THT282 Introduction to sustainable water and sanitation

Sustainable water supply - *surface and groundwater*

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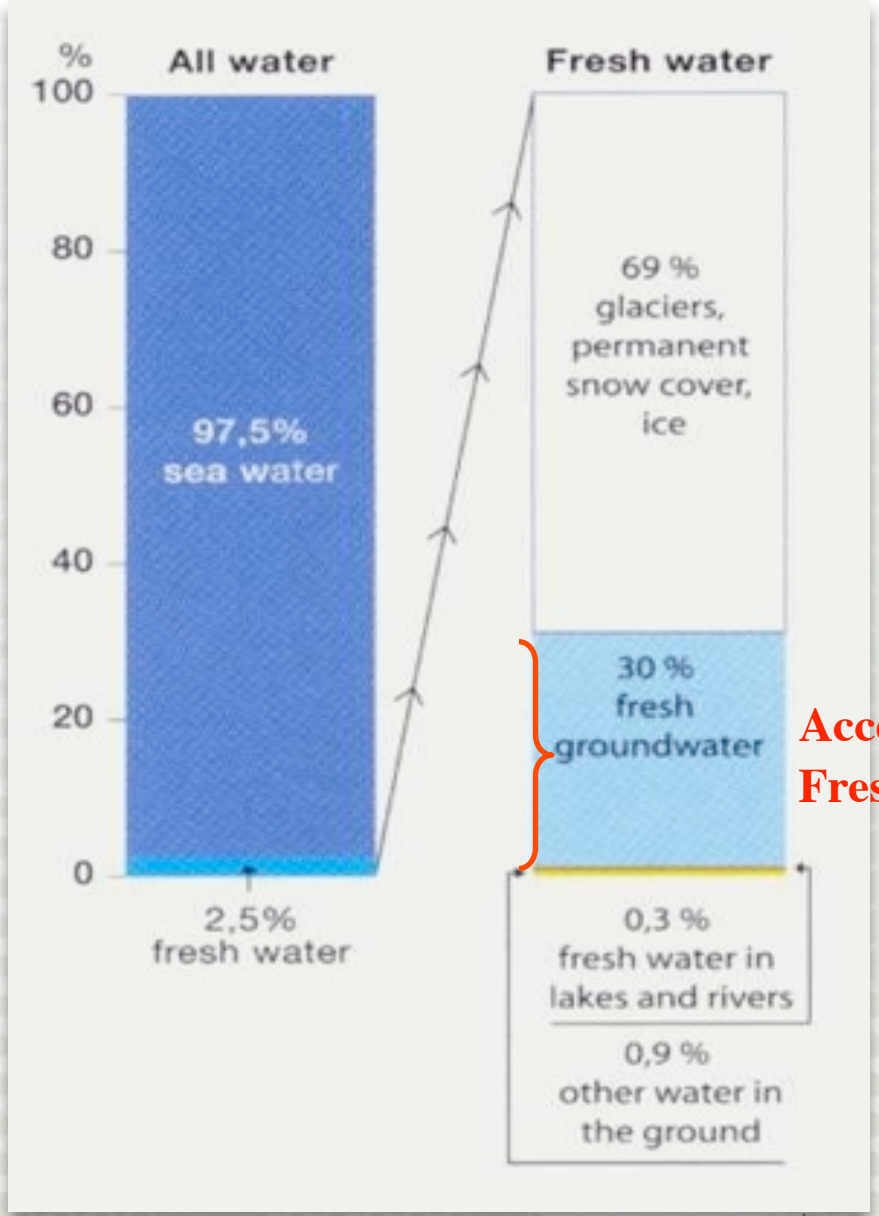
Lecture keywords

- Surface water sources
- Groundwater sources
- Protection of water sources
  - Hygienic barriers
  - Protection zones
  - Well construction

Water resources



Accessible Freshwater

= only 1/3 of the total 2.5 % !

Source: (1)

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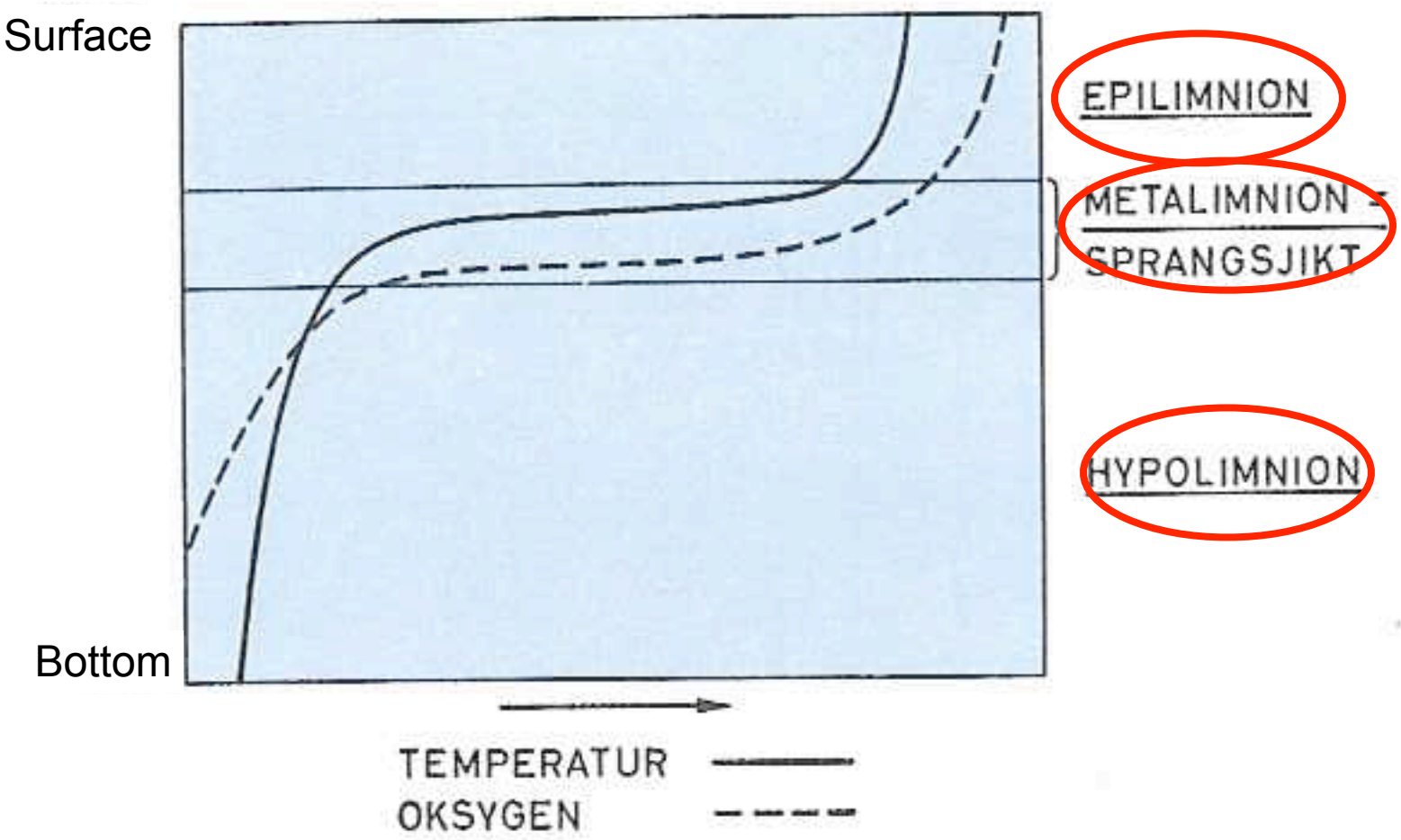
Temperature stratification of (deeper) lakes



Surface water sources - lakes

- Oligotrophic
- Eutrophic
- Dystrophic

Surface water sources - lakes

- **Oligotrophic**
  - very low in nutrients
  - clear water
  - often low in minerals and dissolved solids
  - pH dependent on watershed geology/soils
  - high oxygen status (DO)
  - normally a good water source

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- **Water treatment**
  - pH adjustment
  - Disinfection

Surface water sources - lakes

- **Eutrophic**
  - turbid water
  - rich in nutrients (algae blooms)
  - low in minerals and dissolved solids (soft water)
  - may have anaerobic conditions near the bottom
  - poor water source, requires elaborate treatment

Surface water sources - lakes

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  - turbid water
  - rich in nutrients (algae blooms)
  - low in minerals and dissolved solids (soft water)
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  - poor water source, requires elaborate treatment

- **Water treatment**

– Sedimentation
– Coagulation/flocculation
– Carbon filtration
– Disinfection

Surface water sources - lakes

- **Dystrophic**
  - the water has high color (Pt units)
  - low in nutrients
  - often low pH
  - surrounded by bogs/wetlands
  - requires elaborate treatment to reduce color

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- **Water treatment**

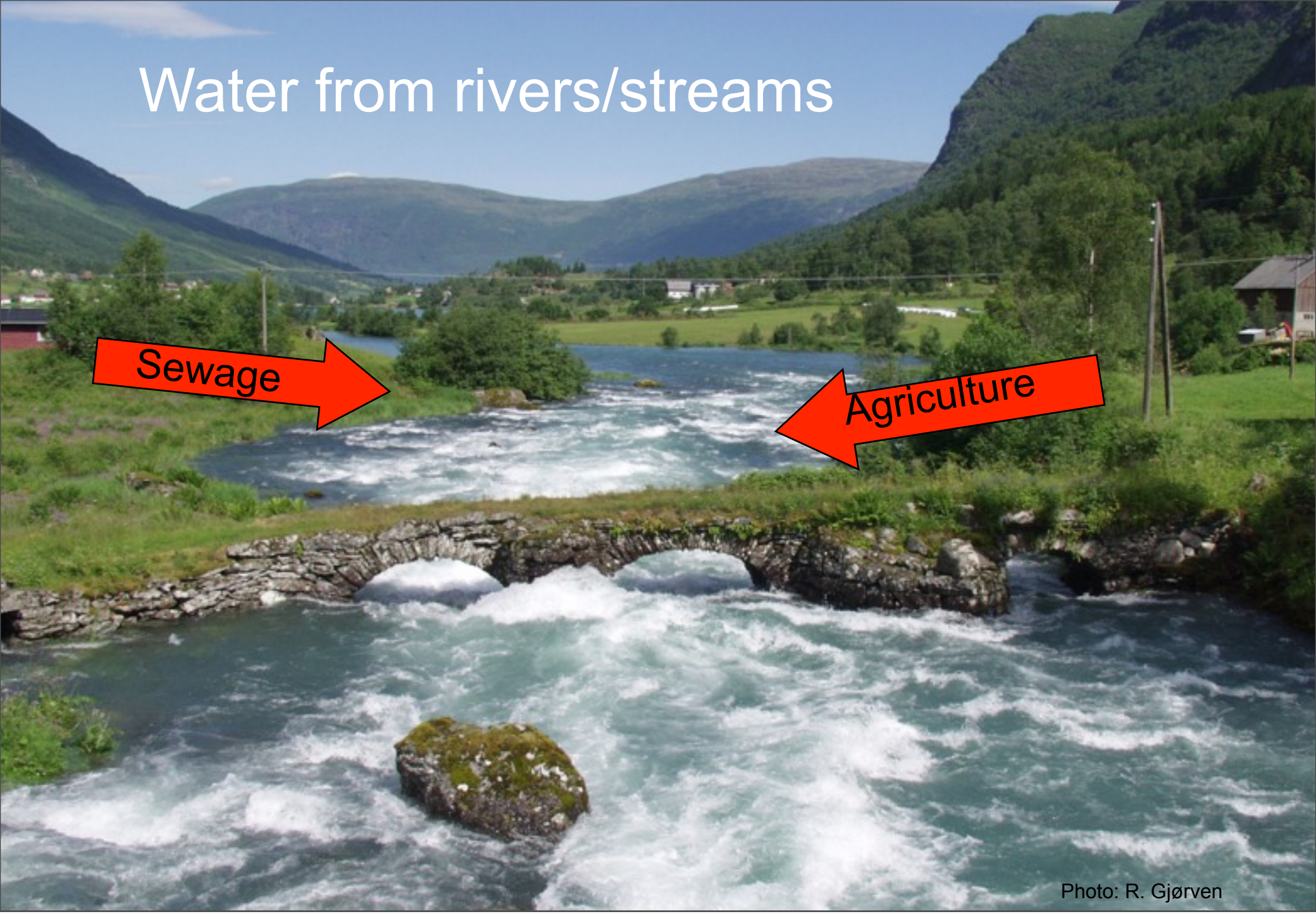
– Coagulation/flocculation
– Ozonation
– Disinfection

Water from rivers/streams

Photo: R. Gjørven

Water from rivers/streams

Water from rivers/streams



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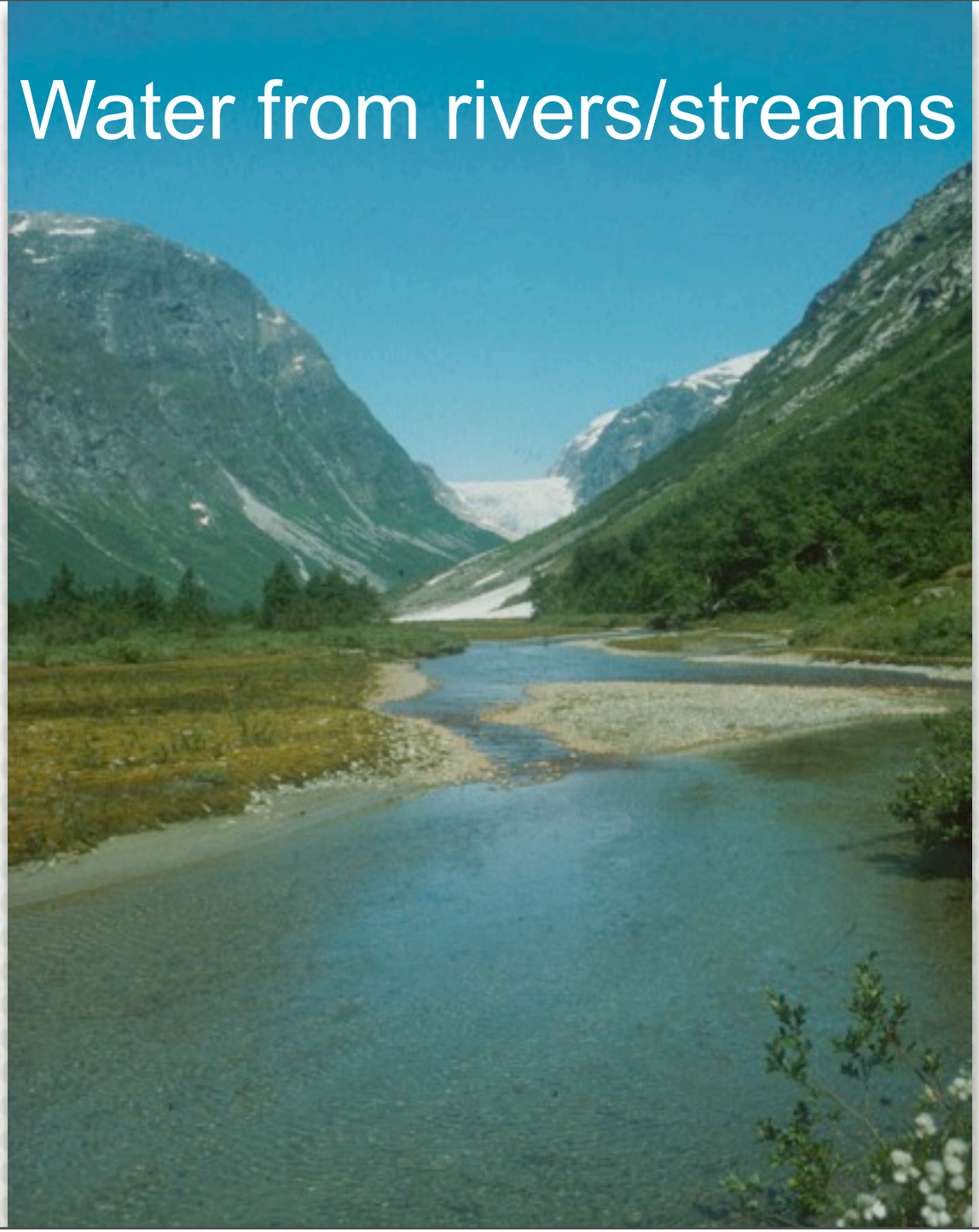
Water from rivers/streams

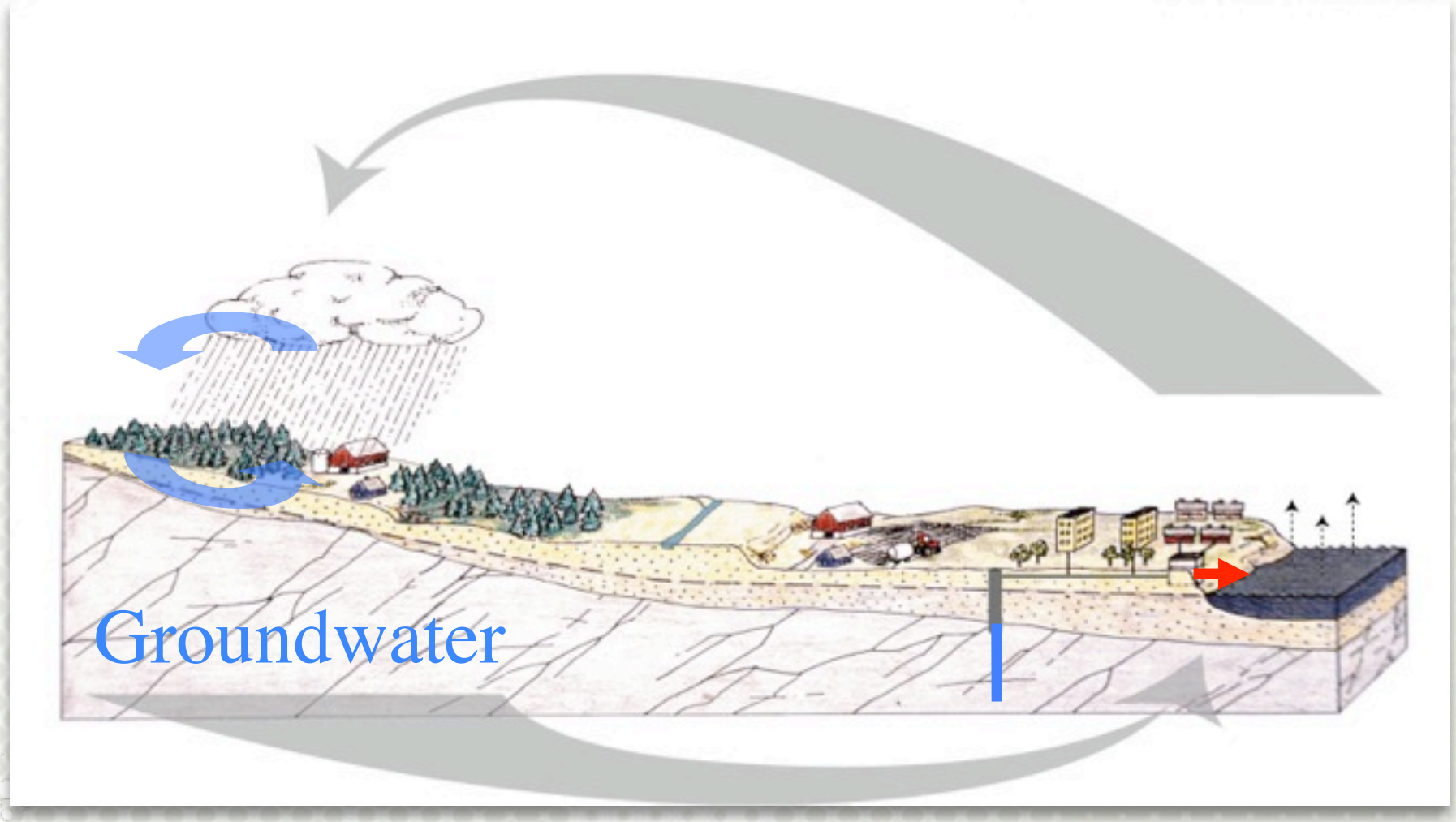


How would you construct a water supply system from a river/stream?

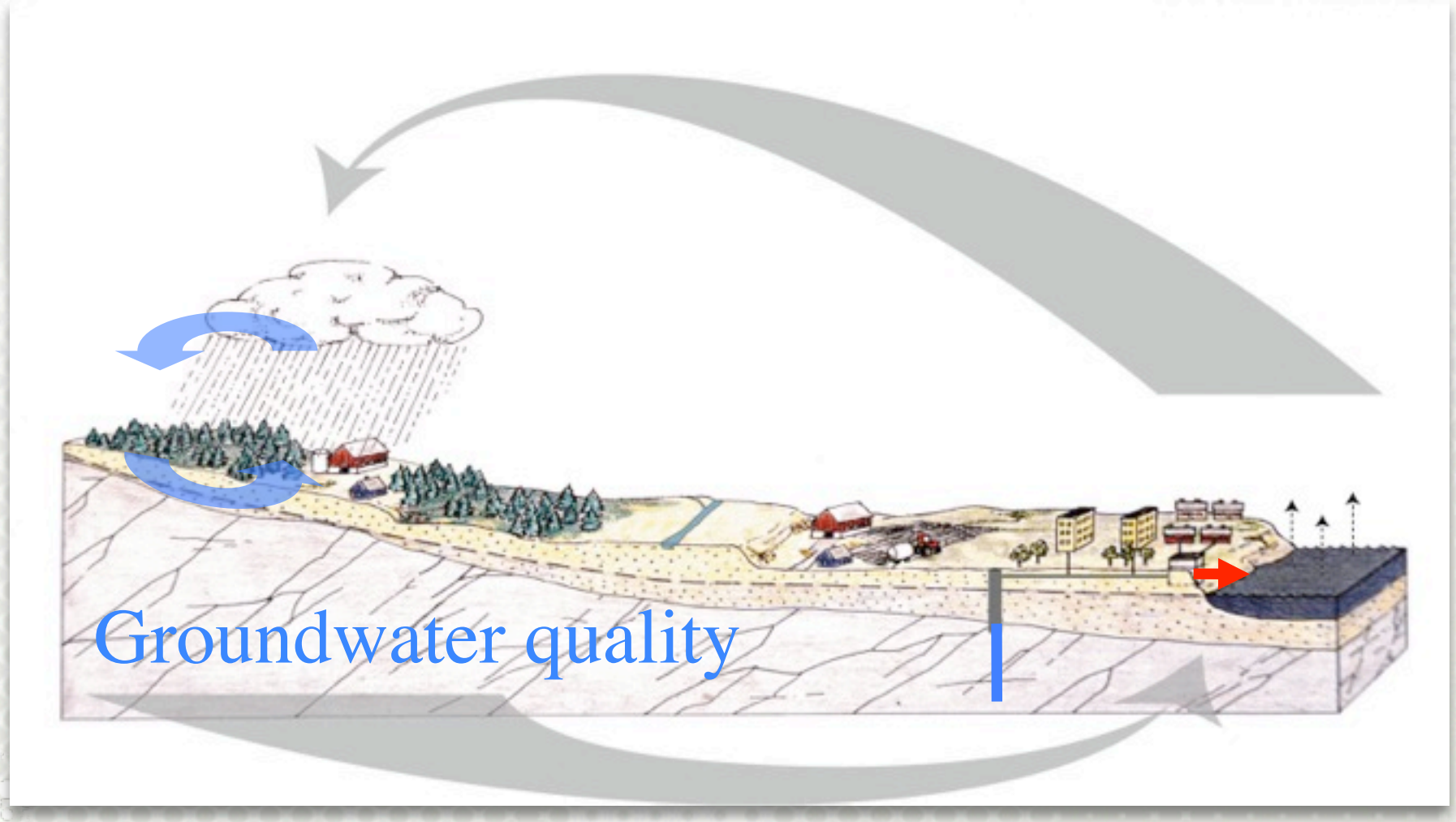
Lecture keywords

- Surface water sources
- **Groundwater sources**
  - Groundwater flow
  - Groundwater vs. surface water
- Protection of water sources
  - Hygienic barriers
  - Protection zones
  - Well construction

Groundwater sources

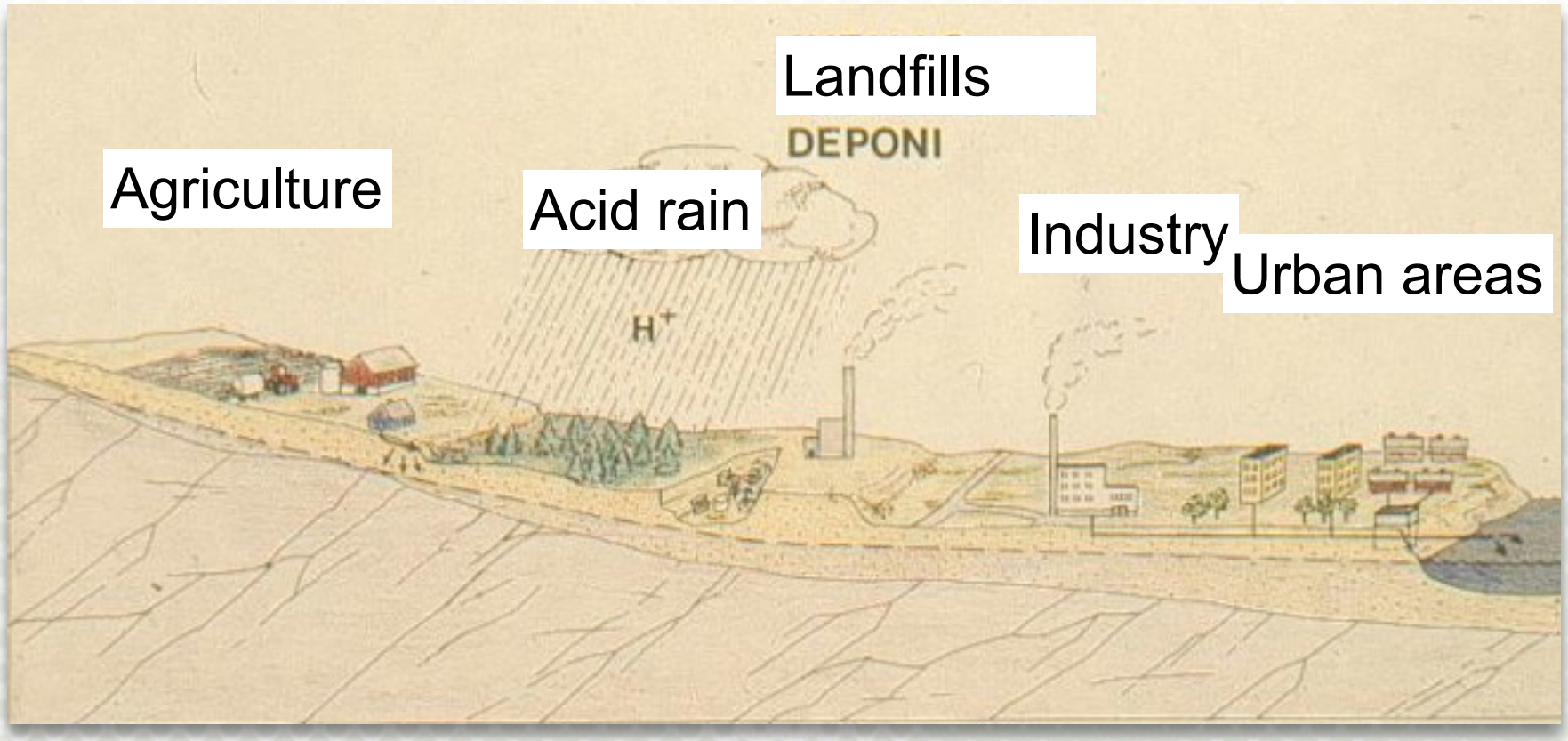


Groundwater sources

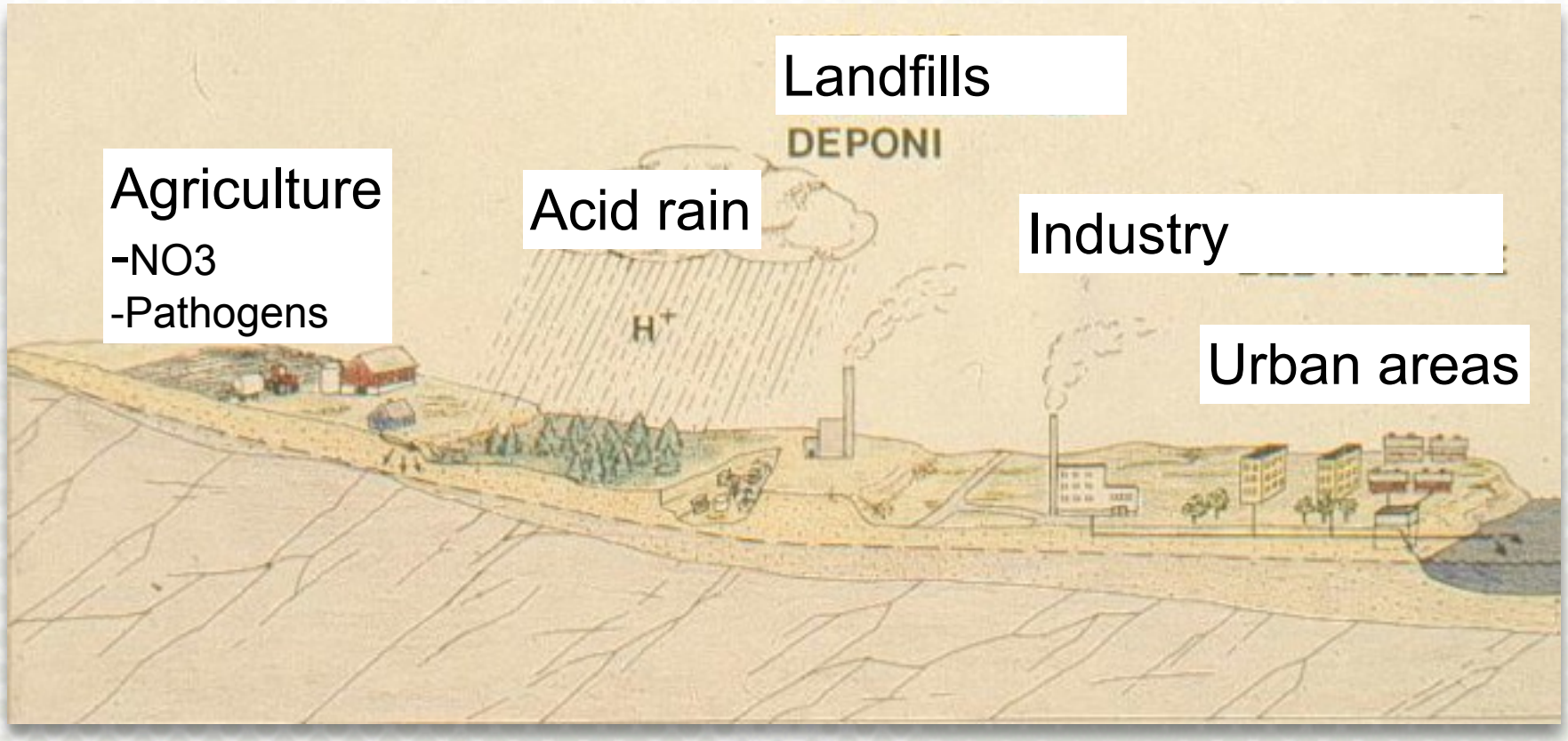


Groundwater quality

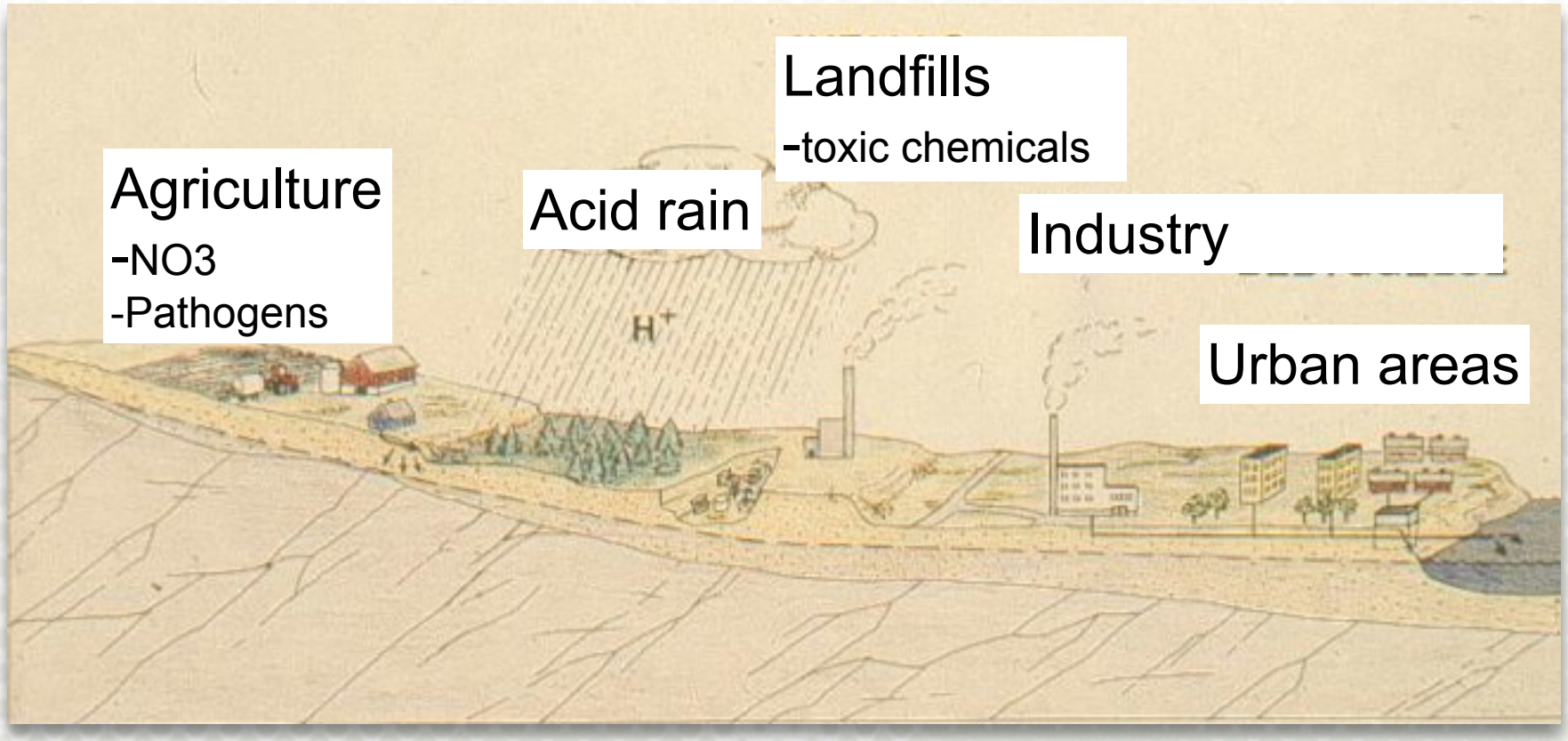
Groundwater pollution



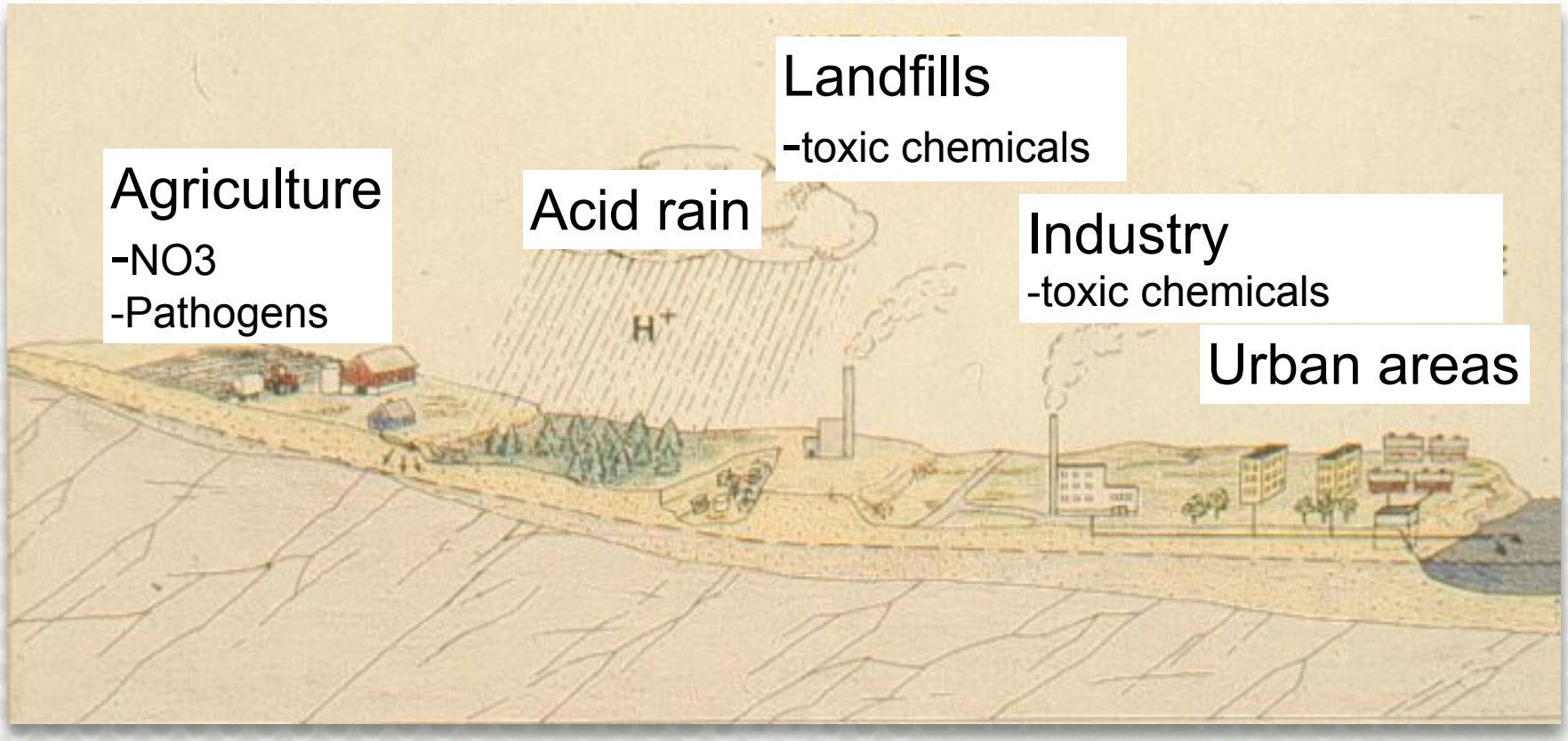
Groundwater pollution



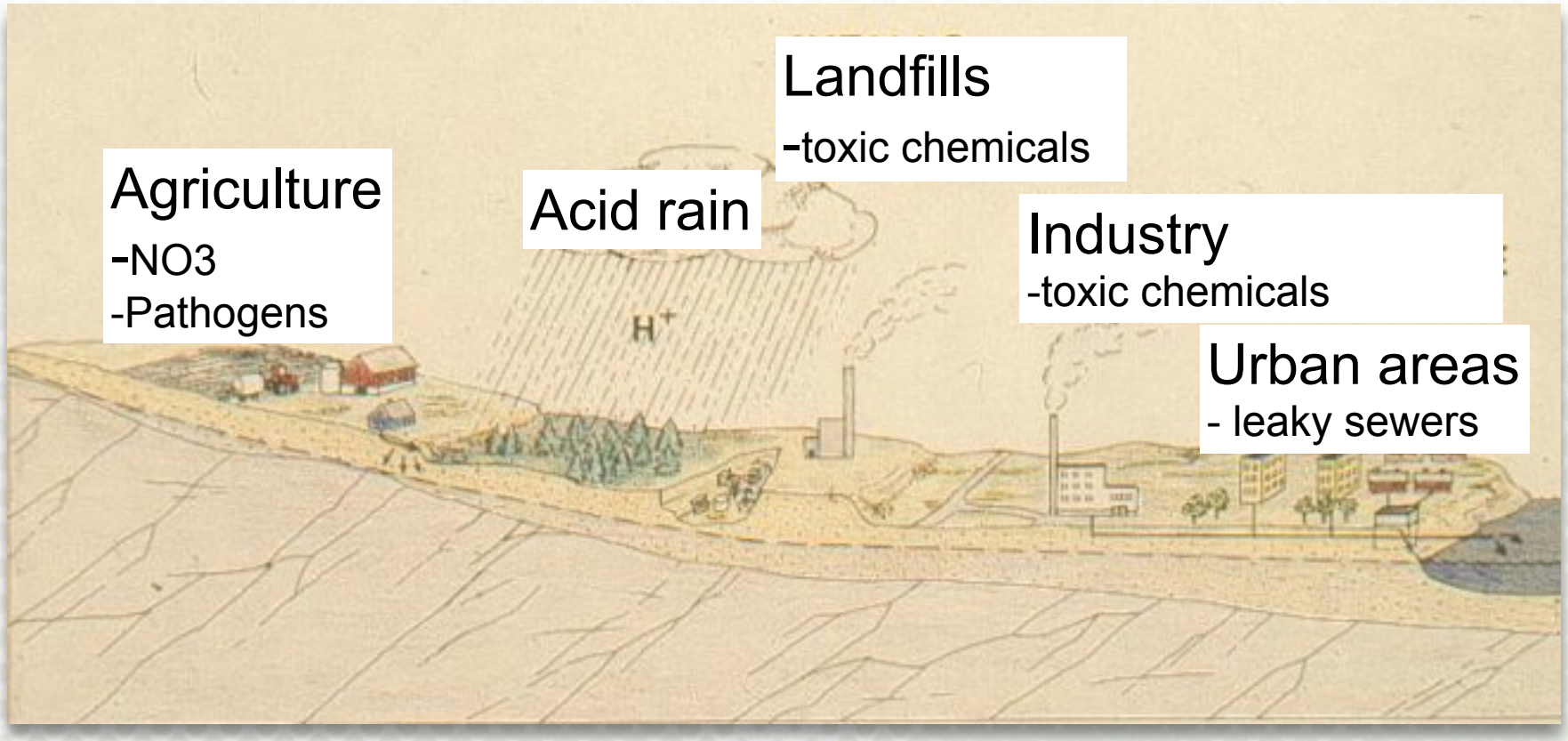
Groundwater pollution



Groundwater pollution



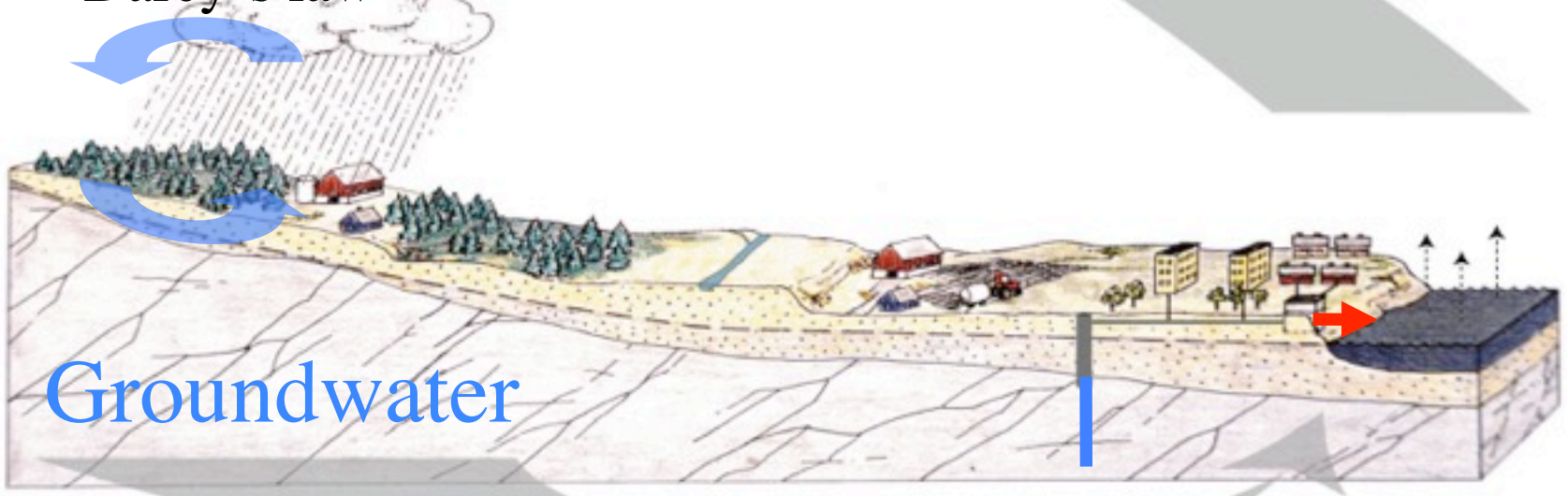
Groundwater pollution



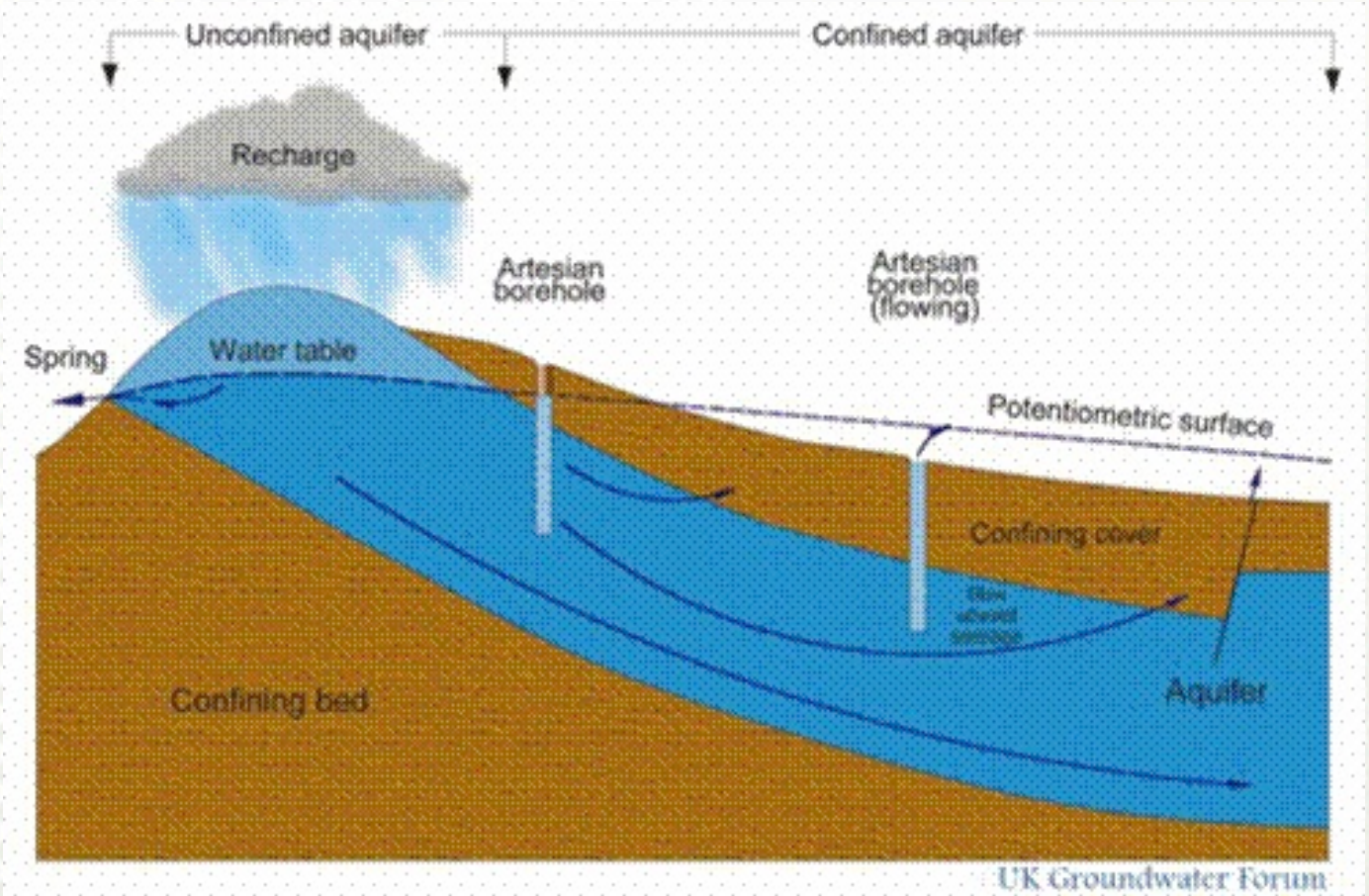
Calculation of groundwater flow and aquifer yield

Aquifer type and geometry
Aquifer properties
- Hydraulic conductivity
- Transmissivity

Darcy´s law



Groundwater – Aquifers



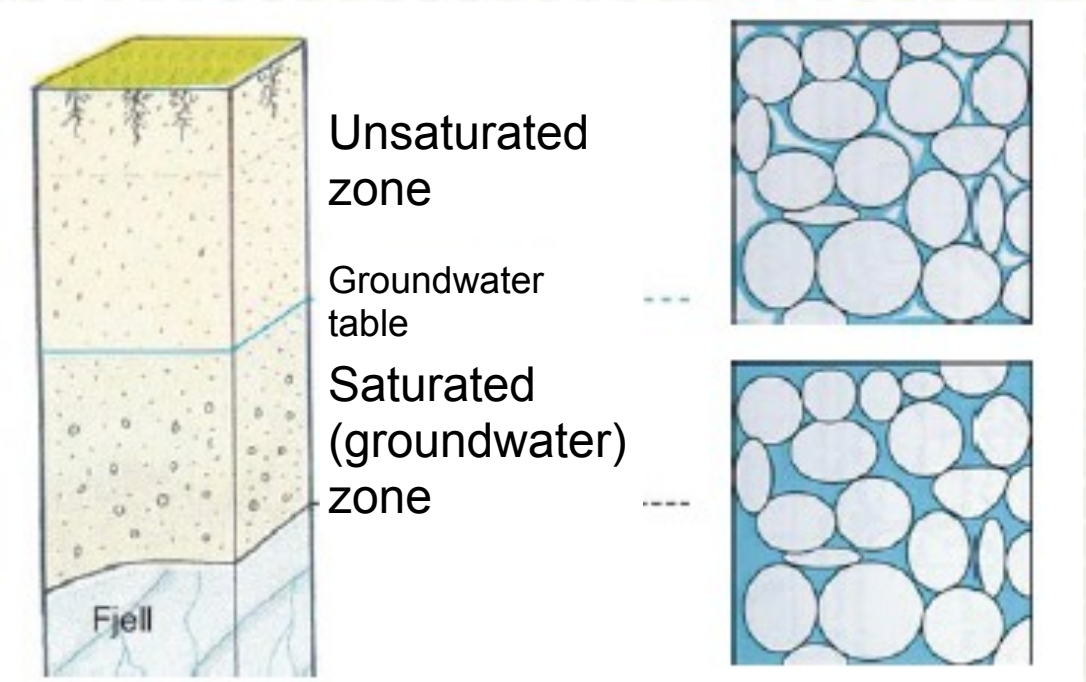
Source: (31)

Aquifers

- **Unconfined aquifer**
  - The water is in direct contact with the atmosphere
  - Usually shallow aquifers

- **Confined aquifer**
  - The water is not in direct contact with the atmosphere
  - the water bearing structure is confined by a layer with lower hydraulic conductivty, often clay

Unconfined aquifer



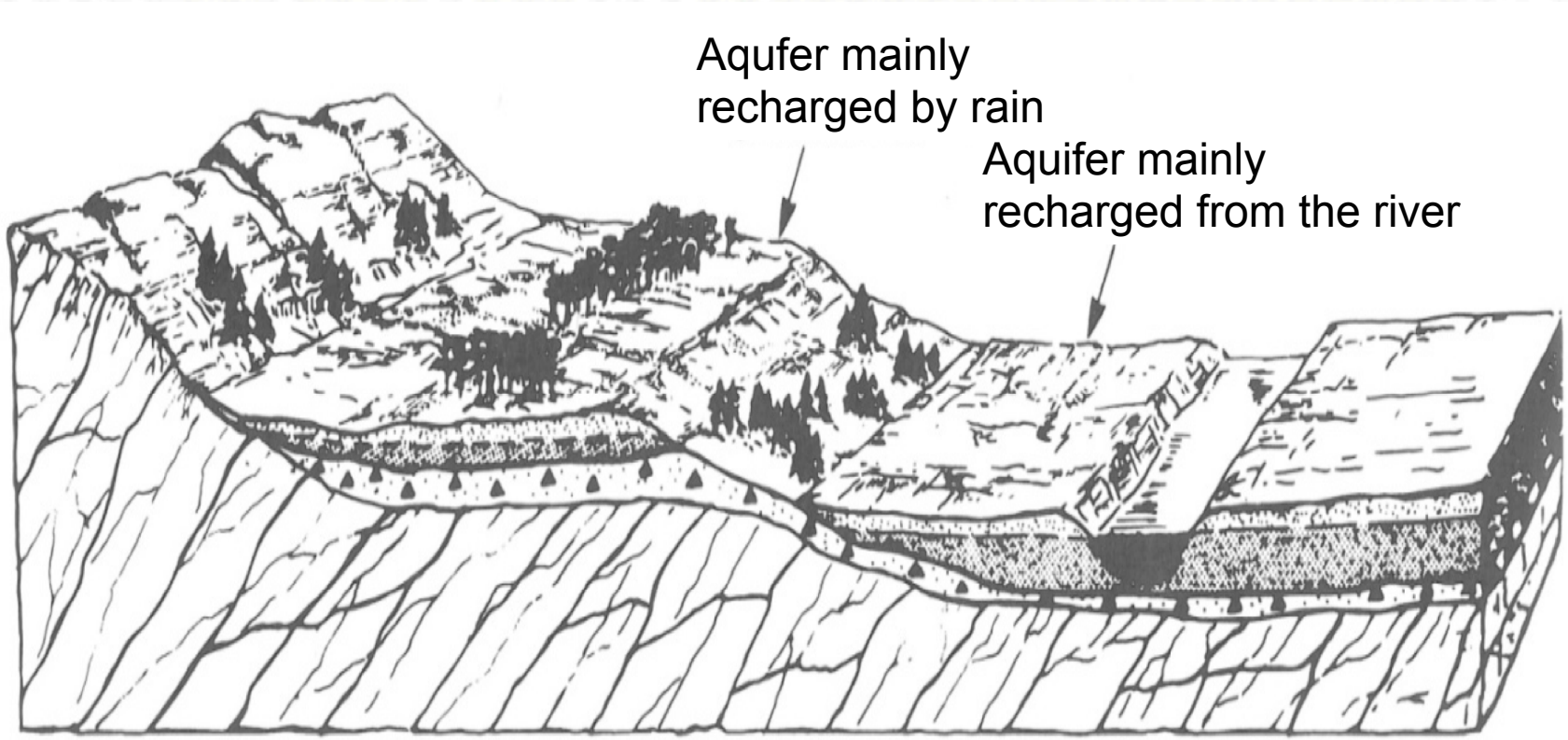
In an unconfined aquifer there is:

- An unsaturated zone (pores not saturated with water, but filled also with air)
- A saturated zone below the water table

Unconfined aquifers

- More likely to be polluted by cesspools, pit latrines and infiltration than a confined aquifer
- Water quality might be OK if cesspool or pit latrines are at some distance, and not dug directly into saturated zone
- The aquifer is better protected if unsaturated zone is thick

Unconfined aquifers



Confined aquifer

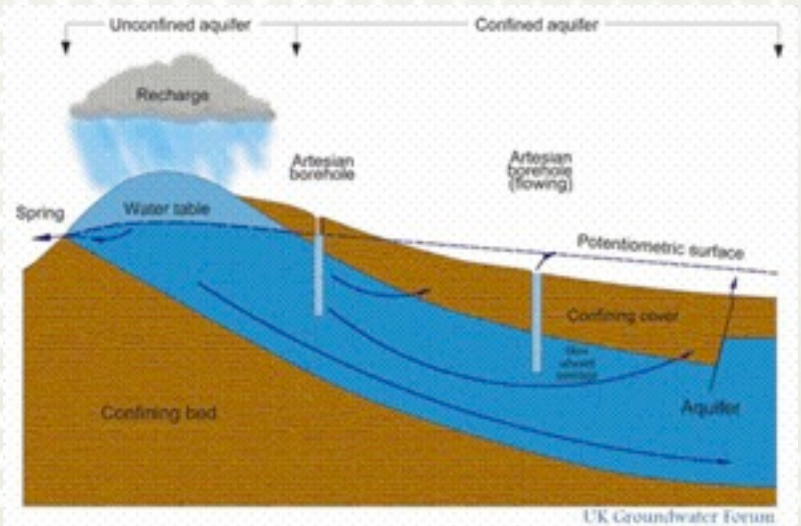
- Less likely to be polluted by cesspools and pit latrines than a unconfined aquifer (to some extent protected by the confining layer)

- Water quality usually changes quite slow.

Confined aquifer

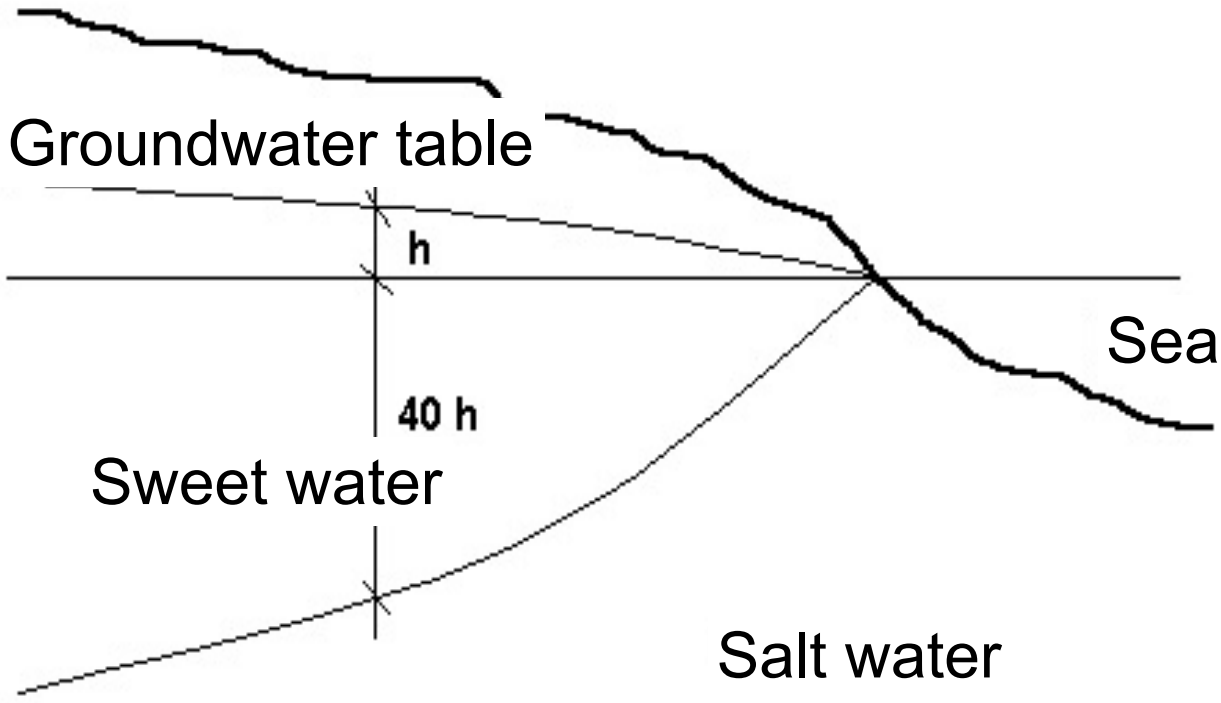
- A confined aquifer often have an unconfined part where the major part of natural recharge takes place

- Alternatively the recharge takes place by leakage from adjacent aquifers through confining or semi-confining layer(s)



Source:

Saltwater intrusion



Darcy´s law: q=K*i

Darcy´s law is an equation used to calculate flow in porous media. The next few slides shows Darcy´s law in one dimensional form and an example of how you can calculate the average velocity of the water flow.

Darcy's law

$$q = - K * i \qquad \text{or} \qquad Q = - A * K * i$$

where

q = specific flow (L/T) average flow velocity - over whole specified cross section

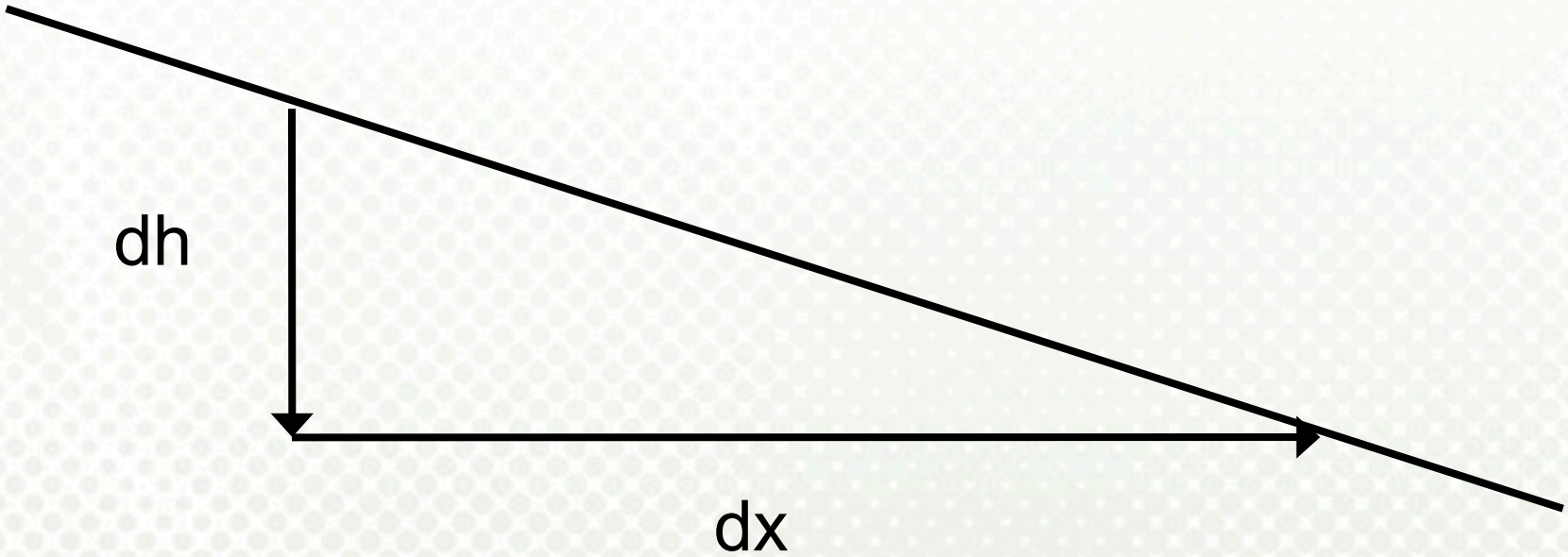
K = hydraulic conductivity (L/T)

i = dh/dx or slope of ground water table (dimensionless)

Q = Volume flow (L^3/T)

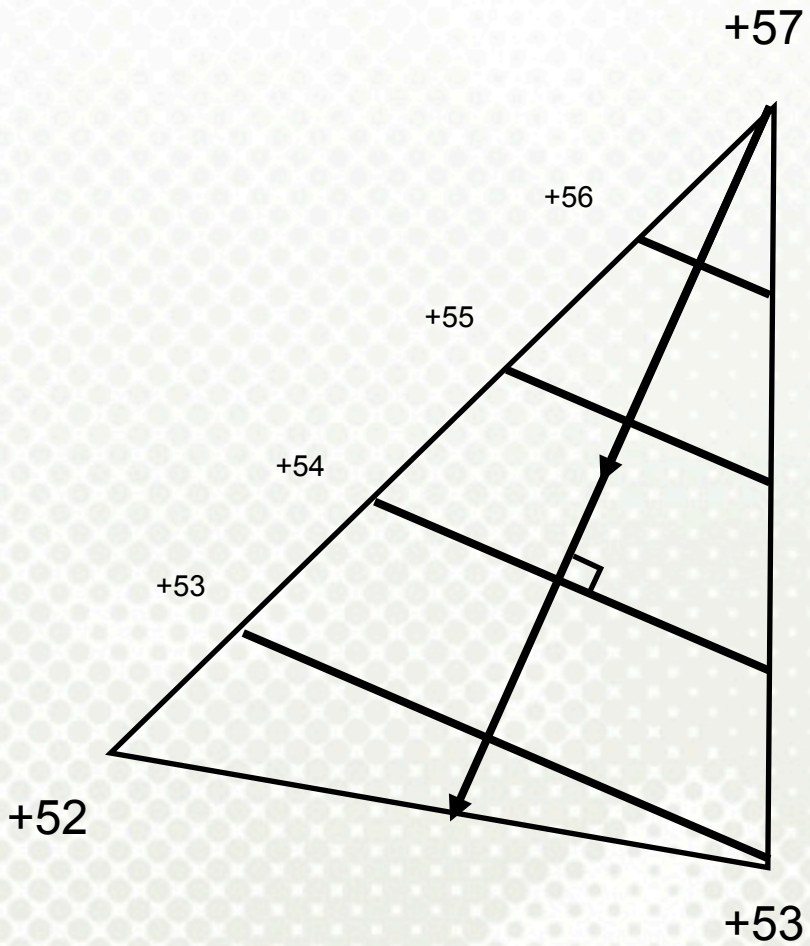
A = cross-section area perpendicular to flow direction (L^2)

Hydraulic gradient i

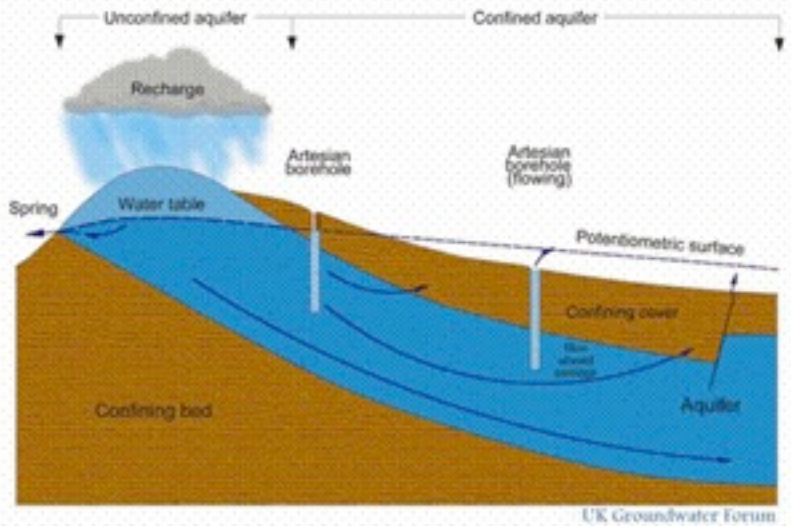


i = dh/dx (or slope of ground water table)

Groundwater flow direction - triangulation



Average flow velocity in the soil pores (v)



$q=K*i,$

q = specific flow (m/d)

K = Hydraulic conductivity (m/d)

i = The slope of the groundwater surface (h/l)

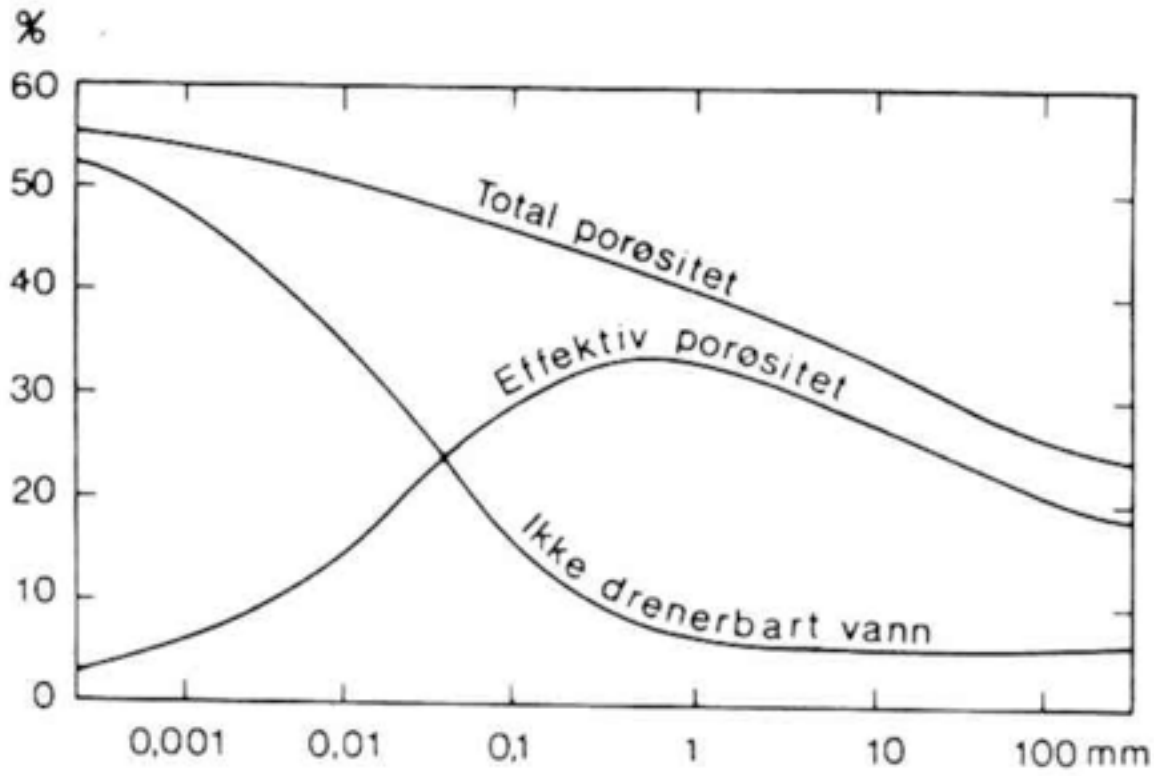
$v=q/n_e$

v = average velocity in the soil pores (m/d)

n_e = porosity available for flow (0 - 1,0)

To find the average flow velocity we have to divide the specific flow with the porosity available for flow n_e

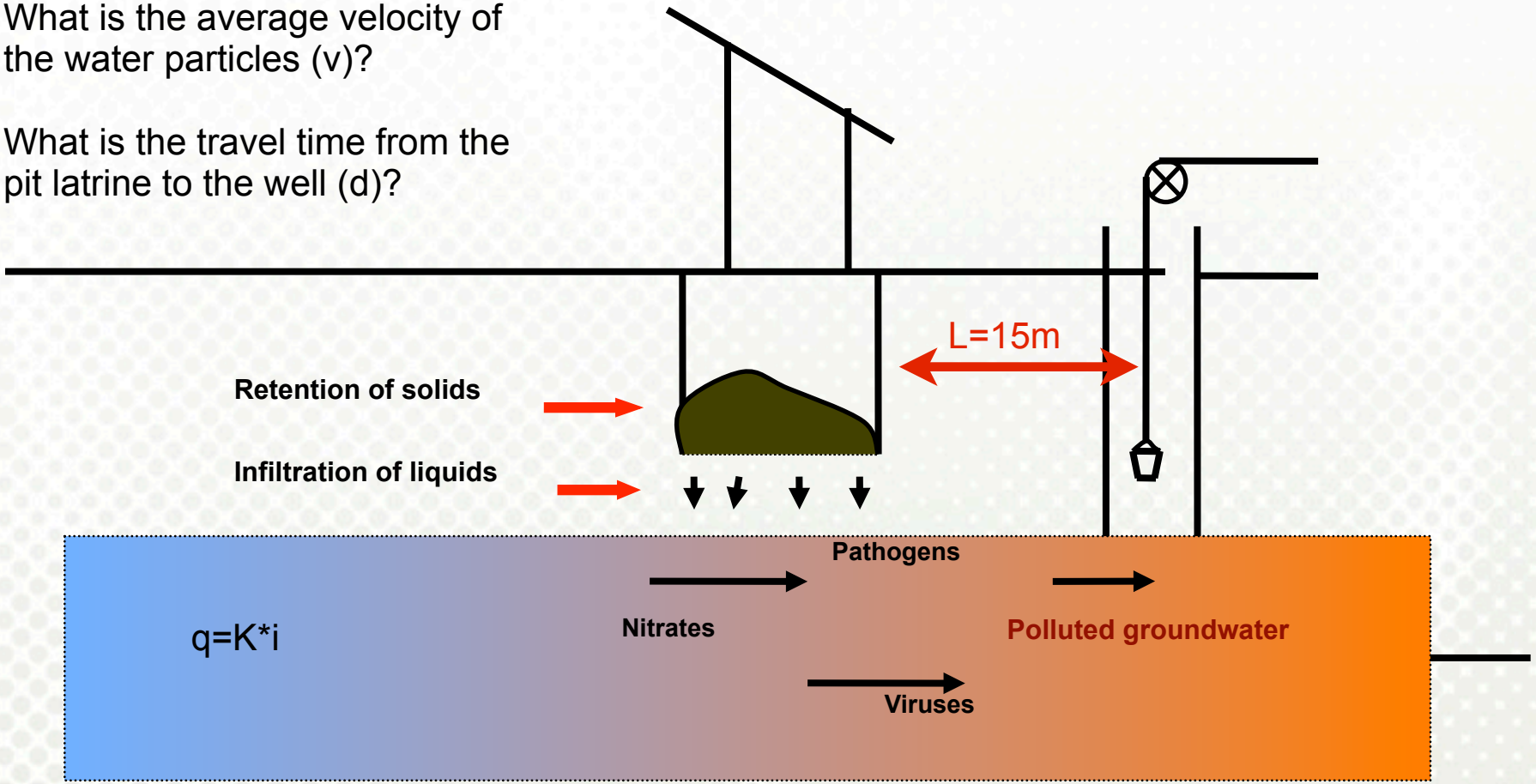
Porosity available for flow n_e



Pit latrine - Risk of pollution

What is the average velocity of the water particles (v)?

What is the travel time from the pit latrine to the well (d)?



Groundwater vs. surface water

Property	Groundwater	Surface water
pH	Higher	lower
SS	Low	High
N	Low	Varying/higher
O_2	Low	High
Hygiene	High quality	Varying quality
Vulnerability	Low	Higher
Restablishment	Slow	Faster
Temperature	Stable	Varying
Capacity/yield	Lower	Higher
Recharge	Slow	Fast

Groundwater vs. Surface water

- What do you think is the dominating water resource in Norway and why?

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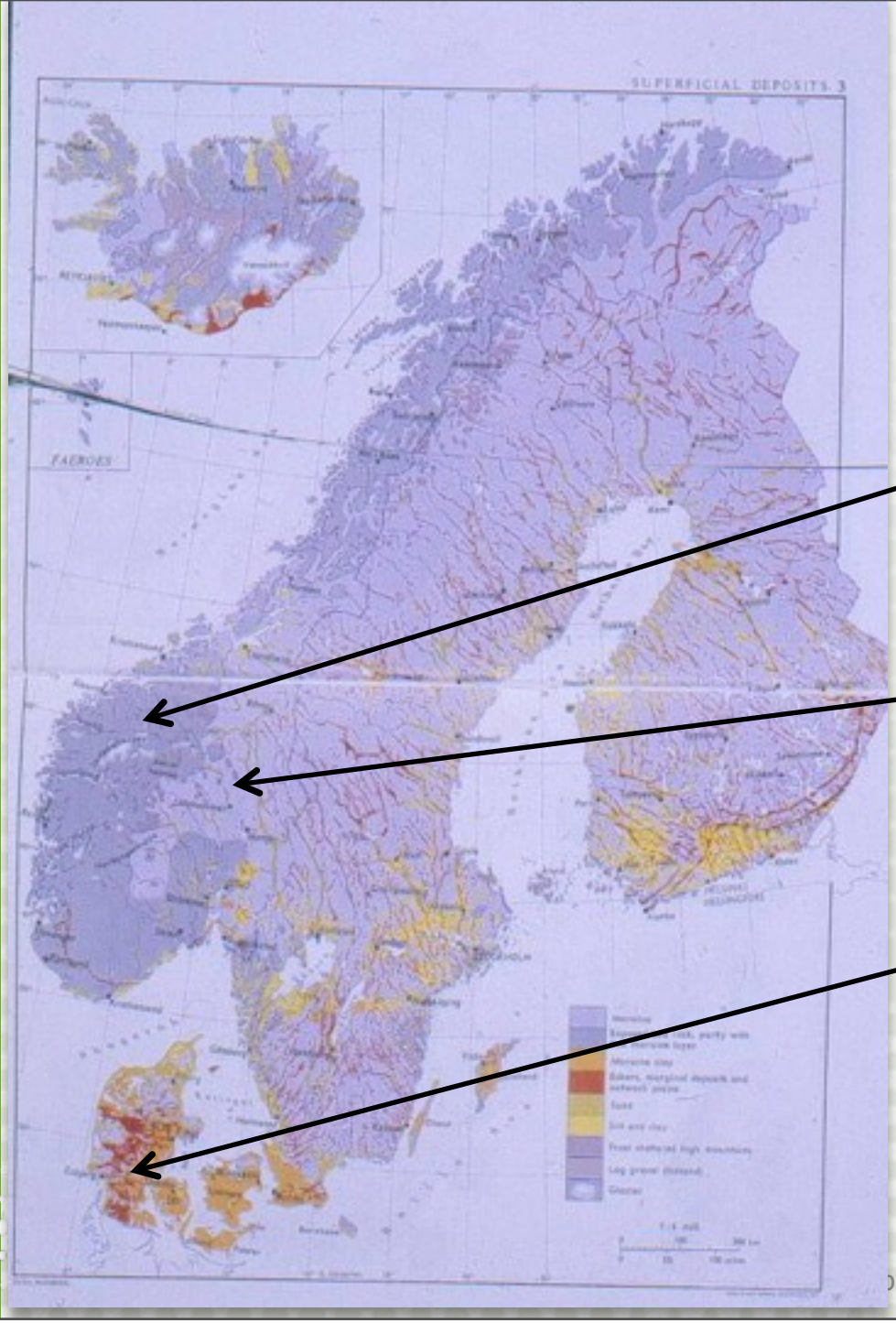

Soils of Scandinavia by genetic origin

Exposed bedrock partly with thin moraine

Moraine

Fluvial and glaciofluvial sediments

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- Groundwater sources
- Selection of a water source
- **Protection of water sources**
  - Hygienic barriers
  - Protection zones
  - Well construction

Hygienic barriers

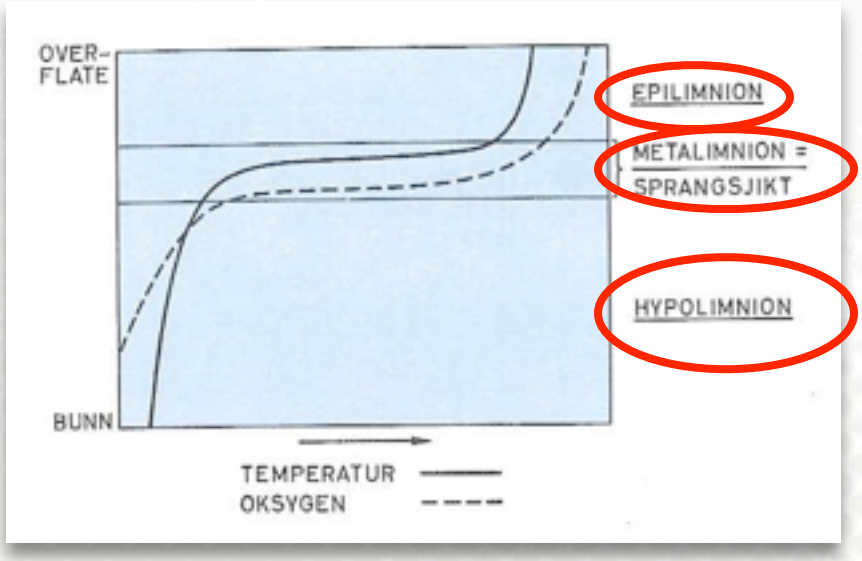
In Norway water supply systems serving more than 100 people needs 2 hygienic

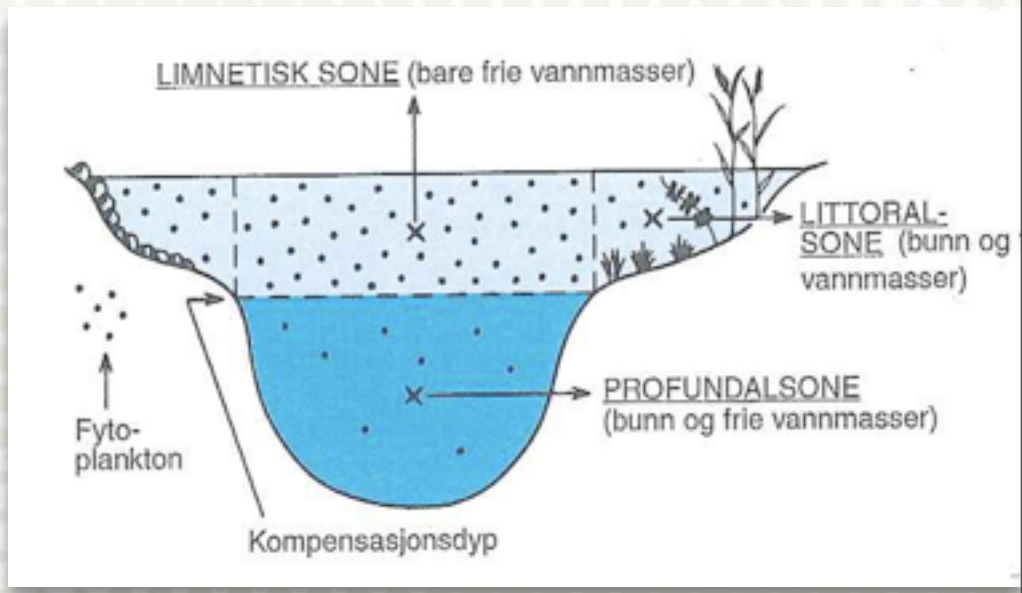
- Natural barriers
- Constructed barriers

Natural barriers

Lakes

Extract the water from the hypolimnion





Natural barriers

Rivers

Extract the water upstream of human activity

Constructed barriers

- Sand filtration (physical/biological)
- UV-disinfection (physical)
- Chlorination (chemical)
- Chemical precipitation (chemical)
- Membrane filtration (physical)
- Well protection (physical/biological)
- Restriction on human activities in the watershed/recharge area (regulatory)

Protection zones (groundwater in sediments)

Zone 0: The well-head area

Zone 1: The close recharge area

–minimum residence time to well 60days

Zone 2: The distant recharge area

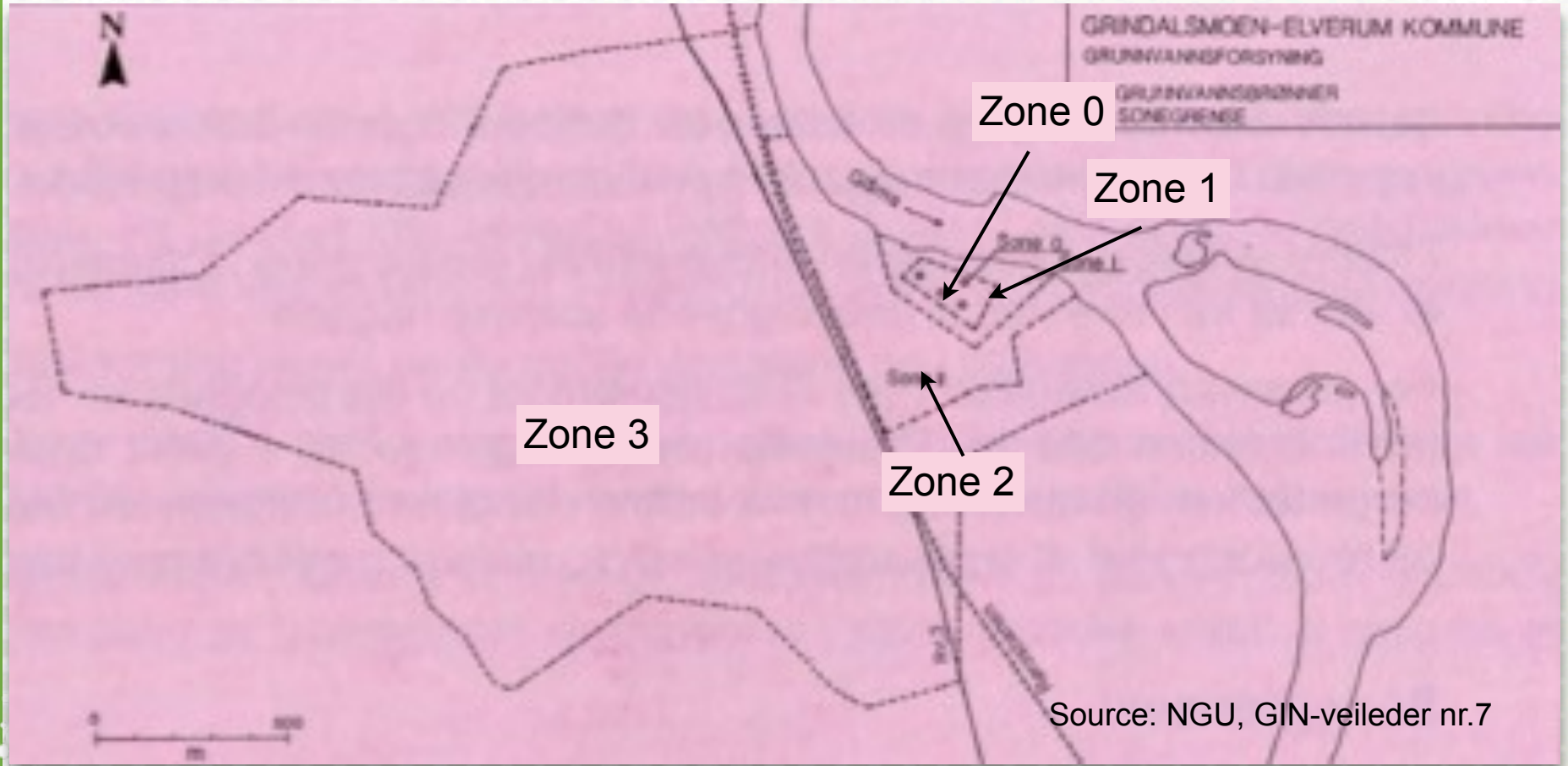
- all water that is pumped from the well is recharged within this area

Zone 3: The maximum protection area

- area where activity may influence the groundwater

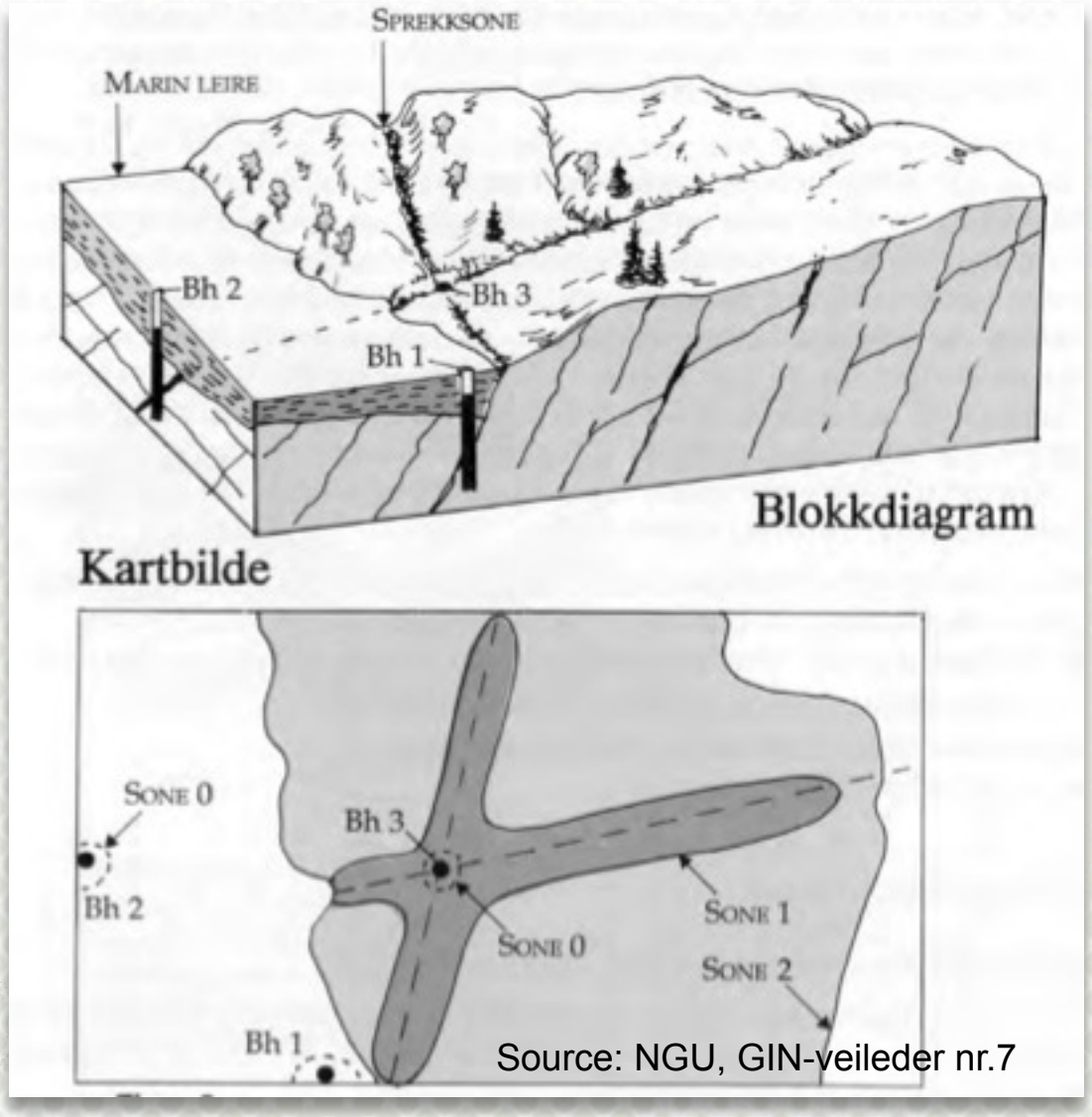
Protection zones (groundwater in sediments)

Elverum groundwater works



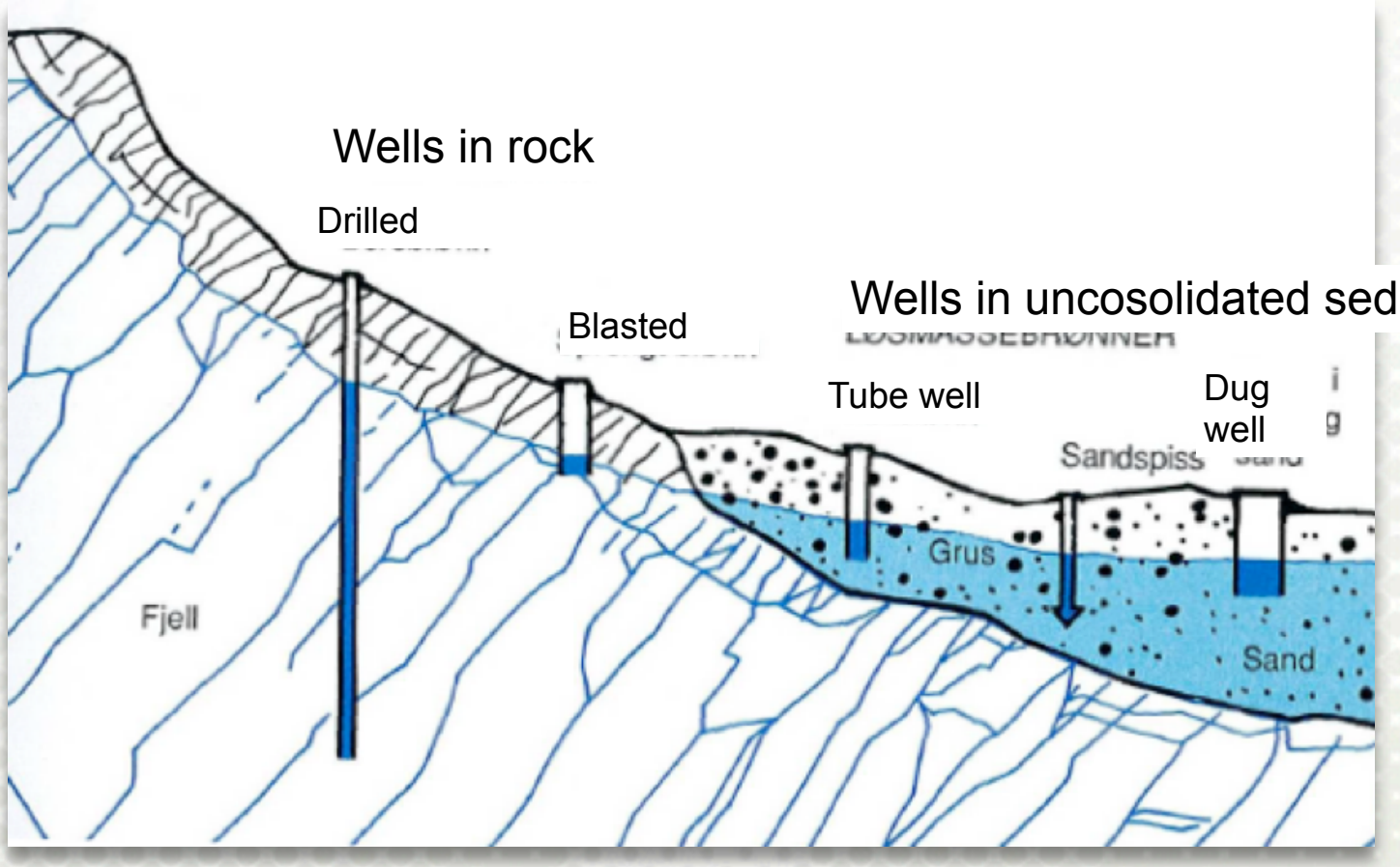
Source: NGU, GIN-veileder nr.7

Protection zones (groundwater in bedrock)

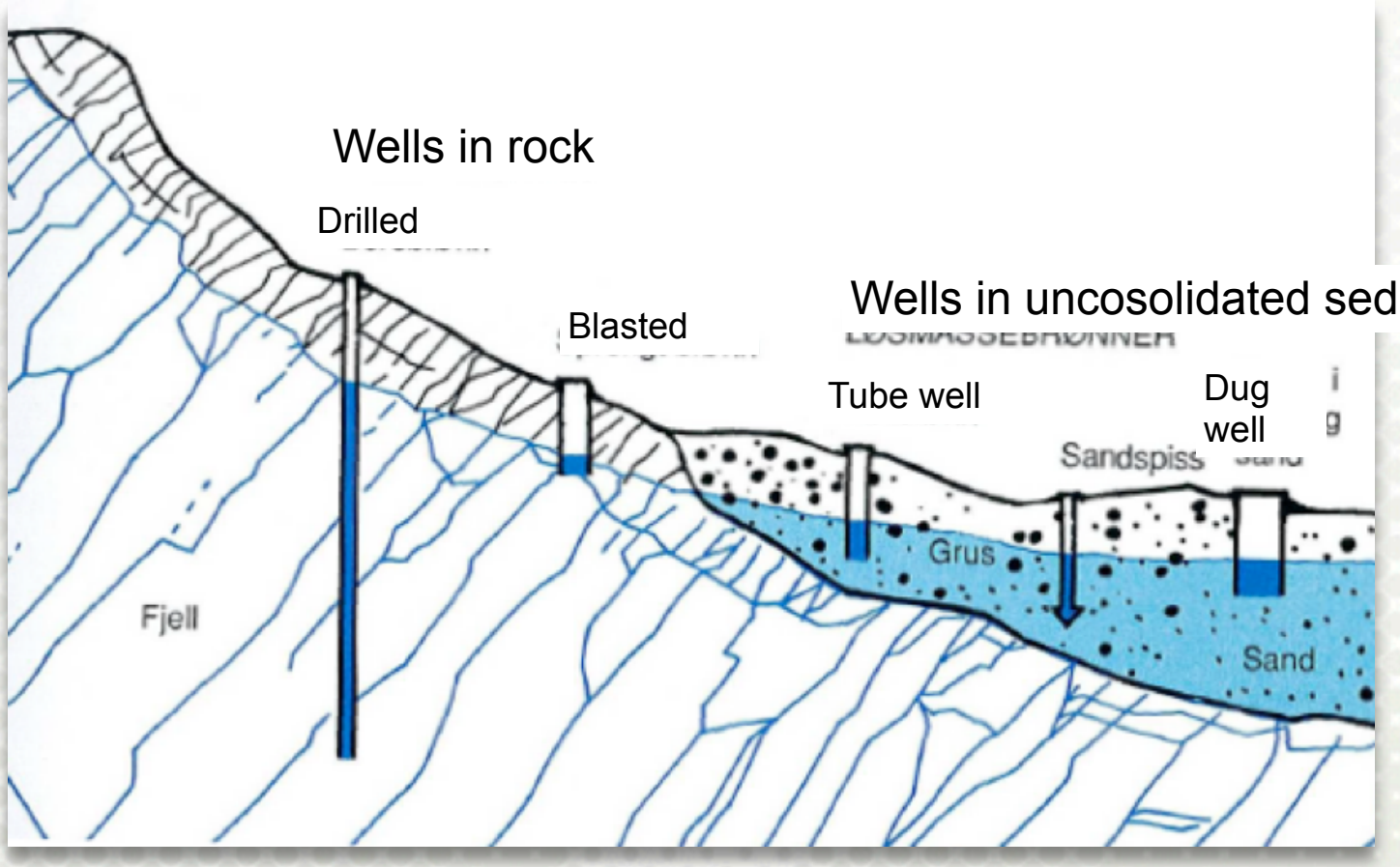


The protection zone for a groundwater supply from a well in bedrock may differ from a well in sediments. In the example to the right the immediate fractures feeding the well constitute Zone 1. Zone 2 is the terrain draining towards the fracture zones.

Groundwater wells



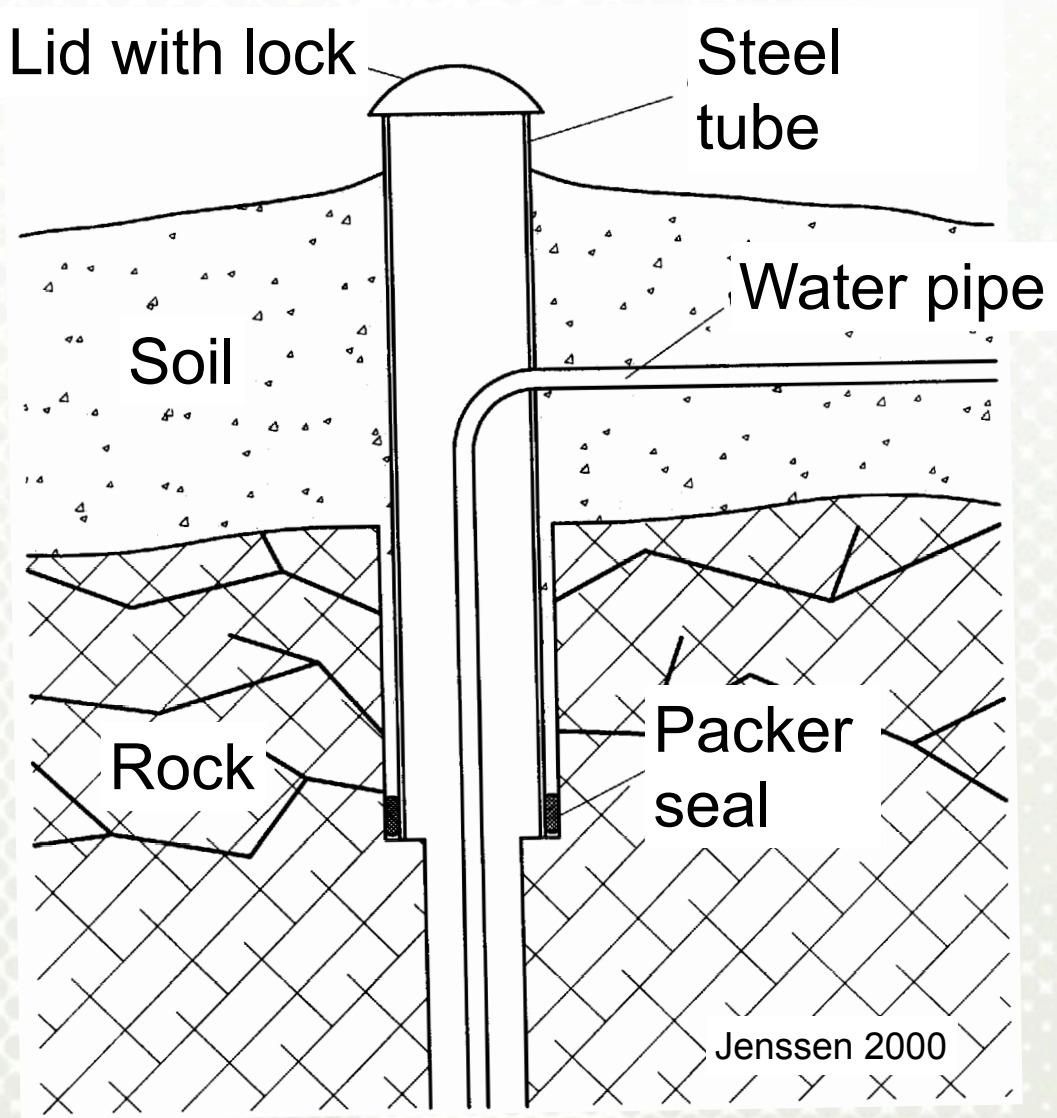
Groundwater wells



Truck mounted drill rig

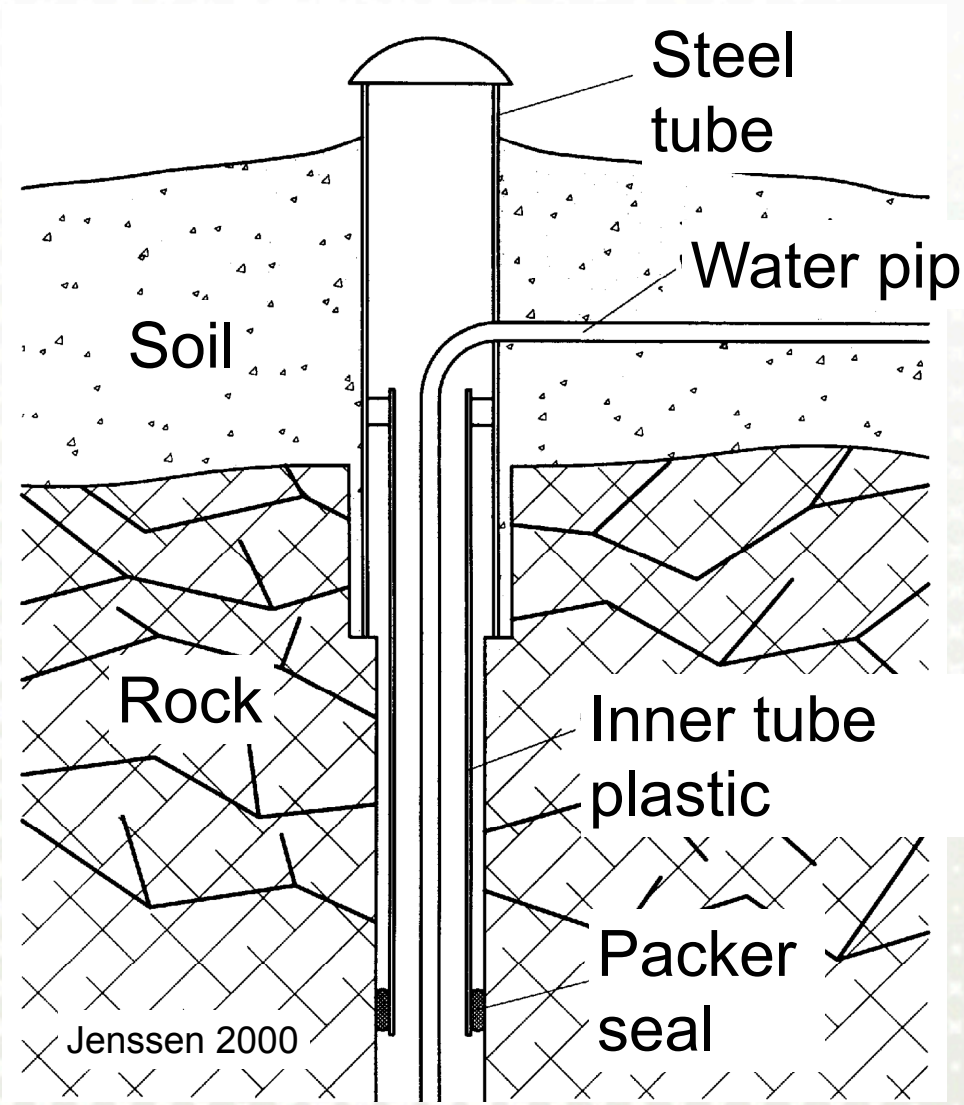
Air compressor

Well construction - drilled well in rock



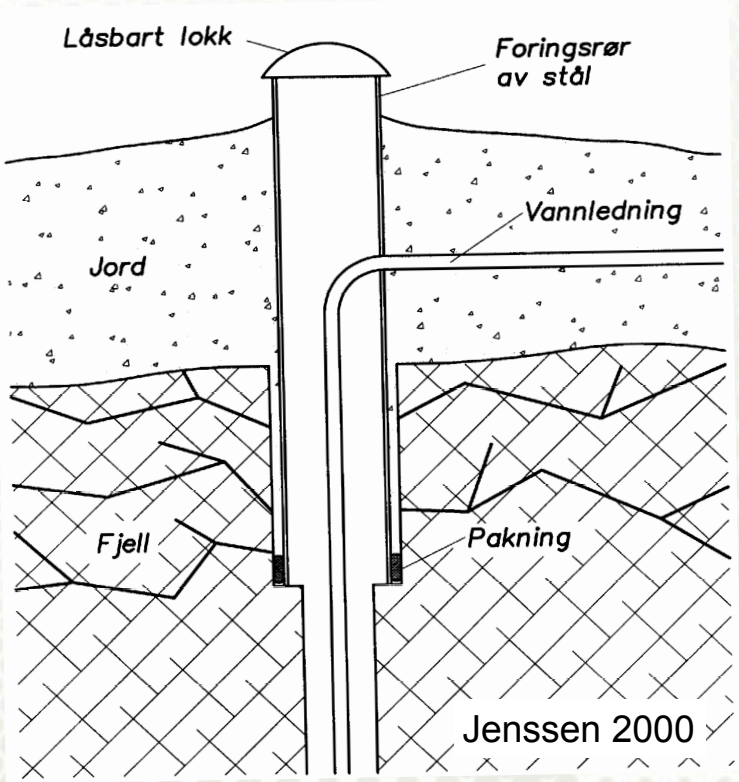
Example of an uprotected well in rock

Uppgrading of a drilled well in rock

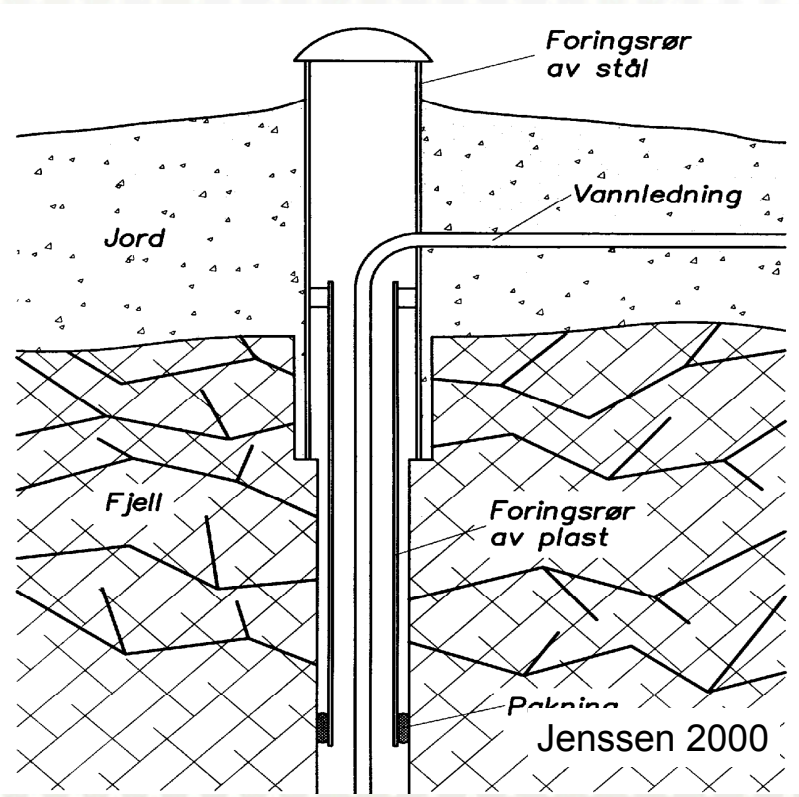


Well construction - drilled well in rock

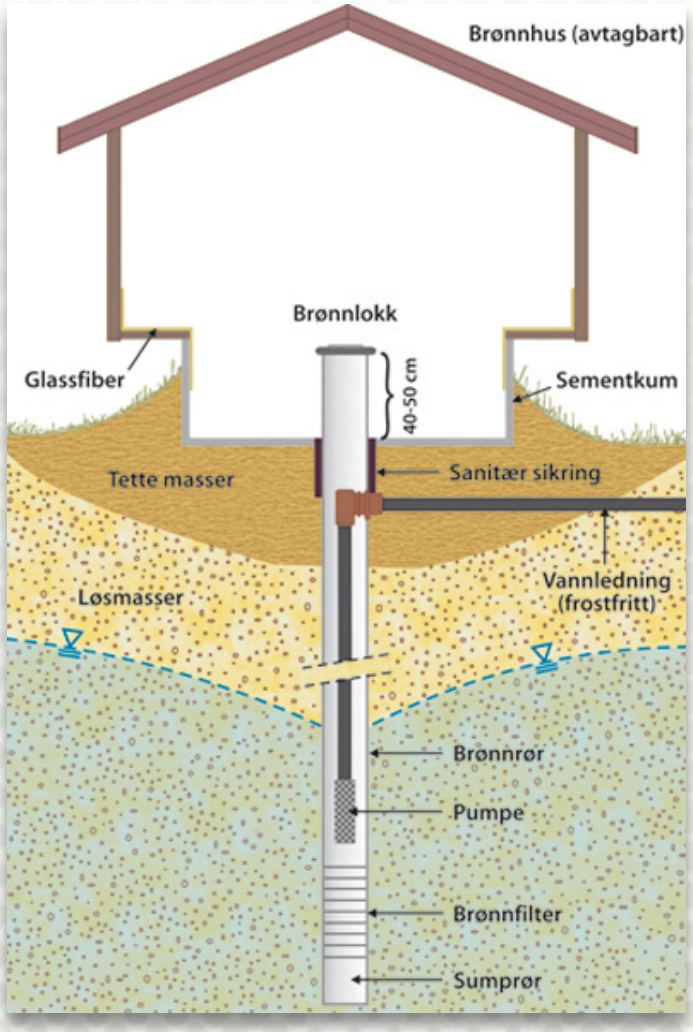
New



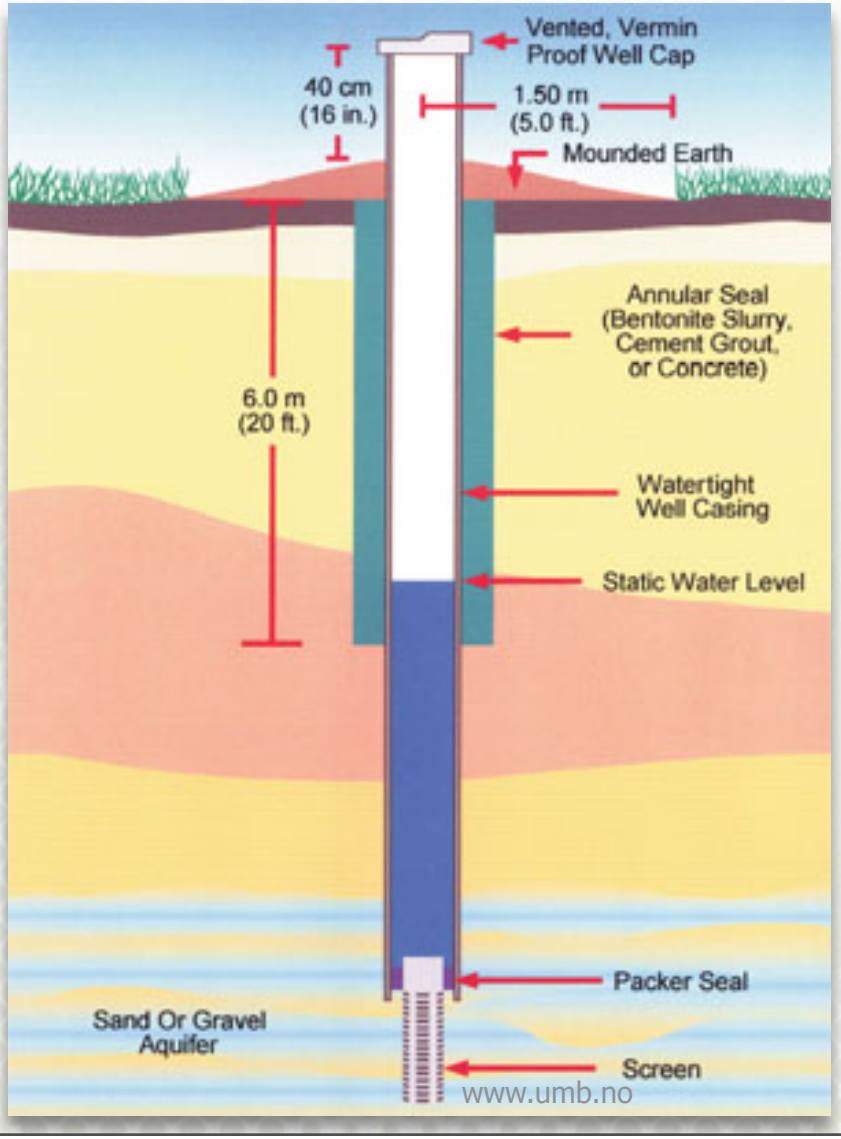
Improved old well



Well construction - tube well

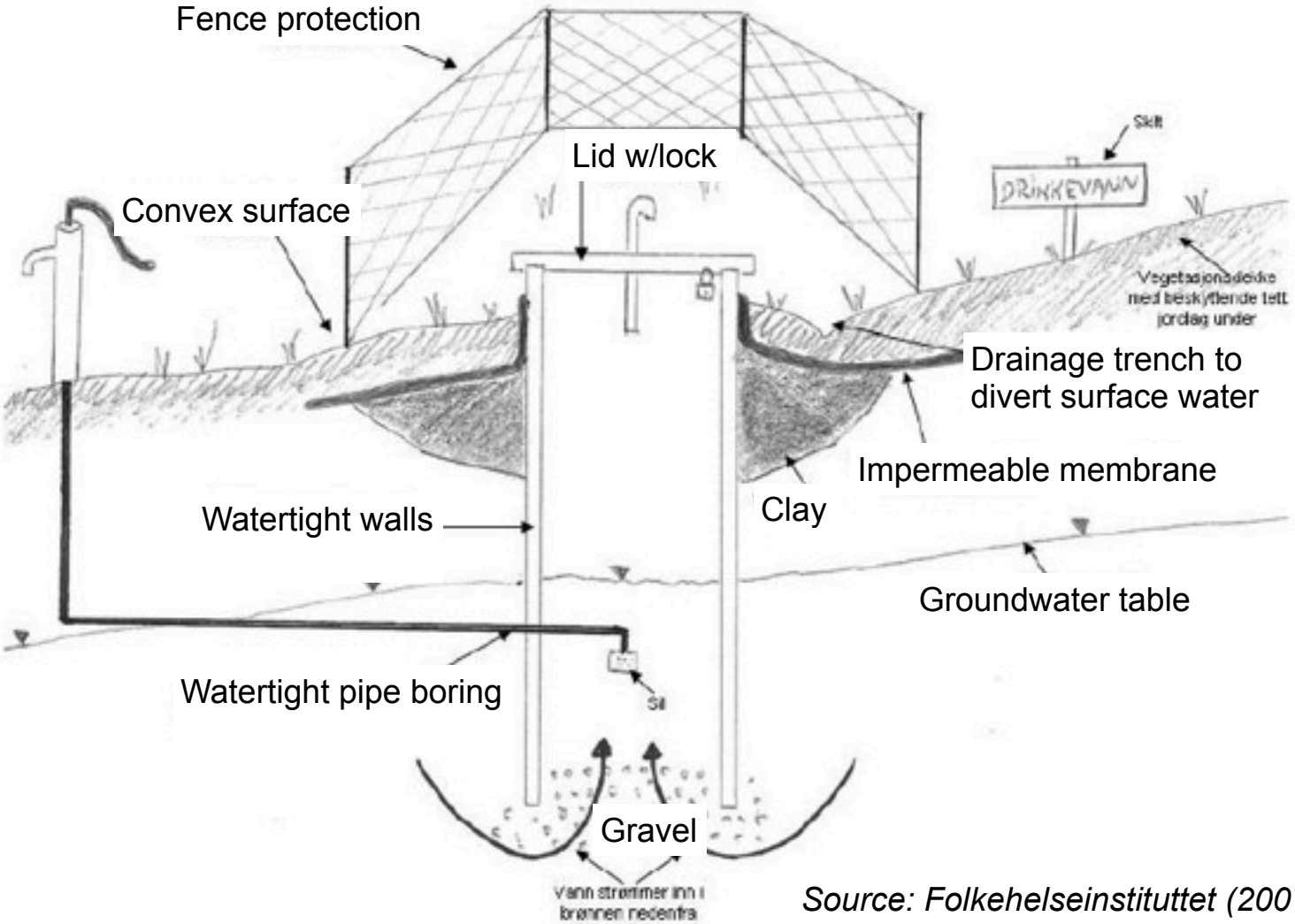


Well construction - tube well



Well construction - dug well

Well construction - dug well



Source: Folkehelseinstituttet (2007)

”The water cycle”