ACC DAR Adapting to Climate Change in Coastal Dar es Salaam

International Workshop

TOWARDS SCENARIOS FOR URBAN ADAPTATION PLANNING

Assessing seawater intrusion under climate and land cover changes in Dar es Salaam, Tanzania

Assessing Seawater Intrusion in the south Pontina Plain

Rome, 22 April 2013

Sappa G. (*), Coviello M.T,

(*) Speaker

Department of Civil Building and Environmental Engineering

Faculty of Engineering

Sapienza University of Rome

Giuseppe.sappa@uniroma1.it

W3.uniroma1.it/giuseppe.sappa

SAPIENZA UNIVERSITÀ DI ROMA

ARDHI UNIVERSITY TANZANIA UTAFITI ELIMU USHAURI

Overwiew

Target:

To analyze the spatial variation of groundwater salinization in the shallower aquifers by different investigation methods in a coastal area characterized by:

- hydrogeological framework complexity
- economical, environmental and political issues (e.g. high water demand until overexploitation of groundwater, unauthorized withdrawal)

Methods:

- Vertical electrical soundings
- Hydrogeochemical and Temperature characterization

Conclusions:

✓ Seawater intrusion is multistratum as inflows at two different levels of the aquifers

✓ Two areas registered values result alarming

Geographical location

The plain hydrogeological system is influenced by:

The elevation of the plain ranges from 0 m to 30 m above mean sea level, and the yearly average precipitation is of 800-900 mm/y.

the LEPINI mountains along the north-eastern side (lowered by a net of faults)

the ACQUE ALTE irrigation canal along the north-western side, that represents a drainage axis of the two shallow groundwater systems

the AUSONI mountains along the south-eastern side (separated with the Amaseno stream discontinuity)

The test site is located in the southern area of the Latium region. It's a coastal area included in the Pontina Plain.

It *is extended for 80 km^2 and it represents a band which extends for 18 km along the coast and for 4 - 5 km inland.*

the CIRCEO carbonatic block

Economical and environmental issues…

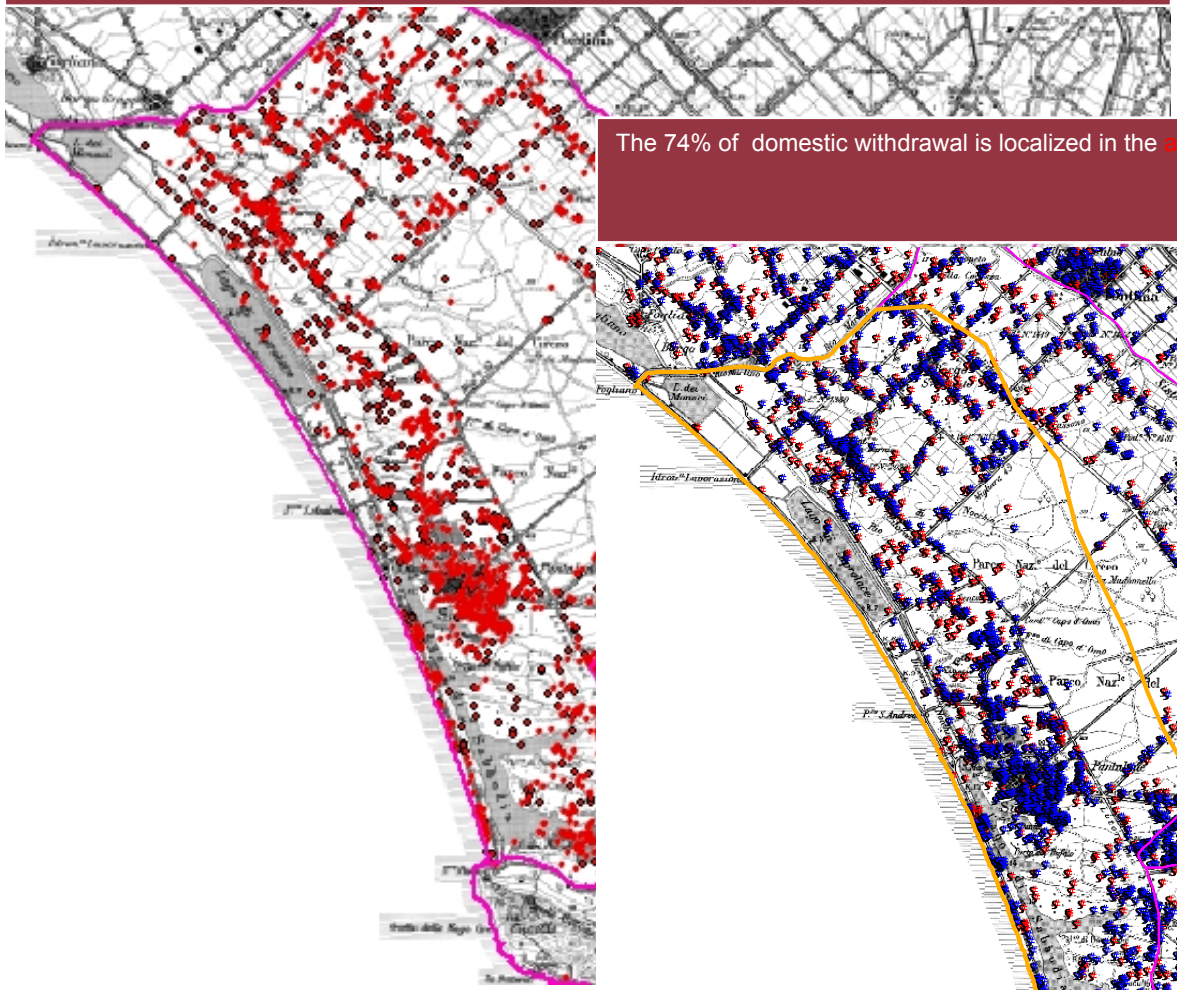
The area, malarious and depopulated until the thirties, is nowadays crossed by a net of irrigation canals.

In this humid region, today a rich agricultural zone, the periodic occurrence of droughts of different intensity is one of the most important factors in the variability of crop yield. Because complementary irrigation is an highly efficient resource to increase such yields, an understanding of groundwater resources is important.

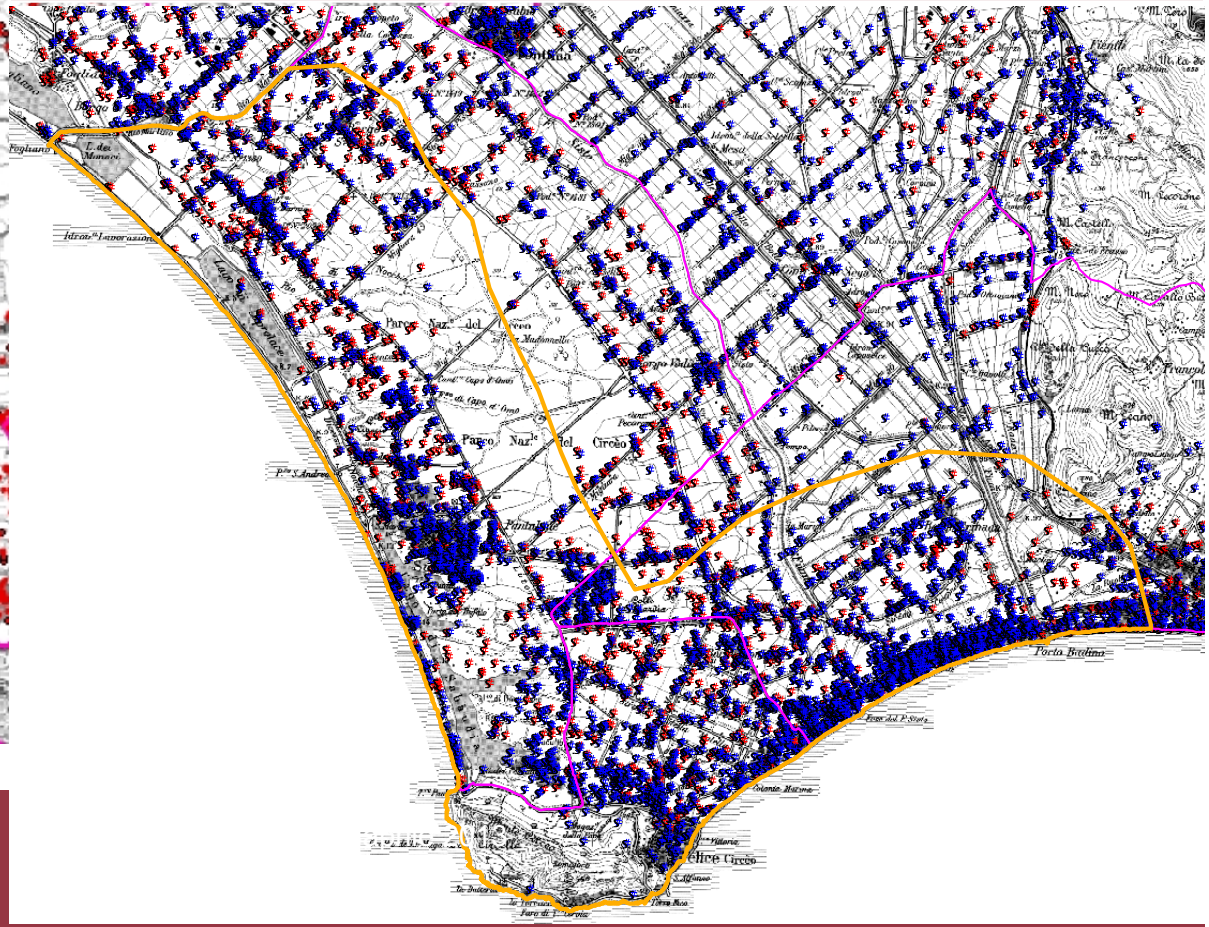
Moreover a large part of the area is occupied by the Circeo National Park, the geo-environvental importance of which is remarkable.

Political issue…

The non domestic withdrawal is rather $8 * 10^6$ mc/y



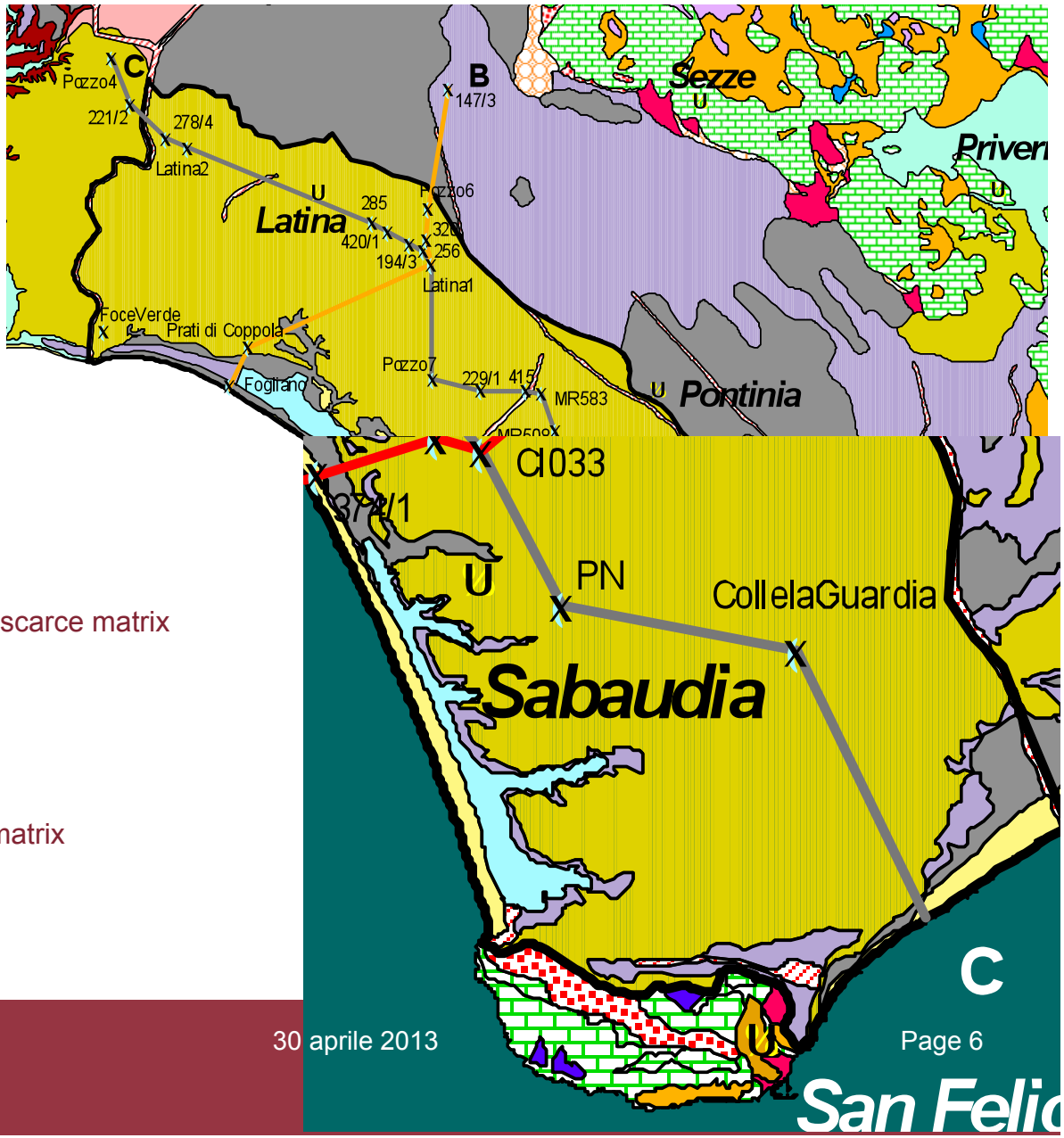
The 74% of domestic withdrawal is localized in the area investigated by the vertical electrical soundings



Assessing Seawater Intrusion in the south Pontina Plain

Geological pattern

The Pontina Plain is a ancient tectonic hollow, over 800 meters deep, and covered by recent Quaternary deposits, made of sands, silts and clays. More ancient outcroppings are located along the south west coast and are represented by organogeous limestones or Pliocene and Pleistocene clay.



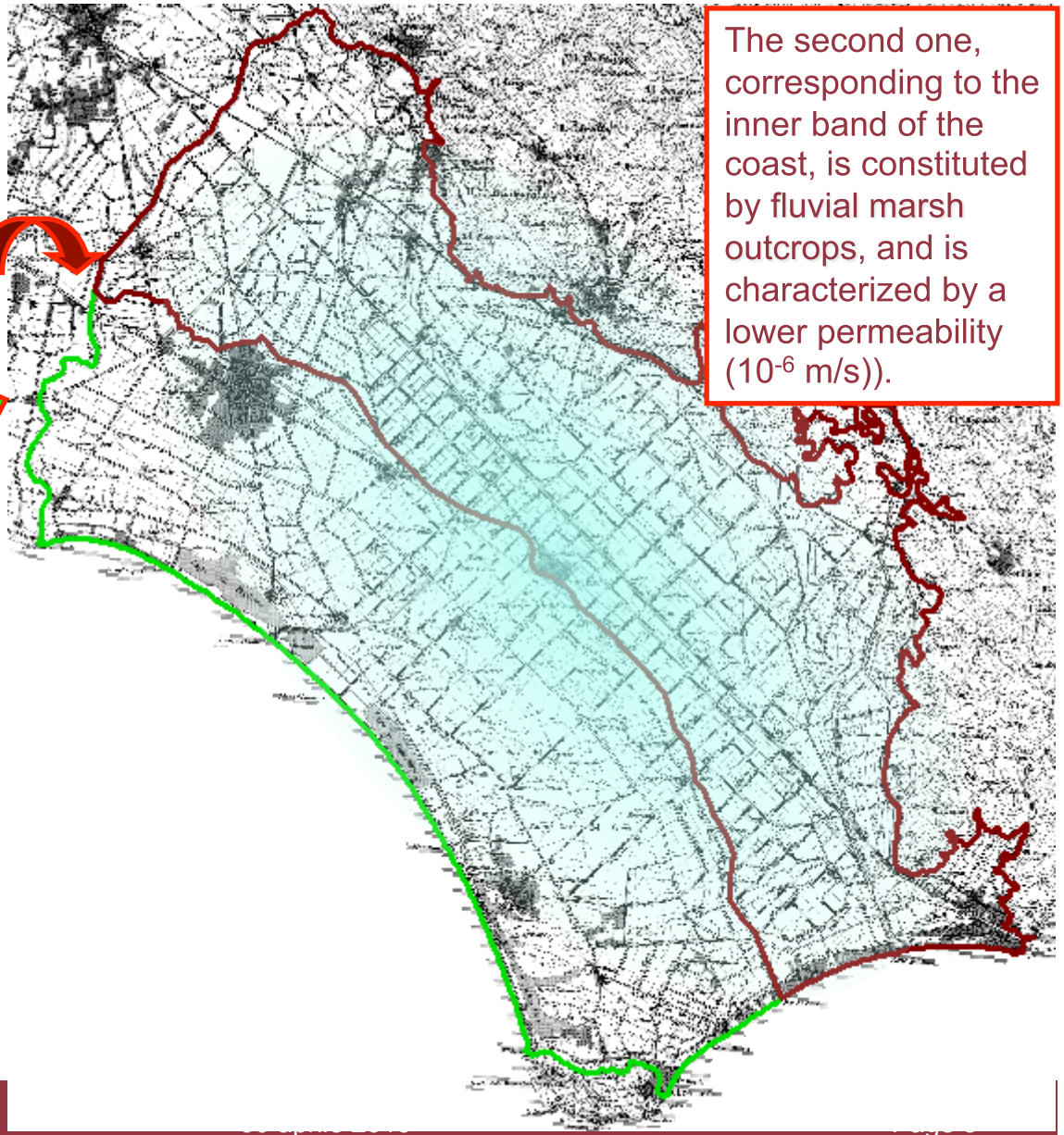
- sand complex
- ancient dune soils
- black lands
- Sandy peat
- Urban
- Sandstone
- Sandy conoids
- Pebbles gravel and sand with scarce matrix
- Ancient conoids
- Monte limestone
- Red lands
- recent alluvial deposit
- terraced alluvial deposits
- Pebbles and gravel with silty matrix
- Conglomerates and breccias
- Travertine
- Pyroclastic rocks
- Lava
- loose tuffs
- Pyroclastic rock

Hydrogeological pattern

In the area under study they are distinguished three different aquifers:
two shallow aquifers (40 – 80 meters b.s.l) made by sands, the first, and by eluvial deposits the latter.

The Sisto stream represents a drainage axis for these two Quaternary formation aquifers. The first of which, the dune aquifer, in fact, floats on the sea and it is drained by the lakes, the sea and partially by Sisto stream, that delimits the Pontina depression at south-west.

a deeper carbonatic one (more than 100 meters b.s.l.) is separated from them by a clay layer.



The second one, corresponding to the inner band of the coast, is constituted by fluvial marsh outcrops, and is characterized by a lower permeability (10^{-6} m/s)).

Geostructural complexity

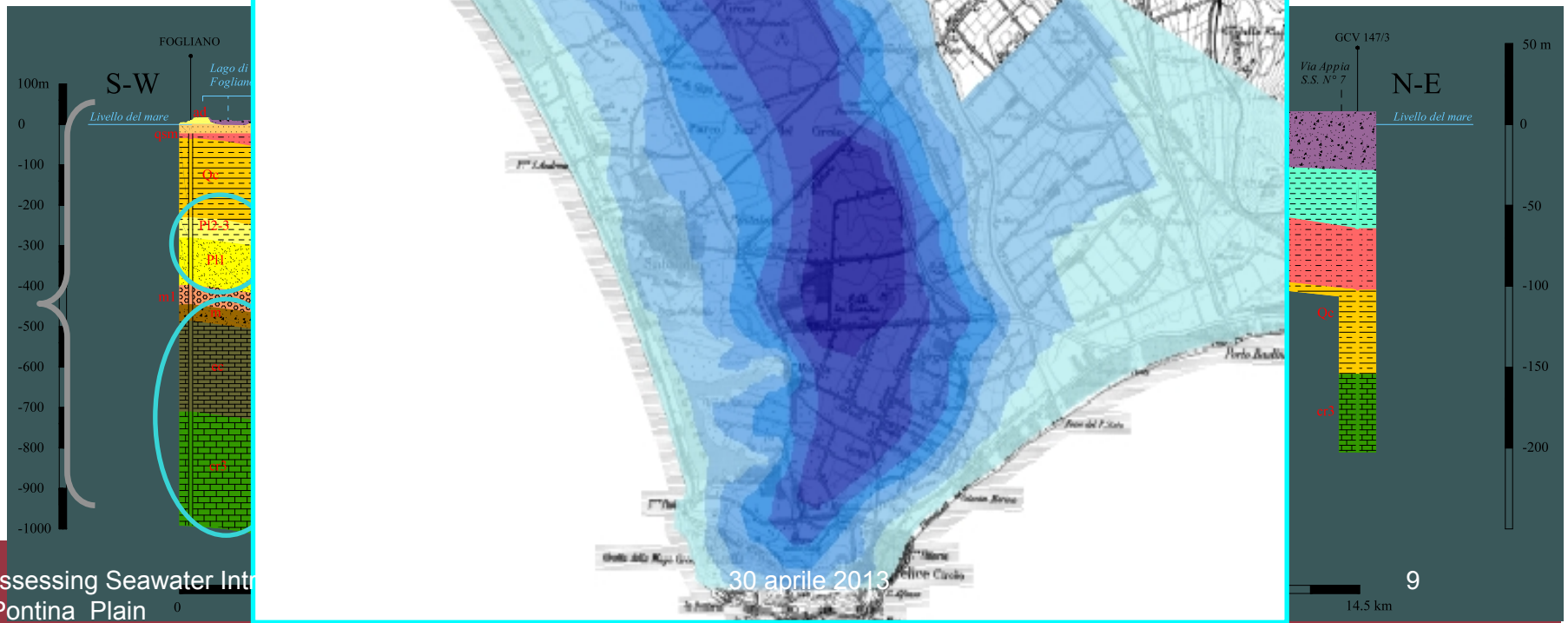
Ancient dune

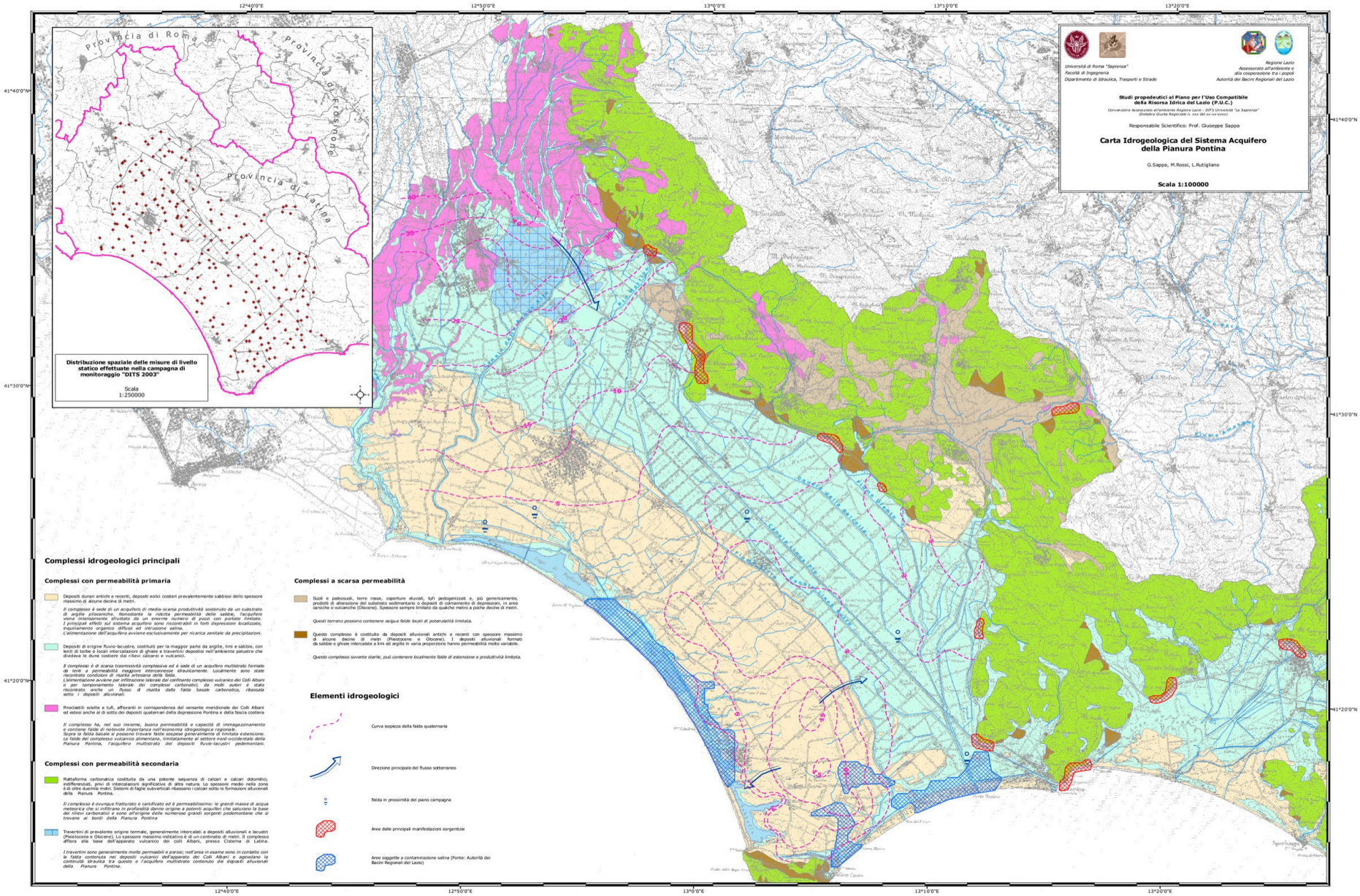
Clayey sands,

Fluvial and lagoon-sand
grave

consequence of
quifer a
can be
e different strata,
gical complexity
area.

stic rocks




Provincia di Roma
Provincia di Frosinone
Provincia di Latina
Distribuzione spaziale delle misure di livello statico effettuate nella campagna di monitoraggio "DITS 2003"
Scala 1:250000
Università di Roma "Sapienza"
Facoltà di Ingegneria
Dipartimento di Idraulica, Trasporti e Strade
Regione Lazio
Assessorato all'ambiente e alla cooperazione tra i popoli
Autorità dei Bacini Regionali del Lazio
Studi propedeutici al Piano per l'Uso Compatibile della Risorsa Idrica del Lazio (P.U.C.)
Convenzione Assessorato all'Ambiente Regione Lazio - DITS Università "La Sapienza" (Delibera Giunta Regionale n. xxx del xx-xx-xxxx)
Responsabile Scientifico: Prof. Giuseppe Sappa
Carta Idrogeologica del Sistema Acquifero della Pianura Pontina
G.Sappa, M.Rossi, L.Rutigliano
Scala 1:100000
Complessi idrogeologici principali
Complessi con permeabilità primaria
Depositi dunari antichi e recenti, depositi eolici costieri prevalentemente sabbiosi dello spessore massimo di alcune decine di metri.
Il complesso è sede di un acquifero di media-scarsa produttività sostenuto da un substrato di argille plioceniche. Nonostante la ridotta permeabilità delle sabbie, l'acquifero viene intensamente sfruttato da un enorme numero di pozzi con portate limitate. I principali effetti sul sistema acquifero sono riscontrabili in forti depressioni localizzate, inquinamento organico diffuso ed intrusione salina. L'alimentazione dell'acquifero avviene esclusivamente per ricarica zenitale da precipitazioni.
Depositi di origine fluvio-lacustre, costituiti per la maggior parte da argille, limi e sabbie, con lenti di torbe e locali intercalazioni di ghiaie e travertini depositisi nell'ambiente paludoso che divideva le dune costiere dai rilievi calcarei e vulcanici.
Il complesso è di scarsa trasmissività complessiva ed è sede di un acquifero multistrato formato da lenti a permeabilità maggiore interconnesse idraulicamente. Localmente sono state riscontrate condizioni di risalita artesiana della falda. L'alimentazione avviene per infiltrazione laterale dal confinante complesso vulcanico dei Colli Albani e per tamponamento laterale dei complessi carbonatici; da molti autori è stato riscontrato anche un flusso di risalita dalla falda basale carbonatica, ribassata sotto i depositi alluvionali.
Prodotti scolte e tufi, affioranti in corrispondenza del versante meridionale dei Colli Albani ed estesi anche al di sotto dei depositi quaternari della depressione Pontina e della fascia costiera
Il complesso ha, nel suo insieme, buona permeabilità e capacità di immagazzinamento e contiene falde di notevole importanza nell'economia idrogeologica regionale. Sopra la falda basale si possono trovare falde sospese generalmente di limitata estensione. Le falde del complesso vulcanico alimentano, limitatamente al settore nord-occidentale della Pianura Pontina, l'acquifero multistrato dei depositi fluvio-lacustri pedemontani.
Complessi con permeabilità secondaria
Piattaforma carbonatica costituita da una potente sequenza di calcari e calcari dolomitici, indifferenziati, privi di intercalazioni significative di altra natura. Lo spessore medio nella zona è di oltre duemila metri. Sistemi di faglie subverticali ribassano i calcari sotto le formazioni alluvionali della Pianura Pontina.
Il complesso è ovunque fratturato e carsificato ed è permeabilissimo: le grandi masse di acqua meteorica che si infiltrano in profondità danno origine a potenti acquiferi che saturano la base dei rilievi carbonatici e sono all'origine delle numerose grandi sorgenti pedemontane che si trovano ai bordi della Pianura Pontina
Travertini di prevalente origine termale, generalmente intercalati a depositi alluvionali e lacustri (Pleistocene e Olocene). Lo spessore massimo indicativo è di un centinaio di metri. Il complesso affiora alla base dell'apparato vulcanico dei colli Albani, presso Cisterna di Latina.
I travertini sono generalmente molto permeabili e porosi; nell'area in esame sono in contatto con la falda contenuta nei depositi vulcanici dell'apparato dei Colli Albani e agevolano la continuità idraulica tra questo e l'acquifero multistrato contenuto dei depositi alluvionali della Pianura Pontina.
Complessi a scarsa permeabilità
Suoli e paleosuoli, terre rosse, coperture eluviali, tufi pedogenizzati e, più genericamente, prodotti di alterazione del substrato sedimentario o depositi di colmamento di depressioni, in aree carsiche o vulcaniche (Olocene). Spessore sempre limitato da qualche metro a poche decine di metri.
Questi terreno possono contenere esigue falde locali di potenzialità limitata.
Questo complesso è costituito da depositi alluvionali antichi e recenti con spessore massimo di alcune decine di metri (Pleistocene - e Olocene). I depositi alluvionali formati da sabbie e ghiaie intercalate a lmi ed argille in varia proporzione hanno permeabilità molto variabile.
Questo complesso sovente sterile, può contenere localmente falde di estensione e produttività limitata.
Elementi idrogeologici
Curva isopieza della falda quaternaria
Direzione principale del flusso sotterraneo
falda in prossimità del piano campagna
Aree delle principali manifestazioni sorgentizie
Aree soggette a contaminazione salina (Fonte: Autorità dei Bacini Regionali del Lazio)
12°40'0"E
12°50'0"E
13°0'0"E
13°10'0"E
13°20'0"E
41°40'0"N
41°30'0"N
41°20'0"N

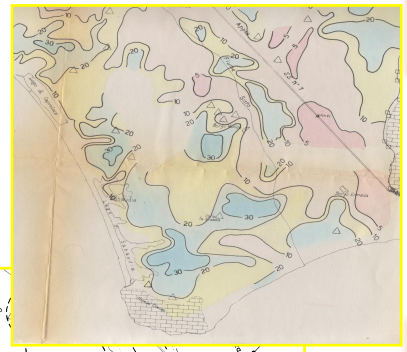
Seawater inflow

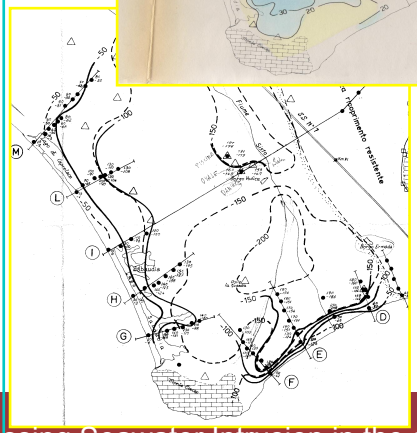
Comparing two previous geophysical investigation campaigns, carried out:

- in the same location
- utilizing the Schlumberger electrode array.

✓ 1952
✓ 1967

✓ 91 VES



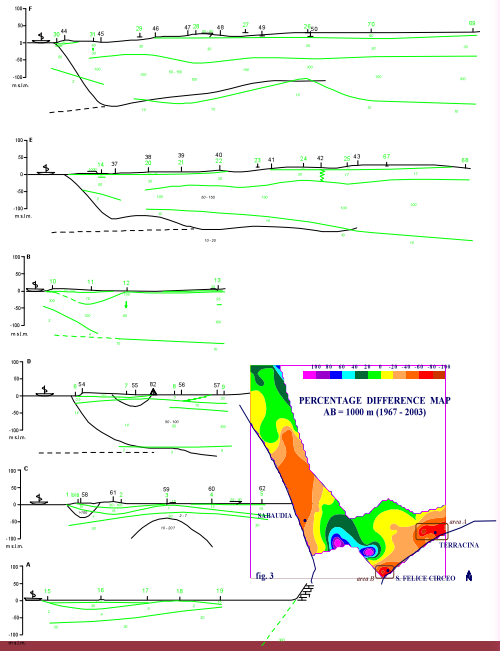


Sequence stratigraphy analysis by a series of calibration drillings

A first idea about the salt water intrusion evolution in the last 30 years

✓ 2003

✓ 82 VES.

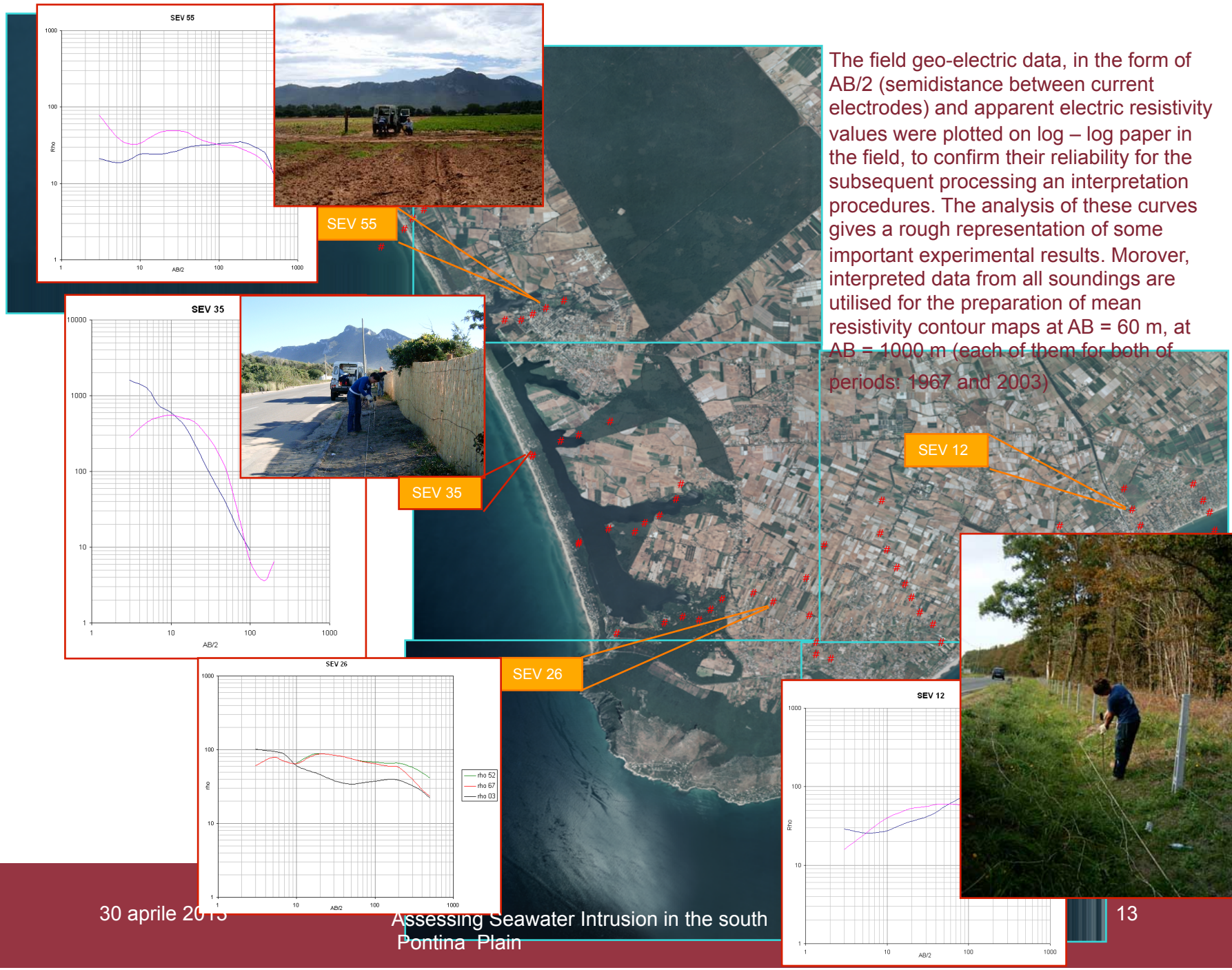


VES 2003

5 SEV AB = 200 m
3 SEV AB = 300 m
7 SEV AB = 400 m
22 SEV AB = 600 m
23 SEV AB = 800 m
22 SEV AB = 1000 m

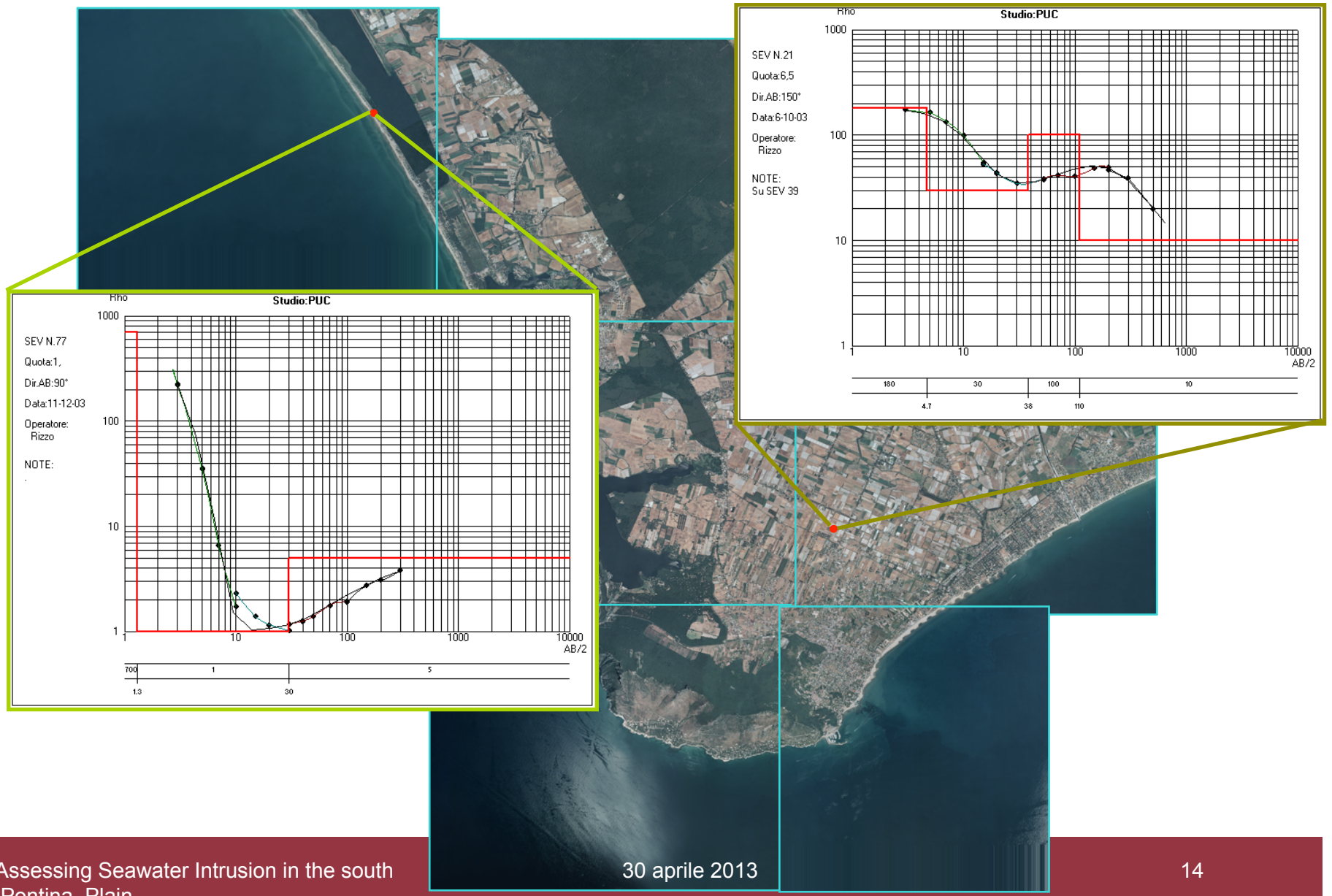
The maximum current electrode (AB) separation of these VES has been 800 – 1000 m, depending on the accessibility of soil for expanding electrodes, an avoiding crossing of power lines or sewerage/water net pipelines when expanding the profile lines and for enabling a better description of the features of the aquifers.

The relative investigation depth ranges from 120 to 200 m below the ground surface.



The field geo-electric data, in the form of AB/2 (semidistance between current electrodes) and apparent electric resistivity values were plotted on log – log paper in the field, to confirm their reliability for the subsequent processing an interpretation procedures. The analysis of these curves gives a rough representation of some important experimental results. Morover, interpreted data from all soundings are utilised for the preparation of mean resistivity contour maps at AB = 60 m, at AB = 1000 m (each of them for both of periods: 1967 and 2003)

Two main groups

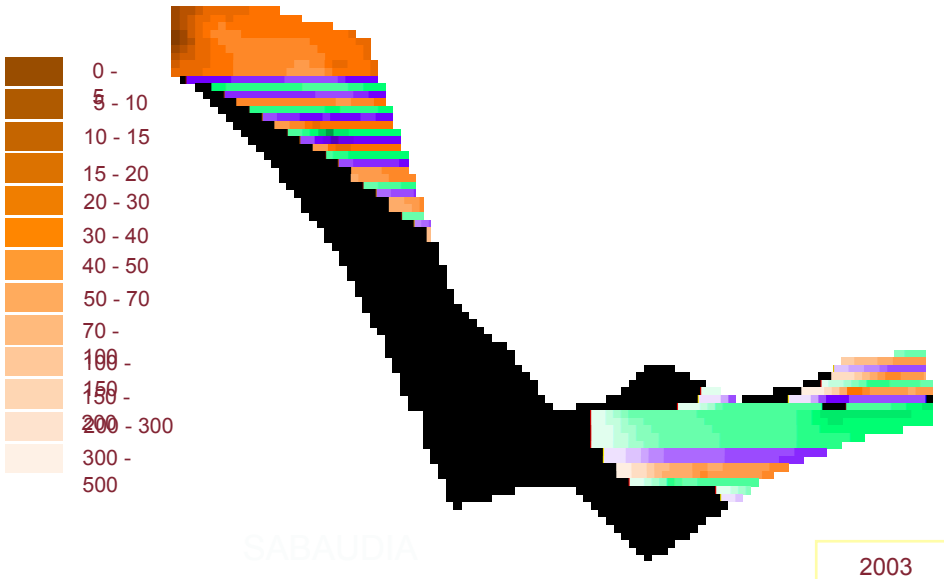


VES AB = 60 m

S. FELICE CIRCEO

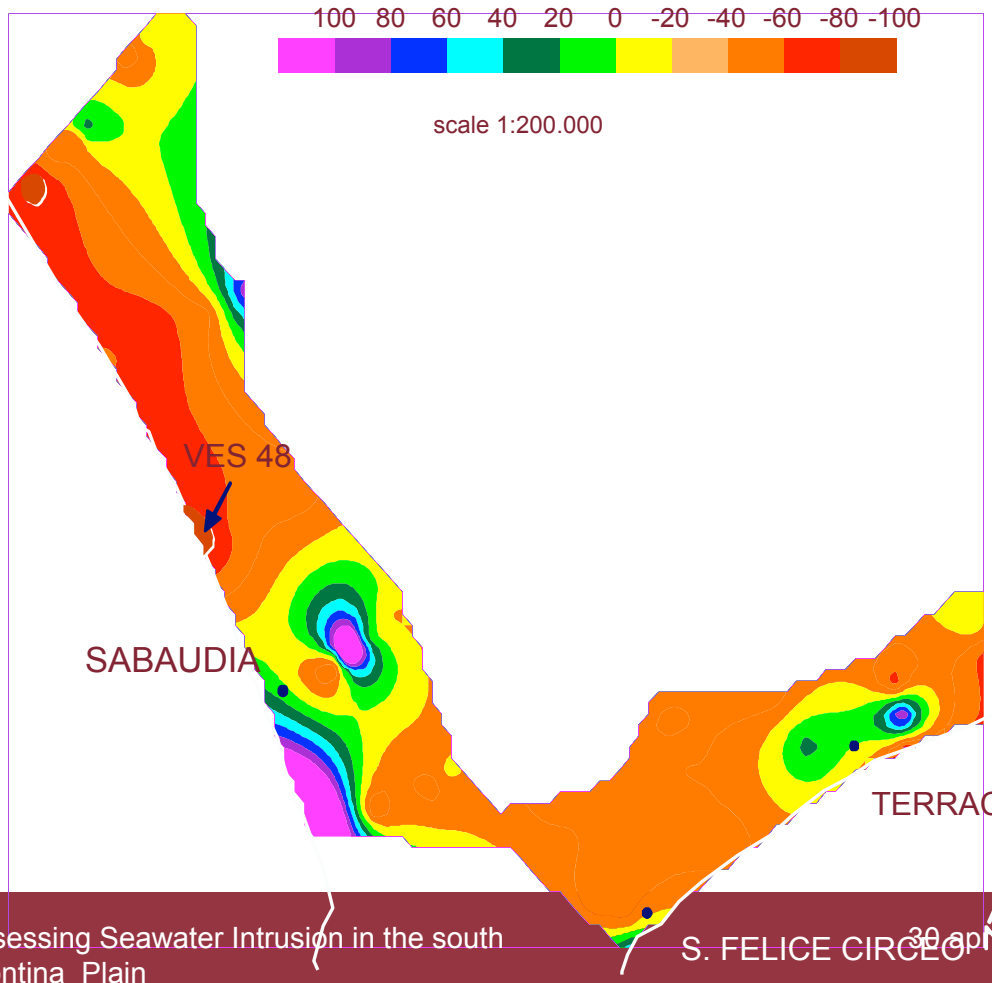
An apparent resistivity map built considering AB = 60 m (1967) shows two different conditions: in the area situated between the Circeo area and Terracina, the resistivity values decrease eastward passing by a range of 50 – 70 ohm.m to north of S. Felice Circeo, untill 5 ohm.m between Borgo Ermada (close to Terracina) and the sea; while in the area to north of Circeo the resistivity values decrease by the coast inaward, and on the recent it is higher than 50 ohm.m.

The same map, built with the values of the 2003, points out as the conductivity area at north of Terracina appears dilated: resistivity value inferior to 40 ohm.m occupies the whole eastern area of S. Felice Circeo



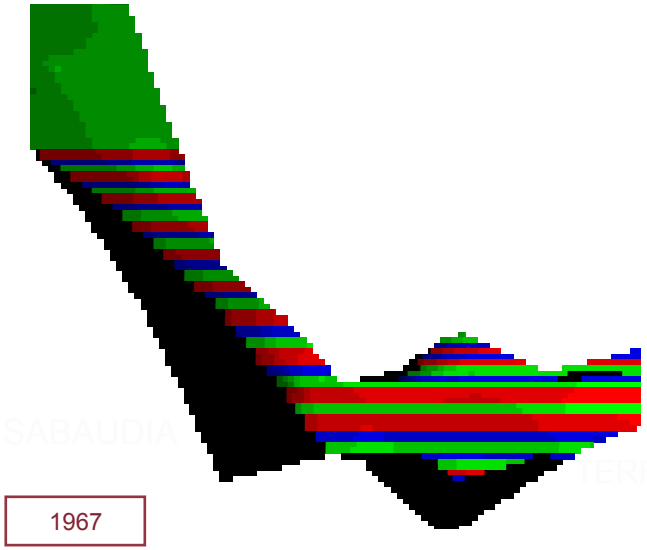
S. FELICE CIRCEO

Percentage difference map
AB = 60 m (1967 - 2003)



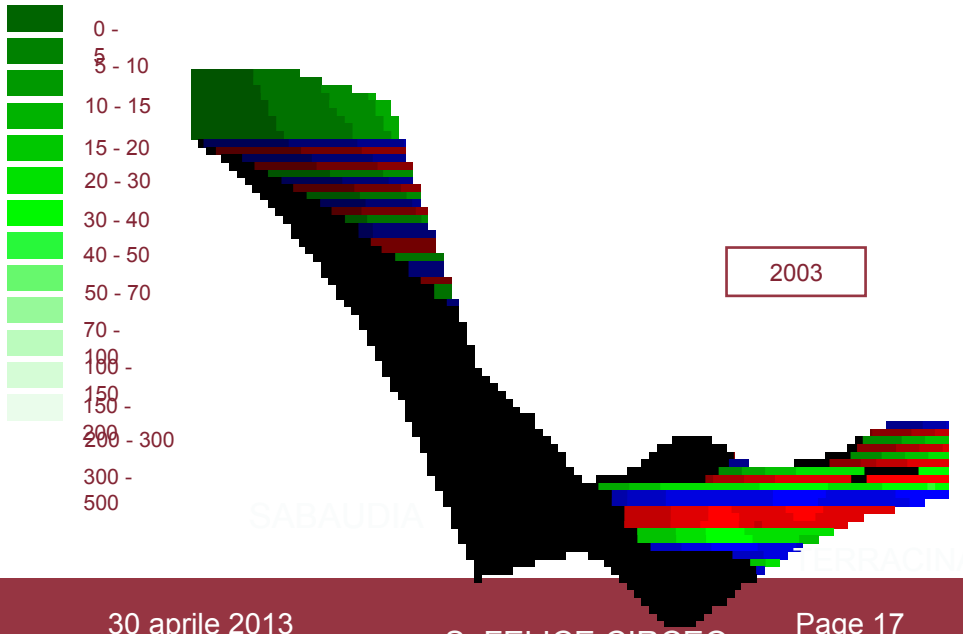
This map reports the percentage difference of the resistivity distribuition in the last thirty years, for a shallow range of depth, inside 10 and 30 m. A widespread resistivity decrease, with tops of 80% in some VES, is shown in it. The lowest values have been registered on Sabaudia shoreline and on the western area of Terracina. In particular it is important to outline the situation pointed out by the sounding data at VES 48.
From this investigation a decrease by 750 to 35 ohm.m has been registered and it is indicative of the elevation of the transition zone.

VES AB = 1000 m



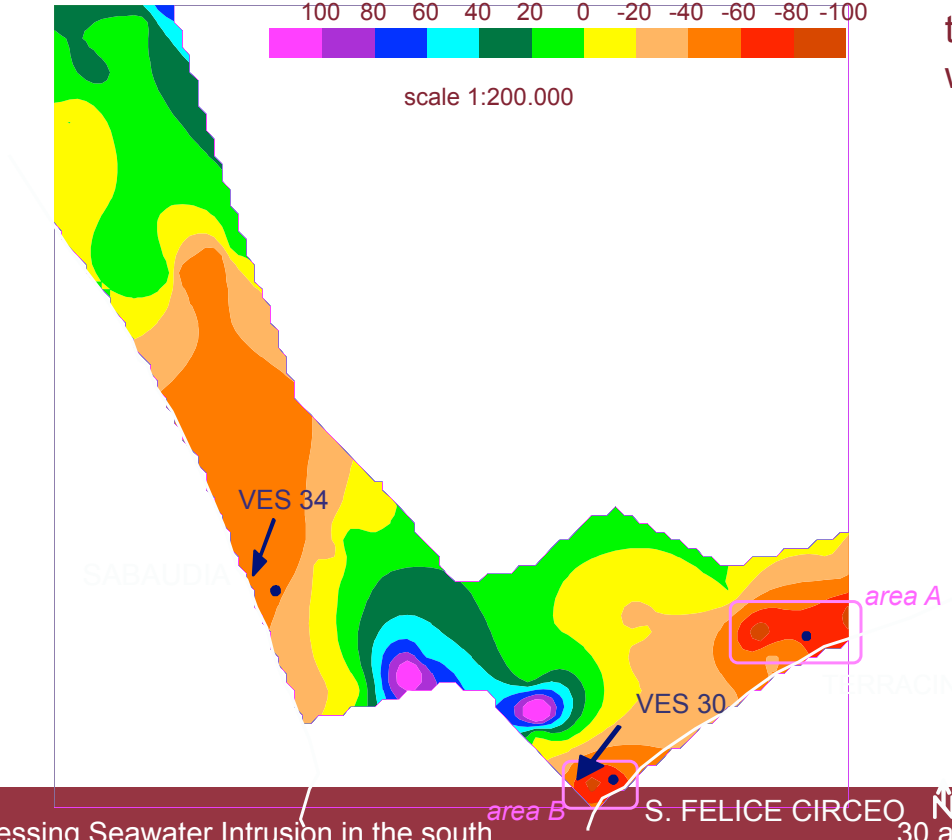
The apparent resistivity map with AB = 1000 m (1967) is relative of a survey depth around 200 m. The lowest resistivity values are located along the northern coast of Circeo block, while the highest in correspondence of VES 34 and 30.

The correspondig map, obtained with the up-to-date sounding data (2003) as a whole follows a similar situation, with very low values at north and along the coast between S.Felice Circeo and Terracina.



Percentage difference map
AB = 1000 m (1967 - 2003)

Looking at the percentage differences is evident a decrease in the resistivity value of 20-60 % along the band between Lago Caprolace and the north of Circeo block. The highest resistivity values with top of 60-80% are registered in correspondence of the VES 30 - 31 included in the area B and VES 6-7-10-12 inside of the area A. In fact they are located in a very anthropic zones which are more rich of turistic infrastructures.

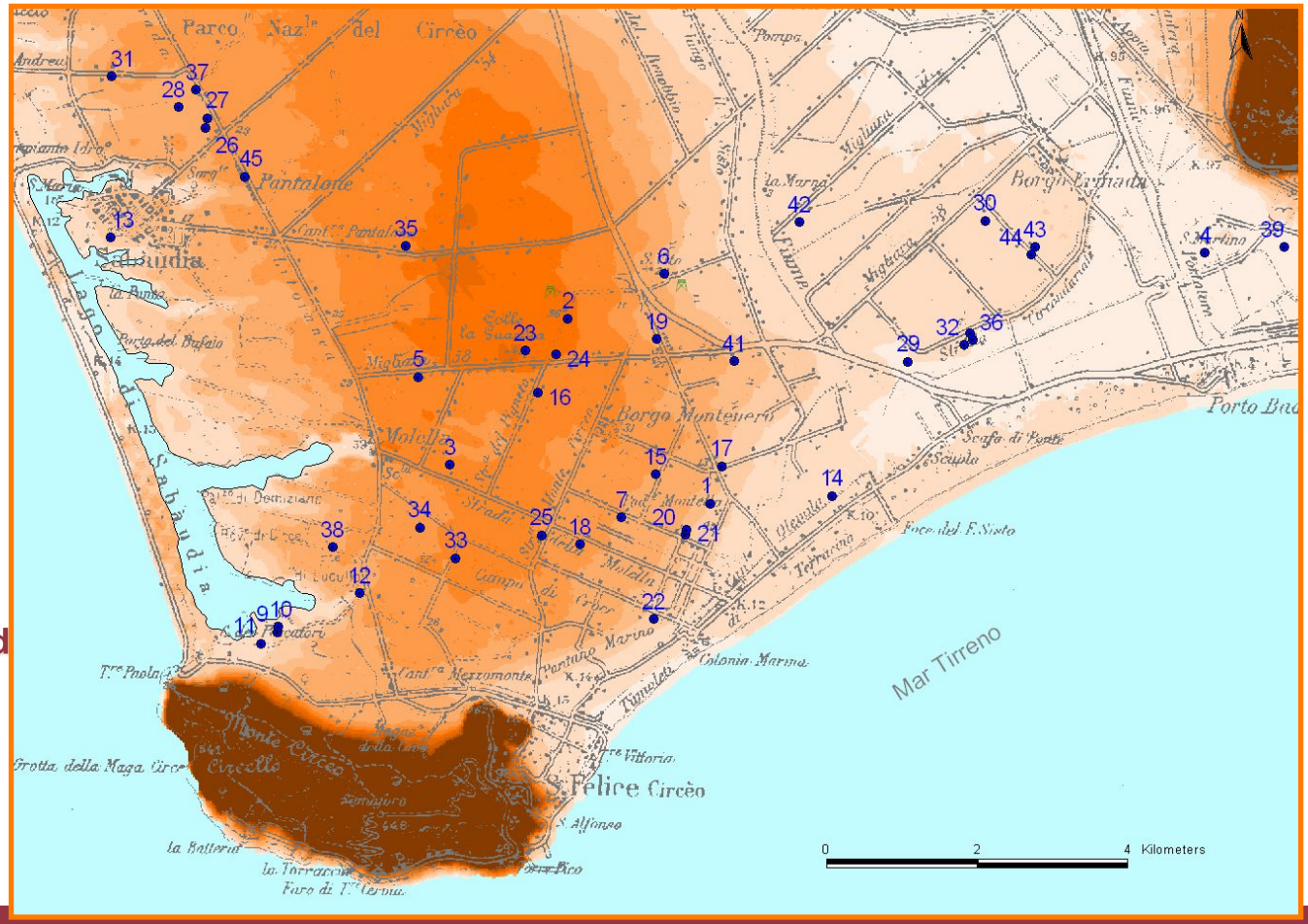


Water sampling results

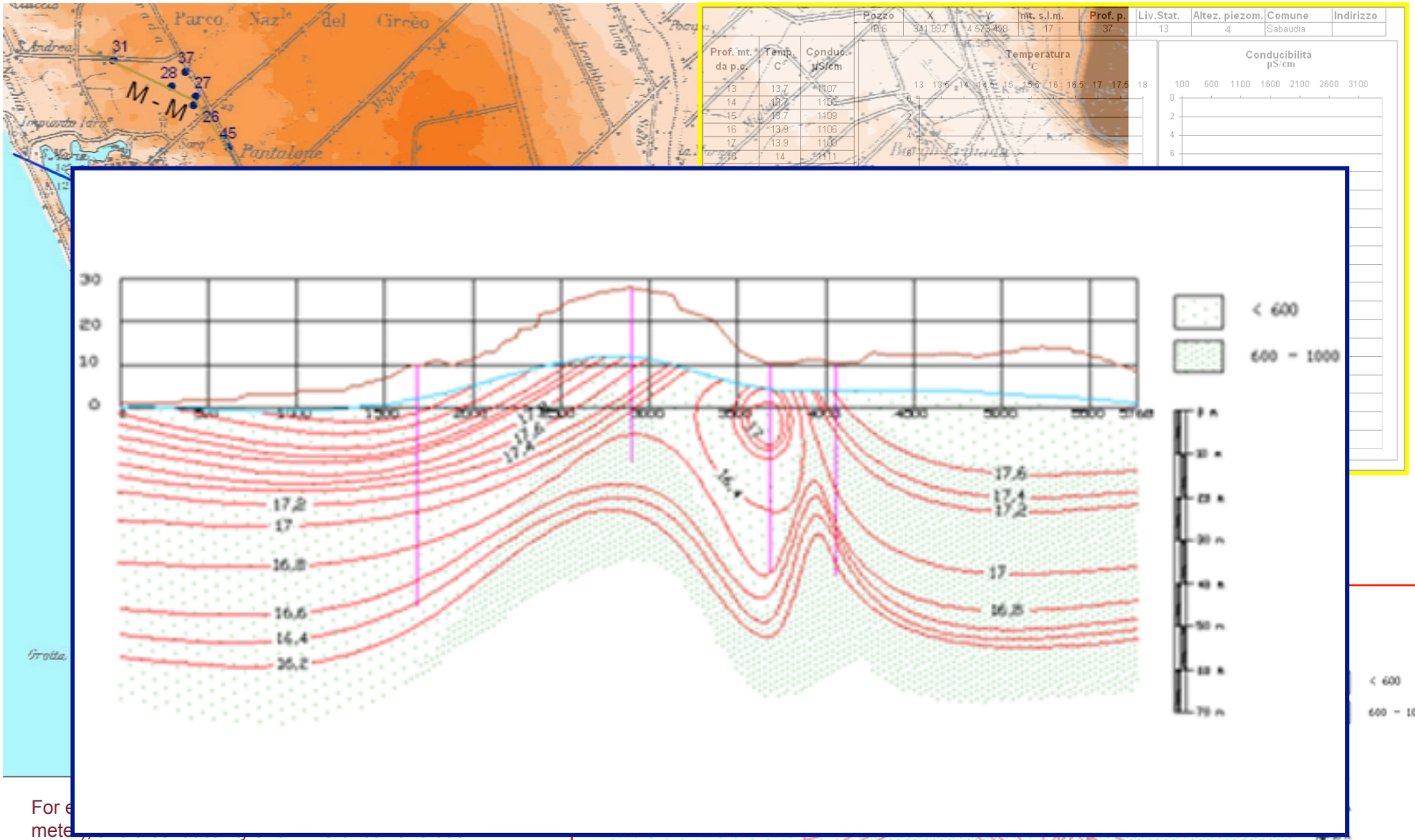
From 45 wells the depth of whom ranges to 40 – 100 m groundwater samples were collected:

ProfiLine LF197

- Latitude
- Longitude
- Quote (m a.s.l)
- Potenziometric head
- Conductivity (µS/cm)
- Temperature (°C)
- TDS (ppm)



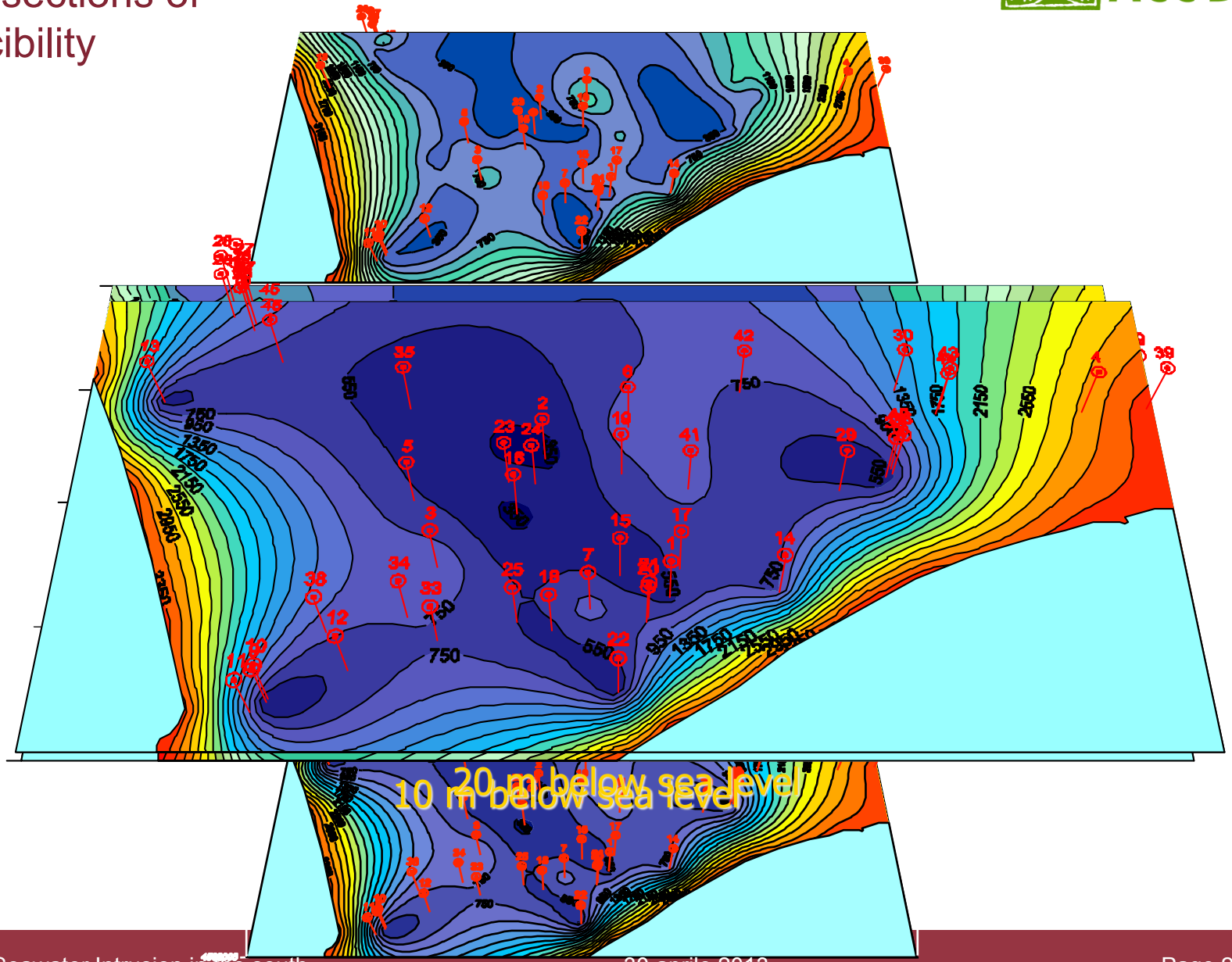
Cross sections



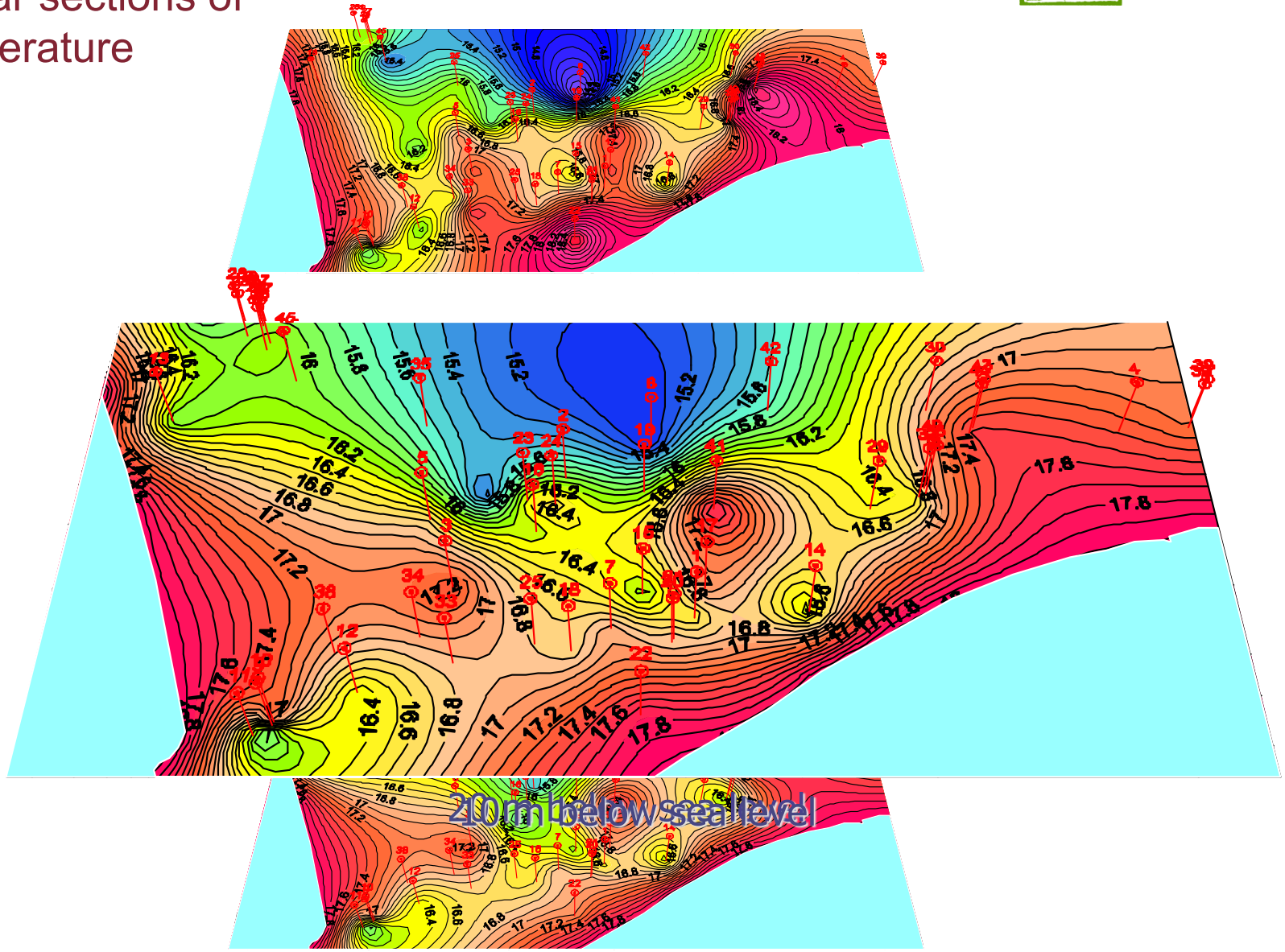
For e
mete
measured

Assessing Seawater Intrusion in the south Pontina Plain

Planar sections of conducibility



Planar sections of temperature



Conclusions

- The comparison between the reports of the VES investigation driver in 1967 and the 2003 ones shows with evidence that seawatwer intrusion grew up as in the vertical direction as in the horizontal one.

- In the thickness of the aquifer the nowadays VES reports show the seawater comes in at two different levels. The first level is located at about 15 – 40 b.s.l. in the more recent sands as the second one starts at about 80 – 100 b.s.l. at the deepness where the more ancient are found. These two levels are divided by a thick level of Plio-pleistocene silts and clayes.

- The deeper of the them contains relatively brackish groundwater, whereas the other one has a relatively high TDS content. The seawater intrusion involves the aquifers and the aquitards below the fresh water down to a depth of 10 meters for the first aquifer, and for 40 meters for the second one. In the horizontal direction seawater intrusion incomes for more than 500 m on the west coast and more than 2 km in the east part.

Conclusions

The high values of temperature and conductivity coincide with the elevated TDS concentration measured in some critic zone. Moreover the Schlumberger sounding resistivity method proves to be a powerful tool for investigating the seawater/freshwater interface in the geological setting of the southern shore of Latium region.

In fact it led to distinguish areas where high temperature values and medium conductivity ones were not due to a sea water intrusion increase but to local phenomenas, from areas where the sea water intrusion is a real emergency.

On the whole, the results of the field investigation witnesses a sensible increase in seawater intrusion, which may have been caused by overexploitation of groundwater. Infact the groundwater exploitation in the investigated area is more the 74% of the average net recharge of the whole Pontina Plan.