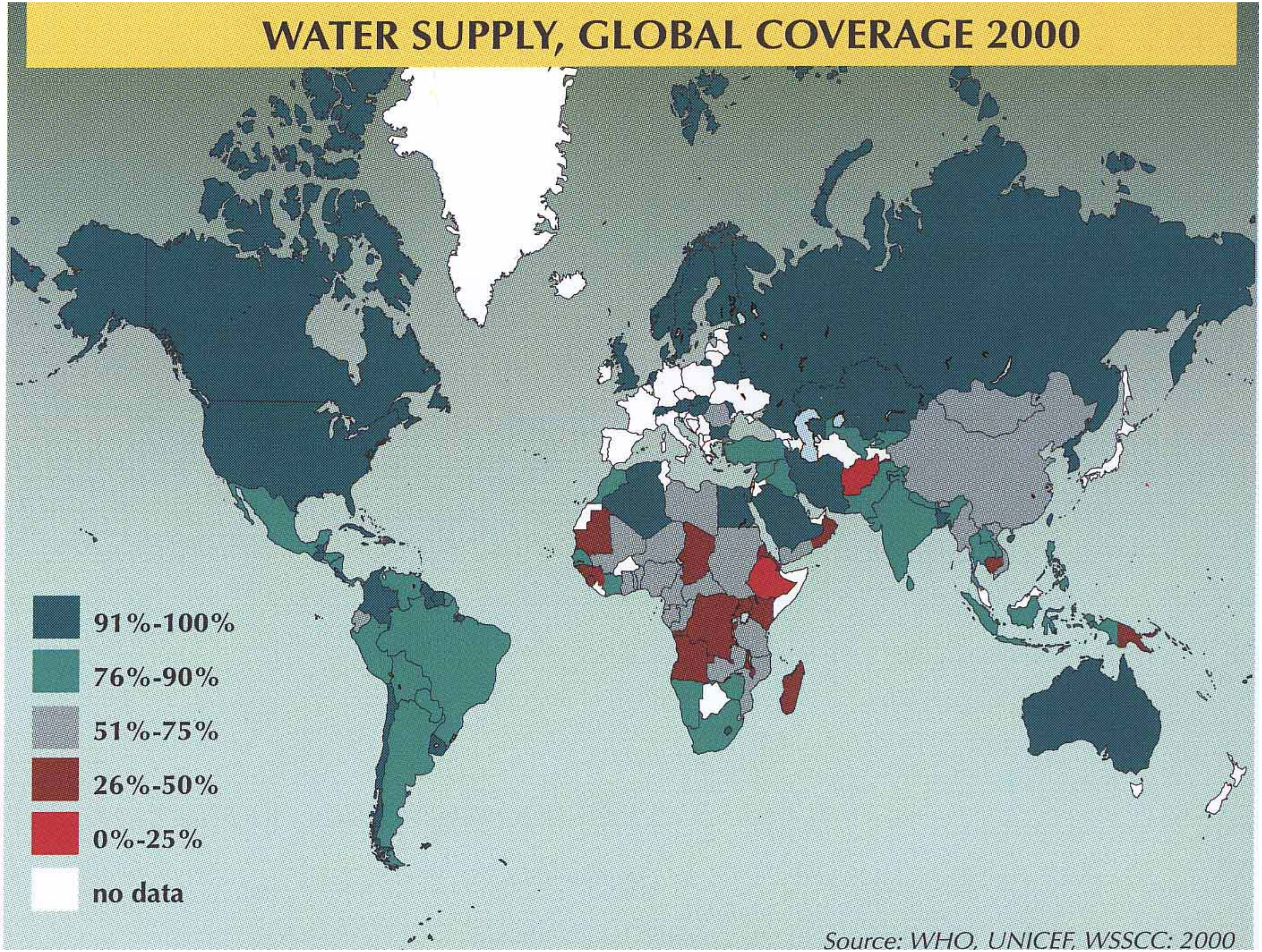
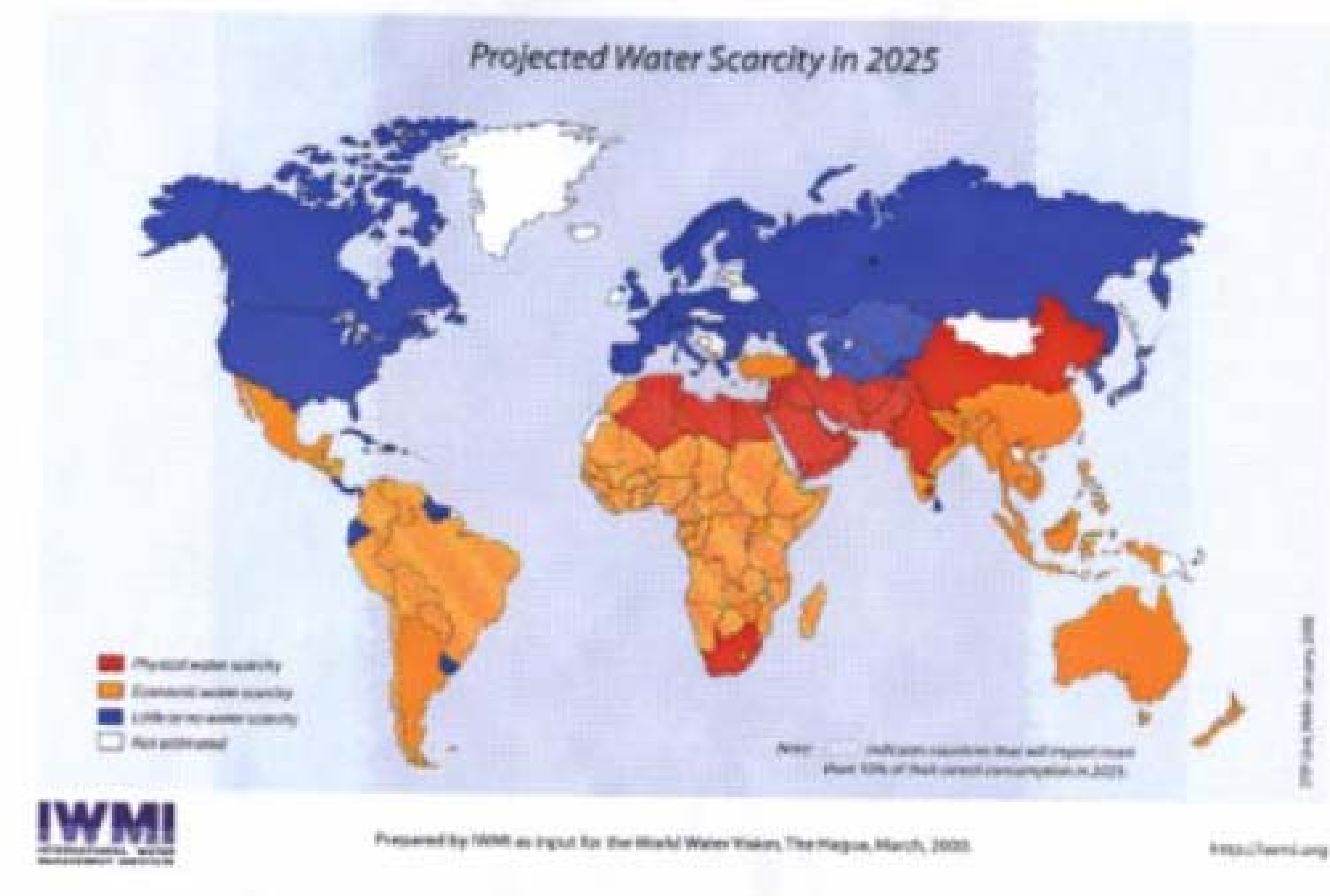
REUSE OF WASTEWATER – POSSIBILITIES AND LIMITATIONS (with an emphasis on potable water reuse)

Hallvard Ødegaard


WATER SUPPLY, GLOBAL COVERAGE 2000
91%-100%
76%-90%
51%-75%
26%-50%
0%-25%
no data
Source: WHO, UNICEF, WSSCC: 2000


Projected Water Scarcity in 2025
IWMI

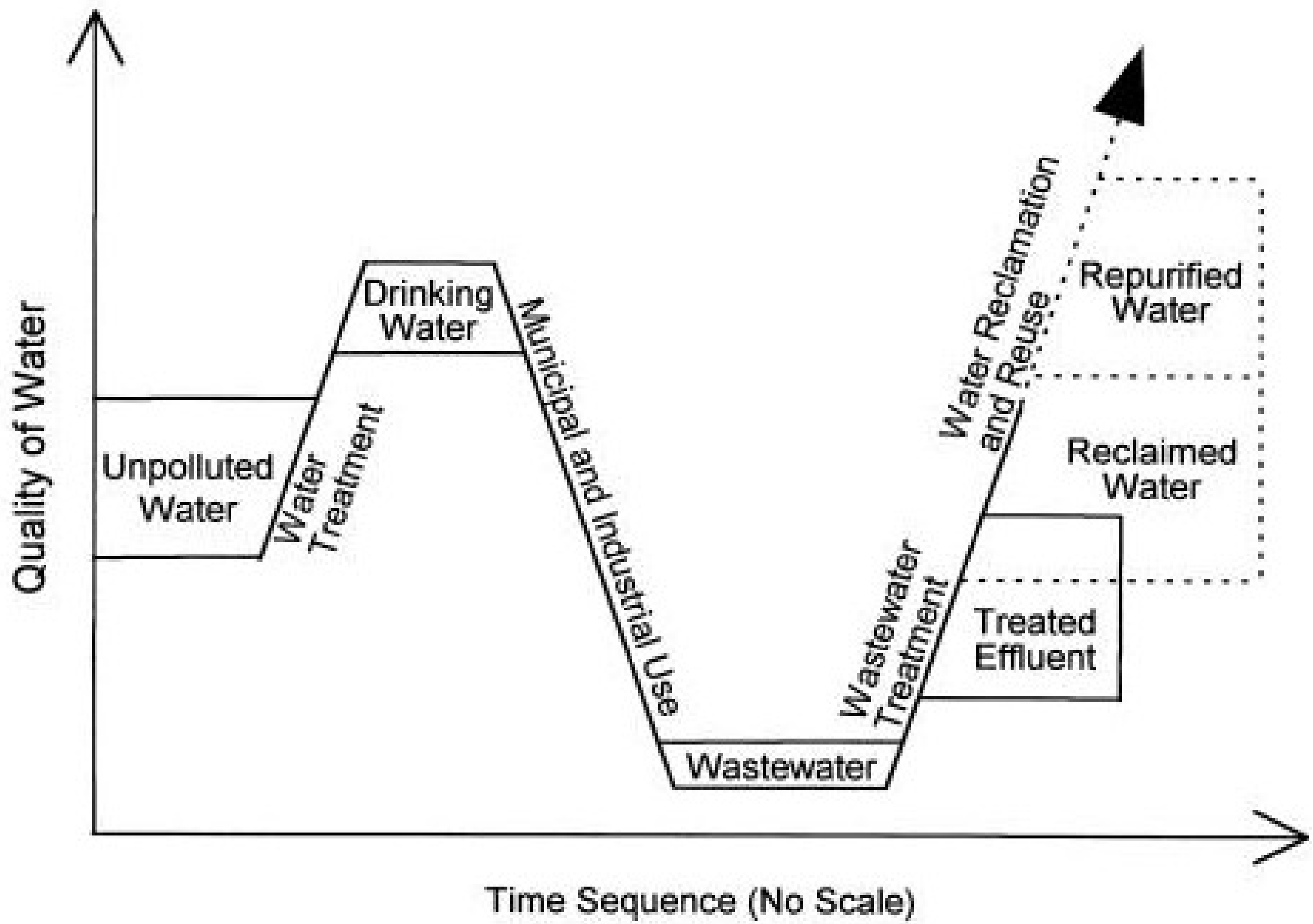
AN HORRIBLE EXAMPLE - THE ARAL SEA FROM 1976 TO 1997

ERA OF WASTEWATER RECLAMATION, RECYCLING AND REUSE: POST 1960

- California legislation encourages wastewater reclamation, recycling and reuse
- Use of secondary effluent for crop irrigation in Israel
- Research on direct potable reuse in Windhoek, Namibia
- US Clean Water Act to restore and maintain water quality
- Pomona Virus Study; Pomona, CA
- California Wastewater Reclamation Criteria (Title 22)
- Health effects study by LA County Sanitation Districts, CA
- Monterey Wastewater Reclamation Study for Agriculture, CA
- WHO Guidelines for Agricultural and Aquacultural Reuse
- Total Resource Recovery Health Effects Study; City of San Diego, CA
- Potable Water Reuse Demonstration Plant; Denver, CO Final Report -- plant operation began in 1984

1960 1965 1970 1975 1980 1985 1990 1995 2000

WATER QUALITY DEFINITIONS

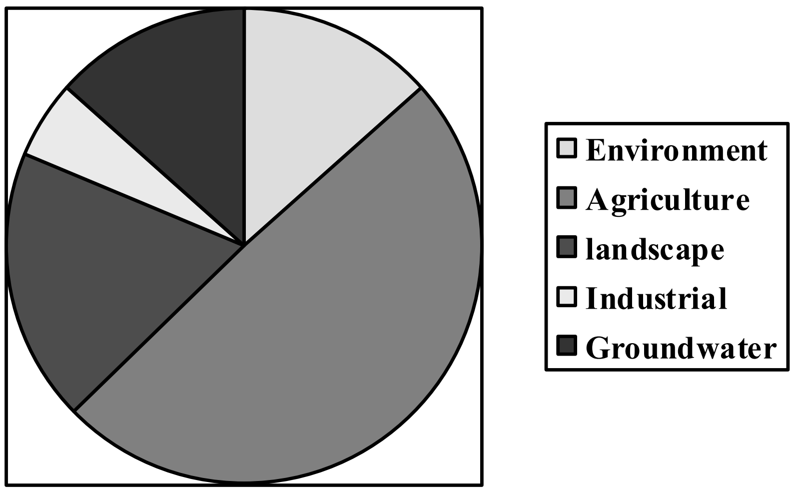


CATEGORIES OF WATER REUSE

1. Agricultural irrigation
2. Landscape irrigation
3. Industrial recycling and reuse
4. Recreational & environmental applications
5. Non-potable urban reuse
6. Groundwater recharge
7. Potable reuse

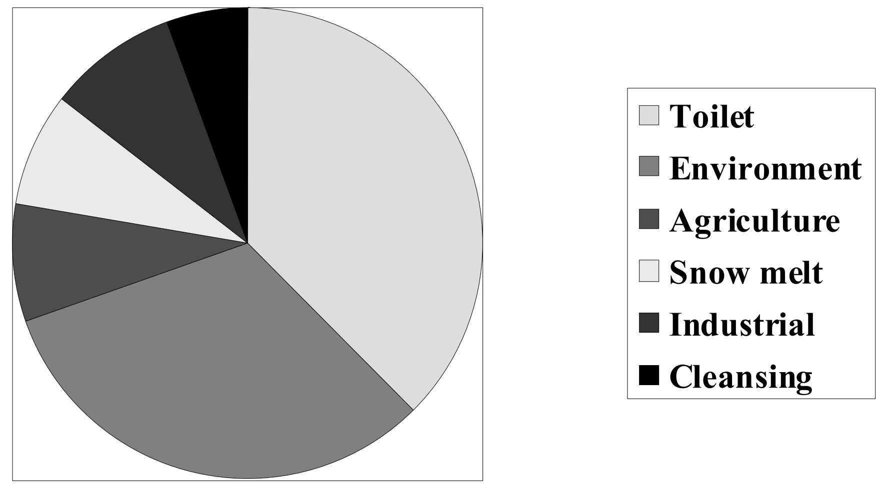
WASTEWATER REUSE IN CALIFORNIA AND JAPAN

California: 401,910 acre-ft/yr.



496 x $10^6 m^3$ (2000 data)

Japan: 167,000 acre-ft/yr.



206 x10^6 m^3 (1997 data)

WASTEWATER REUSE FOR AGRICULTURAL AND LANDSCAPE IRRIGATION

Most iomportant : The water itself – but also its inherent nutrients

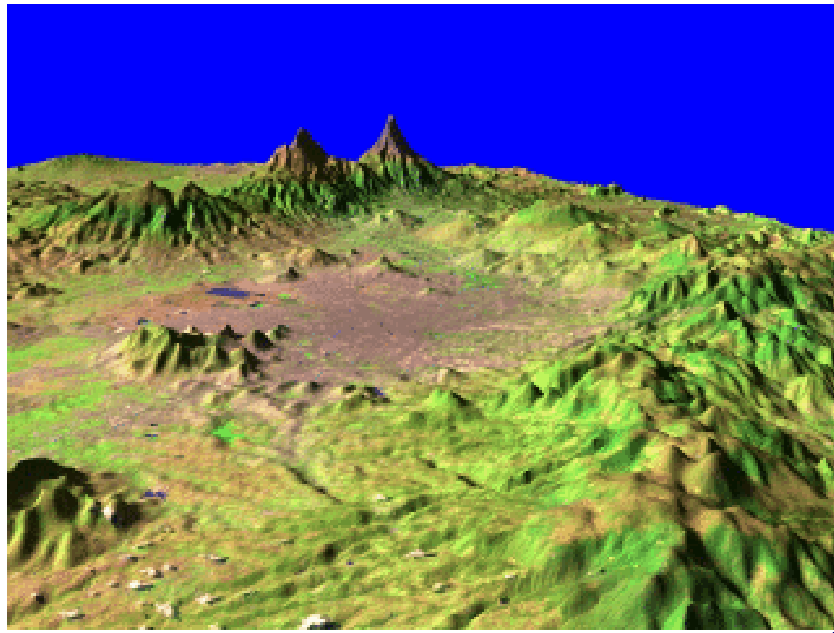
- Irrigation of agricultural land and crops
- Irrigation of sporting grounds (golf courses)
- Irrigation of parks and lawns

The most important challenges:

- Secure hygienic quality
- Prevent soil pollution
- Prevent ground water pollution

CASE : Mexico city

- Hydrological cycle out of balance
- Ground water level sinks 1m/year
- Ground sinks 10-15 cm/year
- 45 m^3/sec wastewater
- Only 29 m^3/sec stays within area



RAW WASTEWATER IRRIGATION IN MEXITAL VALLEY WHERE VEGETABLES ARE GROWN

Ascaris frequent among population

REUSE OF WASTEWATER FOR URBAN LANDSCAPING

Treated wastewater for landscaping (ponds, creeks, wetlands etc)

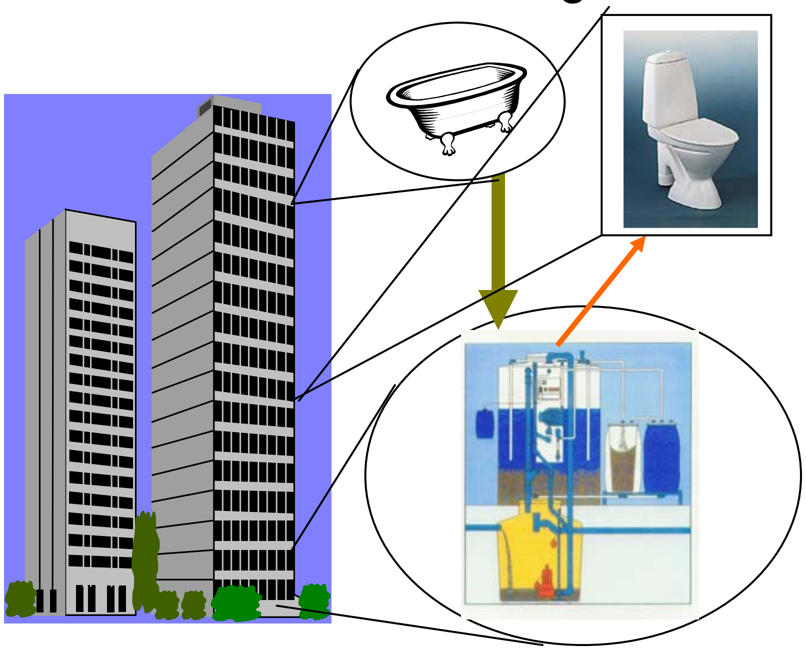
Wetland

Creek from wastewater

CALIFORNIANS ARE BATHING IN THE WWTP OUTLET

REUSE OF WASTEWATER FOR URBAN USE

Treatment of grey-water to be used for toilet flushing



Two principal systems:

- one for the whole town
- local, small-scale systems

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Dep. Hydraulic and Environmental Engineering

Prof. Hallvard Ødegaard

REUSE OF WASTEWATER IN MEGACITIES (Example Tokyo)

RECLAIMED WASTEWATER FOR INDUSTRIAL REUSE

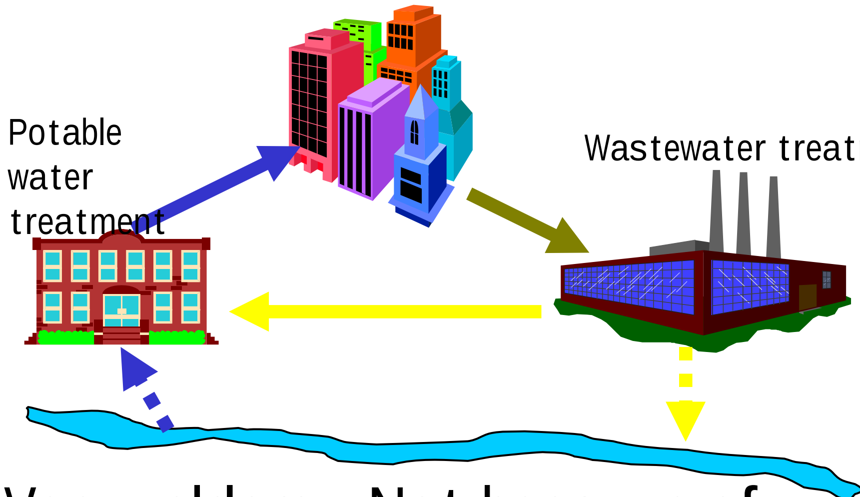
Reuse within the industry

Reuse of reclaimed municipal wastewater

- cooling-system make-up water
- boiler feed water
- process water for production
    - manufacturing
    - iron and steel
    - textile
- wash-down water (car wash)

RECLAIMED WASTEWATER FOR POTABLE WATER SUPPLY

Direct potable reuse:



Very seldom - Not because of inability to treat sufficiently, but because of the public's objection to drink former sewage

Example : Windhoek, Namibia

Groundwater recharge

Quite common -

- Arresting the decline of water level
- Storage of surface water
- Self purification in soil

Example: West Basin, California

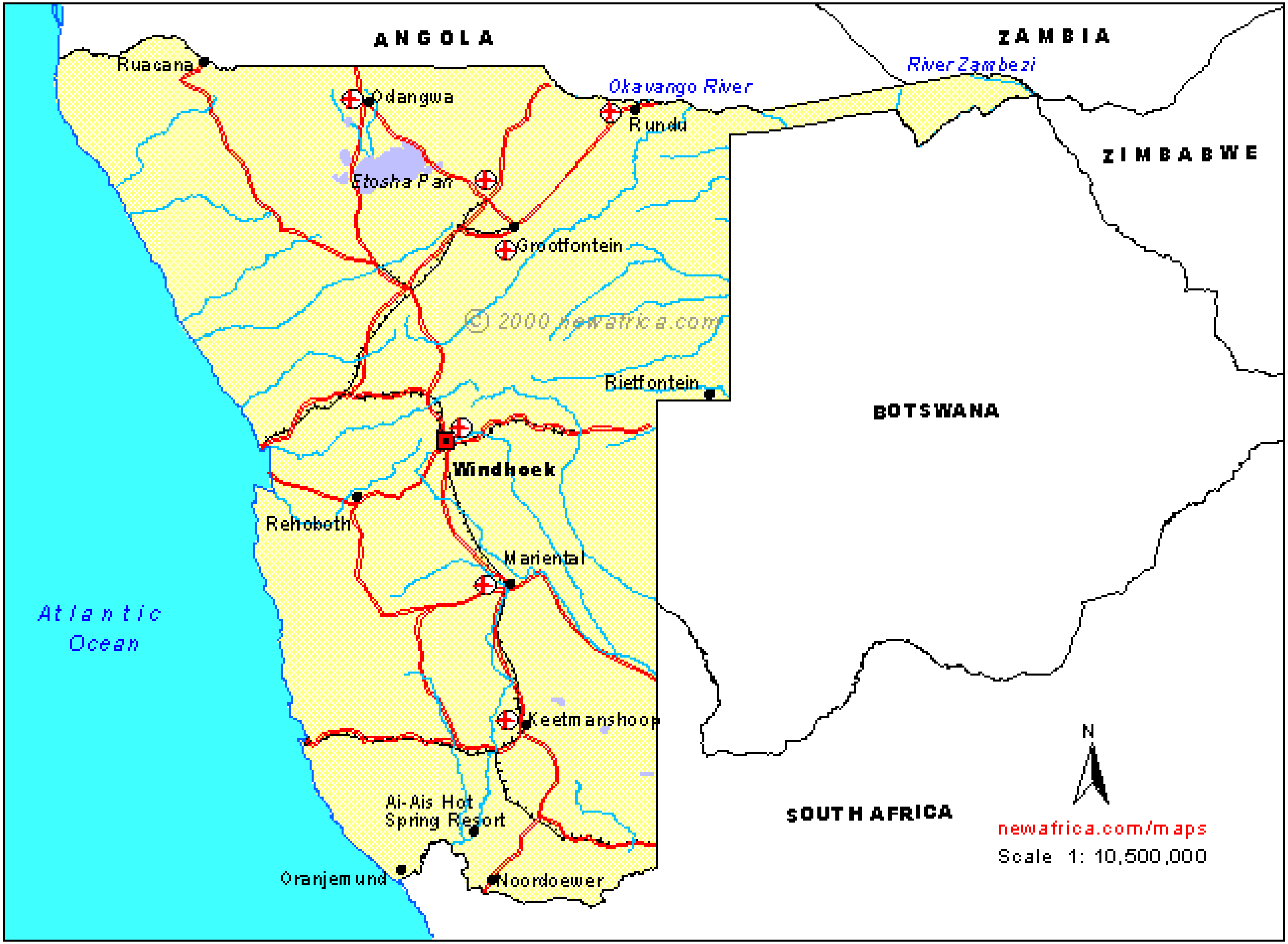
WHY POTABLE WATER REUSE?

- Introduced due to water shortage
- Made possible because of advanced treatment technologies
- Health and safety aspects have resulted in a cautious attitude
- Implemented in communities with no other freshwater supply options
- Small volumes, but great interest from a technological and public health point of view

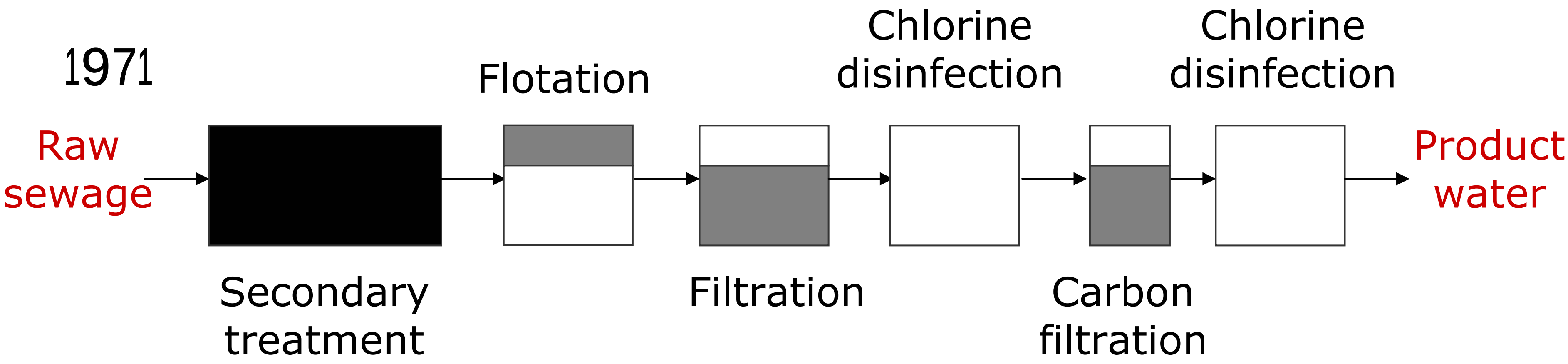
Case: Windhoek, Namibia

- Population of about 250 000
- Severe water shortage in the late sixties
  - reclamation of municipal wastewater for potable reuse was the only short-term solution
- Following pilot-scale testing, a potable reclamation plant was opened in 1971
- Capacity: 4 800 m^3/d
- Several upgrades, and the capacity is now being expanded to 21 000 m^3/d

NAMIBIA OVERVIEW MAP



WINDHOEK DIRECT POTABLE REUSE PLANT

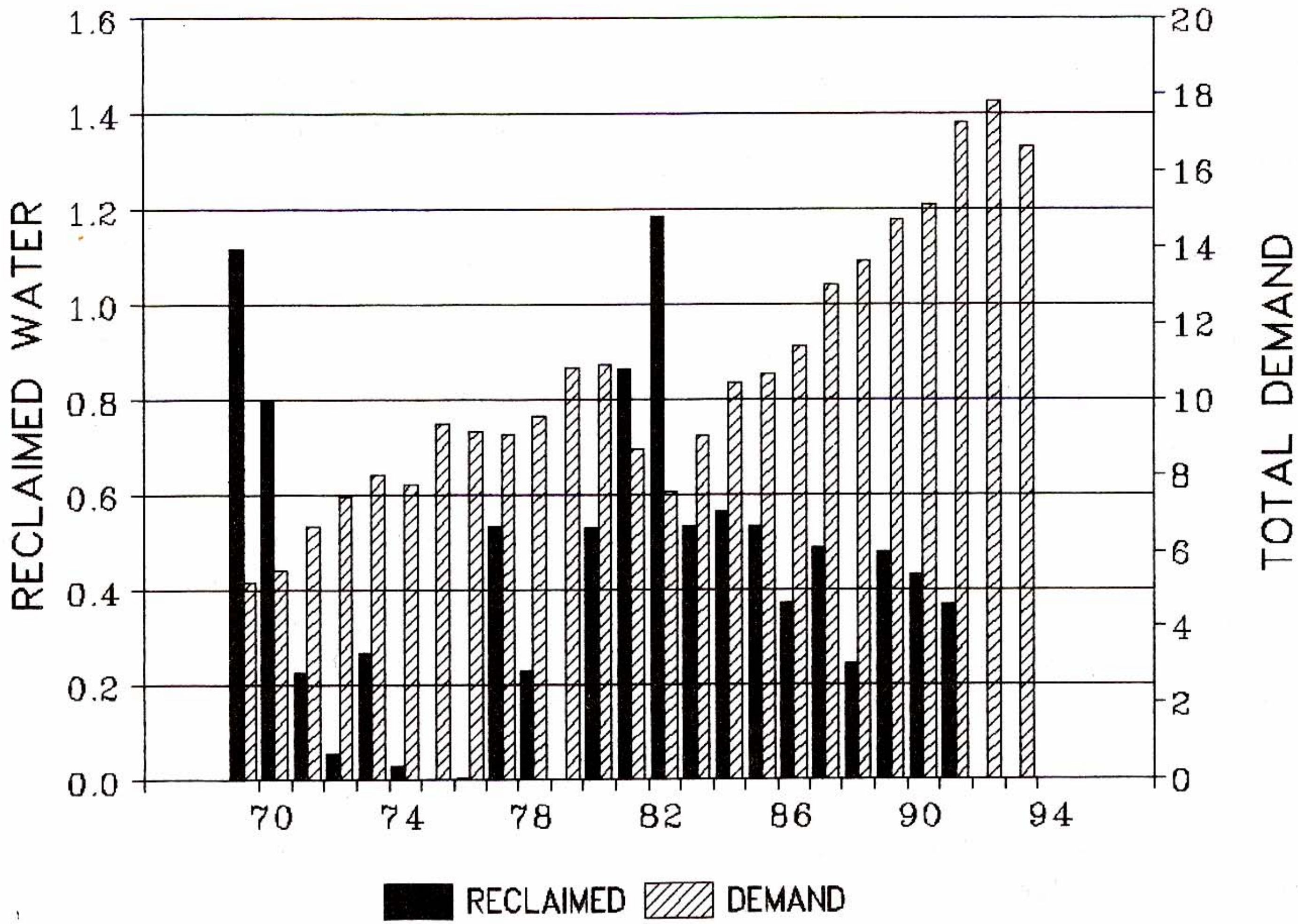


- 1971 Flotation, filtration, carbon filtration and chlorine disinfection
- 1977 Lime enhanced settling. Amonia stripping
- 1980 Alum and lime addition before settling
- 1986 Alum addition and dissolved air flotation

BLENDING OF RECLAIMED WATER

- Blended with conventionally treated water in two steps
  - Blending with treated surface water at the treatment plant
    - Minimum of 1:1 dilution, average 1:3,5
  - In the bulk water system of Windhoek
    - Distribution only to a limited number of supply zones
- In the future, the surface water supply will have almost no benefit compared to the reclaimed water due to deterioration of the surface water
  - Increased use of reclaimed water

CONTRIBUTION FROM RECLAIMED WATER



MONITORING OF THE WATER QUALITY

➢ Chemical	Main chemical constituents
➢ Toxicity	Water flea lethality, urease enzyme activity, bacterial growth inhibition
➢ Virological	Somatic coliphages is used as an indicator for the precence of viruse, 100 % negative
➢ Bacteriological	86%<100 CFU/ml, 3 + on coliform
➢ Algal	chlorofyll levels
➢ Mutagenicity	Ames salmonella mutagenicity
➢ Mortality pattern	Patterns of mortality and cancer were not affected by reclamation

➢ Monitoring represents 20 % of the total production cost

SUCCESS FACTORS FOR THE WINDHOEK-PROJECT

- The public was kept fully informed at all stages
- Separation of industrial and potentially toxic wastewater
- Adequate and consistent effluent quality produced by the secondary wastewater treatment
- Advanced treatment producing acceptable potable water
- Multi-barrier treatment sequence as a safeguard against pathogens

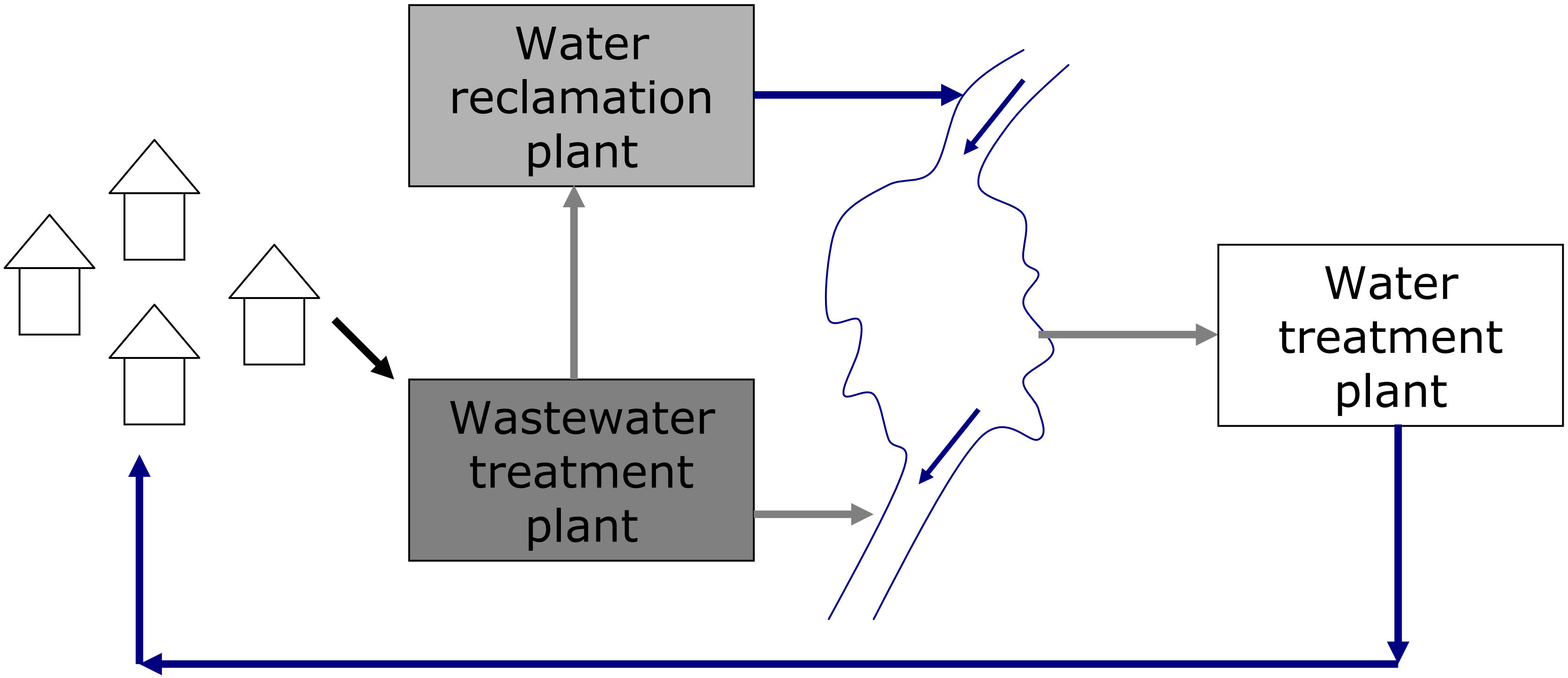
WINDHOEK, EXPERIENCES AND CONCLUSIONS

- The Windhoek experience with wastewater reclamation to potable drinking water standards was an unqualified success during its first 25 years
- If properly informed, consumers will fully accept this perhaps controversial option
- The cost of reclamation was less than the cost of diverting water over long distances from other sources
- Reclamation and reuse is a practical option, not only for technologically advanced countries

Dr. Lucas van Vuuren:

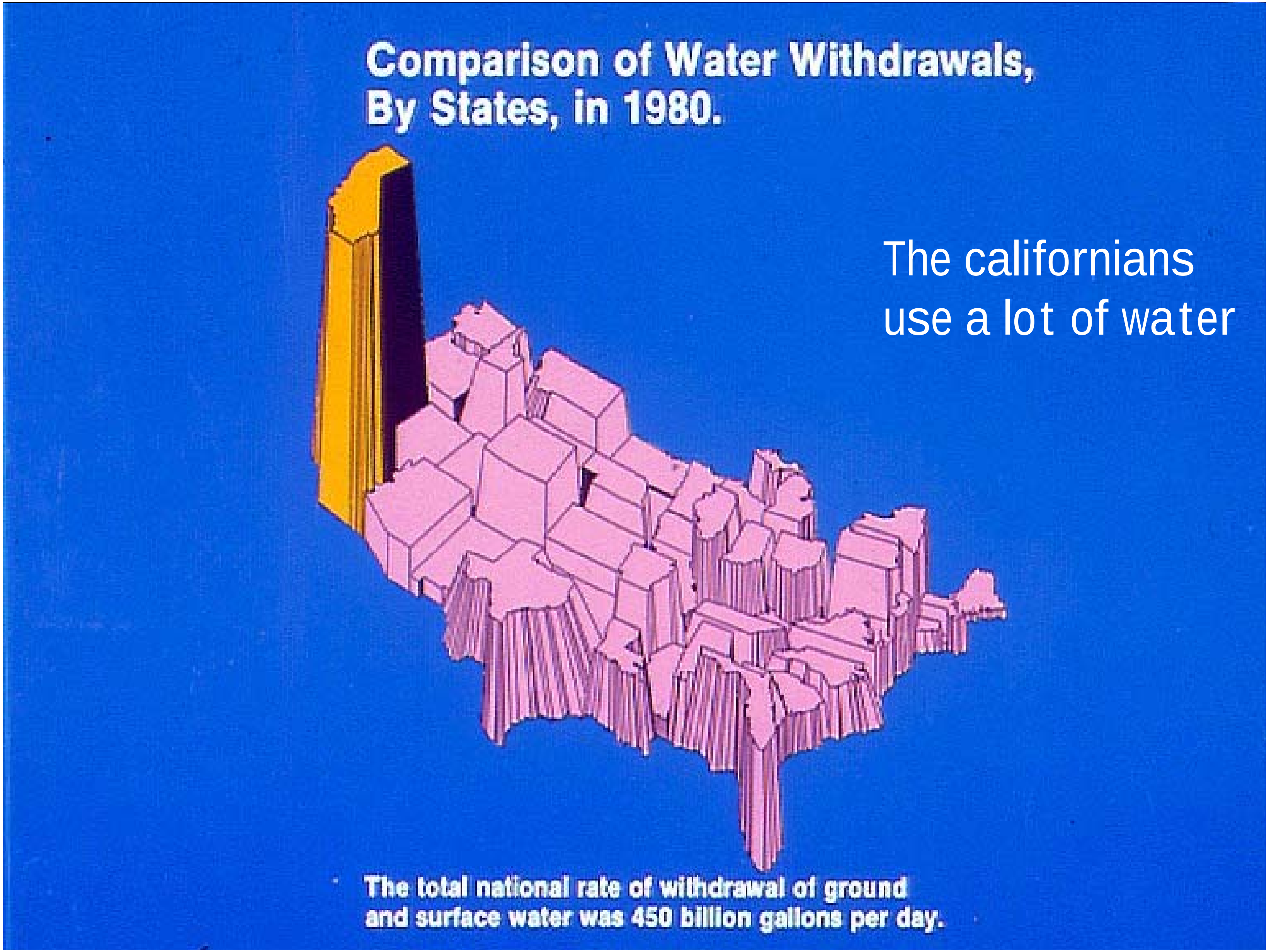
”Water should not be judged by its history, but by its quality”

INDIRECT POTABLE REUSE



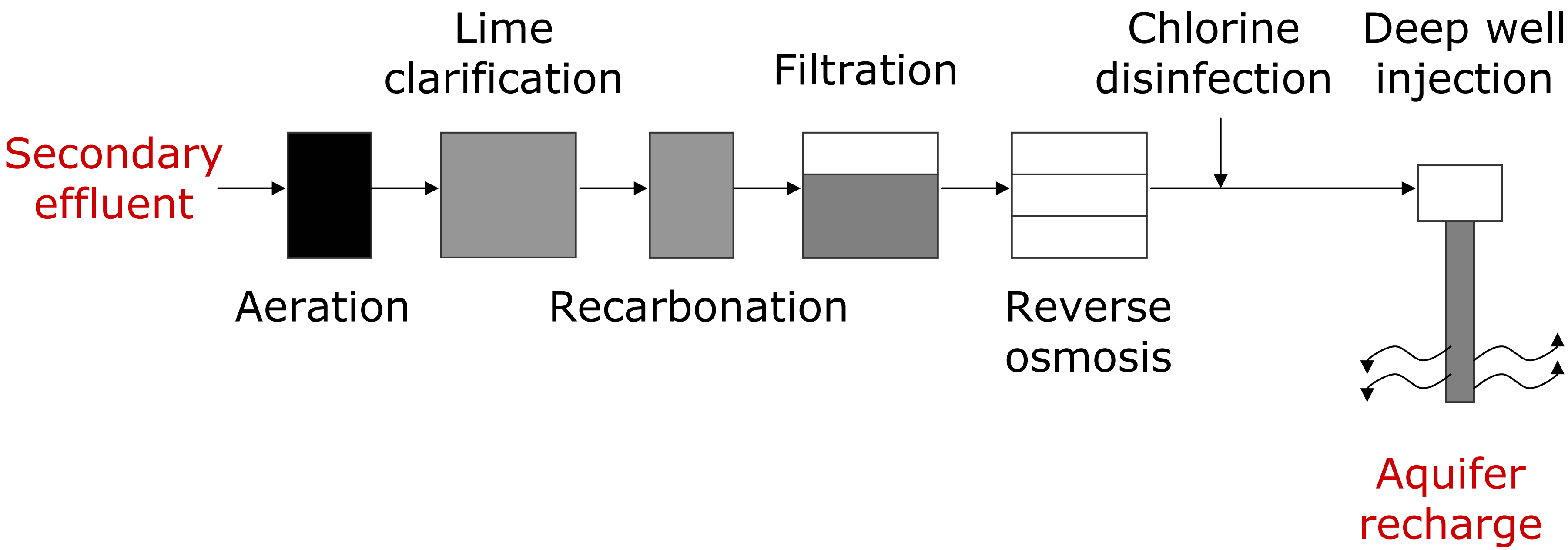
Case: West Basin, California

- From the 1950's imported water have been injected into the ground to protect the aquifers against sea water intrusion
- Groundwater accounts for more than 20 % of the water consumption
- From June 1995, 19 000 m^3/d of highly treated reclaimed water was mixed with imported surface water and injected into the West Coast Basin Barrier.
- A baseline groundwater monitoring program was initiated in 1991 for comparison purposes



The californians
use a lot of water

WEST BASIN WATER RECLAMATION PLANT



WATER QUALITY REGULATIONS

- Reclaimed water (to meet drinking water standard)

BOD_5	<	1	mg/l
SS	<	1	mg/l
Turbidity	<	2	NTU
TOC	<	2	mg/l
Total coliform	<	2,2 per 100	ml
pH		6,5-8,5	
Oil and grease	<	1	mg/l

- Groundwater recharge proposed regulations
  - Retained in aquifer for 12 months prior to extraction
  - Maximum 50 % reclaimed water within 700 m from extraction well
  - Injected water should travel at least 700 m prior to extraction

TRACE ORGANIC COMPOUNDS

- Traditionally organic micropollutants have been monitored according to drinking water standards by following some target compounds
- Several investigations have shown that many other ”non-target” compounds are present
- Levine et al.(2001):
  - Trace organic compounds found were primarily disinfection byproducts as chloroform and bromoform
  - A possible release of base neutral compounds after lime clarification due to the high pH
  - RO is an effective remover of organic micropollutants

EXPERIENCES AND CONCLUSIONS, WEST COAST BASIN

- Use of 50 % reclaimed water for injection is anticipated to improve groundwater quality
- Cost of the 19 000 m^3/d reclamation plant was about $22 million
- Will be built out in 19 000 m^3/d increments to 76 000 m^3/d (extra $40 million)
- The goal is to substitute all the treated, imported surface water currently used for the West Coast Bassin Barrier by reclaimed water

THE POTENTIAL FOR POTABLE WATER REUSE

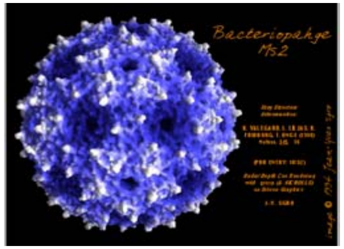
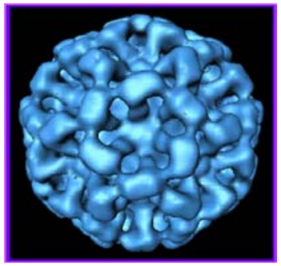
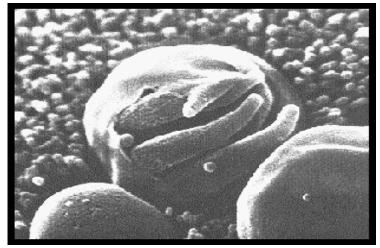
- Treatment technology exist and is continuously improved
- Pioneer projects have showed that it is possible, and this might help public acceptance
- Possibilities for multi-quality recycled water production
- Diversion of industrial and potential toxic wastewater from the main wastewater stream

LIMITATIONS IN POTABLE REUSE

- Public acceptance
- Pathogen transmission control
- Cost competitive compared to other possibilities (desalination, water import)
- Organic chemicals from reclaimed watewater and their toxicological effect
- Demands highly advanced analysis technology

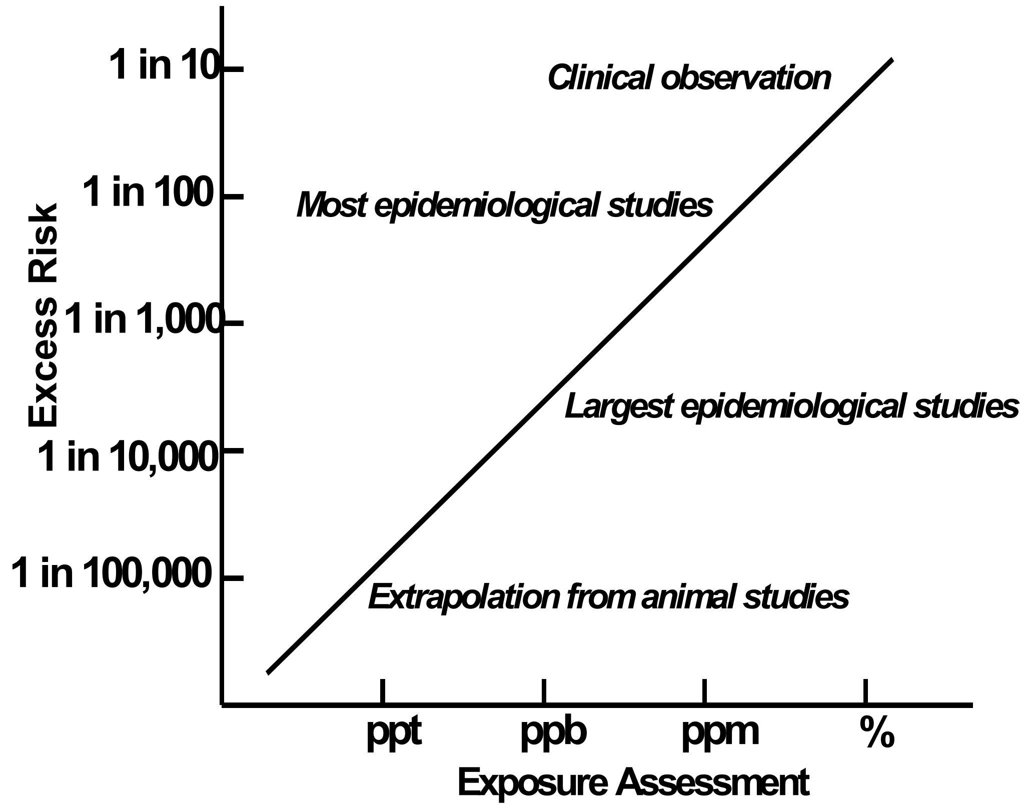
HEALTH AND PUBLIC SAFETY ASPECTS

- Drinking water standards are normally based on the assumption that high quality water sources are used
  - The concept of multiple barriers was introduced primarily for increased safety against pathogenic organisms
- Goal: indirect potable reuse should provide a degree of safety at least equal to that of a communities current water supply
- Health effect testing based on the effects of indirect potable reused water as compared to conventional water supplies
- Additional safeguards:
  - Blending and dilution with conventional raw water
  - Retention time
  - Natural treatment

HOW SAFE IS WATER REUSE?

- Acceptable health risks debate
  – Absolute risk vs. relative risk
- Microbiological risk assessment
  – Enteric virus control by treatment technologies
  – Regulatory oversight
- Chemical exposure risk assessment



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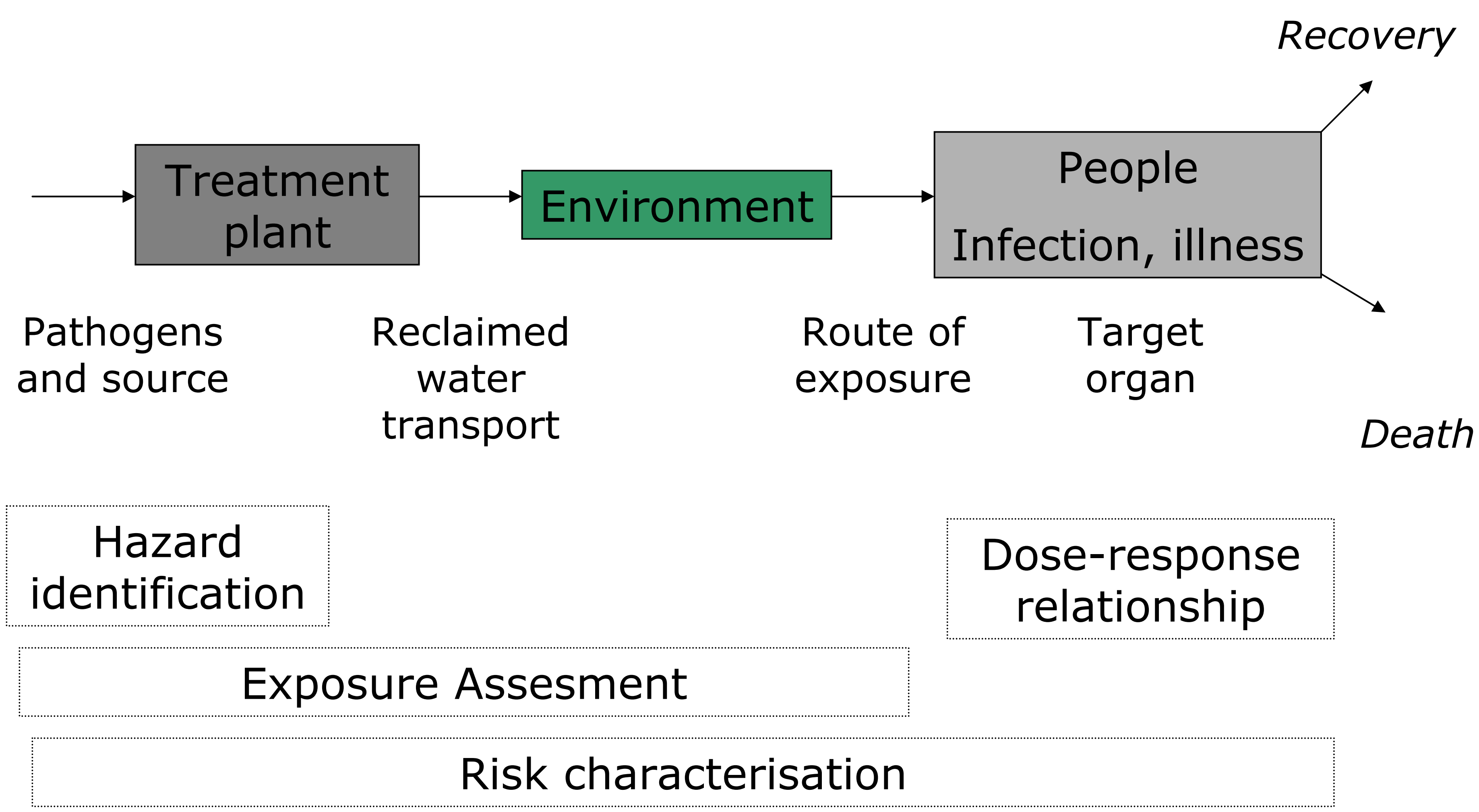
RISK ASSESMENT



POTABLE REUSE REGULATIONS

- International level
  - No regulations for potable reuse
- U.S
  - No federal regulations - state level
  - California, Proposed regulations for potable recharge
    - The groundwater supply should meet all drinking water standards and require no treatment prior to distribution
- In general:

Reclaimed water for potable reuse must meet drinking water standards

SOME QUESTIONS THAT NEED TO BE ANSWERED 1

- What is the likelihood that hazardous substances will be present in the reclaimed water at harmful levels?

- What is the known chemistry and toxicology of the reclaimed water or groundwater and how much of the organic material present is uncharacterized?

SOME QUESTIONS THAT NEED TO BE ANSWERED 2

- What is the best disinfectant or disinfection process for groundwater recharge?
- What are the upper bound, lower bound and most probable risks that could be attributed to lifetime consumption of the reclaimed water, as well as other sources of drinking water?

SOME QUESTIONS THAT NEED TO BE ANSWERED 3

- To what degree do costs influence the treatment alternatives, at the margin, relative to upper bound and most probable risks?

- Which portion of the TOC and the total halogenated organics should be removed by treatment barriers?

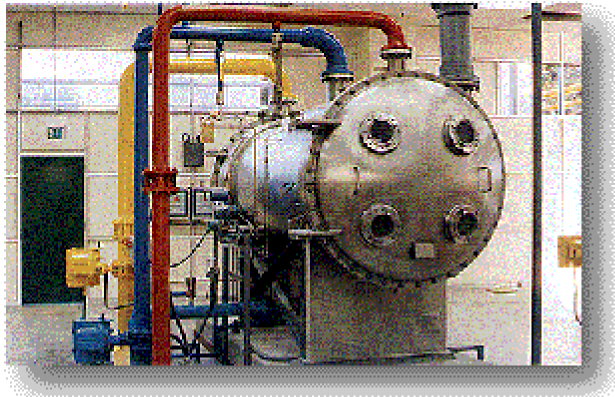
SOME QUESTIONS THAT NEED TO BE ANSWERED 4

- What additional costs would be incurred if groundwater quality changes resulting from recharge necessitated in the future the centralized treatment and distribution of extracted groundwater?

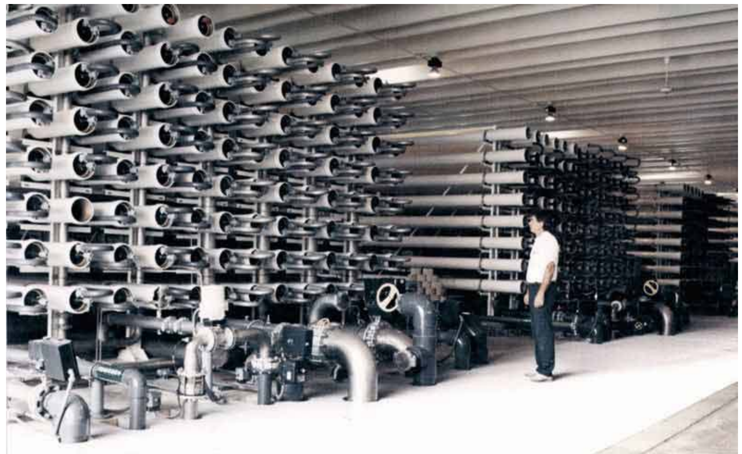
- Is the indirect potable reuse the last resort?

TREATMENT TECHNOLOGIES THAT PROBABLY WILL HAVE TO BE INCLUDED

Oxidation/disinfection technologies
Ozonation/UV, H_2O_2 etc



Advanced separation technologies
Membrane separation



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