# Decades of drinking water treatment using MAR in Finland: aspects of sustainability and resilience


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TURKU WATER SERVICES

International Association of Hydrogeologists
the World-wide Groundwater Organisation

IAH Commission on Managing Aquifer Recharge

Online MAR Seminars

#11. Long-standing experience in MAR

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# Water and Finland


- 56 000 lakes
- 10 % of the surface area is covered by water
- Groundwater is favored in water supply, but aquifers are small
- Surface waters contain natural organic matter (NOM)

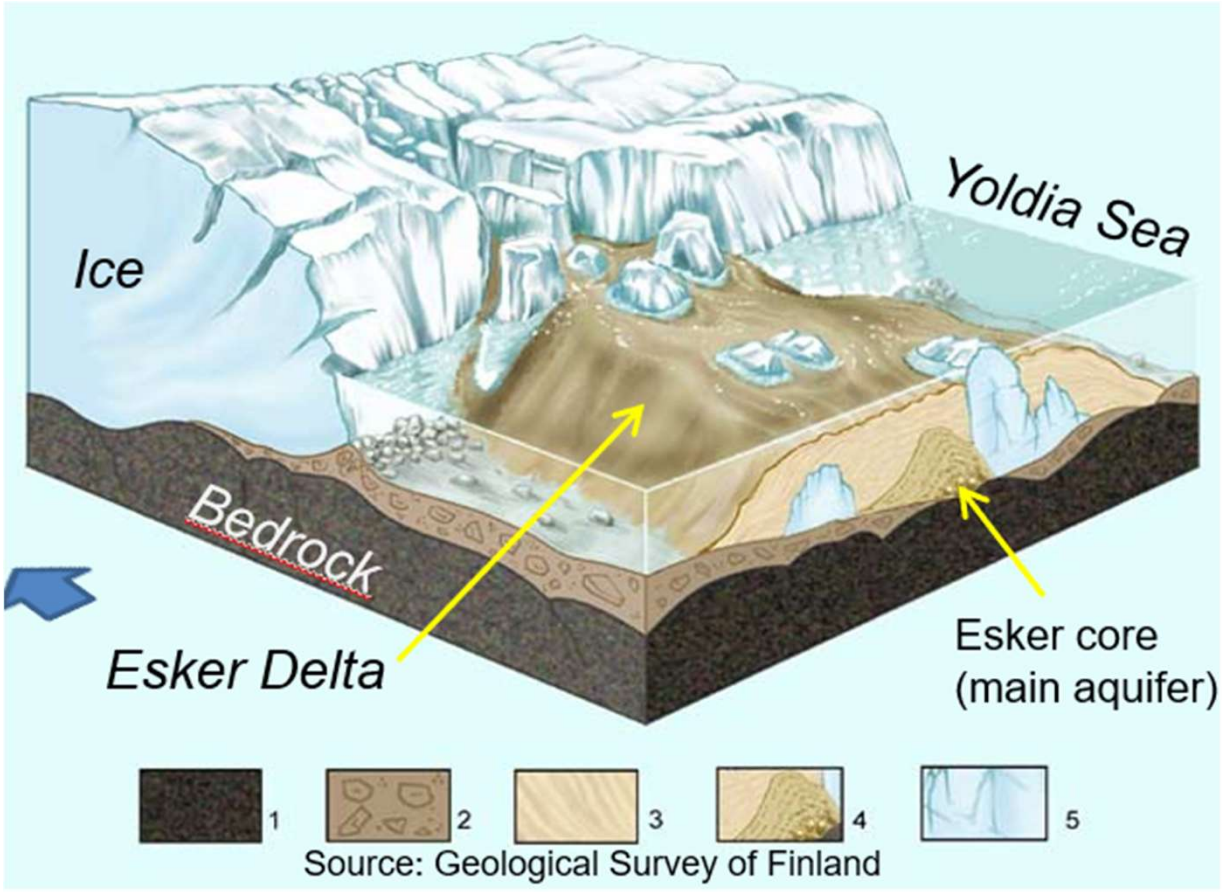
Humic substances increase the colour of water

source of the photo:

Nordic
COUNCIL OF MINISTERS

# Glaciofluvial aquifers

Melting of ice created streams that transported sand and gravel, thus forming eskers

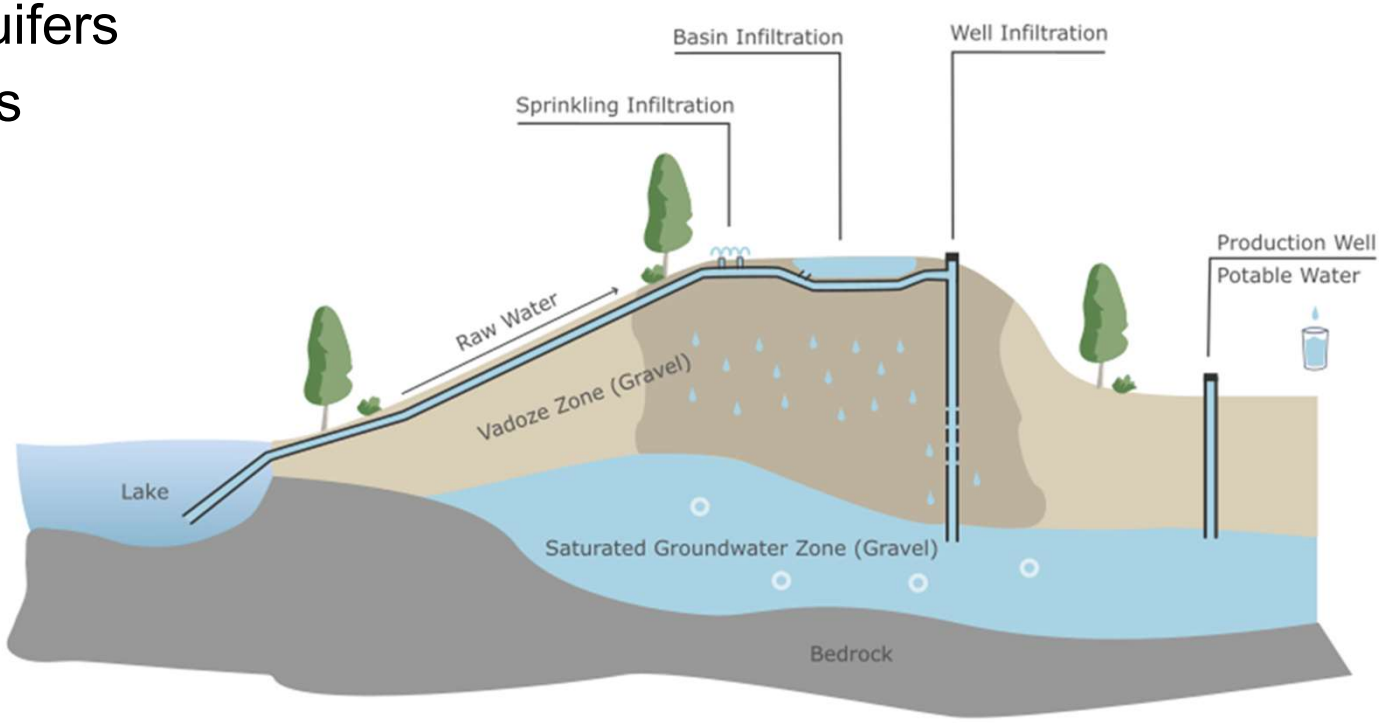



**1**= Bedrock, **2**= Till, **3**= Sand/gravel, **4**= Boulder core, **5**= Buried ice

# MAR is used for drinking water treatment

- Removal of NOM through MAR
- Unconfined esker aquifers
- Almost 30 MAR plants

Basin infiltration during winter



# An example of good quality raw water characteristics (Lake Päijänne)

| Parameter | Unit | Value |
|---|---|---|
| TOC | mgTOC/l | 7.7 |
| Temperature | °C | 2.4–10.8 |
| Oxygen | $mgO_2/l$ | 11.0 |
| Carbon dioxide | $mgCO_2/l$ | 1.9 |
| Turbidity | FNU | 0.61 |
| pH | | 7.2 |
| Alkalinity | mmol/l | 0.27 |
| Iron | µgFe/l | 49 |
| Manganese | µgMn/l | 3 |

TOC to be reduced

Restricted variation of temperature

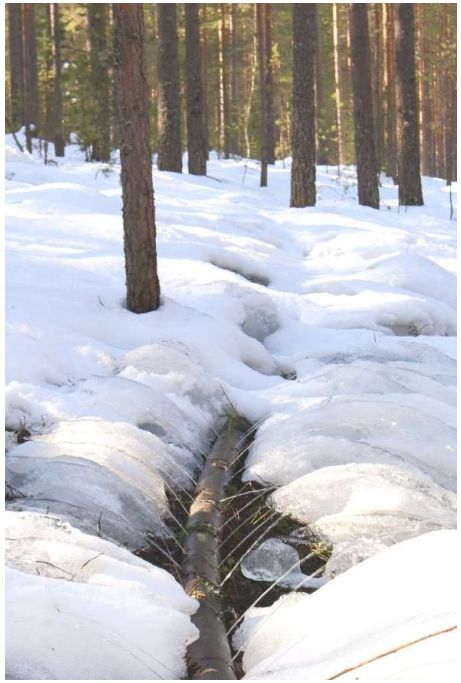
Sufficient oxygen content

Low turbidity

Low iron and manganese concentrations

# Examples of MAR plants (1)

- Ahvenisto MAR plant
- Taken in use in 1976
- Production 7,800 $m^3/d$
- Basin, sprinkling and well infiltration



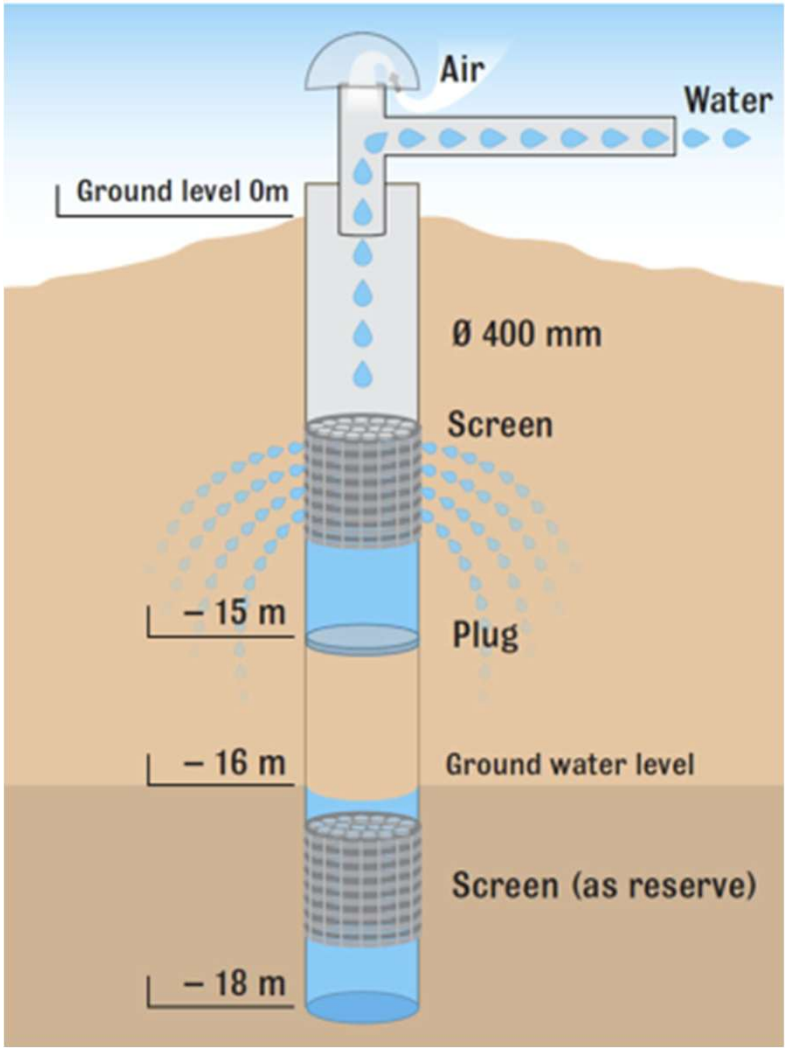
- Vuontee MAR plant
- Taken in use in 2000
- Production 10,000 – 15,000 $m^3/d$
- Sprinkling infiltration

# Examples of MAR plants (2)

- Kuivala MAR plant
- Taken in use in 1992
- Production 22,000 $m^3/d$
- 60 % of the raw water flow is pretreated
- Basin infiltration

# Examples of MAR plants (3)

- Rusutjärvi MAR plant
- Taken in use in 1997
- Production 10,000 $m^3/d$
- Well infiltration since 2007



# Examples of MAR plants (4)

- Virttaankangas MAR plant
- Taken in use in 2011
- Production 63 000 $m^3/d$
- Capacity 105,000 $m^3/d$, the largest MAR plant in Finland
- Fluctuating raw water quality (river)
- Chemical pretreatment given as a condition during the permit process
- Basin infiltration

Water intake

Infiltration basins

River Kokemäenjoki

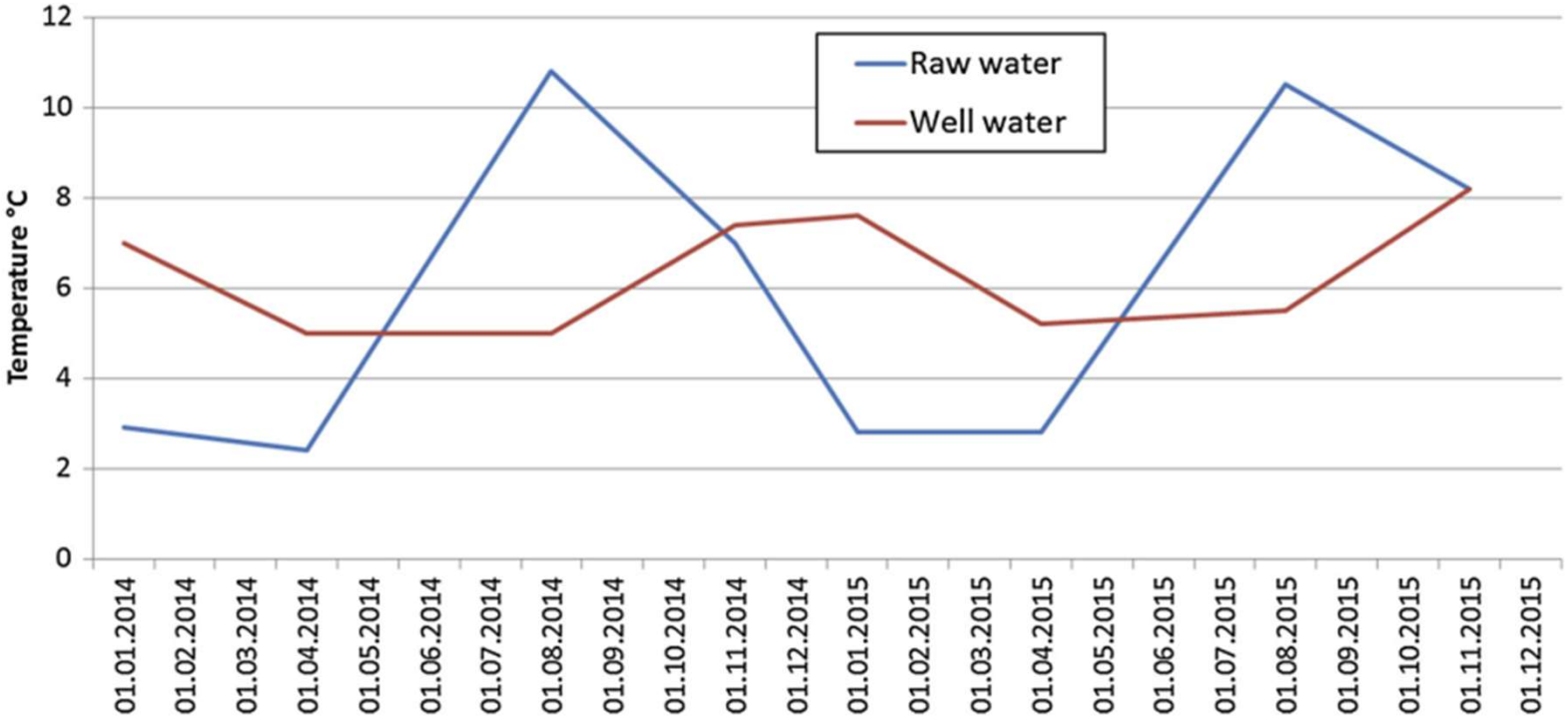
# On sustainability

- MAR treated water is generally of good quality during all seasons:
  - Tasteless, odourless, cool
  - Water less likely to be wasted

- MAR treated water is produced in a natural way:
  - Nature’s own processes decompose NOM
  - The use of precipitation chemicals may be avoided totally
    - In case of chemical pretreatment, the precipitation chemical doses are smaller compared to chemical water treatment
    - For larger production capacity, the avoided amount of precipitation chemicals can be more than one million kg annually

# MAR process reduces temperature variation of abstracted water

- stable water temperature increases lifetime of water pipes
- cool water is more enjoyable to drink




Jäniksenlinna MAR plant (Tanttu & Jokela)

# MAR treatment is cost-effective

**On sustainability**

- MAR investments include especially pipes and pipelines, whose lifetimes are atleast several decades
  - Need for renovation investments is smaller compared to machinery and devices for chemical water treatment
- Operational costs of MAR treatment are small
  - No precipitation chemical costs
  - Robust operational procedures (simple production processes)
  - No backwashing sludges to be disposed of (cf., e.g. > 1000 $m^3$/d for chemical water treatment)
- As an example, for a 100-year life cycle, total costs of a 62 000 $m^3$/d water production process were calculated to be:
  - 0.20 €/$m^3$ for MAR treatment
  - 0.42 €/$m^3$ for chemical water treatment

# MAR treatment is environmentally sound

- Use of chemicals reduced
- No need for manufacturing and transporting of precipitation chemicals
- Decrease of backwashing sludges (and hence reduced load of sewage pumping, sewerage and wastewater treatment)
- Cool, constant temperature MAR treated water can be used to heat the production facilities (heat pump) during winter
- MAR process can be used to maintain groundwater tables at desired level preventing unwanted changes in the nature
- The operational control of MAR (infiltration, abstraction) can be adjusted to counterbalance changes in the environment

# MAR treatment is environmentally sound (2)

- Reduced carbon footprint
  - Case study calculation: 30 $gCO_2/m^3$ from MAR vs. 150 $gCO_2/m^3$ from chemical water treatment => a 5-fold difference
  - No carbon footprint from electricity: carbon-neutral electricity used
  - MAR:
    - Largest share: chemical manufacturing (post treatment)
    - No carbon footprint from heating of the premises (heat pump using water)
  - Chemical water treatment:
    - Largest shares: chemical manufacturing, including activated carbon regeneration, treatment of backwash sludges and heating of the premises

# On resilience (1)

- Raw water pumping can be stopped for a period of time without disturbing water treatment due to the underground water storage capacity
  - Important, e.g., in the case of suspected raw water contamination
  - According to one water permit, this discontinuity could last for 19 days
- Depending on the aquifer size the water storage capacity can be of millions of cubic meters
- The basic technology is simple, electricity is needed
- No need to acquire precipitation chemicals, no need to store them

# On resilience (2)

- A MAR plant can consist of several aquifers that perform independently => problems in one aquifer do not harm the others
- Decentralized systems (infiltration areas, abstraction well fields), spread on a larger area compared to a chemical water treatment plant, are less vulnerable to sudden wide damage
- Capacity of the MAR plant can temporarily be increased substantially in accordance with preset limiting groundwater levels (permitted monthly flowrates vs. annual flowrates)
- Depending on local soil conditions, possibly no need to adjust pH or alkalinity as the final treatment stage

# On resilience (3)

- The long underground detention time equalizes water quality
- May be insensitive to periodical heavy rainfall and flooding
- Core treatment process takes place underground protecting water quality from disturbances above ground
- In case of emergency, the long underground detention time with high adsorption potential helps to minimize the amount of radionuclides (iodine, strontium) in the MAR treated water

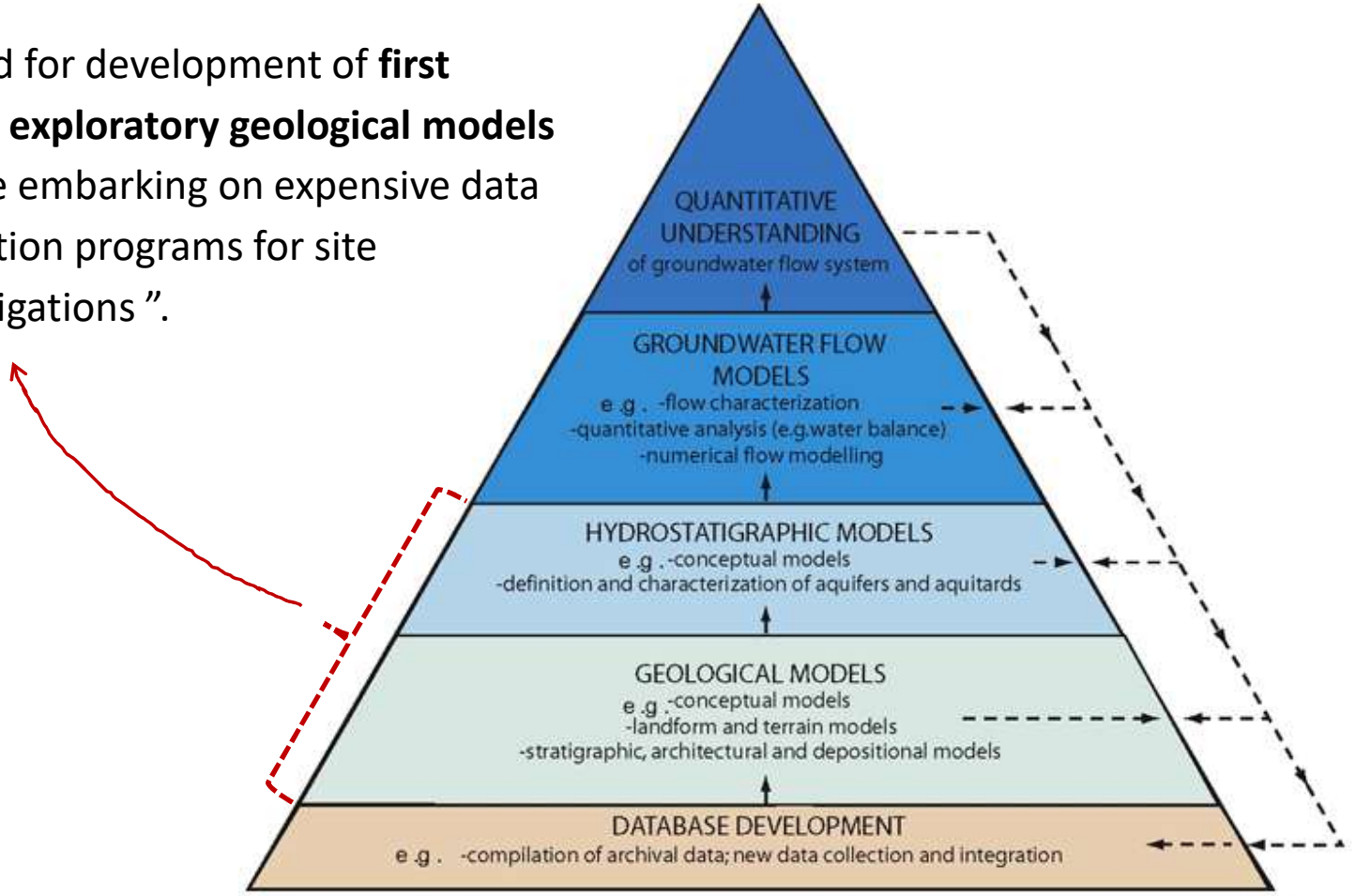
# Concerns

An esker

- MAR planning requires expertise
- Suitable site needs to be found
- MAR projects are time-consuming,
  taking several years from the initial site selection to start-up
- Planned MAR sites can be targets for contradictory interests –
  such as exctraction of gravel or nature conservation. These
  interests may hinder or prevent MAR projects.
- Permit processes are getting longer and the outcome more
  unpredictable

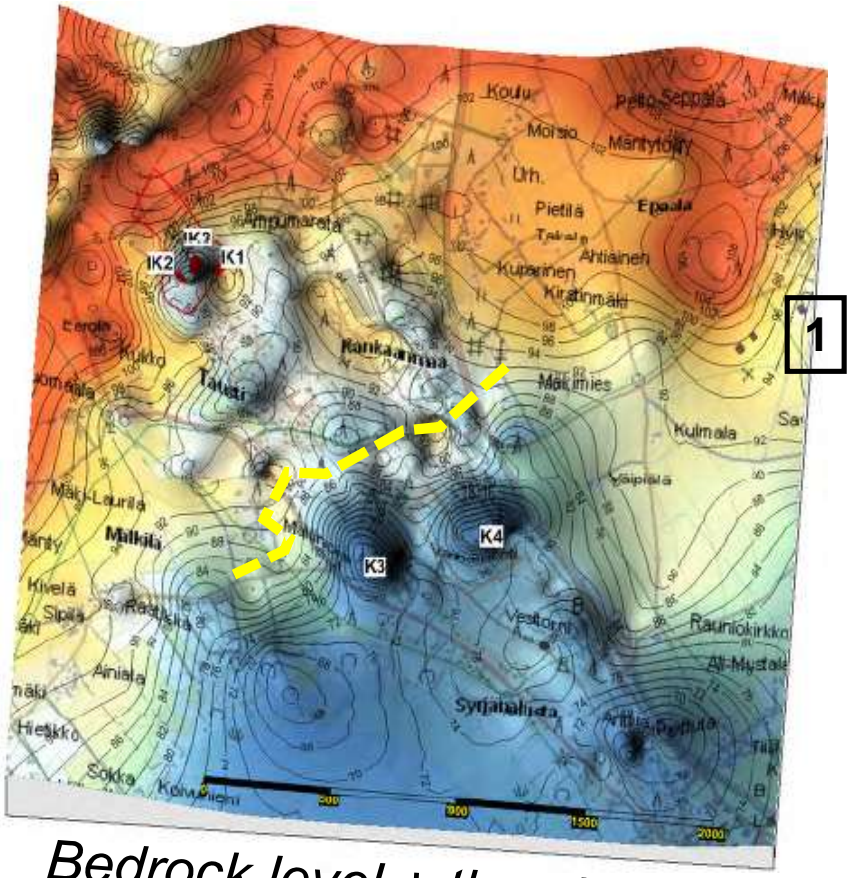
# Aquifer Characterization

" Need for development of **first order, exploratory geological models** before embarking on expensive data collection programs for site investigations ".




(Sharpe et al. 2002)

# Methods




*Bedrock level + thresholds & deposit thickness*

Gravimetric survey

Borehole data + observation wells

**Georadar (GPR) sedimentology**

1

**Depositional stages** and related **large-scale esker structures** that predict the hydrogeological properties and **K -values**

Infiltration + Tracer (NaI) test for flow paths & residence times

2

**Groundwater flow modelling + MAR design**

(Mäkinen et al.)

# Reduction of the environmental impact

(1) Minimizing the use of nature conservation areas

(2) Choice of infiltration methods

(3) Planning and construction of pipelines

(4) Process control to maintain water balance

(5) Excess infiltration to provide sensitive areas with sufficient groundwater supply

drilling

GW monitoring well infiltration

narrow trench

sprinkling infiltration

# Conclusions

- MAR is a secure and cost-effective solution for drinking water production in Finland, based on 50 years of experience
- MAR is getting even more important due to the increasing role of resilience in the society
- MAR and community water supply generally should be given more priority in the (European) legislation