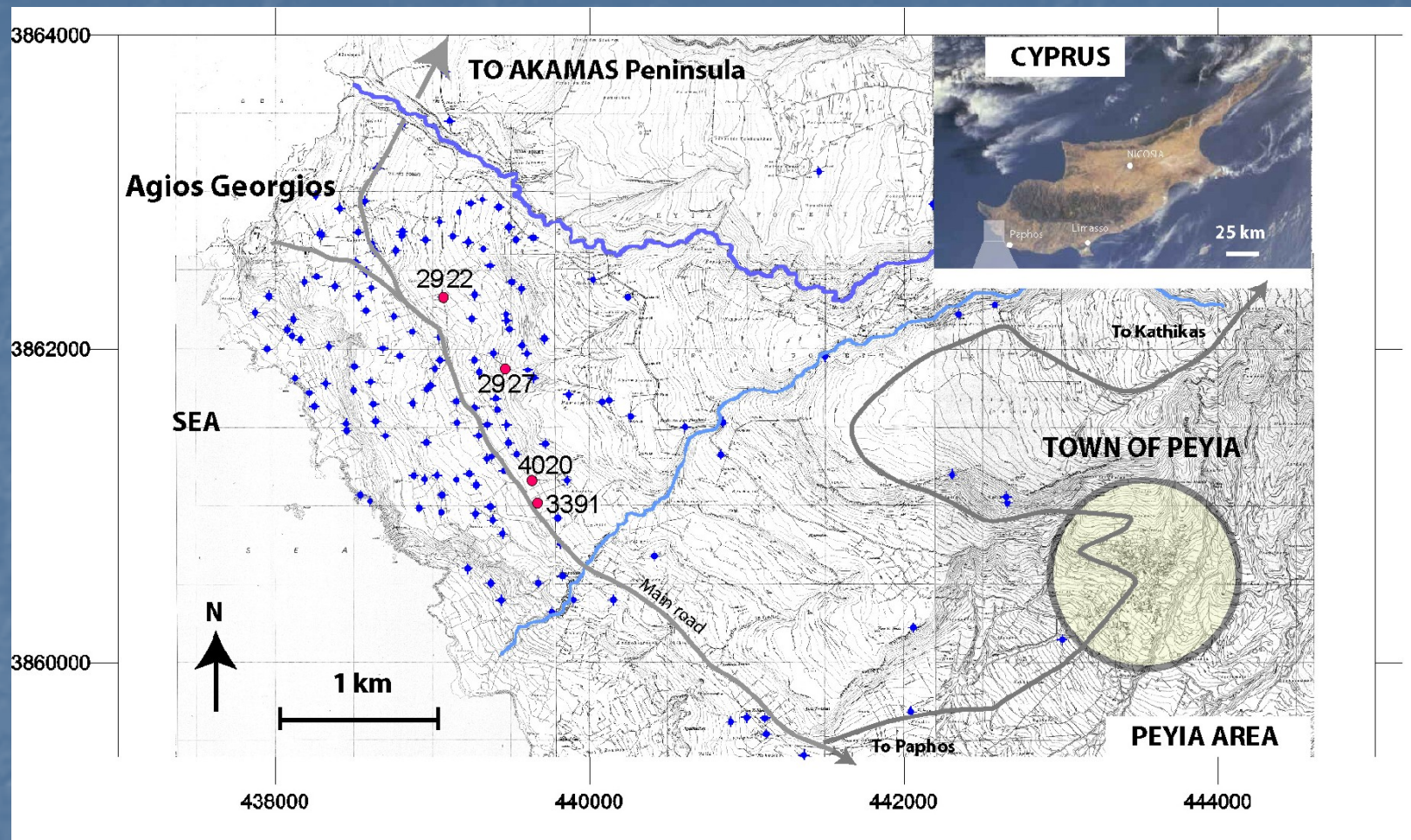


# Pegeia Aquifer



Dr. Andreas Christodoulides

INECO workshop 25-27 October 2007

# Contents

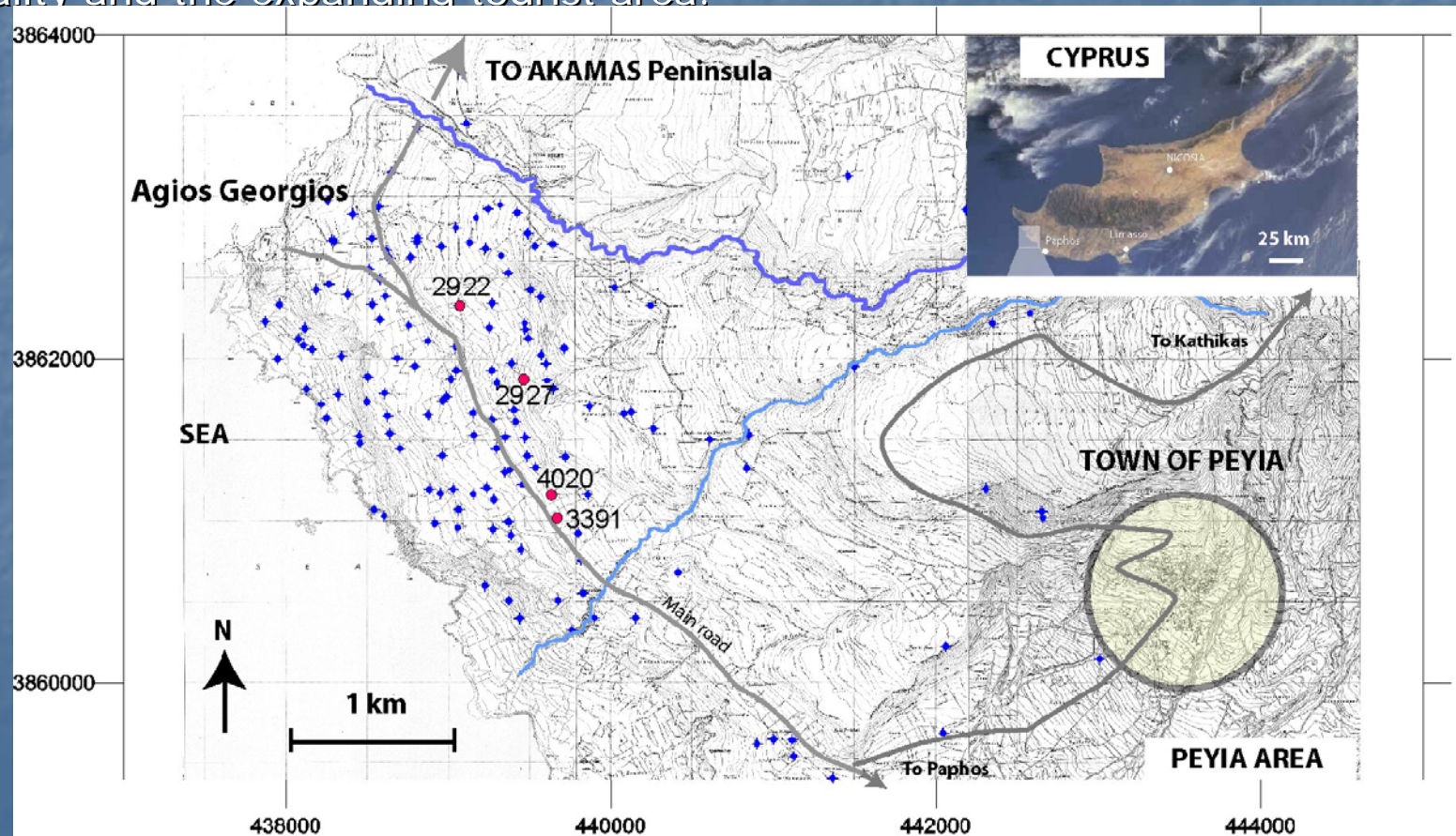
- Location
- Geology
- Hydrogeology
  - Extraction
    - Irrigation
    - Domestic Water supply
  - Recharge
  - Ground water monitoring
    - Quantity
    - Quality
- Summary and conclusions

# • Location

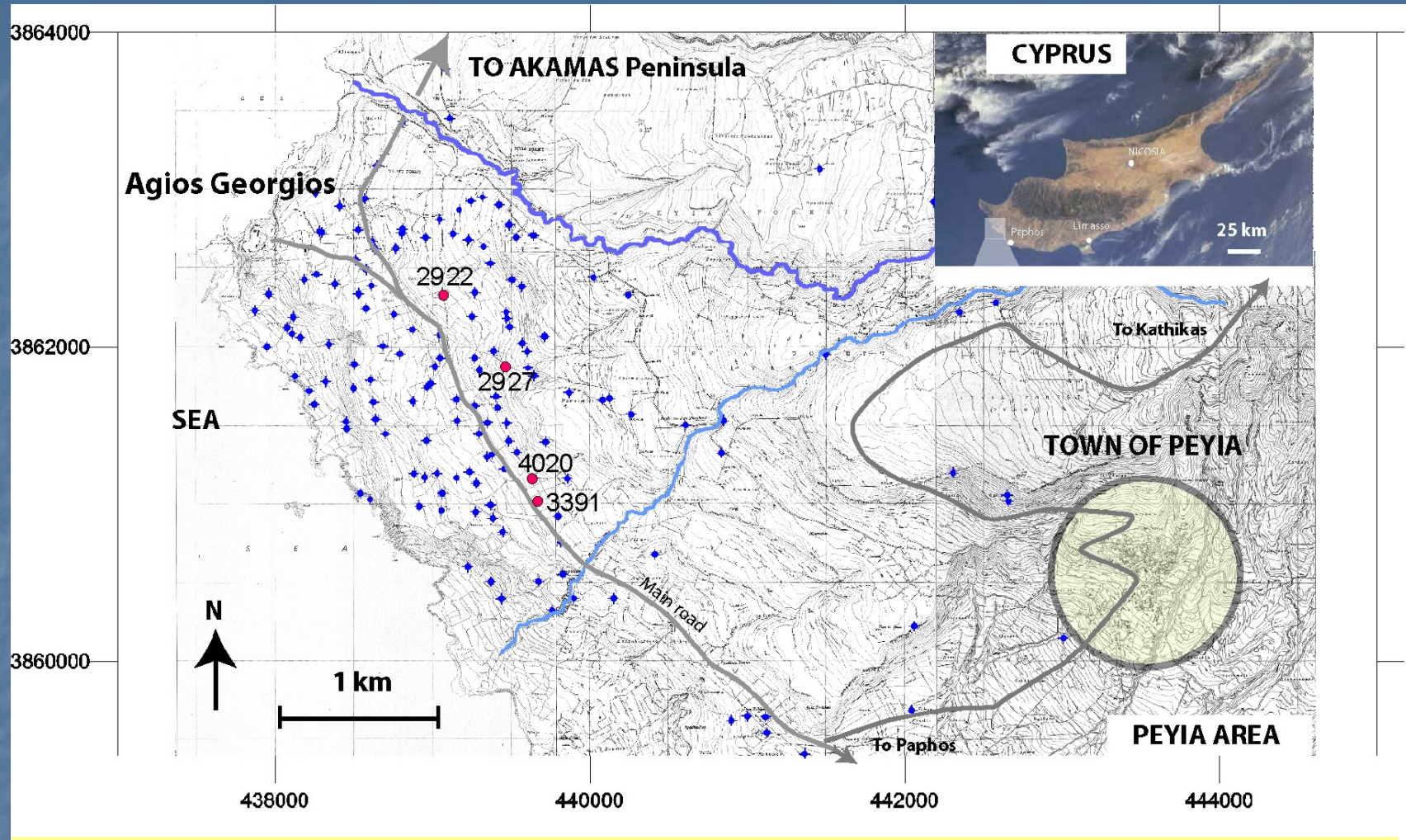
The Pegeia aquifer area is located in the southwest of Cyprus. It covers approximately 20 km<sup>2</sup>, the major part of which lies in the municipality of Pegeia about 15 km north of Paphos, the capital of the district.

The main aquifer covers only a few km<sup>2</sup> and is situated in the coastal area between the two main rivers, close to the Agios Georgios area.

Pegeia aquifer is locally a very important aquifer, supplying water for the Pegeia Municipality and the expanding tourist area.



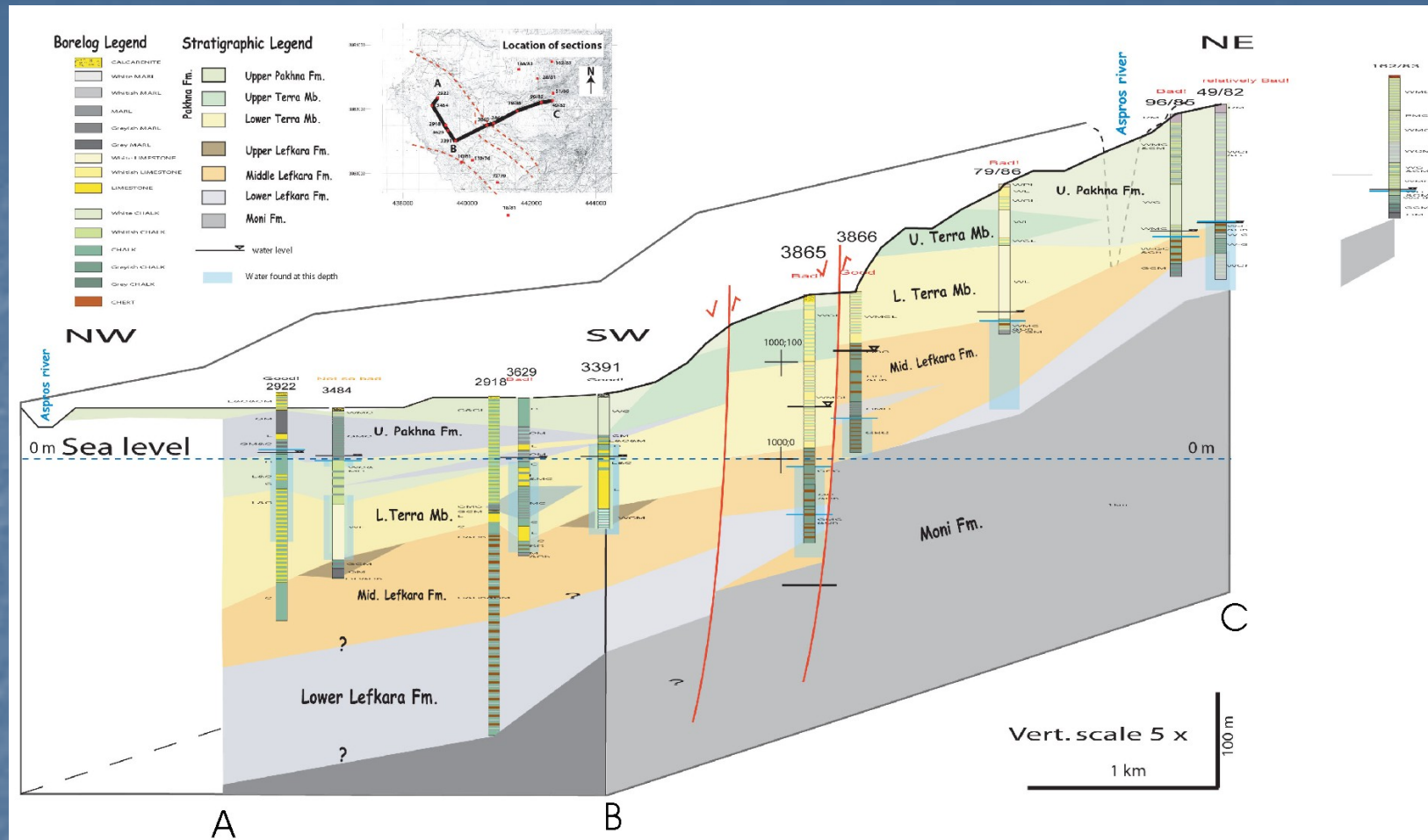
# Pegeia Aquifer



General overview of the study area. Blue dots are boreholes, while blue lines are seasonal rivers. The locations of the water supply wells are indicated in red.

## • Geology

- The general geological setting of south-western Cyprus is characterized by the Mamonia complex, forming the basement of a sedimentary succession of late Cretaceous-Quaternary carbonate deposits.
- The entire area has been subjected to intense tectonic activity, in view of the fact that the aquifer is part of the Pegeia half-graben.
- **Moni Formation:** It consists of igneous and sedimentary breccia or boulders, which float in a dark-grey to dark-green clay matrix. Moni Fm. results from the erosion of the Mamonia basement.
- **Lefkara formation** (pelagic carbonates): It consists of grey marls to white chalky marls, massive white to grey chalks intercalated with layers of chalky marls and marly chalks and cherts.
- **Pakhna formation** consists of reef limestone, chalk, marls, sandstones.
- The uplift in western Cyprus was followed by the formation of a broad basin in the early Miocene. The Pegeia area was located on the structurally higher basin margin, where coral reefs developed, now forming the water-bearing Lower Pakhna formation (Terra Member), while hemi-pelagic, shallow-water redeposited carbonates and basinal chalks were deposited within the basin. This explains why the Terra member shows an important lateral facies variability. Local karst formation within the Pakhna formation is assumed.



The main water-bearing units were identified as the Lefkara formation in the upstream area, while the Terra member of the Pakhna formation acts as main aquifer in the central plain of the Pegeia area.

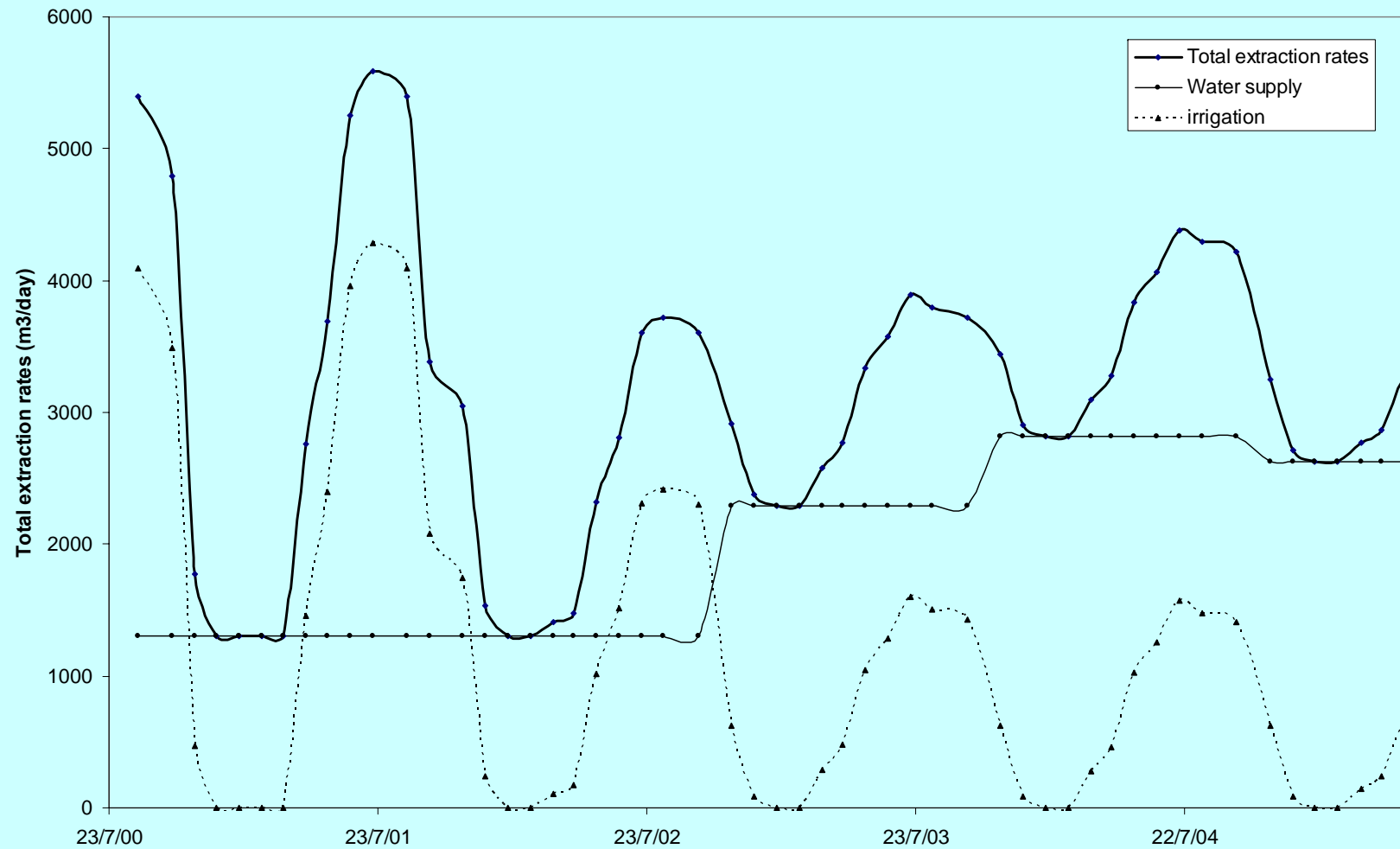
The marls of the Pakhna formation form the upper limit of the aquifer. With its considerable thickness of tens of meters and its low permeability this unit acts to a certain extent as protection from vertical contamination, but it also diminishes the recharge from precipitation.

- **Hydrogeology**

## **Extraction**

- **The total extraction for 2005 was about 1.1 mio m<sup>3</sup> :**
  - **A) 1 mio m<sup>3</sup> for domestic water supply for the Pegeia Municipality and tourist areas, and**
  - **B) about 0.1 mio m<sup>3</sup> for irrigation**
- The calculation of the extraction for irrigation is mainly based on the irrigated areas (the existing crops). After 2001 the farmers have been forced to install water meters. But a number of them were not in operation.
- The calculation of the extraction for domestic water is based on information regarding the yields and hours of operation of the boreholes. Water meters have been installed a couple of years ago but some of them are not functioning at intervals.

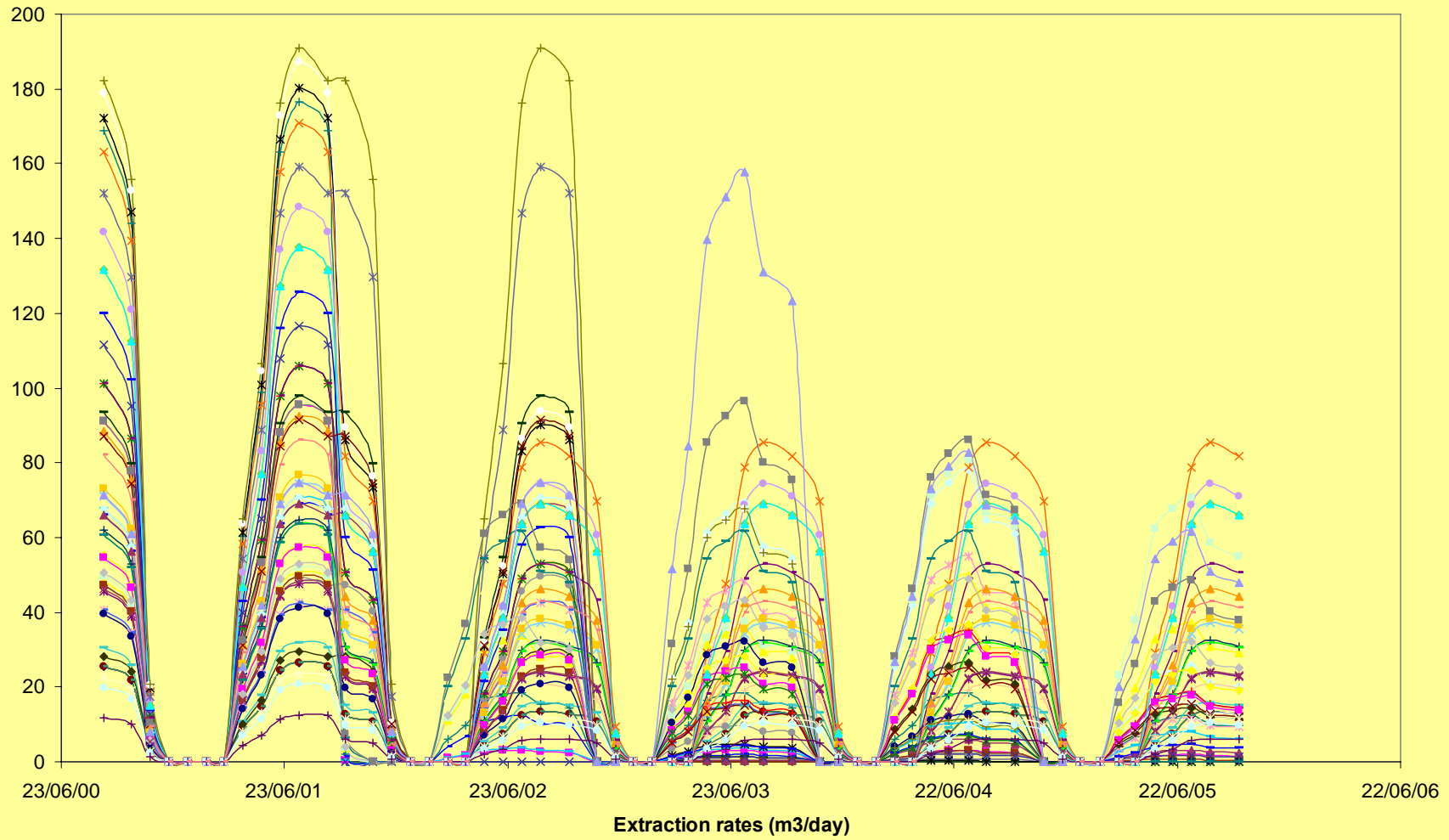
### Transient extraction rates



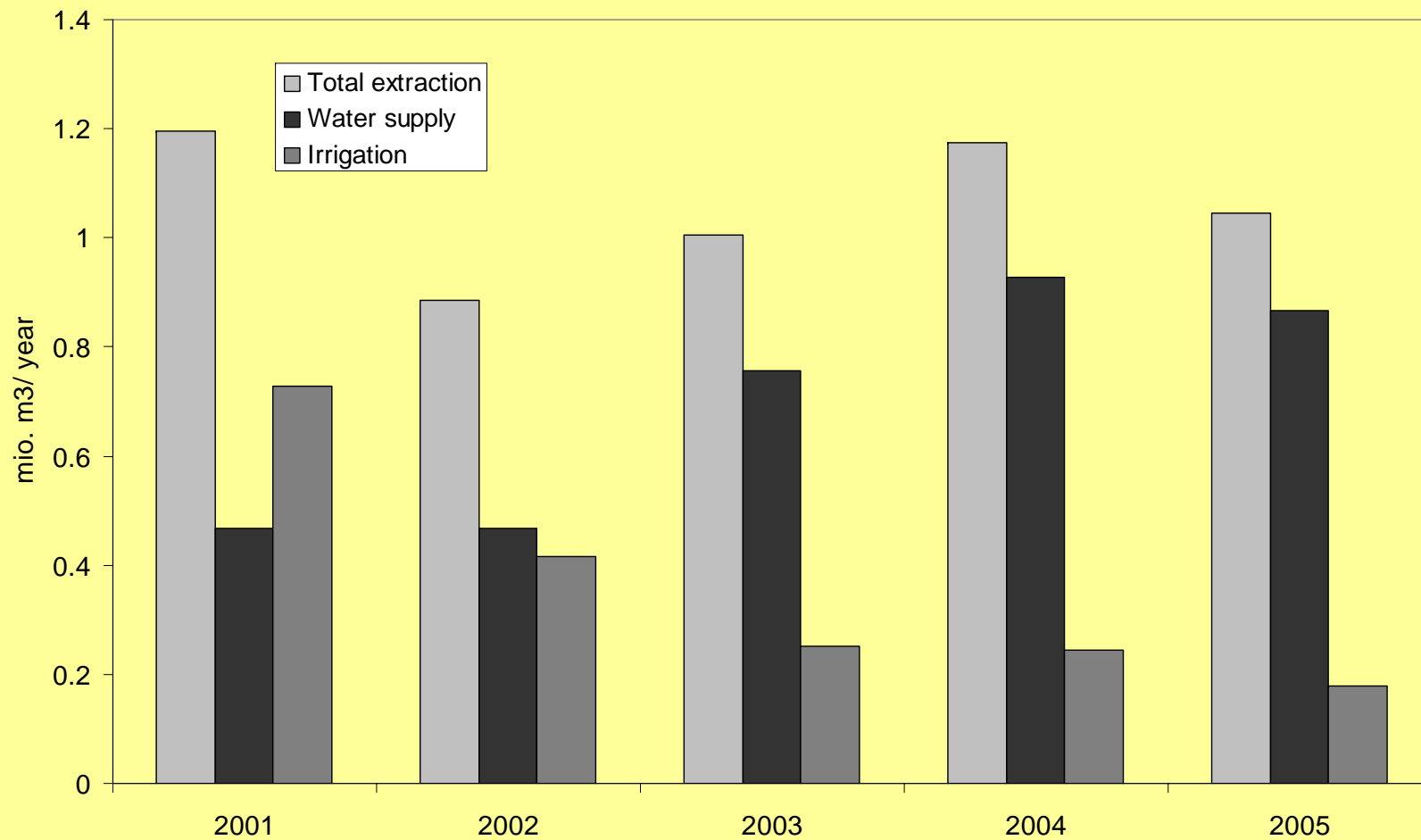
Transient total extraction rates (m3/day) as full lines, water supply extraction rates (full line circles) and irrigation extraction rates (stippled line), showing the decrease of the extraction rates for irrigation purposes and the increase for water supply.



Appendix 4.2: Transient extraction rates of irrigation wells



### Total annual extraction rates



Annual extraction rates for the time-period 2001-2005. The extraction rate (grey), water supply (black) and extraction for irrigation (dark grey) in million m<sup>3</sup>.

## • Extraction

### ■ Domestic W.S:

- The water for domestic supply is mainly extracted from two wells (2922 and 3391). Two more wells (3866, 4020) supply domestic water in lesser amounts.
- The borehole with nr. 4020 has been in operation since 2004.
- The afore mentioned wells supply water for more than 5000 houses and tourist units (End 2006 about 5000 water meters). The four W.S. boreholes are located within the main irrigated area.
- Since June 2004 additional water for domestic purposes has been supplied from the Asprogremmos treatment plant.
- Since July 2007 another three new boreholes have been connected to the system. (Total water extracted for 2007 till today is 51,100 m<sup>3</sup>)
- One borehole (2972) is private and supplies the tourist area with domestic water .
- Due to the growth in tourism in the Pegeia area, the demand on water has increased during the last years.

# 2004

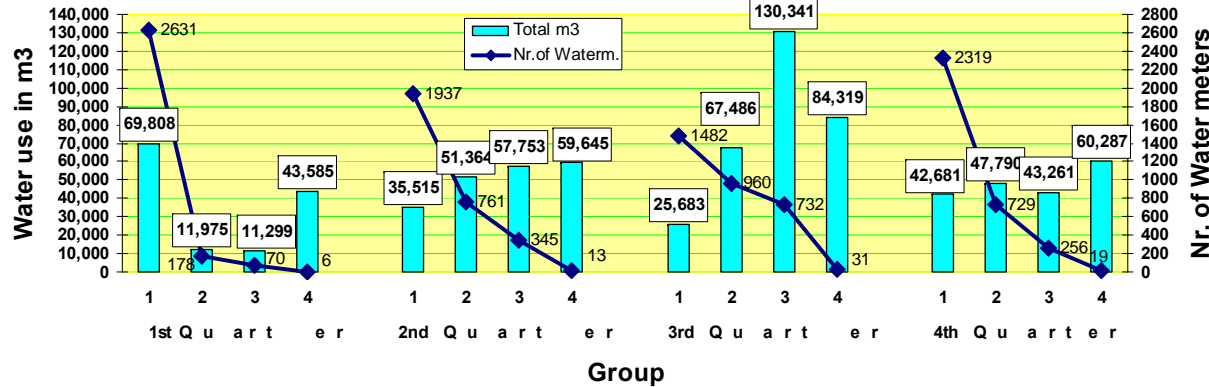
Water use(m3) vs. number of water meters by group(1 - 4)

Water use (cumulative in m3) vs. number of water meters (cumulative) by group(1 - 4)

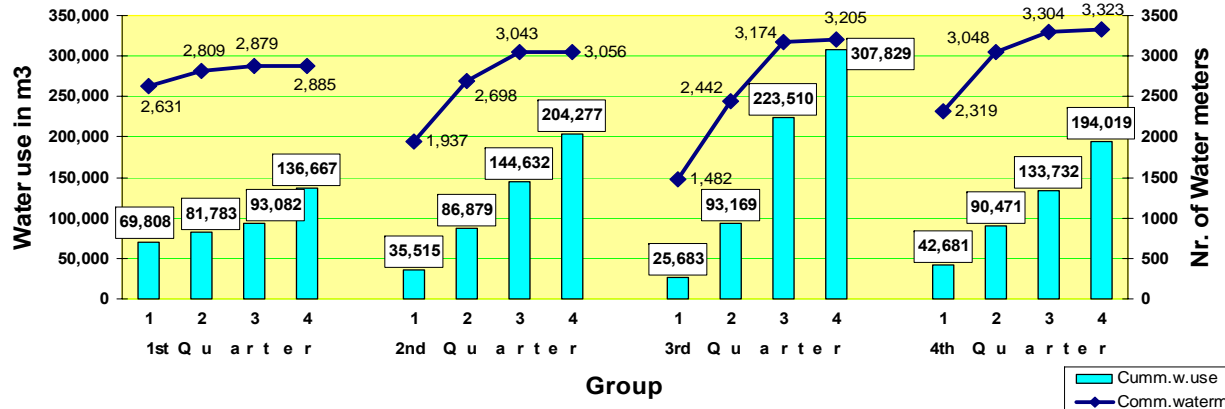
Water use(%) vs. number of water meters(%) by group(1 - 4)

- 1: =< 45m3
- 2: 46-100 m3
- 3: 100-500 m3
- 4: >500 m3

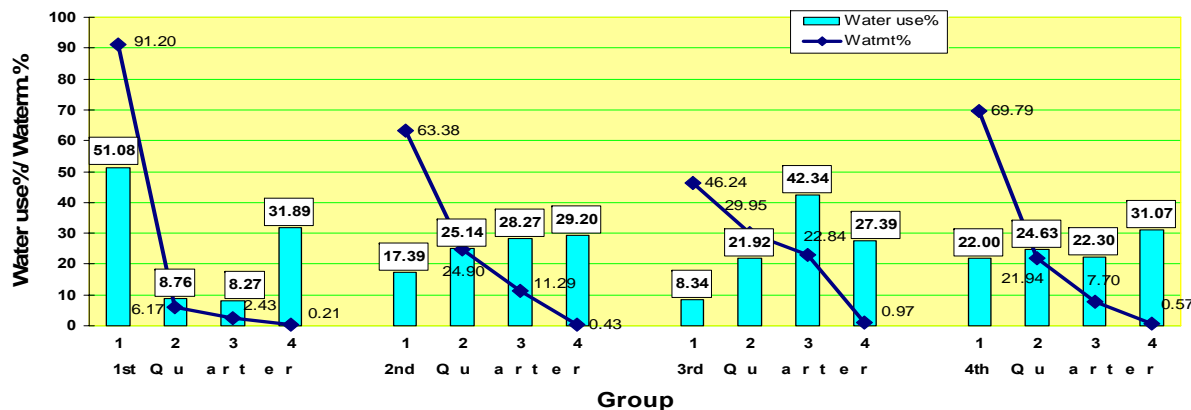
Water use vs Nr of Water meters by group for the four quarters of the year 2004



Commulative Water use vs Nr of Water meters by group for the four quarters of the year 2004



Water use percentage vs Water meters percentage by group for the four quarters of the year 2004



# 2005

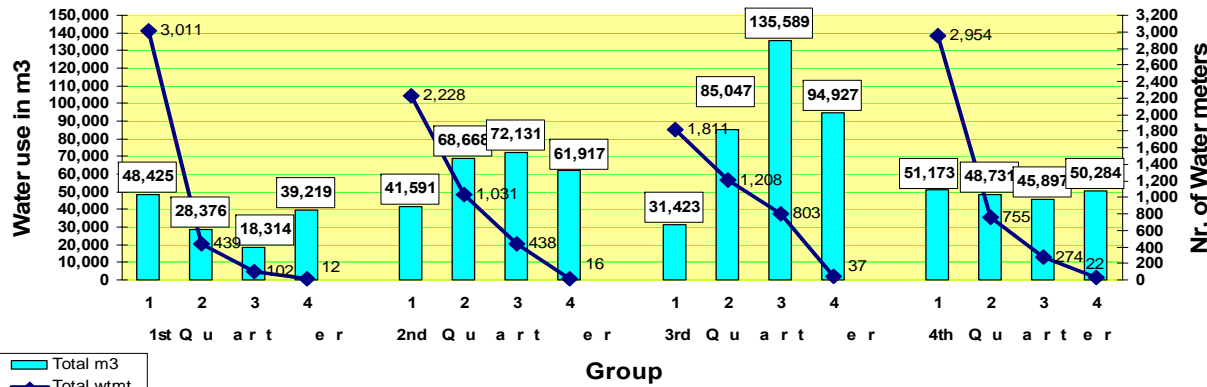
Water use(m3) vs. number of water meters by group(1 - 4)

Water use (cumulative in m3) vs. number of water meters (cumulative) by group(1 - 4)

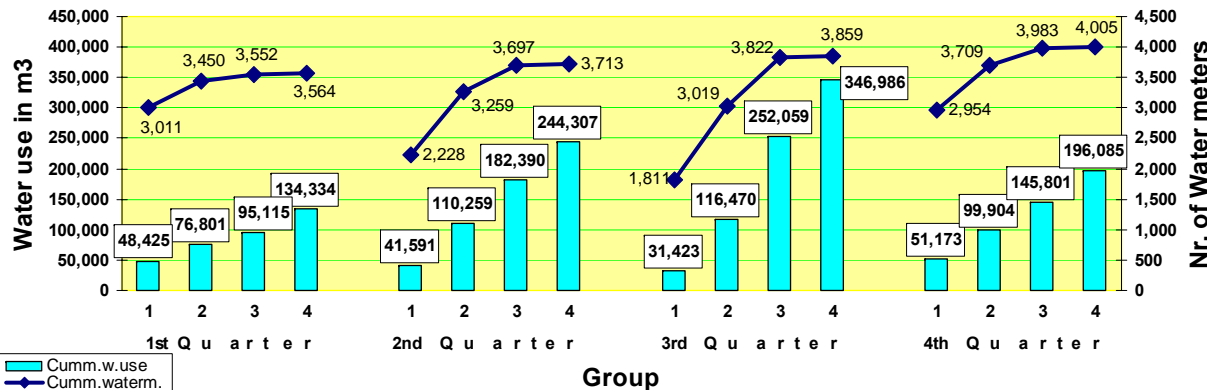
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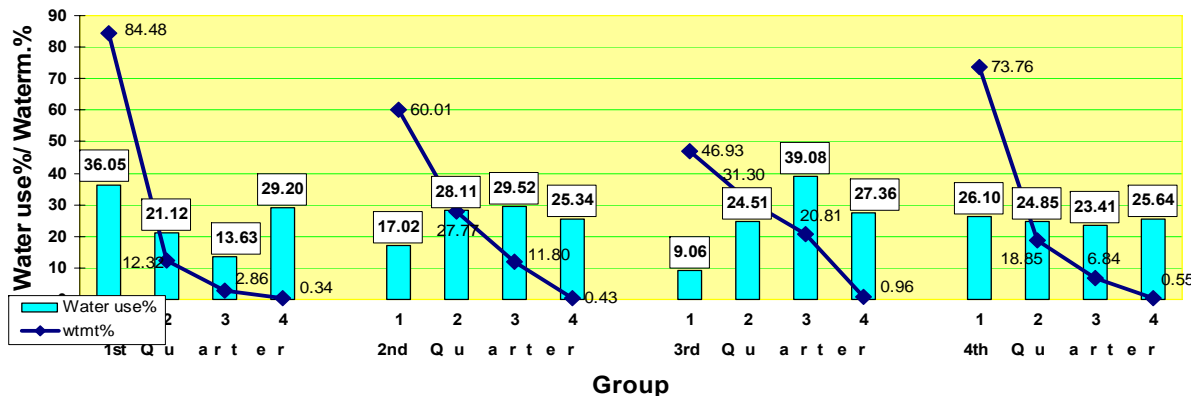
Water use vs Nr of Water meters by group for the four quarters of the year 2005



Commulative Water use vs Nr of Water meters by group for the four quarters of the year 2005



Water use percentage vs Water meters percentage by group for the four quarters of the year 2005



# 2006

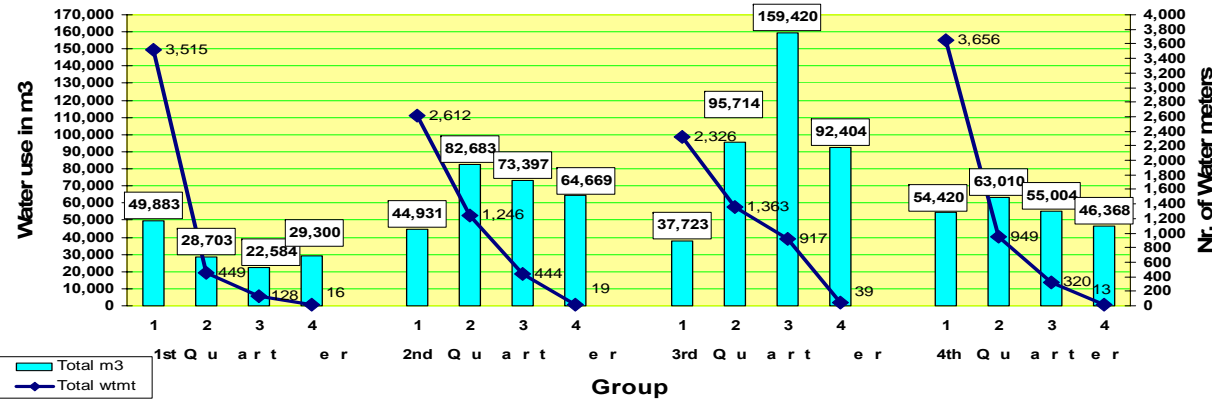
Water use(m<sup>3</sup>) vs. number of water meters by group(1 - 4)

Water use (cumulative in m<sup>3</sup>) vs. number of water meters (cumulative) by group(1 - 4)

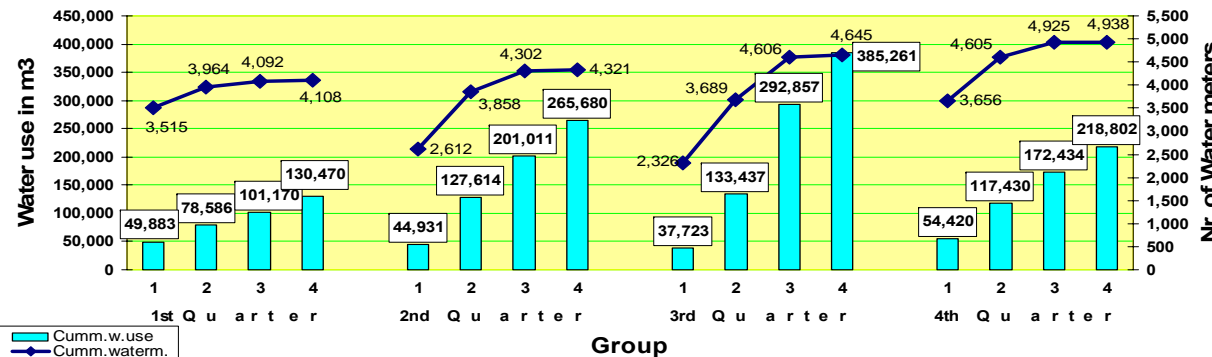
Water use(%) vs. number of water meters(%) by group(1 - 4)

- 1: =< 45m3
- 2: 46-100 m3
- 3: 100-500 m3
- 4: >500 m3

Water use vs Nr of Water meters by group for the four quarters of the year 2006



Commulative Water use vs Nr of Water meters by group for the four quarters of the year 2006



Water use percentage vs Water meters percentage by group for the four quarters of the year 2006

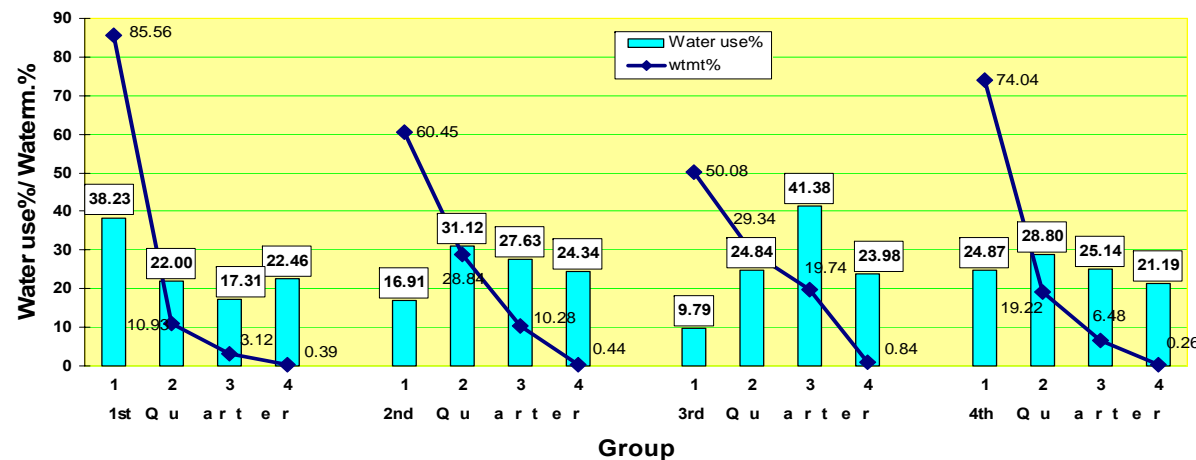
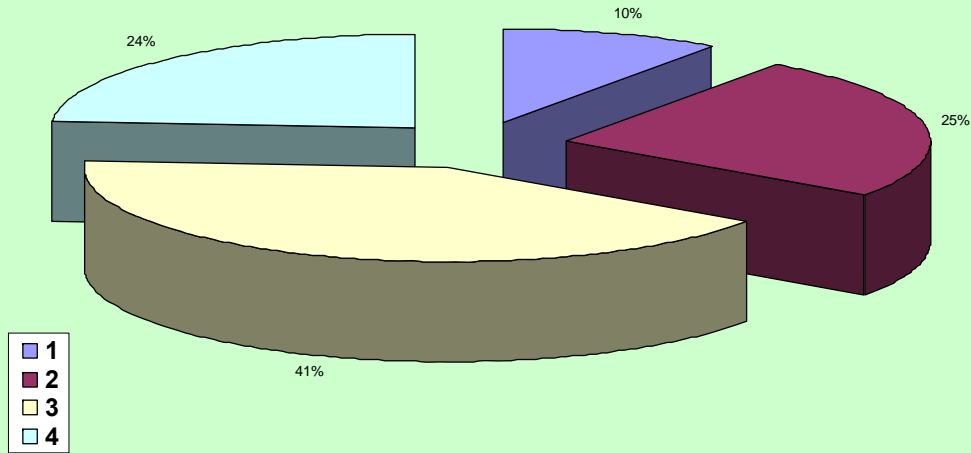
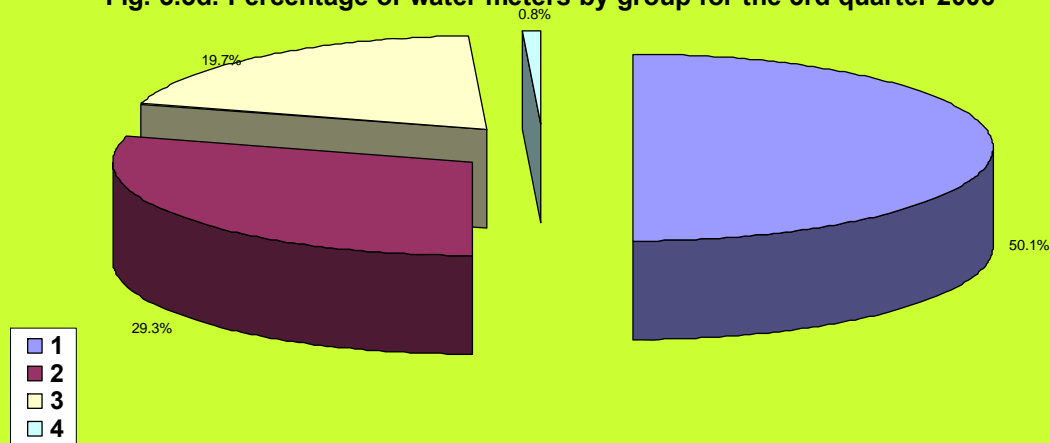


Fig. 3.3c. Percentage of water use by group for the 3rd quarter 2006

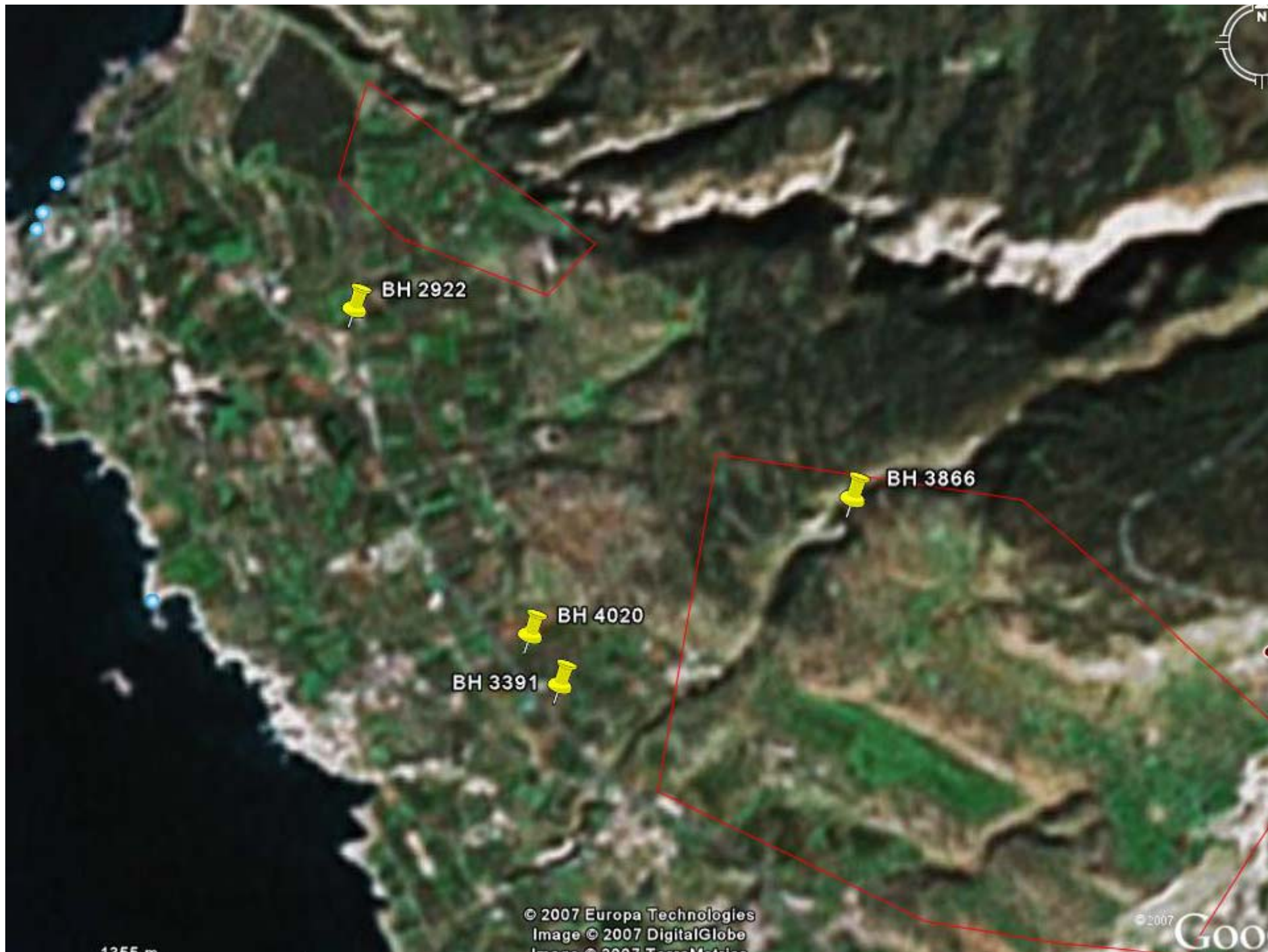


1:  $\leq 45\text{m}^3$   
2: 46-100  $\text{m}^3$   
3: 100-500  $\text{m}^3$   
4:  $> 500\text{m}^3$

Fig. 3.3d. Percentage of water meters by group for the 3rd quarter 2006



Correlation between water use and number of water meters (in percentage) for the 3<sup>rd</sup> quarter 2006 by group(1-4)



BH 2922

BH 3866

BH 4020

BH 3391

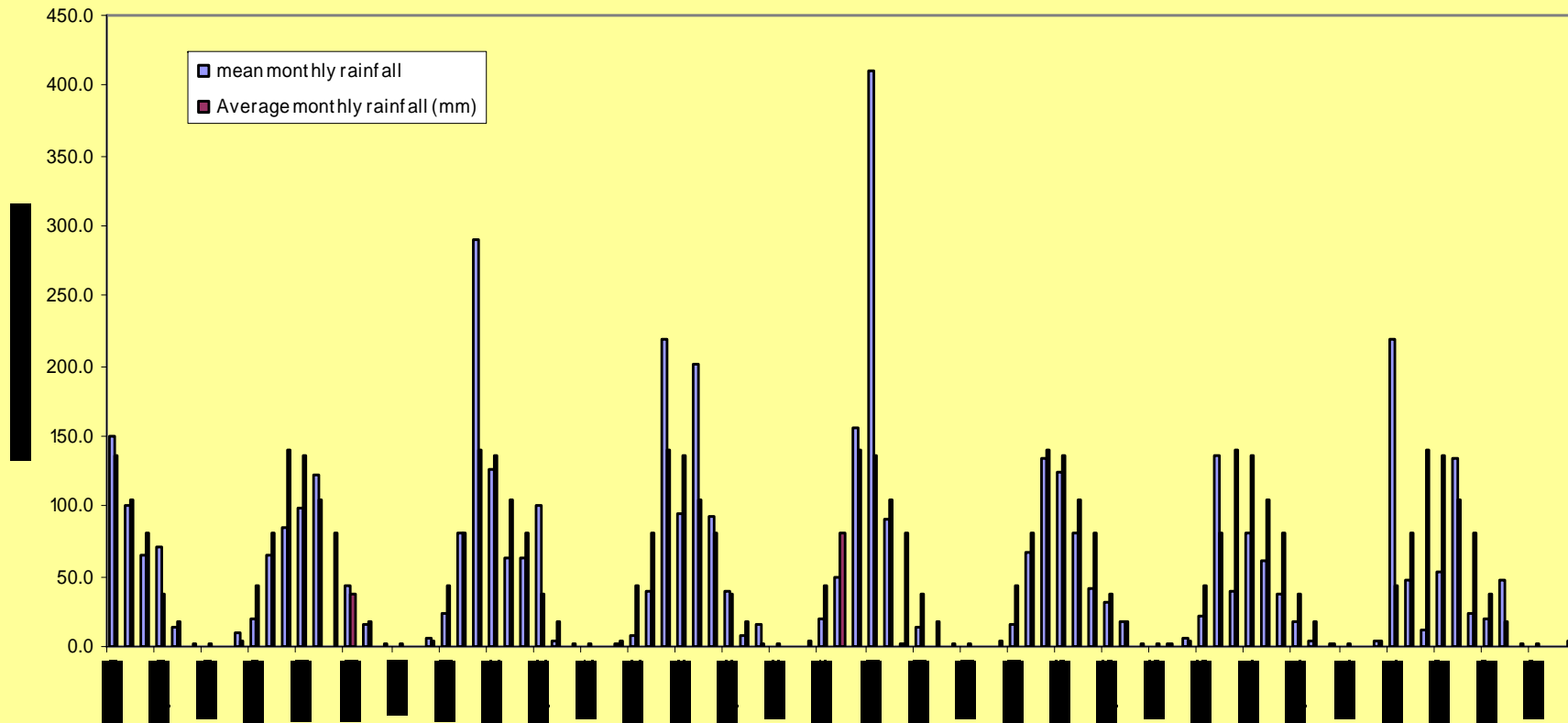


## •Recharge

- The climate of south-western Cyprus can definitely be characterized as semi-arid, with an aridity index of 0.25 (semi-arid conditions =0.2 to 0.5)
  - The average annual rainfall is approximately 500 mm. The annual variation of rainfall is also characteristic of semi-arid conditions.
  - The temporal distribution of precipitation will determine how much and when, recharge of the aquifer by means of infiltration of precipitation can take place.
- In the years 2004 and 2006 water from the Asprogremmos dam has been used for recharge in selected boreholes.
- 2004: Amount of water used for recharge in 6 BHs **262,168 m<sup>3</sup>**
- 2006: Amount of water used for recharge in 6 BHs **97,182 m<sup>3</sup>**

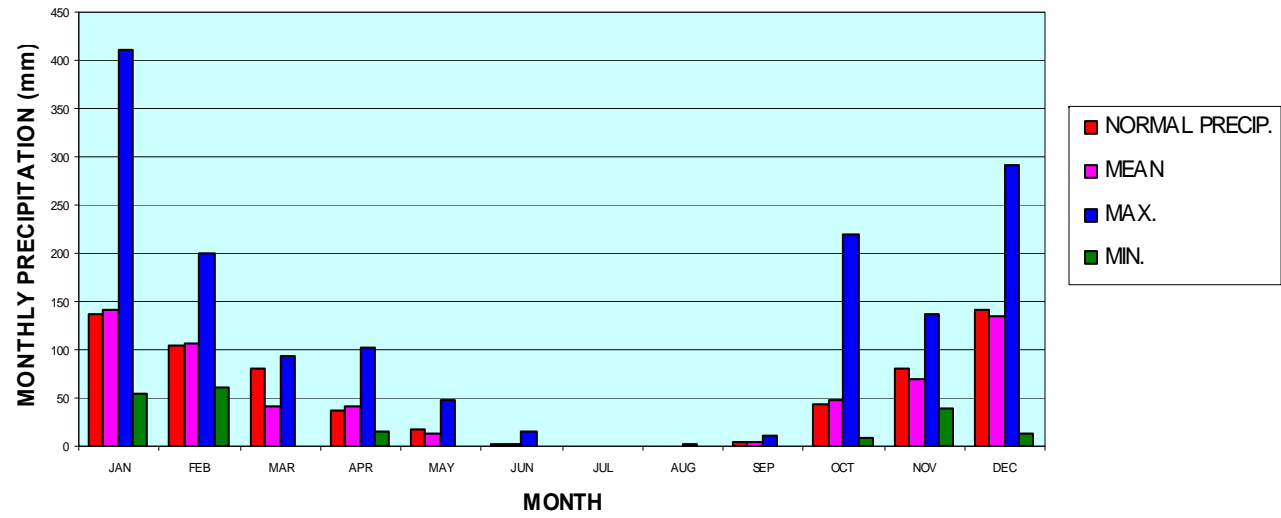
For the time-period 200 - 2007 only for the years 2001 and 2006, the total annual rainfall is lower than 500mm

Rainfall (mm), Kathikas St. Nr. 032

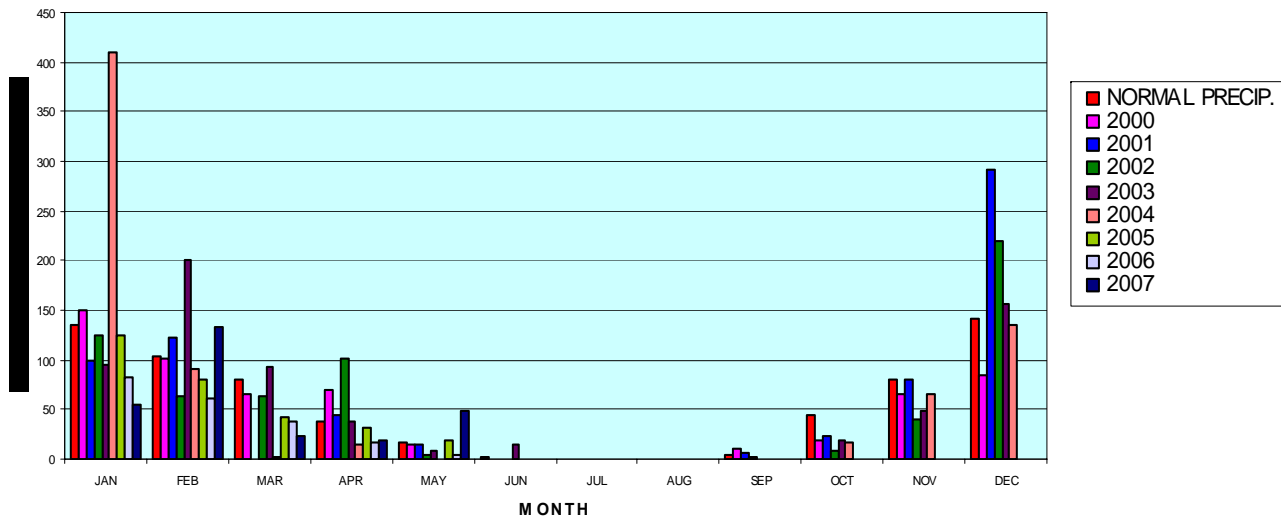


Monthly rainfall (mm) in blue, measured at the Kathikas station (Nr. 032) as compared to the long-term average monthly values (red).

METEOROLOGICAL SERVICE  
STATION KATHIKAS ST. No.032



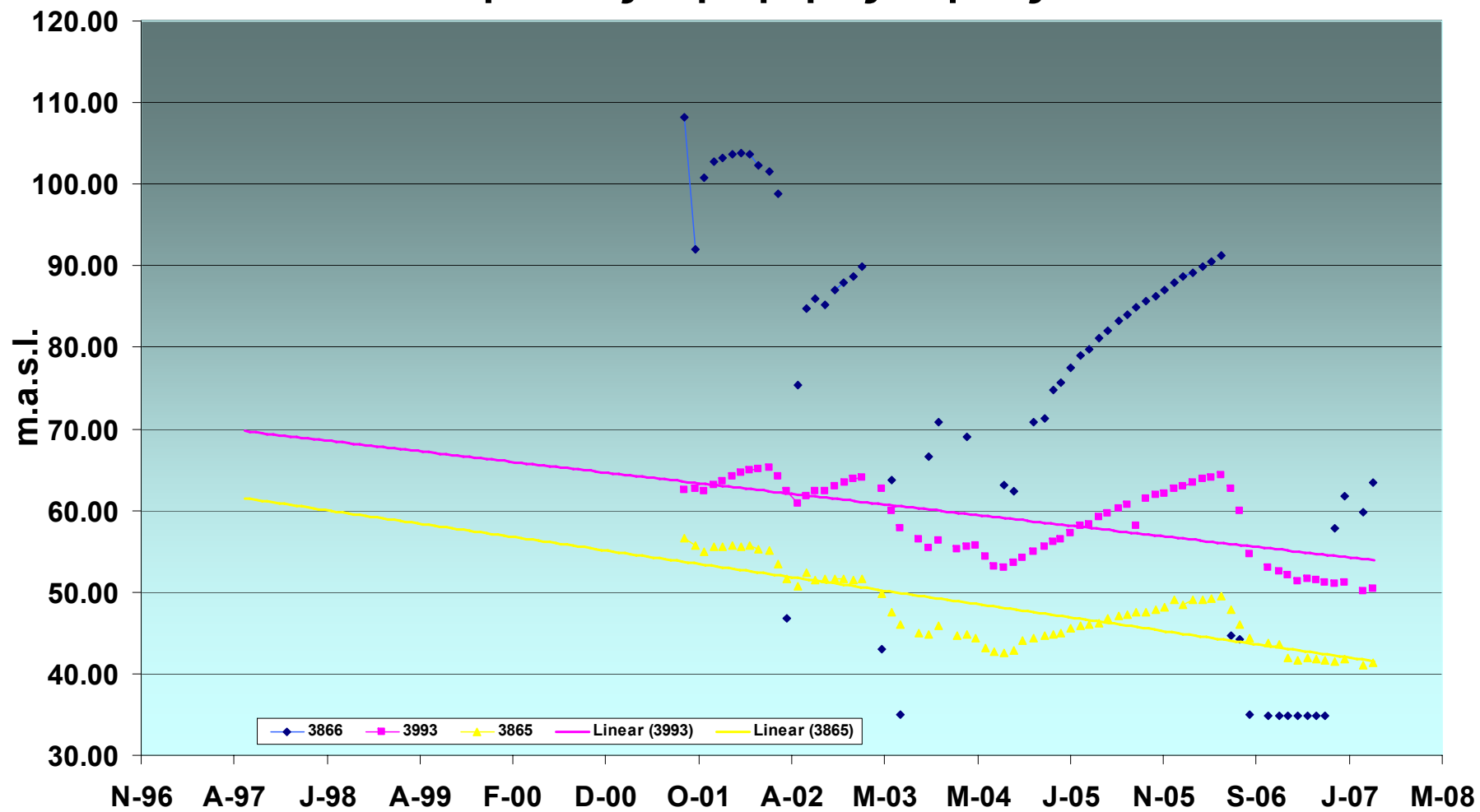
METEOROLOGICAL SERVICE  
STATION KATHIKAS ST. No.032



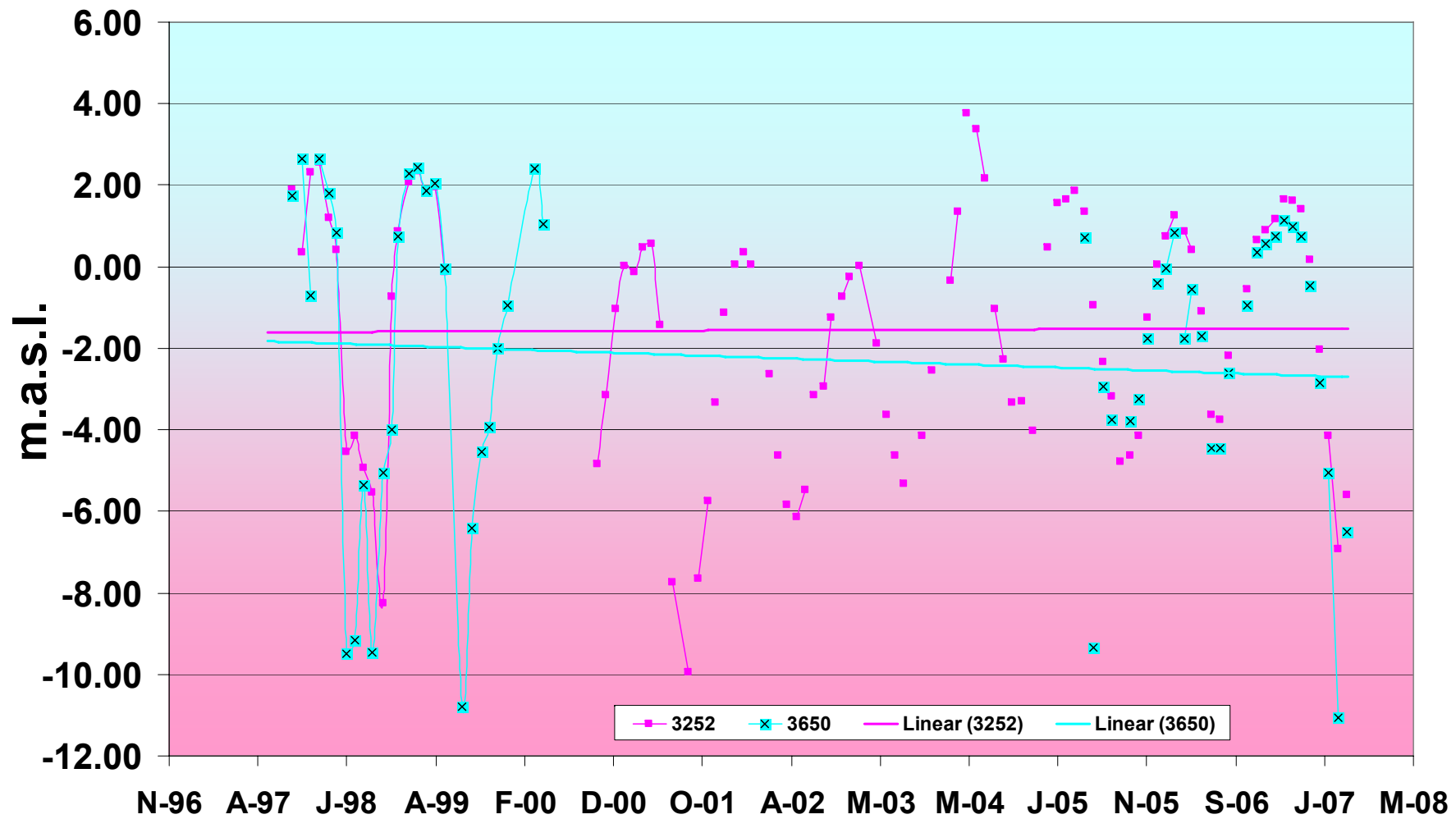
## ■ **Ground water monitoring:**

- **The water table and salinity evolution have been monitored for several years in the Pegeia aquifer.**
- **A network with a relatively great number of boreholes is used for measuring the water level every month.**
- **In four boreholes automatic water level recorders have been installed. From two of them, equipment has been removed, but the other two are still in operation.**
- **Conductivity measurements are carried out in a number of selected boreholes.**
- **New boreholes have been drilled for the purpose of better monitoring. In these boreholes electronic equipment for automatic measuring and storing data regarding conductivity and water level will be installed.**

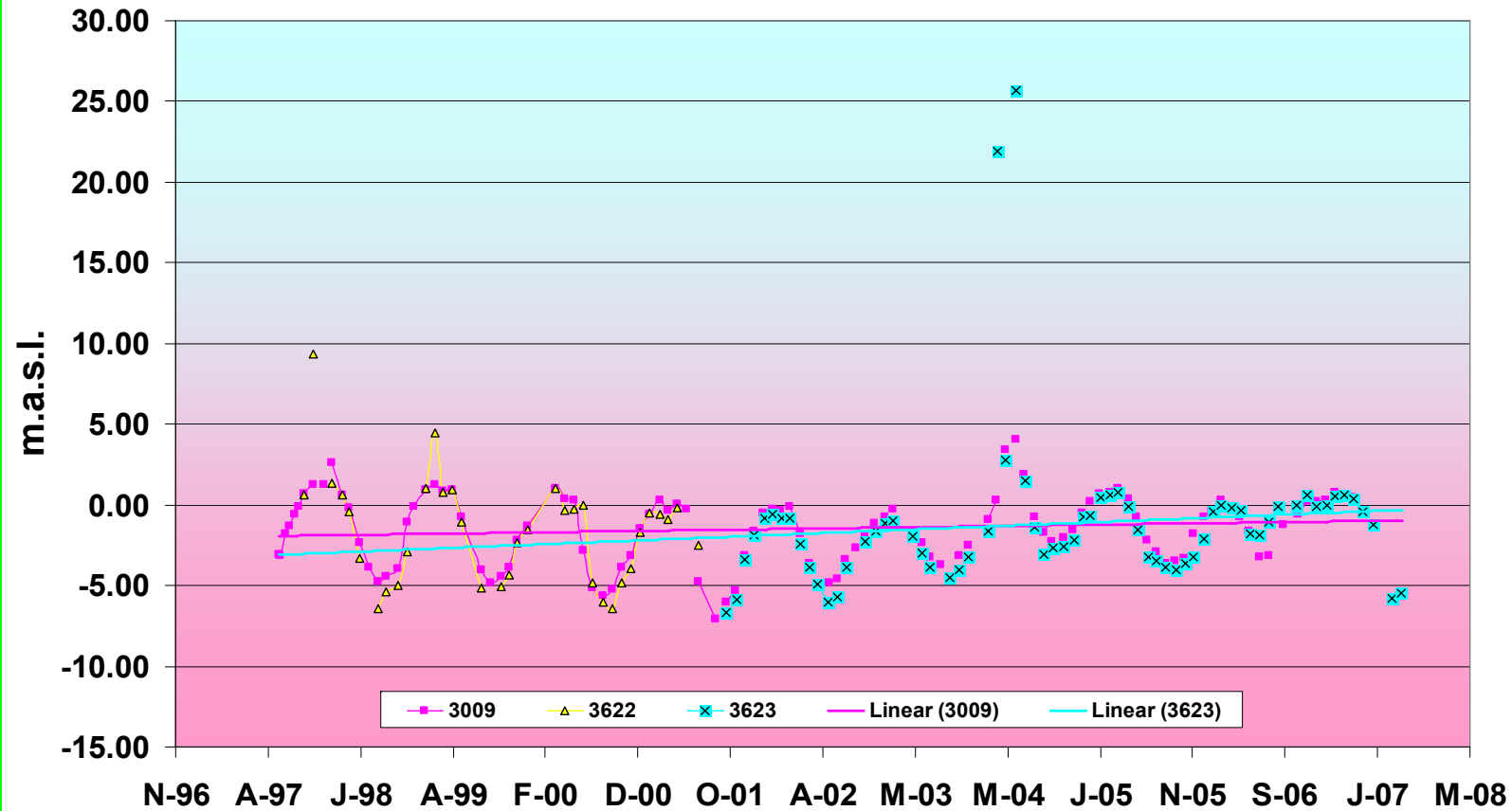
Σχ. 1. Χρονικές διακυμάνσεις της στάθμης σε γεωτρήσεις.  
Παράκτιος υδροφόρος Πέγεια



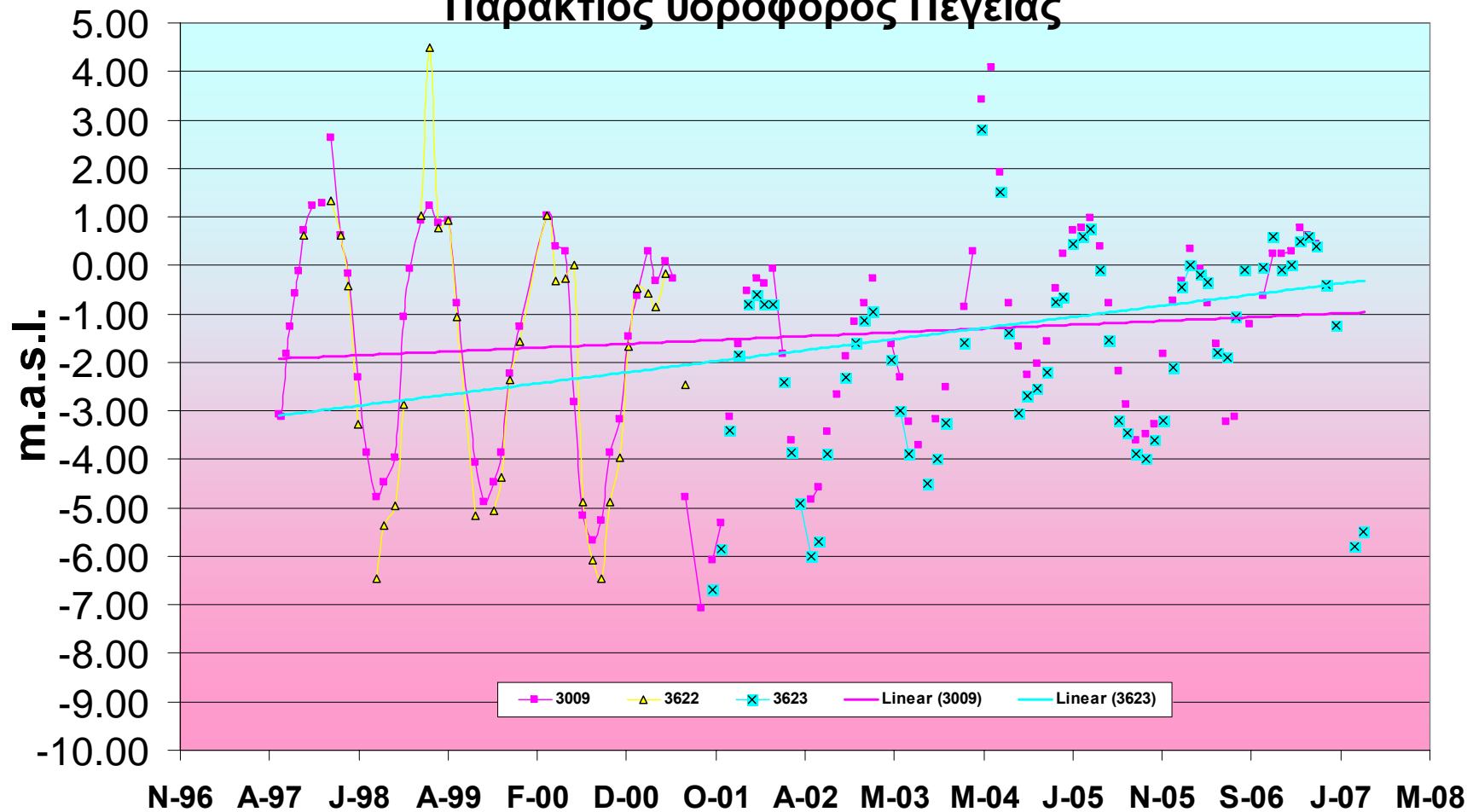
Σχ. 2. Χρονικές διακυμάνσεις της στάθμης σε γεωτρήσεις.  
Παράκτιος υδροφόρος Πέγεια



Σχ. 3. Χρονικές διακυμάνσεις της στάθμης σε γεωτρήσεις.  
Παράκτιος υδροφόρος Πέγεια



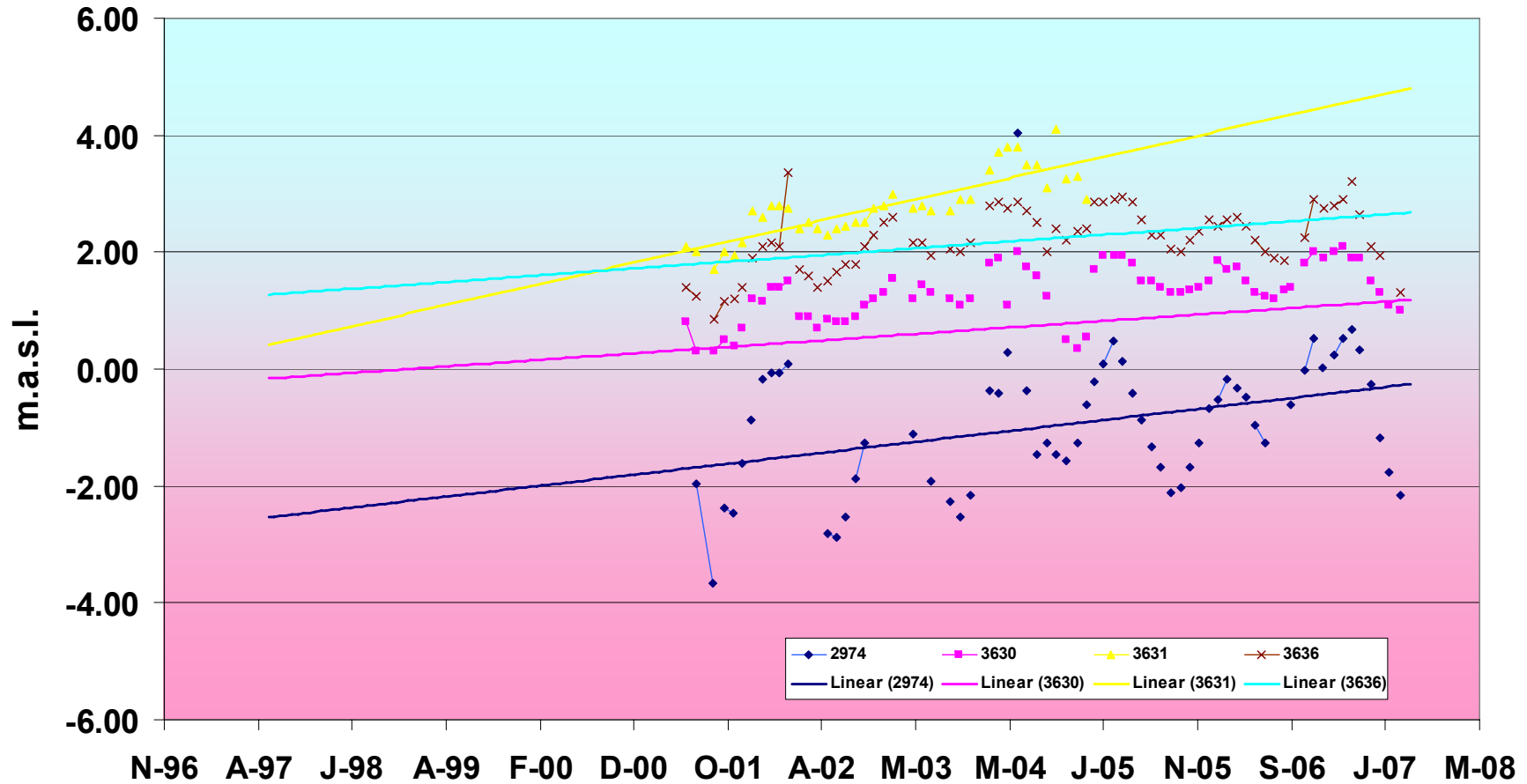
Σχ. 3α. Χρονικές διακυμάνσεις της στάθμης σε γεωτρήσεις.  
Παράκτιος υδροφόρος Πέγειας



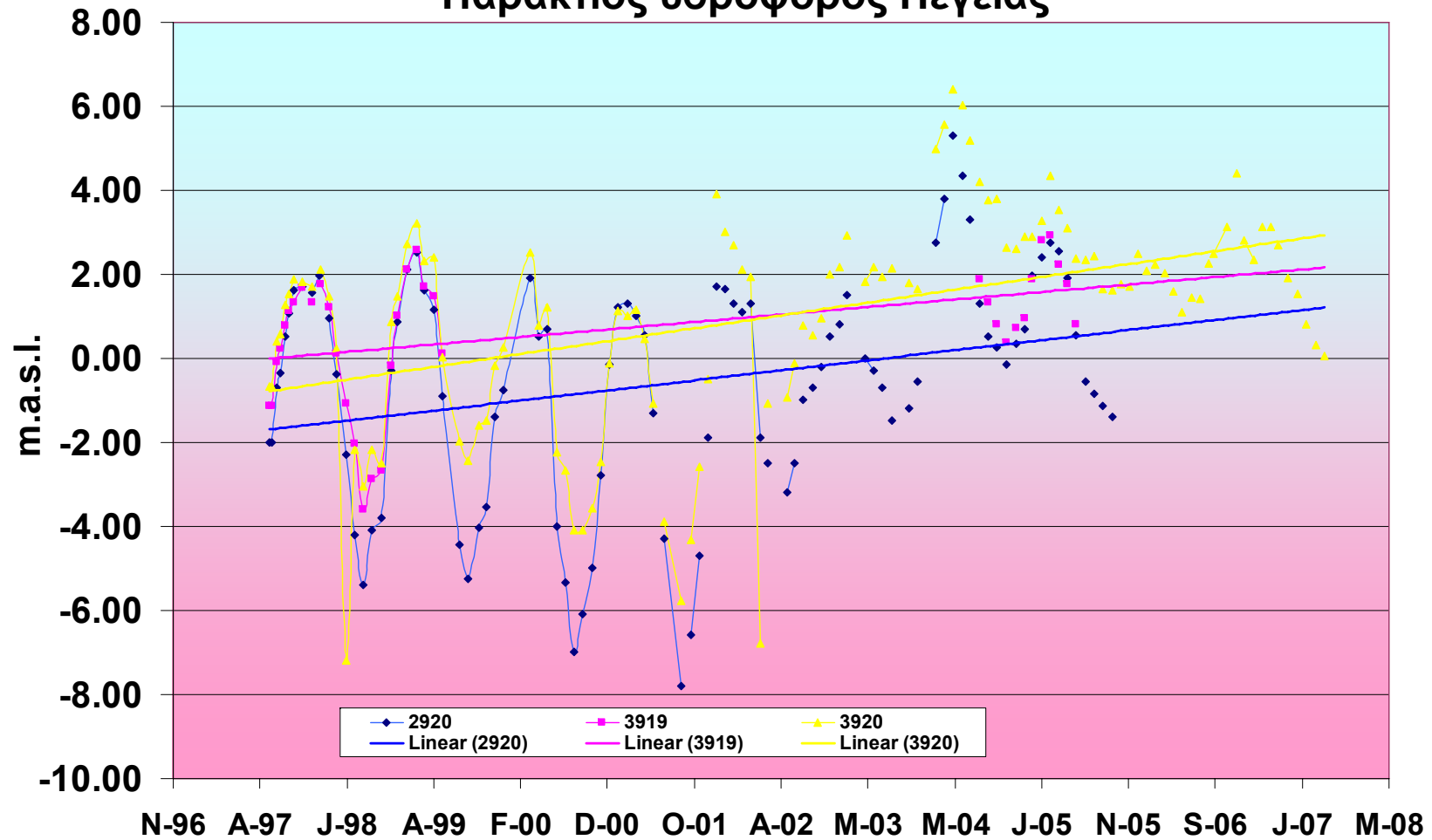
The boreholes are located close to, or between the pumping wells for domestic water



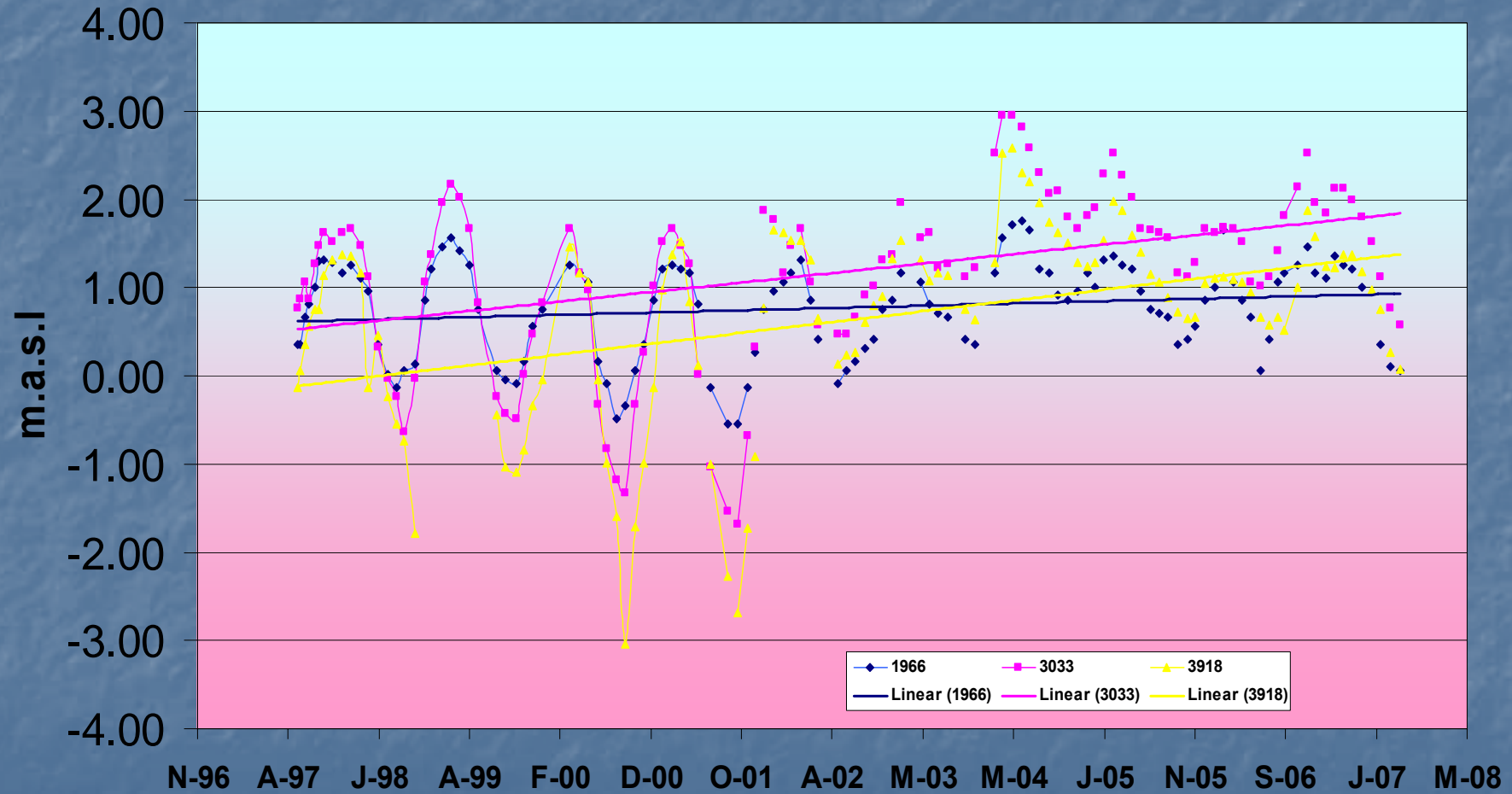
**Σχ. 4. Χρονικές διακυμάνσεις της στάθμης σε γεωτρήσεις.  
Παράκτιος υδροφόρος Πέγειας**



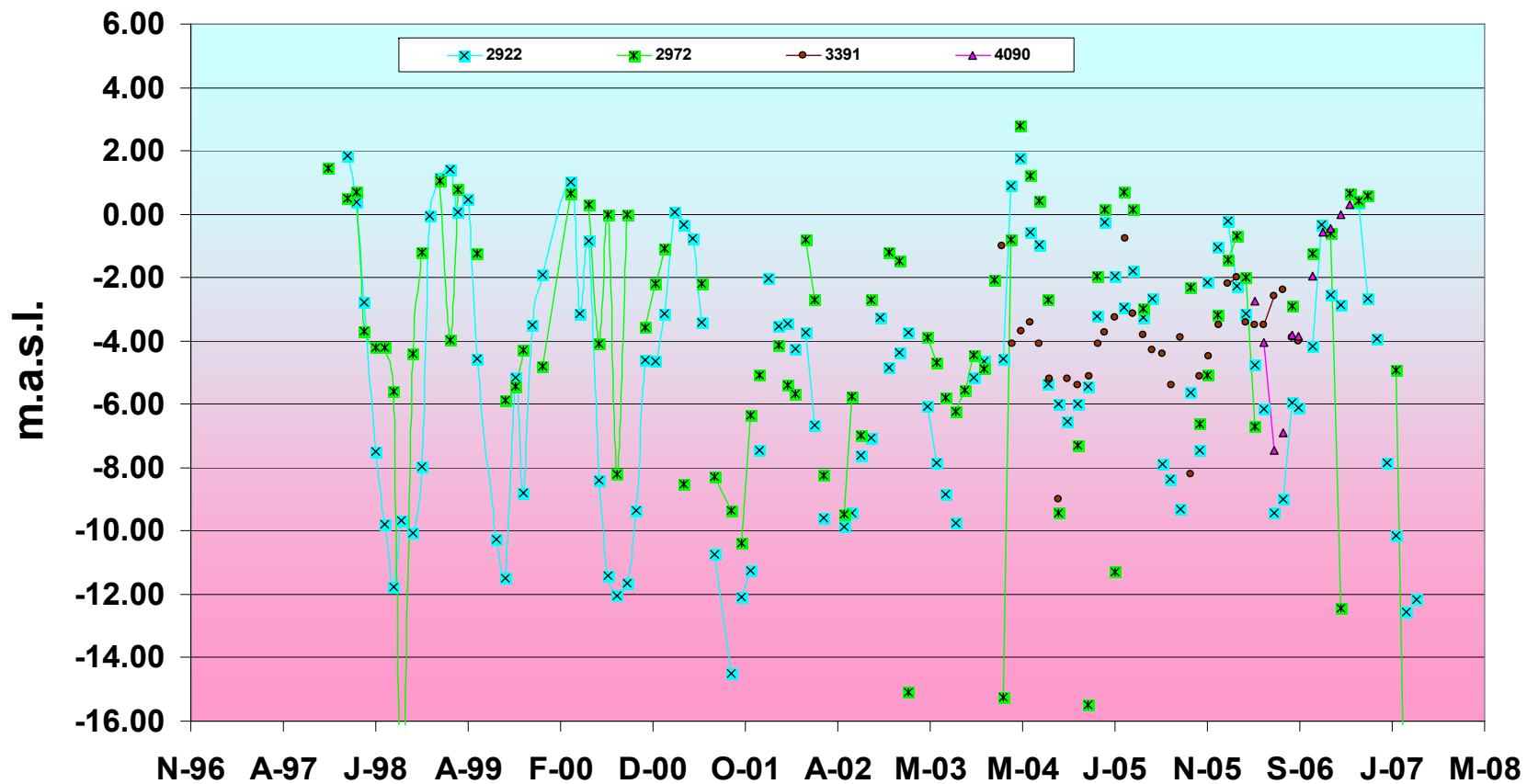
Σχ. 5. Χρονικές διακυμάνσεις της στάθμης σε γεωτρήσεις.  
Παράκτιος υδροφόρος Πέγεια

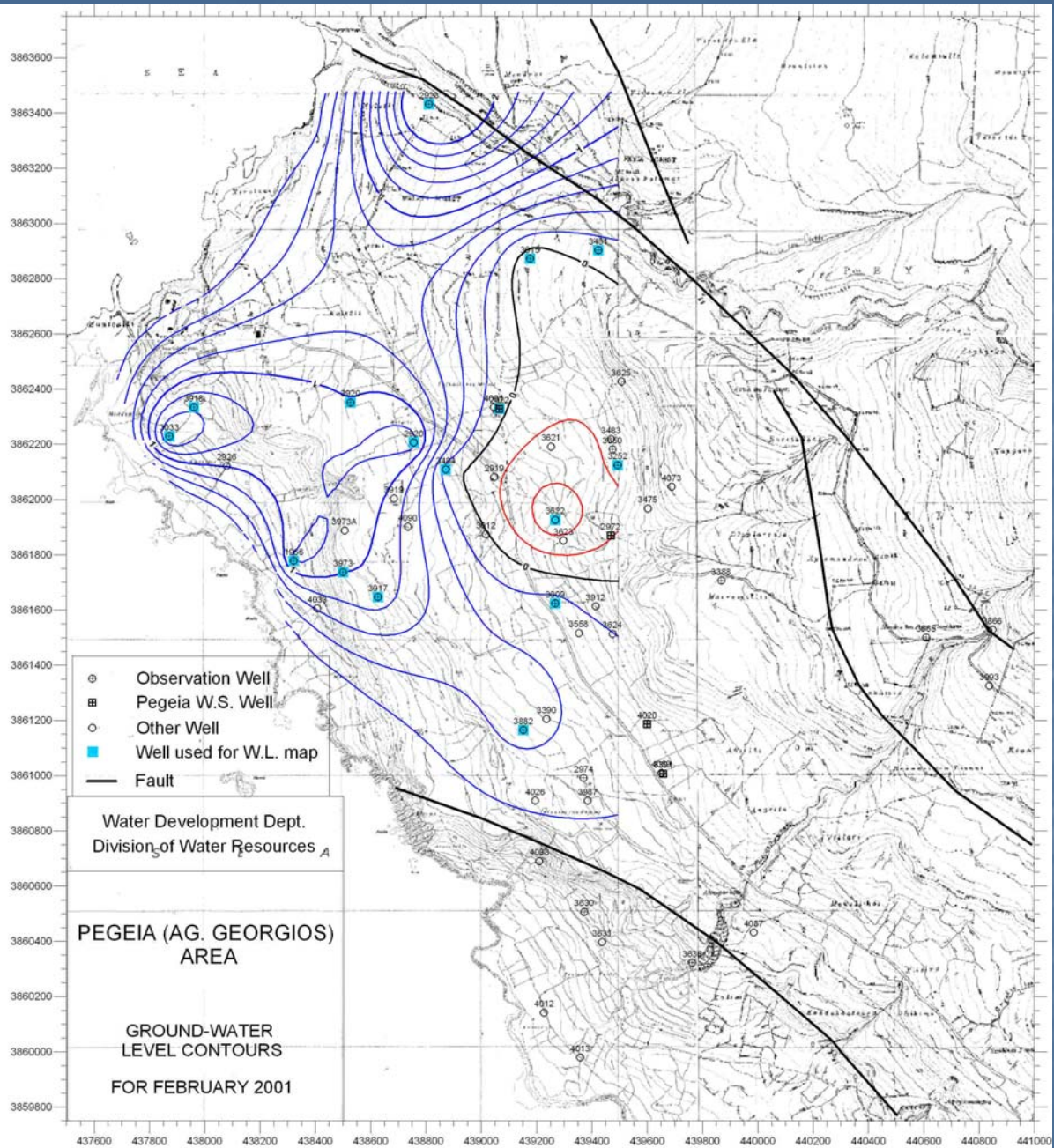


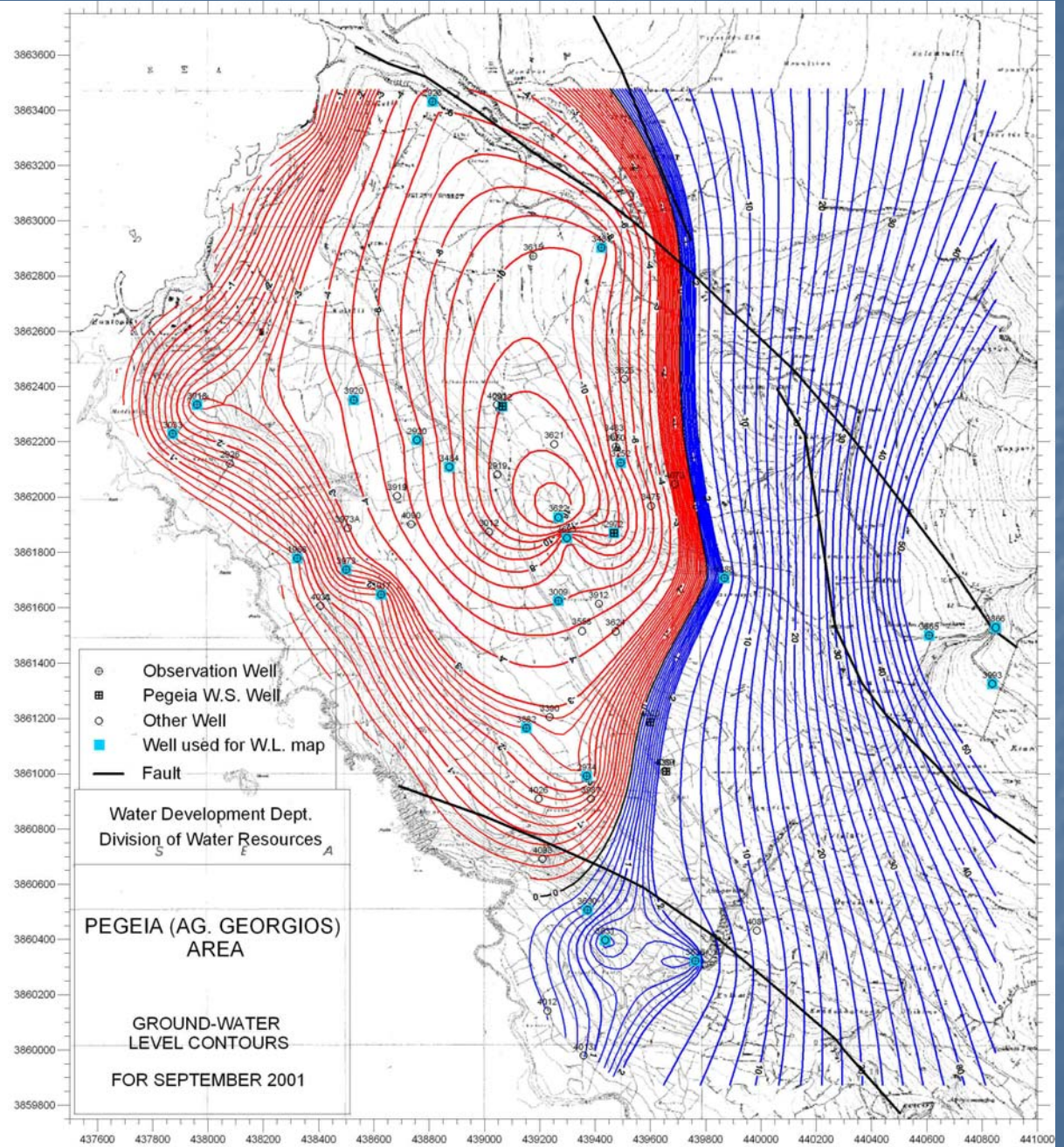
Σχ. 6. Χρονικές διακυμάνσεις της στάθμης σε γεωτρήσεις.  
Παράκτιος υδροφόρος Πέγεια

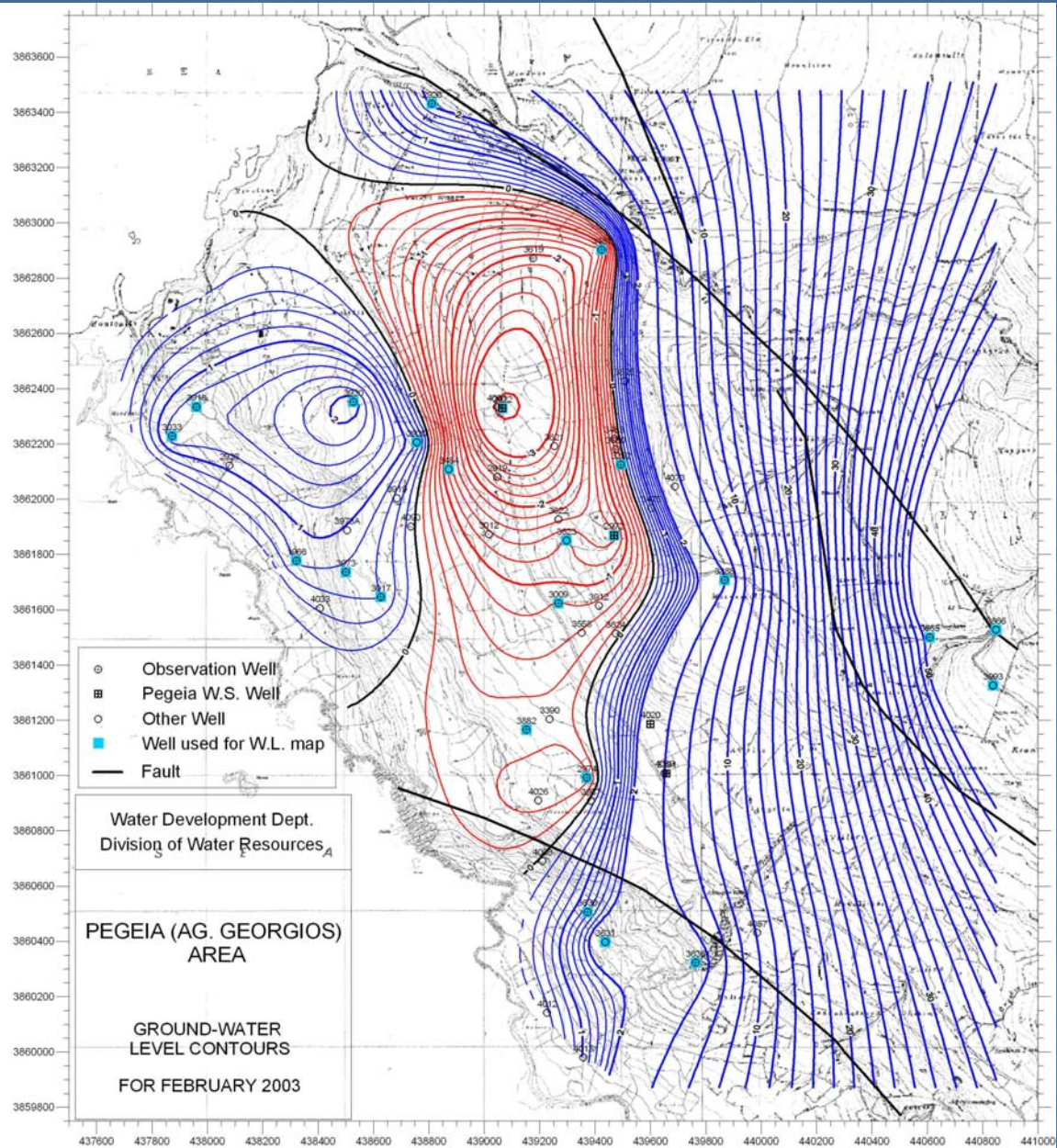


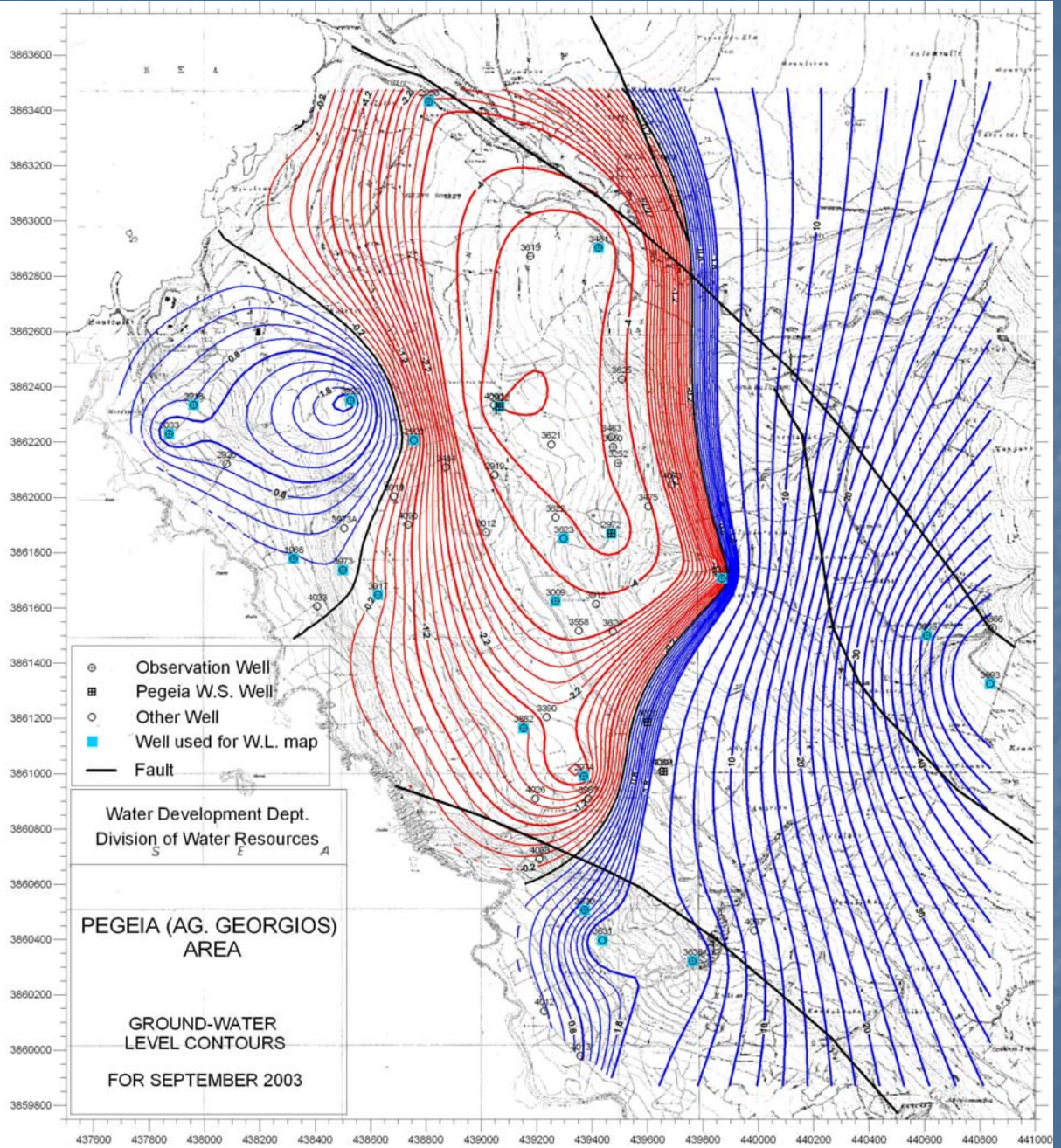
Σχ. 7. Χρονικές διακυμάνσεις της στάθμης σε γεωτρήσεις.  
Παράκτιος υδροφόρος Πέγεια



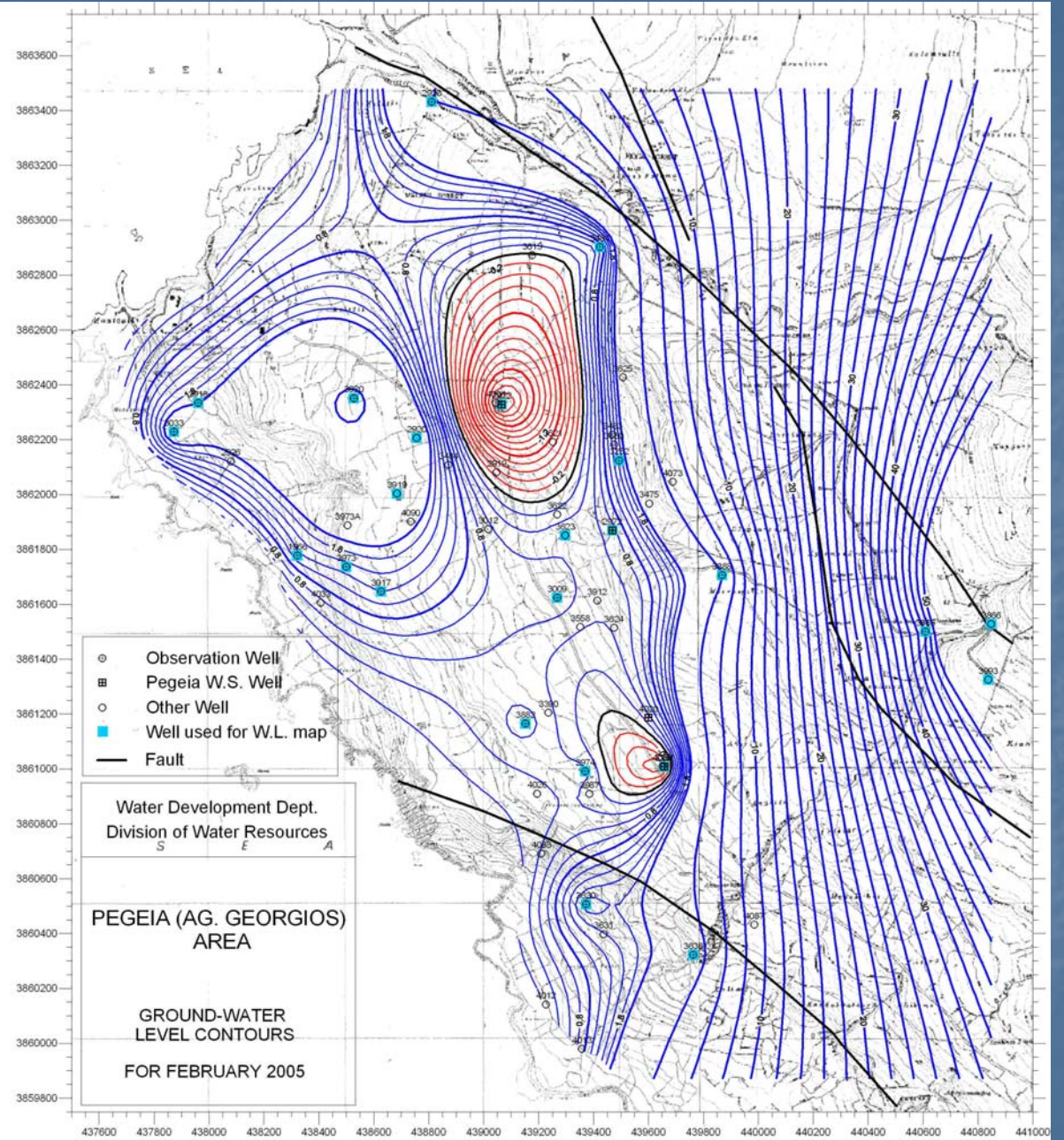


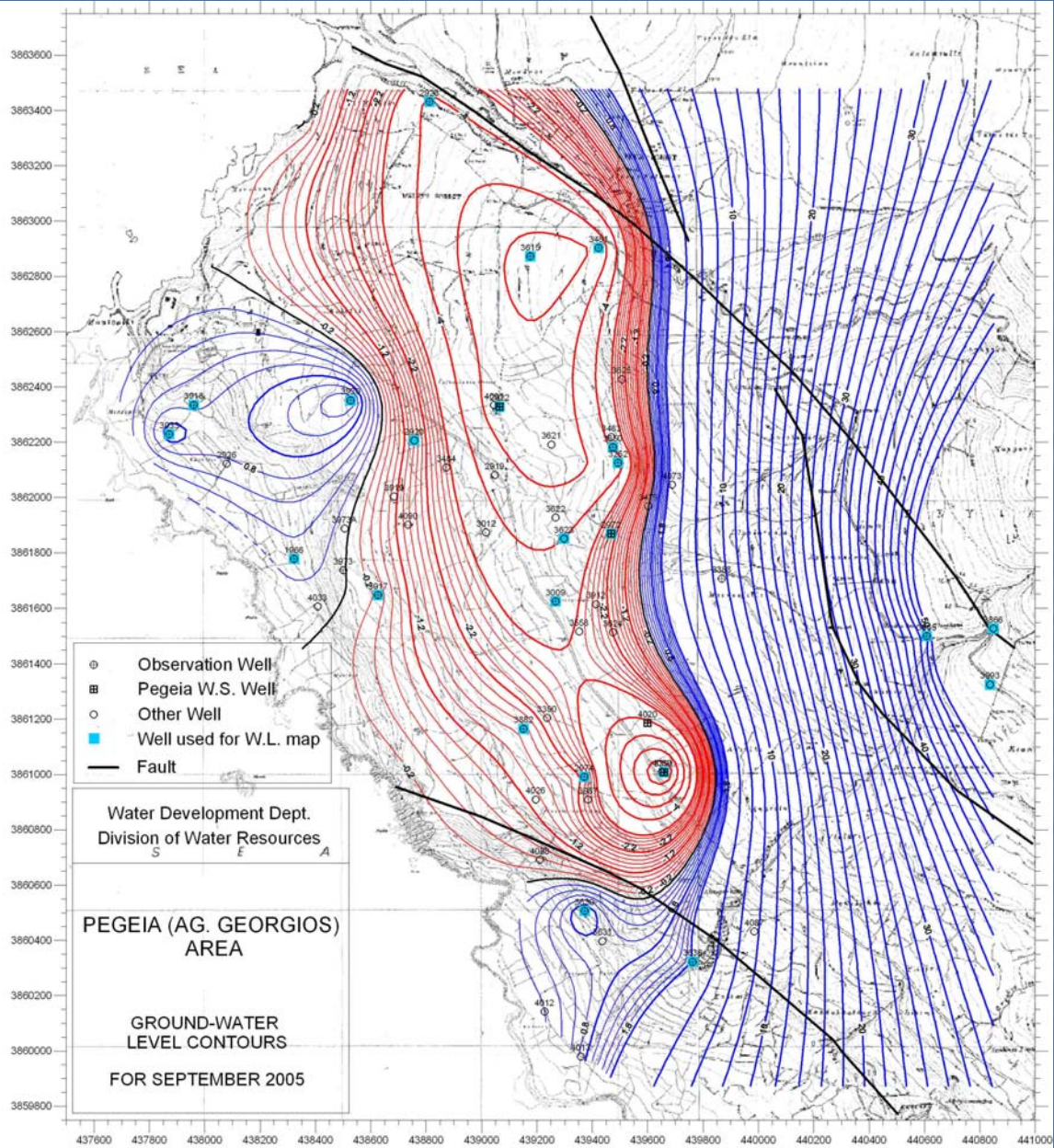


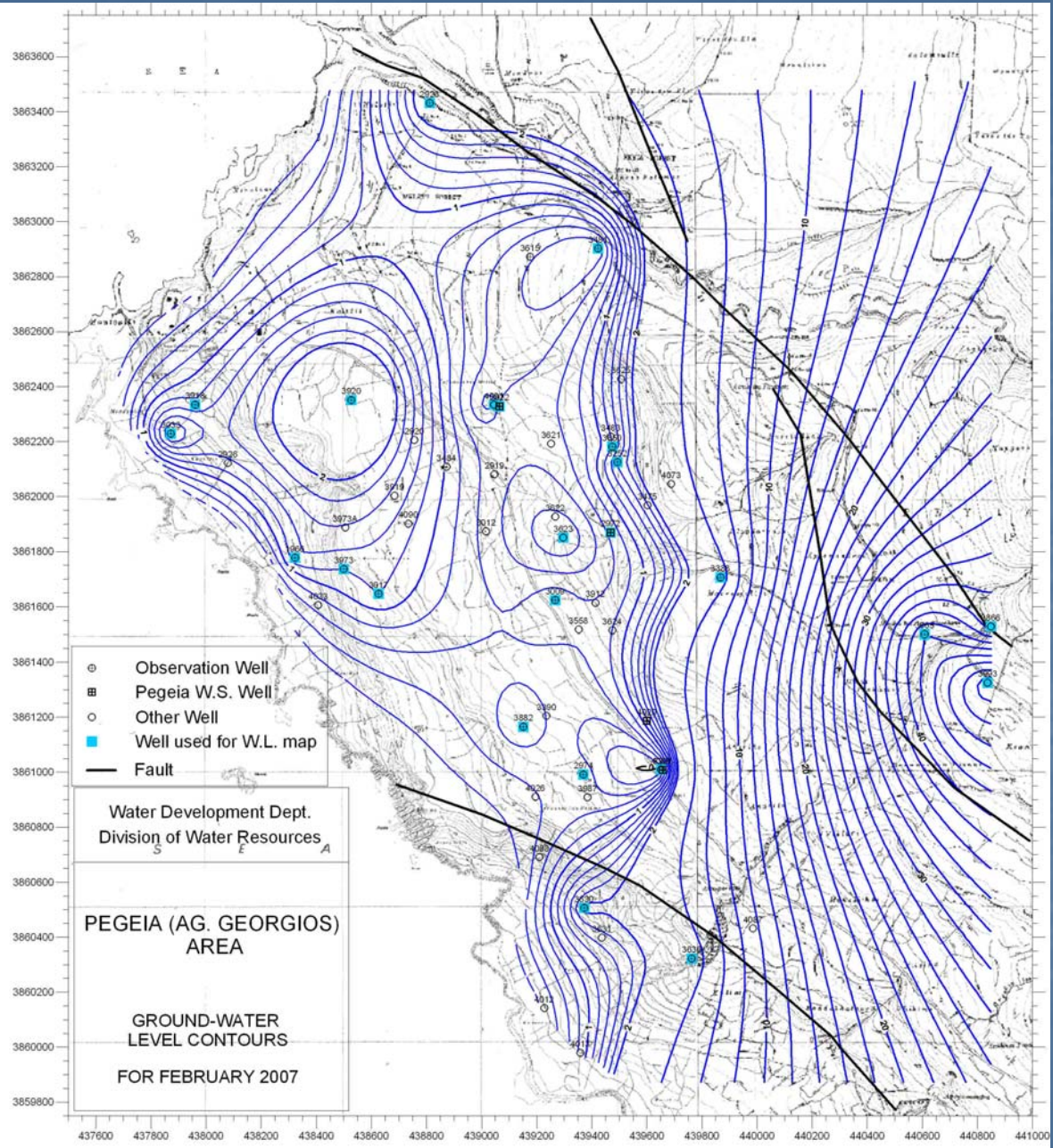


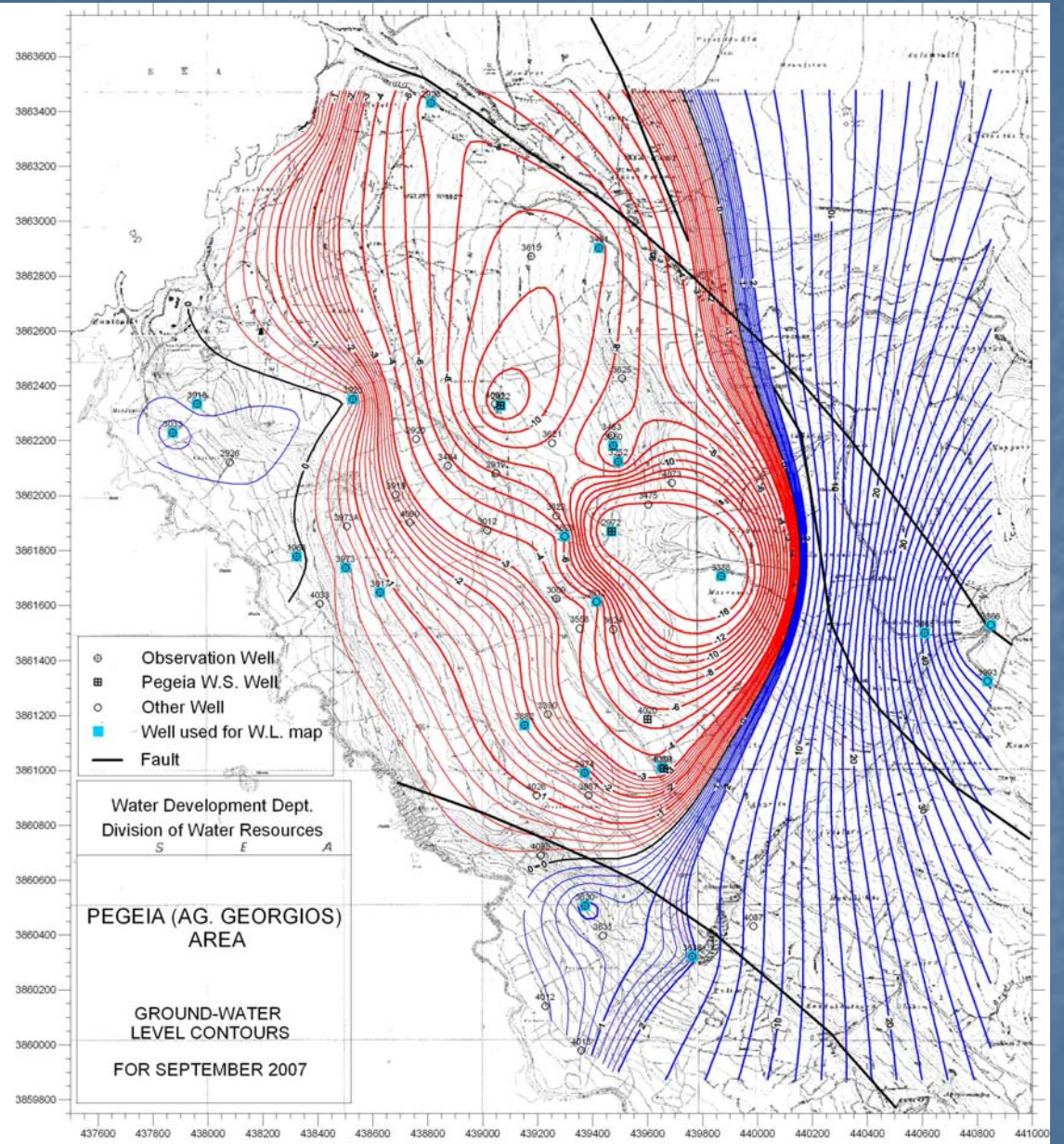


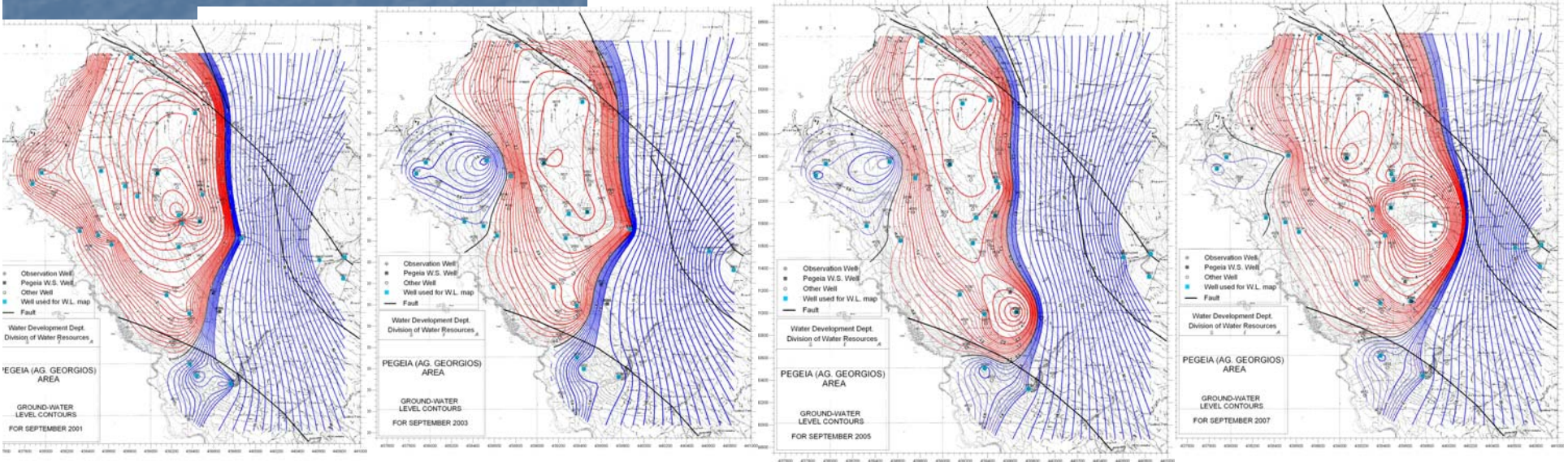
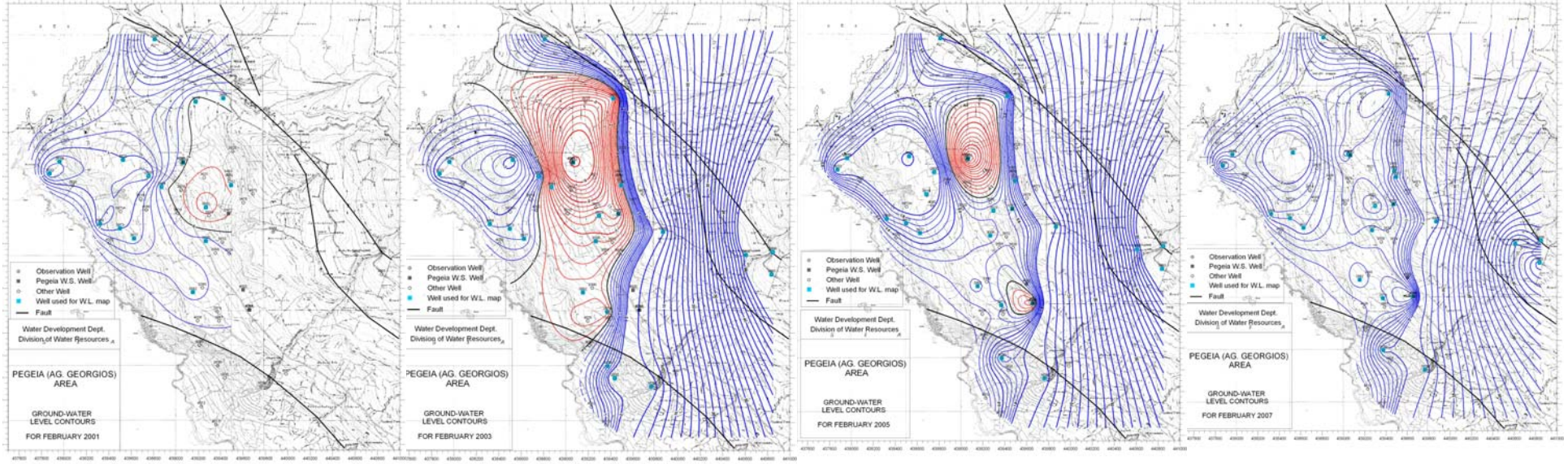




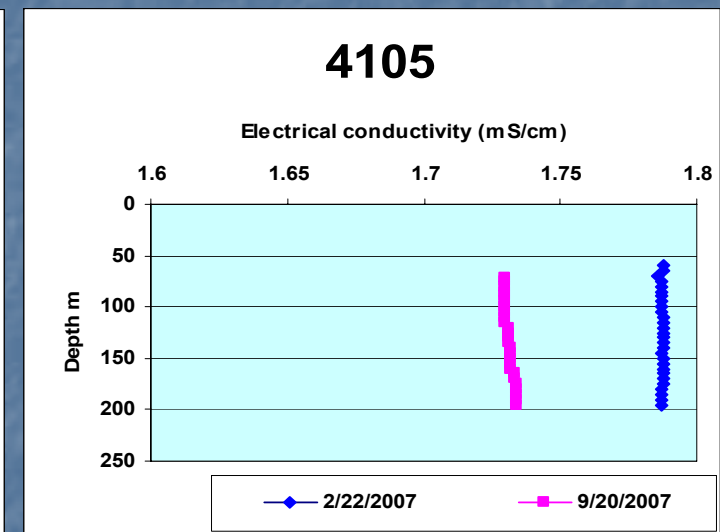
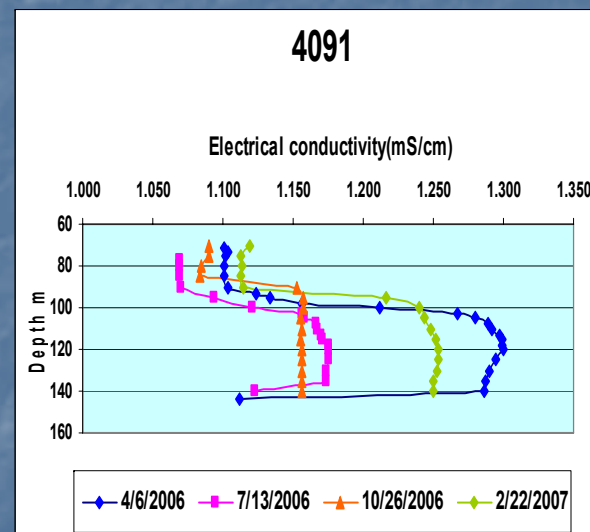
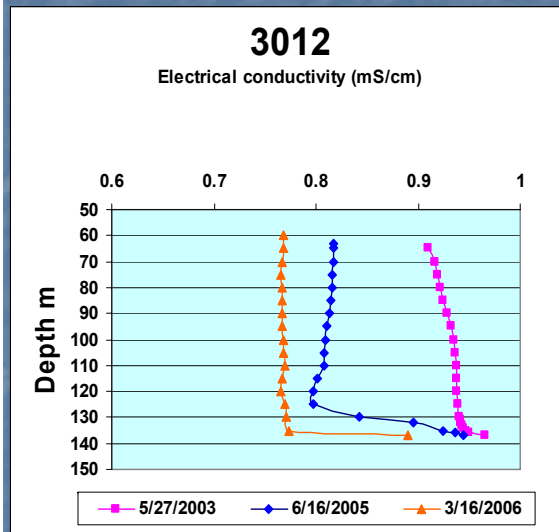
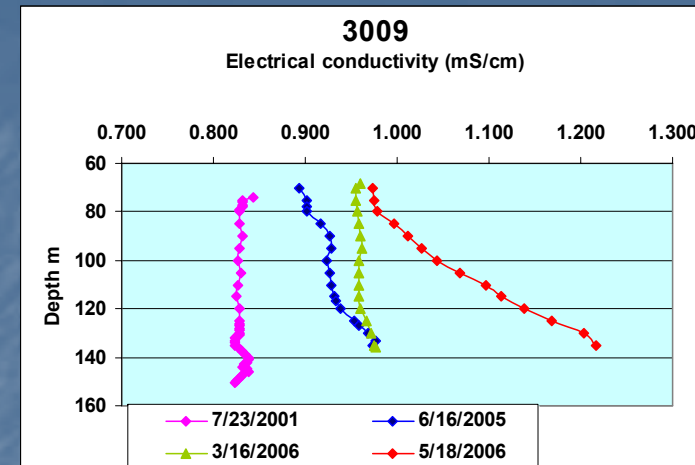
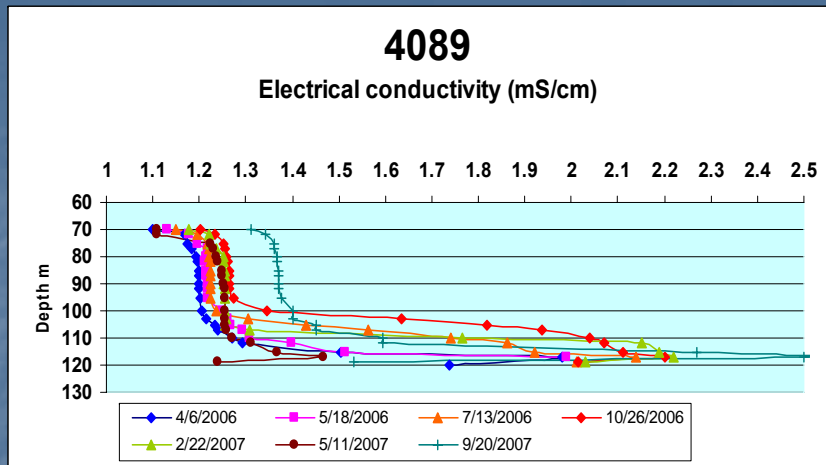






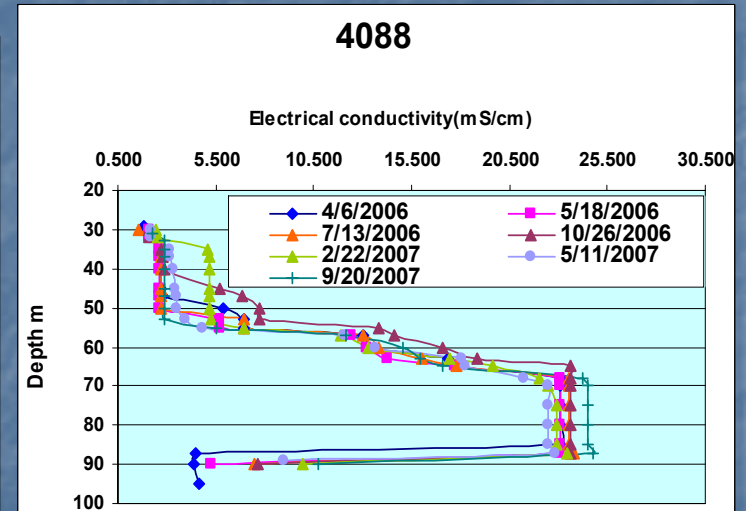
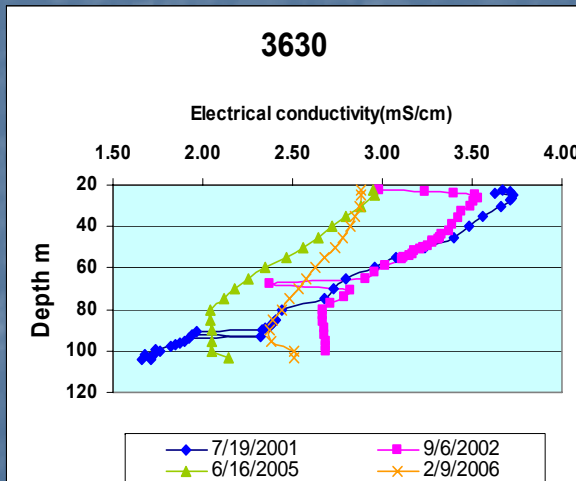
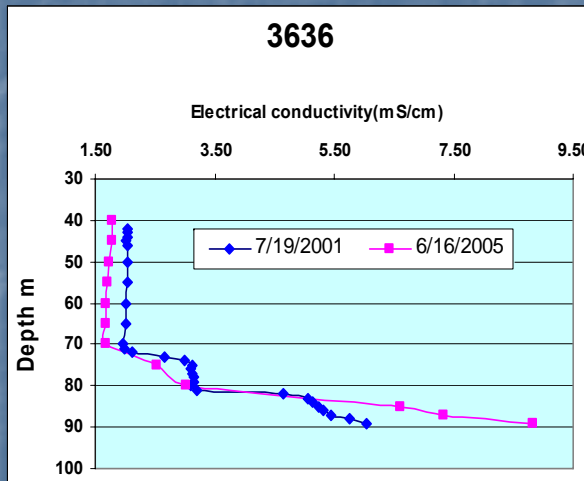
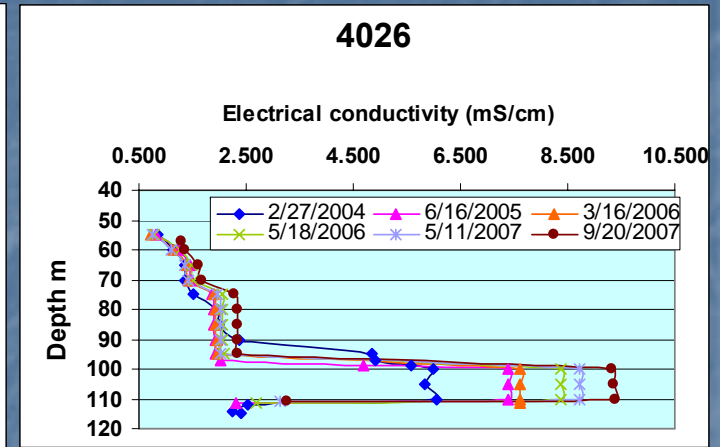
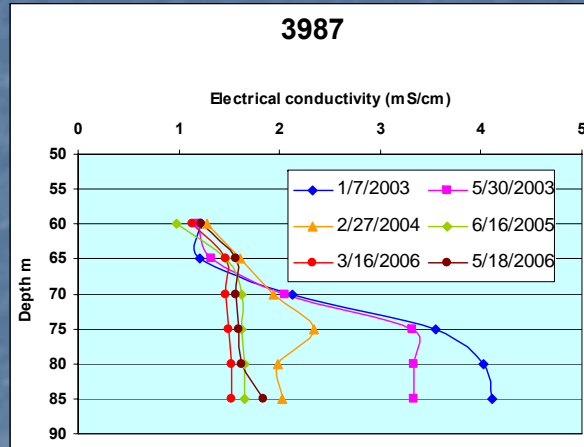
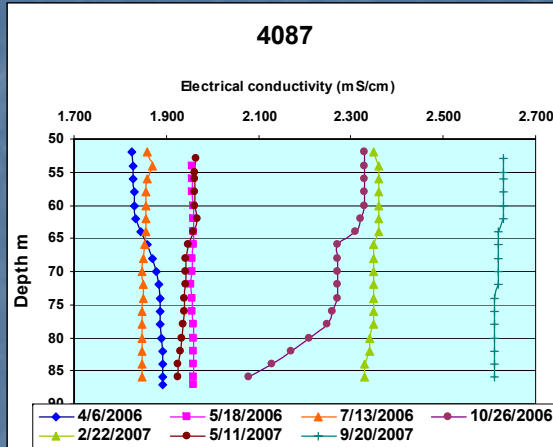


# Electrical conductivities in boreholes

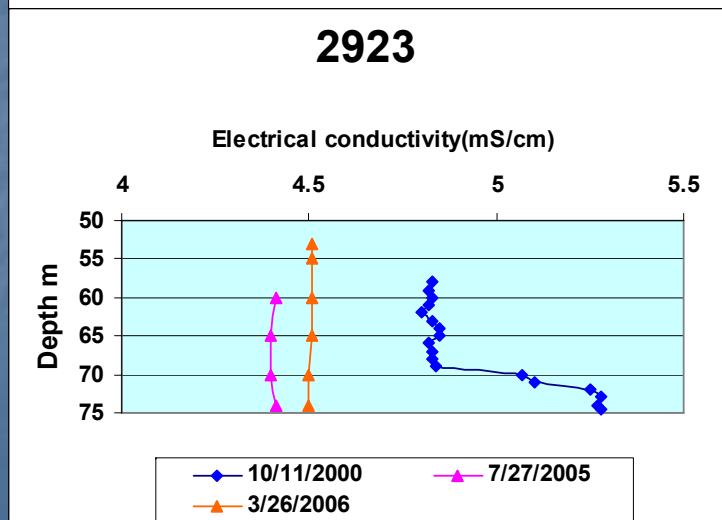
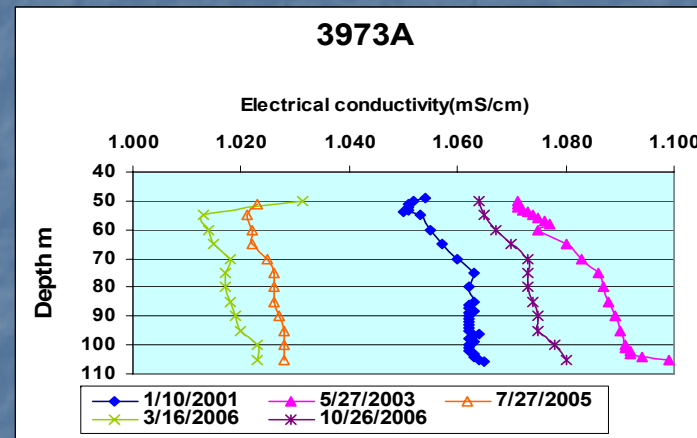
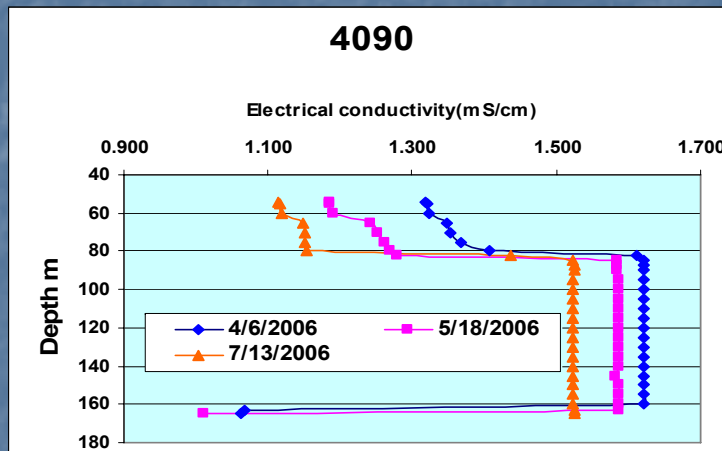


The boreholes are located close to, or between the pumping wells for domestic water

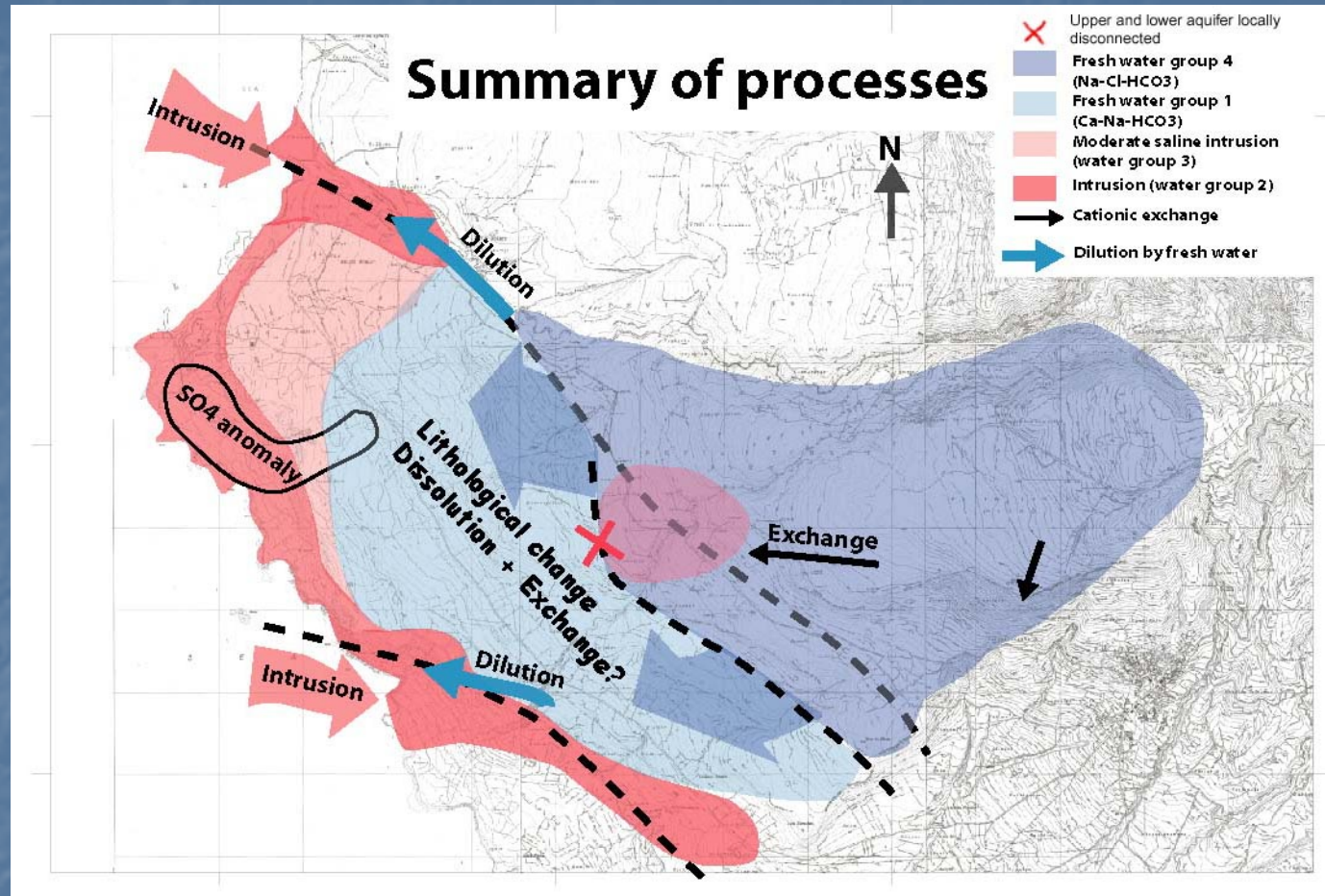
# Electrical conductivities in boreholes



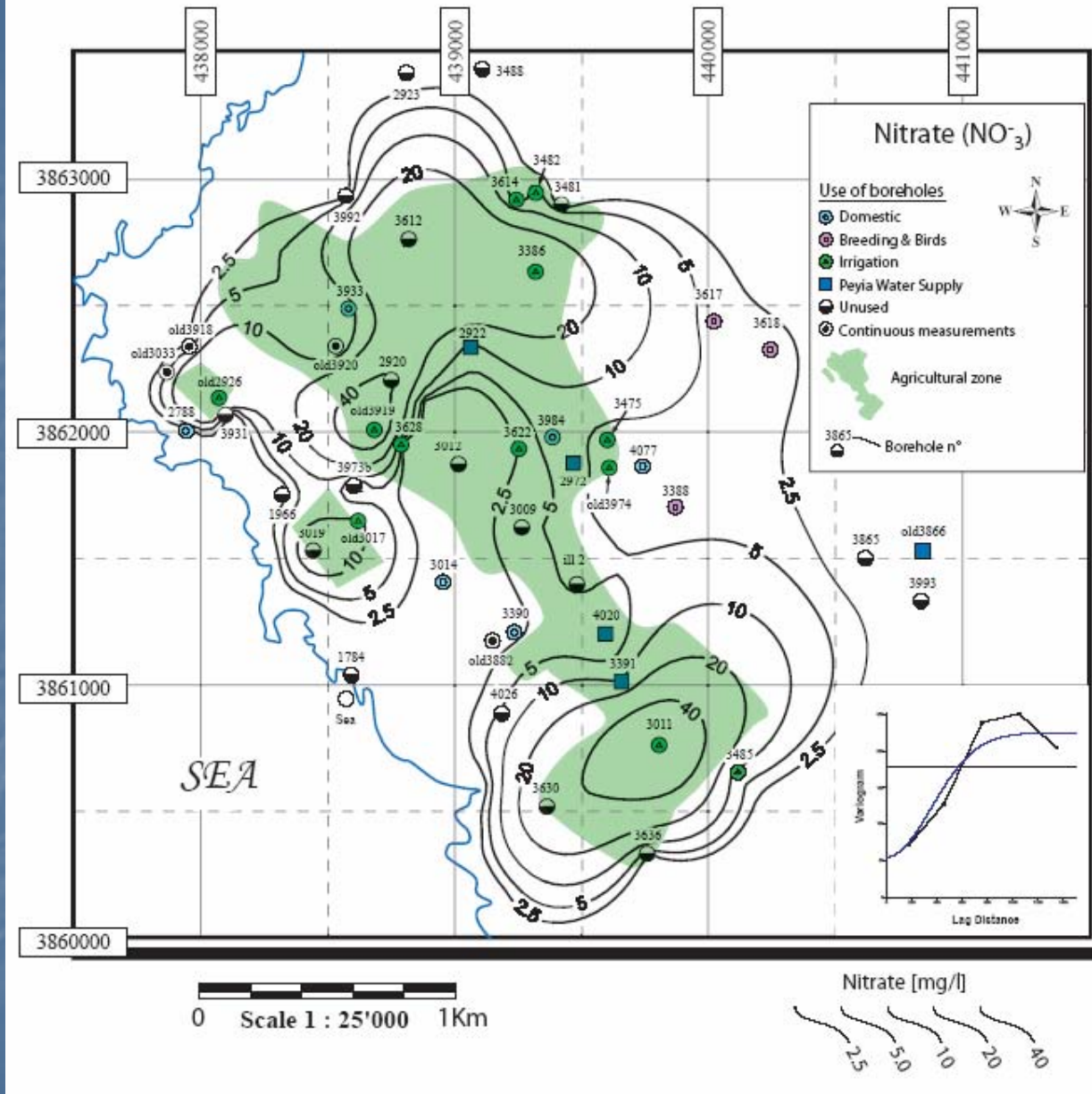
# Electrical conductivities in boreholes



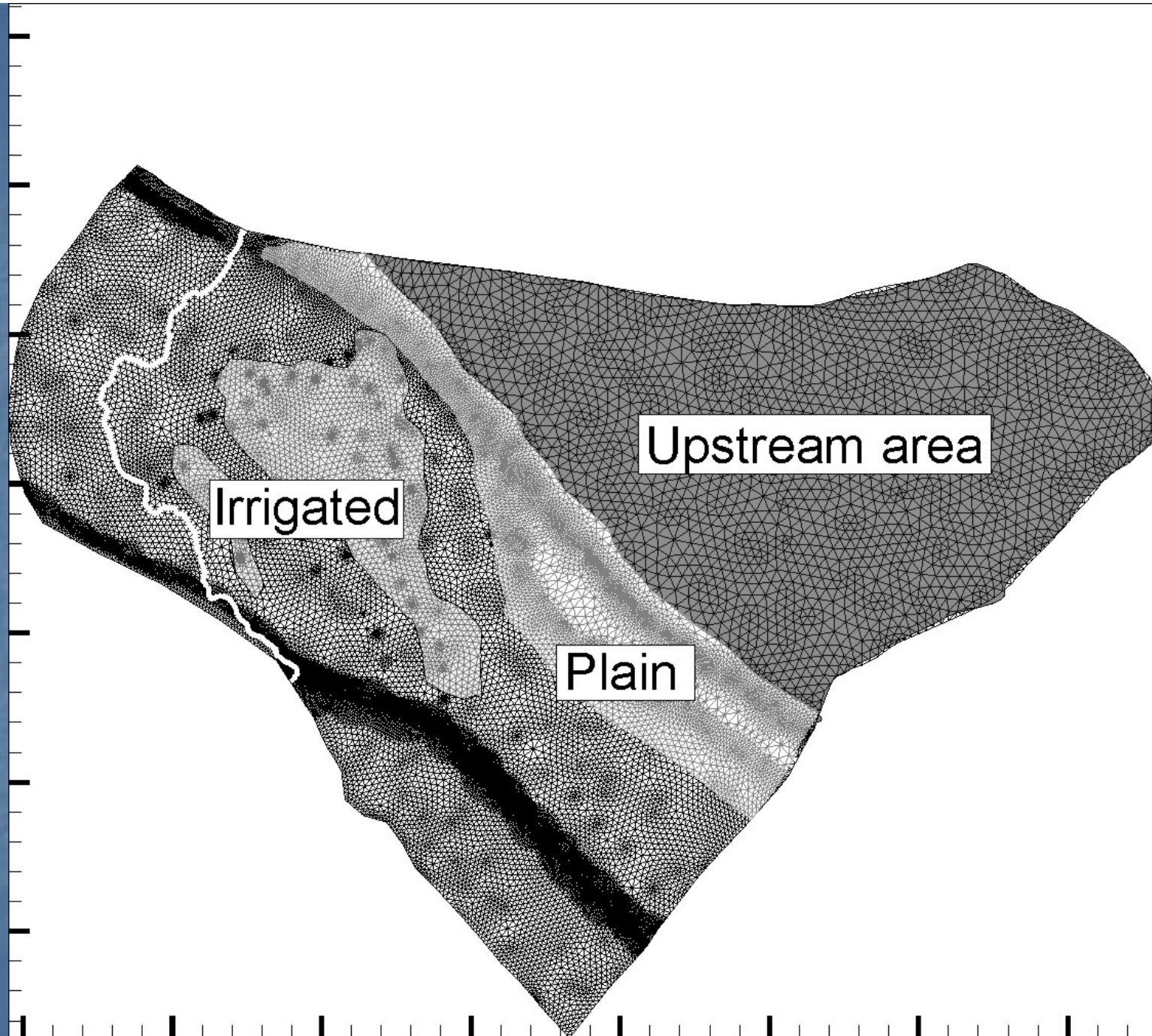


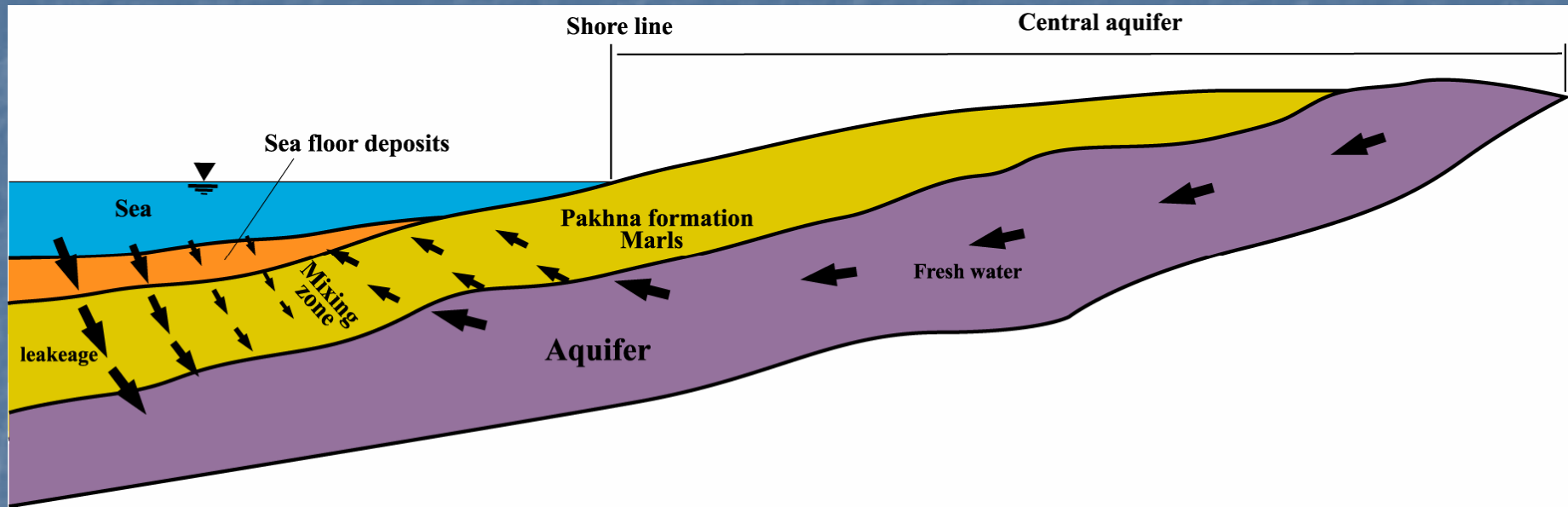


Summary of the physico-chemical processes affecting the aquifer



Nitrate concentration distribution (mg/l) in the Pegeia aquifer in July 2005





Schematic illustration showing how the aquifer plunges below the sea into the north-western direction, covered by low permeable marls of the upper Pakhna formation. The marls of the upper Pakhna formation form a 'lid' on the aquifer.

# Conclusions

- Pegeia aquifer is locally an important aquifer, supplying the Pegeia Municipality and the expanding tourist area with domestic water.
- **Sea intrusion:** Although the Pegeia coastal aquifer is not yet subject to dramatic seawater intrusion, degradation of the water quality due to excessive pumping has been observed in some locations.
- **Protection of aquifer:** Being locally an important aquifer, it is crucial to protect the ground water resources from the **seawater intrusion** and other (agriculture) **contamination**.

A first successful protective measure that has been taken in the past few years has been to limit and decrease the extraction rates by forcing the farmers to use water from the Paphos Project (The coastal part of the aquifer area is included in the Paphos Irrigation Project).

# Conclusions

- **Measures have to be taken:**
  - a) **Quality:** Use of **small sewage treatment units** for every house or group of houses. The recycled water can be used for irrigation. Control of **fertilizers** , in particular, and other **pollutants** used in agriculture.
  - b) **Quantity:** Probably significant losses in the distribution system and over-consumption of water, especially during the summer period (many houses have swimming pools and use domestic water to fill the pools and replenish the water, which evaporates) have to be identified, and the appropriate measures have to be taken.

A significant amount of domestic water is used by the tourist units.

# Conclusions

- **Ground water monitoring:** The water table and salinity evolution have been monitored for several years in the Pegeia aquifer, but the monitoring network may have to be optimized.
- Improvements regarding the management of the aquifer and the distribution system of the domestic water is recommended.
- According to my experience, in studying the Pegeia aquifer a long-term solution of the problem could be the following:
- The aquifer has to be used to supply domestic water for the houses of Pegeia Municipality only and desalination water has to be used for the tourist units.