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TheWaterChannel Webinar #9

October 25, 2013

1300 GMT

Groundwater in a global perspective:
Unveiling what local studies fail to notice

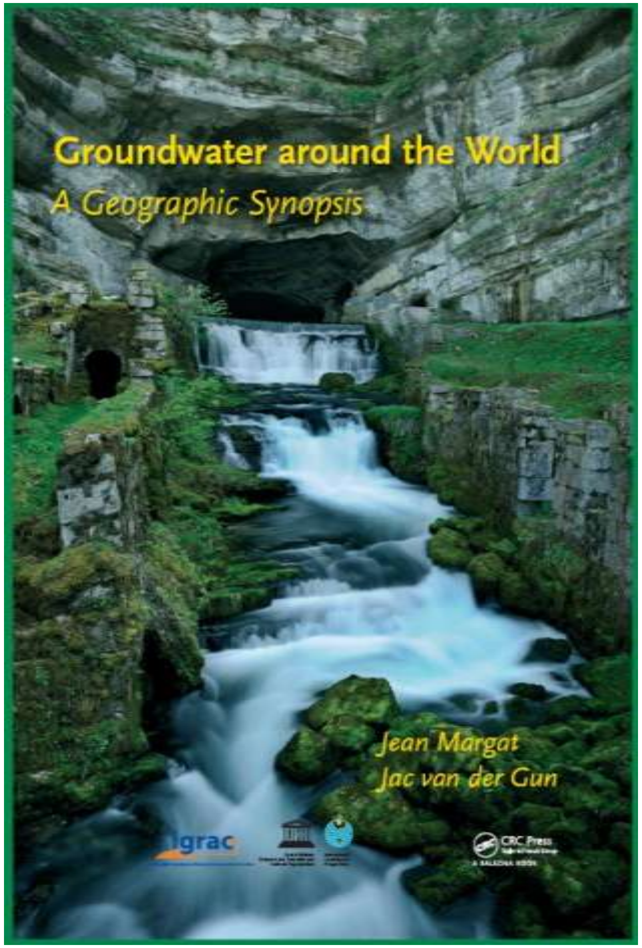
Selected highlights taken from the book

'Groundwater around the World: A Geographic Synopsis'

(Jean Margat & Jac van der Gun, 2013)

Jac van der Gun

Global-scale compilation on groundwater: 'Groundwater around the World'



Introduction

Groundwater in the global water cycle

The world's groundwater systems

Groundwater resources

Groundwater withdrawal and use

Growing needs for management interventions

Groundwater resources management

Final comments

Emphasis on compiling, summarising and showing facts and figures

Easily accessible to non-groundwater specialists

Contributes to shared knowledge base and shared views as an input to groundwater governance

See http://www.crcpress.com/browse/category/WSE05A

Why a *global* or *supra-national* perspective? Isn't groundwater a *locally* exploited resource?

Scientific curiosity

Improved understanding

- *Natural phenomena, processes, patterns and underlying factors*
- *Role and relevance of groundwater in the human society*
- *Interdependencies and impacts of human interventions*

Benefiting from studies/experiences elsewhere

- *Similarities as a guidance for investigation and interpretation*
- *Identifying opportunities and problems, and how to deal with them*

Identifying important global and regional issues

- *Groundwater depletion and related issues (e.g. sea-level rise)*
- *Groundwater quality degradation risks, mechanisms, patterns and trends*
- *Groundwater and climate change (buffers, increasing water scarcity, atolls)*
- *Etc....*

Window # 1:

Quantities of groundwater present below the surface

How does groundwater occur in the subsurface?

land surface

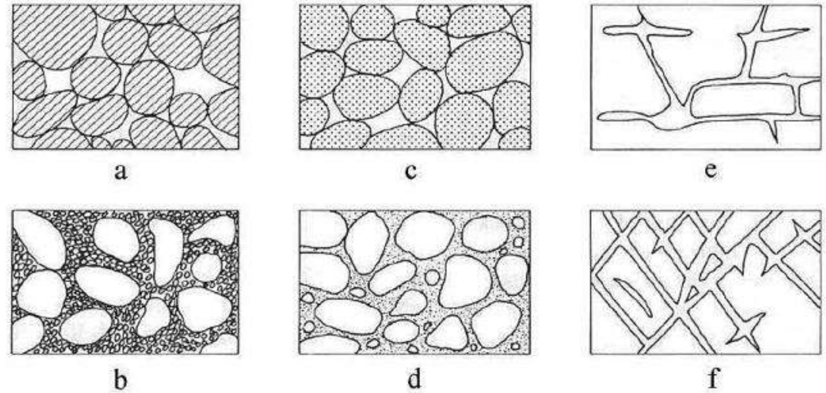
‘dark’ subsurface

Groundwater?

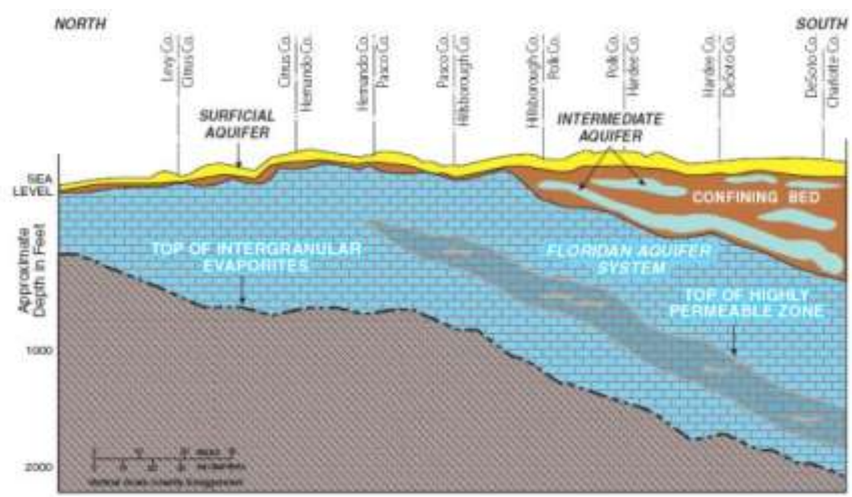
How groundwater occurs in the subsurface depends to a large extent on the local geology

Key factors defining the occurrence of groundwater in the subsurface

- **Type and interconnection of open spaces in the solid matrix *(pores and fissures)***

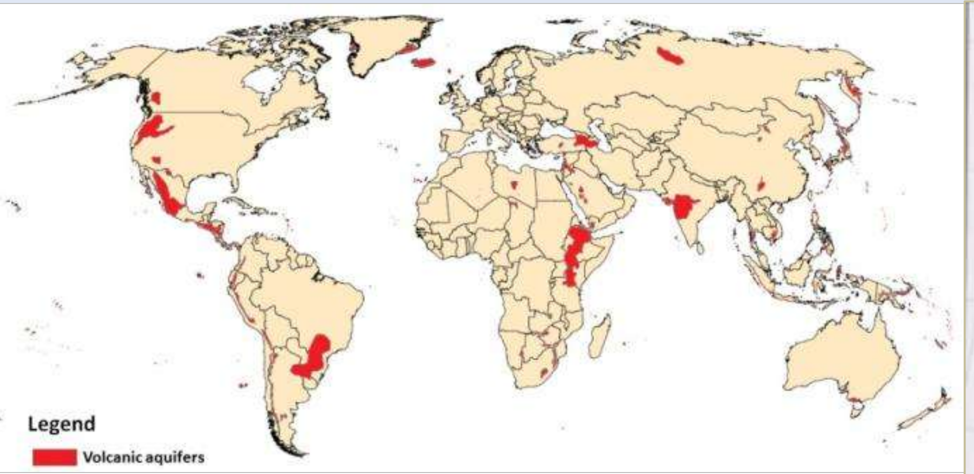


- **The regional structures *(aquifer = reservoir + 'highway' for ground-water flow)***

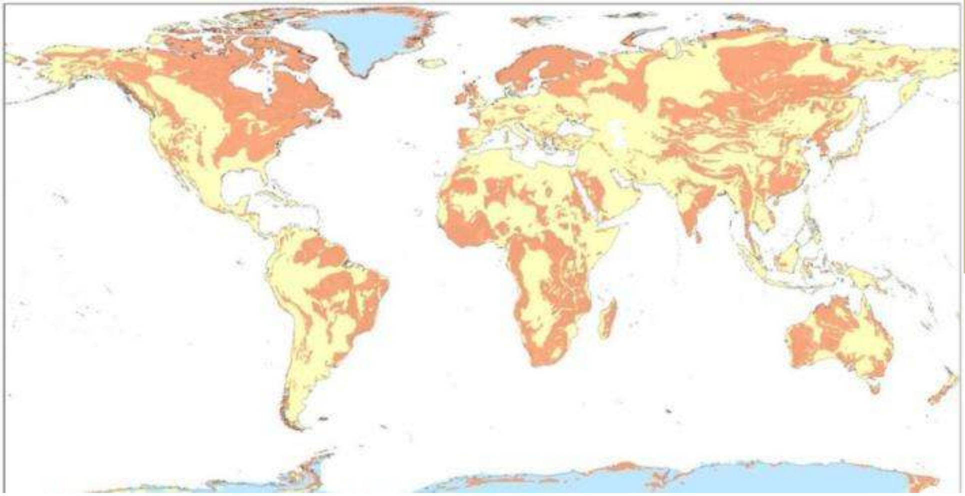


- **Presence/absence of water in the open spaces: *depends on hydrological setting***

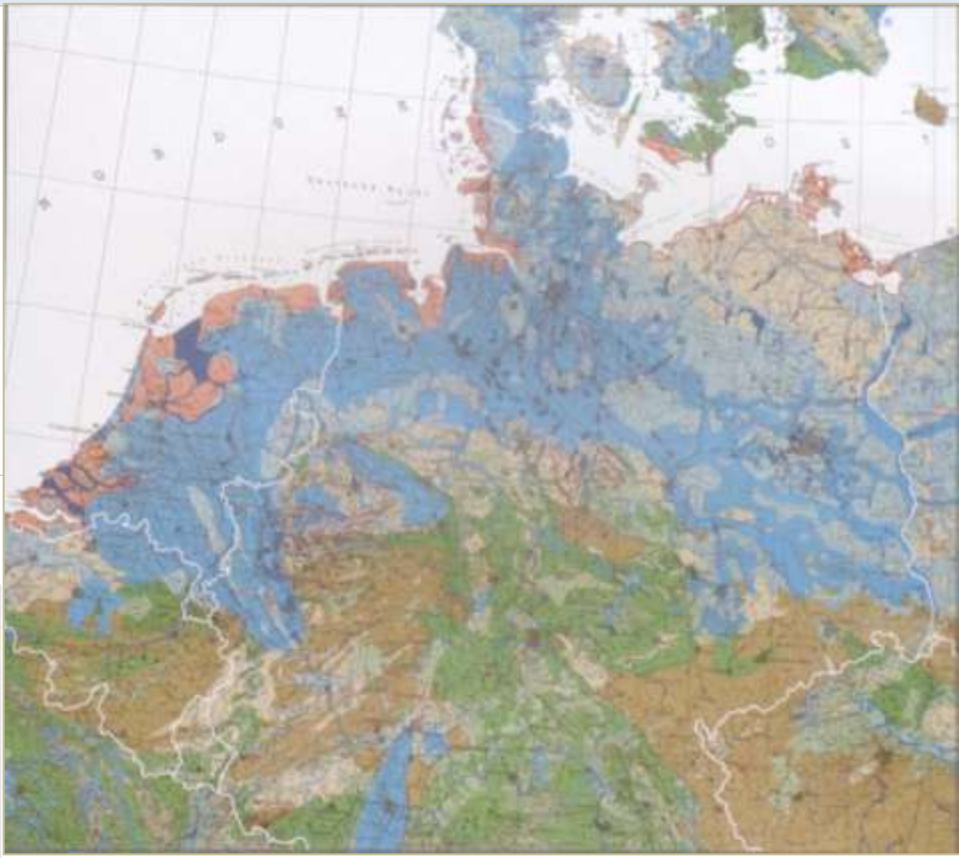
Maps are excellent tools to present aggregated knowledge on the groundwater setting



The world's largest volcanic aquifer complexes



Basement aquifer complexes around the world

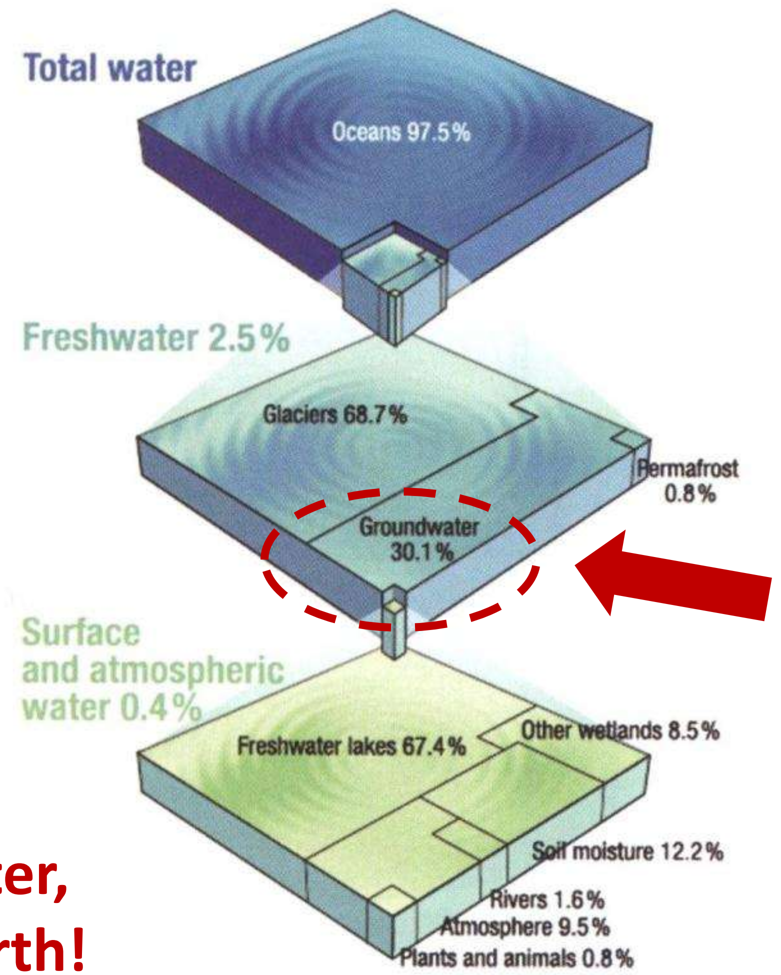


Fragment of hydrogeological map of Europe

Total quantity of groundwater on Earth

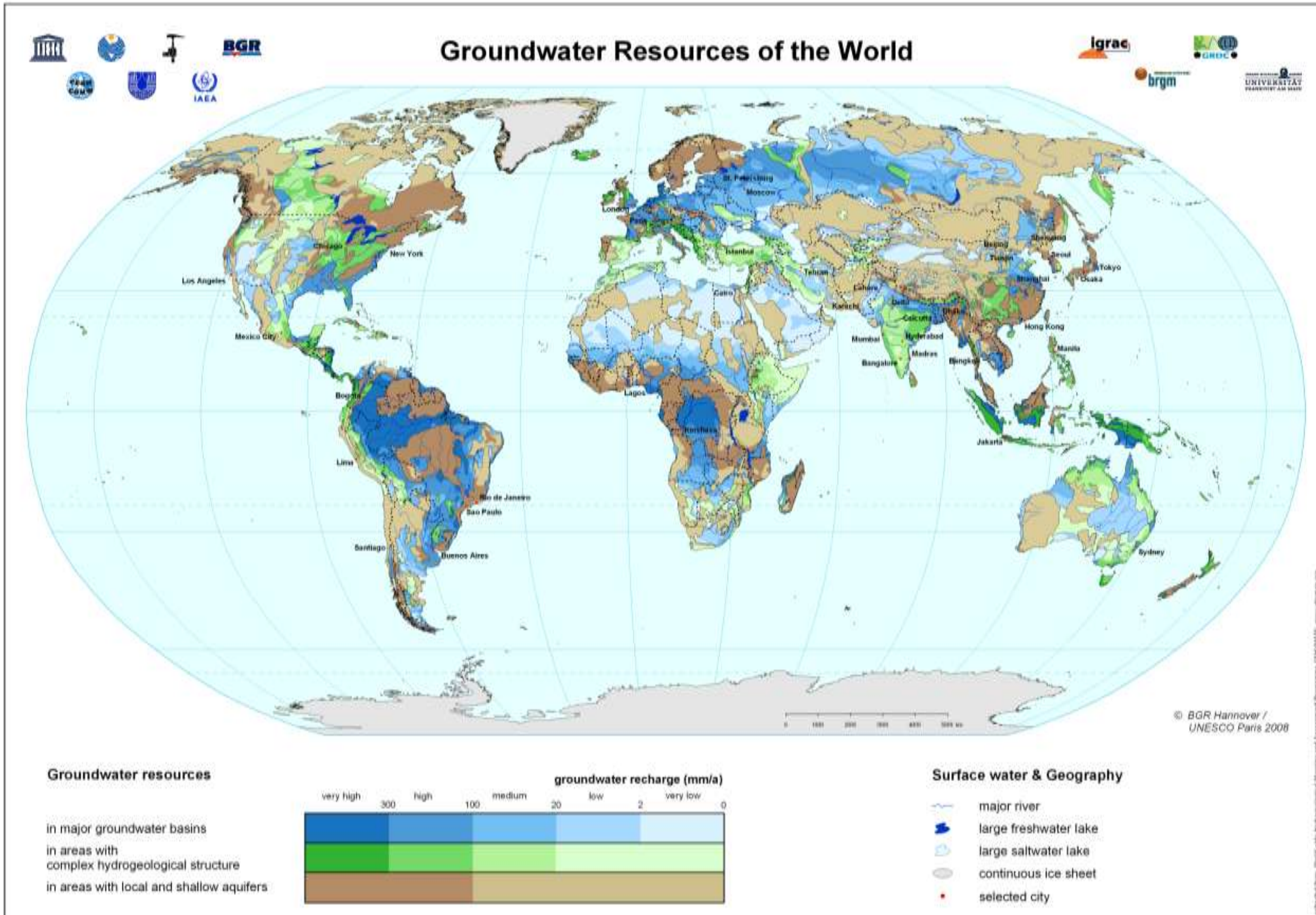
Globally aggregated estimates, for all depths down to 2000 m:

- Total = 22 million km^3
- Of which 10 million km^3 is fresh groundwater

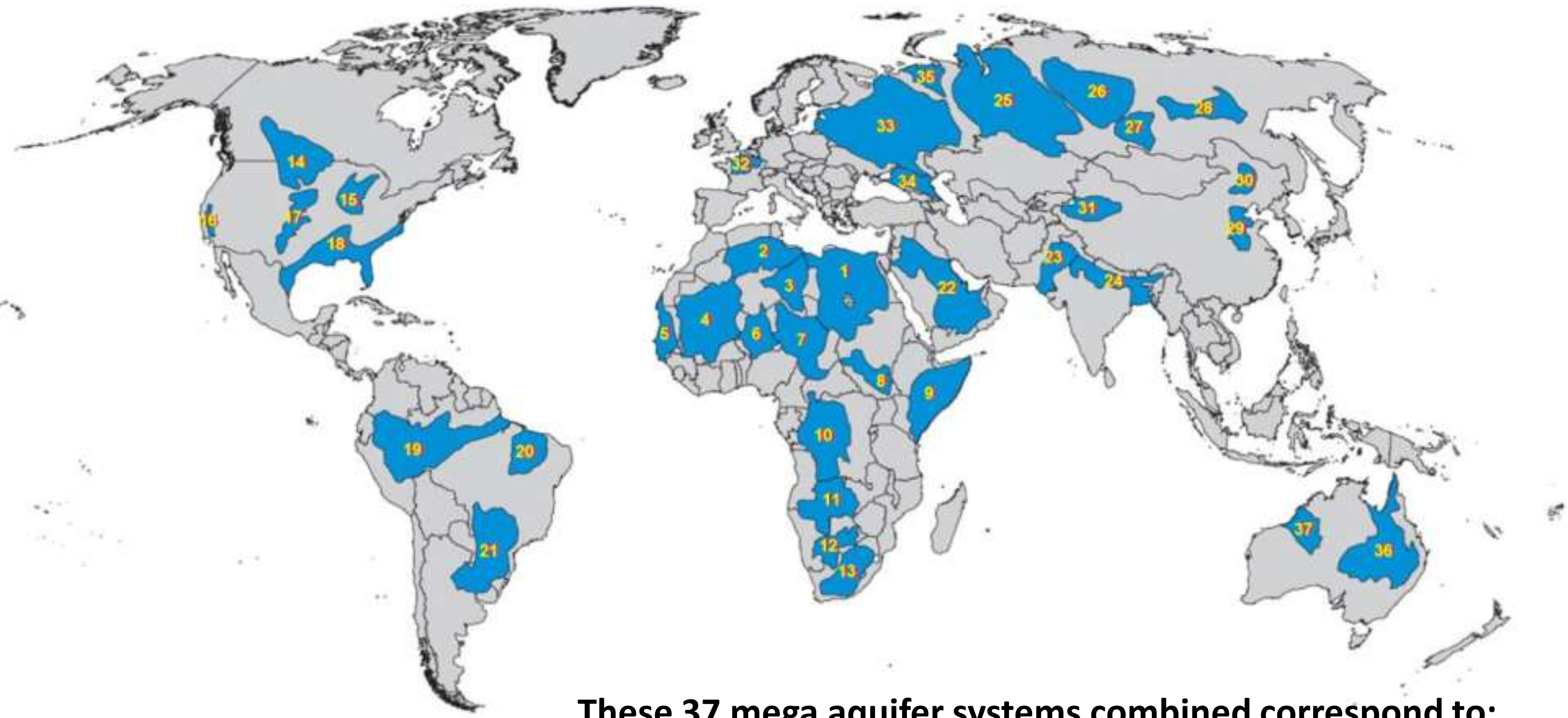


Groundwater represents 1% of all water, but 99% of all liquid freshwater on Earth!

Groundwater reservoirs on Earth: WHYMAP



Groundwater reservoirs on Earth: Mega aquifer systems



These 37 mega aquifer systems combined correspond to:

- **26% of the global land mass (excluding Antarctica)**
- **68% of the global groundwater volume stored**
- **10% of the global groundwater renewal**

‘Re-discovering’ huge groundwater reserves

Breaking News!

Africa sitting on sea of groundwater reserves

By Chris Wickham
LONDON | Fri Apr 20, 2012 10:12am EDT

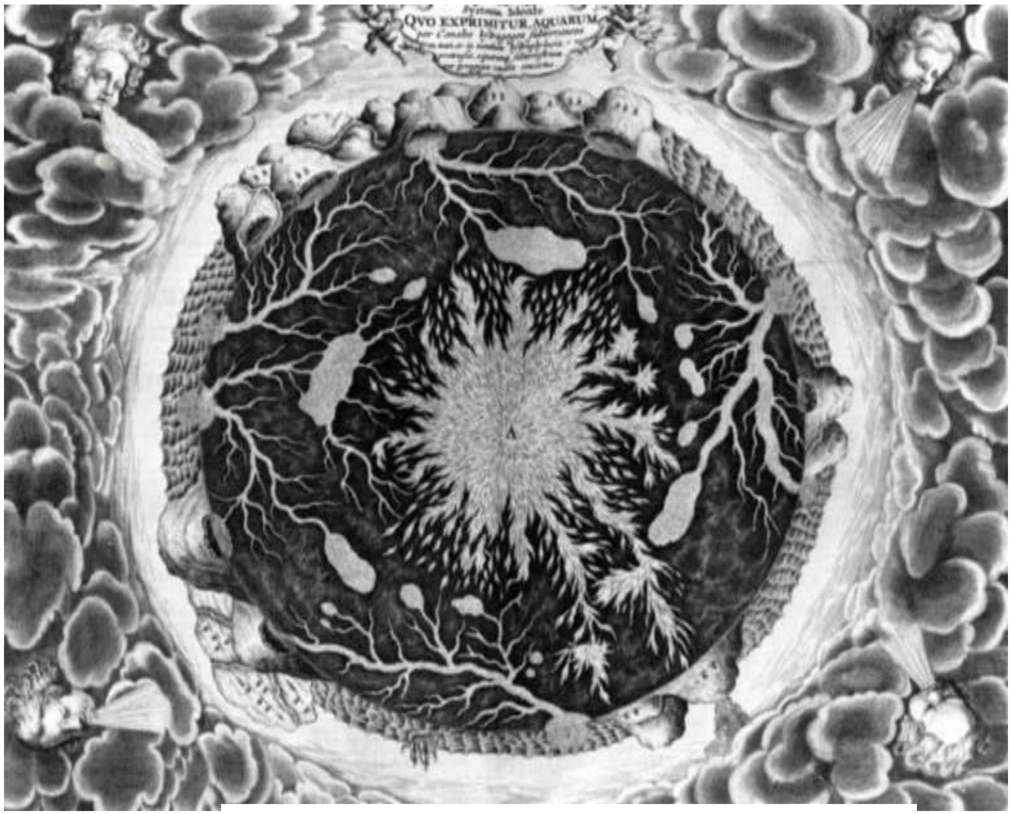
LONDON (Reuters) - Huge reserves of underground water in some of the driest parts of Africa could provide a buffer against the effects of climate change for years to come, scientists said on Friday.

This ‘breaking news’ refers to large North African aquifer systems known and studied already for several tens of years

Window # 2:

Groundwater
and the mysterious Water Cycle

It took long before the hydrological cycle was correctly understood



Athanasius Kircher, 1665

Theories on the origin of groundwater and springs

Oceanus theory

Homeros
Thales of Milete
Plinius the Elder
Johann Kepler
Kircher

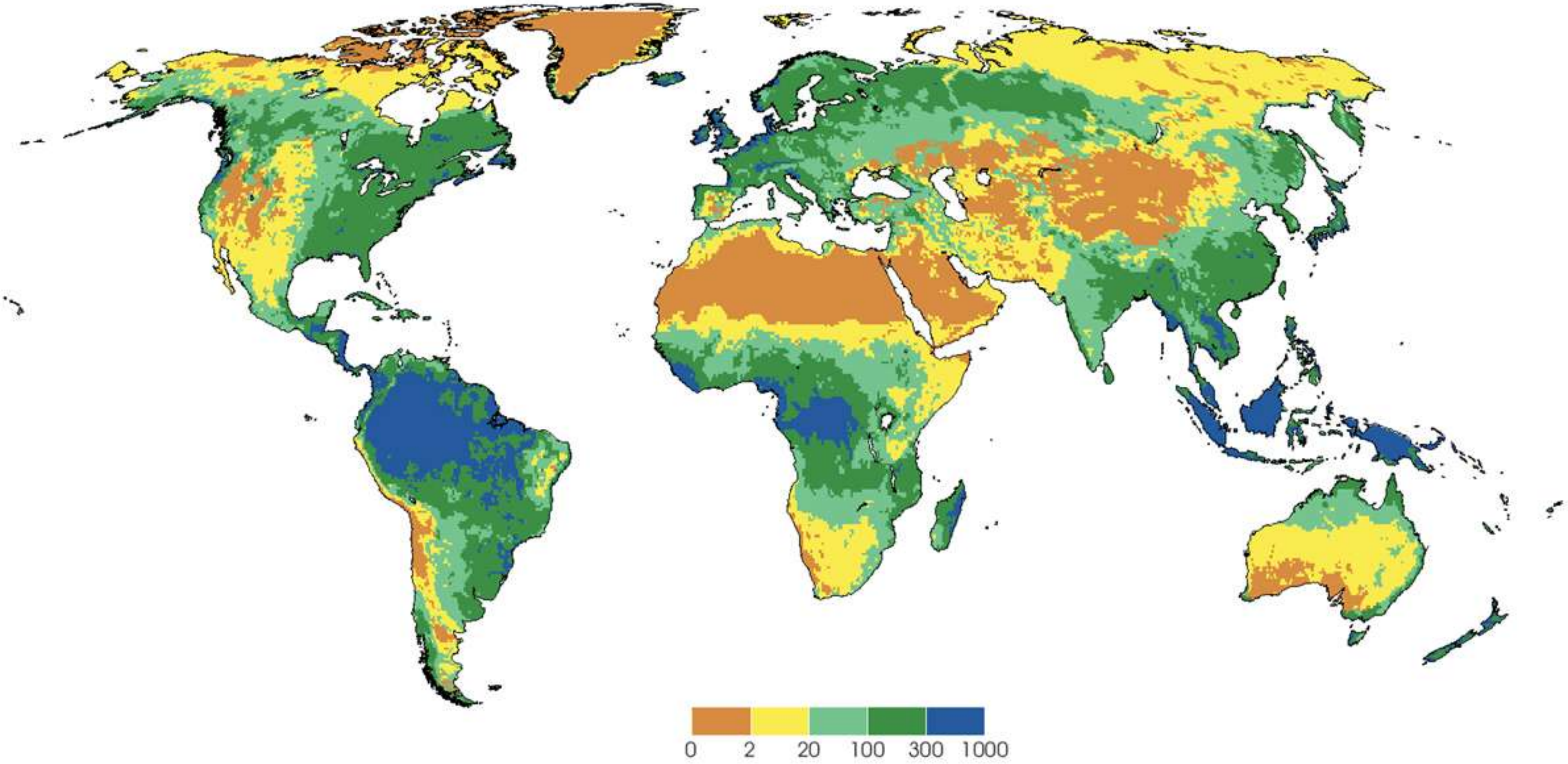
Condensation theory

Aristotle
Seneca
René Descartes

Percolation theory

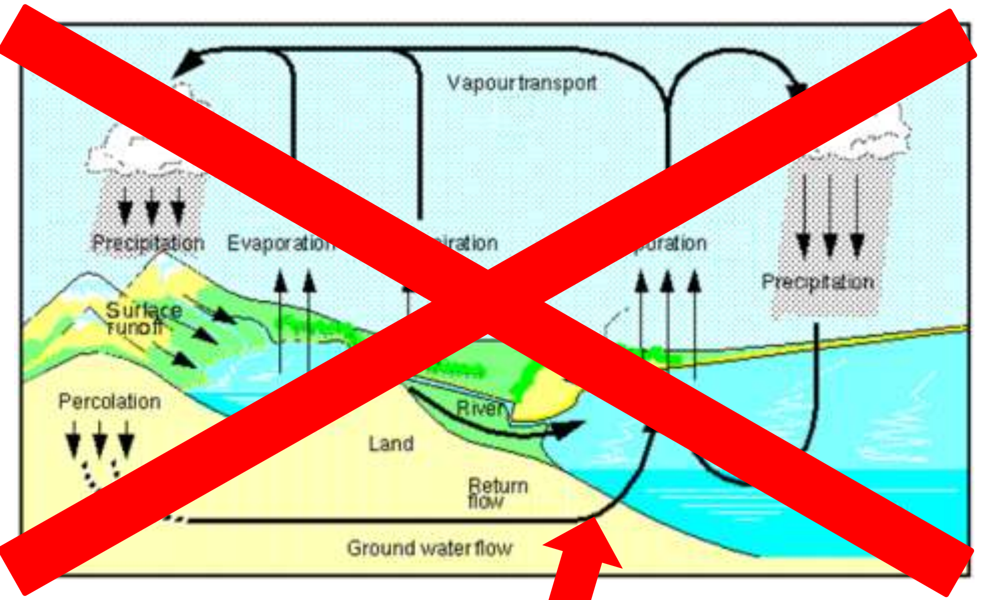
Anexagoras
Vitruvius
Bernard Palissy
Pierre Perrault
Edmund Halley
Edmé Mariotte

Global distribution of mean annual groundwater renewal



Mean annual diffuse recharge, period 1961-1990, in mm/year

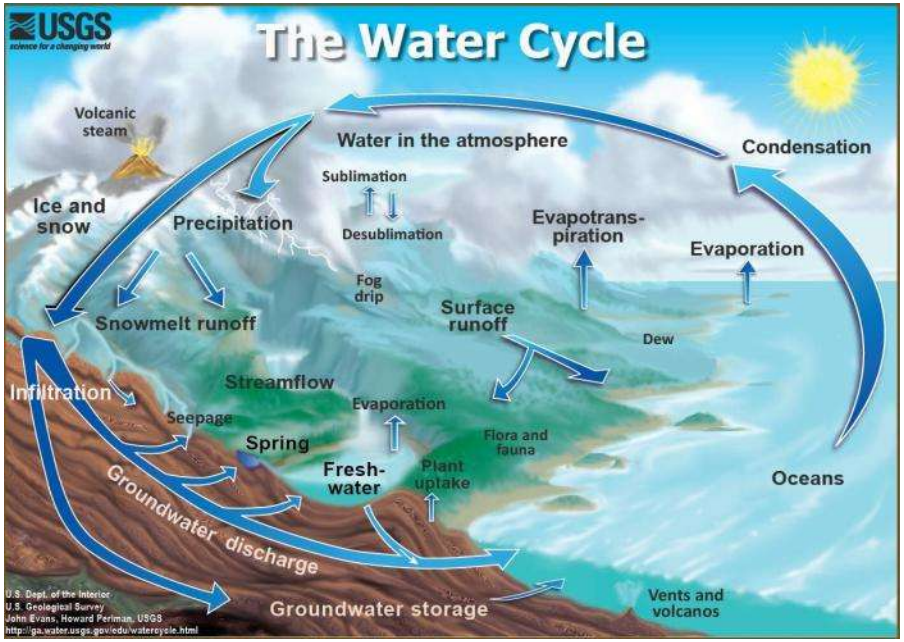
Erroneous views on the relative magnitude of fluxes are still commonplace and persistent ...



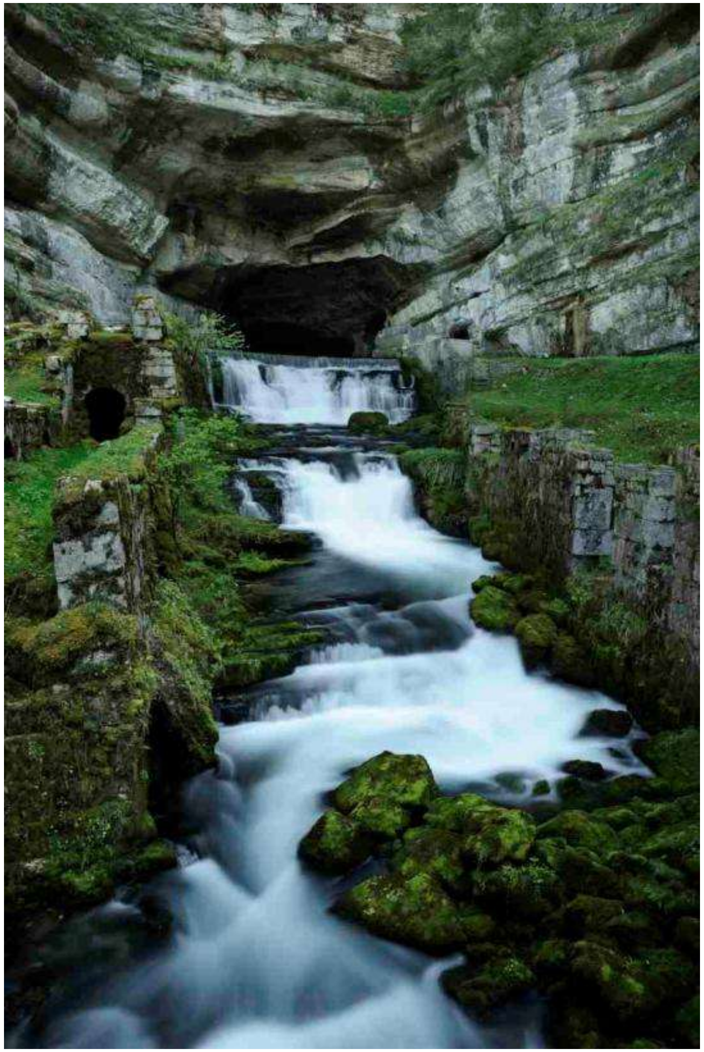
Is direct groundwater outflow into the ocean really the dominant groundwater discharge mechanism?

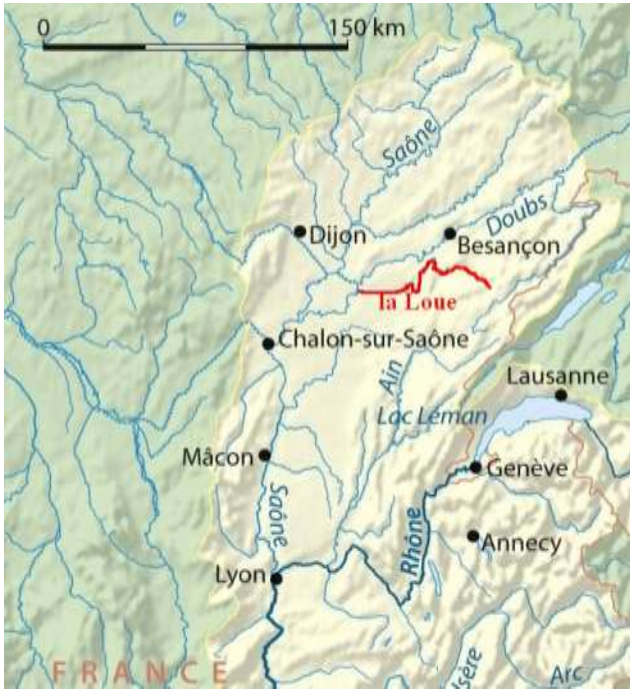
Compiled data reveal:

- 80-90% of the global groundwater flow ends up in streams or is lost by terrestrial evapo(transpi)ration
- Less than 20% discharges directly into sea or ocean



Interplay between groundwater and surface water: karst as an example



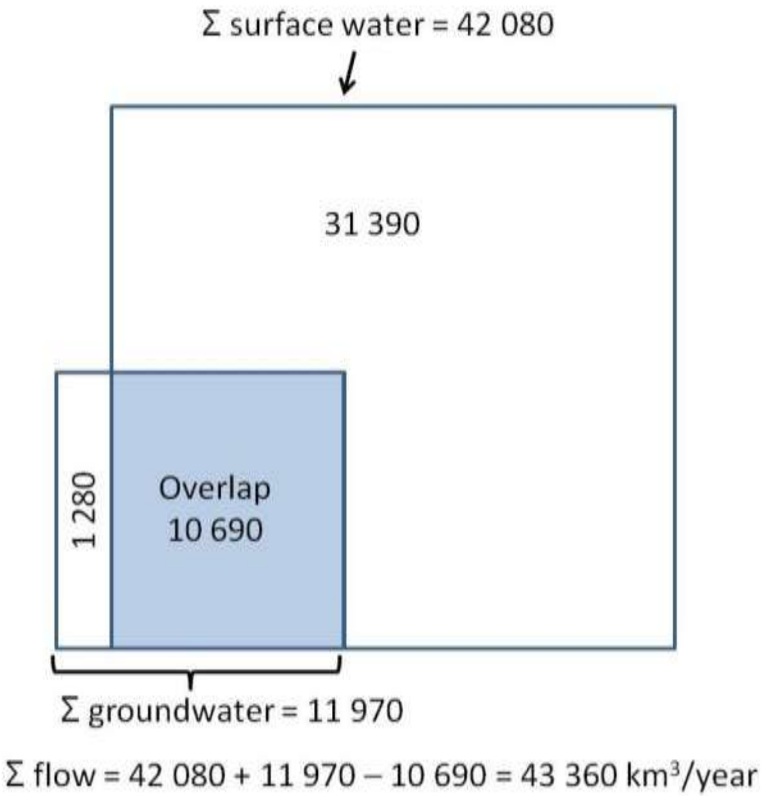


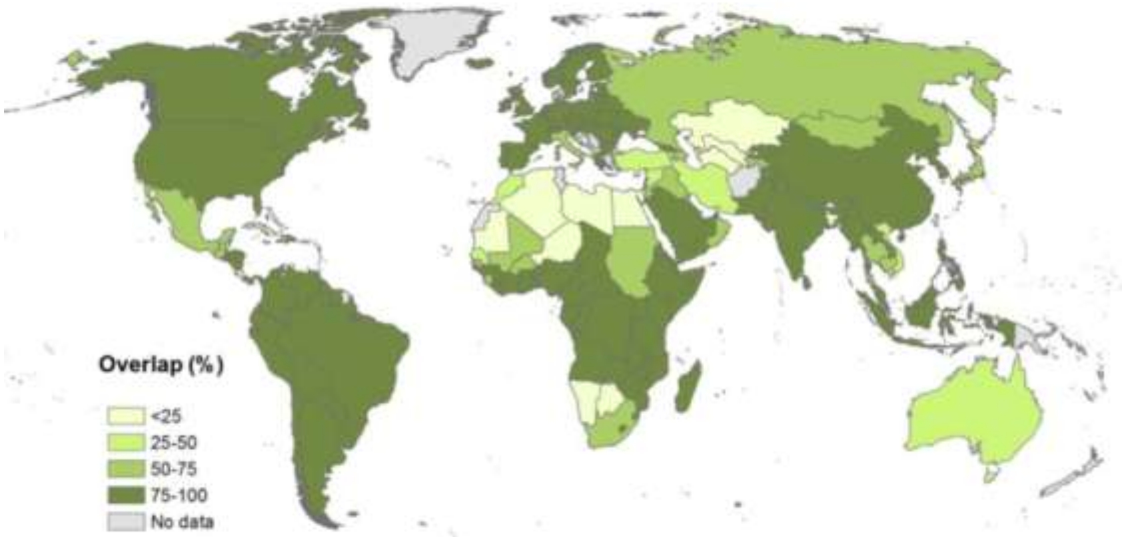
- La Loue river (France) is fed by groundwater through a karst spring
- Groundwater in the karst formation, in turn, is fed by water lost from the Doubs river, more upstream

Interplay between groundwater and surface water: a major source of assessment errors

- **Commonly observed: surface water feeds groundwater and groundwater discharges into surface water, and vice versa**
- **This spatially scattered exchange of water leads easily to confusion and misinterpretation of observations**
- **If the mean annual surface water and groundwater fluxes in one single area are independently assessed, then their sum is overestimating the mean annual renewal of 'blue water'** *(i.e. surface water and groundwater combined)*
- **This sum needs to be corrected for the 'overlap' between groundwater and surface water fluxes, to avoid 'double counting'**

Global groundwater and surface water fluxes and their overlap





Percentage overlap, by country

Global groundwater flux: 27% of total renewal water resources
But overlap with surface water is 89%, globally aggregated

What can we learn from this?

- In spite of its simple conceptual basis *(mass conservation),* assessing the components of the Water Cycle is complex in practice and easily gives rise to errors and large uncertainties

- This it particularly true for the groundwater component: invisible and only to be observed indirectly

- Any estimate of groundwater fluxes or exploitable groundwater resources should therefore be used with caution

- Due to the 'overlap', groundwater resources and surface water resources usually can be properly defined and managed only if viewed together *(IWRM)*

Window # 3:

Getting access to groundwater and bringing it to the surface

Dug wells and non-mechanical water-lifting techniques (1)

6000 BC: wells already present in Mesopotamia

Dug well with pulley, rope and bag

Saqiyah or noria

Shaduf

Dug wells and non-mechanical water-lifting techniques (2)

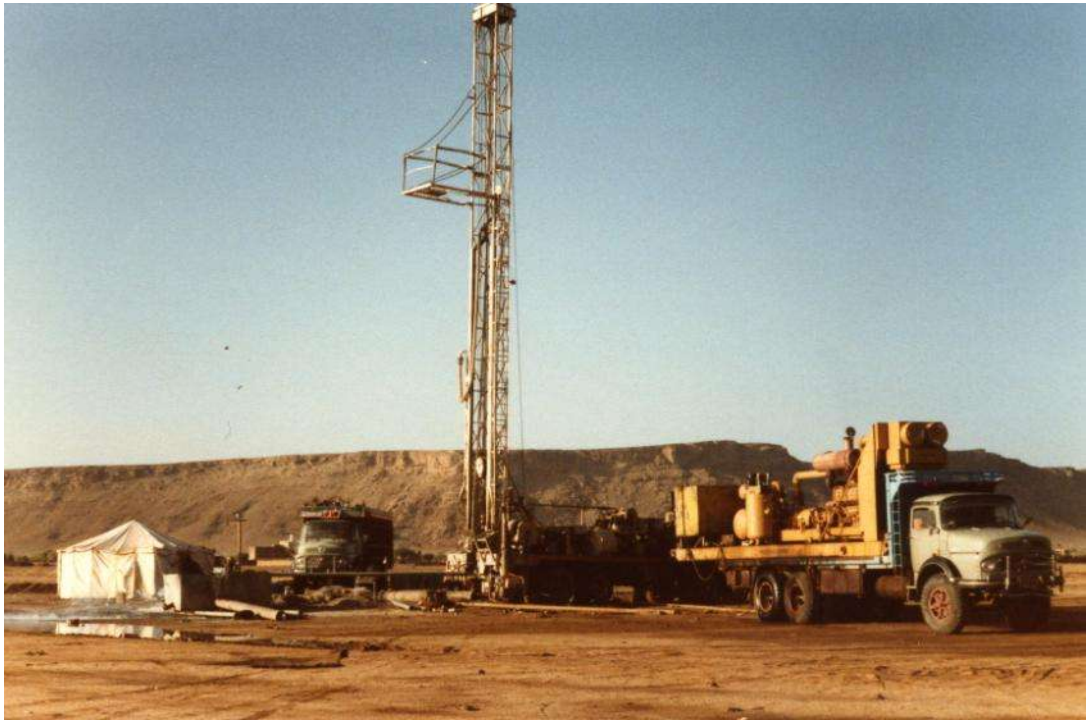
Modern village well with hand pump

Ancient village well with hand pump

Arhor with double pulley

Drilled wells and mechanically powered pumps

Diesel-powered pumped irrigation well



Drilling a well

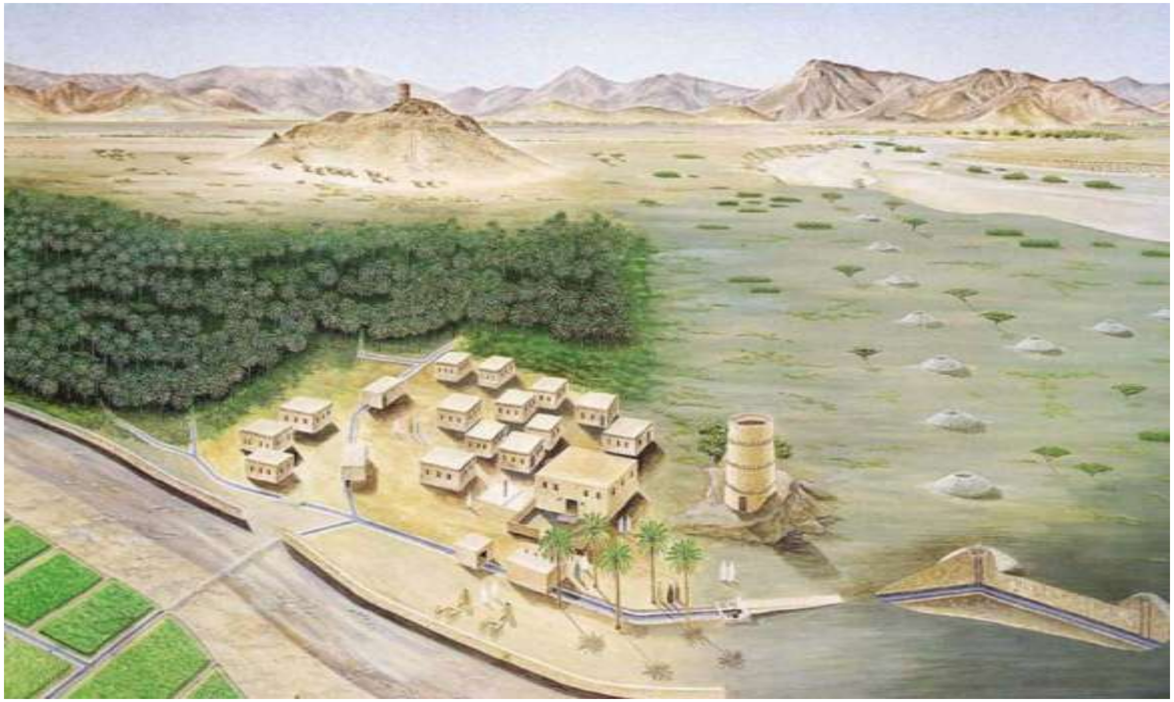
Well with electrically powered pump

Groundwater withdrawal without need for external energy supply

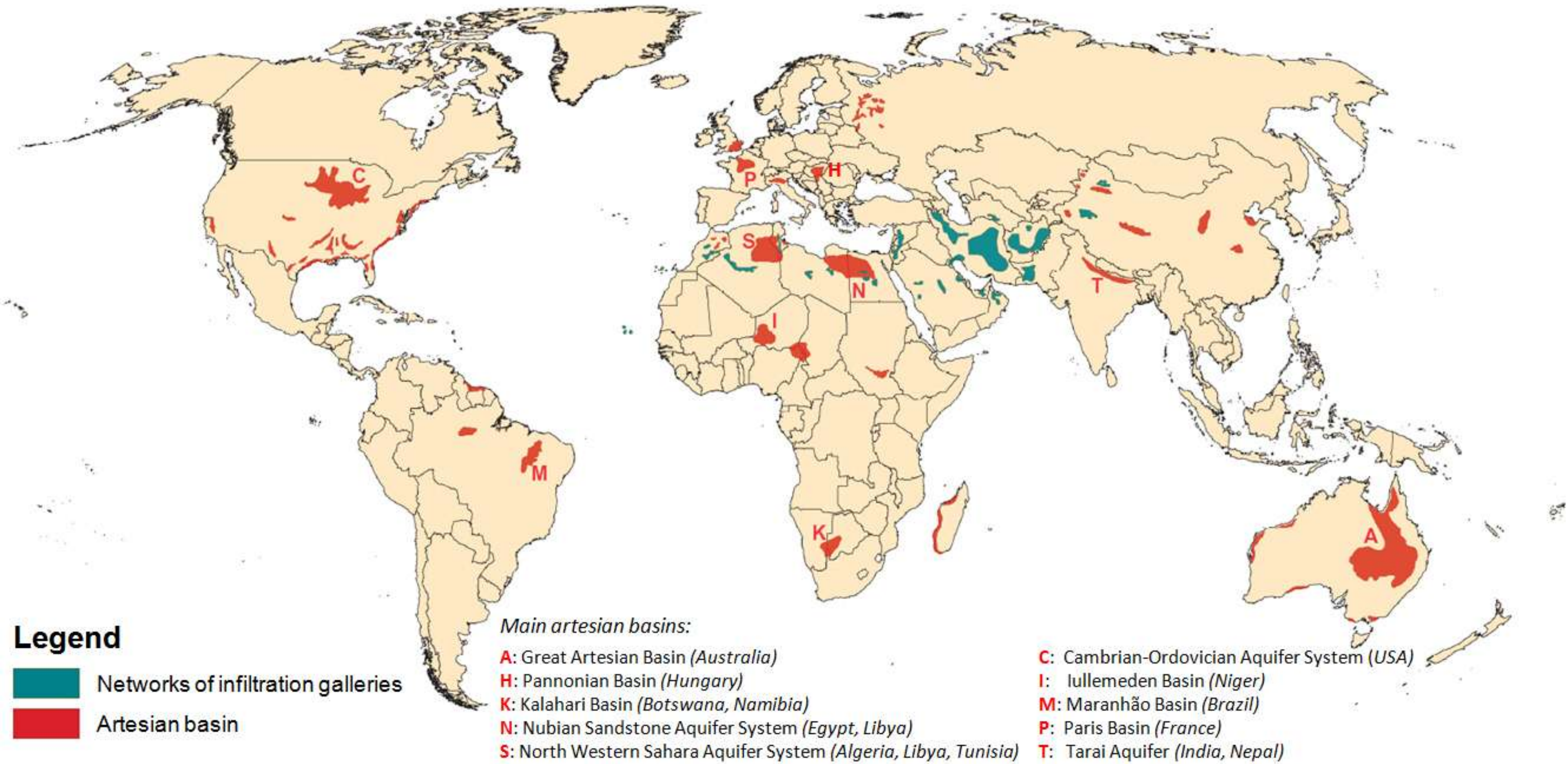
Qanat *(inside view)*

Artesian well *(flowing well)*

Qanat or falaj *(system overview)*



Groundwater withdrawal without need for external energy



Some comments

- **Since time immemorial, a diversity of clever techniques has been developed and widely implemented to bring groundwater to the surface**

- **Before the era of mechanization, emphasis was on gravity-based abstraction works or on minimizing muscular energy demand for systems designed for relatively large discharge** *(e.g. for irrigation)*

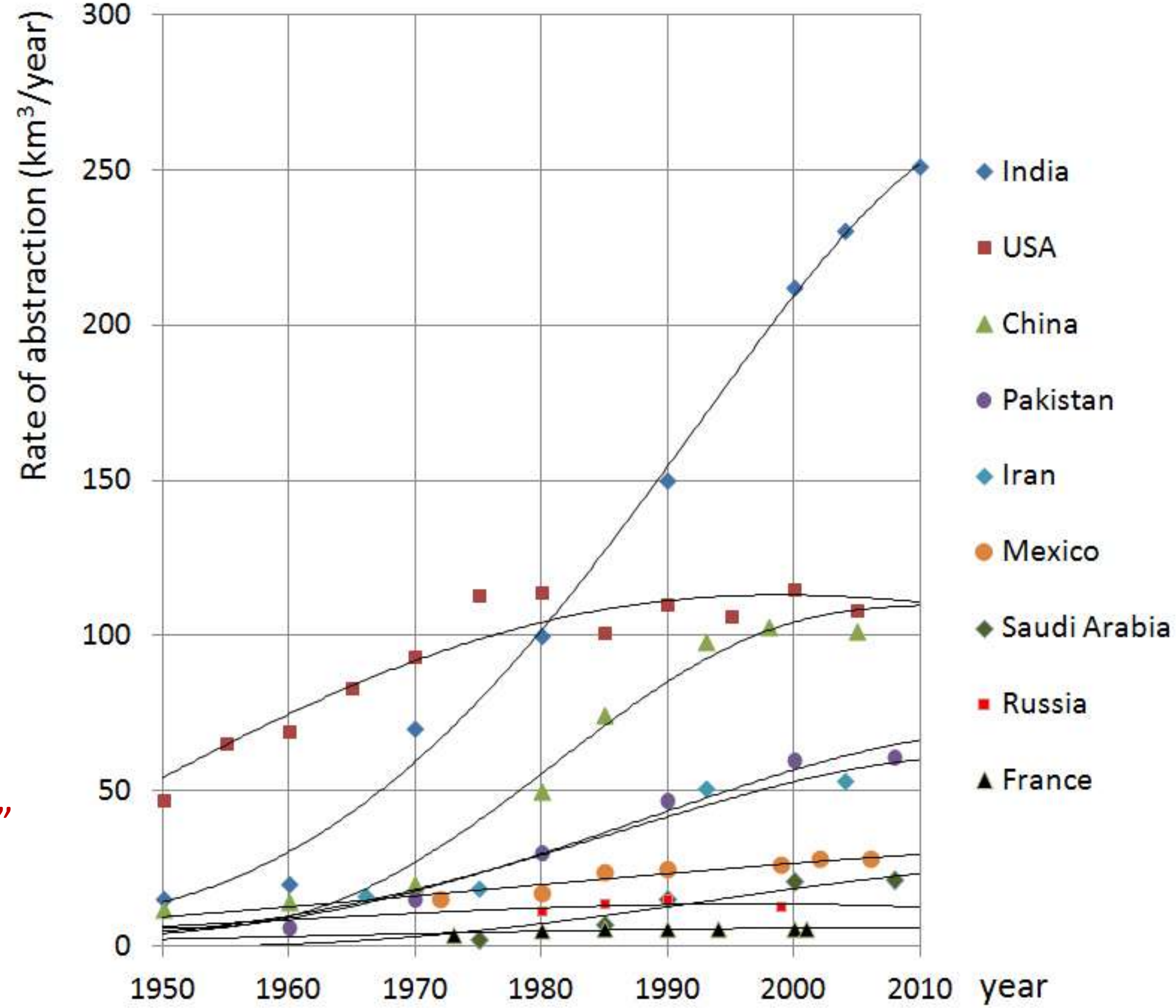
- **During the 20th century, mechanized pumps *(diesel or electricity)* were widely introduced, causing a revolutionary increase in groundwater withdrawal** *(benefits + negative impacts)*

- **Systems using gravity or muscular energy only have not become obsolete, because of some economic and environmental comparative advantages. The scope for gravity-based withdrawal, however, is gradually decreasing.**

Window # 4:

Groundwater abstraction and use

Booming groundwater abstraction during the second half of the 20th century



"The silent revolution"

(M.R. Llamas)

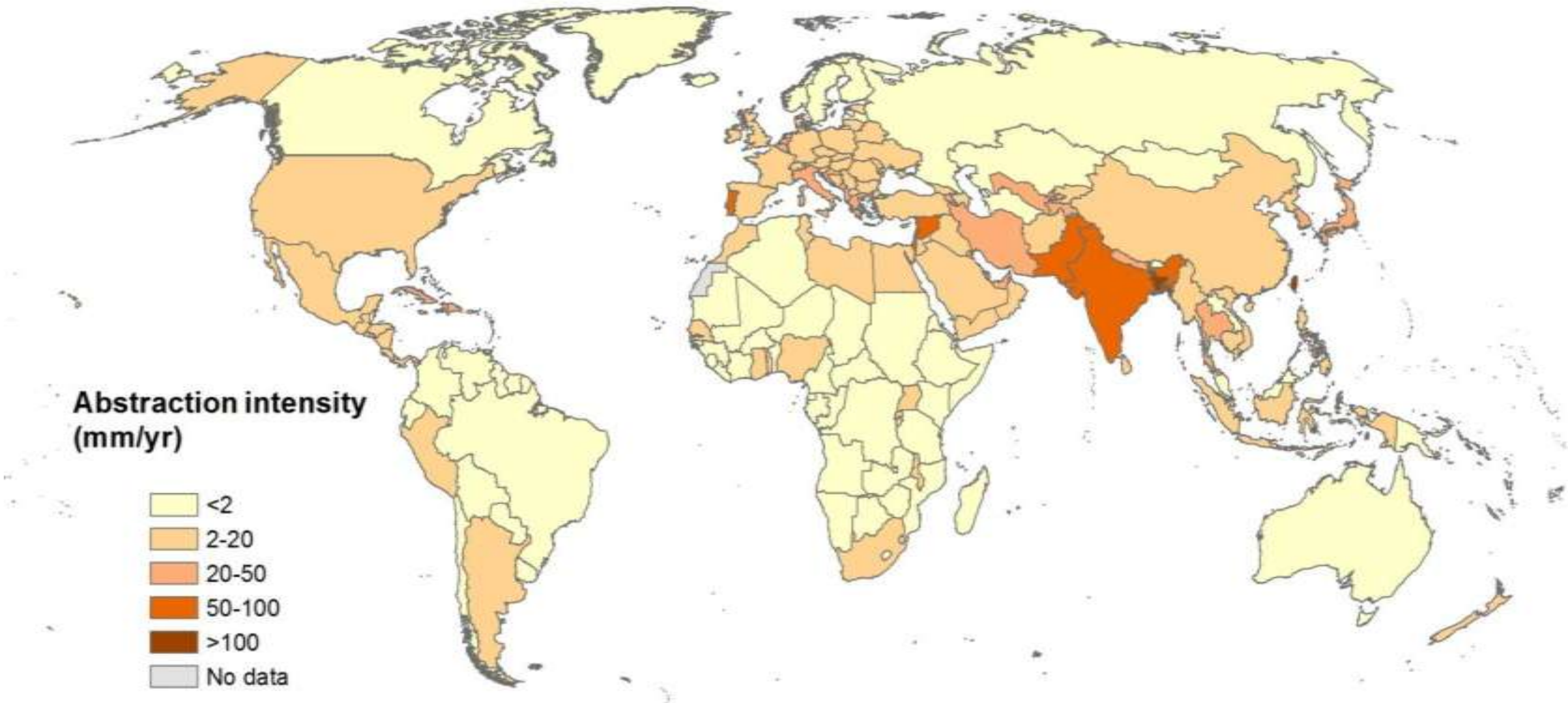
Volume and intensity of the world's groundwater abstraction – year 2010

Global groundwater abstraction in 2010: 982 km^3/yr

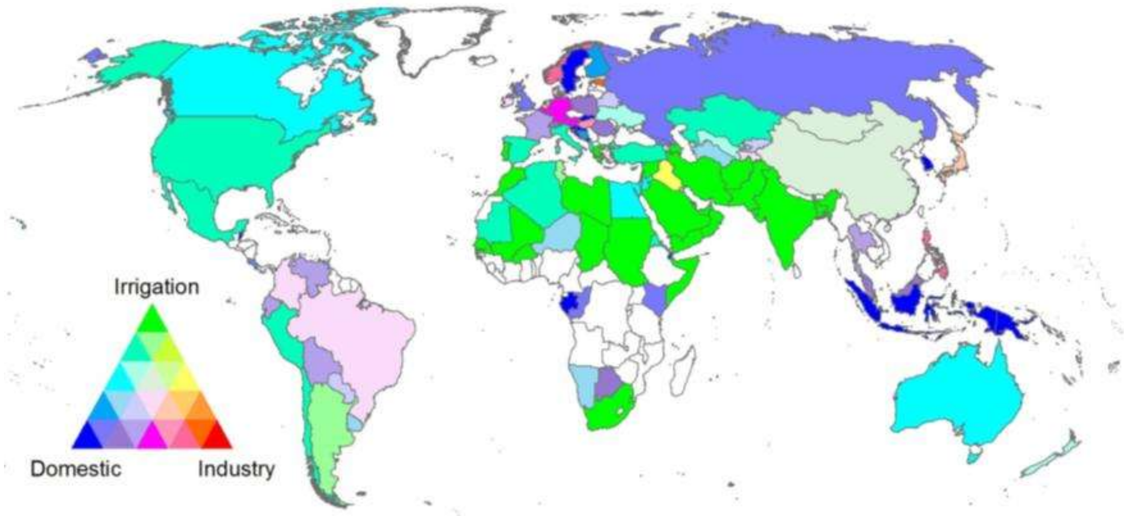
(Equivalent to 26% of total freshwater abstraction, but its share in added value is higher)

India + USA + China abstract 48% of this

Intensity, by country:



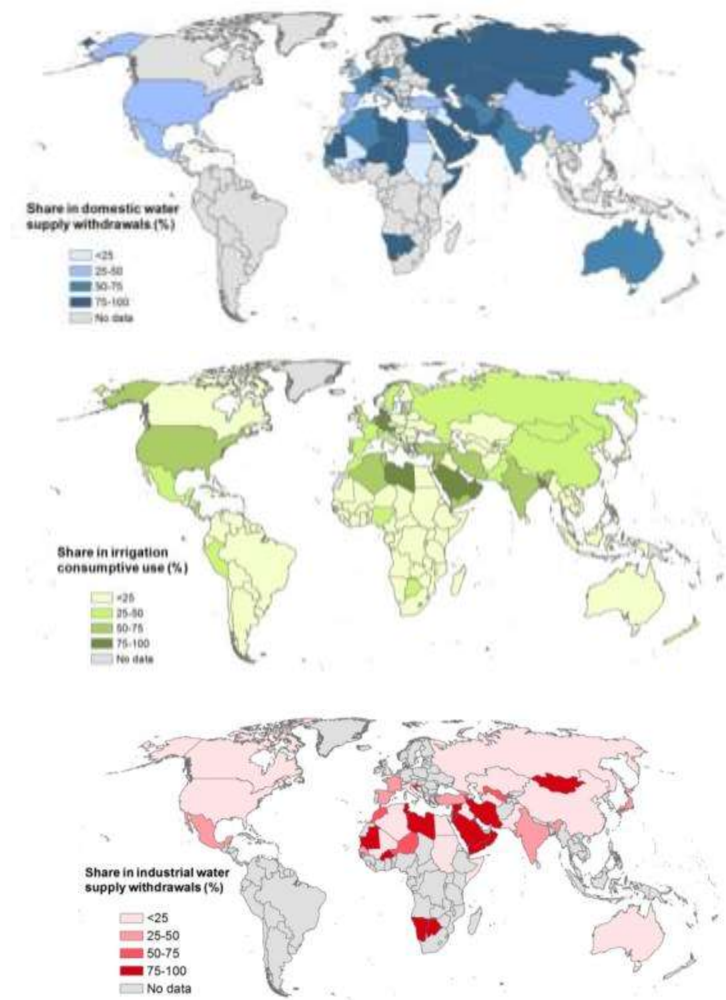
Groundwater abstraction and the three main water use sectors



Global abstraction breakdown by sector:

- 70% for irrigation
- 21% for domestic water
- 9% for industrial purposes

Groundwater share in each sector

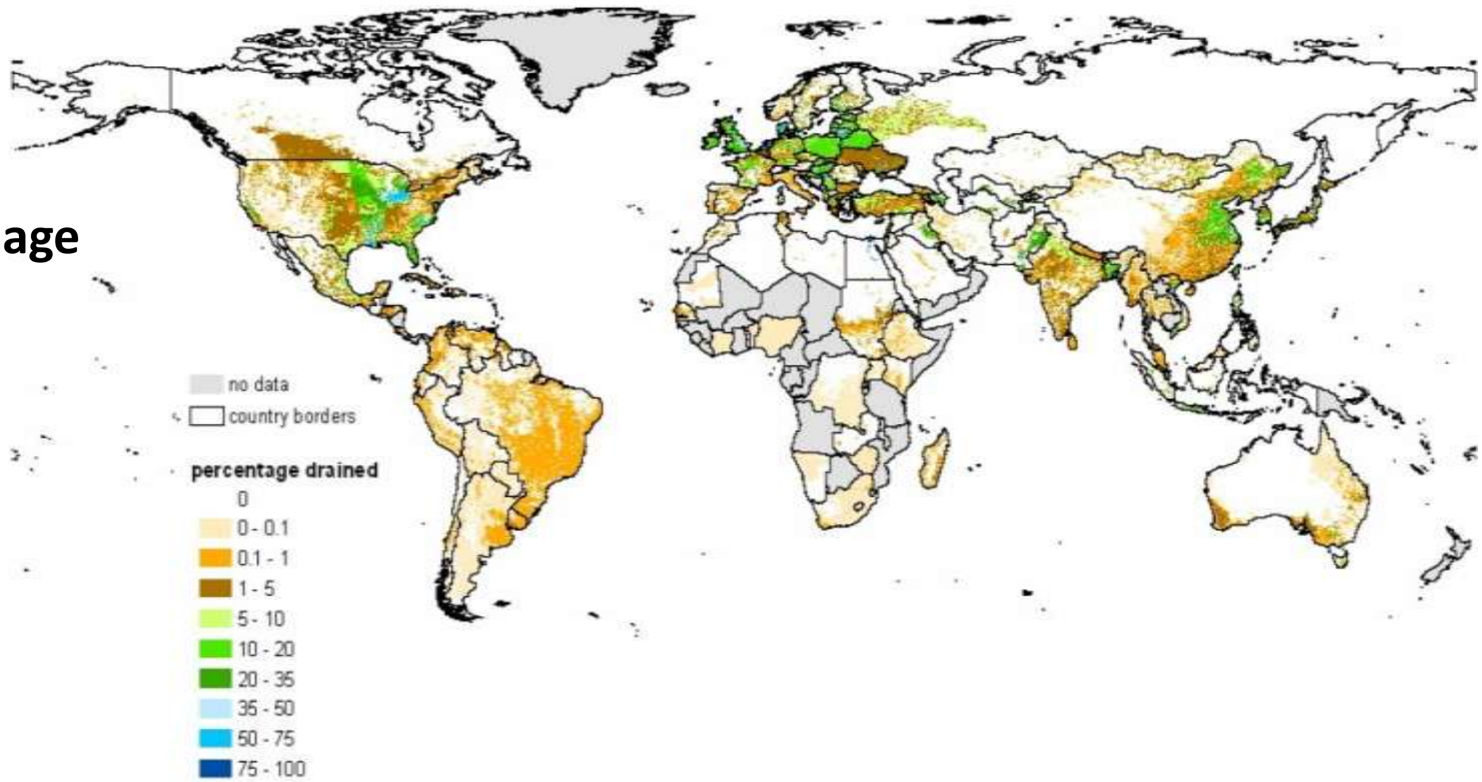


Window # 5:

Other human concerns and interactions with groundwater

Man-made drainage: withdrawing groundwater without the purpose to use it

(1) Land drainage



(2) Drainage for purposes of mining and/or use of the subsurface

It is difficult to assess the quantities of groundwater withdrawn by drainage

Sustainable ecosystems, springs and baseflows

Very sensitive to changes in groundwater level

Groundwater-related instability of the land surface

In sensitive zones, groundwater pumping may lead to collapsing surface (sinkholes) or land subsidence

Groundwater for energy

Development of geothermal energy:

- about 67 000 GWh produced in 2010
- 0.3% of global electric power production
- potential is much higher
- *pumped water is re-injected*
- USA, Philippines, Indonesia, Mexico, Italy, New Zealand, Iceland, Japan, ...

Subsurface heat storage:

- emerging technology
- using heat storage capacity of groundwater
- stored heat is recovered by heat pumps
- *pumped water is re-injected*
- Europe, USA , Canada, Japan, ...

And there is more ....

For instance:

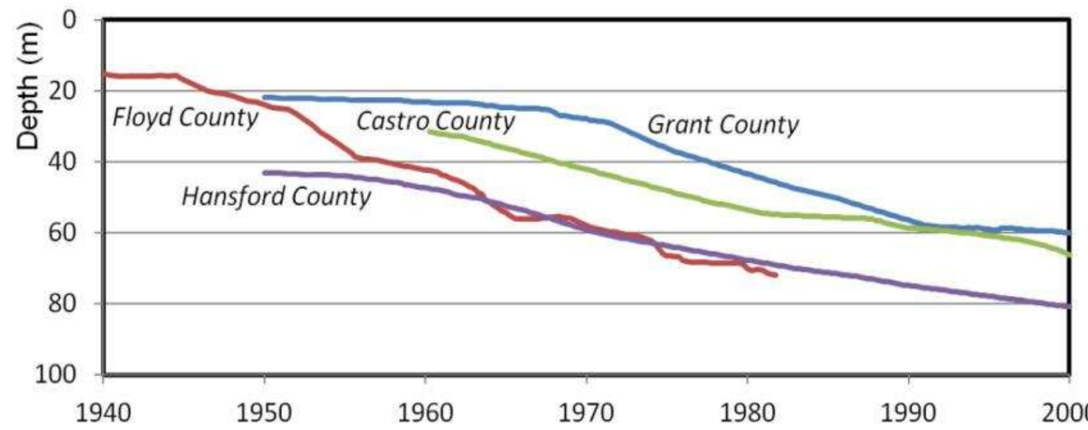
- **Thermal baths or spas**
- **Speleology and karst tourism**
- **Fish ponds**
- **Oil and gas industry**
  (including controversial 'fracking' for shale gas development)
- **Groundwater as a subsurface ecosystem ...**

Window # 6:

A few important groundwater management issues

Key issue 1: Steady decline of groundwater levels and its impacts

This phenomenon is observed in many *intensily exploited aquifers* around the world, in particular in dry climates



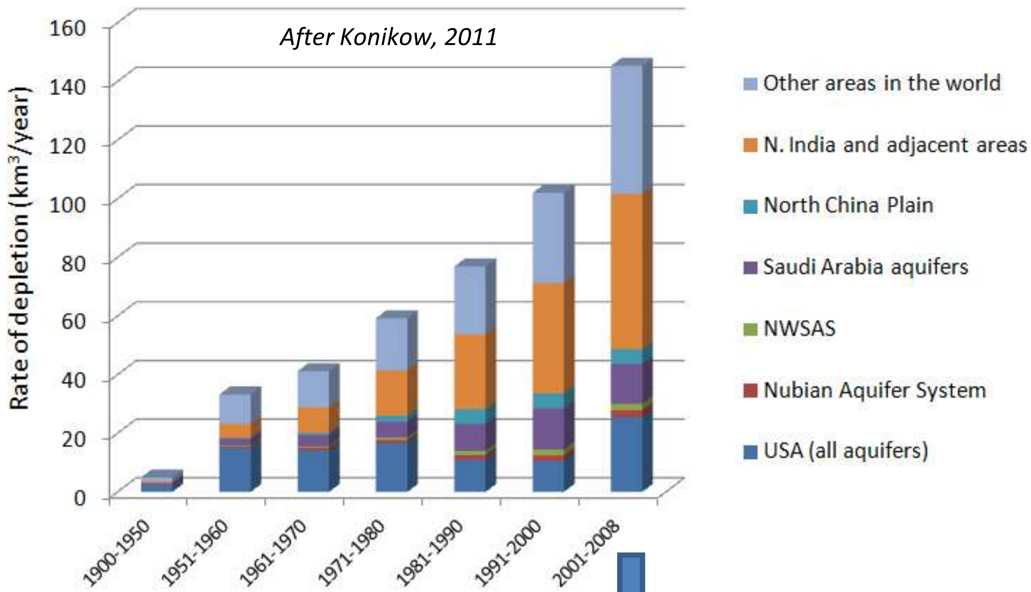
Important potential impacts:

Increasing cost of pumped water	Wells and qanats running dry	Dry springs and reduced baseflows	Damage to wet eco-systems	Land subsidence and surface collapses	Salt water intrusion	Exhaustion of economically exploitable groundwater	Aquifer running dry

Exploitation problems | **Environmental impacts** | **Aquifer system degradation**

Depletion of groundwater reserves

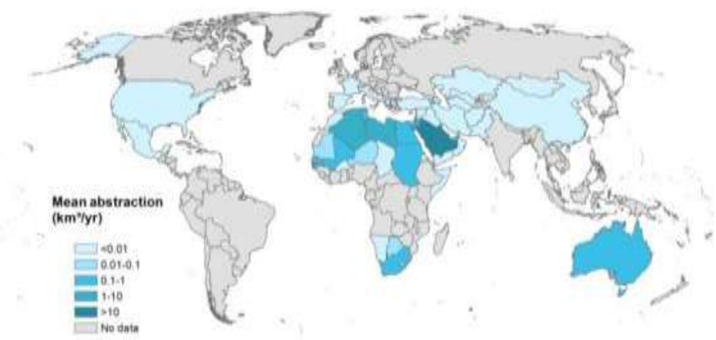
Rate of total groundwater depletion



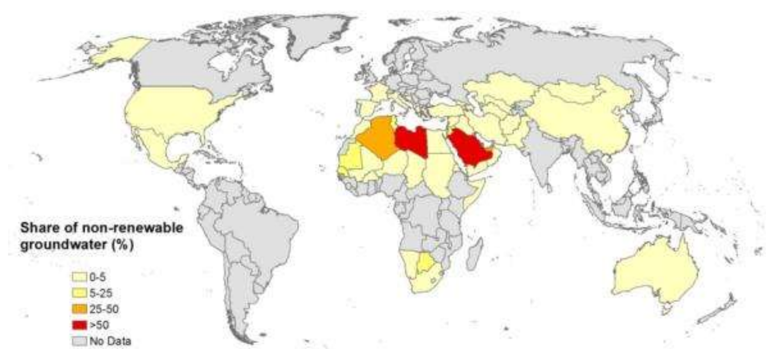
Estimates for conditions 2001-2008 :

- **Total depletion at a rate of 145 km^3/yr**
- **21% corresponds to non-renewable groundwater**
- **Contribution to sea-level rise: 0.403 mm/yr**

Non-renewable groundwater



(a) Annual quantities abstracted

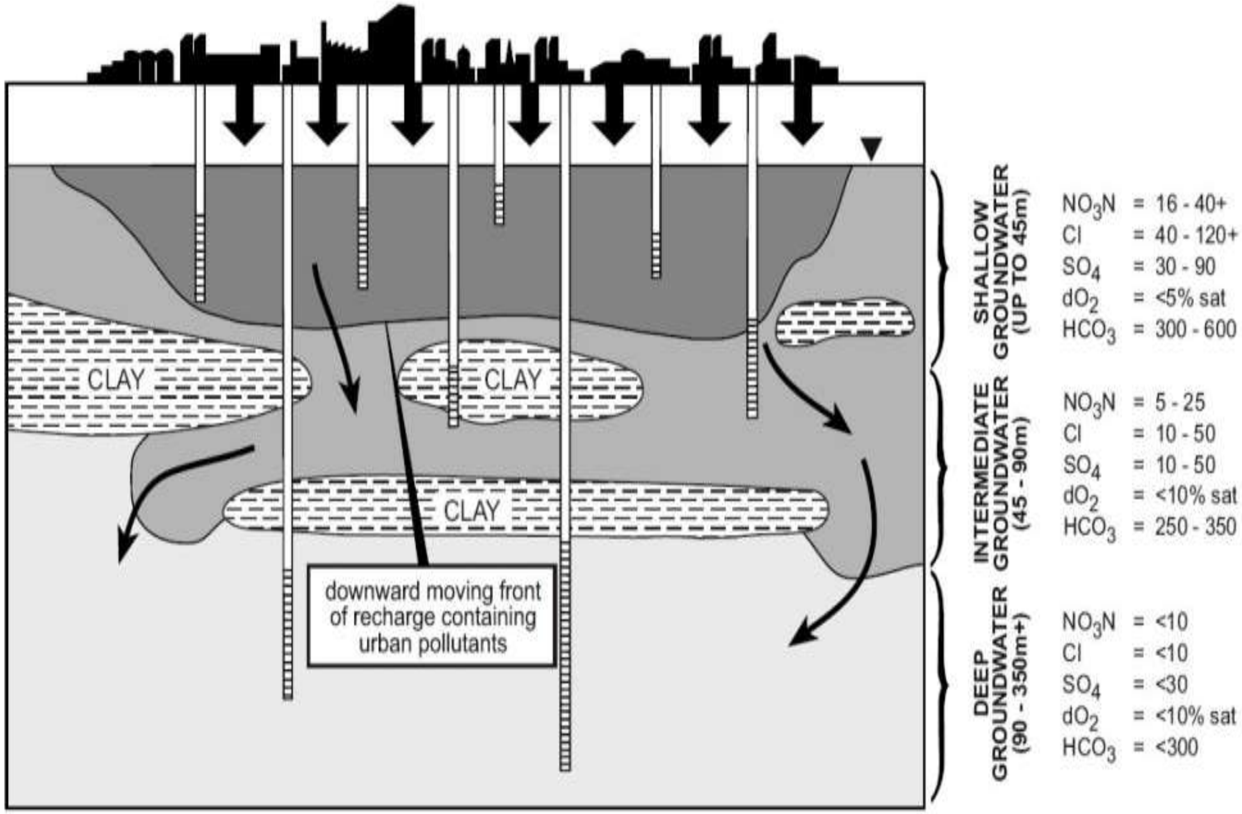


(b) % of all groundwater abstracted

Key issue 2: Steady degradation of groundwater quality by pollution

- **Increasing groundwater pollution is widespread, affecting in particular (but not exclusively) shallow aquifer domains**
- **On a human time scale, it is often almost irreversible**
- **Many different origins:**
  - Treated and untreated sewage and other wastewater flows
  - Leaks from waste dumps and improperly designed land fills
  - Diffuse pollution by agricultural land use (manure, fertilisers, pesticides)
  - Accidental spills in industry and in traffic
  - Underground storage and waste disposal. Etc….
- **Impacts:**
  - Groundwater becomes less suitable for various or all purposes (effective loss of the resource)
  - Groundwater-dependent ecosystems may degrade

Example: groundwater pollution below a city



In additional to ordinary *sewage*, also *industrial pollutants* and pharmaceuticals and personal care products (*PPCPs*)

Without adequate *sewerage* and *wastewater treatment*, shallow groundwater in urban areas is likely to degrade in quality and becomes unfit for most uses

Key issue 3: Groundwater and water security under challenging conditions

- **Groundwater and water security in emergency situations due to natural disasters (earth quakes, tsunamis, flooding, volcanic events, etc.):**
    - Emergency wells to replace damaged water supplies
    - Rehabilitation of affected aquifers and damaged groundwater wells
- **Groundwater and climate change:**
    - Numerous vulnerable groundwater systems may suffer significantly
    - However, the huge groundwater **buffer** may be part of the solution in adapting to climate change
- **Groundwater and sea-level rise:**
    - Higher risk/incidence of seawater intrusion in coastal aquifers
    - Critically shrinking fresh groundwater lenses on small flat islands (e.g. atolls)
- **Groundwater outflow under gravity becomes gradually more rare**
    - Springs, baseflow, artesian wells, qanats, etc.

Window # 7:

Groundwater management and governance

What causes groundwater resources management to be so difficult?

- **Limited knowledge about groundwater among decision-makers and the general public**
  - No ideas about occurrence, quantity, quality, time scales of groundwater, etc.
  - Poor anticipation/understanding of problems and how to prevent/solve
- **Large numbers of people/entities involved with a stake in groundwater**
  - Usually individually operating, often with conflicting interests
  - Externalities are very common (e.g. polluter is affecting other people)
  - Who or which entity is capable to tame the chaos?
- **Often undefined or unclear groundwater ownership and/or user rights**
  - Private ownership, state ownership or common property?
  - Discrepancies between formal legal status and people's perception
- **Groundwater is linked to many other systems** *(surface water, land use, etc.)*
- **Groundwater: a finite renewable resource - in many regions even scarce:**
  - Limited groundwater recharge versus increasing pressures driven by demography, climate change, technological innovation, land use, etc.
  - People have to get used to the idea that not all demands can be met

Examples of successful groundwater resources management

- **Silent revolution in India**
- **Great Artesian Basin Sustainability Initiative**
- **Recharge dams and well licensing in Oman**
- **Seawater intrusion barriers in California**
- **Land subsidence control in Venice & Shanghai**
- **Effective pollution control in many countries:**
  'polluter pays' principle; protection zones; land use management; wastewater management; etc.
- **European Water Framework Directive**
  (Groundwater daughter directive)
- **Transboundary aquifers***:*
  ISARM and UNECE inventories;
  'Draft Articles' UN-ILC;
  Guaraní agreement;
  raising awareness and forging co-operation; etc ....

Groundwater governance

SOME LESSONS LEARNED:

- **Top-down groundwater resources management approaches often are disappointing, in particular if non-technical measures are involved**
- **Relying merely on government agencies is usually not realistic**
- **Groundwater management often intends to change people's behaviour**
- **Hence, local stakeholders need to be actively involved**

In recent years, a new paradigm has emerged: GROUNDWATER GOVERNANCE:

- *"An overarching framework and set of guiding principles that determines and enables the sustainable management of groundwater resources and the use of aquifers".*
- **Good governance is characterized by responsibility, participation, information availability, transparency, custom and rule of law**
- **Process-oriented rather than action-oriented**
- **Only recently, major efforts have started to enhance groundwater governance**

GROUNDWATER has to become EVERYBODY's BUSINESS

The Water CHANNEL

Thank you!

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