

# Diachronic water supply and hydraulic works of water exploitation (Hydrotechnologies) in Greece through the centuries

**Konstantinos Voudouris**

Associate Professor of Hydrogeology

Aristotle University

Dept. of Geology



ILHAM-EC

Mobility strand for  
teachers in Greece

Thessaloniki, 22-26 May 2017

Co-funded by the  
Erasmus+ Programme  
of the European Union



# Overview

- ✓ General characteristics of Greece
- ✓ Water Resources
- ✓ Springs
- ✓ Wells and Boreholes
- ✓ Ancient Technologies
- ✓ Tunnel of Eupalinos
- ✓ Discussion



# Introduction

- The problem of water supply for domestic, irrigation use is a crucial issue for humanity. It is pointed out that the socioeconomic development of a region is usually associated with the availability of water resources.
- Human effort was first made to use surface waters and springs and therefore the settlements were close to them.
- The ancient Greeks avoided living near rivers, probably for protection from floods and water related diseases. The first settlement of many of their towns was on a hill and the water demands were met by springs
- The springs were the first water resource used by ancient people.



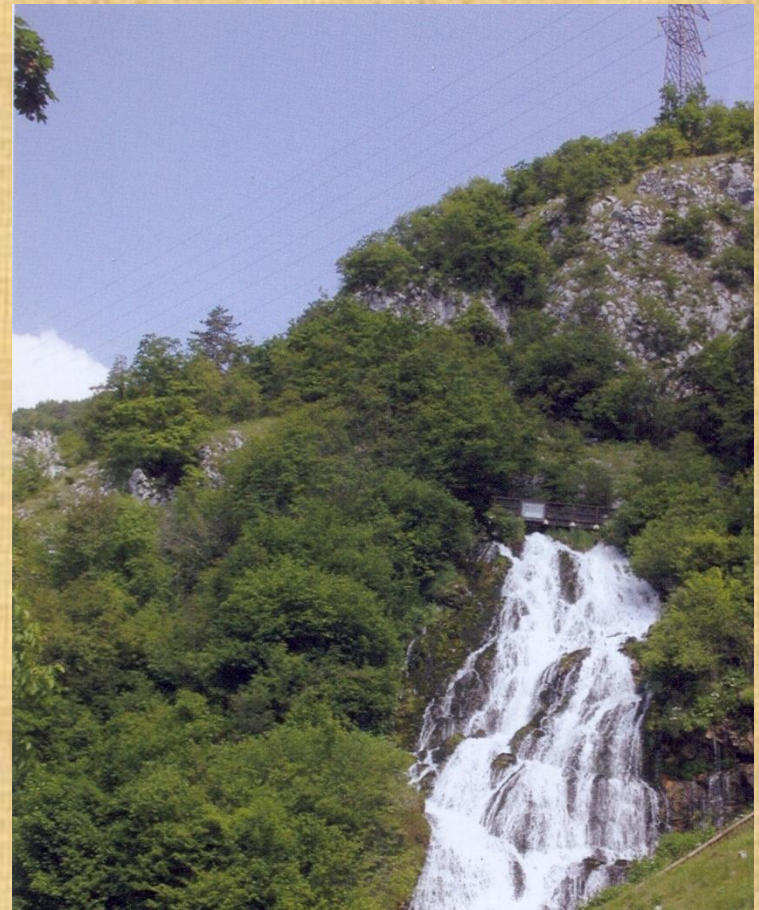
# Relief map of Greece

Total area  
132.000 km<sup>2</sup>



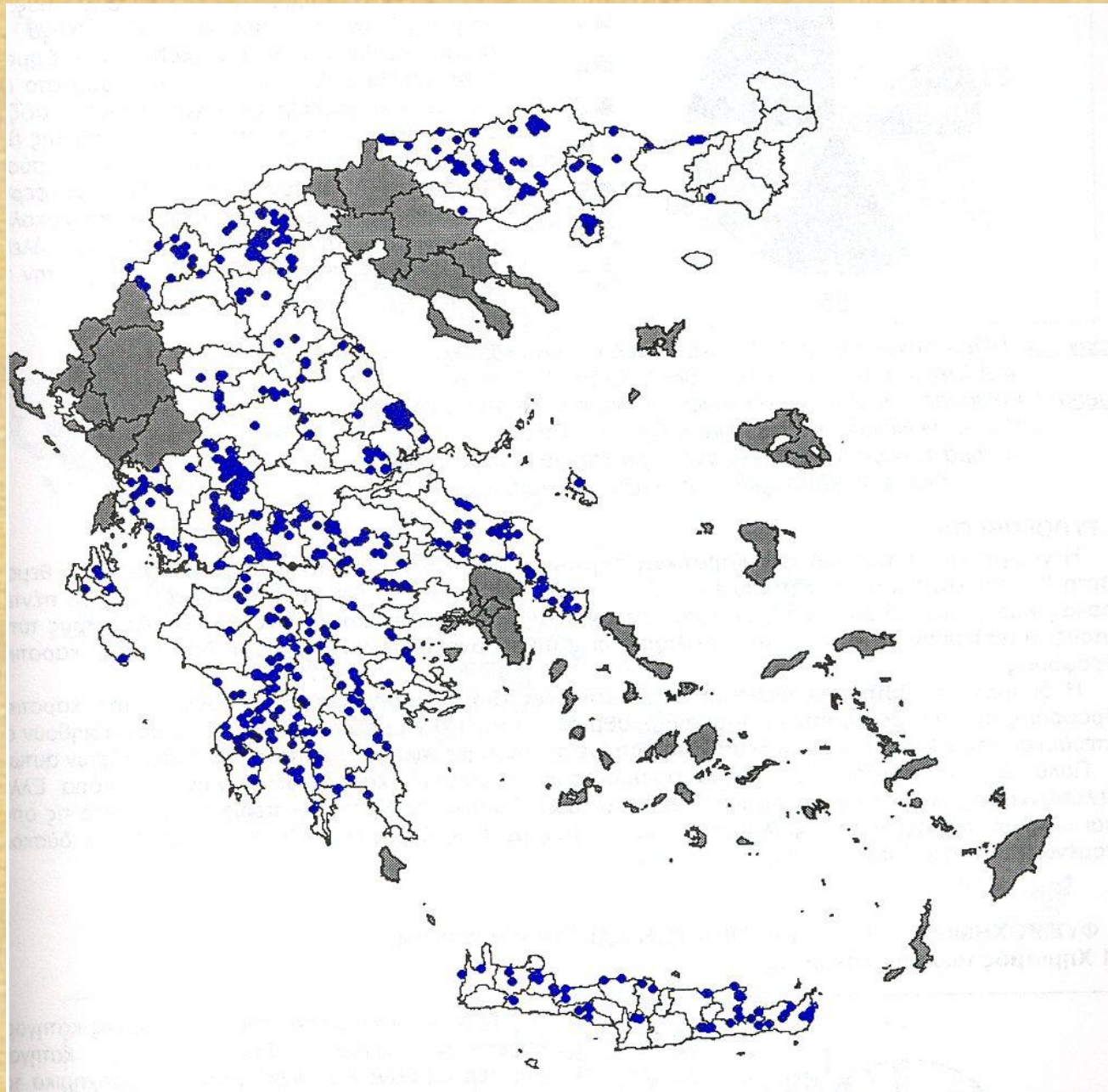


**Springs = natural discharge of groundwater**





## Karstic springs of Greece

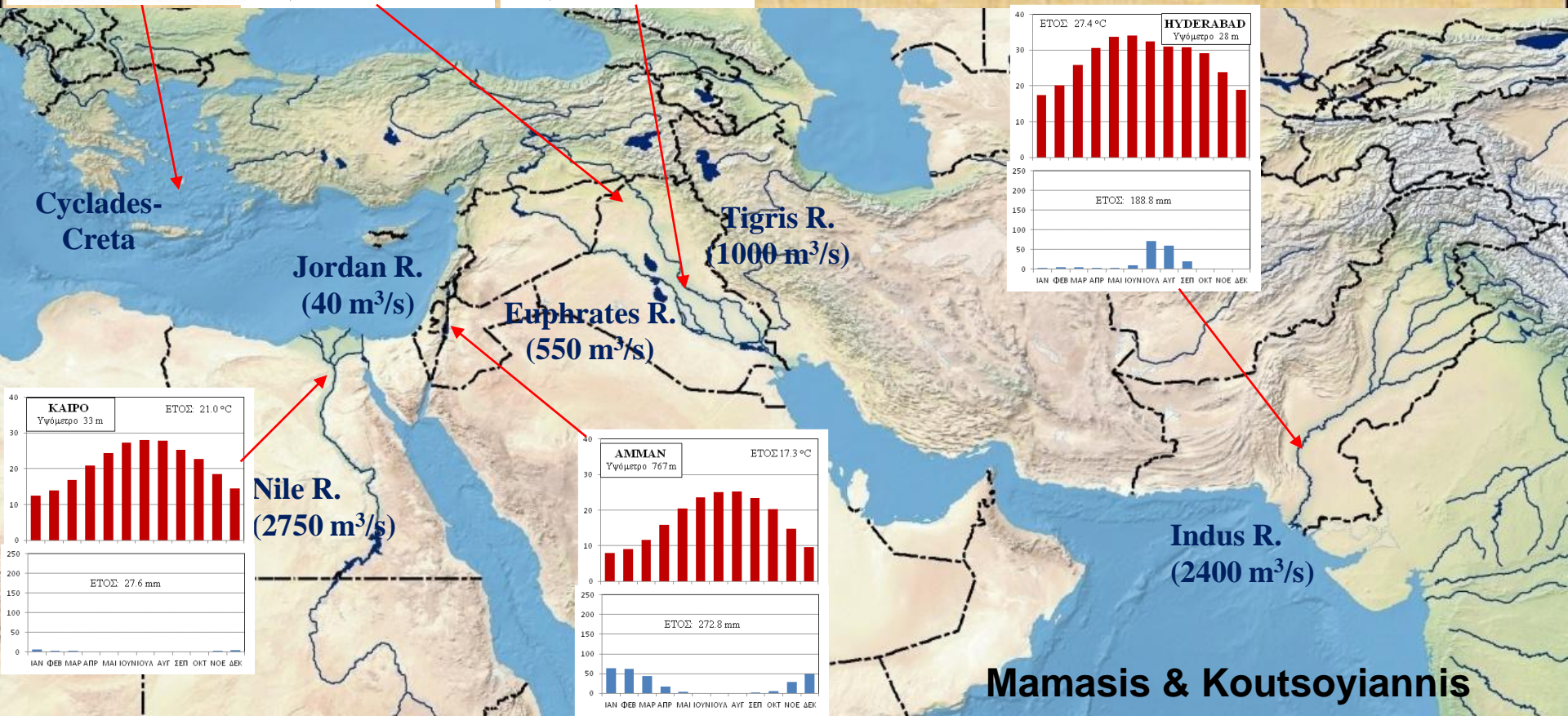
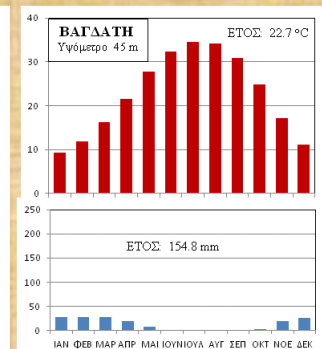
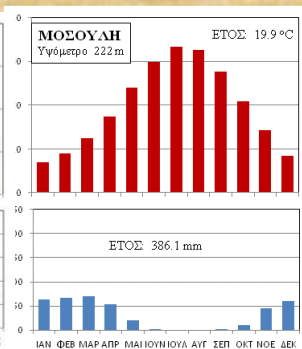
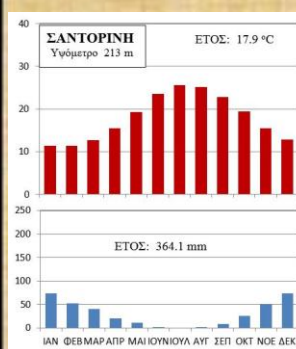




# Climatic changes

- About 7,000 years ago the general climatic conditions in the Eastern Mediterranean became similar to the present day, with less rainfall and warmer temperatures thereafter.
- The most recent glacial period ended 12,000 years ago followed by a warm period up to the present (Holocene). This period is characterised by the development and spread of agriculture and increased water demands.





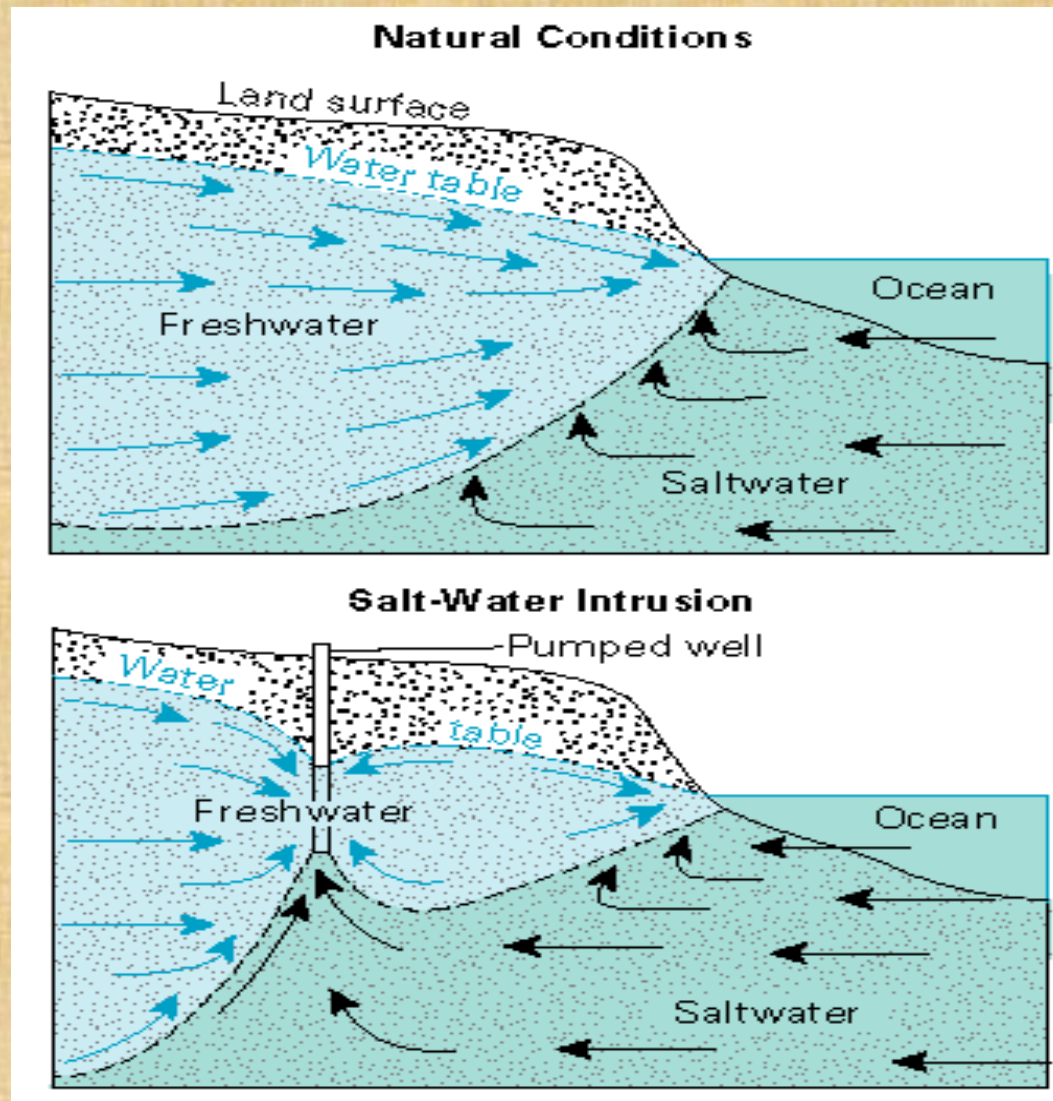


# Pressures on water

- Urbanization. Approximately 65% of the population lives in urban areas and the majority of these people depend on groundwater for freshwater
- The intensification of agriculture. The agricultural sector consumes an extremely high percentage of water resources in Greece (86%)
- Disposal of untreated waste effluent in rivers and abandoned wells and quarries
- Development of lignite mine
- Deforestation
- Climatic changes



# Seawater intrusion in coastal aquifers



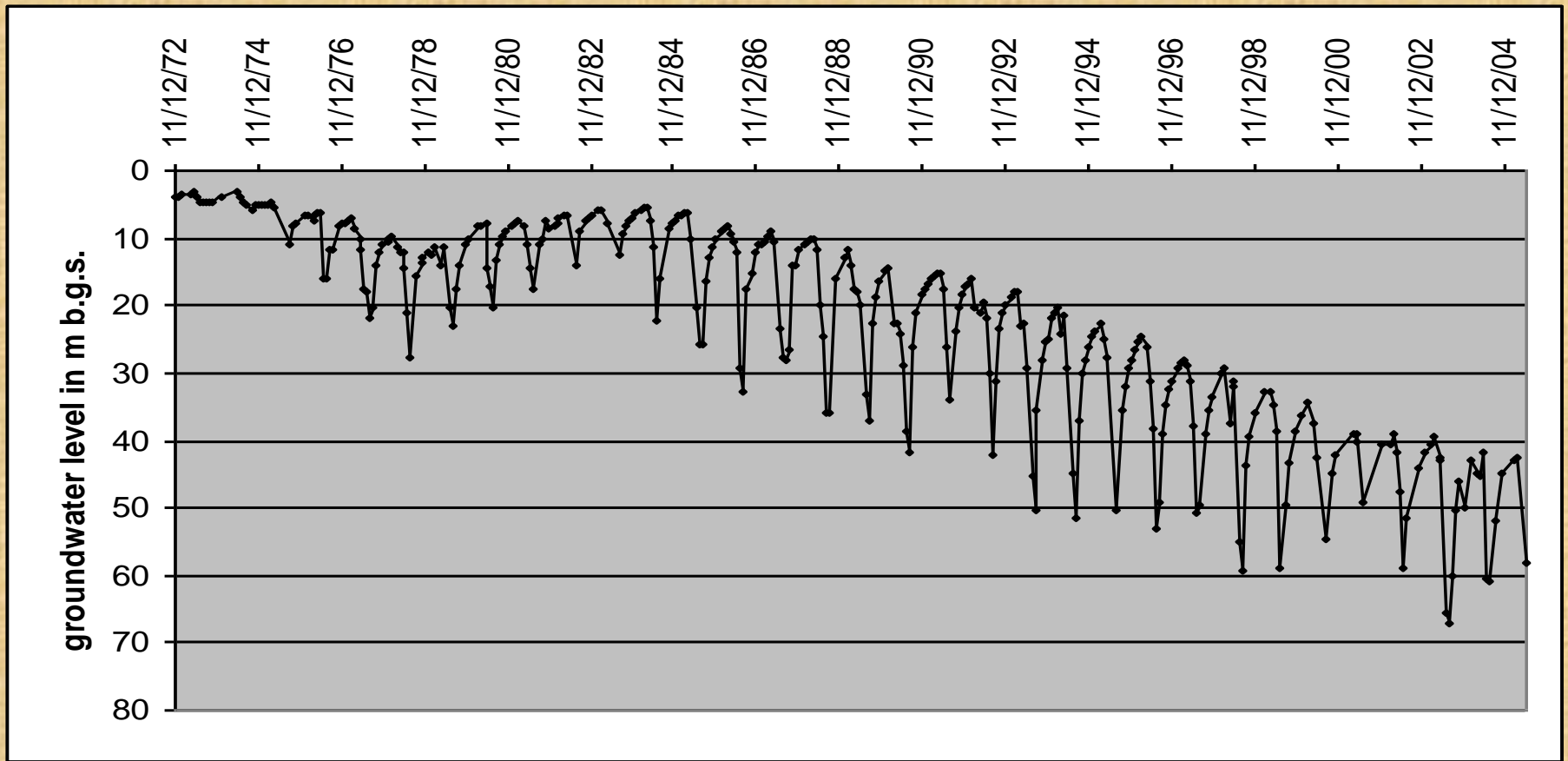


# Groundwater over-exploitation and saltwater intrusion in Greece

The total area of aquifers affected by seawater intrusion was estimated to be 1500 km<sup>2</sup>







**Hydrograph of groundwater table fluctuations (m b.g.s.) in Thessaly**



# Areas affected by nitrate pollution, due to agricultural activities ( $>50$ mg/l)





# ***Important historical periods***

---

**Neolithic:** *ca.* 7000- 3300 BC

**Minoan:** *ca.* 3300- 1200 BC

**Mycenaea:** *ca.* 1600-1100 BC

**Early Iron:** *ca.* 1100- 950 BC

**Archaic:** *ca.* 680- 480 BC

**Classical:** *ca.* 480- 323 BC

**Hellenistic:** *ca.* 323- 67 BC

**Roman:** *ca.* 67 BC - 330 AD

**Byzantine:** *ca.* 330-1204 AD

**Arabian:** *ca.* 826-961 AD

**Ottoman** *ca.* 1240-1898 AD





Hellenic world (Crouch, 1993)



# Ancient Greek literature

- Sustainable water management practices
- Hydraulics works that are not preserved to date
- Impressive conclusions about hydrometeorological phenomena (evaporation, rainfall etc)
- Hydraulic devises (apparatus)

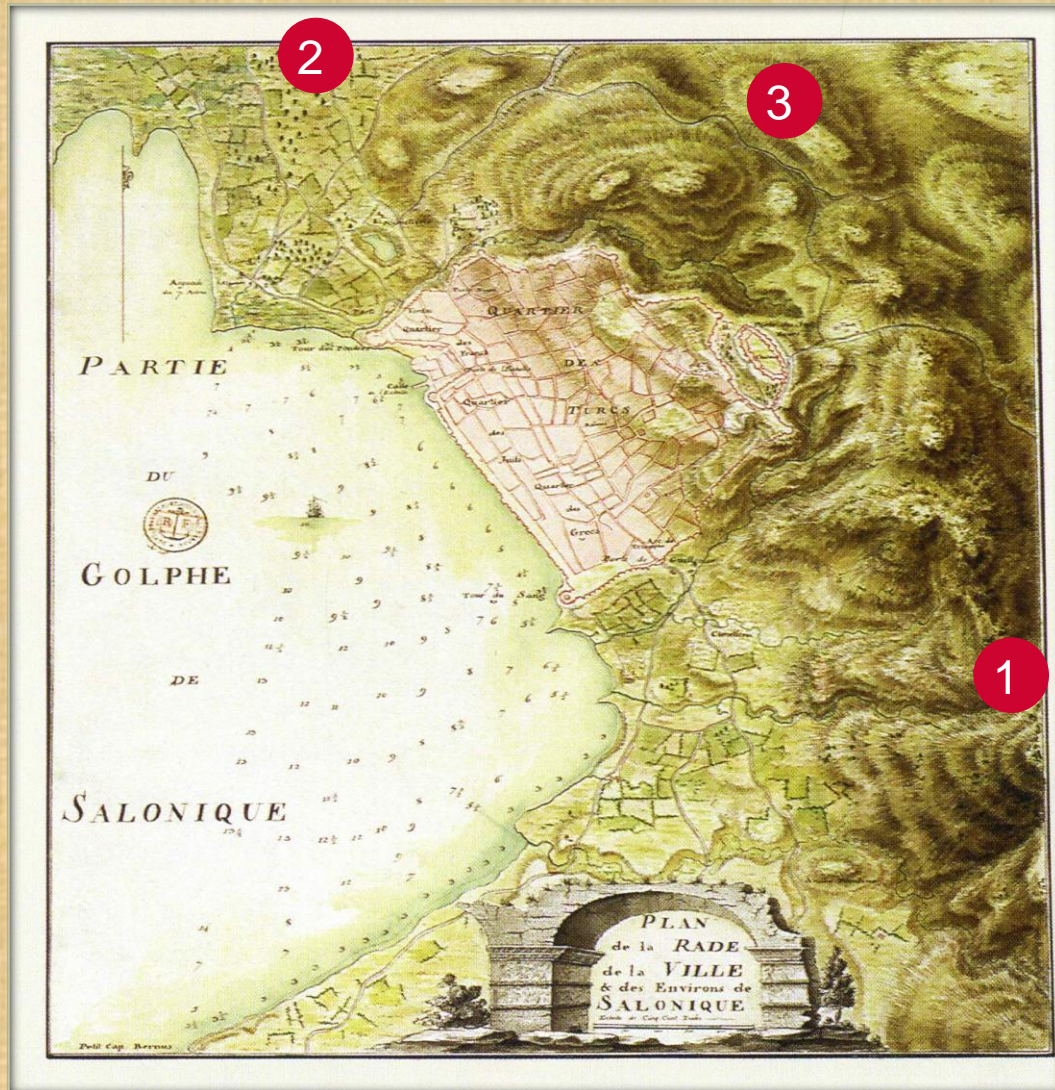


# Availability of water

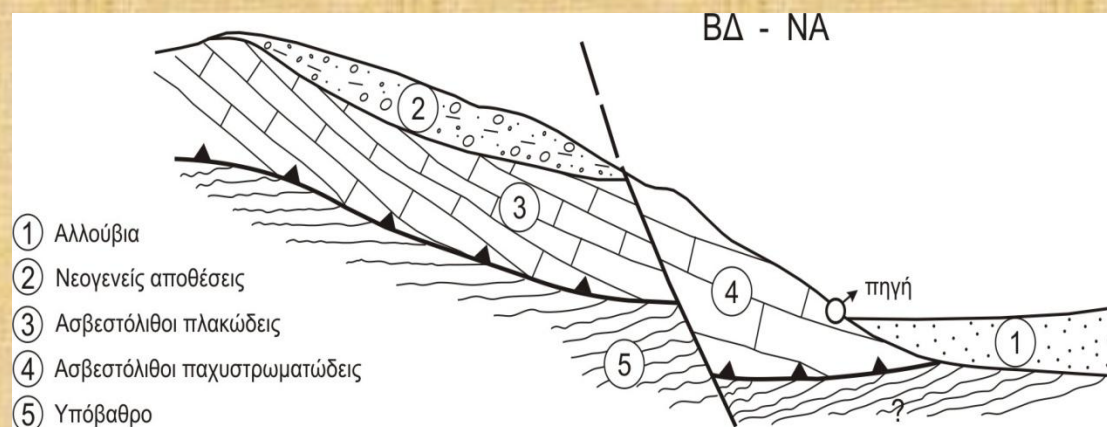
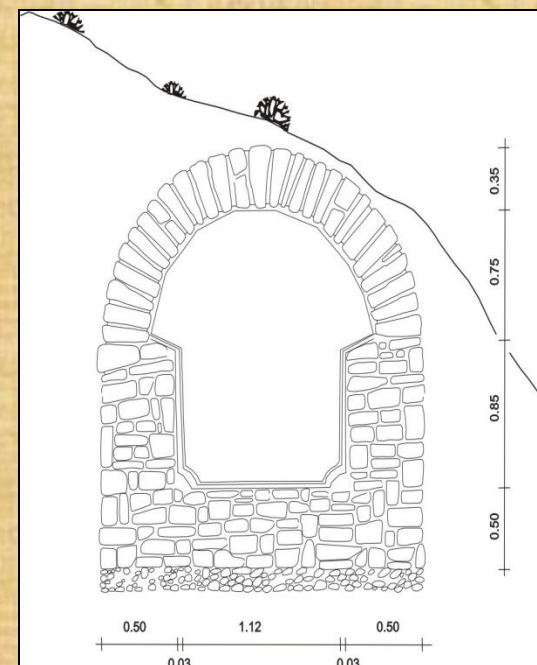
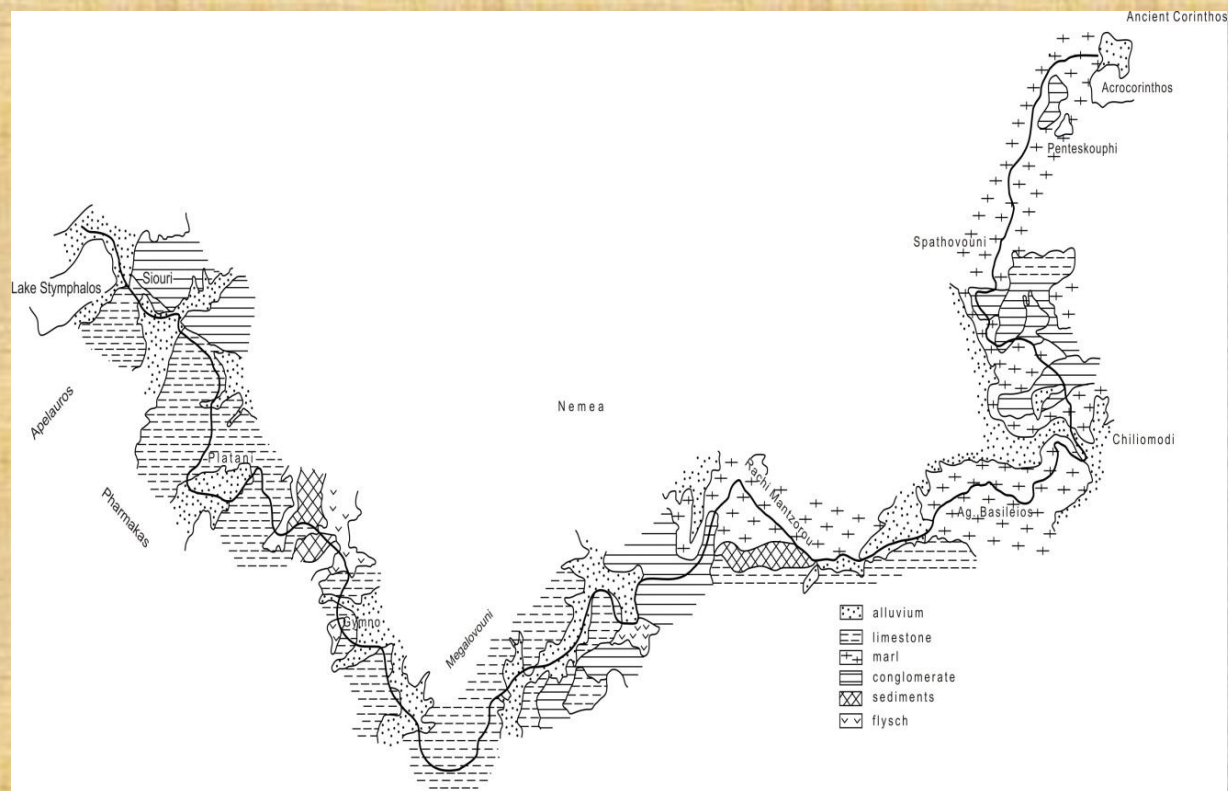
- In the Eastern Mediterranean, Near and Middle East brilliant civilizations of antiquity flourished. At the earliest stage, *ca.* 8,000 years ago, people performed all their activities close to the rivers, since they could not live without water. There was great dependence on surface water from rainfall and this was the driving force for ancient people to explore the groundwater.
- In the dry regions of the Mediterranean, the scarcity of water and the dominance of agriculture resulted in the early development of the art of constructing galleries, dug wells, aqueducts and other hydraulic works for water supply. The network of channels constructed by Hammurabi in the plain between Tigris and Euphrates (1760 BC) is remarkable.
- Irrigation of crops is necessary to sustain agricultural production.



# Thessaloniki







**Hadrian aqueduct in Ancient Corinthos (Lolos 1997)**



# Collection of spring water





# Cisterns



Left: Cistern in Apamea, Syria (Haut & Viviers, 2012)

Right: Cistern in Kourion, Cyprus (<http://itia.ntua.gr/ahw/works>).

**«Cities need cisterns for safe in war»  
Aristotle (Politika)**



# Mycenae

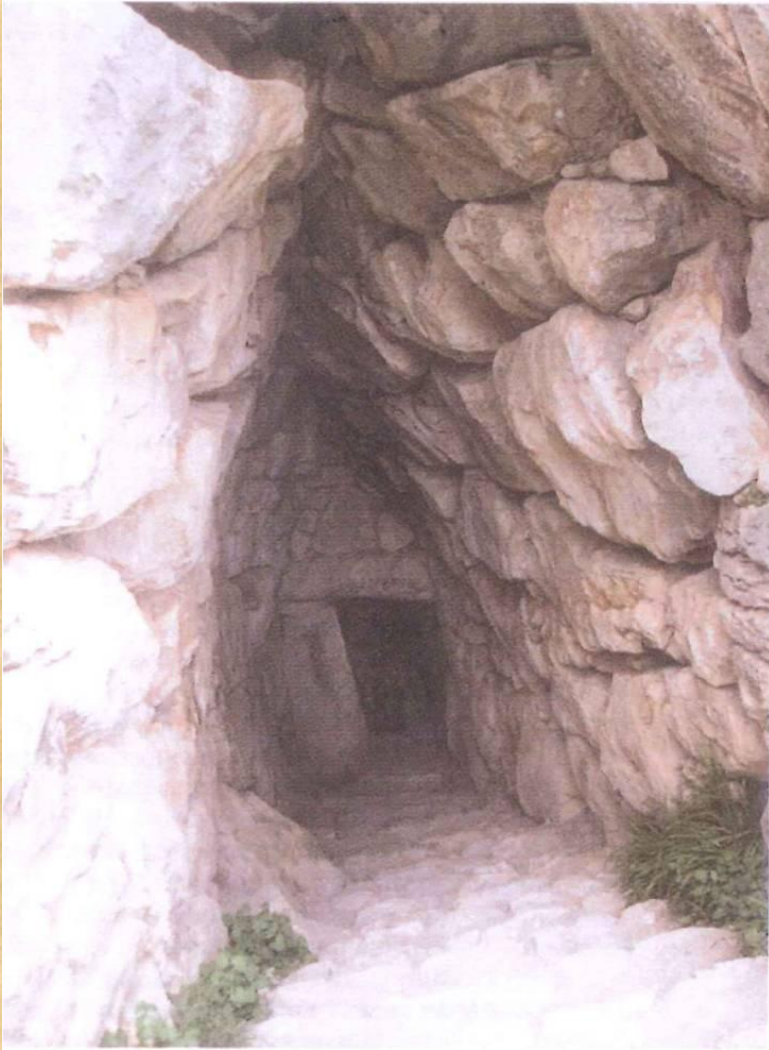


Photo: Dermatas P.



# Minoan Civilization (3500-1100 BC)

- During this period an extended period of technological development.
- Water supply systems were developed in most Minoan palaces
- Wells and groundwater exploitation
- Aqueducts and piping
- Bathrooms and other sanitary facilities
- Collection, storage and use of rainwater





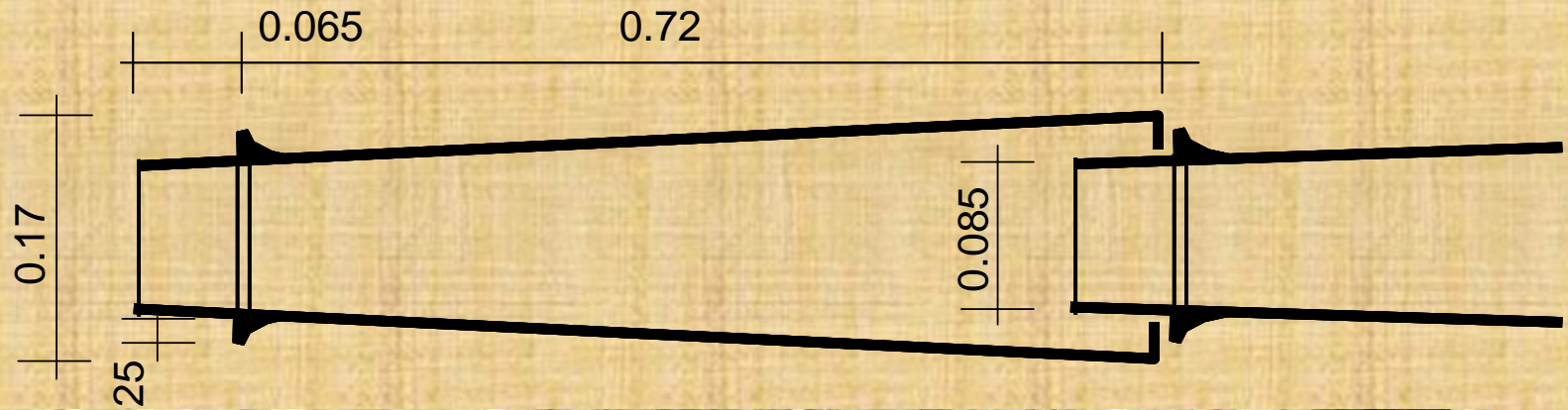
*Archaeological sites of Crete (Angelakis A.)*



# ***Major water supply sources of Minoan palaces and other settlements (ca. 3200 – 1100 BC)***

<b>Source of water</b>	<b>Palaces and other settlements</b>
<b>Rainwater harvesting systems</b>	<b>Phaestos, Chamaizi, Myrtos-Pygros, Knossos, Agia Triadha, Kato Zakros</b>
<b>Wells</b>	<b>Palaikastro, Zakros, Kommos, Knossos,</b>
<b>Aqueducts from sources (e.g. springs)</b>	<b>Knossos, Mallia, Tylissos, Gournia, Lenta</b>
<b>Springs</b>	<b>Syme, Knossos</b>





Pipes for water supply in Minoan period (Angelakis, 2013).





**Minoan well in Creta island**





***Sewerage and drainage system in Knossos palace (Angelakis A.)***



# Minoan civilization (Palace of Knossos)



(a)



(b)



(c)



(d)

**Fig. 1.5** Water components in Knossos. (a) Pipes made of terracotta. (b) Drainage channel. (c) Carved stone elements of rainfall harvesting system collecting water falling from roof. (d) Stepped water channel and sedimentation (desilting basin). Along the stairway is a small channel (for rain-water collection) consisting of a series parabolic-shaped stepped chutes that convey rainwater down stream to the sedimentation tank or basin (copyright permission with L.W. Mays). Color version available in Appendix



# Mycenaean civilization (1600-1100 BC)



(a)



(b)



(c)



(d)

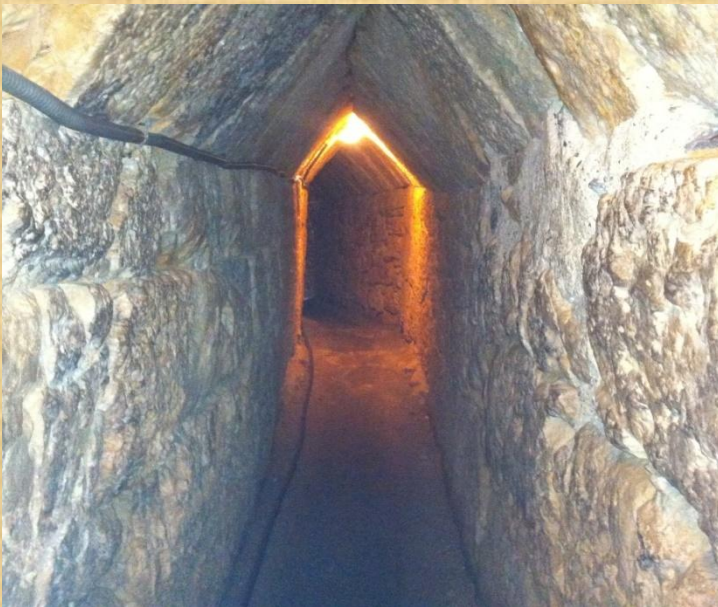
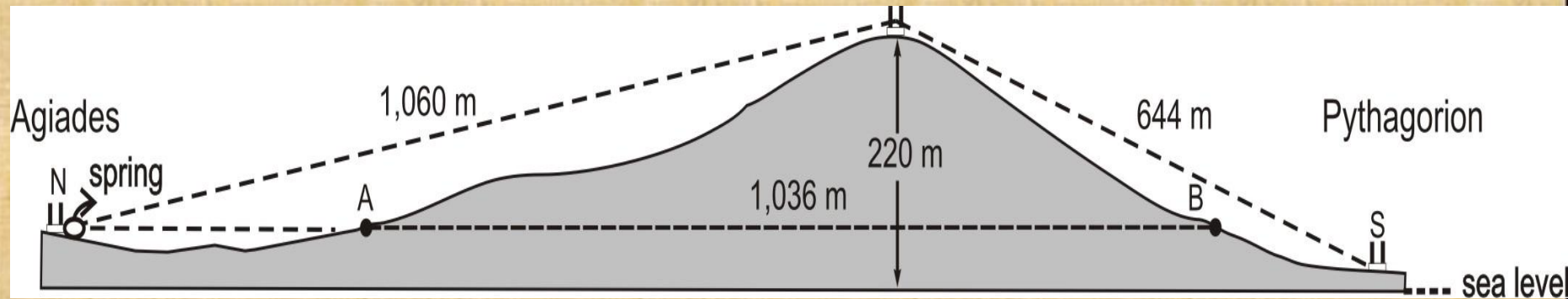


(e)

**Fig. 1.7** Water system in Tylissos, Crete. (a) Aqueduct bringing water from springs. (b) Sedimentation tank in foreground with stone channel connecting to cistern. (c) Sediment tank (d) Channel connecting sediment tank to cistern. (e) Steps leading down to cistern (photos copyright by L.W. Mays). Color version available in Appendix



# Eupalinos tunnel=Peak of ancient hydraulic technology



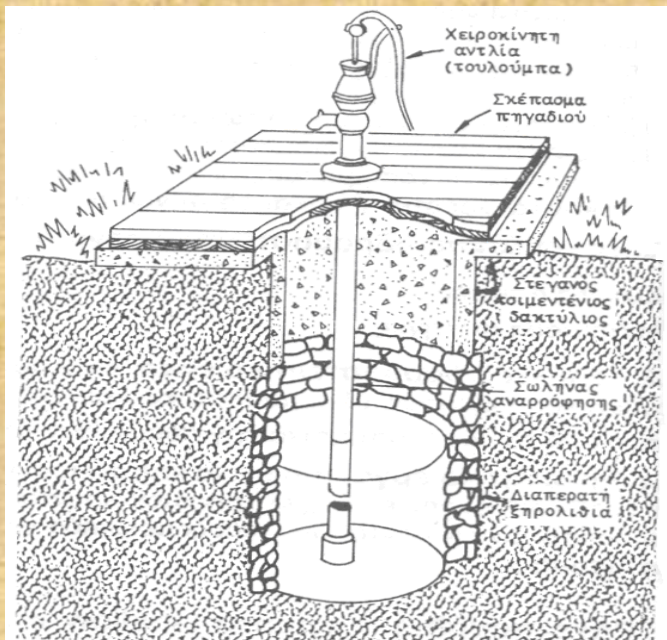




**Aqueduct in Efessos (Haut & Viviers, 2012).**



# Wells

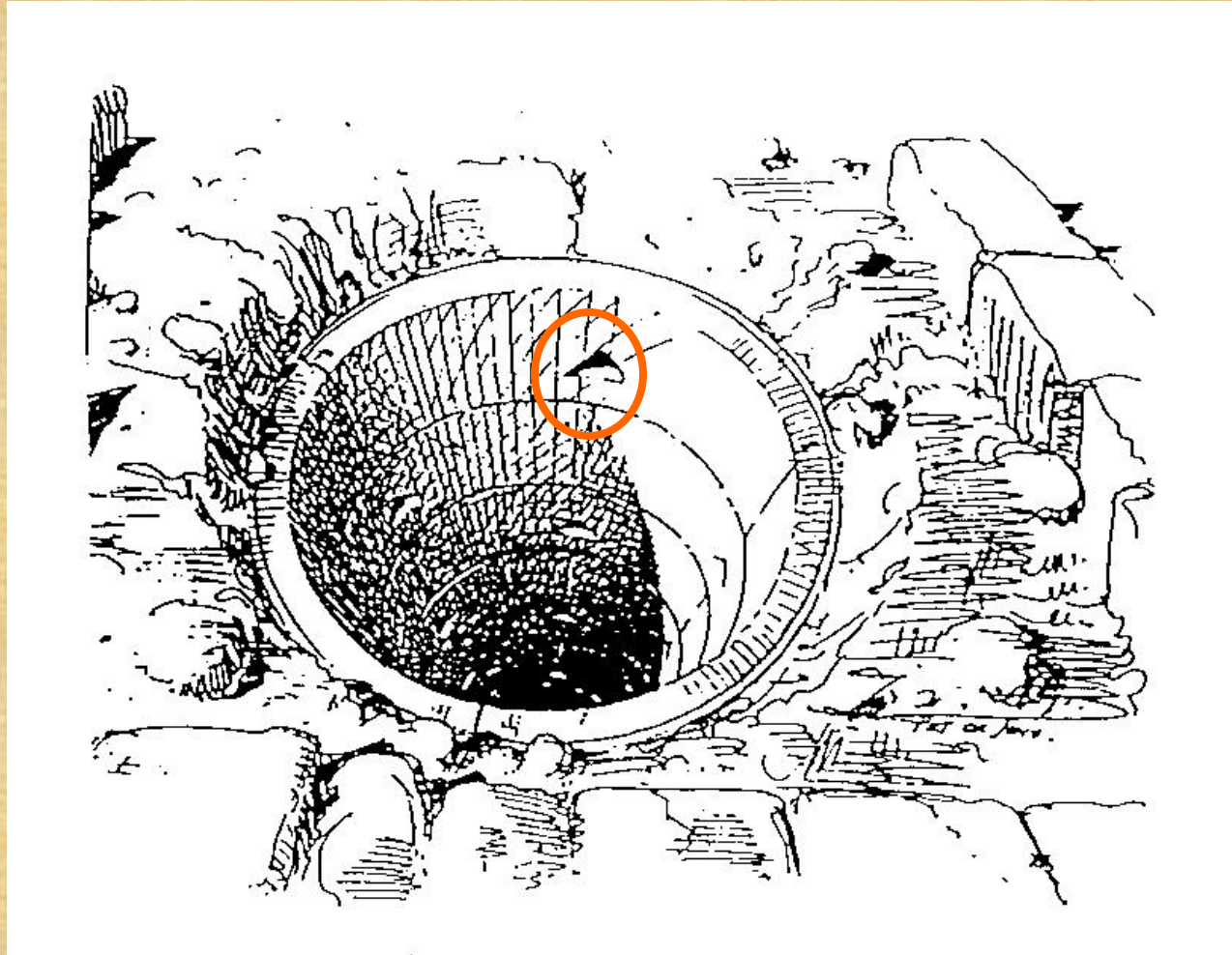


Excavation of wells in Kenya (Polaris/Apeiron/Photos)



# ***Groundwater-Wells***

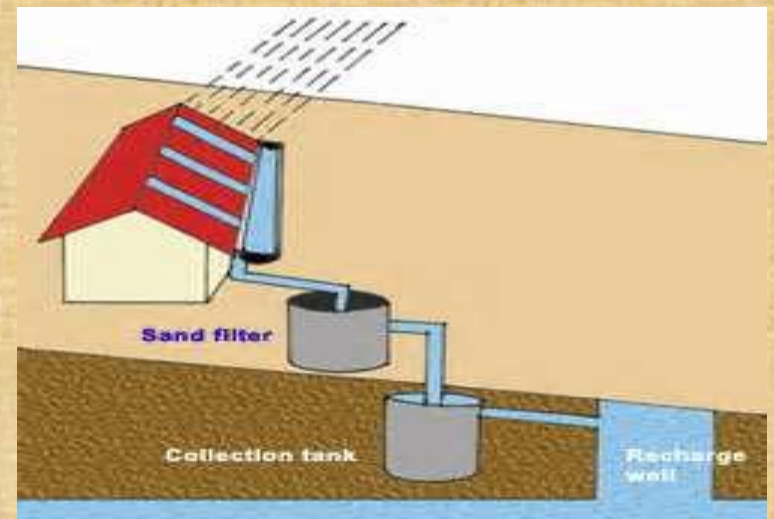
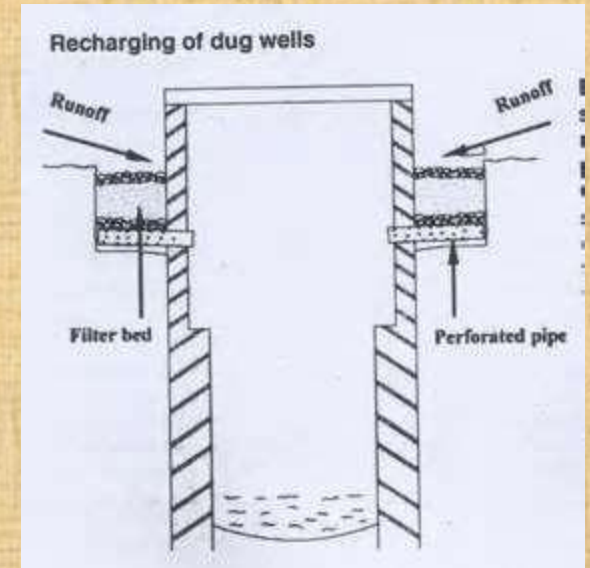
---



Well under House A NW of Knossos with terracotta collars and triangular holes for entering in the well (Angelakis, 2013).



# Rainwater-Harvesting





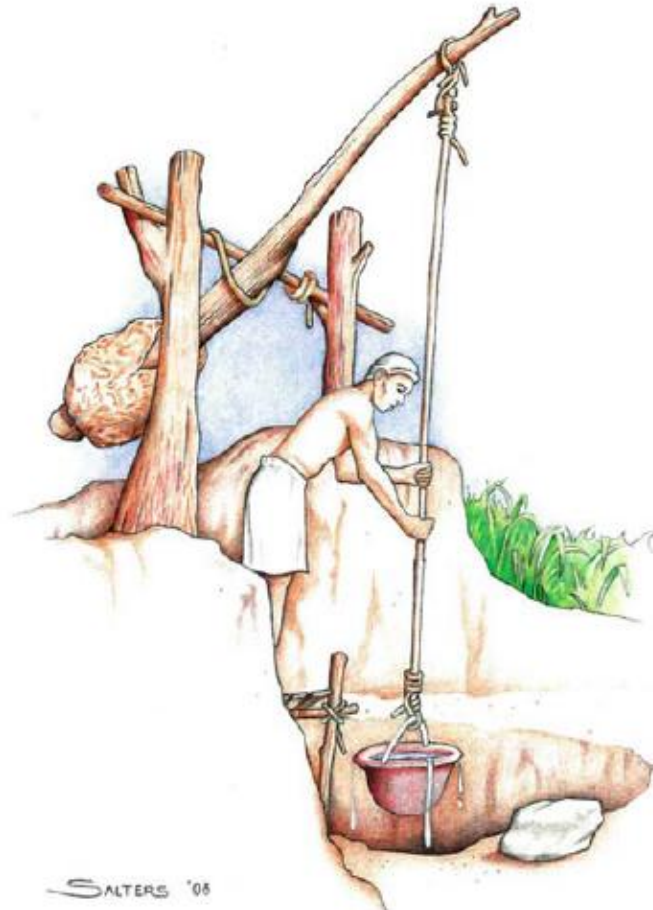
# Collecting rainfall (Aigina Island, 500 BC)



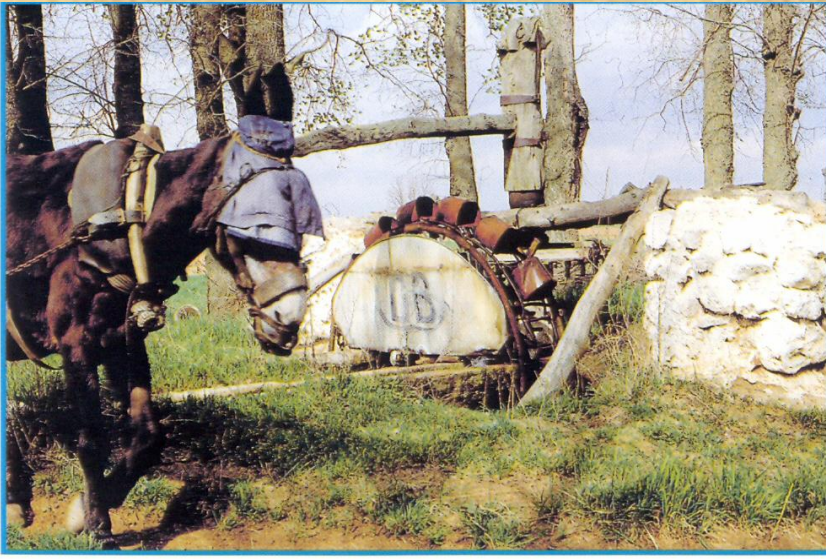


# First device for lifting water

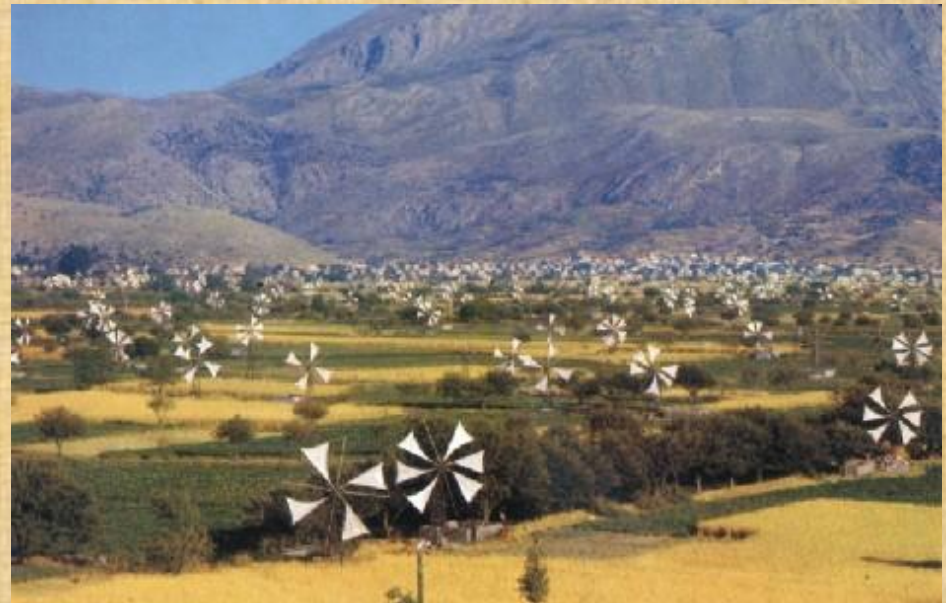
**Fig. 1.1** Shaduf (copyright permission with Bruce Salters, used with permission)







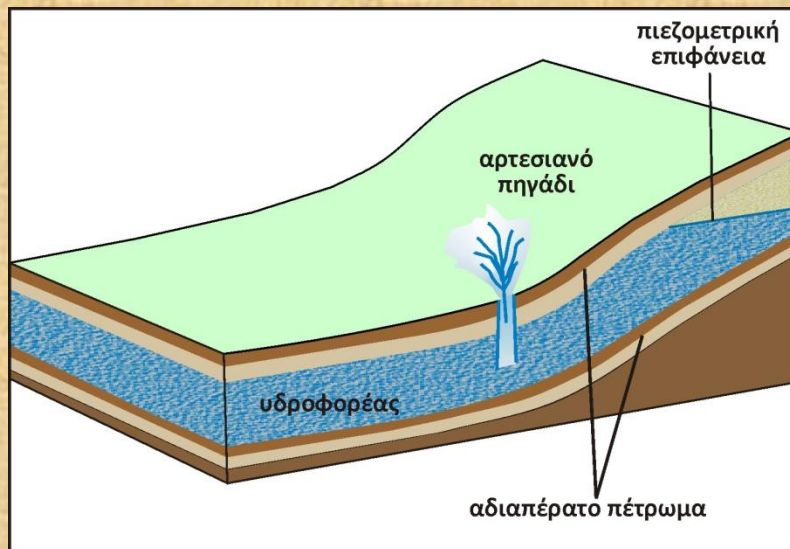
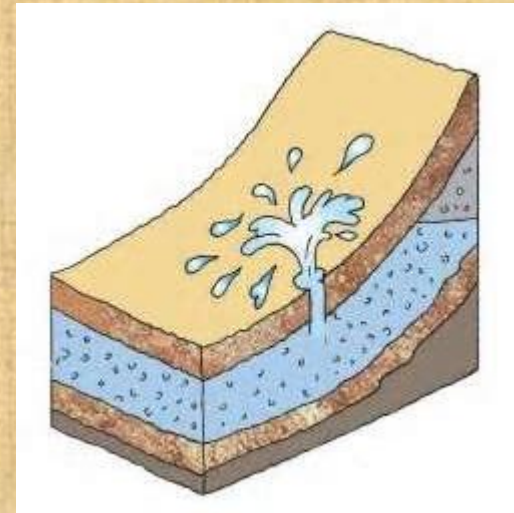
**Water Pumping with animals (IGME, 2001).**



**Lasithi plain (Crete island) Wind pumping**



# Artesian wells



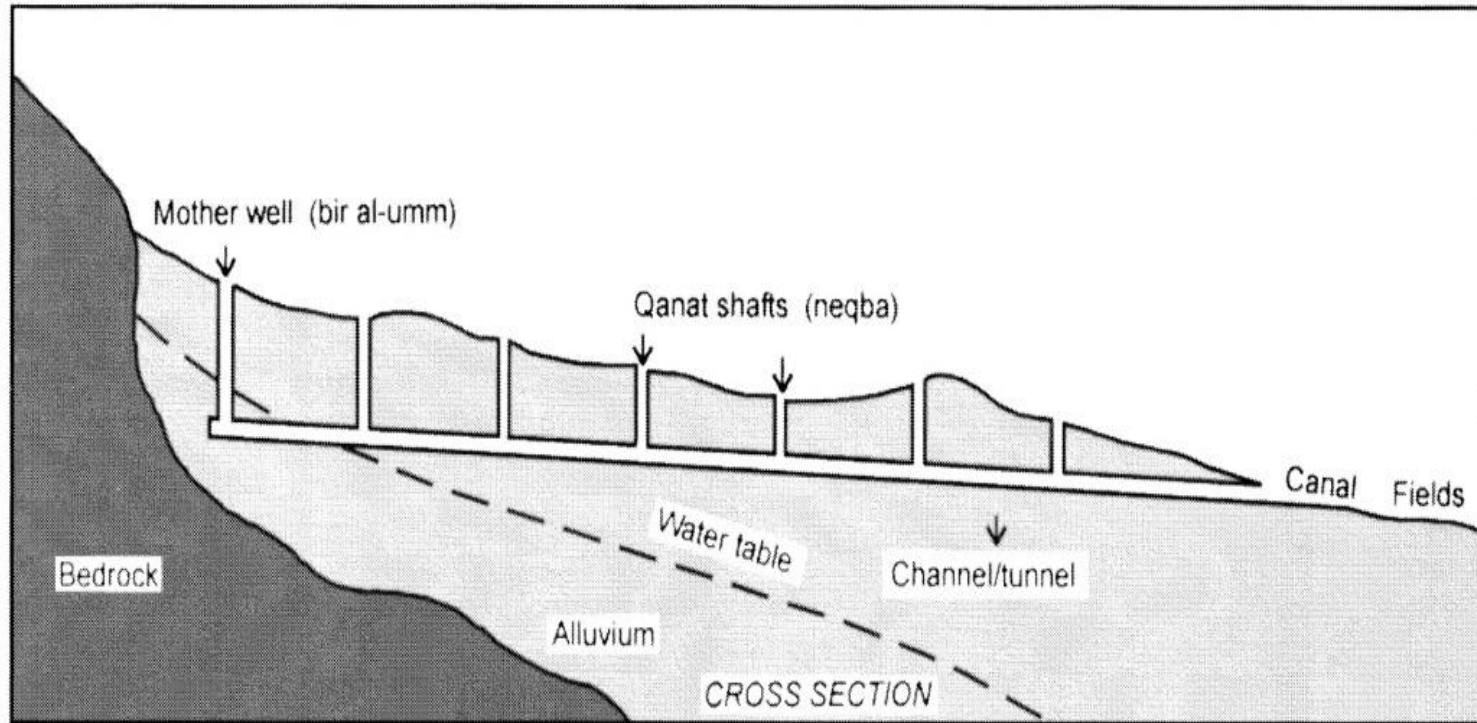


# Qanat – Karez-Kanerjing- Foggara

- Qanat is a technical method used to provide water for human consumption in hot, arid and semiarid regions.
- The idea of qanats was to access and transfer groundwater by drilling a series of wells and linking them underground.
- Qanat is a system of water supply consisting of an underground tunnel connected to the surface by a series of shafts which uses gravity to bring water from the water table of the higher elevation lands to the surface of the lower elevation lands

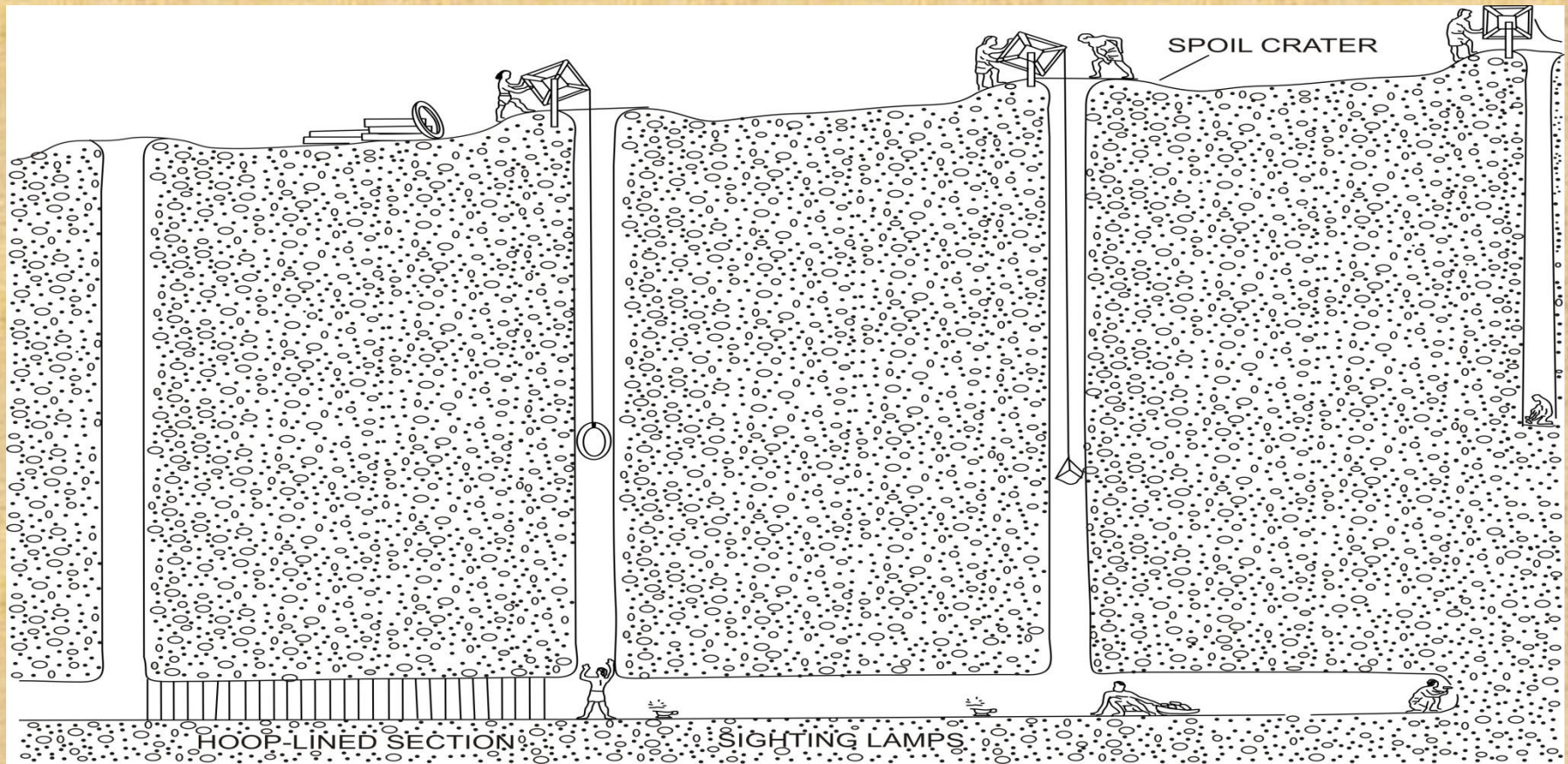


## Typical cross section of a qanat



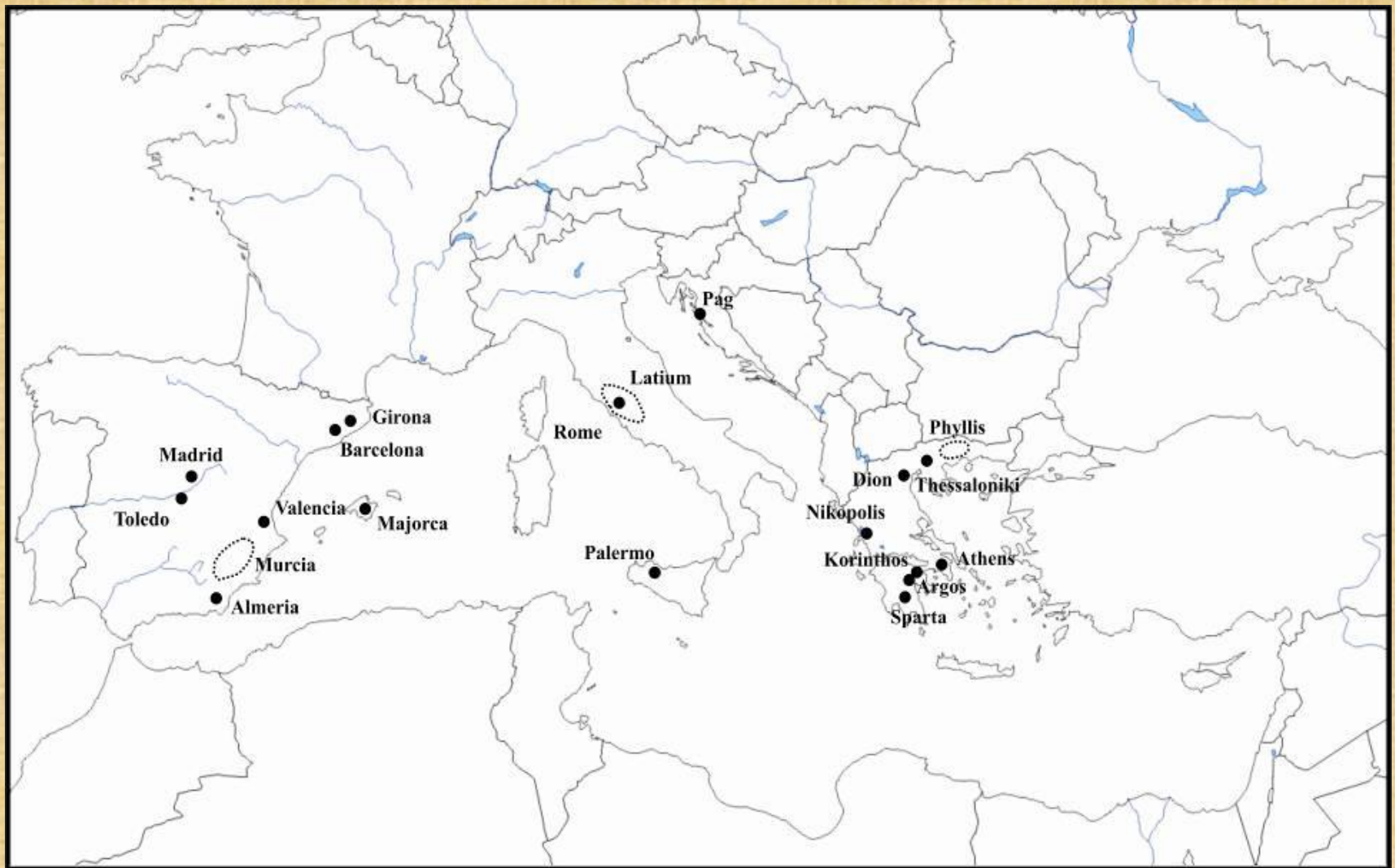
(Lightfoot, 2000)





**Construction of qanat**

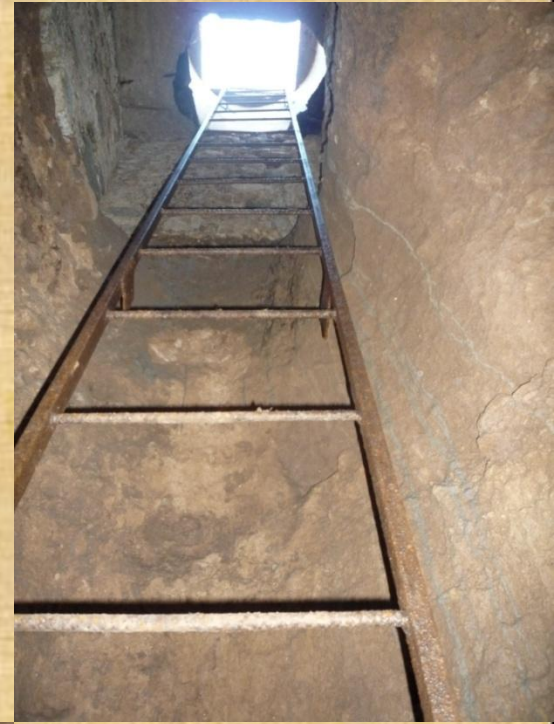




**Location of qanats in Mediterranean countries (Weingartner 2007).**

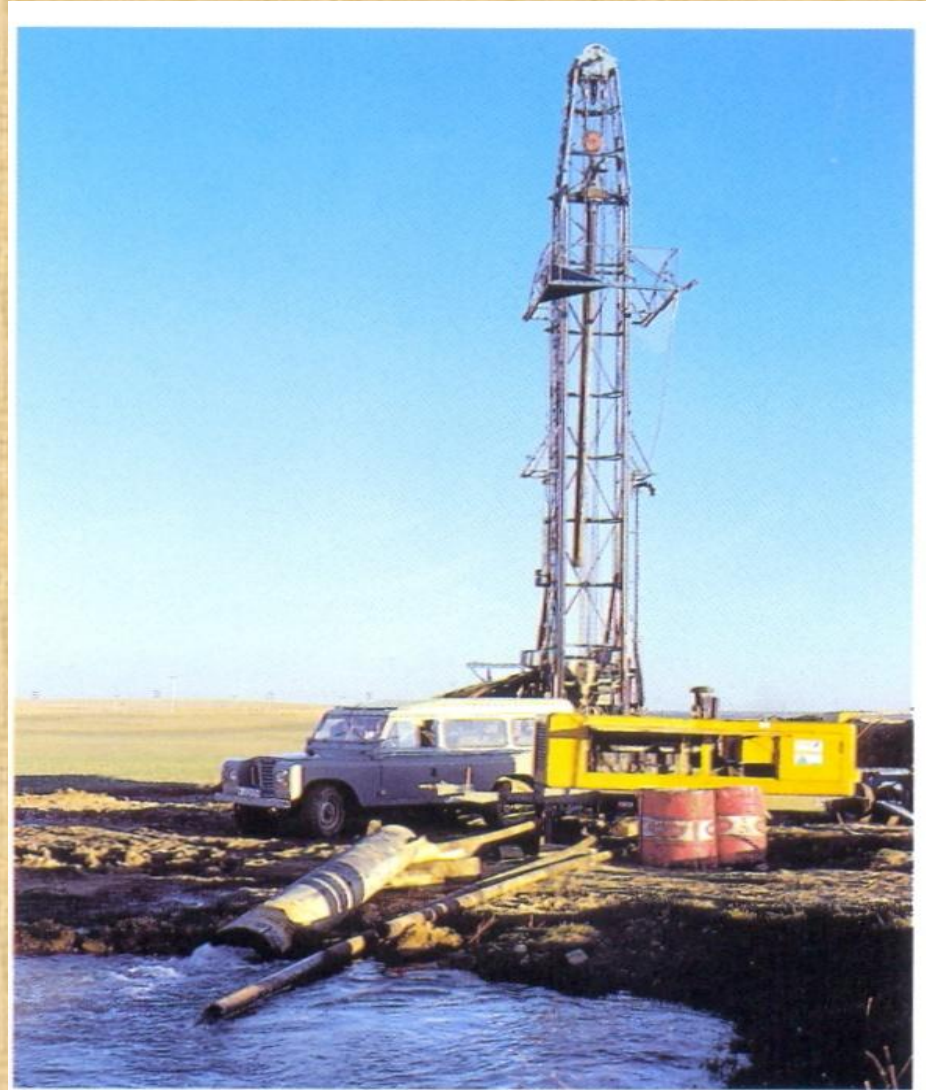
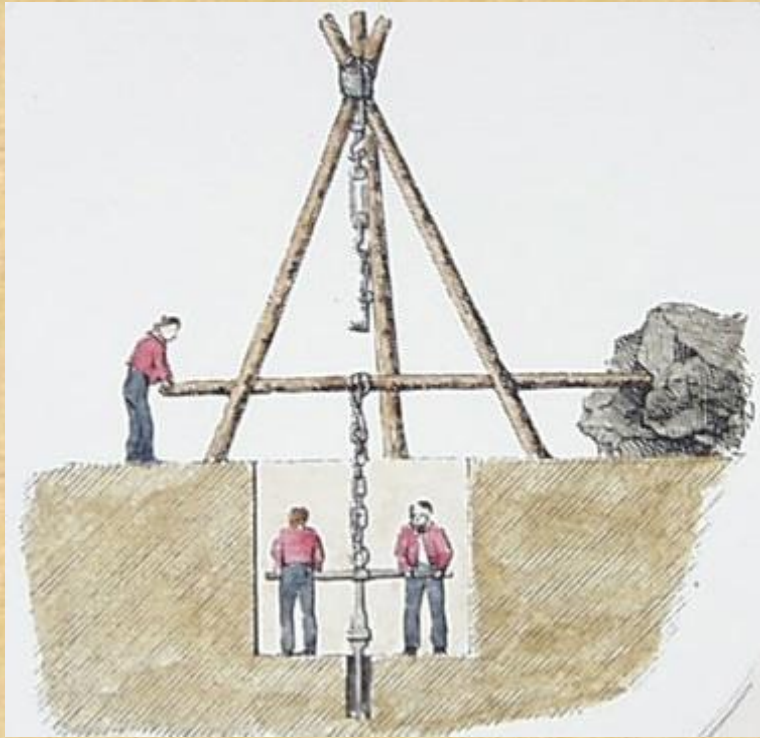


# Serres , North Greece





# Boreholes







The study of ancient hydraulic works  
will help solve the current water problem in many areas.



# Closing Thoughts

---

- a) Hellenic ancient hydro-technologies should be considered not as historical artifacts but as potential models for sustainable water technologies.
- b) Thus, development of an effective water supply management projects, especially in short-water areas could be based on traditional knowledge.
- c) In water-short areas, the development and application technologies of cost-effective, decentralized, and friendly to the environment is essential.
- d) Ancient Hellenic water knowledge could play an important role for sustainable water supply in the future.
- e) The meaning of sustainability in modern times should be re-evaluated in light of ancient public works and management practices.
- f) More than 2.6 billion people do not use improved sanitation and 1 billion people have limited access to drinking water. Lessons from ancient water management must be examined and the applicability of selected ancient Hellenic systems to the today world must be considered.



**Thank you for your attention!**

