Be Buffered by Groundwater

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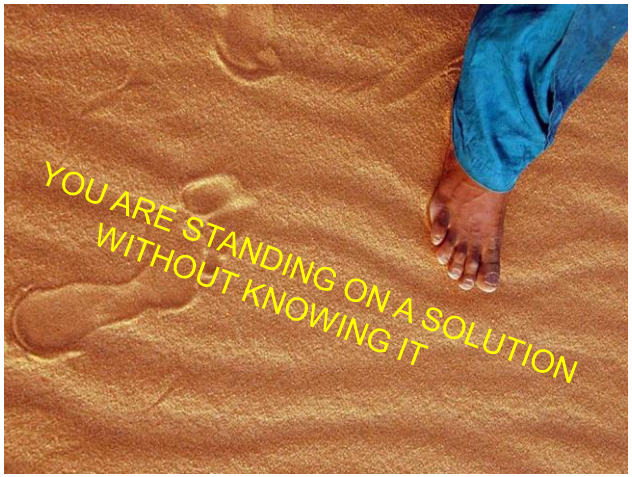
14 June 2012

MHS and IHP Malaysia Technical Talk

United Nations
Educational, Scientific and
Cultural Organization

CONTENT



World scenario

RIVER FLOW
Lower river flows – impacts all water users and decrease water quality

SNOWPACK
Expected 25% reduction by 2050 – affects water supply

HYDROPOWER
Lower reservoir levels - decrease power generation

FLOODS
Higher river flows – increase runoff and flooding

AGRICULTURE
Mixed impacts to crop productivity

DROUGHTS
Higher temperature and lower precipitation – more droughts

HABITAT
Warmer river temperature – stress cold-water species

LEVEES
Sea level rise will threaten levees

WATER QUALITY
Low river discharge – saltwater intrusion

WATER USE
Water demand by all users will increase

GROUNDWATER
Lower water tables and more demand – "dry wells"

Climate change – future rainfall

- More extreme weather conditions in the future (2025-2050) may be expected since higher maximum and lower minimum rainfall are observed.
- Increase in maximum monthly rainfall of up to 51% over Pahang, Kelantan and Terengganu.
- Decrease in minimum monthly rainfall from 32% to 61% for all over Peninsular Malaysia.

Impacts Of Climate Change On Design Rainstorm
By Ir. Mohd Zaki M.Amin
Technical Session in Conjunction with
11th. AGM MHS, 8 May 2012

Climate change – impacts

Climate Change		
Higher rainfall	Lower rainfall[1]	Sea-level rise
• Higher river flows • More severe floods	• Lower river flows • More severe droughts • Deplete reservoir storage • Increase the use of groundwater	• Negative effect on coastal ecosystems • Increase coastal erosion • Negative effect on coastal aquifers

[1]combined with increase evaporation

Affect domestic, industrial and agricultural water supply, water quality, ecosystems, navigation and public health.

Water problems and causes

1. **Too much water**
   - floods
   - natural and anthropogenic
2. **Too little water**
   - droughts
   - natural
3. **Poor quality water**
   - pollution
   - anthropogenic

Land and water management issues – need for IWRM

Development of Public Water Supplies

Urban water supply

- River intakes
- Dams
- Water transfers

Focus on surface water

Rural water supply

- Connection to public mains
- Upgrading of WTPs

Focus on connection to existing facilities

Freshwater Sources and Our Treatment

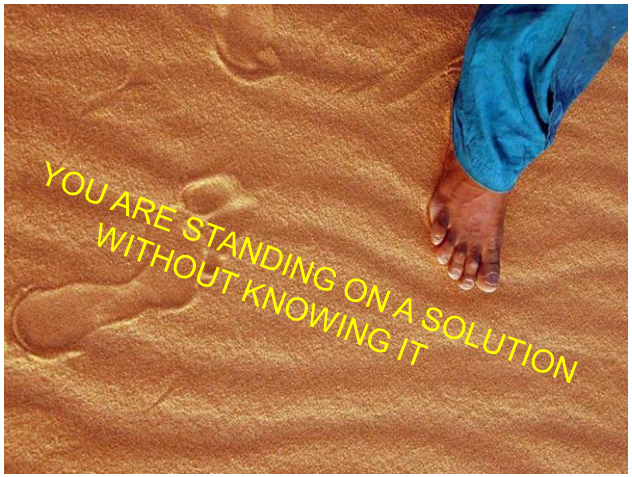
Rain water	River water	Groundwater
• Drain away • Not regarded as a resource	• Damming • Regarded as a resource	• Reluctant to use • Not regarded as a resource

Reasons to the reluctance in using groundwater

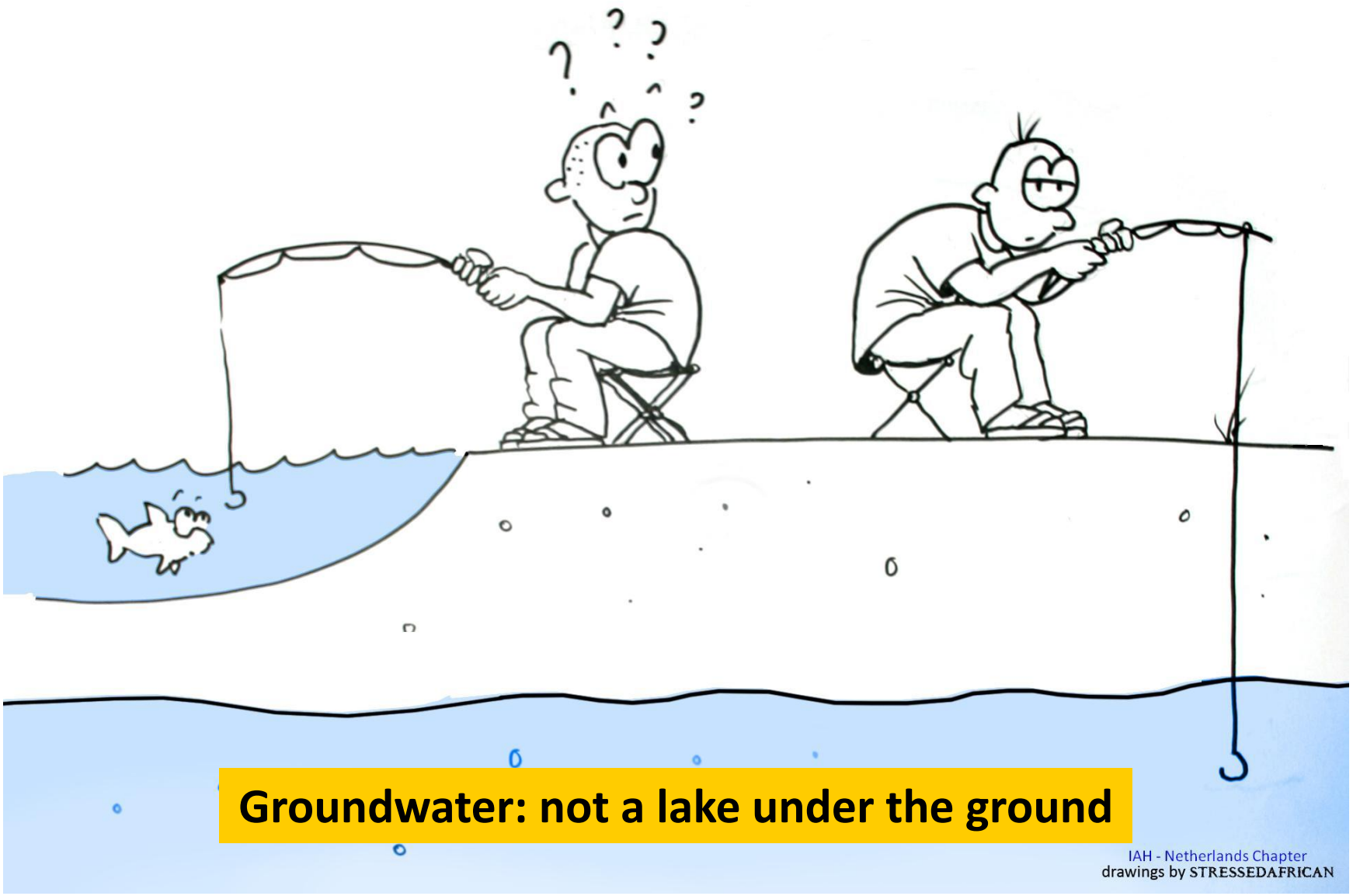
Too little → Negative impacts → Degradation in quality → Rivers will be neglected forever

CONTENT

1. INTRODUCTION
2. GROUNDWATER IS A FRESHWATER RESOURCE
3. GROUNDWATER UTILISATION
4. WHY GROUNDWATER?
5. WATER RESOURCES IN MALAYSIA
6. DON'T BE SAD
7. HUMAN CAPITAL
8. WAY FORWARD
9. FINAL REMARKS

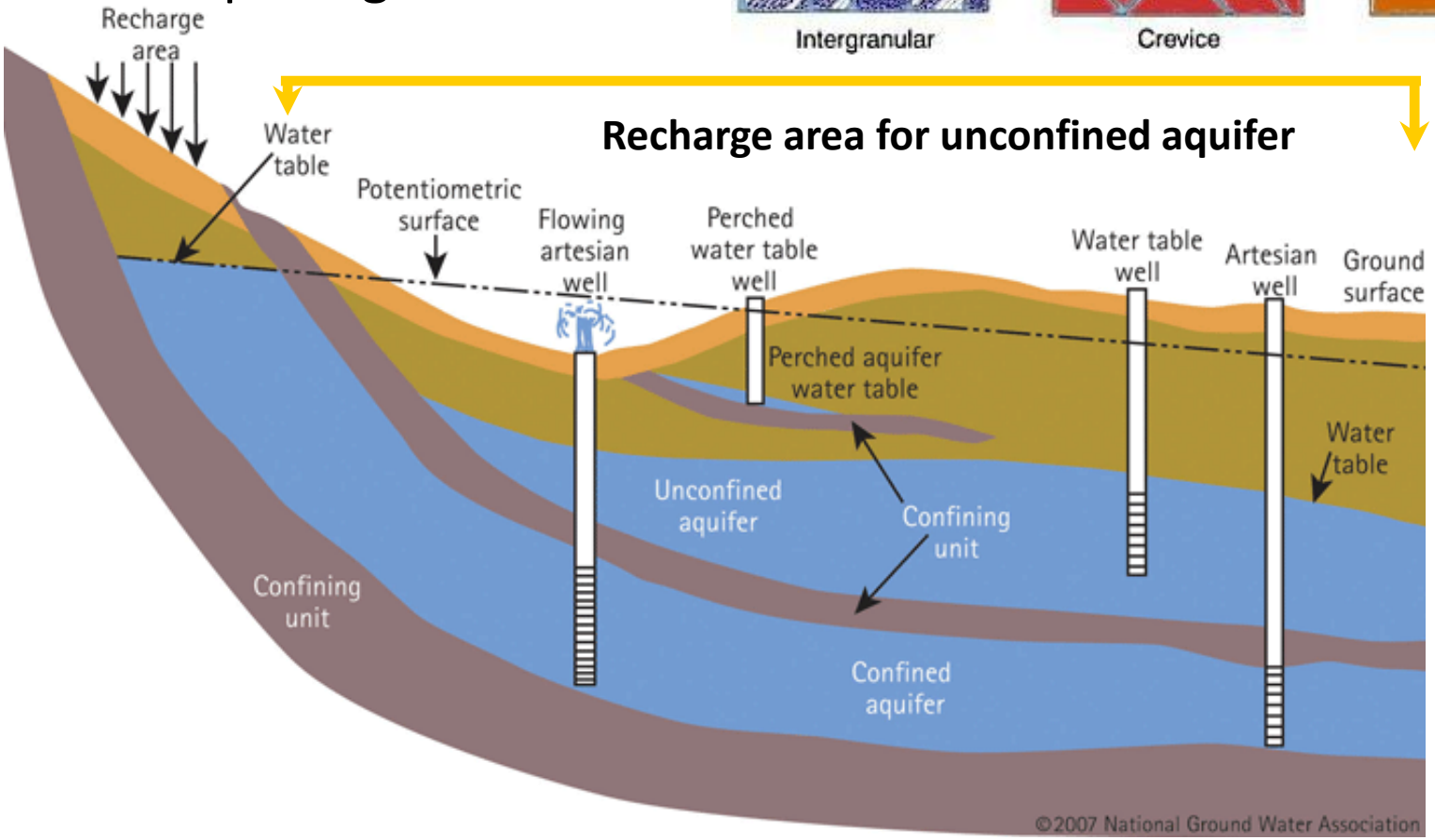


Groundwater resources

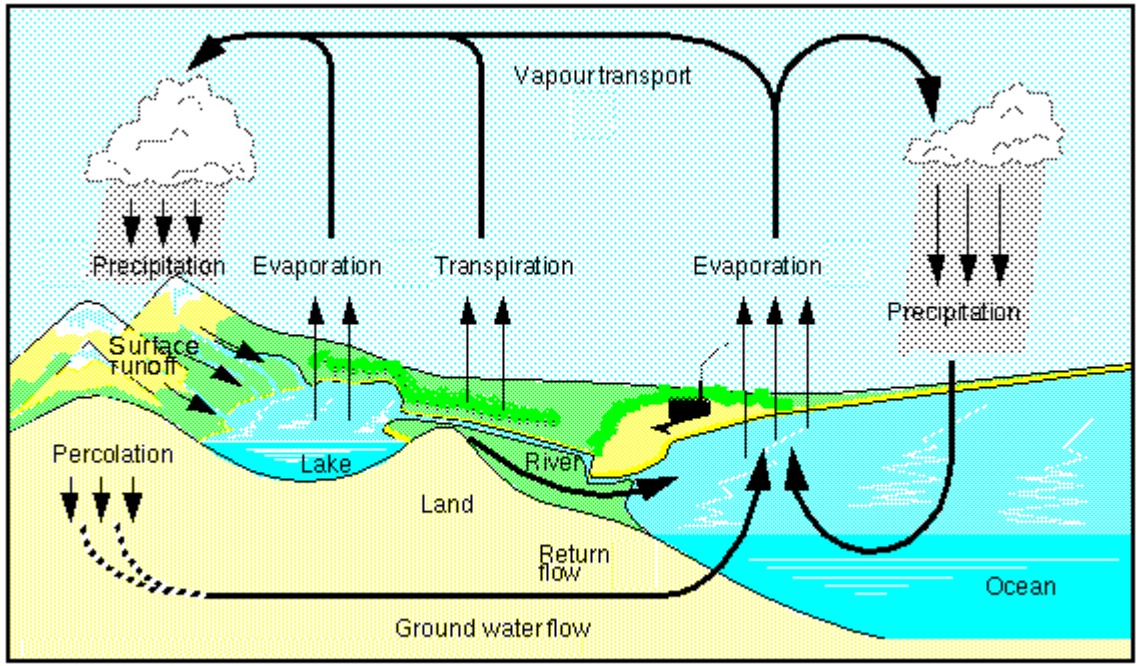


What is groundwater?

- Water that fills spaces between sand grains, in rock crevices and in solution openings



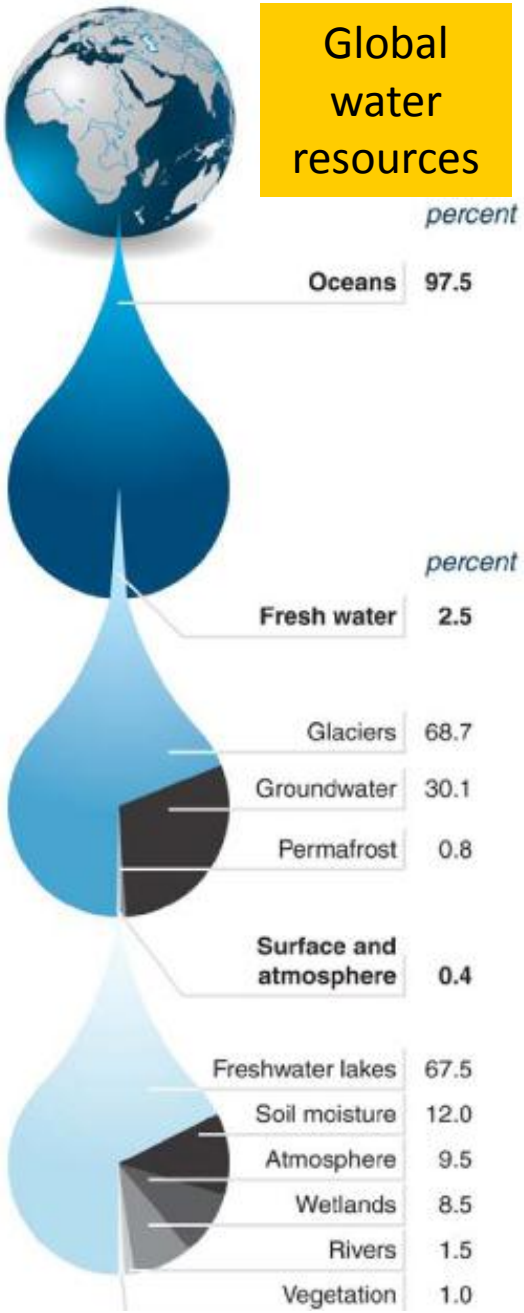
Groundwater is part of water cycle



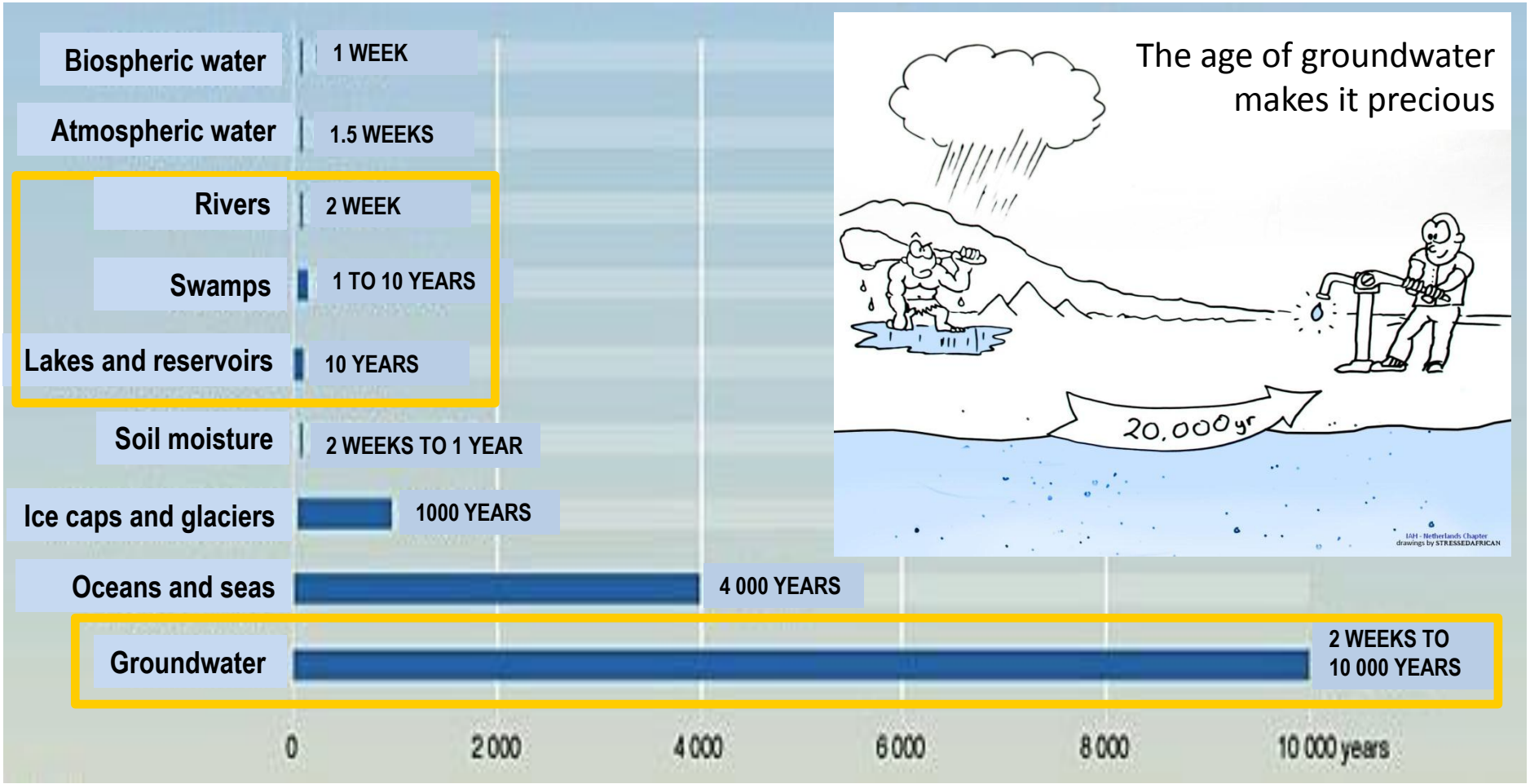
Courtesy Erich Roeckner, Max Planck Institute for Meteorology

Three loops:

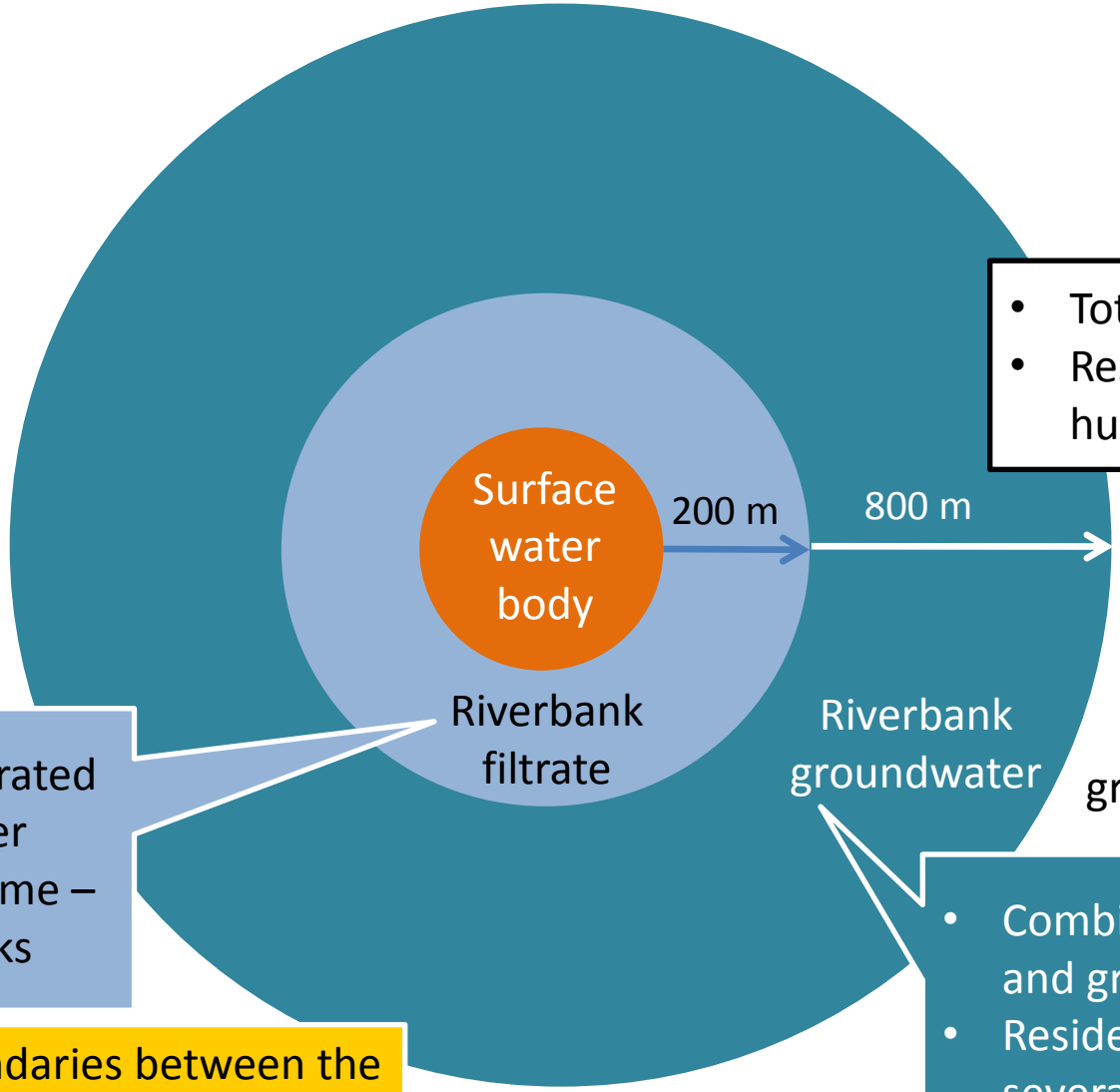
1. Surface runoff loop;
2. Evapotranspiration loop; and
3. Groundwater loop.



Residence times of different water resources



Classification of groundwater

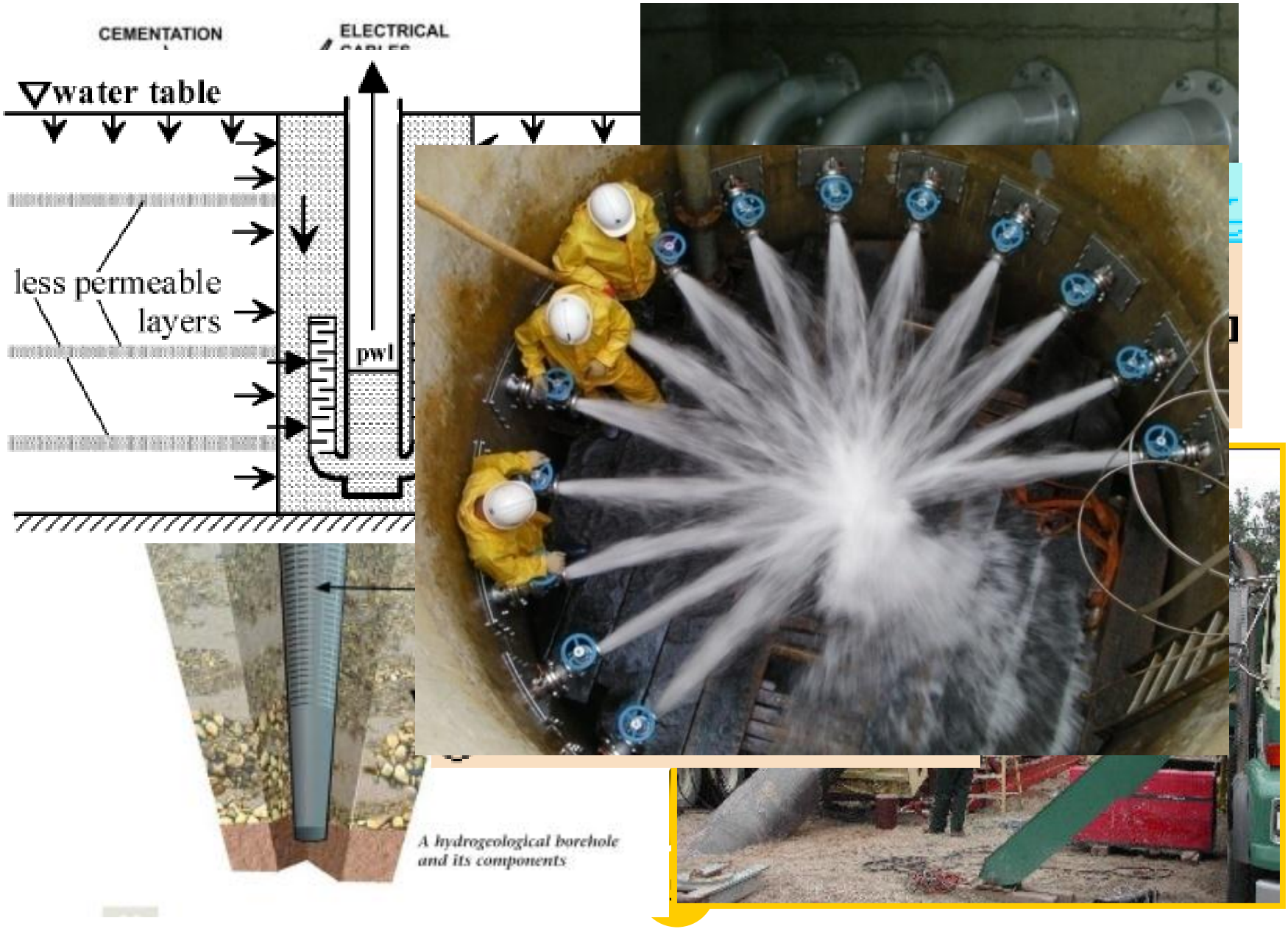


- Totally groundwater
- Residence time – hundreds of years

- Mostly infiltrated surface water
- Residence time – several weeks

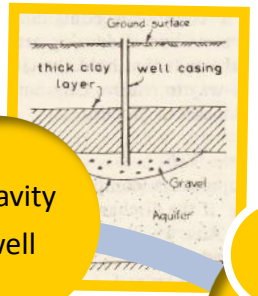
- Combination of surface and groundwater
- Residence time – several years

Well defined boundaries between the three types of water do not exist

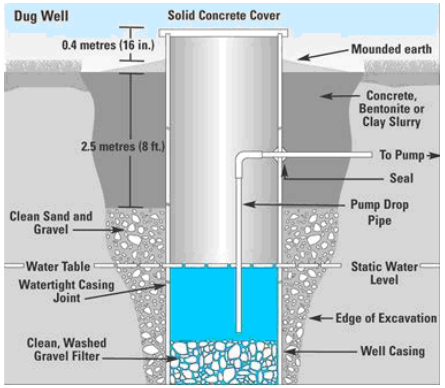

CEMENTATION
ELECTRICAL
water table
less permeable
layers
pwl
A hydrogeological borehole
and its components

Abstraction methods

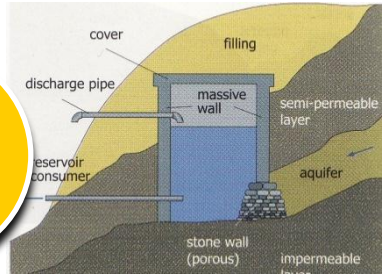
1. Cavity well



2. Dug well

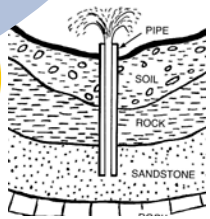


3. Spring water capture

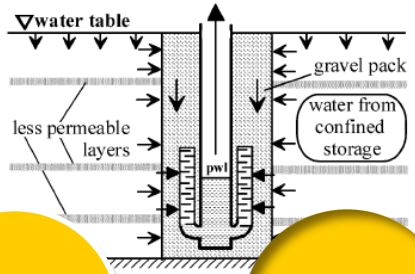


4. Well point system

5. Vertical well

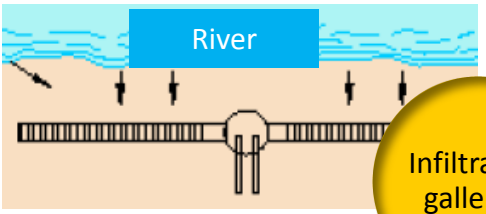


6. Inverted well

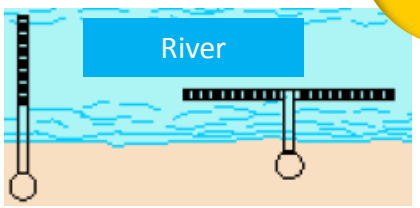


7. Slant well

8. Infiltration galleries



9. Collector wells



Abstraction methods

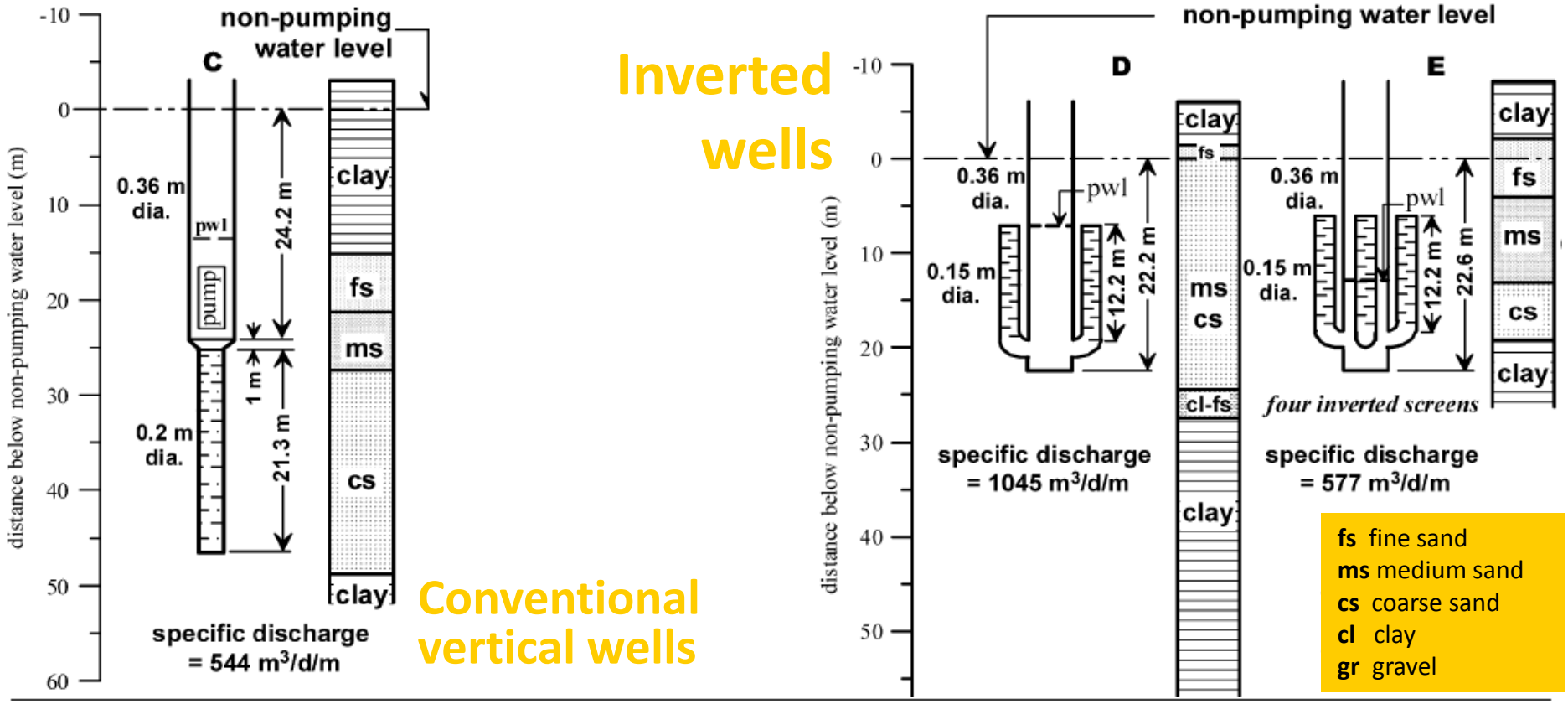
Need to use the right groundwater abstraction method to ensure sustainable groundwater development

Determining factors:

- Geological conditions
- Nearness to surface water bodies
- Depth of water abstraction
- Quantity of water to be abstracted

Support different situations with specific abstraction method

Inverted wells



Conventional vertical wells

No.	Conventional					Inverted				
	Length (m)	Screened length (m)	Qmax (m^3/d)	d/down (m)	Specific discharge (m^3/d/m)	Length (m)	Screened length (m)	Qmax (m^3/d)	d/down (m)	Specific discharge (m^3/d/m)
1	29.3	9.1	2450	7.44	330	29.3	2×9.1+ 2×6.1	7340	7.65	960
2	36.6	2×12.2	3670	14.8	248	32.0	4×9.1	6120	19.0	322
3	50.0	2×12.2	3380	13.7	247	46.9	4×8.7	7340	21.9	335
4	39.0	15.2	2940	4.7	626	32.6	4×9.1	7340	8.9	825
5	44.8	2×12.2	3030	16.9	179	40.8	4×11.6	7340	24.7	297

Inverted wells

Condition

Moderately transmissive aquifers for which permeable strata are within 30 m of the non-pumping water level

Reasons for high yield

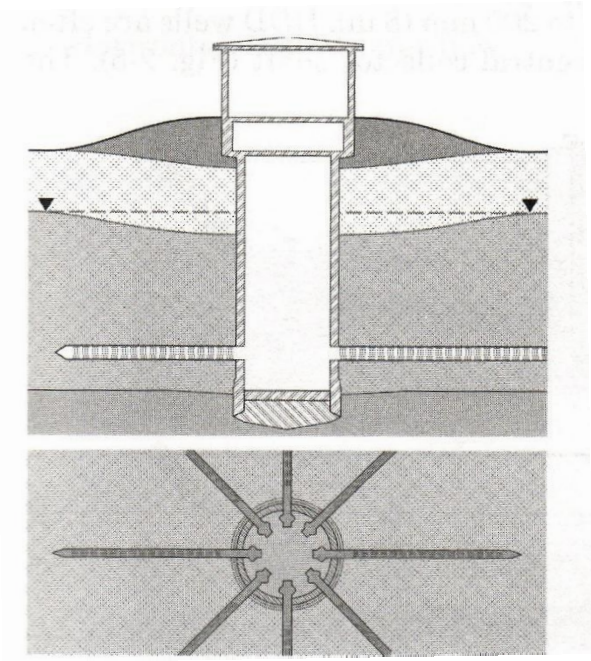
- Pump set at lower level
- Increased area of screen
- Increased radius of gravel pack

Application

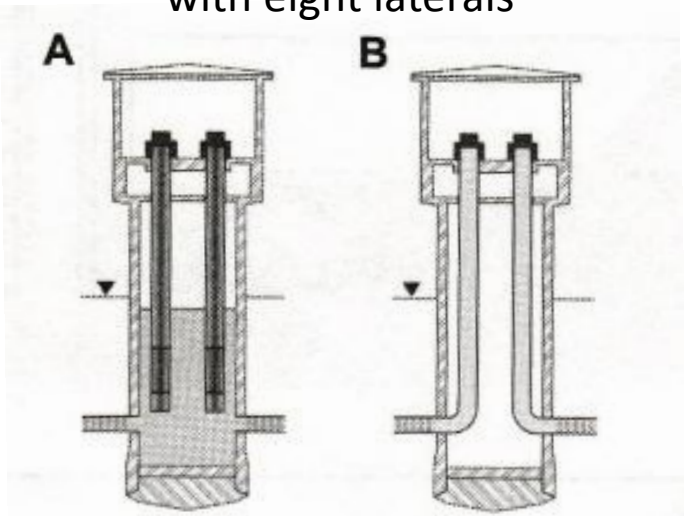
Paddy irrigation

Radial collector well

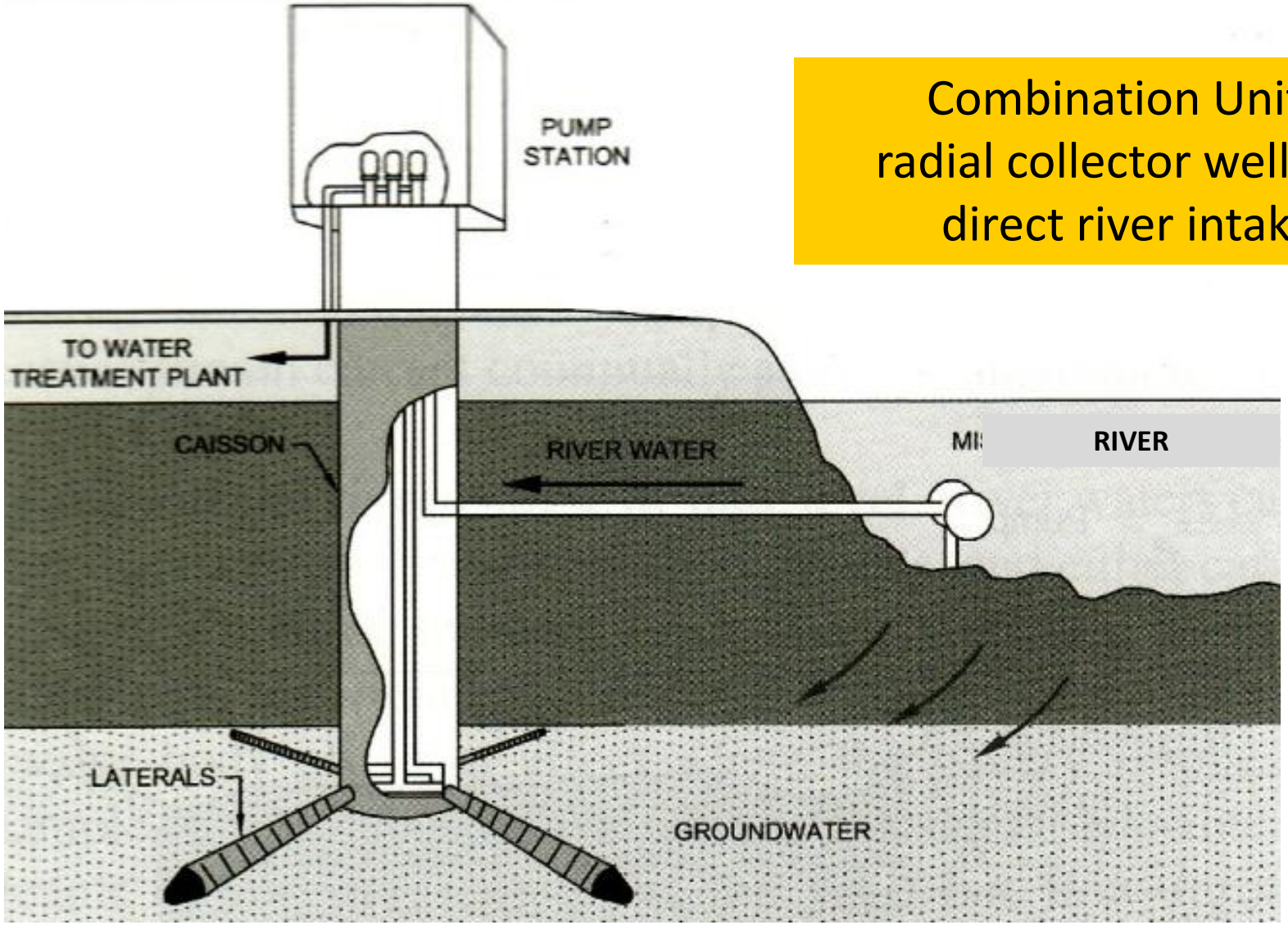
- Higher well yields – up to 250 Mld
- Reduction of surface water-borne organisms
- Lower O & M costs
- Raised caisson offers flood protection
- Simple operator requirements
- Fewer wells required – less connecting pipelines
- Minimise property needs
- Minimise environmental impacts
- Lower and more evenly spread drawdown



Radial collector well with eight laterals



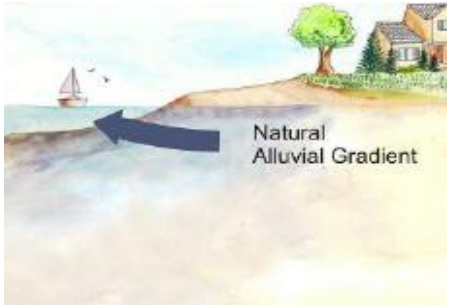
Radial collector well



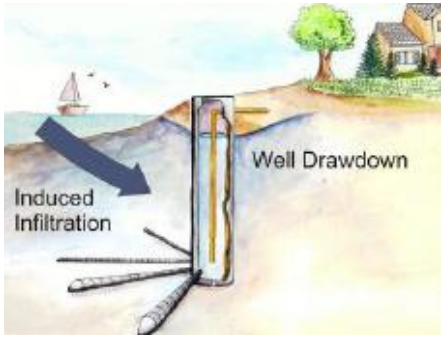
Combination Unit - radial collector well and direct river intake

River bank filtration (RBF) to replace conventional river water intakes

Direct river intake



Groundwater naturally drains to and discharges to surface water bodies



Pumping in an aquifer that is hydraulically connected with surface water body reverses the hydraulic gradient allowing infiltration to recharge the aquifer

- Avoids intake of fishes and other aquatic organisms
- More consistent water quality
- Natural filtration of suspended matters, turbidity etc.
- Reduce vulnerability to weather events

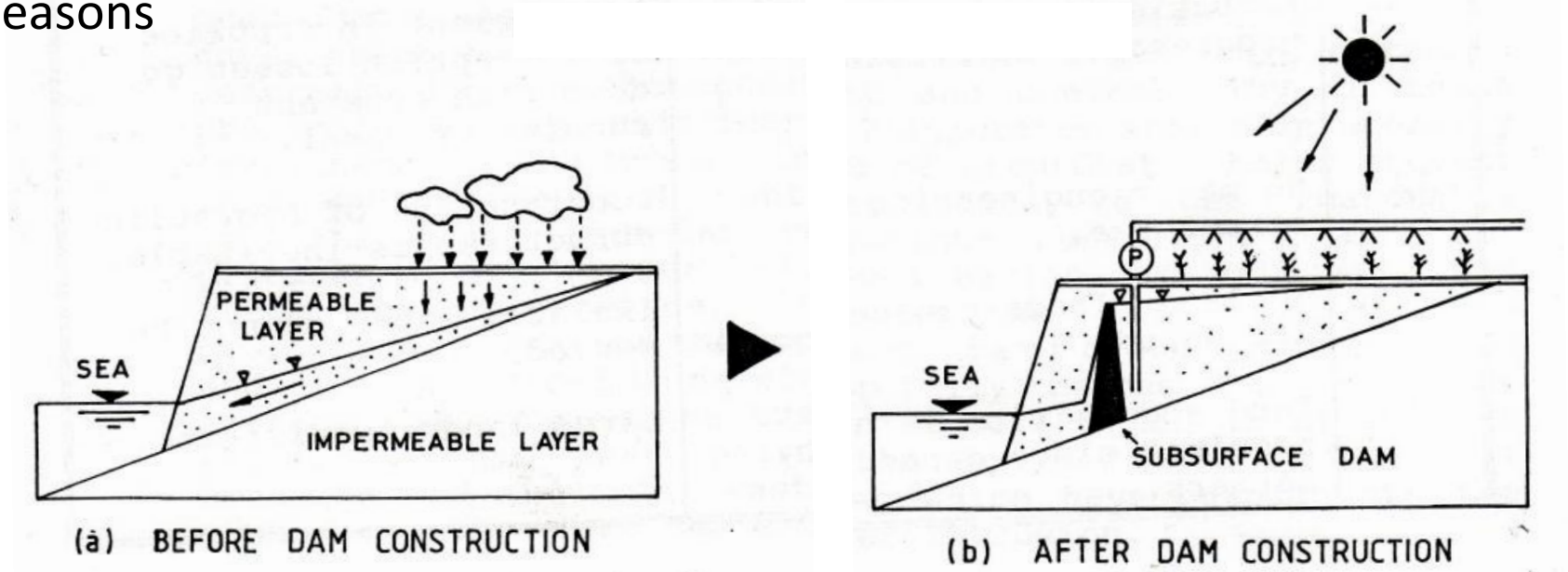
River bank filtration

Criteria to be considered

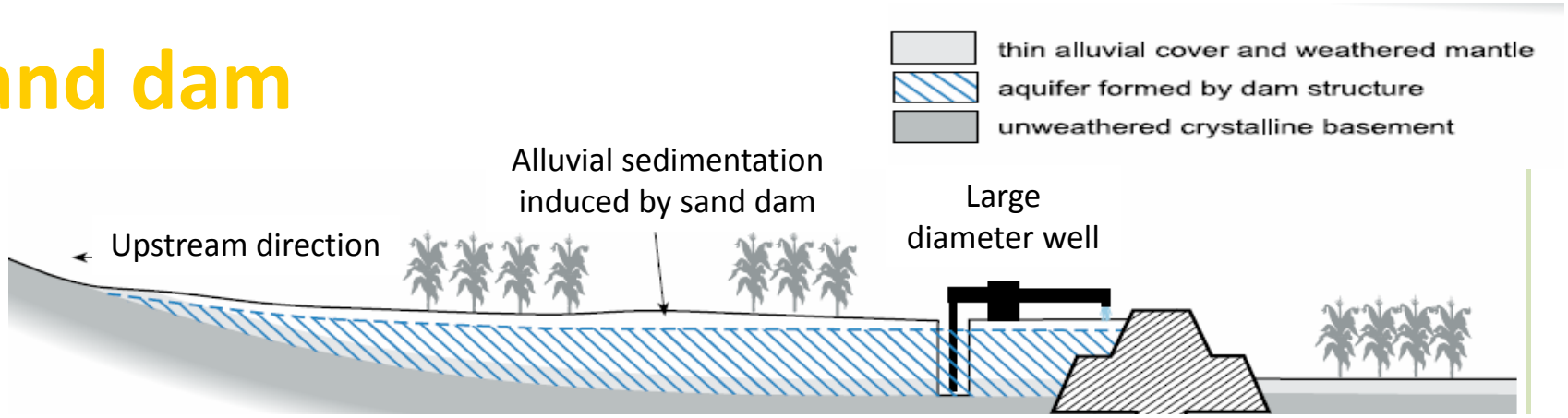
- Availability of river water
  - Sustainable flow in the river for the anticipated abstraction rate
- Efficient hydraulic interconnection between river and aquifer
- Aquifer can convey infiltrated water to the well
- Suitable water quality in the aquifer and river

Underground dam

- Permeable localities
- Useful in small islands
- Rainfall is stored in underground reservoir during wet seasons and utilised during dry seasons
- No submerged land and land use is not disturbed
- Negligible evaporation losses
- No siltation
- No potential disaster from dam breaks
- Sophisticated structure but simple operation

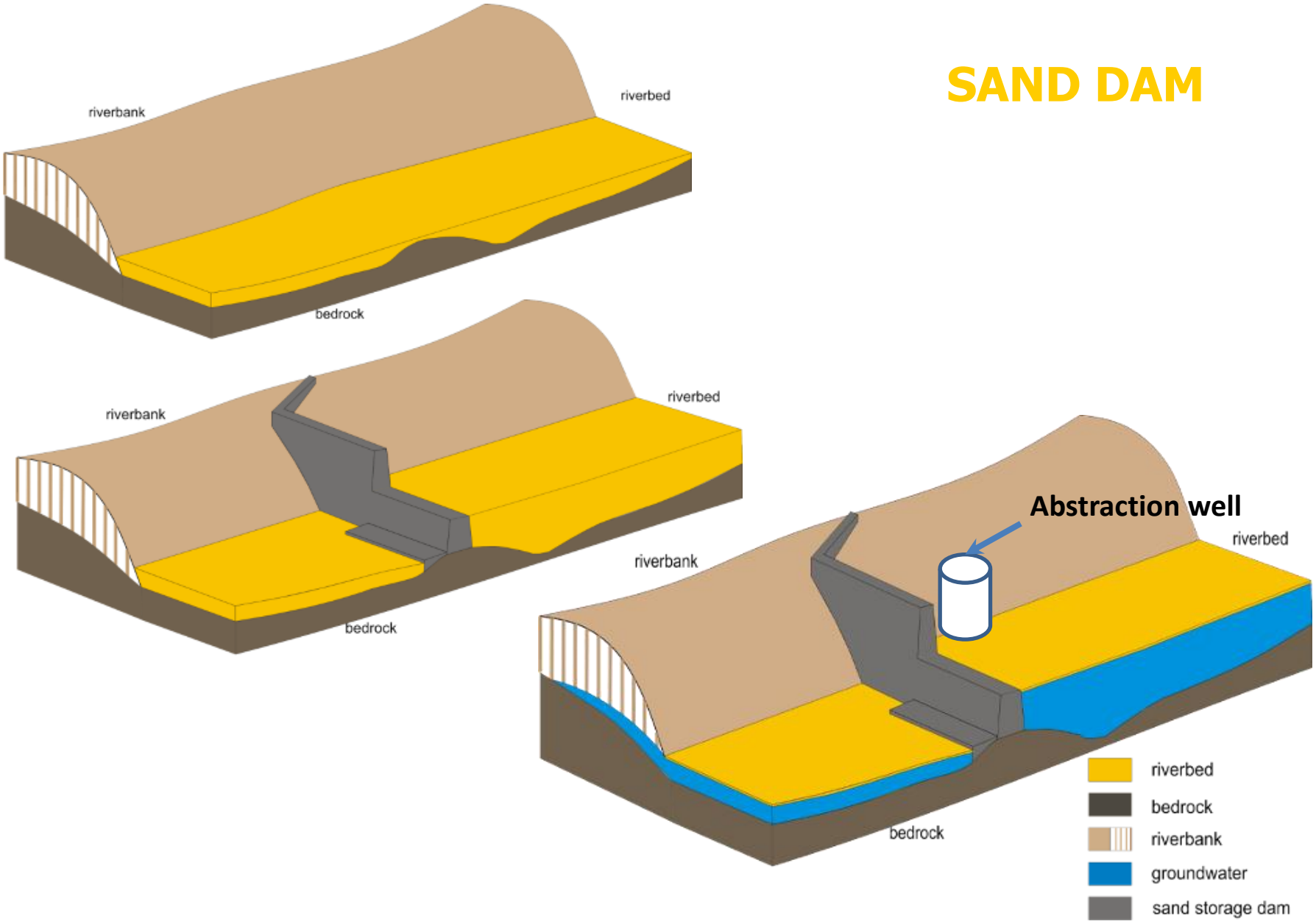


Sand dam


thin alluvial cover and weathered mantle
aquifer formed by dam structure
unweathered crystalline basement
Alluvial sedimentation
induced by sand dam
Large
diameter well
Upstream direction


A sand dam

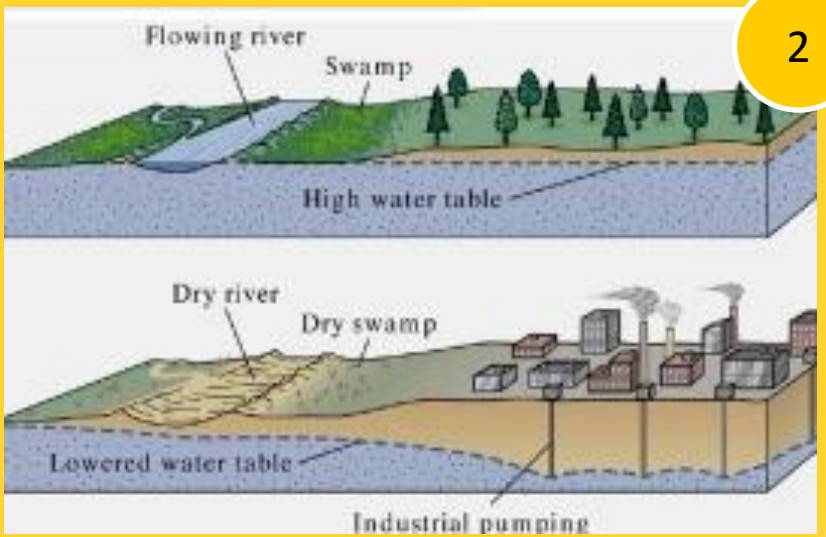
SAND DAM


riverbank
riverbed
bedrock
riverbank
riverbed
bedrock
Abstraction well
riverbank
riverbed
bedrock
riverbed
bedrock
riverbank
groundwater
sand storage dam

Problems associated with groundwater use:

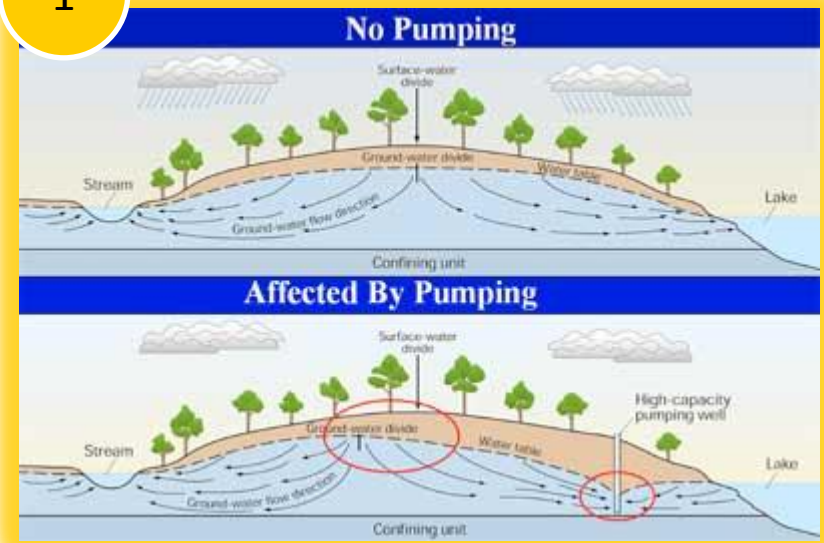
Anthropogenic impacts from over-abstraction

2

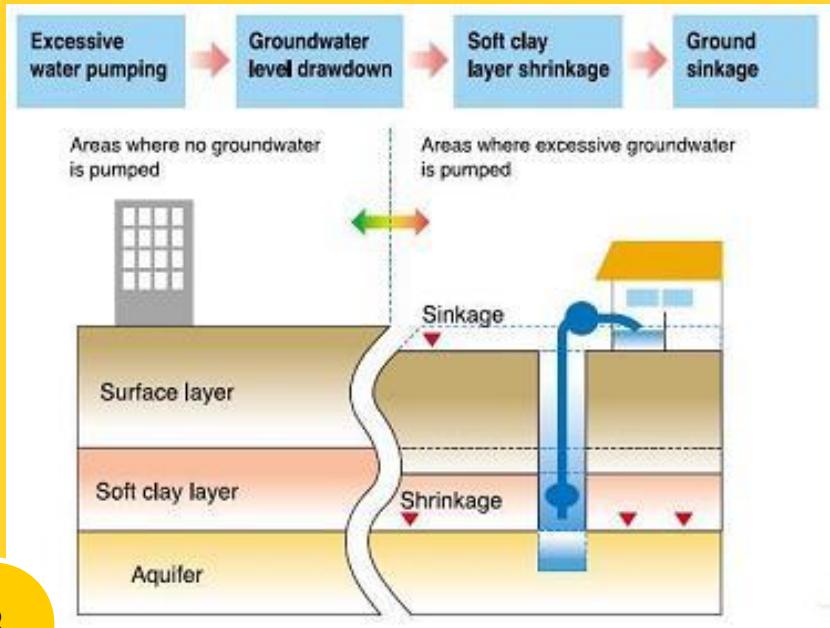


Lowering water table and drying of river and swamp

1



Lowering water table and saline intrusion



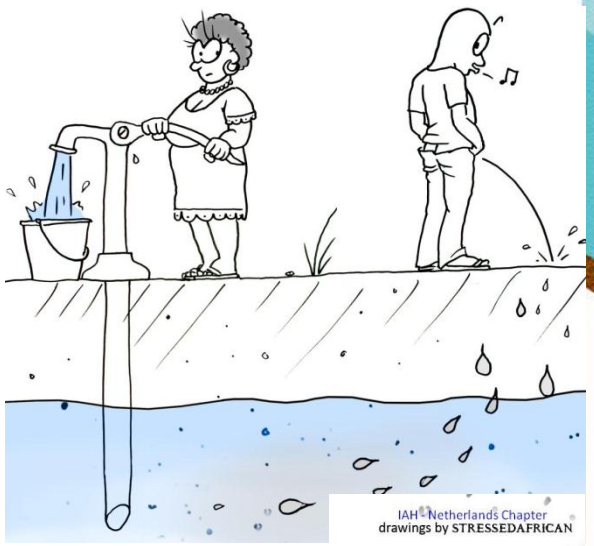
3

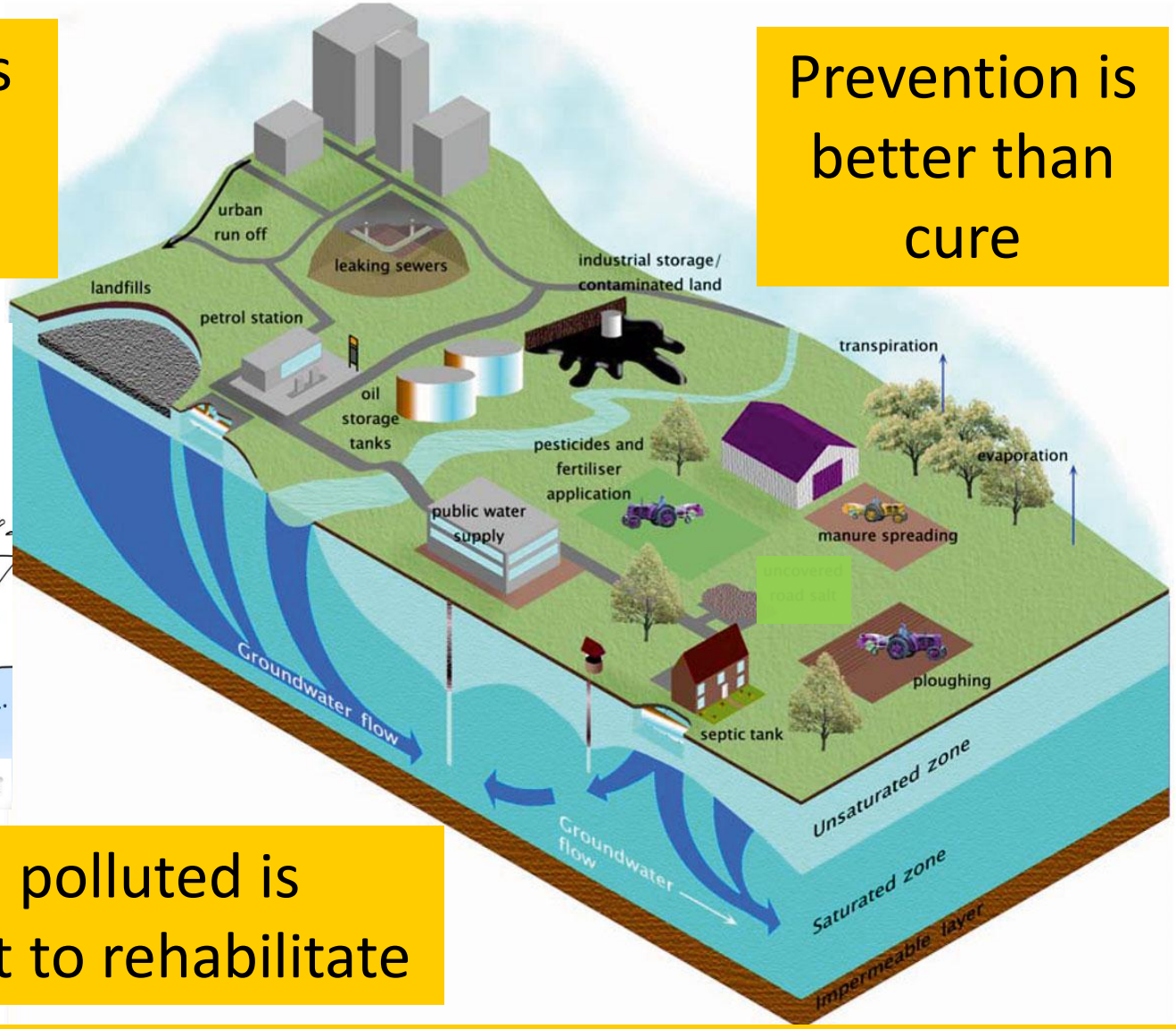
Compaction of clay layer

Groundwater is vulnerable to contamination

Potential sources of groundwater contamination

Prevention is better than cure

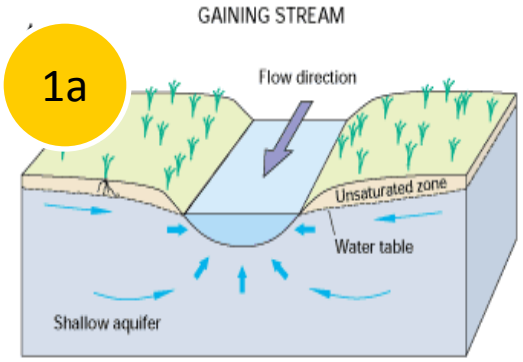




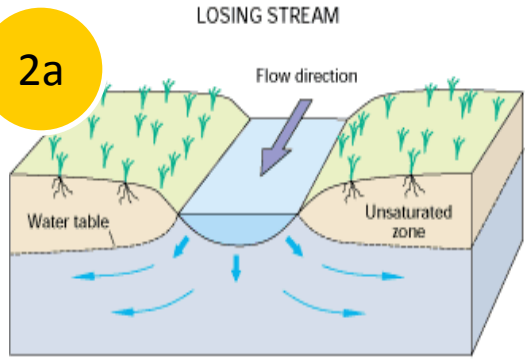
Aquifers once polluted is extremely difficult to rehabilitate

Interaction between surface water and groundwater

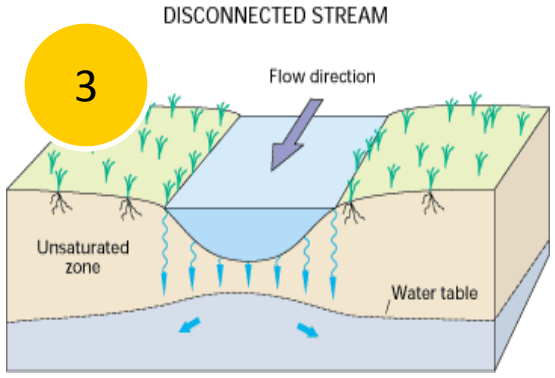
1a



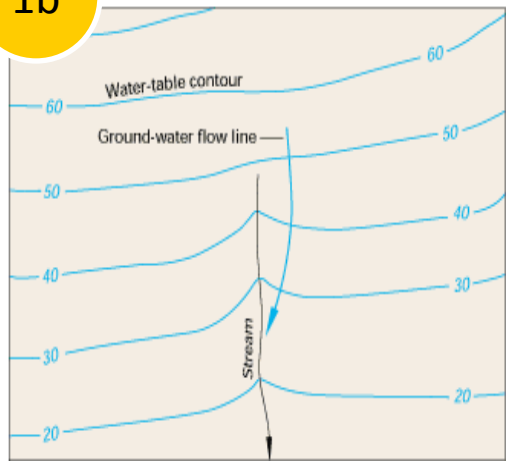
2a



3



1b



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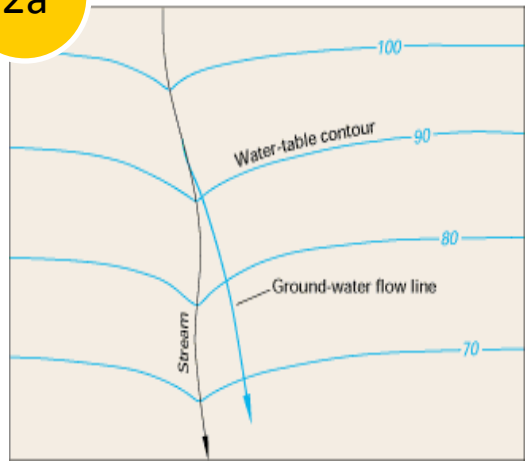

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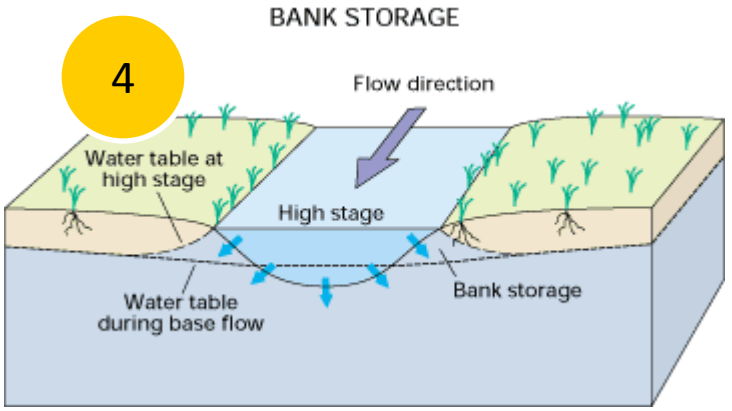

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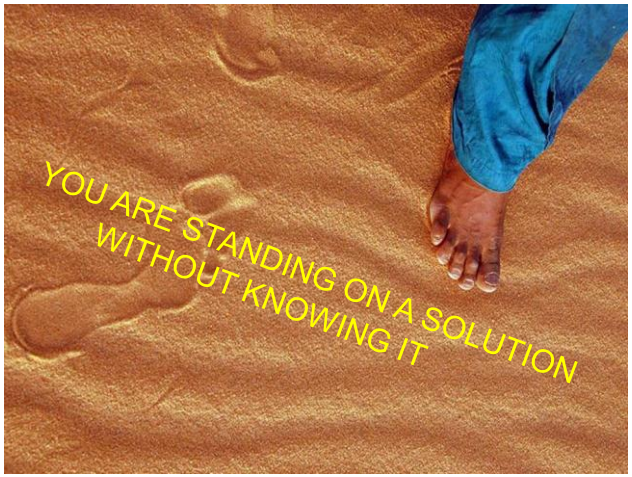
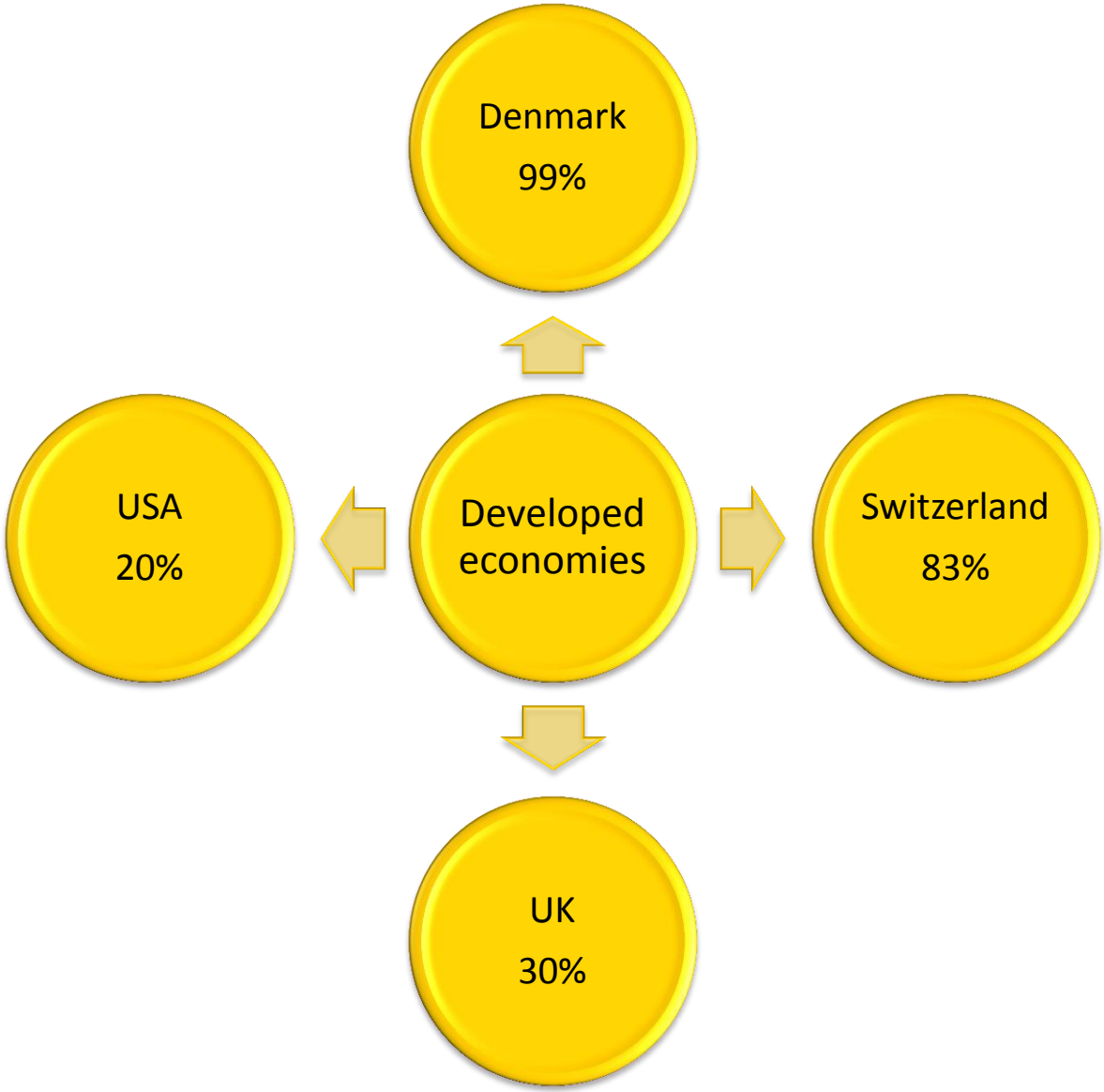


Global public water supplies



Water UK 2011

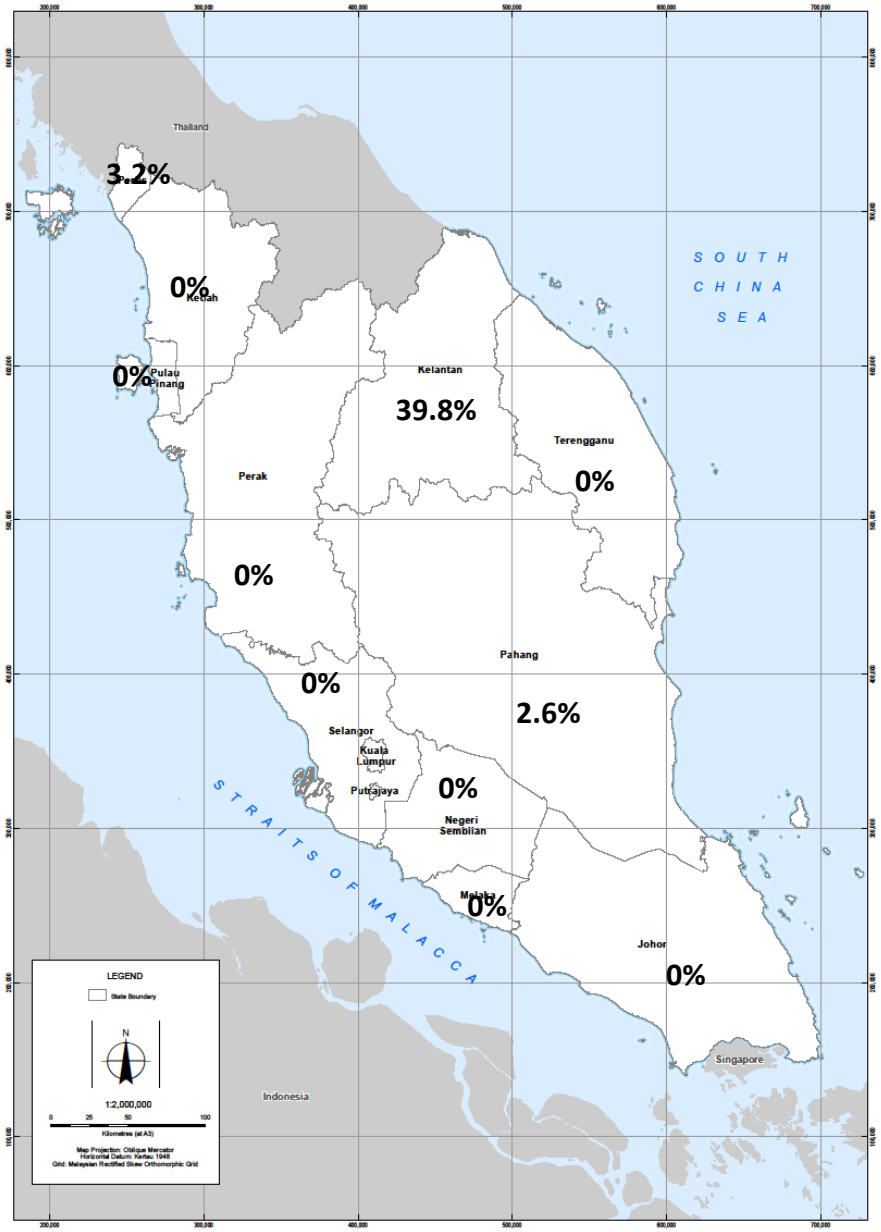
Two-thirds of raw water comes from surface sources and a third from groundwater. Sources vary by region, and in London and the South East, groundwater accounts for around 70% of total water supply.

Water is drawn from more than 1,500 wells, 650 reservoirs and at 600 river abstraction points.

Malaysian public water supplies

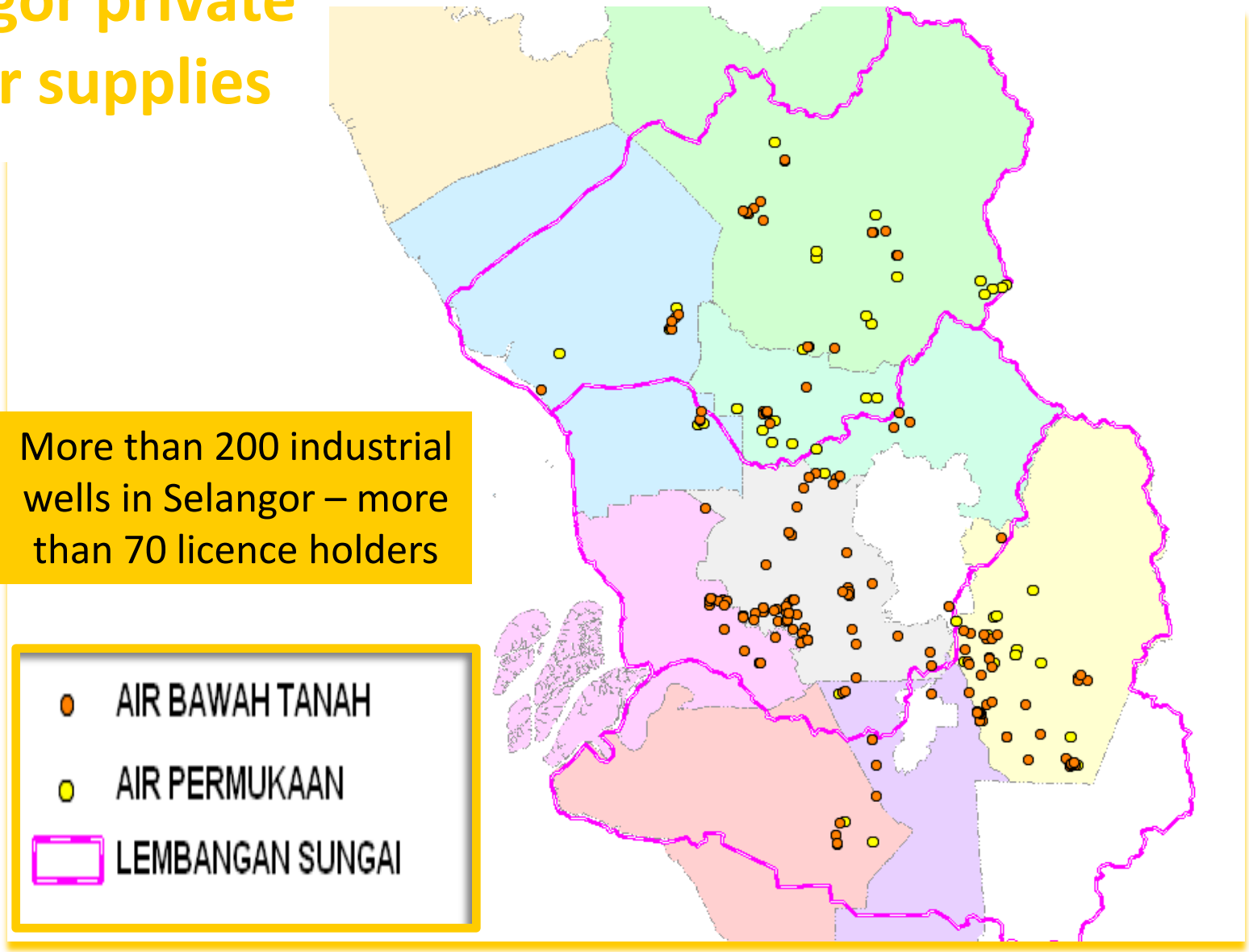
Groundwater contribution		
Kelantan	150 mld	39.8 %
Perlis	5 mld	3.2 %
Pahang	28 mld	2.6%
Sabah	19 mld	1.9%
Labuan	0.3 mld	0.6 %
Sarawak	0.4 mld	0.04%
Malaysia	**204 mld**	**1.3%**

Source: MWIG 2011



Selangor private water supplies

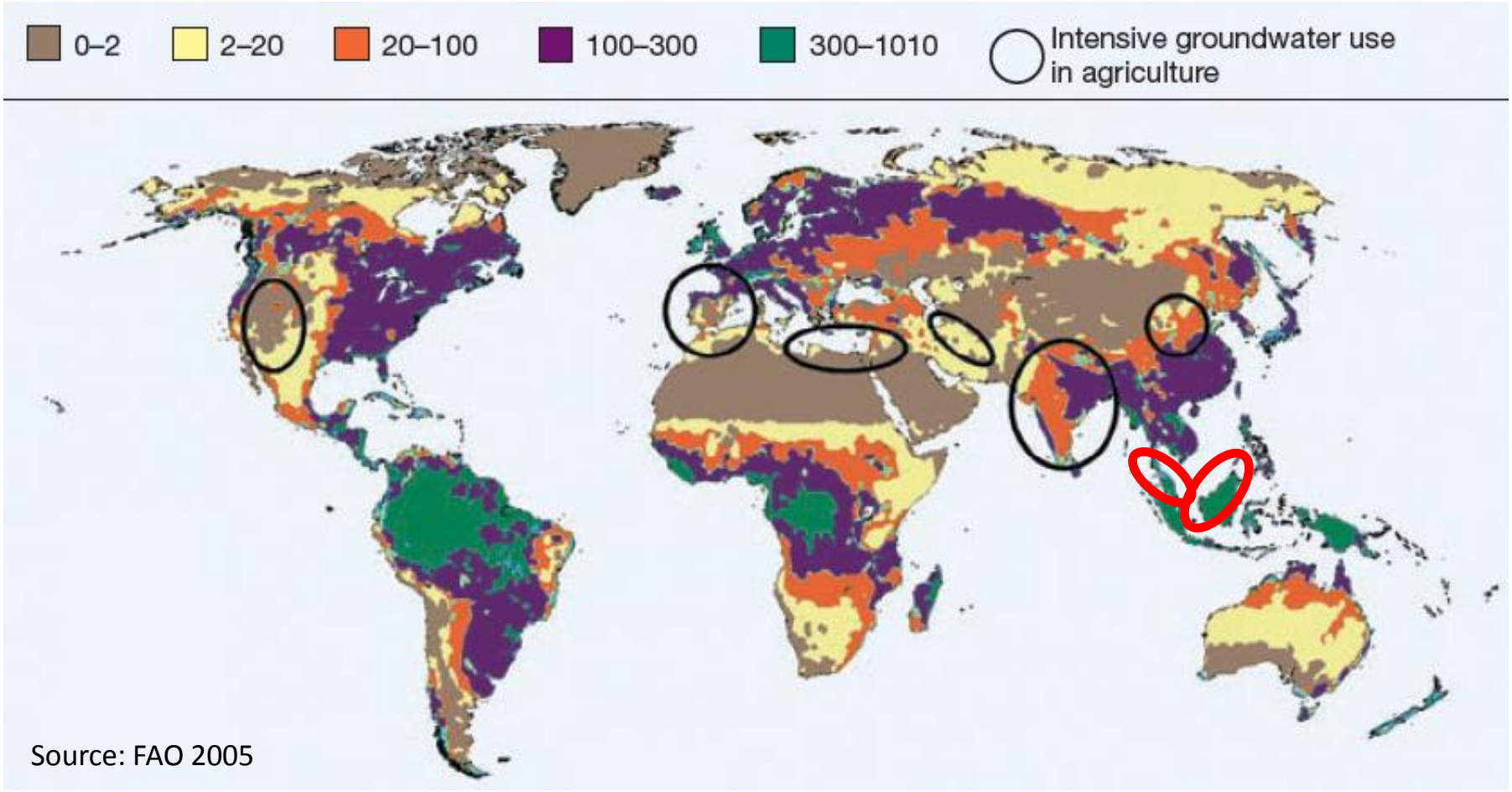
More than 200 industrial wells in Selangor – more than 70 licence holders



Source: LUAS

Global irrigation water supplies

Long term average groundwater recharge (mm per year)



- Groundwater irrigation is minimal in regions with high recharge, and it is intensive where the recharge is too small to sustain intensive groundwater use (notable exceptions are Bangladesh, eastern India and Nepal)

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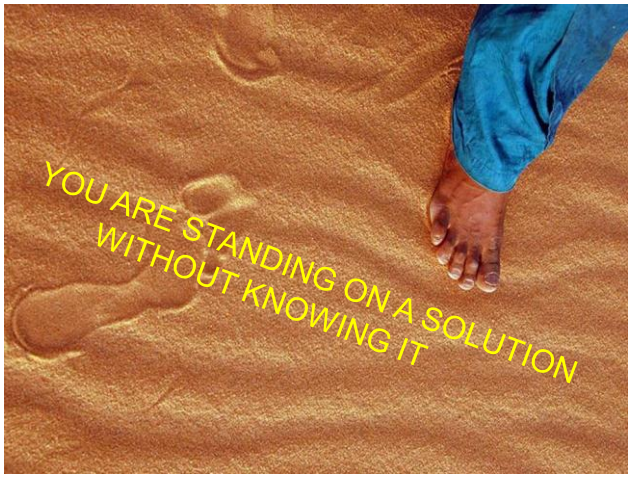
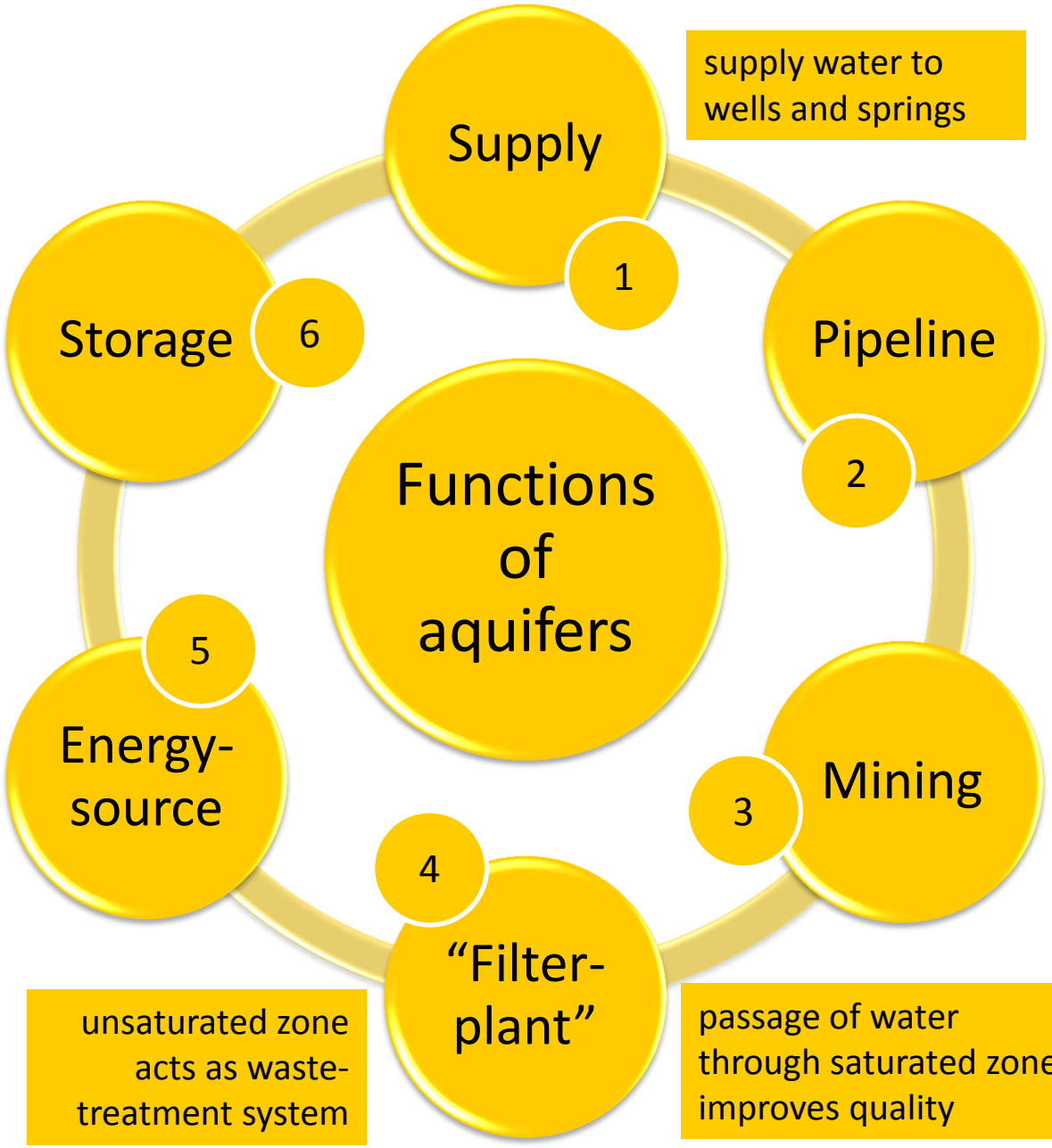
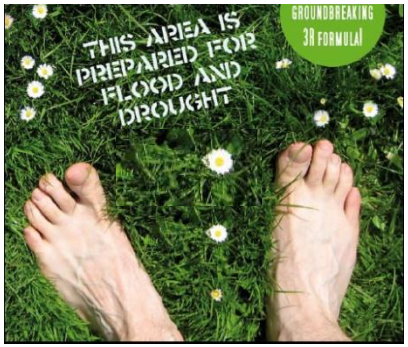



Functions of aquifers
Supply
1
supply water to wells and springs
Pipeline
2
transmit water from one location to another
Mining
3
groundwater can be mined like minerals
"Filter-plant"
4
passage of water through saturated zone improves quality
unsaturated zone acts as waste-treatment system
Energy-source
5
groundwater heat pump is a viable alternative to conventional heat pumps in some localities
Storage
6
groundwater reservoir with unused storage capacity, can store water from wet periods for use during time of drought

Advantages of groundwater

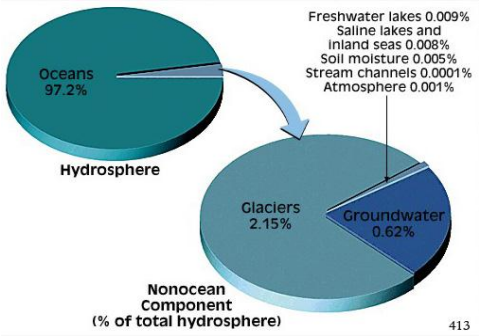


1 Available where needed: universal access

2 Naturally protected: safe and stable quality

4 Environmental flows: wetland and river base-flow

3 Storage capacity: our largest freshwater reservoir



Benefits of groundwater utilisation

Improved water services

- stability of supply – huge groundwater storage and less affected by evaporation and weather condition
- better water quality - soil and rocks act as natural filter and removes most pollutants
- Lower CAPEX and OPEX

Environment friendly

- provide a source of natural storage - no inundation of lands and associated social and environmental problems
- eliminates risk of flooding and dam breaks
- less sludge residues from water treatment process - groundwater is of better quality

Green Development

Consequences of not using groundwater - expensive CAPEX and large impacts

Expensive CAPEX

- Inter-basin and inter-state water transfers
- Dams, diversion channels, tunnels and long pipelines

Large impacts

- Social and environmental impacts
- Intervention on river flows
- Water intakes, weirs, barrages and dams

Unsustainable Development

Consequences of not using groundwater - public water supply is easily affected by droughts

- Dry reservoirs

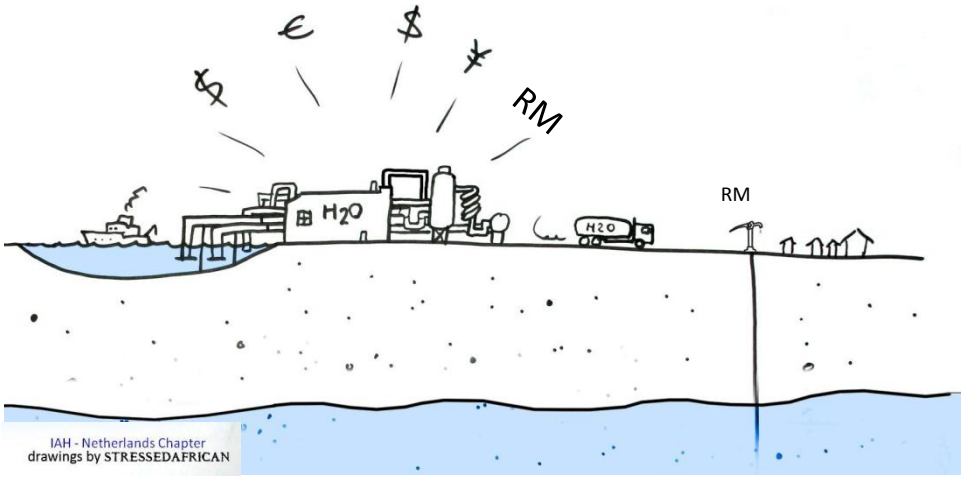
- Public suffers

- Economic losses

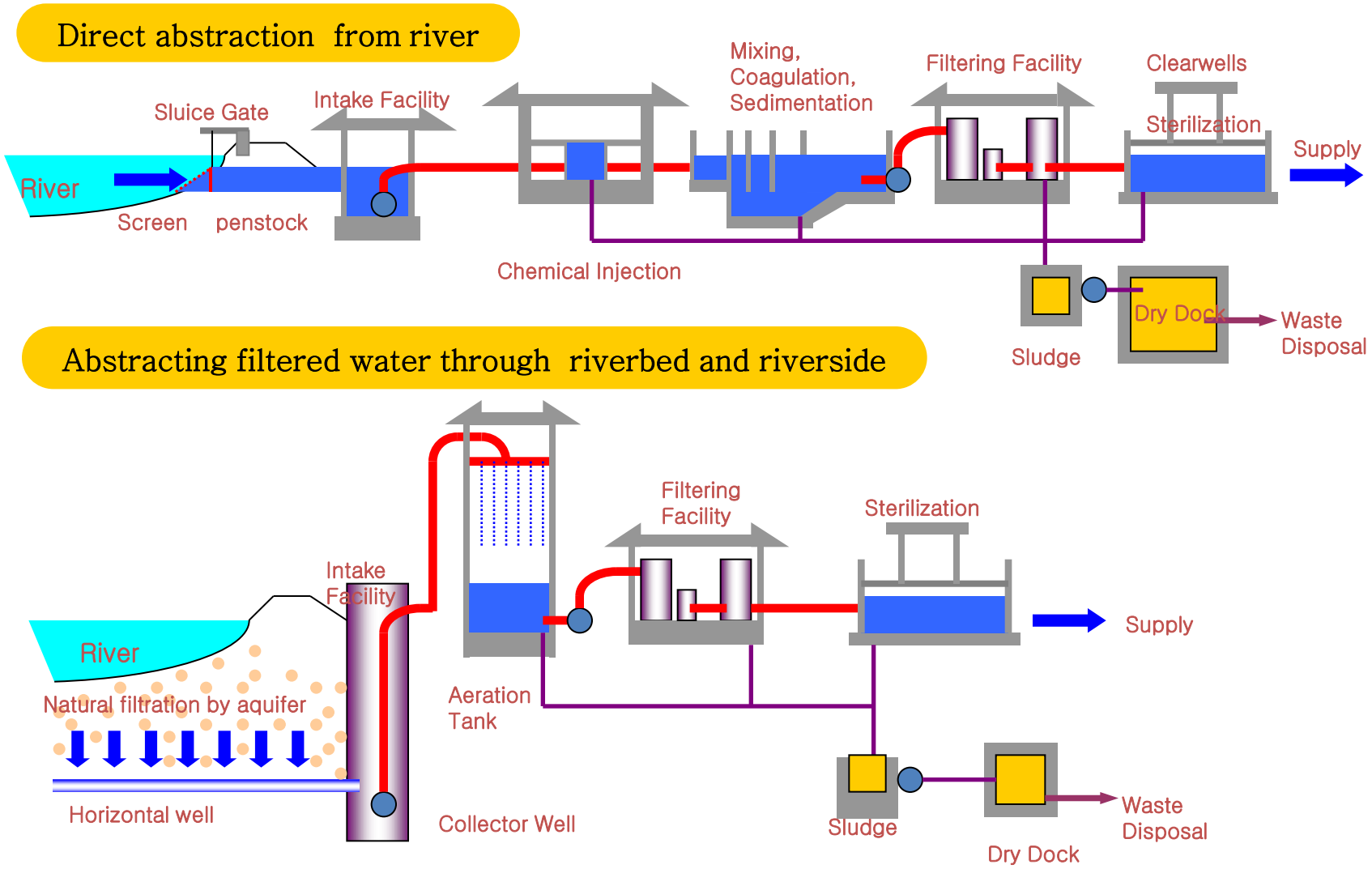
Groundwater is cheaper

Dutch water sector (2000)
– yearly costs for an average family (water consumption of 130 m^3/yr)

Type of company	Name of company – supply area	Yearly cost (€/y)
Surface water companies		
Most expensive supply area	PWN – Region Haarlem	248
Cheapest supply area	Water supply company Amsterdam	166
Groundwater companies		
Most expensive supply area	Vitens – Friesland	166
Cheapest supply area	Groningen – Province (excluded city)	101

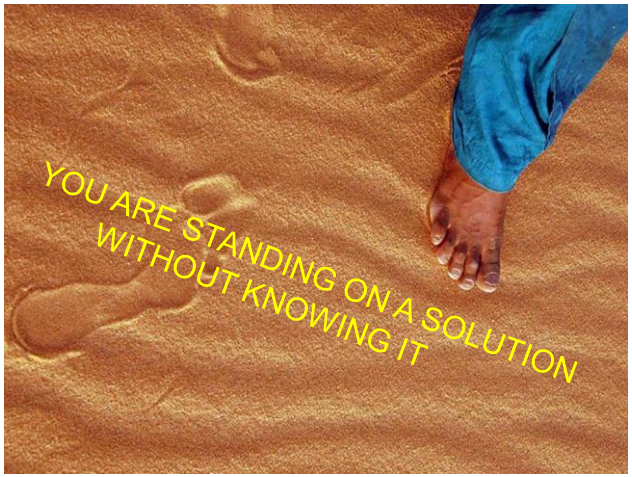


Simpler water treatment process



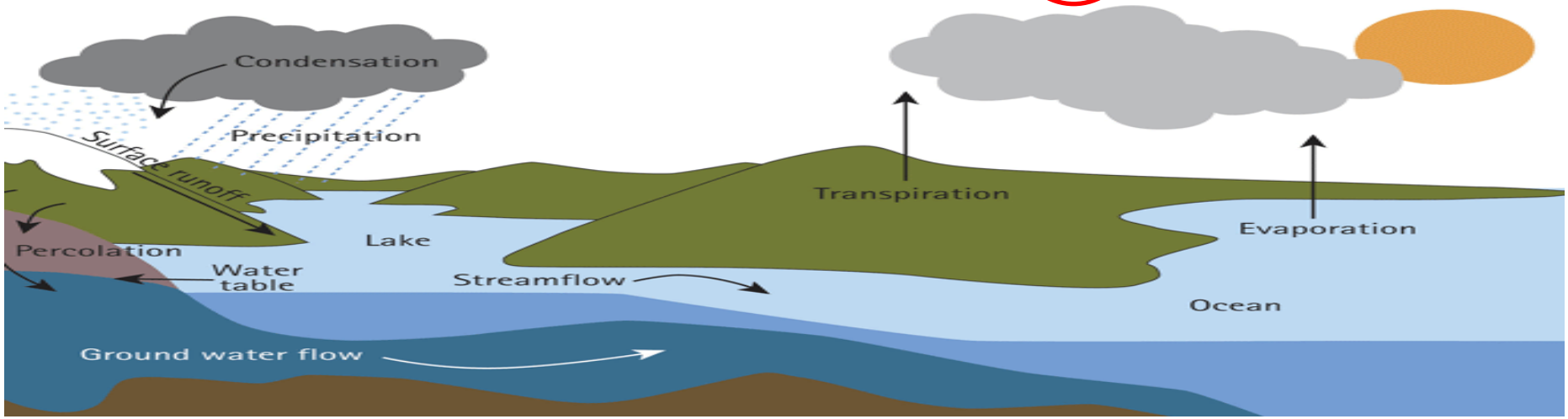
CONTENT

1. INTRODUCTION
2. GROUNDWATER IS A FRESHWATER RESOURCE
3. GROUNDWATER UTILISATION
4. WHY GROUNDWATER?
5. WATER RESOURCES IN MALAYSIA
6. DON'T BE SAD
7. HUMAN CAPITAL
8. WAY FORWARD
9. FINAL REMARKS



National water resources

	Rainfall	Surface runoff	Groundwater recharge	Evaporation
Peninsular Malaysia	2,490 mm	1,060 mm	148 mm	1,280 mm
Sabah and Sarawak	3,240 mm	1,790 mm	221 mm	1,230 mm
Malaysia	2,940 mm	1,500 mm	192 mm	1,250 mm



National water resources

Region	Area (km^2)	Rainfall	Actual evaporation	Groundwater recharge	Surface runoff
Peninsular	132,388	2,490	1,280	148	1,060
Sabah	73,631	2,560	1,190	190	1,180
Sarawak	124,450	3,640	1,250	240	2,150
Labuan	91	3,100	1,480	150	1,470
Malaysia	330,560	2,940	1,250	192	1,500

Source: RNWRS 2000-2050, 2010

Unit: mm

Region	Area (km^2)	Groundwater recharge			Raw water for public water supply (Mld)[1]
		mm	MCM	Mld	
Peninsular	132,388	148	19,590	53,680	13,000
Sabah	73,631	190	13,990	38,330	998
Sarawak	124,450	240	29,870	81,830	1,049
Labuan	91	150	14	37	51

[1]Source: MWIG 2011

Selangor water resources

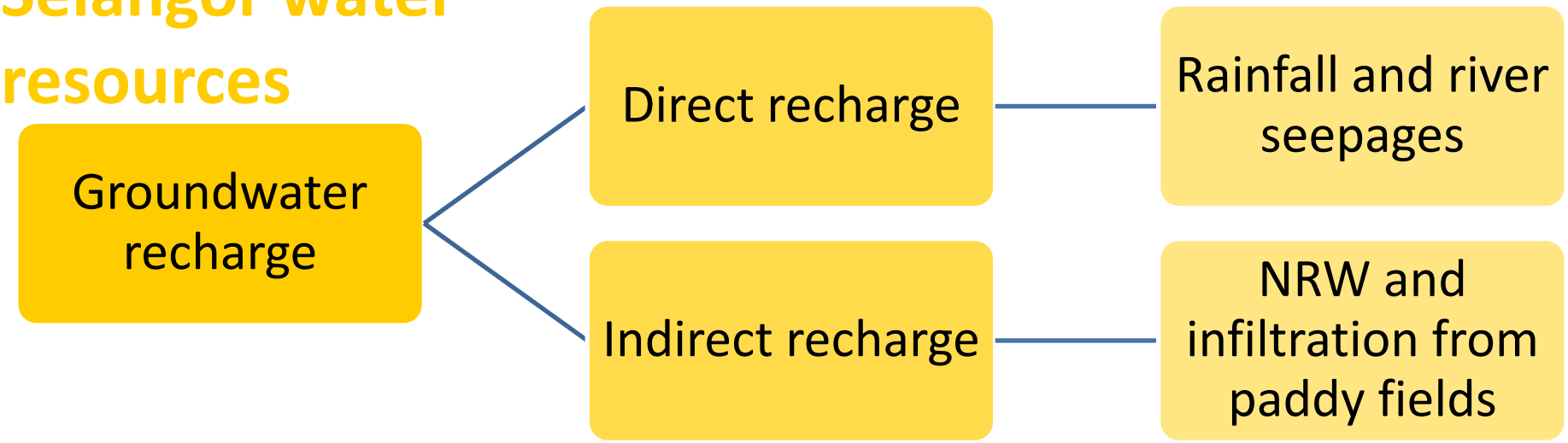
Area (km^2)	Rainfall	Actual evaporation	Groundwater recharge	Surface runoff
8,153	2,190	1,280	150	760

Unit: mm

Dam	Catchment Area (sq.km)	Capacity (MCM)
Tasik Subang	10.28	3.5
Klang Gates	77.16	32
Sg. Langat	41.45	37.48
Sg. Batu	50	33.6
Sg. Semenyih	56.7	62.6
Sg. Tinggi	40	122.5
Sg. Selangor	197	235
Total	472.59	526.68

Groundwater recharge of 150 mm is equivalent to 1,220 MCM or 3,350 Mld

Selangor water resources



Unit	Groundwater recharge			
	Direct	Indirect		Total
	Rainfall	NRW[1]	Paddy fields[2]	
MCM	1,220	240	40	1,500
Mld	3,350	660	120	4,130

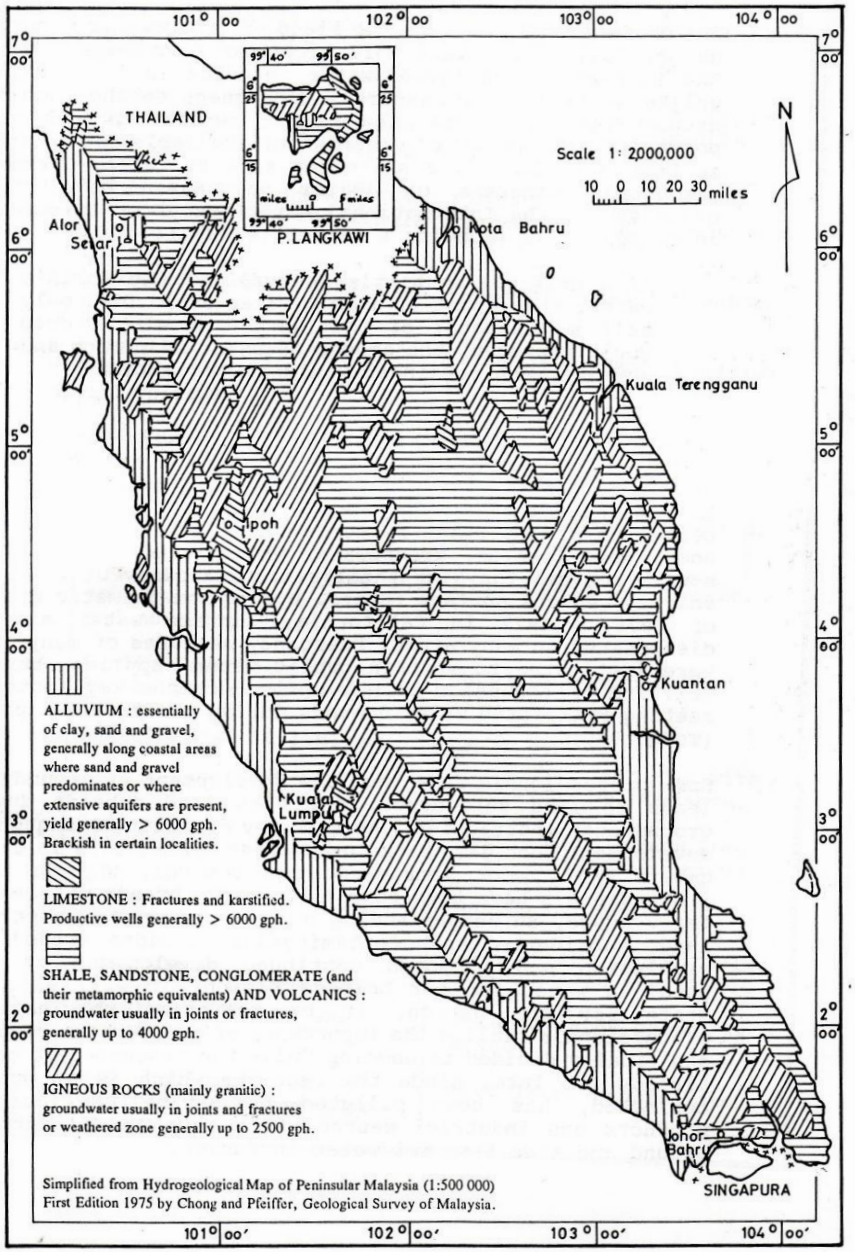
[1]: 480 MCM in 2010; assume 50% physical losses

[2]: Tanjong Karang Irrigation Scheme with an area of 18,195 ha; assume 8 months inundation and infiltration rate of 1 mm/d

Treated water productions are 4,063 Mld (2010 – MWIG) and 4,219 Mld (March 2012 – SYABAS); Volume of raw water abstracted in 2010 was 4,158 Mld

Groundwater distribution

- Unconsolidated alluvium or poorly consolidated alluvial or elluvial rocks; intergranular aquifers;
- Karstic limestones; hardrock aquifers; and
- Other sedimentary, igneous and metamorphic rocks; hardrock aquifers.



Groundwater potential

- cannot be uniquely defined, potential and specifically well success depend on the end use of water

20 l/s	• Paddy irrigation • D & I water supply
5 – 10 l/s	• Vegetables and tobacco crops • Rural water supply

CONTENT

1. INTRODUCTION
2. GROUNDWATER IS A FRESHWATER RESOURCE
3. GROUNDWATER UTILISATION
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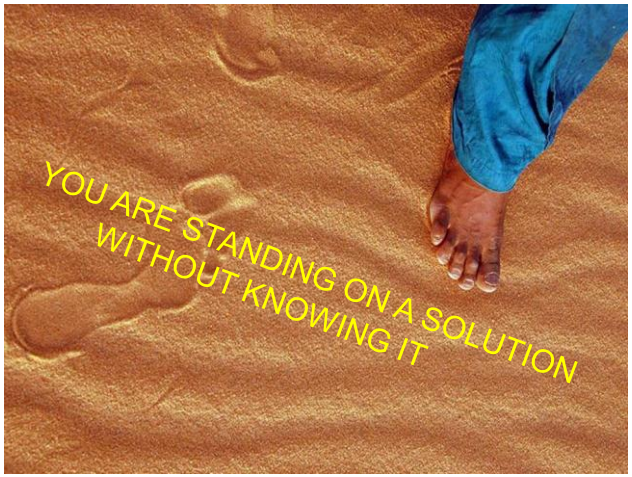
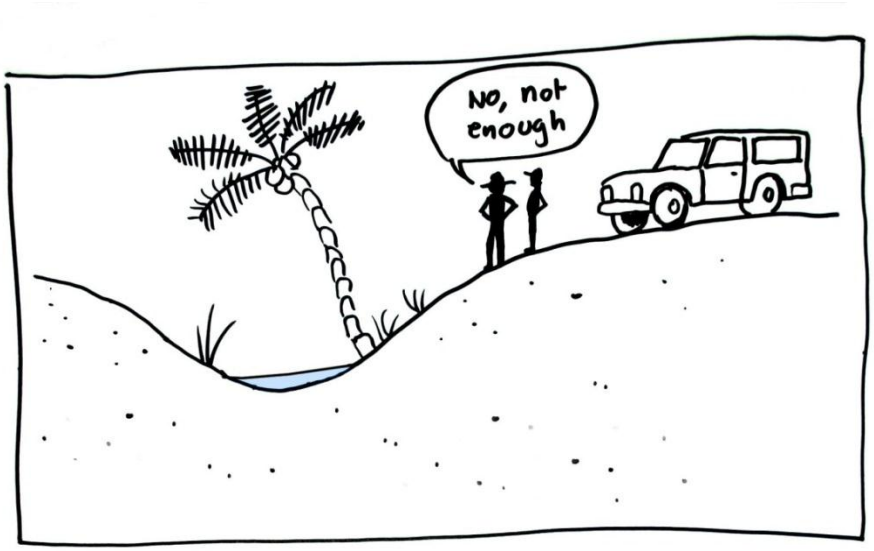
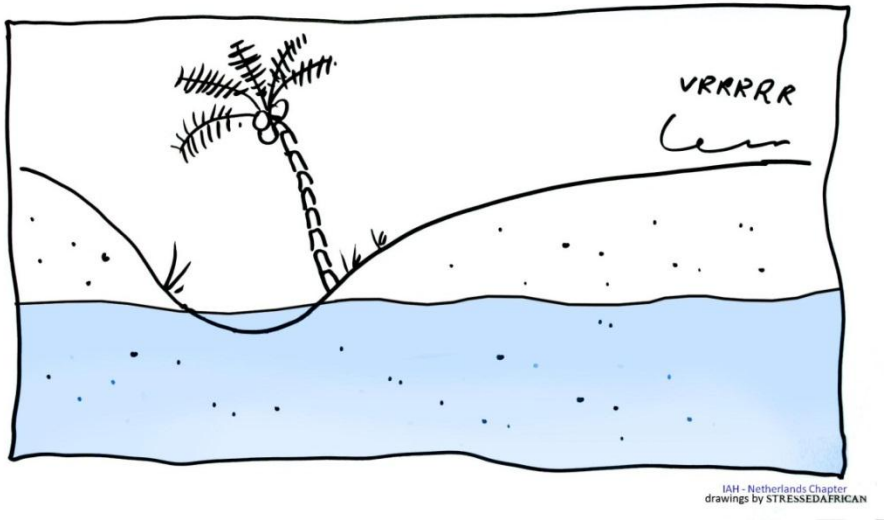
6. DON'T BE SAD
7. HUMAN CAPITAL
8. WAY FORWARD
9. FINAL REMARKS



Groundwater is a hidden liquid asset

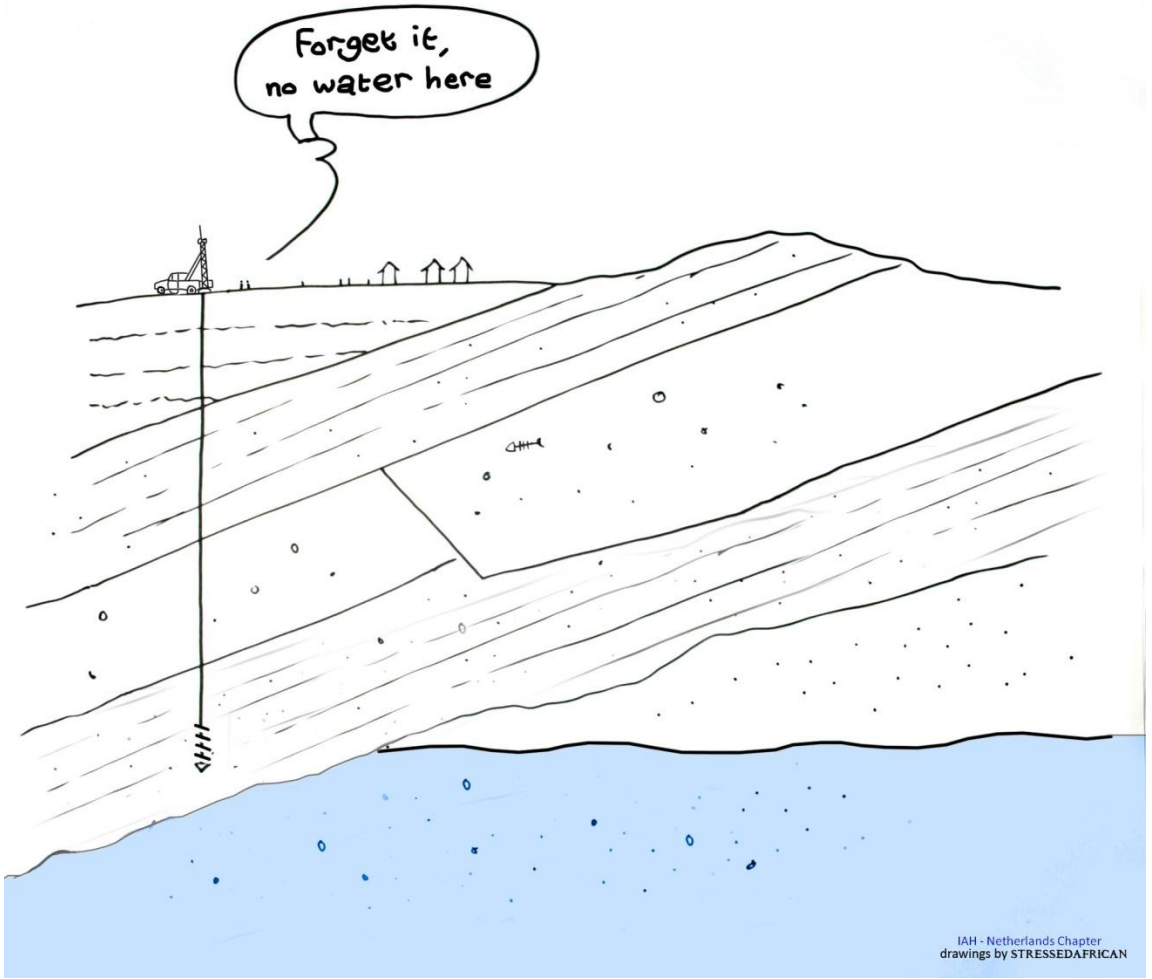
- Don’t be sad when the area is reported as unsuitable for development because of not enough water





Groundwater development requires proper investigations

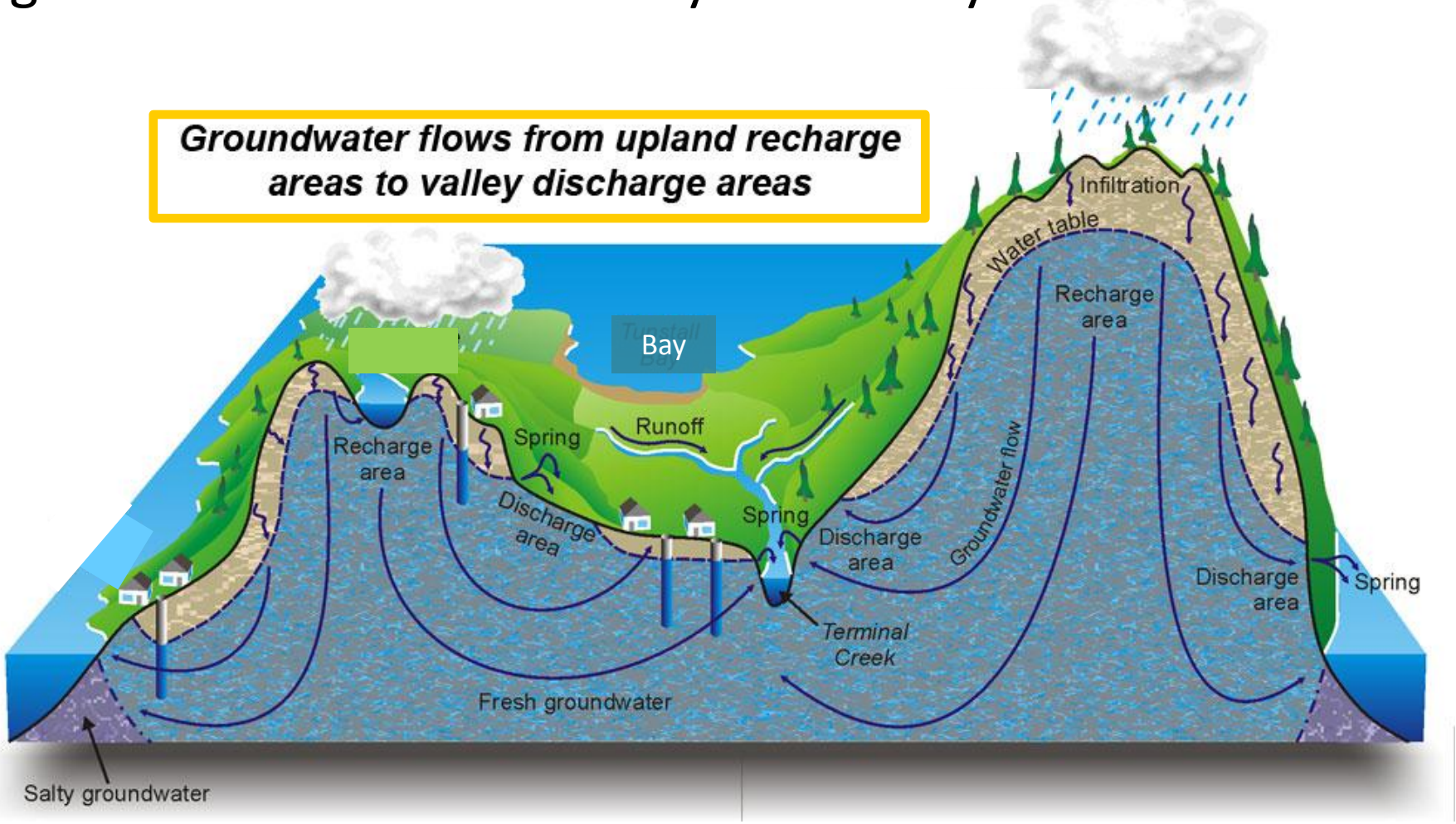
- Don’t be sad when the area is reported to have no groundwater



Sustainable groundwater development involve multi-disciplinary professionals

Aquifers are mega-watershed

- Don’t be sad when the area is reported to have limited groundwater due to thin layer of sandy alluvium



Aquifers are mega-watershed

- Deep-seated freshwater aquifers that was thought previously as “fossil” in nature (non-renewable)
- Deep well drillers have discovered freshwater at depths exceeding 3 km in fractured rocks

Constraint by technology

- Inability to investigate deeper rock structures
- We have been placing straws in only the upper portion of our water-filled glass (or aquifer)

Constraint by misguided belief

- Recharge could not continuously replenish the deeper aquifers
- Do not want to be dependent on a non-renewable resource

CONTENT

1. INTRODUCTION
2. GROUNDWATER IS A FRESHWATER RESOURCE
3. GROUNDWATER UTILISATION
4. WHY GROUNDWATER?
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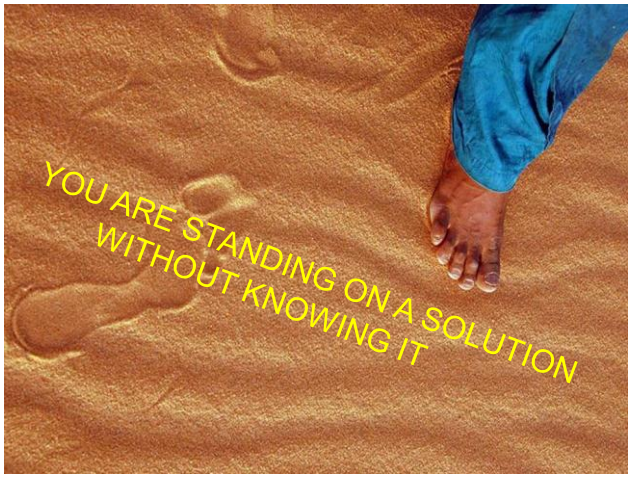
6. DON'T BE SAD
7. HUMAN CAPITAL
8. WAY FORWARD
9. FINAL REMARKS



Human capital

Investigation and development

- Hydrogeologists
- Geophysicists
- Master drillers
- Pump test experts

Support services

- GIS experts
- Groundwater modellers
- Water quality experts

Operation and maintenance

- Groundwater treatment process experts
- SCADA experts
- Water supply operators
- Groundwater resource and quality experts

Human capital

Investigation and development

Hydrogeologists	Geophysicists	Master drillers	Pump test experts
Geologists	Geophysicists	Geologists	Geologists
Engineers	Physicists	Civil and mechanical engineers	Engineers
		Technical assistants (geologists/ engineers)	

Human capital

Support services

GIS experts	Groundwater modellers	Water quality experts
Geoinformatics	Mathematicians	Chemists
Geographers	Hydrogeologists	Geologists
Geologists		Chemical engineers
Engineers		Civil engineers

Human capital

Operation and maintenance

Groundwater treatment process experts	SCADA experts	Water supply operators	Groundwater resource experts
Hydrogeologists	Electrical & electronic engineers	Hydrogeologists	Hydrogeologists
Water quality experts	Programmers	Engineers	Groundwater modellers

CONTENT

1. INTRODUCTION
2. GROUNDWATER IS A FRESHWATER RESOURCE
3. GROUNDWATER UTILISATION
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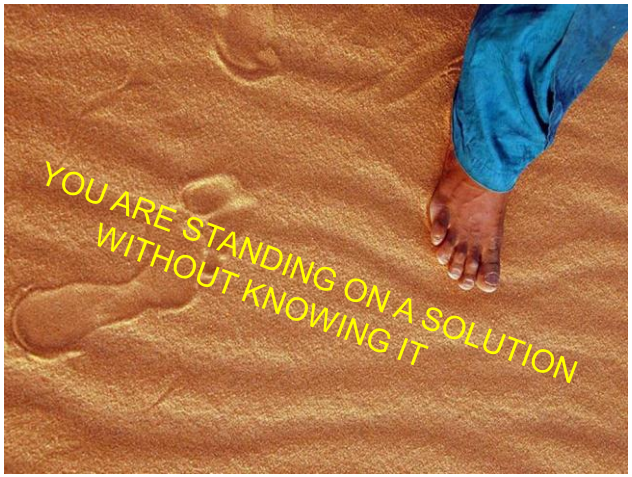
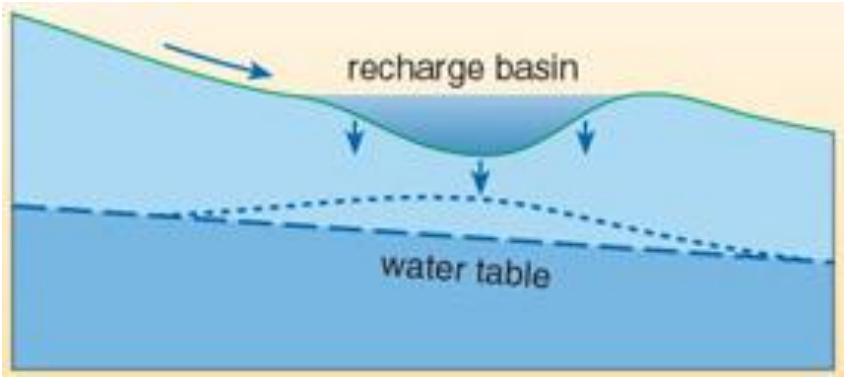
6. DON'T BE SAD
7. HUMAN CAPITAL
8. WAY FORWARD
9. FINAL REMARKS



Implement conjunctive water use

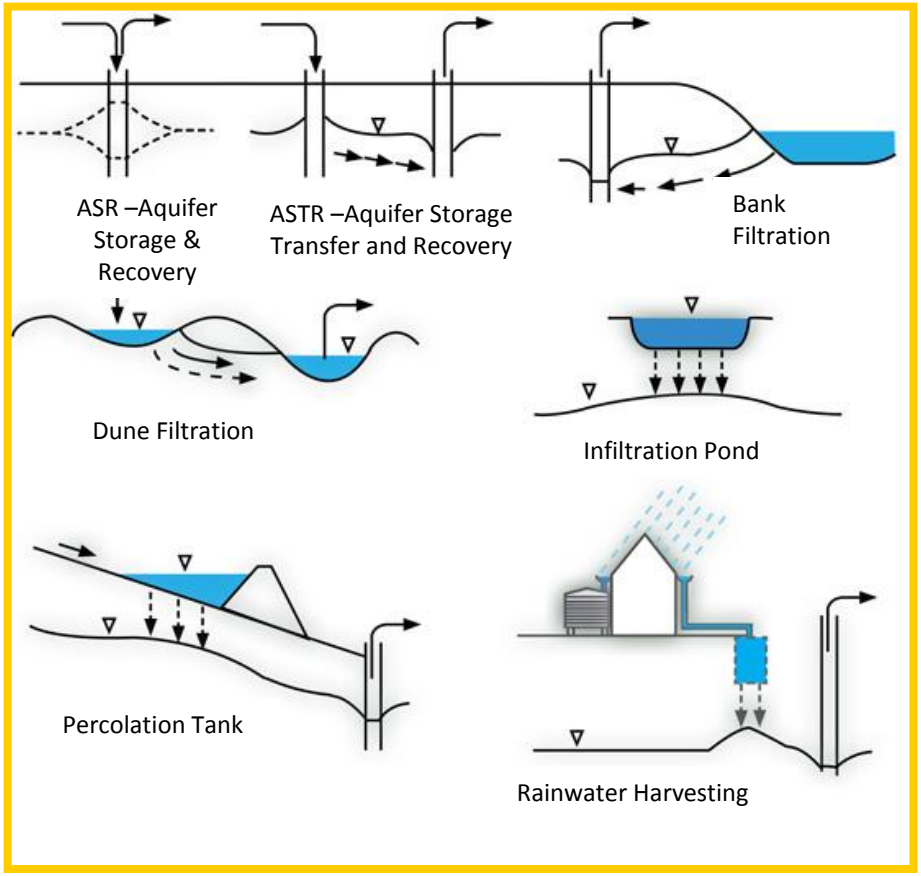
Raining season	• Use river water • Artificial aquifer recharge
Dry season	• Use groundwater • Pump groundwater into river

Stream support system pumps groundwater into a river to increase the flow

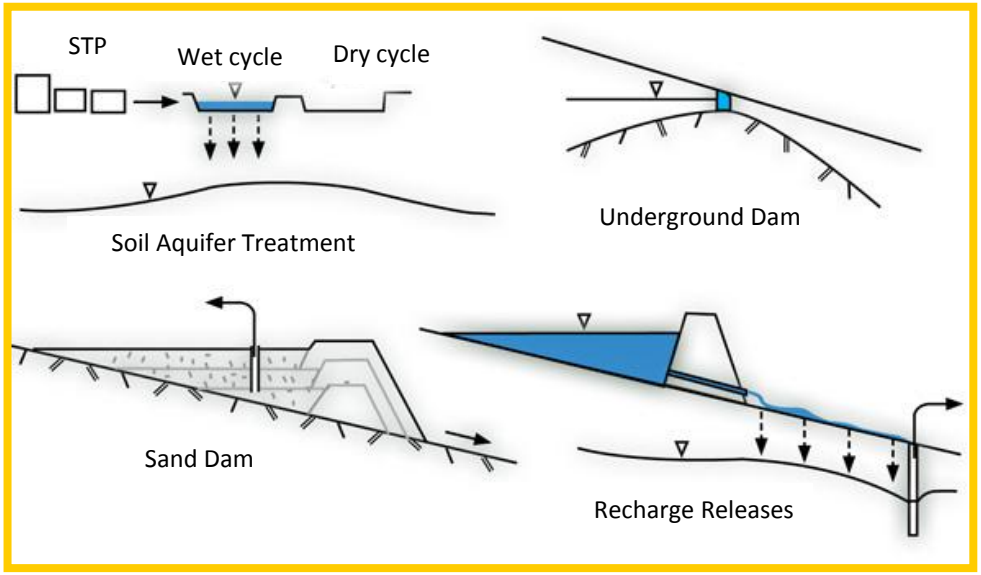


Runoff is collected in recharge basin and infiltrates into the ground

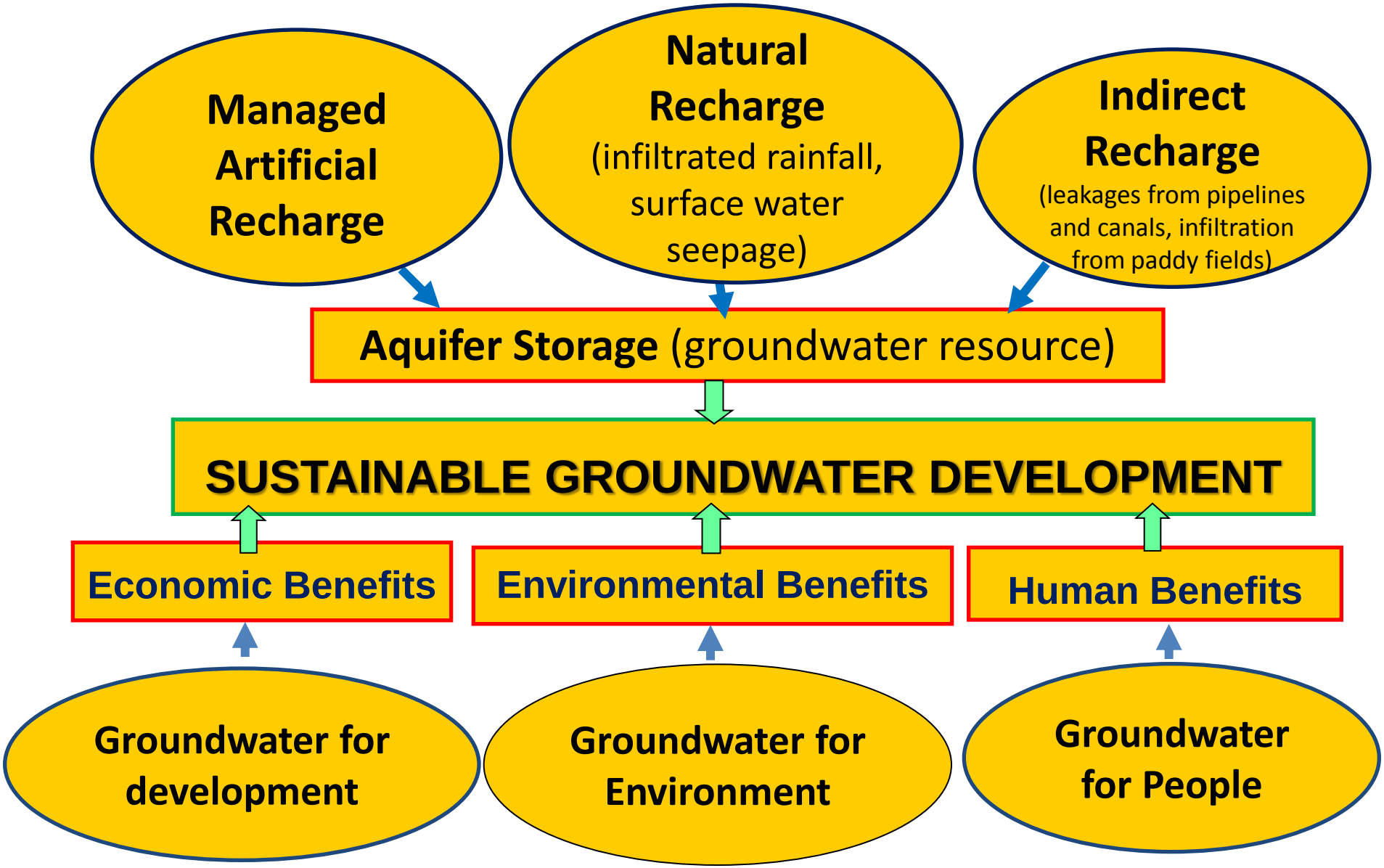
Implement managed aquifer recharge (MAR)



- To take advantage of the increase in rainfall; and
- To mitigate the impact of lowering of groundwater levels



Implement integrated groundwater management



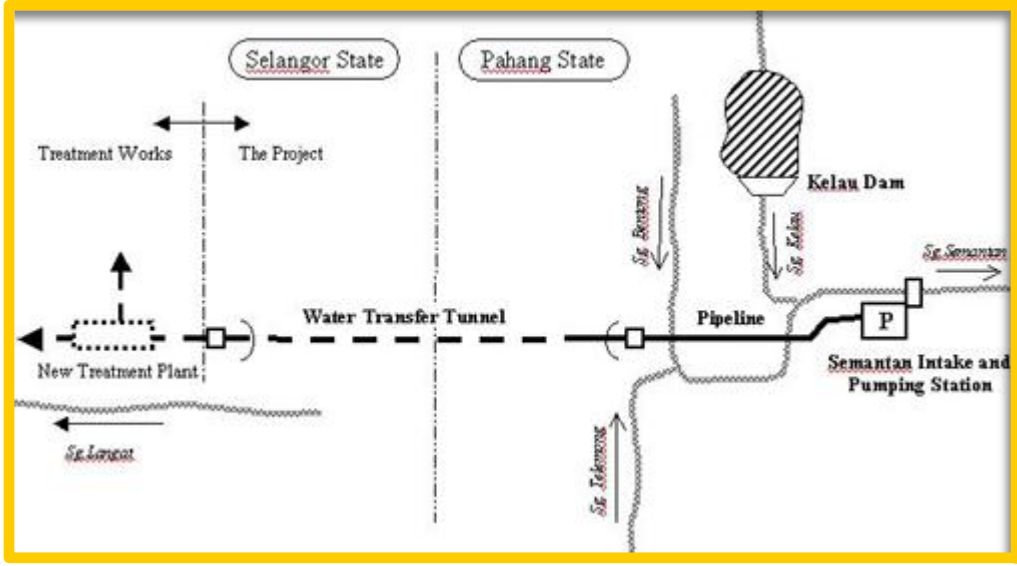
Implement IWRM

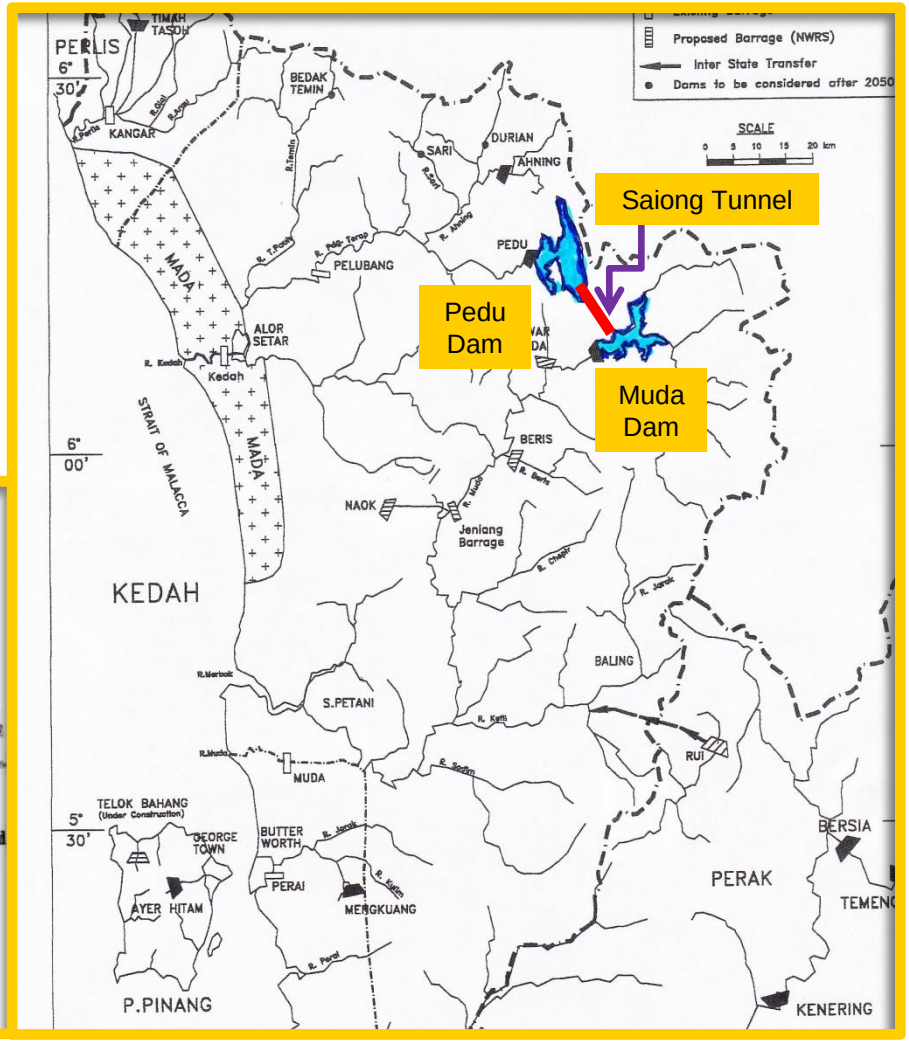
IWRM

- considers different users of water together – different water users are interdependent.
- water allocations & management decisions consider the effects of each use on the others.
- the goal is sustainable development & management of water resources.

IWRM – Malaysian Way

- Sharing of water between river basins: inter-basin water transfers
- Sharing of water between states: inter-state water transfers





Implement water neutral development

Harvest local water resources

- Rainwater
- Stormwater
- Groundwater

Efficient water use

- Potable use
- Non-potable use

Treatment of wastewater

- Recycle
- Reuse
- Discharge to water bodies

To be coupled with other green building initiatives

Regulate groundwater industry

- It is critical to regulate groundwater activity at an early stage
- Once catalysed, groundwater development is impossible to regulate
  - difficult to initiate reforms once there are large number of unregulated groundwater users
  - avoid groundwater anarchy; tame the beast before it becomes too big to tame

Grandpa's well

Father's well

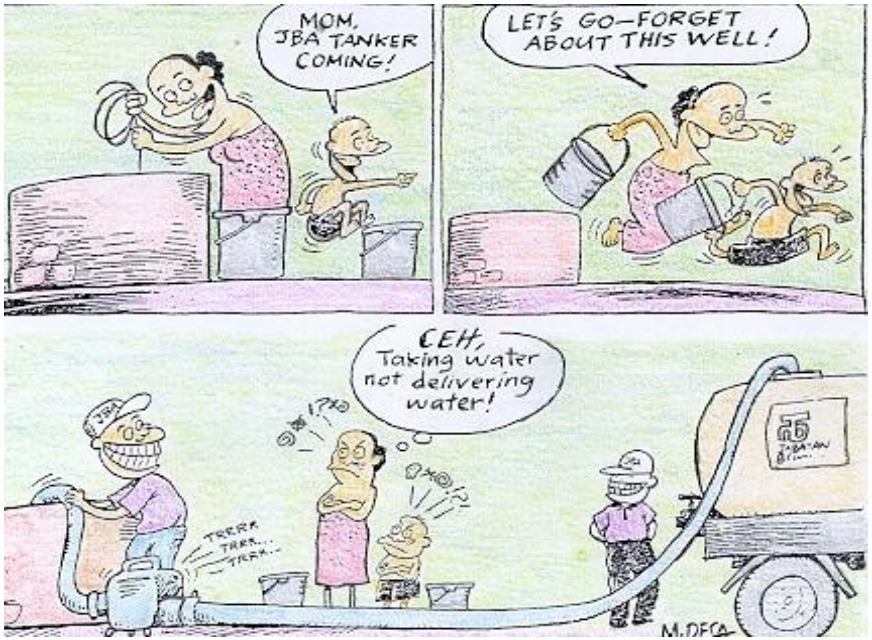
Grandson's well

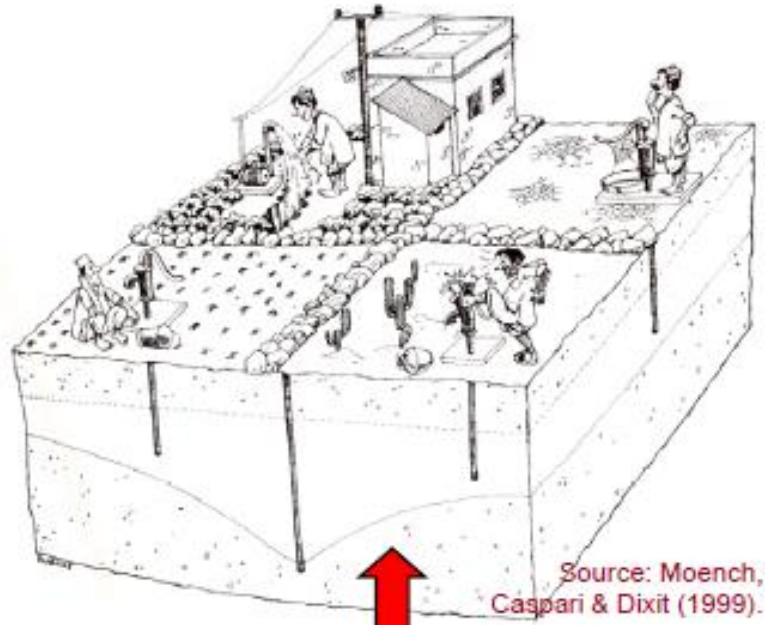
Paradigm shifts in water management

- Rain to be regarded as a resource – paradigm shift from drain to retain
- Groundwater first and dam last option in the development of water resources - paradigm shift from utilising man-made water storages to utilising natural water storages
- Focus on decentralised projects – paradigm shift from spending millions RM on one project to spending millions RM on several projects

Focus on groundwater

- Malaysia needs groundwater supply systems - systems are in place to address lack of surface water and to adapt to climate change
- Introduce policy on groundwater use, say 30 % groundwater use in public water supply system by 2020.
- Ensure sustainable development of groundwater resources – avoid groundwater anarchy

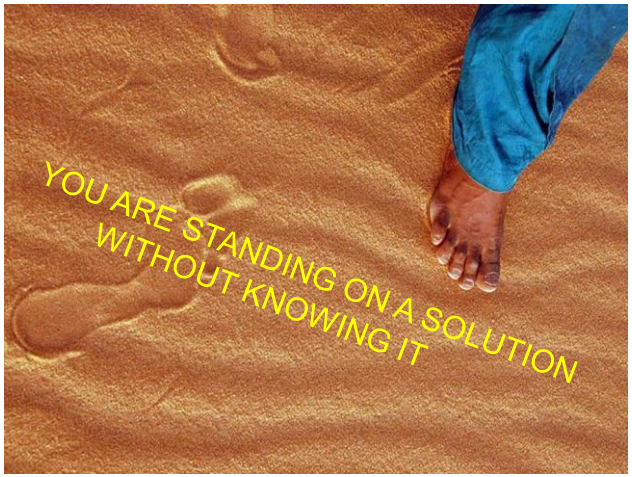




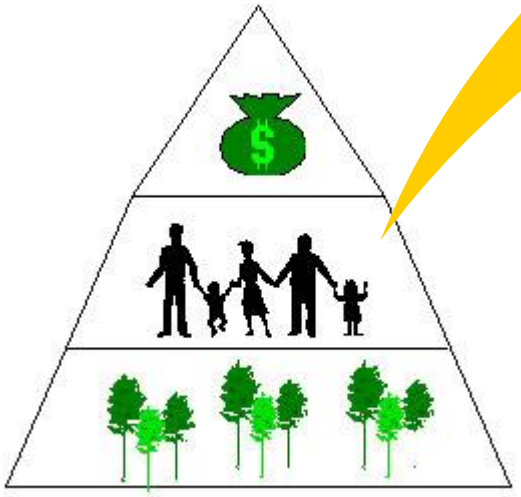
Groundwater anarchy

CONTENT

1. INTRODUCTION
2. GROUNDWATER IS A FRESHWATER RESOURCE
3. GROUNDWATER UTILISATION
4. WHY GROUNDWATER?
5. WATER RESOURCES IN MALAYSIA
6. DON'T BE SAD
7. HUMAN CAPITAL
8. WAY FORWARD
9. FINAL REMARKS



SUSTAINABILITY

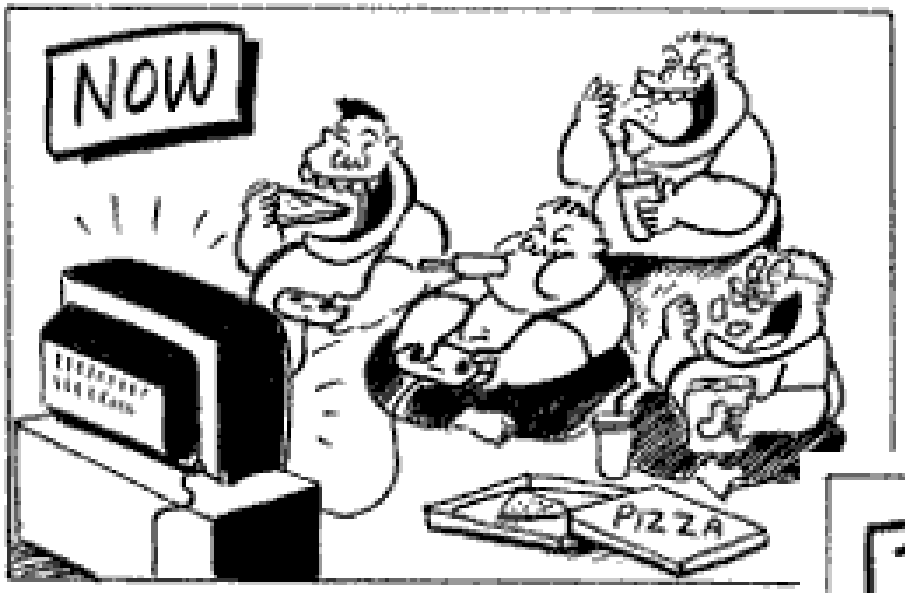


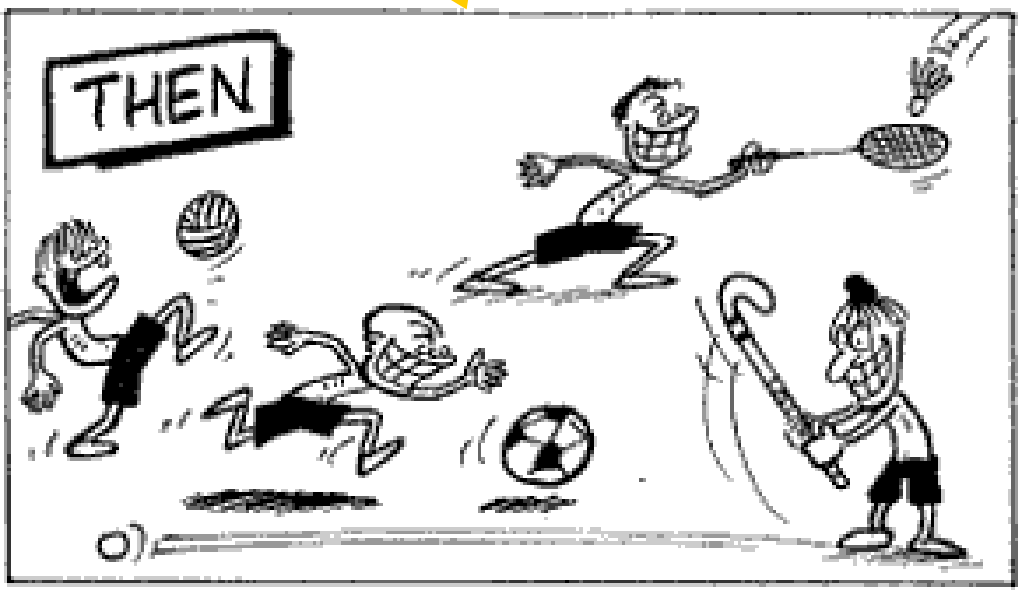
Create wealth

Prosperous life

Healthy environment

SUSTAINABILITY





Political will in groundwater development

Launching of National Water Resources Policy in conjunction with the launching of World Water Day 2012 on 24 March 2012 (MM 25 March 2012)

Tingkatkan Sumber Air Negara

"…….. kajian dan pembangunan sistematik sumber air tanah bagi membantu merealisasikan jaminan bekalan air dan bekalan makanan negara pada masa hadapan."

Media launch of IGM Outreach Programme and Groundwater Conference on 12 April 2012 (The Star, 13 April 2012)

Groundwater to be tapped for sustainable supply

"Climate change brings about a lot of uncertainty. Water from some rivers is just too polluted so we are studying if groundwater can be exploited."

Launching of IGM Outreach Programme and Groundwater Conference on 8 May 2012 (The Star, 9 May 2012)

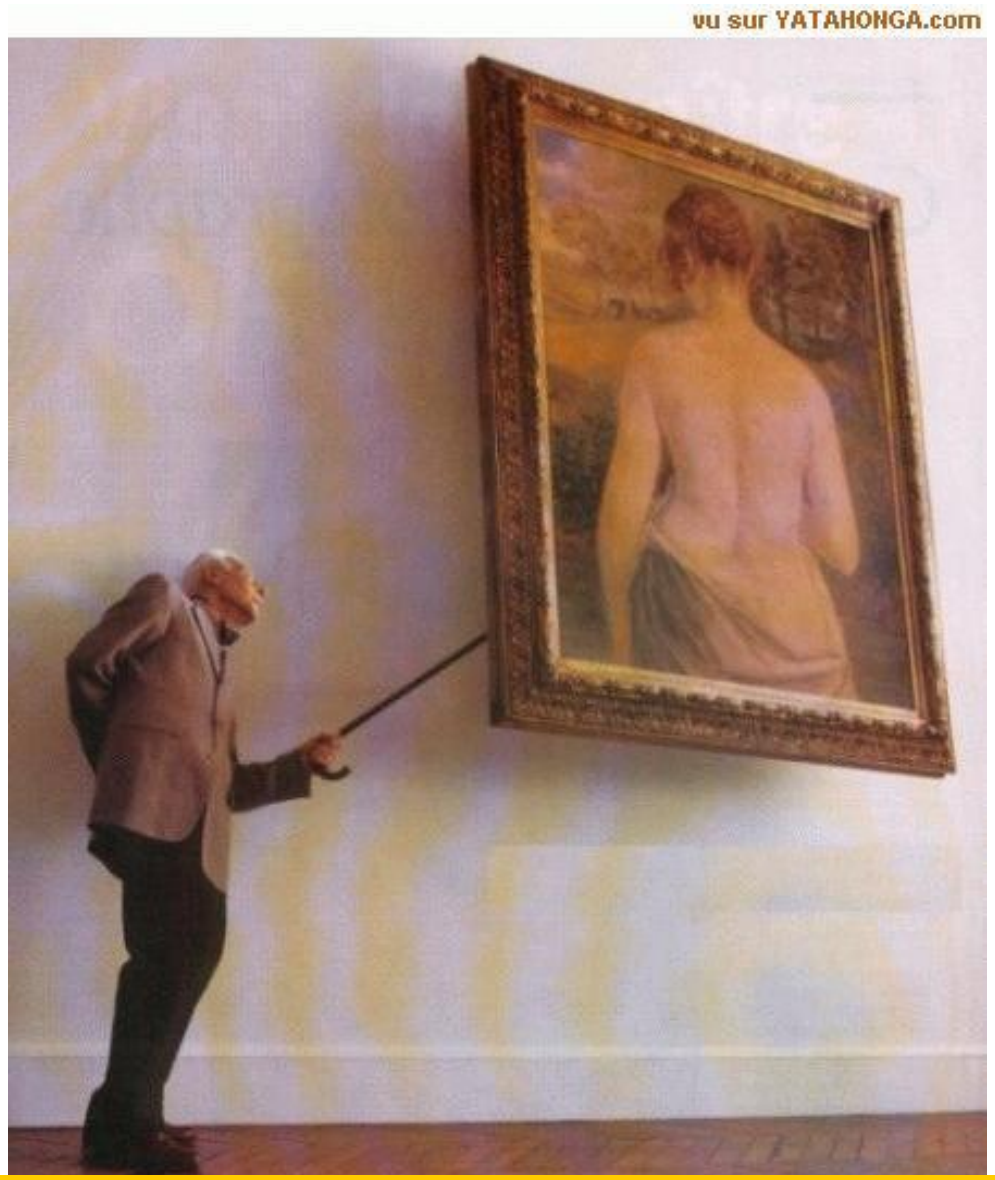
Sultan: Tap groundwater

"Groundwater to be developed as an alternative, so as to prepare for prolonged periods of drought in Selangor. If we are too reliant on surface water sources, consumers will be affected if there is a prolonged drought."

Final remarks

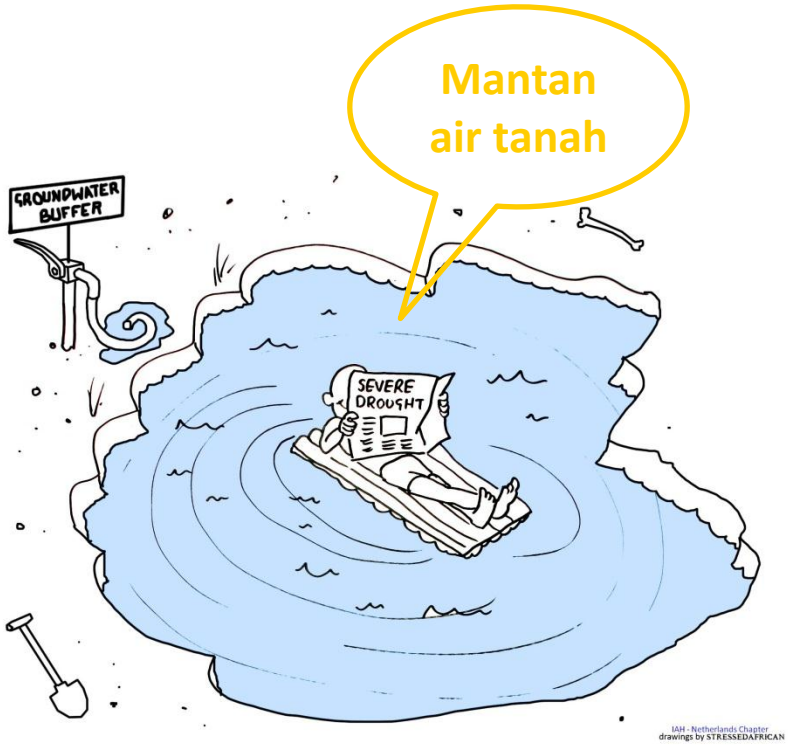
Groundwater development takes two sides –
Need to see the picture from both sides

SUSTAINABLE GROUNDWATER DEVELOPMENT HAS ONLY ONE SIDE – POSITIVE SIDE



Final remarks

Groundwater is, in general, a very reliable supply of water both in terms of quantity and quality.



Developing groundwater resources in a sustainable way, is a promising option in improving water supply services and adapting to climate change.

THANK YOU

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