Integrating Managed Aquifer Recharge into Regional Water Management in Jordan

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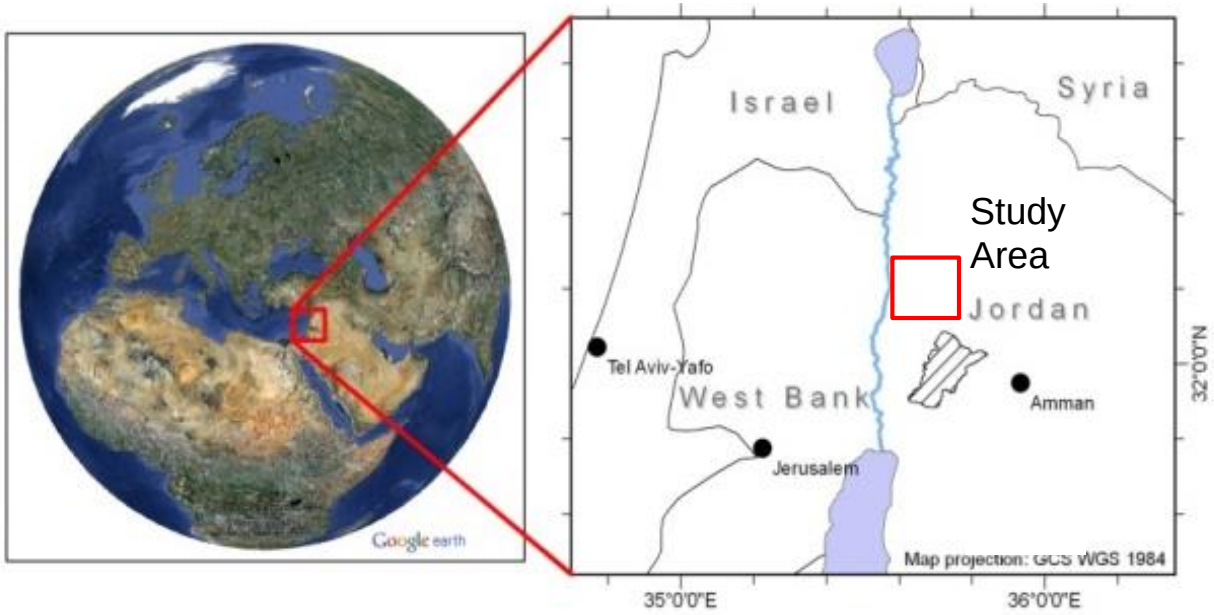
Introduction



- Arid to semi-arid climate, natural water resources are low
- Jordan's water resources: total renewable per capita : < 500 m^3/c/y
- Situation will aggravate
  - High population growth
  - Climate change

Water resources in Jordan

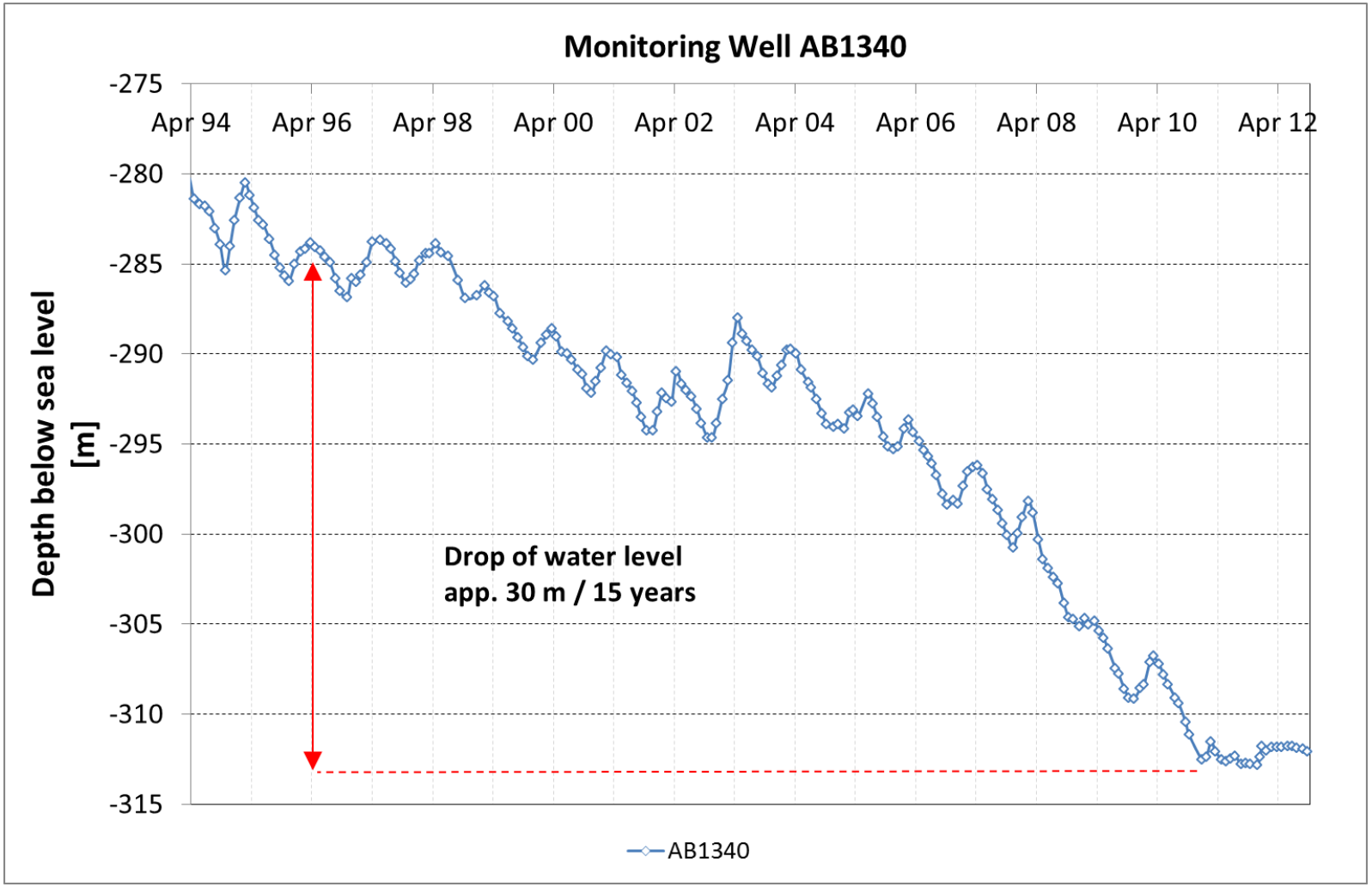
- Water availability and demand in Jordan

Water Resources	Jordan	
(MCM/a)	2010	2025
Freshwater resources	780	483
Inland brackish water desalination	57	82
Seawater desalination	--	370
TWW reuse in agriculture	100	247
Total water demand	1,315	1,652
Deficit of water (demand – resources)	372	462
Population (million)	6.1	11.5

- Overexploitation of freshwater resources
- Declining of water levels

Klinger et al. 2016, modified

Water resources in Jordan – Groundwater level



Further reading: Liesch & Ohmer (2016)

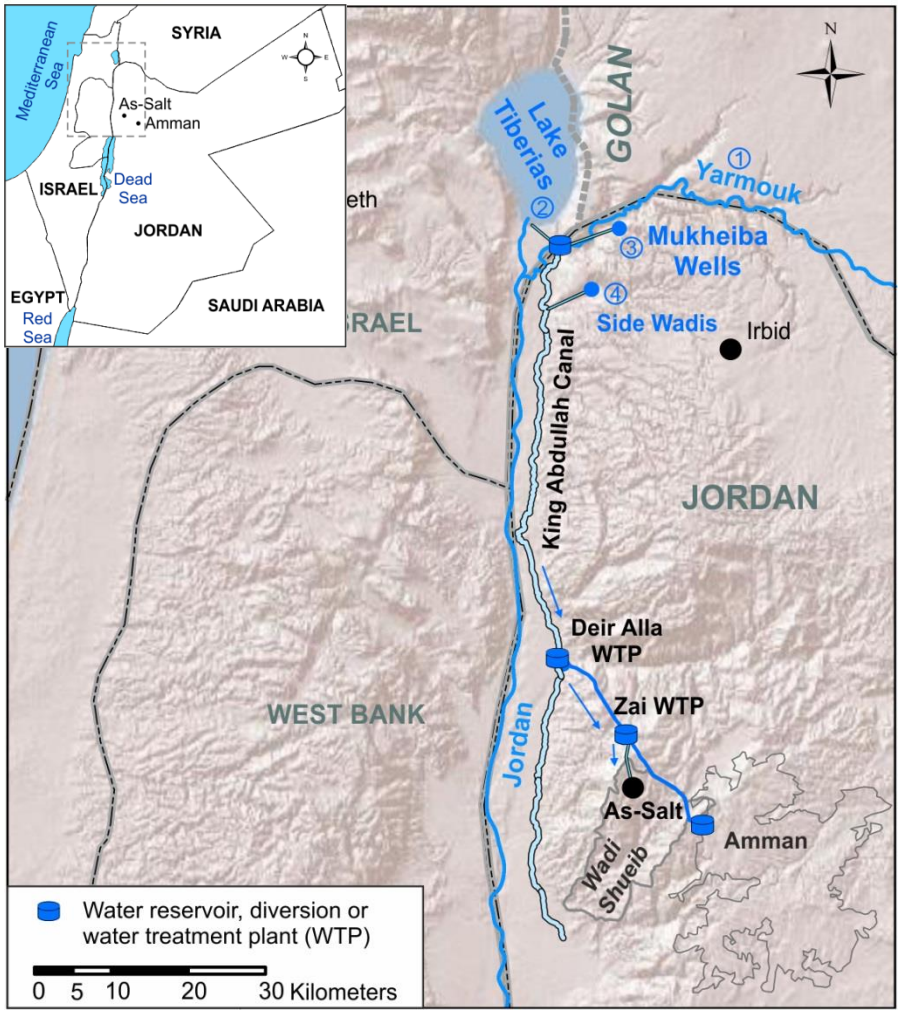
Water resources in Jordan

- Large infrastructural projects
  - Disi Pipeline (100 MCM/a, 320 km, 1.1 Billion US$)
  - Red Sea – Dead Sea Canal (1.800 MCM/a, 180 km, 8-10 Billion US$)
- Water Strategy (February 2016)
  - Water reallocation by MAR is an important technology
  - Focus is on existing infrastructure and large scale reservoirs
- Alternative water management options?

The Hashemite Kingdom of Jordan
Ministry of Water and Irrigation

WATER SECTOR
CAPITAL INVESTMENT PLAN
2016 – 2025

Water distribution in Jordan Valley



- King Abdullah Canal (KAC)
  - Major water carrier
  - Length ~ 100 km
  - Open channel system
  - App. 20 m³/s high peak
  - 75 MCM/a
- Deir Alla Pump Station
  - Pumps raw water from JV to Zai
  - ➔ Amman, As-Salt
- Topographical gradient:

Deir Alla: - 200 m. b. sl

Zai TP: 1.200 m. a. sl.

Grimmeisen et al. (2016)

Critical issues

- Risk of pollution: incidents 1987, 1998
- High evaporation

- Treatment in Zai generates sludge and backflush concentrates
- Approximately 10 % of the pumped water is conveyed to adjacent Wadi

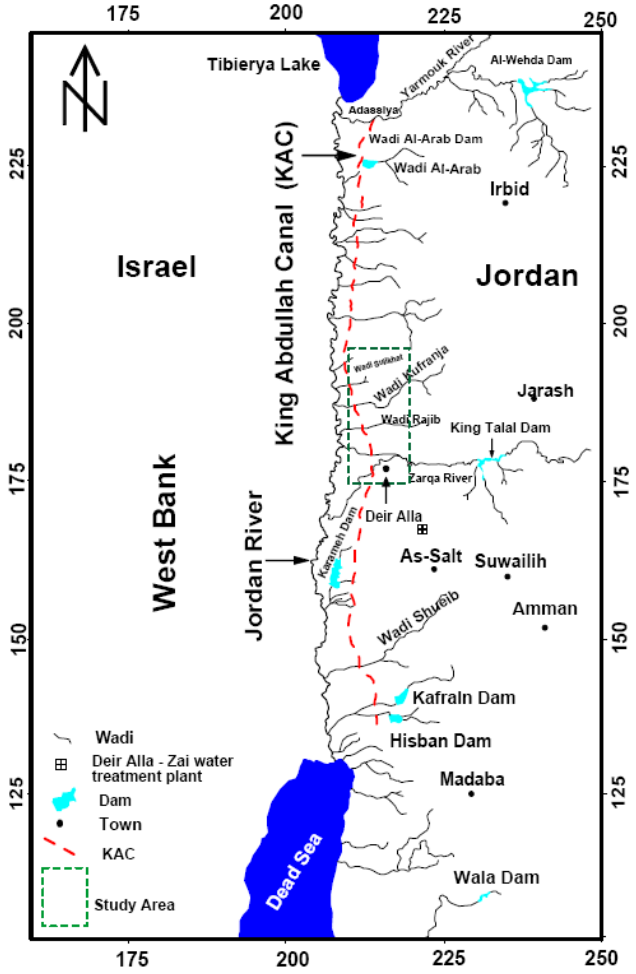
- Energy / Maintenance
  - 75 MCM raw water is pumped to Zai
  - → high material wear of pumping

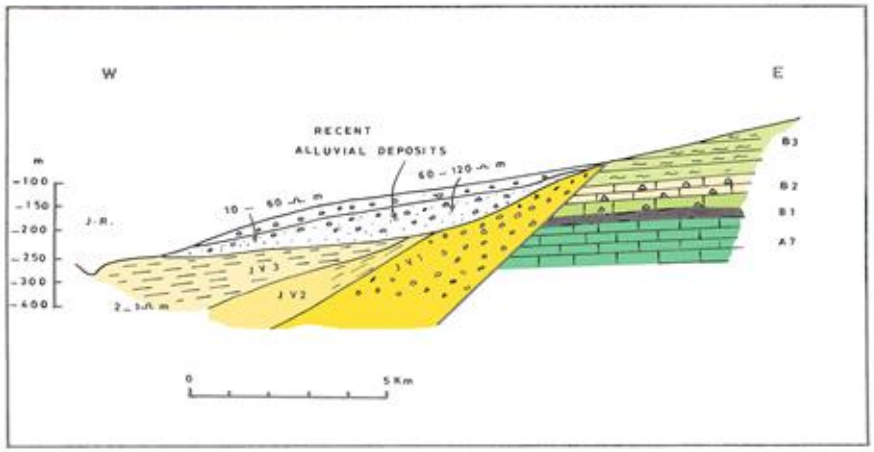
Implementation concept for MAR

- Store KAC water in excess times (winter)
- Pump / use water it if demand is high / pollution events
- Assess general distribution scheme

- Hydrogeological feasibility study
  - Geophysical investigations
  - Drillings
  - Field- and laboratory investigations
  - Numerical modelling
  - Economic assessment

Results – geophysical investigations



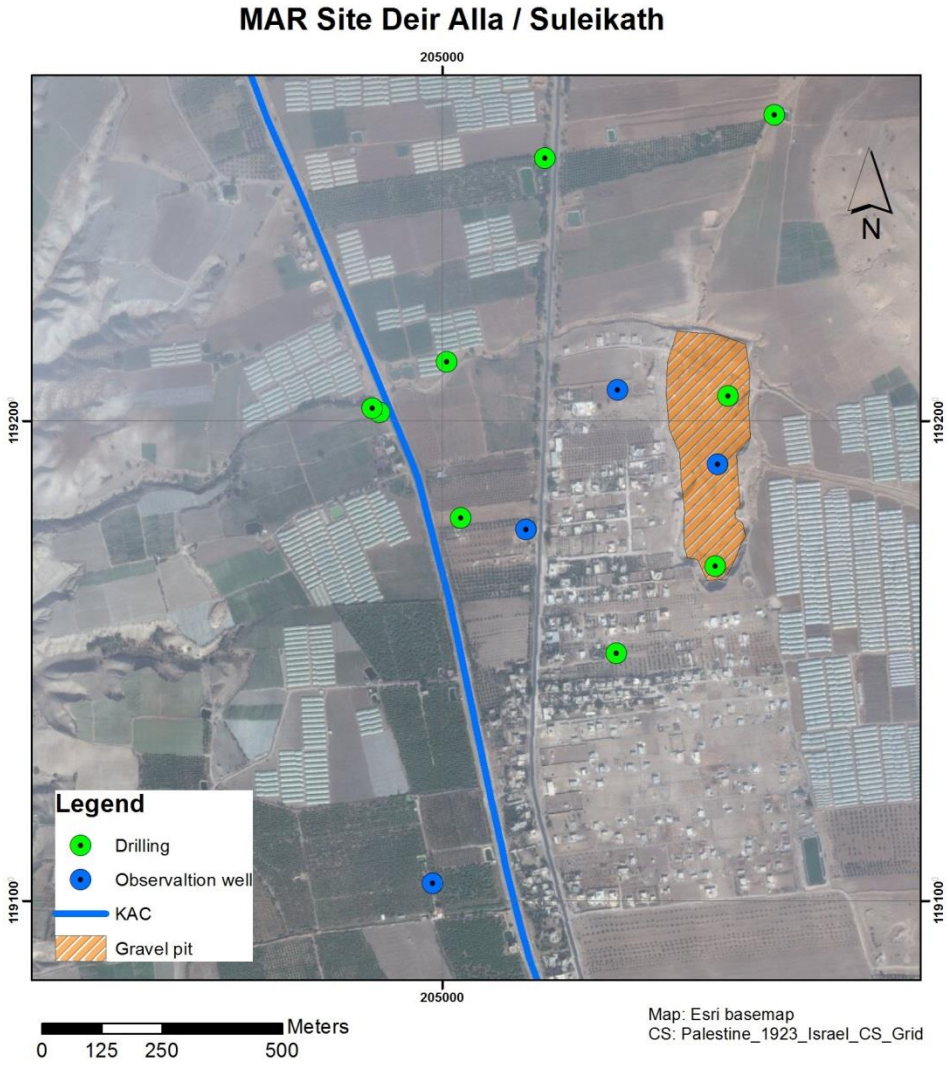


Quarternary deposits

- Alluvial Fans: sand, gravel, (0 - 100) m

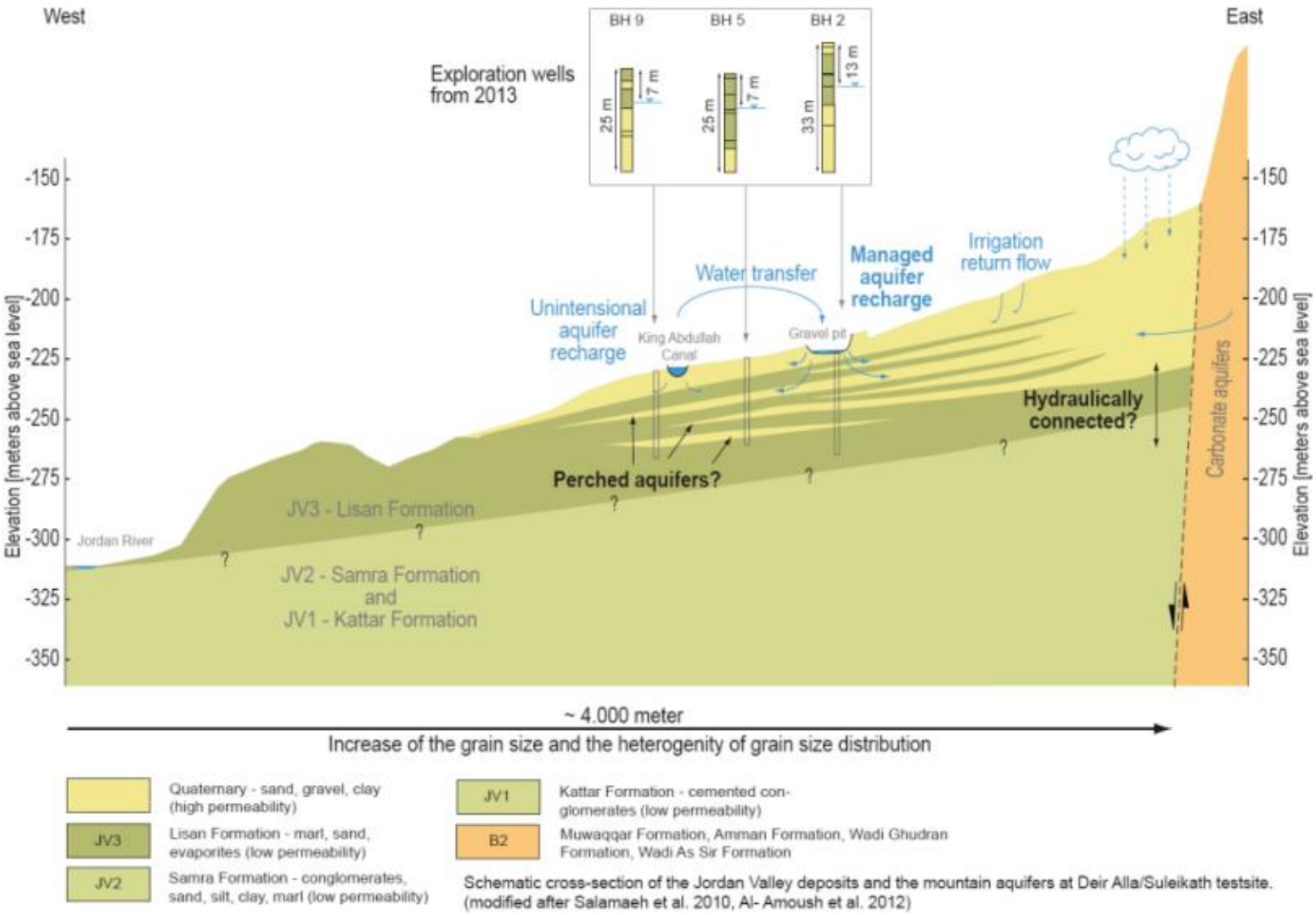
- JV3: Lisan, silt, marl, clayey, 300 m
- JV2: Conglomerates, sand, silt, clayey, 100 m
- JV1: Conglomerates, sand, silt, clay, (350 m)

Results – hydrogeological investigations



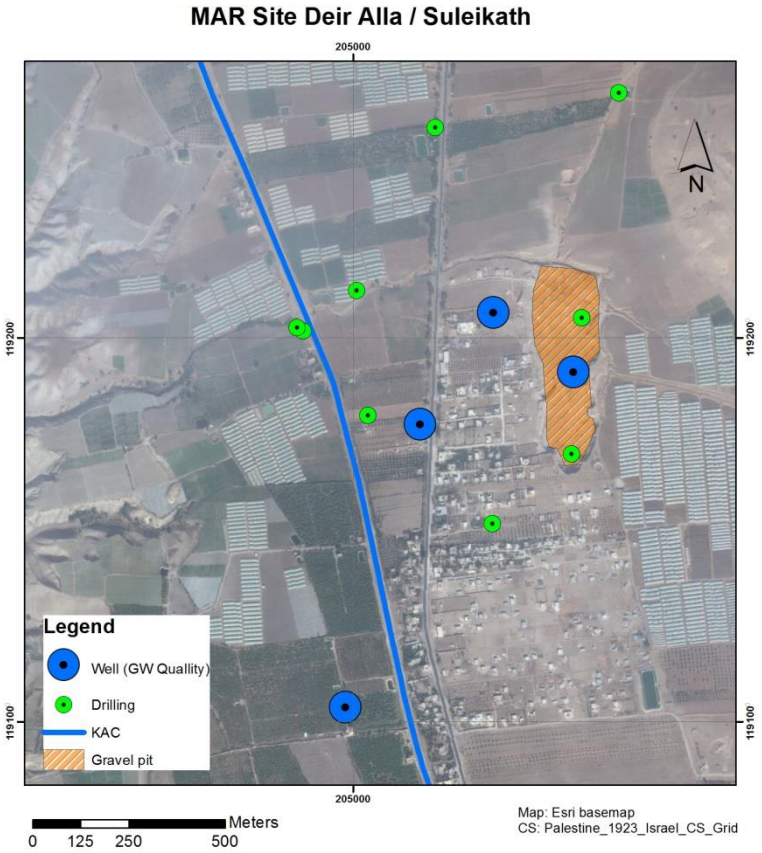
Parameter		Unit
Infiltrationrates (saturated)	9,6	cm/min
Effective Porosity	15	%
Thickness unsaturated zone	6 to 15	m
Thickness aquifer	40 to 50	m
Hydraulic conductivity (aquifer)	$6{,}3*10^{-5}$ to $1{,}1*10^{-4}$	m/s

Results – hydrogeological profile

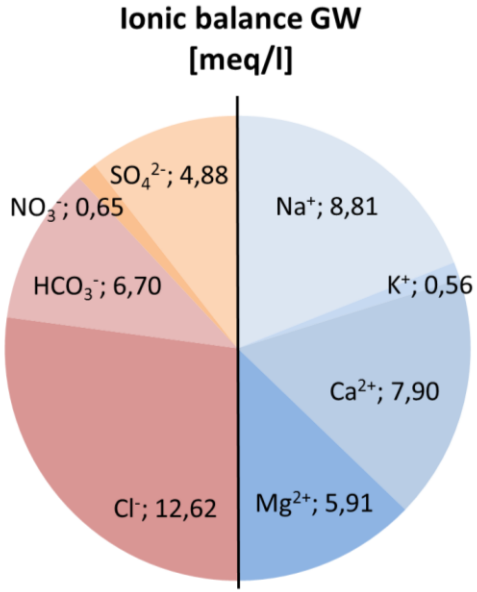


Schematic cross-section of the Jordan Valley deposits and the mountain aquifers at Deir Alla/Suleikath testsite. (modified after Salamaeh et al. 2010, Al- Amoush et al. 2012)

Results – water quality data from wells / KAC

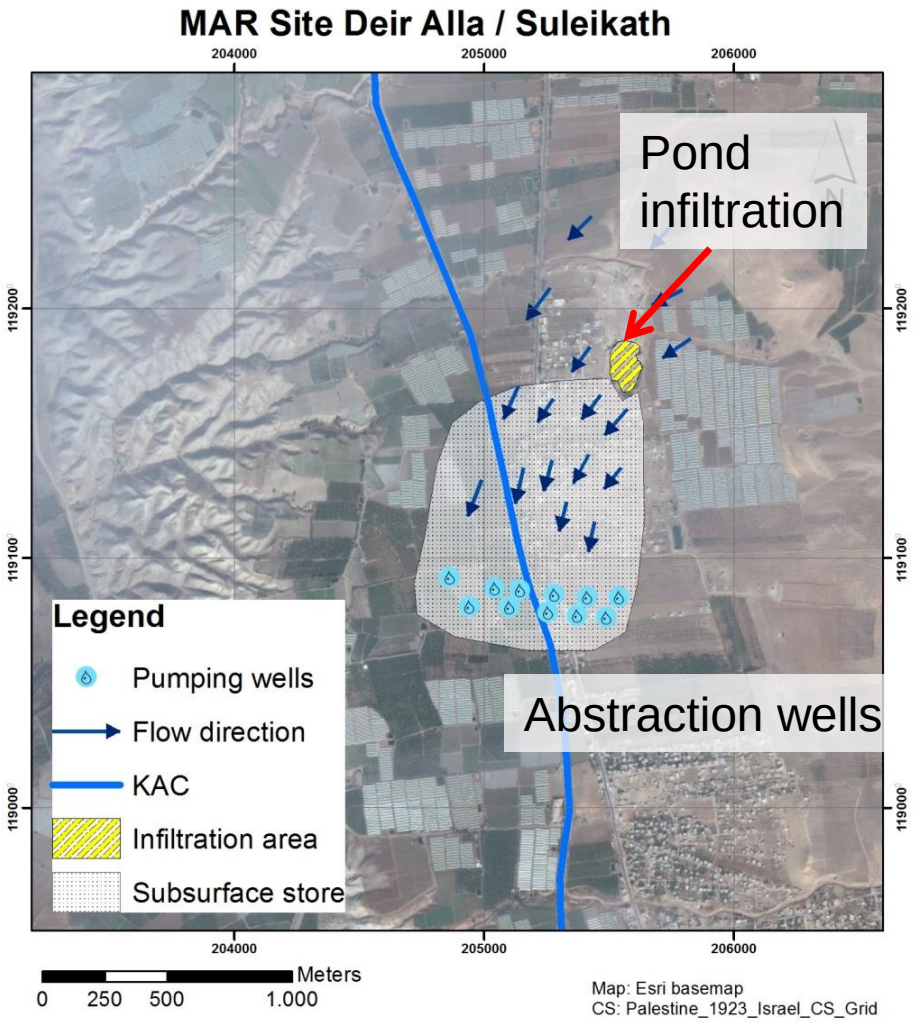


Compartment	Water level (average N=3) [m/b g]	EC (average N=3) [µS/cm]
Well SM1	11,33	1116
Well SM2	5,90	1992
Well SM3	13,81	2343
Well SM4	14,80	2178
KAC		800



- Water level quite stable
- GW: brackish
- Water quality deterioration is not expected

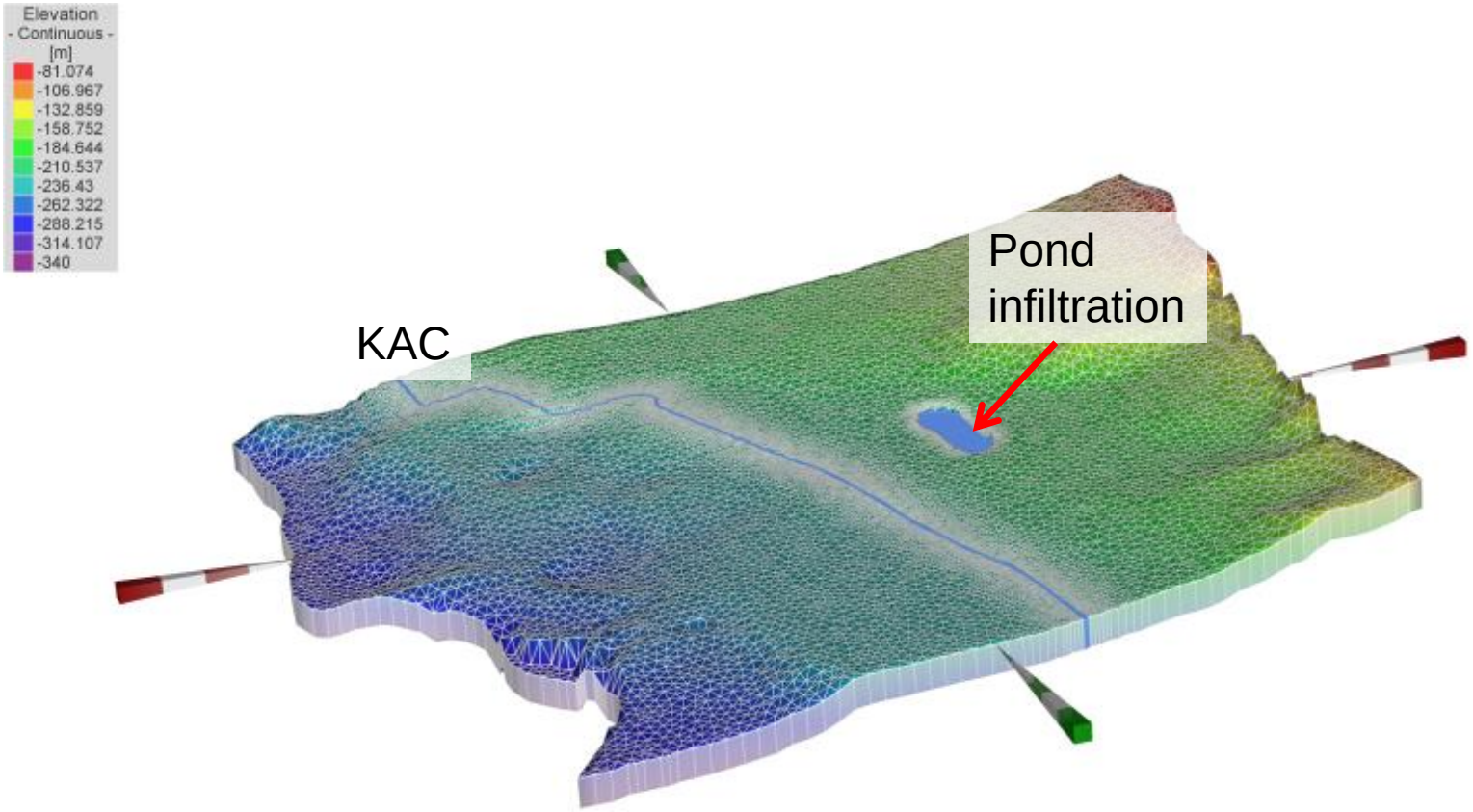
Results – MAR Scheme



Compartment	
Gravel Pit - Infiltration Area	20.000 m^2
Subsurface Storage Area	850.000 m^2
Thickness Alluvial Fan	30 m
Compartment Alluvial Fan	25.500.000 m^3
Storage Capacity	3.825.000 m^3

Water management is currently validated and optimized by a numerical model

Results – numerical groundwater flow model



3D steady state

50 slices

Summary and conclusions

- Alluvial fans provide delineated small scaled structures for temporal storage of freshwater
- Alternative water management option to ensure continuous water supply
  - During droughts
  - Contamination events
- Structures along the JV provide a storage capacity of several 10th MCM
- Implementation requires
  - Permanent dialog with decision makers
  - Economic assessment

Contact and Acknowlegements

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- SMART-MOVE (2015 – 2018), FKZ: 02WM1335A-J

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Publications

Al-Amoush, H., Salameh, E., Al-Raggad, M. (2012): "Hydro-Geoelectrical Investigation for the Potential of Underground Water Storage along the lower reaches of King Abdullah Canal-Deir Alla Area/Jordan." Journal of Water Resource and Protection 4.07 (2012): 545.

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