TARH

The WARBO project is an extremely multidisciplinary project, with different approaches from the hydrogeological, chemical and geophysical fields. Therefore different kind of investigations were applied in all three test sites, with obviously different kinds of results. Those ought to be condensed in a hydrogeological conceptual model in order to predict the groundwater flow, and to explain the monitoring results. The WARBO test sites conceptual models construction gave a different set of challenges. The hydrogeological investigations carried on were:

In Mereto:

- Sieve analysis of collect soil sample in the bottom of the pond
- Analysis of the a non vadose zone infiltration test carried out (OGS)
- Interpretation of pumping tests carried out in the aquifer at a local scale; (Botti)
- Development of a preliminary infiltration model and a conceptual model in order to access the boundaries of the recharge system impact
- The developed model acted like a decision making tool in order to enhance the monitoring network on site.
- Placement of multi-parameter probes in the new piezometers
- Analysis of the long term piezometric data and interpretation of the results, considering the water level variations in the pond; Re-calibration of the hydrogeological conceptual model;
- Tracer test (Fluroscein) on the recharge site, and collection in the surrounding piezometers;

Main conclusions: the hydrogeological investigations greatly improved the Mereto test site, especially by pre estimating the extent of the influence area, and improving the monitoring network. The Vadose zone permeability was estimated in the order of 10^{-5} m/s whereas the aquifer had a permeability of 10^{-4} m/s. The monitoring carried out by Udine University, showed that the aquifer was undoubtly recharged with few influence in the level, but a clear one in terms of quality. The tracer tests carried out in May 2014 also shown a clear influence in the perched aquifer and a slower recharge of the main aquifer through what it seems to be, two preferential ways. The intertwining with the different subjects was extremely important: Geophysical and log interpretations were fundamental for the finding of the perched aquifer, whereas the water chemical profile allowed the recharge confirmation through the use of natural tracers (nitrates and sulfate).

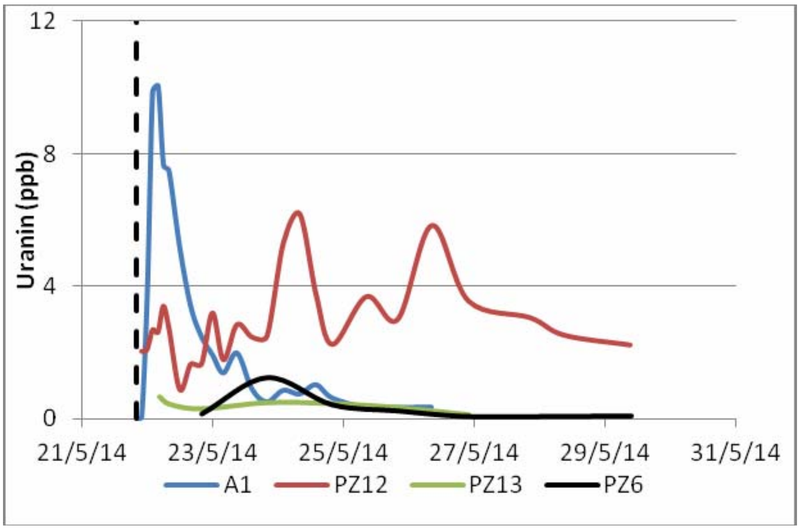

Fig. 1 – Tracer test results in the different monitoring wells (tracer begun at 20h on the 21st May, with a injection of 10 g of tracer)

Fig. 2 – Tracer test in Mereto

In ZIPR:

- Interpretation of pumping tests carried out in the aquifer at a local scale, (Botti);
- Estimation of the water resources throughout the year

Main conclusions: Although that in the ZIPR area the aquifer is multistrata all efforts were directed to the phreatic aquifer with 16 m thick and a very shallow water level, between 2 and 3 meters from the surface. The water available from recharge, from the phytodepuration pond rounds 2200 m^3/d. Hydraulic conductivities are very high in the order of 10^{-3} m/s.

In Copparo:

- Characterization of the available piezometer information
- Interpretation of pumping tests carried out in the aquifer at a local scale (Botti);
- Collection of Sediments in the bottom of the pound (together with UNIFE) for sieve analysis;
- Development of a preliminary infiltration model;
- Estimation of the pond/aquifer connection area;

Main conclusions: Hydraulic permeability of the aquifer was comprehensibly studied and estimated at 10^{-5} m/s. Storage coefficient rounds 10^{-4}, which is typical of a confined aquifer, however non-confined at a local level. The connection area between the Pond and the aquifer (paleochannel) was estimated in the 2300 m^2, and therefore the infiltration capacity of the test site shall reach the 6 l/s, depending on the hydraulic gradient between the aquifer and the pond level.

The connection with the other subjects was fundamental for the development of the hydrogeological conceptual model. Chemical analysis were very important for the aquifer characterization and to show the merits of the MAR in such a facility, while the geophysical interpretation was fundamental for the assessment of the aquifer geometry and to clue for a recharge efficiency, due to a salt water displacement.

A DPSIR model for the groundwater stress was developed, with a focus on the artificial recharge and its intertwining with the other factors. Managed aquifer recharge is by excellence the technical Response for addressing aquifer and groundwater problems. In theory and if effectively applied at a suitable scale it can positively tackle the negative impacts brought to the system, by influencing the State parameters such as groundwater quality and quantity with positive feedback in the Impacts.

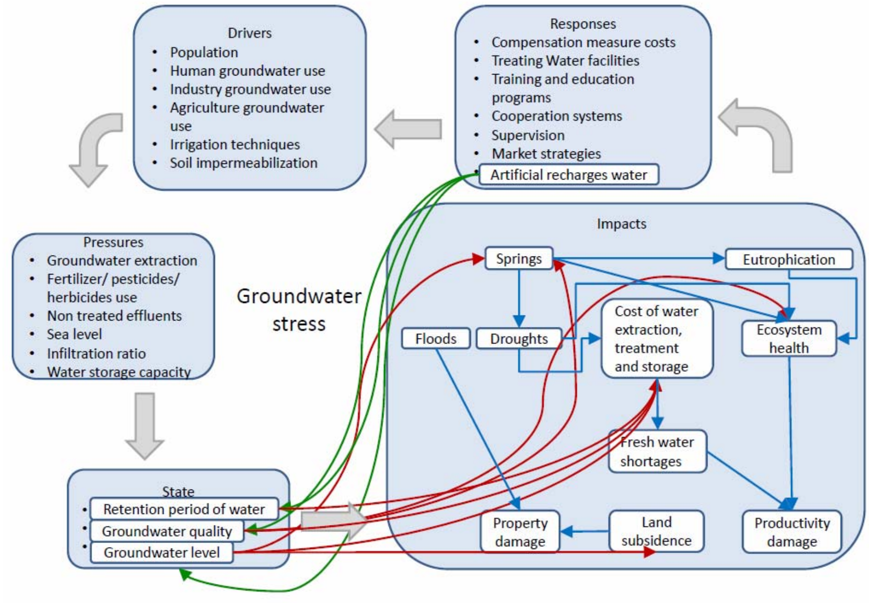

Fig. 3 – Managed aquifer recharge role in the DPSIR model.

The effects of the prolonged MAR activities were predicted within this framework:

In Mereto:

- Water quality improvement, mainly in its nitrate content (positive, medium significance and reversible impact);
- Water level rise in the perched aquifer (positive, low significance and reversible impact);
- Algae Growth in the pond (negative, low significance and reversible impact)
- Biodiversity, by the creation of a permanent wet area (positive, low significance)
- Clogging (negative, significance to be accessed, reversible impact)

In ZIPR:

- Surface water quality improvement specially in the temperature and heavy metals parameters (positive, low significance and reversible impact)
- Water level rise at a local level might saturate the soil with consequences in the deep root trees (negative, low significance, reversible)
- Groundwater quality which will slight enrich in chlorine and sodium content, within the legislation limits (negative, low significance and reversible impact);
- Clogging (negative, significance to be accessed, reversible impact)
- Biodiversity (positive, low significance)

In Copparo:

- Groundwater quality improvement (positive, low significance and reversible impact)
- Fossil water intrusion barrier (positive, low significance and reversible impact)
- Biodiversity improvement thanks to the water mirror quality improvement (positive, significate, reversible impact)

A summary of the predicted impacts is summarized in the following table:

Table 1 - Significance of the predicted impacts in all 3 test sites (0 equals to neutral; + equals to positive and – to negative. One signal: low significance; Two signals: medium significance; Three Signals: significative; Four signals: very significative;

Impact	Mereto	ZIPR	Copparo
Groundwater Quantity	+ (in suspended aquifer)		+
Water extraction cost	0	0	0
Groundwater quality	+ +		+
Water treatment cost	0	0	0
Sea water/fossil water barrier	0	0	+
Subsidence mitigation	0	0	0
Superficial stream flow	0	+ +	0
Algae and microorganism growth		?	?
Clogging			0
Plagues		?	
Biodiversity improvement	+	+	+ + +
Evaporation losses			

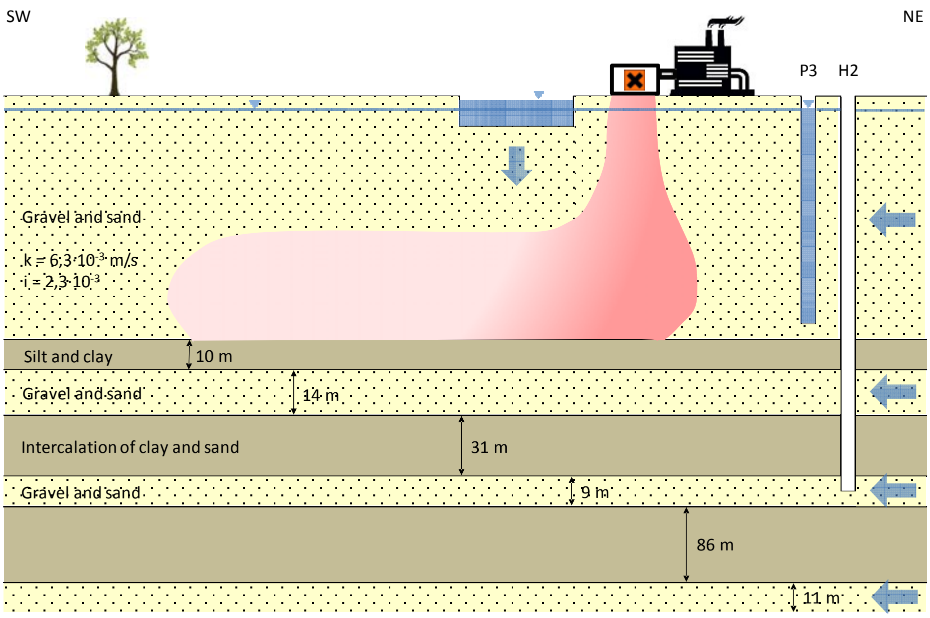

Fig. 4 – Hydrogeological Conceptual Model for ZIPR

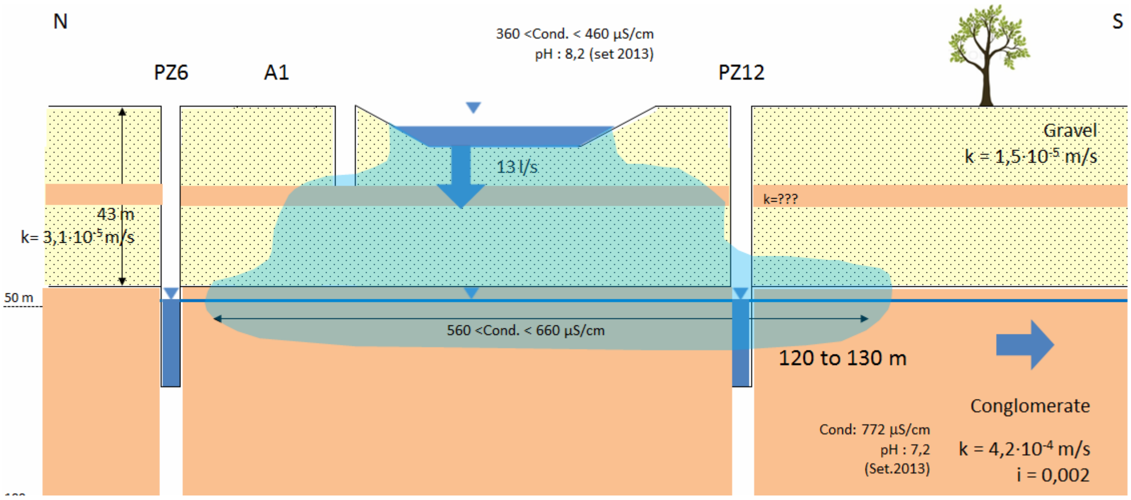

Fig. 5 – Hydrogeological Conceptual Model in Mereto

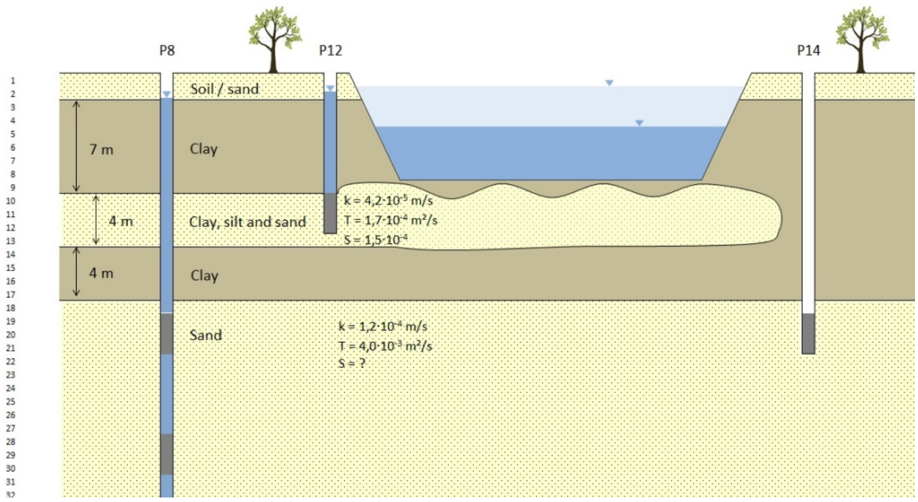

Fig. 6 - Hydrogeological Conceptual Model for Copparo