GROUNDWATER FLOW MODELING APPLICATION TO MANAGED AQUIFER RECHARGE (MAR) OF MARECCHIA RIVER ALLUVIAL FAN (RIMINI, ITALY): MODELING APPROACH FOR THE FEASIBILITY STUDY AND FOR SUPPORTING EXPERIMENTAL PHASES

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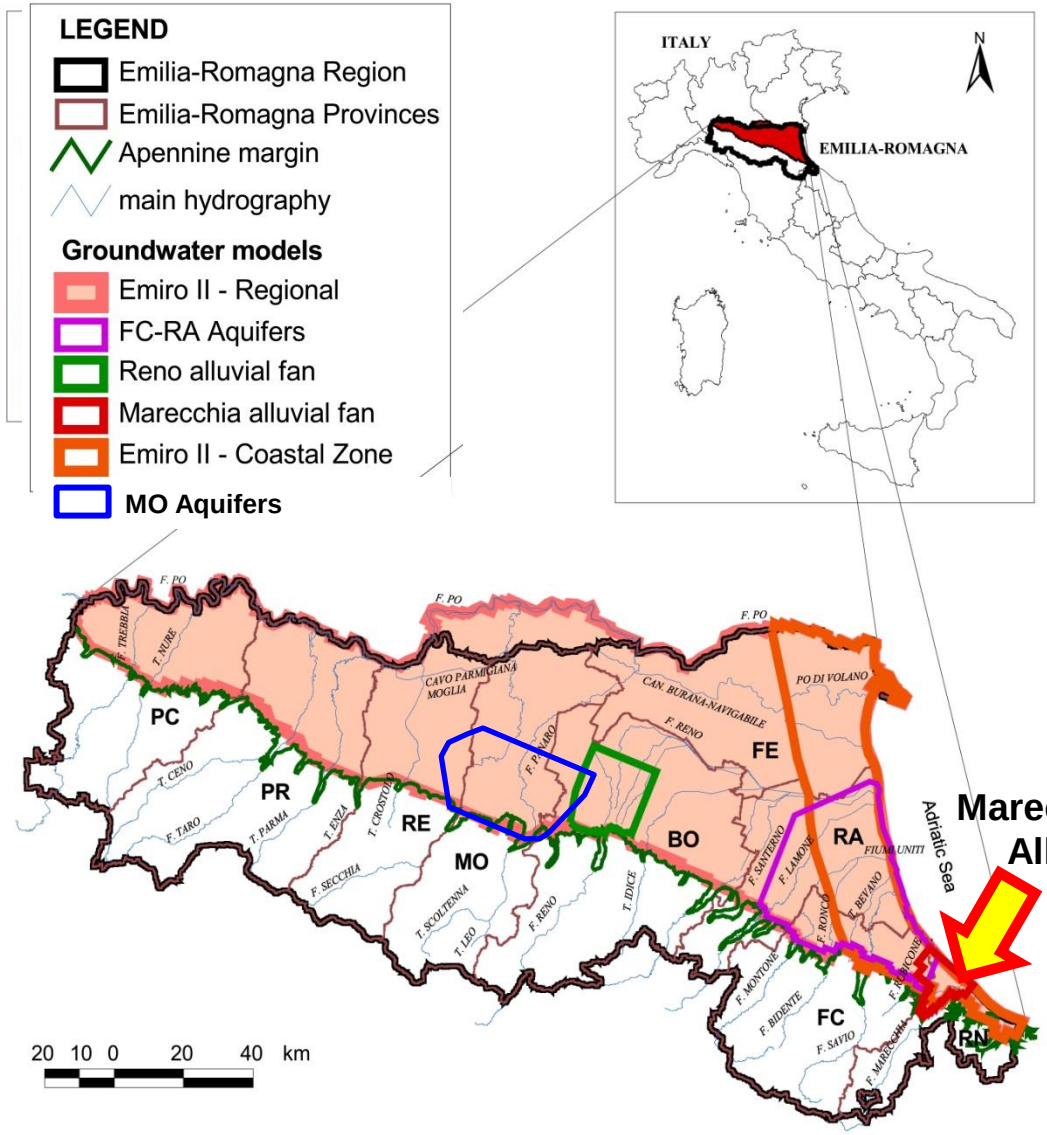
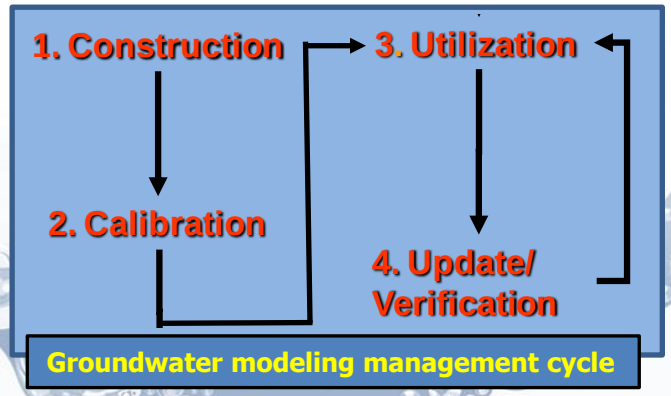
Arpa Emilia-Romagna experience in groundwater modeling development and application

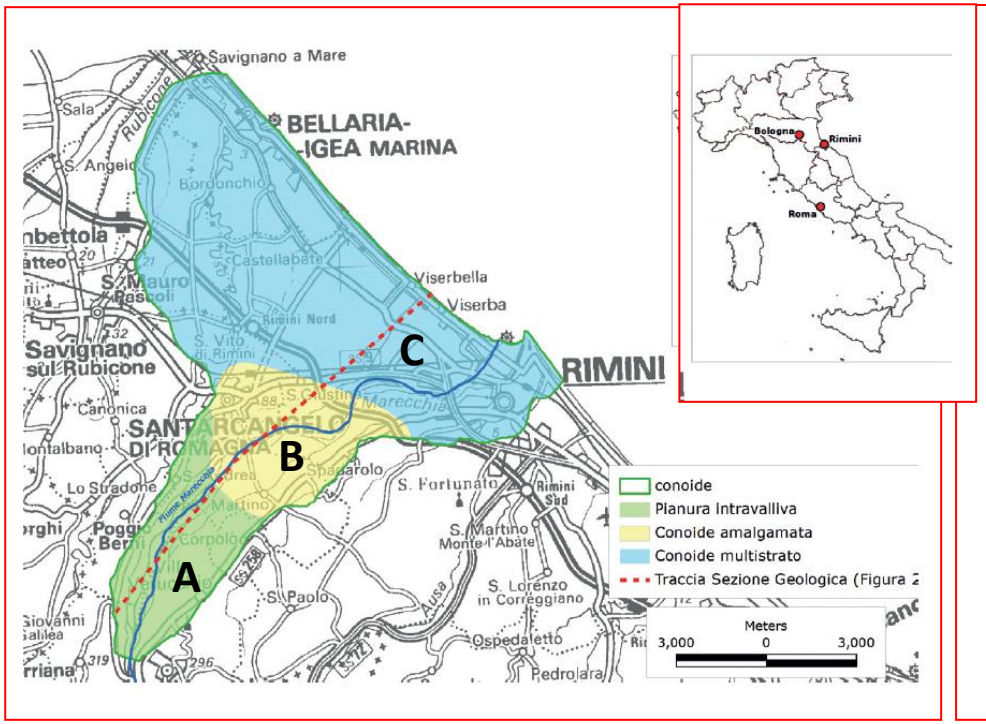


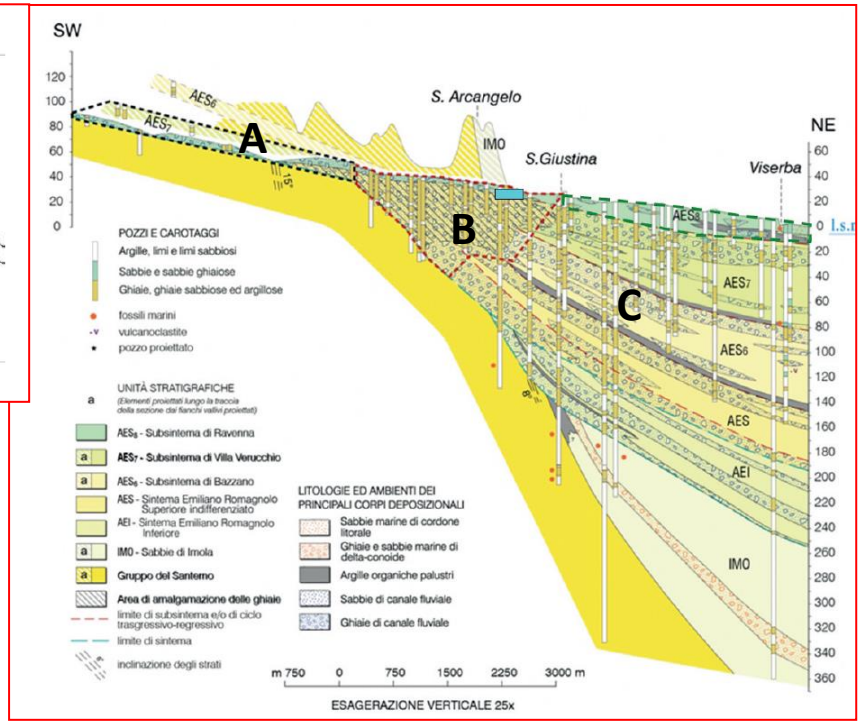
Two approaches at different spatial scale:

- Emilia-Romagna groundwater flow model: a model of the whole regional aquifer designed to support Emilia-Romagna planning actions.
- Groundwater flow models at a more detailed scale (e.g. alluvial fan): applied to specific situations, such as in case of very high groundwater withdrawals, nitrate occurrence, land subsidence.



Marecchia alluvial fan territorial and hydrogeological context

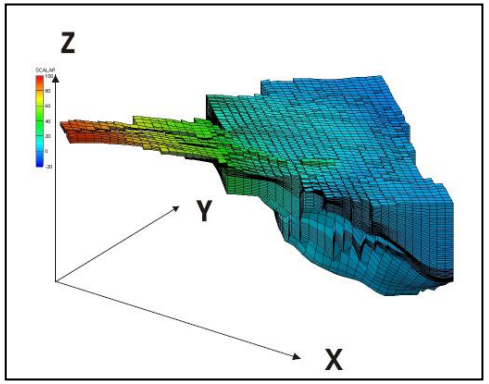




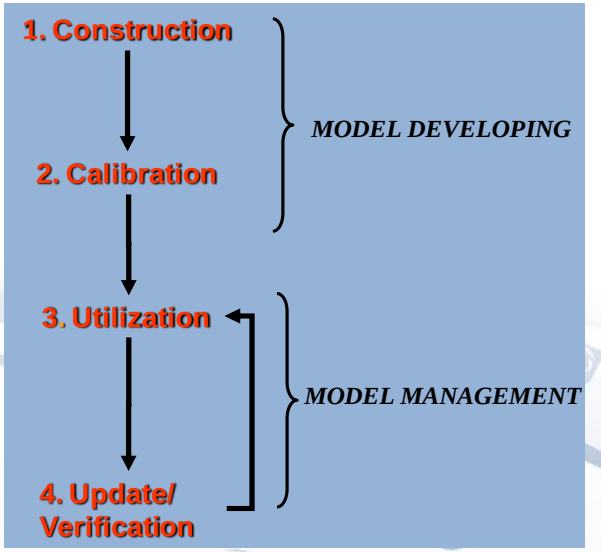
- Marecchia alluvial fan has an extension of 130 km^2 , it is located in the southeastern part of Emilia-Romagna Region, along the Adriatic coast near Rimini town.
- Average annual groundwater withdrawals (almost 30 Mm^3) are mainly referred to local drinking water demand (high values during summer due to touristic activity).
- From the geological point of view, alluvial fan is divided into three different sectors : a thin intremontane portion (**A**), a portion characterized by amalgamated gravel (phreatic aquifer - recharge area, **B**), a portion with gravel levels alternated with clay levels (mainly used for drinking water withdrawal, **C**).

Marecchia Alluvial Fan groundwater flow model

- Marecchia alluvial fan groundwater flow model was born in 2006 as a part of a wide hydrogeological study concerning water quality and quantity issues finalized to water resource management.
- Main Territorial Authority, Public Administrations and water private companies took part to the project in order to fix common objectives and strategies.



- First implementation of the groundwater model covered the time period 2001-2002. The Model is a 3D MODFLOW-2000 transient flow model. All data were collected and arranged on a seasonal time basis.



- Following the "Model Management" loop Marecchia Alluvial Fan groundwater flow model was updated and verified many times.
- Today the model covers the period 2002-2014 on a monthly time step basis. All data transfer necessary for updating process are currently "active" (recharge, withdrawals, heads from monitoring networks).
- **Groundwater modeling applications have been performed for several purposes….**

Marecchia Alluvial Fan groundwater modeling application fields

- Hydrogeological knowledge verification and improvement.
- Groundwater resource planning.
- Groundwater resource management.
- Groundwater resource evaluation in water crisis prediction and management.
- Artificial recharge of groundwater.

Two main opportunities of groundwater modeling applications for supporting Managed Aquifer Recharge

1
Feasibility study (2008)

2
Experimental phase supporting (2014…)

Marecchia Alluvial Fan groundwater modeling application: approach for MAR feasibility study

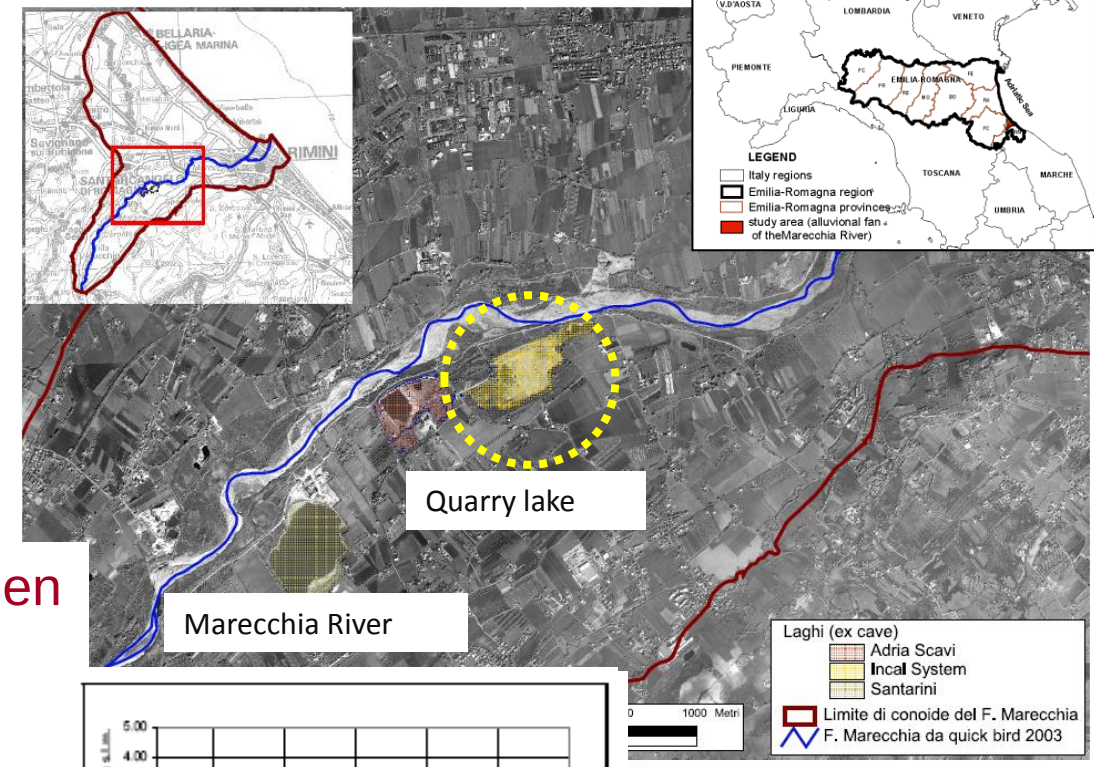
What would be the effects of MAR on Marecchia alluvial fan groundwater flow?

How could groundwater model application help to achieve this goal?

- Two groundwater flow model simulations have been set up

Case 0: no MAR is active in the lake.

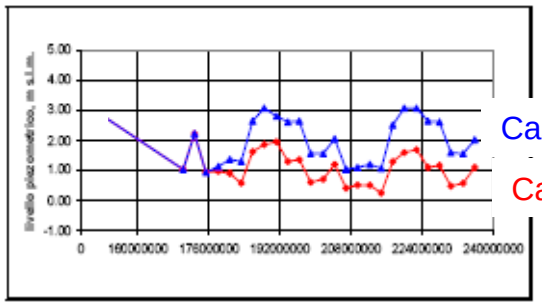
Case 1: MAR is active from October 2006 to May 2007 and for the same period of the following season. The infiltration rate is supposed to be 1 m^3/s.



- Comparison of results has been referred to model outputs

piezometric levels

water balances

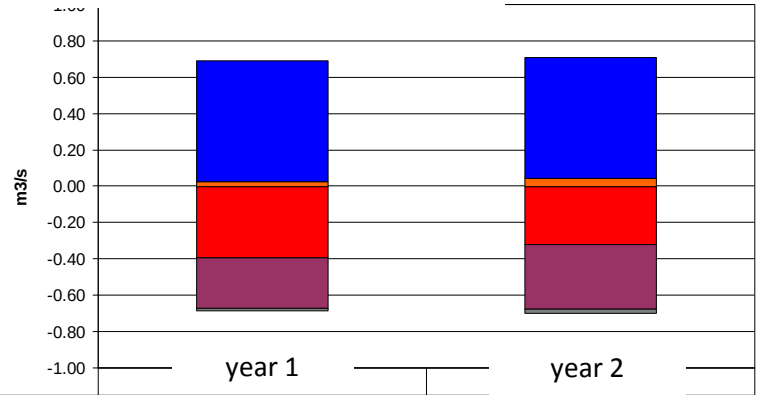


Case 1: MAR is active

Case 0

Comparison of water balance simulation results

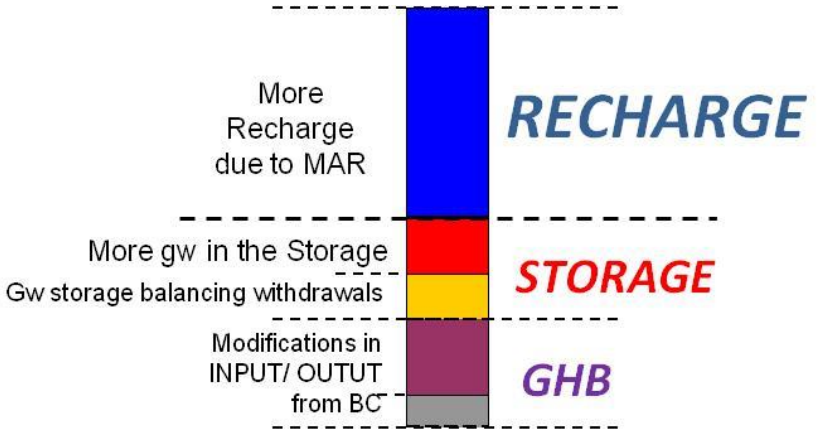
Annual water balance (m^3/s)



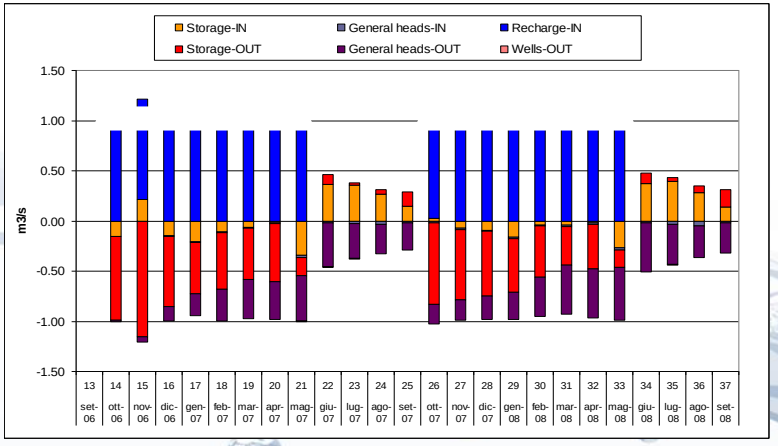
	year 1	year 2
Recharge-IN	0.67	0.67
Storage-IN	0.03	0.04
General heads-IN	-0.01	-0.02
Wells-OUT	0.00	0.00
General heads-OUT	-0.28	-0.36
Storage-OUT	-0.39	-0.32

case 1 (MAR is active) – case 0 (no MAR)

Water balance analysis



Monthly water balance (m^3/s)



Average groundwater storage:

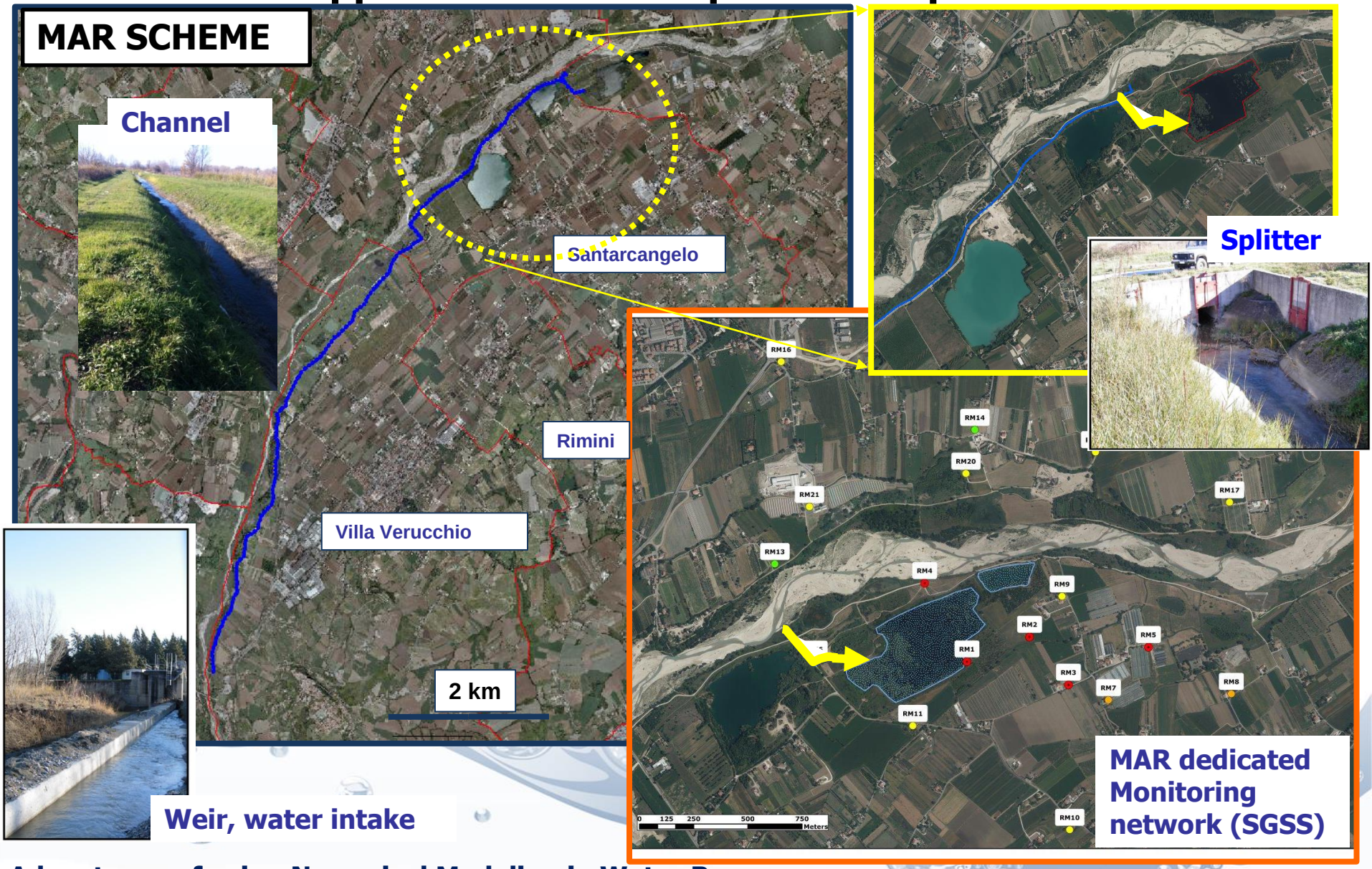
0.36 m^3/s (/0.67 m^3/s from Oct to Sept)

General head boundary condition:

0.32 m^3/s (/0.67 m^3/s from Oct to Sept)

AVERAGE EFFICIENCY ~ 53%

Marecchia Alluvial Fan groundwater modeling application: approach for MAR experimental phases



Marecchia Alluvial Fan groundwater modeling application: approach for MAR experimental phases

In order to follow and support MAR experimental phases two main WORKING LINES are being developed:

1. Improving as much as possible capability of the Marecchia alluvial fan groundwater flow model already used for the feasibility study

2. Implementing a new groundwater flow (and transport) model at scale of very high detail near the lake

Comparing the capability of the two models

Approach for MAR experimental phases – working line 1 improving the existing Marecchia alluvial fan groundwater flow model

1. Keep always update groundwater flow model over time (last update carried out on December 2014)
2. Import all the new monitoring network data for a better calibration and verification of the behavior of the model near the lake;
3. Modeling groundwater-surface water (Marecchia River) interactions by Modflow SFR2 package;
4. Modeling groundwater-surface water interactions by Modflow LAKE package;
5. Refining grid size of the model near the lake.

Work progress

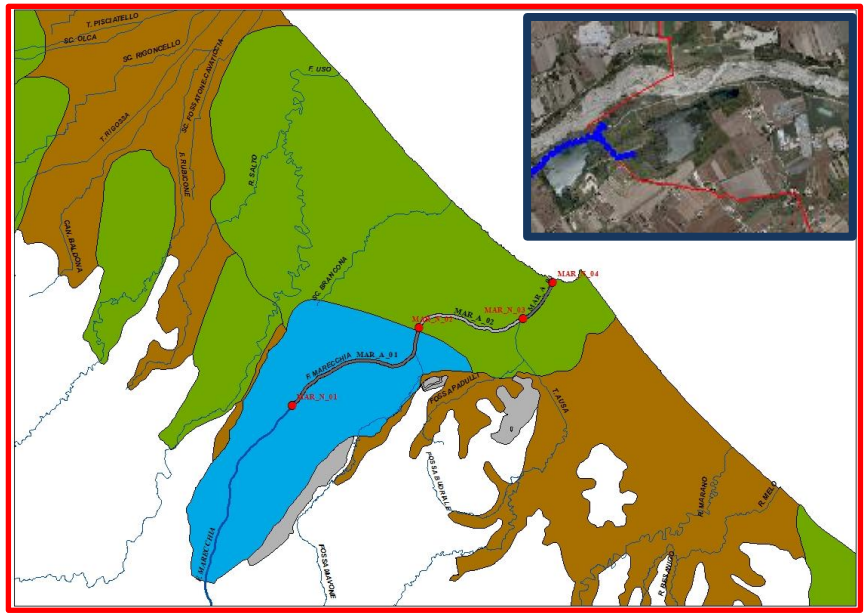
Approach for MAR experimental phases – working line 2: implementing a new groundwater flow model at a scale of very high detail near the lake

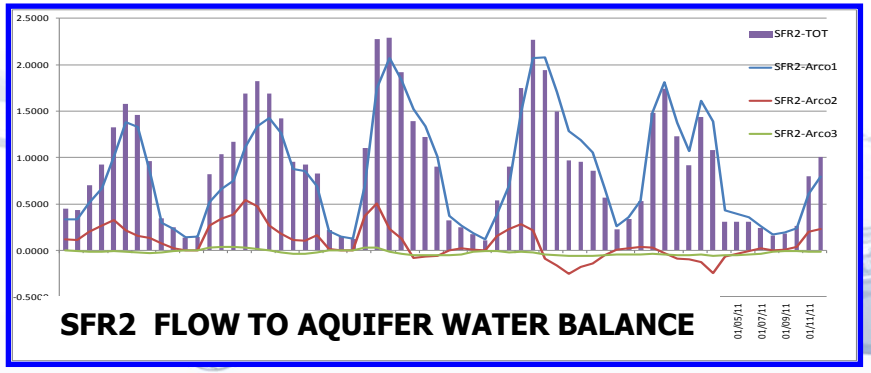
1. Make a high definition and fully 3D reconstruction of the subsurface of the study area near the lake
2. Build a new groundwater flow model from the new 3D geological solid model
3. Keep alive the possibility to link the new model to the Marecchia alluvial fan groundwater flow model
4. Build a transport model

Work progress

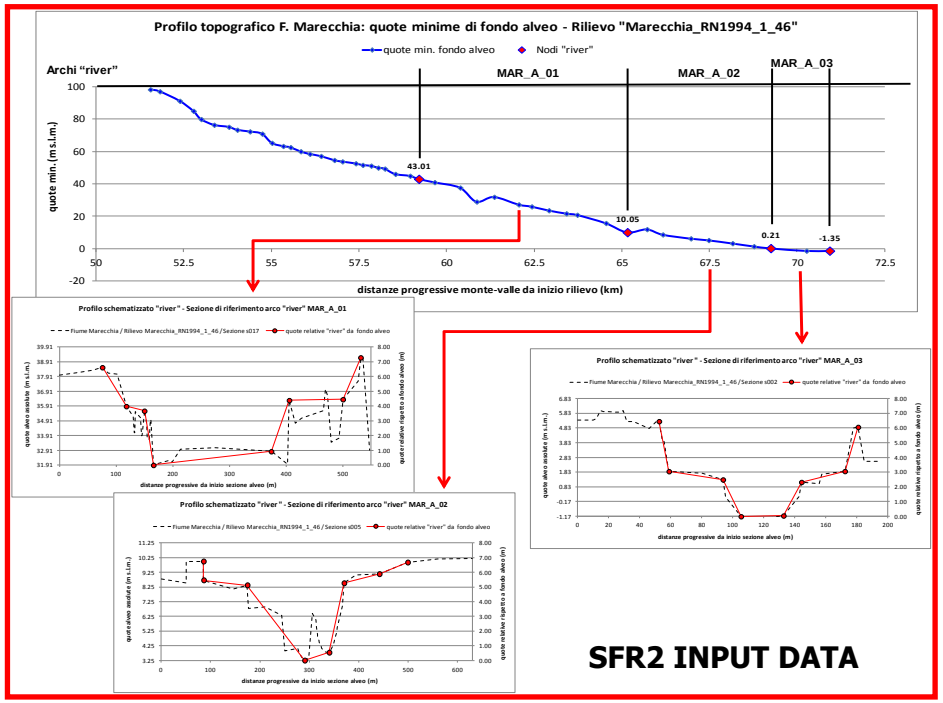
Approach for MAR experimental phases – working line 1: preliminary results on SFR2

Modeling groundwater-surface water (Marecchia River) interactions by Modflow SFR2 Package

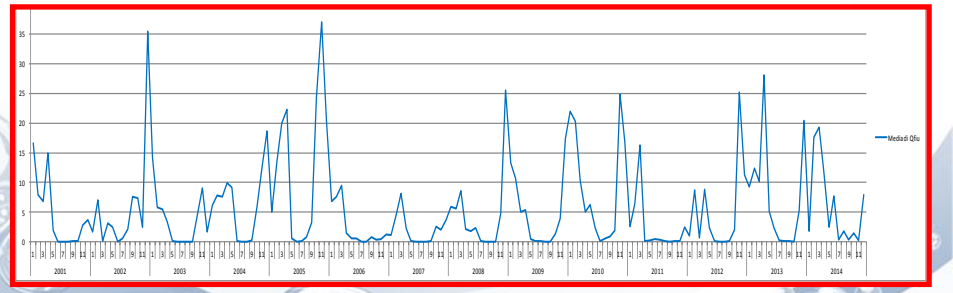




SFR2 FLOW TO AQUIFER WATER BALANCE



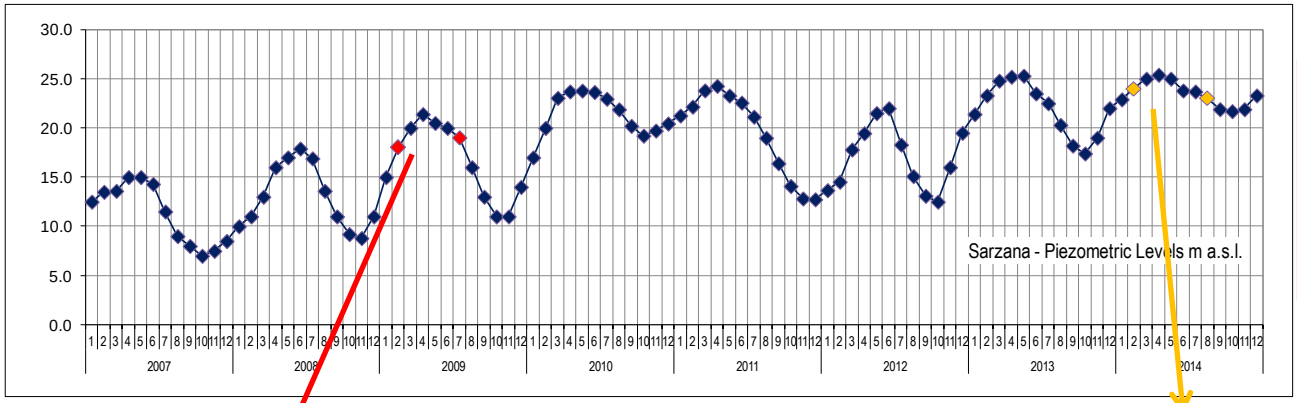
SFR2 INPUT DATA

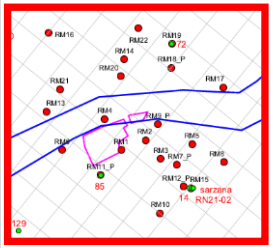


MARECCHIA RIVER FLOW RATE

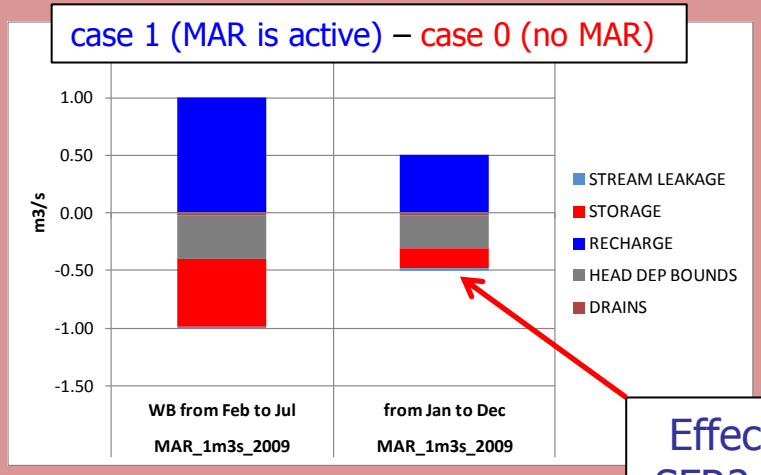
Approach for MAR experimental phases – working line 1: preliminary results on SFR2

Two groundwater flow model simulations have been set up





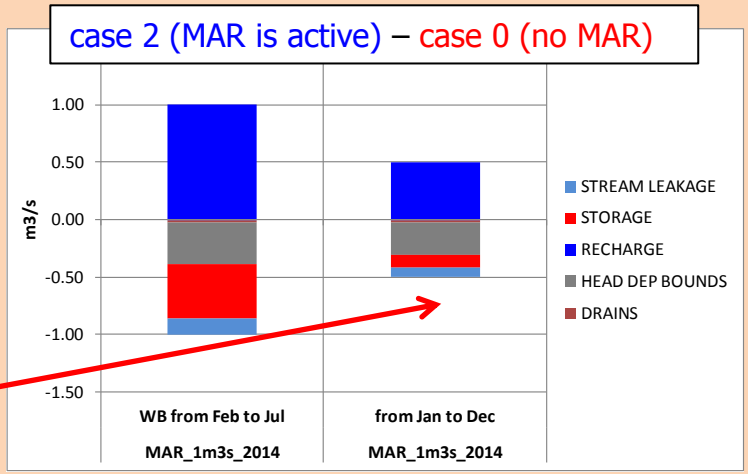
MAR active (relatively low groundwater levels)



EFFICIENCY ~ 35%

Effects on SFR2 water budget

MAR active (relatively high groundwater levels)

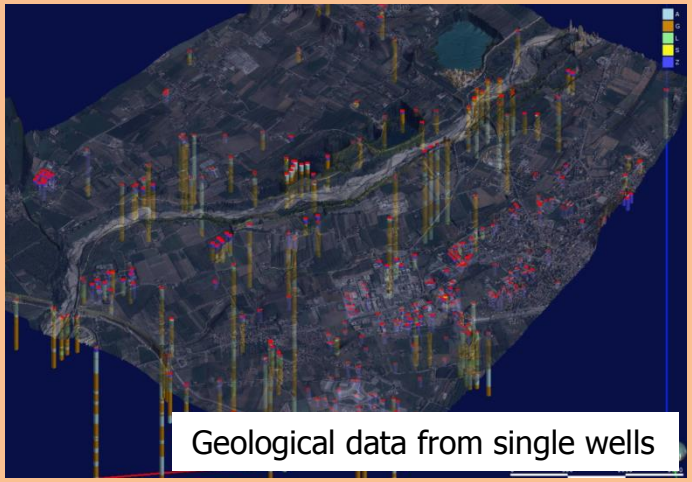


EFFICIENCY ~ 23%

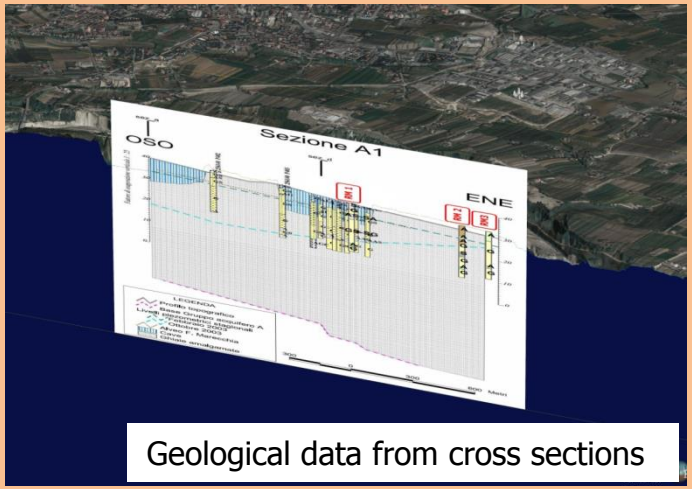
Approach for MAR experimental phases – working line 2: preliminary results on 3D geological modeling

make a high definition and fully 3D reconstruction of subsurface of the study area near the lake.

collect every kind of available geological information



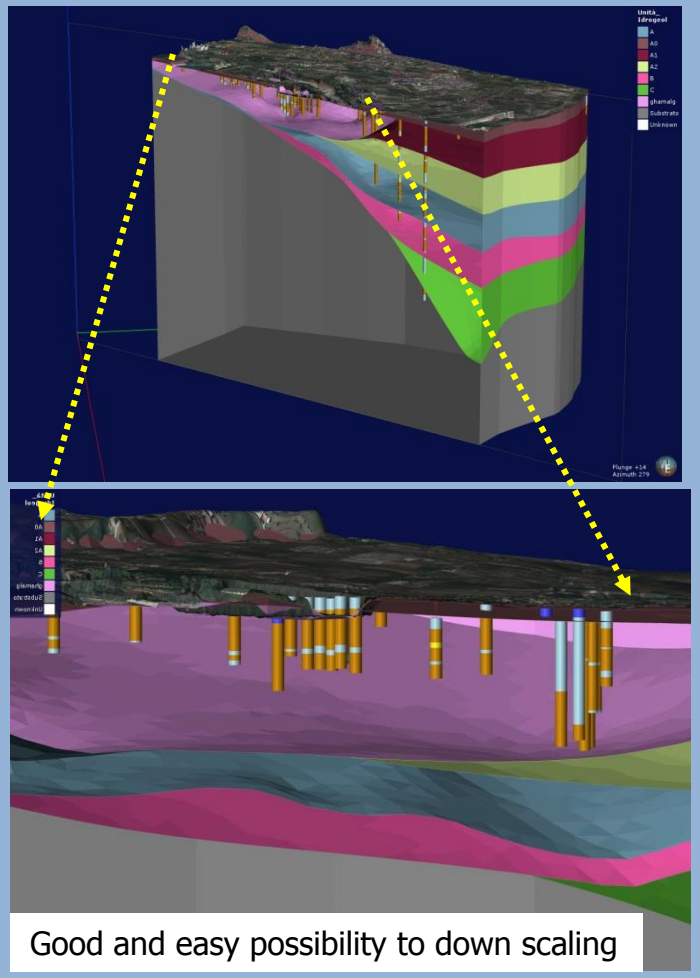
Geological data from single wells



Geological data from cross sections

3D GEOLOGICAL MODELING

elaborate at every scale



Good and easy possibility to down scaling

To take home

- A long time experience in groundwater modeling: construction, calibration and utilization of Marecchia Alluvial Fan model.
- Groundwater flow model management: it is important to continuously update and verify the model and to keep alive data flow that feeds the model (monitoring networks, heads and concentrations), and sources/stresses (withdrawals, recharge).
- Groundwater flow model application: the updated groundwater flow model could be used for several purposes. Dedicated simulations could support specific issues and the model could be adapted to specific needs. A double application example of groundwater flow model applicaton to MAR has been reported (feasibility study and for experimental phases).
- It is important the availability of new dedicated monitoring data for better understanding the phenomenon and for groundwater flow model verification.
- Many efforts must be done in order to represent model results in a synthetic and effective way. Flow model outputs can be aggregated in space and/or in time, according to the objectives of the analysis. In most cases a comparison of results of many simulations (scenario runs) is required.
- This is the way to support decision-makers with all necessary information for their own purposes.

THANKS TO:

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