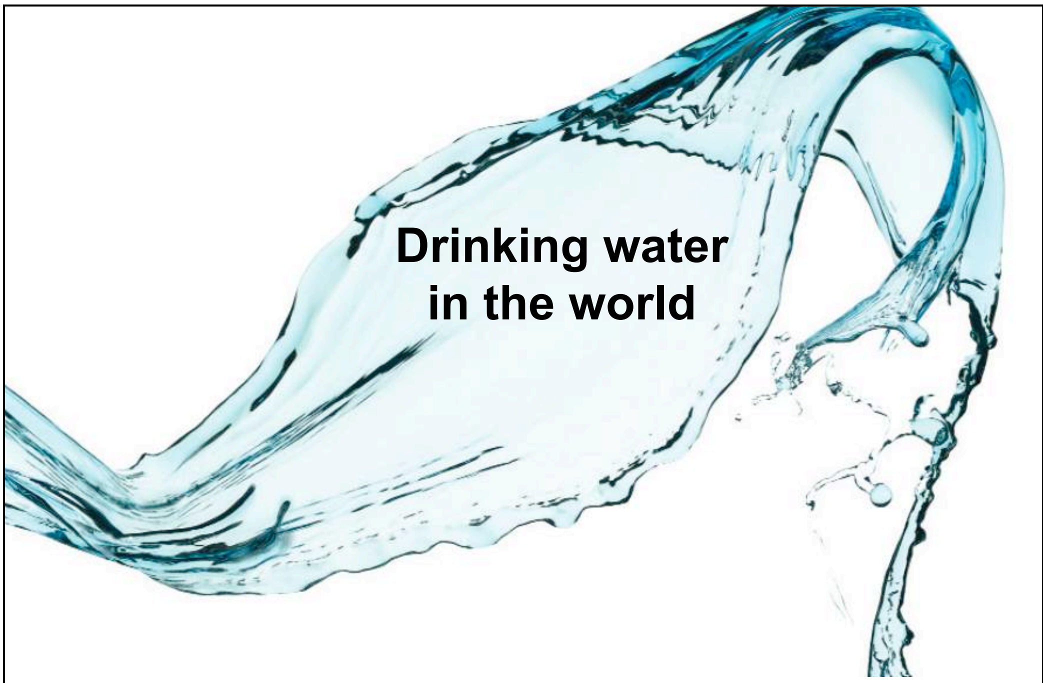
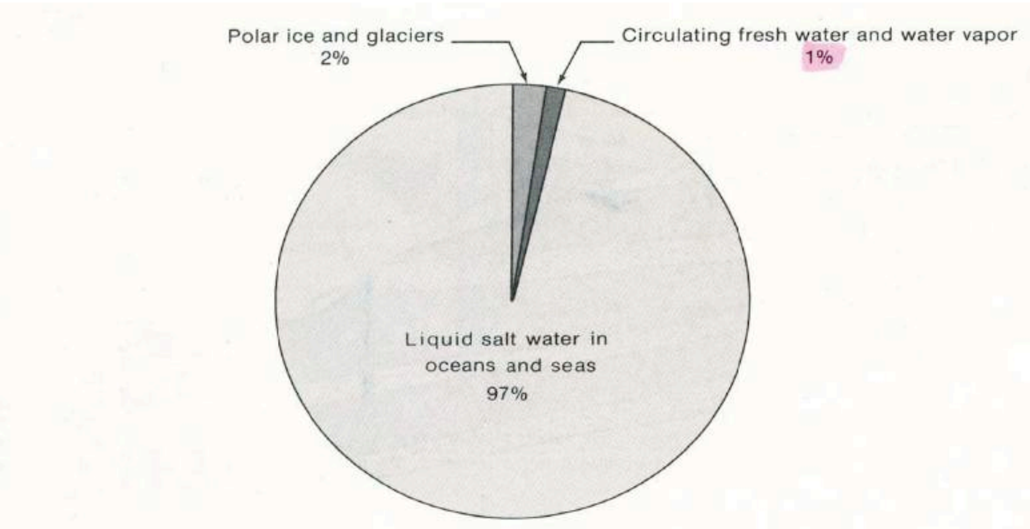


Drinking water in the world

Structure of the lecture

- Introduction – the global situation
- Freshwater management in the Netherlands and abroad
- Sustainable (urban) water management
- Collective versus individual infrastructures
- Rainwater utilization (Europe, Australia, Burma)
- The imperative of integrated system approaches
- Riverbed filtration and groundwater utilization
- Desalination of saltwater (Spain)
- Wastewater recycling (Africa and Asia)

Introduction - The Global Situation



Water and sanitation crisis

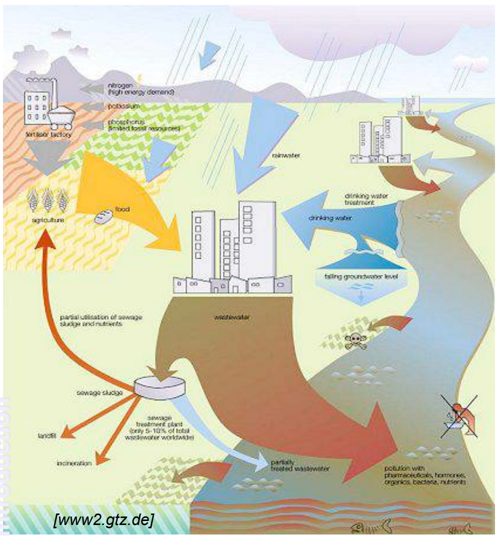
- Every month, water-related diseases kill more than 250,000 individuals (1 individual every 10 seconds, or 1 plane crash every hour)
- More than 1.1 billion people worldwide, or one-sixth of the global population, do not have access to safe drinking water, and
- nearly 2.6 billion lack access to basic sanitation, according to the World Health Organization

Water Pollution

- Discharges of sewage (e.g. sewer overflows) and by agriculture are effecting freshwater bodies and coastal areas
- A visible effect is the increasing growth of algae, even though protective measures are implemented

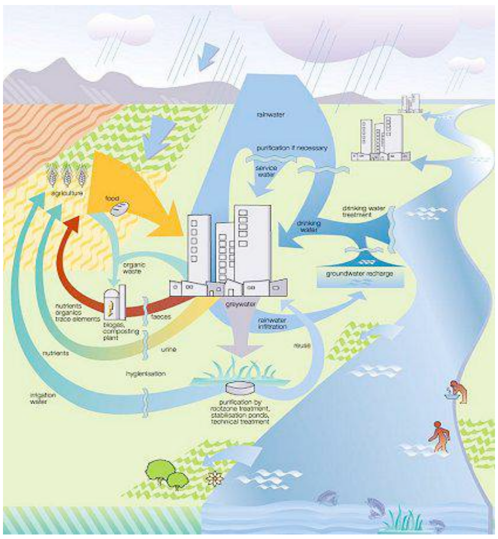
Water Pollution

centralized water systems
"end of pipe technology"

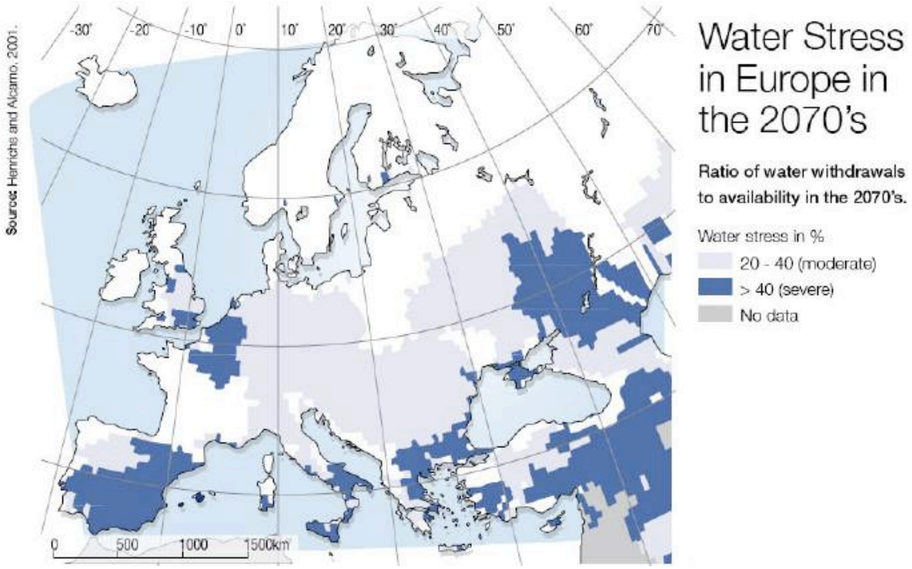


[www2.gtz.de]

decentralized water systems
considering "ecosan"



Climate change – water stress



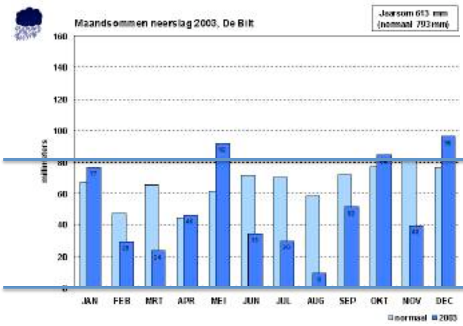
9 Assist. Prof. Dr.-Ing. Thorsten Schuetze TUDelft

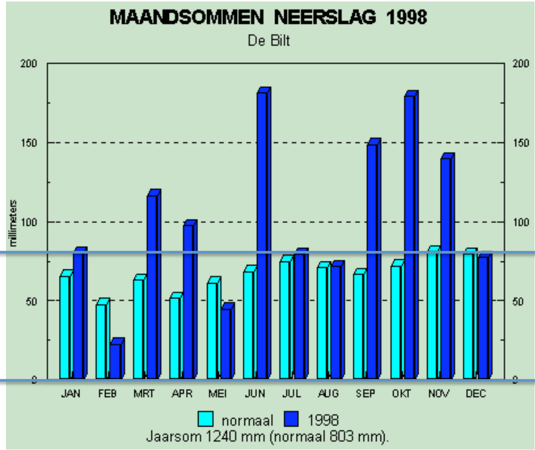
Freshwater managment in the Netherlands and abroad

10 Assist. Prof. Dr.-Ing. Thorsten Schuetze TUDelft

Precipitation in the Netherlands – extreme years

- 1998: 1240 mm
- 2003: 613 mm





Climate change – low flows and drought

- The rising sea level and more frequent low river discharges during the summer will allow the salty sea water to flow further inland.
- The salination of the river water will cause problems for the freshwater supply for drinking and regional agriculture.
- Especially in case of salination of the Hollandsche IJssel, the Haringvliet and the Spui.

Rijkswaterstaat, 2007

Fresh surface water

- 73% of the **fresh surface water** in the Netherlands originates from the **Rhine** (approx. 65%) and the **Meuse** (approx. 8%). The remaining 27% are originating from smaller rivers and from precipitation.
- The **water use** is water supply (for drinking water, agriculture, industry and cooling water) as well as for transport (shipping) and recreation.

Middelkoop, 1999

Water Resources & Withdrawal

- **Total renewable water resources**: 89.7 cu km (2005)

Total Freshwater withdrawal:

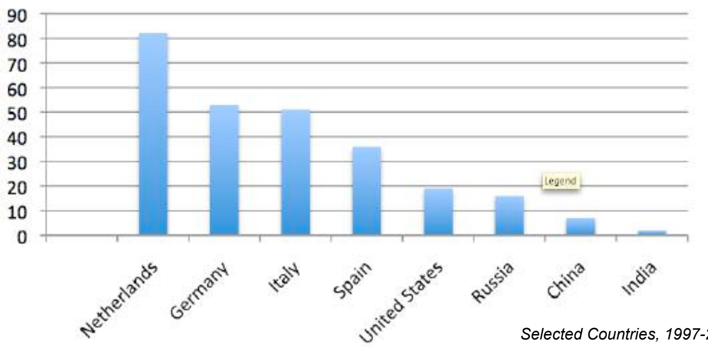
- 8.86 cu km/yr
- Domestic: 6%
- Industrial: 60%
- Agricultural: 34%
- per capita: 544 m3/yr (2001)

Middelkoop, 1999

Water Import Dependence

- The ratio between the water footprint of a country's imports and its total water footprint yields.
- (Beef 1/13500, Soybean 1/2750, Rice 1/1400, Milk 1/790)

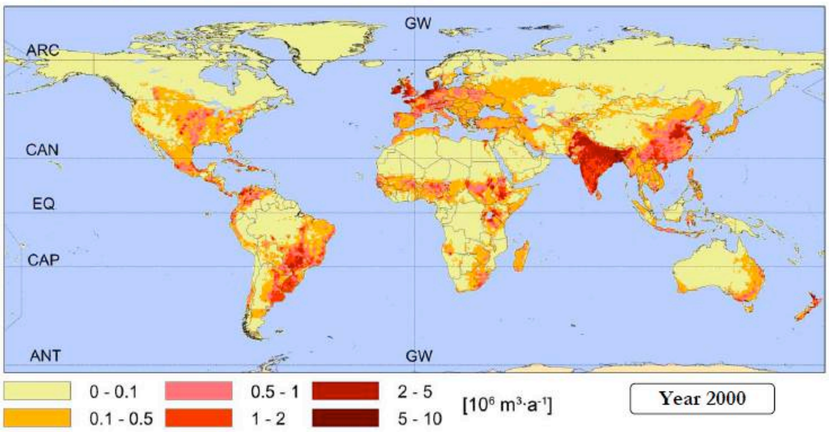
Water Import Dependence (percent)



Selected Countries, 1997-2001, Chapagain and Hoekstra, Water International, March 2008 / World Water Council

Livestock Water Demand

- Based on 6 major types of livestock in the world (cattle, buffalo, sheep, goats, pigs and poultry/chickens)

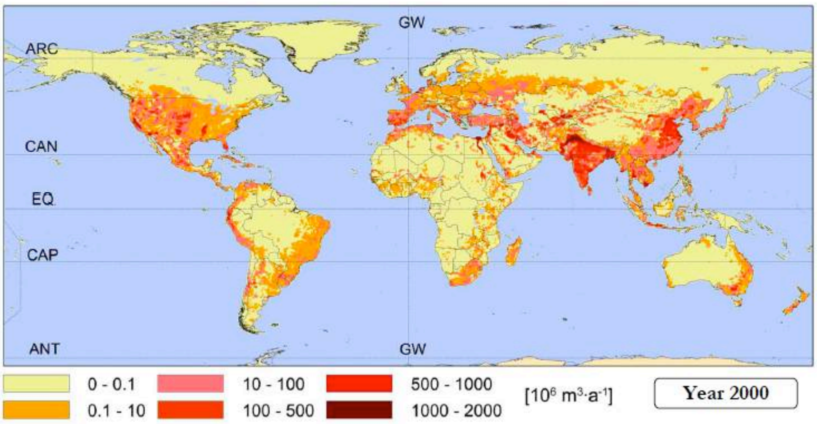


Data: FAO livestock densities

[Yoshihide Wada, 2010]

Irrigation Water Demand

- Based on monthly irrigated areas and crop calendars for 26 crops around the year 2000

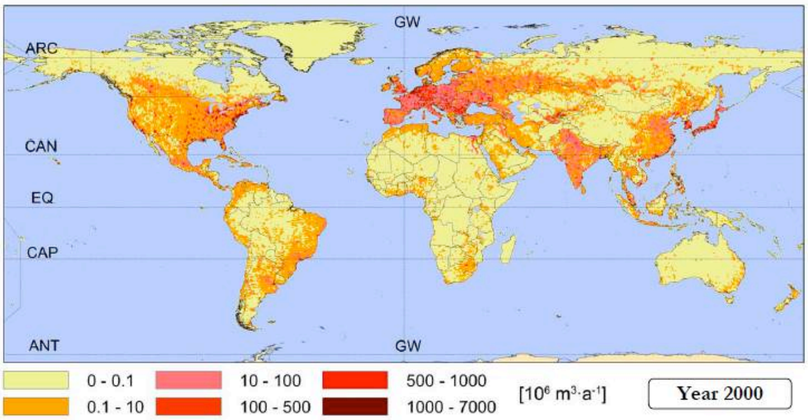


Data: MIRCA2000 and GCWM (University of Frankfurt)

[Yoshihide Wada, 2010]

Industry Water Demand

- Based on industrial water withdrawal data of World Water Assessment Programme

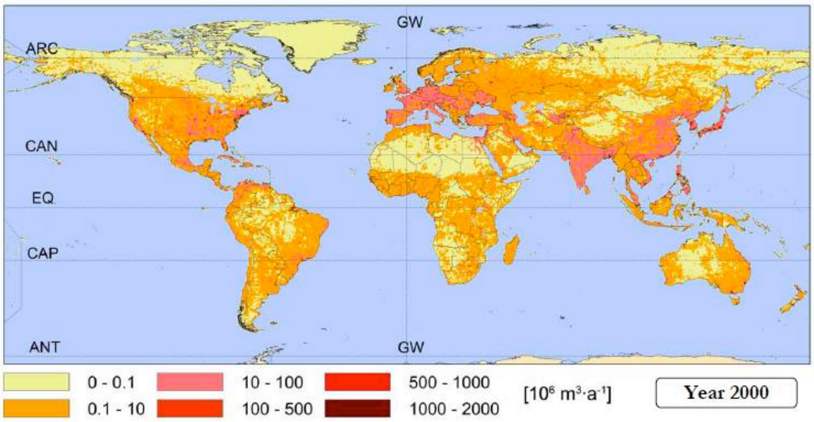


Data: WWAP (WWDR-II)

[Yoshihide Wada, 2010]

Domestic Water Demand

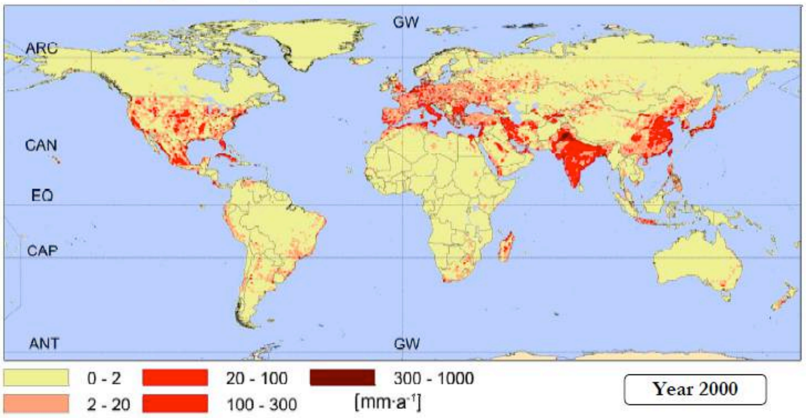
- Based on gridded population map and county per capita water withdrawal



Data: PBL HYDE (Netherlands Environmental Assessment Agenc[y] *[Yoshihide Wada, 2010]*

Gridded Groundwater Abstraction

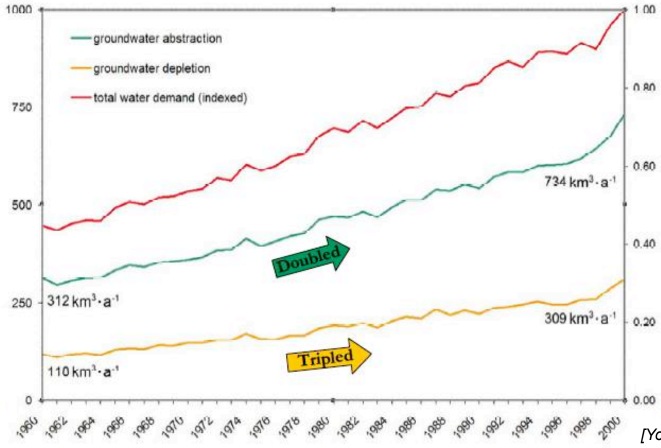
- Downscaled to spatial resolution of 0.5° using water demand as a proxy considering sub-grid variability on countries' borders (up to four countries in a grid cell)



[Yoshihide Wada, 2010]

Historical Trends

- Past groundwater abstraction is relative to past total water demand.
- Past groundwater depletion = past groundwater abstraction – average groundwater recharge from 1958 to 2001



[Yoshihide Wada, 2010]

Large-scale abstraction of groundwater leads to a sea level rise of 0.8 mm per year.

This is about one fourth of the current rate of sea level rise of 3.1 mm per year.

Wada, Y., L. P.H. van Beek, C. M. van Kempen, J. W.T.M. Reckman, S. Vasak, and M.F.P. Bierkens (2010), Global depletion of groundwater resources, Geophysical Research Letters doi:10.1029/2010GL044571, in press.

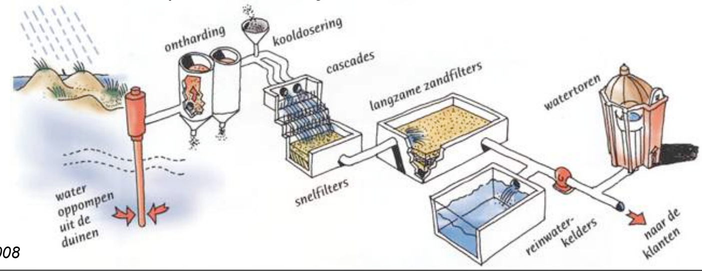
Freshwater Management in the Netherlands and abroad

Water and Water Supply Policy

- The total **drinking water** produced in the Netherlands origins to approx. 60% **from groundwater** and 40% of **surface water.**
- High population densities and intensive farming practices cause a continuing increase of **pollution** and potentially hazardous substances in fresh water resources.
- 15 – 20% of the delivery costs for drinking water are often spent for the **tracing and treatment of pesticides**.
- **Collected river water** is purified by sedimentation, aeration and the adding of iron-sulphur (elimination of phosphate), before it is either infiltrated in dunes for artificial groundwater recharge or stored in lakes.

Drinking Water from river water

- **Nature-orientated purification** by the “river-dune” or “river-lake” method (100 days holding time)
- **Further treatment** in form of:
- **softening** in a reactor,
- **treatment with activated carbon** (for the elimination of pesticides and a better taste) and finally
- **sand filtration**



Duinwaterbedrijf Zuid Holland, 2008

Responsibilities

The Waterworks, represented in the Association of Dutch Water Companies (VEWIN), are responsible for

- the **supply** and quality of drinking water
- the **management** and
- the **quality** of all pipes up to the home water meter

- The **European legislation is leading** for the **National Government** (creates the legal conditions for the waterworks in form of the ‘**Water Supply Act**’ and the corresponding ‘**Decree on the Water Supply**’).
- The **Provincial Government** is responsible for the **regulation**.

Responsibilities

The Water Boards (District Water Control Boards) together with the **department of Public Works and Water Management** are responsible for

– the **quality and quantity of regional water.**

The Water Boards

– **control** the quality of surface waters
– **monitor** the physical water levels,
– **discharge** water if necessary
– physically maintain waterways and canals.

The water boards are organized in the Association of Dutch Water Boards.

National Water Supply Priority Series

- The **National Water Supply Priority Series** determines the distribution of fresh water in state-managed waters around the country in periods of water shortage.
- It applies to all areas to which **the state-managed water** can be supplied.
- The remaining areas are governed by **regional priority series**, which are generally based on the national series.
- The series gives different **priorities to four categories**.

National Water Supply Priority Series

CATEGORY 1	CATEGORY 2	CATEGORY 3	CATEGORY 4
Flood protection and prevention of irreversible damage	**Public utilities**	**Small-scale, high-value use**	**Other interests (economic considerations, also relating to wildlife)**
1. stability of flood defence structures 2. compaction and settling (peat and moorland) 3. wildlife (linked to soil conditions)	1. 1.drinking water supply system 2. 1.power supply system	– temporary spray irrigation of capital-intensive crops – process water	– navigation – agriculture – wildlife (provided damage is not irreversible) – industry – water-related recreation – freshwater fisheries

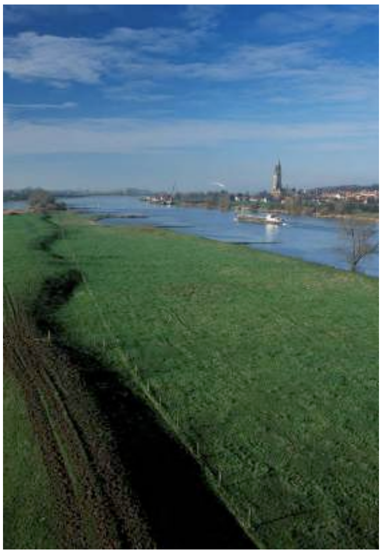
COMES BEFORE → COMES BEFORE → COMES BEFORE →

EU Water Framework Directive

- The EU WFD provides a framework for the **integrated management of groundwater and surface water** for the first time at European level.
- For all **surface waters** general requirement for ecological protection, and a general minimum chemical standard were introduced, which are defining the two elements "**good ecological status**" and "**good chemical status**".
- **A good ecological status** is defined in terms of the quality of the biological community, the hydrological characteristics and the chemical characteristics.

Competition of ecology and other uses

- Set of uses, like **essential drinking water supply** and **flood protection**, can adversely affect the status of water.
- Derogations from the EWFD requirement are provided to achieve good status for these cases, as long as all **appropriate mitigation measures** are taken.



Rijkswaterstaat, 2007

Competition of ecology and other uses

- **Navigation and power generation** is also adversely affecting the status of water, but these activities are open to alternative approaches. Derogations for those cases are subject to the exclusion of alternatives because they
- are **technically impossible**,
- are **prohibitively expensive**,
- produce a **worse overall environmental result**.



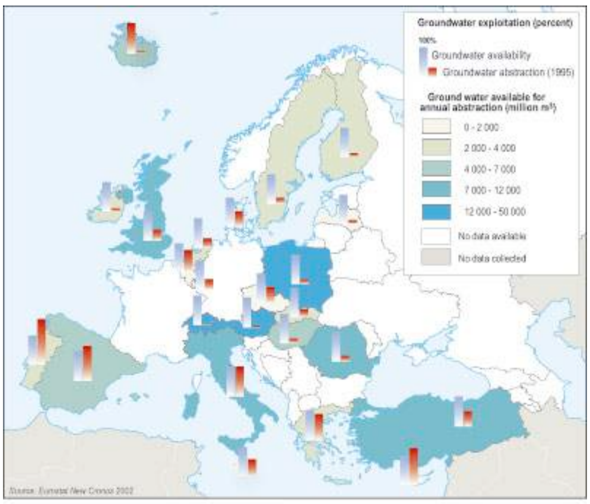

Rijkswaterstaat, 2007

Groundwater

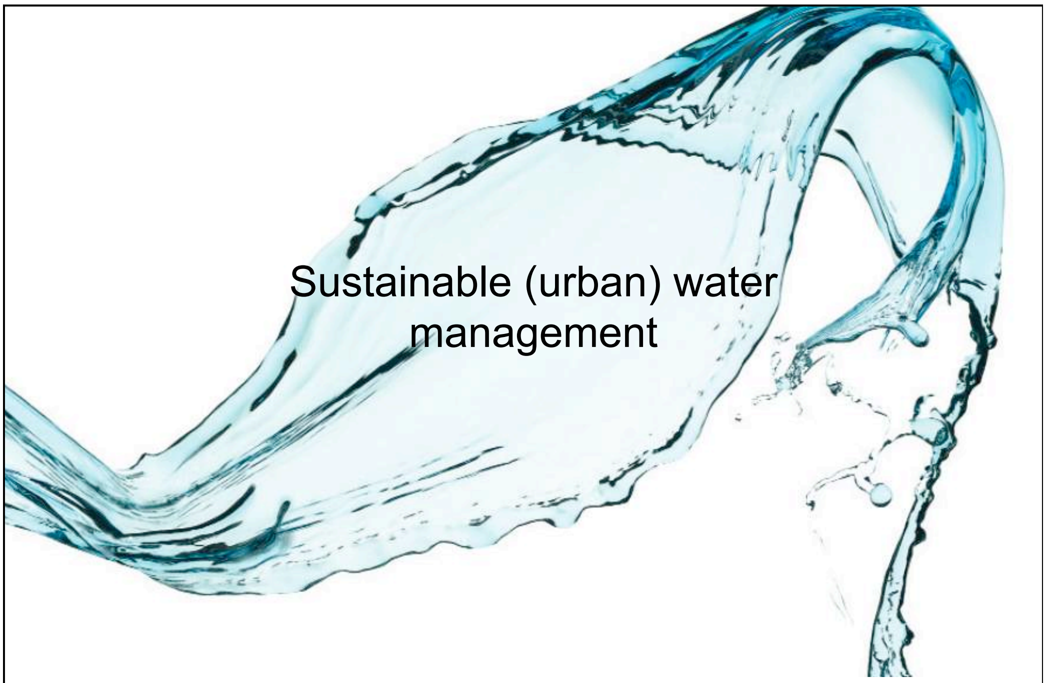
- For **groundwater** the EU WFD is defining the **chemical and quantitative status.**
- Groundwater should not be polluted at all.
- For the general protection of groundwater from all contamination, **direct discharges to groundwater are prohibited.**
- **Indirect discharges have to be monitored** to facilitate the detection of changes in chemical composition, and to reverse any anthropogenic induced pollution.

Groundwater

- Abstracted may only be the amount of total yearly groundwater recharge, which is exceeding the demand of connected ecosystems, like surface water bodies or terrestrial systems (e.g. forests or wetlands)



UNEP, 2004

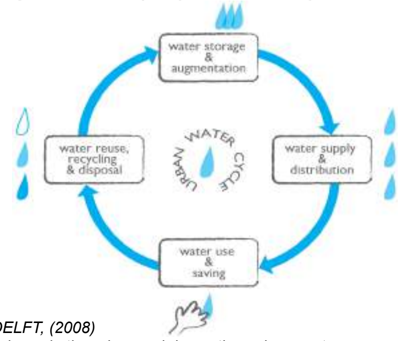


Sustainable (urban) water management

Sustainable Water Management

- Sustainable (urban) water management is including the different sections of the urban water cycleand water issues which are relevant in the framework of the concept of ***Integrated Water Resource Management*** (e.g. flooding, drainage, irrigation an sanitation):

- water supply & distribution
- water use & saving
- Water reuse and recycling
- water storage and augmentation

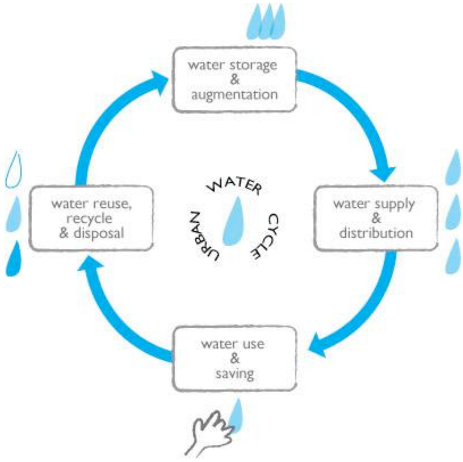


Schuetze et al. UNEP IETC DTIE & TU DELFT, (2008)
Every Drop Counts, Environmental Sound Technologies for water use efficiency in the urban and domestic environment.

Sustainable Water Management

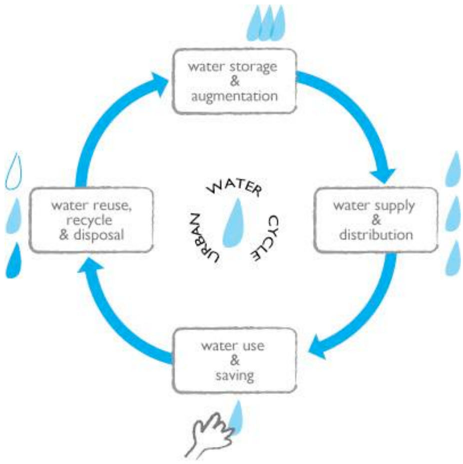
Focus:

- Efficient use of ESTs
- ***Efficient*** is: optimizing the balance between demand and safe and sufficient supply
- ***Efficient* and *fit***: selection and combination technologies that fit in with sustainable perspectives for the local situation



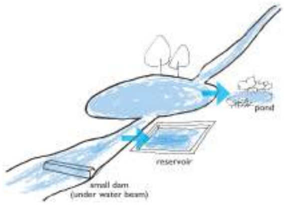
Environmentally Sound Technologies in the Urban Water Cycle

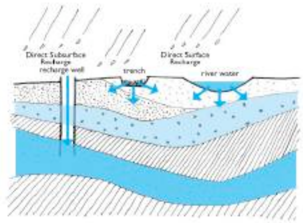
- Technological Description
- Construction, operation and maintenance
- Relative Costs
- When appropriate technological approach
- Advantages, disadvantages and constrains
- Cultural acceptability
- Extent of use
- References, Links and Literature



Storage and Augmentation ESTs

- Ponds and Reservoirs
- Artificial recharge of Groundwater
- Water Tanks
- Rainwater runoff in surface water
- Rainwater runoff in groundwater
- Rainwater runoff in tanks
- Effluent in surface water
- Effluent in ground water

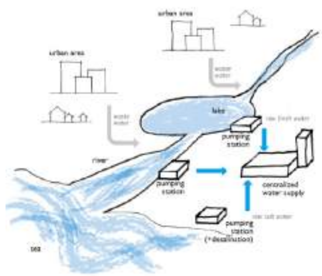


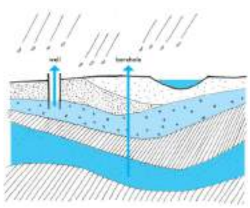


39 Assist. Prof. Dr.-Ing. Thorsten Schuetze TUDelft

Supply and distribution ESTs

- Surface water abstraction
- Groundwater abstraction
- Water supply reservoirs (tanks)
- Transfer of water
- Single pipeline systems (one quality)
- Dual pipeline systems (two qualities)
- Water containers (bottles, tanks)
- Centralised treatment systems
- Point of use treatment systems

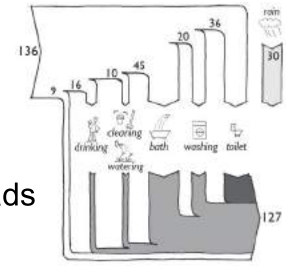


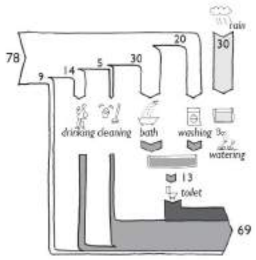


40 Assist. Prof. Dr.-Ing. Thorsten Schuetze TUDelft

Use and Saving ESTs

- Waterless toilets (compost- and dry-)
- Water saving toilets
- Water saving urinals
- Waterless urinals
- Water saving taps
- Water saving showerheads
- Pressure reducers
- Water saving household appliances
- Economised water use: personal hygiene
- Economised water use: cleaning & watering

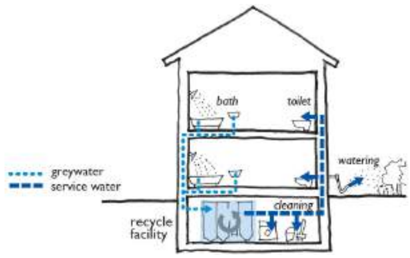


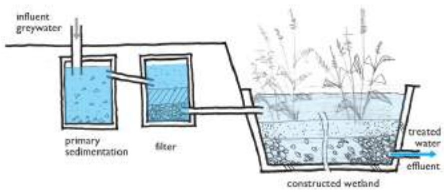


Reuse, recycle & disposal ESTs

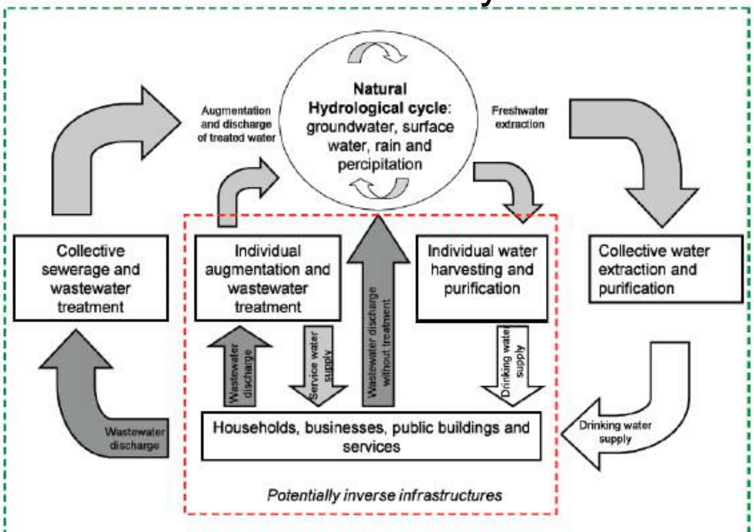
quality and treatment issues

- Domestic rainwater use
- On-site treatment of grey water
- Constructed wetlands
- On-site and near-site treatment of black water and mixed sewage
- Separating rainwater from sewer systems
- Environmentally sound centralized sewage treatment in developing countries

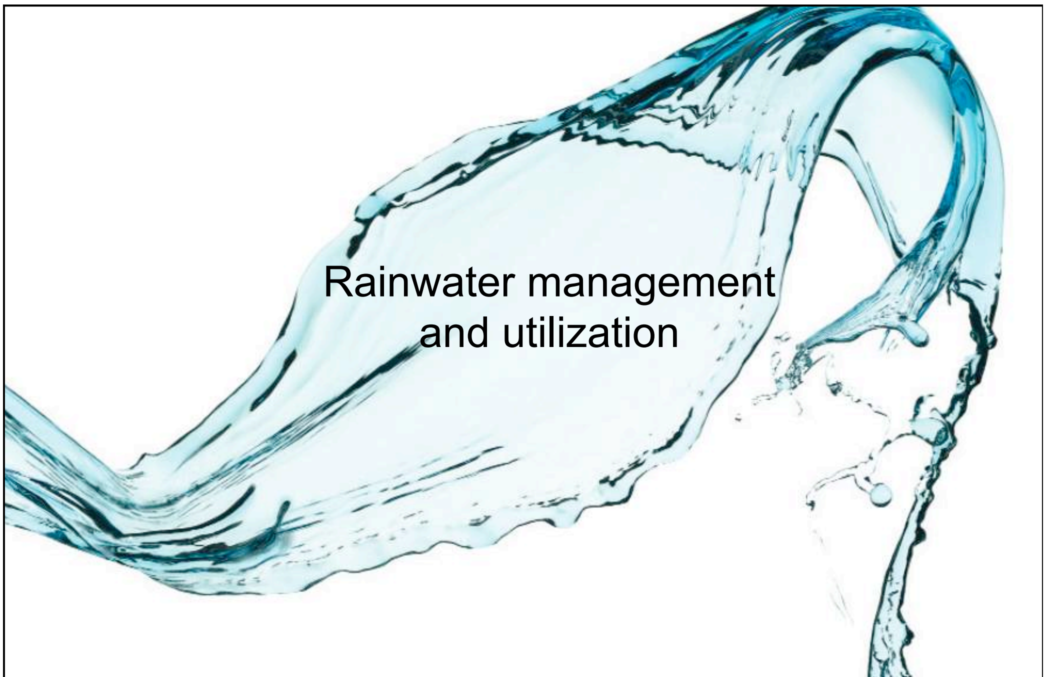




The urban water system



Conventional infrastructuresfor water and sanitation in relation to the natural hydrological cycle



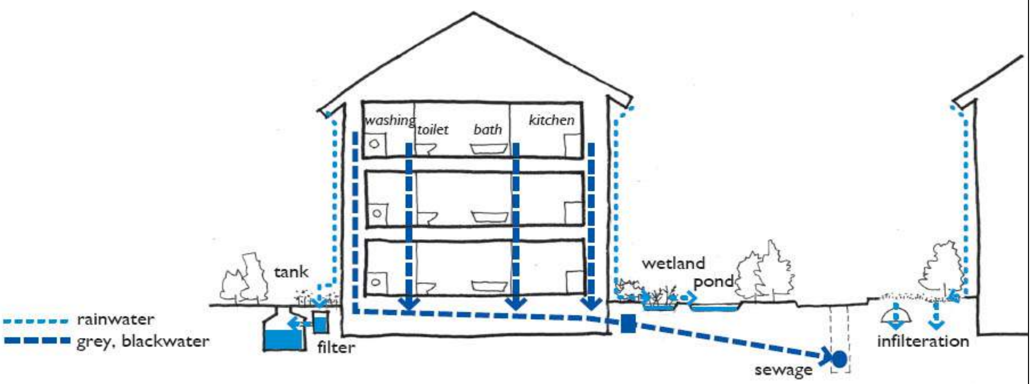
Rainwater management and utilization

Rainwater Management

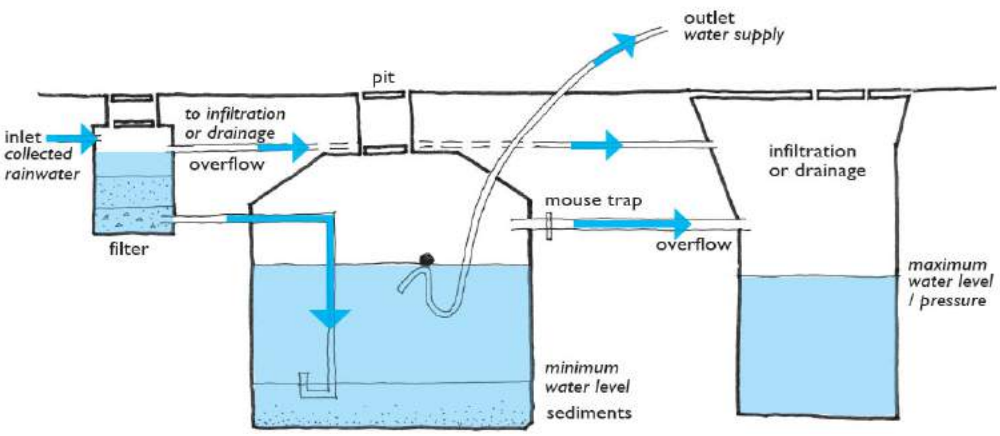
Sustainable Urban Rainwater Management in general consists of different modules which can be summarized to the following main topics which are interacting:

- **rainwater retention and purification (e.g. by soil and sand on green roofs or in tanks and basins, lakes and open water systems),**
- **rainwater infiltration (on surfaces like unsealed traffic areas, in swales, infiltration ditches or infiltration wells)**
- **rainwater evaporation (by open water surfaces and plants, e.g. lakes, green roofs, gardens or lawn areas),**
- **rainwater harvesting (from roofs or open spaces like pavements courtyards and parking lots and roads)**
- **rainwater utilisation (for cleaning, toilet flushing, garden watering)**

Decentralized Rainwater Utilization



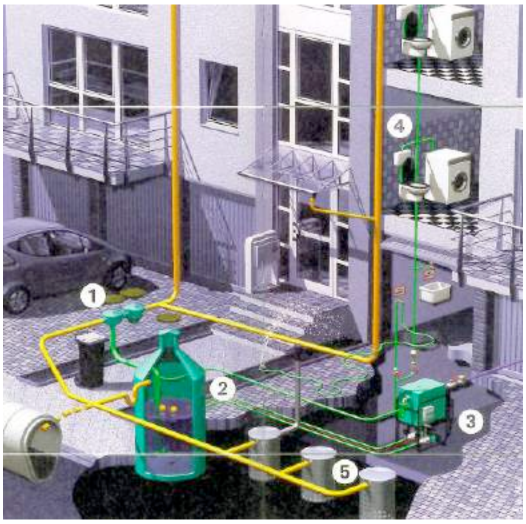
Decentralized Rainwater Utilization



Assist. Prof. Dr.-Ing. Thorsten Schuetze

Decentralized Rainwater Utilization

- Rainwater collection and utilization
- in many countries allowed for service water purpose
- Possible drinking water source in areas with polluted fresh water resources (e.g. Arsenic, Fluor, Tin, etc.)



Assist. Prof. Dr.-Ing. Thorsten Schuetze

Supportive regulations for rainwater utilization

- In Europe Belgium, England, France and Germany, provide norms or guidelines for the utilization of rainwater.
- In **France** “Veolia” supports the formulation of appropriate regulation for decentralized and individually operated and maintained systems.
- In **Germany** since 2003 the planning, installation, maintenance and is regulated via standards (DIN 1989 Rainwater Harvesting Systems, DIN 1986 Rainwater Pipes, DIN 1988 Drinking Water Installation), facilitating an easy planning and installation process for the end-users and service providers.
  - ***Despite the relative large savings on the water fee, generally the installation and operation of such inverse infrastructures is not economically profitable for private households.***

Supportive regulations for rainwater utilization

- Nevertheless, about 75,000 new Rainwater Harvesting Facilities are installed in Germany per year.
- So far, a total of 1.6 million functioning facilities exist in 3.8% of the 39.5 million households in Germany.
- Their installation is subsidized by some federal states. In Nordrhein-Westfalen up to 1,500 Euro subsidies are paid per facility and Bremen covers one third of the installation costs, up to 2,000 Euro.
- In London/ England, the decentralized retention and infiltration of rainwater is required in all new urban developments to cope with declining groundwater tables (source of drinking water supply).

Supportive regulations for rainwater utilization

- **In Belgium, all new buildings** (with roofs bigger than 75m²) **have to be equipped with rainwater harvesting and utilization facilities!** (building code by the Ministry of Environment - Vlarem II (art. 6.2.2.1.2.).
- The rainwater systems has to be:
  - 1. collected and utilized
  - 2. infiltrated on the own property
  - 3. retention and discharge in natural or artificial surface water bodies
  - 4. discharge in the rainwater sewer in the street

  (1. is not obligate for existing buildings, however 2., 3. and 4. have to be applied as much as possible)

Supportive regulations for rainwater utilization

4.3 Gebruik van hemelwater

4.3.1 Hoeveel water verbruiken wij?

Het gemiddelde dagelijkse waterverbruik per persoon in België en de verdeling over de verschillende verbruiksposten, staat in de tabel hieronder.

Bestemming	Liter/dag/persoon	%
Bad/douche	44	40
WC	30	27
Was	17	15
Afwas	8	7
Drinken en koken	3	3
Tuin	4	4
Schoonmaak	4	4
Totaal	110	100

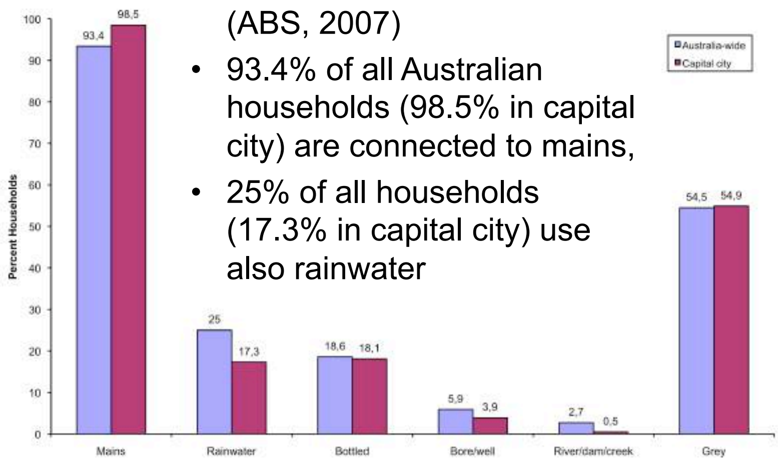
Elke persoon gebruikt gemiddeld 110 liter per dag. Zowel op het gebruik als op de verdeling over de verschillende toepassingen zit een grote spreiding. Het verbruik van een gezin is niet enkel afhankelijk van het aantal personen, maar ook van de gewoontes. Iedereen kan eenvoudig de evolutie van zijn verbruik

Horizontale dakoppervlakte	Minimale tankinhoud
50 tot 60 m²	3000 l
61 tot 80 m²	4000 l
81 tot 100 m²	5000 l
101 tot 120 m²	6000 l
121 tot 140 m²	7000 l
141 tot 160 m²	8000 l
161 tot 180 m²	9000 l
181 tot 200 m²	10 000 l
> 200 m²	5000 l per 100 m²

Rainwater utilization in Australia

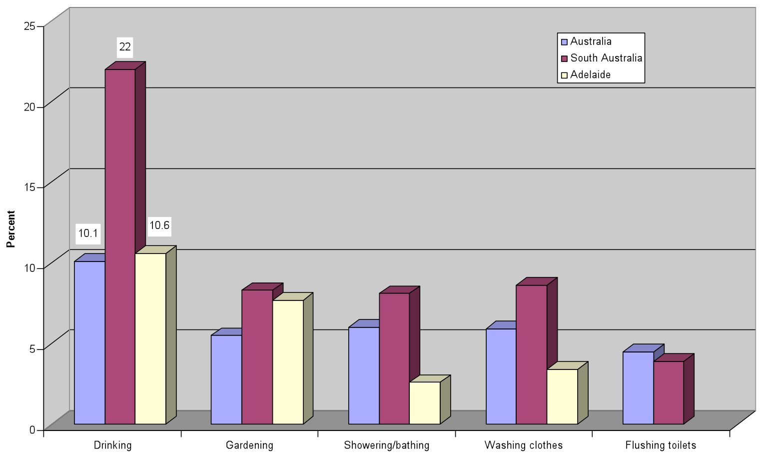
Rainwater utilization in Australia

- Water sources in Australia (ABS, 2007)
- 93.4% of all Australian households (98.5% in capital city) are connected to mains,
- 25% of all households (17.3% in capital city) use also rainwater



Rainwater utilization in Australia

- Rainwater use in Australia (ABS, 2007)



Rainwater utilization in Australia

- Area – metropolitan Adelaide and Mount Barker
- On average, the collected rainwater from 10.1% of all installations (2.5% of all households) is used for drinking.
- In South Australian households this percentage is even 22%(Rodrigo, 2009).

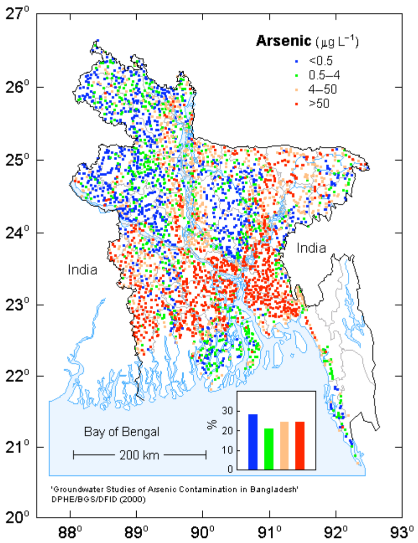
Rainwater utilization in Australia

- Over 3 Million people drink rainwater without any sophisticated treatment
- water supply company delivered poorly treated water from the Murray River to households
- many people in Adelaide and Mount Barker decided to install individual rainwater collection tanks fro drinking water supply.
- People stick to their systems, even after extension of centralized systems
- Soci-economical and quality reasons

Rainwater utilization in Bangladesh

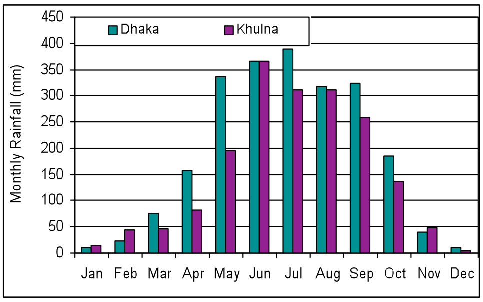
Arsenic Contamination of GW

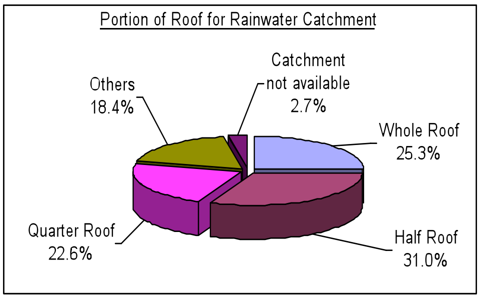
- District: 59 out of 64
- Southern and Northeastern districts are worse affected
- 25% of shallow tube wells
- Estimated 30 million are exposed to Arsenic above BDWS
- BD Standard for As : 50 μg/L
- WHO Standard: 10 μg/L



- Providing Safe Arsenic Free Potable Water is the most difficult challenge for the water supply sector
- Rainwater Harvesting is considering the most suitable option
- Pond sand filter, Rain-feed pond water, Rainwater harvesting are the commonly used water supply options in the Coastal areas in Bangladesh

- Analysis of 21-years rainfall from 1982 to 2002 - average yearly rainfall is 2634mm
- Excess rainwater in monsoon has to be stored for use in dry season
- A roof catchment area of about 17 m^2 is sufficiently enough to collect the required water needed for a family of 6-7 members for domestic water requirements during the dry period.





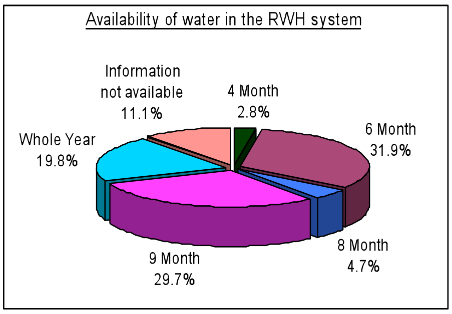
- Household storage reservoirs (51.3%) varies from 2000 to 3200 l
- Community Based: Capacity > 10,000 l

Promoting and Constructing RWH Systems

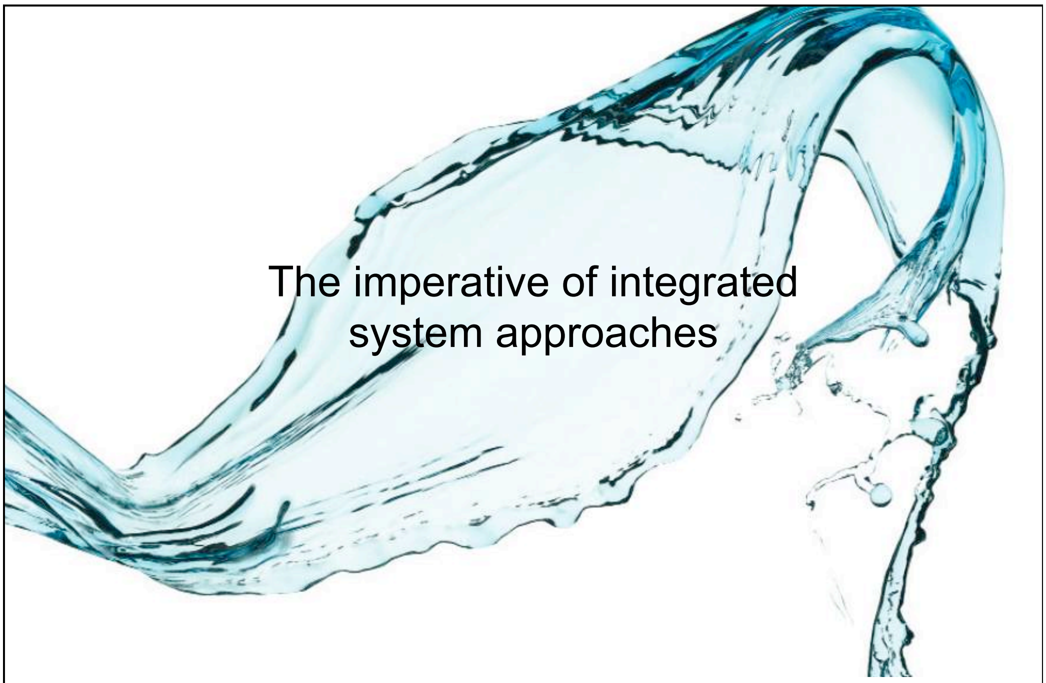
- NGOs (58.4%)
- Department of Public Health Engineering (28.5%)
- Local Government Engineering Department (7.4%)
- Personally (5.7%).

61 Assist. Prof. Dr.-Ing. Thorsten Schuetze TUDelft

- Tank size (mass balance is required)
- Leakages in collection systems
- During the dry period, the users depend on other unsafe sources (unsafe pond water, sometimes far away from the household premises)
- The women need a long walk and time for water collection.
- WHO guideline (2008) can be followed for the safe and sustainable rainwater harvesting in Bangladesh



62 Assist. Prof. Dr.-Ing. Thorsten Schuetze TUDelft



The imperative of integrated system approaches

The imperative of integrated system approaches

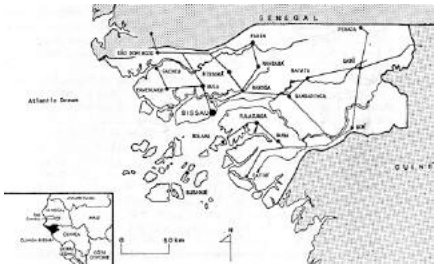
- At the local decision level there is a need for practical criteria that can guide “the actors” in the planning process.

- What is efficient ?
  - ➢ high results (sufficient sanitation and water for households, farming, industry, health)
  - ➢ low efforts (money, time, resources, human energy)

- But this is not all...
- Let’s look at a case where quite a lot of things went really wrong, due to lack of an integrated system approach …

The imperative of integrated system approaches

- Example of a case in Bissau



[Hoong PUB, 2008]

The imperative of integrated system approaches

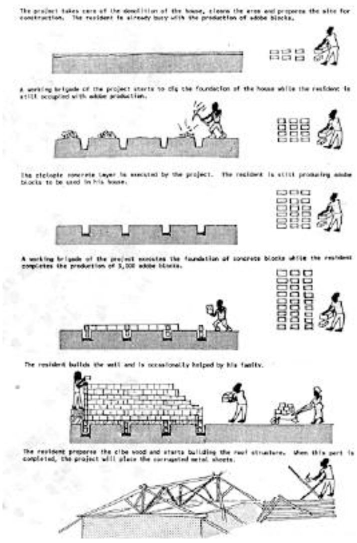
- Current situation Problems of erosion and pollution (storm water & waste management)

The imperative of integrated system approaches

- Freshwater from wells
- Poor sanitation
- Open defecation and wastewater discharge

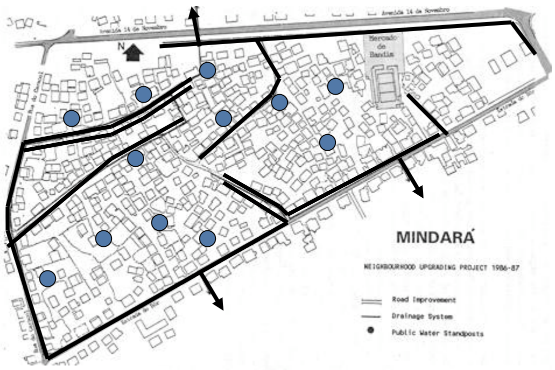
The imperative of integrated system approaches

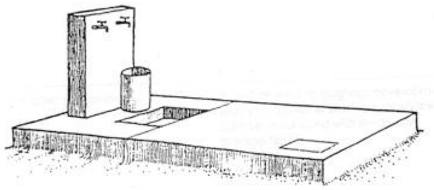
- Self help construction project

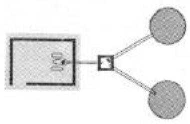


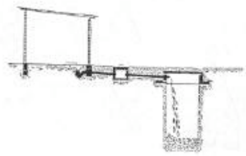
The imperative of integrated system approaches

- New long distance water supply and water taps.
- New pour flush toilets and pit latrines for infiltration of sewage liquids.
- In principle good?
- Manifold problems!



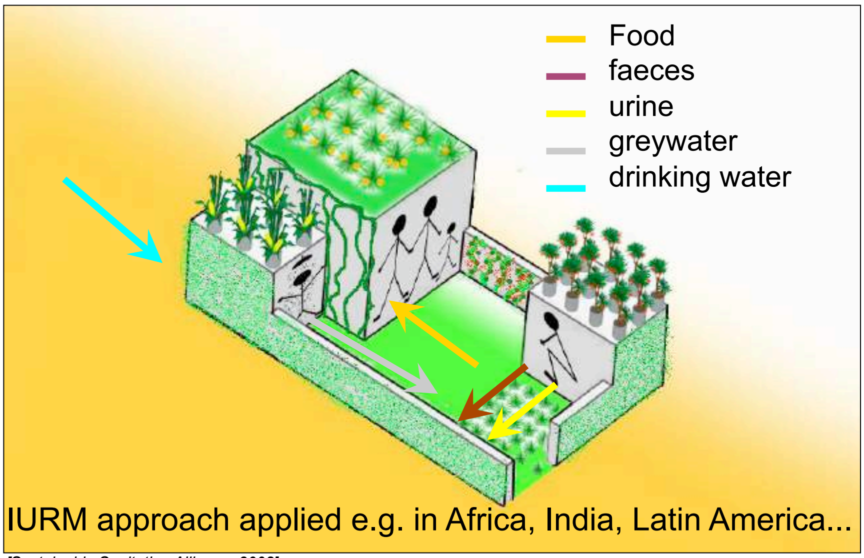






- Electricity blackout = no water supply
- Use of old wells
- Water is contaminated by infiltrated sewage = health thread
- Less groundwater recharge through drainage of rainfall
- Drained rainfall leads to the erosion of fringe and threatens even houses
- Plans have to be based on an integrated system approach = for flows areas and actors have to fit together.

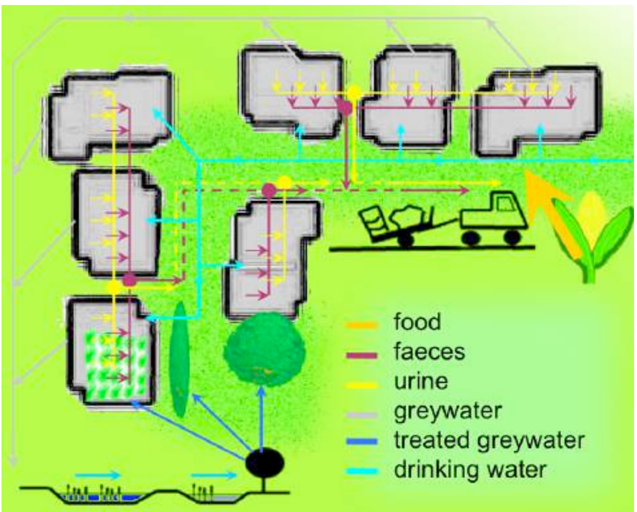
IURM related to water and sanitation



[Sustainable Sanitation Alliance, 2008]

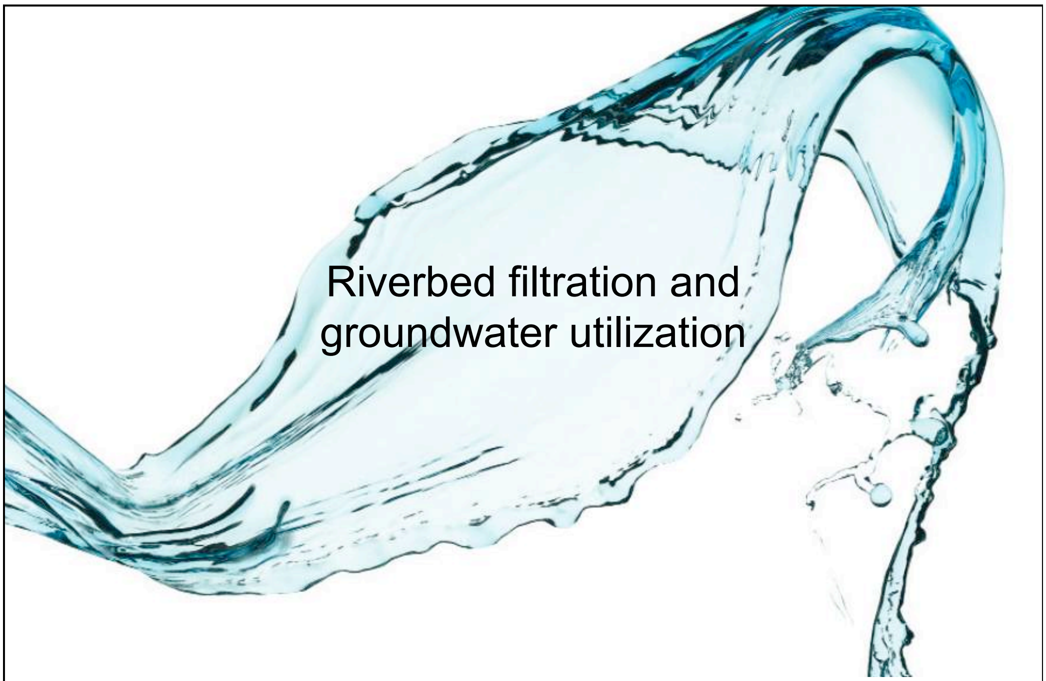
71 Assist. Prof. Dr.-Ing. Thorsten Schuetze TUDelft

IURM related to water and sanitation



IURM approach applied e.g. in Sweden, India, Africa, Latin America

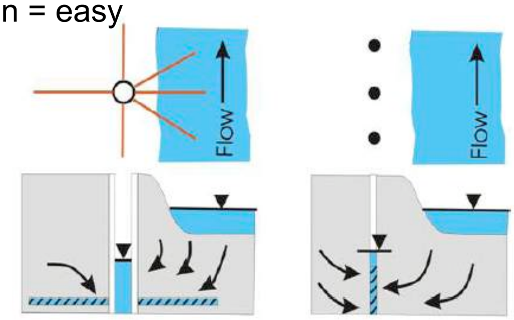
72 Assist. Prof. Dr.-Ing. Thorsten Schuetze TUDelft



Riverbed filtration and groundwater utilization

Riverbed Filtration & Groundwater recharge

- In Berlin, riverbed filtration is used since 1850, based on natural surface water and “recycling of domestic sewage”
- 75% of Drinking Water is produced in this way
- Efficient and cost effective method to purify water
- Additional purification = easy
- Horizontal wells
- Vertical wells



Riverbed Filtration & Groundwater recharge

- In Berlin, aeration and sand filtration are the only additional measures which are applied to produce drinking water
- Degradation of: organic substances (DOC/ AOX), trace elements, microorganisms, algae and toxic substances

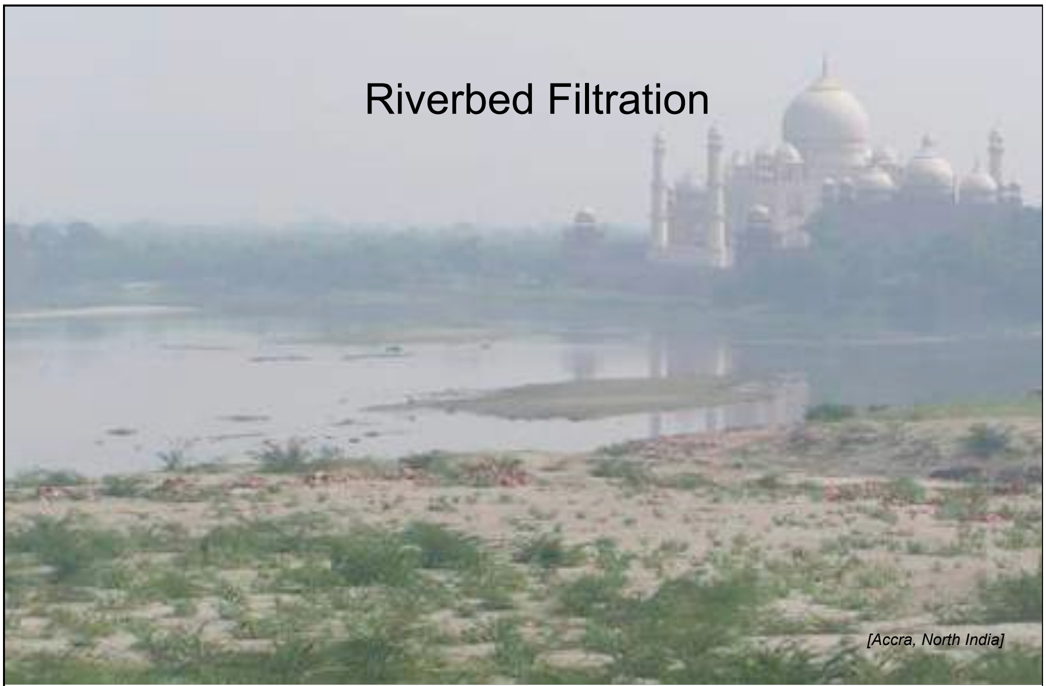
[Berlin, Germany]

Feldstandorte am Tegeler See

Uferfiltration	Grundwasseranreicherung
• Natürliches System	• Künstliches System (15 Mio. m^3/a)
• Anoxisch/Anaerobe Bodenpassage	• Meist oxische Bodenpassage
• Entfernung Ufer – Brunnen 80-100 m	• Entfernung Ufer – Brunnen ~100 m
• Aufenthaltszeit ~4.5 – 5 Monate	• Aufenthaltszeit ~50 Tage

[Jekel 2005, Germany]

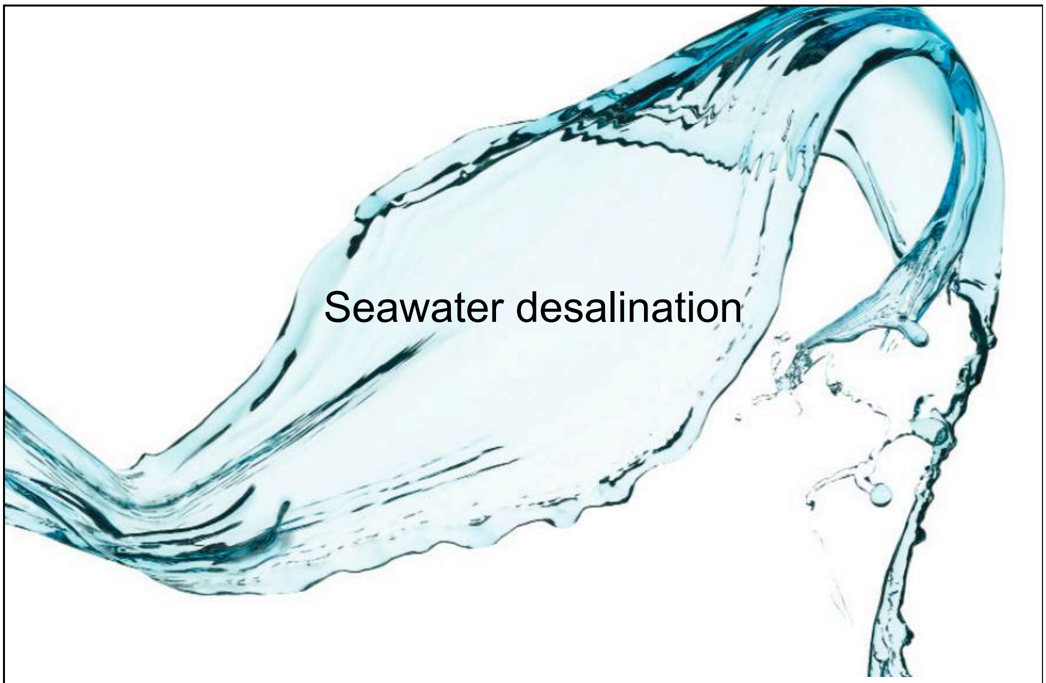
Riverbed Filtration



77 Assist. Prof. Dr.-Ing. Thorsten Schuetze TUDelft

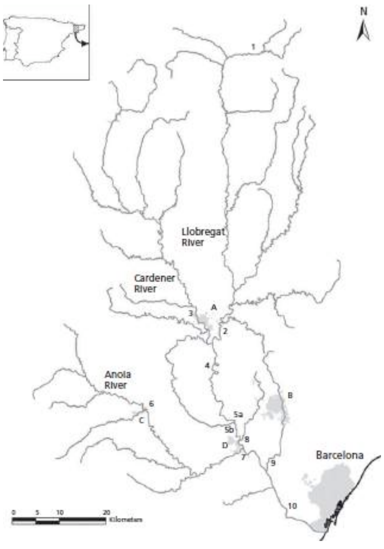
Riverbed Filtration

78 Assist. Prof. Dr.-Ing. Thorsten Schuetze TUDelft

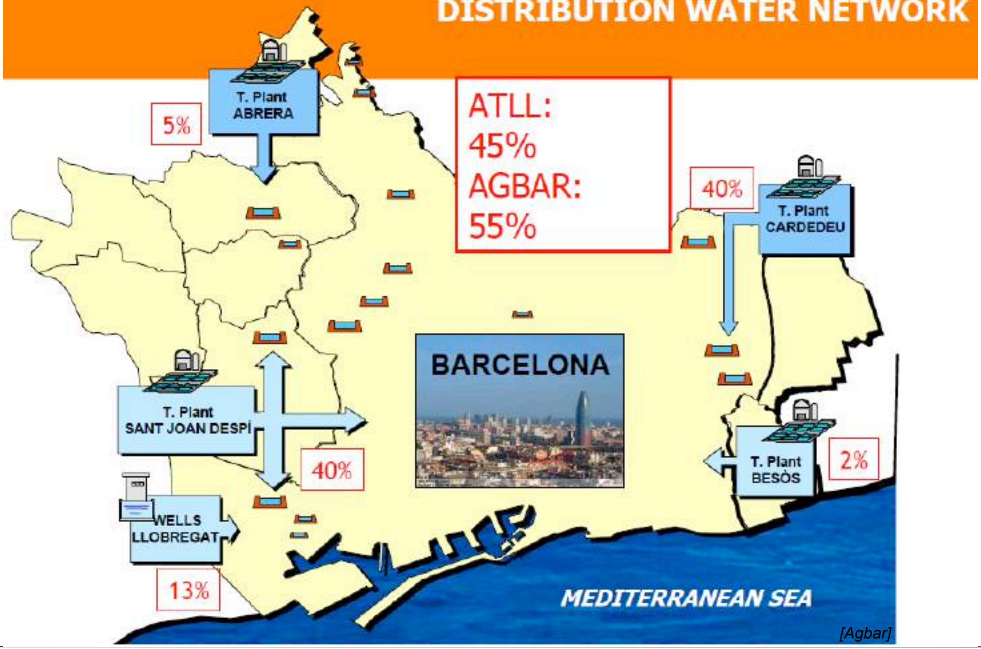


Seawater Desalination – Barcelona, Spain

- Barcelona has immense water demand in an arid region
- Less than 5% of the original wetlands in the area remain
- Big part of agricultural land has been lost in the last decade
- By the end of the 1980s, the Llobregat River was one of the most polluted and degraded in Western Europe.
- Overexploitation of ground water had led to salinization of the aquifer, rendering 30% unusable



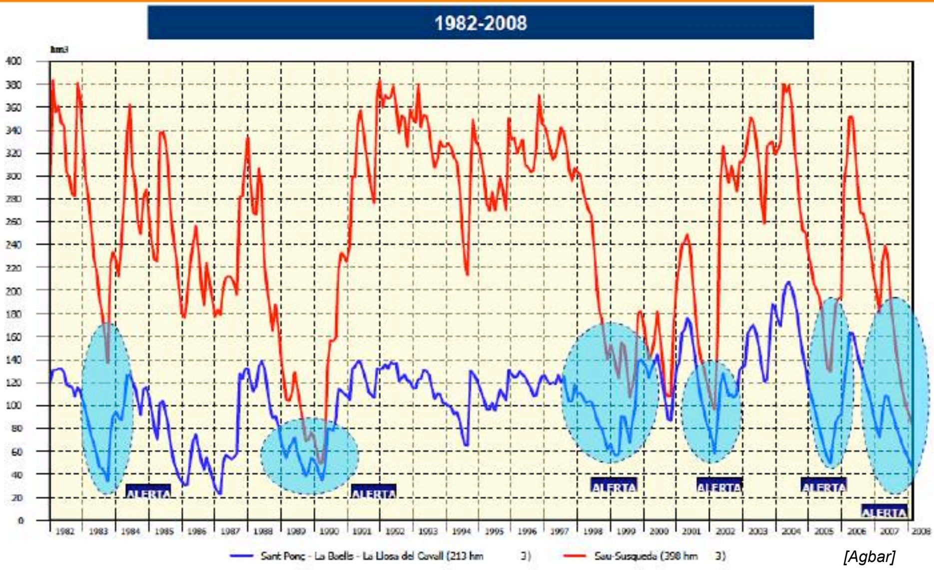
DISTRIBUTION WATER NETWORK



[Agbar]

81 Assist. Prof. Dr.-Ing. Thorsten Schuetze TUDelft

EVOLUTION OF RESERVES IN DAMS



[Agbar]

82 Assist. Prof. Dr.-Ing. Thorsten Schuetze TUDelft

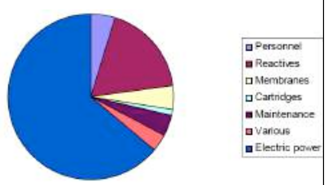
- Water supply for the Barcelona Metropolitan area:
- Ter River supply (50%)
- Llobregat River (40%)
- Groundwater (10%)
- Since 2009 a seawater desalination plant with a capacity of 60 Mm3/year (covering 25% of total demand)

Projected multi-purpose use of reclaimed water in Llobregat Delta for 2015

	WWTP El Prat de Llobregat Mm³/yr	WTTP San Feliu de Llobregat Mm³/yr
Agriculture	11.83	7.32
Rzver stream flow	10.37	-
Wetlands	6.31	-
Seawater barrier	0.91	-
Municipalities	-	0.11
Recreation	-	0.37
Industry	5.48	-
Total	**34.9**	**7.8**

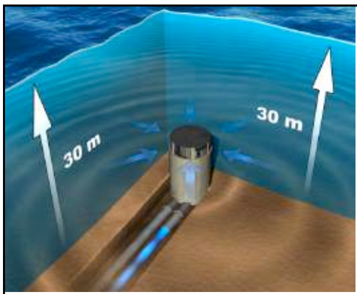
CHARACTERISTICS OF THE DESALINATION PLANT

- **PRODUCED VOLUME**:
  - Yearly production: 60 hm³
  - Nominal daily production: 180.000 m³
  - Maximum daily production: 200.000 m³
- **TECHNOLOGY**: Reverse osmosis (RO)
- **CONVERSION**: 45%
- **INSTALLED ELECTRICAL POWER**: 36.000 kW
- **CONSUMPTION**:
  - Total: 4 kWh/m³
  - RO process: 3 kWh/m³



Electric power cost per cubic meter: 0,21 €

[Agbar]


30 m
30 m


CAPTACIÓ
ESTACIÓ DE BOMBAMENT
2.2 Km
LLOBREGAT

[Agbar]


BARCELONA
DESSALINITZADORA DEL LLOBREGAT
EL PRAT DE LLOBREGAT
DIPOSITS FONTSANTA
SANT JOAN DESPI

[Agbar]

[Agbar]

[Agbar]

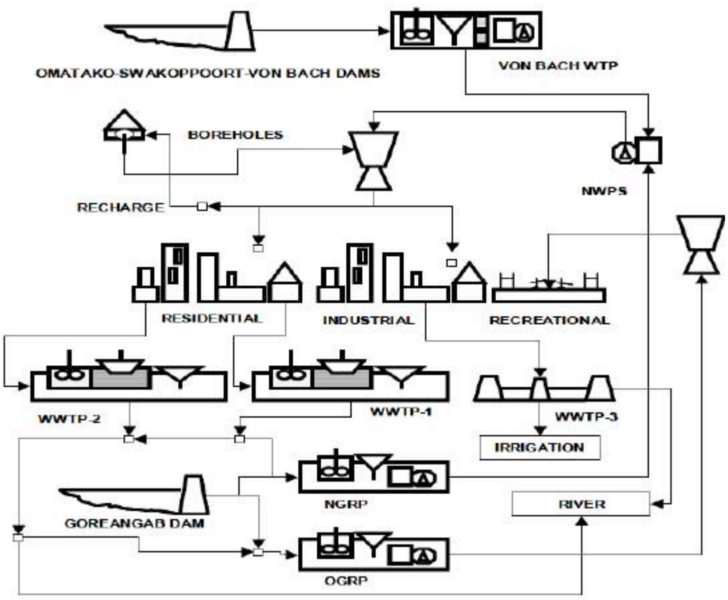
[Agbar]

Wastewater Recycling

Sewage to Drinking Water – Windhoek Namibia

- Windhoek is the only city in the world directly reclaiming treated wastewater effluent for drinking water for the past 35 years
- situated in the center of one of the most arid countries in Africa, with perennial rivers either 500 km to the North or South,
- mainly depends on water supply from boreholes and three surface dams in ephemeral rivers some 60 to 200 km away.
- supply of water from further away through the North Eastern Water Carrier is not economically feasible (Central Areas JV Consultants, 2004).

- The water cycle of Windhoek
- Drinking water mix from sewage & dam water
- Standard 25% - max 35% reclaimed water

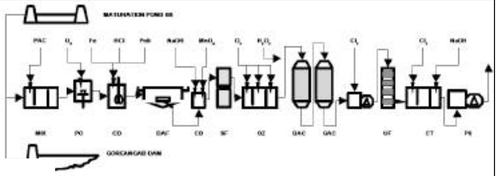


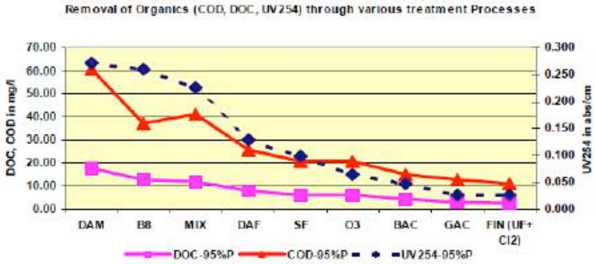
Principles for reuse and reclamation in order of priorities:

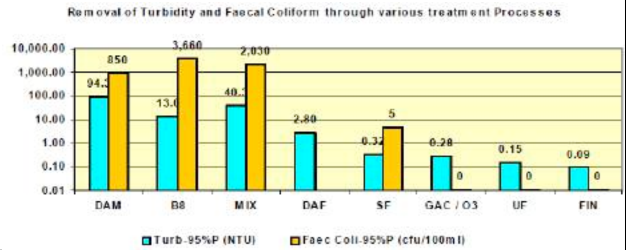
1. Industrial: cooling & process water, construction activities
2. Agriculture: crop and commercial nurseries
3. Landscape: public parks, golf course, school yards, cemeteries, greenbelts, residential
4. Recreation/environment: lakes, ponds, marsh enhancement, stream flow augmentation, fisheries
5. On site re-use of Grey water: lawns, trees, ornamentals and food crops
6. Non-potable urban: fire protection, air conditioning, toilet flushing
7. Groundwater recharge
8. Potable reuse: through advanced water treatment based on multi barrier approach provided that reclaimed water is blended with water from other sources.

New Goreangab Reclamation Plant (NGRP) - 21,000 m3/day:

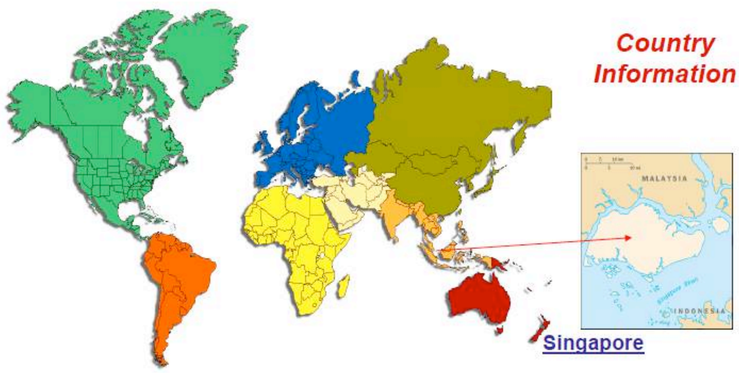
- *Powdered activated carbon*
- *Pre-ozonation*
- *Chemical dosing and coagulation*
- *Dissolved air flotation (DAF)*
- *Chemical dosing: Caustic (NaOH) and permanganate (MnO^4)*
- *Rapid sand filtration*
- *Ozonation and ozone contact*
- *Chemical dosing*
- *Bacteriological activated carbon (BAC) filters*
- *Granular activated carbon filters (GAC)*
- *Ultra filtration (UF)*
- *Chlorination and chlorine contact*
- *Stabilisation (pH)*







Sewage to Drinking Water – NEWater Singapore



Singapore

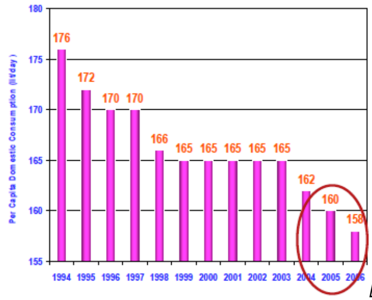
Land Area	700 km^2
Population	4.7 mil
Average Annual Rainfall	2,400 mm
Average Water Demand	1.6 mil m^3/day (approx 600 Olympic size swimming pools)

[Hoong PUB, 2008]

Sewage to Drinking Water – NEWater Singapore

- Singapore's' aim is water independency in the long term
- NEWater = water that has been purified with advanced membrane and ultraviolet technologies.
- NEWater is expected to meet 40% of Singapore's water needs by 2020 (from 15 - 30% in 2010 with totally 5 plants).

Collection of used water (100% sewered)



[Hoong PUB, 2008]

Sewage to Drinking Water – NEWater Singapore

- The third "tap" in the "Four National Taps" strategy to provide Singapore with a sustainable and diversified supply of water.

Water for All | Conserve, Value, Enjoy

- Local catchment
- Imported water (Johor)
- NEWater
- Desalinated water

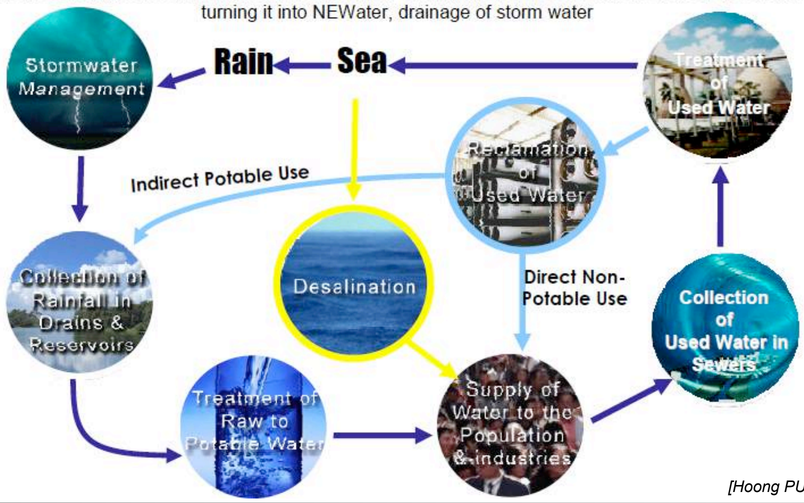
- Conserve Water
- Value Our Waters
- Enjoy Our Waters

[Hoong PUB, 2008]

Sewage to Drinking Water – NEWater Singapore

PUB manages the complete water cycle

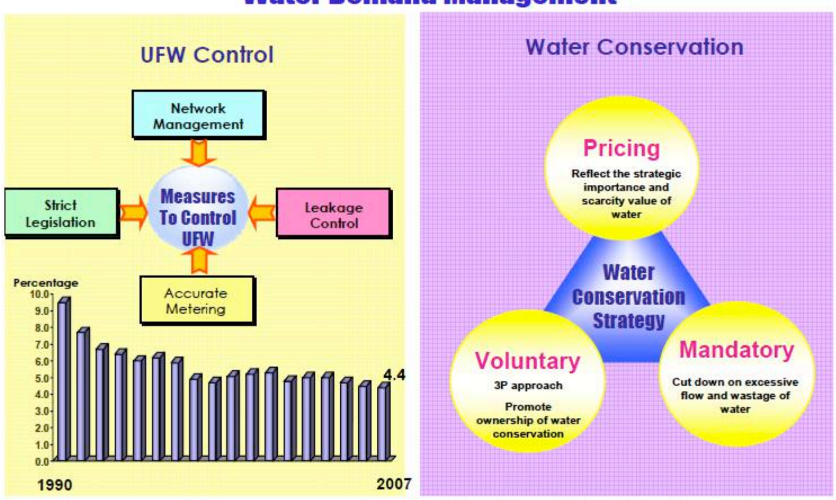
From sourcing, collection, purification and supply of drinking water, to treatment of used water and turning it into NEWater, drainage of storm water



[Hoong PUB, 2008]

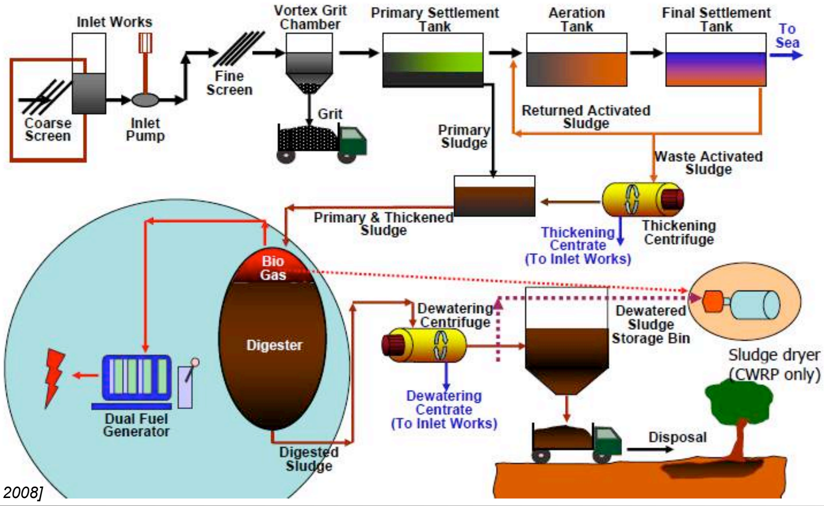
Sewage to Drinking Water – NEWater Singapore

Water Demand Management



[Hoong PUB, 2008]

- **NEWater** = water reclamation process that puts used water through four barriers to become drinking water.



[Hoong PUB, 2008]

Sewage to Drinking Water – NEWater Singapore

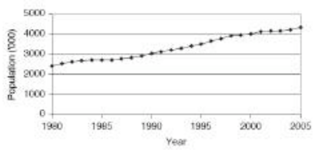
- **First barrier:** conventional water treatment process where used water is treated to globally recognized standards.
- **Second barrier**: Microfiltration to filter out everything but dissolved salts and organic molecules.

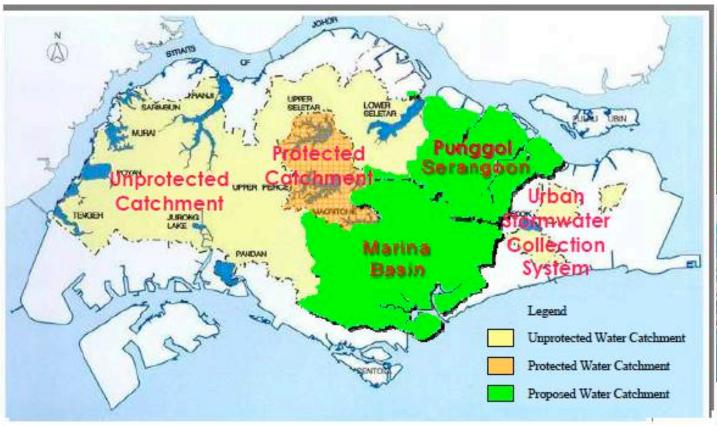
Sewage to Drinking Water – NEWater Singapore

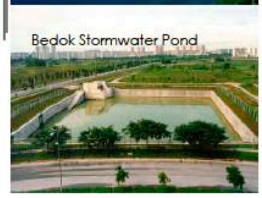
- **Third barrier**: Reverse osmosis traps bacteria, viruses, heavy metals, dissolved salts, aromatic hydrocarbons, pesticides, etc. Only small molecules like H_20 pass through
- **Fourth barrier**: Ultraviolet disinfection as an added safety back-up, residual microorganisms are inactivated.
- **Final stage:** Chemicals restore the water's pH balance

Sewage to Drinking Water – NEWater Singapore

- indirect potable use since Sep 2002:
- Mixing NEWater with raw water in the reservoirs before undergoing conventional treatment at the waterworks for supply to the public for potable use
- The amount will be increased from 1% (2002) progressively to about 2.5% of total daily water consumption (2011).







- **Half of Singapore** is already water catchment
- Catchment area will be increased from half to **two-thirds by 2011**

[Hoong PUB, 2008]

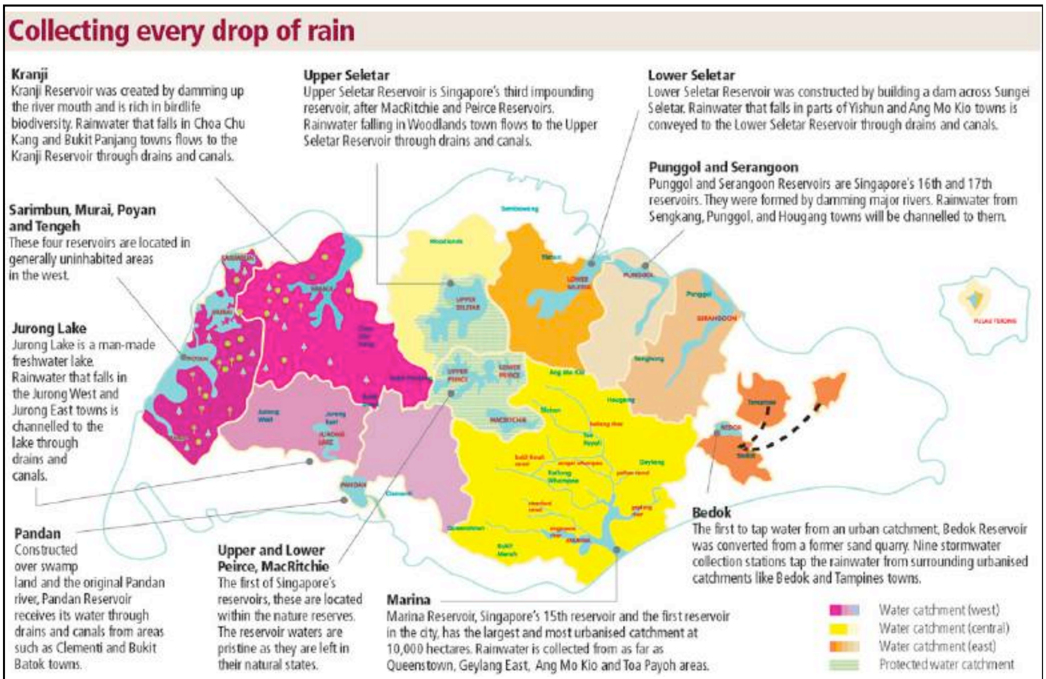
3-in-1 Marina Barrage

Water supply Flood Control Lifestyle attraction

"Creating a reservoir in the city centre of Singapore"

[Hoong PUB, 2008]

[Hoong PUB, 2008]



- Future water demand is set to double by 2060, when industry is expected to account for 70 % of water demand.
- Singapore wants to triple its output of recycled water by 2060, to meet growing demand.
- Water catchments will be expanded to cover 90% of Singapore's land area in the long term

Where our water comes from

	Newater	Desalination	Reservoir and imported water
Now	Up to 30%	Up to 10%	Rest of demand
2060	Up to 50%	Up to 30%	Rest of demand

Water catchment area: From 67% now, it will grow to 90% of land area by 2060.

ST GRAPHICS

ABC
Active, Beautiful, Clean Waters for All

[Hoong PUB, 2008]

ABC Waters Programme

ABC Waters Programme is about:

A. ACTIVE
New recreational spaces

B. BEAUTIFUL
Integration of waters with urban landscape

C. CLEAN
Improved water quality

"… Turn Singapore into a city of gardens and water"

Prime Minister Lee Hsien Loong,
At ABC Waters Public Exhibition Opening
(Feb 07)

[Hoong PUB, 2008]

[Hoong PUB, 2008]

[Hoong PUB, 2008]

Enjoy Water

- **Cultivate a strong sense of bonding and ownership of water through water-based activities**

Through the opening up of our reservoirs, waterways & encouraging recreational use of them

- Kayaking centres at MacRitchie, Bedok, Lower Seletar Reservoirs, Jurong Lake etc
- Upgrading of facilities at MacRitchie and Bedok Reservoirs



[Hoong PUB, 2008]

115 Dr.-Ing. Thorsten Schuetze TU Delft