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Modelling human interventions in the Rhine basin using the hydrological model SIMGRO

Erik Querner

Contents

- Introduction SIMGRO model
- Framework of the study
- Model application to the Rhine basin
  Climate and land use scenarios
- Adaptation measures
- Conclusions

- Demonstration user interface (case Evrotas basin, Greece)

Aim: try to keep it simple

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Criteria for a model

- Physically based (white box)

  sub-processes conceptual (‘grey box’)
- Simulate processes as accurately as possible
- Not <u>too</u> much input data
- Modular set-up

  sub-modules standalone

  select sub-modules best suited for project goal
- For practical problems and hydrological research

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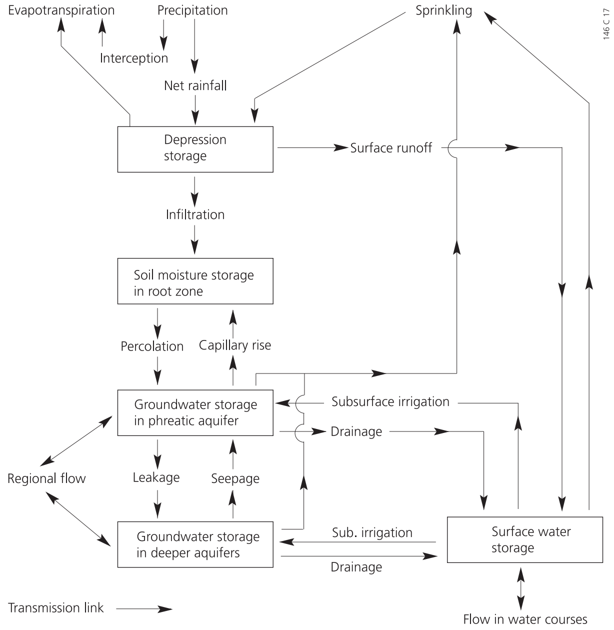
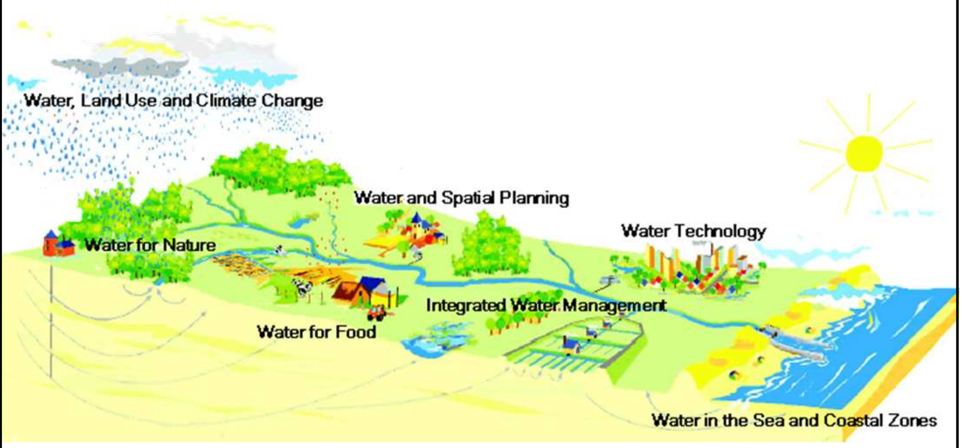
Groundwater and surface water flow



River basin



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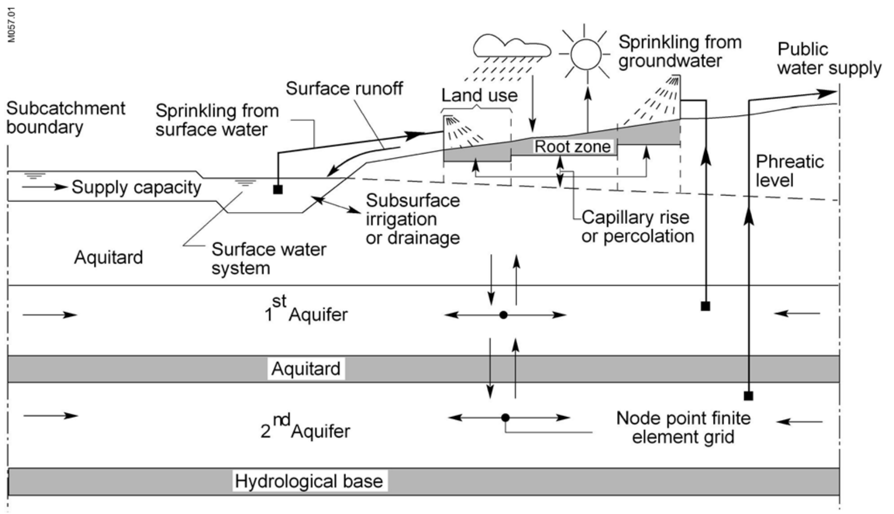
Schematisation in SIMGRO



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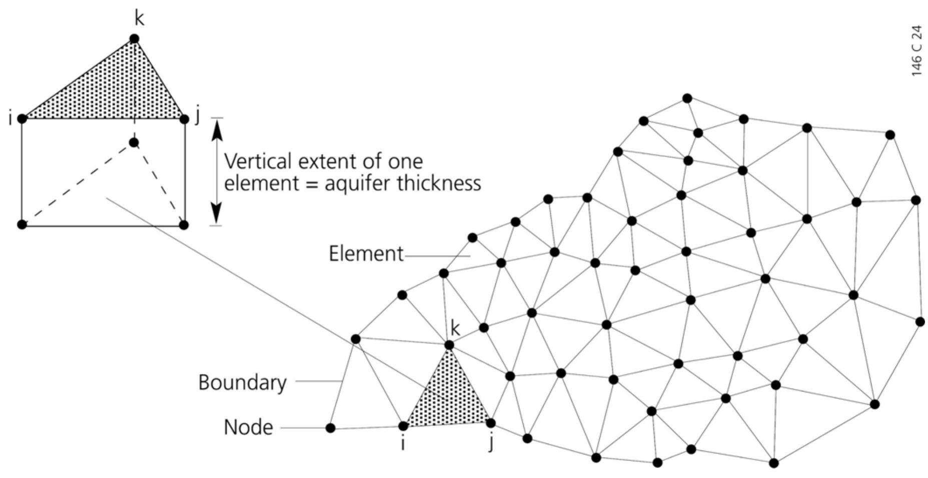
Finite element network



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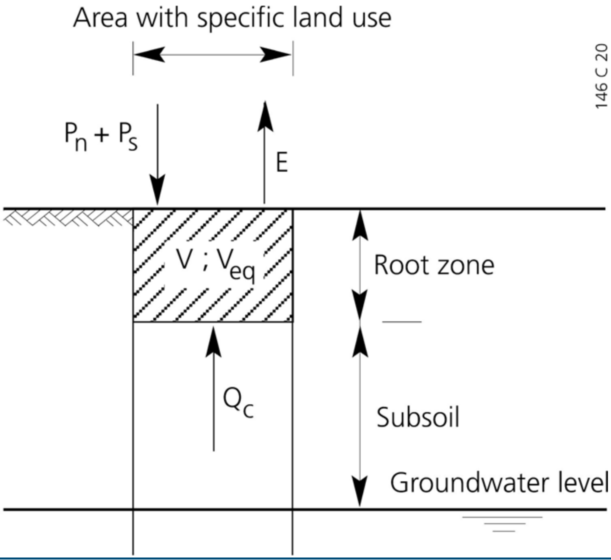
Unsaturated zone



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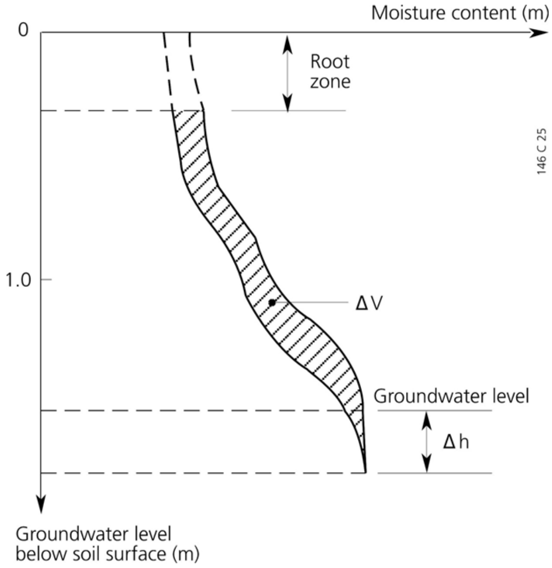
Storage coefficient



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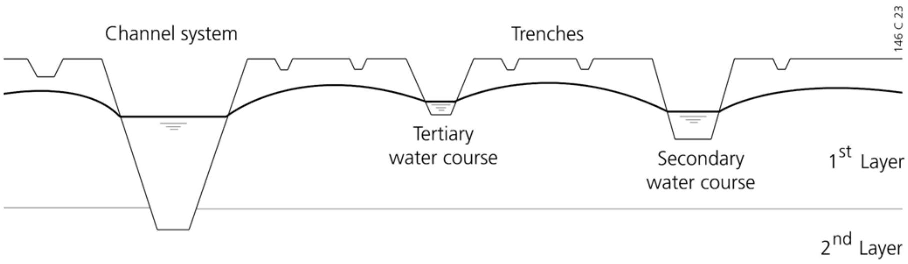
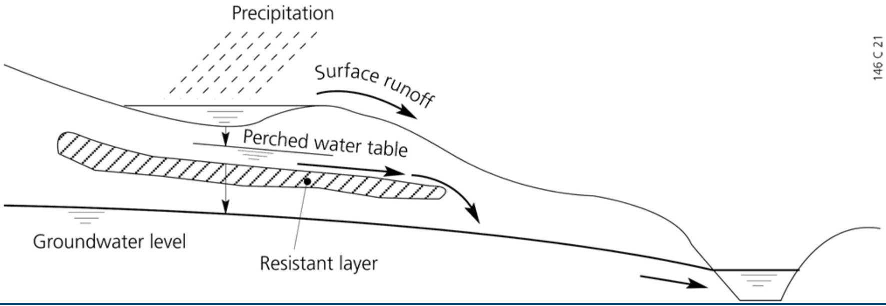
Interaction surface water - groundwater



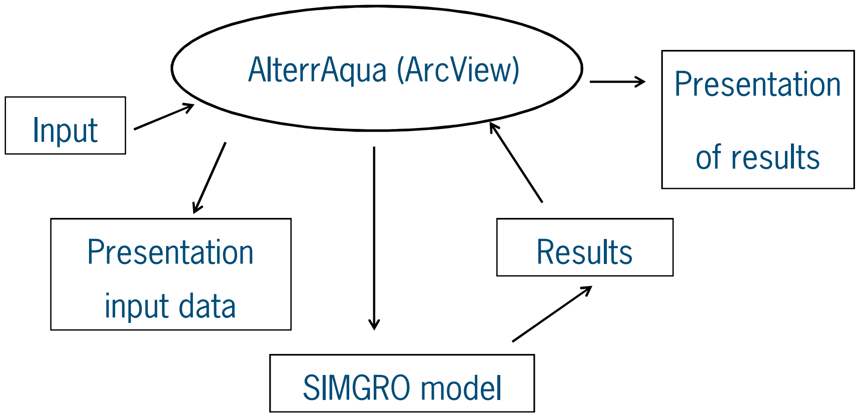
Processes unsaturated zone

- Perched water tables
- Hysteresis
- Preferential flow
- Surface runoff

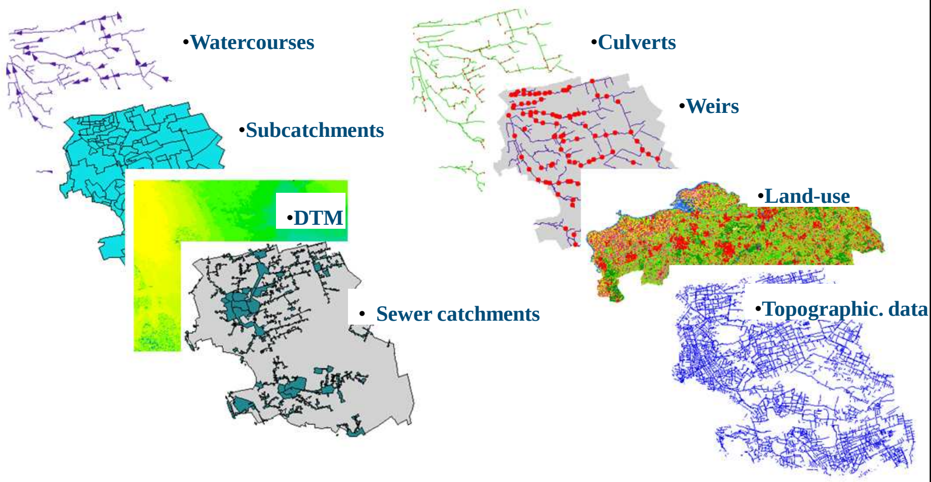


SIMGRO/AlterrAqua

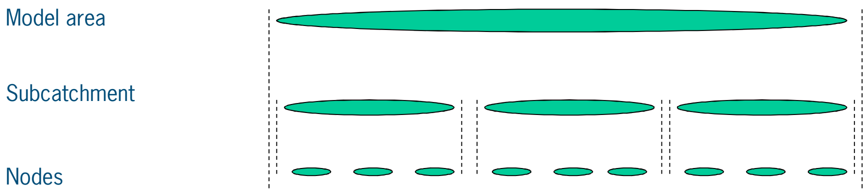
GIS-application:



Example input data



Discretisation



Subcatchments: Surface water

Nodes: Groundwater

Objective of the Rhine basin study

- How does a physical based hydrological model perform for a basin as the Rhine (incl. snow module)
- Quantify the effect of land use and climate change on river flows
- What are the changes on droughts or low flows

Modelling the Rhine basin

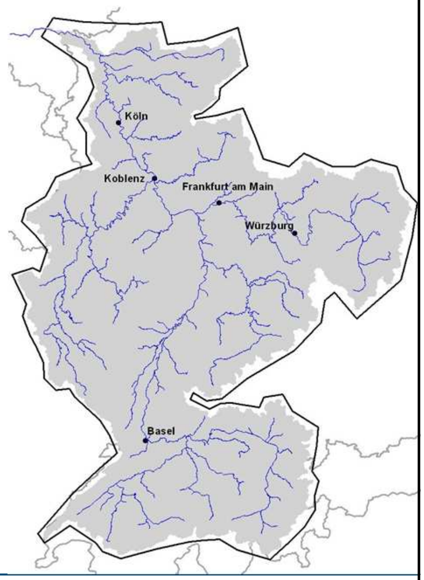
Basin area: 160 000 km^2

Mainly Switzerland, Germany, France,
Luxemburg, Belgium >> Netherlands

Finite element network:
5 x 5 km ; 8144 cells

Surface water:
Larger rivers >400 km^2
630 sub catchments

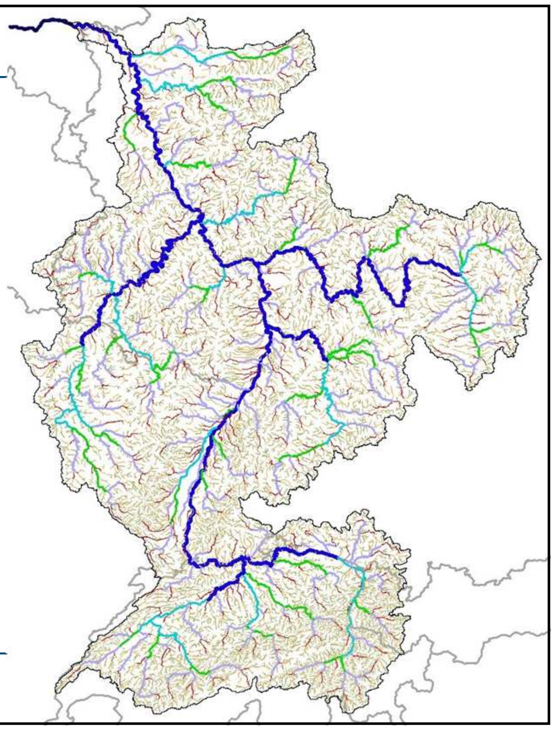
Groundwater:
data Rhine Commission (CHR)
Land use: CORINE
Soil map FAO



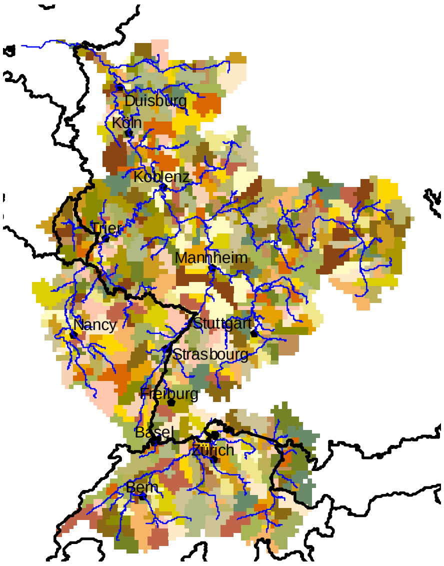
Surface water

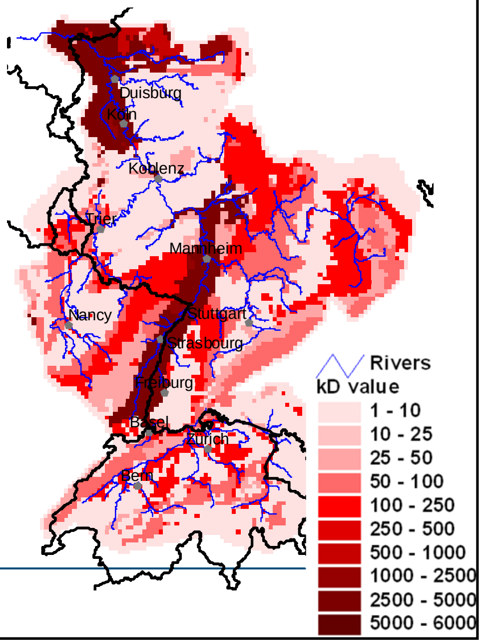
Drainage network is derived from DTM (Vogt e.a., 2007)

Important for interaction groundwater – surface water



SW: sub catchments | GW: transmissivity





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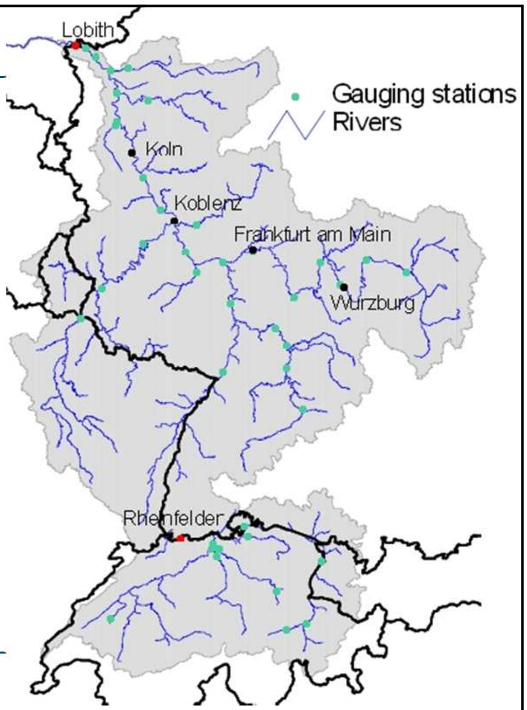
Gauging stations

42 gauging stations used

Procedure to compare calculated - measured discharges (Nash-Sutcliffe model efficiency)



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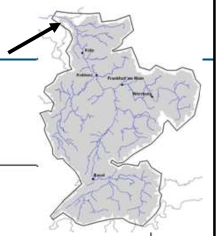
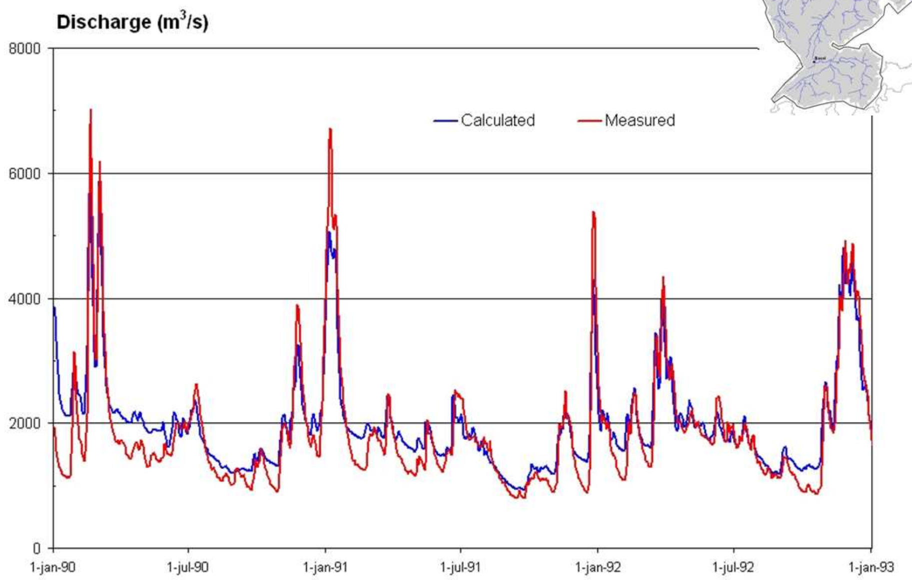
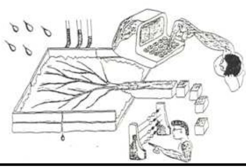
Lobith – compare measured and calculated





Nash-Sutcliffe modelling efficiency (sim. period 1990-1995)

Lobith	0.90
Main	0.74
Neckar	0.65
Moselle	0.79
Switzerland (5 stat)	0.30
Downstr. Switzerl. (13 stat)	0.79



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Scenarios

- Land use change (extreme)

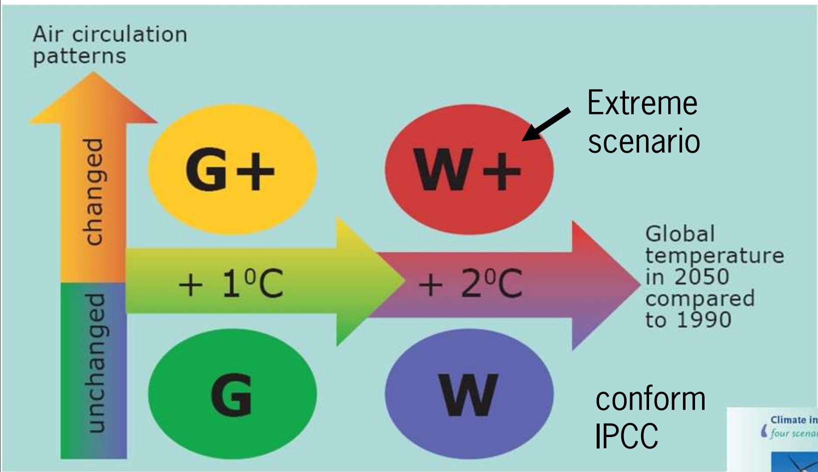
  all crops to grass ~ 33% area changed

  all crops to forest ,,

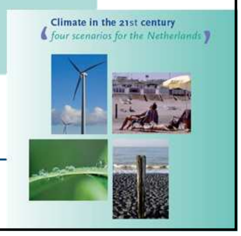
- Climate change

  scenarios from Dutch Meteorological Institute (standardized)

Climate scenarios for the Netherlands

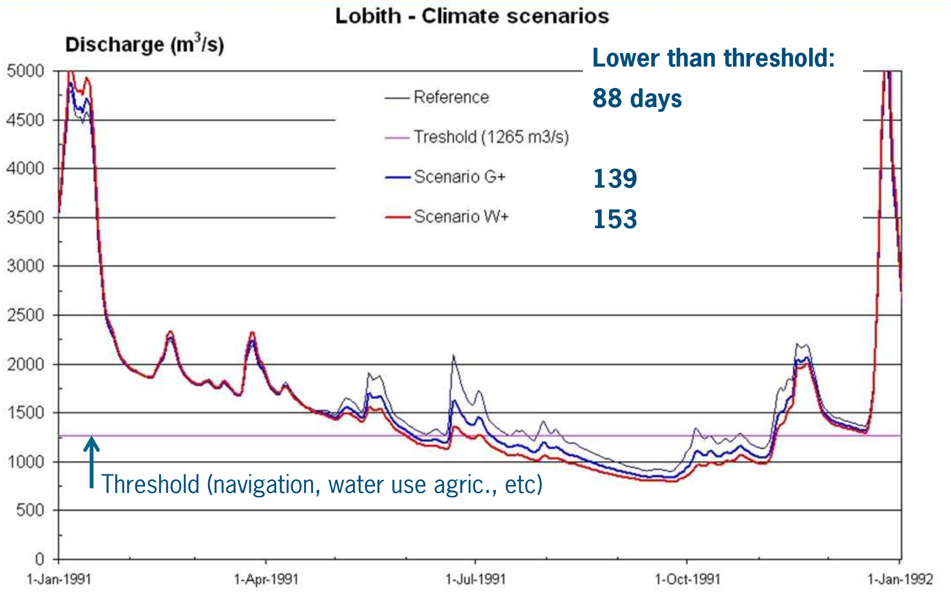


Moderate Warm

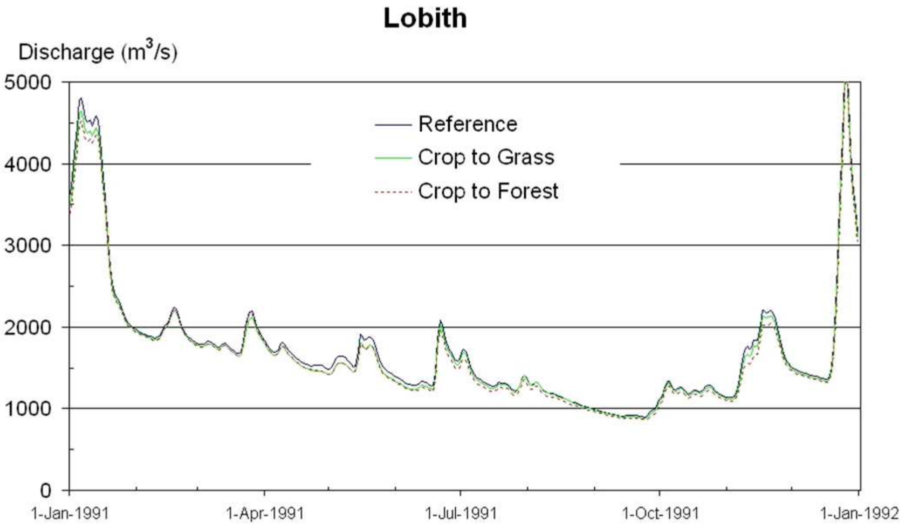


Climate scenarios: some details

		G	G+	W	W+
Global temperature rise		+1°C	+1°C	+2°C	+2°C
Change in air circulation patterns		no	yes	no	yes
Winter[3]	average temperature	+0.9°C	+1.1°C	+1.8°C	+2.3°C
	average precipitation amount	+4%	+7%	+7%	+14%
Summer[3]	average temperature	+0.9°C	+1.4°C	+1.7°C	+2.8°C
	average precipitation amount	+3%	-10%	+6%	-19%
	potential evaporation	+3%	+8%	+7%	+15%



Scenario – land use



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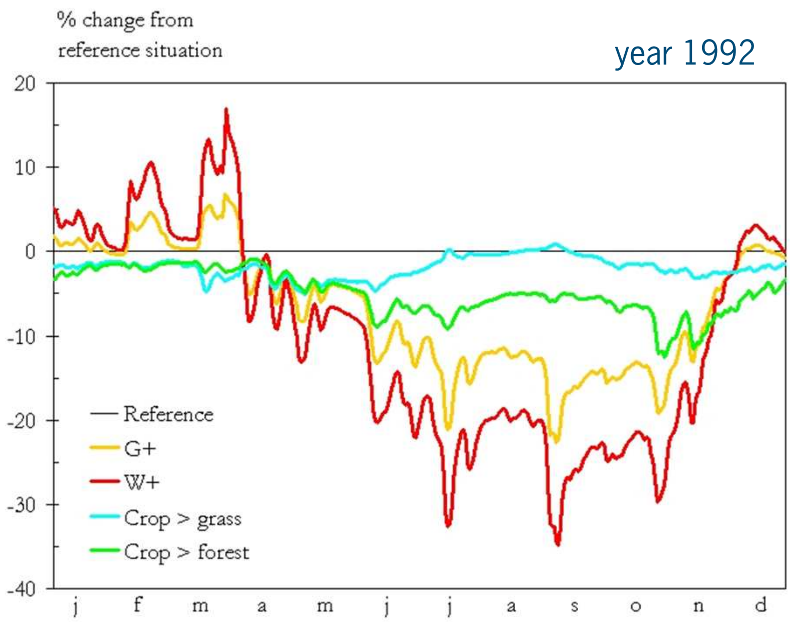
year 1992



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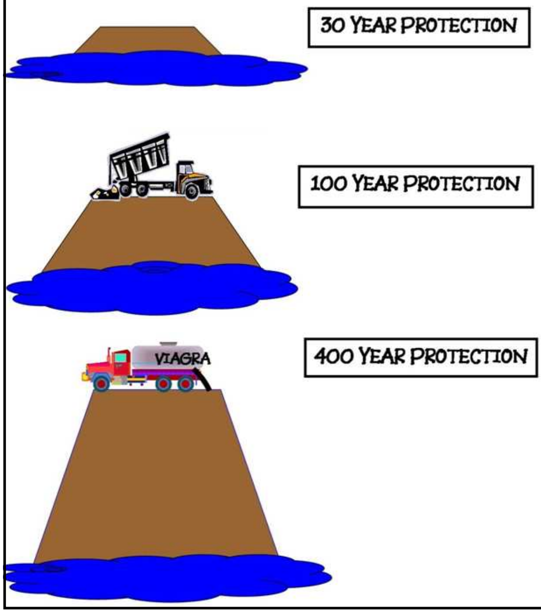
Looking in the past

Note the marks on high water levels (Moselle)

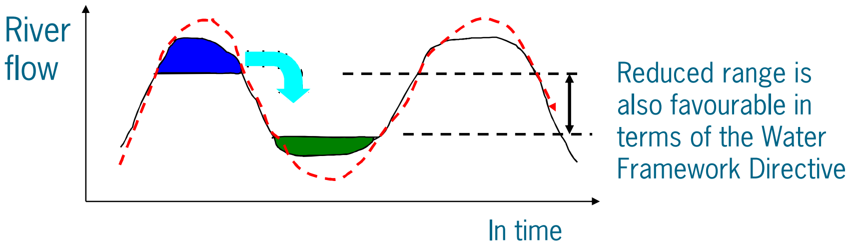
1947 1924 1882 1956 1918 1958 1919 1983

In the past: use of flood levees



There is an end in raising dikes

Strategy: analysis concept



- Reduce floods and droughts

- Further implications of climate change

- Make use of the groundwater system (retain water in the ground)

  Before the wet season have enough storage cap. available to cope with peak flows

  After the wet period save water for the dry period

- Natural flood defenses

  The Ecoflood report gives guidelines

  on how to restore flood plains

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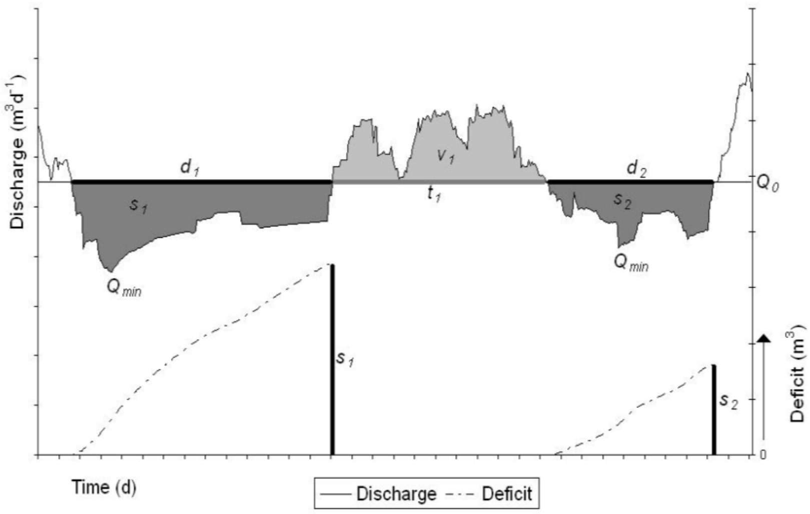
Drought analysis – Threshold method



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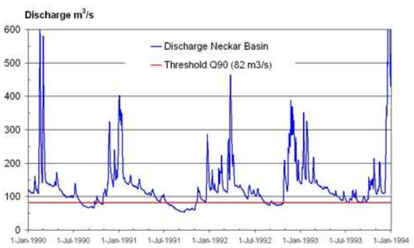
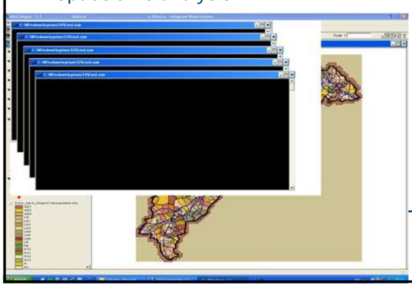
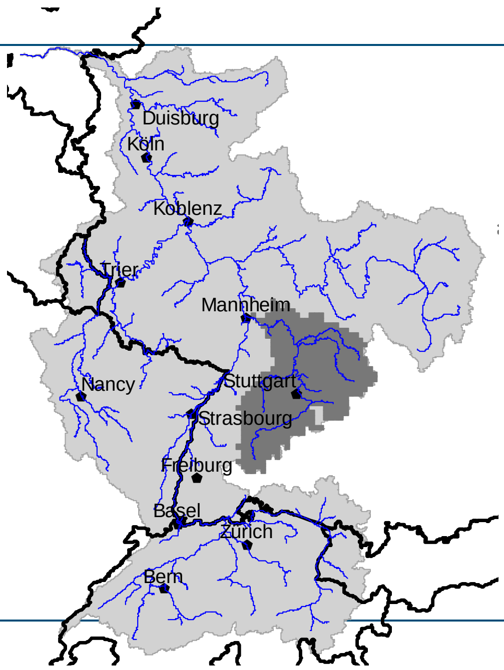
Neckar sub-basin



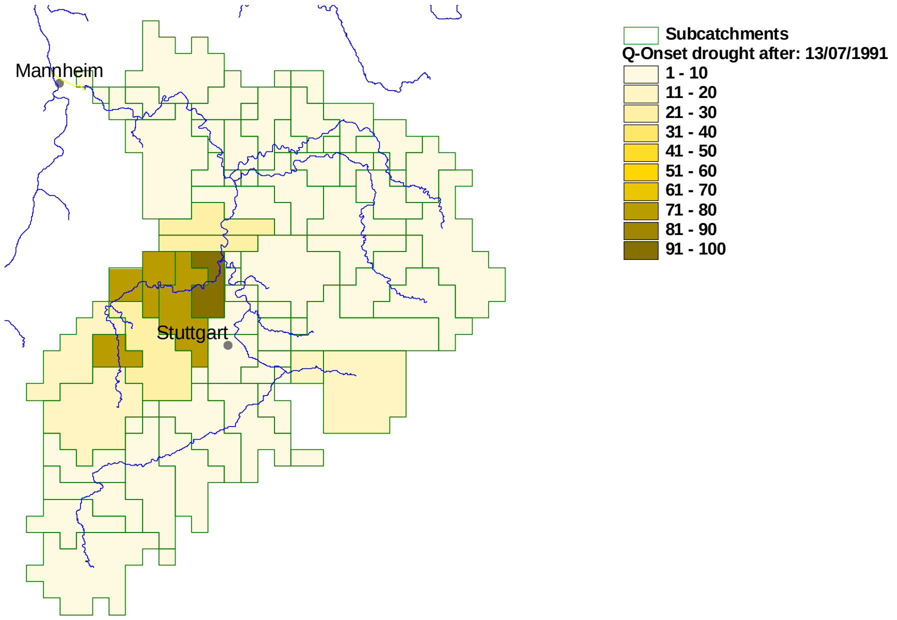
Neckar – outflow

Space-time analysis:

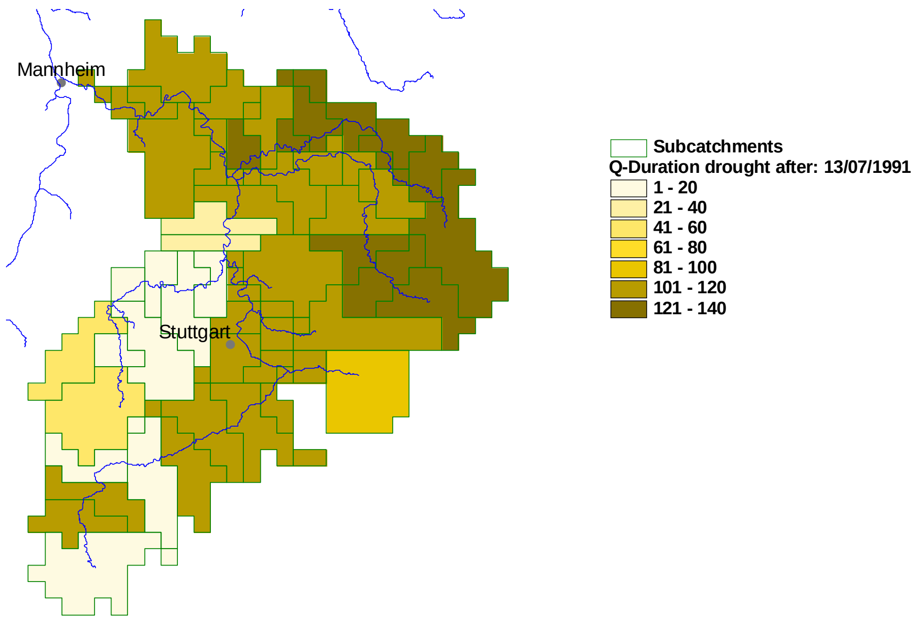




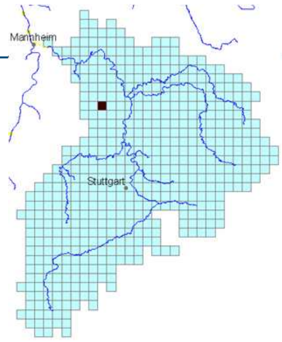
Drought per sub-basin: onset after 13th July 1991



Drought per sub-basin: duration after 13th July 1991

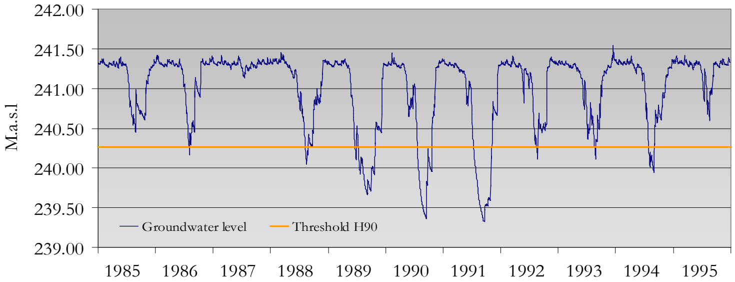


Groundwater levels



or groundwater recharge, drainage

Example for groundwater level:

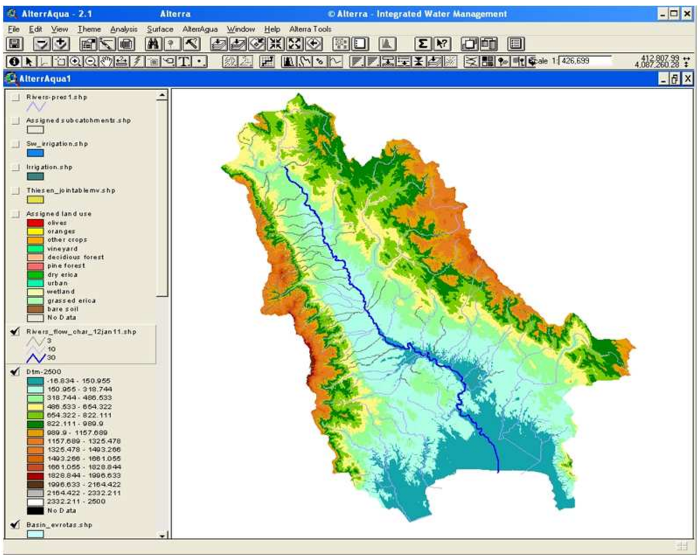


Conclusions

- SIMGRO model: has the ability to model practical situations (scenarios like land use and climate change)
- Climate change has a much larger impact on discharges and droughts than extreme changes in land use
- Consider natural flood defence measures to reduce floods and droughts

Is this the challenge we are facing?

A short demonstration of the user interface AlterrAqua:



Example case study

MIRAGE

Mediterranean Intermittent River ManAGEment

Case study sites

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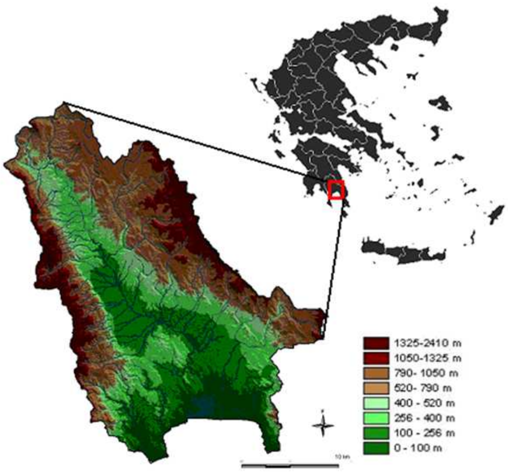
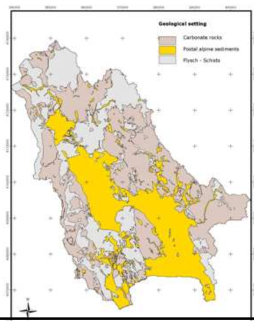
Evrotas River basin, Greece



Catchment:	2420 km^2
Elevation:	0 - 2400 m
Precipitation:	870 mm
Evapotranspiration:	811 mm

Geology: Karst and sediments



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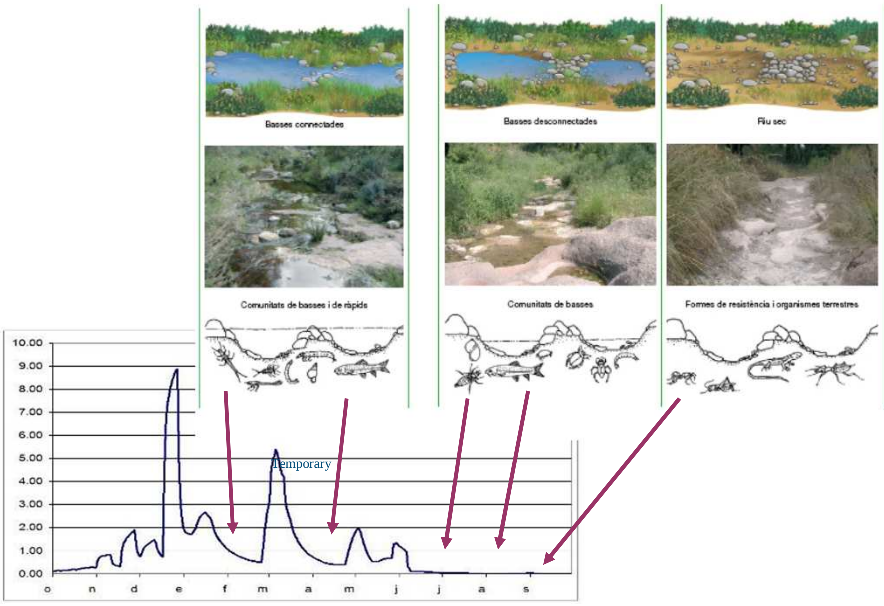

Linking hydrology to ecology

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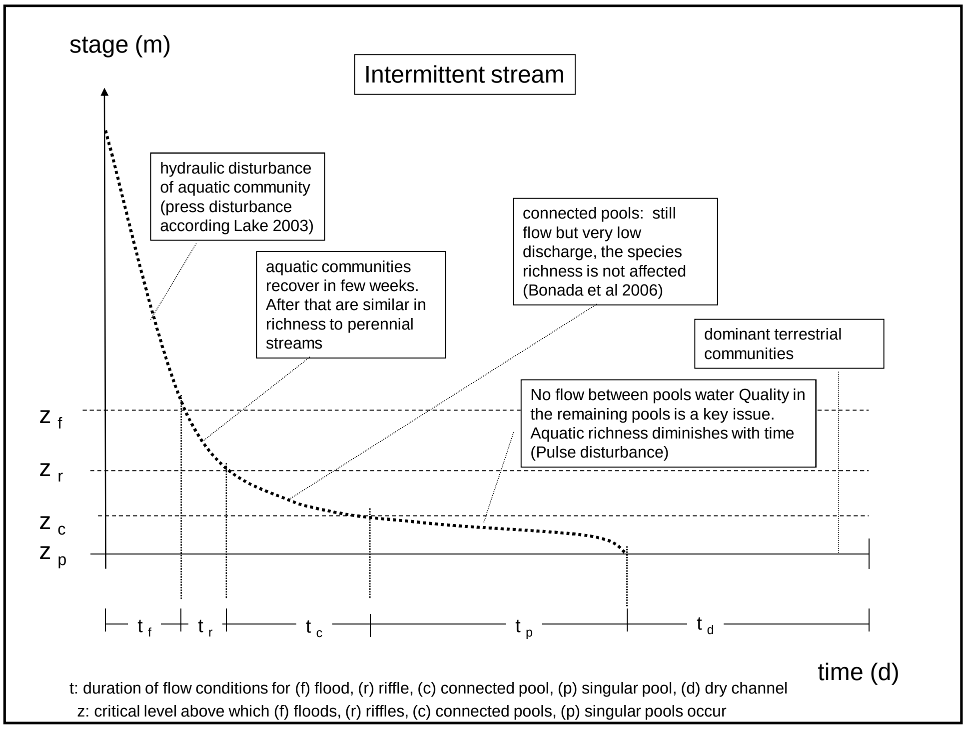
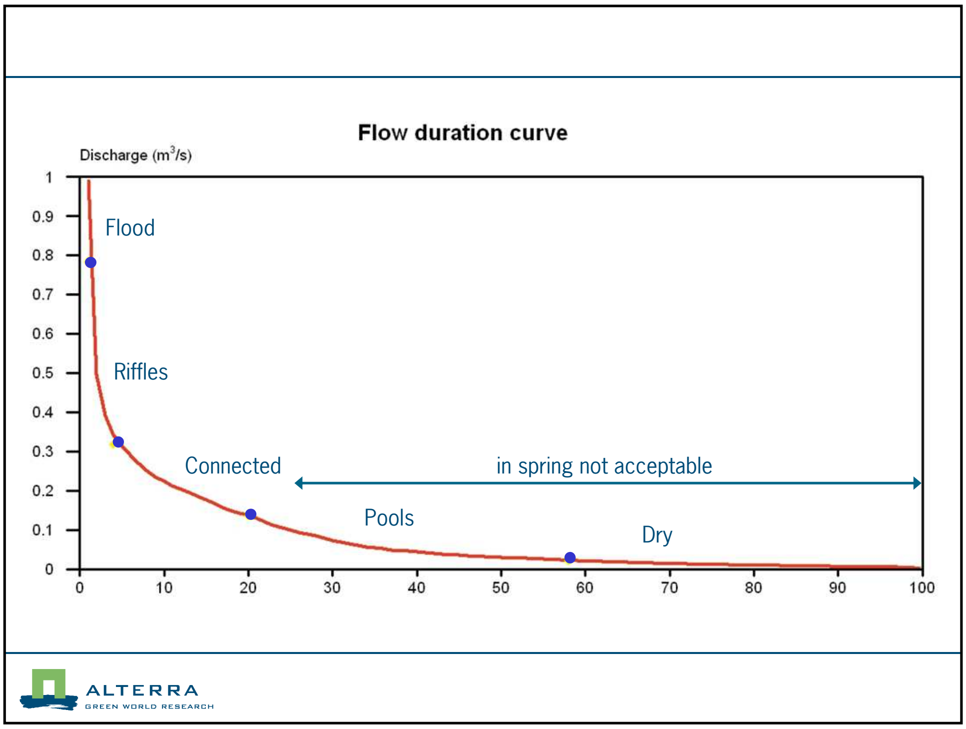

stage (m)
Intermittent stream
hydraulic disturbance of aquatic community (press disturbance according Lake 2003)
aquatic communities recover in few weeks. After that are similar in richness to perennial streams
connected pools: still flow but very low discharge, the species richness is not affected (Bonada et al 2006)
dominant terrestrial communities
No flow between pools water Quality in the remaining pools is a key issue. Aquatic richness diminishes with time (Pulse disturbance)
Z f
Z r
Z c
Z p
t f
t r
t c
t p
t d
time (d)
t: duration of flow conditions for (f) flood, (r) riffle, (c) connected pool, (p) singular pool, (d) dry channel
z: critical level above which (f) floods, (r) riffles, (c) connected pools, (p) singular pools occur


Flow duration curve
Discharge (m3/s)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
70
80
90
100
Flood
Riffles
Connected
Pools
Dry
in spring not acceptable
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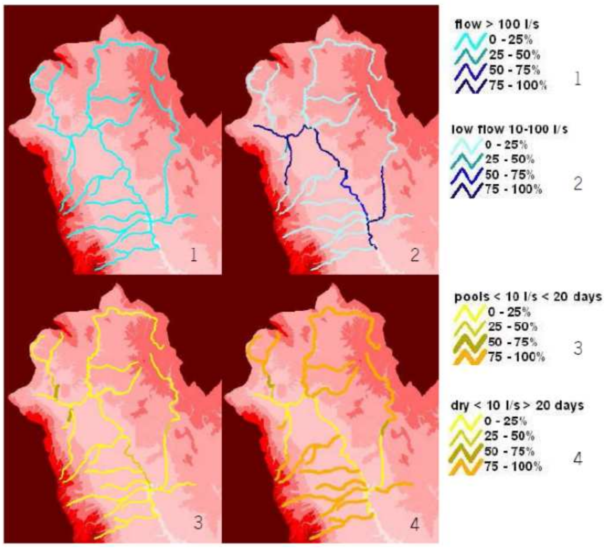

Upstream part:

Flow characterization:

Dry; pools; low flows; flowing

Visualize changes for different **irrigation** intensities

Acceptable from an **ecological** point of view

August 2007


Thank you