Adapting Water Allocation Systems: Challenges and Opportunities
The Upper Guadiana and Llobregat Delta cases.

Jesus Carrera

GHS UPC-CSIC

IDAEA, CSIC

April, 25th, 2019

Adapting Water Rights to Face Climate Change Impacts: A Comparison of California and Spain

The Botin Foundation *and* Rosenberg International Forum on Water Policy

I am going to:

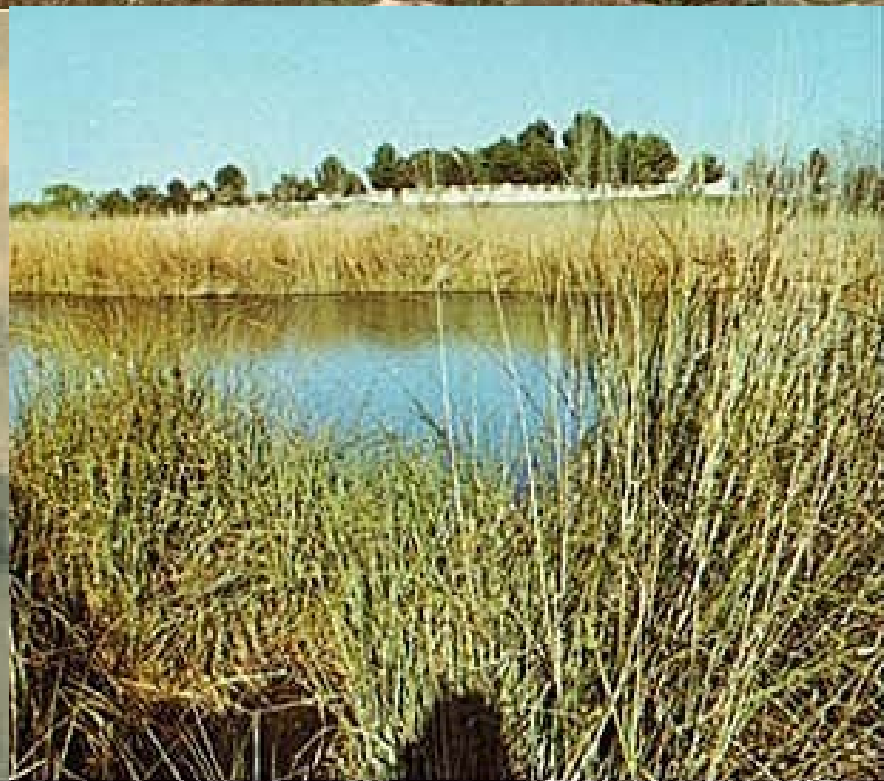
- Briefly summarize the main challenges, and why I am discussing the two cases I will be discussing
- Addressing climate change at the Upper Guadiana Basin
- Addressing seawater intrusion at the Llobregat Delta Aquifer

Rainfall patterns of Spain similar to those of California

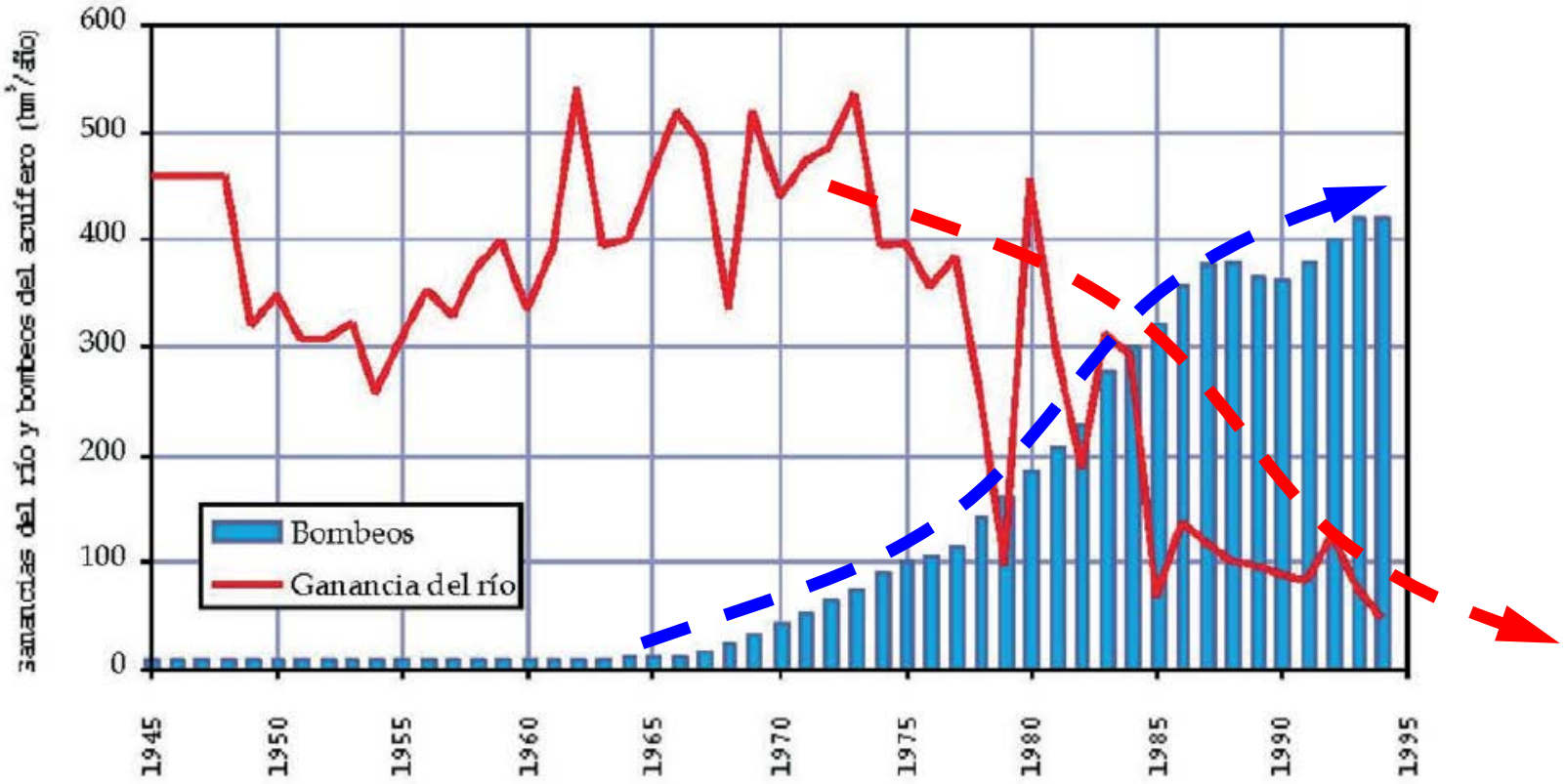
And we face similar challenges:
1) water over use (and loss of base flow)

Guadiana River, now…

… and before



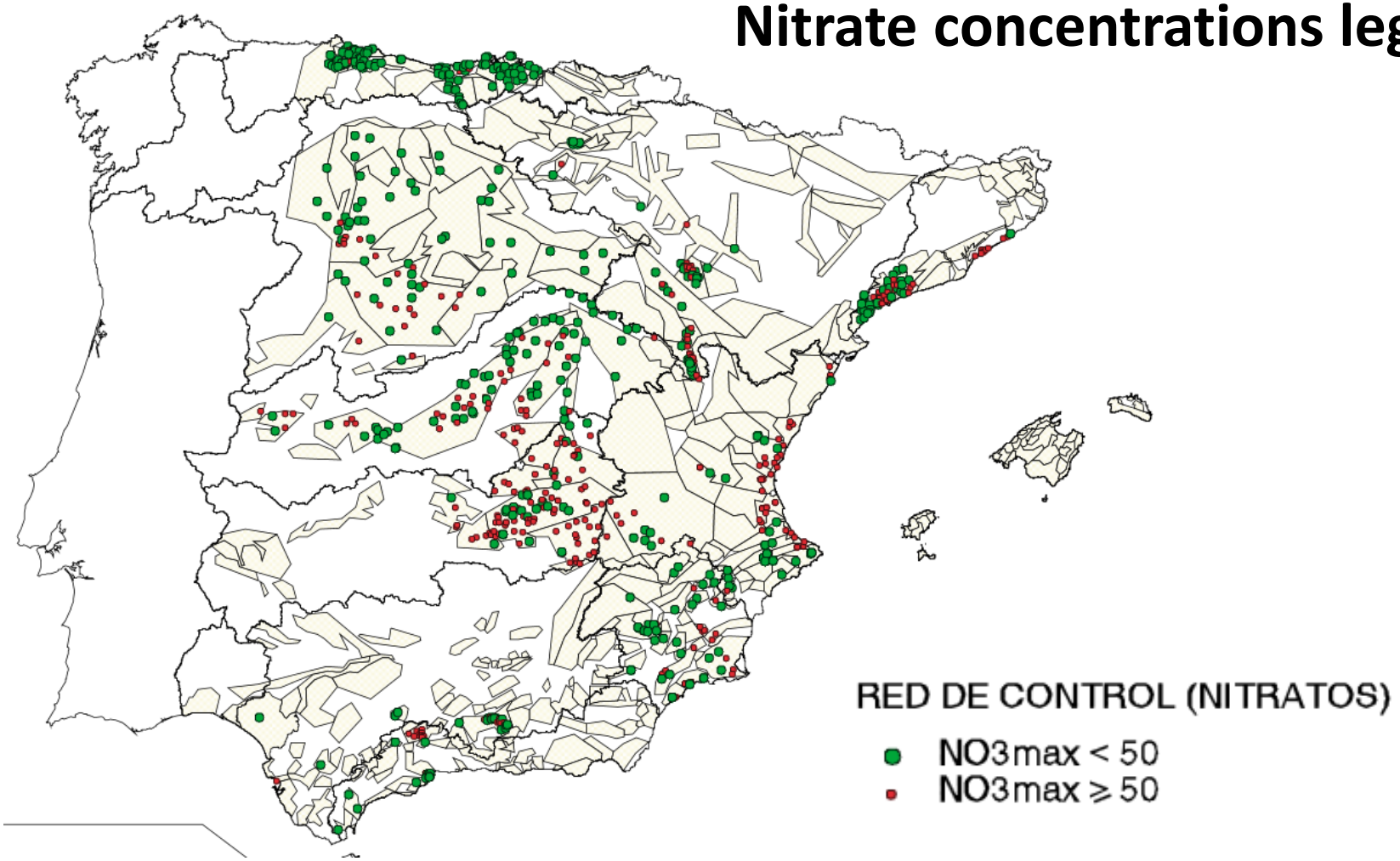
After pumping starts, the river flow rate decreases progressively (by the same amount but with 10 y delay)



(MIMAM, 2000; Custodio, 2017).

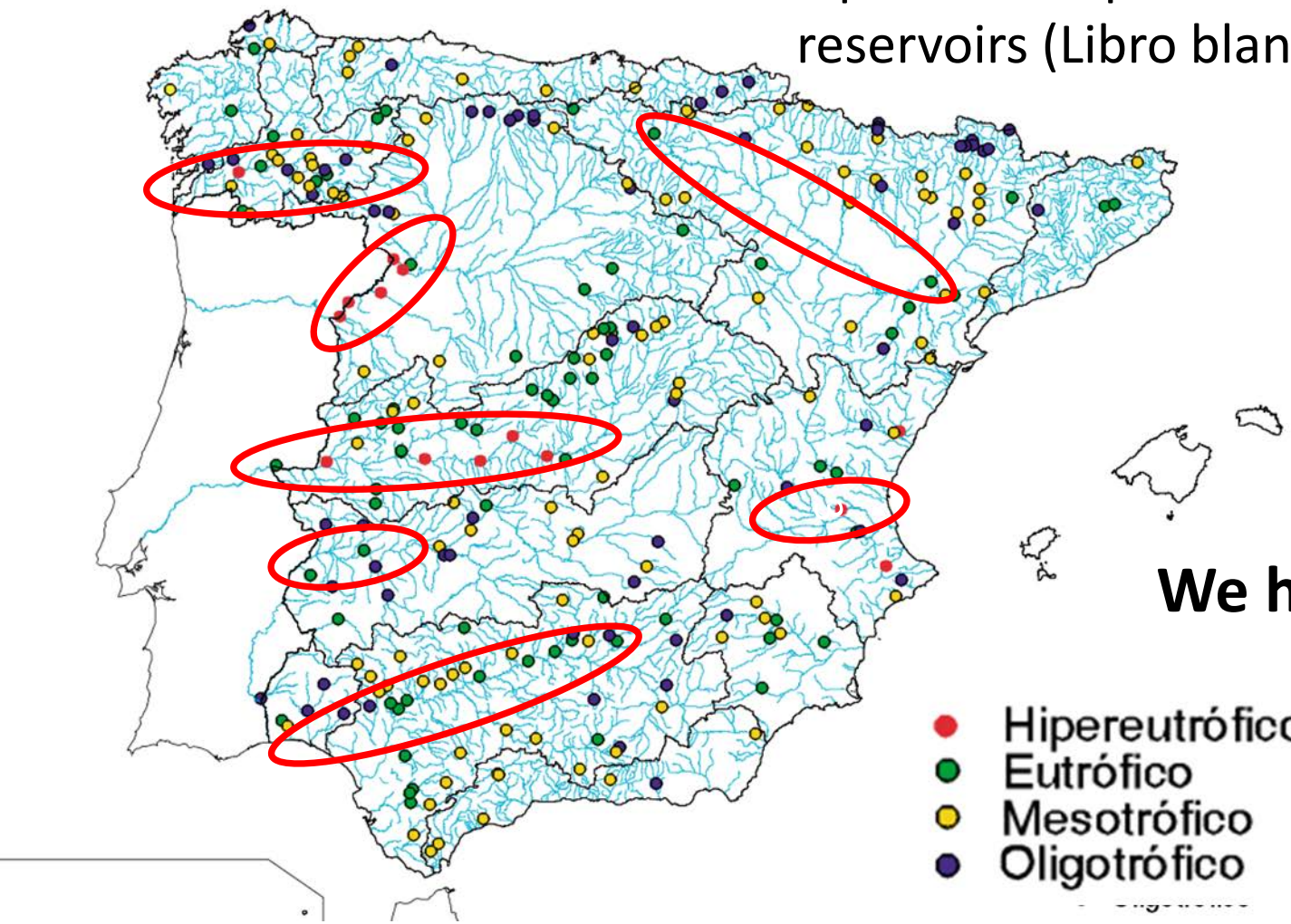
And we face similar challenges:
2) Agricultural pollution

Nitrate concentrations legally OK



But all our large reservoirs are eutrofized

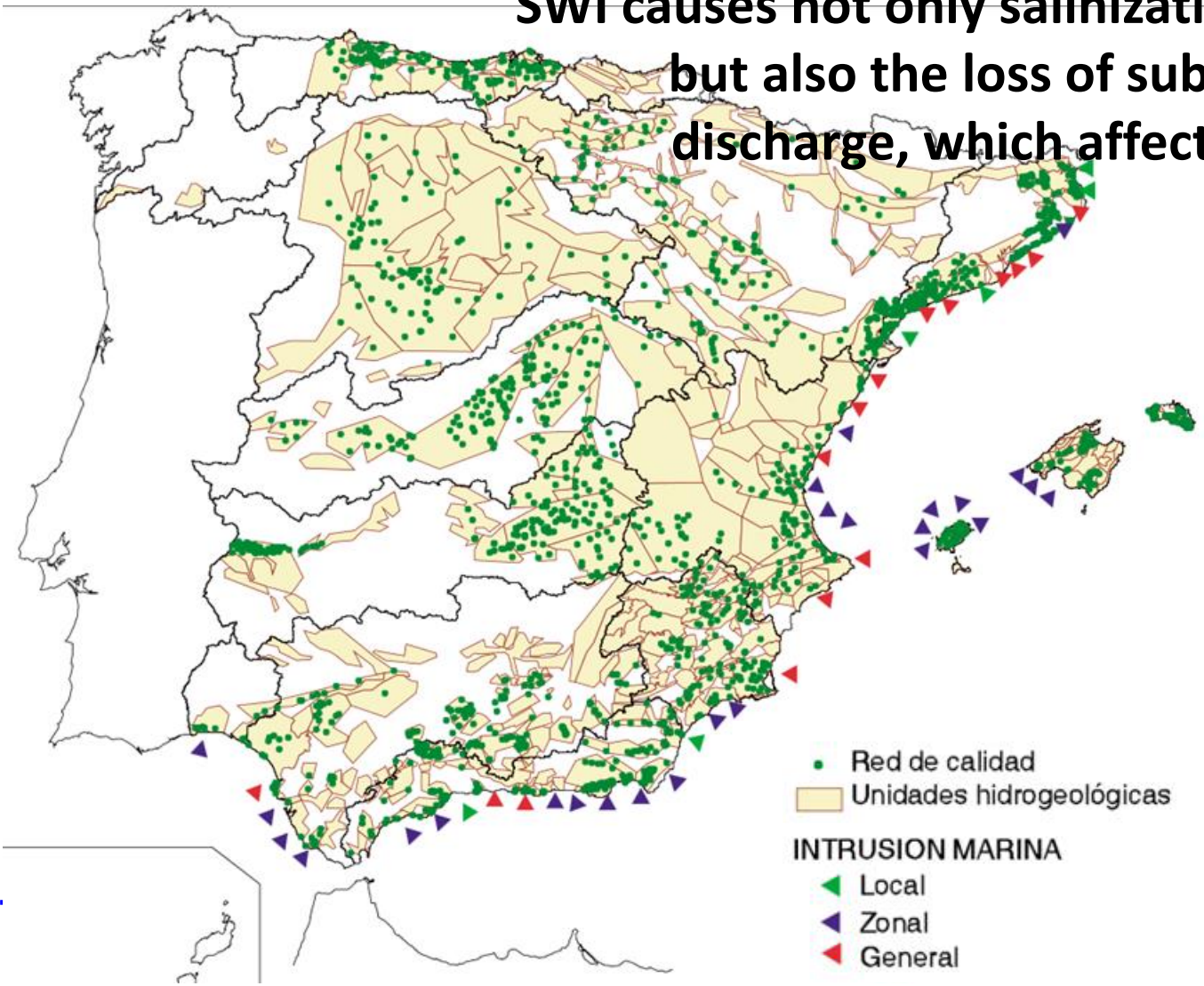
Map of the trophic state of more 10 hm3 reservoirs (Libro blanco del agua, 2005)



We have a problem with the law

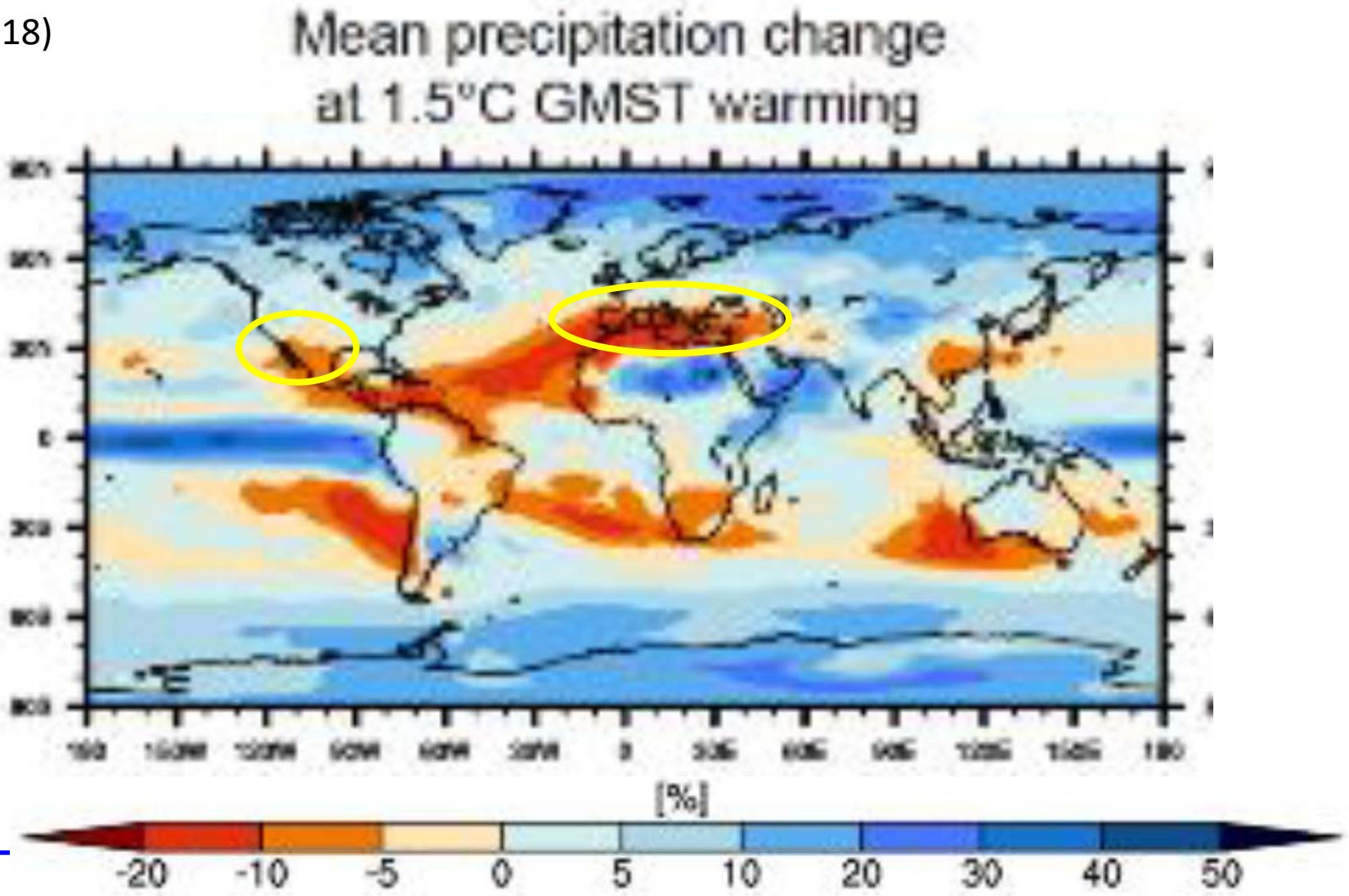
And we face similar challenges:
3) Seawater intrusion in all our Med aquifers

SWI causes not only salinization of costal aquifers, but also the loss of submarine groundwater discharge, which affects coastal ecosystems



And we face similar challenges:
4) Rainfall is dropping due to climate change

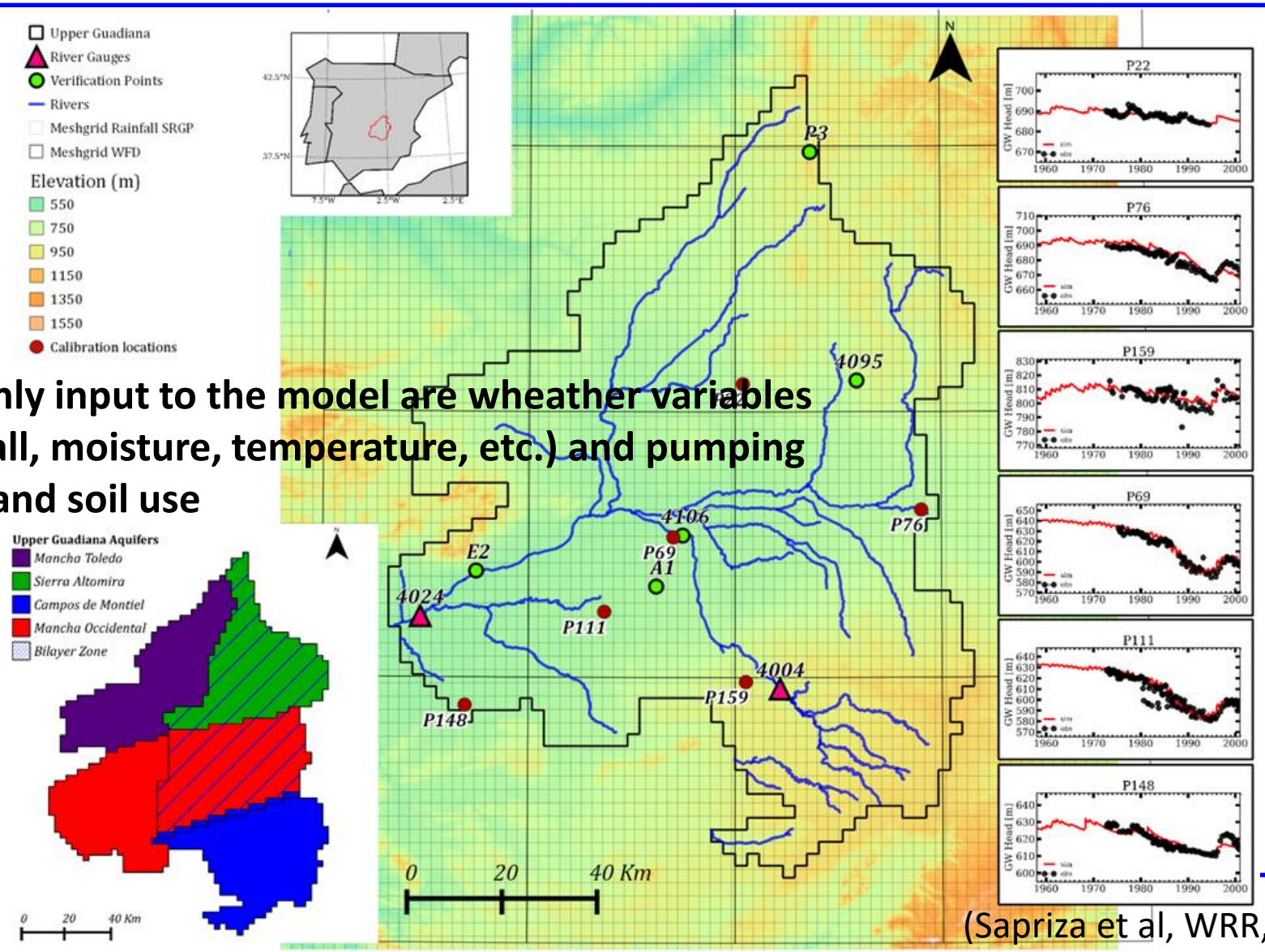
(IPCC, 2018)



The Upper Guadiana case

- Relevant because overpumping for irrigation was causing
  - The drying of an important wetland (Tablas de Daimiel) and only fed by surface water
  - The loss of the Guadiana River

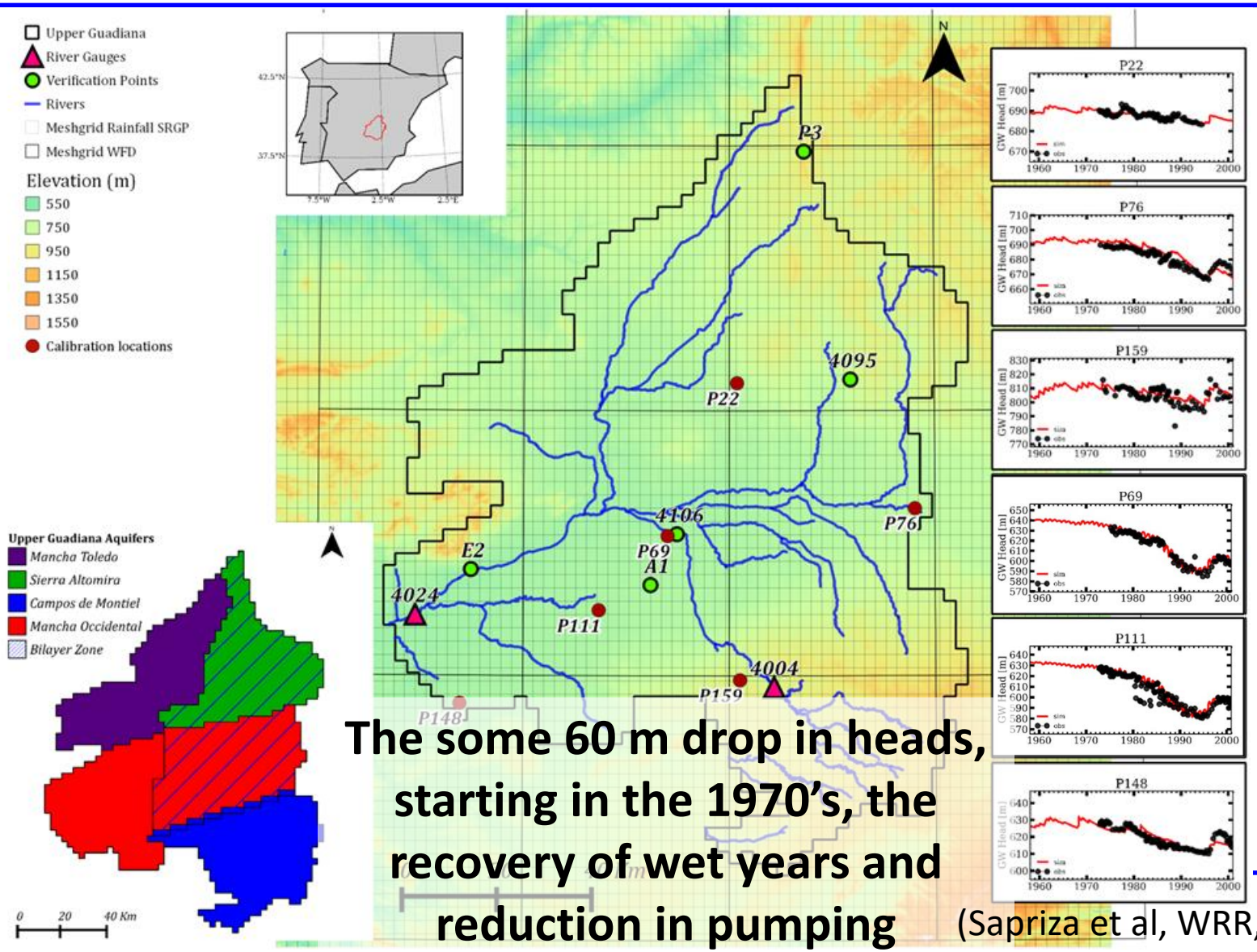
For proper understanding, we built a «fancy» coupled groundwater surface water model



The only input to the model are wheather variables (rainfall, moisture, temperature, etc.) and pumping rates and soil use

(Sapriza et al, WRR, 2015)

The model reproduces the fall of heads, and Guadiana River and Daimiel wetland drying…



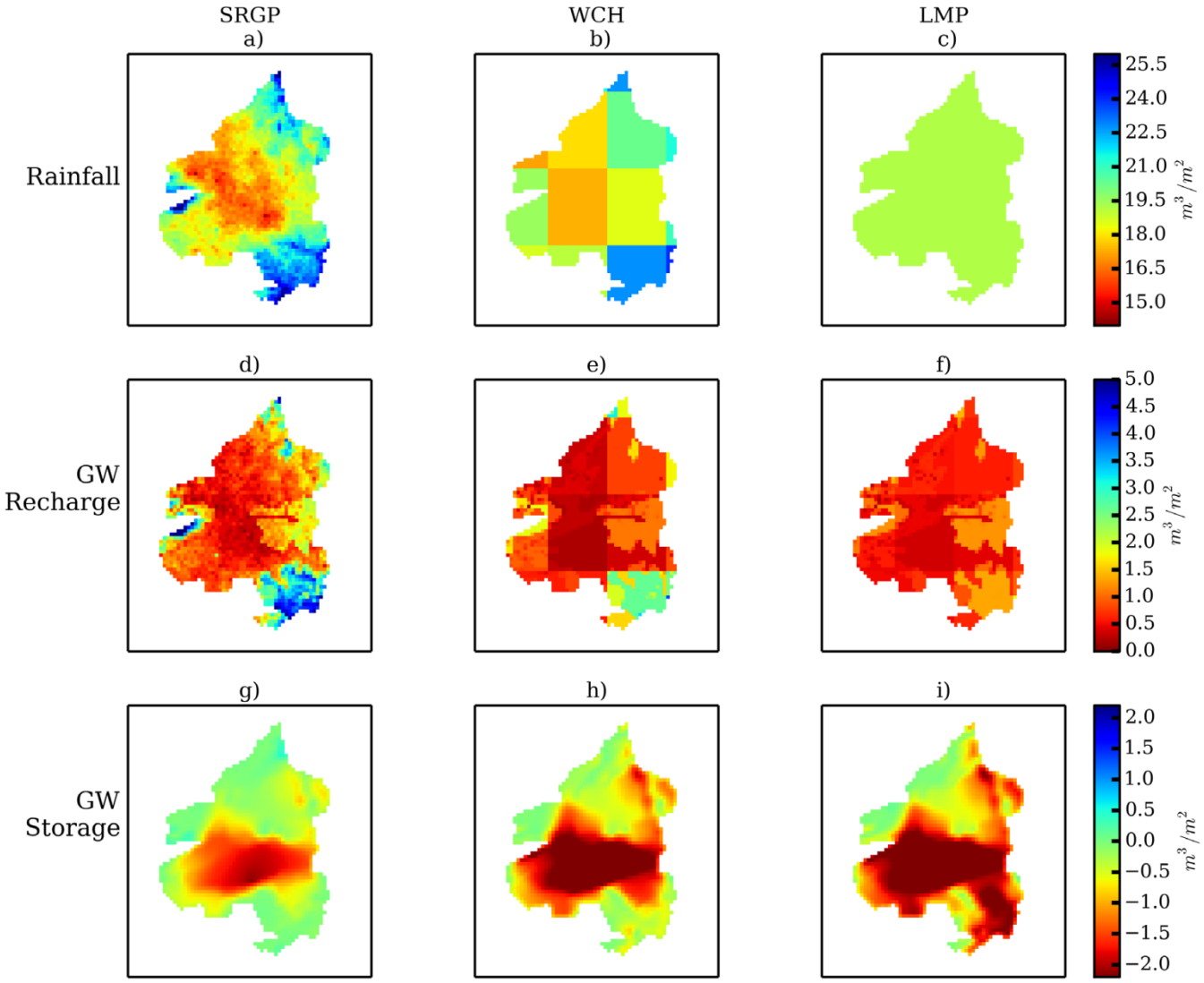
The some 60 m drop in heads, starting in the 1970's, the recovery of wet years and reduction in pumping

(Sapriza et al, WRR, 2015)

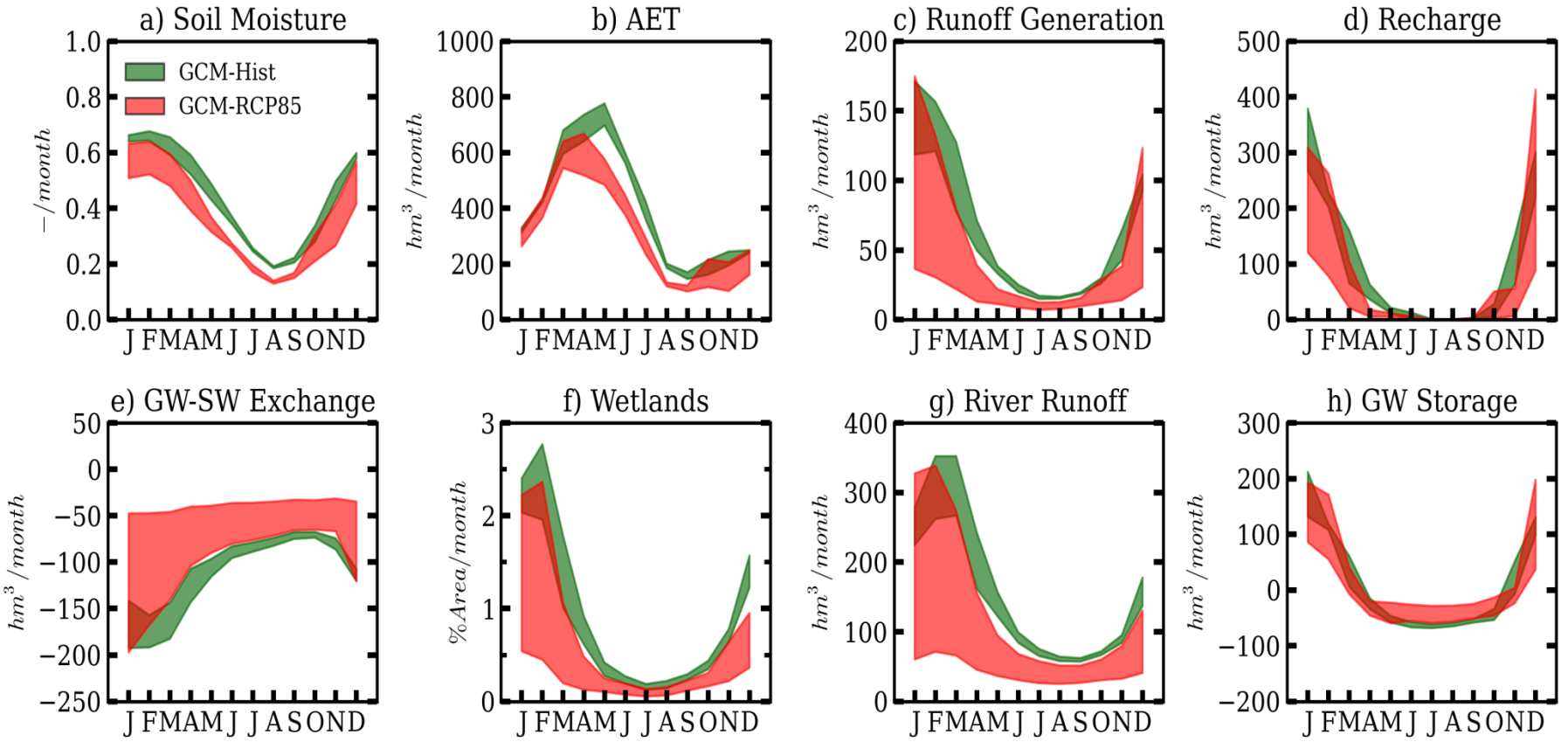
We addressed the impact of climate change by looking for changes in circulation paterns

1. Find which GCMs did best during historical records.
2. Calibrate during the historical record the rainfall for each circulation pattern
3. Examine the future by simply assuming that the GCMs produce reliable circulation patterns

We had to downscale for accuracy



Response to Climate Impacts: GCM historical (1960-1999 Green) and GCM-RCP85 (2060-2099 Red)

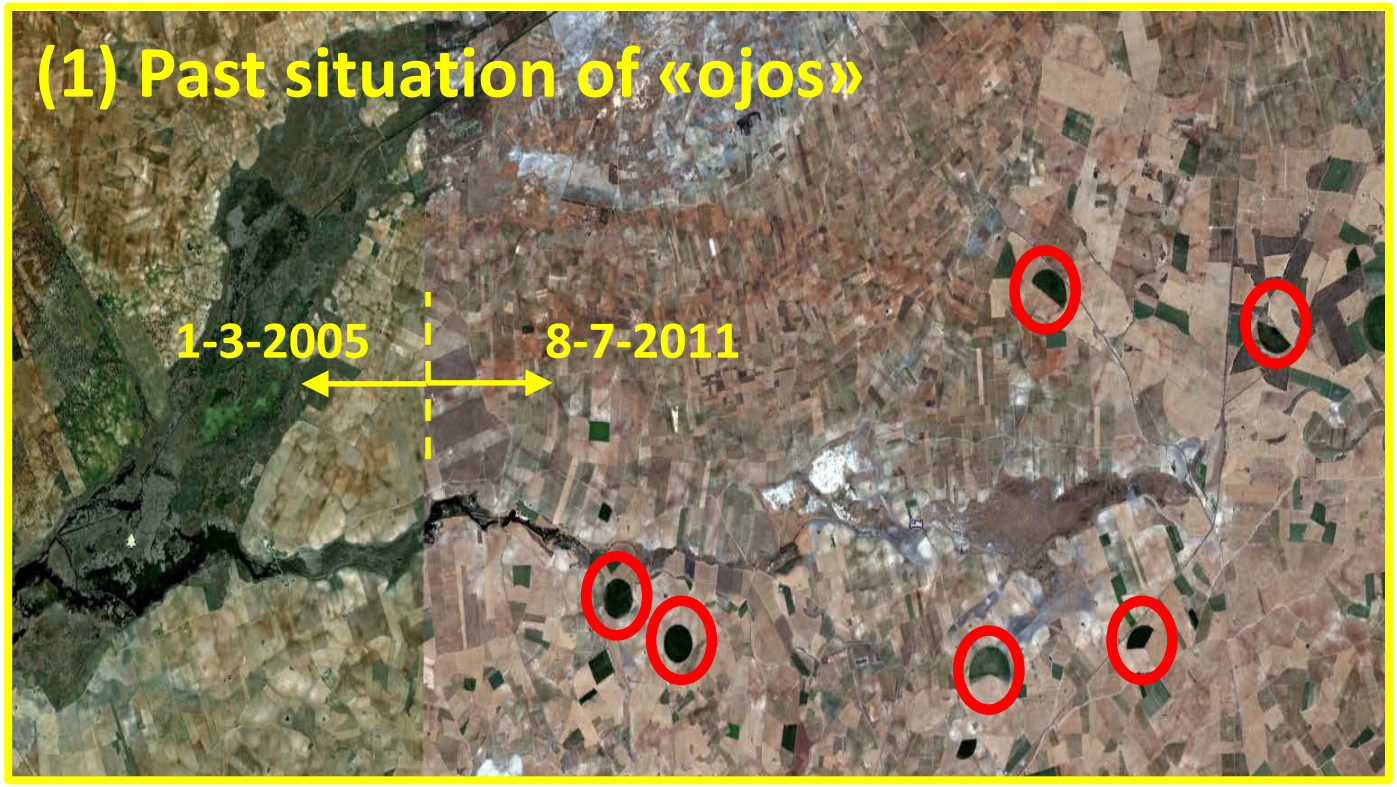


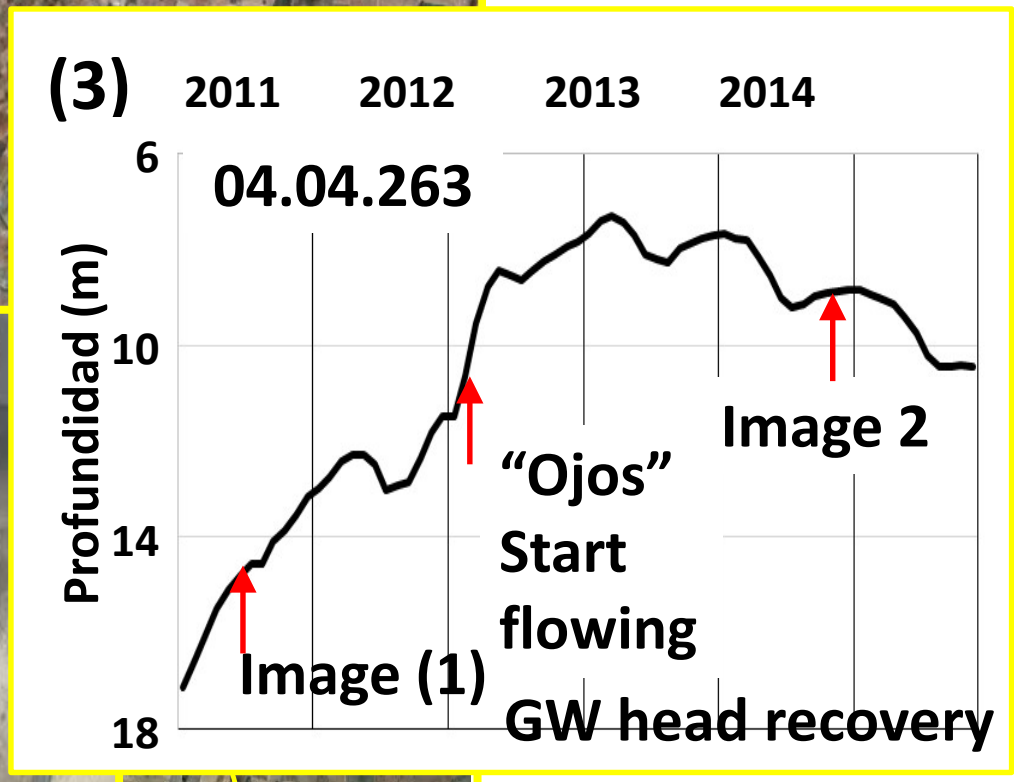
So, we went to the Guadiana River Basin Authority (the President was a classmate)

Response:

1) We are forced to use the «legal» climate change projections
2) We cannot enforce water use
3) What we do is to buy (i.e., rent) yearly water rights (which had been appropriated, contrary to Spanish law)

Has it worked? Google Earth images

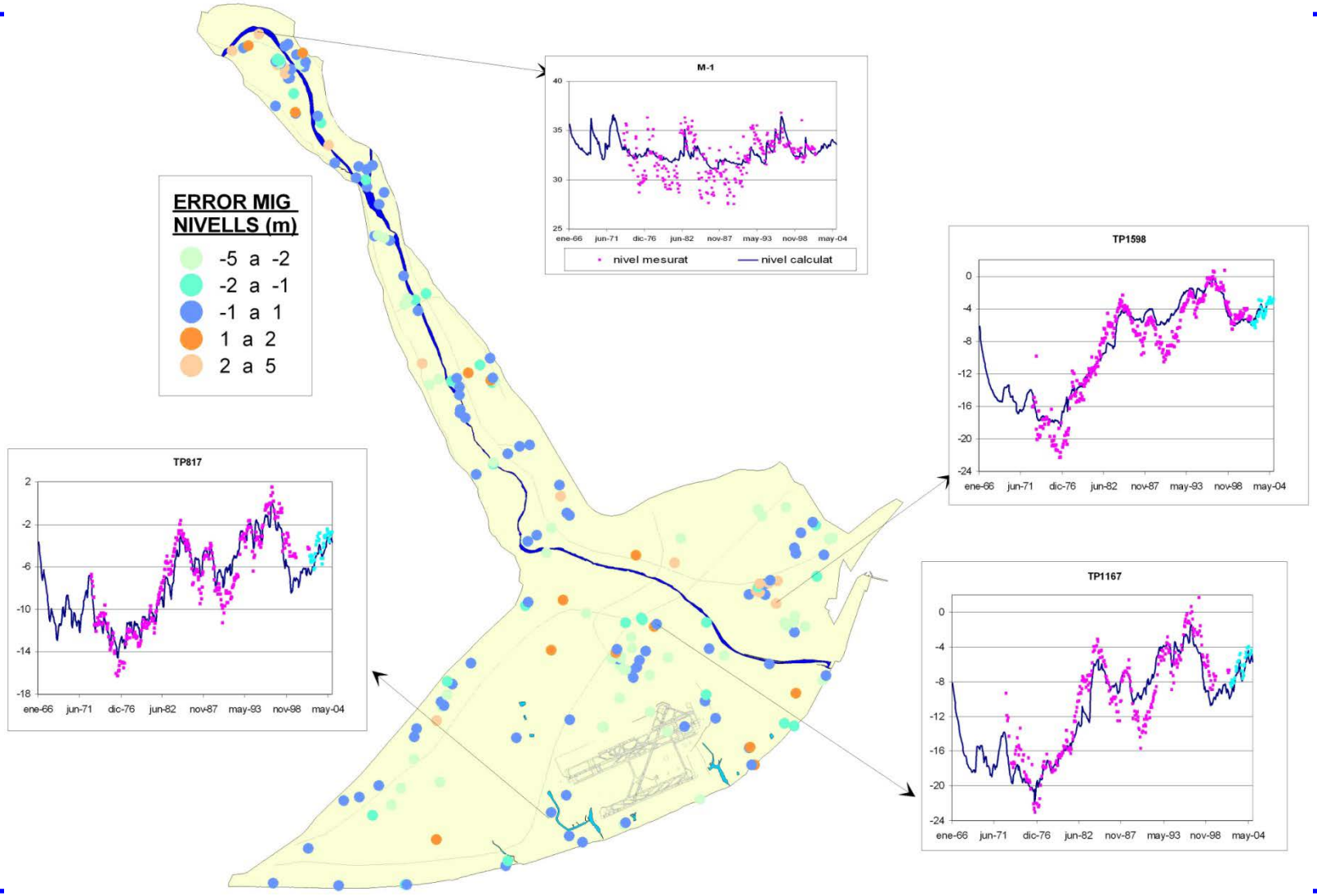




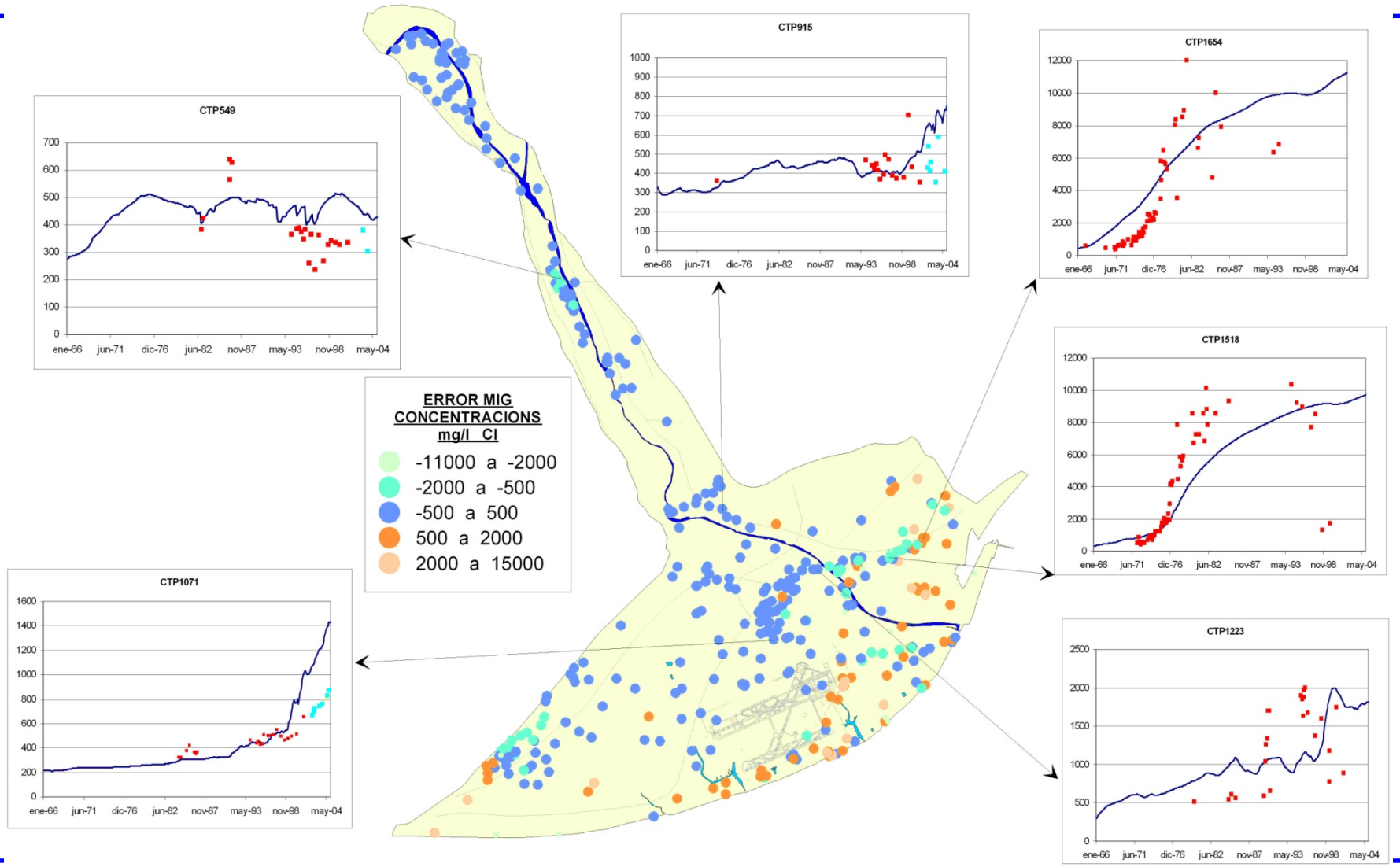
It has dried again (because of drought and economic crisis), ….
But we are close!

Second case: the Llobregat Delta suffered severe seawater intrusion threatening the water supply of Barcelona

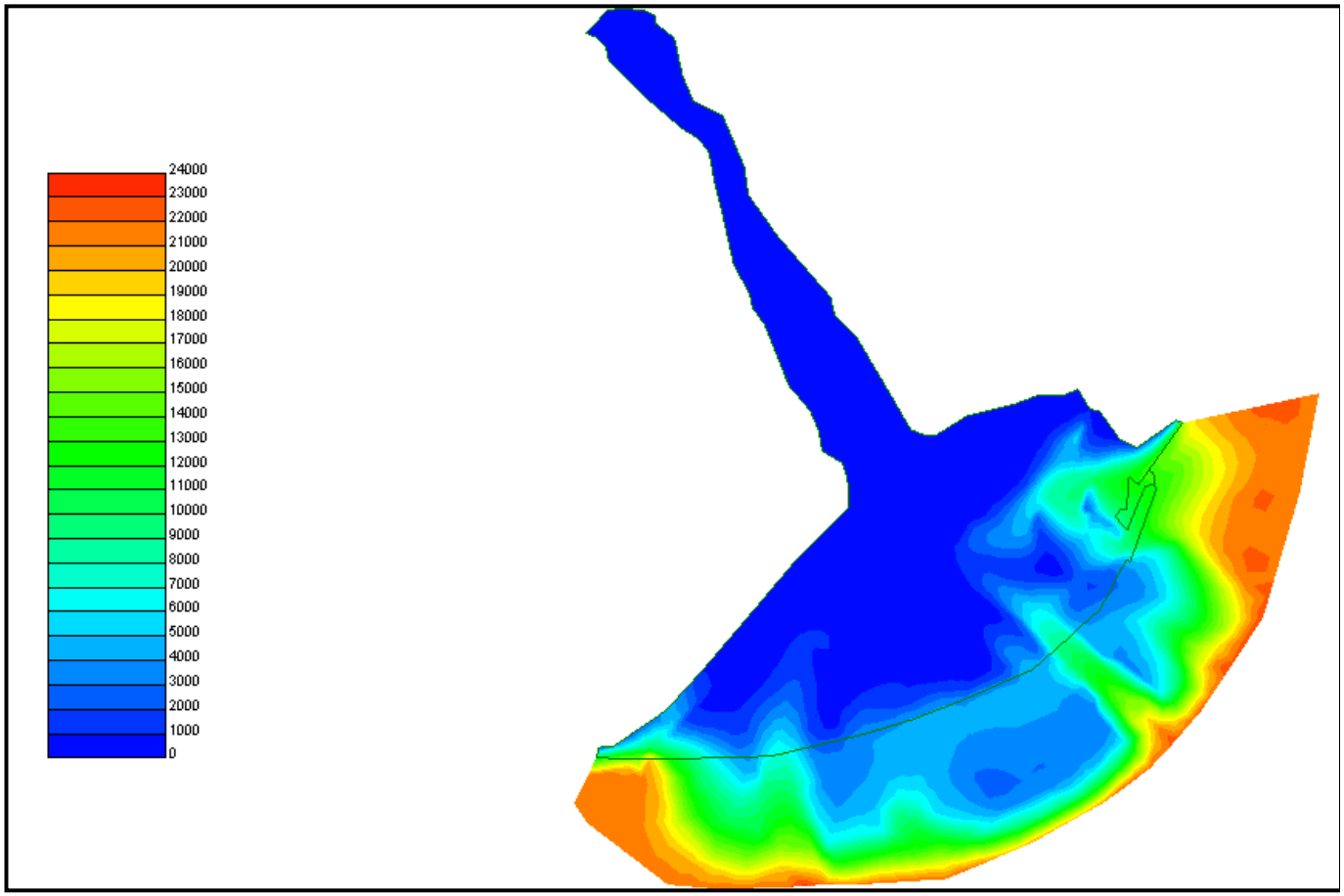
Again, we calibrated (1965-2001) and validated (2002-2004) a fancy numerical model



Also for salinity

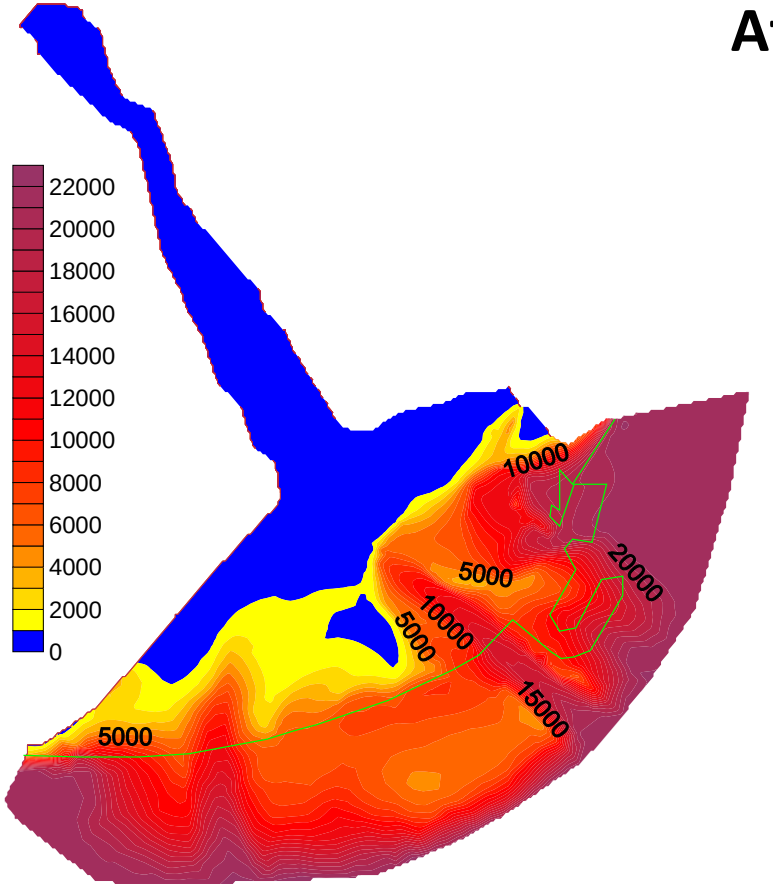


The state of salinization was bad



1995

And it could get much worse



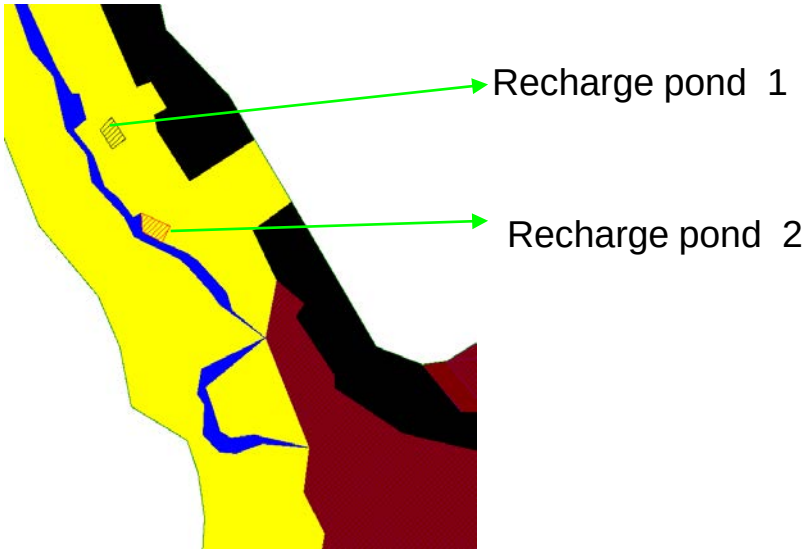
After 36 years of pumping

Proposed actions: Reduce pumping and adopt corrective measures to increase resources

ARTIFICIAL RECHARGE PONDS

2 recharge ponds
Toral area = 11 ha
Projected infiltration rate = 0.25 m/d

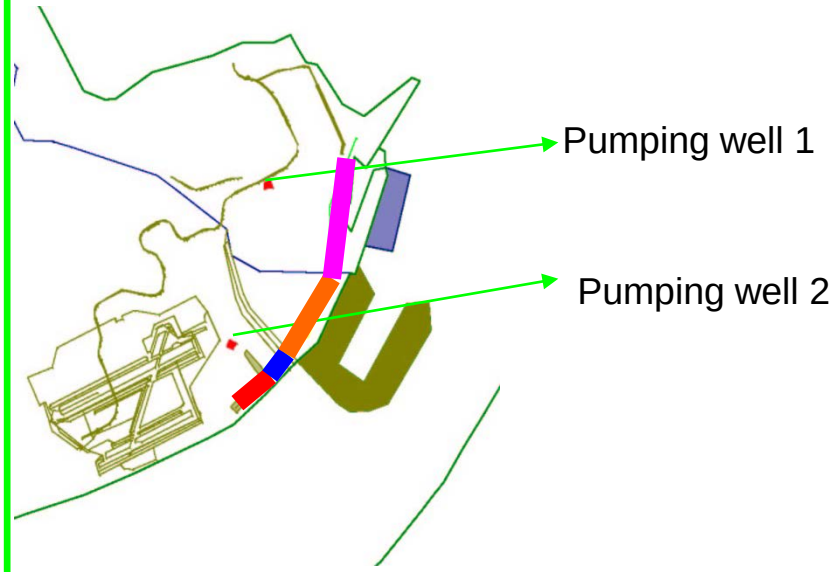
Total projected recharge =11hm³/y



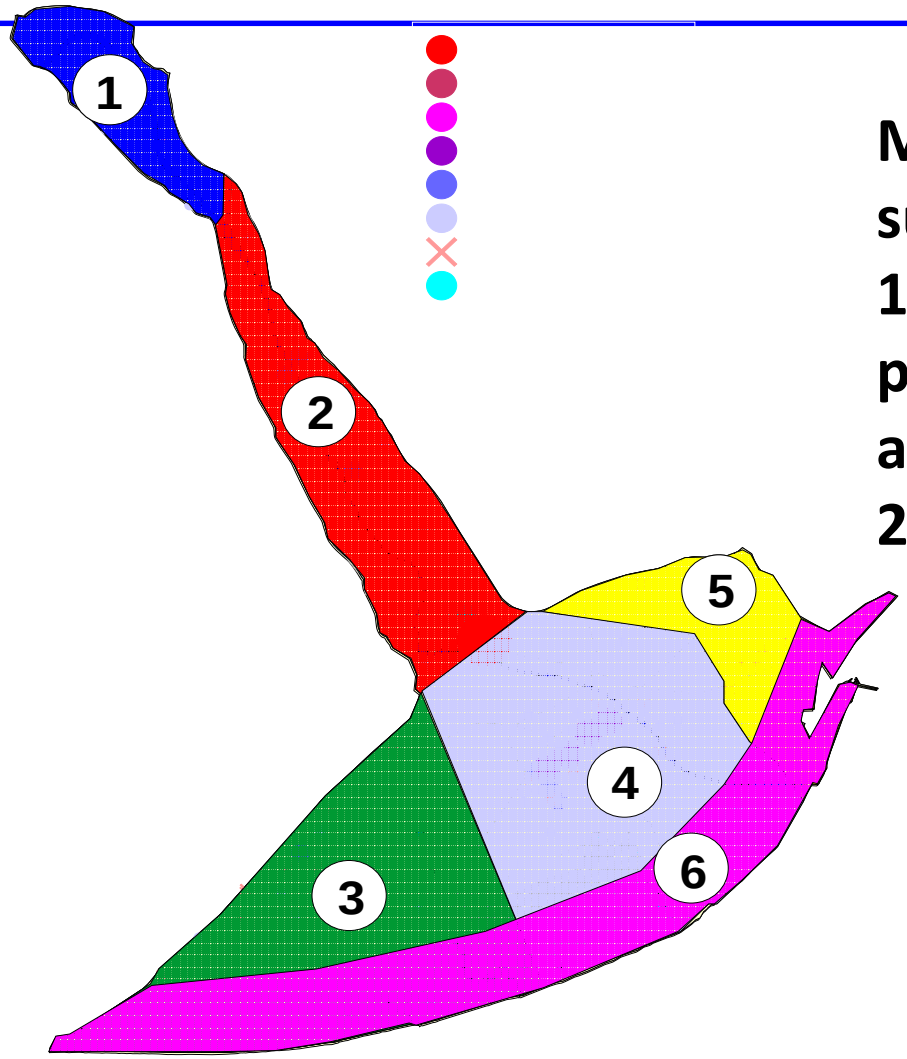
SEAWATER INTRUSION BARRIER

Divided in 4 sectors
+ 2 pumping wells (extract trapped salt)

Total injection rate = 3.65 hm³/y



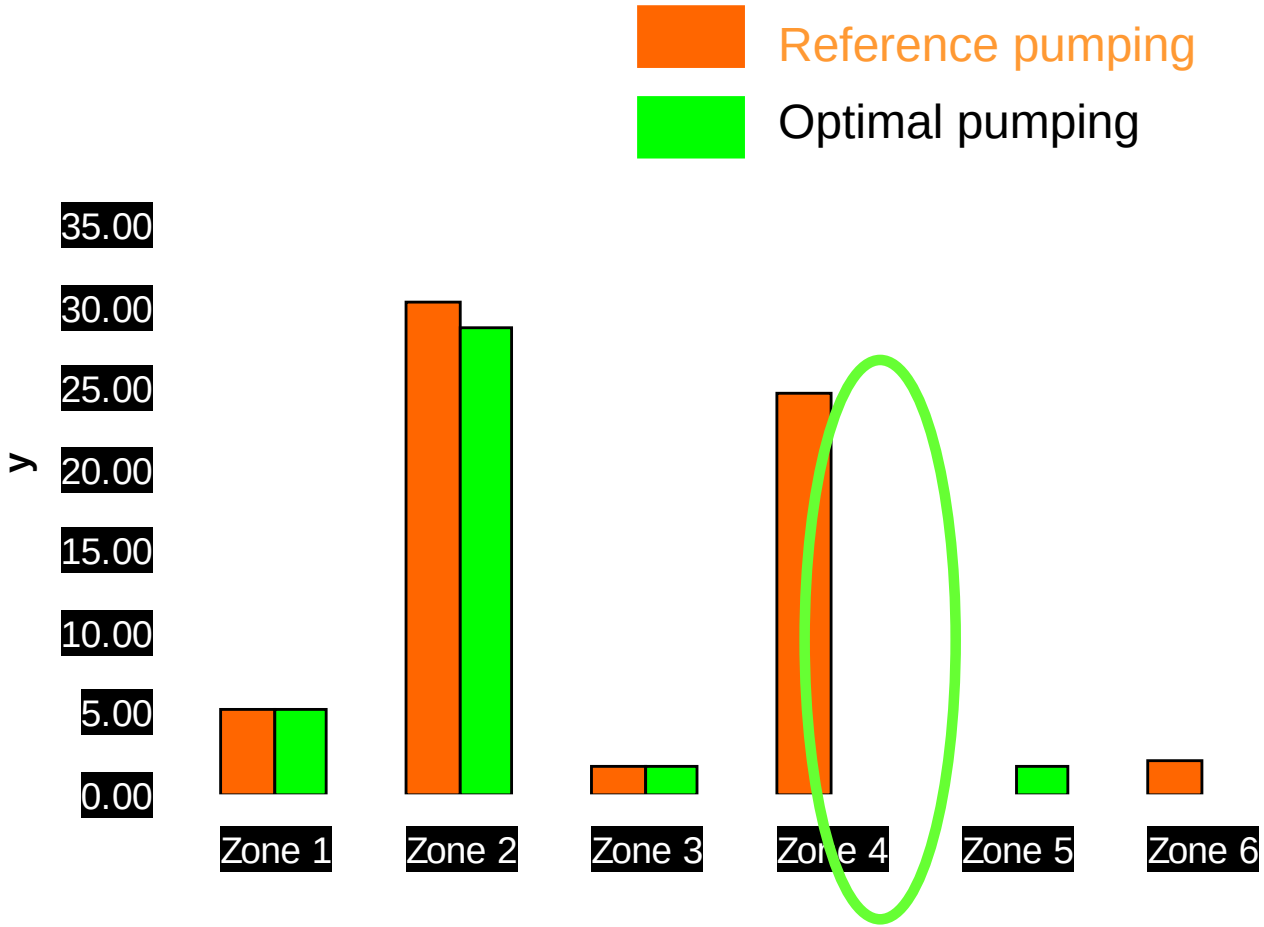
We posed the problem as an linear programing problem

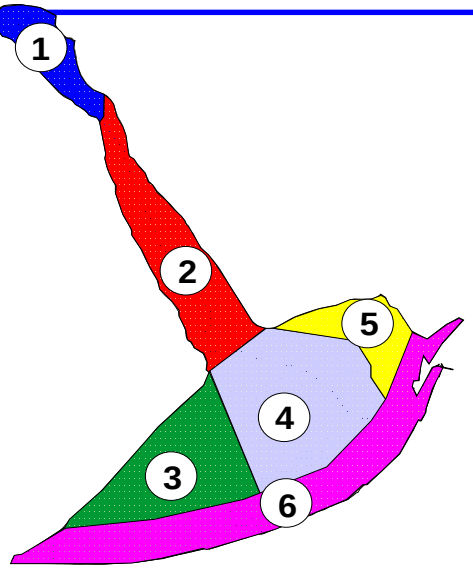


Maximize pumping
subject to:
1) high heads at the shore, to prevent SWI
and
2) fixed artificial recharge rates

Results: unacceptable without corrective actions

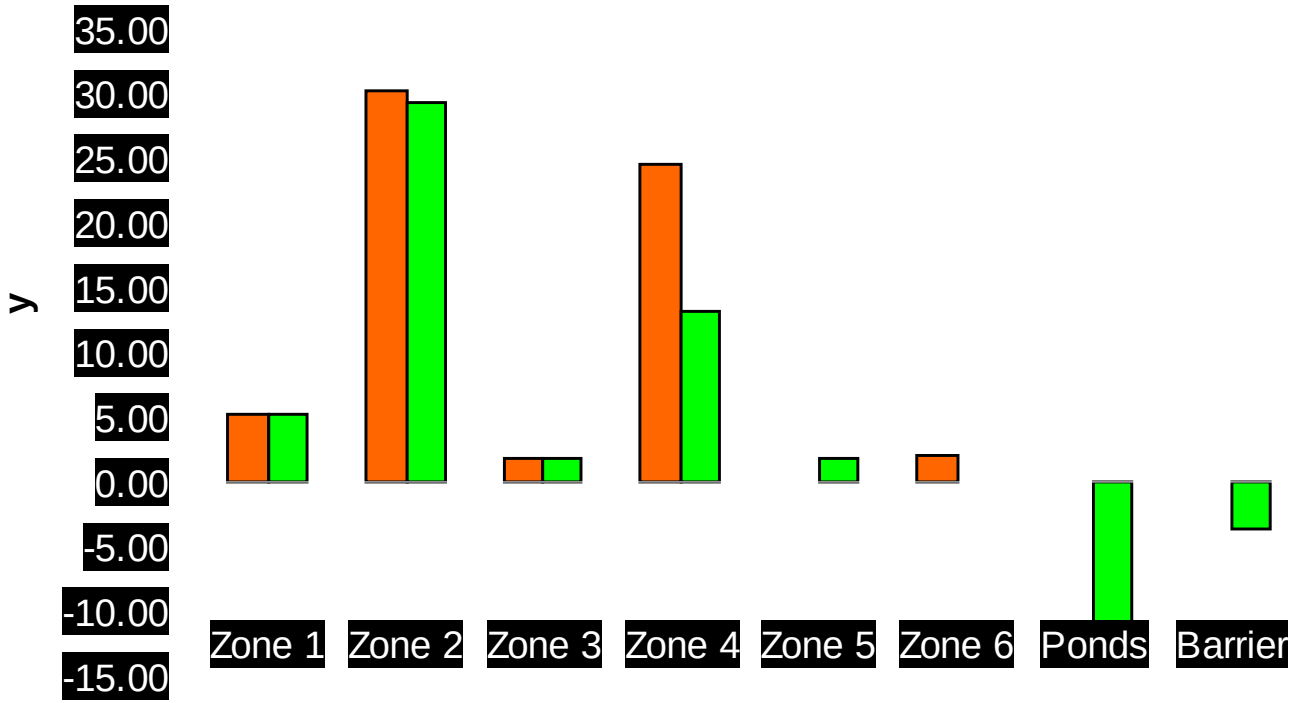
Without corrective measures

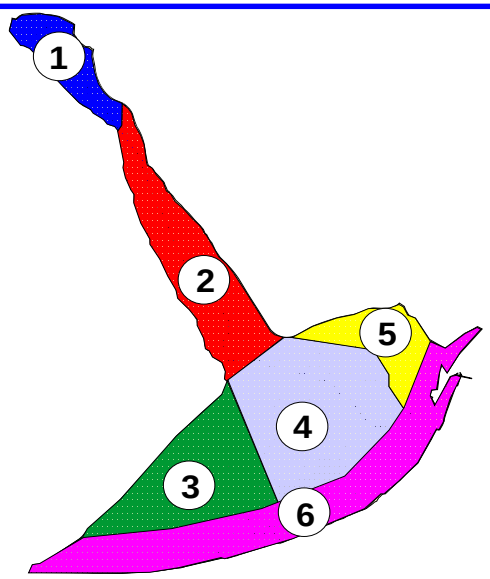




Results: OK with corrective actions

With corrective measures





But the most interesting results where the shadow prices (hydraulic efficiency)

- **ARTIFICIAL RECHARGE PONDS = 0.6**
- **SEAWATER INTRUSION BARRIER = 1.7**

The end of the story

1) The seawater Intrusion Barrier was built, but with osmotized water (a negative influence of California!!) so it stopped operation during the crisis
2) The Groundwater Users community did not want to hear of “imposed” pumping reductions, but they adopted the model have been using it themselves for self-control
3) SWI has been controlled

In summary

- Reliable models are possible. Do not trust GCMs for rainfal, but for circulation patterns
- The present is not bad for the people (good quality water supply, good agricultural production).
- But the present is concerning for water dependent ecosystems (rivers in poor shape, depleted coastal ecosystems)
- Water rights, often appropriated (not acknowledged by the law), often exceed availability
- The administration lacks tools to enforce «scientific» allocation plans.
- What works are «user's communities» and the «rental» of water rights.