7th EUREGEO

Bologna, Italy, June 12th – 15th 2012

SIMPLIFIED METHOD TO EVALUATE THE GROUNDWATER BALANCE OF A HYDROGEOLOGICAL BASIN BY MEANS OF A CALIBRATED 3D MATHEMATICAL MODEL: THE EXAMPLE OF THE TARO RIVER HYDROGEOLOGICAL BASIN (WESTERN EMILIA – ROMAGNA REGION, NORTHERN ITALY)

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INTRODUCTION

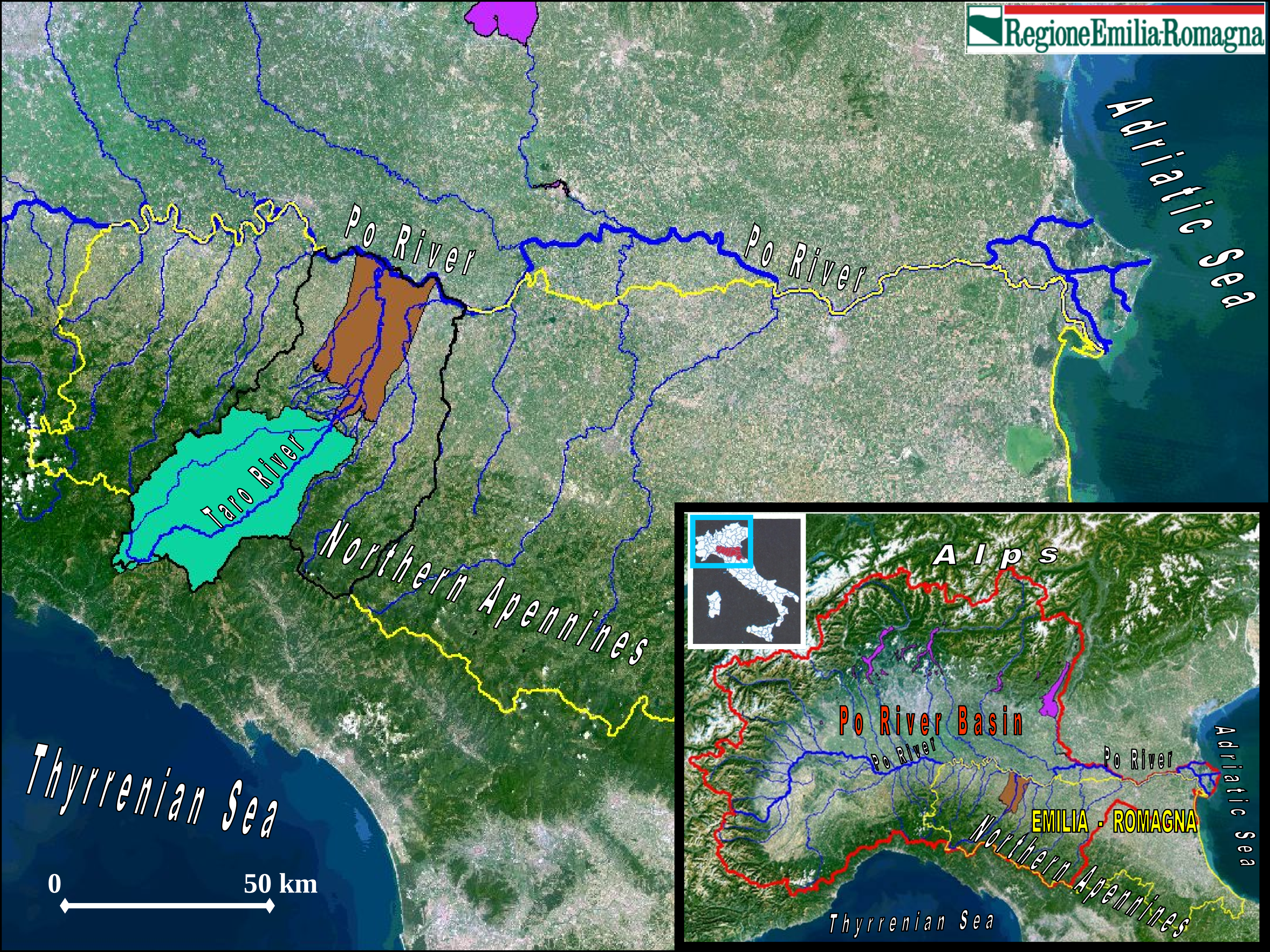
The **evaluation of the groundwater budget in a Hydrogeological Basin** is generally performed in two ways:

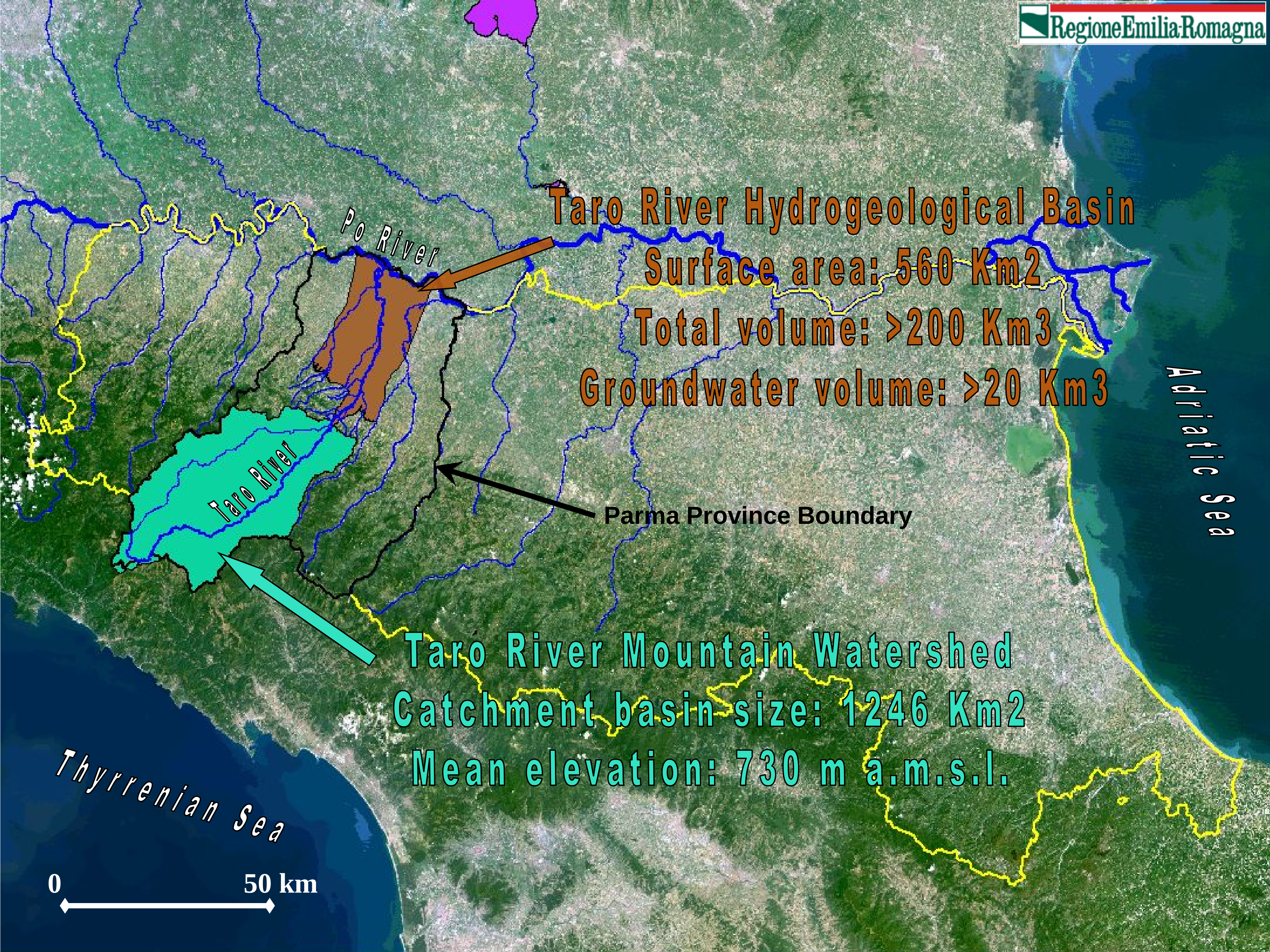
1. we could know the three dimensional distribution of the storage properties of the terrains and the difference of piezometry between the initial and final stages of the considered time period, so we could get the balance through Geographic Information System operations.

2. Alternatively we could have a calibrated mathematic model of the basin available and so we could run it to perform the balance calculation.

However, all the two ways are really **time and money consuming**.

In this presentation I'll show you that if we have **a calibrated mathematic model of the Hydrogeological Basin** available, there is a simplified method to evaluate the groundwater balance of it, a method that doesn't need the running of the model but uses only its **calibration data** and the **rainfall recordings**.


RegioneEmilia-Romagna
Adriatic Sea
Po River
Po River
Taro River
Northern Apennines
Thyrrenian Sea
0
50 km
Alps
Po River Basin
Po River
Po River
EMILIA - ROMAGNA
Adriatic Sea
Northern Apennines
Thyrrenian Sea



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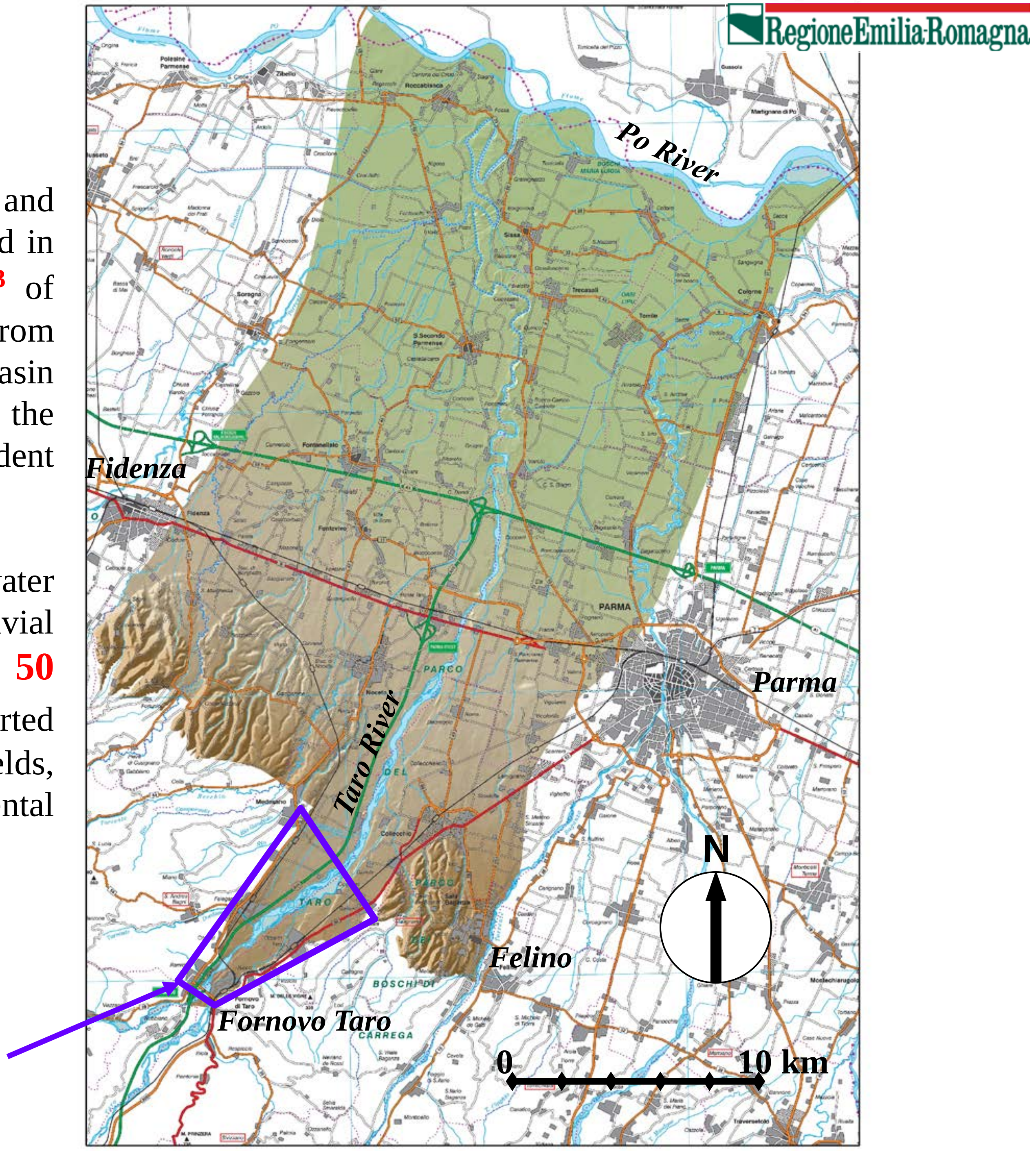
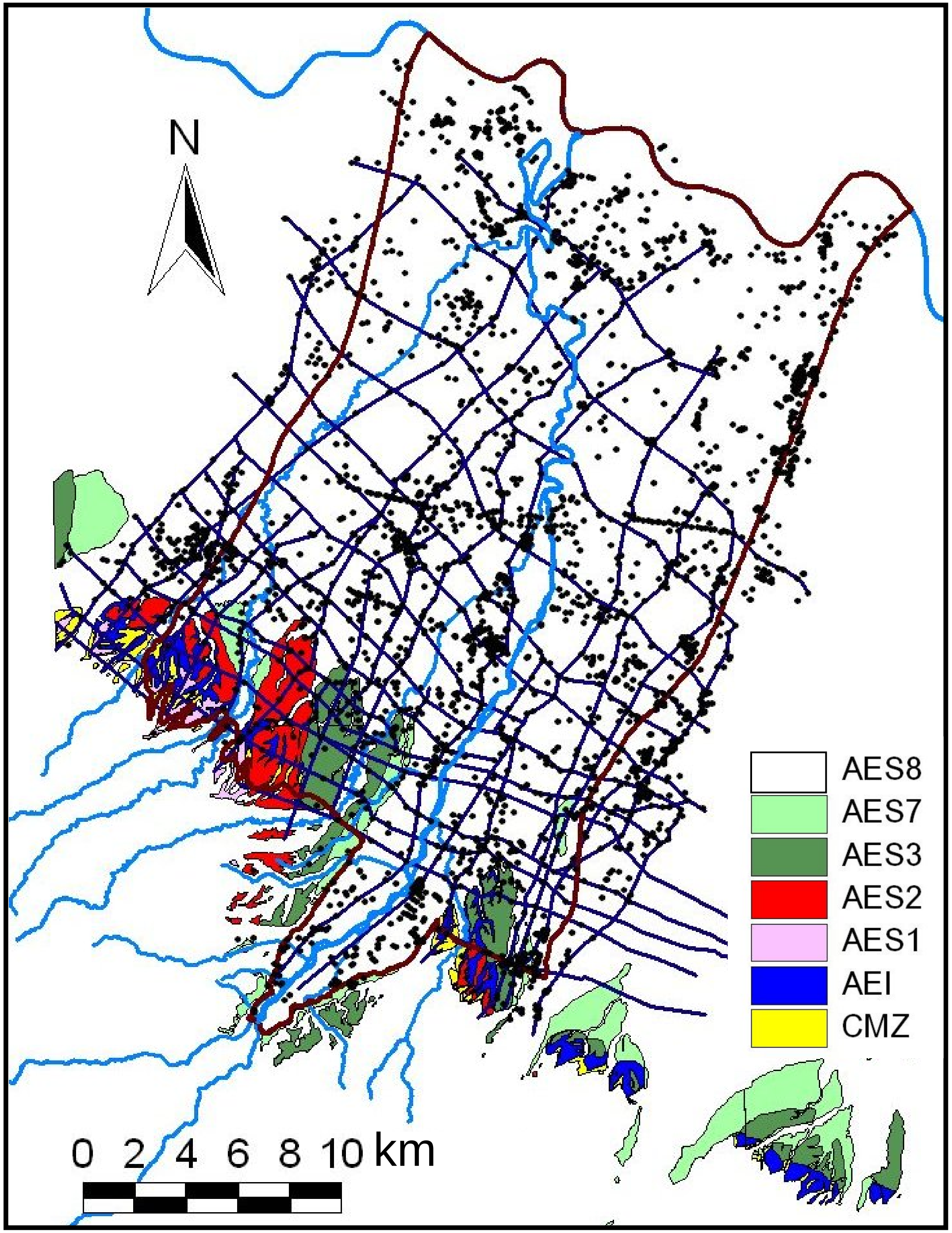
Taro River Hydrogeological Basin
Surface area: 560 Km2
Total volume: >200 Km3
Groundwater volume: >20 Km3
Po River
Taro River
Parma Province Boundary
Adriatic Sea
Taro River Mountain Watershed
Catchment basin size: 1246 Km2
Mean elevation: 730 m a.m.s.l.
Thyrrenian Sea
0
50 km

STUDY AREA

Many important agricultural and industrial activities are concentrated in the study area. Almost **90 Mm³** of groundwater are yearly pumped from the Taro River Hydrogeological Basin to sustain economic activities and the drinking water demand of the resident population.

Because surface water and groundwater reservoirs are lacking in the Alluvial Fan Apex, every summer almost **50 Mm³** of stream water are diverted from the Taro River into the fields, generating huge environmental impacts.

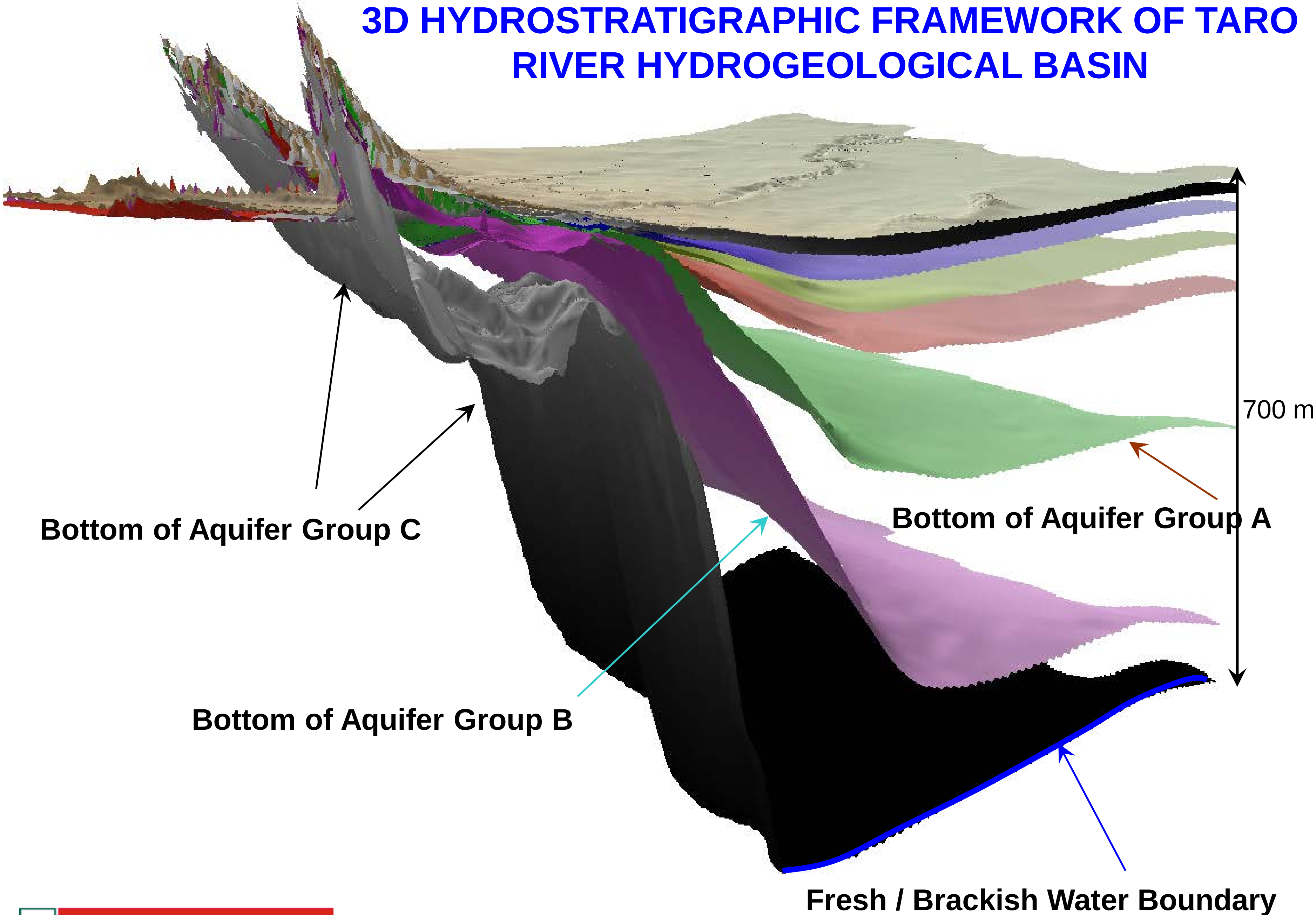




More than **2100** water well-logs have been correlated to build a detailed 3D sequence – stratigraphic and hydrostratigraphic framework of the fan-deltaic, alluvial fan and fluvial deposits.

A network of hydrostratigraphic sections has been developed for an overall lenght of **683 Km**.

3D HYDROSTRATIGRAPHIC FRAMEWORK OF TARO RIVER HYDROGEOLOGICAL BASIN



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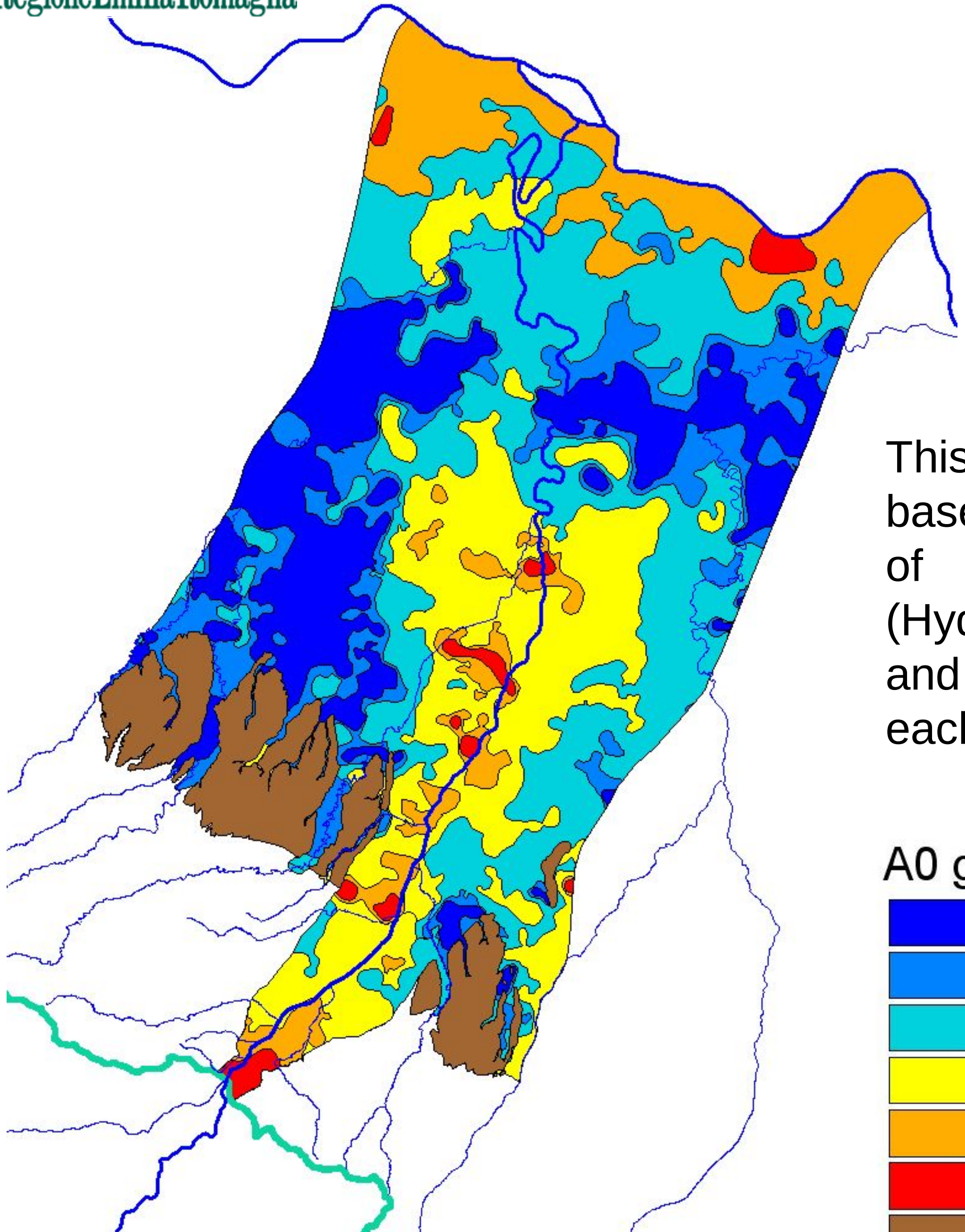
GRAVELS AND SANDS DISTRIBUTION IN THE AQUIFER COMPLEXES



This kind of maps represents the base for setting the areal distribution of the hydrogeologic parameters (Hydraulic Conductivity, Storativity and Storage Compressibility) inside each hydrostratigraphic unit.

A0 gravels and sands isopercent map

- 0 - 10 % gravels and sands
- 10 - 20 % gravels and sands
- 20 - 50 % gravels and sands
- 50 - 80 % gravels and sands
- 80 - 90 % gravels and sands
- 90 - 100 % gravels and sands
- No Deposits

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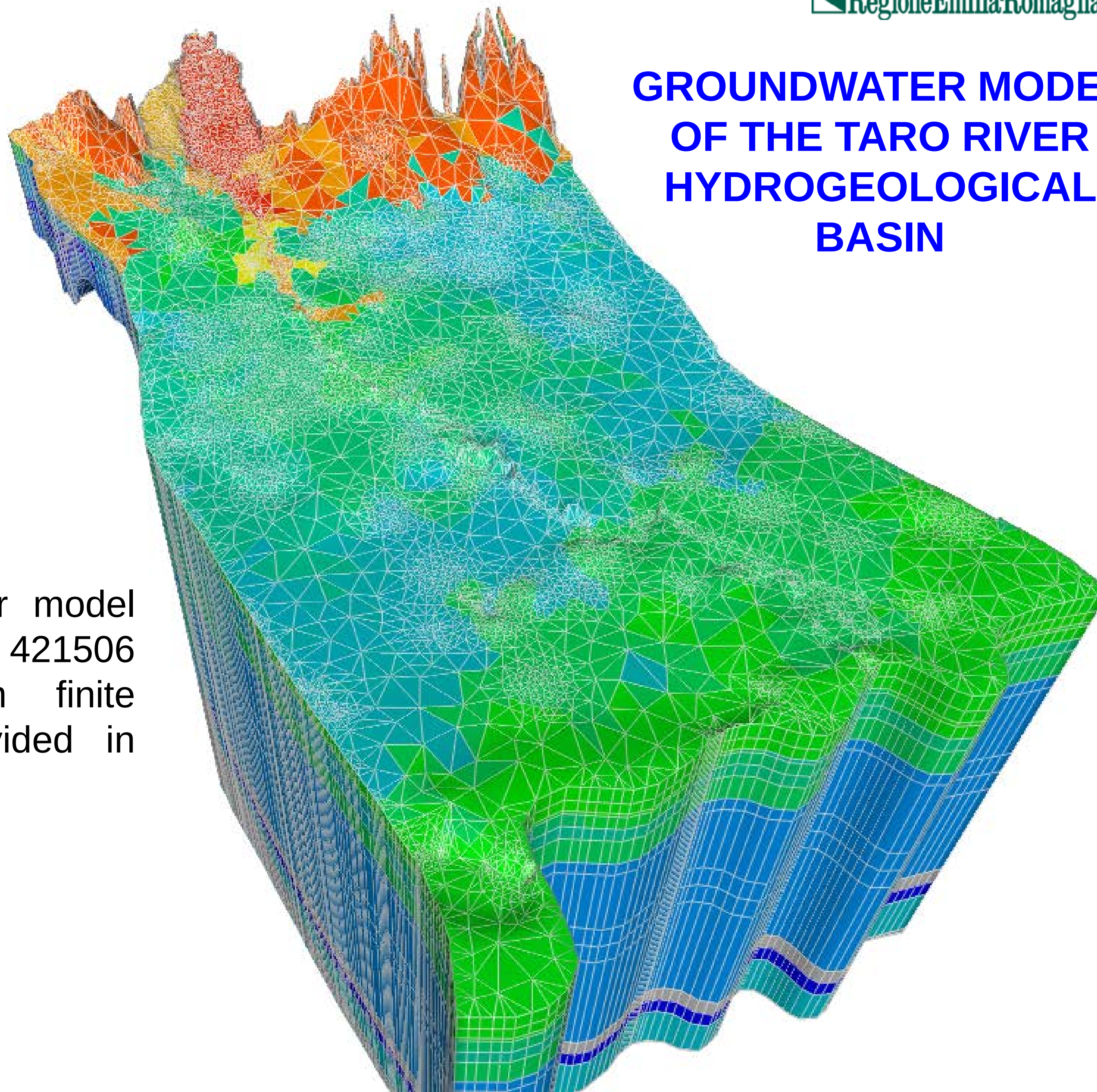
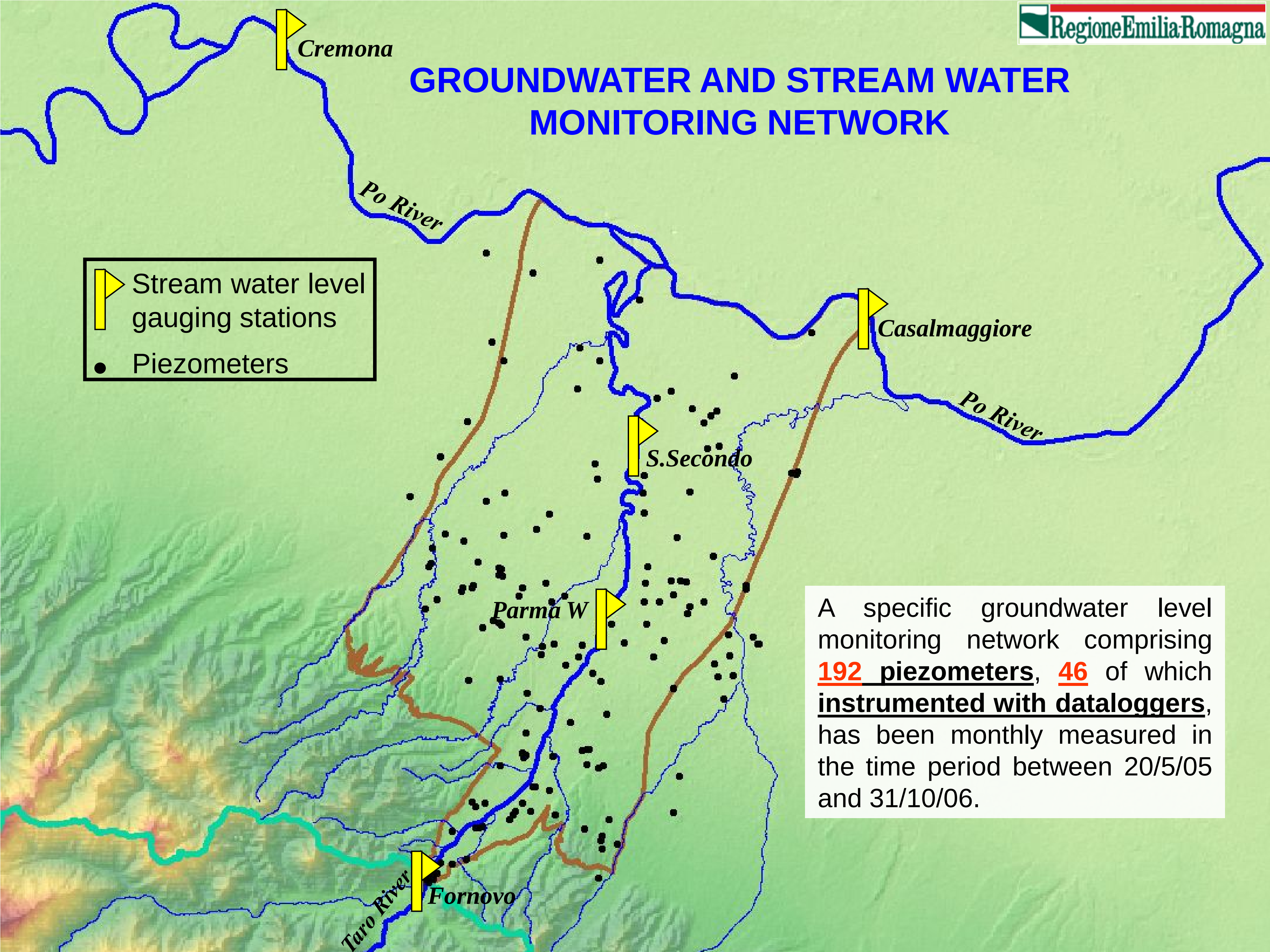
GROUNDWATER MODEL OF THE TARO RIVER HYDROGEOLOGICAL BASIN



The groundwater model is formed by 421506 triangular prism finite elements subdivided in 18 layers.

GROUNDWATER AND STREAM WATER MONITORING NETWORK



A specific groundwater level monitoring network comprising **192 piezometers**, **46** of which **instrumented with dataloggers**, has been monthly measured in the time period between 20/5/05 and 31/10/06.

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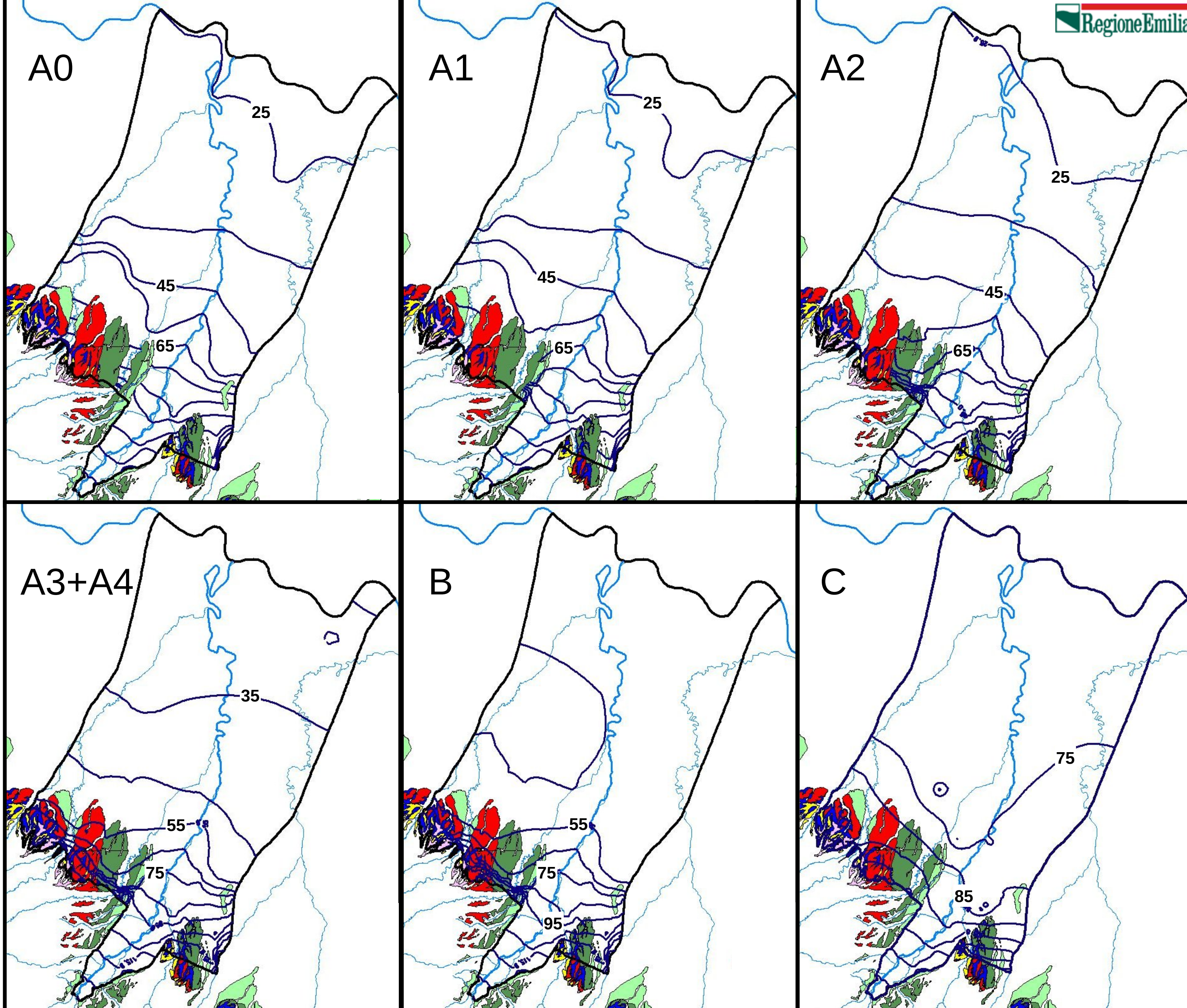
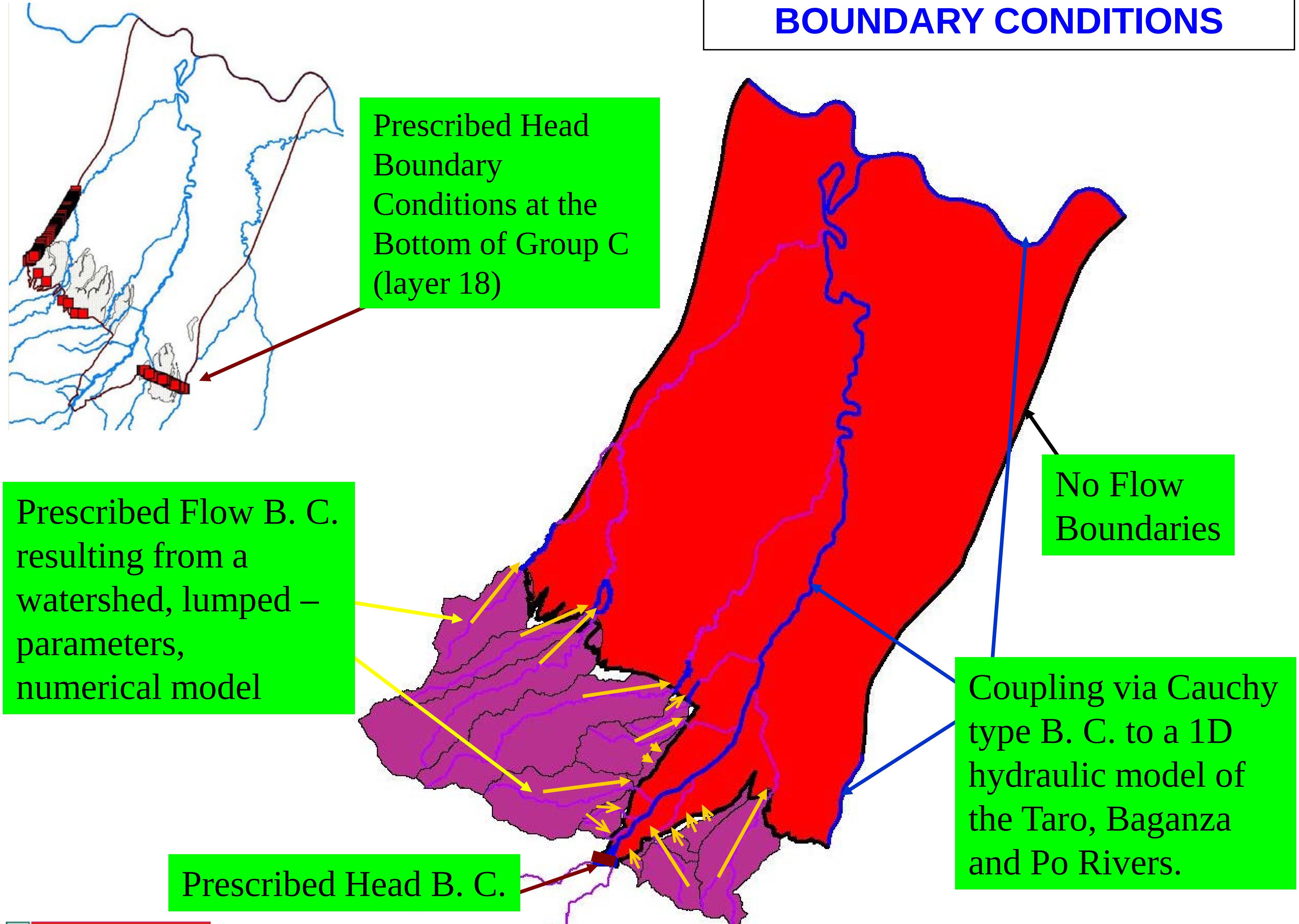
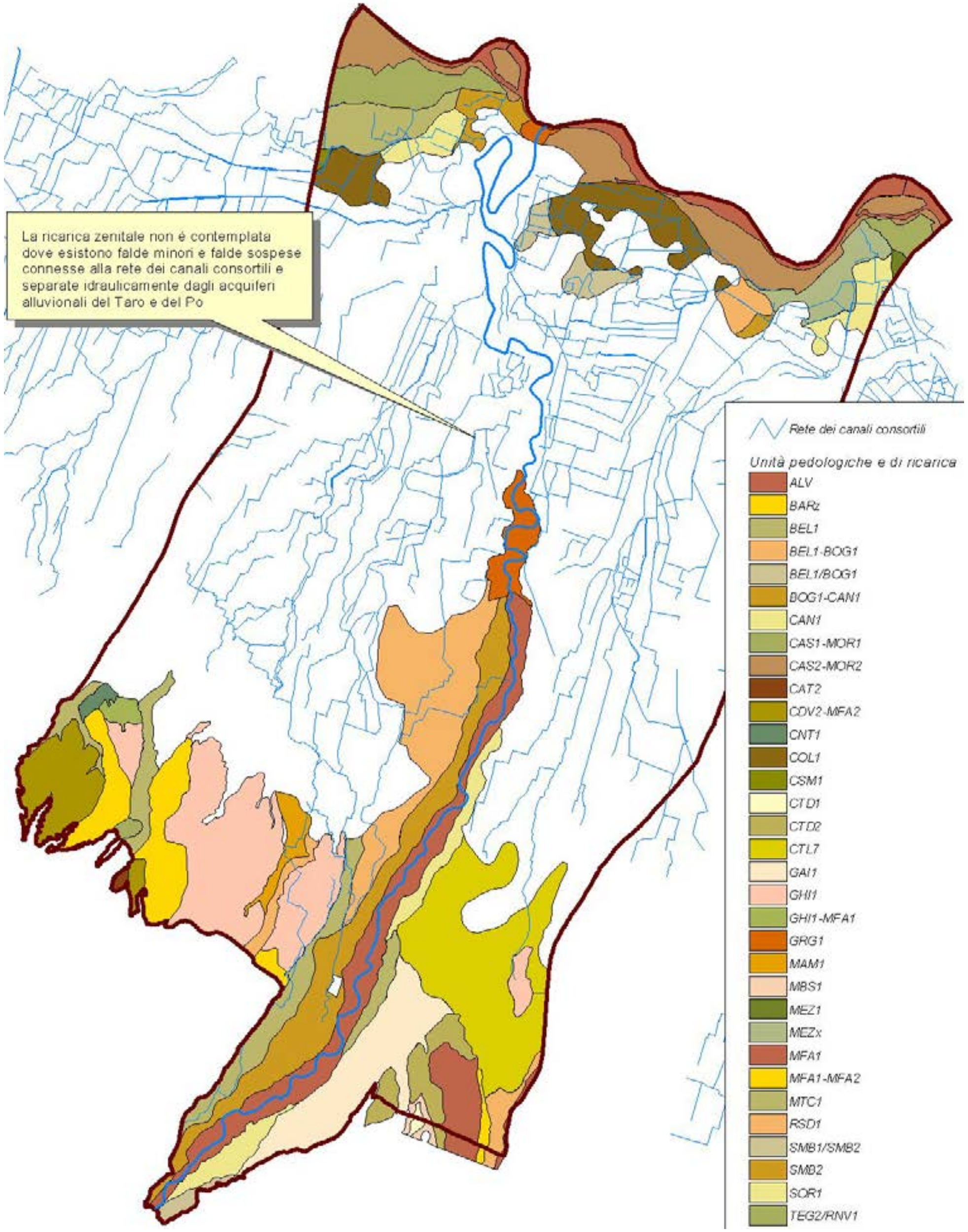


BOUNDARY CONDITIONS





AREAS OF INFILTRATION AND DIRECT RECHARGE FROM PRECIPITATION

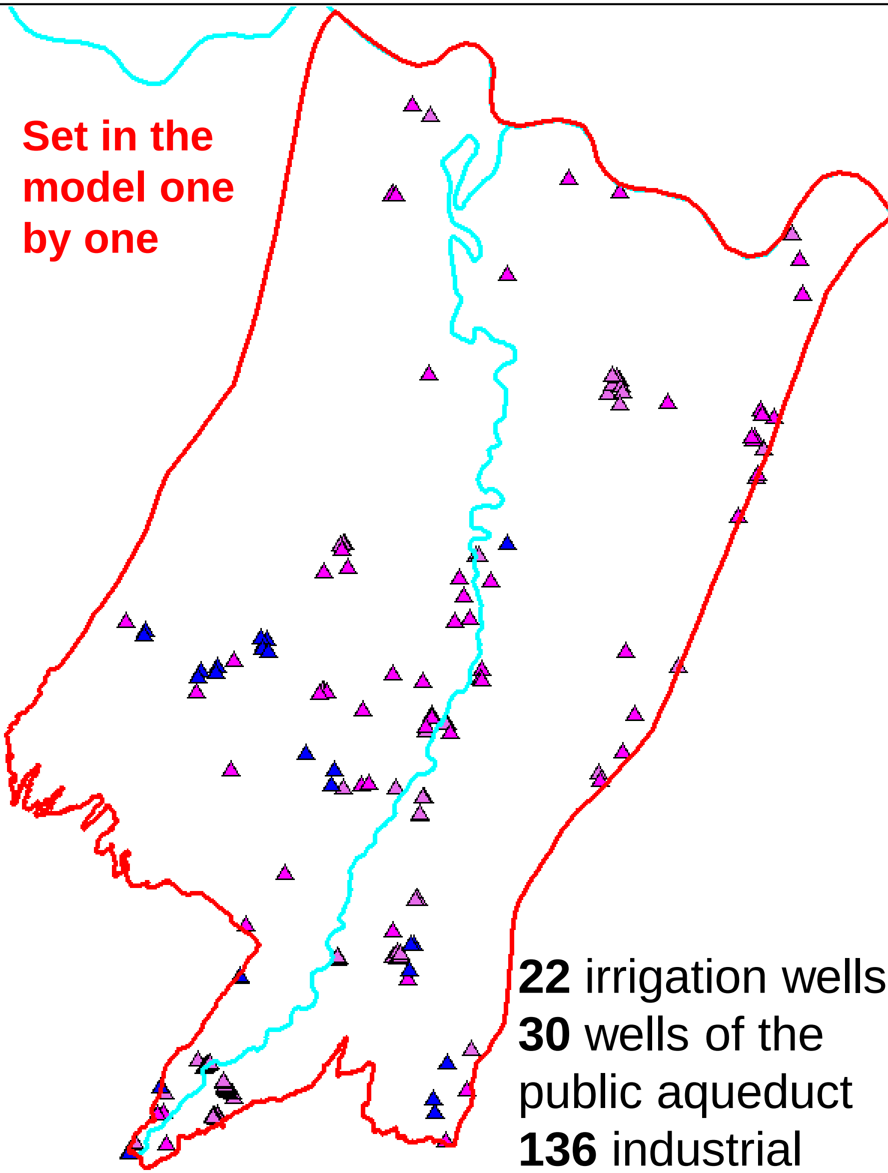
Daily zenithal recharge calculated by the mathematical model MACRO (LARSSON & JARVIS, 1999).

MACRO calculates coupled unsaturated-saturated water flow in cropped soil basing on pedological, climatic and cultivation data.

Local groundwater flow systems strictly connected to the irrigation channels network and hydraulically separated from the main aquifer systems have been intentionally removed from the hydrogeologic model of the Basin

PUMPING WATER WELLS

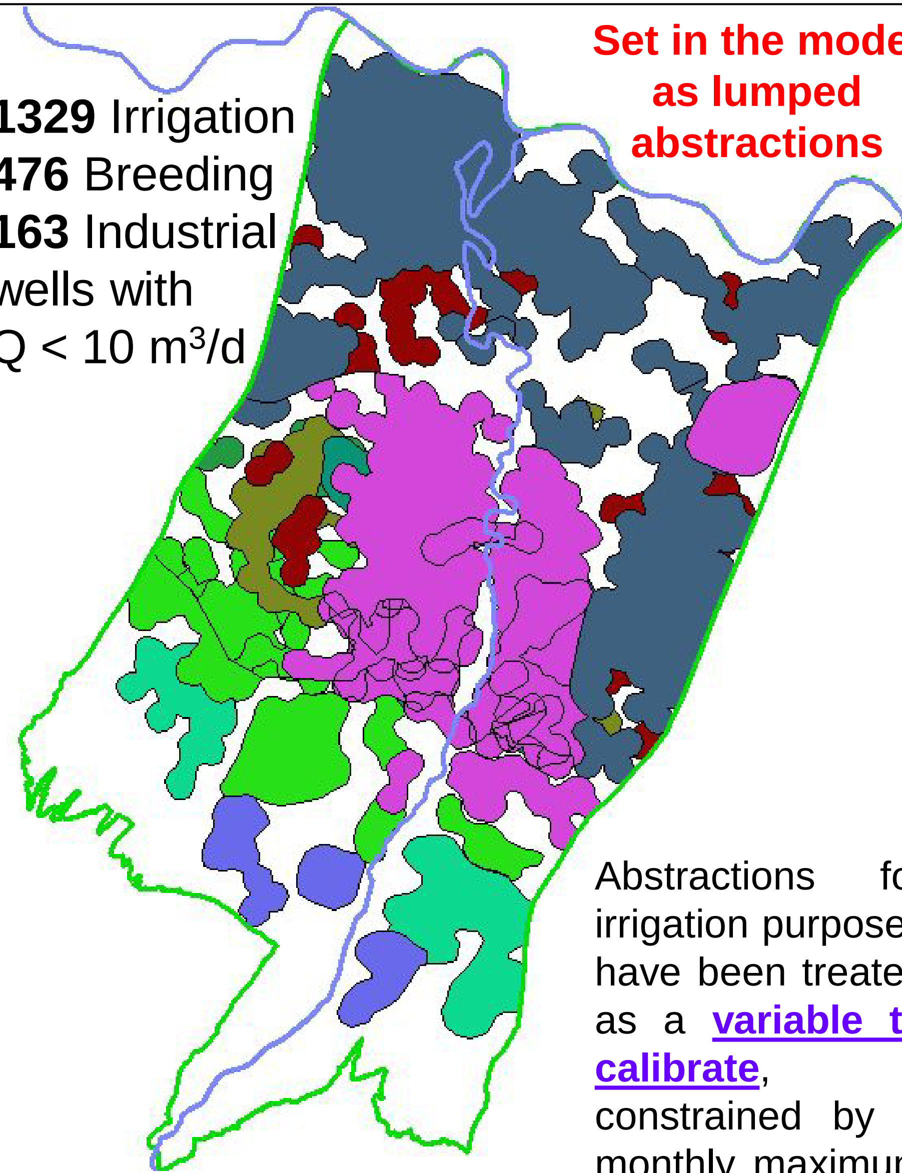
Set in the model one by one



22 irrigation wells
30 wells of the public aqueduct
136 industrial wells Q > 10 m³/d

1329 Irrigation
476 Breeding
163 Industrial wells with Q < 10 m³/d

Set in the model as lumped abstractions



Abstractions for irrigation purposes have been treated as a **variable to calibrate**, constrained by a monthly maximum limit.

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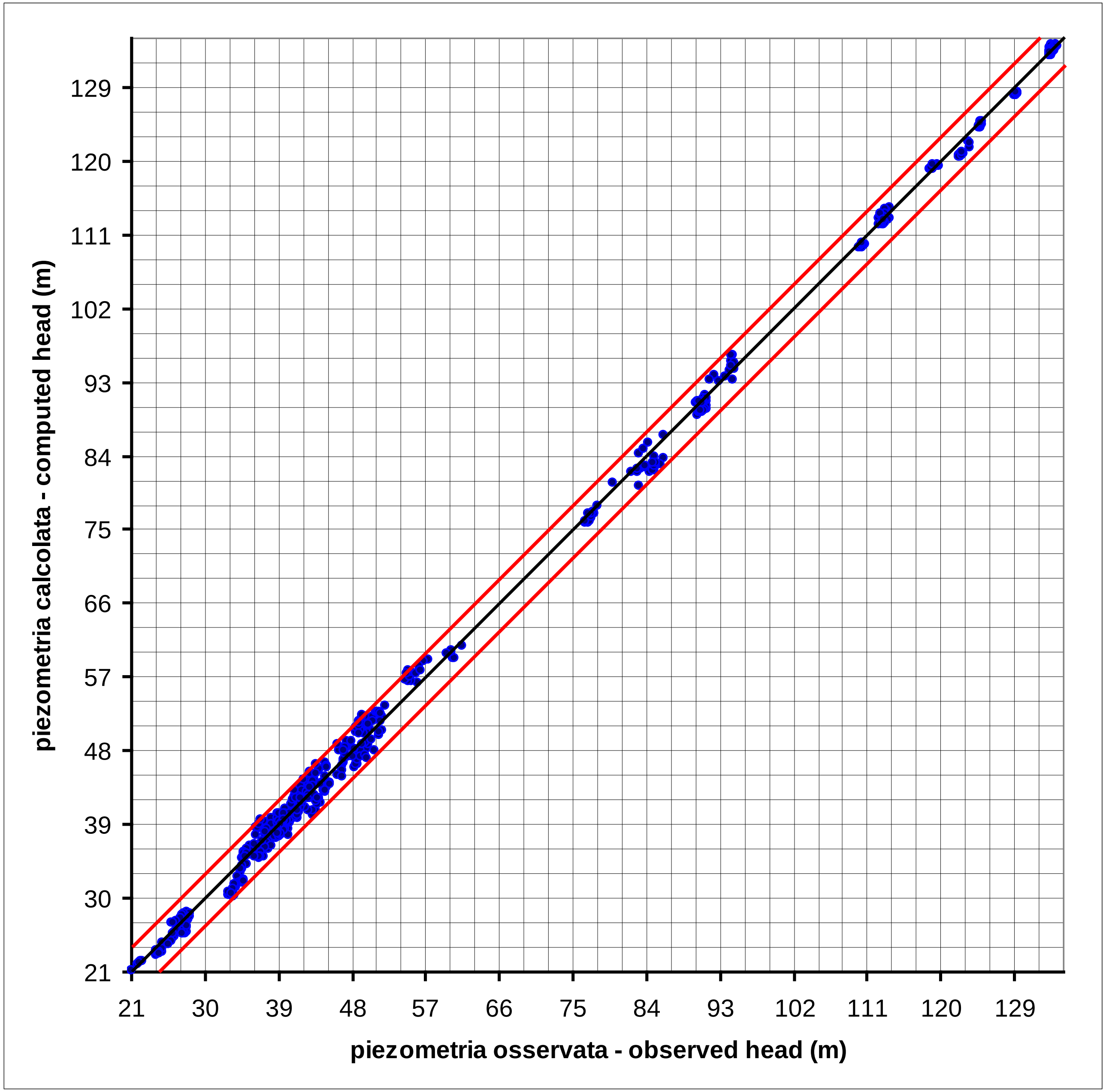
MODEL CALIBRATION



The 3D model of THRB has been calibrated simulating transient groundwater seepage and stream flows in the time period between 20/5/2005 and 31/10/2006.

Calibration Target: to find such a distribution of the hydrogeologic parameters and of the abstractions for irrigation purposes, that both the absolute value and the scattering of the differences between measured and simulated heads in the monitoring network fell below **3 meters**. This value may be considered consistent with the well heads elevation evaluation and the geometrical approximations allowed to build the hydrostratigraphic model.

Water Budget of the Hydrogeological Basin computed by the mathematic model	*from October 1st 2005 to September 30th 2006*

Water volumes entering the Hydrogeological Basin (Mm^3)	
Direct recharge from rainfall	**29.94**
Recharge from the Taro River bed	**39.98**
Recharge from the Baganza River bed	**11.58**
Recharge from the Taro River Minor Tributaries of the southern margin	**32.40**
TOTAL (Mm^3)	**113.90**
Water volumes leaving the Hydrogeological Basin (Mm^3)	
Leakage towards the Po River bed	**-13.23**
Pumping from breeding wells and industrial wells pumping less than 10 cubic meters per day	**-4.96**
Pumping from irrigation wells (CALIBRATED DATUM)	**-43.35**
Pumping from wells of the public aqueduct	**-17.00**
Pumping from industrial wells (pumping more than 10 cubic meters per day)	**-22.11**
TOTAL (Mm^3)	**-100.65**
Water volume stored into the Hydrogeological Basin (Mm^3)	**13.25**

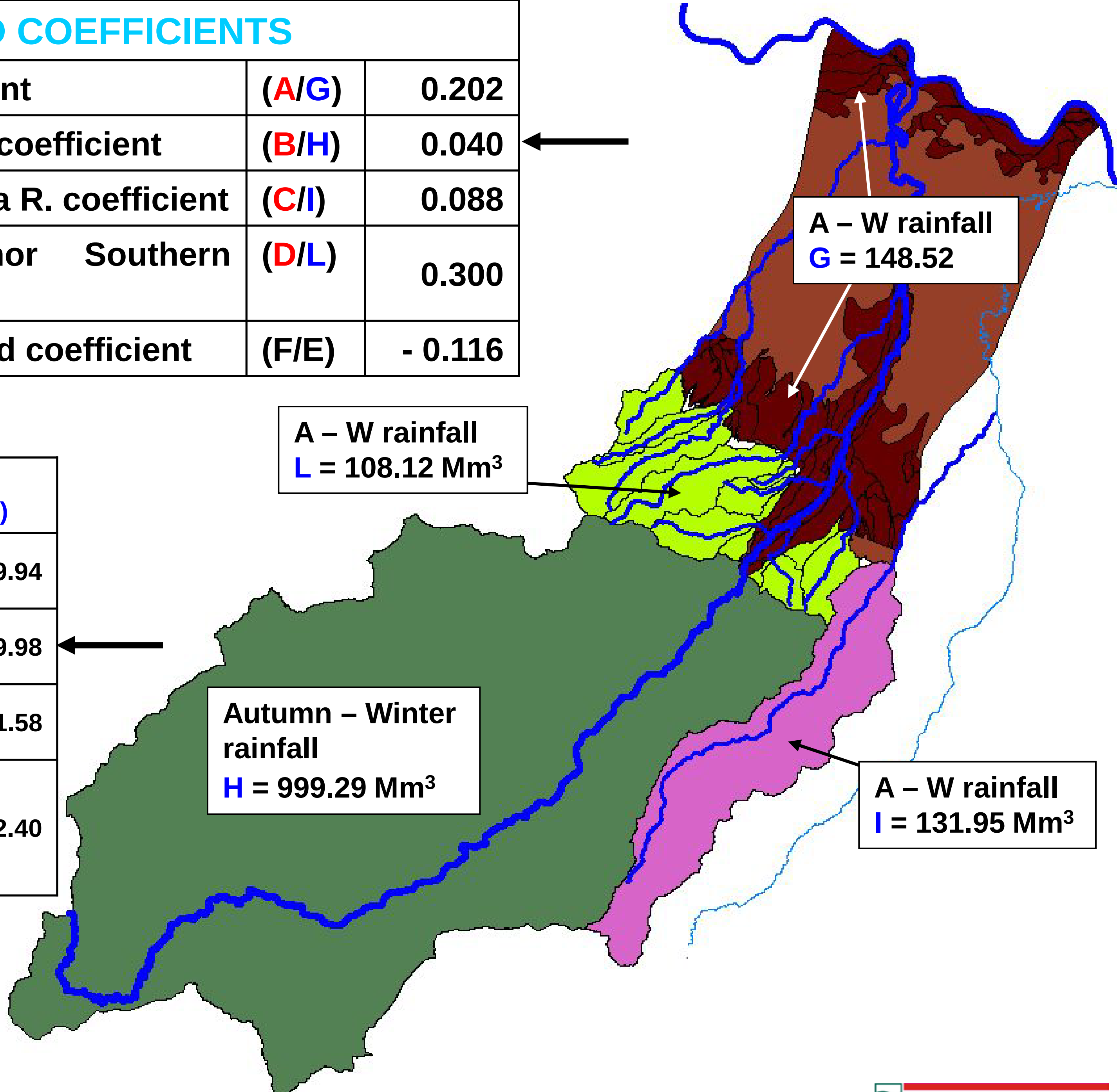
Recording the annual rainfall on the Hydrogeological Basin and on the mountain watersheds of the Taro River, Baganza River and Taro River Minor Tributaries of the southern margin, some **recharge and leakage coefficients** can be derived from the previous water budget:

Water volumes entering the Hydrogeological Basin (Mm^3)		
Direct recharge from rainfall	A	**29.94**
Recharge from the Taro River bed	B	**39.98**
Recharge from the Baganza River bed	C	**11.58**
Recharge from the Taro River Minor Tributaries of the southern margin	D	**32.40**
TOTAL (Mm^3)	E	**113.90**
Water volumes leaving the Hydrogeological Basin (Mm^3)		
Leakage towards the Po River bed	F	**-13.23**
Autumn – Winter rainfall (Mm^3) on the		
Hydrogeological Basin (221 km^2)	G	**148.52**
Taro River mountain watershed (1246 km^2)	H	**999.29**
Baganza River mountain watershed (164 km^2)	I	**131.95**
Taro River Minor Tributaries southern watersheds (150 km^2)	L	**108.12**

DERIVED COEFFICIENTS

Net infiltration coefficient	(A/G)	0.202
Recharge from Taro R. coefficient	(B/H)	0.040
Recharge from Baganza R. coefficient	(C/I)	0.088
Recharge from Minor Southern Tributaries coefficient	(D/L)	0.300
Leakage to Po River bed coefficient	(F/E)	- 0.116

Water volumes entering the Hydrogeological Basin (Mm³)		
Direct recharge from rainfall	A	29.94
Recharge from the Taro River bed	B	39.98
Recharge from the Baganza River bed	C	11.58
Recharge from the Taro River Minor Tributaries of the southern margin	D	32.40



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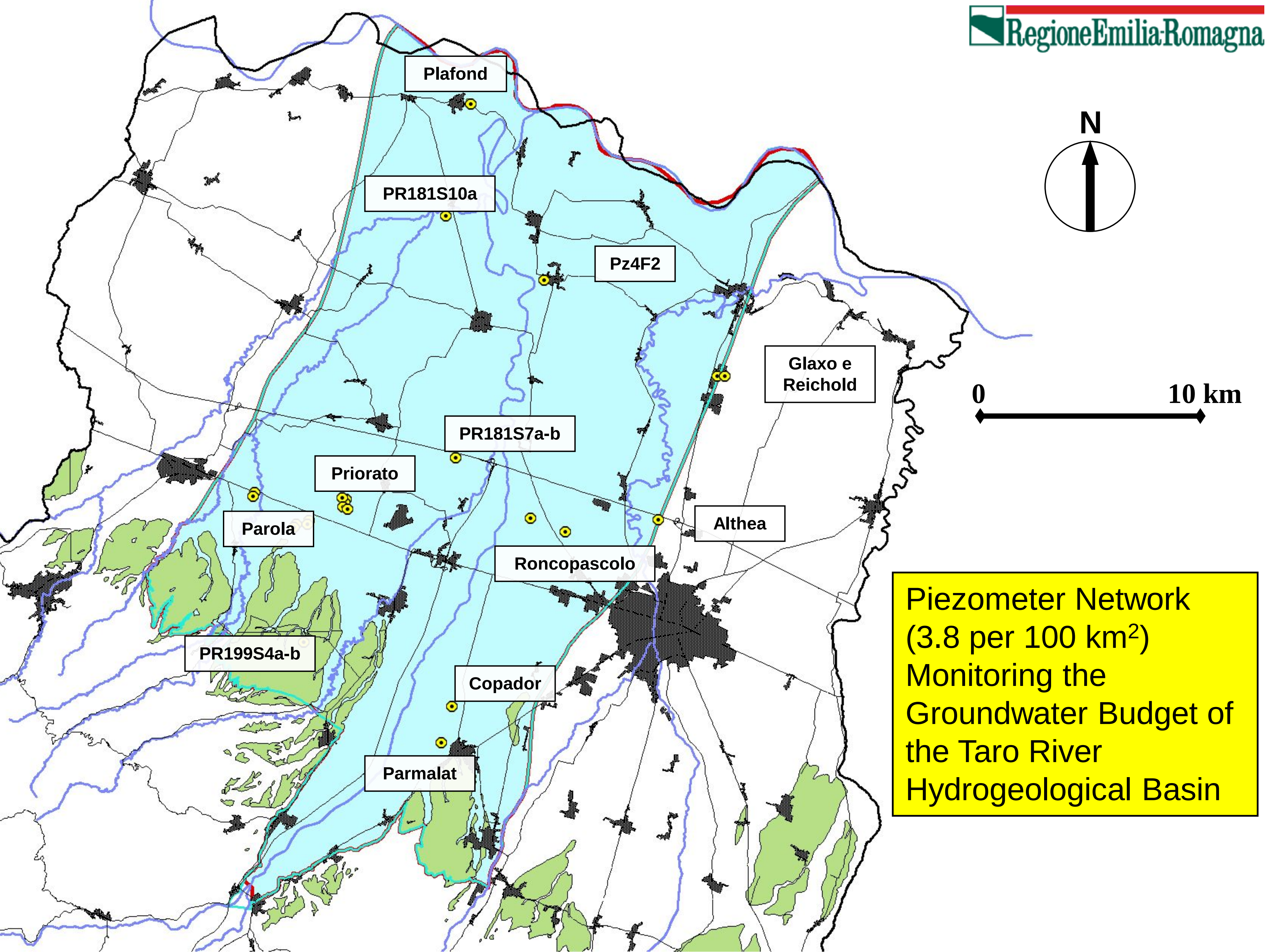

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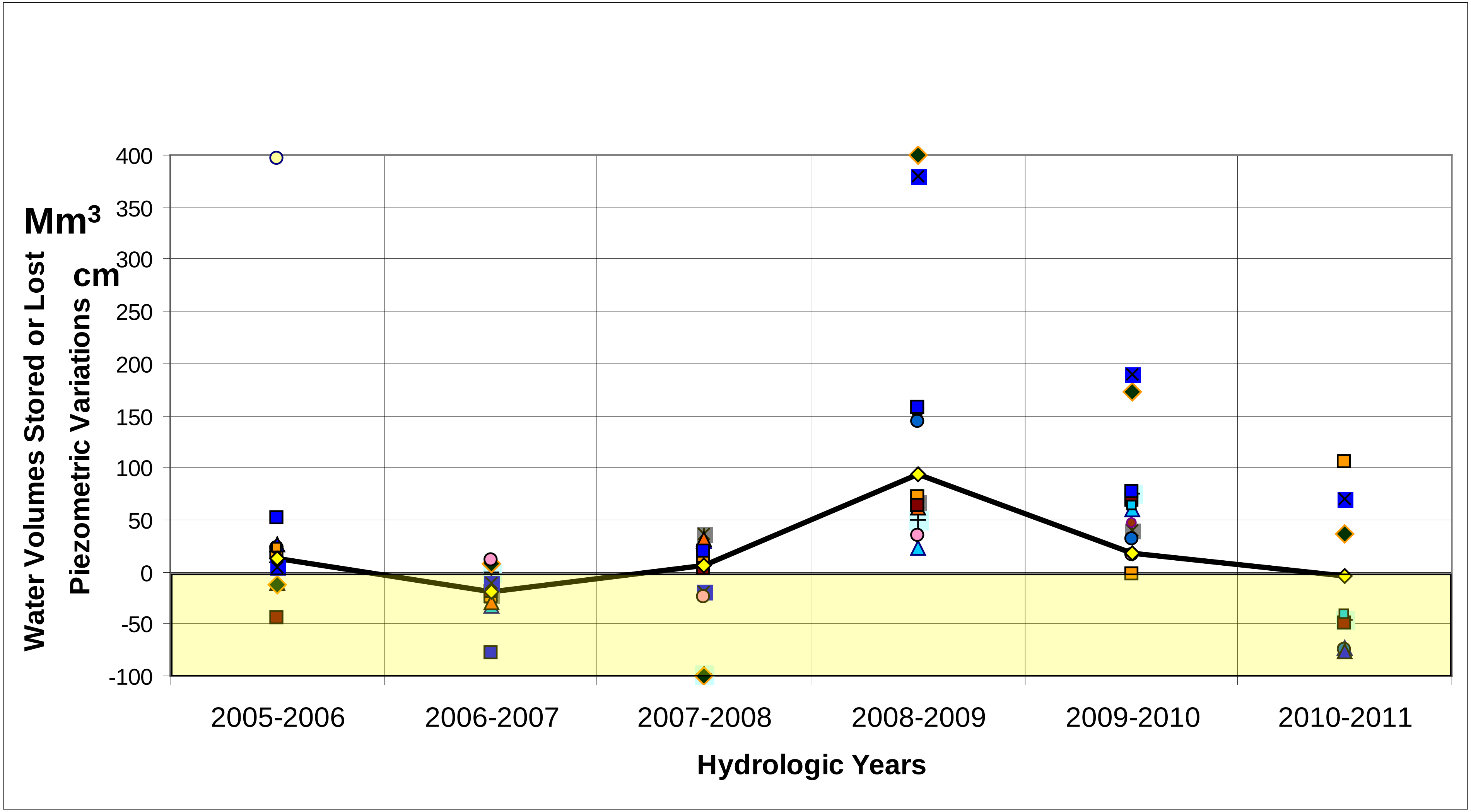
Plafond
PR181S10a
Pz4F2
Glaxo e
Reichold
N
0
10 km
PR181S7a-b
Priorato
Parola
Althea
Roncopascolo
PR199S4a-b
Copador
Parmalat
Piezometer Network
(3.8 per 100 km2)
Monitoring the
Groundwater Budget of
the Taro River
Hydrogeological Basin

Water budget variations (black line) obtained by means of the derived recharge and leakage coefficients, compared with the variations of the piezometry recorded in the 21 piezometers of the monitoring network



CONCLUSIONS

The availability of a detailed and calibrated model of a Hydrogeologic Basin enables the evaluation of its water budget for a particular hydrologic year, even without running the original mathematic model.

This is possible by means of the exposed method of the **recharge and leakage coefficients** derived from the recordings of the annual rainfall. This method can be validated by monitoring the annual variations of the groundwater level in the Hydrogeological Basin on an essential piezometer network specifically designed for this target.