Mapping of low enthalpy geothermal resources. The example of Parma

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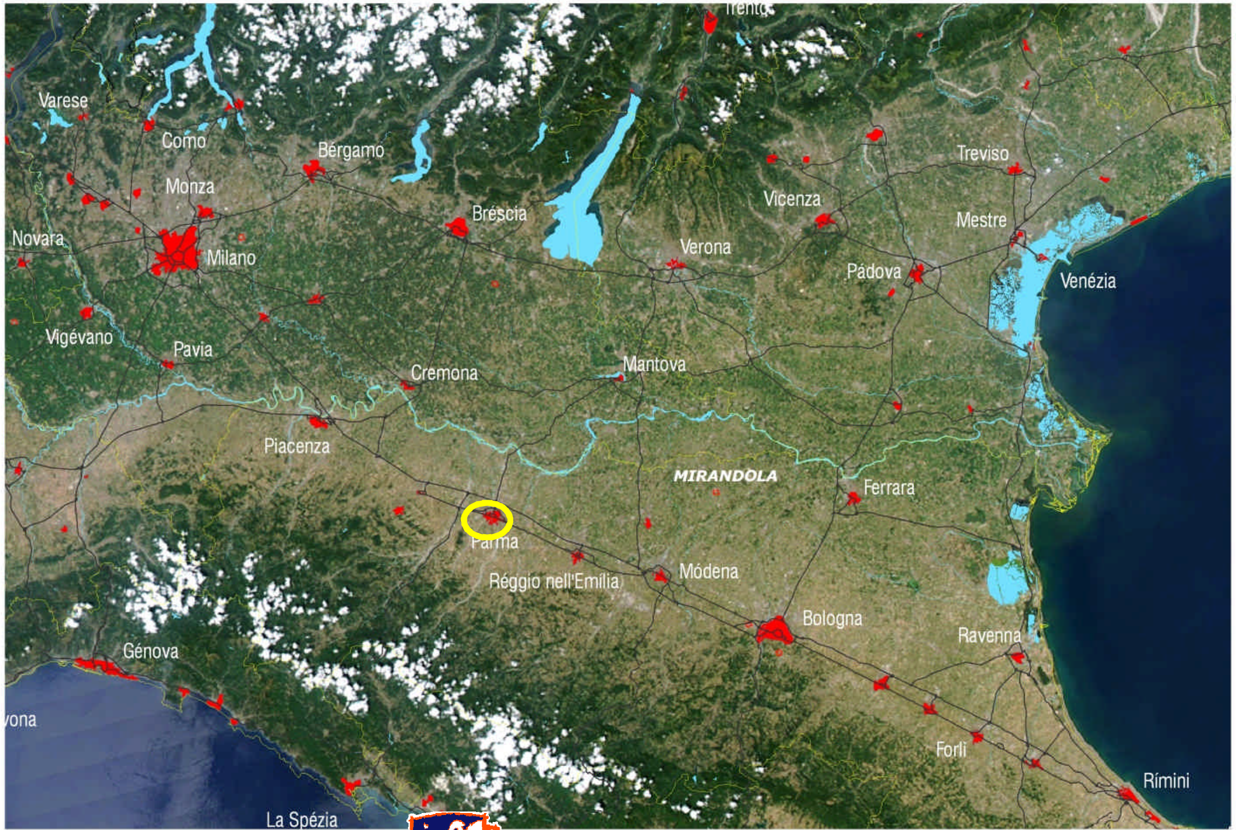
STUDY AREA

We study the area of the city of Parma in the Emilia-Romagna Region, located in the flood plain at the foot of the Apennine chain (Figura 2).

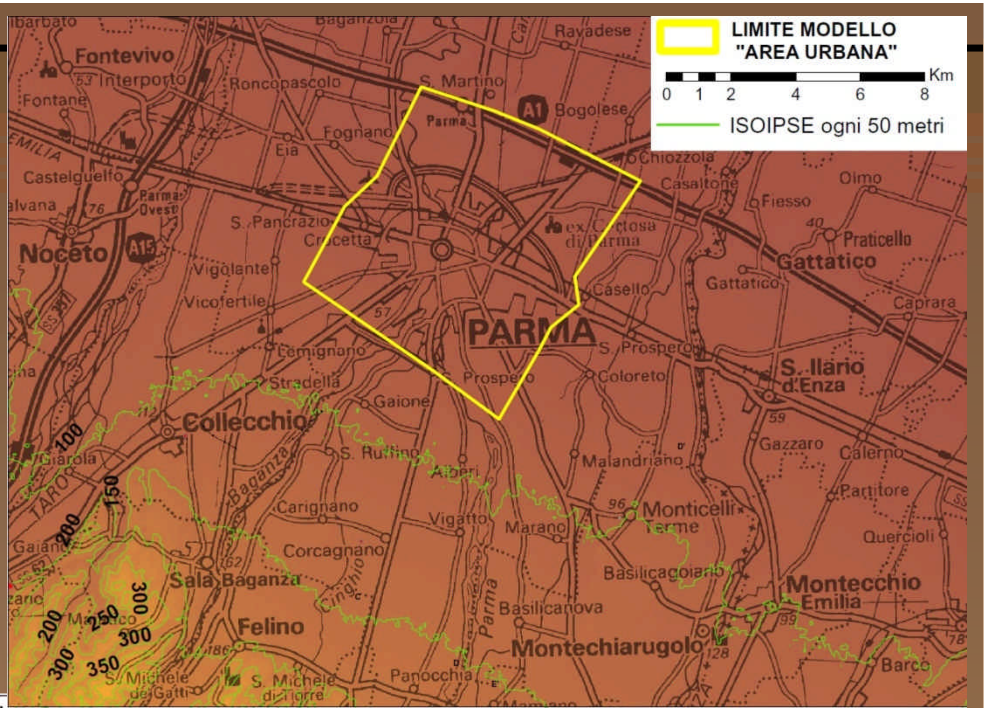
The city of Parma has a population of about 180,000 people and is the second city after Bologna.

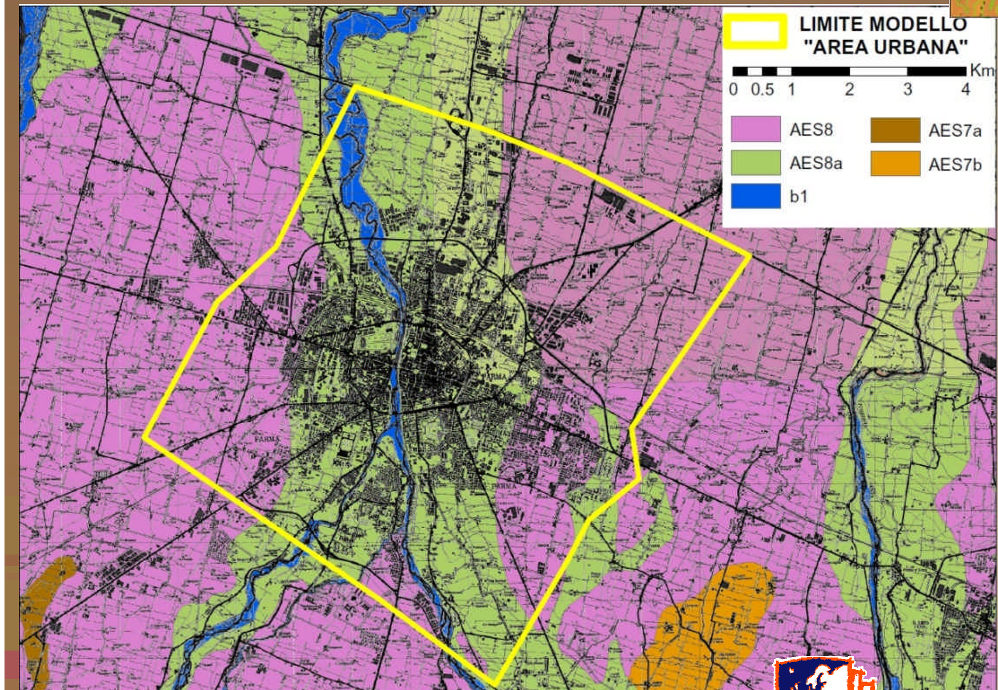
In recent years the urban area have been authorized and carried out various low entahlpy plants both open and closed loops.



GEOMORPHOLOGICAL FRAMEWORK

The study area including the portion of high and medium padan plain. The quote is reaching higher in south with about 75 m a.s.l. while toward noth the surface degrade to about 40 m a.s.l.. The entire area is drained bt t. Parma and t. Baganza.





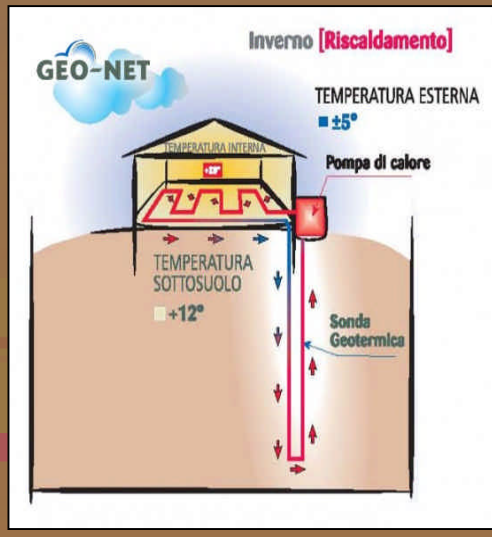
GEOLOGICAL FRAMEWORK

In surface the geological units belong to Higher Sintema of Emilia-Romagna (AES). The subsintema outcropping is the Ravenna Unit (AES8) and Modena Unit (AES8a). These geological units are charactherized by alluvial deposits both coarse (gravel and sand) that fine (mud and silt).

The exploitation of low enthalpy geothermal reservoir

In the city of Parma is spreading the practice of conditioned buildings through the heat pump system using geothermal energy.
From the technical point of view the geothermal reservoir can be explioted by means of:

1. Extraction of groundwater through wells and sending the fluid to the heat pump – refrigerator unit. The system with water with drawl is called open loop.

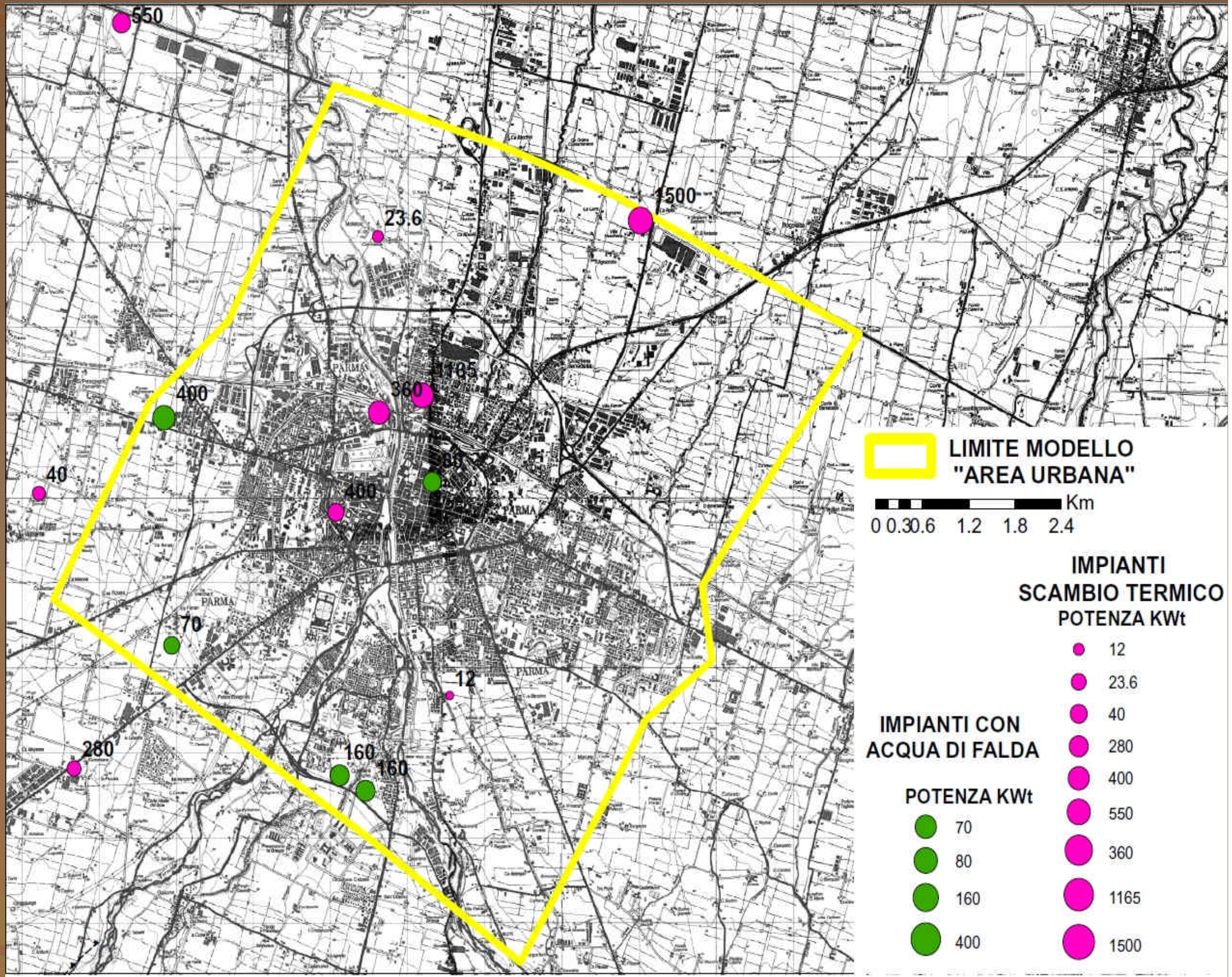


2. Heat exchange with the geothermal reservoir through fluids circulating in closed loop pipes cemented in to the ground, without the taking of groundwater. The system without water withdrawl is also called closed loop.

LOW ENTHALPY GEOTHERMAL PLANTS IN THE STUDY AREA

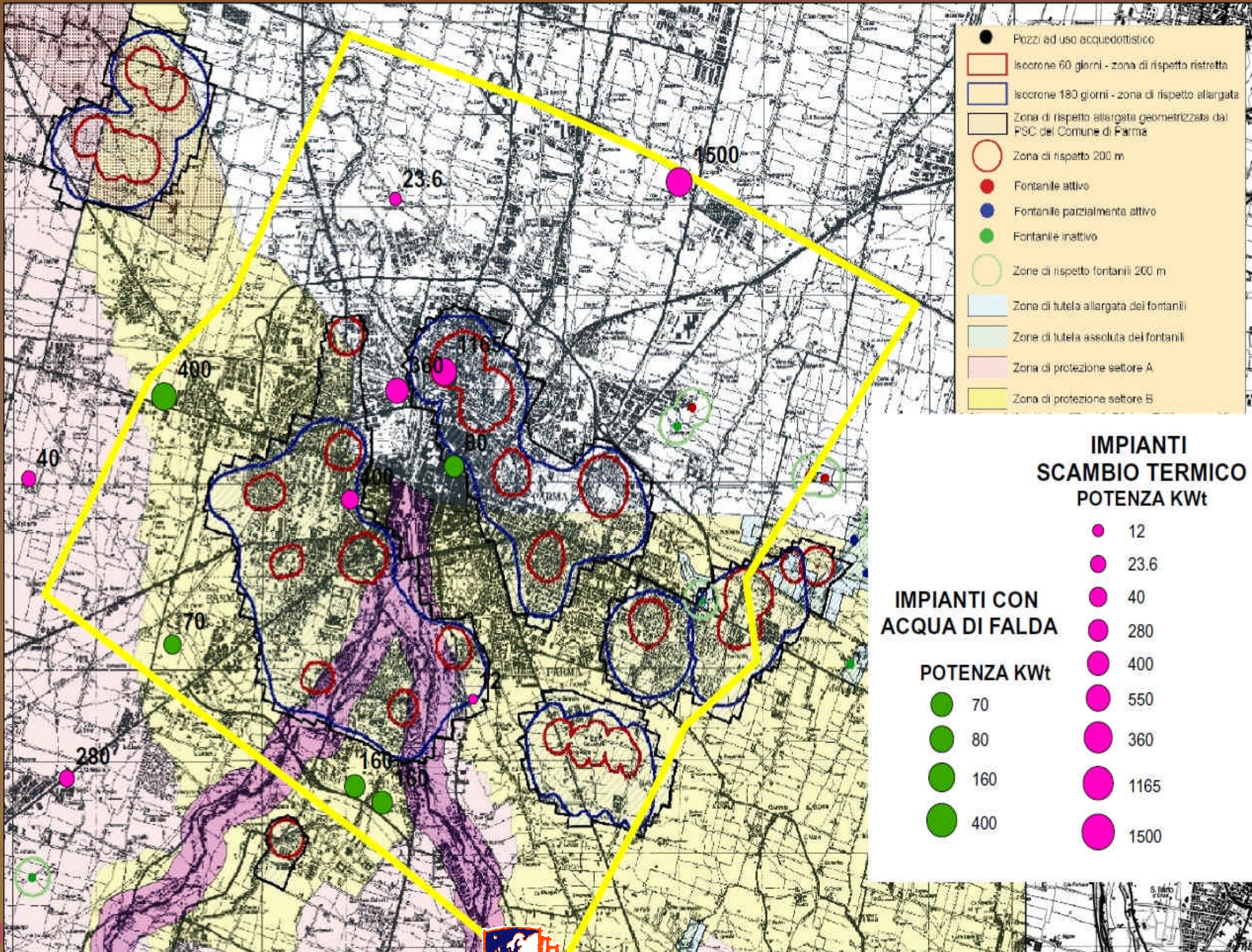
In recent years have been installed, in the urban area, some geothermal plants. Today were approved 5 open loop plants that reached the total power of about 800 KWt and the wells have an average depth of about 30-35 meters.

The plants approved wirh heat exchange in the underground (closed loop) are 6 and reached a total installed capacity of about 3500 KWt. The average depth of gothermal probe is about 120-130 meters.



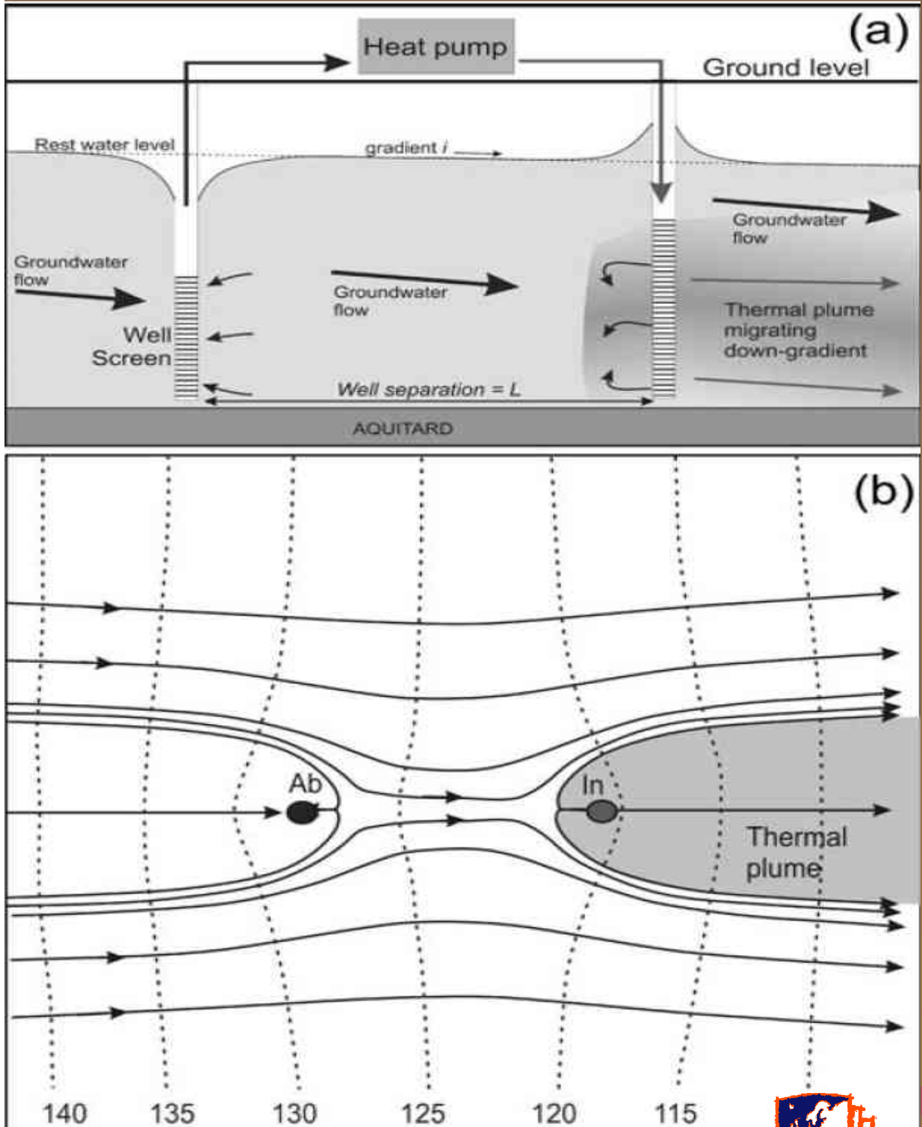
POSSIBLE IMPACTS ON THE TERRITORY

GEOTHERMAL PLANTS APPROVED AND ZONE OF PROTECTION OF GROUNDWATER RESOURCES

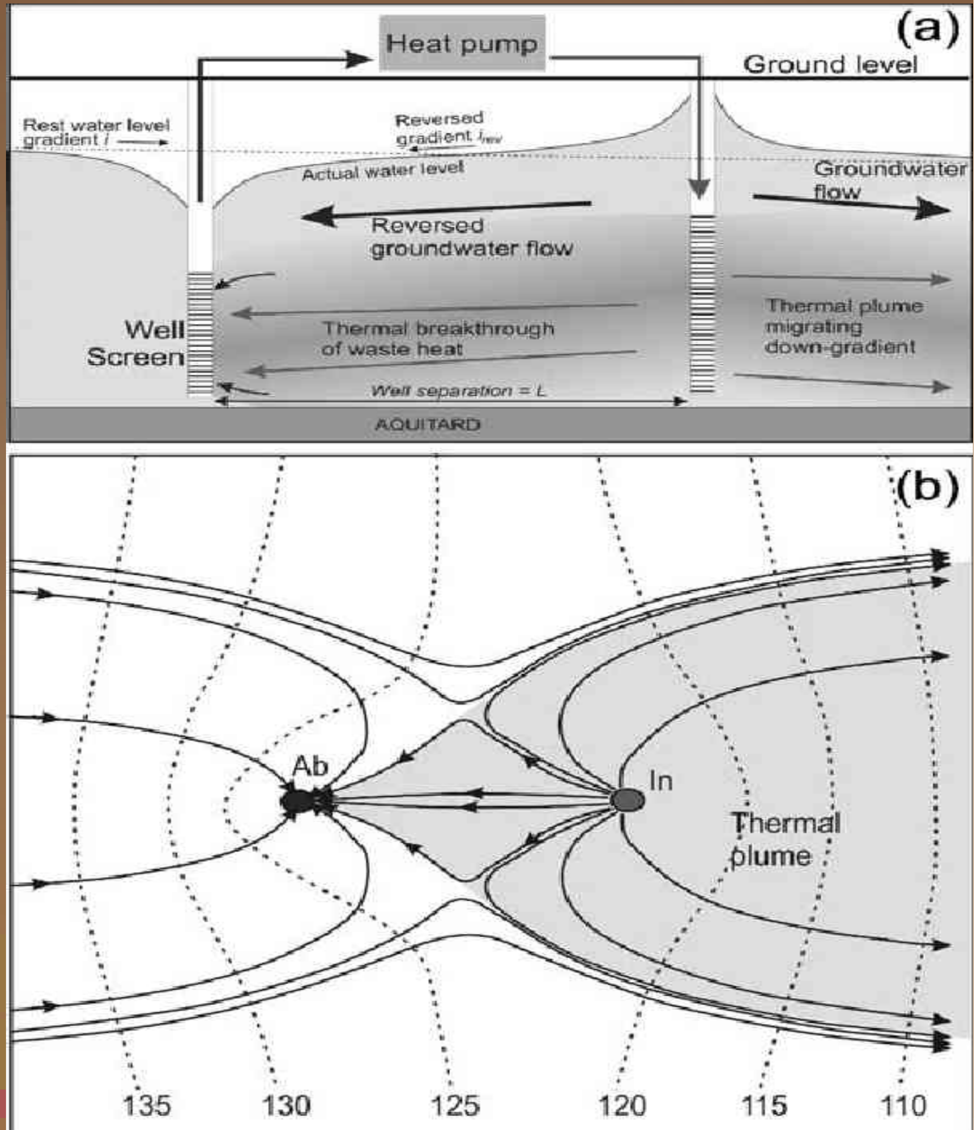


THE PHENOMENON OF THERMAL SHORTING

Vertical section and plan view diagram of a doublet geothermal wells without thermal interference (Banks, 2009).



Vertical section and plan view diagram of a doublet geothermla wells with potential thermal ineterference (Banks, 2009).

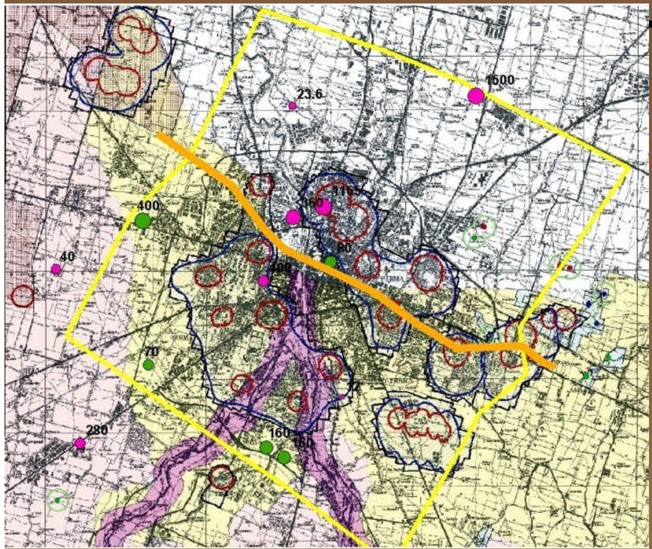


CURRENT STATE OF KNOWLEDGE

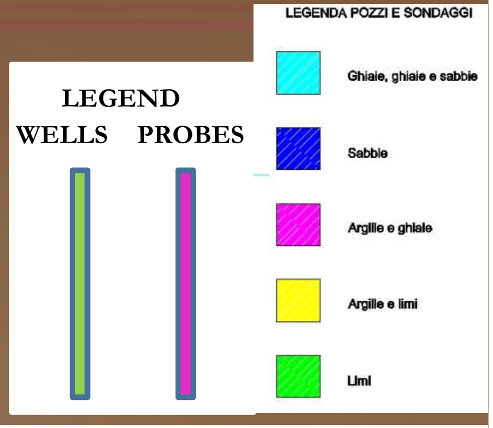
Example of mathematical model of open loop geothermal system serving a spa-hotel.

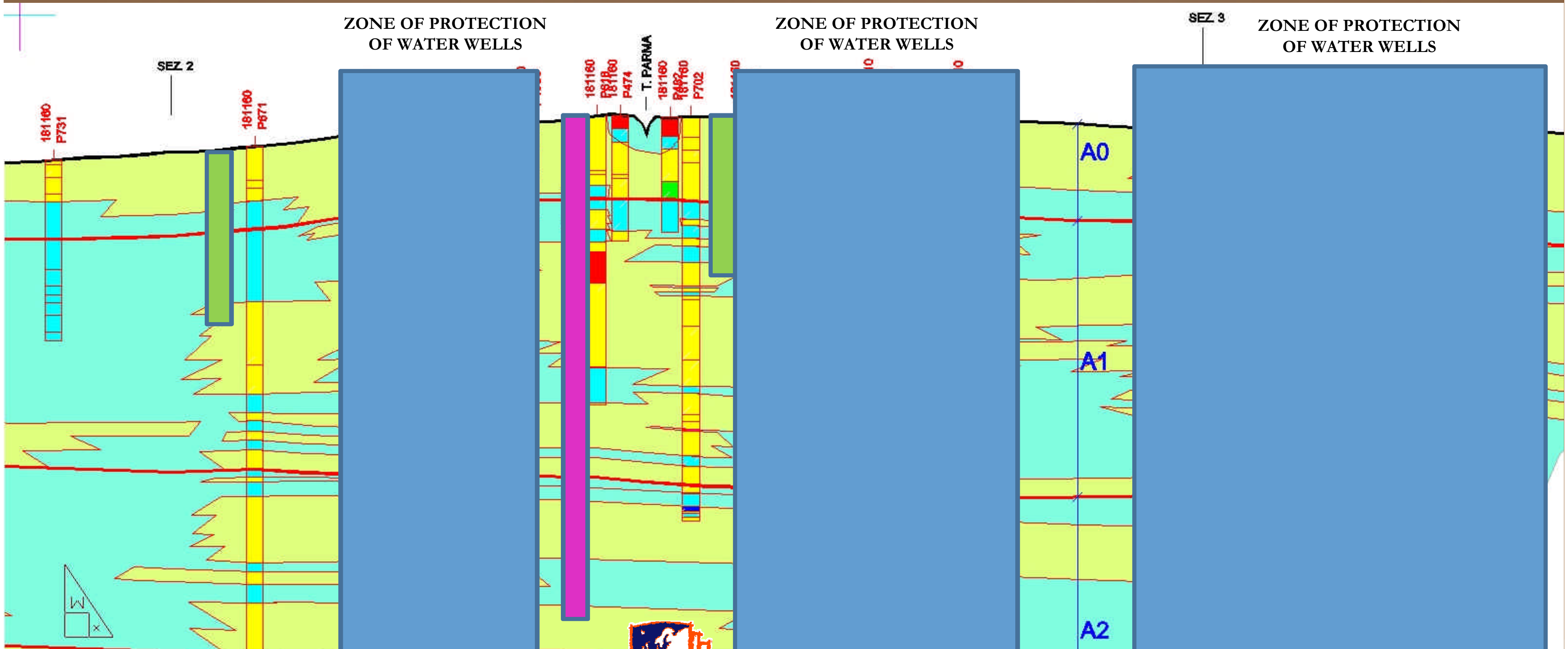
Open loop system type consisting of 2 drawing wells and 2 restitution wells.
Heating Power Peak 1043 KW
Cooling Power Peek: 668 KW
Flow rate instant peek: 40 liter/second

Plume of cold water after 20 years of operation and areas of influence of withdrawl and restitution



EXAMPLE OF GEOLOGICAL SECTION WITH THE PRESENCE OF GEOTHERMAL SYSTEMS AND THE LIMITS OF PROTECION AREA OF WATER WELLS





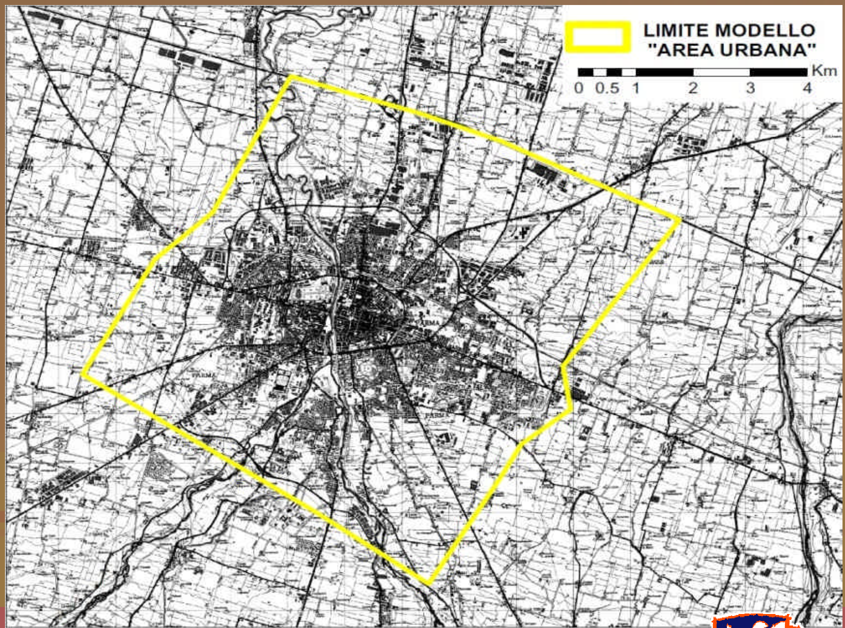
PURPOSE OF THE PROJECT

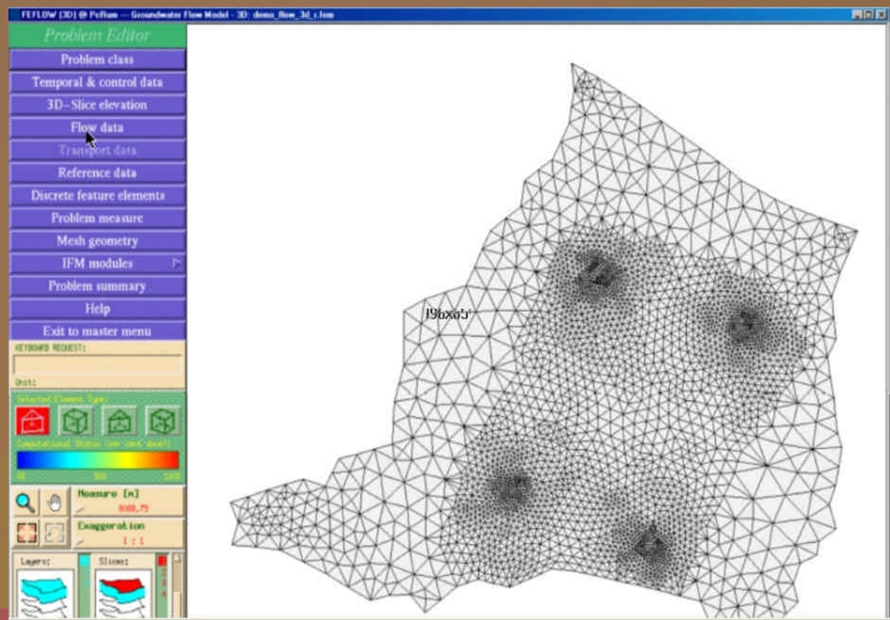
The main purpose of the study is the creation of thematic maps aimed at zoning of the territory according to the sustainability of hydrogelogicl system for heat exchange with the subsurface.

The cartographic maps will be operational tools for the industry, both public and private.

For the achievement of this objective is necessary to develop a mathematical flow and heat transport 3D model in steady state.

The software to be used is the finite element code «FEFLOW 6» (WASY).





METHODOLOGY OF WORK

The work methodology is based on three phases:

I) On an accurate recostruction of the 3D subsurface stratigraphic model with the mapping of the main stratigraphic surface (bases of different aquifers complex) that will identify the different layers of the model and tha mapping of isopercentual of coarse deposit (gravels and sands - aquifers) compared to fine deposits (clays and silts – aquiclude) within the different layers.

II) Input of stratigraphic and hydrogeological data in the mathematical model and setting of the boundary conditions of the flow model.

III) Run and calibration of the mathematical flow model in steady state.

IV) Input of physical data related to sedimentay deposits and to open and closed loop system in the model and setting the boundary condition of heat transport model

V) Run and calibration of the flow and heat transport model in steady state condition in order to simulate the different operating condition, both open and close loops system, in the different aquifer complexes in the study urban area and falling within the physicla domain of the model.

METHODOLOGY OF WORK

Before carrying out simulations will be estabilished hydrogeological costraints the main ones are:

- the maximum variation in temperature between extraction and re-entry
- The maximum distance, with respect to the points of disturbance, that is considered acceptable for a given thermal variation

The matematical model simulates the formation of thermal plume in grondwater and soils caused by the use of geothermal heat pumps both in closed and open loops system. In this way the maps will be zoned to give the limits of sustainability in relation to the density of existing hydrogeological constraints. Infact the envirinmental impact and efficiency of these system depend mainly on the density of the plants on certain portion of the urban area.

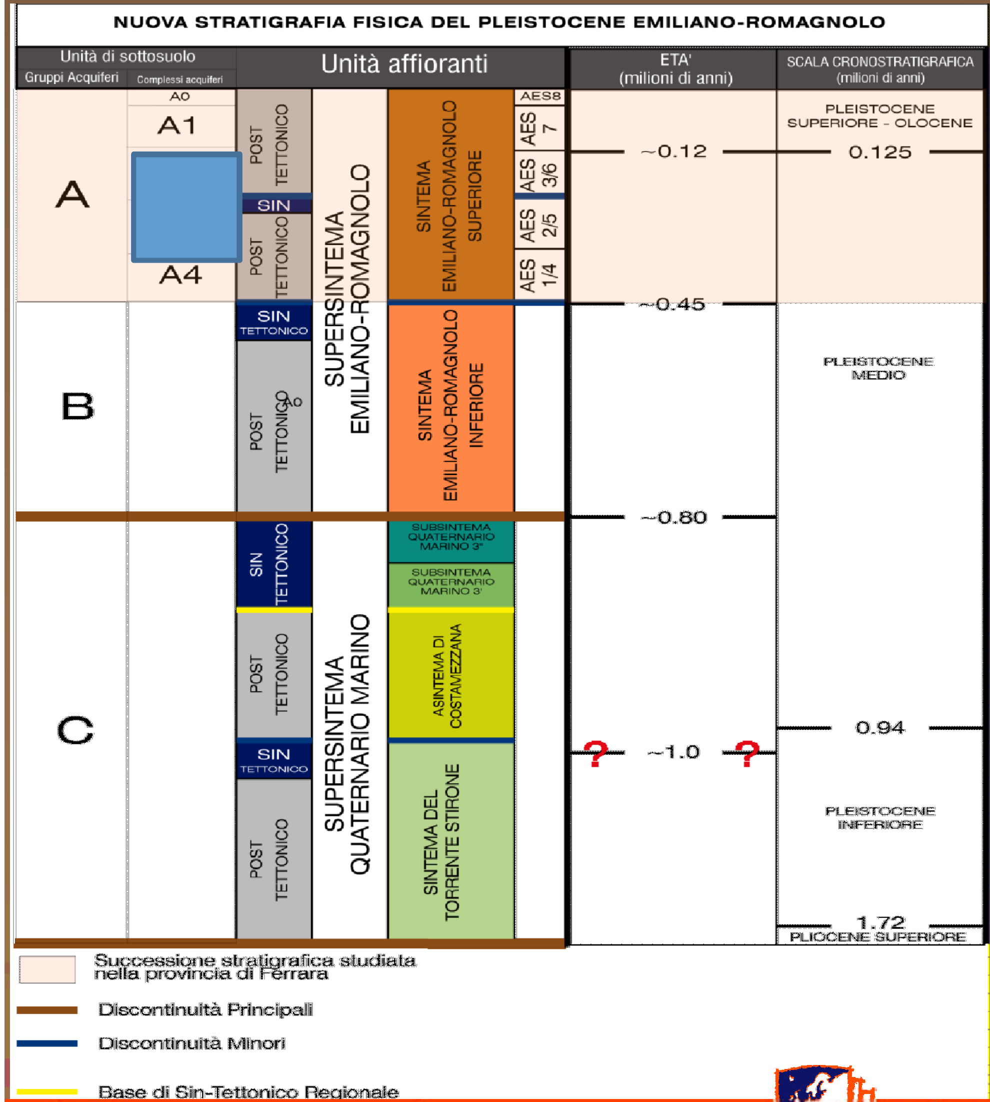
The maps will be used to etimate both the environmental impact of possible geothermal plants to protect the efficinecy of the same, in order to avoid thermal interference.

FIRST PHASE– PARMA URBAN AREA PROJECT

SUMMARY OF MAJOR ACTIVITIES HELD DURING THE FIRST PHASE OF THE PROJECT.
REFERENCE PERIOD OCTOBER 2011 – MAY 2012

The activities during the first phase of the project had as main purpose the reconstruction of a three-dimensional model of the hydrogeological system in the urban area. This goal has been achieved through the development of bathymetric GRID of the main hydostrtigraphic surfaces that have been identifid in the physical domain of the model

HYDROSTRATIGRAPHIC REGIONAL MODEL

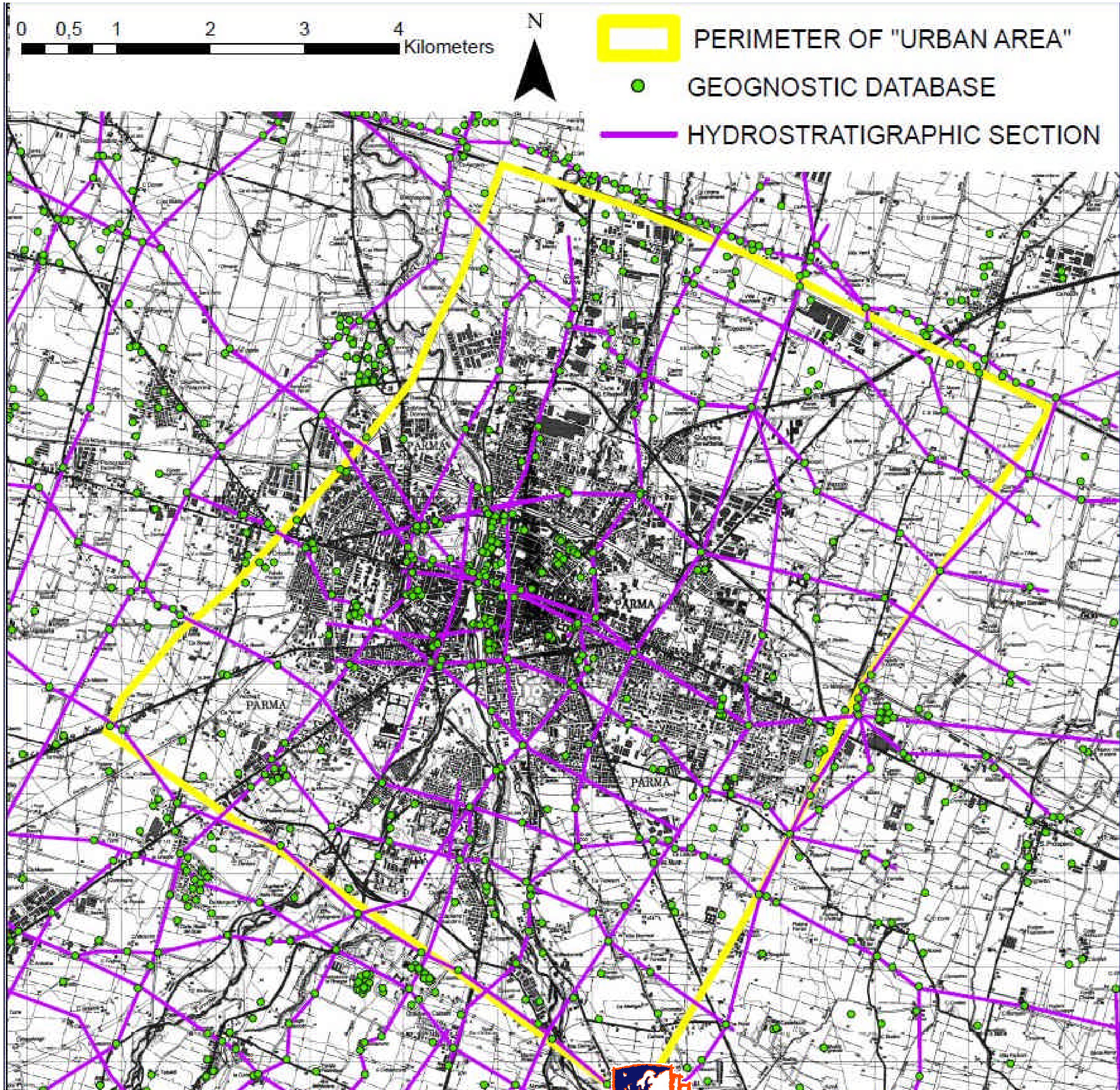


In Emilia-Romagna region exist a reference hydrostrigraphic model (RER-ENI, 1998).

The physical domain of the model will include the aquifers complex A0, A1 and A2 belonging to Group Aquifer «A». The base of the model coincide with the base of aquifer Complex «A2».

The choice of the physical model domain is due to the fact that in the urban sector the major aquifers complex exploited, especially for aqueduct purpose, are precisely the aquifer system A1 and A2.

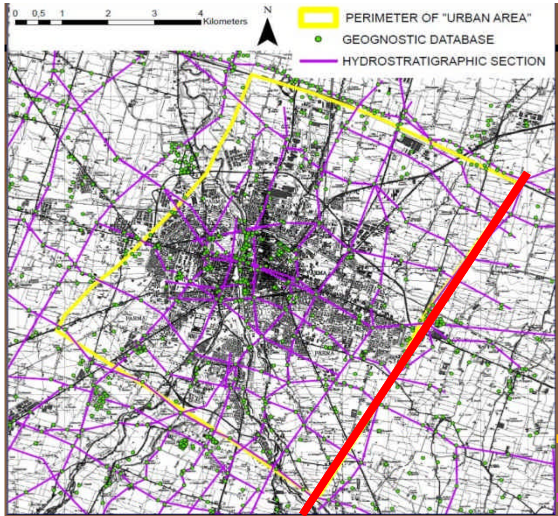
In the study area the base af aquifer complex A2 reaches the maximum depth of about 140 meters. This means that most of the geothermal power plants already made and future hardly exceed the order of 150 meters depth.



GEOGNOSTIC DATABASE

ABOUT 500 BETWEEN WATER WELLS, SONDAGGI E POVE PENETROMETRICHE

NETWORK OF 18 HYDROSTRATIGRAPHIC SECTION



I STEP - HYDROSTRATIGRAPHIC SECTION

Review and geometry control of hydrogeological sections regarding the study area, on which were highlighted four main stratigraphic surfaces

Surface P1: base of Unit Aes8 (A0)

Surface P2: base of Unit Aes7b (A1sup)

Surface P3: base of Unit Aes7a (A1inf)

Surface P4: base of Unit Aes3 (A2)

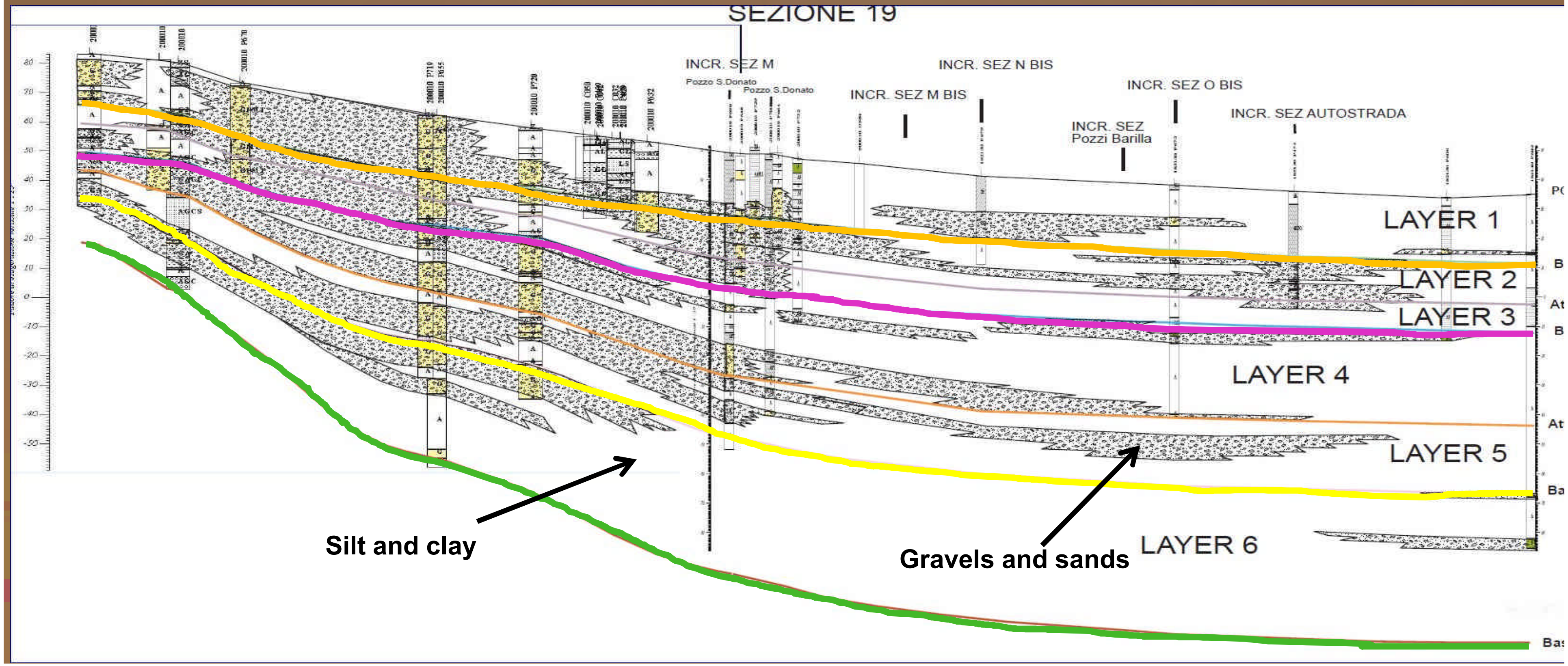
MAIN STRATIGRAPHIC SURFACES OF THE MODEL

- Base of Aquifer Complex A0
- Base of Aquifer Complex A1-sup.
- Base of Aquifer Complex A1-inf.
- Base of Aquifer Complex A2

In addition are also highlighted two surfaces of activation of river systems called respectively

Surface P1r

Surface P2r



II Step – CREATION OF SHAPE FILE

Using the wells point in the hydrostratigraphic sections and the points of intersection of the sections have been created shape file for each surface of the model

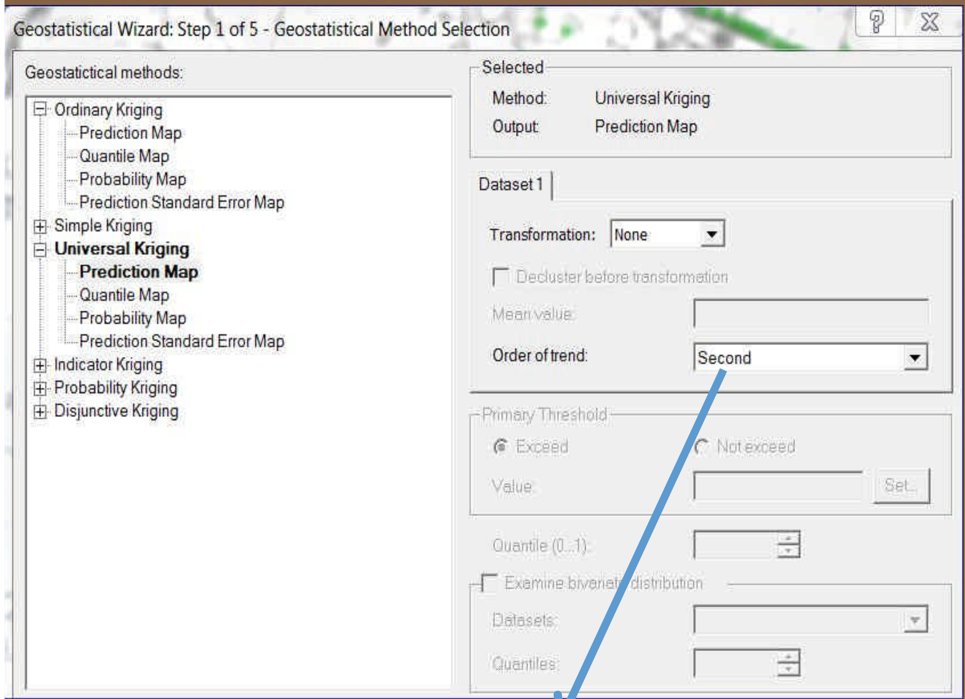
The shape files have the following table of Attribute:

Shape *	ID	ID_Pozzo	X	Y	PC	P1	P1_slm
Point	1	181160P4001	604627	966746	42,467991	-21,5	20,97
Point	2	181160P4038	605186	966732	40,014671	-20	20,01
Point	3	181160P4039	605353	966653	39,94323	-20	19,94
Point	4	181160P405	603553	961758	56,805691	-18,1	38,71
Point	5	181160P427C	604144	962667	53,813019	-20,5	33,31
Point	6	181160P436B	604222	962631	54,027748	-20,2	33,83
Point	7	181160P437	604112	962636	53,853611	-20	33,85
Point	8	181160P451	604979	962772	51,965988	-25	26,97
Point	9	181160P453	605155	962795	51,311668	-25,5	25,81
Point	10	181160P501	601237	962051	59,80674	-17	42,81
Point	11	181160P607	601111	961974	61,59856	-15	46,6
Point	12	181160P613	601638	961727	61,212872	-15,5	45,71
Point	13	181160P616	602609	962639	54,589199	-19	35,59
Point	14	181160P618	604493	962326	55,106979	-21,5	33,61
Point	15	181160P619	603242	961942	55,506229	-16,8	38,71
Point	16	181160P621	604045	962442	54,237469	-20	34,24
Point	17	181160P623	604471	966197	42,91325	-22	20,91
Point	18	181160P624	604488	966572	42,634449	-22	20,63
Point	19	181160P640	602283	962785	54,350269	-18	36,35
Point	20	181160P647	601705	963031	53,337971	-15	38,34
Point	21	181160P653	601391	961834	61,7719	-17	44,77
Point	22	181160P657	603393	964739	45,763729	-21	24,76
Point	23	181160P658	603206	964575	46,05645	-20	26,06
Point	24	181160P670	603603	963610	49,602299	-19,4	30,2
Point	25	181160P671	603138	963847	47,64011	-18	29,64
Point	26	181160P688	605369	965296	42,84988	-22,2	20,65
Point	27	181160P691	605016	964323	48,137489	-23	25,14
Point	28	181160P700	604084	962359	54,530239	-20	34,53
Point	29	181160P702	604991	962068	54,630939	-22	32,63
Point	30	181160P704	602963	962441	54,215519	-17,5	36,72
Point	31	181160P705	601556	961795	60,896839	-15	45,9

III STEP – GEOSTATISTICAL ANALYSIS

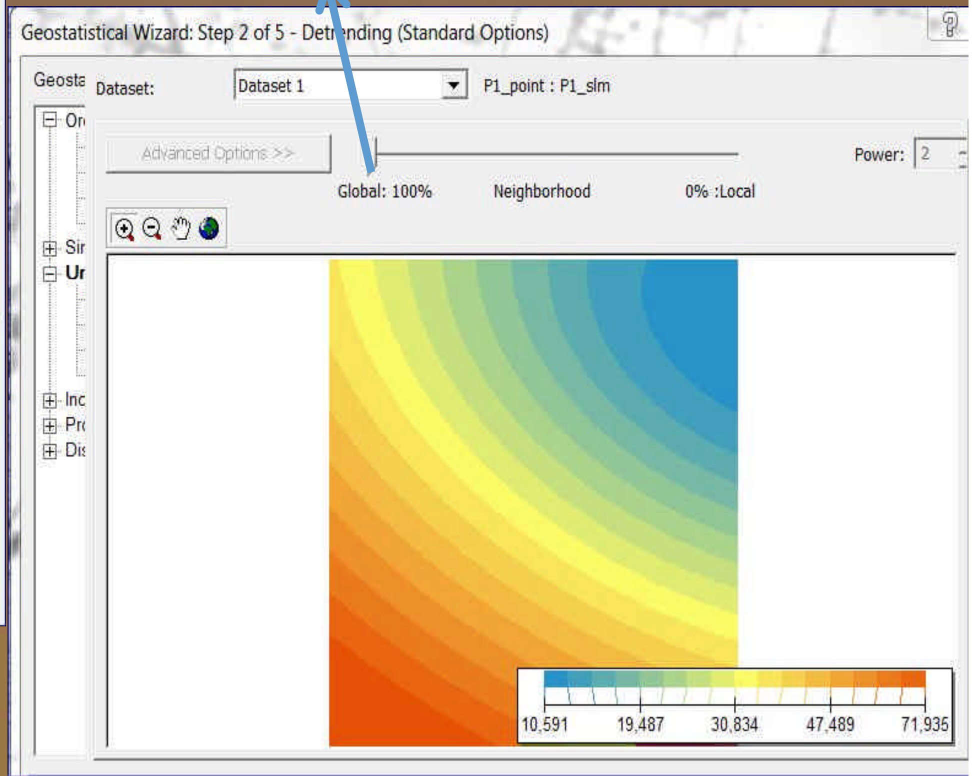
Using geostatistical methods, in particular the Kriging, was analyzed tha spatial distribution of the quoted points in order to obtain the bathymetric GRID related to the principal stratigraphic surfaces of the model.

Kriging is a moderately quick interpolator that can be exact or smoothed depending on the measurement error model. It is very flexible and the flexibility of kriging can require a lot of decision-making. Kriging, like most interpolation techniques, is built on the basis that things that are close to one another are more alike than those farther away .



Order of trend= second
It is a parabolic algebric function that best approximates the behavior of model surfaces

Global Neighborhood = exact interpolator

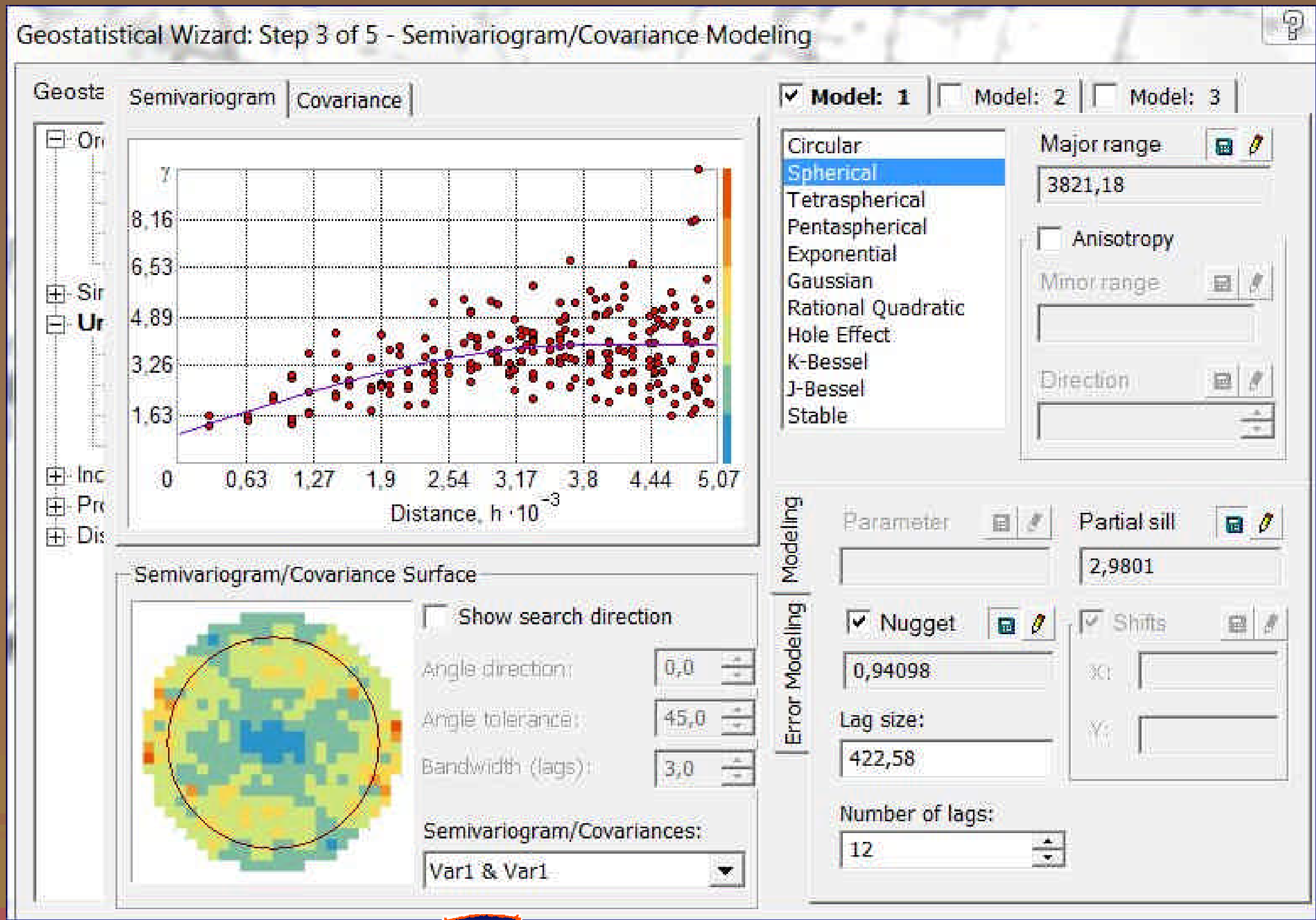


SEMIVARIOGRAM ANALYSIS

The semivariogram depicts the spatial autocorrelation of the measured sample points

The empirical semivariogram is a means to explore this relationship. Pairs that are close in distance should have a smaller difference than those farther away from one another. The extent that this assumption is true can be examined in the empirical semivariogram.

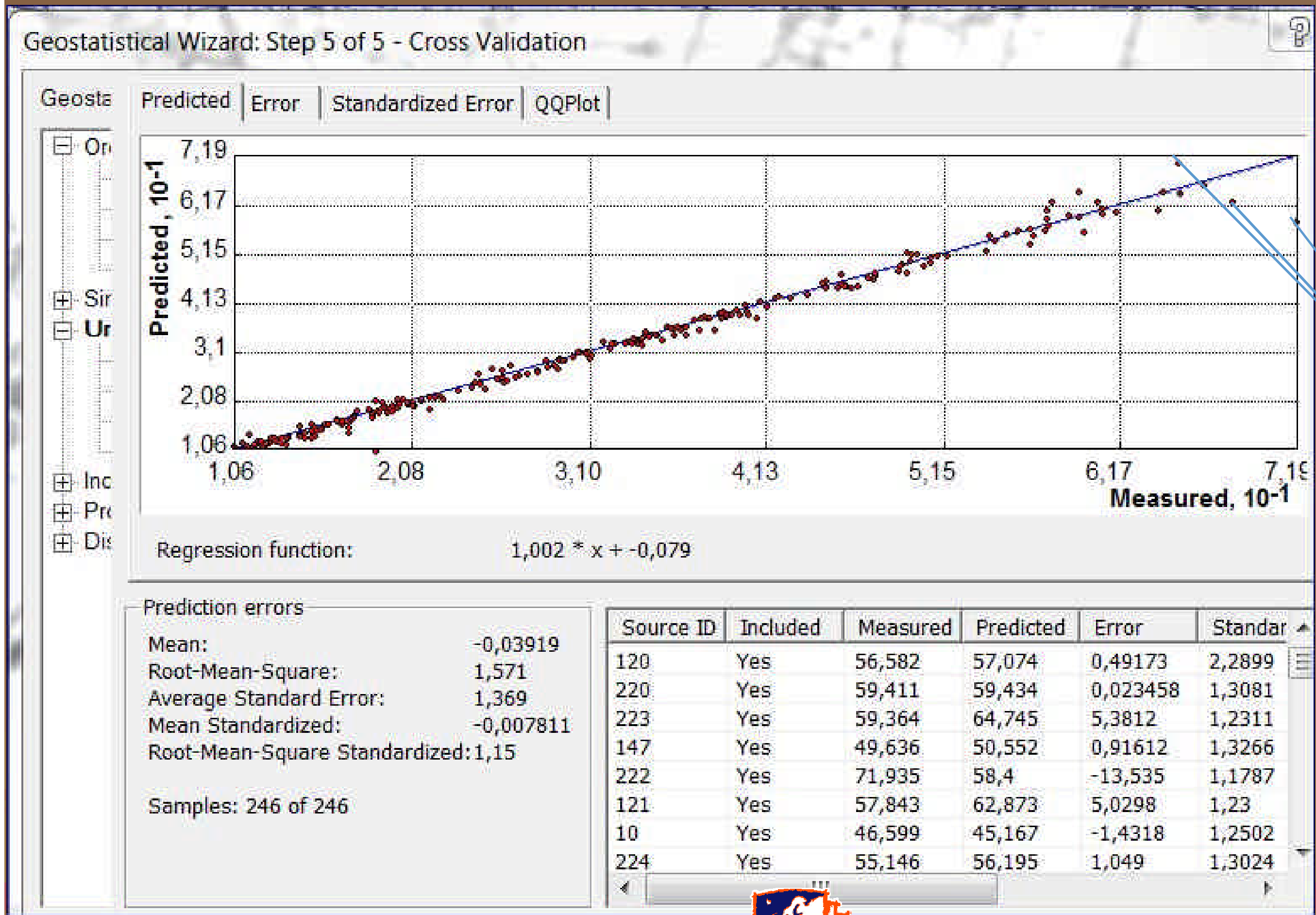
The Semivariogram that best fitting with the data spatial distribution of our data is Spherical: $Y=1/2(Px1-Px1-h)^2$



CROSS VALIDATION

Cross-validation uses all of the data to estimate the trend and autocorrelation models. It removes each data location, one at a time, and predicts the associated data value.

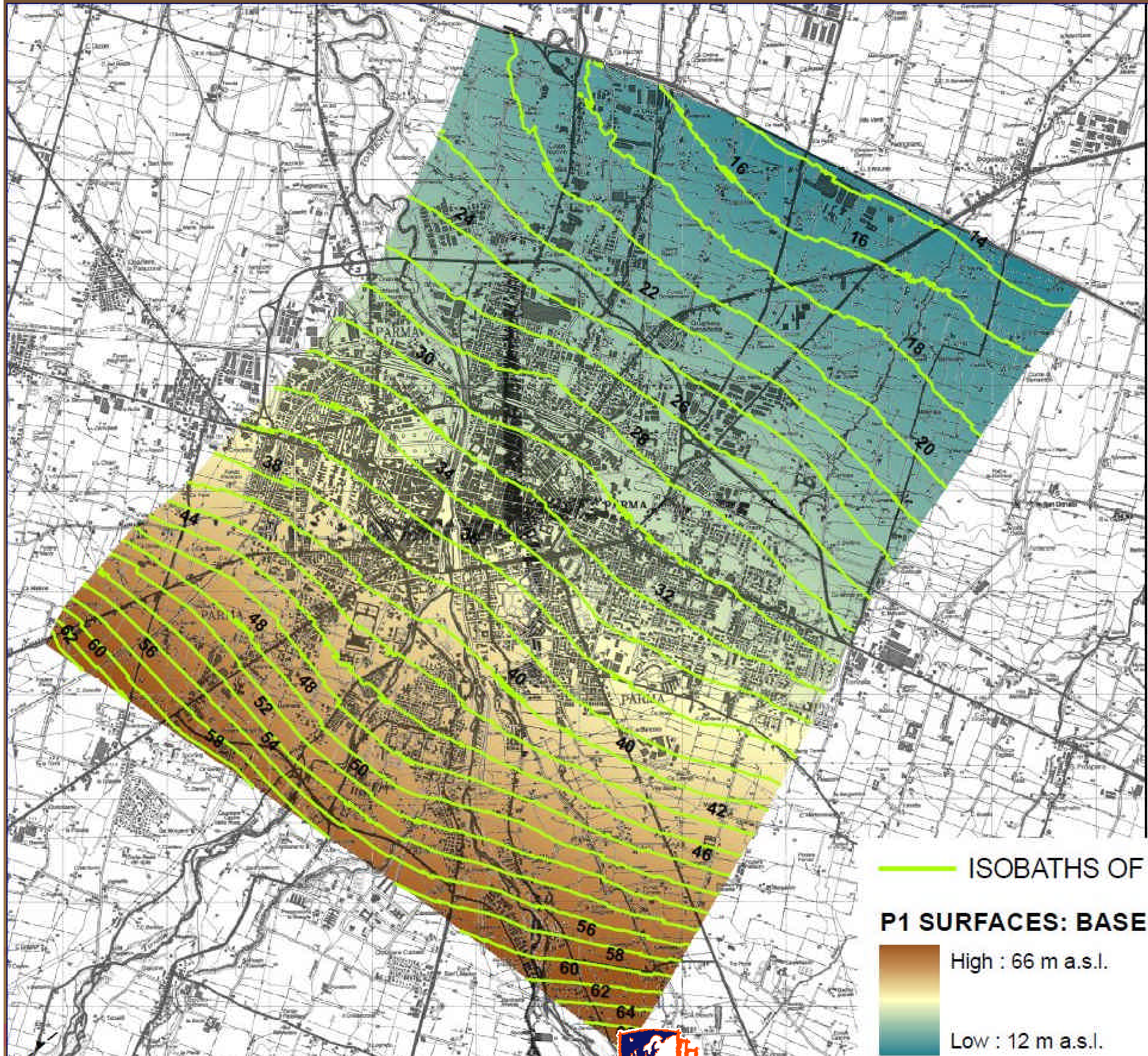
This procedure is repeated for a second point, and so on. For all points, cross-validation compares the measured and predicted values.



Example of Cross-validation for point data of model surfaces P1.

Points out of model area

OUTPUT OF GEOSTATISTICAL ANALISYS: P1 SURFACE ISOBATH GRID



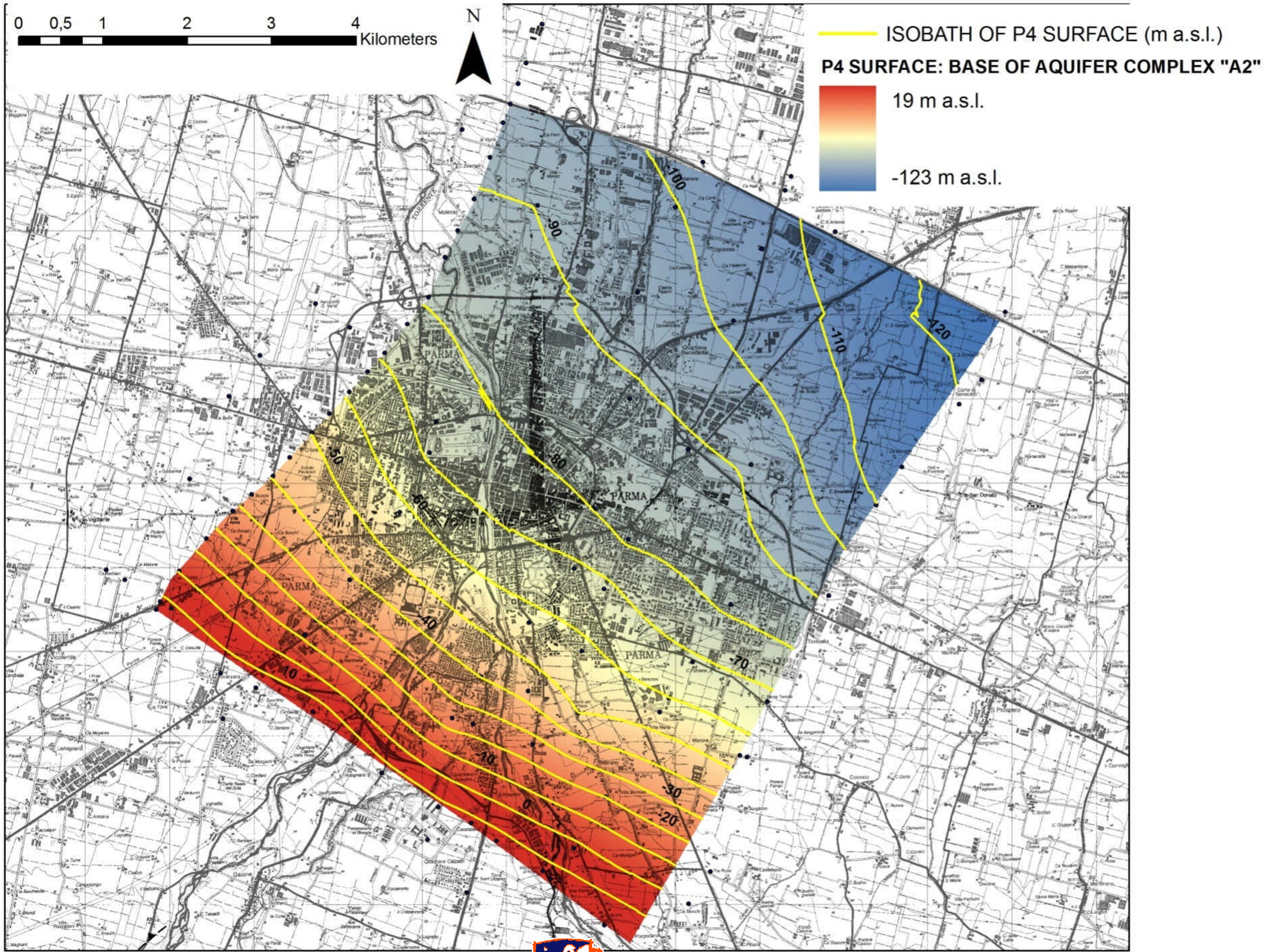
ISOBATHS OF P1 SURFACE (m a.s.l.)

P1 SURFACES: BASE OF AQUIFER COMPLEX "AO"

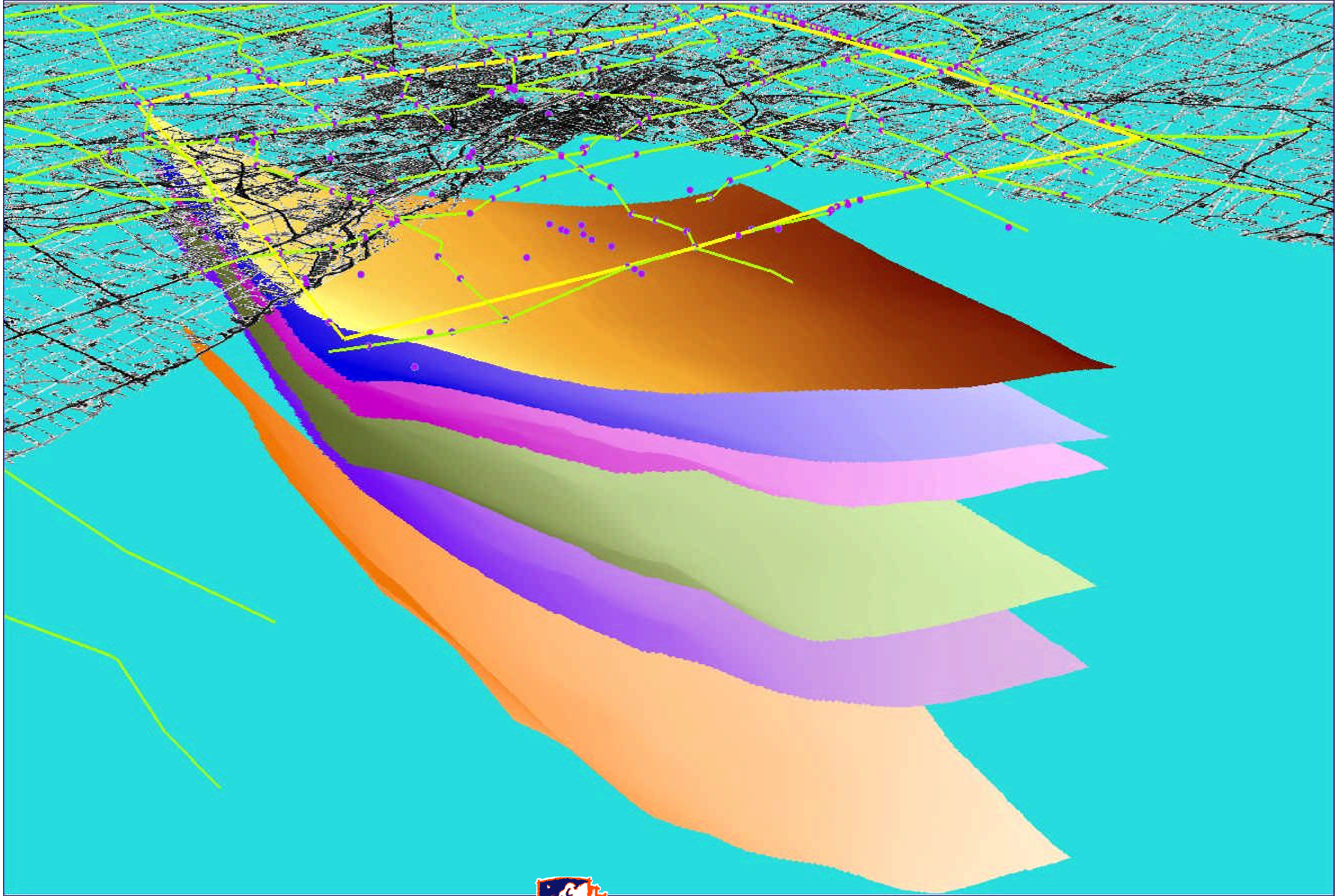
High : 66 m a.s.l.

Low : 12 m a.s.l.

OUTPUT OF GEOSTATISTICAL ANALISYS: P4 SURFACE ISOBATH GRID
Base of the physical model domain



3D SURFACES MODEL VIEW



THE NEXT PHASES OF
THE PROJECT ARE
WORK IN PROGRESS........

THANKS FOR YOUR
ATTENTION