More than just a case-study: the long-term relationship between a hydrologist and a water supply utility

Elena Toth ⟷ Romagna Acque Società delle Fonti S.p.A.

Courtesy of RomagnaAcque – Società della Acque SpA

Romagna Acque-Società delle Fonti is a public owned company and it manages all the drinking water sources for civil use in Romagna.

Water abstraction, treatment and delivery to the cities (inside which a different water retailer carries out the distribution).

Dipartimento di Ingegneria Civile, Chimica, Ambientale e dei Materiali,
Alma Mater Studiorum - Università of Bologna

The Ridracoli reservoir

The most important source is the artificial reservoir of the **Ridracoli Dam,** 33 Mm^3 capacity, which meets **about 50% of the total water requirement for the Romagna Region (~ 60 mil m^3/yr).**

The reservoir was filled completely for the first time in 1986 and from 1988 the dam is supplying drinking water to almost one million of resident customers plus millions of summer tourists .

Water scarcity conditions in 2002, 2007, 2011, 2017
$\Rightarrow$ implementation of a set of mitigation measures, including a few limitations to the population's water consumption

A complicated, interesting case study for a hydrologist

Basins that feed the reservoir:

- the headwater catchment of the Bidente di Ridracoli River (closed at the dam)

Courtesy of RomagnaAcque – Società della Acque SpA

+ four additional diversion watersheds,
i.e. drainage areas that are joined to the reservoir through an underground water channel.

Storyline

It starts as a case study (a one-sided attachment…)

2007: Start of my «Data Quest», following the 2007 drought

2010/11 (Idra2010+EGU2011): R/R modelling

2012 (EGU Leonardo): simulation of past streamflow in the ungauged diversion basin

I was not alone: help of a number of students (almost always «native», i.e. romagnoli) – over 20 theses in the last 15 years

XXXII Convegno Nazionale di Idraulica e Costruzioni Idrauliche (IDRA 2010)
Palermo, 14-17 September 2010

Idra2010: **reconstruction and reconciliation of the hydro-meteorological time series**, at hourly and daily time-steps, for the basins that feed the reservoir;
+ **rainfall-runoff modelling**

EGU Leonardo 2012: **R/R model regionalization** for the last diversion basin, Fiumicello (where only daily data are available until mid-2009) in order to obtain an estimate of hourly streamflow time-series

European Geosciences Union
Leonardo Conference 2012
Torino, 14-16 November 2012

Storyline

Finally reciprocated: an official relationship

Research contract UNIBO/RomagnaAcque 2014-2020

Mattia Neri involved in the relationship (starting from his Master thesis (2016) and then as research fellow and PhD student)

+ Armando Brath, with Alessio Pugliese, Alessio Domeneghetti and Cristiana Bragalli, working on different issues

SIMTWIST JPI WaterWorks Project 2019-2022

Other partners: Wageningen (NL) and Alicante (ES) university

DATA COLLECTION, VALIDATION AND PROCESSING

Meteo-hydrological data for all the basins that feed the reservoir; data on reservoir operation; data on user demand and its drivers, data on the other water sources.

RAINFALL-RUNOFF MODELLING

Set up of a number of rainfall-runoff models, and their successive refinement. Gauged basins allowed to regionalize the model in order to simulate streamflows in the ungauged ones.

ASSESSMENT OF RESERVOIR BEHAVIOUR IN DIFFERENT SCENARIOS

Simulation of the [basins + diversion channel + reservoir] system behavior for assessing increase in annual water availability under different operation options

OPTIMISATION OF THE RESERVOIR OPERATION

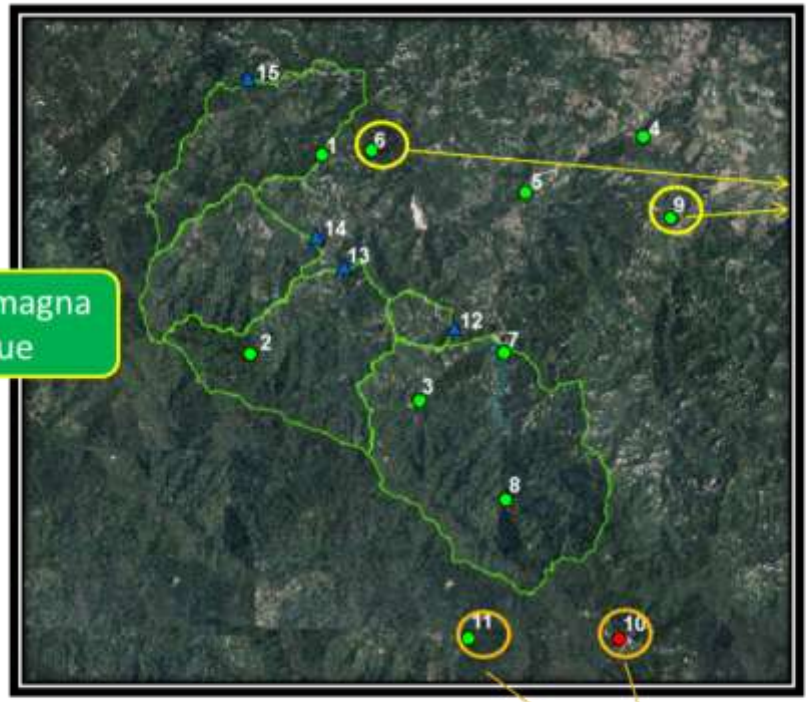
Multiobjective optimization: maximising annual water withdrawal + avoiding water deficit conditions, considering the other supply sources (not to be overexploited)

INTEGRATED WATER SOURCES

Understanding the repercussions of hydrological droughts (at Ridracoli) on the management of the different local surface and subsurface water supply sources

MODELLING THE URBAN DEMAND: ROLE OF TOURISM

Studying water consumption in touristic cities and their main drivers, both in current and future scenarios, in order to analyze tourism's role in water scarcity



ARPA - SIMC

Dati DEXTER

Stazioni di Corniolo (6) e Lastra (9)

Dati Romagna Acque

Servizio idrologico regionale

Dati SIR Toscana

Stazioni di Camaldoli (11) e Badia Prataglia (10)

Stazioni termo/pluviometriche
Stazione solo pluviometrica
Stazione idrometrica

Data reconnaissance: several years (and yearly update still running…)

Disponibilità di dati di livello idrometrico

Stazione	INVASO		BACINE		CAMPIGNA		CELLE		FIUMICELLO Derivazione		FIUMICELLO Valle		GRONDA	
Anno	giorno	ora	giorno	ora	giorno	ora	giorno	ora	giorno	ora	giorno	ora	giorno	ora
1974														
1975														
1976														
1977	Ridra													
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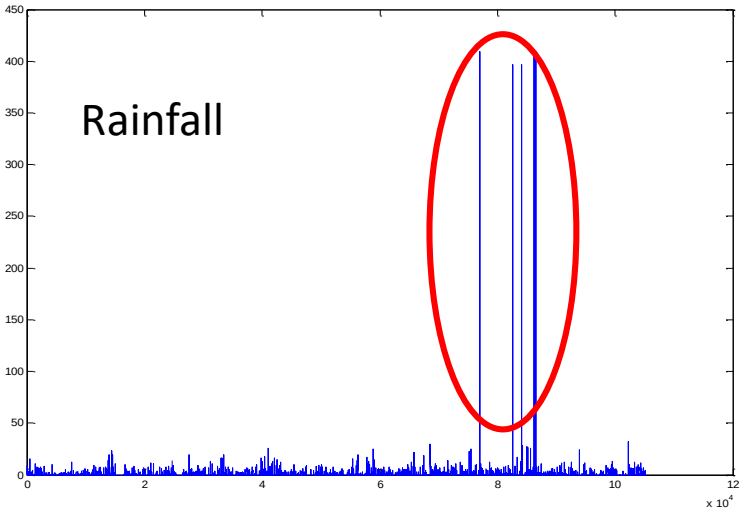
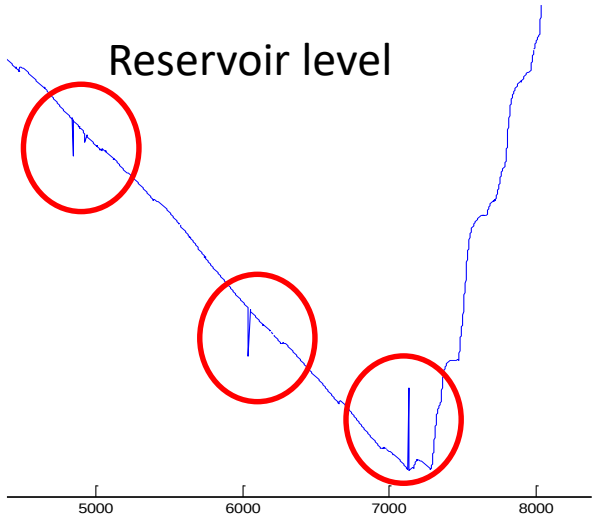
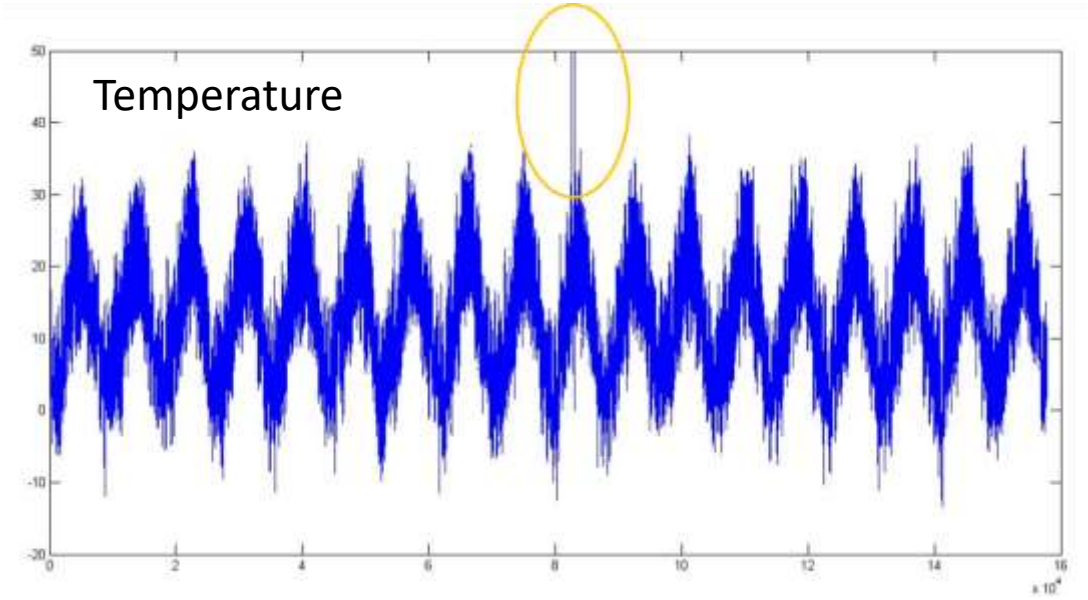
	DAL 1977 AL 1981 DATI INCOMPLETI	DA 02/04/96							Da 1/05/2009		Da 1/05/2009			

Different owners (public bodies), different time-resolution, different observation periods
(even georeferencing to be checked)

Data validation, gap filling, reconciliation of the hydro-meteorological time series







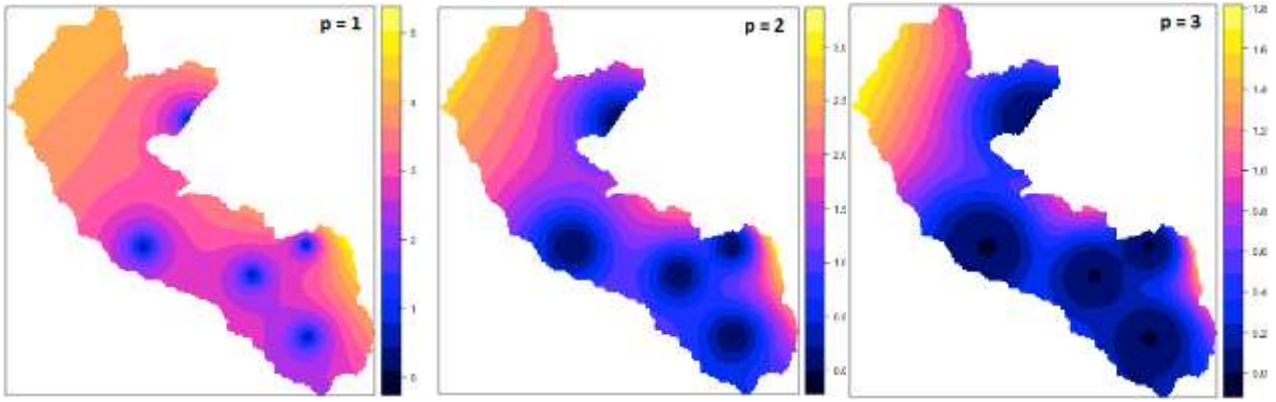
Inflow from the catchment closed at the dam: from water balance,
+ increase in stored volume
- inflow from diversion basins
+ outflow and losses

$$Q_{dir,t} = \frac{\Delta V}{\Delta t} - Q_{gronda,t} + Q_{deriv,t} + Q_{sf,t} + Q_{sc,t} + Q_{evap,t}$$

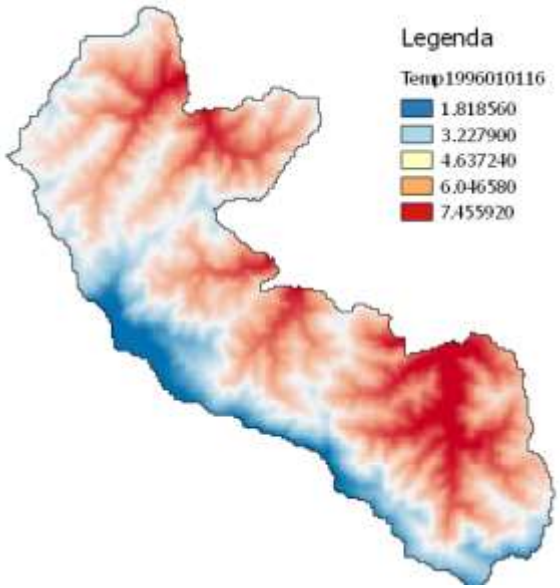
- Hourly reservoir level: **lm** – *subject to fluctuations due to wind and hydraulic operations: Hodrick-Prescott noise filter*
- Reservoir volume: **V(lm)**
- Inflow from diversion basins: **Qgronda**
- Discharges delivered, though the penstock, to the hydroelectric power station (and then to the water purifying plant): **Qderiv**
- Spillway discharge: **Qsf(lm)**
- Discharges from the bottom and intermediate outlets: **Qsc(lm)**
- Evaporation loss: **Qevap(lm, T, Tdew)**

Spatialisation of temperature and precipitation gage data

(Mattia's MSc thesis)



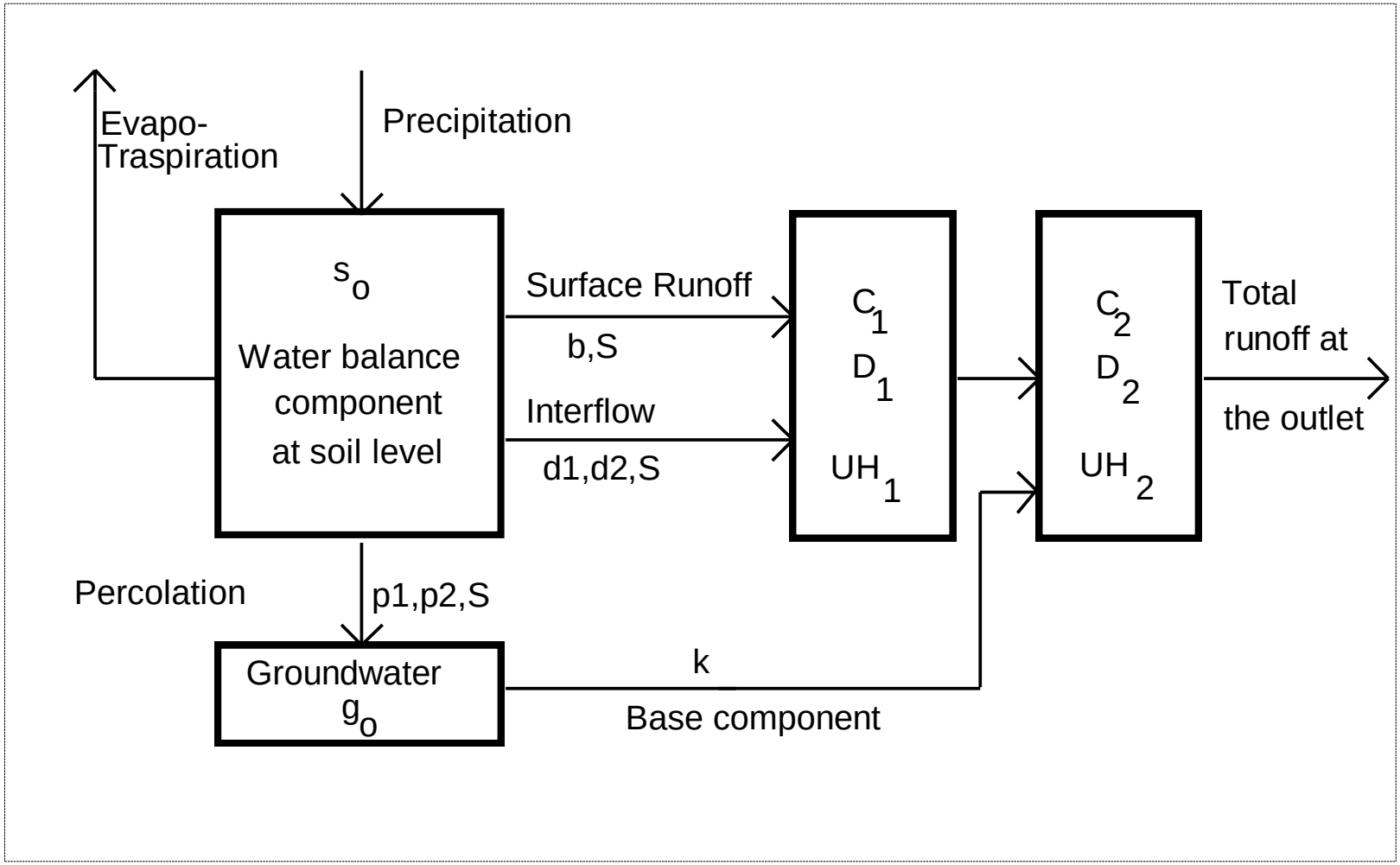
Precipitation fields: inverse distance weighting (power 1,2,3)



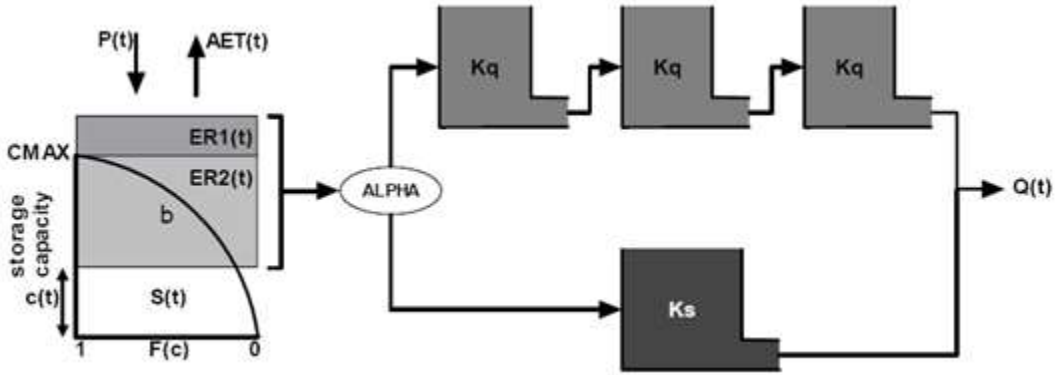
Temperature fields: multiple linear regression based on gage location

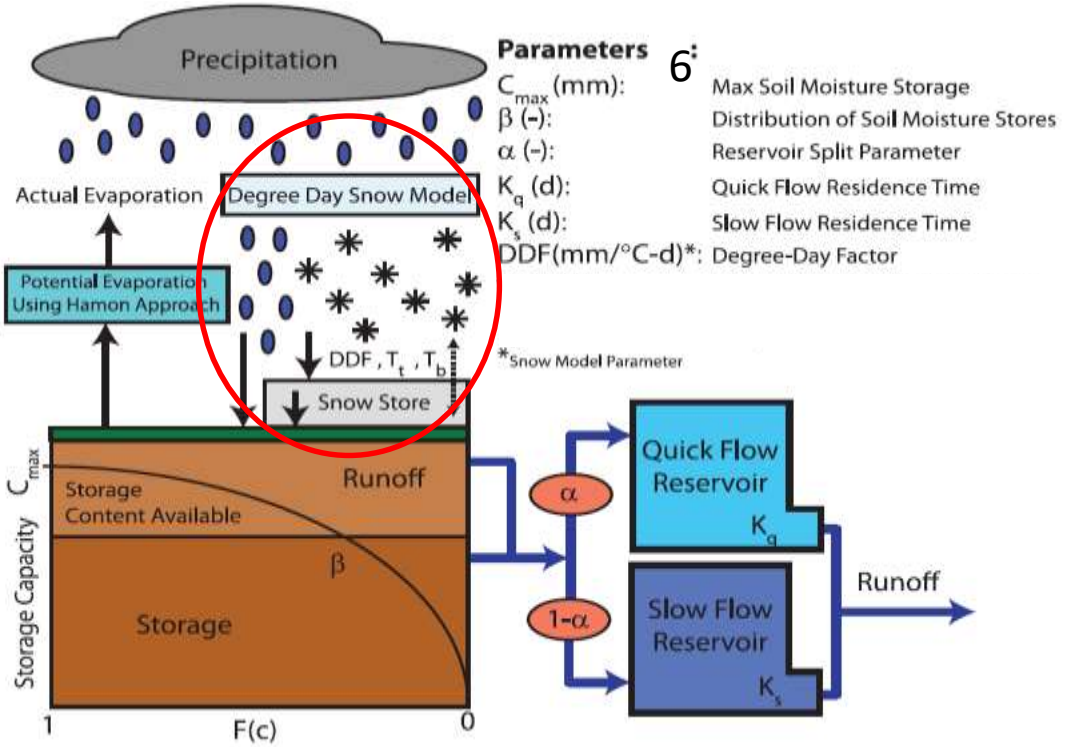
Finally, the Rainfall-Runoff modeling!

ADM model

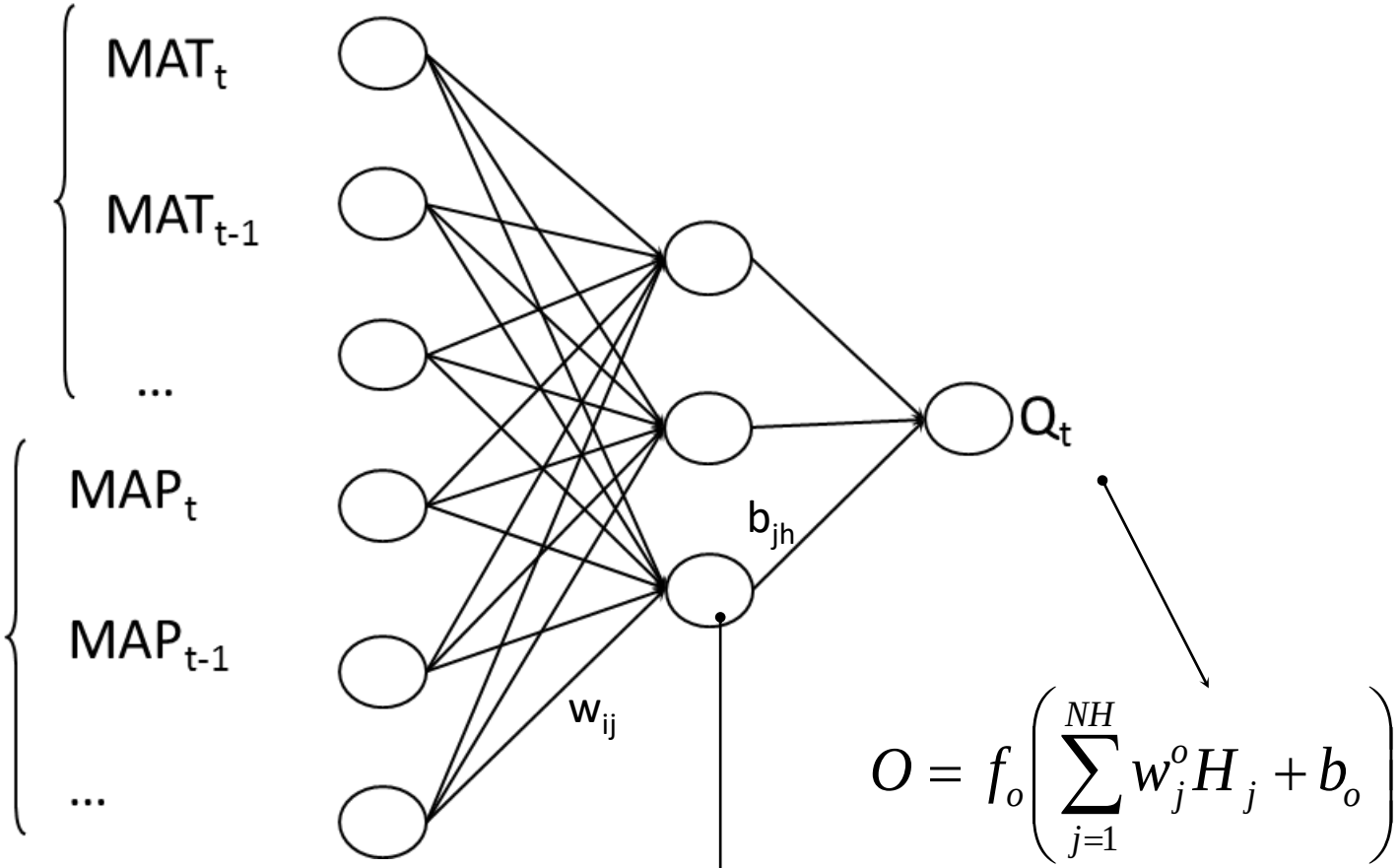


HYMOD Model: without and with snow modelling





Artificial neural networks models

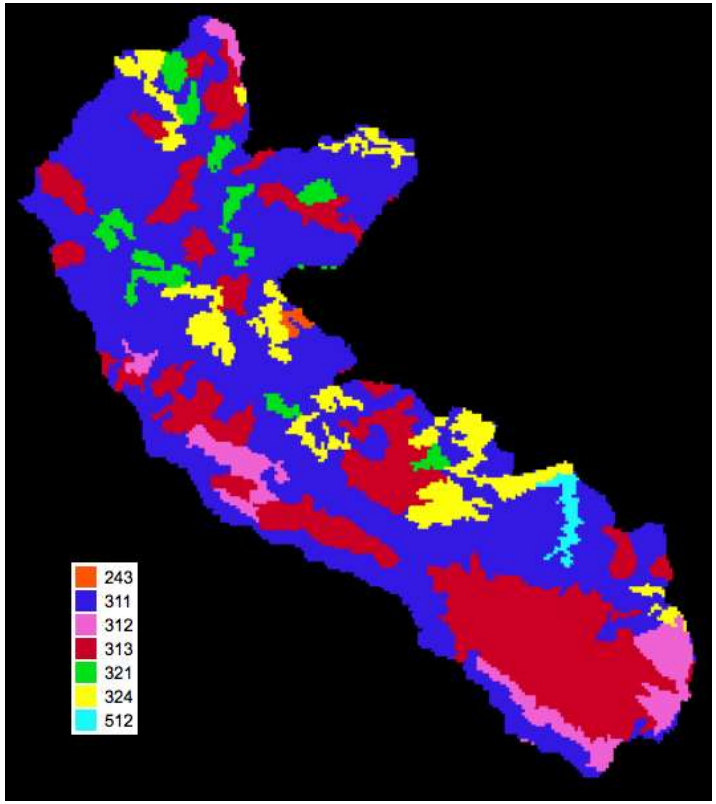


$$O = f_o\left(\sum_{j=1}^{NH} w_j^o H_j + b_o\right)$$

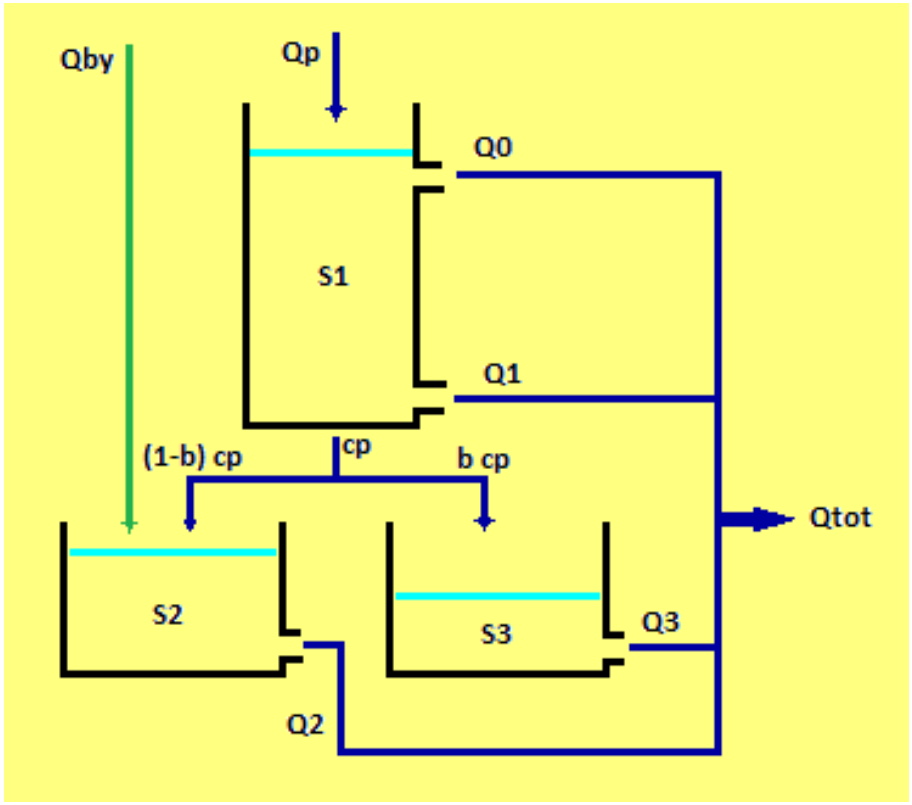
$$H_j = f_h\left(\sum_{i=1}^{NI} w_{ij}^h I_i + b_{jh}\right)$$

Spatially-Distributed (grid based) HBV model

Master student helped by Juergen Komma @ TUW

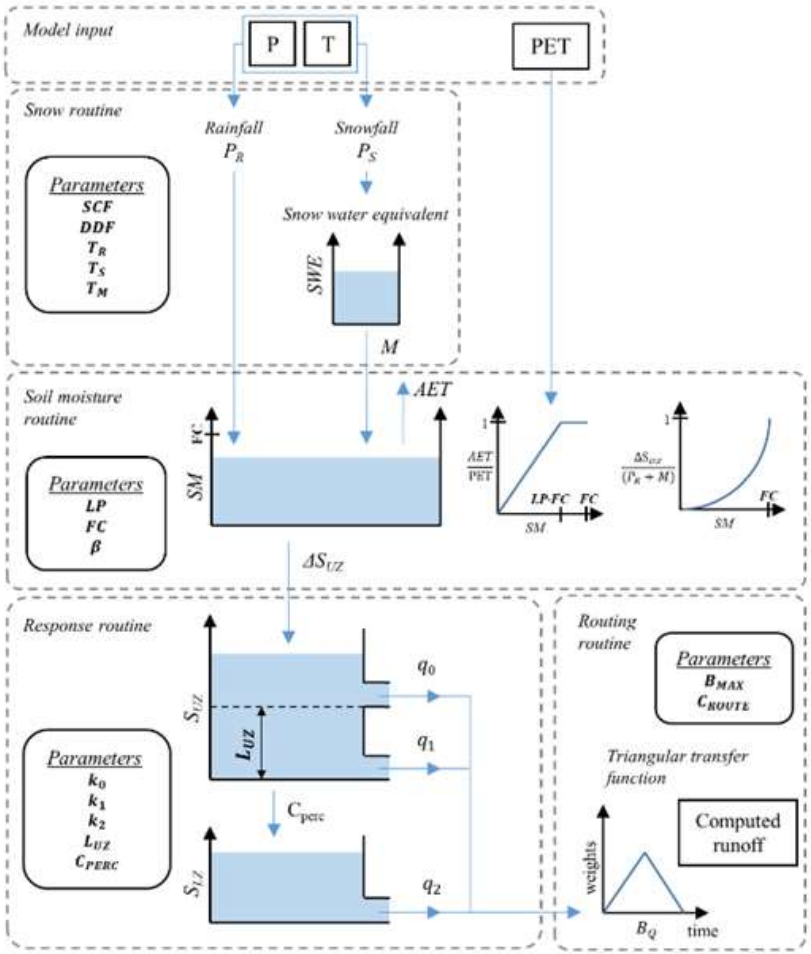


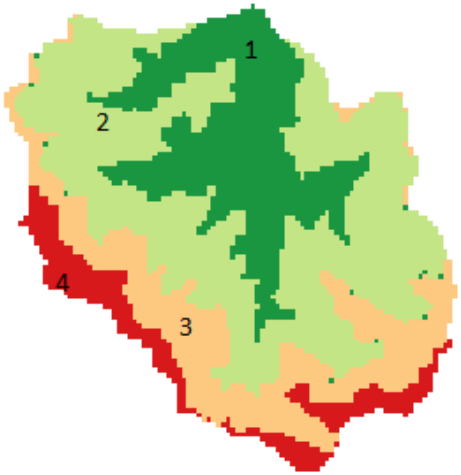
Hydrological Response Units (HRU) based on land-use



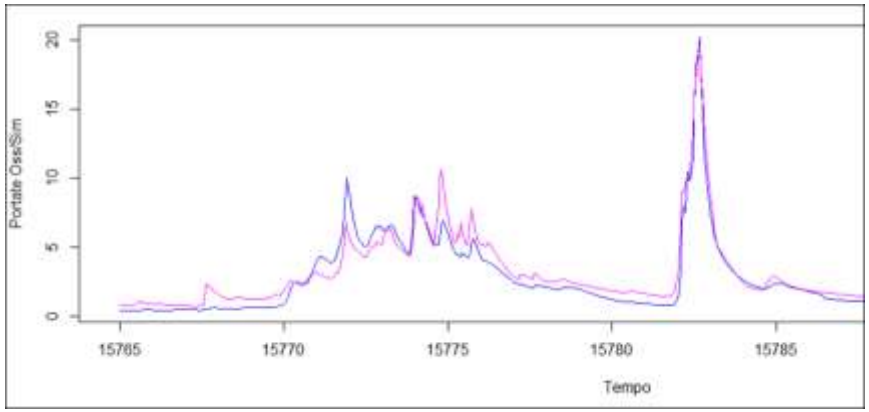
TUW model: semi-distributed version of the HBV model

(Viglione and Parajka, 2019)





Inputs averaged over 200-m elevation zones



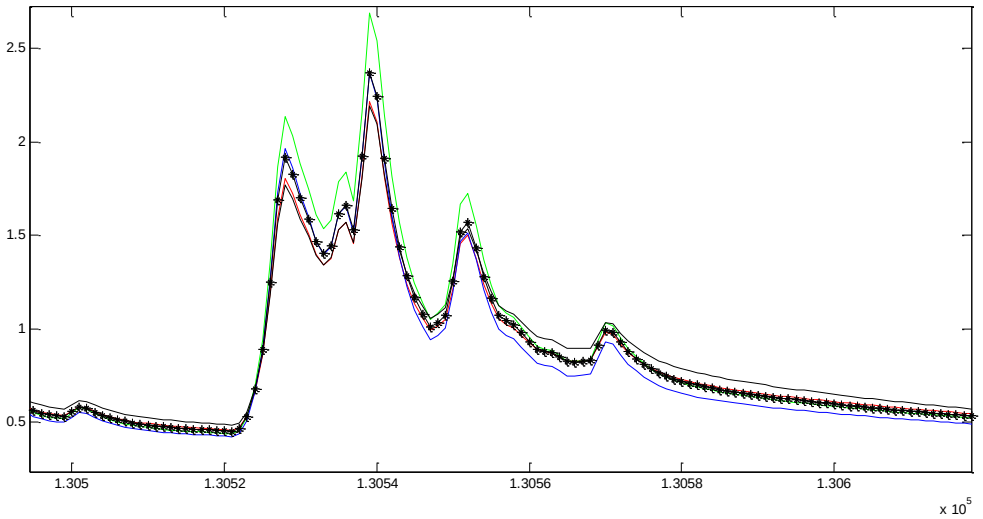
Once we have the models:
Model regionalisation at the ungauged diversion watershed area

(where only daily data were available until recently)

Rainfall-runoff simulation for the ungauged diversion watershed area (Fiumicello)

Calibration of a conceptual rainfall-runoff model for the three gauged diversion watersheds and for the catchment closed at the dam

⇒ a regional parameterisation approach is then applied for modelling the streamflow generated in the fourth, ungauged at hourly scale (until recently), diversion watershed.



Once we have what (we hope) are reliable observed (or simulated) historical data on the meteorological and hydrological processes in the basins and on the reservoir behaviour,
we have a very good academic case study,
but what practical use do we have for such data?

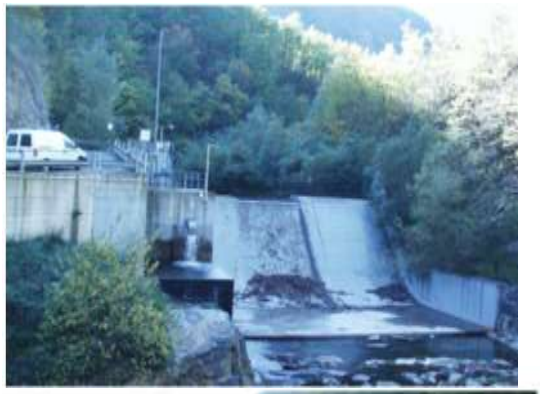
RomagnaAcque is a water supplier, its first - and still foremost for some employees – task is the water withdrawal from the Ridracoli reservoir.
How can we help them to increase such withdrawal volumes, to reduce the exploitation of groundwater (see salt intrusion and subsidence on the coast)?

Simulating the impact of different scenarios and different operation rules, assessing the impact of potential future actions:

- **Increasing the water abstractions from the diversion basins, through i) the improvement of the efficiency of the water intakes (economically sustainable?) and/or modifying the minimum releases downstream of the water abstractions (environmentally sustainable?)**
- **Connecting additional diversion basins to the reservoir**
- **Modifying the reservoir withdrawal rules for minimizing overspill losses**

Scenario analysis: through the simulation of the behavior of the catchments/reservoir/diversion tunnel system (water balance + operation rules) when forced by historical hydrological conditions.

Increasing the water currently abstracted from the existing diversion catchments modifying the water intake structures (currently undersized)



Potential increase in reservoir water availability, assuming to increase the water intake capacity (constrained by the tunnel capacity)

Modifying the current practices for releases downstream of diversion water intakes

Minimum flow downstream of intakes structures

Official water permit rules

20 l/s Ridracoli

10 l/s Celle
10 l/s Campigna 10 l/s Fiumicello

Good practice

20 l/s Ridracoli

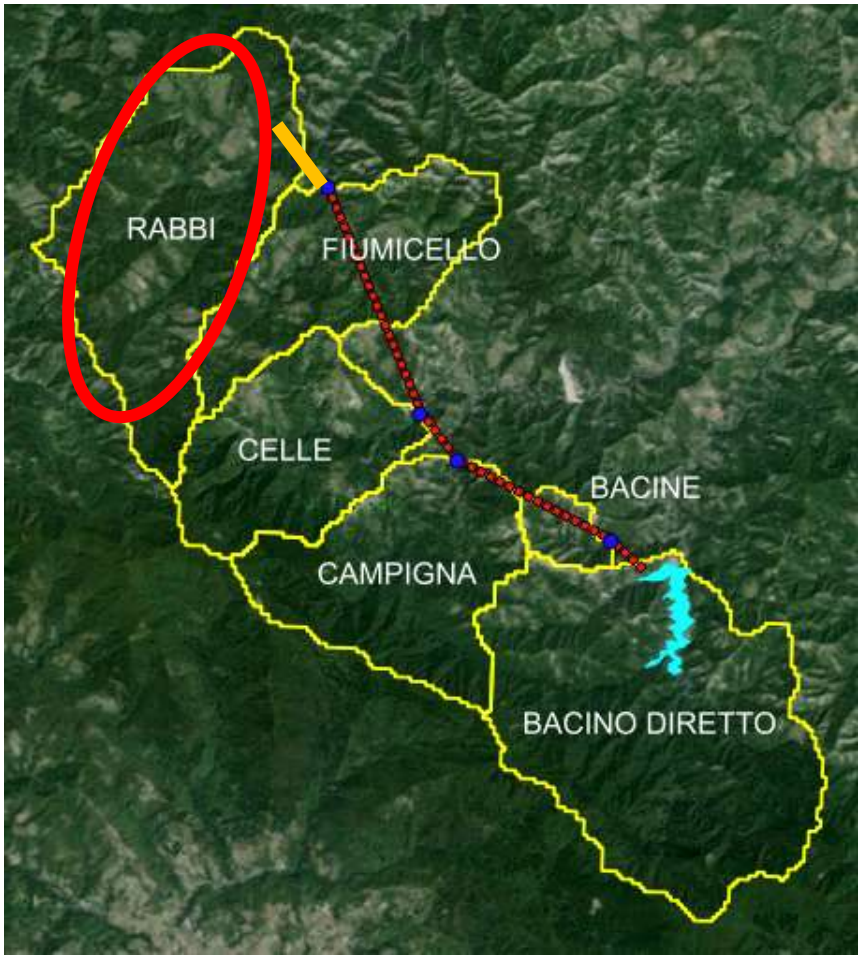
20 l/s Celle
20 l/s Campigna
20 l/s Fiumicello

Summer: no diversions except during flood events

Potential increase in reservoir water availability, assuming to take from the four diversion catchments all the streamflow exceeding either the current (good practice) or the official minimum flow requirements

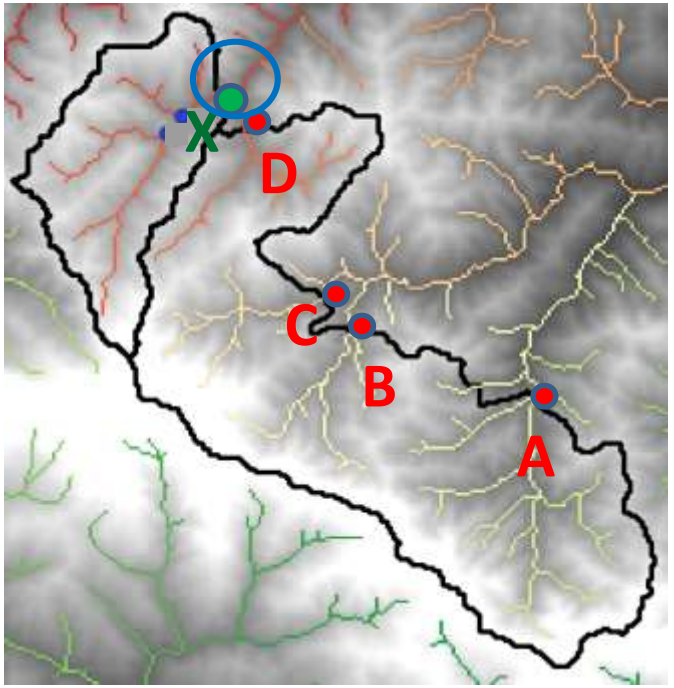
Extension of the diversion tunnel to collect water also from a fifth off-line basin?

In order to augment the inflows to the reservoir,
other neighbouring catchments might be joined through new tunnels or extending the existing one

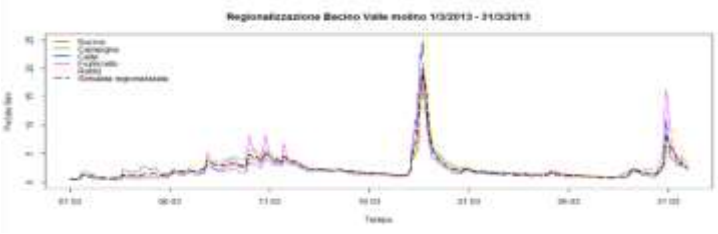


Extension of the diversion tunnel to collect water also from a fifth off-line basin?

Survey for choosing the river section to which extending the tunnel (two alternatives identified)



Regionalisation of the TUW model over such sections, to simulate the historical flows and assessing their potential contribution to the reservoir volume



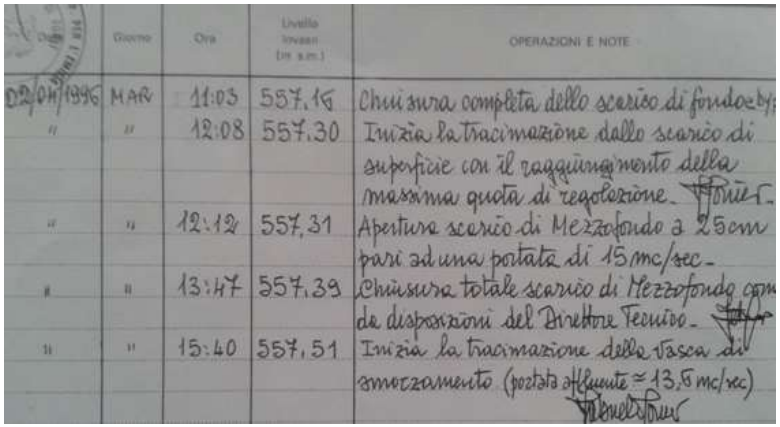
Modifying the reservoir operation rules (no hard engineering works needed..)

Other information needed: reconstruction of the operation rules of the reservoir/diversion tunnel system

Some (few) rules are written, but the majority are good practices, defined over the years, that we had to **infer from interviews** with the managers of the reservoir and diversion tunnel system and with the managers of the water treatment plant

- Rules for the safety of the dam (on max levels, on maximum increasing/decreasing rates, …)
- Rules for mantainance of the outlets
- Rules for mitigating the withdrawals from the diversion basin that is tributary of a different river
- Rules for regulating the turbidity of the water intake sent to the treatment plant
- Rules for maximising the hydropower potential during overspill

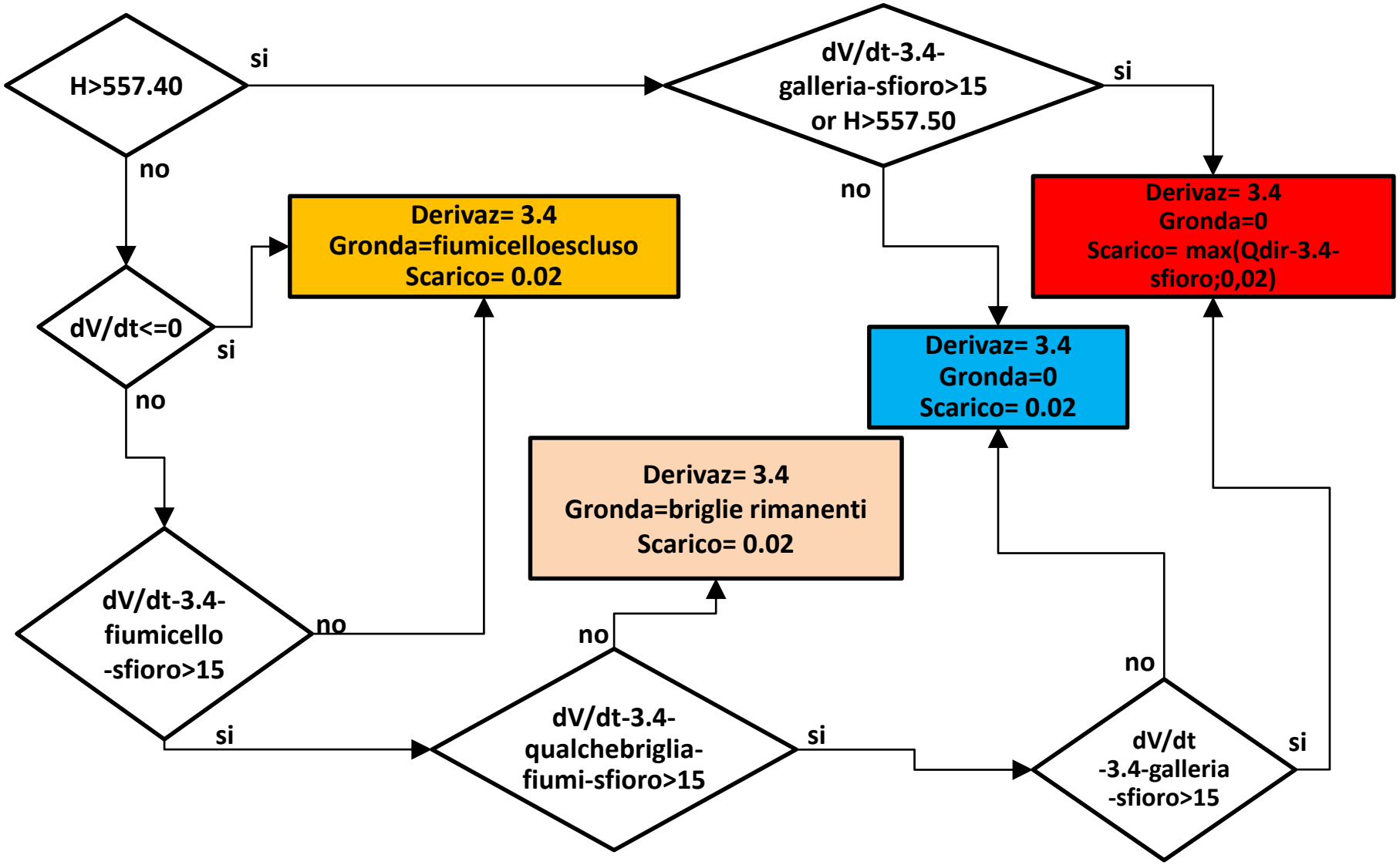
Some rules are theoretical, and not actually implemented or implementable, as verified checking the books where historical maneuvers are reported



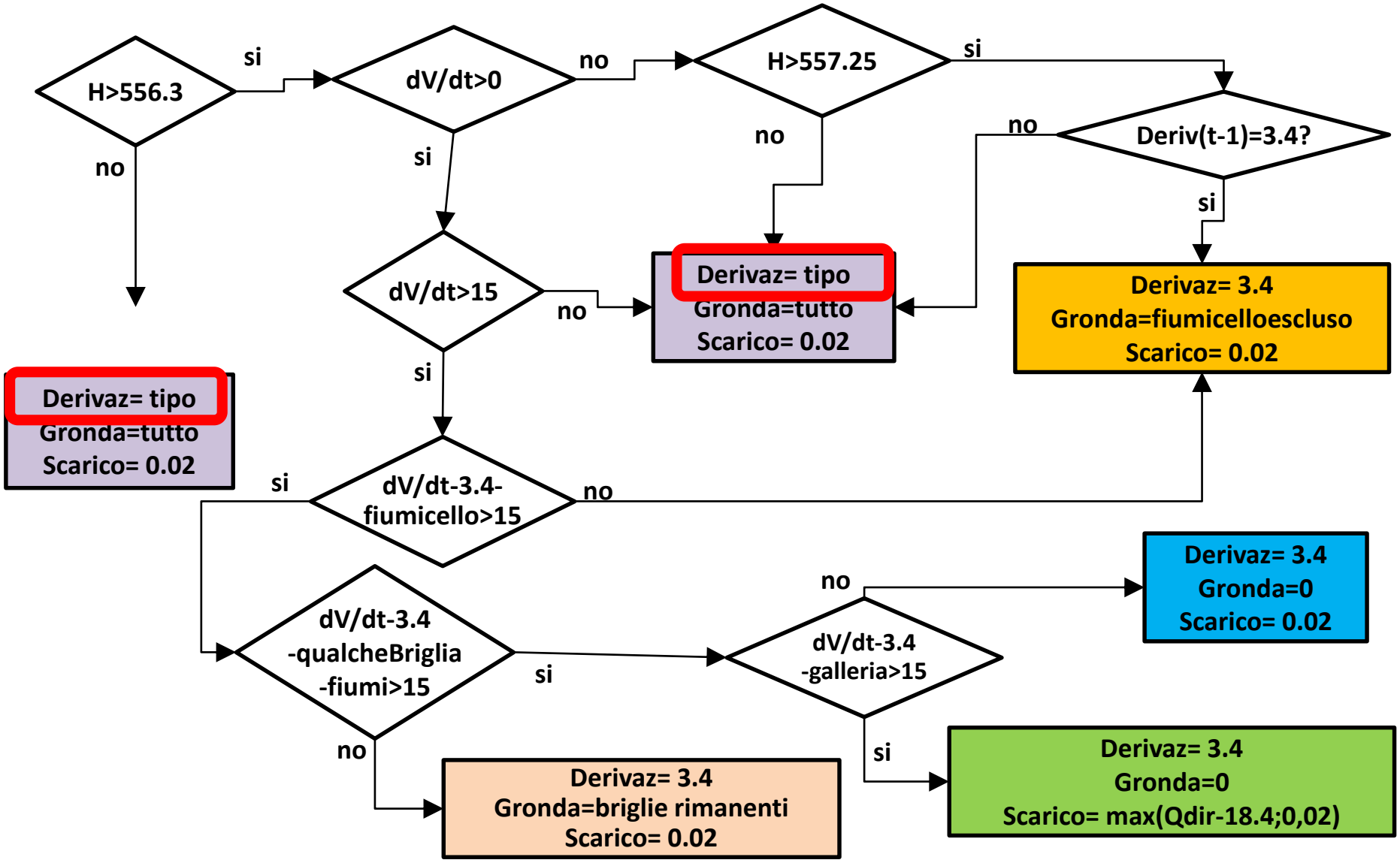
Giorno	Ora	Livello lavaggi (m s.m.)	OPERAZIONI E NOTE
02/04/1996 MAR	11:03	557.15	Chiusura completa dello scarico di fondo [illegible]
" "	12:08	557.30	Inizia la tracimazione dallo scarico di superficie con il raggiungimento della massima quota di regolazione.
" "	12:12	557.31	Apertura scarico di Mezzofondo a 25cm pari ad una portata di 15 mc/sec.
" "	13:47	557.39	Chiusura totale scarico di Mezzofondo con le disposizioni del Direttore Tecnico.
" "	15:40	557.51	Inizia la tracimazione della vasca di smorzamento (portata affluente ≈ 13,5 mc/sec)

Reservoir Operation Rules above the spillway level

Max abstraction from the reservoir, no abstraction from the diversion basin on the Rabbi



Reservoir Operation Rules below the spillway level (H< 557.3 m s.l.m)



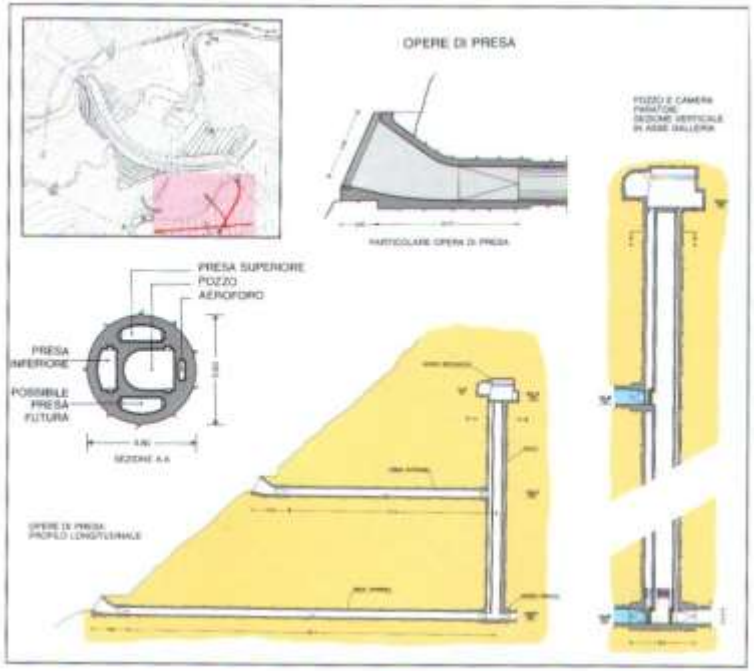
Derivazione “tipo”????

What is the typical withdrawal?

True Grail Quest: defining the rules for water intake from the reservoir

- How much water is it possible to treat and to convey in the water supply main pipe (MAX)?

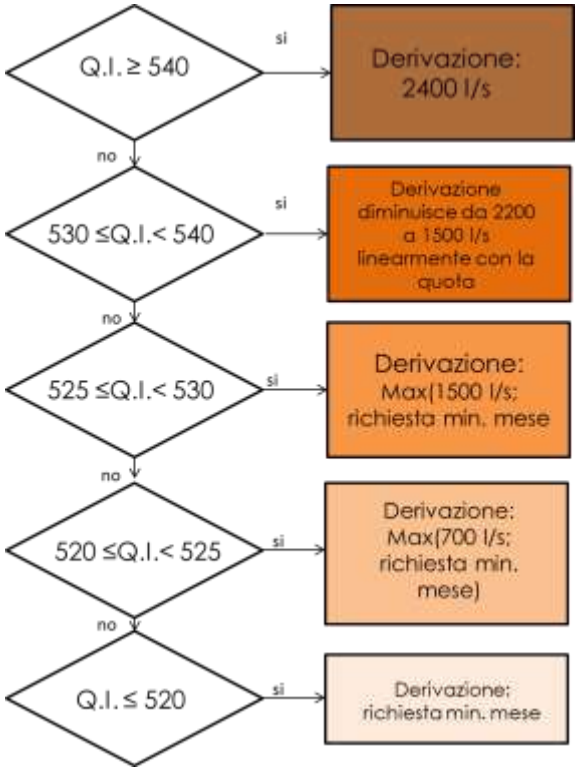
- How much water is mandatory to abstract - demand not covered by other local sources – (MIN)?

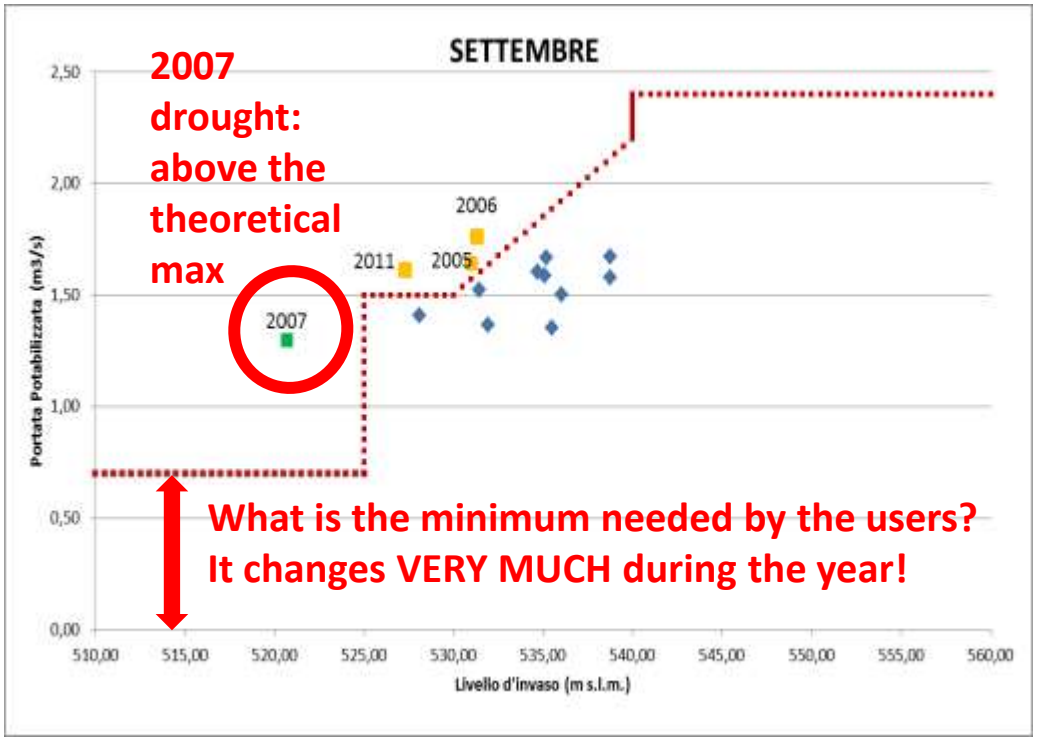


No clear rules available:
treatment plant processes modified in the years, the other sources acquired only recently (no integrated planning)
It is still a **policy choice**.

Technical constraints on withdrawals as function of reservoir level and of minimum monthly demand

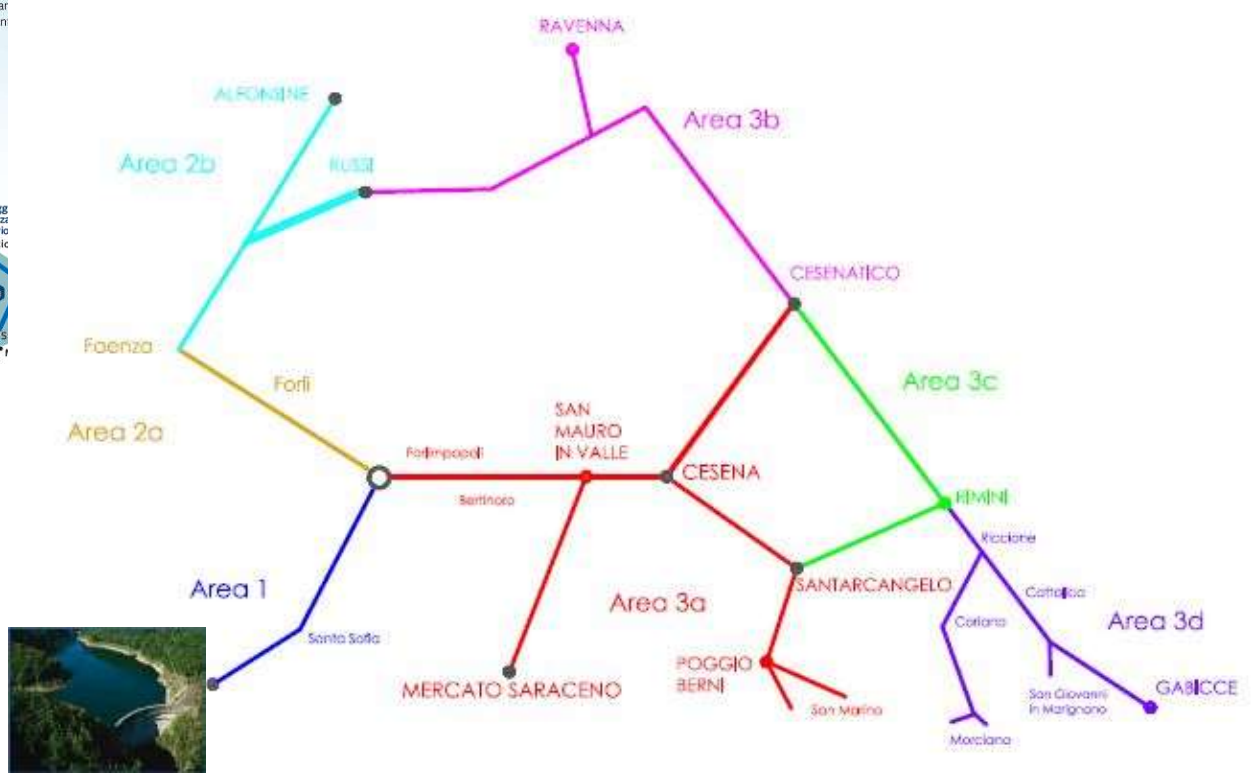
(based on a number of interviews with different staff)





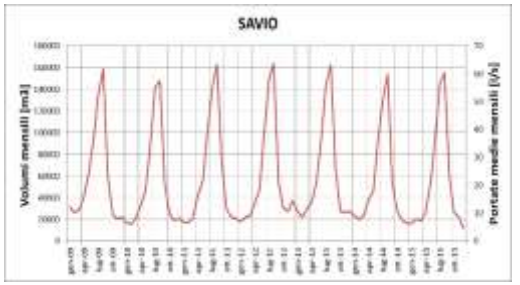
Withdrawal rules need to be optimised to reduce the overspill (loss), but avoiding future water scarcity conditions (empty reservoir)

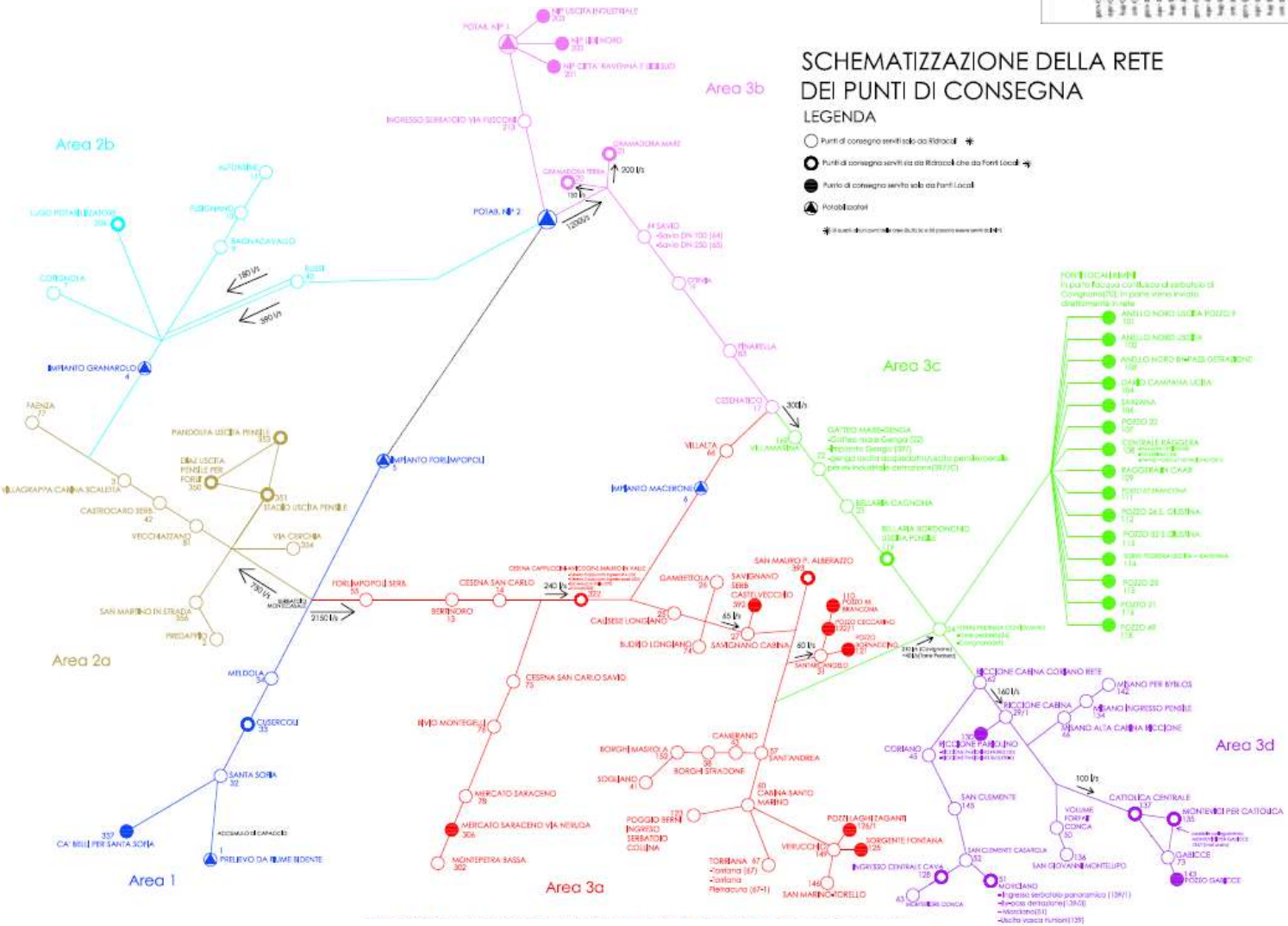
Hic sunt leones…
The demand: what is beyond the reservoir?



Network divided in 7 areas hydraulically semi-autonomous, with specific, not-shareable local sources

The demand data:
mapping of the water supply points and local sources (more than 100 points) and validation/reconciliation of the past monthly water consumptions





The demand

Monthly water demand for the overall network and for the different sub-areas

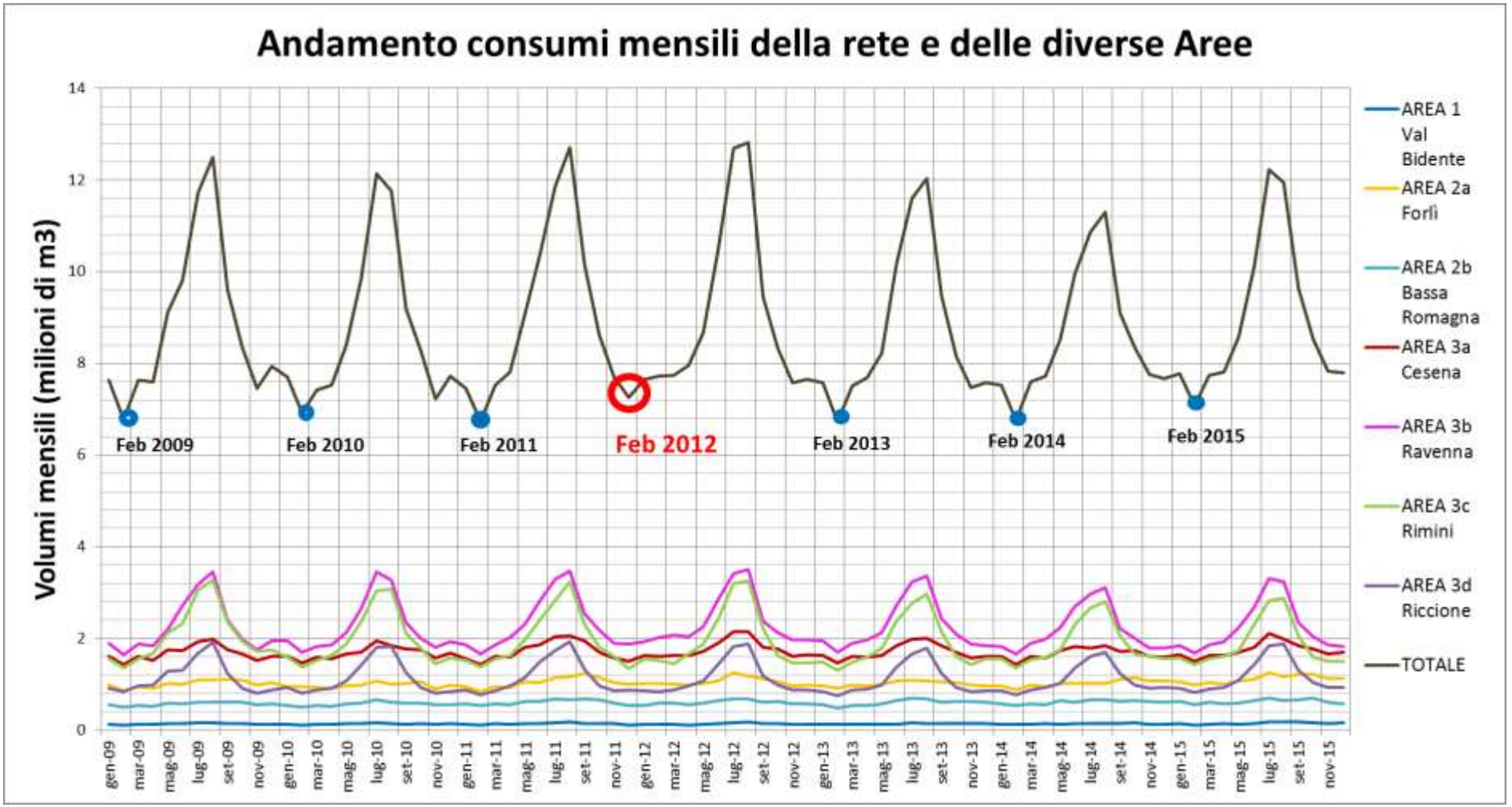


Figura 26 Andamento consumi mensili dell'intera rete a confronto con quelli delle diverse Aree nel periodo 2009-2015

The «critical» demand:
maximum demand in the past for each month and for each area

The alternative sources («Fonti Locali»): water abstraction permits and technical limitations to the intake from the other sources

What cannot be supplied by the other sources must necessarily come from Ridracoli

Monthly minimum requirement from Ridracoli =
= most critical demand from the users – max possible contributions from the other sources

Going back to the optimisation of the reservoir operation

Simulation of the catchments/diversion tunnel/reservoir, of the potential increase of water supply abstracted from Ridracoli

AIM: reducing exploitation of local water sources, mainly groundwater, less environmentally sustainable and and more energy-demanding.

Constraints:

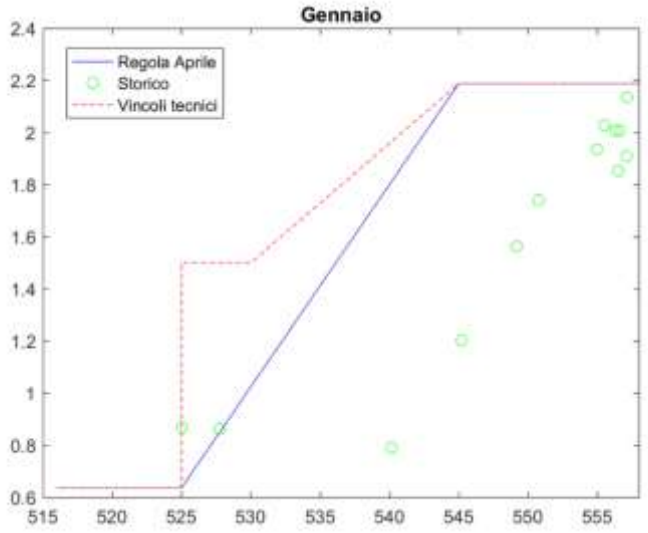
- Reservoir operation constraints
- Maximum withdrawal: compatible with water supply network capacity
- Minimum withdrawal: minimum volumes needed by the users under critical conditions

Objective:

- Maximising the withdrawal

But also:

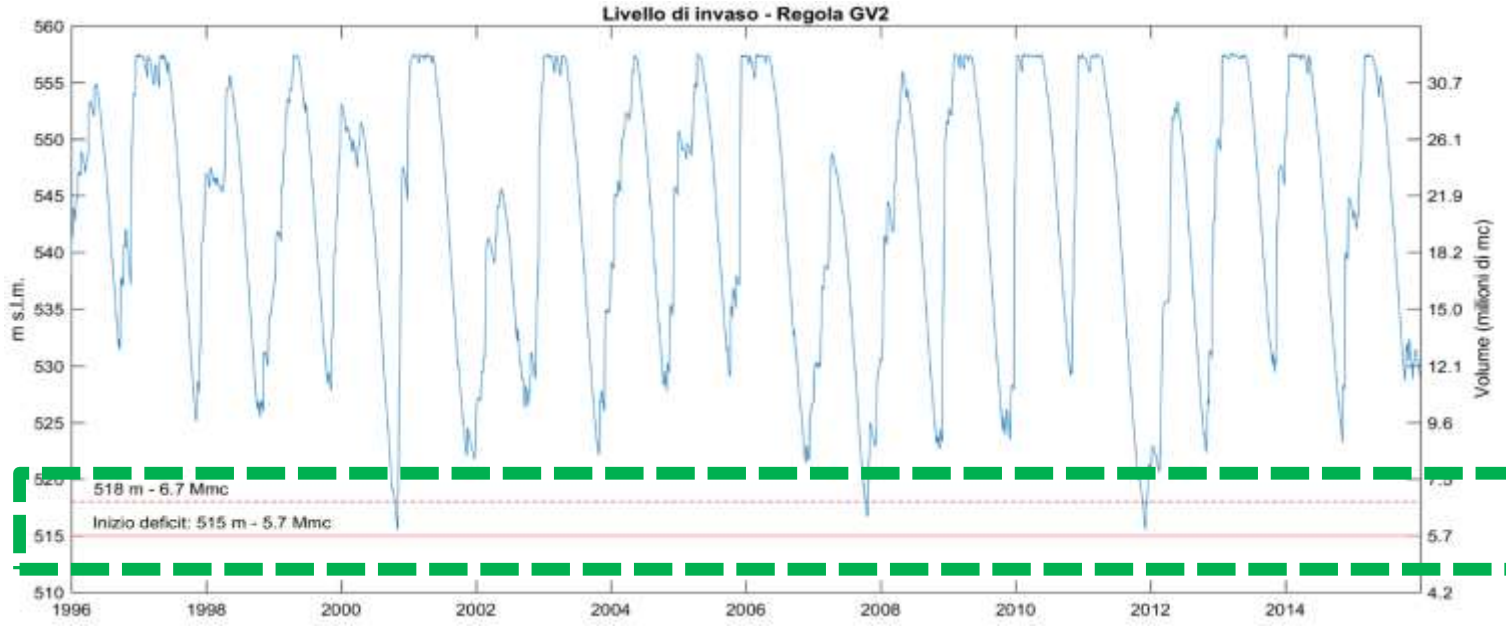
- verifying the occurrence of possible ‘deficits’, i.e. going below minimum reservoir volume



Simplification of the monthly functions defining the withdrawal discharge vs the reservoir level

(subject to the technical constraints)

Comparison with historical values (green dots): past policies were often too conservative!



Check on deficit conditions: are they admissible?

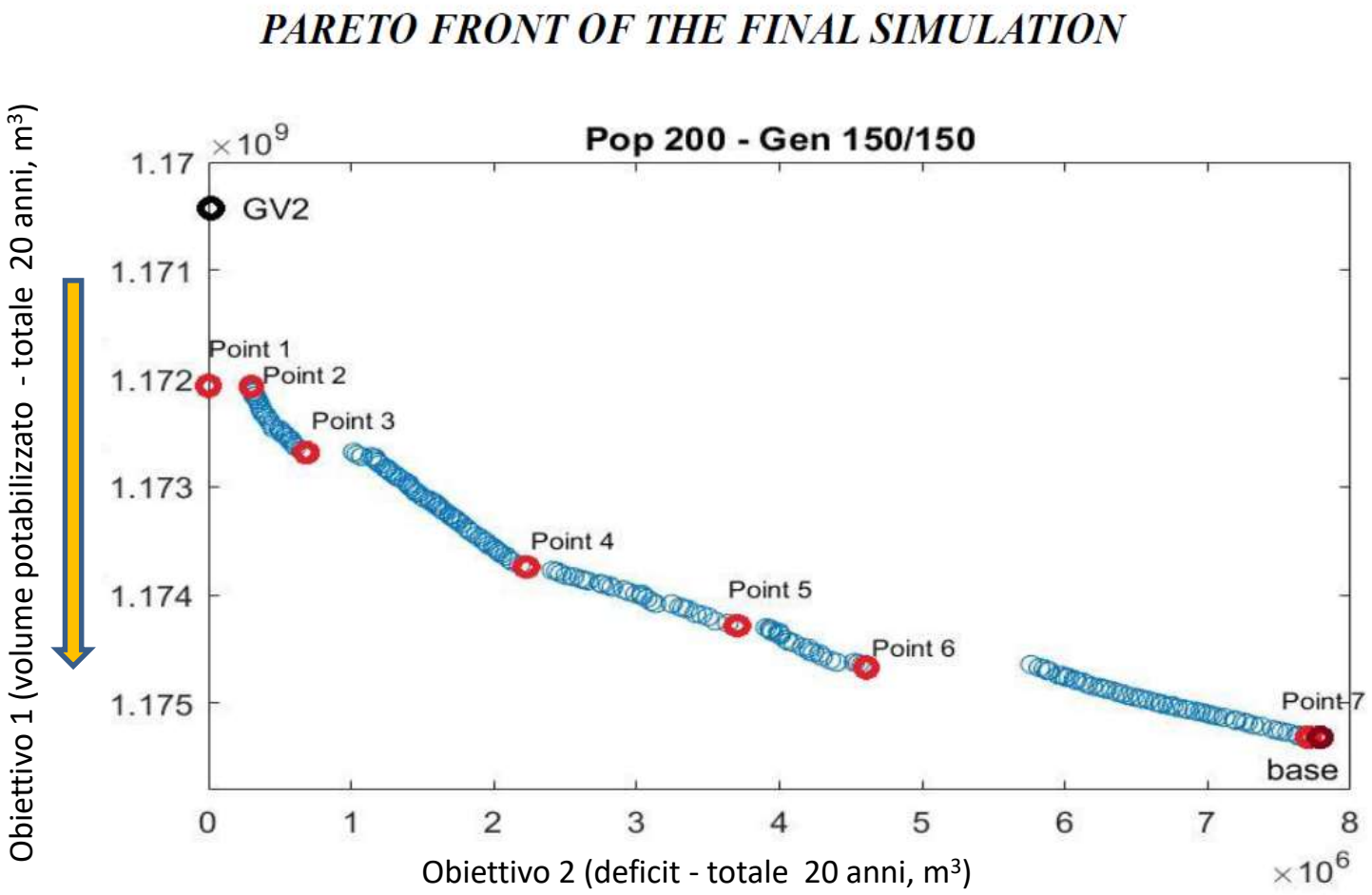
Discussion with the utility staff

Historical deficit

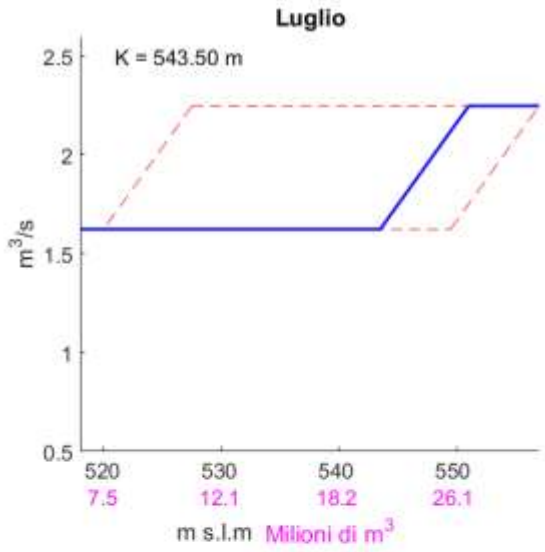
Multiobjective optimisation:

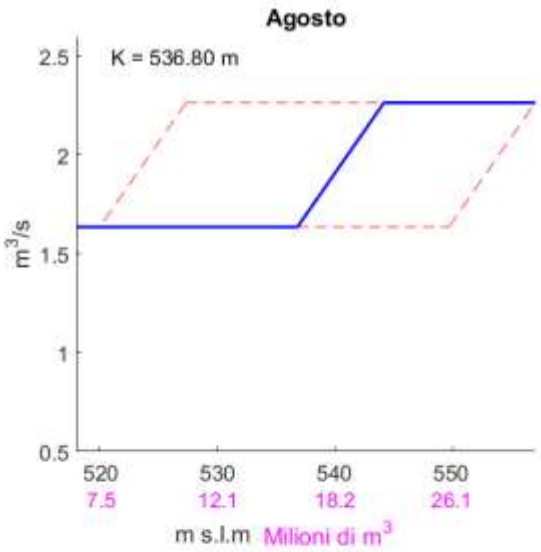
OF1: y-axis maximum overall withdrawal

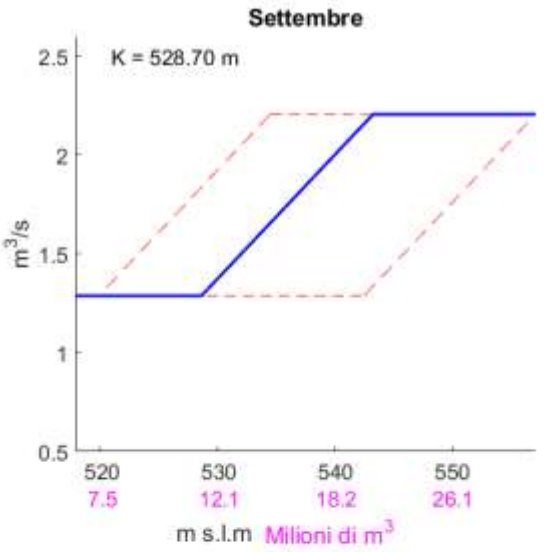
OF2: x-axis: minimum deficit conditions

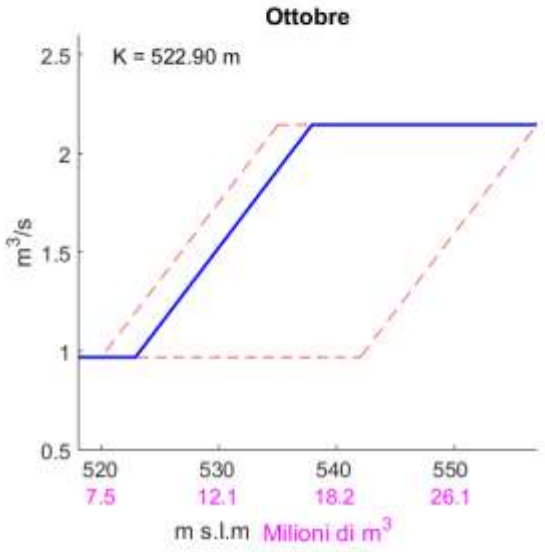


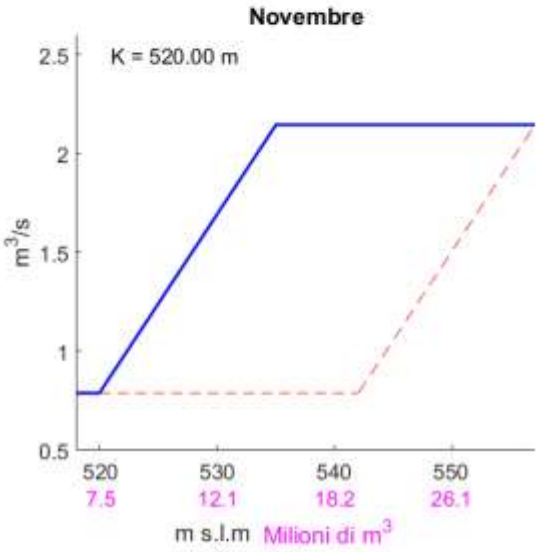
Optimised water withdrawal rules as a function of reservoir level (and fulfilling the constraints)

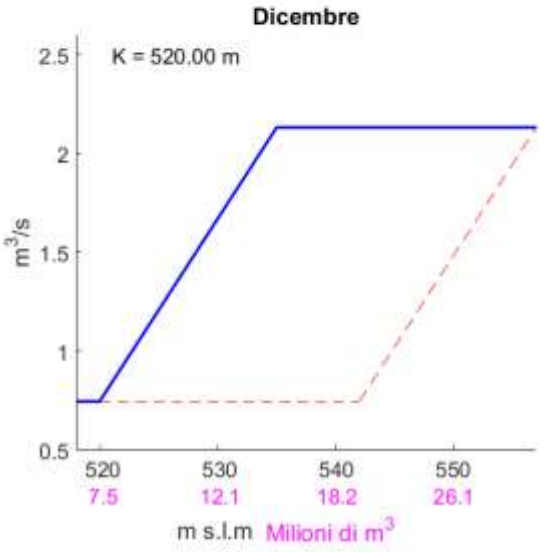




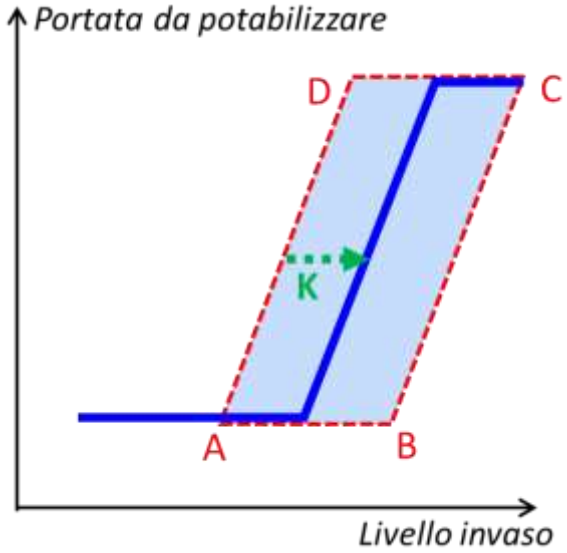




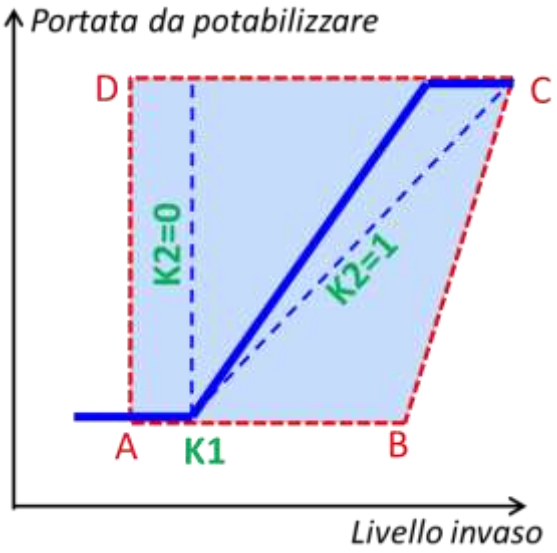




Optimisation of the withdrawal rules



Domains for the rules to be optimised



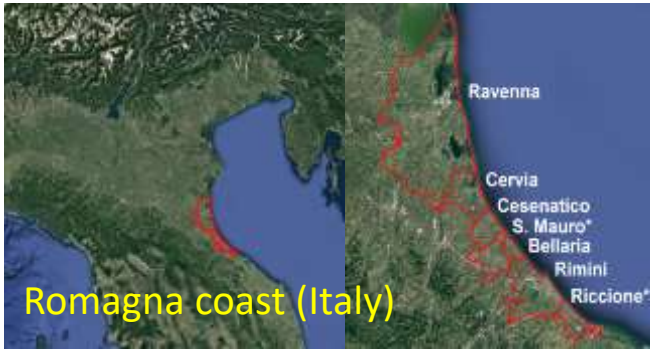
A lot of interaction with the RomagnaAcque staff

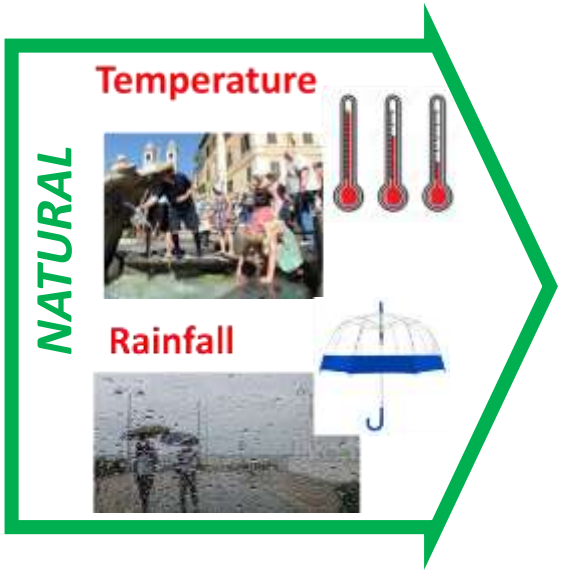
- on the feasability of the rules implementation (speed of change in target withdrawals, for example),
- on what is absolutely to avoid in terms of deficit (very different opinions…)
- on different scenarios of long-term availability for the other sources

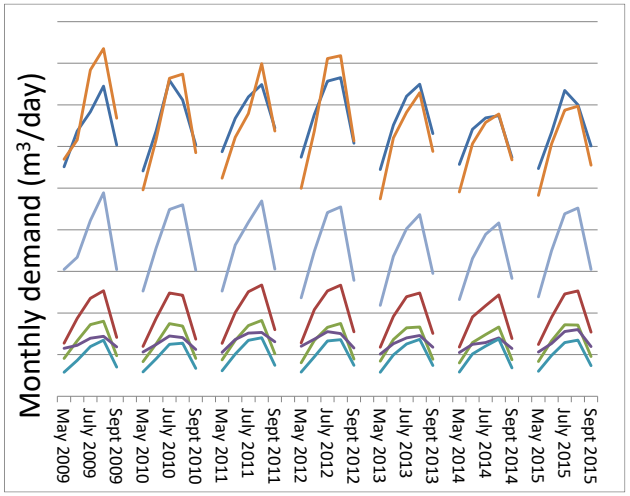
⇒ Constraints and shape of rules changed many times over a couple of years (and each time a new optimisation was run…)

⇒ And the demand may be different in the future

Not only observing, but understanding and modeling the demand: many Romagna cities are tourist destinations







AIM: modelling monthly urban demand for a set of seaside resort towns


Environmental Modelling & Software 103 (2018) 52–61

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journal homepage: www.elsevier.com/locate/envsoft

ELSEVIER

Assessing the significance of tourism and climate on residential water demand: Panel-data analysis and non-linear modelling of monthly water consumptions

Elena Toth*, Cristiana Bragalli, Mattia Neri

Department DICAM, School of Engineering, University of Bologna, Bologna, Italy

Summer months

Not only more people…

- More lavish use of water and laundry
- Additional water-intensive touristic activities

JPI WATER (2018 Call) Project – SIMTWIST
SIMulating Tourism Water consumption with Stakeholders
https://www.simtwist.eu/

Wageningen University- University of Alicante – ***University of Bologna***

Case Studies: **Rimini (Italy)** & Benidorm (Spain)

The touristic factor has not been adequately addressed **in urban water demand studies**, so far, and it is often **neglected also by the water utilities.**

Our research activities in SIMTWIST contributes to

analyze the tourism's role in water scarcity (supply vs demand)

-understanding the **repercussions of hydrological droughts (at Ridracoli) on** the **management** of **the different surface and subsurface water supply sources.**

-analysing the **features of touristic activities** (**hotel and bathing establishment) that have more influence on the water demand patterns.**

-quantifying and predicting the **future trend of water consumption in touristic cities**

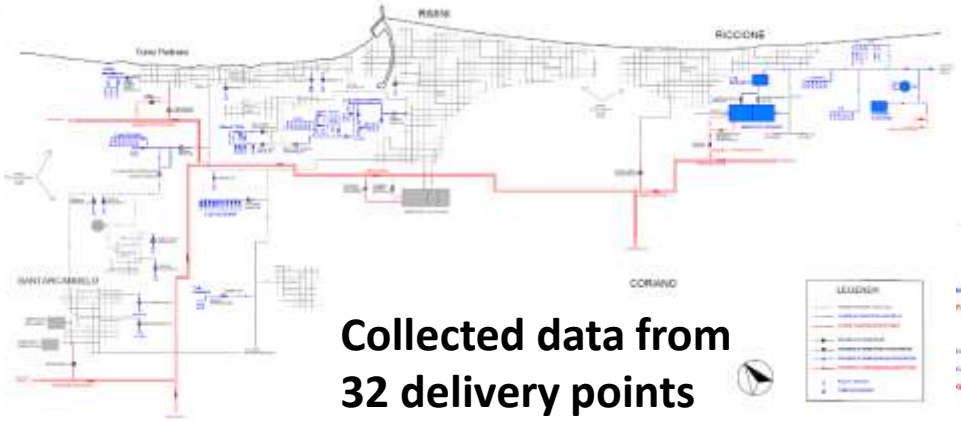
Repercussions of hydrological droughts on the **management** of the different surface and subsurface **water supply sources**

Water supply sources and inflows to the Rimini distribution network

Rimini local sources (mainly well-fields)

Supply from Ridracoli reservoir through «Acquedotto della Romagna», ADR

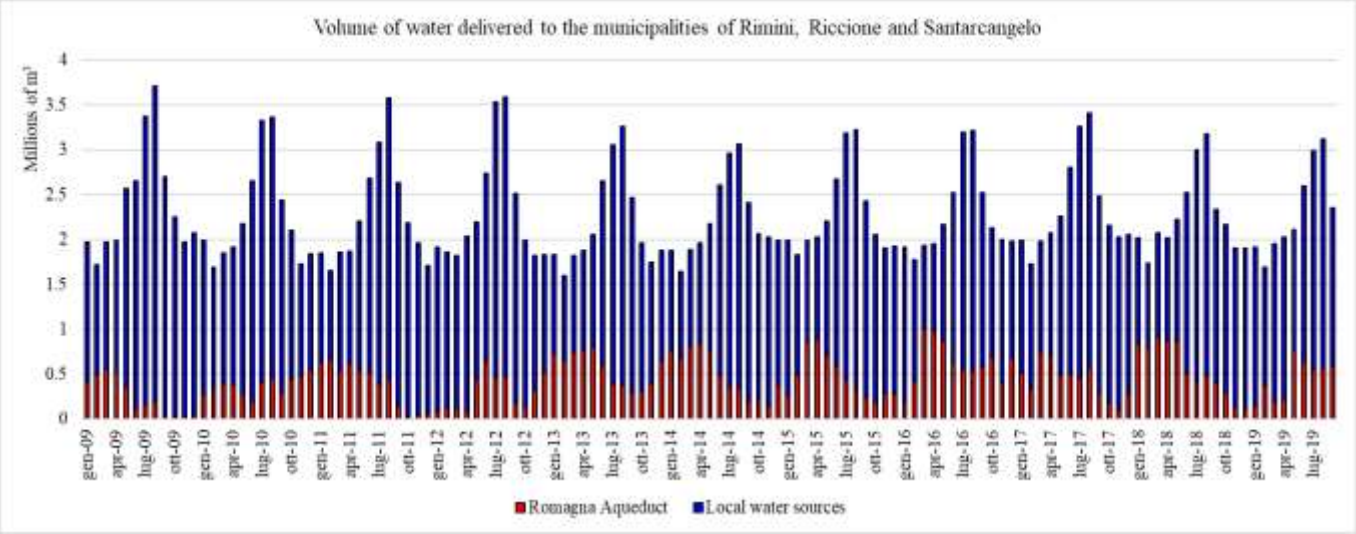
Romagna Acque
Ridracoli Dam



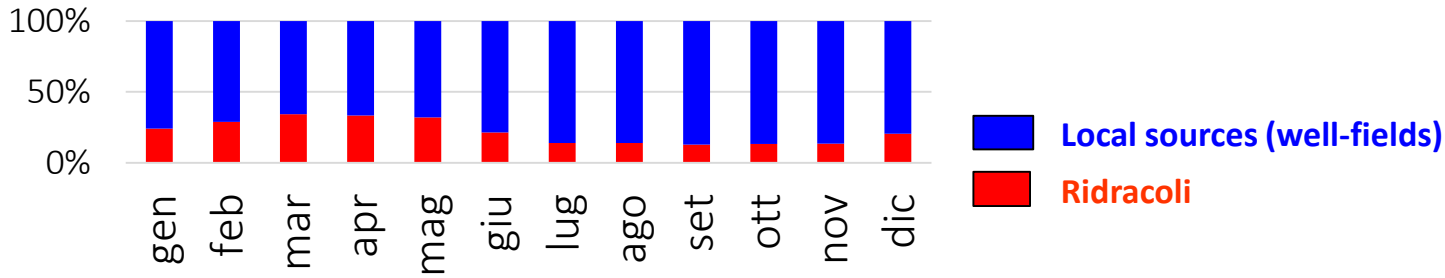
Collected data from 32 delivery points

Repercussions of hydrological droughts on the management of the different surface and subsurface water supply sources

Overall water consumption - Total monthly billed inflows from Ridracoli reservoir and from groundwater sources



Avg percentage of monthly volumes delivered by the sources

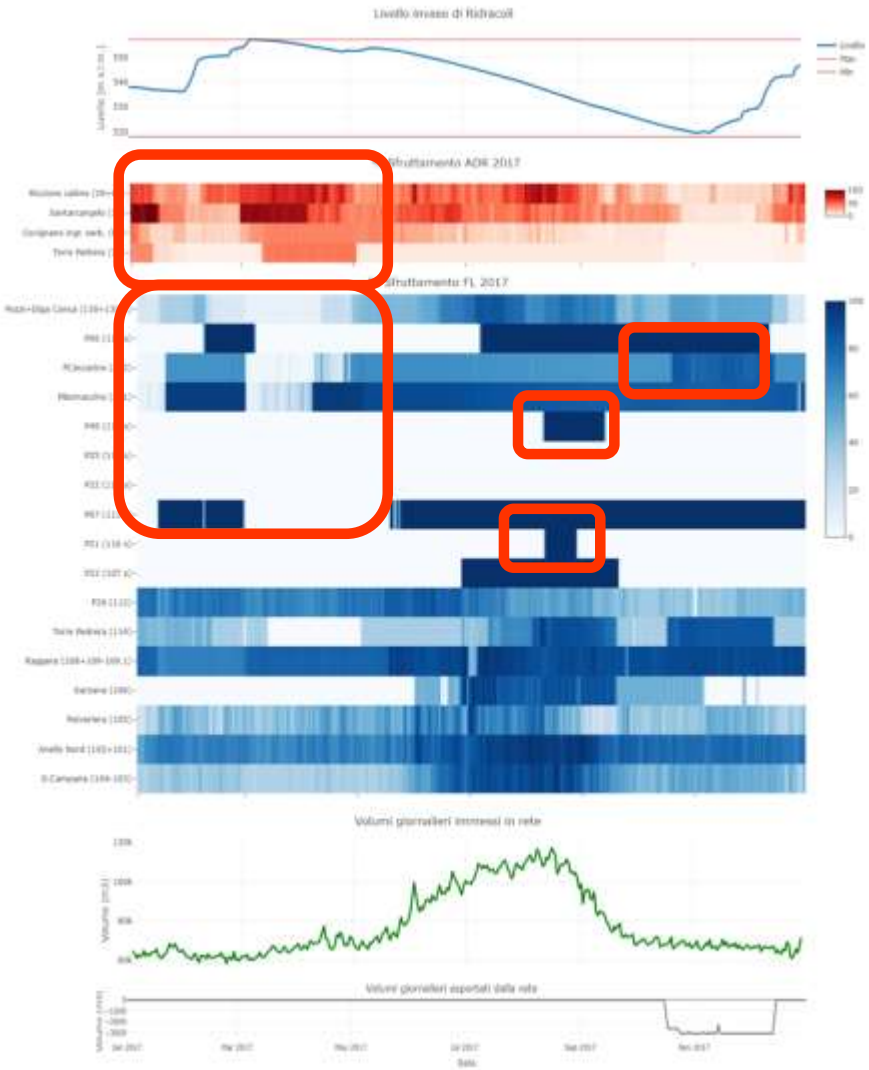


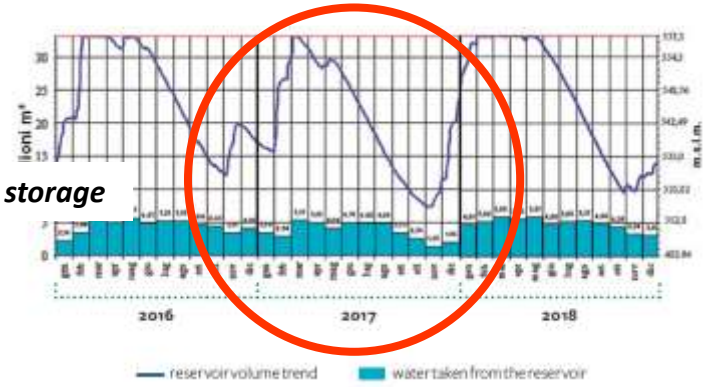
Water management policies: the choice of the source to be exploited depends also on the hydrological availability (storage in the Ridracoli reservoir)

Analysis on the exploitation of the supply sources along the year

2017

Water scarce





Driver: reservoir storage

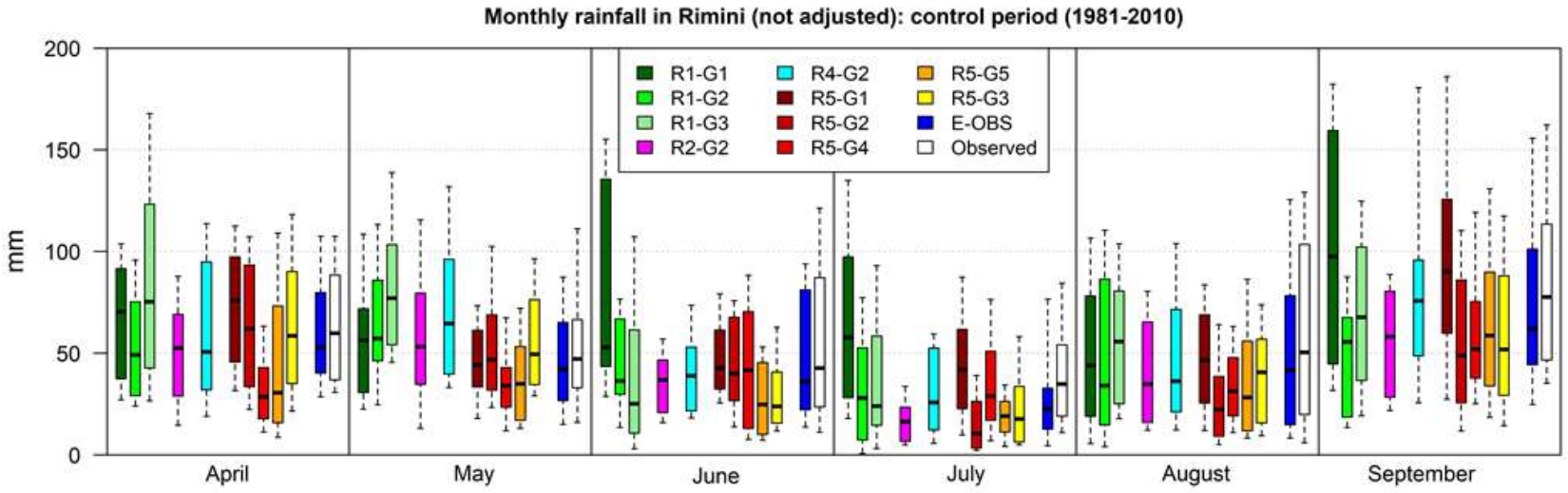
- **Reservoir emptier in winter/spring 2017**
- **Less exploitation of Ridracoli reservoir (red) in winter/spring**
- **Much more exploitation of local sources (blue) along all the year**

Driver: City water demand

Quantifying and predicting the **future trend of water consumption in touristic cities: climatic drivers**

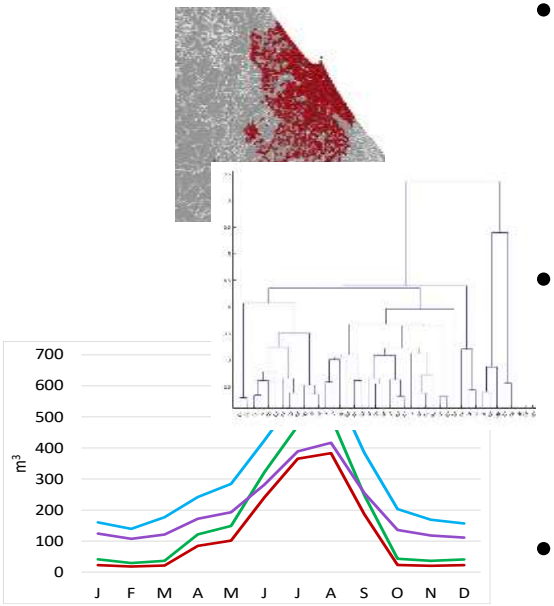
Analysis and validation of EUROCORDEX climate scenarios

Re-oriented local domain for E-OBS and EUROCORDEX grids over Rimini and over the Ridracoli area



Monthly rainfall in Rimini: climate models (raw and bias-corrected – see Dosio, 2016; Dosio & Fischer, 2018) output vs observations over the control period

Characterization of hotels and bathing establishments annual and monthly water uses for understanding urban demand in touristic cities



- Collection and geo-referencing of all the city water-meters
- Association of all hotels (>1000) and bathing establishments (>200) to single-users' water-meters (through tourist office info and addresses since tariff is not unique…) and their past monthly demands
- Characterisation of hotels (category, number of rooms, water-demanding services such as restaurant, pools, etc.) and bathing establishments (number of umbrellas, hot showers, jacuzzi)
- Hierarchical clustering of hotels in classes with similar characteristics
- Identification of monthly water demand patterns in the classes

PS: Water demand data validation: declining frequency of meter readings (still done traditionally) in the last years ⇒ smart-meters are sorely needed!

PS: Water demand data validation: declining frequency of meter readings (still done traditionally) in the last years

⇒ **smart-meters are sorely needed!**

Smart-meters are being installed, at our request, by the water distribution utility (HERA), in a set of representative hotels and bathing establishments.

Rimini, July 8th 2021- with the owners of one of the hotels

What I learned from my long-term relationship on how transferring our understanding to the engineering practice (1/2)

Real water resource problems are very complex: we do not necessarily understand until **we step inside the problems *with the water managers***.

Working with RomagnaAcque I was forced, in order to better understand, to **zoom-out from my comfort zone,** along the years:

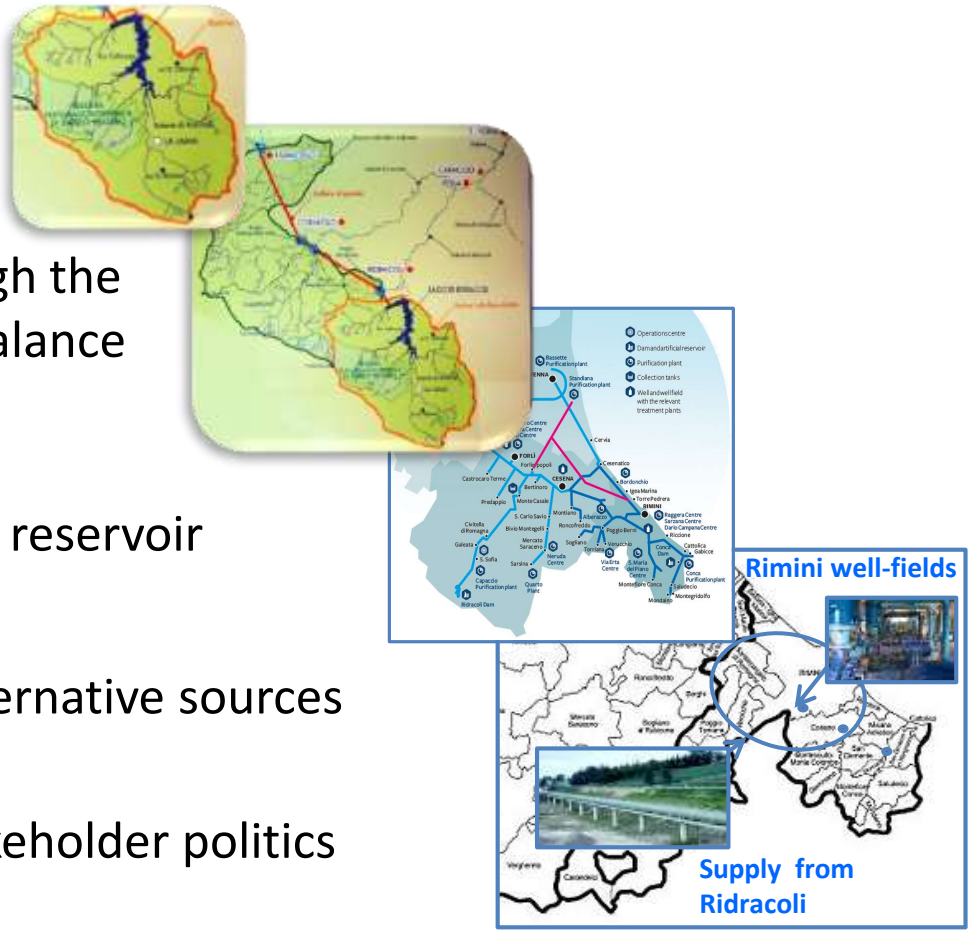
From the main basin closed at the dam

To the diversion basins connected through the tunnel and the tunnel/reservoir water balance and operation rules

To the water supply network beyond the reservoir

To the supply delivery points and the alternative sources

To the single users' demand and the stakeholder politics



What I learned from my long-term relationship on how transferring our understanding to the engineering practice (2/2)

"I dati parlano" (as Gunter says, in Italian!): need for data, to inform our models and to sustain our (expected or novel) hypotheses. Need for a cultural shift inside the water companies, where the monitoring and the data storage becomes a primary task and not a hobby or done in order to please us…

And useful information is not formalised nor written: we need to extract it from the pracsome very titioners working with us.
They do not share a single mind: different people, different opinions, different languages and different priorities (based on their professional role/responsibility/past experiences) inside the company.

Need to keep them engaged (practitioners get easily bored by too much detail and then we lose them, and they stop providing us with interesting insights)

Good relationships are based on trust: they need to understand that we care (and we are not only interested in fine-tuning our model or in writing our final report and get paid…).

Many thanks to all the friends in RomagnaAcque-Società delle Acque SpA who keep believing in our relationship…