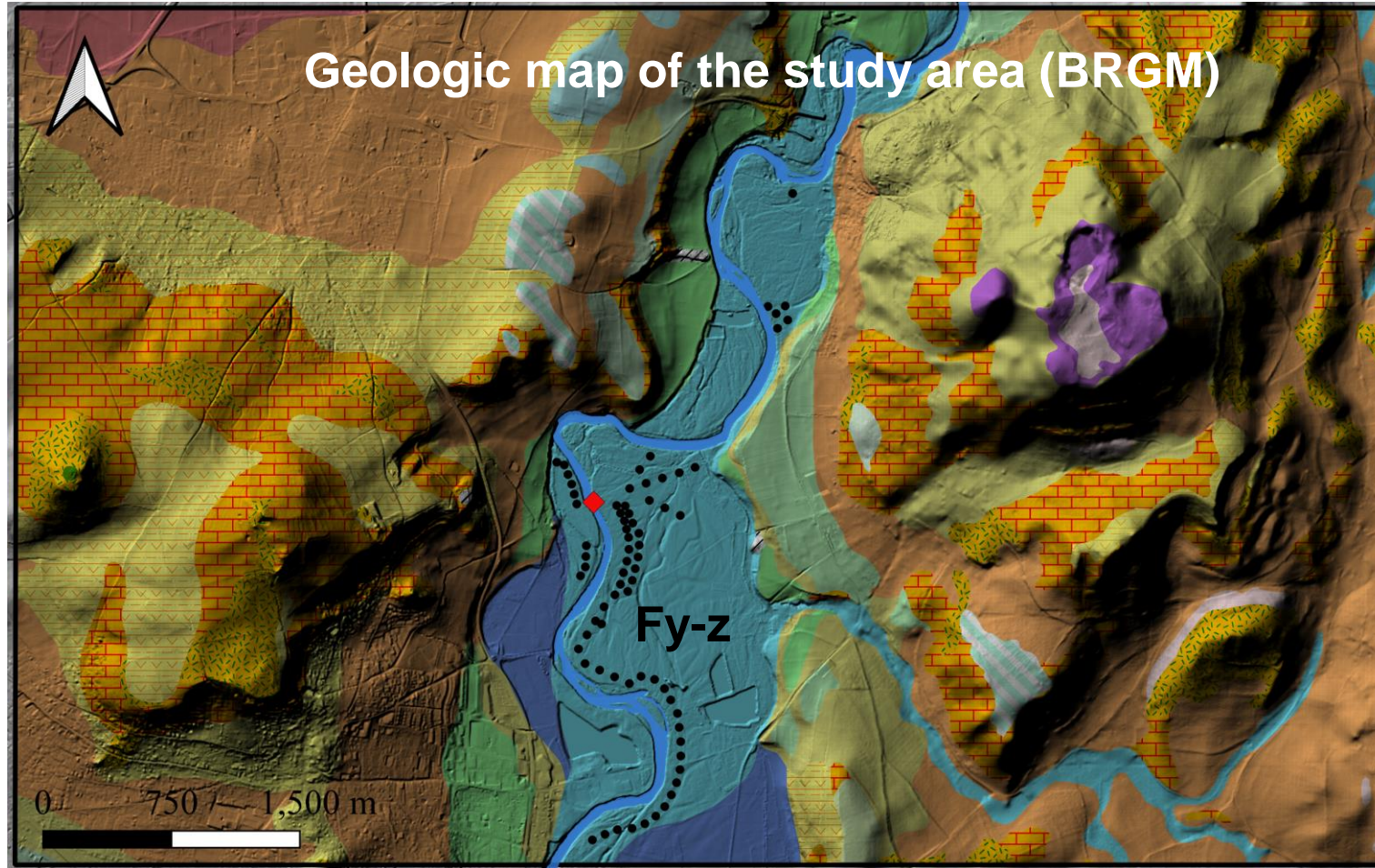
...Considering the regional importance of the Allier alluvial hydrosystem for **irrigation**, **industries** and **domestic supply** – Water stakeholders are wondering:



<https://www.zoomdici.fr>

How extreme low-flows affect groundwater levels of an exploited alluvial aquifer?

Taking the case of a municipal well-field:

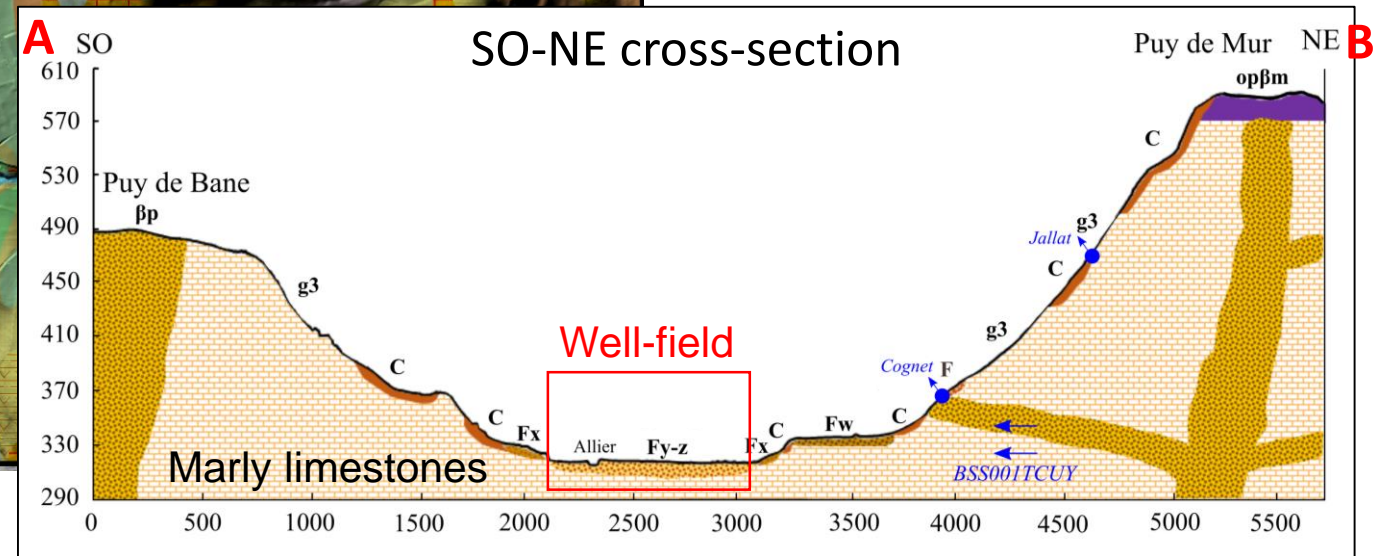
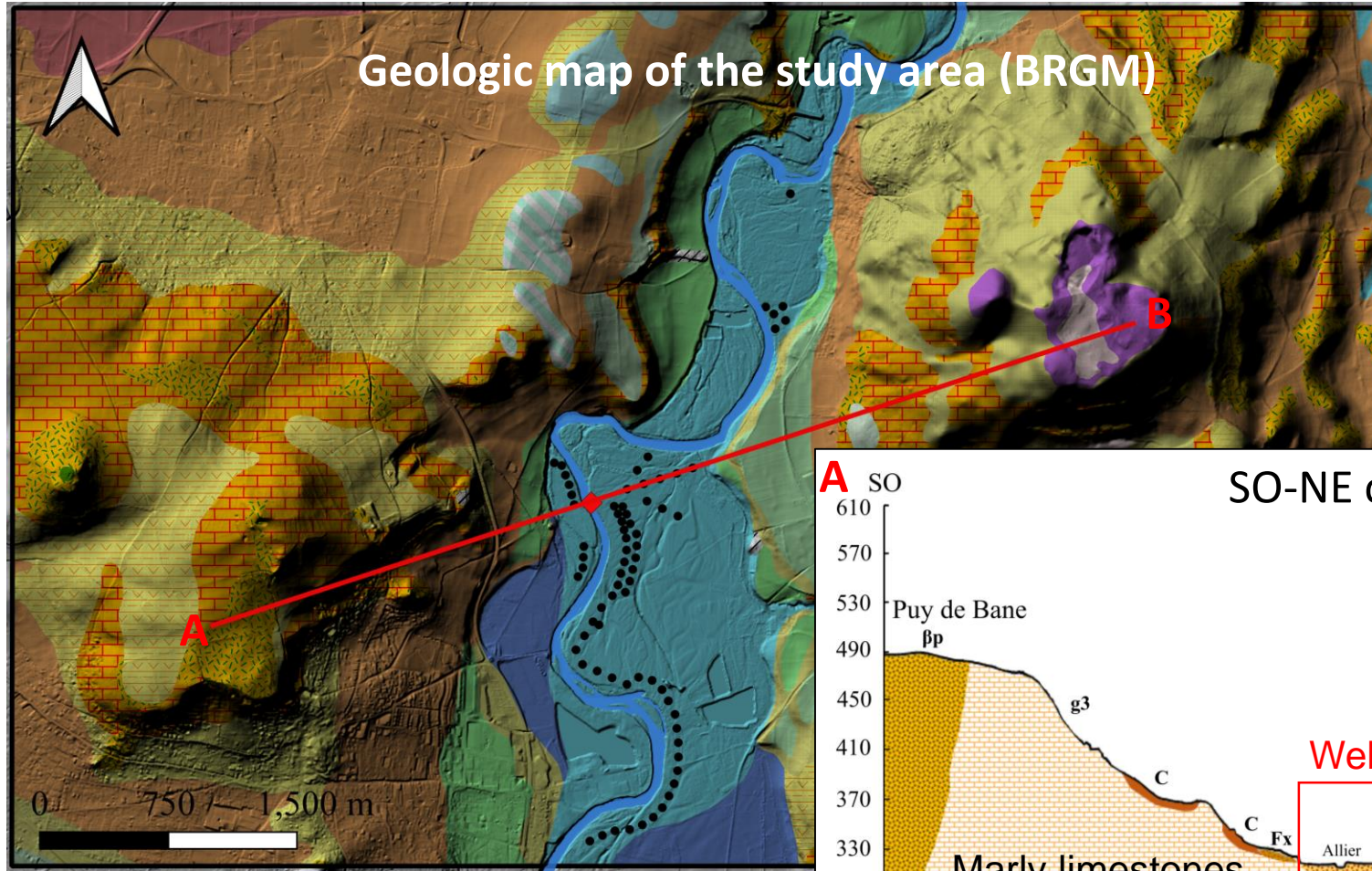


The Val d'Allier well-field:

- 71 pumping wells
- 8 millions of m³ per year for the 100,000 inhab. of the Clermont-Ferrand municipality
- On the recent Allier River terrace (Fy-z)

Studied site: the Val d'Allier well-field

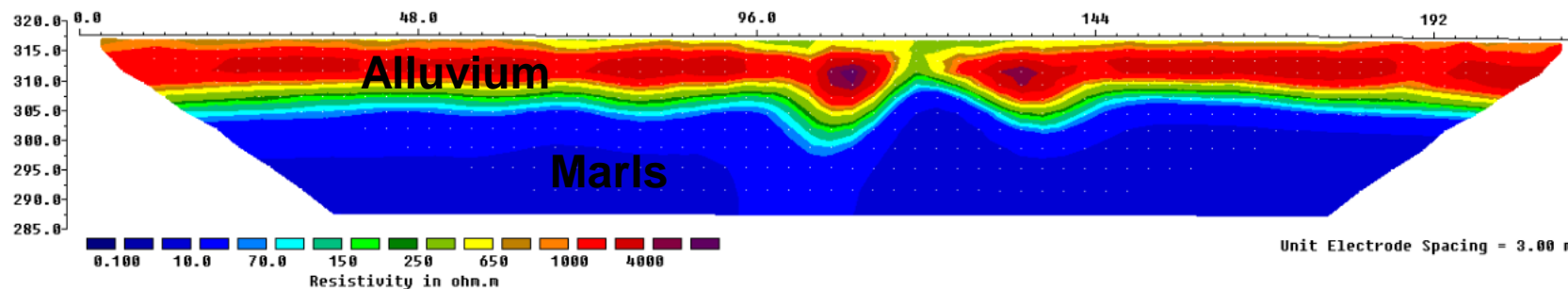
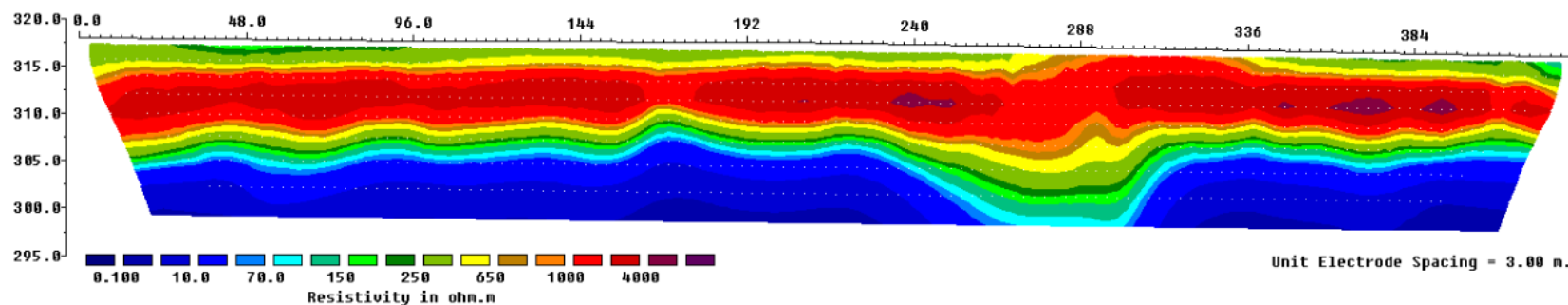
Taking the case of a municipal well-field:



Groundwater Vistas 8 (MODFLOW-2005)

Model based on:
Geological investigations
Groundwater/River levels monitoring
ERT surveys

Imaging the interface between marls and alluvium

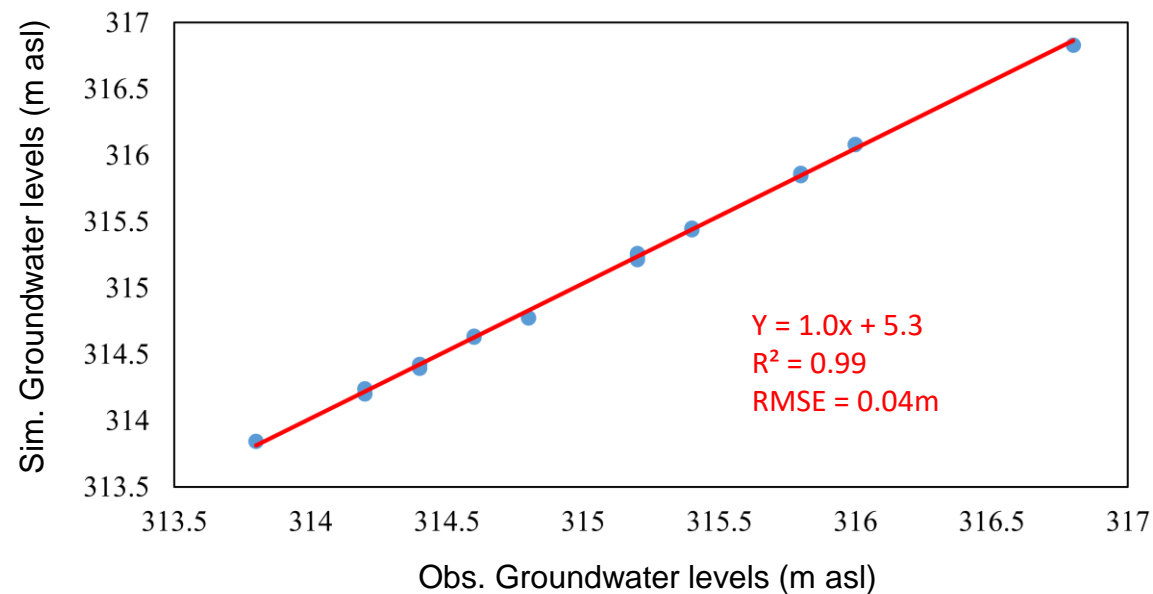


Groundwater Vistas 8 (MODFLOW-2005)

Model based on:
Geological investigations
Groundwater/River levels monitoring
ERT surveys

Steady-state calibration
(PEST & pilot points)

Calibrate the model in natural flow conditions (no change in hydraulic heads over time)

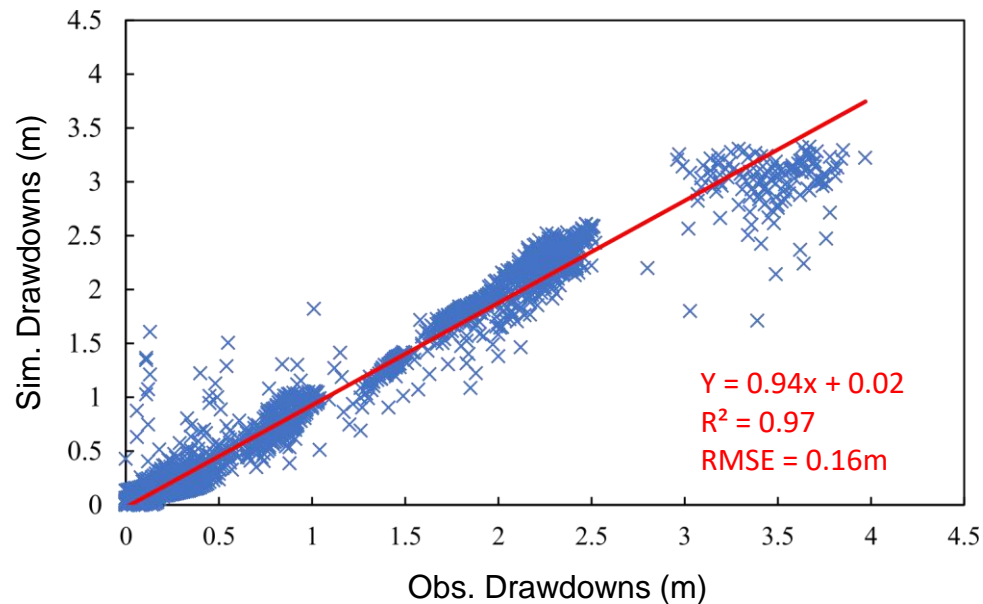


Allocate the hydraulic conductivities (K_x , K_y) over the modeled area

Groundwater Vistas 8 (MODFLOW-2005)

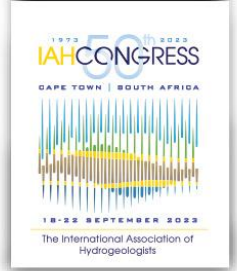


Calibrate the model in forced flow conditions (hydraulic heads may vary over time)

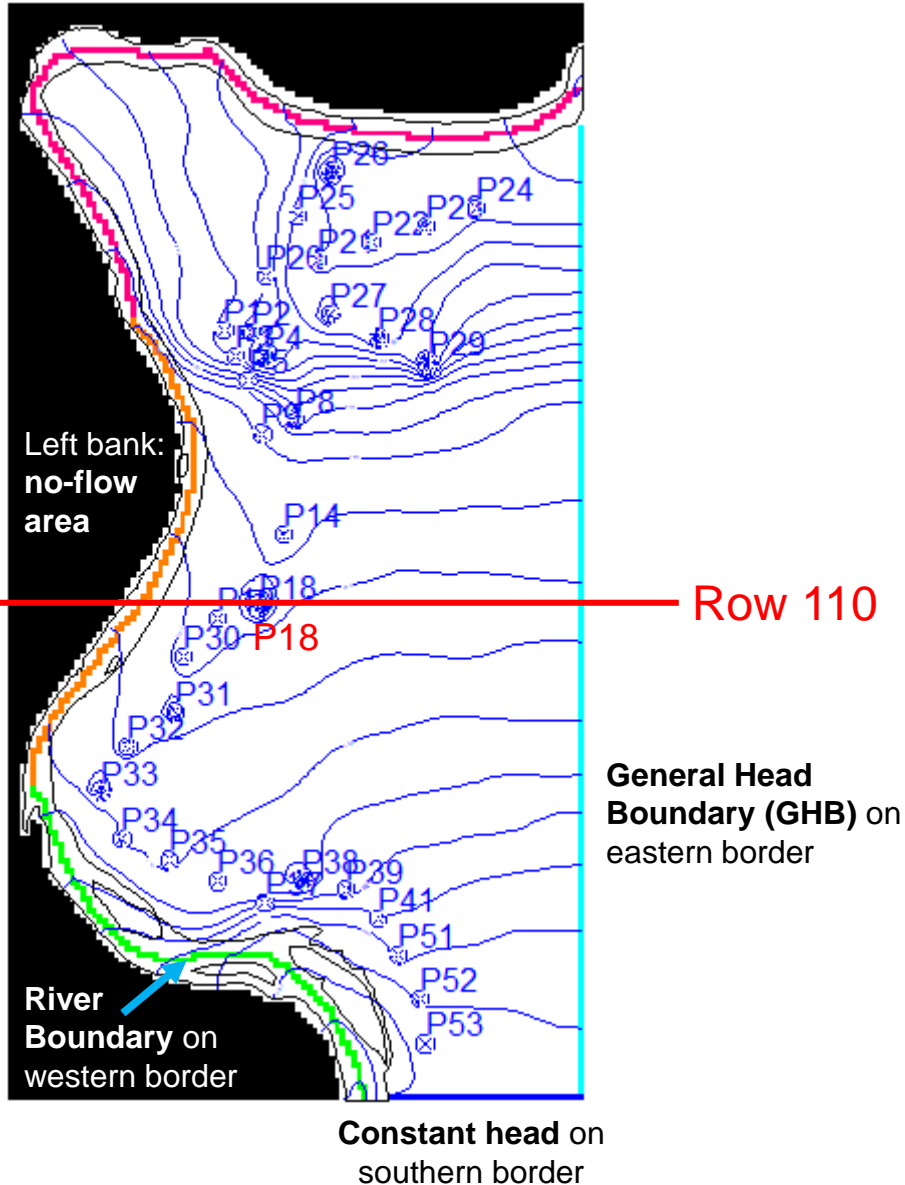


Allocate the specific yield S_y over the modeled area

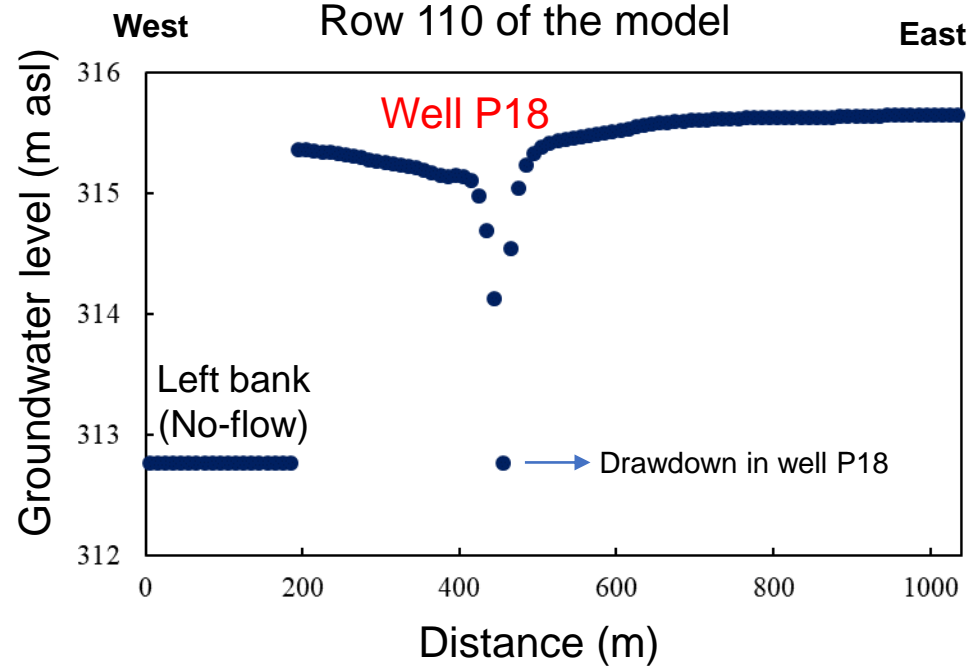
Results: reactivity of groundwater levels with extreme low-flows



West Model grid extent East



West-East profile of the water-table level

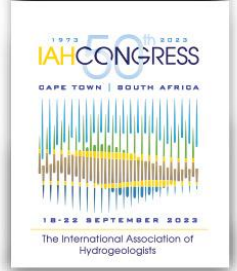


For 2 months:

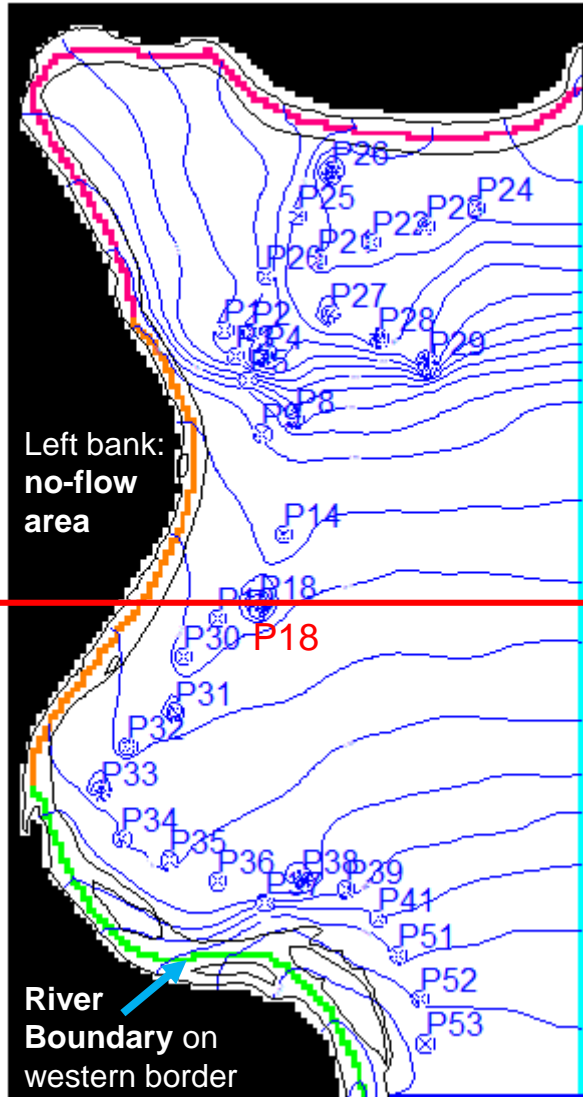
- 1) Normal flow conditions $Q_{RIVER} = 30m^3/s$

Pumping schedule:
 12h pumping
 12h recovery

Results: reactivity of groundwater levels with extreme low-flows



West Model grid extent East



Left bank:
no-flow
area

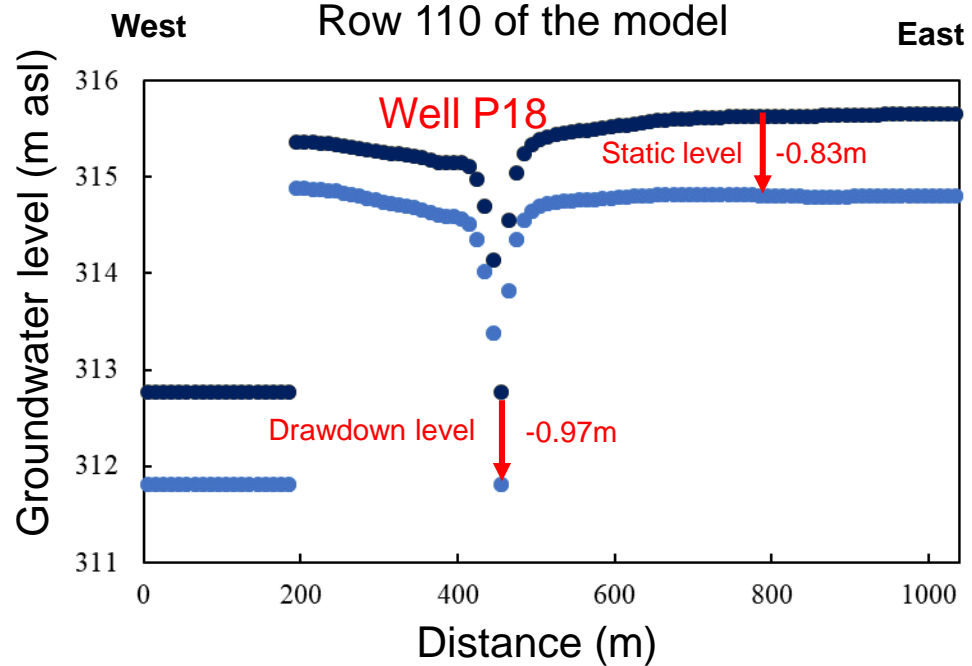
River
Boundary on
western border

Row 110

General Head
Boundary (GHB) on
eastern border

Constant head on
southern border

West-East profile of the water-table level



West

Row 110 of the model

East

Well P18

Static level -0.83m

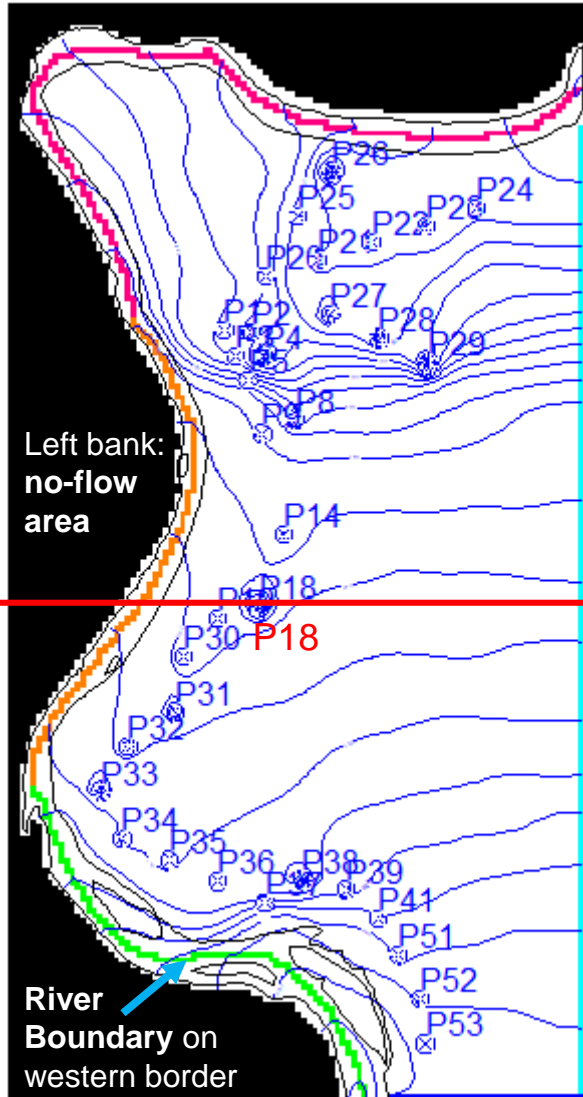
Drawdown level -0.97m

For 2 months:

- 2) Extreme low-flow conditions
- $Q_{RIVER} = 2\text{m}^3/\text{s}$
- Pumping schedule:
- 12h pumping
- 12h recovery

Results: reactivity of groundwater levels with extreme low-flows

West Model grid extent East



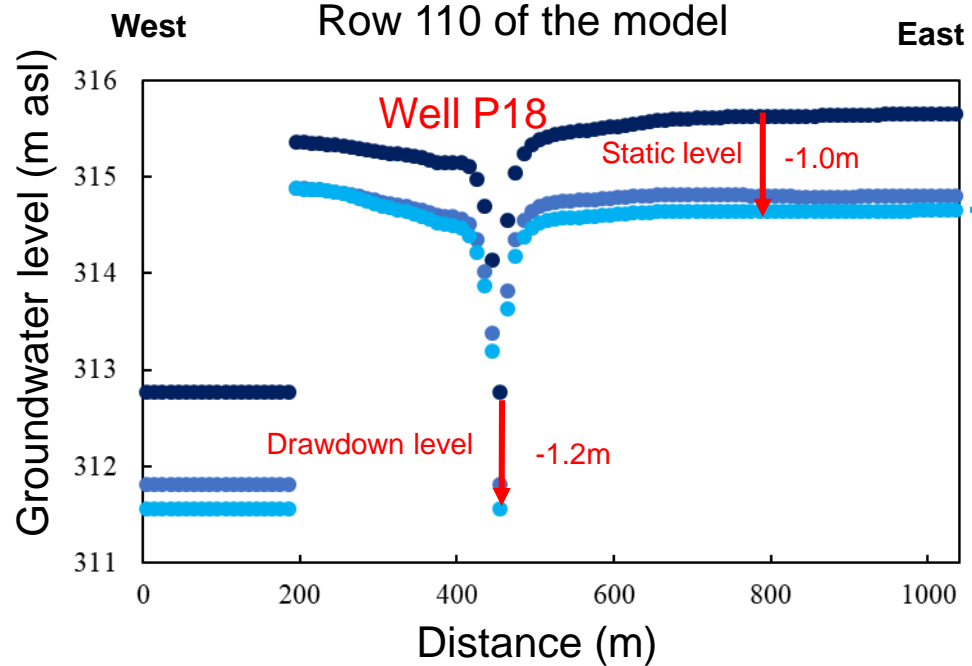
Row 110

General Head Boundary (GHB) on eastern border

River Boundary on western border

Constant head on southern border

West-East profile of the water-table level

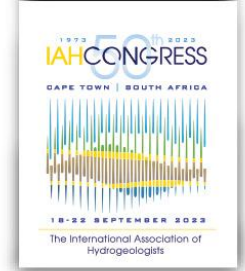


For 2 months:

- 2) Extreme low-flow conditions
- $Q_{RIVER} = 2m^3/s$
- Pumping schedule:
 - 20h pumping
 - 4h recovery

(to anticipate higher domestic water needs)

Conclusion and study outlook



- Low-flows are a major issue for connected hydrosystems such as River/alluvial aquifers
- Extreme low-flows in the River also affect the groundwater levels (static & drawdown levels are decreasing)
- Could be a threat for drinking water production
- Provide more accurate answers to water stakeholders and to give them some tools to anticipate future potential water crisis

Limits:

- The model still needs to be improved:
 - i) it is calibrated in transient conditions on a daily basis,
 - ii) it needs to be calibrated and validated on a monthly time-scale to consider the alternance of low/high flow periods

Thank you for your attention

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