# Water Resources Engineering and Management

(CIVIL-466, A.Y. 2024-2025)

5 ETCS, Master course

**Prof. P. Perona**
Platform of Hydraulic Constructions

Lecture 1-1: Introduction, rationales for Water Resources Engineering and Management and definitions

# General infos

Discipline: Civil and Environmental Engineering

Language: English

Session: Summer

Semester: Spring

Exam type: Written

Classroom: INM 10

Charge: 150 h

Weeks: 14

Hours week: 5

Course: 3 h

Exercises/project: 2 h

This course will be delivered in collaboration with the Swiss engineering company Gruner Ltd, which is one of the leading professionals dealing with water problems within both the national and the international panorama.

# Course “credo”

Student:

“I want to study Water Resources Management because I believe that the solutions to water problems are in management, not technology“

Instructor:

“You are right, but you must work through a technical route (i.e.,water engineering) to become a player“

(Source: Grigg – Water Resources Management 1996)

# Instructors

Academic and CO: Prof. **Paolo Perona**

Teaching Assistants: Dr. Giulio Calvani

Junjia Kang

External (Gruner Ltd): Dr. **Martin Bieri**

External (Gruner Ltd): Dr. **Marcelo Leite Ribeiro**

# Course content

EPFL: Perona

GRUNER: Leite Ribeiro

EPFL: Perona

GRUNER: Bieri

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

**Academic Calender 2024-25 Water Resources engineering and Management (CIVIL-466) in INM 10 classroom**

| | | | Date | Time | Lecture topic | Delivery date | Who |
|---|---|---|---|---|---|---|---|
| 1 | WATER RESOURCES ENGINEERING | Introduction, history and main definitions | 17.02.25 | 13:15 - 14:00 | WREM-L1.1 - Introduction, history and program | | PP |
| | | | | 14:15 - 15:00 | WREM-L1.2 - Context of WREM | | |
| | | | | 15:15 - 16:00 | WREM-L1.3 - Definitions and International river basins | | |
| | | | | 16:15 - 17:00<br>17:15 - 18:00 | NO Exercise | | GC, JK |
| 2 | | Hydrological cycle, water bodies and uses | 24.02.24 | 13:15 - 14:00 | WREM-L2-1 - Water Resources - hydrol cycle and availability | | PP |
| | | | | 14:15 - 15:00 | WREM-L2.2 - Water Resources: catchment hydrology and surface water bodies | | |
| | | | | 15:15 - 16:00 | WREM-L2-3 - Water Resources: catchment hydrology and subsurface water bodies | | |
| | | | | 16:15 - 17:00<br>17:15 - 18:00 | Exercise L2 | | GC, JK |
| 3 | | Pipeline hydraulics and hydraulic machines | 03.03.25 | 13:15 - 14:00 | WREM-L3.1 - Review of hydraulics of pressure systems (NEW) | | PP |
| | | | | 14:15 - 15:00 | WREM-L3.2 - Review of hydraulic pipe and network design and operation | | |
| | | | | 15:15 - 16:00 | WREM-L3.3 - Pumping systems: desgin and operation | | |
| | | | | 16:15 - 17:00<br>17:15 - 18:00 | Exercises L3 | | GC, JK |
| 4 | | Water uses: design and operations for traditional and non-traditional uses | 10.03.25 | 13:15 - 14:00 | WREM-L4.1 - Water Uses: definitions, consumptive vs non cons., tradition. Vs non trad.; reservoir design | | PP |
| | | | | 14:15 - 15:00 | WREM-L4.2 - Water uses: domestic water supply, population growth, distribution networks | | |
| | | | | 15:15 - 16:00 | WREM-L4.3 - Water uses: industrial water supply, aqueduct operations and emergency supply | | |
| | | | | 16:15 - 17:00<br>17:15 - 18:00 | Exercises L4 | | GC, JK |
| 5 | | | 17.03.25 | 13:15 - 14:00 | WREM-L5.1 - Water uses: Energy production, hydropower schemes design and operation | | PP |
| | | | | 14:15 - 15:00 | WREM-L5.2 - Water uses: navigation, flood control, | | |
| | | | | 15:15 - 16:00 | WREM-L5-3 - Water uses: non-traditional uses, environmental flows, static and dynamic | | |
| | | | | 16:15 - 17:00<br>17:15 - 18:00 | Exercises L5 | | GC, JK |
| 6 | | Data analysis and modelling | 24.03.25 | 13:15 - 14:00 | WREM-L6.1 - Data analysis: 1 | | PP |
| | | | | 14:15 - 15:00 | WREM-L6-1 - Data analysis:2 | | |
| | | | | 15:15 - 16:00 | WREM-L6.3 -Data analysis: 3 - Hurst effect | | |
| | | | | 16:15 - 17:00<br>17:15 - 18:00 | Exercises L6 | | GC, JK |
| 7 | | | 31.03.25 | 13:15 - 14:00 | WREM-L7.1 - Data modelling, lin stoch models | | PP |
| | | | | 14:15 - 15:00 | WREM-L7.2 - Data modelling, ARMA and discharge modelling | | |
| | | | | 15:15 - 16:00 | WREM-L7.3 - Data analysis and modelling: precips and droughts | | |
| | | | | 16:15 - 17:00<br>17:15 - 18:00 | Exercises L7 | | GC, JK |
| 8 | | EIA, conflict & cooperation, optimisation | 07.04.25 | 13:15 - 14:00 | WREM-L8.1 - Environmental Impact Assessment and sustainability | | PP |
| | | | | 14:15 - 15:00 | WREM-L8.2 - Conflicts and cooperation: game theory | | |
| | | | | 15:15 - 16:00 | WREM-L8.3 - Optimisation: linprogramming | | |
| | | | | 16:15 - 17:00<br>17:15 - 18:00 | Exercises L8 | | GC, JK |
| 9 | WATER MANAGEMENT | | 14.04.25 | 13:15 - 14:00 | WREM-L9.1 - Water Management: Allocation, balancing demand and supply | | MLR |
| | | | | 14:15 - 15:00 | WREM-L9.2 - Water Management: conflict of interest & International river basins | | |
| | | | | 15:15 - 16:00 | WREM-L9.1 - Water Management: ESG & Sustainable Development | | |
| | | | | 16:15 - 17:00<br>17:15 - 18:00 | Practical Work: Case study hydropower - basic input data analysis and generation | | GC, JK |
| 10 | | Optimisation, Engineering economics and Optimal Water Allocation Model | 28.04.25 | 13:15 - 14:00 | WREM-L10.1 - Optimisation: dynamic and quadratic programming | | PP |
| | | | | 14:15 - 15:00 | WREM-L10.2 - Engineering economics, indicators | | |
| | | | | 15:15 - 16:00 | WREM-L10.3 - Engineering economics, marginal analysis | | |
| | | | | 16:15 - 17:00<br>17:15 - 18:00 | Practical Work: Case study hydropower - basic input data analysis and generation | | GC, JK |
| 11 | | | 05.05.25 | 13:15 - 14:00 | WREM-L11.1 - Basin water allocation model AQUARIUS 1 | | PP |
| | | | | 14:15 - 15:00 | WREM-L11.2 - Basin water allocation model AQUARIUS 2 | | |
| | | | | 15:15 - 16:00 | WREM-L11.3 - Basin water allocation model AQUARIUS 3 | | |
| | | | | 16:15 - 17:00<br>17:15 - 18:00 | Practical Work: Case Study Hydropower - AQUARIUS optimisation model | | GC, JK (assistants) |
| 12 | | Financial analysis and optimisation in practice | 12.05.25 | 13:15 - 14:00 | WREM-L12.1 - Water Management: Environemntal, Social and Governance | | MB |
| | | | | 14:15 - 15:00 | WREM-L12.2 - Water Management: economics and financing, definitions, discounted cash-flow | | |
| | | | | 15:15 - 16:00 | WREM-L12.3 - Water Management: Sponsor's vs lender's perspective | | |
| | | | | 16:15 - 17:00<br>17:15 - 18:00 | Practical Work: Case Study Hydropower - Alternative Study and Cost Estimate | | GC, JK (assistants) |
| 13 | | | 19.05.25 | 13:15 - 14:00 | WREM-L13.1 - Water Management: Risk Management, performance criteria | | MB, MLR |
| | | | | 14:15 - 15:00 | WREM-L13.2 - Water Management: Optimization techniques in practice | | |
| | | | | 15:15 - 16:00 | WREM-L13.3 - Decision making | | |
| | | | | 16:15 - 17:00<br>17:15 - 18:00 | Practical Work: Case Study Hydropower - Cash Flow, Economic and Financial Analysis | | GC, JK (assistants) |
| 14 | | Wrap up and exemplary exam questions | 26.05.25 | 13:15 - 14:00 | WREM-L14.1 - WREM wrap up and conclusions, exam questions | | PP |
| | | | | 14:15 - 15:00 | WREM-L14.2 - Guest lecture | | |
| | | | | 15:15 - 16:00 | WREM-L14.3 - Guest lecture | | |
| | | | | 16:15 - 17:00 | | | |
| | | | | 17:15 - 18:00 | | | |

# Course learning map

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

**Water Resources Engineering**: L1–L8-9

**Water Resources Management**: L8-9–L14

L1. Introduction, history of WRM, defs. → L2. Water availability and freshwater bodies → L3. Hydr. engineering and machines (Review) → L4-5. Water uses → L6-7. (Input) Data analysis and modelling → L8-9. EIA, conflict&coop optimisation → L10--11. Optimisation, eng. Economics, AQUARIUS → L12-13. Financial analysis and optimization in practice → L14. WRAP-UP and exam questions

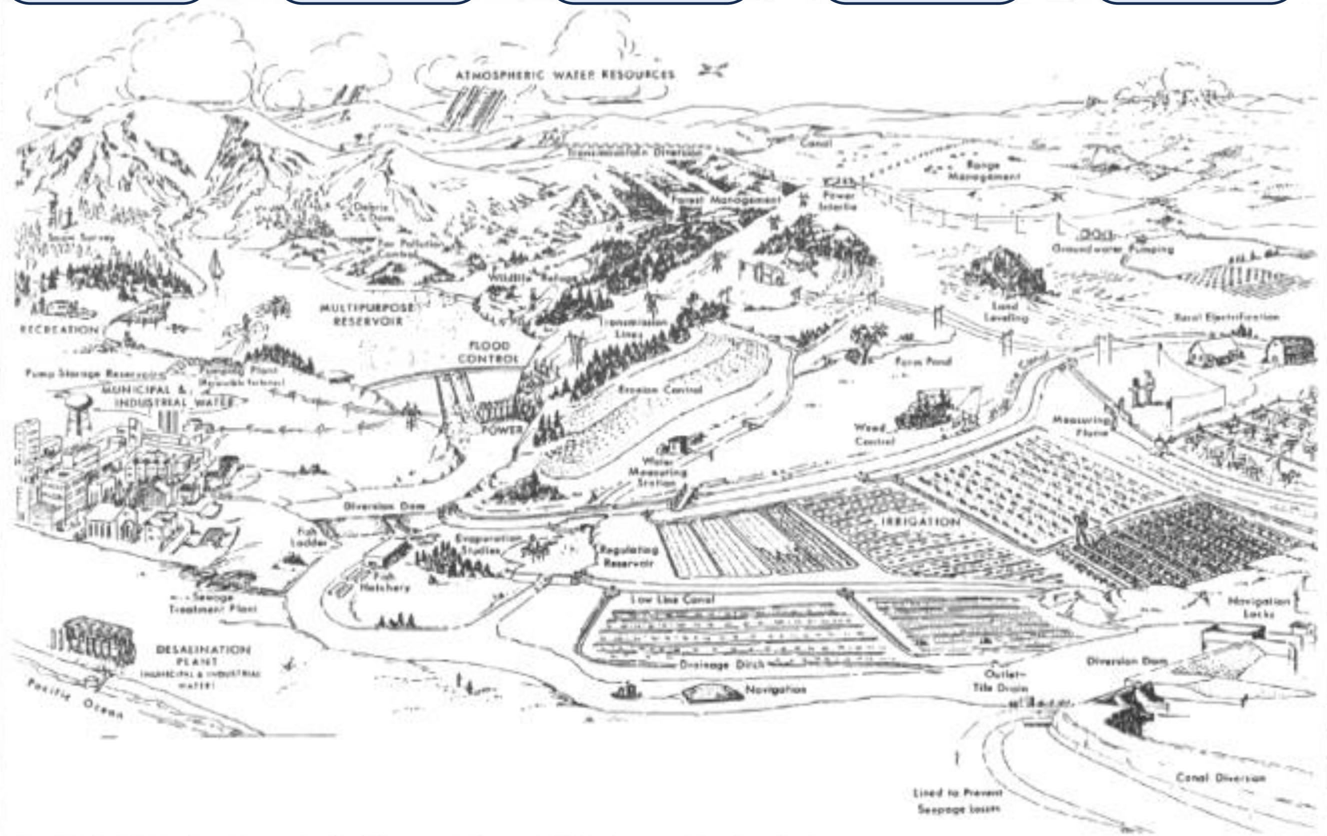



Figure 19.1 Comprehensive watershed diagram (Source: U.S. Bureau of Reclamation.)

# Teaching philosophy

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

- To provide differential viewpoints and perspectives to the **importance** and related **consequences** of **designing, planning and managing** water resource infrastructures and uses at the local, regional and transboundary scales.

- To illustrate the **mathematical tools** and to learn about their **quantitative use** in order to improve professional skills of engineering students.

- To drive the formation of today' engineering students toward **sustainability criteria** that embrace **technical**, **economic** and (important!) **ecological and social** aspects.

# Learning objectives and transversal skills

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

## LEARNING OBJECTIVES

- Assess and model water resources availability at different scales;
- Calculate different water needs and design of related infrastructures;
- Formulate an integrated and sustainable water management concept;
- Perform a basic economic analysis and assess the economic value of water projects
- Distinguish between project development with or without profitability goal
- Evaluate key economic indicators (NPV, IRR, etc.)
- Optimise the use of water resources
- Evaluate the water issue in the current economic context

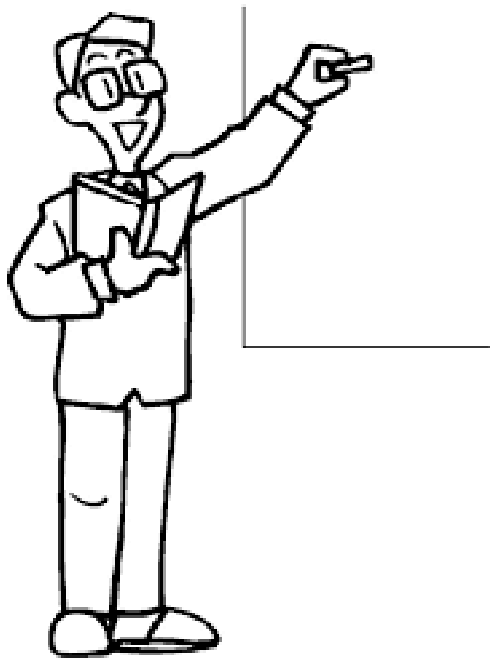
## TRANSVERSAL SKILLS

- To gain awareness of the environmental impacts in relation to the effect of actions and decisions on environmental components;
- To become aware of and comply with relevant legal guidelines and the ethical code of the engineering profession.
- To plan and carrying out intervention actions to optimize available time and resources.

# Teaching method and student activities



Ex cathedra, with audiovisual means and board
complementary explanations/derivations



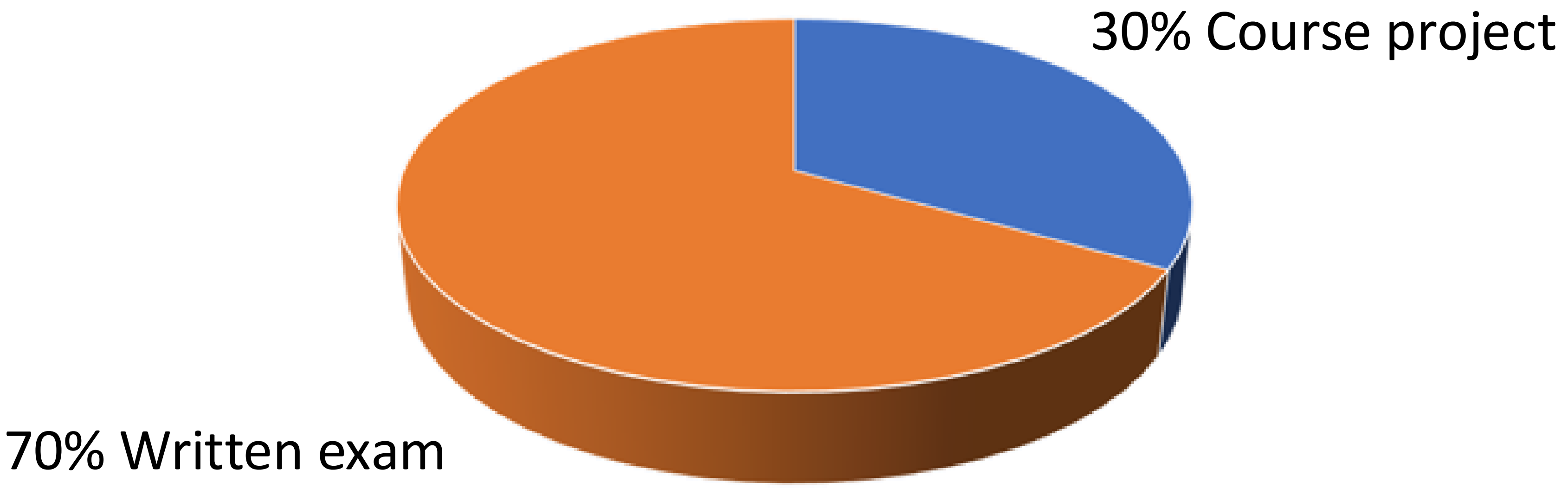
Course organisation

Lectures (3 hrs/week)

Exercises (2 hrs/week, 7 weeks)

Project work (2 hrs/week, 5 weeks, group of 3)
Compulsory for the exam (grade counts!)

# Assessment methods




$$G_{final}=1+5*(0.3*G_{proj}/100+0.7*G_{exam}/100)$$

Both grades for project and exam are expressed in percentage

- Exercises are not compulsory in order to access the final exam, but they are propedeutical for passing it;
- The project assignment (individual) is compulsory to access the exam, and it contributes to the final grade per 30%. The hand-in date is May 30;
- The exam is <u>only</u> written:
  - In general, 2 questions will concern with theoretical aspects, and 2 questions are exercises of the type developed during the exercise sessions
  - The exam lasts 2 hours, it is <u>closed book</u> and the official language (lecture+exam) is english.

# References

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

Lecture slides from the course will be provided by the instructor, and will be downloadable from the course‘s web page.

Books and Manuals (non compulsory)


- Dinar et al. (2007) *Bridges over Water: understanding transboundary water conflicts, negotiation and cooperation*. World Scientific Singapore
- Grigg, N.S. (1996) *Water Resources Management: Principles, Regulations and Cases.* McGraw-Hill, USA
- Loucks and van Beek (2017) Water resource systems planning and mangement. (open access online)
- Diaz, G., Brown, T. C., Sveinsson, O. (2000) *AQUARIUS: a modeling system for river basin water allocation*. General Technical Report USDA
- Mays L.W., Water Resources Engineering, Wiley, New York, 2005


•Articles

- See Lectures

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

# Enjoy the course, the semester and…remember…

# EPFL has great locations where to relax!



EPFL

# Water Resources Engineering and Management

CIVIL-466

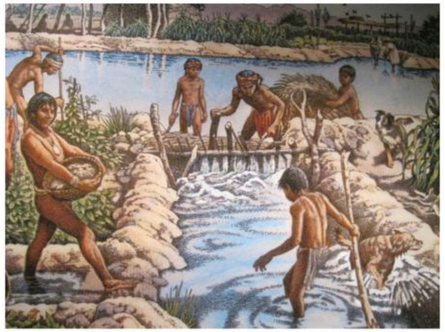
# A few historical notes (water conveyance and use)

- First documented concerns about water quality appear dated about 2000 B.C. – purify water by boiling and filtering it.
- Ancient Romans awareness of the benefits of water quality management – aqueduct systems to provide the Roman Empire with fresh water.
- Seventeenth century – concerns over pollutant emissions to air (poorly controlled combustion of low grade fuels, such as sulfur-containing coal, for light industry, domestic heating, and cooking.

Other uses (irrigation): The artificial supply of water to crops to supplement natural rainfall; the aim is to create favorable conditions for production, in terms of both quantity and quality.

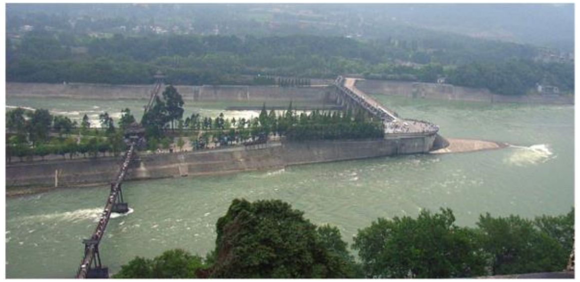
6000 B.C. Ubaid and Sumerians (Ancient Mesopotamia)

1600 – 1400 B.C. The native americans Hohokam



1750 B.C Hammurabi Babylonian king

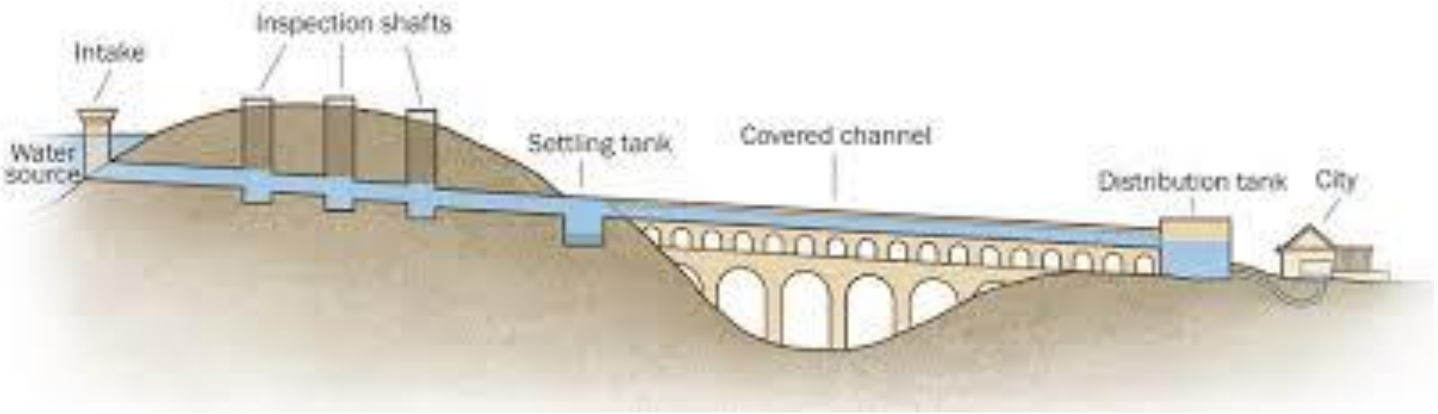
250 B.C. Chinese engineer Zheng-Guo (Yellow River)



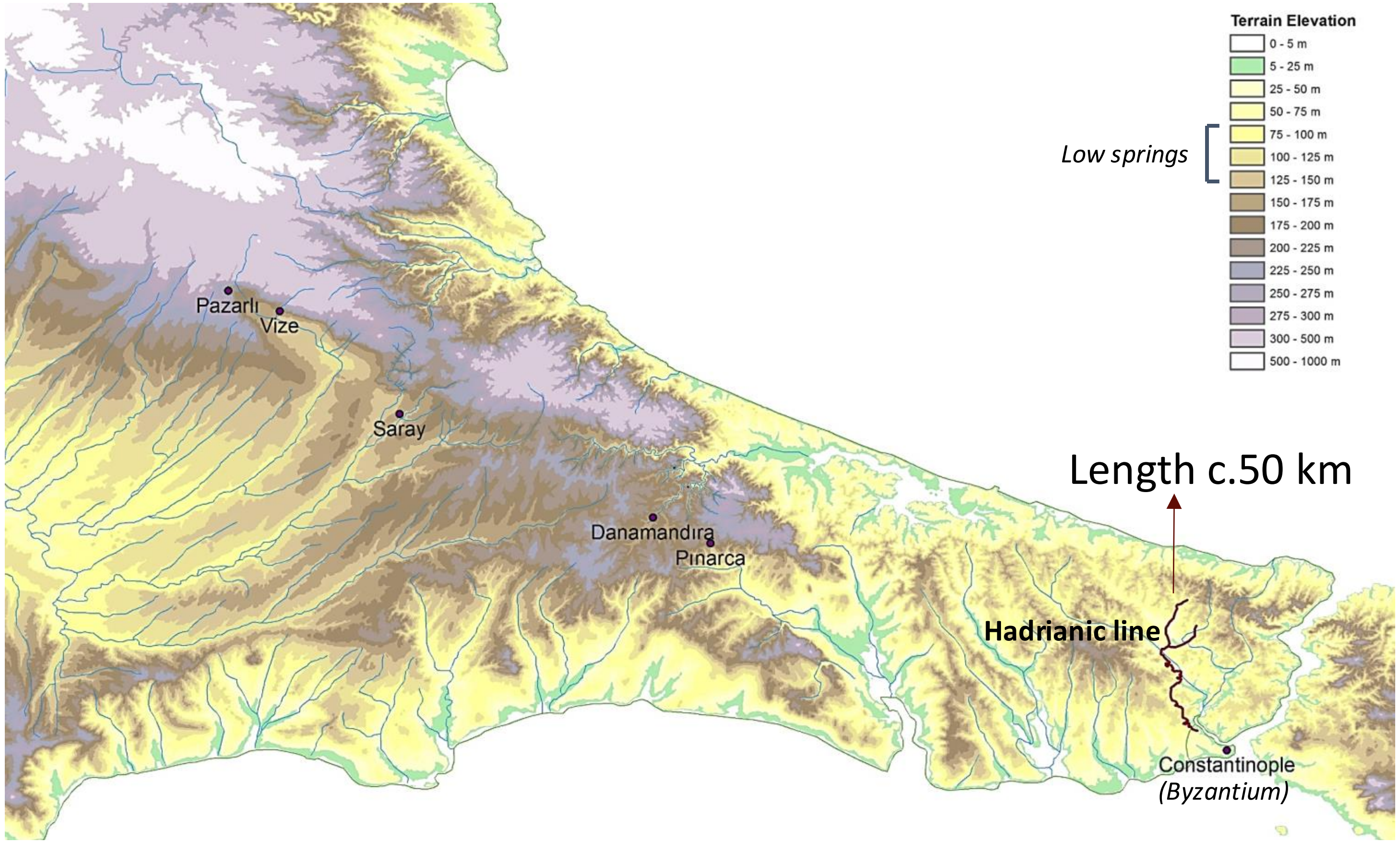
1250 – Les Bisses (Wallis)

# Ancient water conveyance structures

Water management implies knowing the hydraulics of conveyance structures and of pipeline, of networks and hydraulic machines

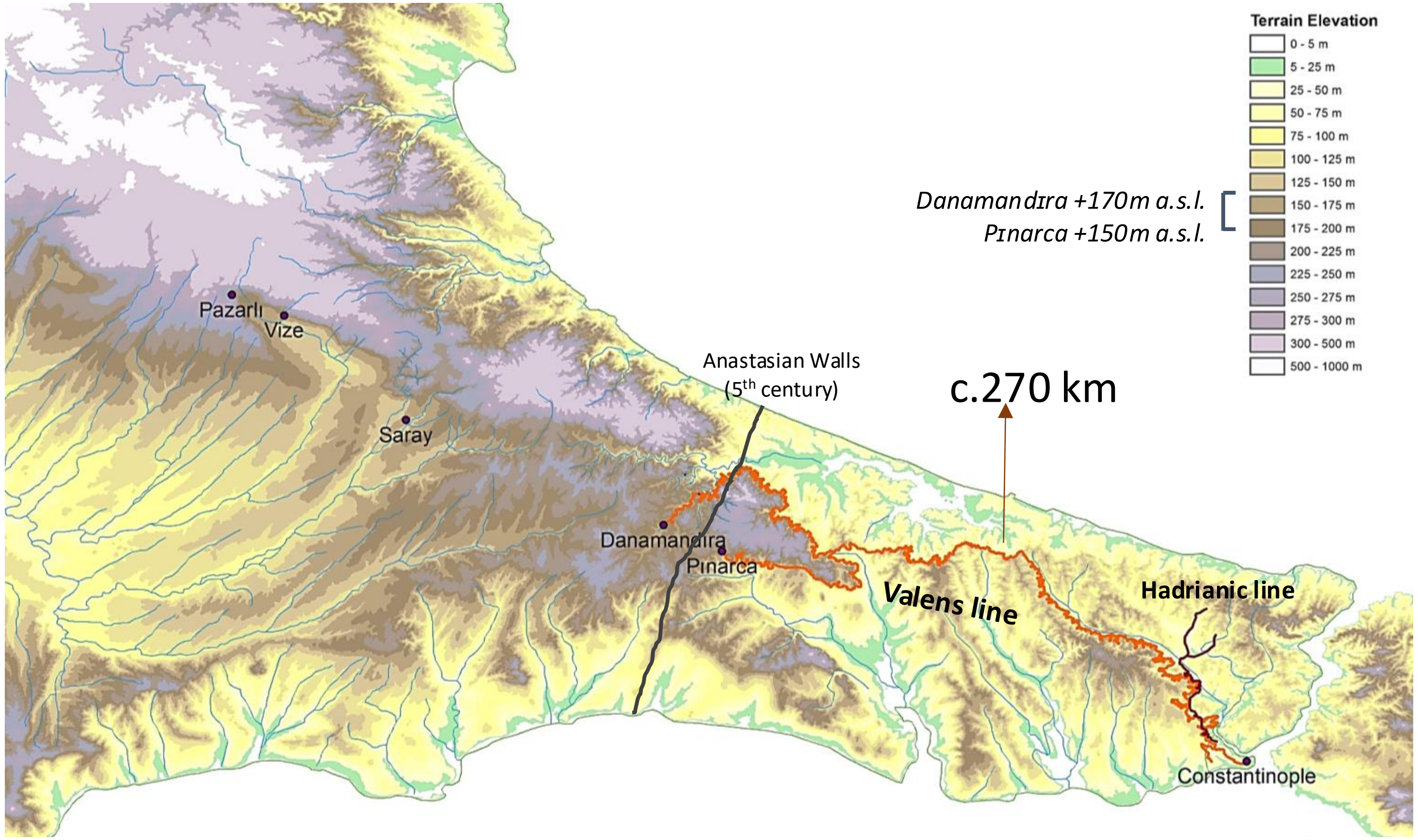


# Hadrianic line (Emperor Hadrian 117-138 AD)



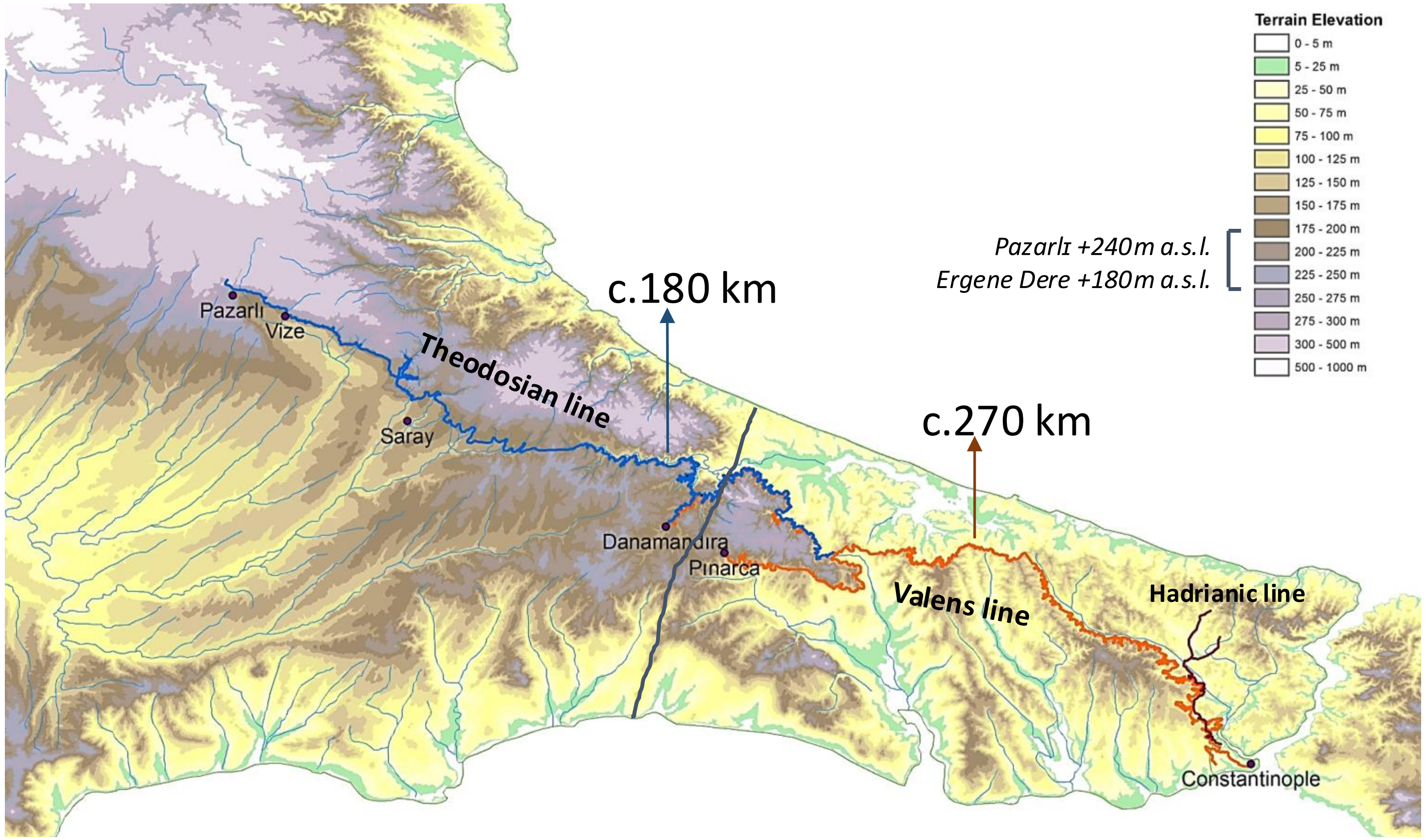

Map of Turkish Thrace

# Valens line (357-368/373 AD)



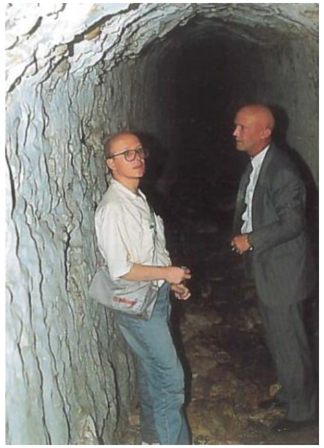

Map of Turkish Thrace

# Theodosian line (> 400 AD)

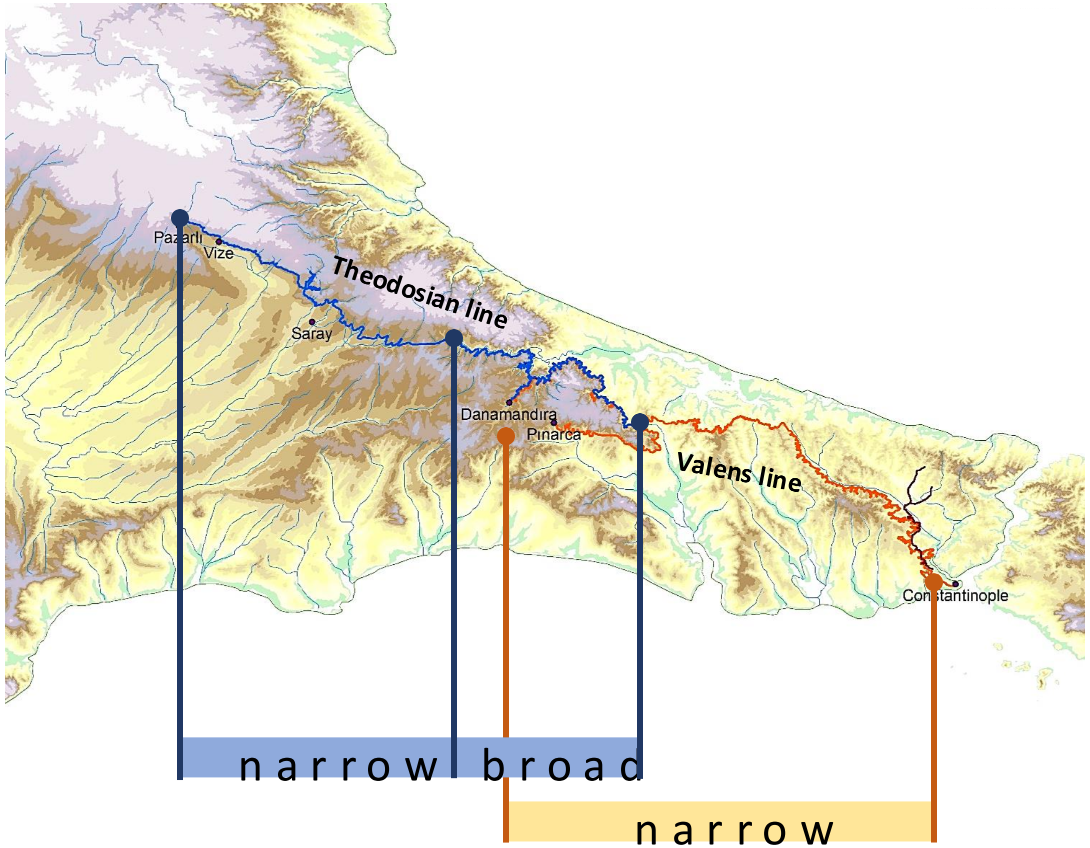



Map of Turkish Thrace

# Channels



**Broad channel**
*1.6m x 2.0m*




**Narrow channel**
*0.65m x 1.60m*

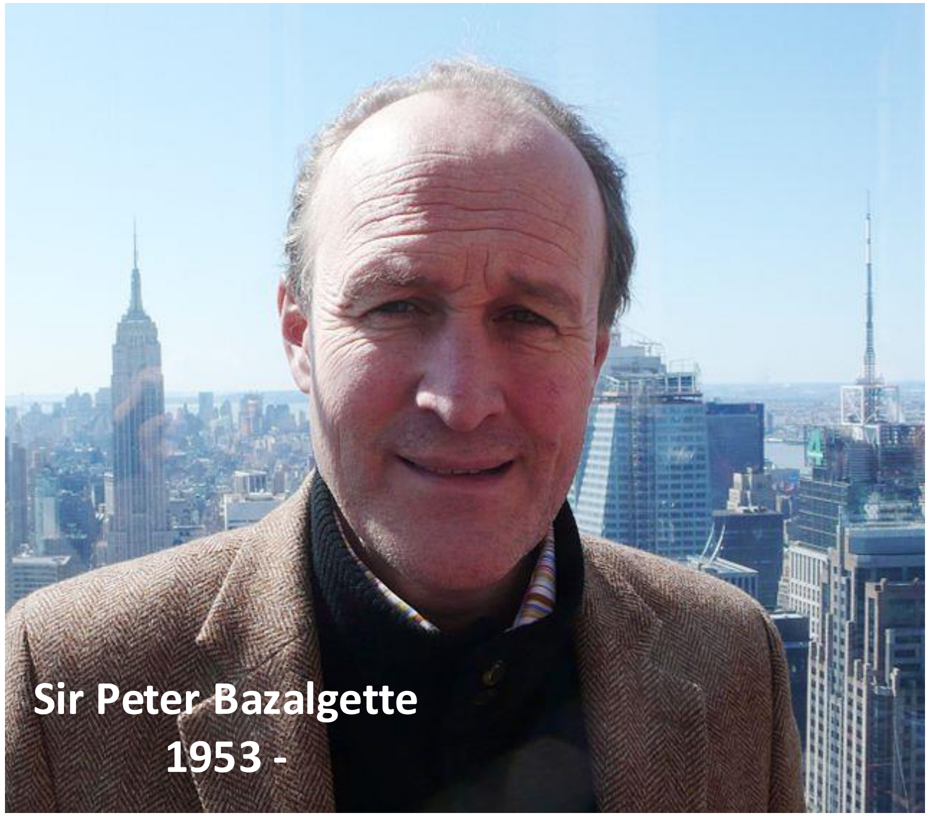
# A few historical notes (sewer systems)

- First documented concerns about water quality appear dated about 2000 B.C. – purify water by boiling and filtering it.
- Ancient Romans awareness of the benefits of water quality management – aqueduct systems to provide the Roman Empire with fresh water.
- Seventeenth century – concerns over pollutant emissions to air (poorly controlled combustion of low grade fuels, such as sulfur-containing coal, for light industry, domestic heating, and cooking.

Today: better understanding of climate change effects shifts again the attention to the future water availability, scarcity and security


London Cholera epidemic 1851-1854

# An interesting curiosity about sewer systems




https://en.wikipedia.org/wiki/Peter_Bazalgette

https://www.youtube.com/watch?v=QHbGjA_RXaY


https://en.wikipedia.org/wiki/Joseph_Bazalgette

# Not much has changed today in ODA countries

Photo credit: Martin Crapper, Malawi

Photo credit: Paolo Perona, Lake Turkana, Kenya

# What is Water Resources Management?

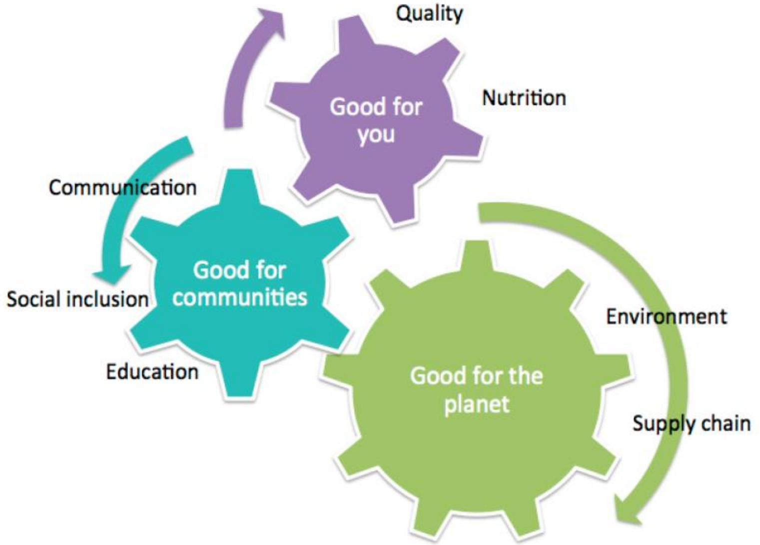
PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

## 1950-1970' Policy

WRM is a primary engineering task to build dams, lay pipelines, install pumps, and operate systems

## Today's Policy

WRM must pursue sustainable development with measures that manage water for human system, but at the same time protect and nurture natural systems for the benefit of future generations (Sustainable Water Management)



# Water Resources Engineering and Management's expertise

Education is clearly one of the leading drivers and players are involved in WREM problems at different levels of engagement

A time of construction 1920 -

Engineers/ design, operation

environmental engineering students interacting with several disciplines!!

*(Adapted from Hirji et Davis, 2009; Ligget, 2002)*

# Water Resources Management policy

Today WRM‘ policies imply dealing with complex problems

This may imply dealing with deep conflicts

WR manager requires skills well beyond technical training (e.g., pure engineering, science, management, or law)

WR manager must be able to communicate, cooperate in teams, speak other languages, work with other cultures, understand environmental problems and resolve conflicts via cooperation

…but what are the problems, exactly and what is their origin?