PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

Irrigation and Drainage Engineering

(Soil Water Regime Management)

(ENV-549, A.Y. 2024-25)

4ETCS, Master option

Lecture 8-2. Impact of irrigation

Prof. Paolo Perona
Platform of Hydraulic Constructions

EPFL

Possible negative impacts

Inadequate network design, inappropriate maintenance or poor management can have highly damaging adverse impacts:

1. Alteration of soil properties
2. Lowering the water table
3. Contamination of surface and ground water by fertilisers and pesticides
4. Damage to downstream ecosystems
5. Spread of diseases propagated by vectors associated with water bodies (malaria, schistosomiasis, onchocerciasis)

1. Soil properties alteration

- Hydromorphy
- Leaching
- Various alterations
- Salinisation

* According to the FAO, >5 million ha (> 50,000 km2) are taken out of production each year as a result of soil degradation.

Hydromorphy (waterlogged soils)

Causes

Excessive irrigation, low permeability soils, poor drainage or rising groundwater close to the surface

Effects

- deterioration in soil structure
- lower yields
- difficult or delayed access to plots
- spread of water-borne diseases

Remedies

- changing irrigation scheme
- control of water inputs
- improving soil drainage capacity
- drainage, bio-drainage, etc.

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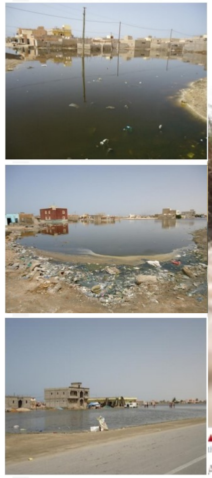
Example: the case of Nouakchott (Mauritania)

Intensive water use for drinking and irrigation (gardening) has detemined the rise of 1 m of the water table.

This produces constant wetland zones and the flooding of other urban areas during the rainfall season.

Dramatic situation causing spreading of cholera and other waterborne diseases

https://www.epfl.ch/schools/enac/eira/

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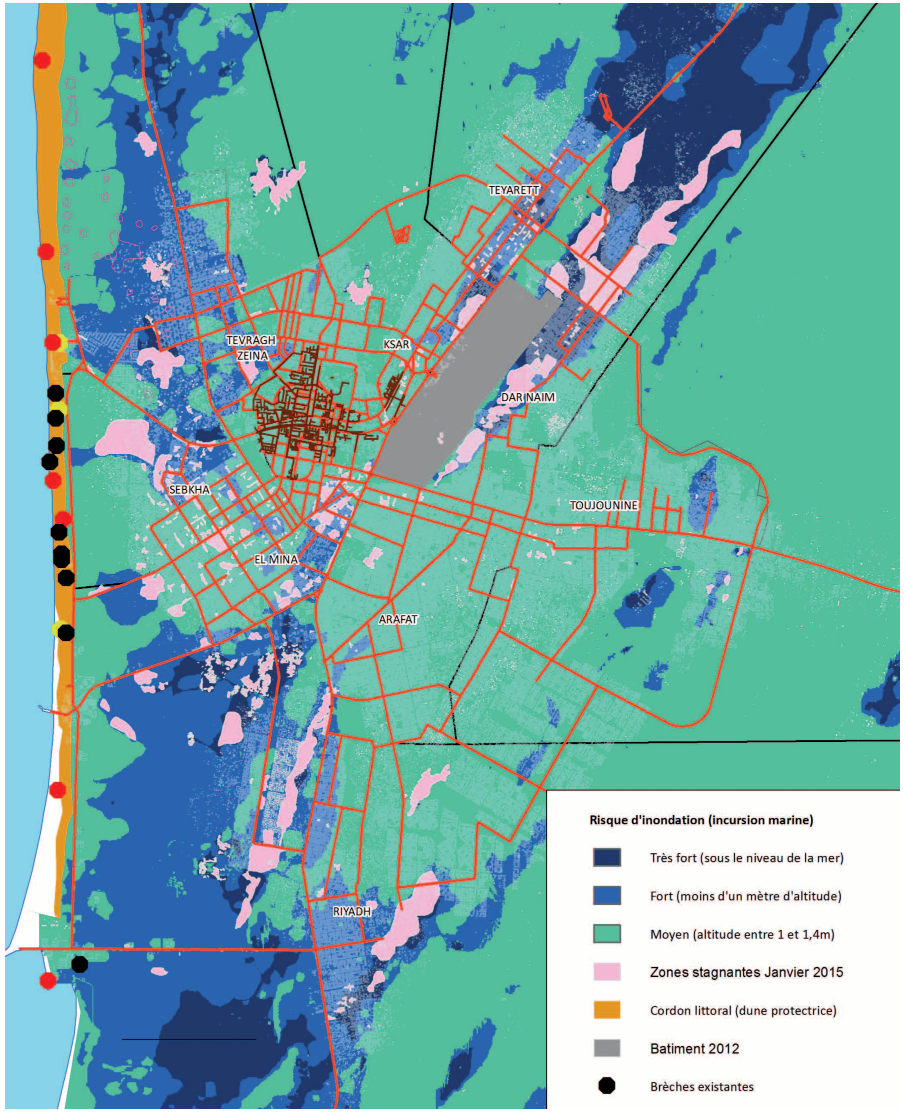
'The best solution? Move the Mauritanian capital': water on the rise in Nouakchott

▲ A flooded street in the Socogim PS neighbourhood of Nouakchott, Mauritania, seen at the end of June – during the dry season. Photograph: Alex Duval Smith

A prisoner of climate change, Nouakchott faces challenges of flooding and erosion that have been exacerbated by preparations for the Arab League summit



https://mediaspace.epfl.ch/media/ENAC+Research+Day+2023+-+Session+2/0_jfmxhdcj?st=979&ed=1396

Soil leaching

Too much irrigation can be just as harmful as too little water

- especially with gravity irrigation, on very permeable soils with low water retention capacity and low CEC
- requires large inputs of fertilisers (N, P, K), soil improvers and even trace elements
- can also affect soil colloids

Preventing soil leaching

- judicious choice of irrigation method
- abandoning crops that require too much water and carefully controlling irrigation doses
- regular inputs of organic matter
- choose an appropriate chemical fertiliser and, if necessary, split up the inputs
- regular monitoring of the chemical composition of the soil solution

Various soil alterations

- Soil compaction during flood irrigation
- Appearance of a crust of sand in silt-sand soils, especially in sprinkler irrigation
- Extraction of sterile horizons during land levelling operations
- Risk of acidification

Soil salinisation

Poor irrigation management can have considerable adverse impacts, particularly soil salinisation:

- ✓ 10 to 15% of irrigated land (20 to 30 million ha) suffers, to varying degrees, from salinisation problems
- ✓ 0.5 to 1% of irrigated land is lost to cultivation each year (1.5 to 2 million ha, or 15,000 to 20,000 km2)
- ✓ almost half of all irrigated land is under long-term threat

Serious salinisation problems (Tunisia)

- Effects of excess dissolved salts in the soil solution

- increased osmotic pressure, making it harder for plants to mobilise water

$$\Psi = M + \Pi + \Omega + G$$

- toxicity of certain ions to plants (B, Cl, Na, etc.)

- soil degradation (changes in structural state, reduced hydraulic conductivity, etc.)

Végétation herbacée halophile

- Main causes of salinisation

- **use of irrigation water of mediocre quality and insufficient natural leaching**
- **rising groundwater and salinisation through capillary action**

Example of salt application by irrigation:

Annual water requirement: 600 mm

Salt concentration in irrigation water : 1g/l

→ Annual salt input: 0.6 kg/m2

Rise in the groundwater table following irrigation

Périmètre d' irrigation		Nappe souterraine	
		Prof. à l' origine (m)	Montée (m/an)
Nubaria	Egypte	15 – 20	2 - 3
Beni Amir	Maroc	15 – 30	1.5 – 3
Murray Darling	Australie	30 – 40	0.5 - 1.5
Salt Valley	USA	15 – 30	0.3 – 0.5
Khaipur	Pakistan	4 – 10	0.1 – 0.3

Risk factors for soil salinisation

- quality of irrigation water
- climatic conditions
- soil conditions
- hydrogeological context

Risk prevention (project design stage)

- data collection (water, soil, climatic and hydrogeological context)

If risks are proven:

- reducing water losses: appropriate technical choices, control of inputs, etc.
- Sensible and considerate choice of irrigation method
- adequate network of pipes
- if necessary, effective control of the water table, drainage network, etc.
- consideration of leaching water requirements

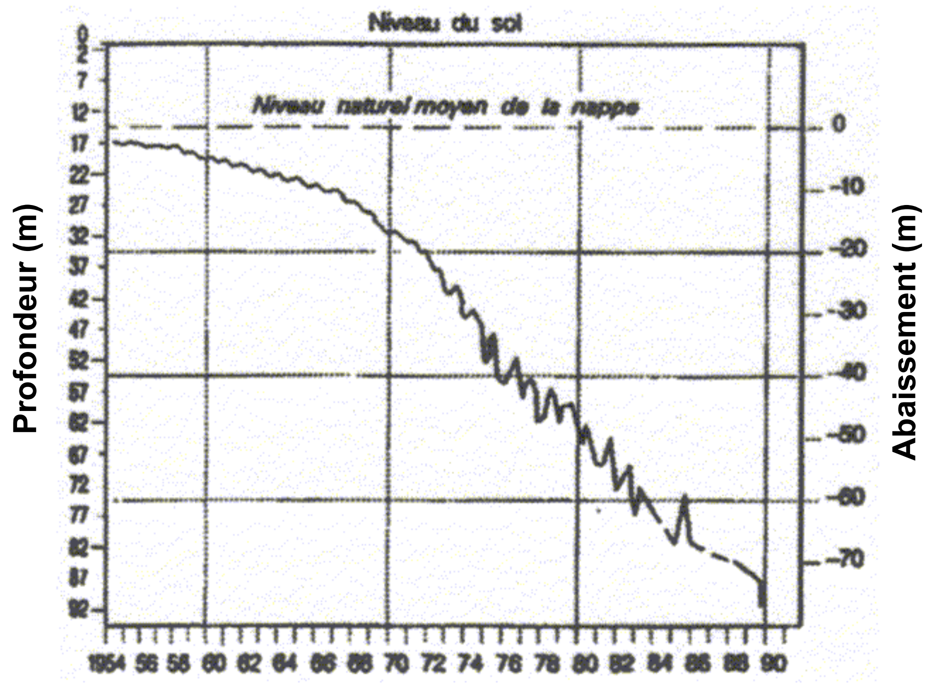
Soil salinisation: curative measures

- Leaching of soluble salts
- Maintains the water table at a sufficient depth
- Reduces evaporative demand*

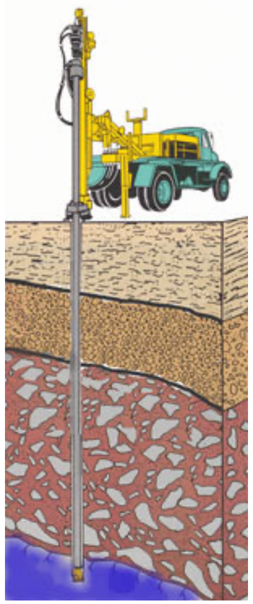
* shelterbelts, judicious choice of cultivation techniques, improved structure, mulch, selection of crops that require little water, etc..

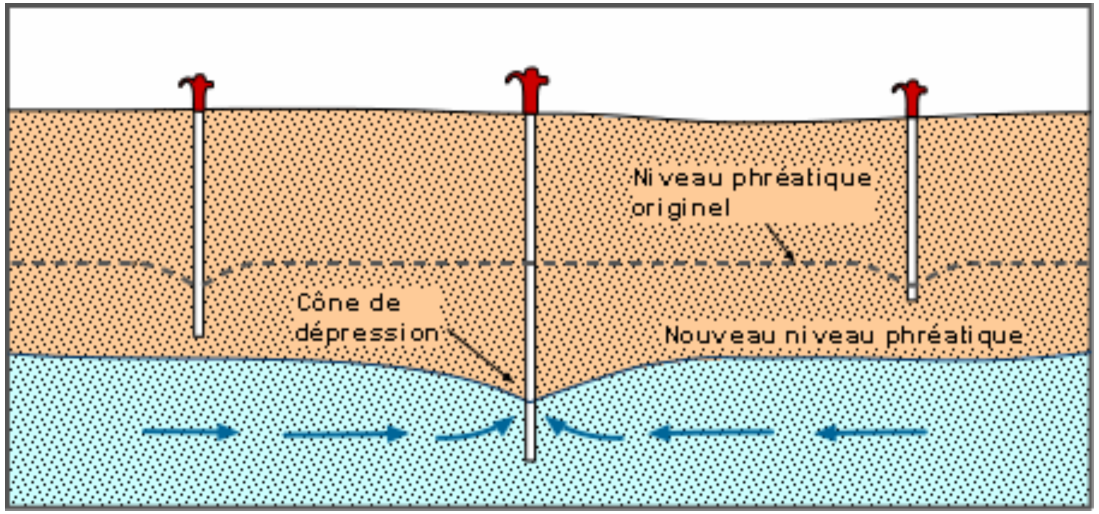
2. Lowering of the water table

Over 30% of irrigation water withdrawn from groundwater table



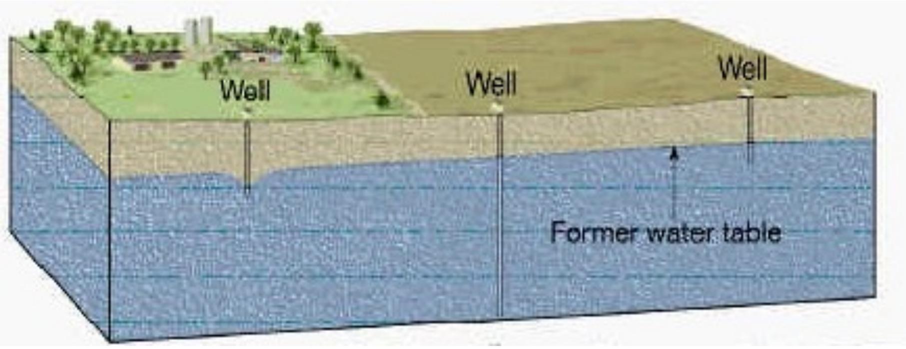
Example of lowering of the water table following excessive pumping (Libya)



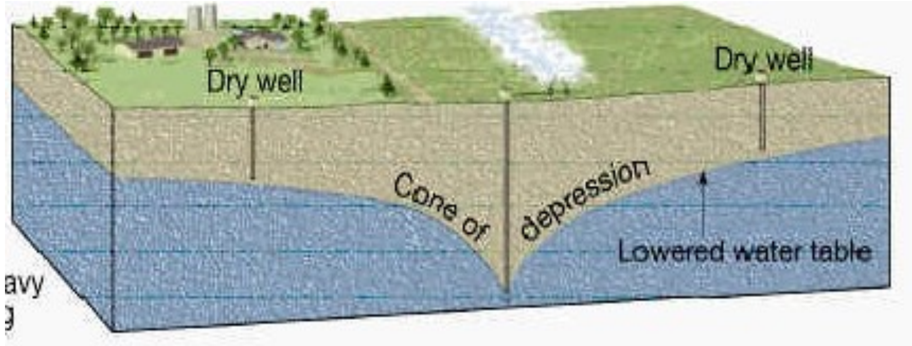


Impacts of lowering the water table

- risk of ground settlement and subsidence
- shortage of water supply and effects on:
  - cultivated plants
  - natural environments
- risks of drying up or reducing the flow of wells and springs
- reduced low-water flows in rivers
- salt water intrusion along coastlines

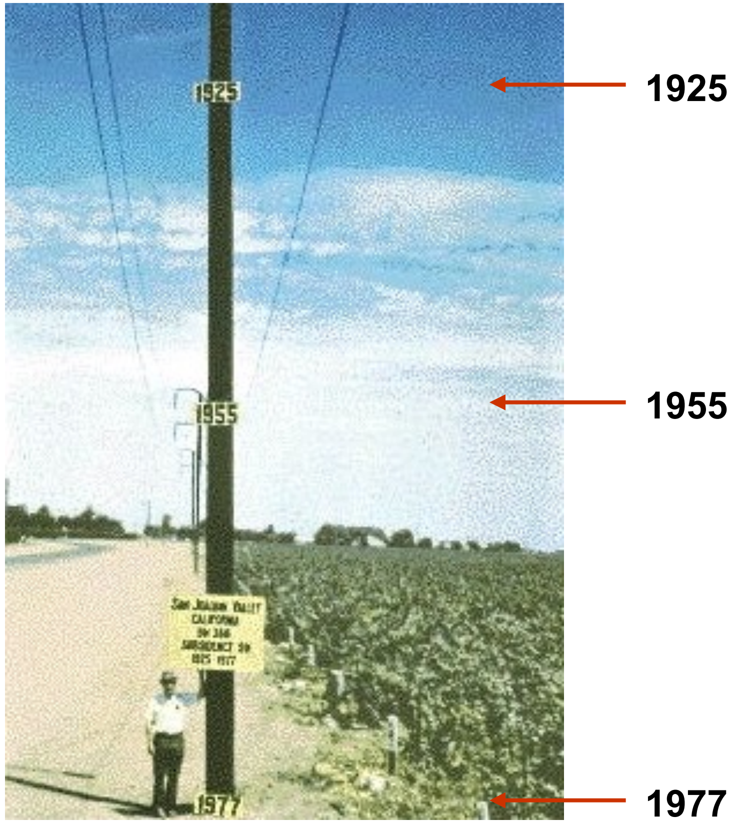


Before intensive pumping



After intensive pumping

Soil compaction and subsidence due to lowering of the water table



Example of the San Joaquin Valley

(California)

Causes:

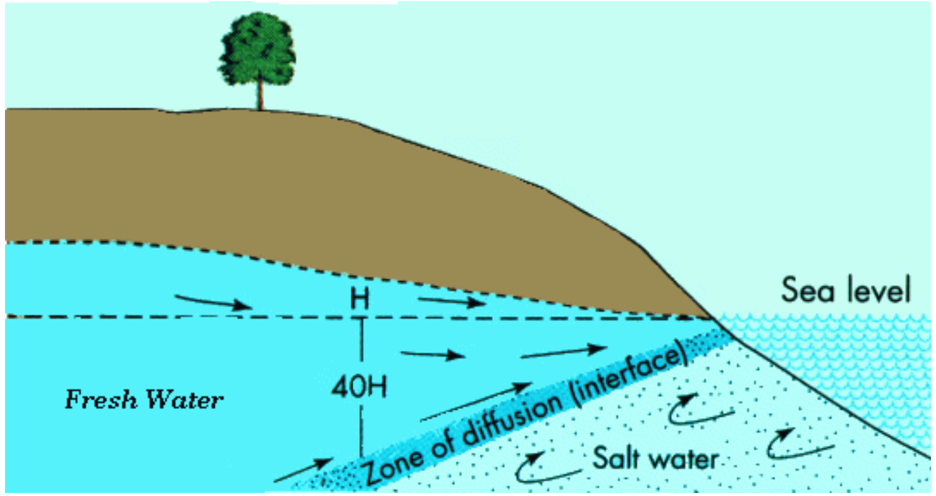
- drainage of marshy areas
- excessive pumping of groundwater for irrigation

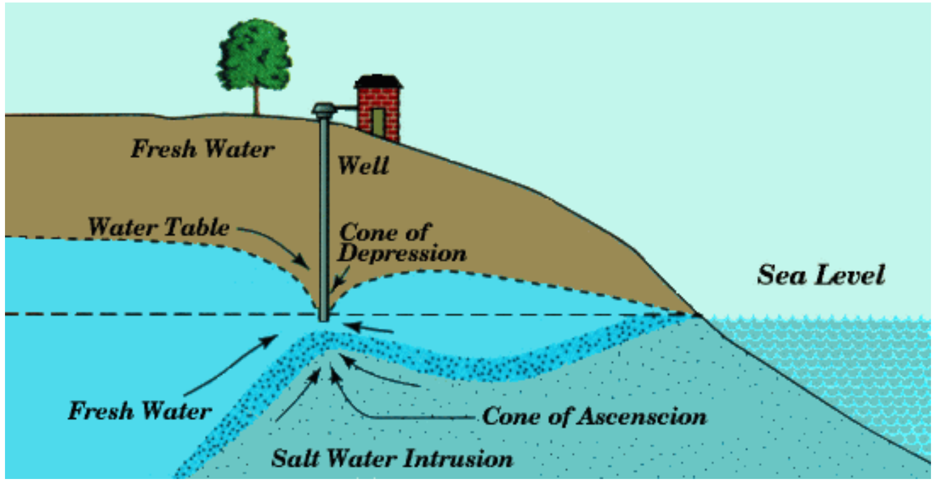
Consequences:

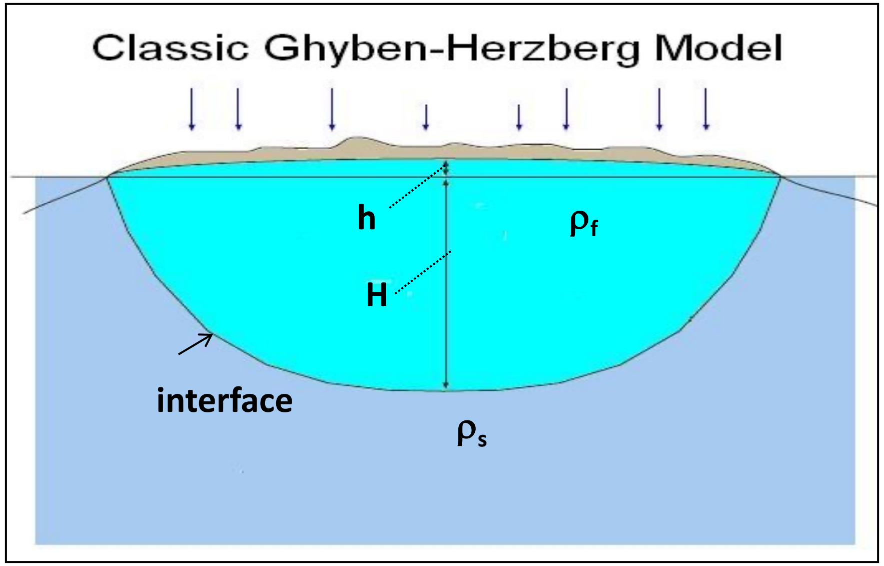
- subsidence of peat soils (2 to 5 m)
- compaction of fine mineral soils (clays) as a result of increased intergranular pressure (several metres)
- damage to buildings and infrastructure, severe flooding

http://webworld.unesco.org/water/ihp/db/glossary/glu/ZZ/GP1240.HTM

Intrusion d’eau salée







$(H + h)\,\rho_f = H\,\rho_s$

$\rho_f = 1\ g/cm^3$

$\rho_s = 1.025\ g/cm^3$

➔ $H = (\rho_f / (\rho_s - \rho_f))\,h = 40\,h$

A drop in the level of freshwater in the aquifer causes a 40-fold rise in the level of saltwater.

3. Contamination of surface and ground water

- Intensive use of fertilisers, soil improvers, pesticides, etc.
- Use of marginal water (raw wastewater, treated wastewater, drainage water, brackish water, etc.)
- Leaching of salts

Strategies to minimise water pollution from agricultural activities:

Encouraging the rational use of fertilisers, soil improvers and pesticides*.

introduction of regulatory measures relating to the use of fertilisers, soil improvers and chemical substances and effective incentives

* training programmes for farmers, setting up agricultural extension organisations or other structures to support farmers

4. Alteration of ecosystems and downstream flow

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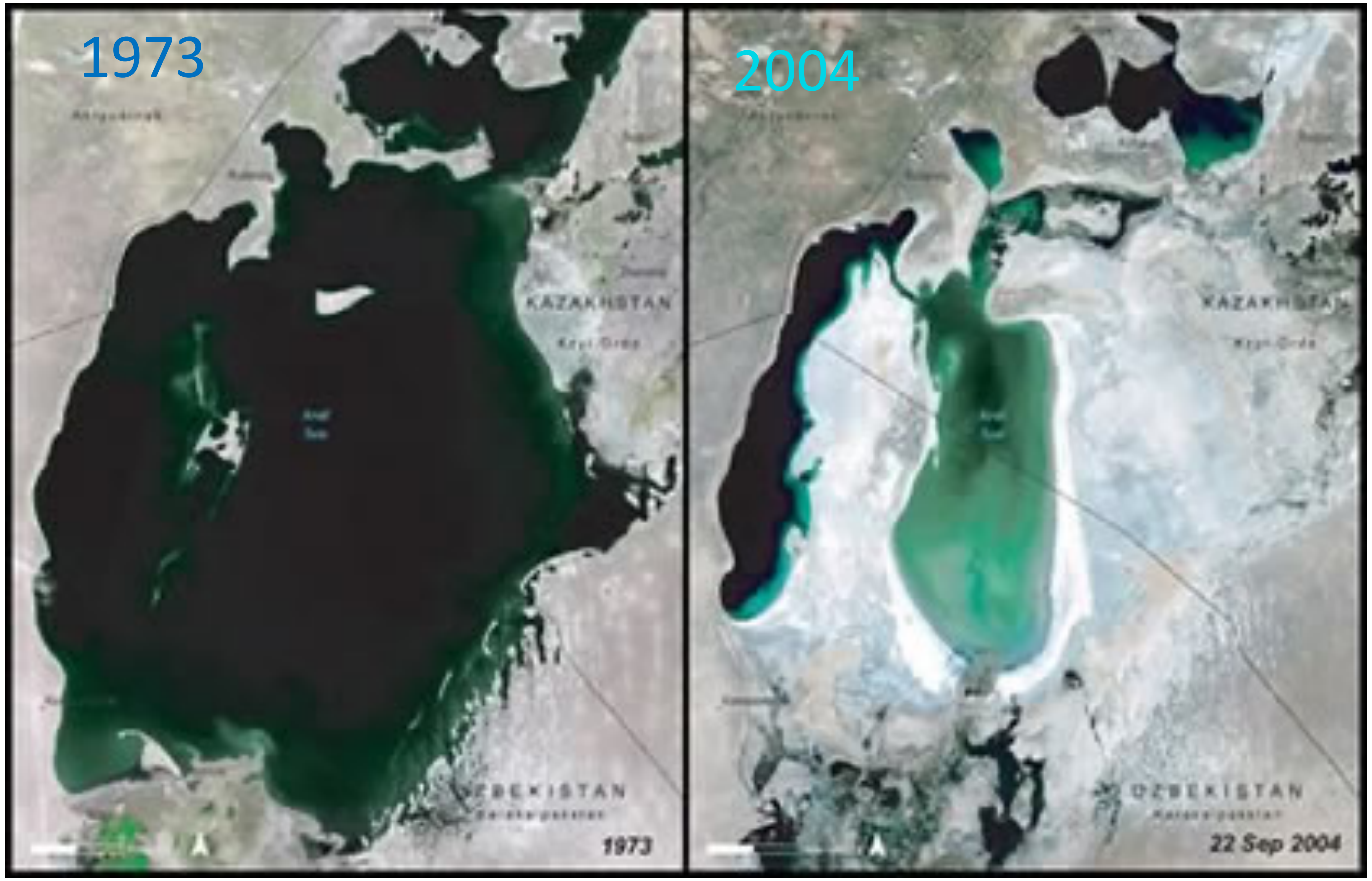
- changes in flora and fauna: replacement of xerophytic plants by hydrophilic plants
- increased populations of insects, birds and other animals

- Possible effects of changes in downstream flow on :
- groundwater recharge
- water quality
- ecosystems **
- local residents

* if the downstream flow is insufficient to dilute pollutants

** particularly those in wetlands rich in animal and plant species (reduction in biological diversity)

The Aral sea case



- 1960s: Soviet planners decide to intensify cotton growing in Central Asia (the world's fourth largest cotton producer in the 1980s).
- Essential irrigation supplied by diverting the Amou-Daria and Syr-Daria rivers, tributaries of the Aral Sea
- Flow into the Aral Sea: 60 km3/year in 1960; 1.3 km3/year in 1986
- Surface area of the water body: 70,000 km2 in 1960, 20,000 km2 in 2010, now increasing…
- Salinity: 10 g/l in 1960; over 50 g/l today → destruction of flora and fauna, fishing disaster
- Farmland sterilised by salt-laden spray carried by the wind → 200 km in all directions