UNITED NATIONS

Economic and Social Commission for Western Asia

UN-ESCWA

Managed Aquifer Recharge - MAR: Regional Overview and Recent Developments

Doha, Qatar
22-24 April 2012

Ralf Klingbeil
Regional Advisor Environment & Water

UNITED NATIONS
Economic and Social Commission for Western Asia

UN-ESCWA

The 10th Gulf Water Conference

مؤتمر الخليج العاشر للمياه

Note of appreciation:

Thank you to WSTA, KAHRAMAA and GCC for their kind invitation, allowing me to attend and contribute to this 10th GWC.

Region's Perspectives?

Cornish, 2009. Australias Drought, www.slideshare.net/mrcornish/australias-drought , accessed 25 Mar 2012

Outline

- Reasons for MAR
- What falls under MAR?
- Challenges:
  - Technological, scientific
  - Socio-economic
  - Governance, regulations
- Examples from the region
- What can be done at regional level?
  - Exchanging knowledge
  - Supporting each other

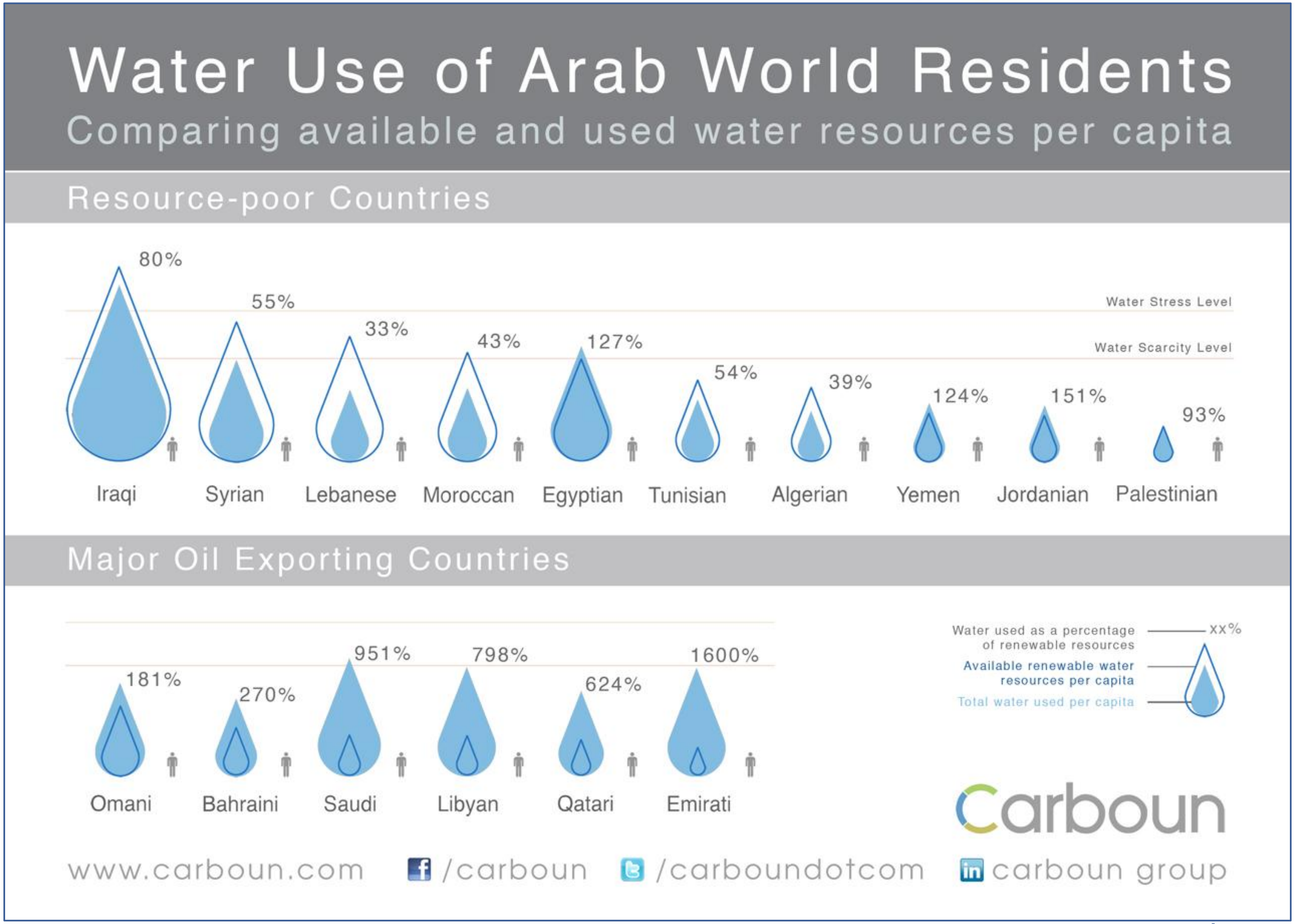
Reasons for Managed Aquifer Recharge

UN-ESCWA

- Strategic water reserve for emergency situations
- Short-term or seasonal peak demands
- Intermediate storage instead of runoff and evaporation
- Preparation for drought periods / dry years
- Vulnerability of desalination to pollution / algae
- Constant desalination production vs. variable demands
- Recharging brackish groundwater reserves
- Preventing or reversing saltwater intrusion / controlling salinity upconing
- Injection of excess rain / storm / flood waters
- Additional uses for Treated Sewage Effluent (TSE), intermediate aquifer storage, use mainly for agriculture
- Water storage in surface reservoirs / dams: evaporation losses too high

...

Arab Countries' Water Availability and Use



www.carboun.com, 2011

What falls under Managed Aquifer Recharge?

- Human enhanced and managed groundwater recharge

- [with the purpose of later abstraction or use either as a fresh groundwater resource or as hydraulic barrier against other threats such as seawater or saline water intrusion].

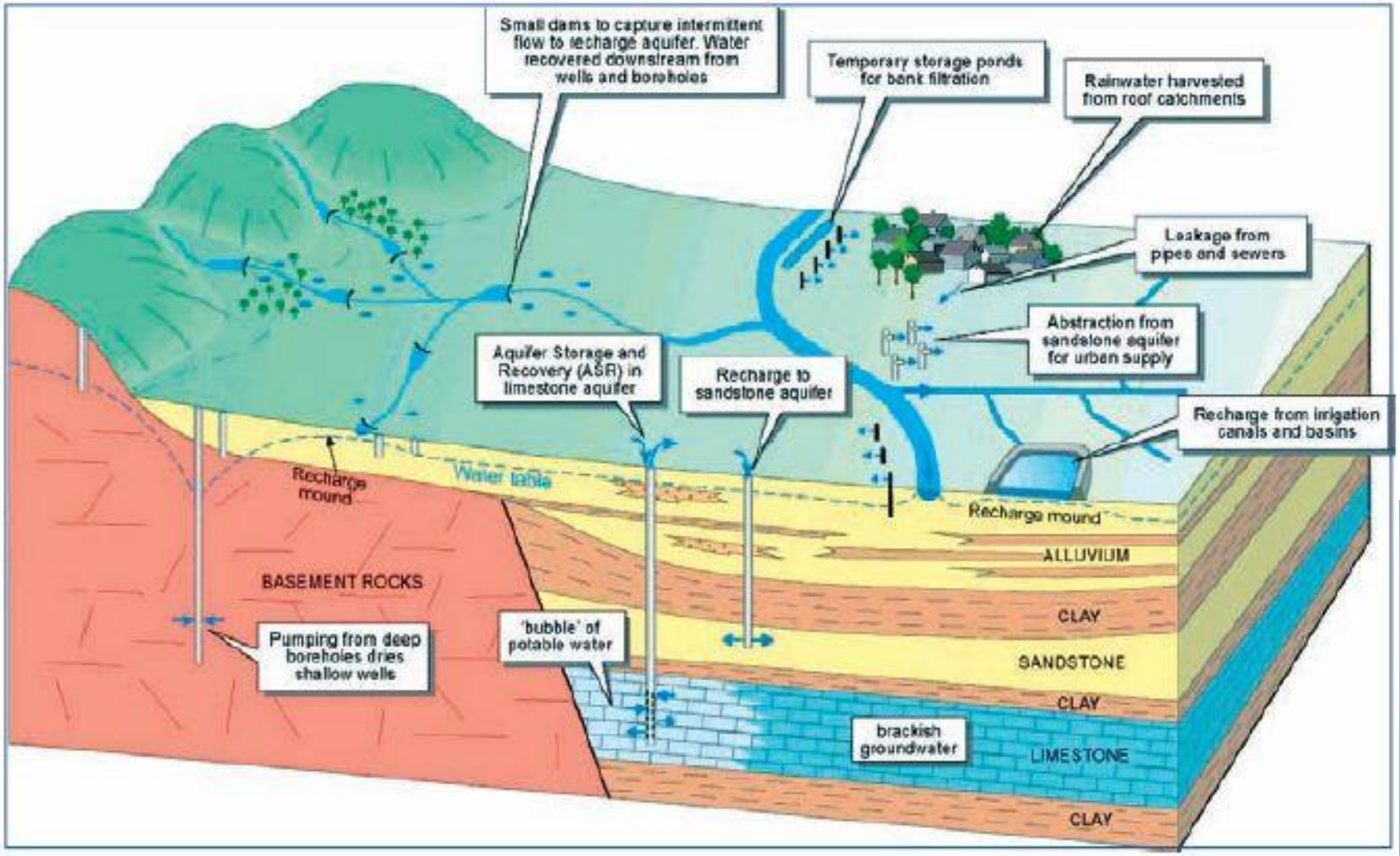
What falls under Managed Aquifer Recharge?

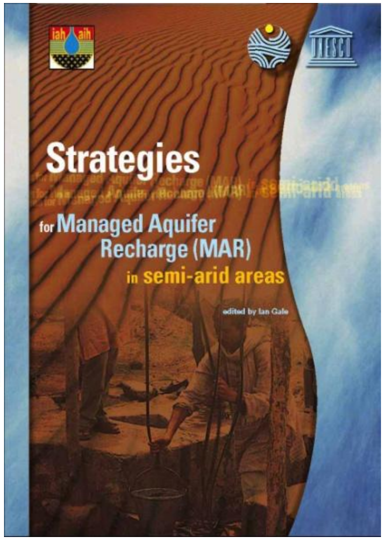
UN-ESCWA

<table>
<tr><th></th><th>Technology</th><th colspan="2">Sub type</th></tr>
<tr><td rowspan="8">Techniques referring primarily to getting water infiltrated</td><td rowspan="4">Spreading methods</td><td colspan="2">infiltration ponds & basins</td></tr>
<tr><td colspan="2">flooding</td></tr>
<tr><td colspan="2">ditch, furrow, drains</td></tr>
<tr><td colspan="2">irrigation</td></tr>
<tr><td colspan="3">Induced bank infiltration</td></tr>
<tr><td rowspan="3">Well, shaft and borehole recharge</td><td rowspan="2">deep well injection</td><td>AS(TR)</td></tr>
<tr><td>ASR</td></tr>
<tr><td colspan="2">shallow well/ shaft/ pit infiltration</td></tr>
<tr><td rowspan="6">Techniques referring primarily to intercepting the water</td><td rowspan="4">In-channel modifications</td><td colspan="2">recharge dams</td></tr>
<tr><td colspan="2">sub surface dams</td></tr>
<tr><td colspan="2">sand dams</td></tr>
<tr><td colspan="2">channel spreading</td></tr>
<tr><td rowspan="2">Runoff harvesting</td><td colspan="2">barriers and bunds</td></tr>
<tr><td colspan="2">trenches</td></tr>
</table>

International Groundwater Resources Assessment Centre, 2007, www.un-igrac.org

What includes Managed Aquifer Recharge?

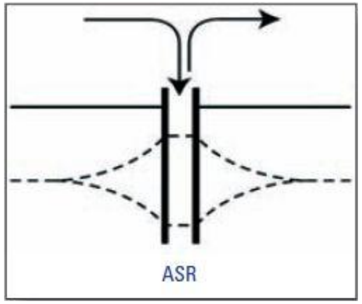




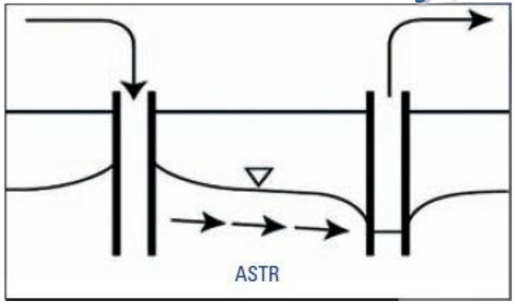
UNESCO, 2005

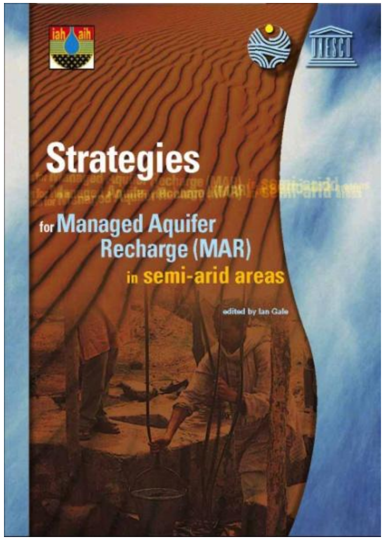
What includes Managed Aquifer Recharge?

- **Aquifer Storage Recovery (ASR):**
  "well/borehole is used for both injection and recovery, costs are minimised and clogging is removed during the recovery cycle."



- **Aquifer Storage Transfer and Recovery (ASTR):**
  "Water can be injected into a borehole and recovered from another, some distance away, to increase travel time and benefit from water treatment capacity of the aquifer"





UNESCO, 2005

Challenges: Technological, Scientific

- **Groundwater level rise:**
  → risk of flooding, esp. in case of unconfined aquifers
- **Hydrochemical mixing:**
  → risk of precipitation causing clogging of well screens or aquifer pore space
  → risk of mineral dissolution causing mobilization of harmful substances or development of cavities
- **System efficiencies:**
  → injected vs. recovered volumes
- **Health risks:**
  → potential risks to human health when injecting / infiltrating treated sewage effluent, mobilizing minerals from the aquifer matrix

…

Challenges: Socio-Economic Viability

- **Investigation of economic alternatives:**
  → cost of surface vs. groundwater storage
  → direct use of TSE vs. intermediate storage
  → infrastructure, access to injection / recovery sites
  → compromise between deep groundwater table to prevent flooding and shallow to reduce energy costs for pumping
  → alternative feasibility studies
  → environmental costs – environmental impact assessments
- **System efficiencies:**
  → injected vs. recovered volumes
- **Social acceptance:**
  → health and environmental risk analysis
  → awareness raising campaigns

...

Challenges: Governance, Regulations

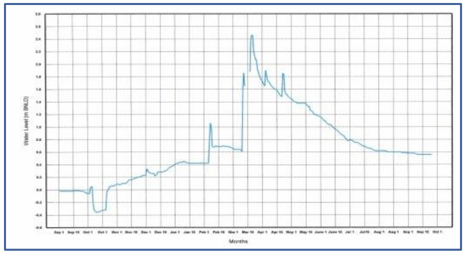
- Are all necessary **laws, regulations and guidelines** in place and officially approved to ensure prevention of negative impacts on the groundwater, ecosystems, water users, the people?
- **Accountable and transparent decision making** and tendering processes?
- Do we have mechanisms in place to allow for **participation and constructive criticism**?
- International / national **advisory bodies with multi-sectoral experiences**?

…

Bahrain:
Isa Town: Stormwater Runoff

UN-ESCWA

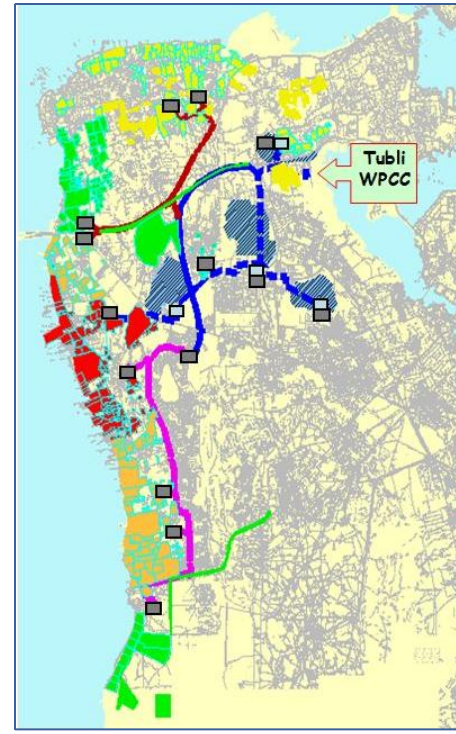
- Unique gravity-fed aquifer recharge system:
  - Gulleys, catchpits, delivery pipes, oil trap, filter chamber, and recharge well
  - Direct urban stormwater flows from suitable low points to targeted Khobar aquifer
- Estimated 1,389 m^3 recharged
- Water level rise 0.6 m
- Reduced salinity
- Necessity for monitoring potentially harmful substances (esp. nickel, zinc, copper)

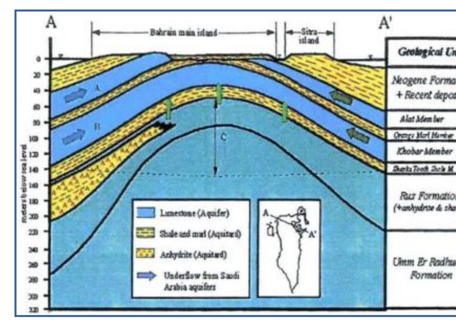


Al-Noaimi, 2010

Bahrain: Potential Larger Scale ASR / ASTR

- 1986: TSE recharge to Khobar aquifer
- 2010: Dammam Aquifer Regional Simulation Modeling Study
- 2010: Feasibility of GW Recharge by TSE
- National Approach to Assessing Reuse of Treated Sewage Effluent (TSE) and Managed Aquifer Recharge (MAR)
- Future TSE production:
  - 2015: 390,000 m^3/day
  - 2030: 500,000 m^3/day
- More direct TSE reuse in agriculture
- Potential target aquifers: Alat (A) and Khobar (B), both Dammam Formation
- Expected total volume of TSE to be stored: 24 MCM





Al-Mannai, 2010, MoW, 2011

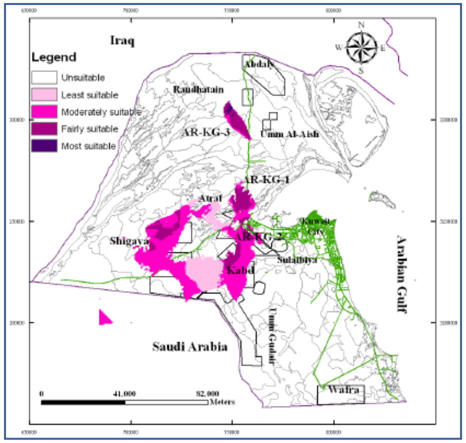
Kuwait: Dammam, Kuwait Group

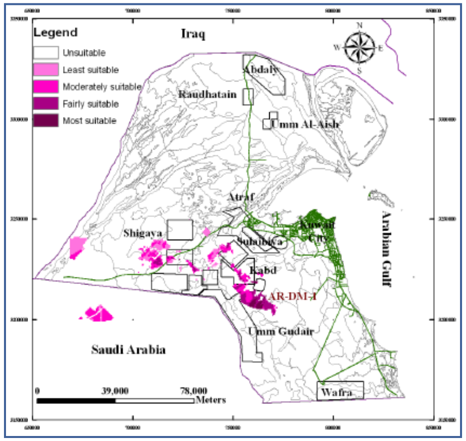
- 1964: Raudhatain, passive infiltration in depression (Parsons)
- 1972-1973: Raudhatain, injection of desalinated water
- 1992: Sulaibiya, injection in Dammam limestone and Kuwait Group
  - 200,000 m^3 injected desalinated water in two wells (18,000 and 180,000) over 30 days
  - Dammam: Injection possible, but low system efficiency (10-20 %)
  - Kuwait Group: severe clogging of the injection well, due to suspended solids and dissolved air
- 1994: Physical Properties of Dammam Formation in Contact with Fresh Water
- 1997: Compatibility of Desalinated Water with Dammam Formation Aquifer at Pilot Recharge Site

Abdel-Jawad/KISR, 2008; Dawoud/EAD, 2005; Mukhopadhyay/KISR, 2010

Kuwait: Dammam, Kuwait Group

- 2002: Numerical Modeling of Artificial Recharge Options for Dammam Formation at Pilot Recharge Site
- 2004: Laboratory Investigation Compatibility of Desalinated Water, RO-processed Treated Wastewater with the Kuwait Group Aquifer
- 2010: Selection of Suitable Sites for Artificial Recharge
  - Kuwait Group: Mutla, Sulaibiya, Raudhatain areas
  - Dammam Formation: Kabd area

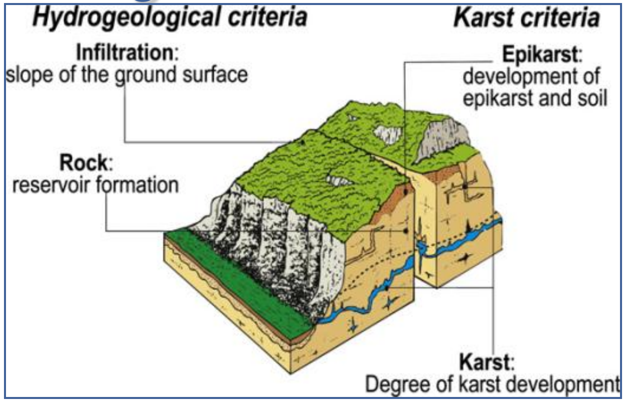


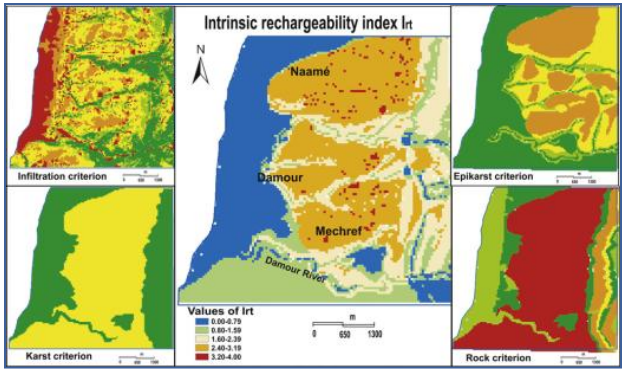


Abdel-Jawad/KISR, 2008; Dawoud/EAD, 2005; Mukhopadhyay/KISR, 2010

Lebanon: Damour, Aquifer Recharge in Karst?

- Aquifer Rechargeability Assessment in Karst - ARAK
  - Determine the ability of a given karst aquifer to be artificially recharged and managed
  - Best sites for implementing artificial recharge from surface
- Multi-criteria indexation analysis modeled on karst vulnerability assessment methods
- Four independent criteria, i.e. Epikarst, Rock, Infiltration and Karst
- Rechargeability index: the product of two factors, intrinsic rechargeability and feasibility index
- Damour site: MAR system interesting solution to cope with salinization and insufficiency of the resource

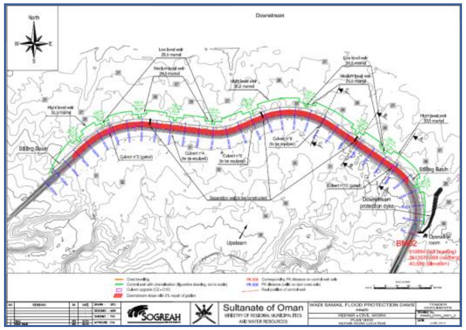




Daher, 2011

Oman: Groundwater Recharge Dams

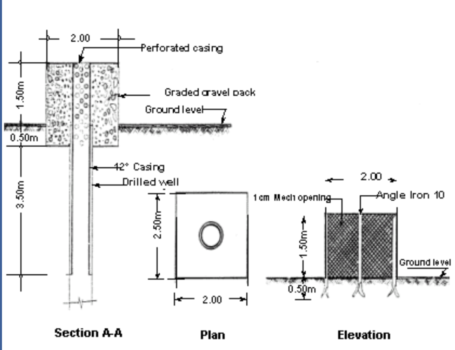
- > 30 groundwater recharge dams, intercepting wadi runoff, allowing for controlled recharge downstream of dam
- Managed to hold about 1064 MCM of flood waters until end of 2009
- Substantial experiences in siting and dimensioning of groundwater recharge dams



Qatar: Northern GW Basin, ASR

- 1976: “Artificial recharge with desalted sea water to permit additional agricultural development appears technically feasible but its practicability needs to be examined further.” (Vecchioli)
- 1992-1994: Feasibility study for injection of desalinated water in Rus and Umm er-Radhuma, result positive for both formations

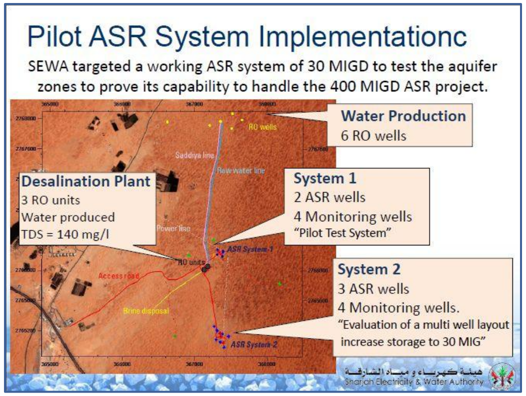
- 2012: QNFSP/KAHRAMAA: Investigation of four sites in northern groundwater basin for storage of 30 billion gallons (136 MCM) as long-term security in the event of an interruption to desalination supplies.
- ASR as two-fold opportunity: Imperative for utilities to treat wastewater to tertiary level and TSE available for non-potable applications such as agricultural irrigation possibly with intermediate aquifer storage.

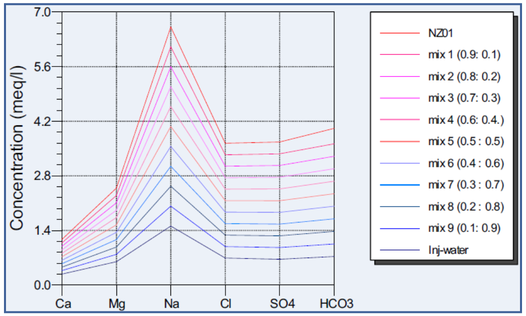


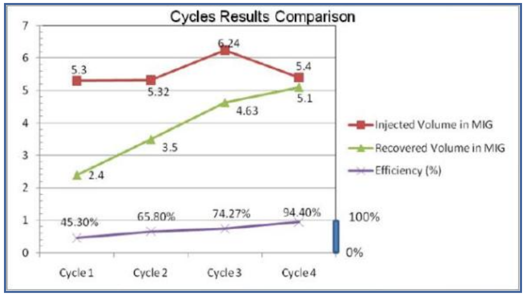
Dawoud/EAD, 2009; MEED, 2012; Streetly, 1998; Vecchioli/USGS, 1976

United Arab Emirates: Nizwa, Sharjah: 1st Operational ASR

- 2001-2002 feasibility study
- 2003-2004 pilot project
- ASR to replace seasonal peak load capacity
- Site characterization and evaluation, geophysics, trial boreholes, monitoring network
- Hydrochemical modeling: Mixing of injected RO product (250 µS/cm) and native groundwater
- Pilot project: Cycles of injection - storage - recovery, currently in 10th cycle,
- 4th Cycle: 24700 m^3 over 26 days injection, 30 days storage, 23400 m^3 over 19 days recovery, system efficiency 95% recovery of injected water, cost efficiency 10% of equivalent surface storage
- Planned for 400 MIG (1.8 MCM)



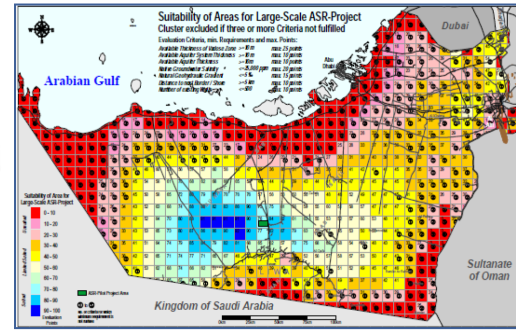


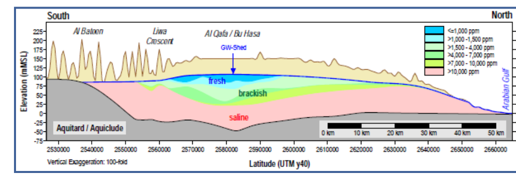


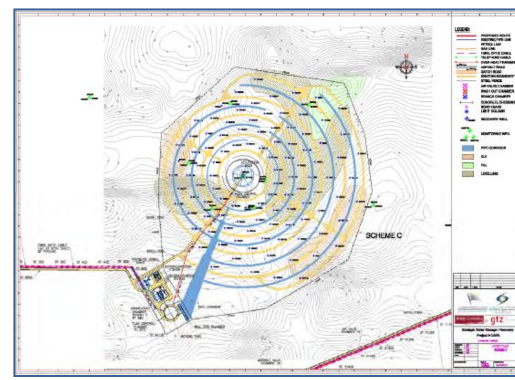
SEWA, 2009

Liwa, Abu Dhabi: large scale SWSR

- 2003-2005 feasibility study
- 2006-2009 pilot project
- 2010-2013 construction of “Strategic Water Storage and Recovery Project (SWSR)”, Liwa
- Planned for 23 MCM of surplus desalinated seawater
- Emergency water supply for Abu Dhabi up to three months at 40 MIG/d (181,800 m^3/d)
- Extensive site characterisation, shallow aquifer system, semi-consolidated Aeolian dune sands
- When completed: Benchmark for water management in arid regions







Koziorowski, 2012 ; Wolke, 2011

What can be done at regional level?

- **Technical and scientific challenges** are to be addressed appropriately to make any MAR schemes successful.
- **Socio-economic aspects** have to take a greater role in the overall assessment stages and require close interaction between economists, engineers, social and natural scientists.
- More **regional knowledge exchange** is required on technical, scientific, socio-economic and regulatory approaches for MAR.
- **Exchange visits** between countries develop staff capacities and build networks to learn from each other.
- Projects can benefit from **advisory bodies** with experts from different sectors and countries.
- Need to **move from planning into implementation of MAR**.

UNITED NATIONS

Economic and Social Commission for Western Asia

UN-ESCWA

THANK YOU

Managed Aquifer Recharge - MAR: Regional Overview and Recent Developments

The 10th Gulf Water Conference - WSTA, KAHRAMAA and GCC

Doha, Qatar
22-24 April 2012

Ralf Klingbeil
Regional Advisor Environment & Water