



THE
AUSTRALIAN
WATER
PARTNERSHIP



Groundwater Innovations

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Outline

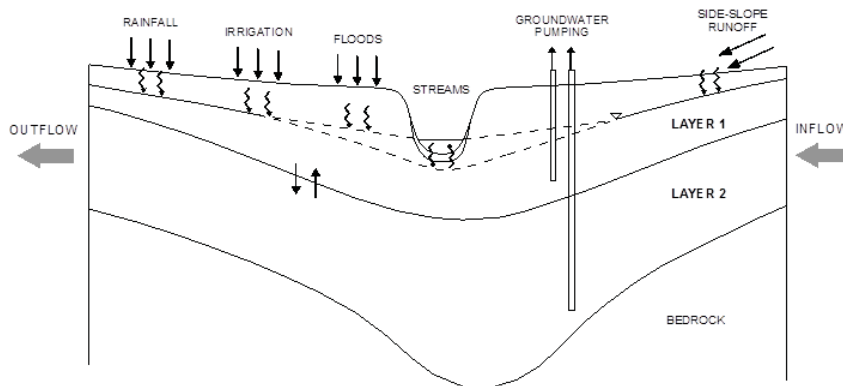
1. Aquifers are unique natural endowments
2. If you can't measure – You can't manage
3. Bandwidth of Aquifer Resilience
4. GWL : static, rise or fall – PROBLEM!
 1. Waterlogging & Salinization
 2. Saline water intrusion & up-coning
 3. Flooding
5. Urban Water Management
 1. Managed Aquifer Recharge
 2. Green Disposal of Treated Waste Water
6. Possible areas of support from ADB to DMCs

Aquifers Store, Treat and Transfer Water



Inflow

- recharge from rainfall;
- recharge from floods;
- recharge from irrigation;
- recharge from farm tanks;
- recharge from rivers;
- inflow from other basins;



Outflow

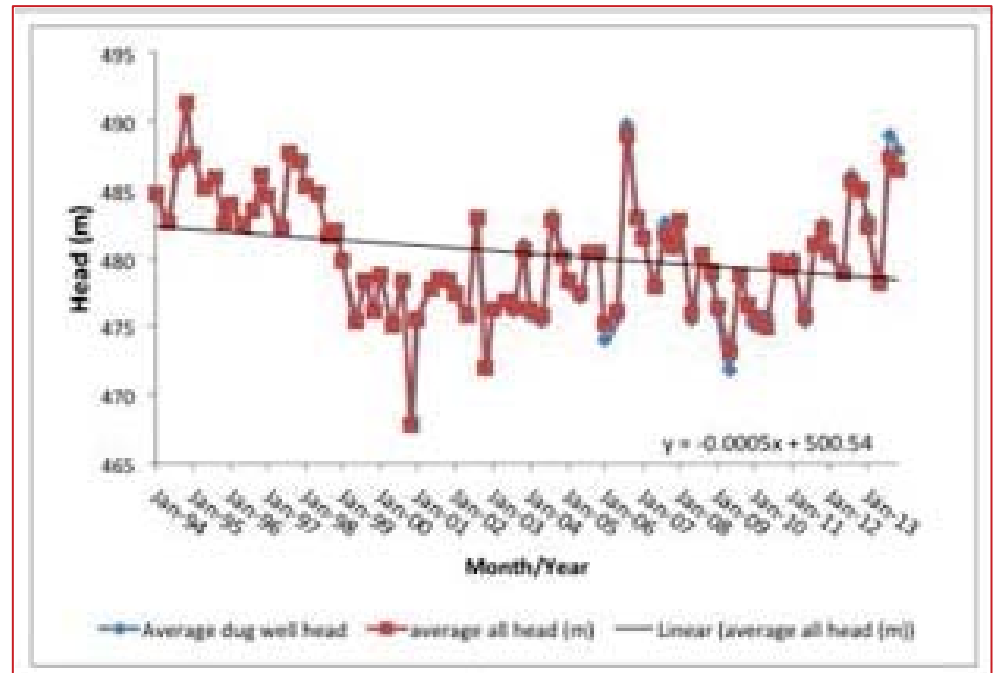
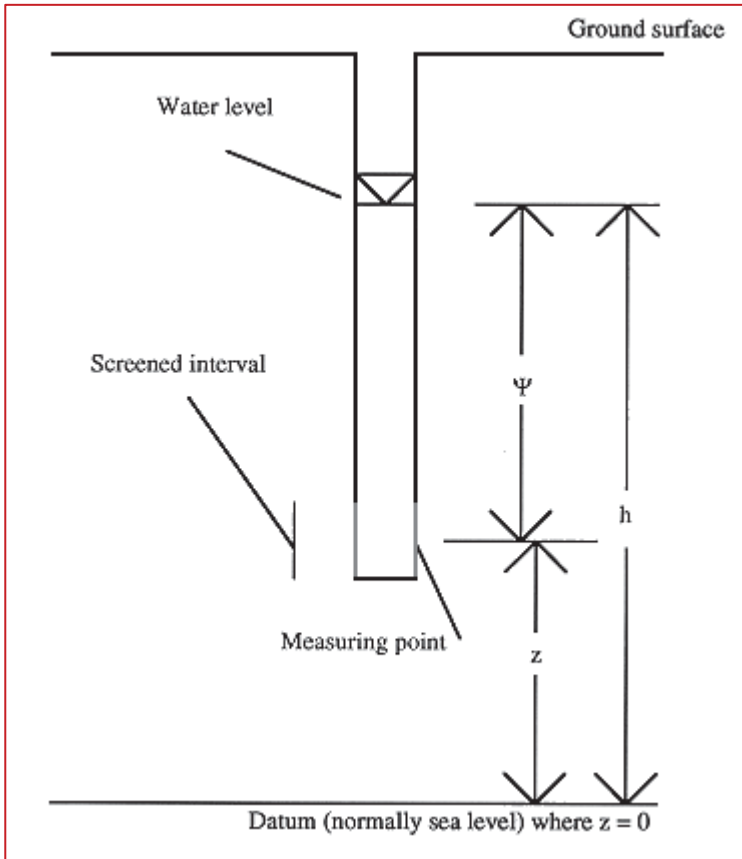
- evapotranspiration from groundwater;
- pumping from groundwater;
- discharge to rivers;
- outflow to other basins; and

ΔS = change in groundwater storage.

Except for pumping, none are directly measurable

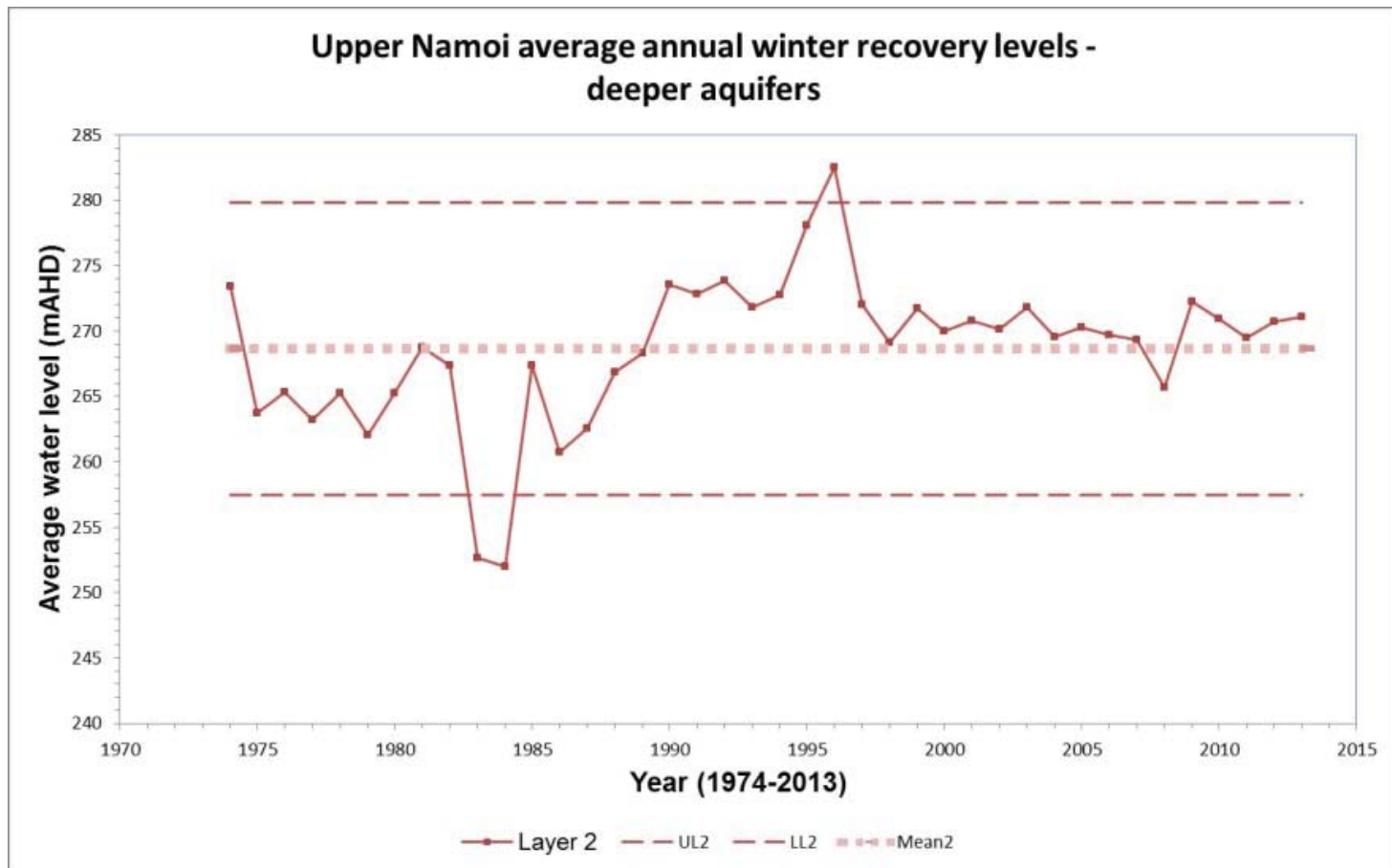
IF YOU DON'T MEASURE IT
YOU CAN'T MANAGE IT

Groundwater Levels fluctuate!



Bandwidth of Aquifer Resilience

Prathapar et al. 2015



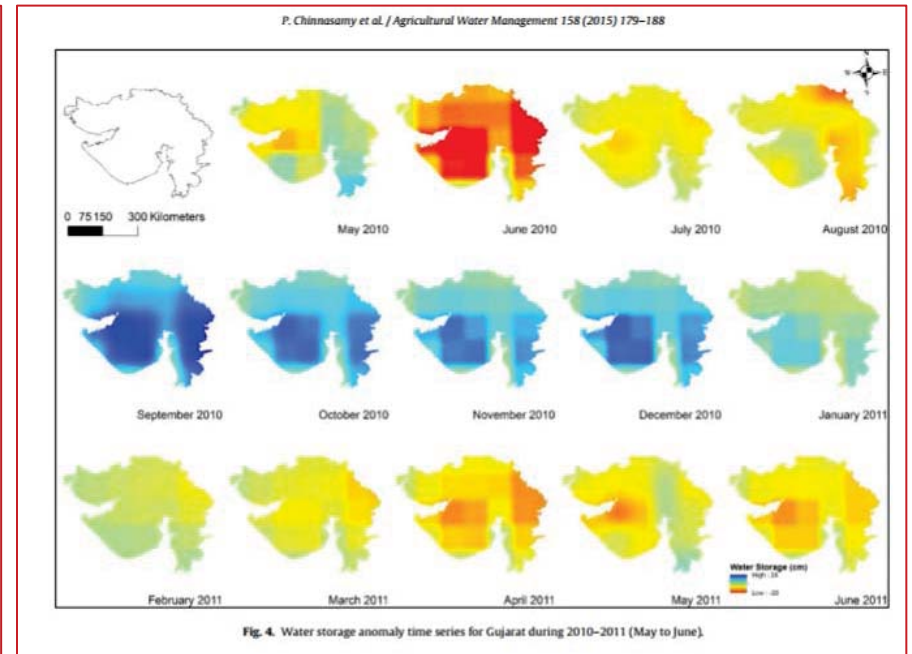
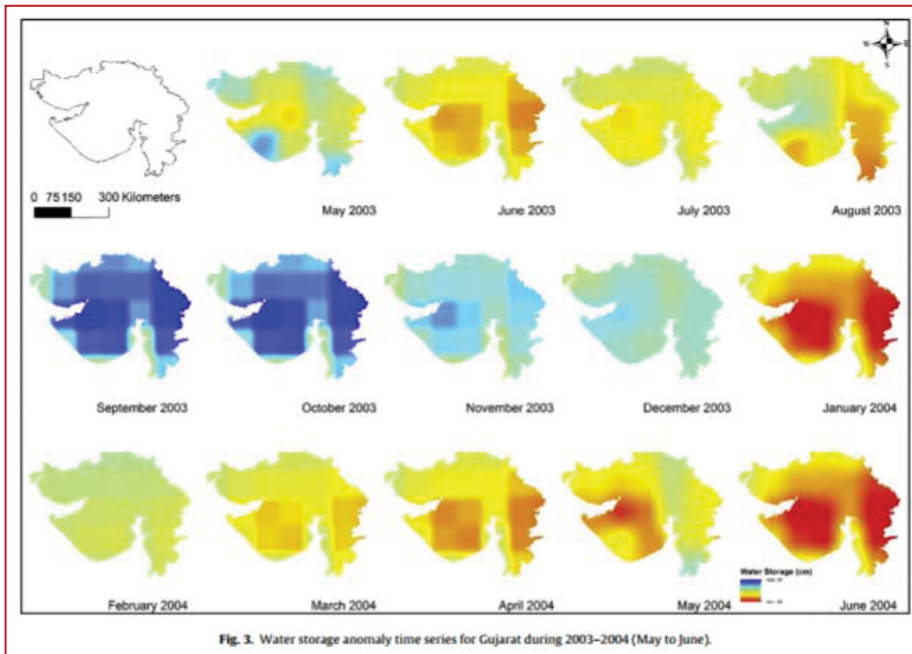
In the absence of piezometric data

Chinnasamy et al. 2015



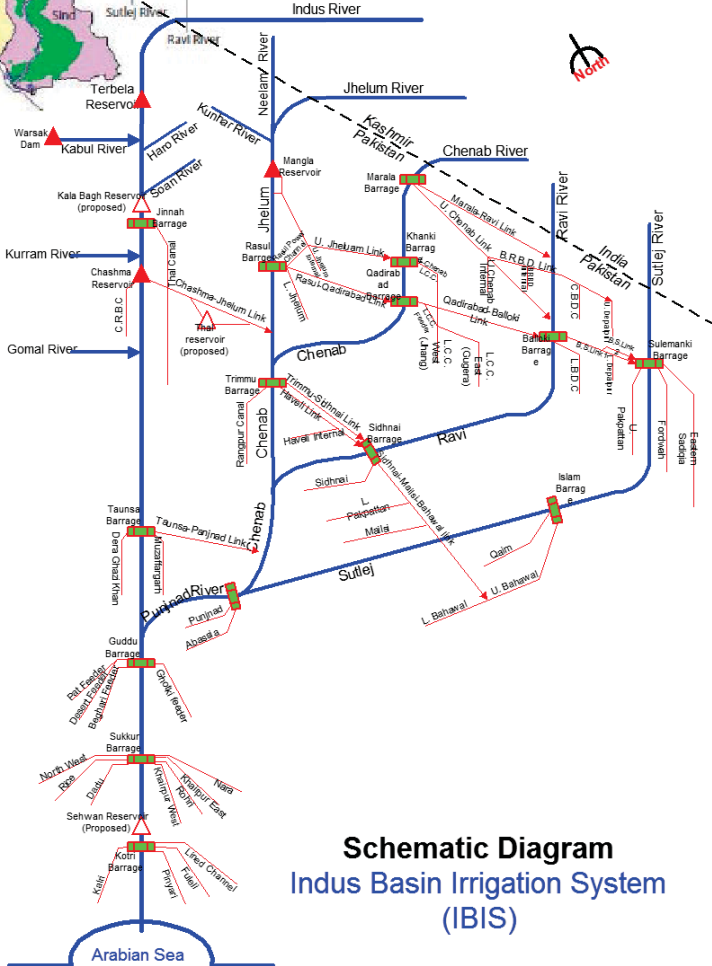
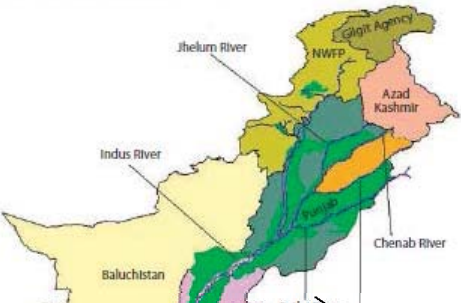
Water Storage Anomaly 2003-2004, Gujarat, India

Water Storage Anomaly 2010-2011, Gujarat, India

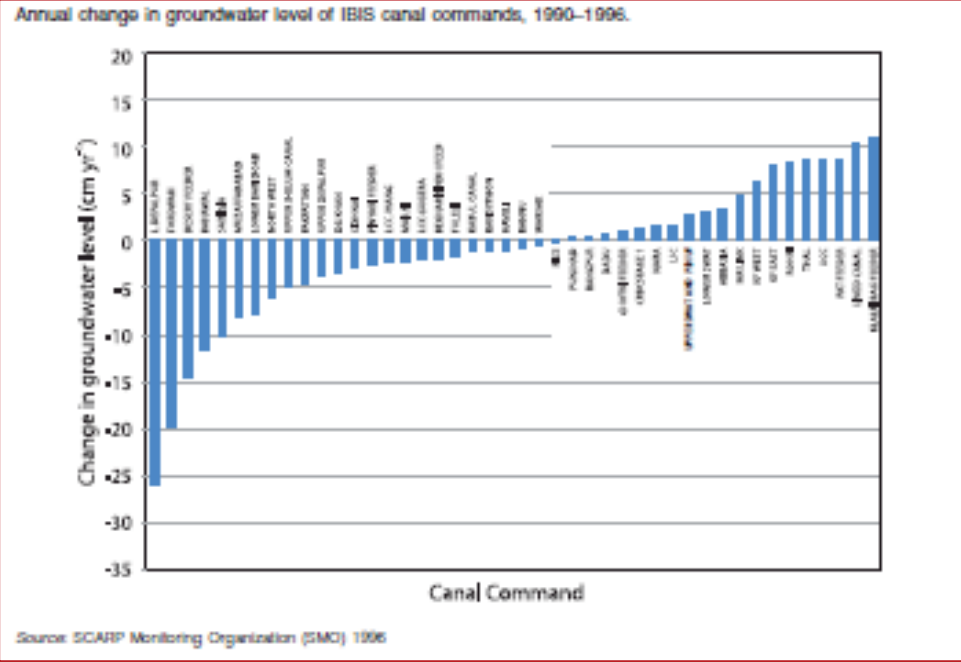


GRACE Anomalies

Changes to Groundwater Levels in IBIS Aslam & Prathapar (2006)



Schematic Diagram
Indus Basin Irrigation System
(IBIS)



Source: SCARP Monitoring Organization (SMO) 1996

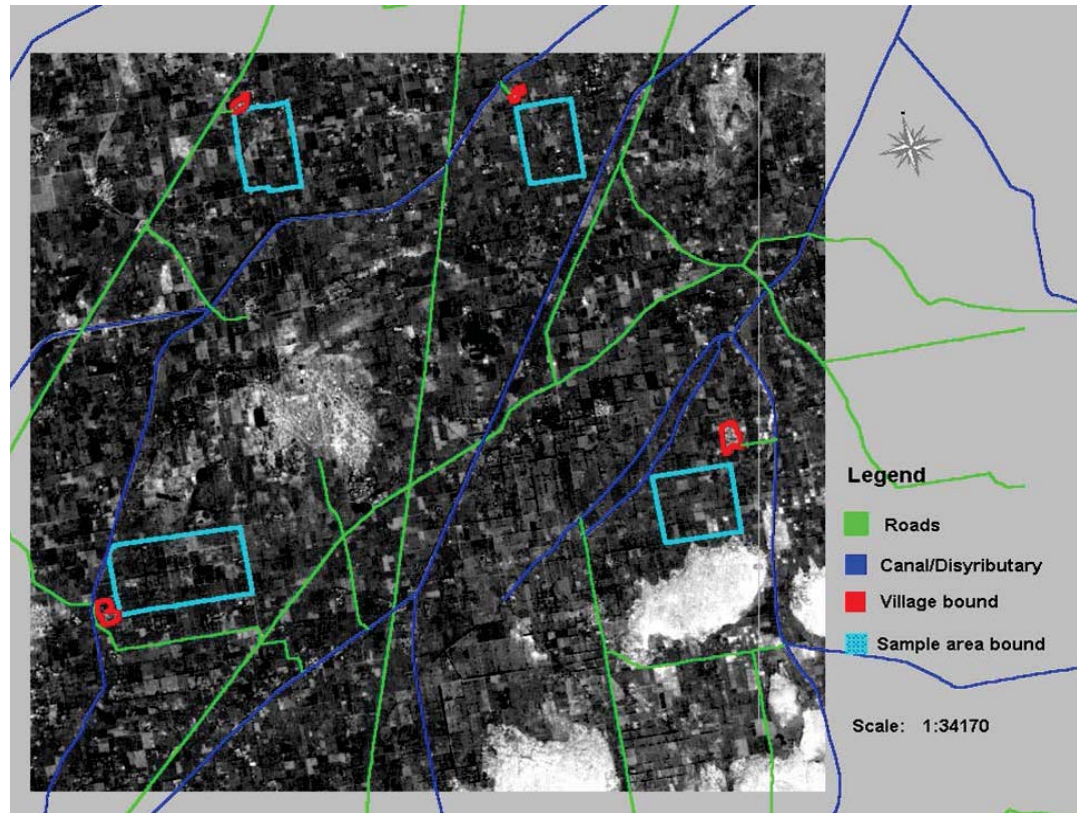


Rise, Static or Fall, PROBLEMS!

Managing Groundwater Induced Salinization



Sindh, Pakistan



NSW, Australia

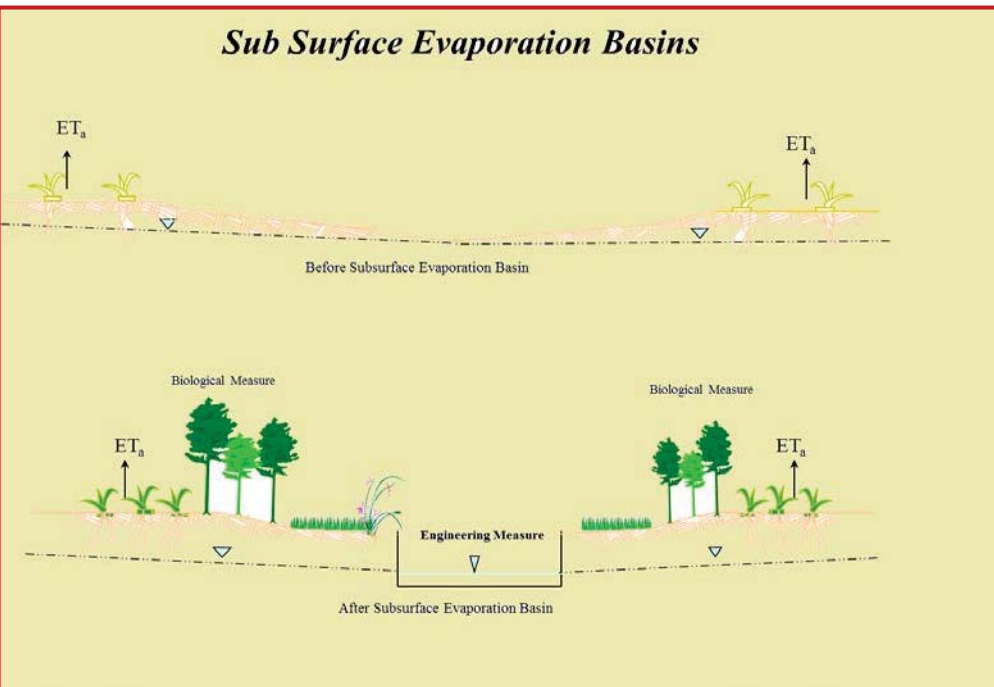


Subsurface Evaporation Basins

Surinaidu et al. 2016



Sub Surface Evaporation Basins



- Saline groundwater is discharged through bare soil resulting in salinity.
- Bare soil evaporation rates are usually less than 10% PE.
- By re-directing saline groundwater to ponds where evaporation equals PE, area salinized will be reduced.
- Other benefits:
 - Agro-forestry/Fodder
 - Aquaculture
 - Industrial Salts

Managing Up-coning: Skimming Wells



Asghar et al. 2001.

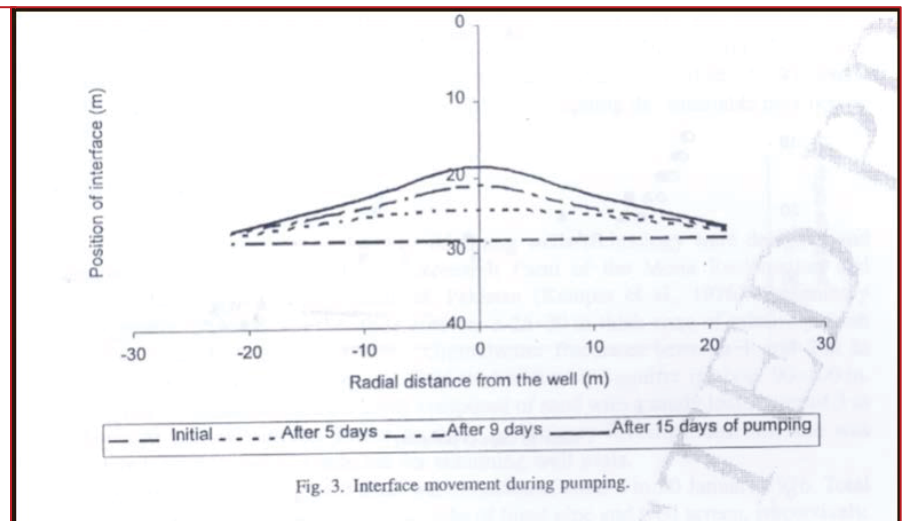
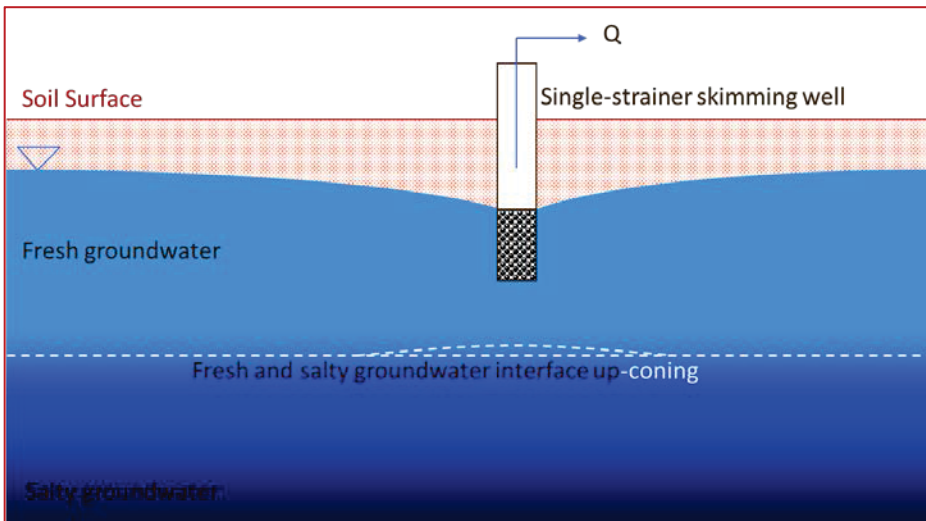


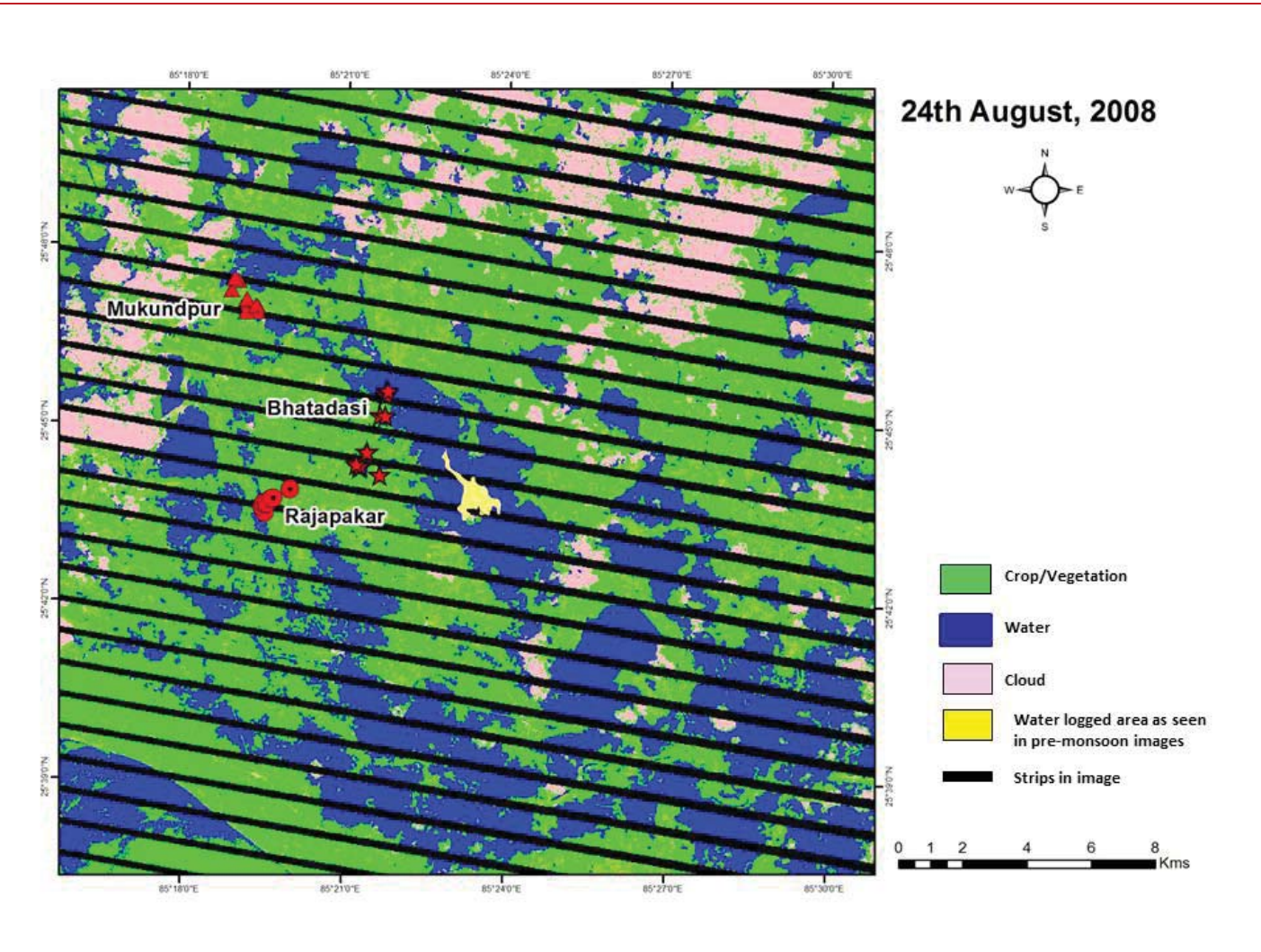
Fig. 3. Interface movement during pumping.



When Groundwater Level Rises

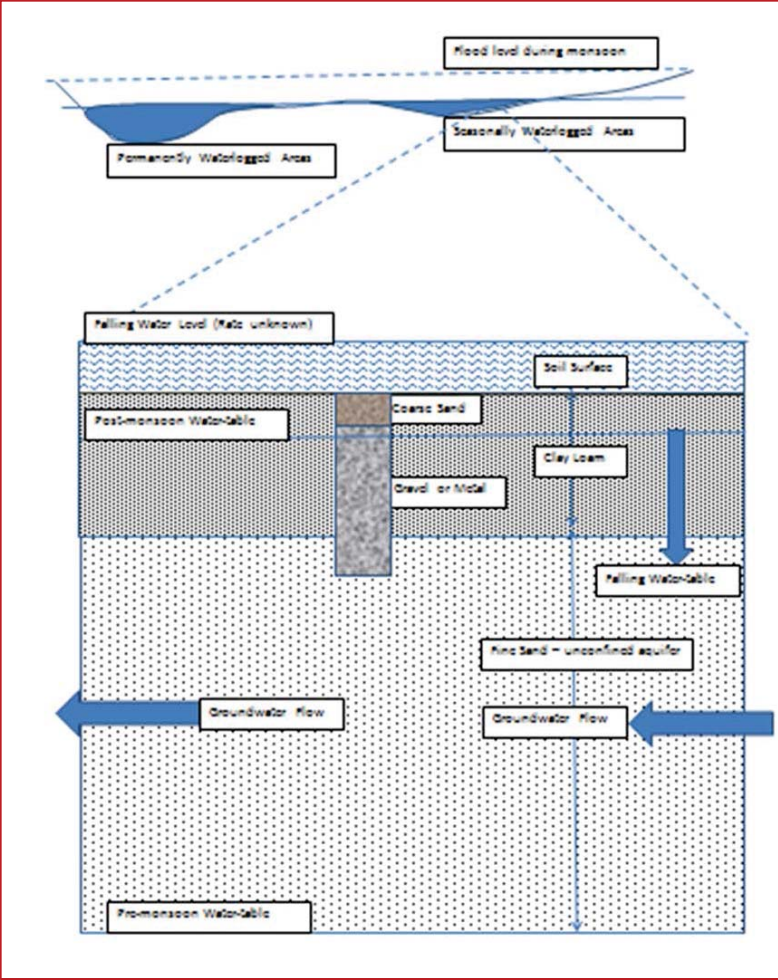
Increasing Flood Resilience

Surface Drainage or Horizontal Sub-surface Drainage is infeasible in Flood Plains of Bihar, India



Vertical Drains

Prathapar et al. 2018

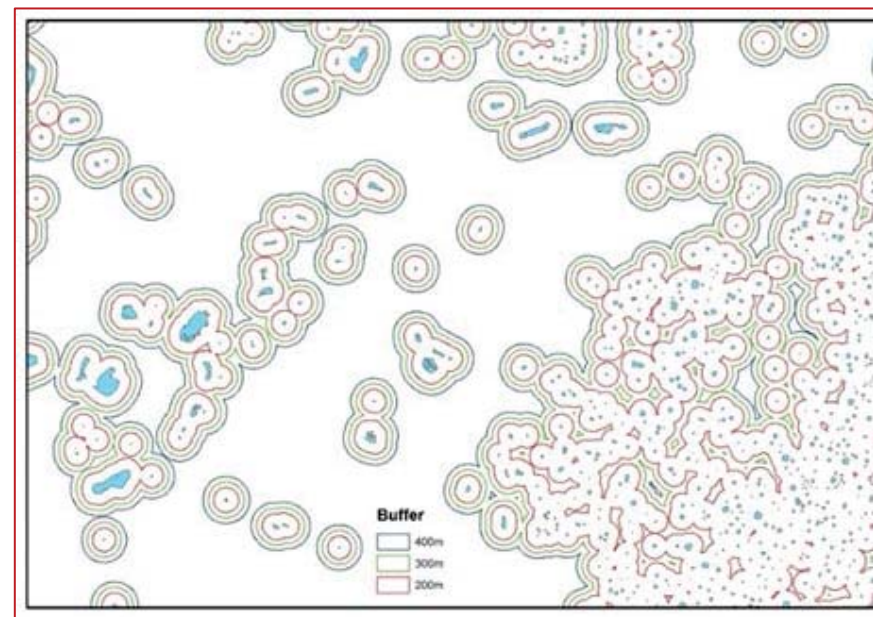


Rehabilitate Village Ponds in the EGP

Okwany et al. 2015



District	Total Tanks		Permanent Tanks		Temporary Tanks	
	# Tanks	Area (ha)	# Tanks	Area (ha)	# Tanks	Area (ha)
Dhanusa	2858	547	1956	473	902	74
Dinajpur	22116	3239	12703	2555	9413	683
Kochbihar	14115	2097	2639	1146	11476	951
Madubhani	15561	2971	7519	2249	8042	722
Maldah	36415	7932	15812	4635	20603	3297
Purnia	9169	2205	1376	724	7793	1481
Rajshahi	41004	6550	27974	5382	13030	1168
Rongpur	14952	1834	4440	1077	10512	757
Saptari	2844	516	1848	426	996	90
Sunsari	1283	197	707	136	576	60



Resilience through Rehabilitated Ponds

Bastakoti et al. 2015



Before

After



Managed Aquifer Recharge

Managing Groundwater Depletion

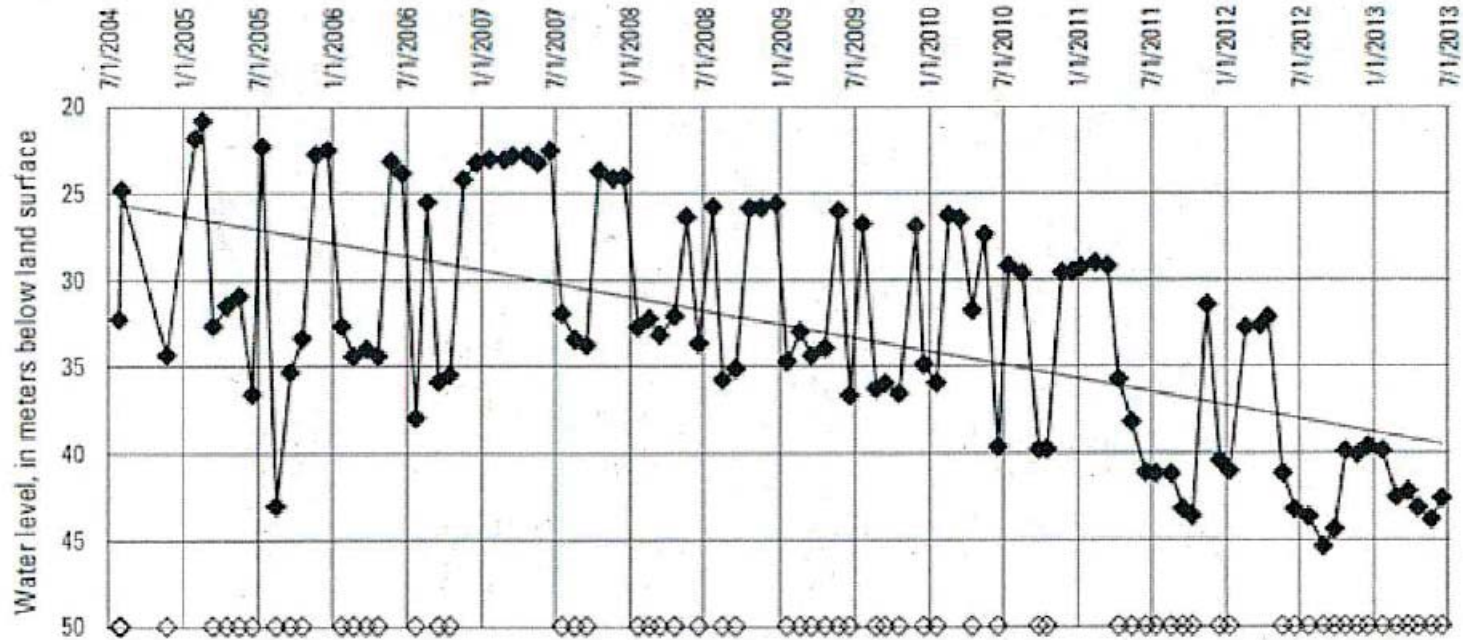


Figure 12: Typical well hydrograph from USGS, Taher et al, 2007 [7]

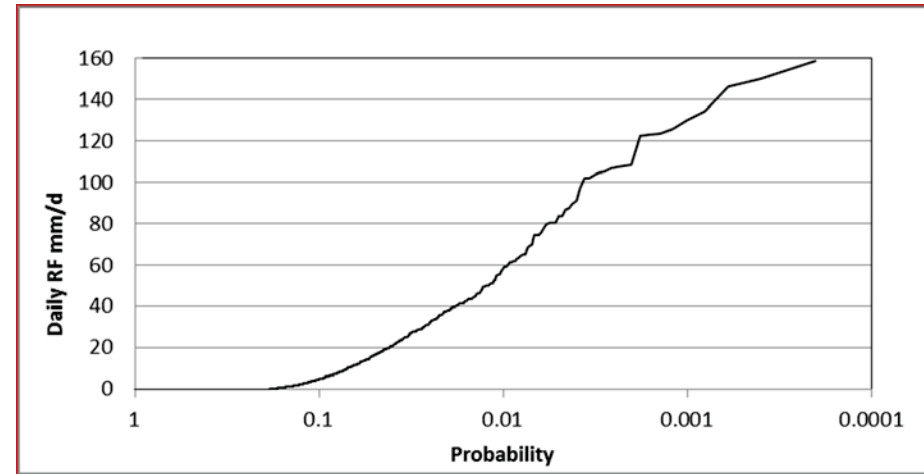
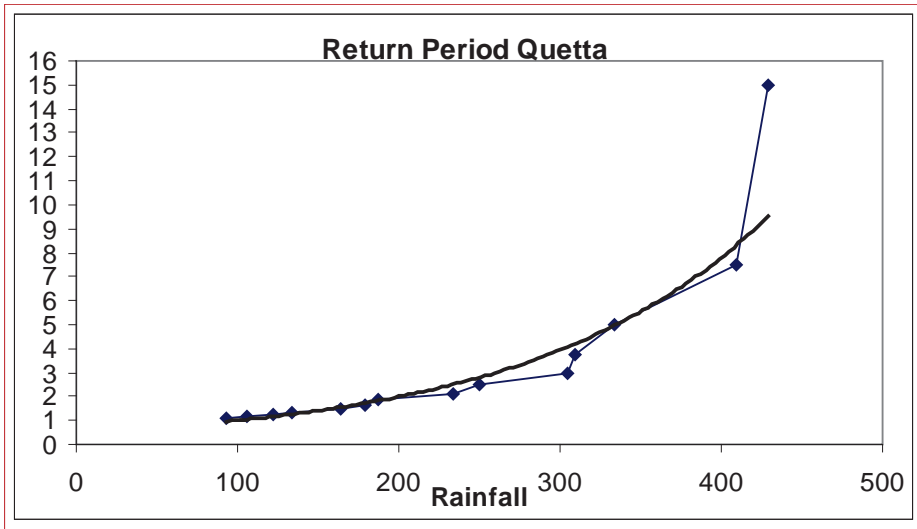
Groundwater Levels in Kabul

Water Availability is Limited

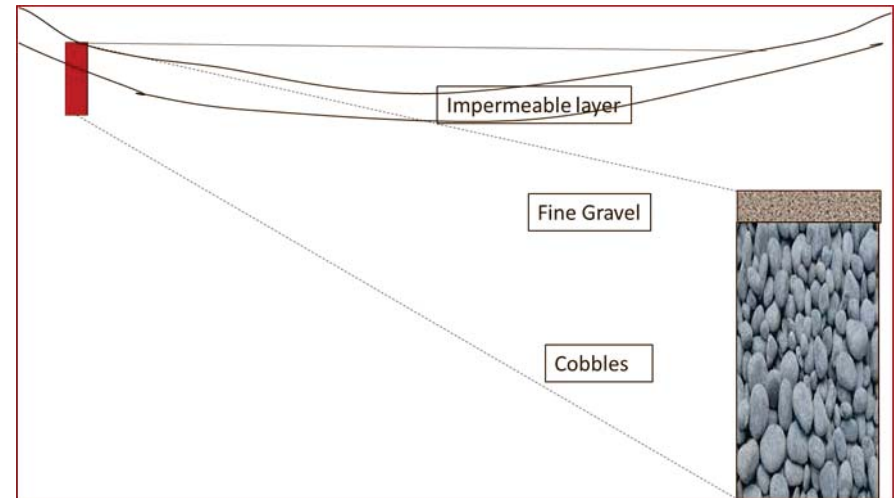


Rainfall in Baluchistan, Pakistan

Extreme Events in Punjab, India



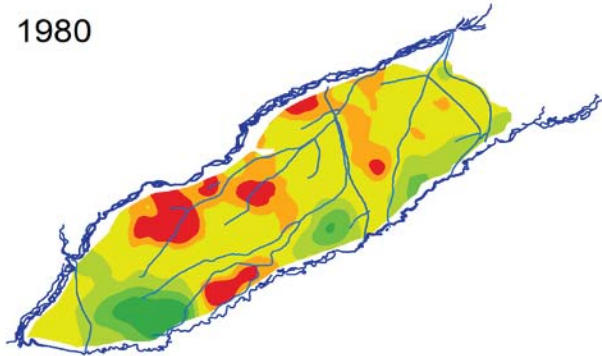
Land for MAR is also limited



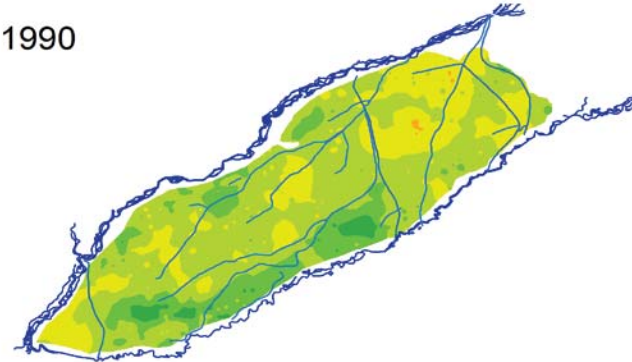
Consider Aquifer Capacity



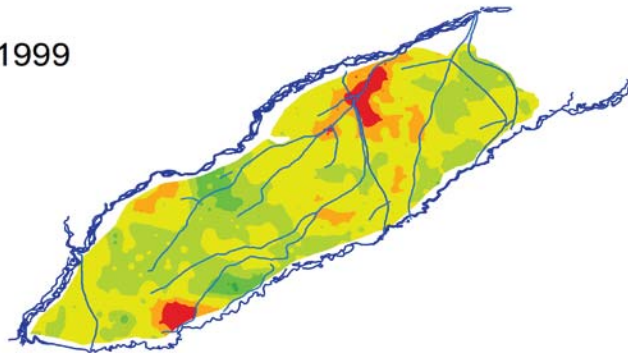
1980



1990



1999



Temporal Change in Depth to Water Table
Rechna Doab, Punjab, Pakistan

Legend

Depth to Water Table (cm)

- 0 - 100
- 100 - 150
- 150 - 300
- 300 - 450
- 450 - 600
- 600 - 1,200
- >1,200

— Canal
— River



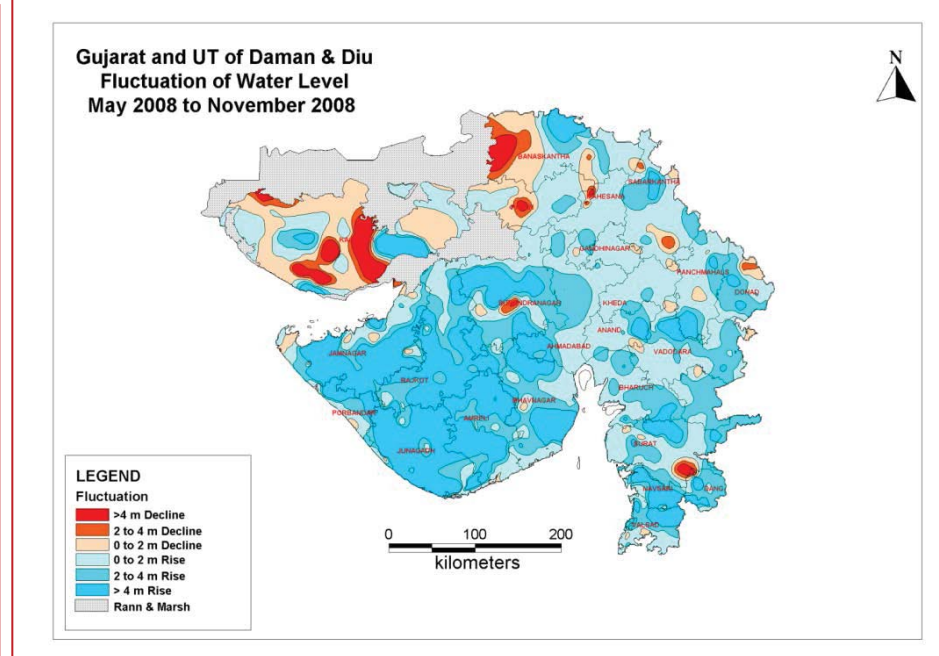
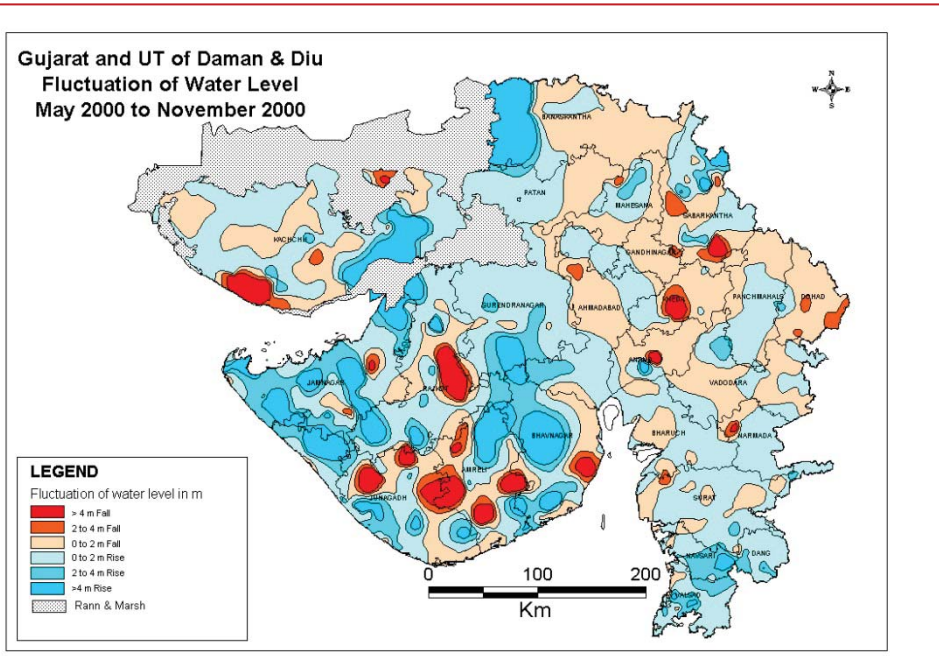
0 40 80 160 Kilometers

Consider Aquifer Type



May-Nov 2000

May-Nov 2008



Acknowledgement: Shah

Kandeel Delay Action Dam at Muslim Bagh,

Balochistan

Acknowledgement: Ashraf



27 12:49 PM

Managing Silt

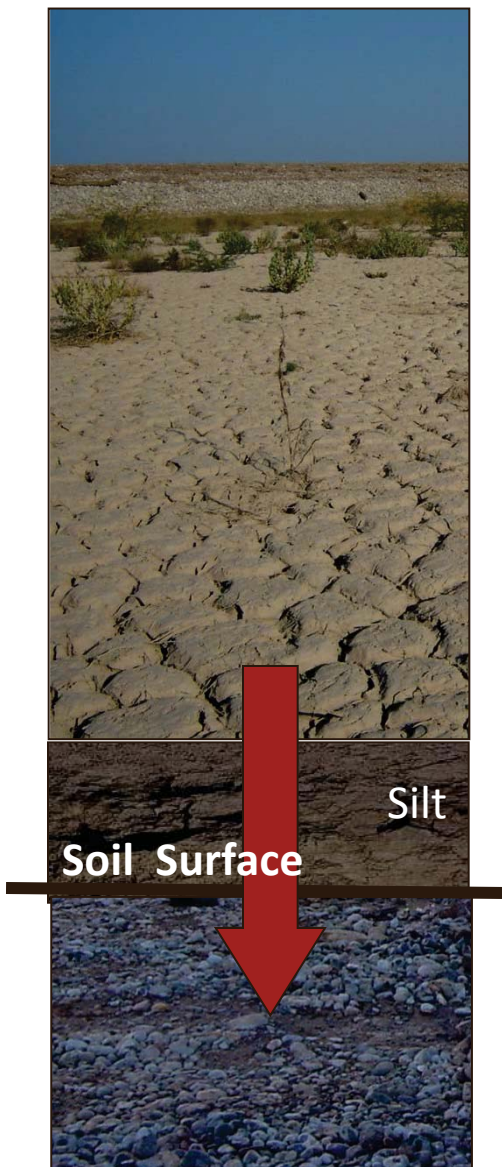


Leaky Dam, Balochistan



Recharge Dam, Oman

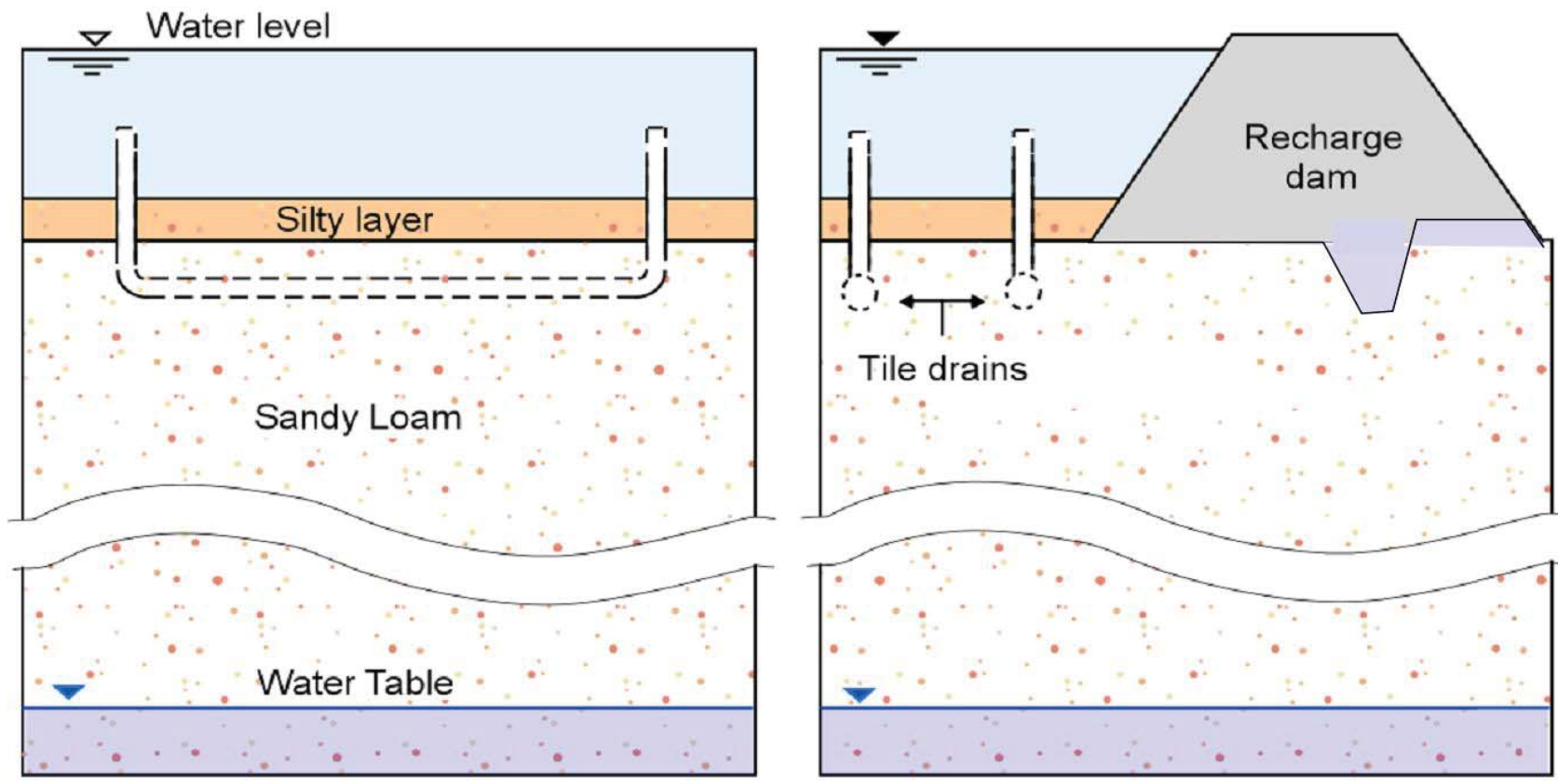




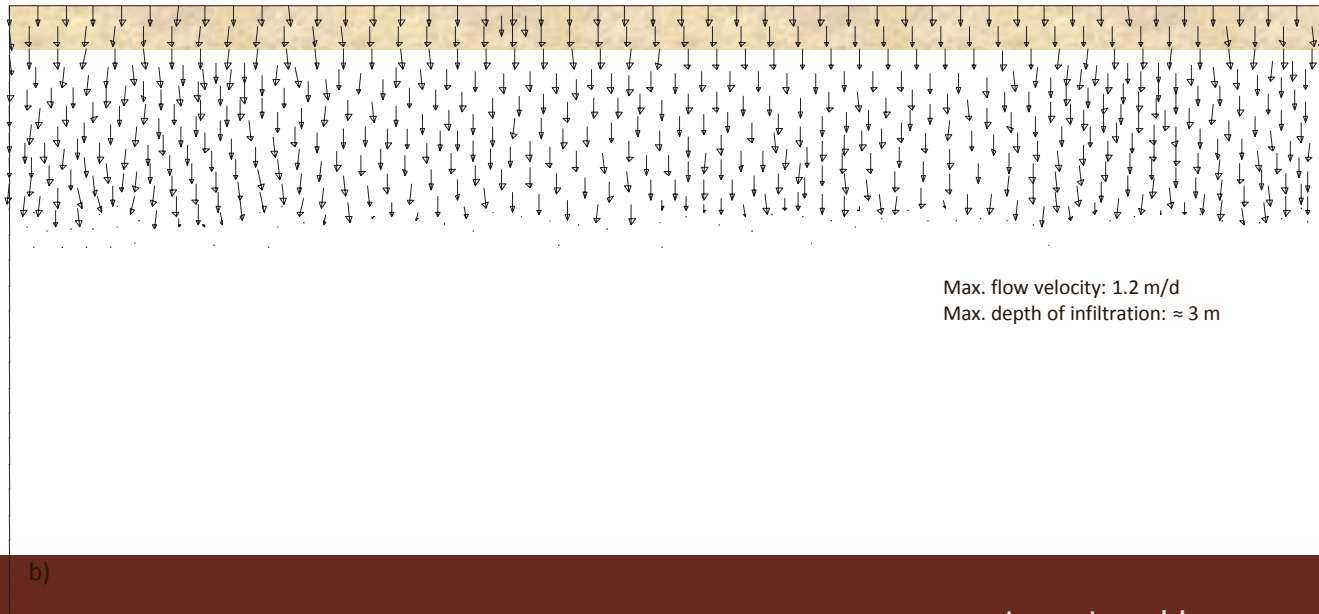
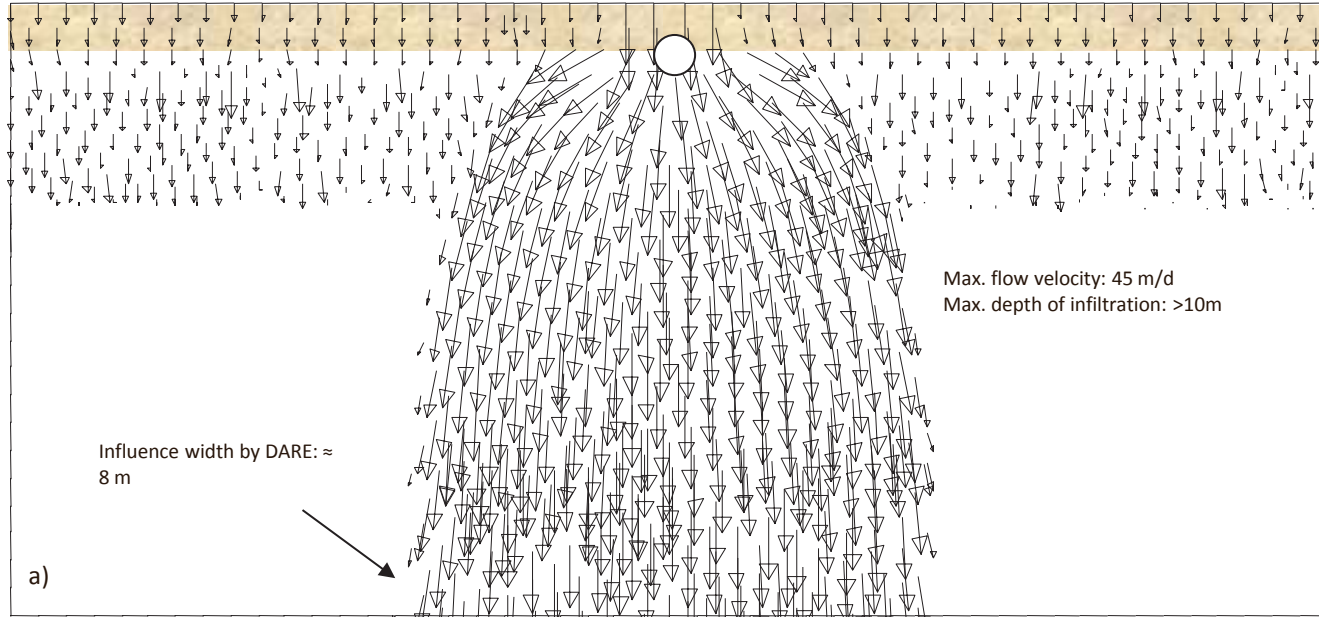
How to by-pass the silt deposition during inundation?

Drain Accelerated Recharge: DARE

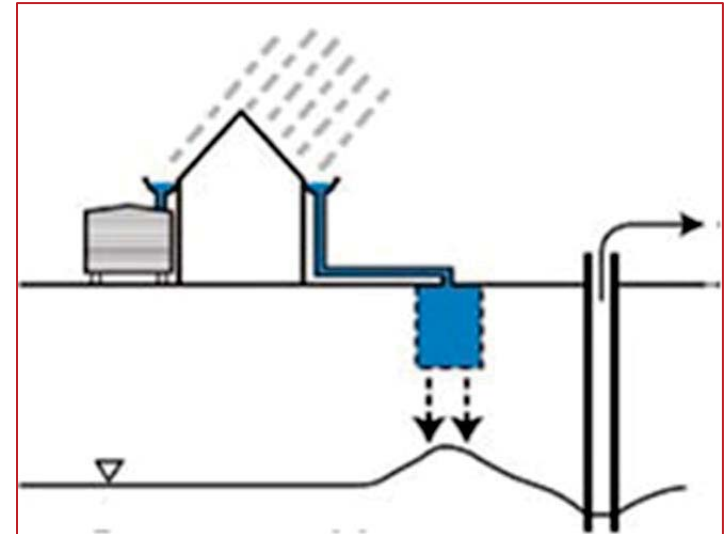
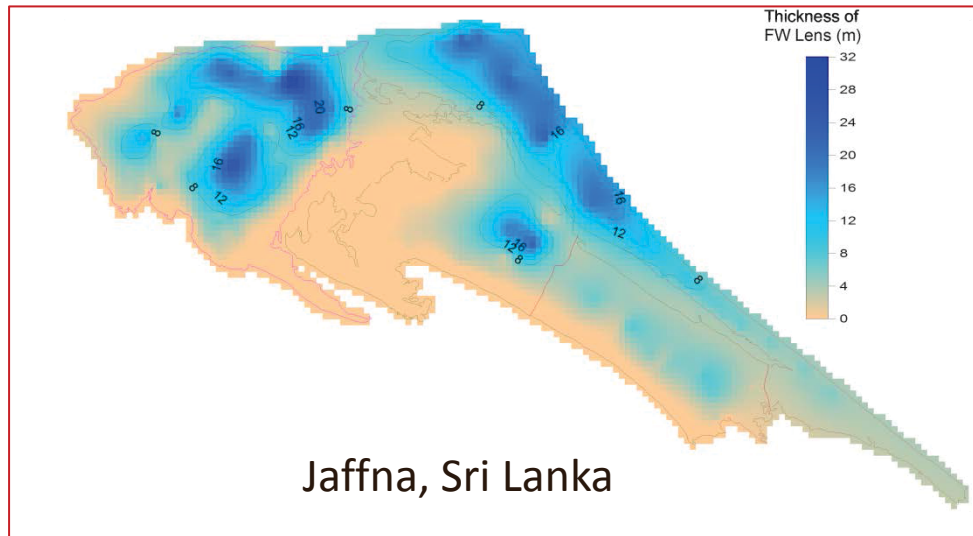
Prathapar et al. 2004



Velocity Vectors



Roof-top Rainwater Harvesting to increase storage and minimize sea water intrusion



TREATED WATER MANAGEMENT

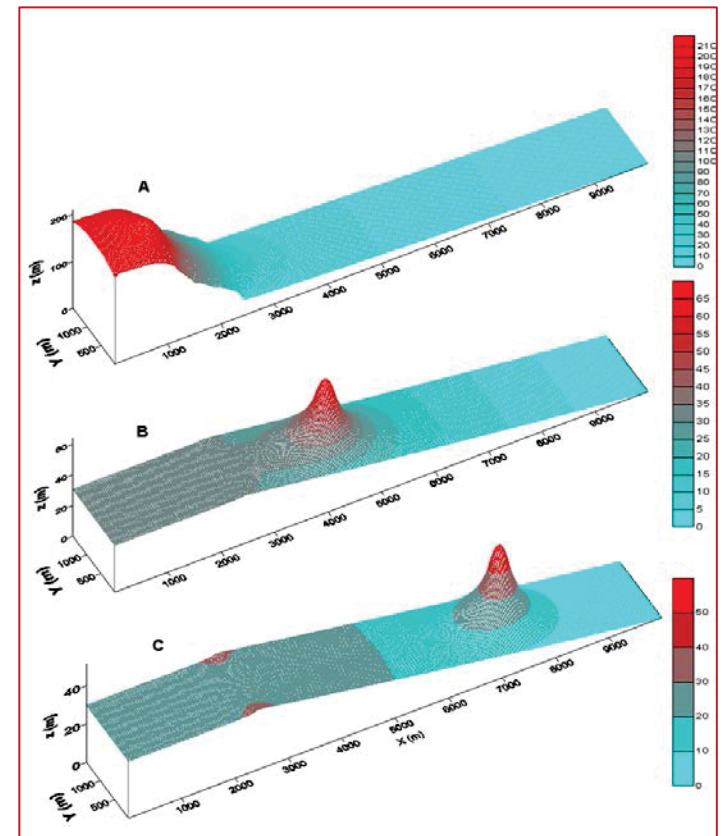
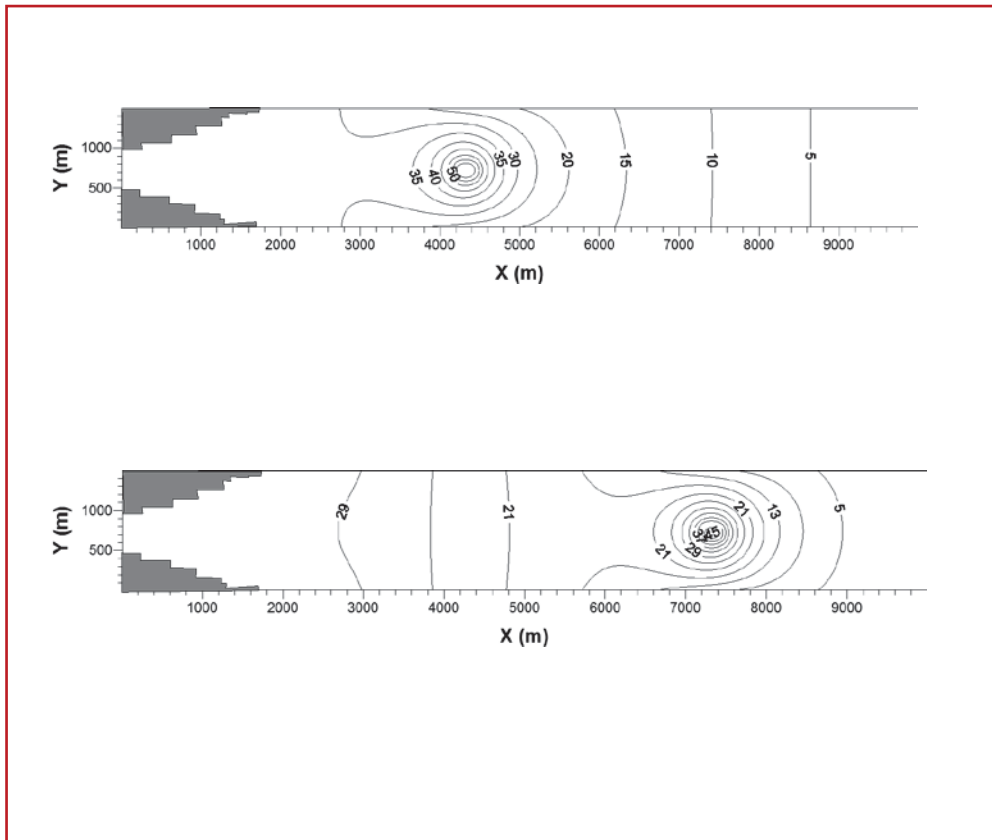
MAR of Treated Waste Water in Oman

Prathapar et al. 2009



SPREADING BASIN

INJECTION

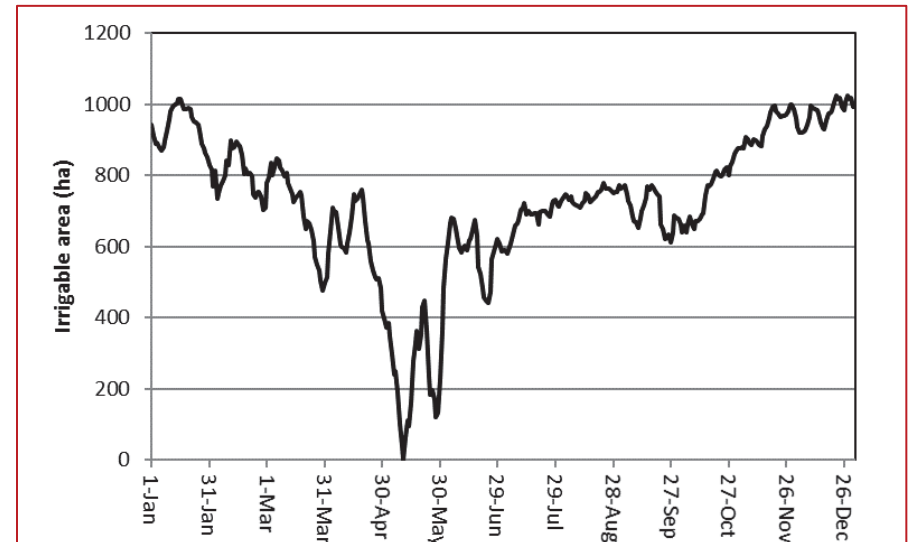
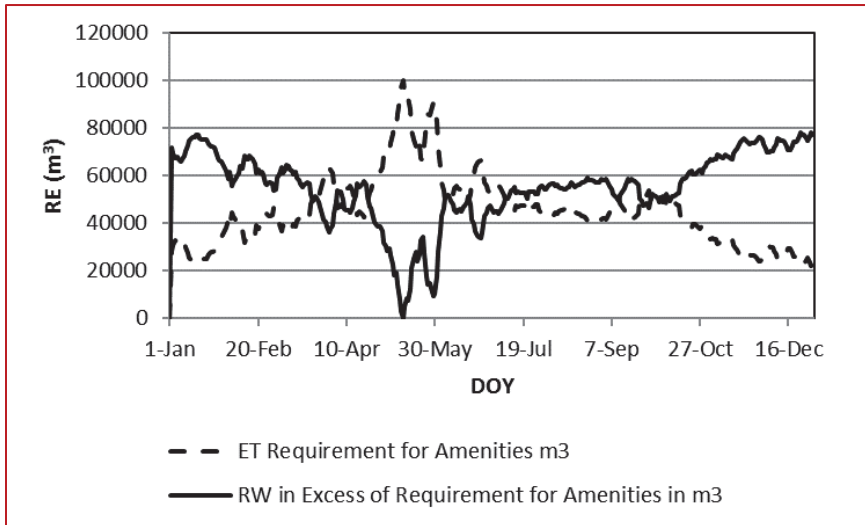


Treated Water Use in Greenhouses – Abu Dhabi



Excess TW Disposed

Greenhouse area irrigable with Excess TW



Treated Water in Conjunctive Use – Oman

Khamisi et al (2012)

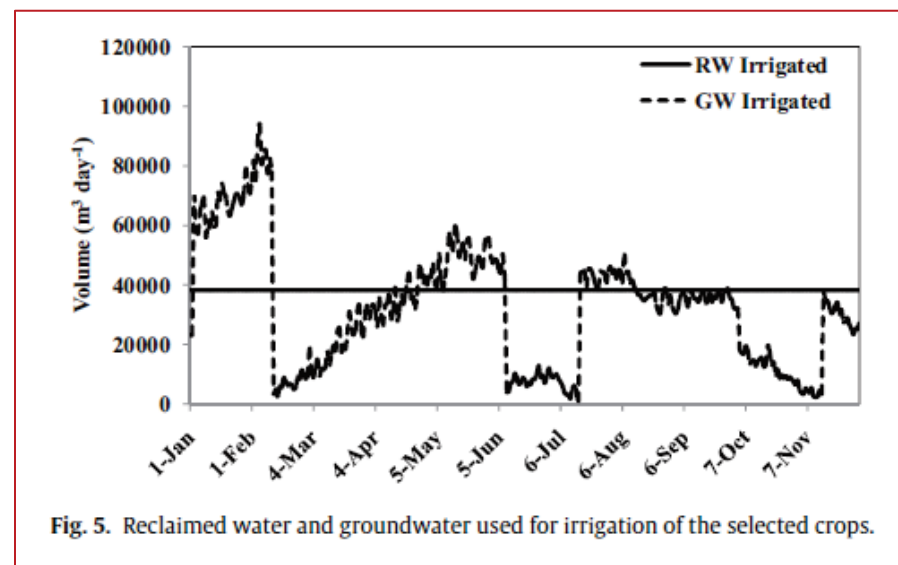
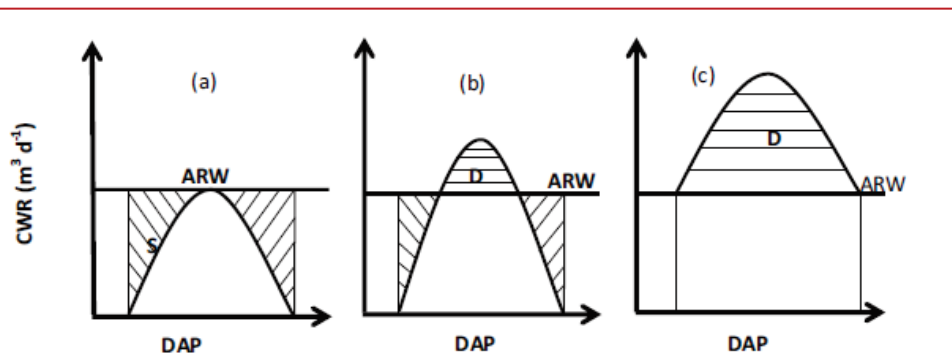


Fig. 5. Reclaimed water and groundwater used for irrigation of the selected crops.

Greywater Treatment and Reuse in Oman

Prathapar et al. 2006

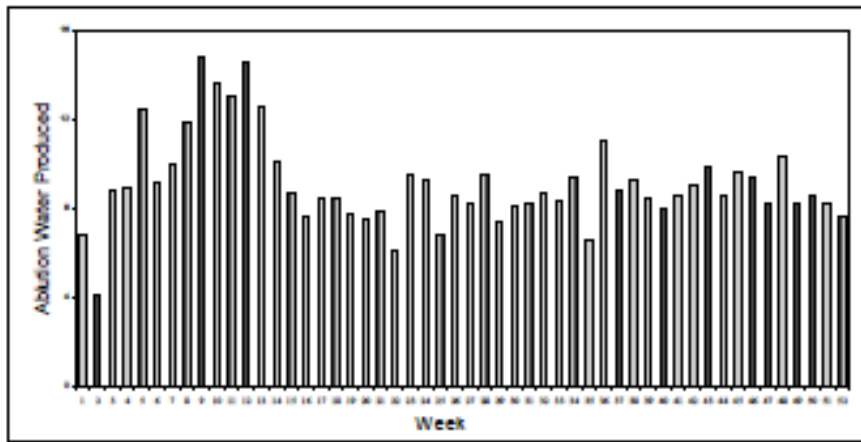
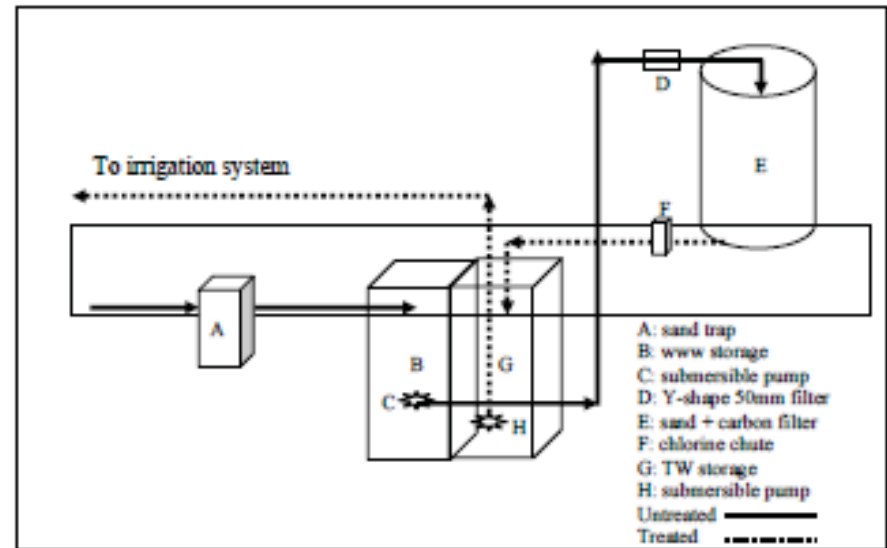


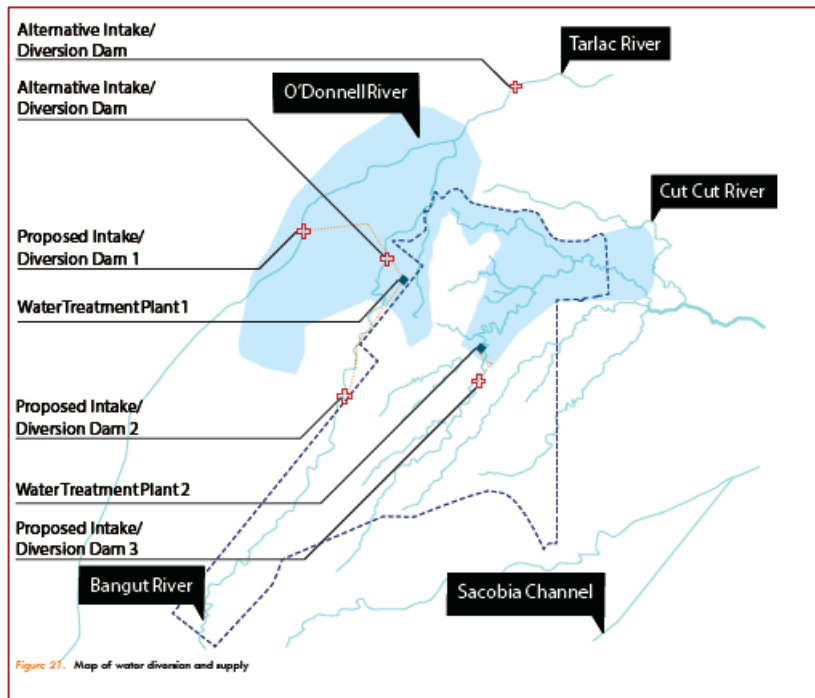
Figure 1: Weekly abluion water production at Al Hail South mosque (m³/week)



NEW CLARK CITY – PFS



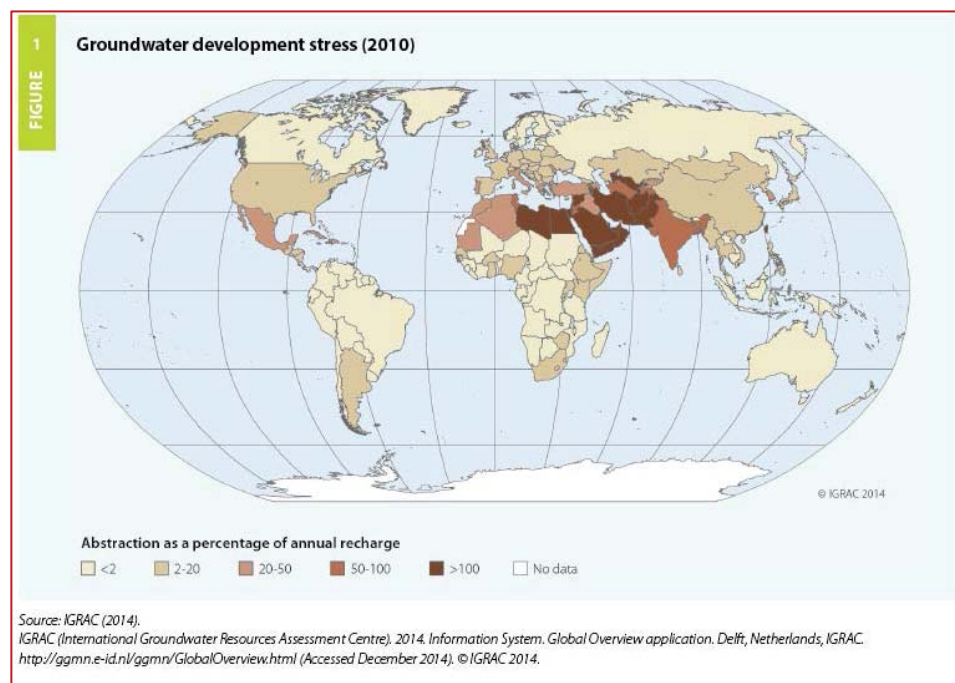
- Assessment of Water Demand
- Assessment of Surface Water Resources
- Assessment of Groundwater Resources
 - Quantity
 - Quality
- Assessment of Waste Water disposal options
 - Disposal to the River
 - Irrigating Public Green Area
 - Irrigated Agriculture
 - Greenhouse Agriculture
 - Aquaculture
 - Managed Aquifer Recharge



How can ADB help?



- Determination of measures for governments and communities to adopt
- DMCs have IDs and WSSDs but Groundwater Institutions are weak
- Groundwater monitoring program
- Increase awareness
- Develop and implement enforceable regulations
- Identify 'groundwater protection zones'
- Encourage MAR in urban and rural areas.
- Encourage green solutions to dispose treated waste water



Australia

water partners for development

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www.waterpartnership.org.au

