A numerical approach for the evaluation of sustainable yield of shared aquifer basins: a case study from the Mediterranean countries

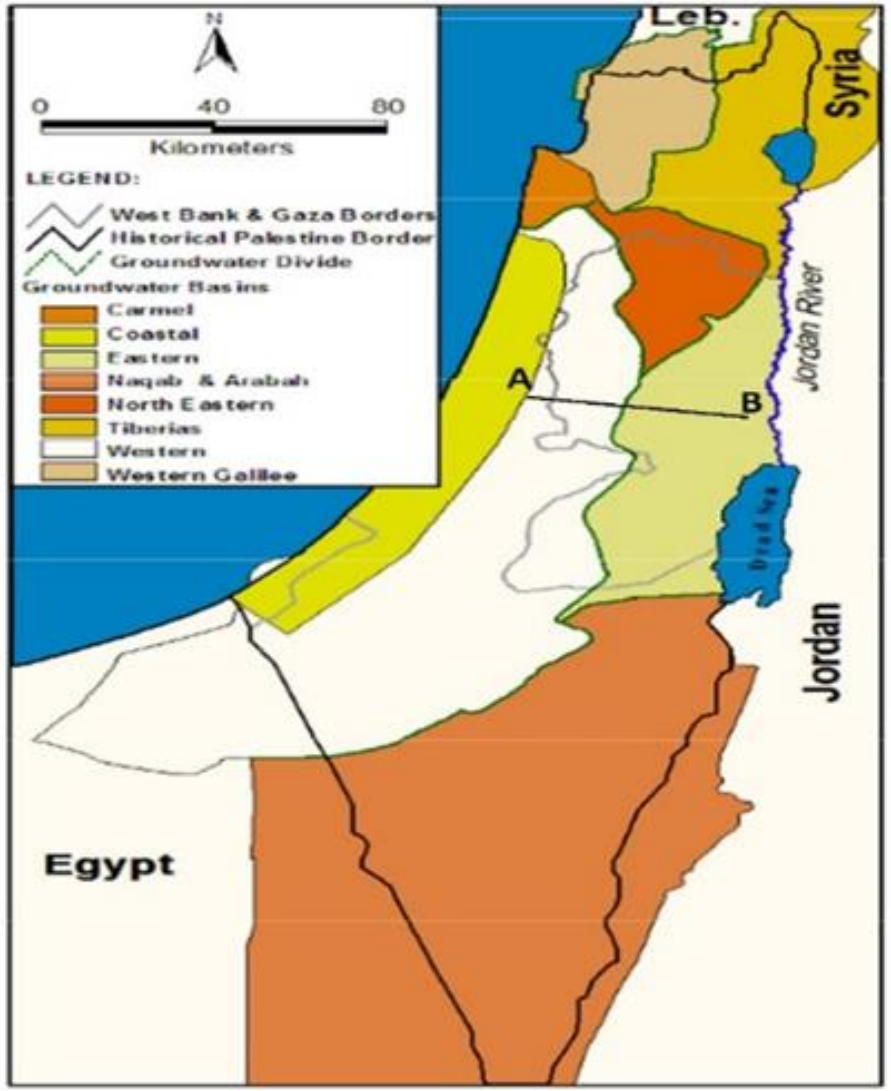
Dr Amjad Aliewi
Research Scientist, Kuwait Institute for Scientific Research
aaliewi@kisr.edu.kw

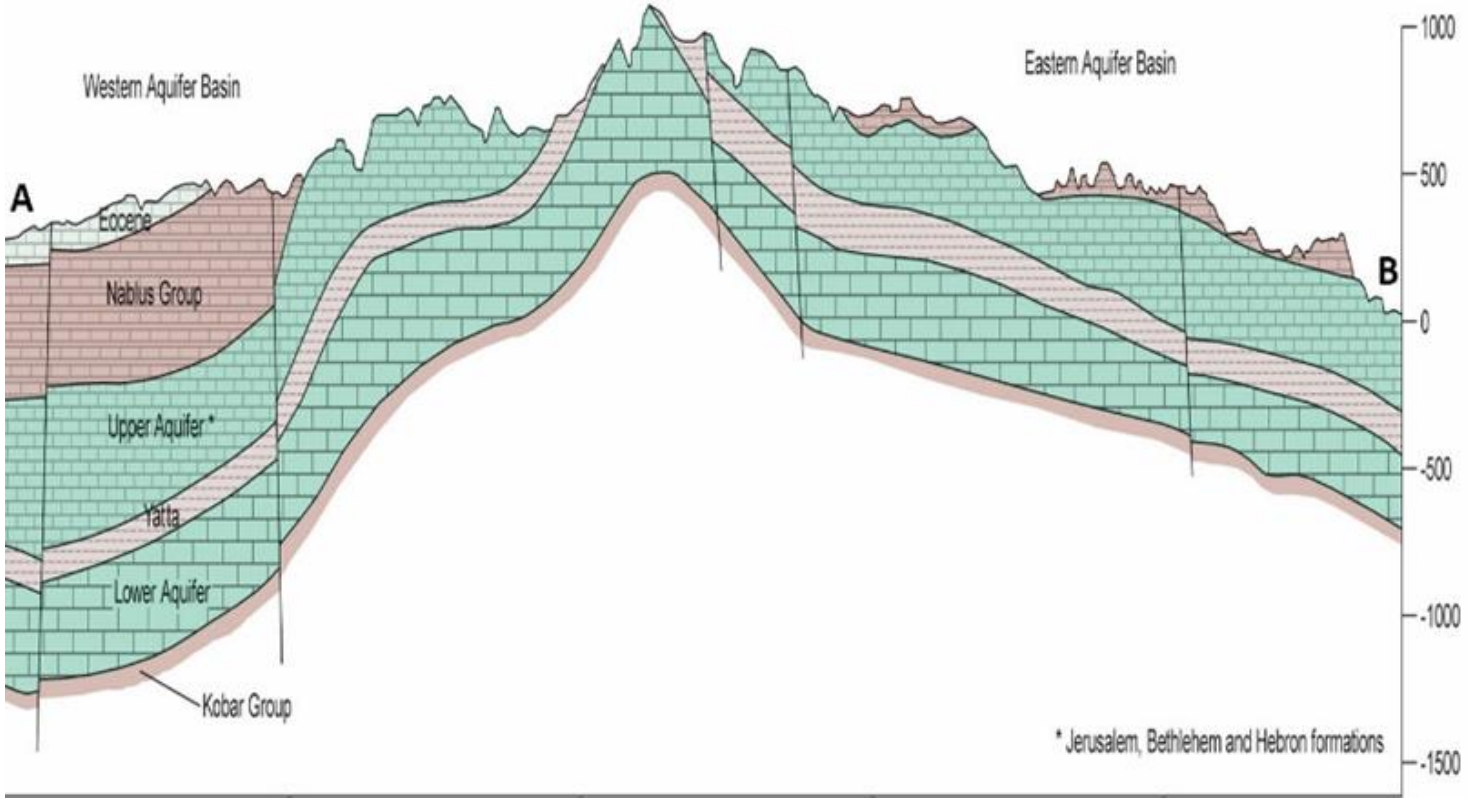
Overview

- Introduction
- Methodology
- Results
- Discussion
- Recommendations

Introduction

- The aim of current research is to assess the sustainable yield of shared aquifer basins within their hydrogeological boundaries using numerical modelling as the main approach.
- Sustainable yield of shared aquifers is that part of their annual recharge that can be extracted by each sharing country through means of pumping wells without causing severe drop in the water levels and without causing severe deterioration in their water quality.
- This research adopted numerical approach (using the Visual MODFLOW-GMS software) for a shared aquifer basin in Palestine in order to determine the sustainable yield of this shared aquifer basin.



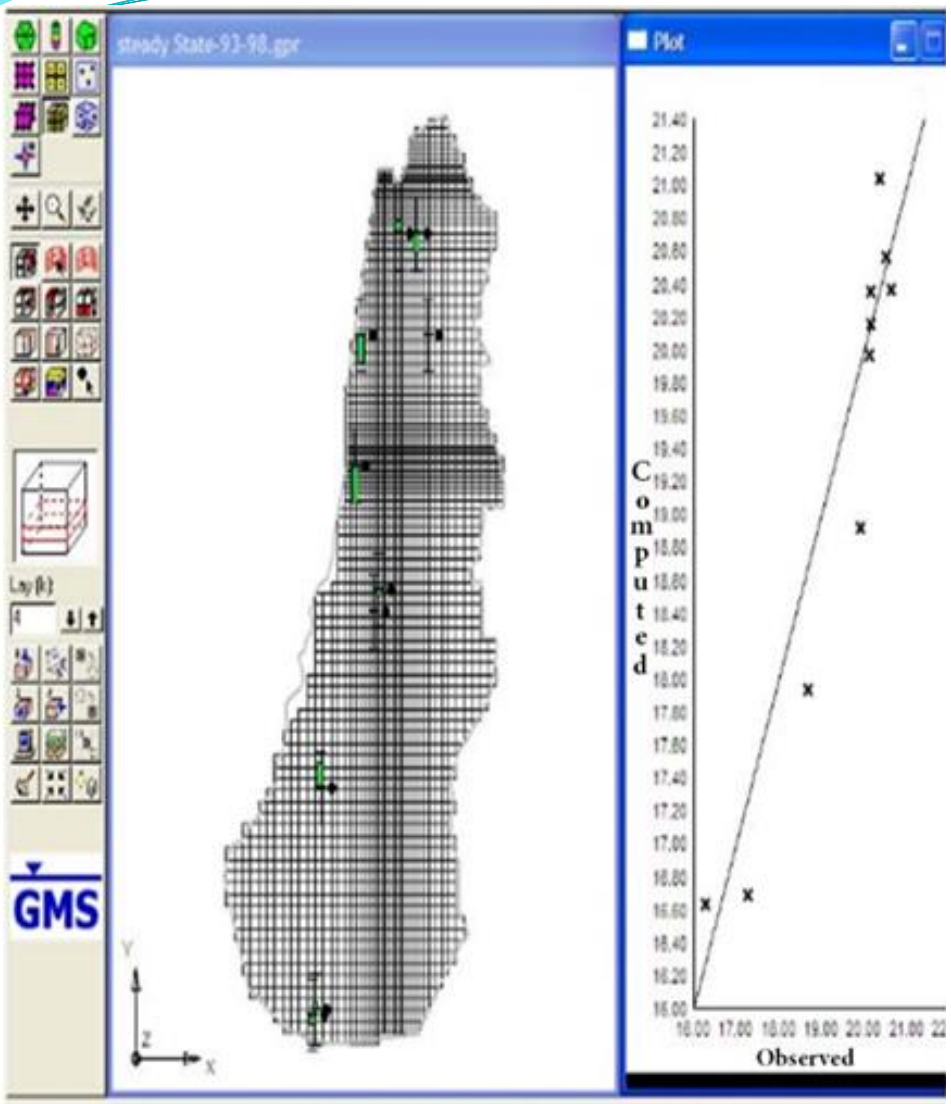


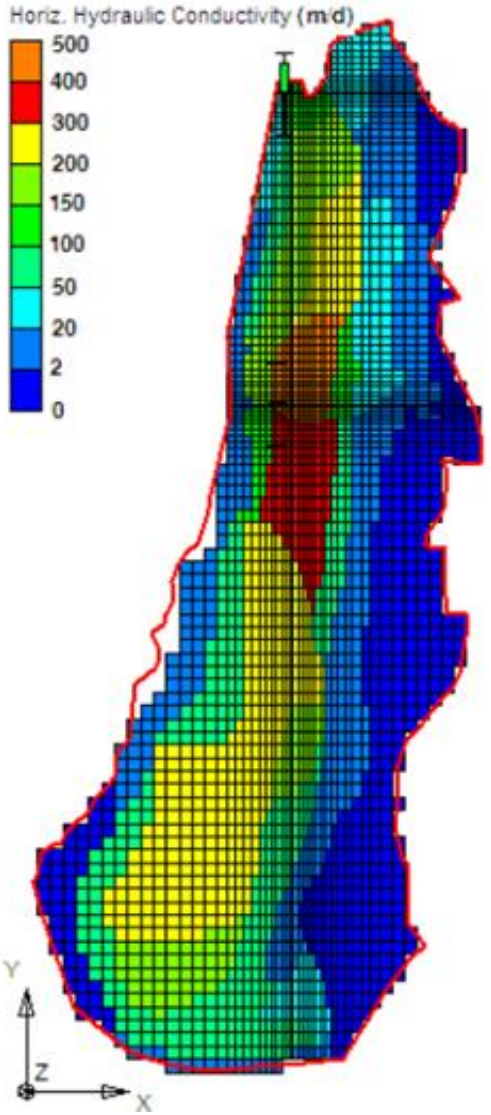
The study area

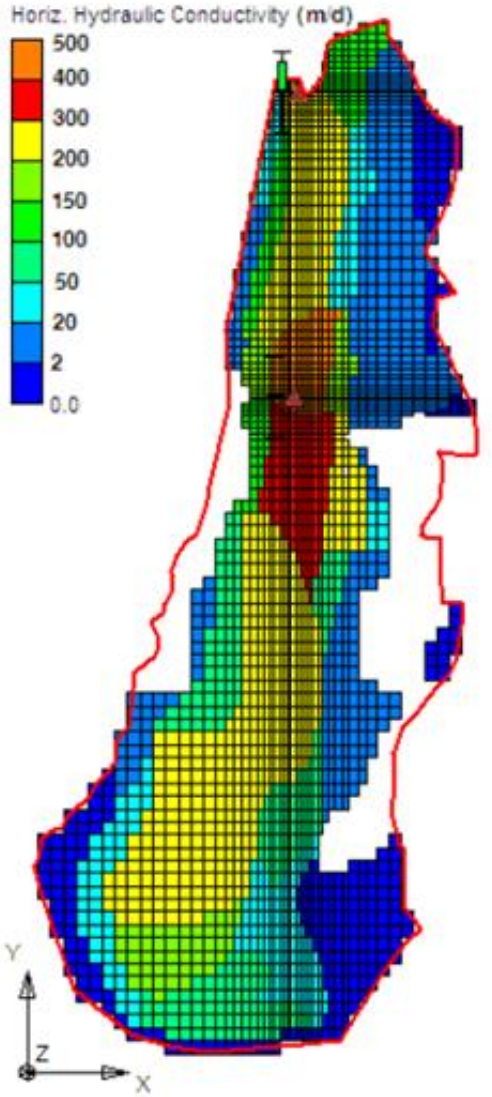
Methodology: Numerical modelling using Visual MODFLOW

- Geometry of the aquifers (Spatial distribution of thickness of UA&LA units):
  - Geological cross sections.
  - Seismic data.

- Hydraulic properties of UA&LA Units:
  - Pumping tests
  - Uncertainty was reduced through a thorough calibration process for hydraulic conductivity and storage parameters.


steady State-93-98.gpr
Plot
Computed
Observed
GMS

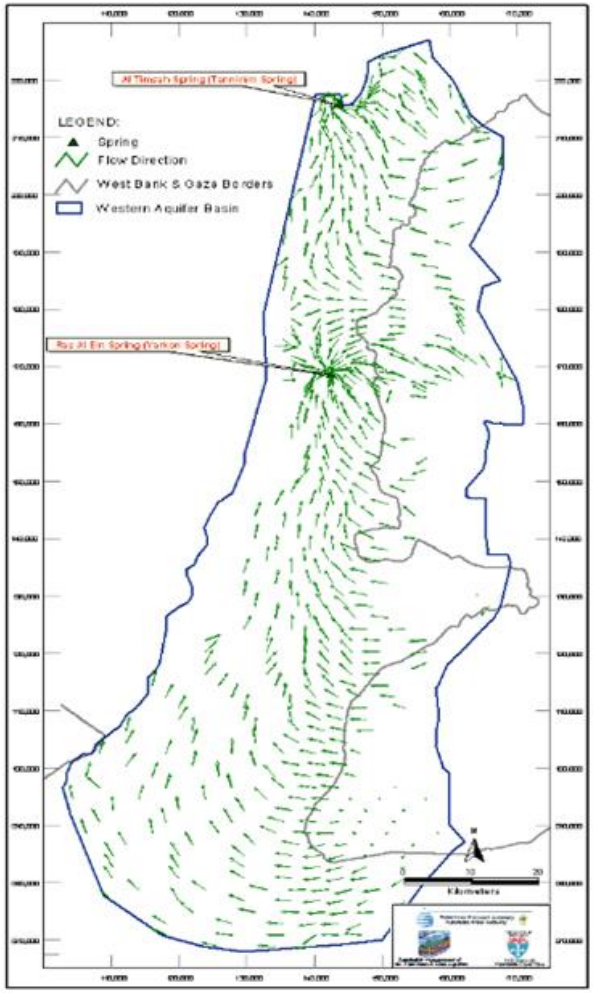

Horiz. Hydraulic Conductivity (m/d)
500
400
300
200
150
100
50
20
2
0


Horiz. Hydraulic Conductivity (m/d)
500
400
300
200
150
100
50
20
2
0.0

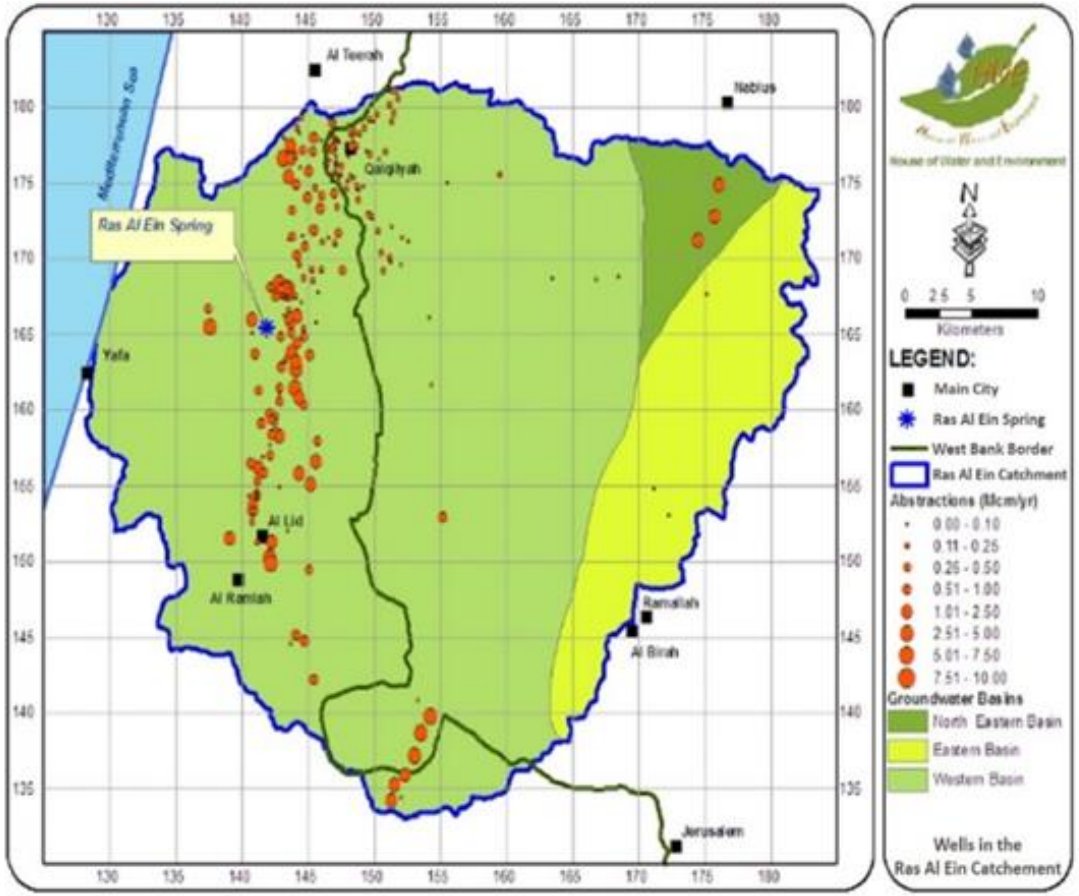
Methodology: determination of aquifer sustainable yield

- We developed an object-oriented approach based on aquifer outcrops to estimate recharge for each node of the grid of the model.
- We develop a soil moisture balance with wetting threshold concept for each node of the grid.
- We then incorporated recharge from the following sources
  - Rainfall.
  - Urban activities.
  - Irrigation losses.
  - Wadi runoff in the wadis.
- Historic spring discharges from the shared aquifer basin before development (before drilling pumping wells) was assessed as initial sustainable yield to the aquifer basin.
- After calibrating the model for K and S parameters, it was possible to approximate recharge parameter under pumping conditions to assess the sustainable yield of the shared aquifer basin.

Results



Steady Sate GW directions



Drilled wells around Ras Al-Ain Spring

Results

Spring Complex	Observed discharge (Mm^3/yr)	Modelled Discharge (Mm^3/yr)	Relative error
Al-Timsah	101.3	100.9	0.4%
Ras El-Ein	254.5	257	0.9%
Total	355.8	357.9	0.6%

All numbers in Mm^3/yr

Aquifer Unit	From Rainfall	From rainfall runoff	From wastewater runoff	From water supply leakage	From sea water intrusion	Sub-Total
UA	244.92	16.99	1.55	5.47	3.6	272.53
Yatta	21.1	1.45	0.02	0.25		22.82
LA	55.4	3.75	0.29	0.71		60.15
Sub-total	321.42	22.19	1.86	6.43	3.6	355.5

Results and discussion

- Calibrated recharge = 357.9 Mm^3/yr ≈ Measured springs discharges at 355.8 Mm^3/yr with a relative error less than 1%.
- Thus sustainable yield of the shared aquifer basin is modelled at 357.9 Mm^3/yr.
- The Ras Al-Ein spring emerges from both the LA and the UA as they are connected hydraulically near the spring complex.
- The spring was subjected to heavy pumping (around 220 Mm^3/yr) around it.
- Operating these wells has almost dried these springs in 1991 and led to the change in groundwater flow direction towards the springs, and subsequently drying up the springs.
- Extreme rainfall events **in** 1991/1992 raised the water levels in the aquifer to high levels of 50 years back causing Ras Al-Ein and Timsah springs to discharge water again.
- The spring complex is located in a strong karstic system in both the UA and LA.

Conclusions and Recommendations

- Sustainable yield was 357.9 Mm^3/yr.
- The sustainable yield of a shared aquifer basin in Palestine of karstic carbonate nature was determined in this study by utilizing the developed and calibrated numerical groundwater flow models.
- The MODFLOW- GMS software packages was used to estimate the sustainable yield of the shared aquifer basin.
- Numerical approach is recommended for sustainable yield determination.

Credits and Acknowledgements

- The funding and efforts of Kuwait Institute for Scientific Research and Newcastle University are very much appreciated to conduct this research.

THANK YOU