World Congress on

Climate Change

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Efficacy of managed aquifer recharge to reduce the impact of climate change on coastal aquifers

Consiglio Nazionale delle Ricerche, IRSA,
Sede Secondaria di Bari.
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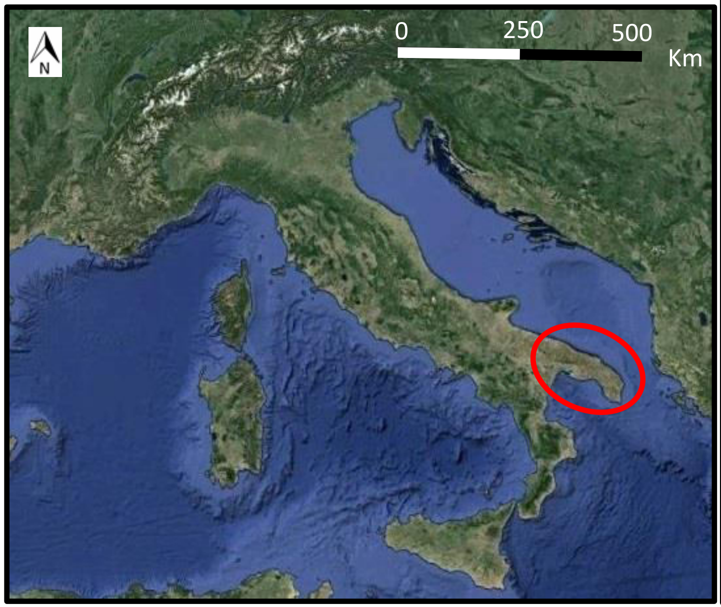
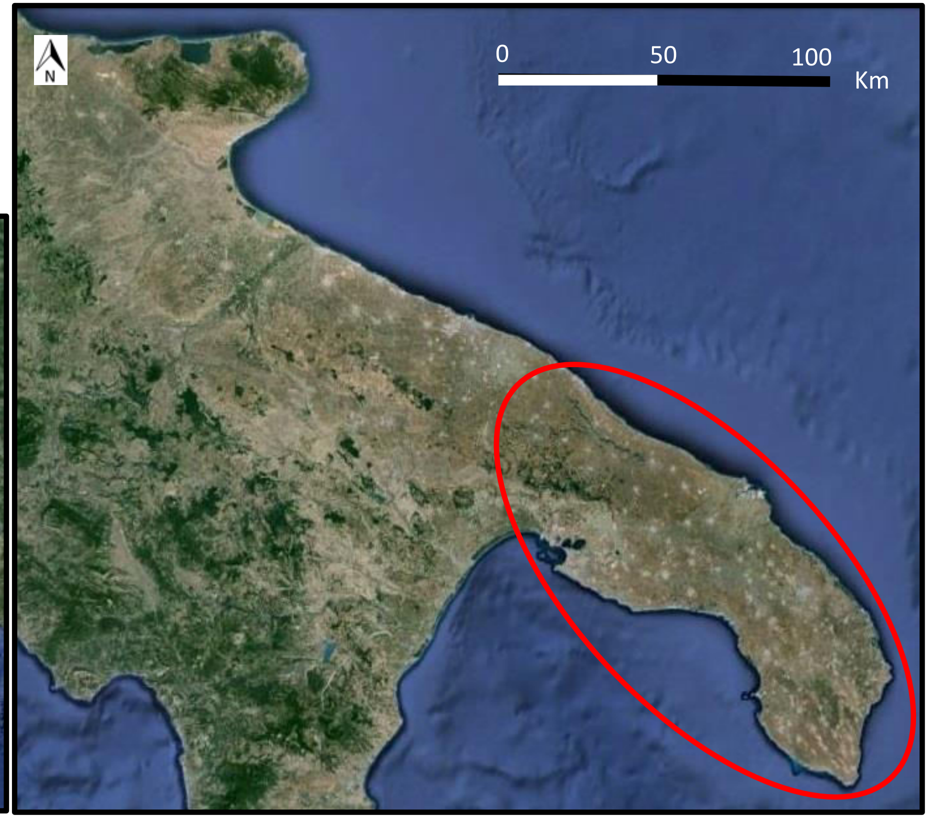
Outline

- Study area: geology, water quality
- Driver: Sea-level rise
- Impacts: Coastline displacement, Groundwater availability reduction
- Adaptation: MAR & DSS
- Conclusion

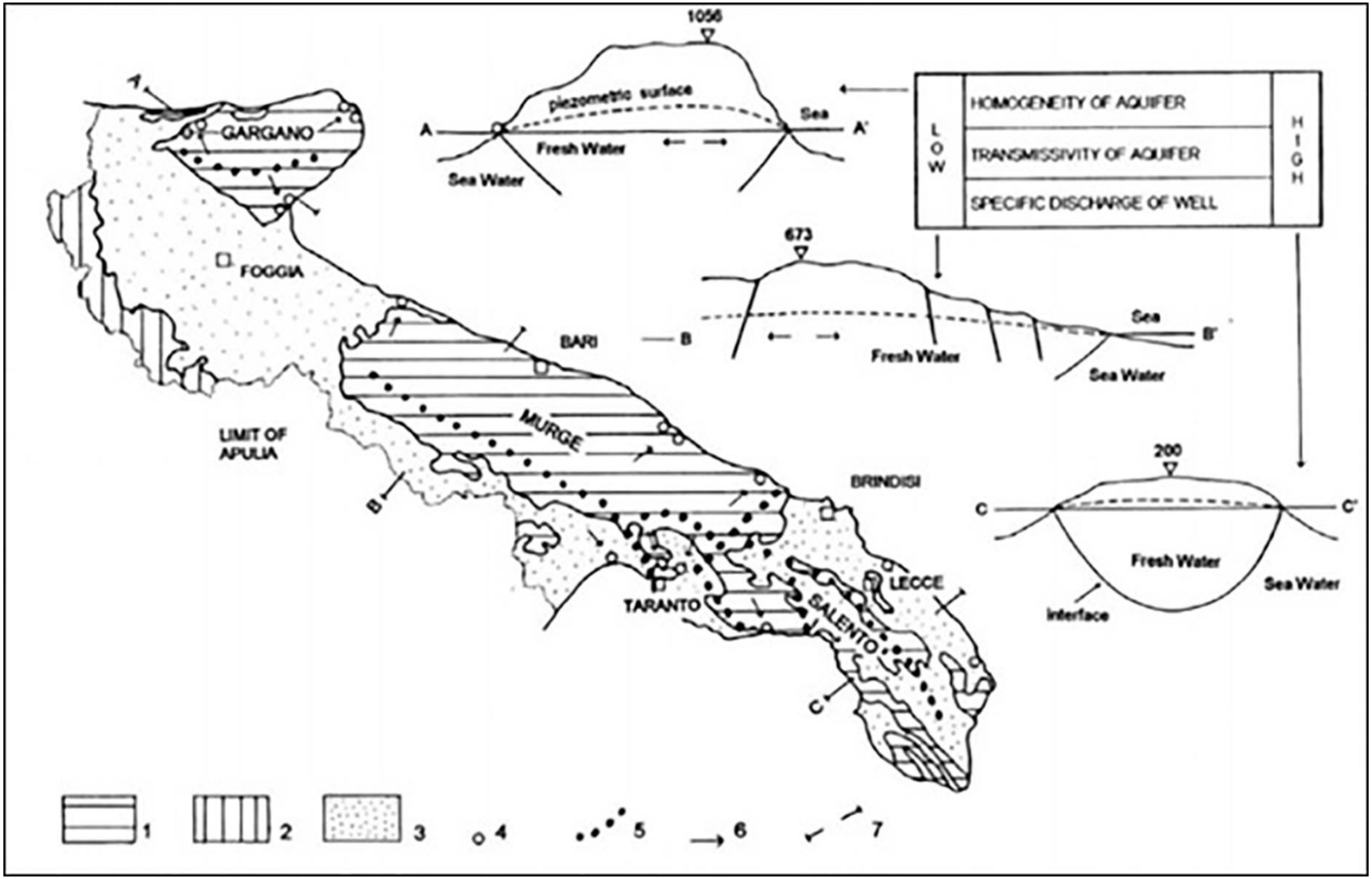
Tested area: Fractures coastal aquifer of Ostuni (Southern Italy)

- Average rainfall < 600 mm/y: natural recharge is unable to refill groundwater sufficiently.
- Absence of relevant surface water sources: groundwater has traditionally been freshwater source for locals
- Agriculture is the main economic activity in Apulia Region
- ***Total demand of water is not enough to supply the total uses***
- ***Freshwater is coming from aquifer***



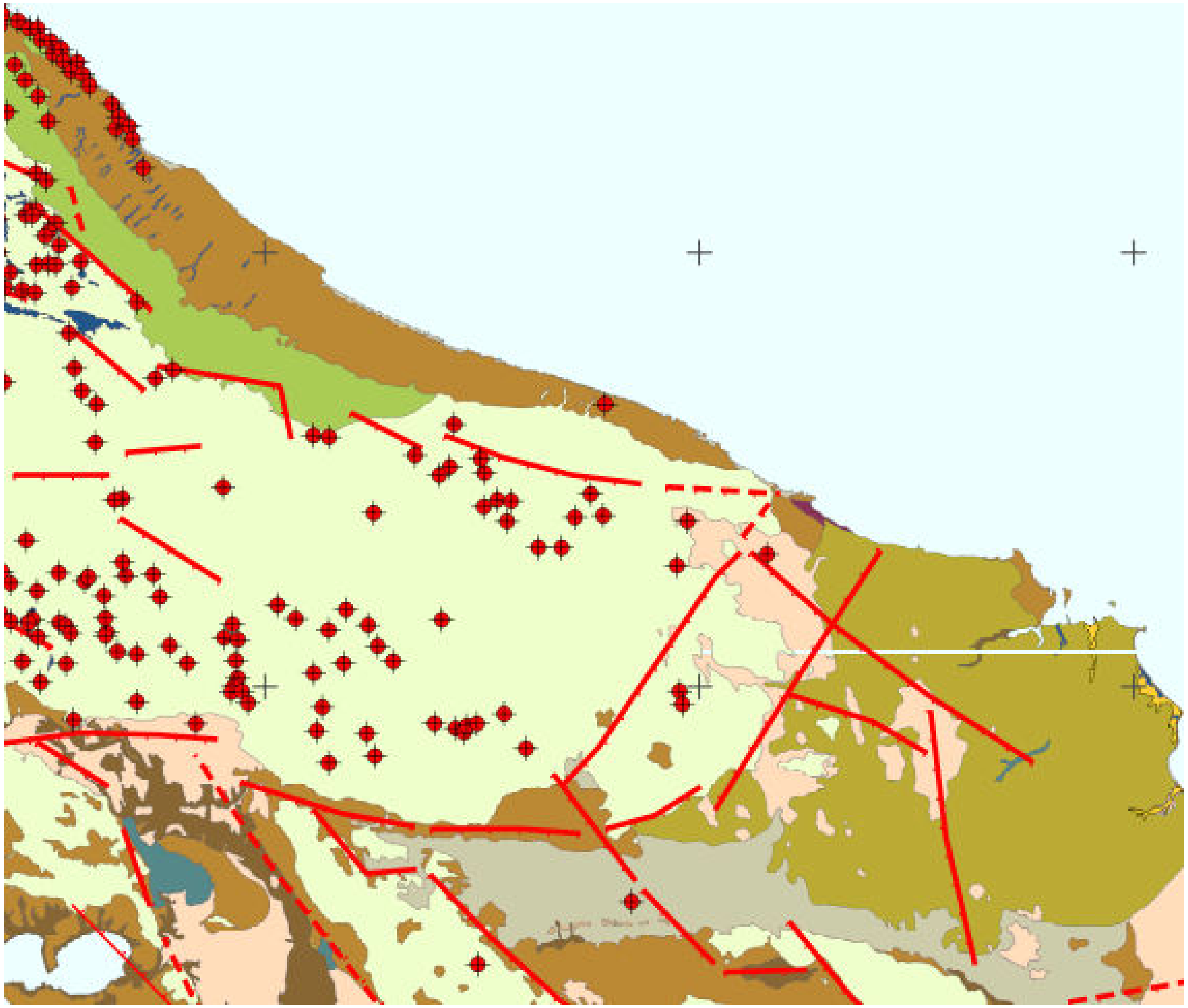


Hydrogeological features



1= mesozoic dolomitic-limestone rocks; 2 = Appennine rocks; 3 = Plio-pleistocenic sediments; 4 = mail coastal springs; 5 = hydrogeological boundary; 6 = groundwater flow direction

Schematic geo-lithological map



- Spring or Sinkhole
- Fault
- Dolomitic rock
- Limestone sands
- Sandstone
- Calcarenite
- Limestone thin strata
- Limestone big strata

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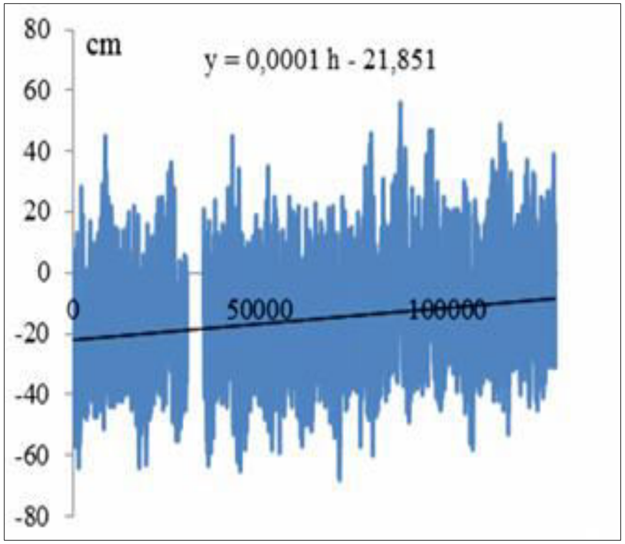
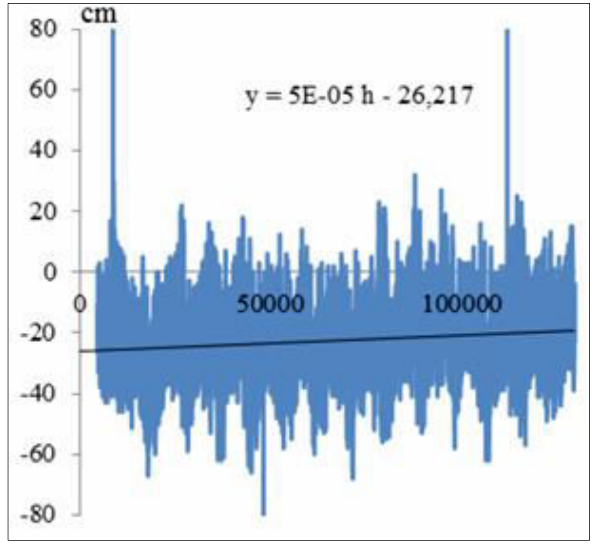
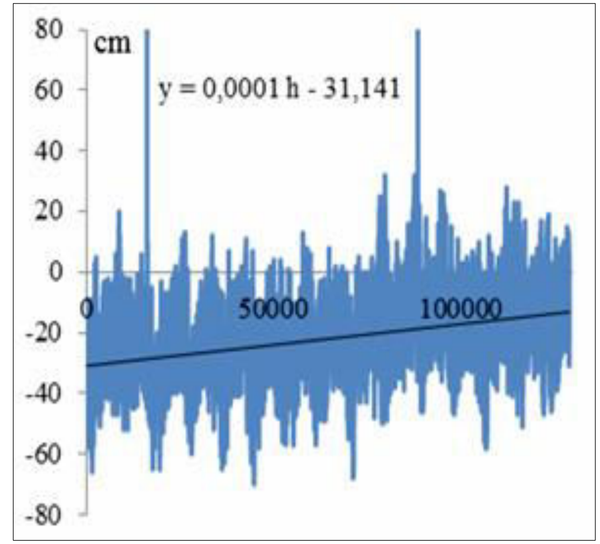
Data collected from tide-gauge stations during 2000-2014



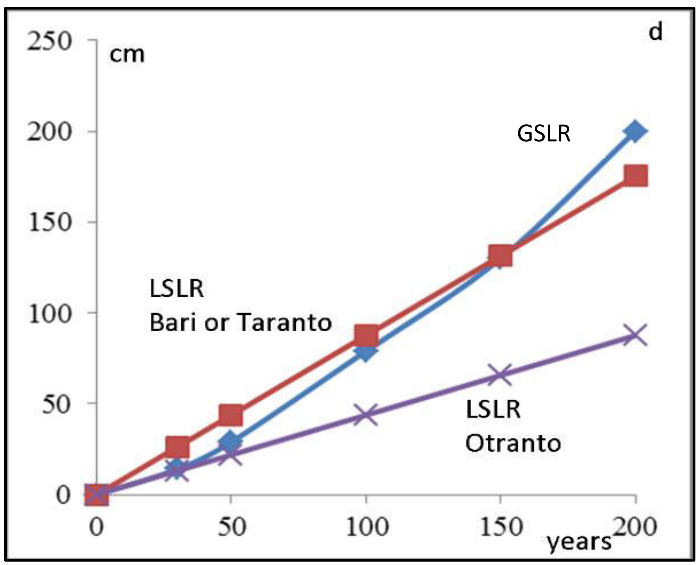
Bari
LSLR 8,76 mm/y



Taranto
LSLR 8,76 mm/y

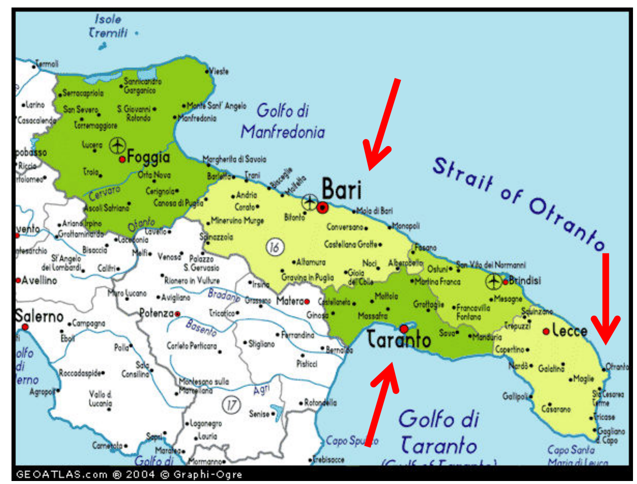


Otranto
LSLR 4,38 mm/y



Kopp* 2014
GSLR

(Kopp et al. 2014. Probabilistic 21 and 22 century sea-level projections at a global network of tide-gauge sites. Earth's future, 2, 383-406, doi: 10,1002/2014EF00023 9)*



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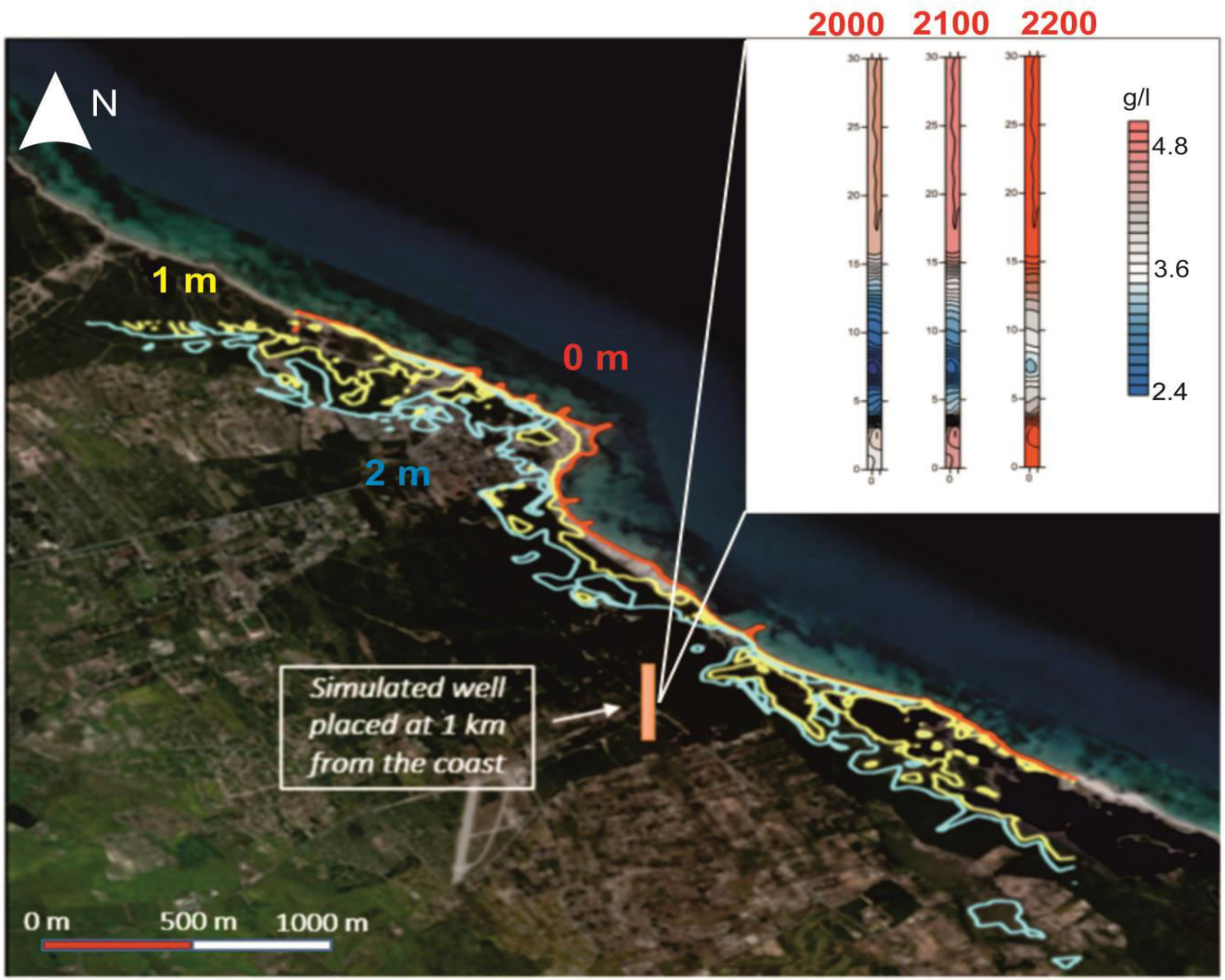
Water Salinity Increase in Simulated Well



SCENARIO UNTIL 2200

- *Coastline advancement: range*

40-600 m

BEST FIT CONSTANTS

- C_{so} = 1,54 g/L
- A_s = 12,02 g/L
- D_s = 592,65 m

PARAMETERS

- C_{salt} salt concentration in well
- d distance between well and Ghyben-Herzberg interface

$$C_{salt} = C_{s0} + A_s \left[exp - \frac{d}{D_s} \right]$$

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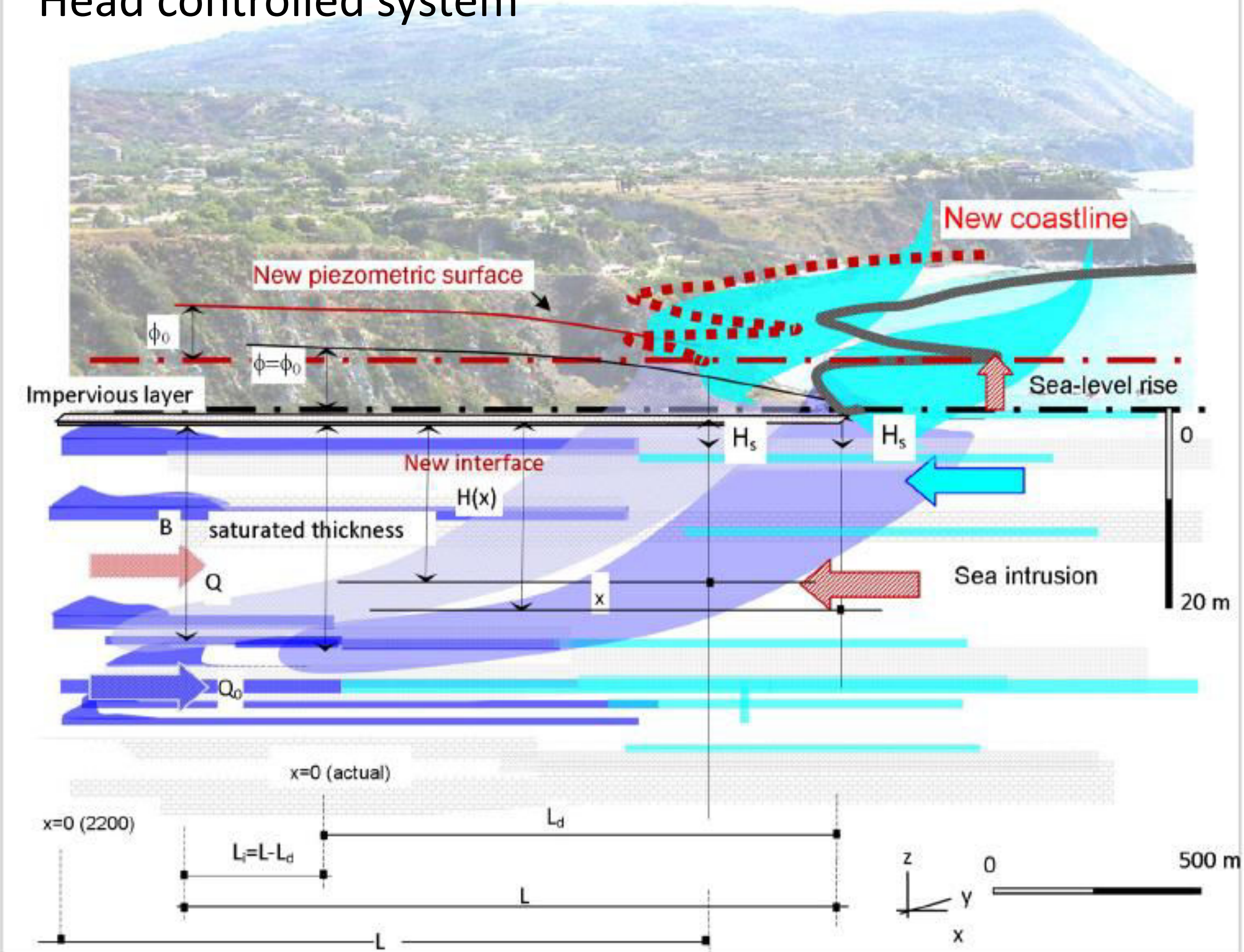
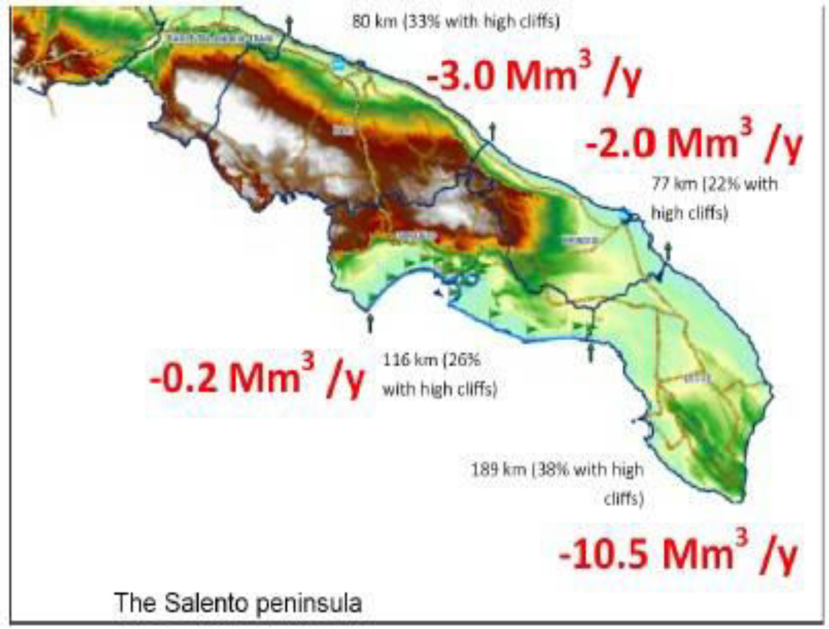
Head controlled system



1. Estimation of climate change impacts on groundwater discharge: reduction of 60 L/s of the Ostuni freshwater discharge during year 2200

$$\Delta Q = Q_0 - K\frac{B^2 - H_s^2}{2\delta_\gamma (L_i + L_d)}$$



Li= Intrusion length, due to 2 m LSLR, derived from soil digital elevation model;

Ld= Current intrusion toe position defined by groundwater flow model;

Q0 = Current groundwater (freshwater) outflow, without sea intrusion (i.e., or Li=0);

B = Actual Saturated thickness of groundwater (freshwater);

Hs = Freshwater thickness at the outflow section;

2. Evaluation of surface water quality status at Ostuni Test Area

		19/11/14	13/01/15	17/2/15	17/03/15	26/05/15	14/07/15	Mean	TVs
Basic analysis									
Total Suspended solids	g/L					10	31	21	
COD	mg O_2/L	51	39	29	34	24	28	34	
Ammonia nitrogen	mgN/L	0	10	5	3	3	5	4	
Nitric nitrogen (N-NO3)	mgN/L	7	7	4	5	5	6	6	
Nitrous nitrogen (N-NO2)	mgN/L	0.0	**2.3**	**0.9**	**2.1**	**0.7**	**0.8**	**1.1**	**0.5**
Phosphorous (P-PO4)	mgP/L	7						7	
pH		7	7	7	7	8	7	7	
Potassium (K+)	mgK/L					36	57	47	
Salinity related analysis	µS/cm								**2000**
Electrical conductivity		1647	1730	1859	1932	1541	1590	1717	
Microbiological analysis	CFU/mL								
Total bacteria count at 22 °C	CFU/mL	553	783	707		917	4660	1524	
Total bacteria count at 36°C	MPN/100mL		4983	4533	5760	7600	10767	6729	
Total coliforms	MPN/100mL	31783	5245	5618	6858	34733	45867	21684	
E. coli	CFU/100mL	3638	104	106	600	4537	3733	2120	**10**
Enterococci	CFU/100mL		1168	130	2204	1598	1787	1377	
Clostridium spores	PFU/100mL	2000	3567	2077	5450	5467	7500	4343	
Bacteriophages (somatic coliphages)	number/L	600	2367	1500	3425	3400	7650	3157	
Giardia cysts	number/L			68	36		70	58	
Cryptosporidium oocysts				6	4		3	4	
Enterovirus	particles/L						2.49E+05	2.49E+05	**0**
Adenovirus	particles/L						*4.70E+03*	*4.70E+03*	**0**

In red color are reported concentrations over threshold values (TV) to assess the good chemical status of Italian surface waters (D. Lgs 30/2009) and over main quality parameters (D. Lgs n. 185/03) for agricultural reuse of municipal wastewater effluents

2. Evaluation of ground-water quality status at Ostuni Test Area

		19/11/14	13/01/15	17/2/15	17/03/15	26/05/15	14/07/15		Mean	TV
Basic analysis										
Total Suspended solids	g/L					22	10		16	
COD	mg O_2/L	56	13	11	12	11	14		19	
Ammonia nitrogen	mgN/L	0	0	1	0	0	0		0	
Nitric nitrogen (N-NO3)	mgN/L	3	3	3	2	2	3		2	
Nitrous nitrogen (N-NO2)	mgN/L	0.0	0.1	0.0	0.0	0	0.0		0.0	**0.5**
Phosphorous (P-PO4)	mgP/L	13							13	
pH		7	7	7.125	6.975	7	7		7	
Potassium (K+)	mgK/L					31	35		33	
Salinity related analysis										**2000**
Electrical conductivity	µS/cm	3954	4934	4763	5728	5410	5428		5036	
Microbiological analysis	CFU/mL									
Total bacteria count at 22 °C	CFU/mL	85	400	188		369	353		279	
Total bacteria count at 36°C	MPN/100 mL	-	450	286	386	552	608		456	
Total coliforms	MPN/100 mL	30800	155	788	291	1338	1280		5775	
E. coli	CFU/100mL	**67**	1	2	1	**78**	8		**26**	**10**
Enterococci	CFU/100mL	-	51	22	21	369	292		151	
Clostridium spores	PFU/100mL	200	500	475	1725	1330	1950		1030	
Bacteriophages (somatic coliphages)	number/L	0	0	0	0	0	0		0	
Giardia cysts	number/L			1			0		1	
Cryptosporidium oocysts				0	0		1		0	
Enterovirus	**particles/L**						**5.07E+04**		**5.07E+04**	**0**
Adenovirus	**particles/L**						**1.50E+03**		**1.50E+03**	**0**

In red color are reported concentrations over threshold values (TV) to assess the good chemical status of Italian surface waters (D. Lgs 30/2009) and over main quality parameters (D. Lgs n. 185/03) for agricultural reuse of municipal wastewater effluents

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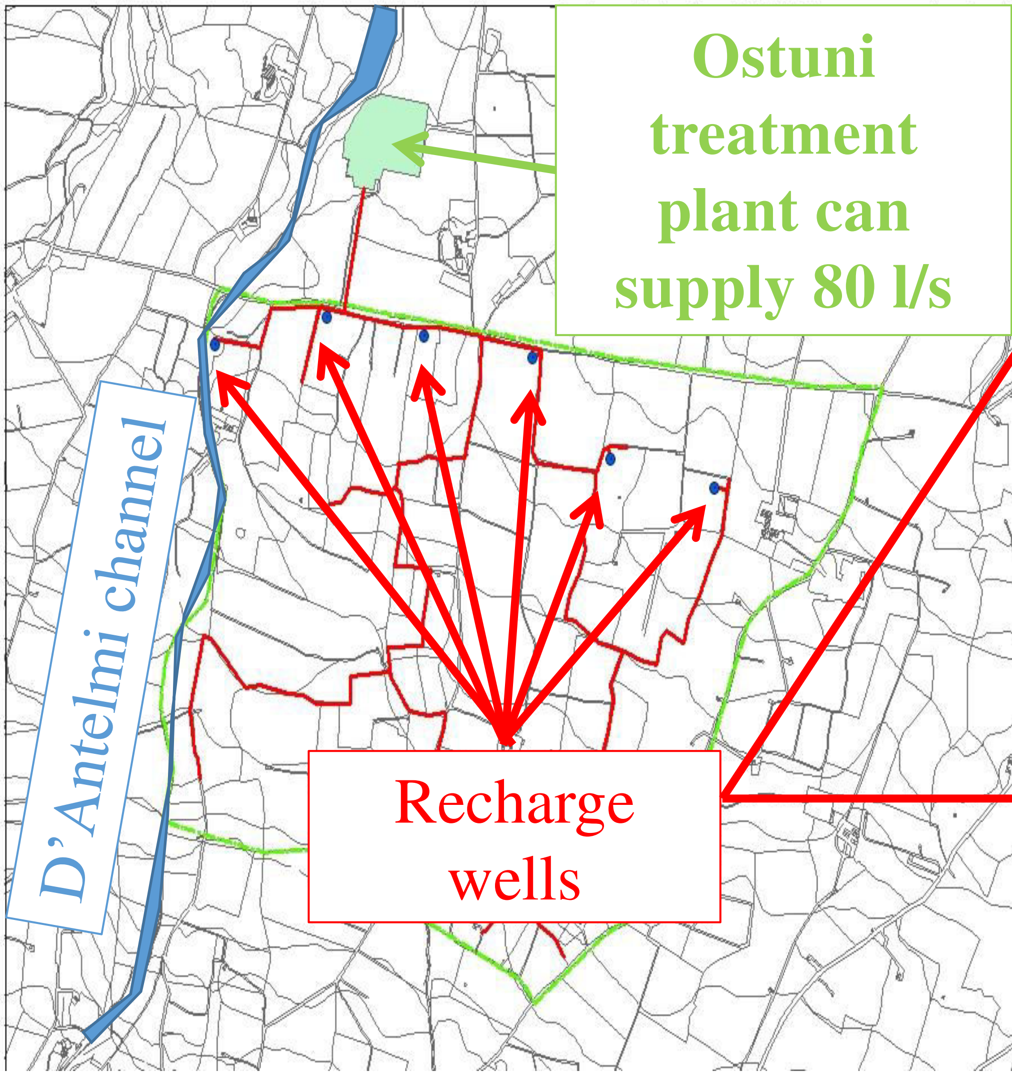
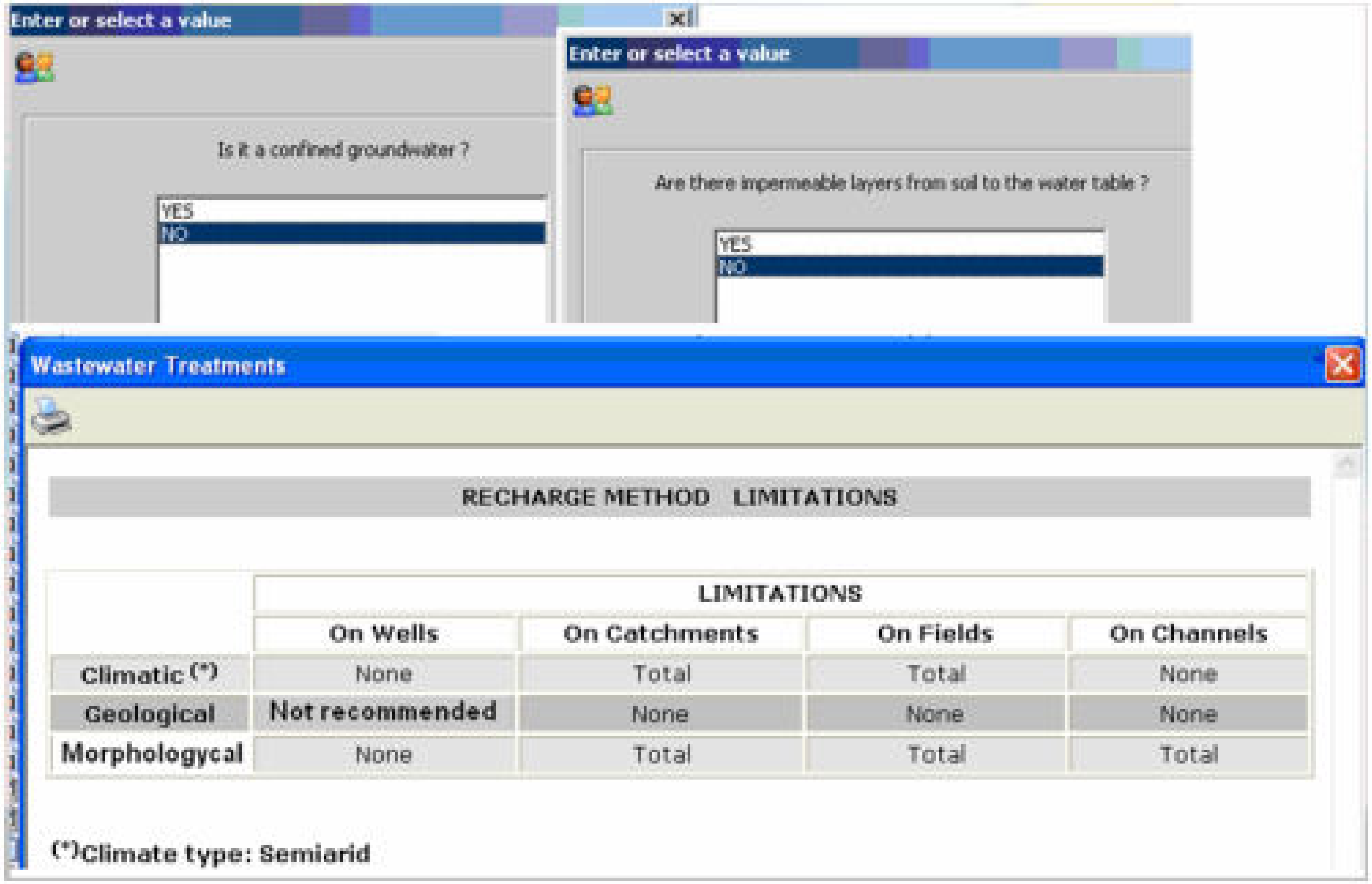
Implementation of MAR technique to cope with drinking touristic need in Test Area



a DSS

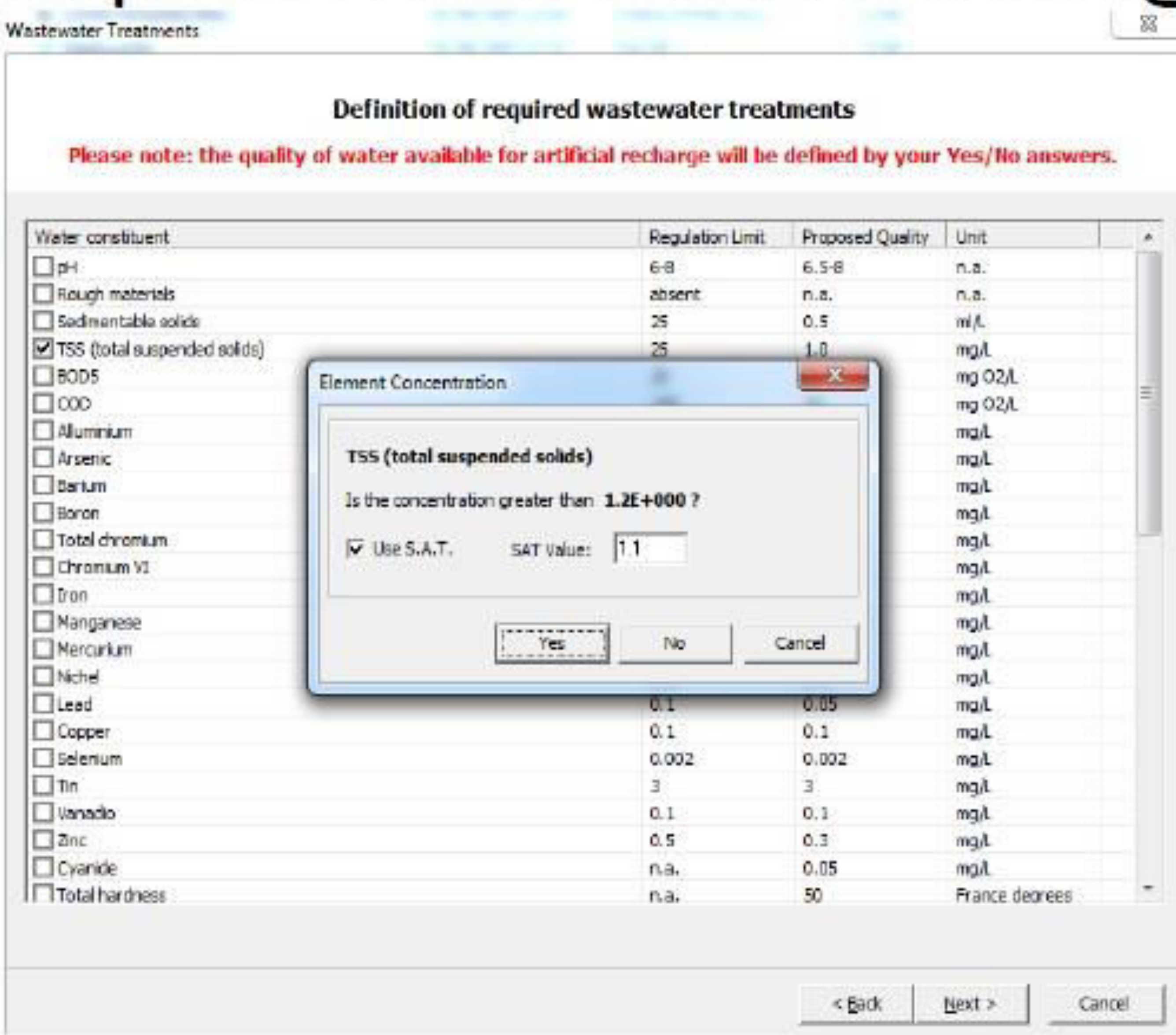


	LIMITATIONS			
	On Wells	On Catchments	On Fields	On Channels
Climatic (*)	None	Total	Total	None
Geological	Not recommended	None	None	None
Morphologycal	None	Total	Total	Total

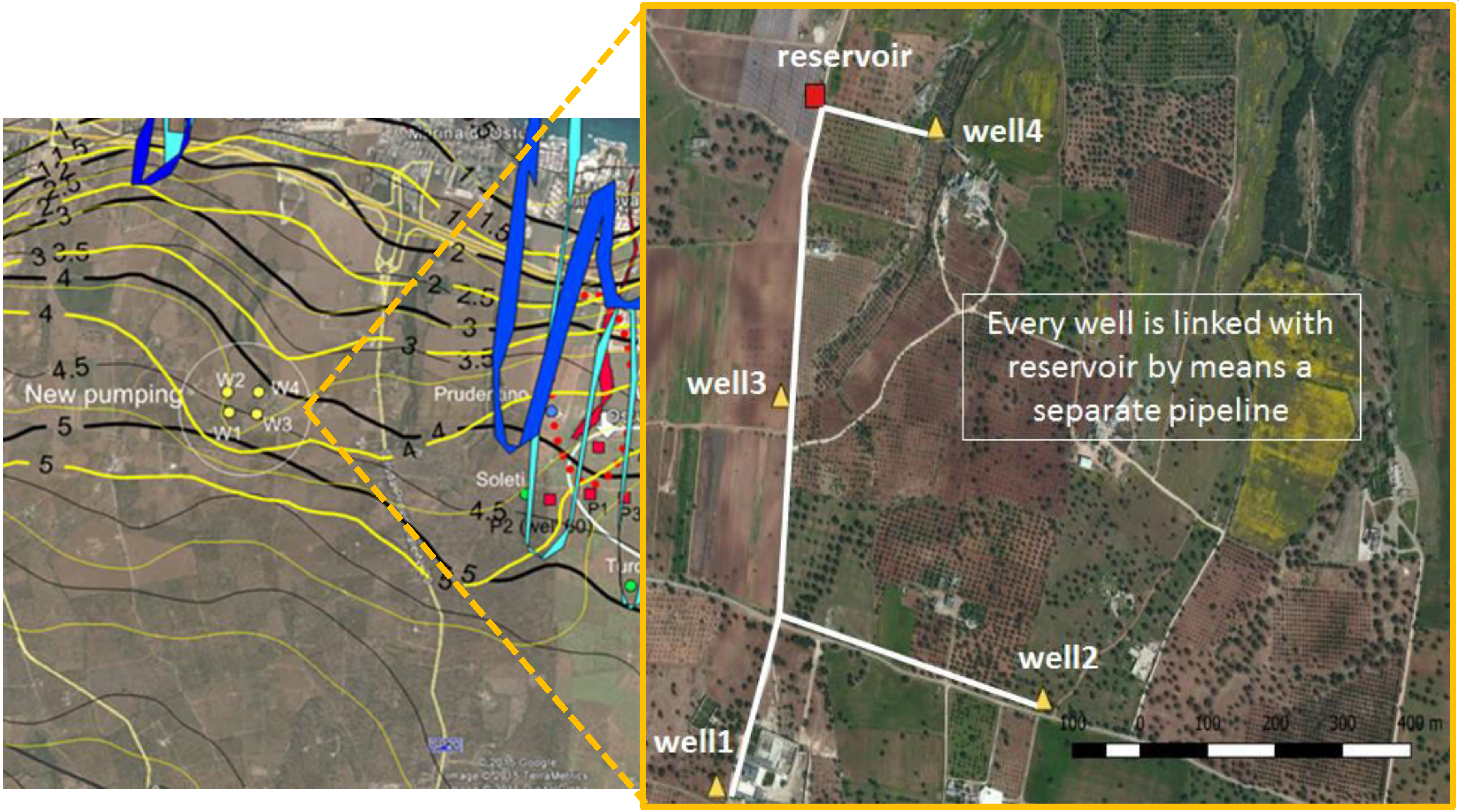
A DSS has been implemented (https://youtu.be/xhmQti2zrgs)

"A suitable tool for sustainable management of groundwaters" by C. Masciopinto, M.Vurro, V.N. Palmisano, I.S. Liso (WRM under review)

MAR implementation using DSS



Estimated recovered freshwater with MAR: 80 L/s



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The cost rate of MAR: 0.05 Euro/m^3

Annual payback rate: 60,000 €

Maintenance costs: 6,000 €

Electric power costs: 5,000 €

The specific tariff is estimated by considering the total annual volume injected (or recovered 80 L/s), and assuming a recharge period of seven months (i.e., 210 days): the MAR tariff is about 0.05 €/m^3.

This value is about 5% of the base tariff of 1 Euro/m^3 applied in Puglia for domestic drinking water supplies.

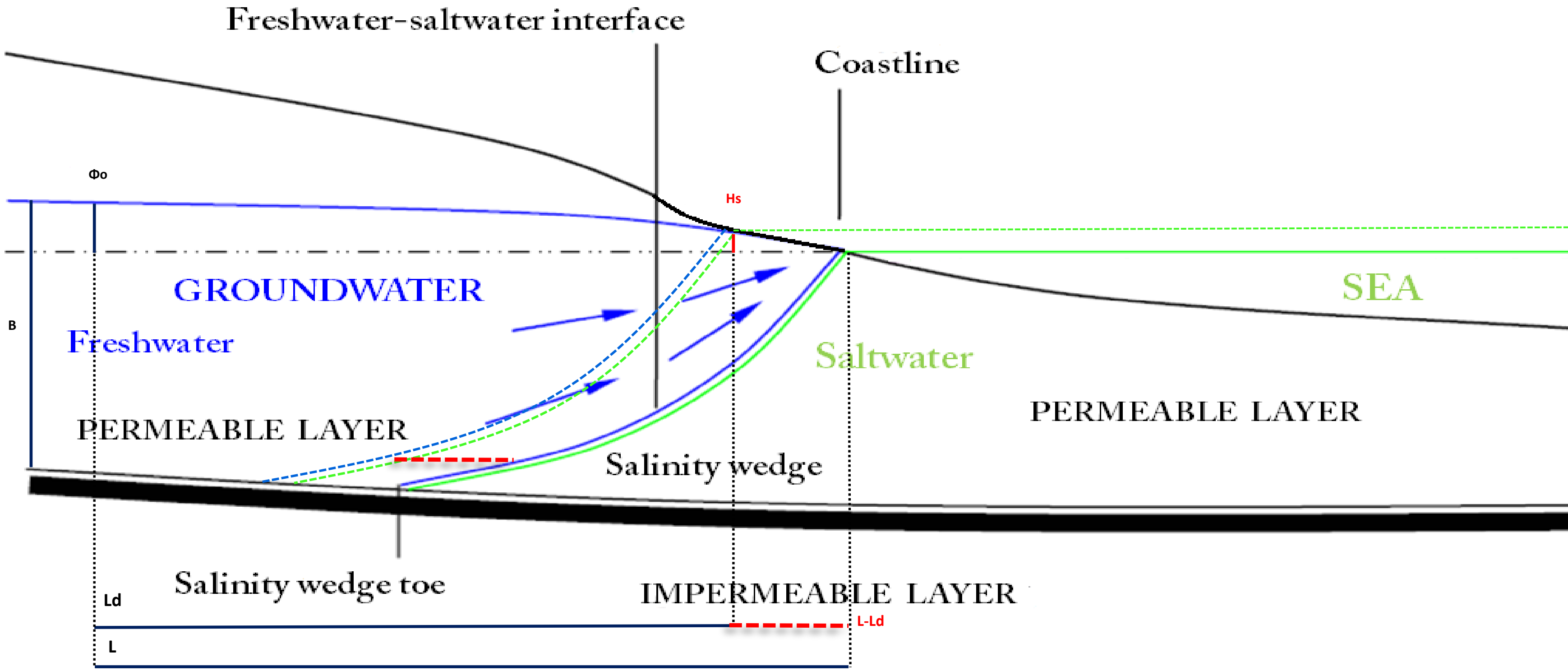
MAR benefits

- MAR actions will recover about 420,000 mc of freshwater, due to reduction of groundwater salinity; this value is the volume of recovered freshwater
- A new seasonal pumping at 80 L/s can provide freshwater supply for touristic area of Ostuni during summer.
- Groundwater up gradient with respect to the recharge plant will have a reduction of groundwater salinity and it can be used for irrigations.

First Geophysical Observatory in Puglia Region (XIII Century)

Thank you for your attention…

… from here we'll help water managers in solving problems ….



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$$\Delta Q = Q_0 - n \frac{b_i^2}{3} \frac{\gamma_f}{\mu_f} \frac{B^2 - H_s^2}{2\delta_\gamma [(L - L_d) + L_d]}$$

	Bari	*Brindisi*	*Lecce*	*Taranto*
K	0,0037 m/s	0,0037 m/s	0,008 m/s	0,0008 m/s
B	15 m	15 m	15 m	15 m
Ld	1400 m	1250 m	2800 m	2500 m
L-Ld	157 m	125 m	480 m	190 m
Φo	1 m	1 m	1 m	1 m
Coastline length	80 Km	77 Km	189 Km	116 Km
ΔQ	2,5 Mm3/y	2,5 Mm3/y	9,25 Mm3/y	0,3 Mm3/y
% GROUNDWATER AVAILABILITY REDUCTION	**9,7% of current freshwater volume withdrawal for drinking porposes**	**3,2% of current freshwater volume withdrawal for drinking porposes**	**11,9% of current freshwater volume withdrawal for drinking porposes**	**1,2% of current freshwater volume withdrawal for drinking porposes**