

Water reuse and desalination

Urs von Gunten

Eawag, Swiss Federal Institute of Aquatic Science and
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Heat wave in summer 2018 – Is this the future of Switzerland/Central Europe?



Water crisis Cape Town 2017/2018



Frankfurter Allgemeine 15.3.2018

SAVE LIKE A LOCAL

CAPE TOWN IS EXPERIENCING ITS WORST DROUGHT EVER. PLEASE USE AS LITTLE WATER AS POSSIBLE.

www.capetown.gov.za/thinkwater

5 WATER SAVING TIPS – GUESTS

- Take a short **2-minute shower.**
- Only **flush** the toilet **when necessary.** Don't use it as a dustbin.
- Use a cup** instead of running taps in the bathroom or kitchen, for brushing teeth, shaving, drinking etc.
- Collect** your shower, bath and basin water and re-use it to flush your toilet.
- Use your **towels more than once.**

CITY OF CAPE TOWN
ISIXEKO SASEKAPA
STAD KAAPSTAD
Making progress possible. Together.

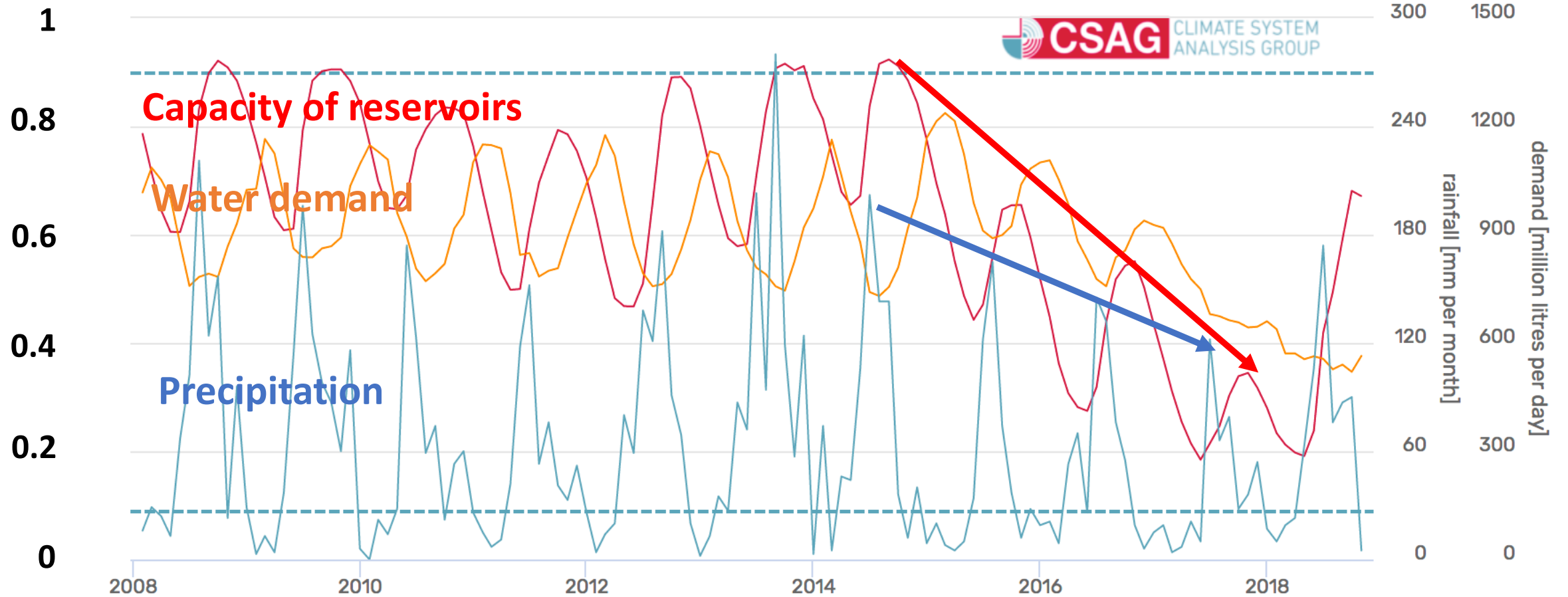
CAPE TOWN & WESTERN CAPE
marketed by **WESGRO**

<https://www.kapstadtmagazin.de/wasser-spahren-kapstadt>

Water crisis in Capetown: They barely made it!

km³

BIG SIX WCWSS DAMS



Water crises worldwide



- Windhoek (Namibia, end of 1970s)
- Australia (2000s, Perth, Brisbane)
- California (drought: 2011-2017, 2019-?)
- South Africa (2017/2018)
- Italy, Spain, Greece
- Singapore (water autonomy)
-

San Francisco Chronicle, 20. Nov. 2018

Drought in Switzerland in 2018 (2022): Most severe in a century



- Water supply
- Agriculture
- Water fauna
- Cargo ships
- Hydropower
- Forests
- Tourism
-



Precipitation in Switzerland – Forecast 2060

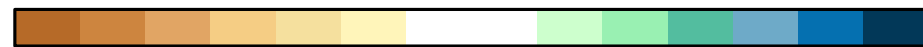
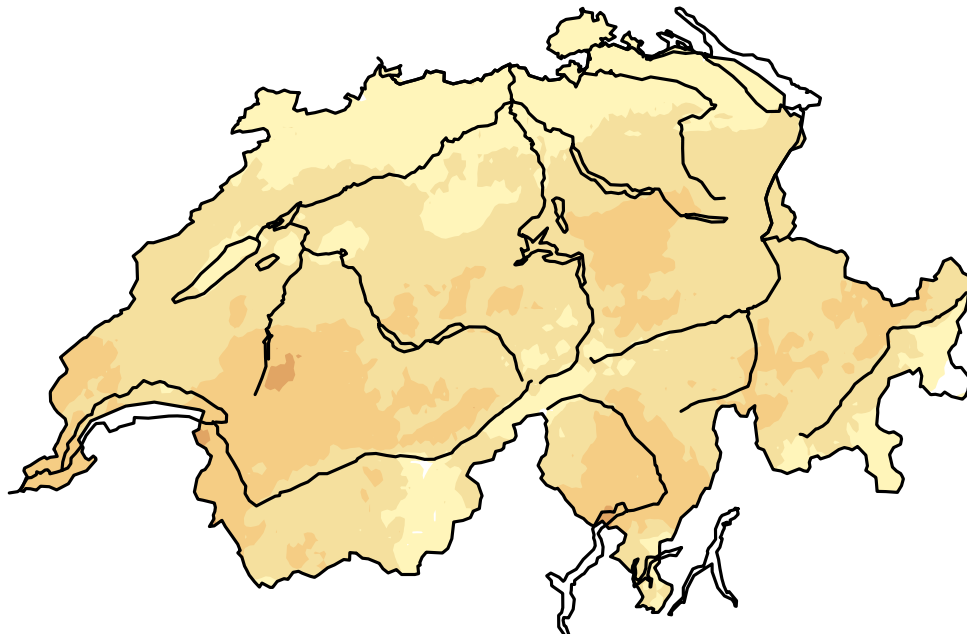
Precipitation Deviation (%)

Abweichung von der Normperiode 1981-2010

Summer 2060

RCP8.5

Mittlere Schätzung



-25 -15 -5 5 15 25

Deviation %

© Klimaszenarien CH2018

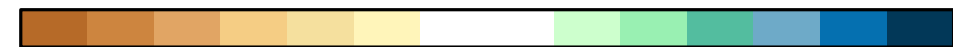
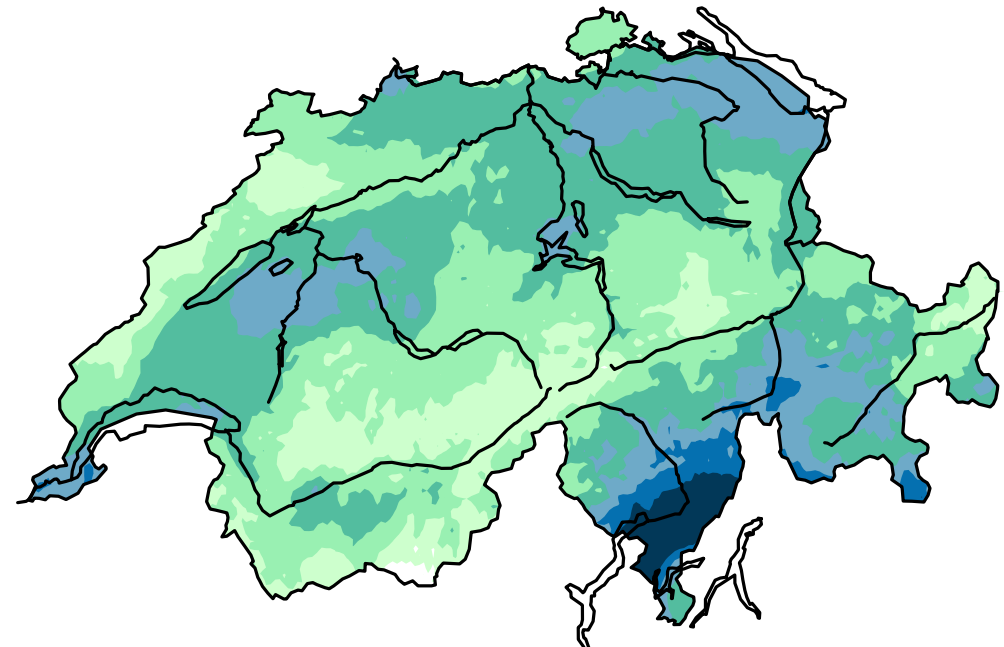
Precipitation | Deviation (%)

Abweichung von der Normperiode 1981-2010

Winter 2060

RCP8.5

Mittlere Schätzung

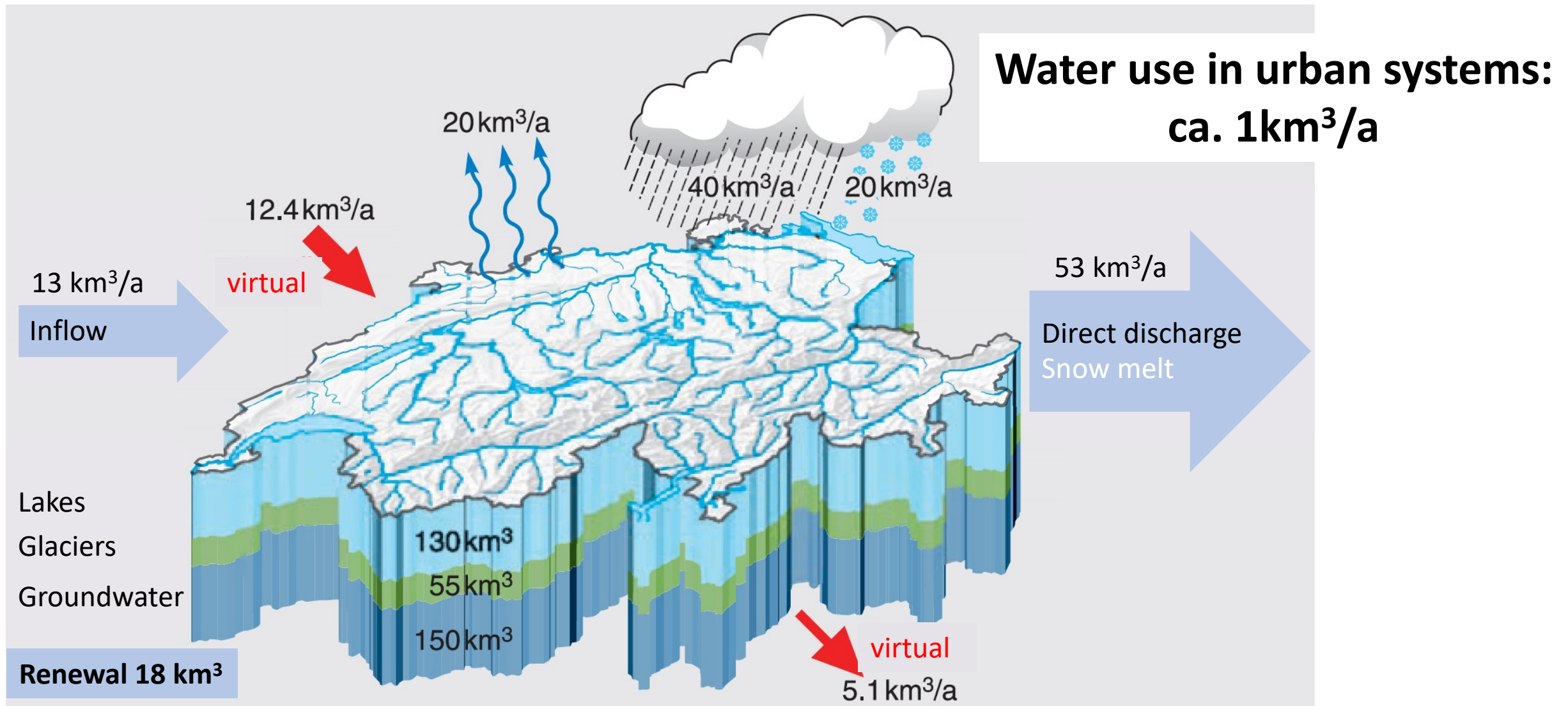


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Deviation %

© Klimaszenarien CH2018

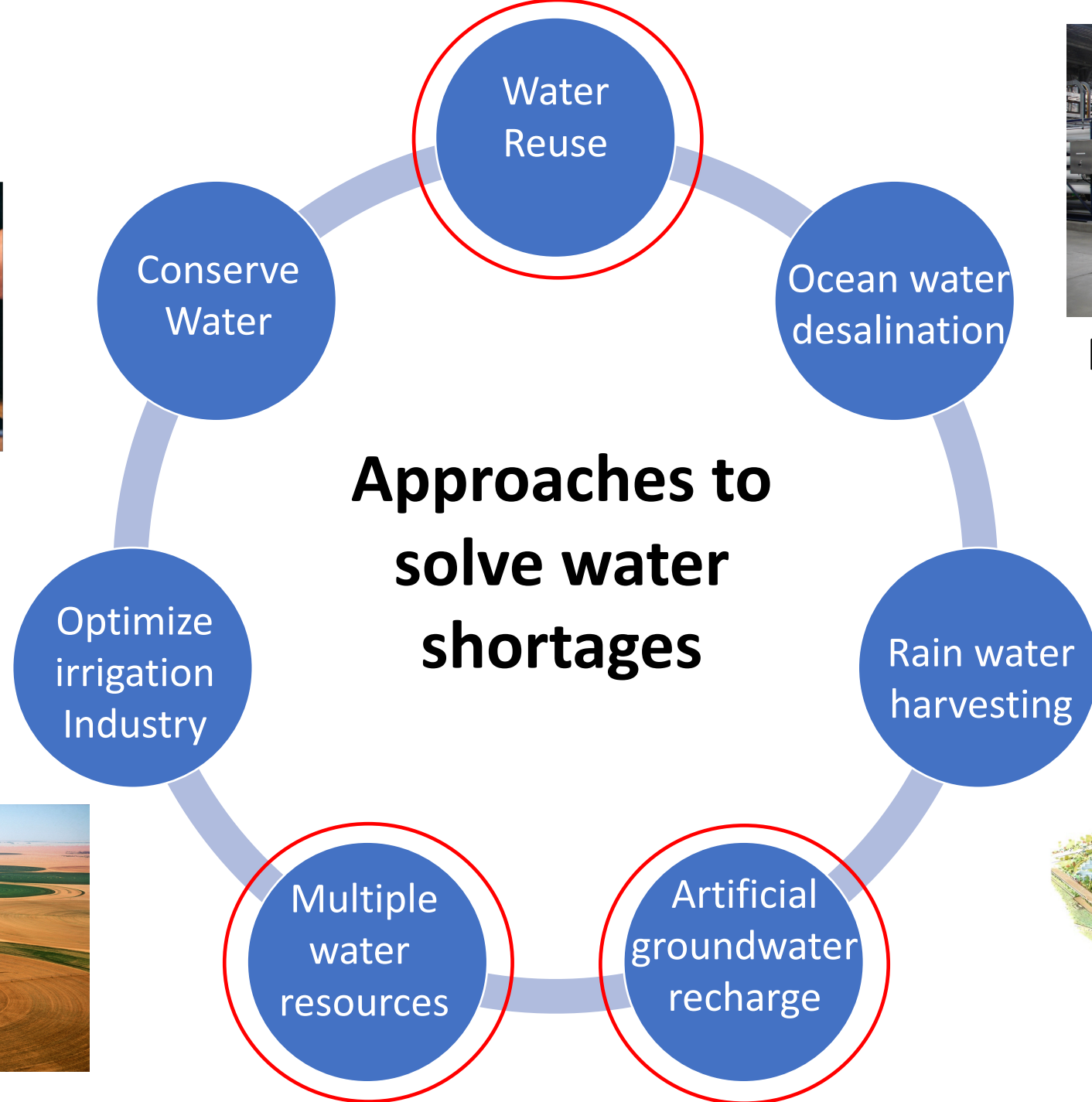
Water crisis in Switzerland? Water balance in Switzerland





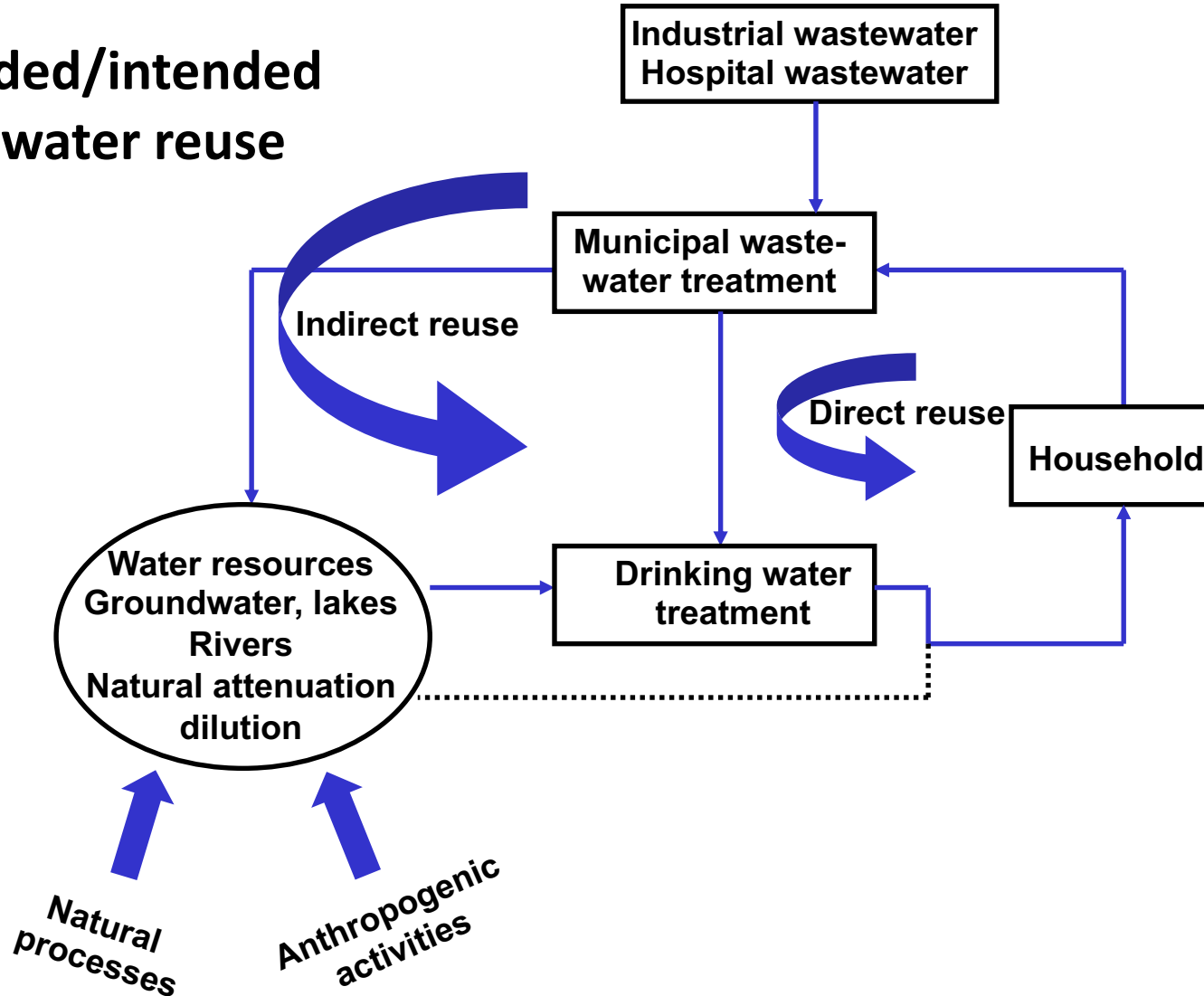
Reverse Osmosis

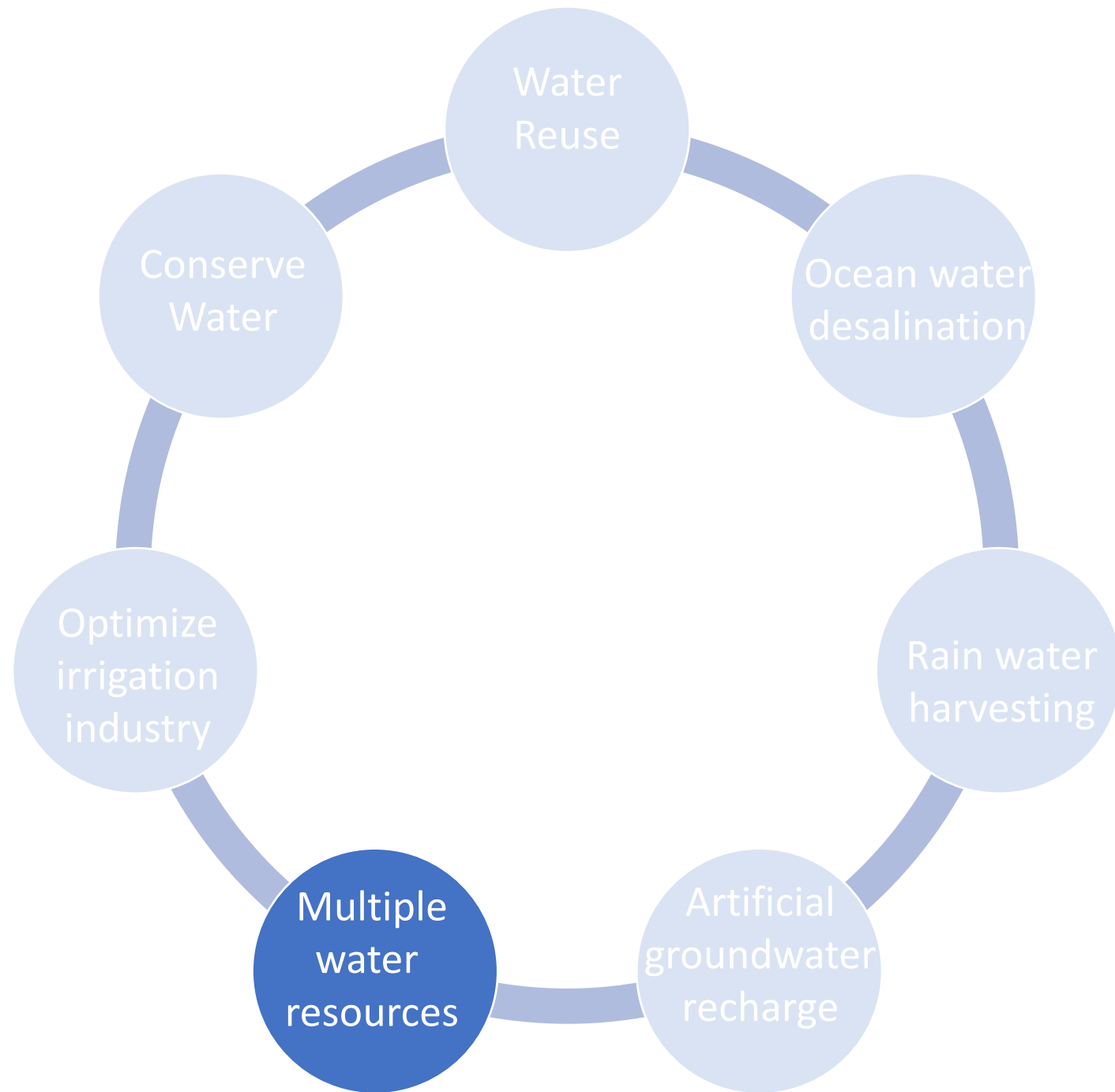
Rory M. Shaw
Wetland Park, LA



The urban water cycle

unintended/intended
indirect water reuse





Multiple water resources

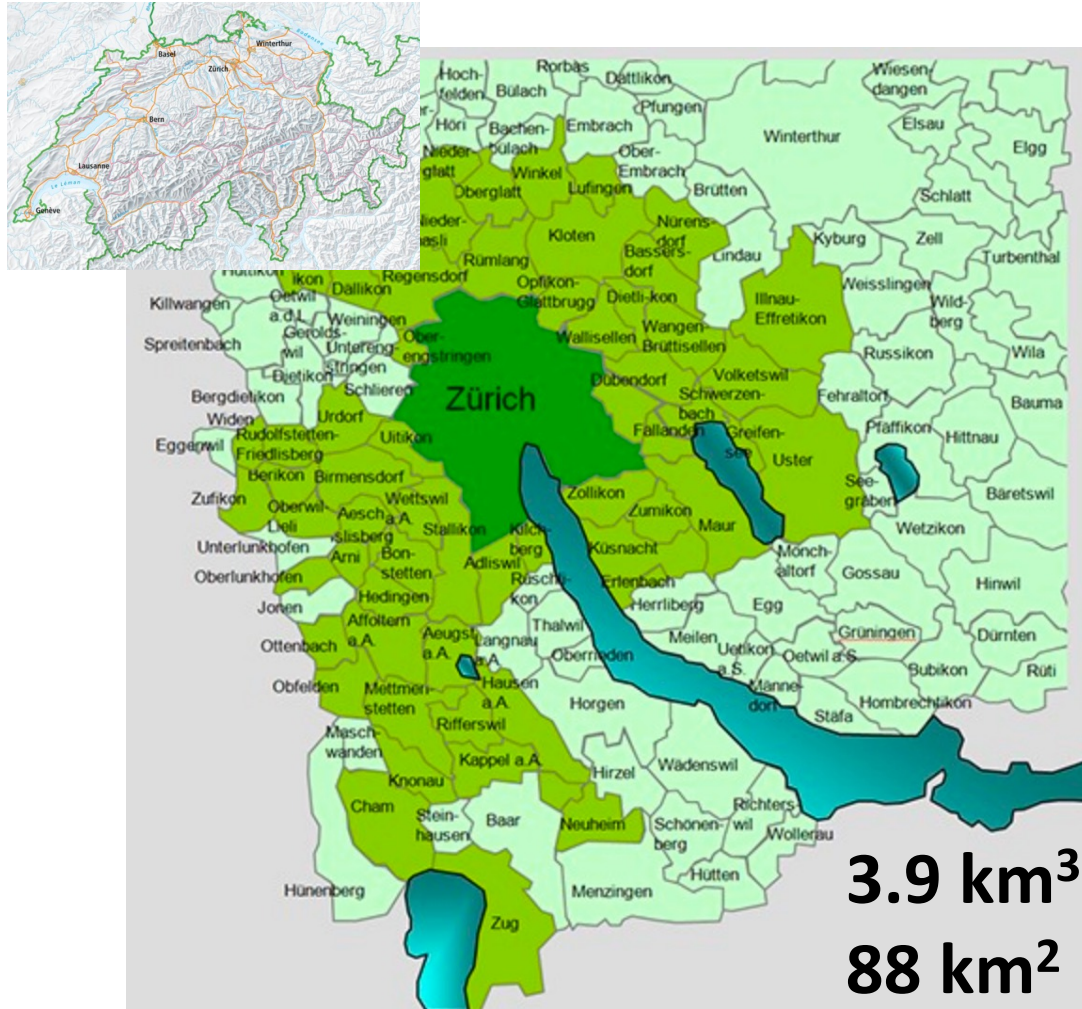
Lake Water Spring Water
Seewasser Quellwasser



Brunnen am Zumiker Rastplatz Mühlitobel, Zürichsee-Zeitung, 16. August 2016

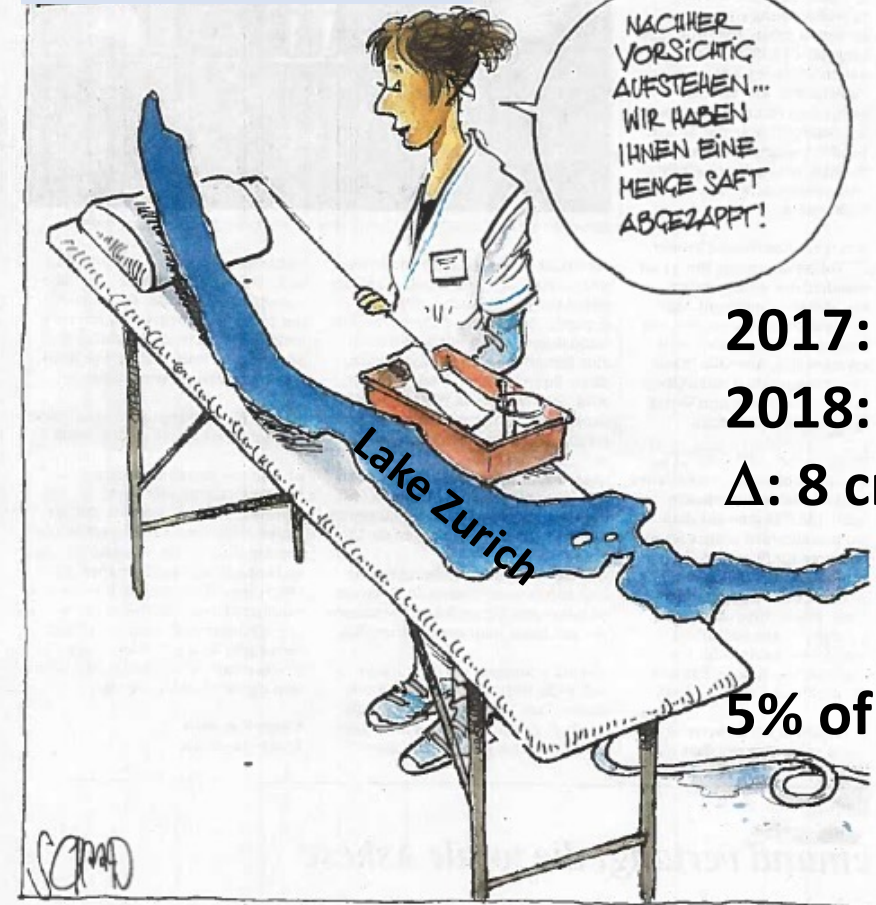
A resilient solution through multiple water resources

Water provision from the water supply Zurich to 67 communities



Water donation

Summer 2018

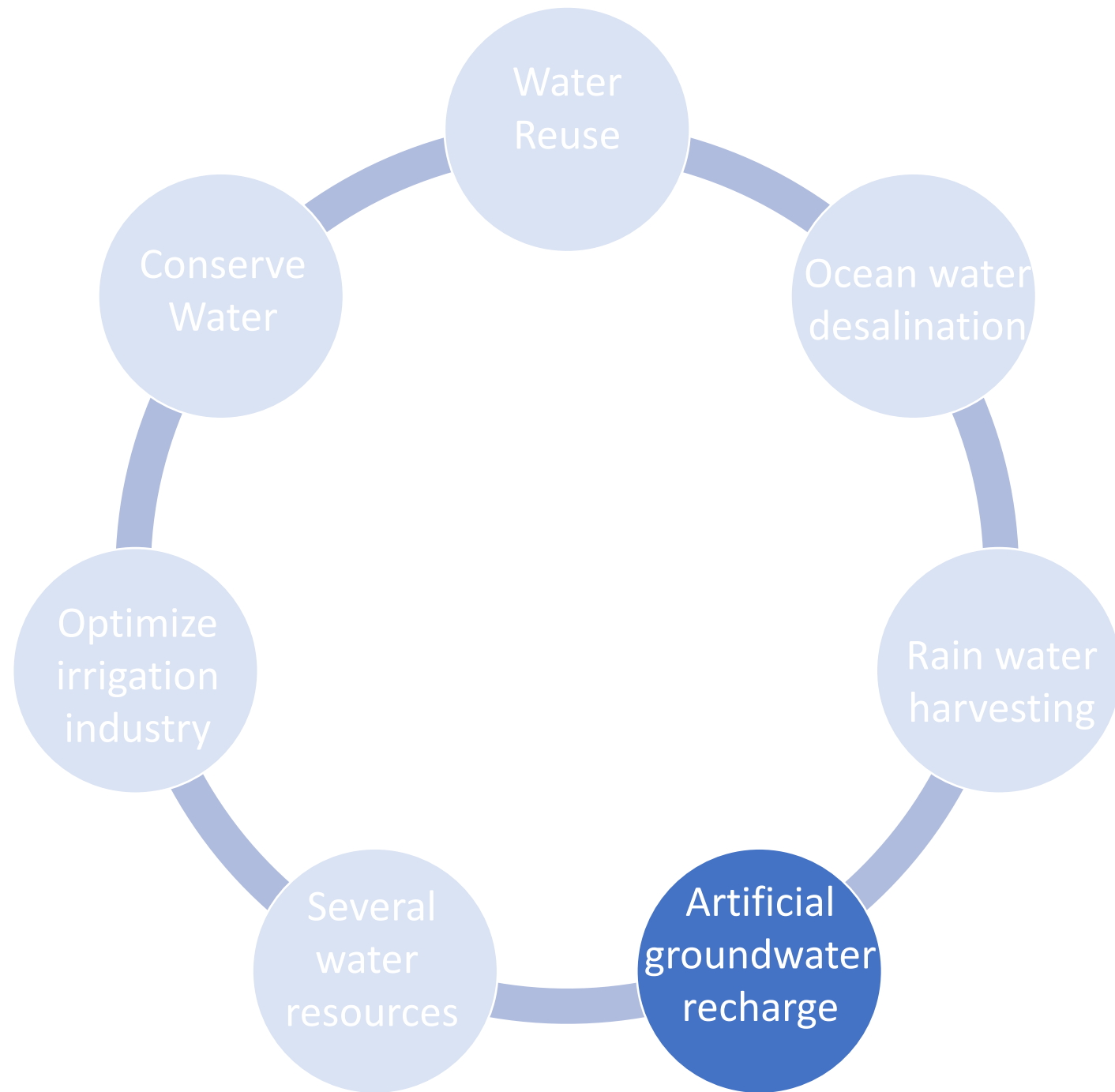


2017: 43 cm

2018: 51 cm

Δ : 8 cm

5% of the inflow

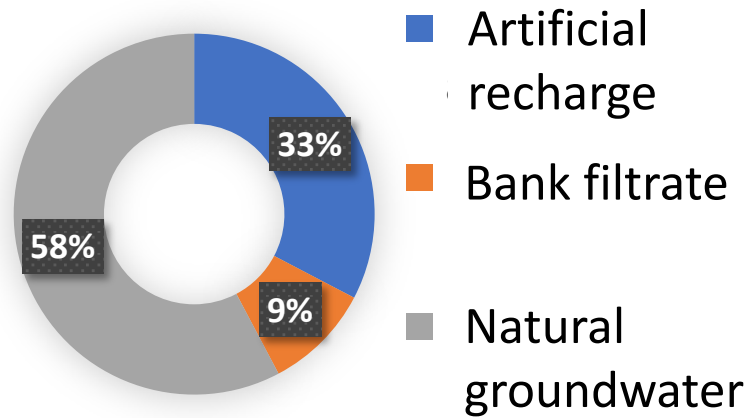


Artificial groundwater recharge in Hardwald BL

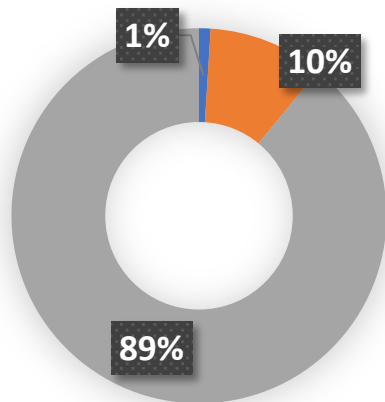


Use of groundwater in Switzerland: Proportion of artificial recharge and bank filtration

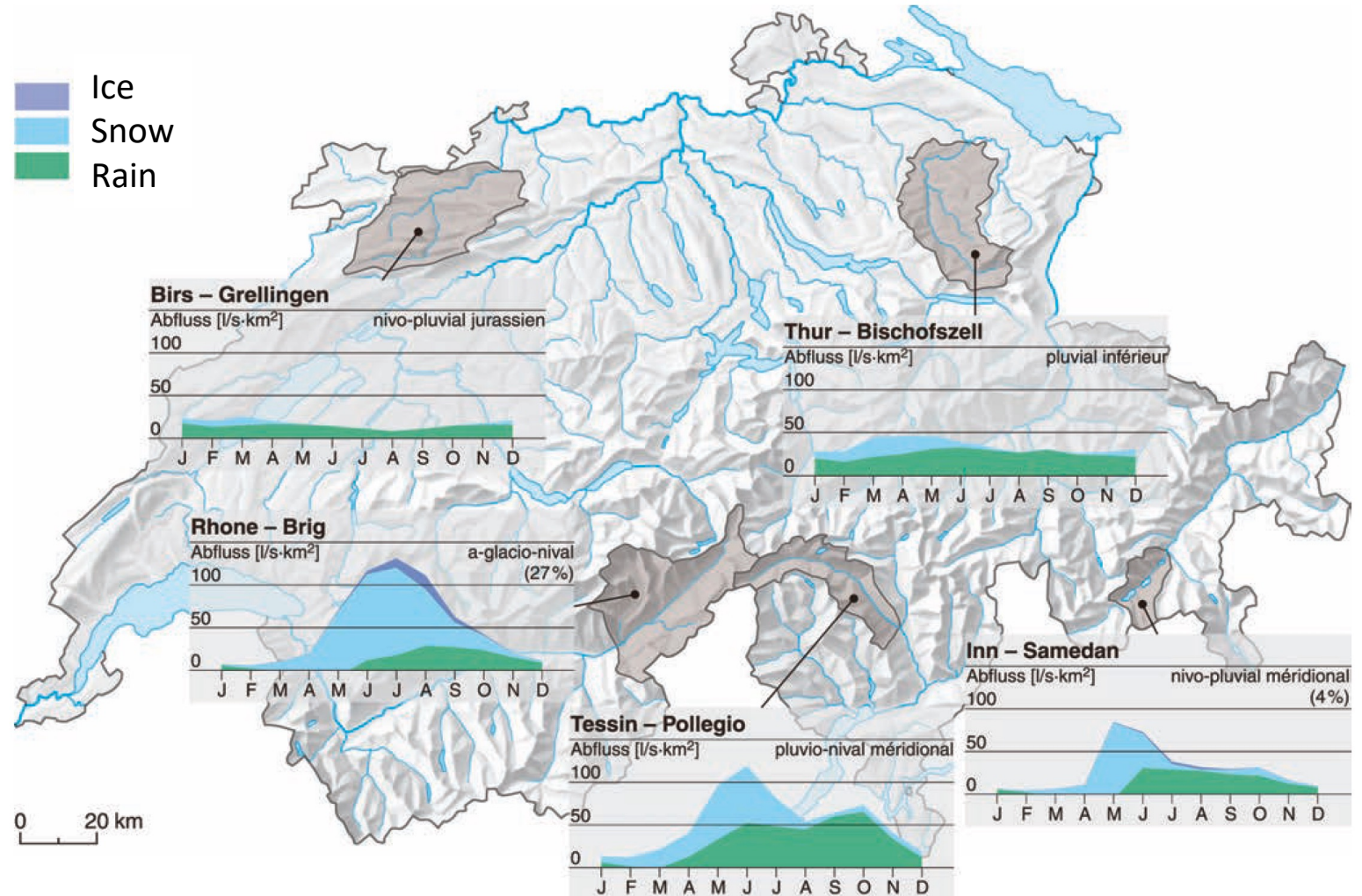
> 50000 Inhabitants

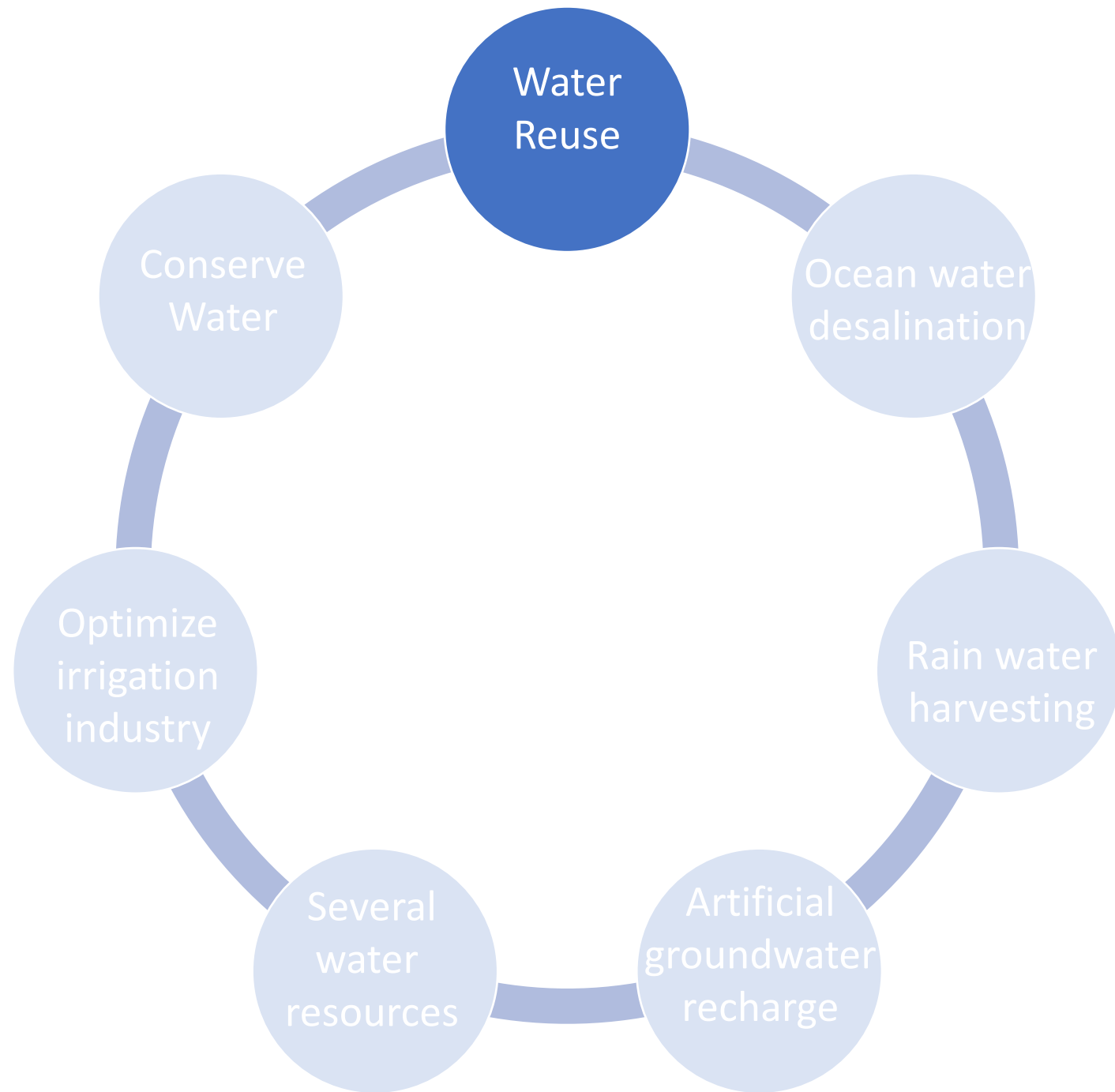


< 10000 Inhabitants



Catchment characteristics





The Rhine River: Water resource and “Sewer” for 50 Mio people

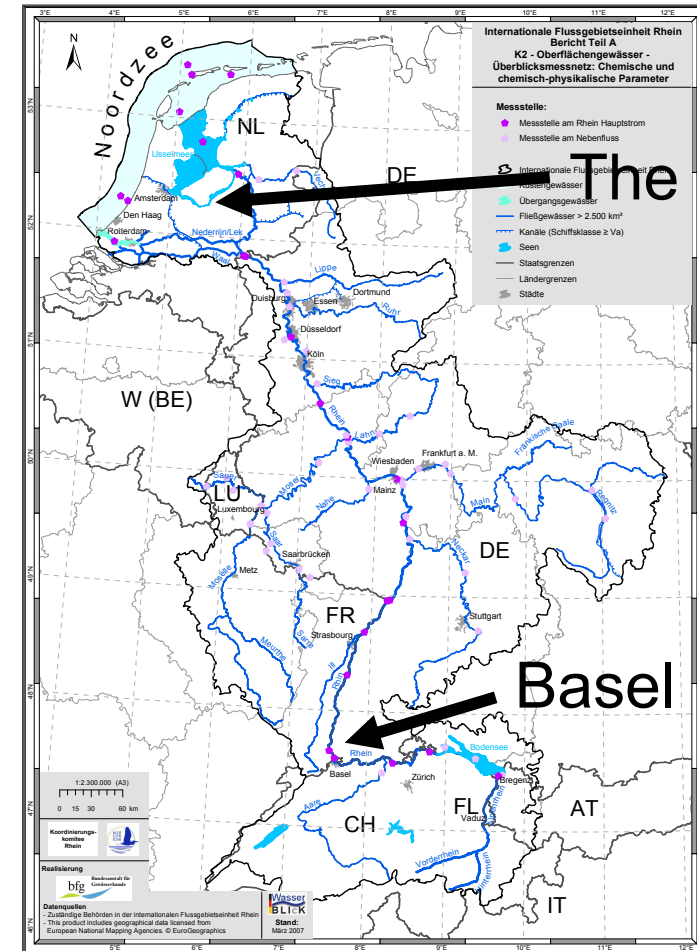
Drinking water from the Rhine river: Indirect usage of recycled wastewater

- Proportion of recycled wastewater

Basel ca. 10%

The Netherlands ca. 30 – 60%

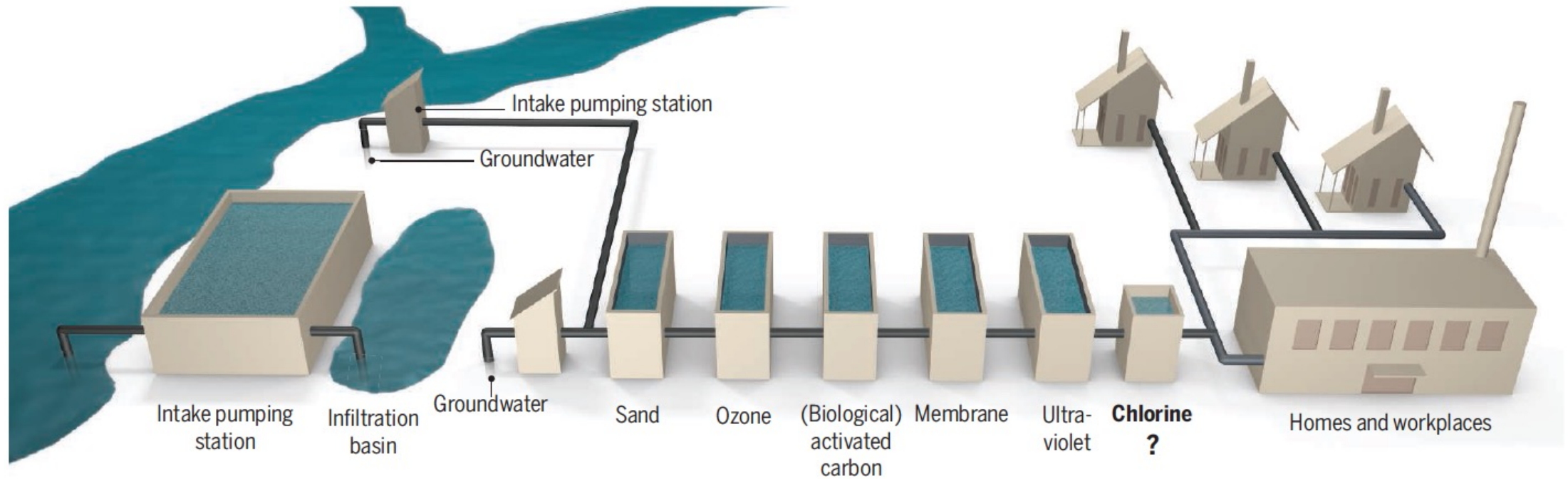
- Bank filtration or artificial infiltration as important barrier
- Physical-chemical und biological treatment depends on the water quality (CH<D<NE)



The Netherlands

Basel

“Unintended reuse”: Drinking water treatment as a multibarrier system



Protection of water resources

- Active watershed management
- Riverbank filtration
- Artificial recharge
- Groundwater

Resources protection

Water treatment

Multibarrier treatment (ozone, ultraviolet light, advanced oxidation processes, biological filtration, membranes, chlorine)

Treatment

Distribution system

- Maintain and replace infrastructure
- Water-quality monitoring
- Hydraulic integrity

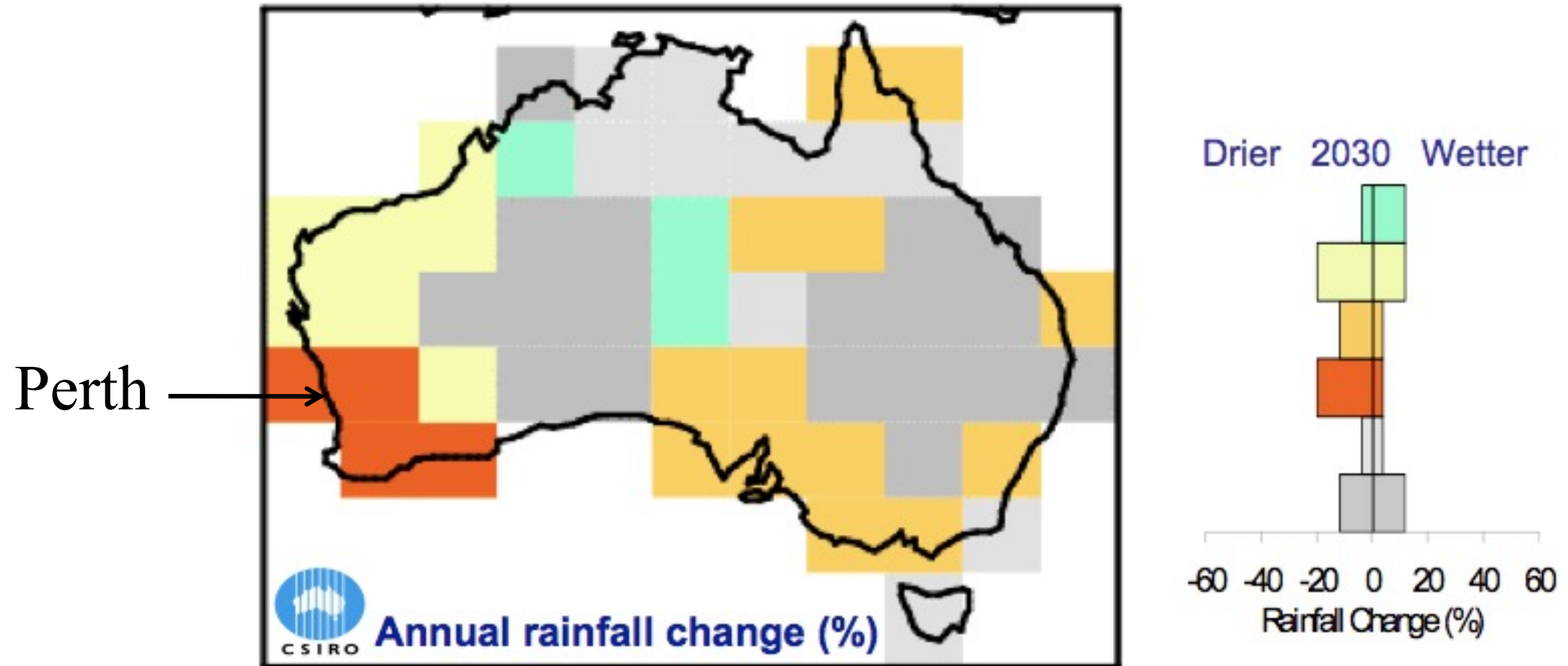
Distribution

Water Reuse Systems

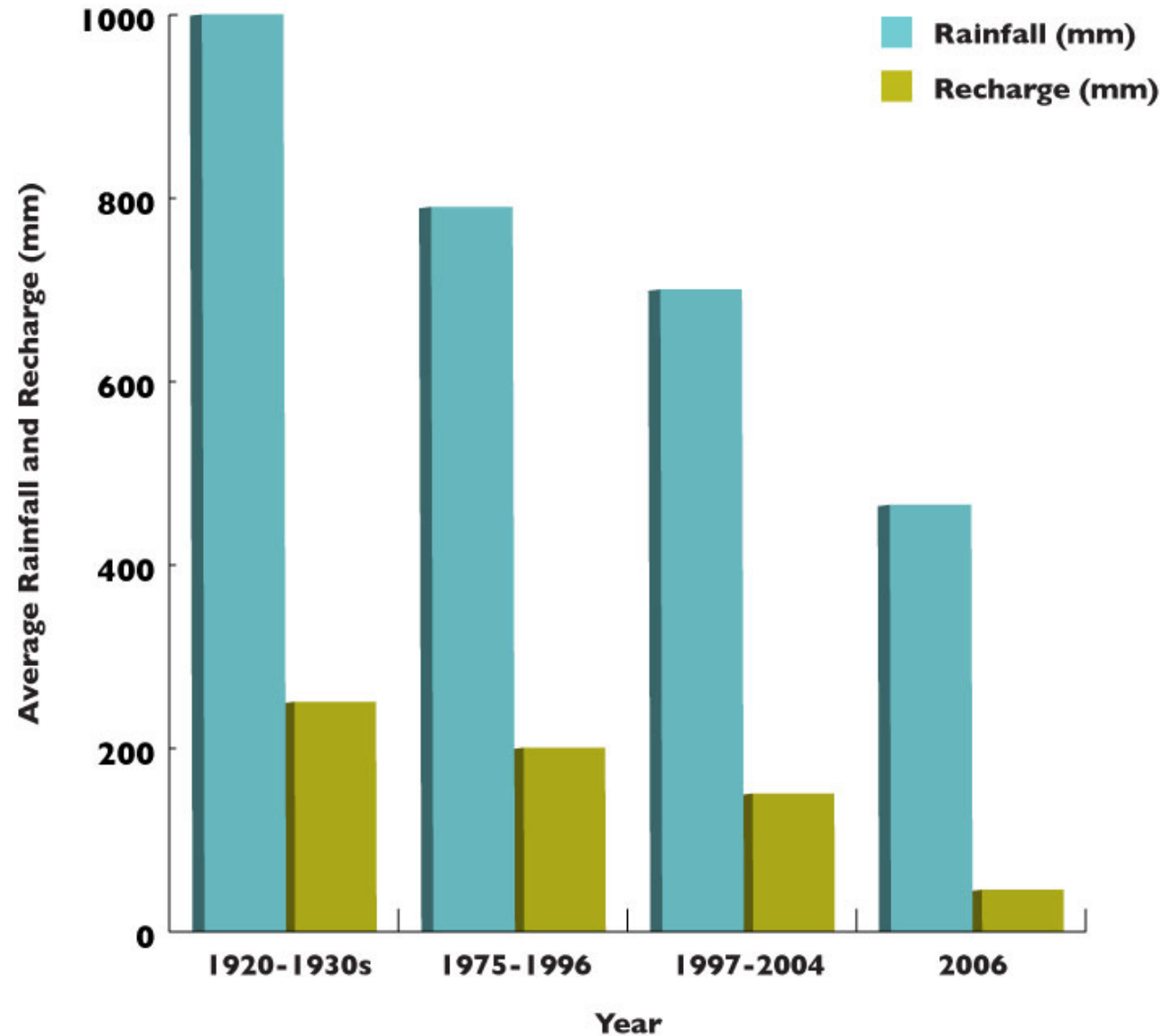
Case study 1

Perth, Western Australia

Projection for Rainfall in Australia for 2030

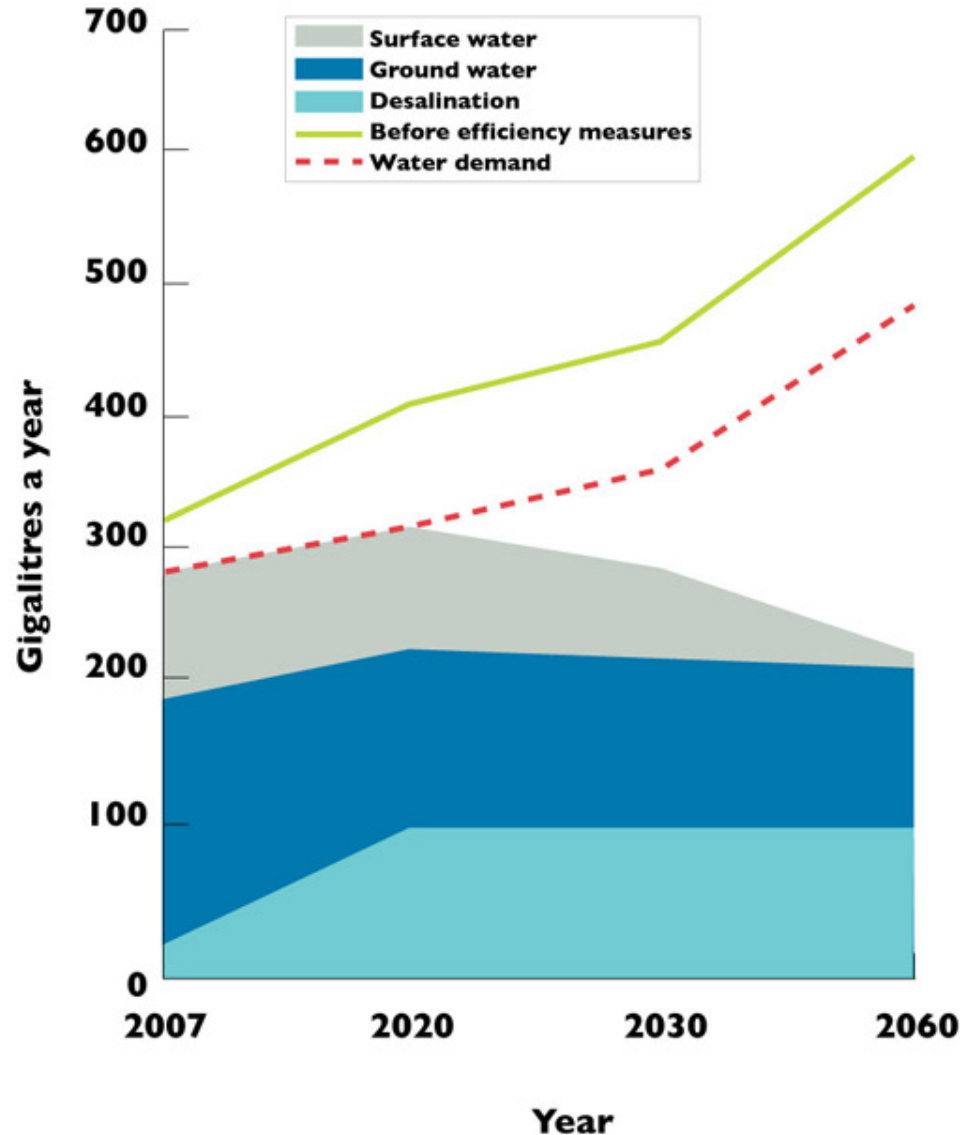


Average rainfall and recharge for Gwangara Mound



Projection of water use in the Perth metro area

255GL (0.255 km³) shortfall by 2060



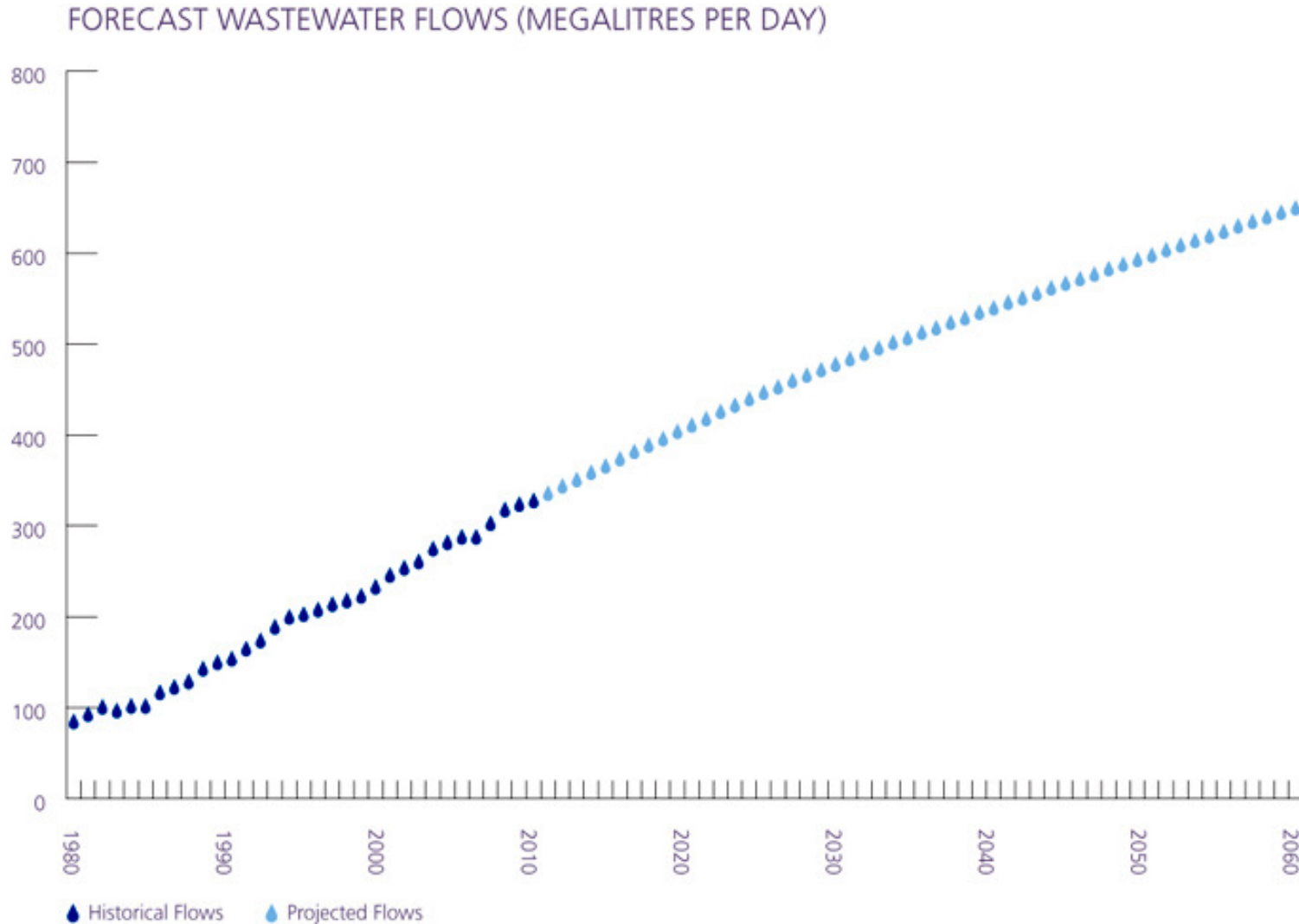
Based on availability of current sources

By 2020 - 5GL shortfall

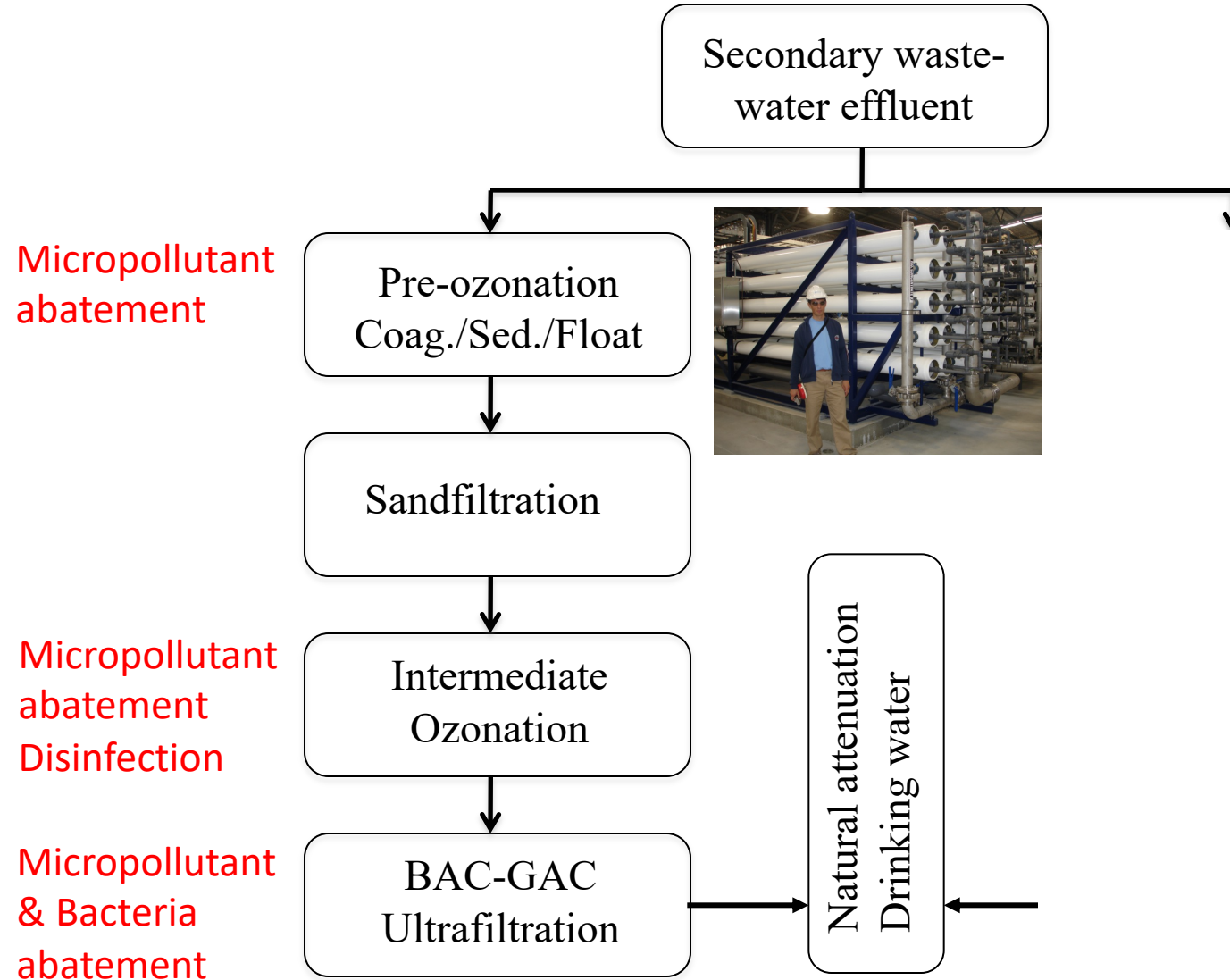
By 2030 - 75GL shortfall

By 2060 - 255 GL shortfall

Wastewater flows increase with population



Intended (in)direct potable reuse



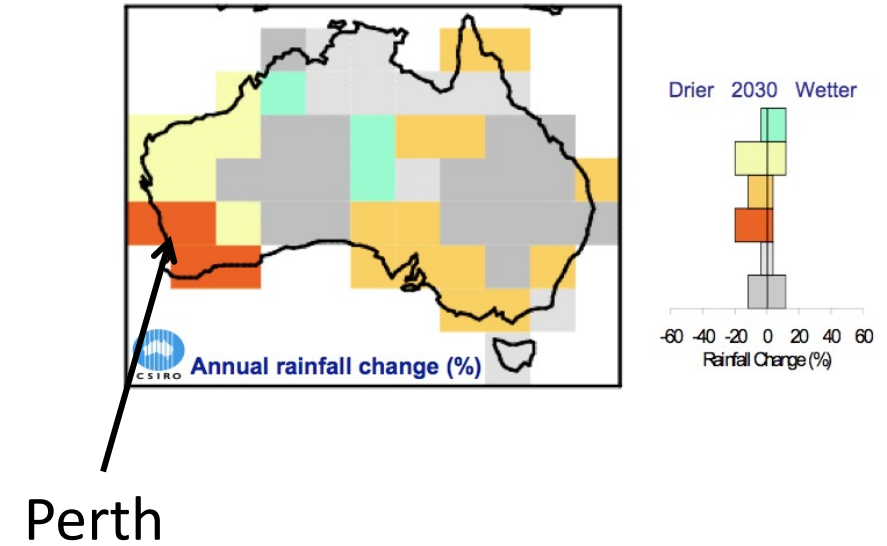
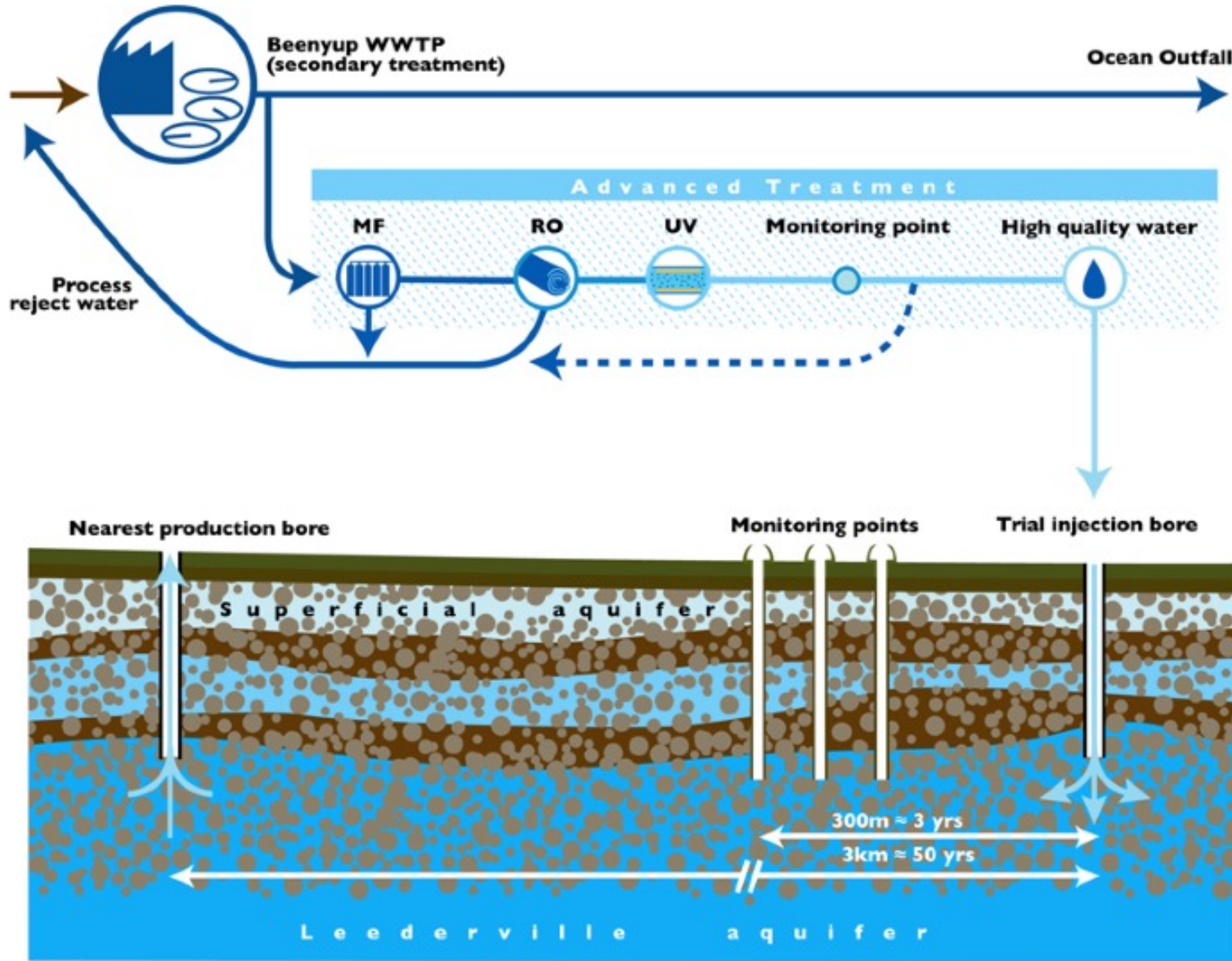
Water reuse trial plant (Perth, WA)

WWTP Effluent Screening



Groundwater

Wastewater-recycling in Perth – Western Australia



What is the perception of recycled wastewater in the media/in the public?



By Paul Lachine

The Yuck Factor



Source: <http://www.hcn.org/issues/354/17227>

Groundwater recharge in WA

Contaminants to be recycled in taps

ACCEPTED WASTE

These are allowed to be dumped into Brisbane's sewers

- Grease and oil
- Ammonia
- Nitrogen
- Phosphorus
- Sulphate
- Chlorine
- Aluminium
- Iron
- Manganese
- Pesticides
- Arsenic
- Lead
- Mercury
- Cobalt
- Zinc
- Cyanide



Greg Roberts

A WIDE range of industrial contaminants including pesticides, cyanide, grease and fertilisers can be included in waste that will be recycled as drinking water for the 2.6 million residents of southeast Queensland.

The Bligh Government insists the contaminants will not pose a health risk as the levels are low.

Industrial and hospital effluent dumped in the sewers of Brisbane and Ipswich will constitute 12 per cent of the wastewater to be recycled.

The first recycled water will be pumped to Wivenhoe Dam, Brisbane's main storage facility, in February. The quantity will rise

from 60 to 230 megalitres per day next year.

Brisbane City Council guidelines covering the disposal of so-called trade waste to the sewer stipulate maximum levels for a wide range of contaminants.

The guidelines are designed to "protect the environment, the health of sewerage workers, the operation and maintenance of the conveyance system and wastewater treatment facilities".

The guidelines have not been amended to take account of the recycled water plan.

Six toxic organochlorine pesticides, including DDT and dieldrin, are allowed in trade waste at very low levels — up to 0.1mg/L. Organochlorine pesticides have

been banned because of human health concerns and remain in the environment for many years.

Higher levels of less toxic organophosphate pesticides including malathion and azinphos can be dumped, along with up to 50mg/L of formaldehyde and 30mg/L of petroleum hydrocarbons. The council guidelines say formaldehyde and petroleum hydrocarbons can "adversely affect the safety of operations and maintenance personnel".

The guidelines list 13 allowable metals including arsenic, lead, mercury, cobalt and zinc.

Bromine, sulphide and cyanide, which "may produce toxic atmospheres in the sewer", are allowed, as are ammonia, nitro-

gen, phosphorus, and grease and oil. The guidelines allow "gross solids" to be dumped if they are less than 20mm.

Treatment processes that may be required before dumping in the sewer include the neutralisation of acidic wastes and the chemical reduction of chromium.

Food preparation wastes must pass through an approved grease trap before reaching the sewer.

Polluted water from the motor trade may result from the degreasing of mechanical parts, the washing of workshop floors contaminated with hydrocarbons, and removing paint wastes from smash repair shops.

Queensland Water Commission chief executive John Bradley

said trade waste controls prevented hazardous material from entering sewage networks.

"Councils issue approvals for trade waste after considering the relative risk of the waste to the sewage treatment system and the effluent water quality," Mr Bradley said.

Referring to a mixup at the Gold Coast's Pimpama treatment plant which resulted in unsafe recycled water being put in drinking water, Mr Bradley said the Western Corridor Recycled Water Scheme was safe. "The system that will produce purified water will have real-time online monitoring that will shut down the plant immediately if regulated standards are not being met."

Launching an advertising campaign for the introduction of fluoridated water, Premier Anna Bligh said the only thing that would stop the recycling plan would be overflowing dams.

"This is something that we can be proud of, not fearful of," Ms Bligh said.

Opposition Leader Lawrence Springborg said recycled water should be used for drinking only as a last resort, echoing the sentiments of National Health and Medical Research Council water chief Don Bursill, which were reported in *The Australian* yesterday. "If something goes wrong, there's a breakdown in the system; you've got nowhere to go," Mr Springborg said.

1001: i had to take the

2 • SATURDAY, FEBRUARY 28, 2009

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News

thewest.com.au

Recycled sewage plan for WA taps

ALANA BUCKLEY-CARR
EXCLUSIVE

Recycled sewage will constitute as much as 10 per cent of Perth's drinking water by 2030 under a new plan for the State's water supply.

In a draft policy on future water supplies to be released next week, the Water Corporation has set a target of recycling 30 per cent of Perth's waste water by 2030 and as much as 60 per cent by 2060.

Water industry policy manager Meredith Blais said a quarter of

poses. But a three-year trial is due to begin late this year into recycling waste water for drinking.

"Recycling water for drinking is highly technical and complex from a regulatory perspective, given that this has only recently been considered a new potential source of drinking water in Australia," the report said.

"While highly feasible, ground water replenishment (recycling water for drinking) will require health and environmental approvals and significant community support."

In an alarming profile of how the

reduce water use but said more needed to be done to meet the 2030 aim of reducing current use by a quarter.

"Since 2001, the average water use per person has decreased by 20 per cent. This translates to a saving of approximately 61GL of water over the last seven years," the report said.

Sources independent of rainfall would have to be created, including tapping groundwater from the Collie coal basin and building desalination plants north and south of Perth.

But prices would also have to increase "to ensure they send appro-

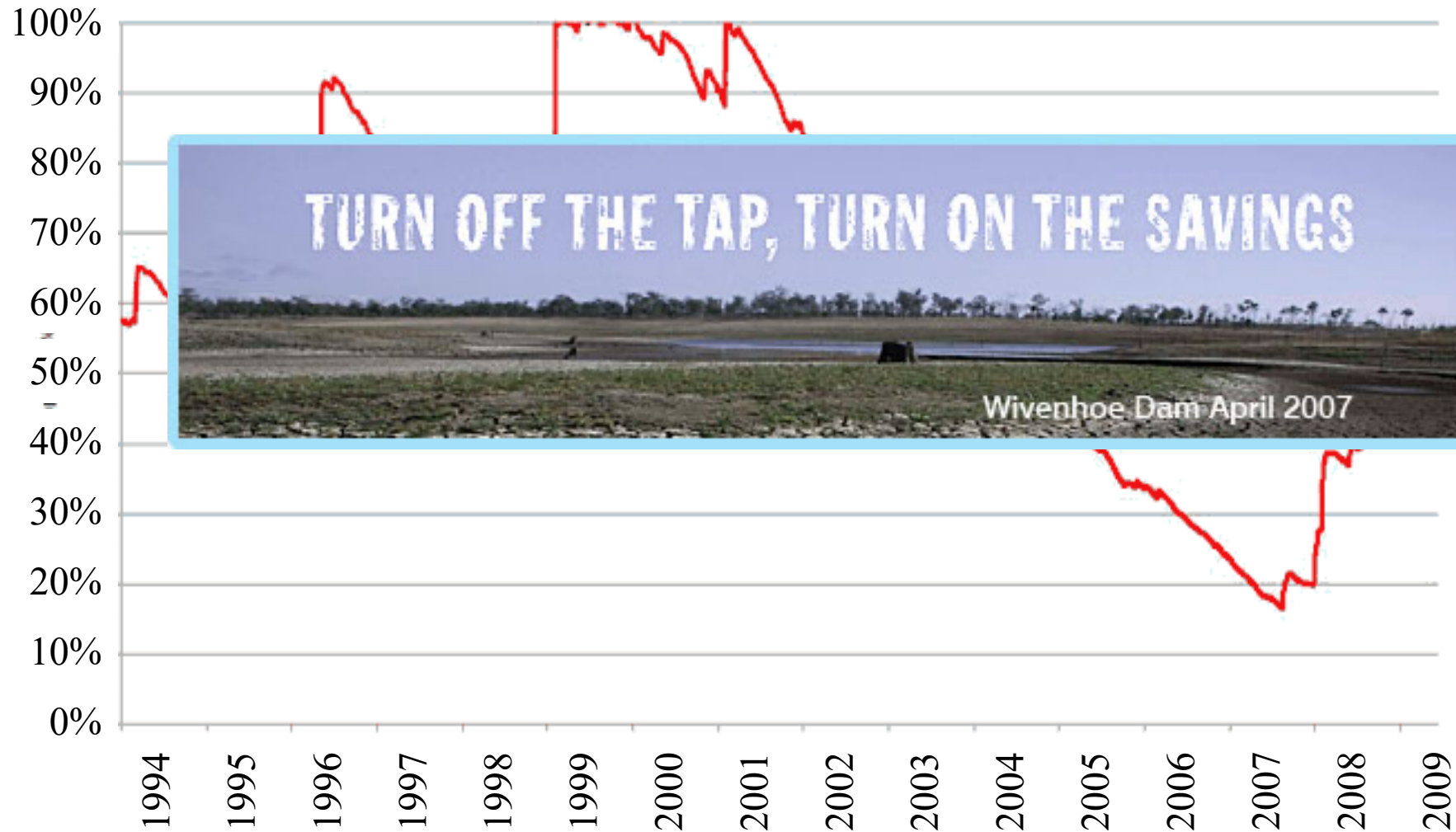
THE WEST AUSTRALIAN

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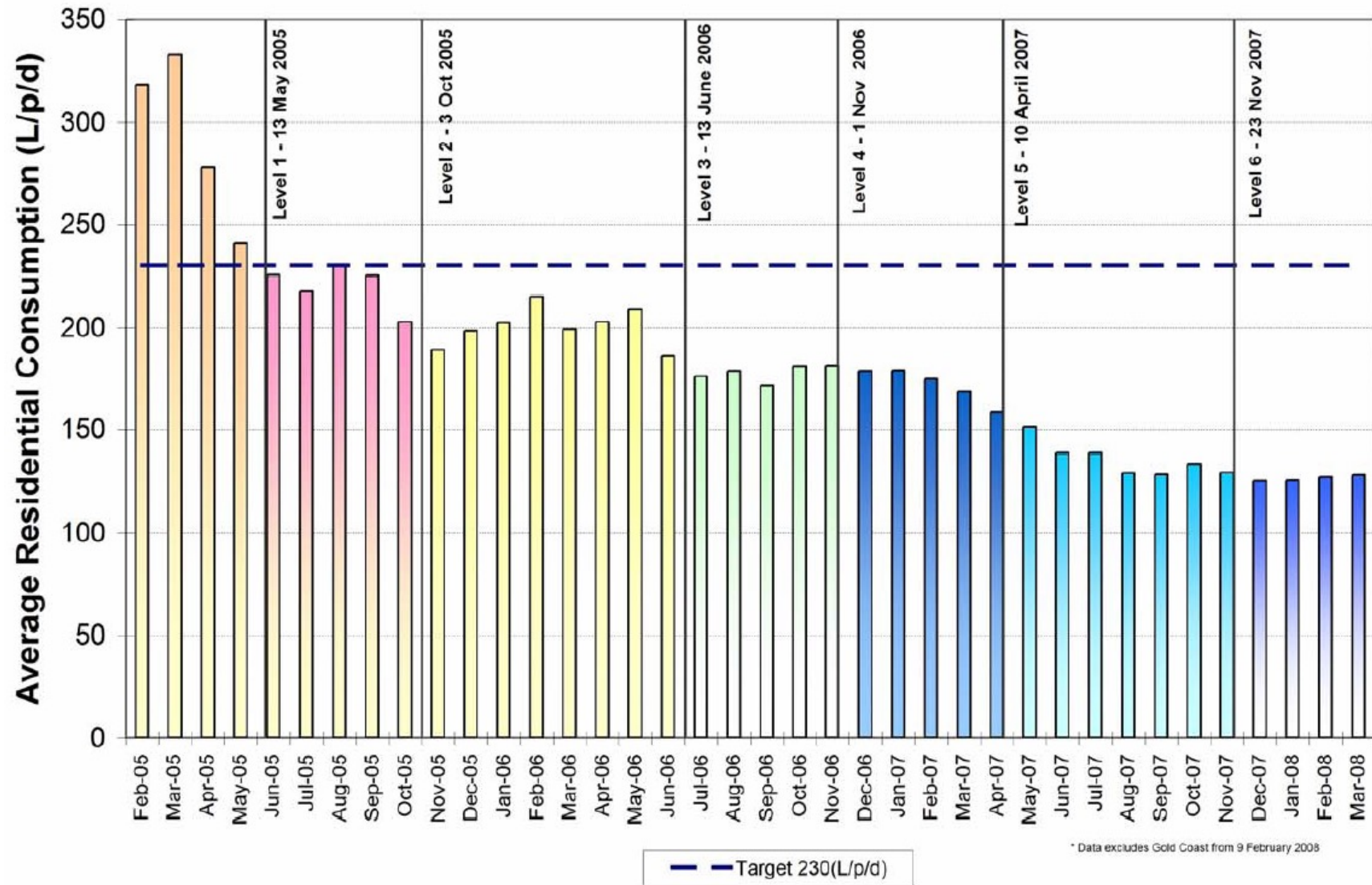
Case study 2

Brisbane, Queensland
Water recycling plans

Combined storage capacity of main dams in Brisbane (total capacity 1760 GL = 1.76 km³)

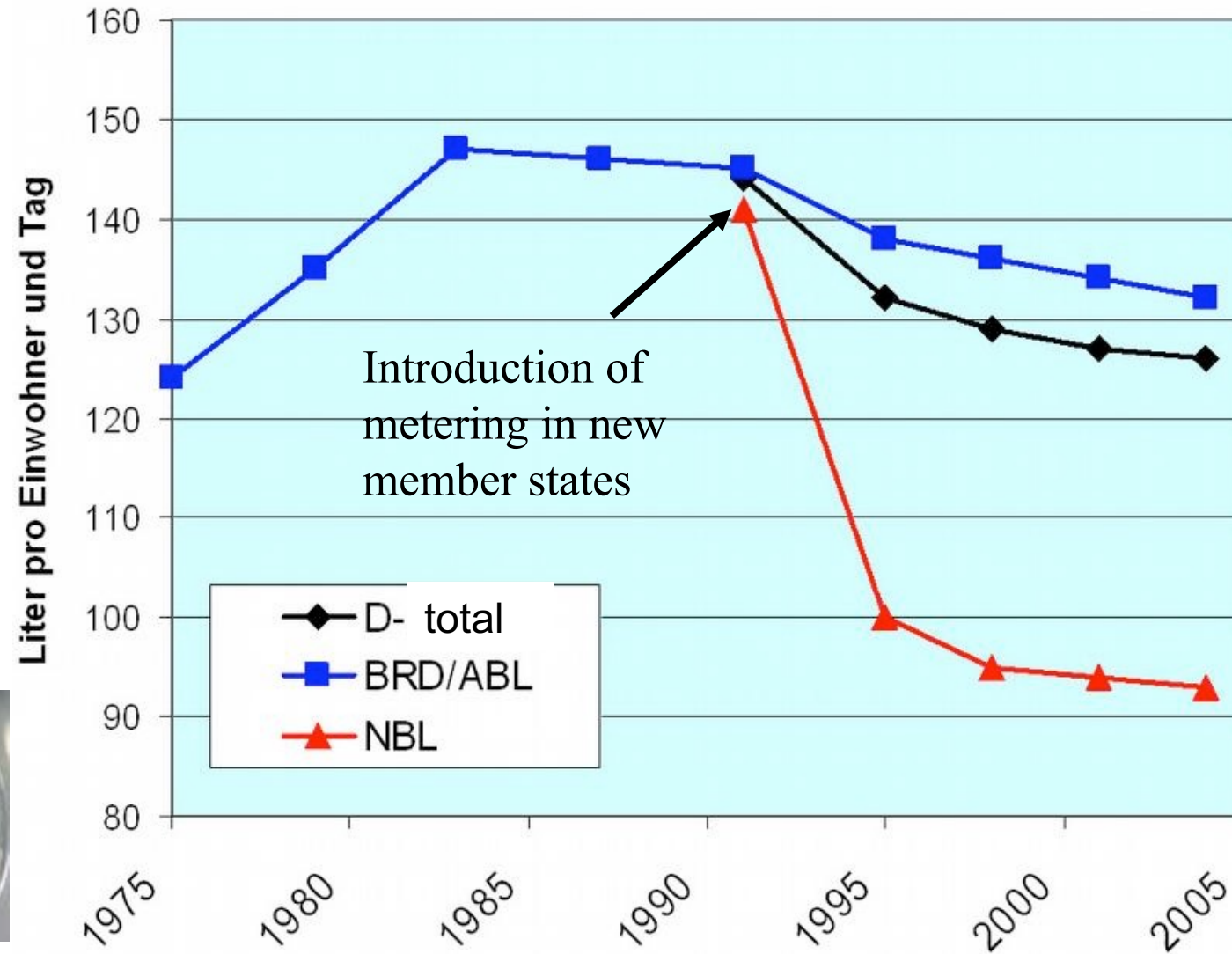


Water Reduction & Savings



Drinking water use in Germany

Old and new member states



What happened next ...

- Public surveys suggested 70-75% support for water recycling to dam
- Detailed assessment of water quality with experts from around the world
- Concerted media campaign against the water recycling for drinking water
- A lot of rain...
- Public support dropping....
- State election – new government
- Project put on hold...



And then...

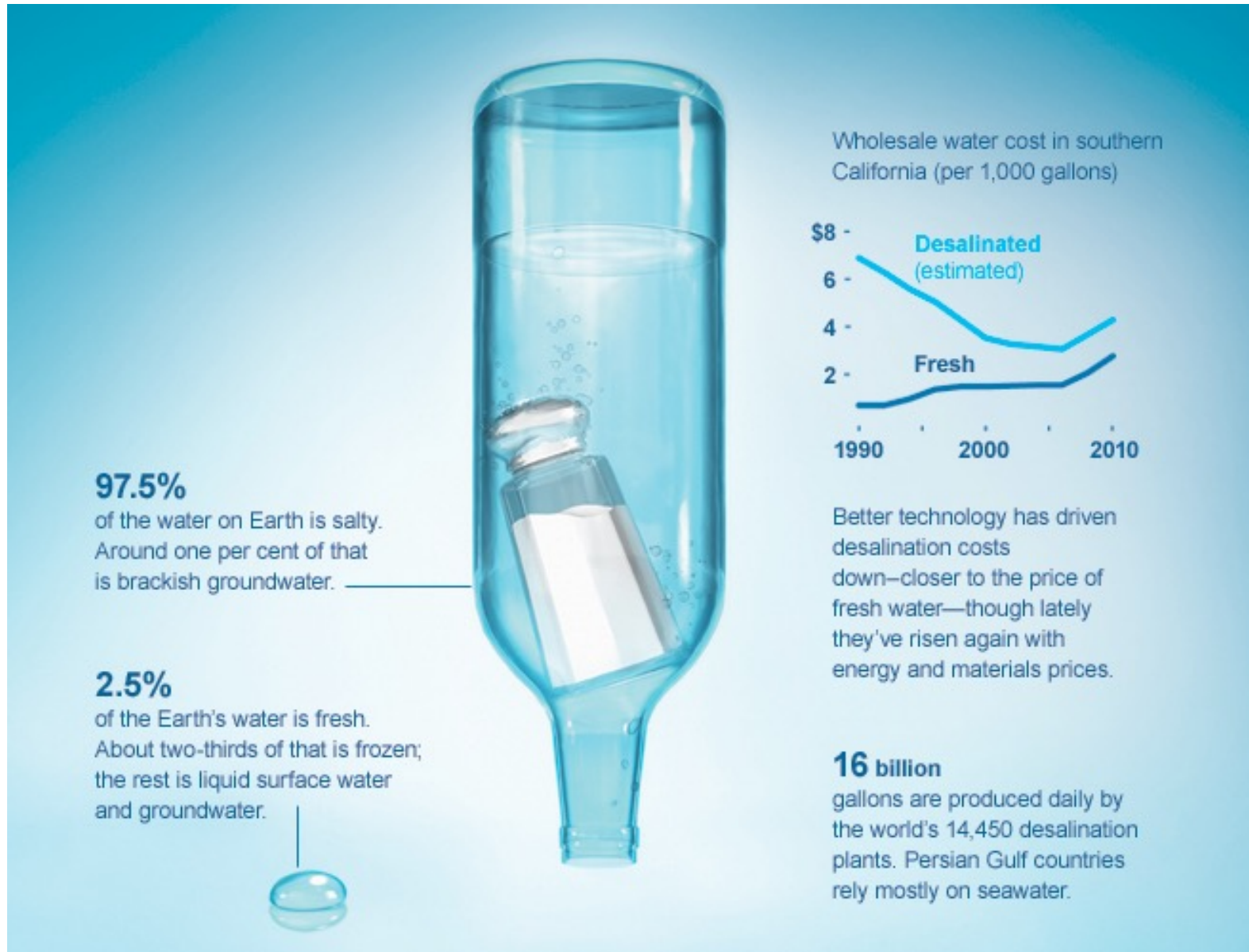


Queensland: Wivenhoe dam during drought and flood
In 2020 the recycling project is reconsidered again..

Closing the anthropogenic water : (in)direct potable reuse

- Technical feasibility has been demonstrated
- Process optimization for improvement and/or alternatives
- Public perception as an important factor (Singapore vs Australia)
- Scientists and engineers must be engaged in public debate and clearly communicate benefits and problems to allow an objective assessment

Desalination

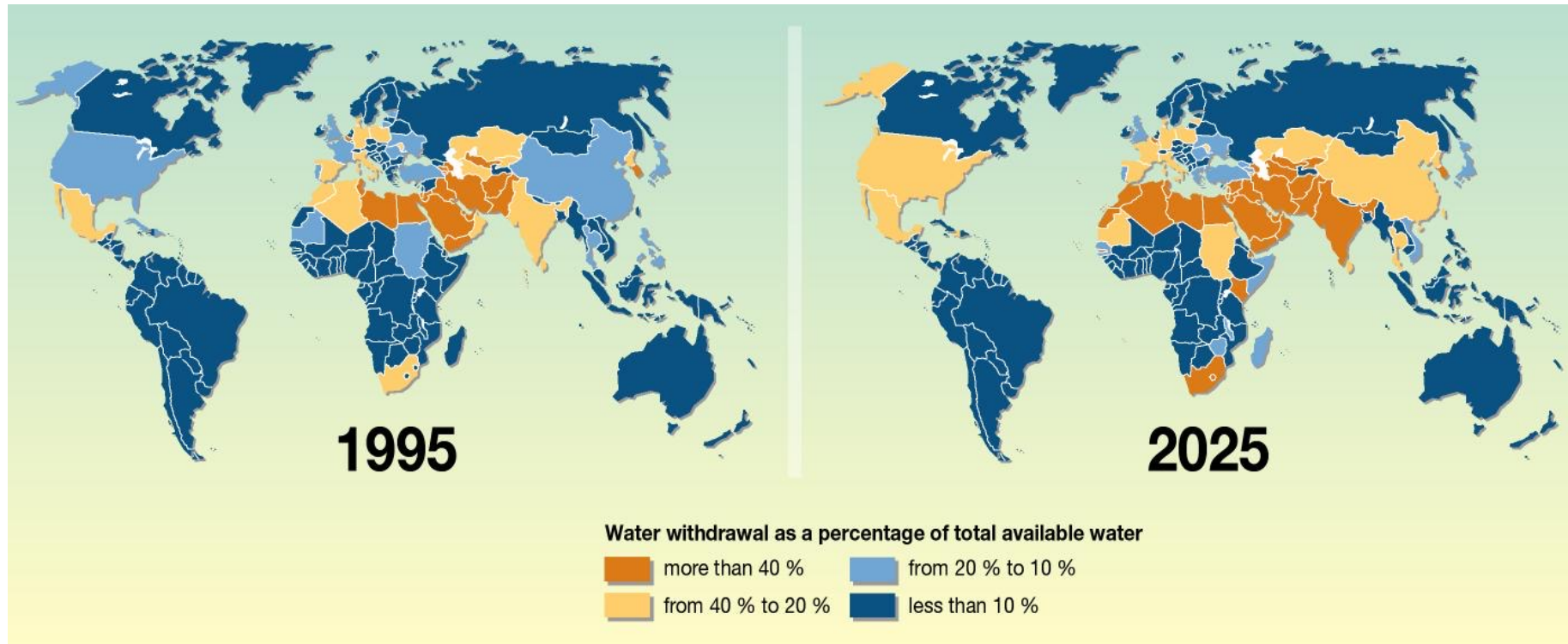


Desalination / RO

Water scarcity is one of the most important problems of the future

Most problems occur in coastal regions → Rapid increase in desalination capacity

At present: total desalination capacity ca. 40 Mio m³/day
drinking water for ≈ 100 Mio people



Environmental concerns with Desalination

Ecological

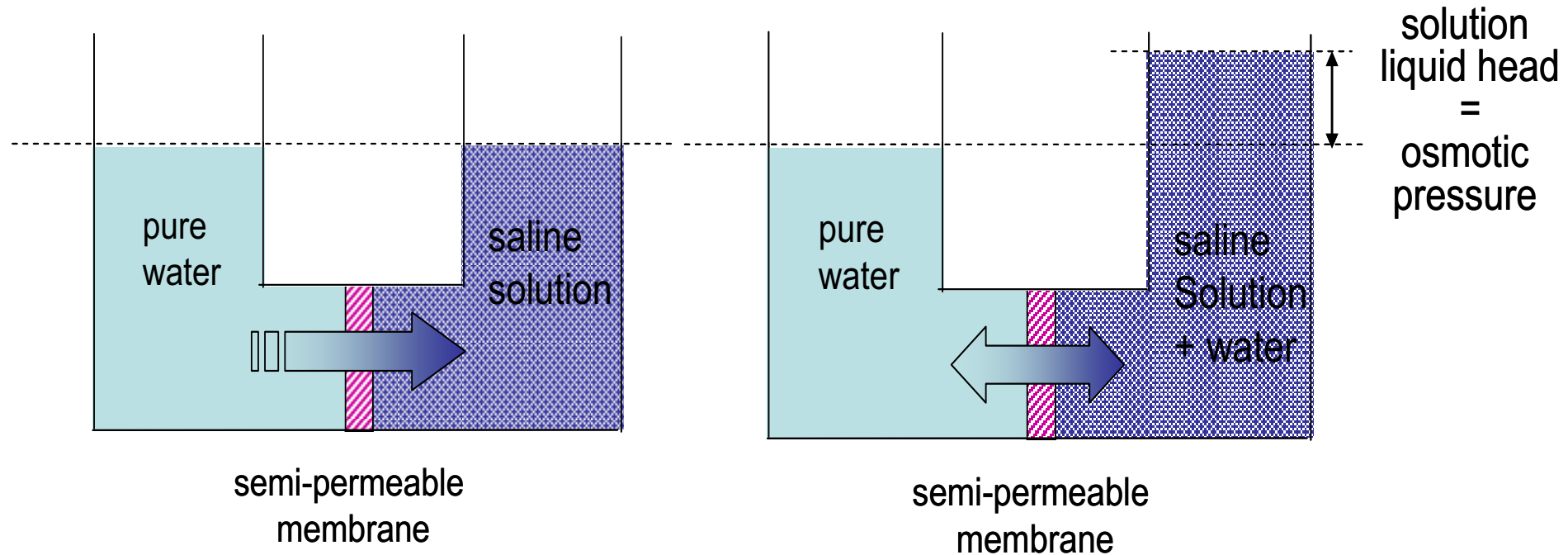
- Perturbations at intake
- Discharge of the brine

High Energy consumption



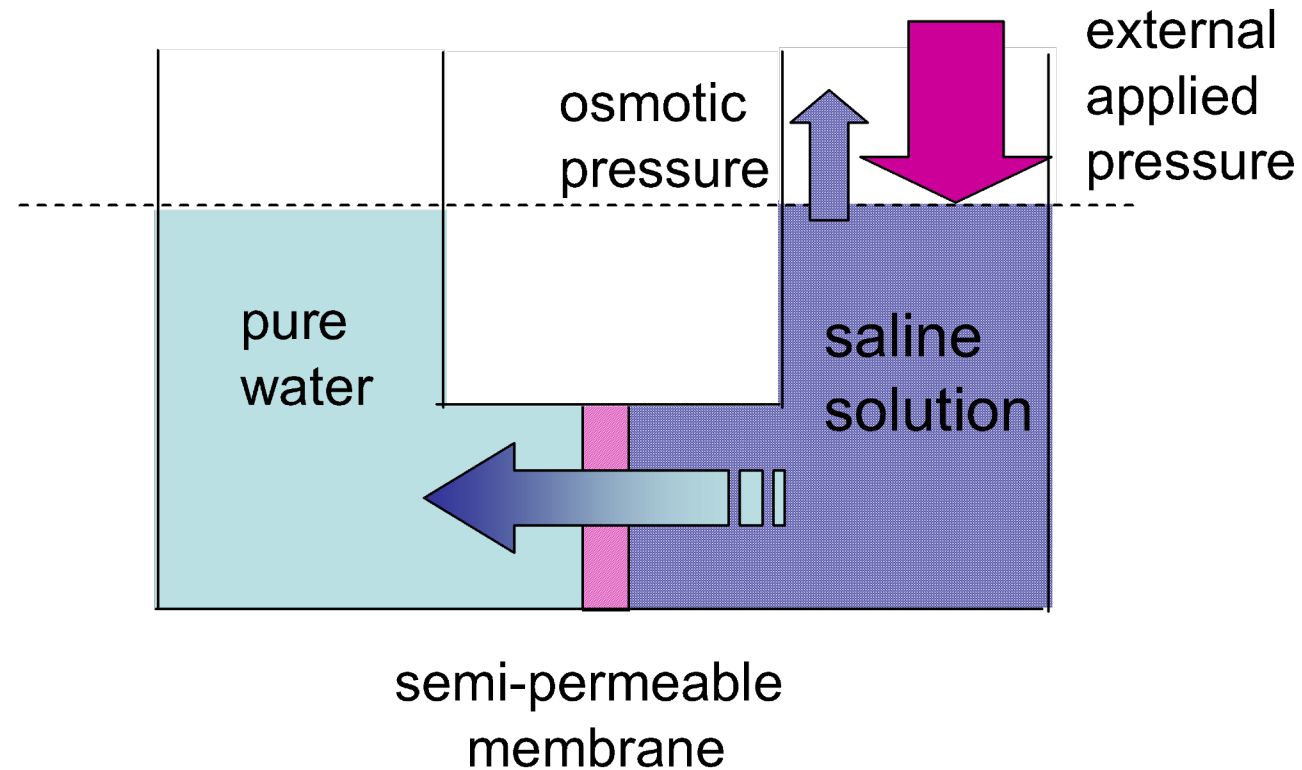
Osmotic pressure

In principle, only water is transported:
results in an *osmotic pressure*



Reverse osmosis

Applied pressure has to be higher than osmotic pressure



Osmotic pressure

Van't Hoff:

$$\Pi = \beta \cdot \frac{n_i}{V} \cdot R \cdot T = \beta \cdot c_i \cdot R \cdot T$$

Π	osmotic pressure [bar]
n_i	amount of dissolved substances [mol]
V	volume of the solution [L]
R	universal gas constant = 8.3144 [J/mol/K] = 0.083144 [bar L /mol/K]
T	absolute temperature [K]
c_i	molar concentration of substance i [mol/L]
β	$= 1 + \alpha (v - 1)$ [-]
α	degree of dissociation [-]
v	stoichiometric coefficient of the dissociation reaction (number of ions formed from dissociation from 1 original salt [-])

Example: Calculation of Osmotic pressure

Osmotic pressure of seawater as NaCl-solution
(other salts not taken into account) at 25 ° C.

NaCl-content: 30 g/l;

molar weight : Na = 23; Cl = 35.5

$\alpha = 1$;

$v = 2$ (Na⁺, Cl⁻)

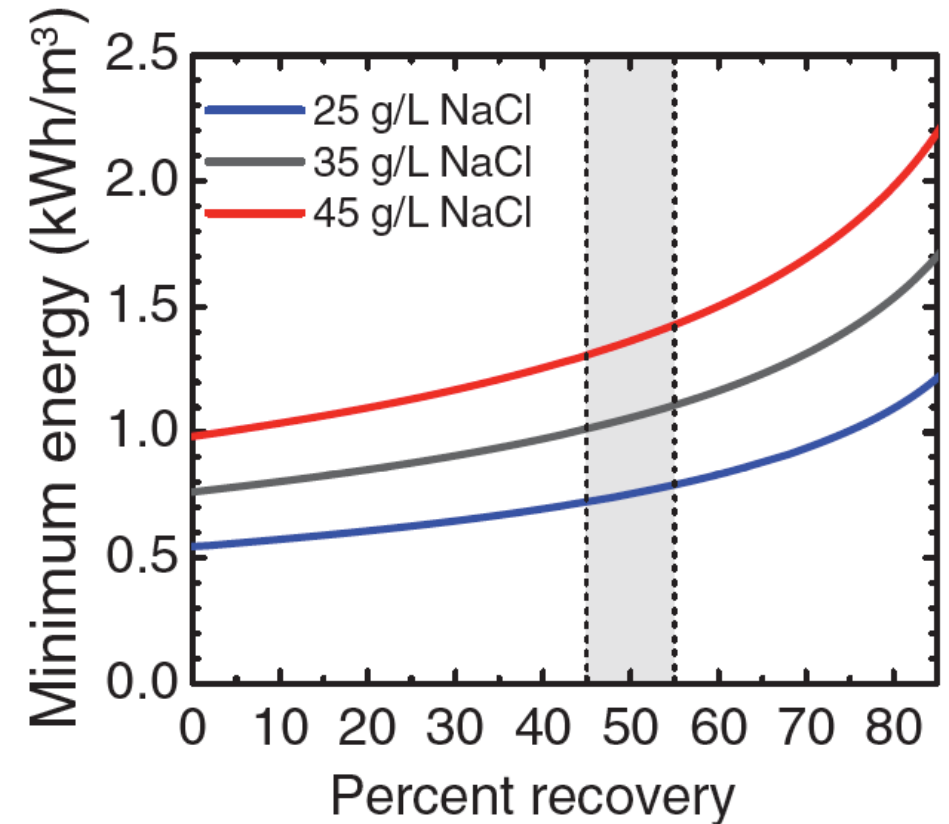
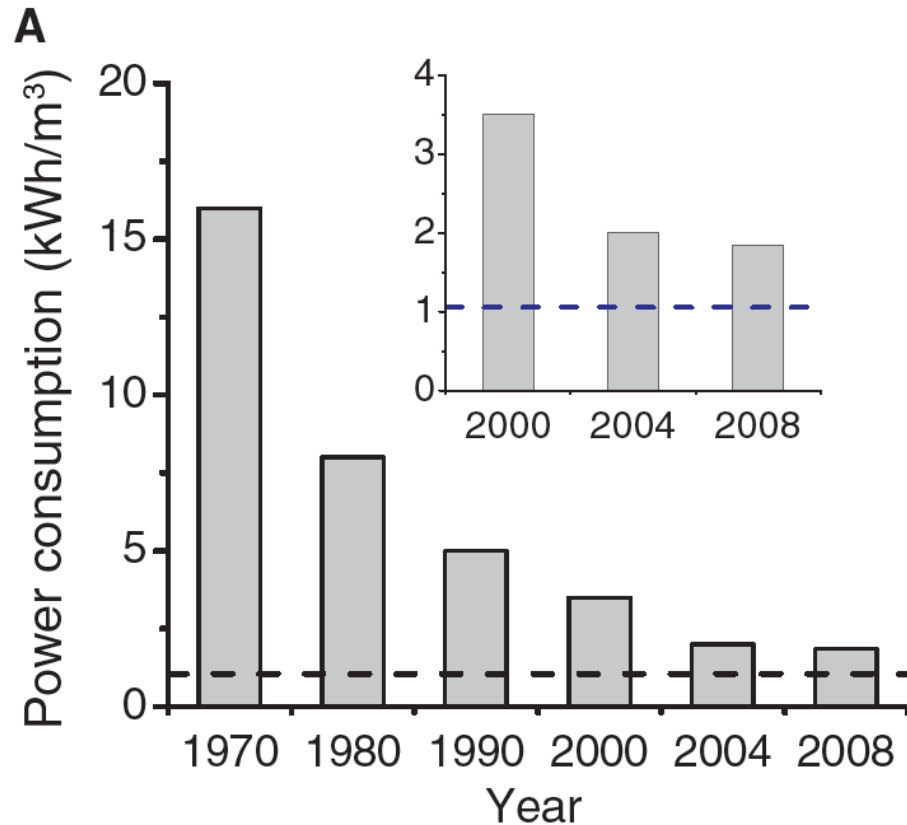
$\beta = 1 + \alpha (v - 1) = 1 + 1 \times (2 - 1) = 2$

$$c_{\text{NaCl}} = \frac{30 \text{ g/L}}{(23 + 35.5) \text{ g/mol}} = 0.51 \text{ mol/L}$$

$$\Pi = \beta \cdot \frac{n_i}{V} \cdot R \cdot T = \beta \cdot c_i \cdot R \cdot T$$

$$\Pi = 2 * 0.51 \text{ (mol/L)} * 8.3144 \text{ (bar L/mol/K)} * 298 \text{ K} = 25.4 \text{ bar}$$

Energy requirement for desalination with RO



Total energy requirement: 3-4 kWh/m³

ΔE results from energy for pre-/post-treatment

Sea water: ca. 35g/L dissolved salts

Conclusions

- Worldwide there is an increasing pressure on water resources
- Water reuse is a viable option to solve/mitigate water scarcity in urban areas (acceptance issues, indirect vs direct potable reuse)
- In coastal areas desalination is an alternative, however the energy demand is high
- To solve water scarcity problems, water use in agriculture and industry has to be considered as well
- Water reuse or desalination are too expensive for irrigation in agriculture (improvement of irrigation methods, adapted crops)