Sustainable Management of Groundwater

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Some Principles for Sustainable WRM

- Integral framework for all waters: surface, ground, rain, storm runoff, saline, treated effluents
- Two different roles of water use: for life, for production
- Quantity and quality must be considered jointy
- Demand side management is at least as important as supply side, often more, in agriculture, urban and industrial uses
- Environmental quality must be rehabilitated and sustained
- Social equity in water and sanitation services and pricing in participatory planning

Some Conditions for Sustainable WRM

- Effective laws and regulations
- Institutional structure within the water sector and its position in the regional/national governance framework
- Trained, dedicated and well-paid manpower in all segments of the water sector
- Government that utilizes expertise effectively
- Monitoring, analysis, modeling, comprehension
- Mechanism for transferring knowledge to the field
- Research and development

Properties of Groundwater

- "Hidden" to the public & political eyes and to the law
- Usable depths of 10s to 100s m → 1,500 m
- Very large volumes, used as storage and source
- Distributed in space, allows staged development
- Time response can be out-of-sinc with surface water
- Complex and often unknown aquifer properties
- Natural replenishment variable and uncertain
- Subject to pollution from land surface
- Very difficult to remediate

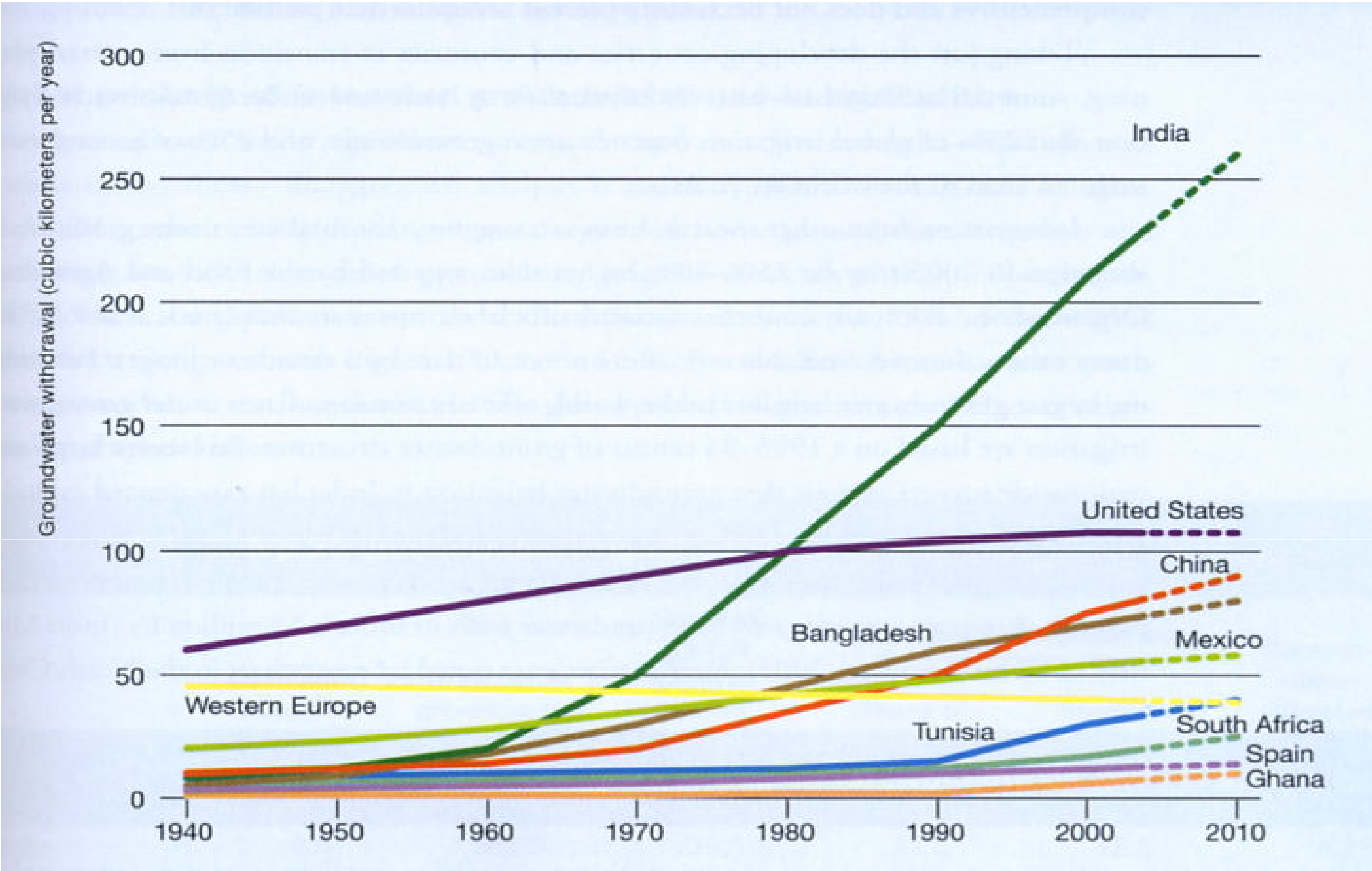


Figure 1.2: Groundwater abstraction trends (km^3/year) in selected countries (Shah et al., 2007) [WWDR4, Chapter 3.2.1]

Some Conditions for Sustainable WRM

- Sustainability: of the welfare of people and the environment, for present and future generations, while not necessarily maintaining the resources in their original state of quantity and quality
- This relates also to the use of fossil groundwater, which is in great abundance in the world, for example:
  - Disi aquifer: extraction and delivery to Amman and other cities
  - Guarani aquifer: potential for incremental and geographically distributed development, following monitoring and extemsive study

Schematic outline of the Disi to Amman project

50-60 wells; depth 400-600 m; 325 km pipeline; 1 m diameter; 100 mcm/year for more than 50 years

Location maps of the Disi Fossil Aquifer in Jordan and across the border with Saudi Arabia

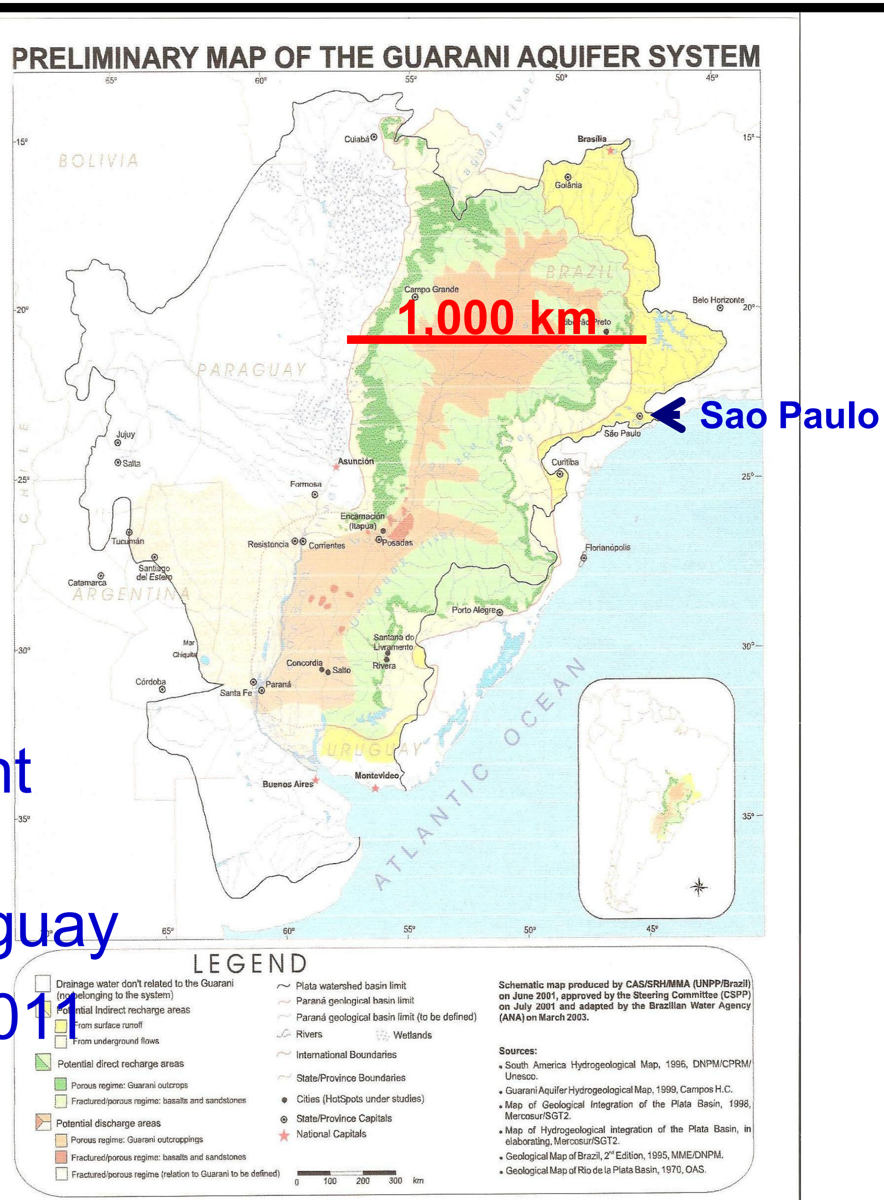
Guarani: ~ fossil aquifer

- Area=1.2 Mil Km^2;
- Volume= 37,000 km^3
- Depth=50-800-1,800 m
- Recharge=166 km^3/year

  = 0.5% of the volume
- Huge potential for development

Brazil, Argentina, Paraguay, Uruguay

GAS Agreement in September 2011

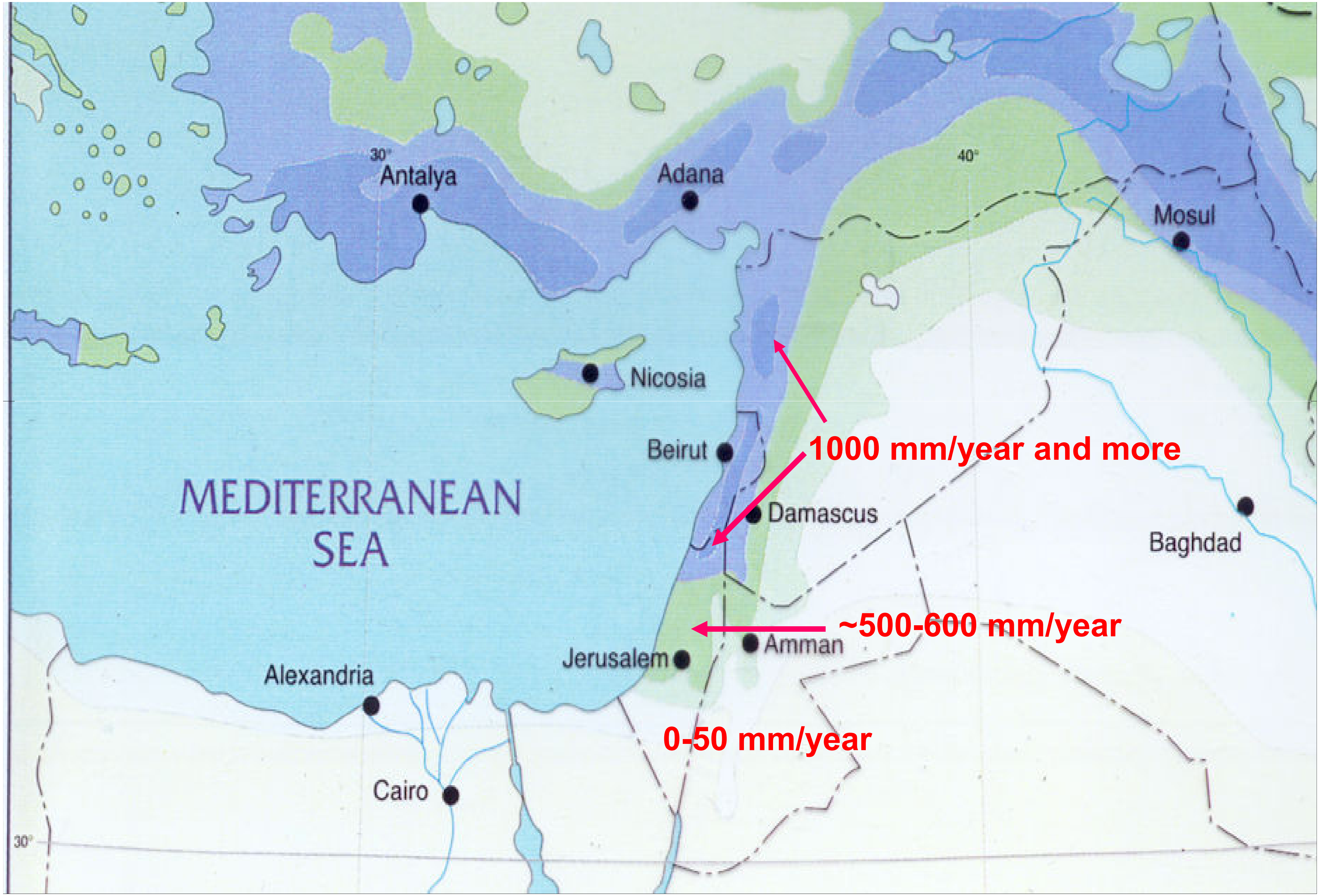


Location Map of the Guarani Aquifer

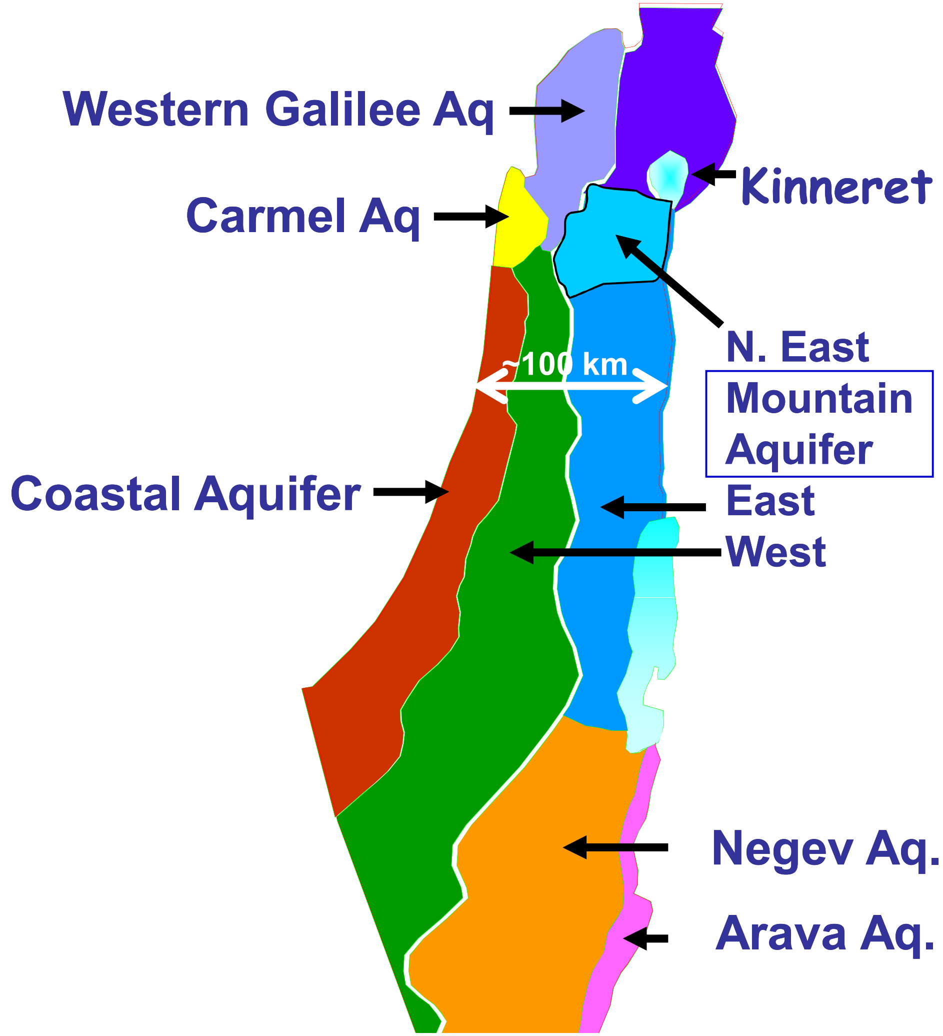
Israel's Water Management: Integrated use of groundwater

Similar challenges face other countries in the region and in the world, but responses have to be adjusted to local conditions and capabilities

Rainfall Distribution in the Region



WATER SOURCES



Highly integrated national and regional water systems

Average Annual Potential
~1,200 mcm/yr Israeli control
~1,700 mcm/yr whole area

Challenges → Pressures

- In the past >70% of the water was used for the (politically powerful) agricultural sector
- As long as water for agriculture was subsidized, the Ministry of Finance refused to allow the development of new sources, in particular large-scale sea-water desalination
- Result: overutilization of the sources, both surface (Kinneret) and aquifers, and decline of their quality
- Urban growth → more demand for urban water → today 50%-60% of the natural fresh water goes for urban consumption

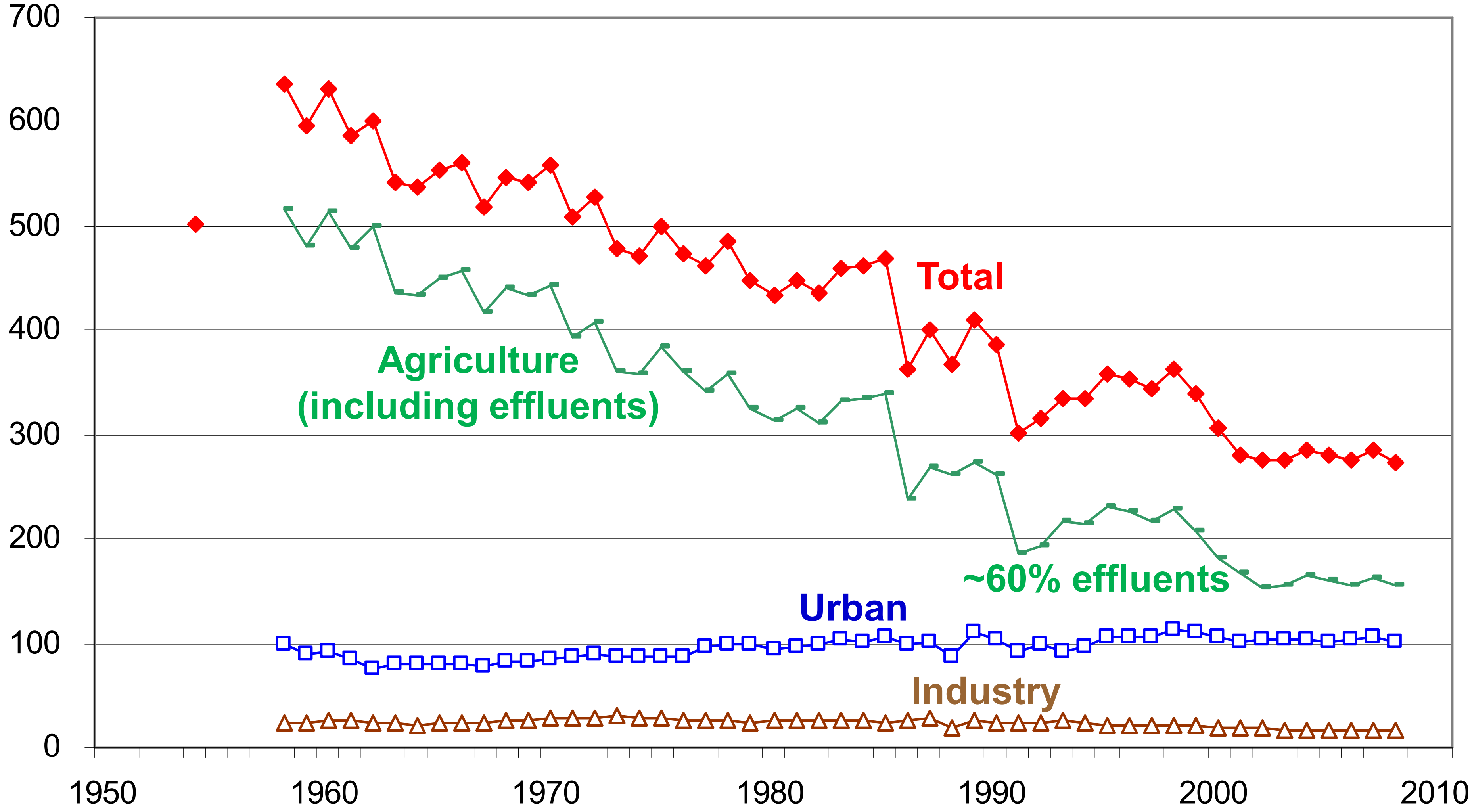
Challenges → Pressures

- Large hydrological variability and uncertainty with respect to the effects of climate change
- Declining water quality in the sources
- Rising quality standards for potable water and effluents (we have excellent quality at the house connection, good quality effluents)
- Frequent changes in the political arena, internal and external policies
- Regional geo-political situation and uncertainty: sustaining the existing agreements and preparing for future ones

Pressures → Responses

- Reduced by more than 60% the use of fresh water in irrigation
- Replaced by properly treated effluents, 80% of urban sewage is converted to usable effluents
- Water & effluents productivity in agriculture has multiplied by 5-10
- Water prices moved to full-cost for urban use, also gradually for irrigation
- Conservation in the urban sector: 100 m^3/cap/year → 85-90 m^3/cap/year for all uses

Water (incl. effluents) consumption, m³/cap/year



Source: Prof. Yoav Kislev

Private homes

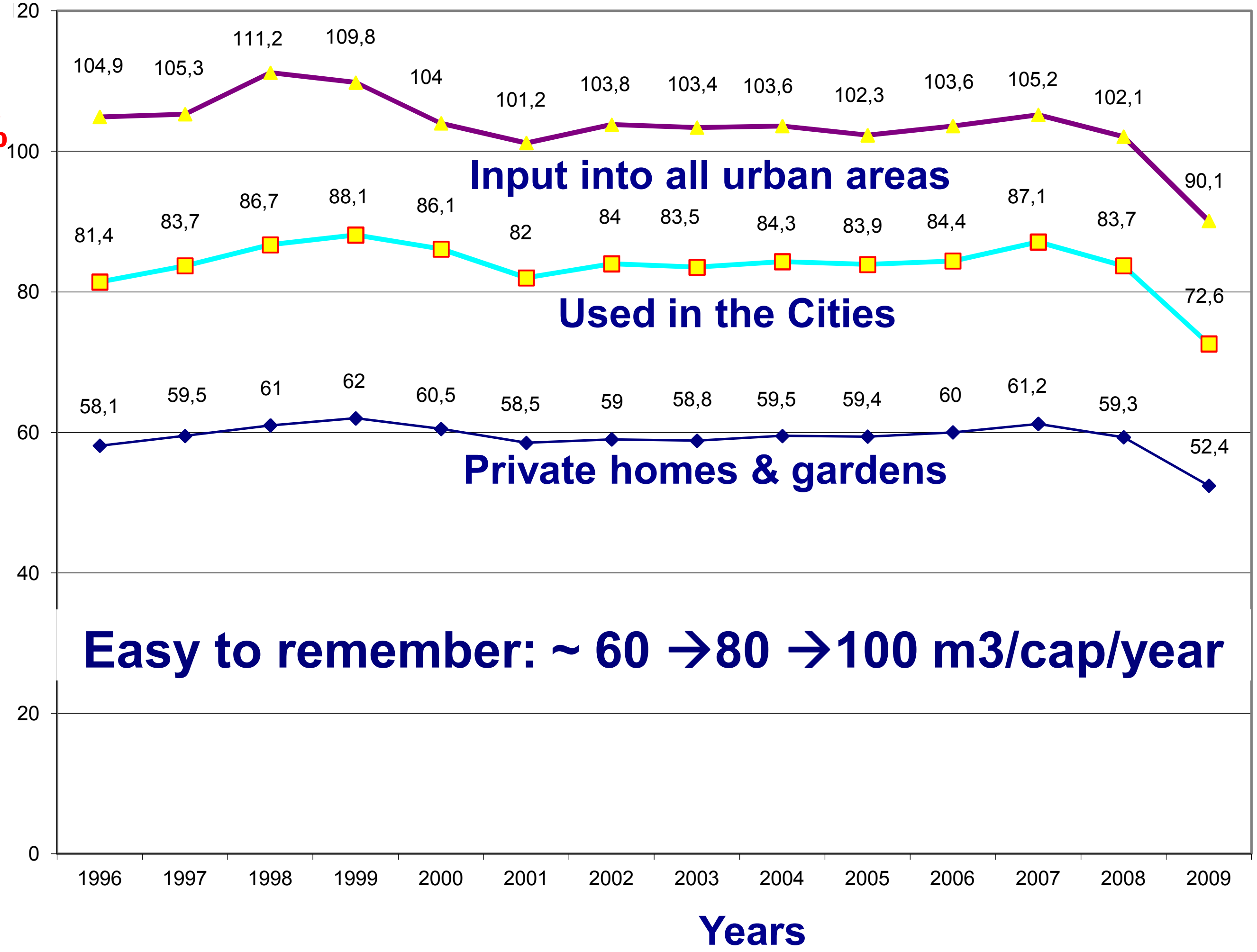
Annual Per Capita Consumption, 1996-2009 (m^3/capita/year)

Reduction 2008→2009

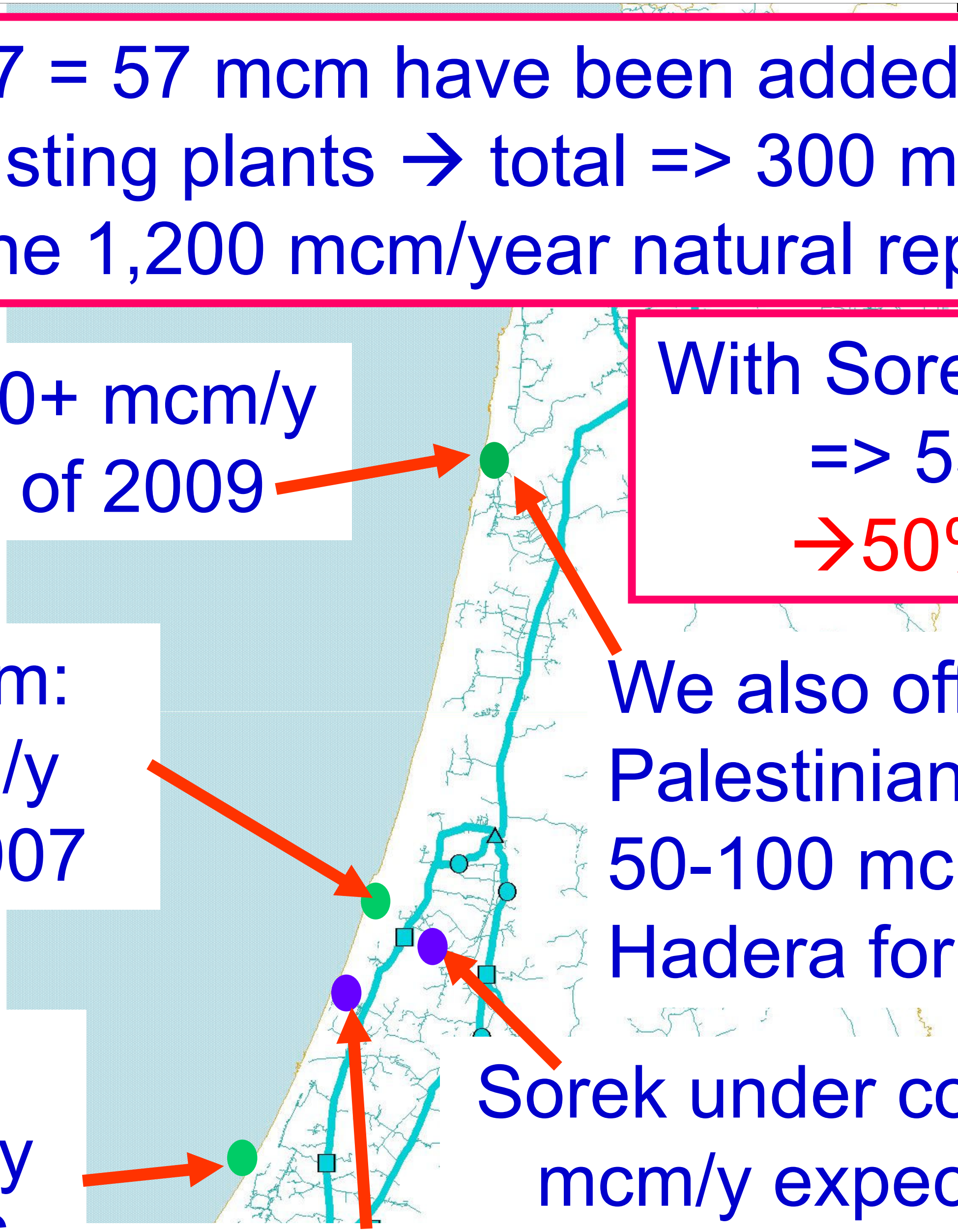
(102.1-90.1)/102.1=12% = 90 mcm

(83.7-72.6)/83.7=13%

(59.3-52.4)/59.3=12%



15+15+27 = 57 mcm have been added to the three existing plants → total => 300 mcm/yr
25% of the 1,200 mcm/year natural replenishment



Hadera: 100+ mcm/y since end of 2009

With Sorek and Ashdod => 550 mcm/y →50% of 1,200

Palmachim: 30+ mcm/y since 6/2007

We also offered the Palestinians to locate a 50-100 mcm plant at Hadera for the WB

Ashkelon: 100+ mcm/y since 2006

Sorek under construction 150 mcm/y expected in ~2013

Ashdod : 100 mcm/y expected in ~2013

Pressures → Responses

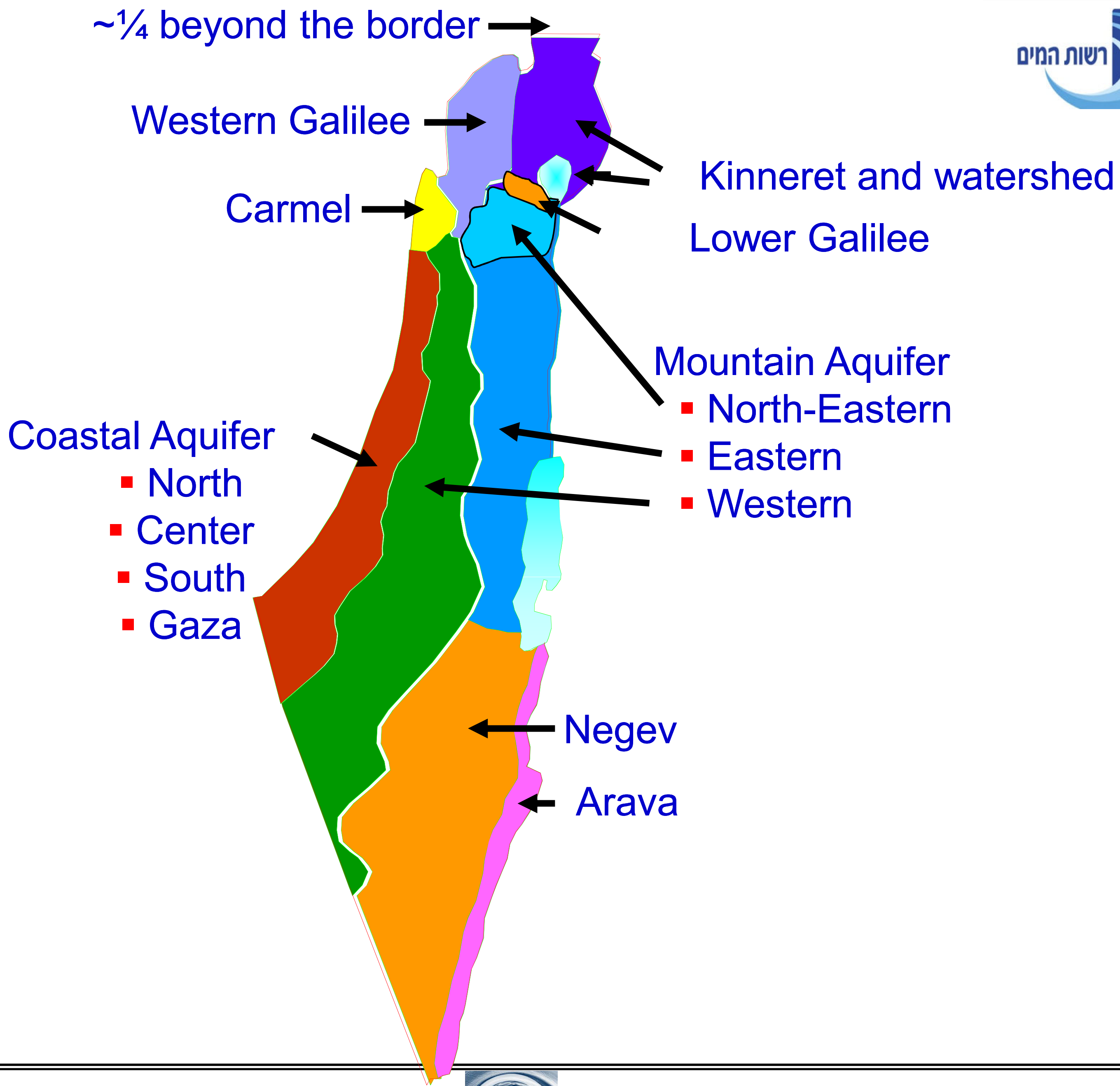
- Recall: average annual replenishment of all sources in Med Sea–Jordan area 1,700 mcm/year, Israel's expected share 1,200→1,100 mcm/year
- Since 2006 large-scale desalination program:
  - Operating today 300 mcm/year (25%)
  - By 2013 550 mcm/year (50%)
  - Planned by 2020 750 mcm/year (~70%)
- Desalination of saline gw → 50 mcm/year
- Sewage reclamation: 300→500 mcm/year

Israel's Main Accomplishments

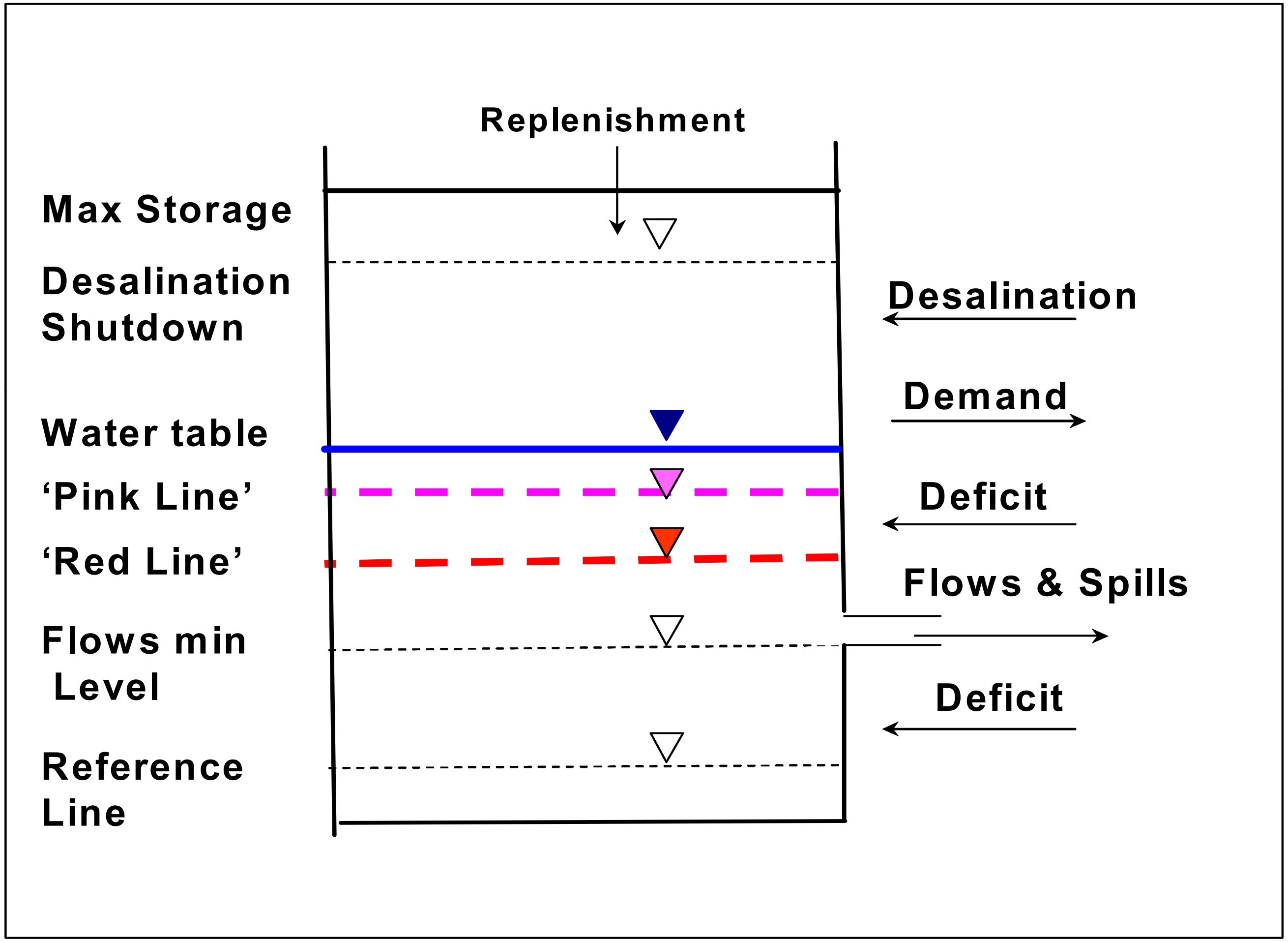
- Powerful water law, updated
- Integrated policy and control
- Highly integrated physical system
- Tight control on groundwater management
- Efficient use of water in agriculture
- Efficient use of water in the urban areas
- Treatment and reuse of sewage effluents
- Large scale sea-water desalination
- Desalination of brackish groundwater

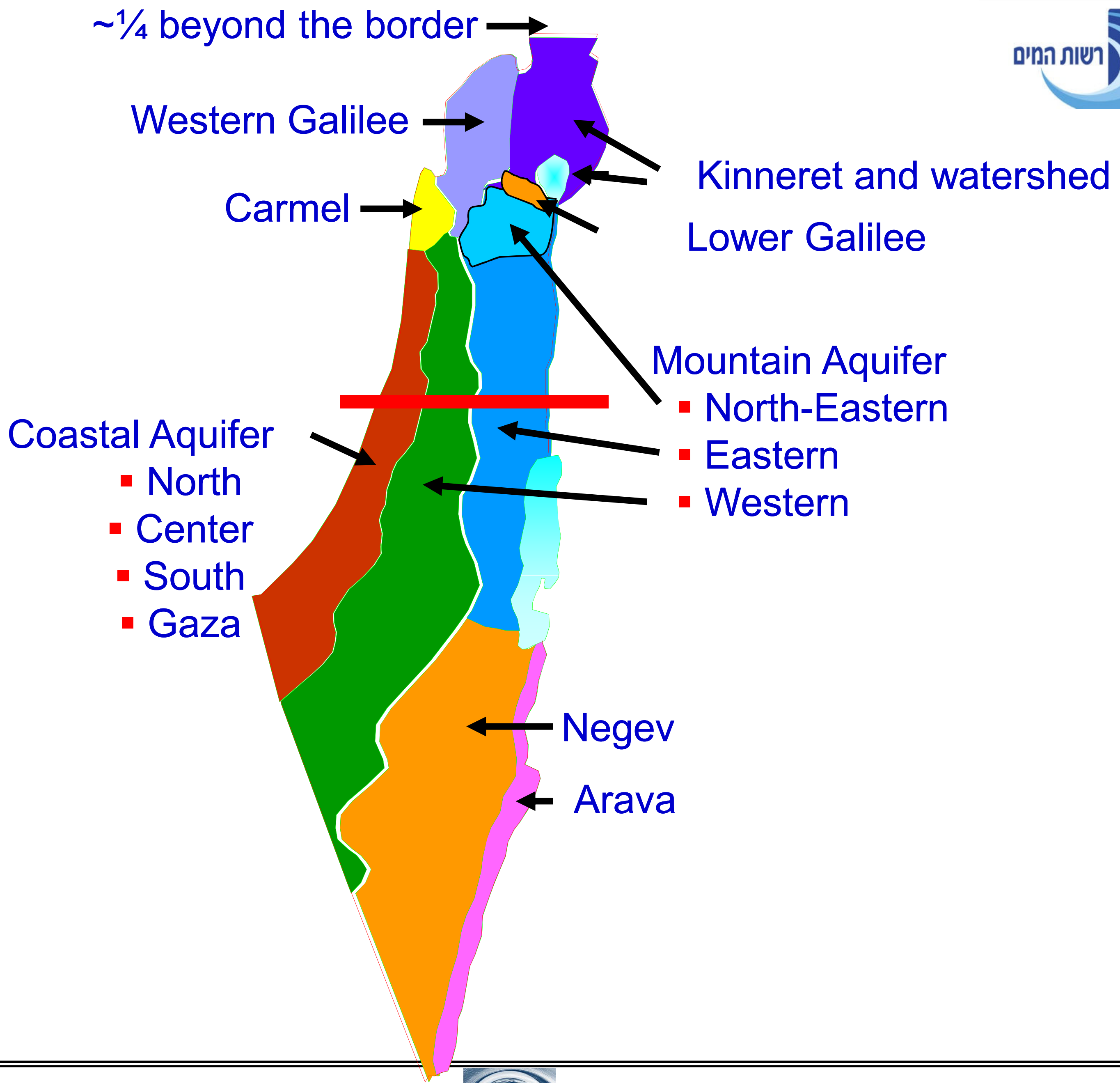
Israel's Main Failures

- Overuse of the natural resources, until the crisis resulted in adoption of the desalination program
- Detrioration of source water quality, resulting from the overuse
- Delayed decision on the desalination plan
- Insufficient attention to urban conservation, until the last few years
- Inadequate national regulation of the sector: no national coordination of infrastructure sectors; creation of (too many) municipal corporations; rapid rise in urban water prices, causing unrest


~¼ beyond the border
Western Galilee
Carmel
Kinneret and watershed
Lower Galilee
Mountain Aquifer
North-Eastern
Eastern
Western
Coastal Aquifer
North
Center
South
Gaza
Negev
Arava

Single-cell model of the entire water storage in all sources, used in a stochastic analysis of water supply vs. demand, with historical time-series of replenishment

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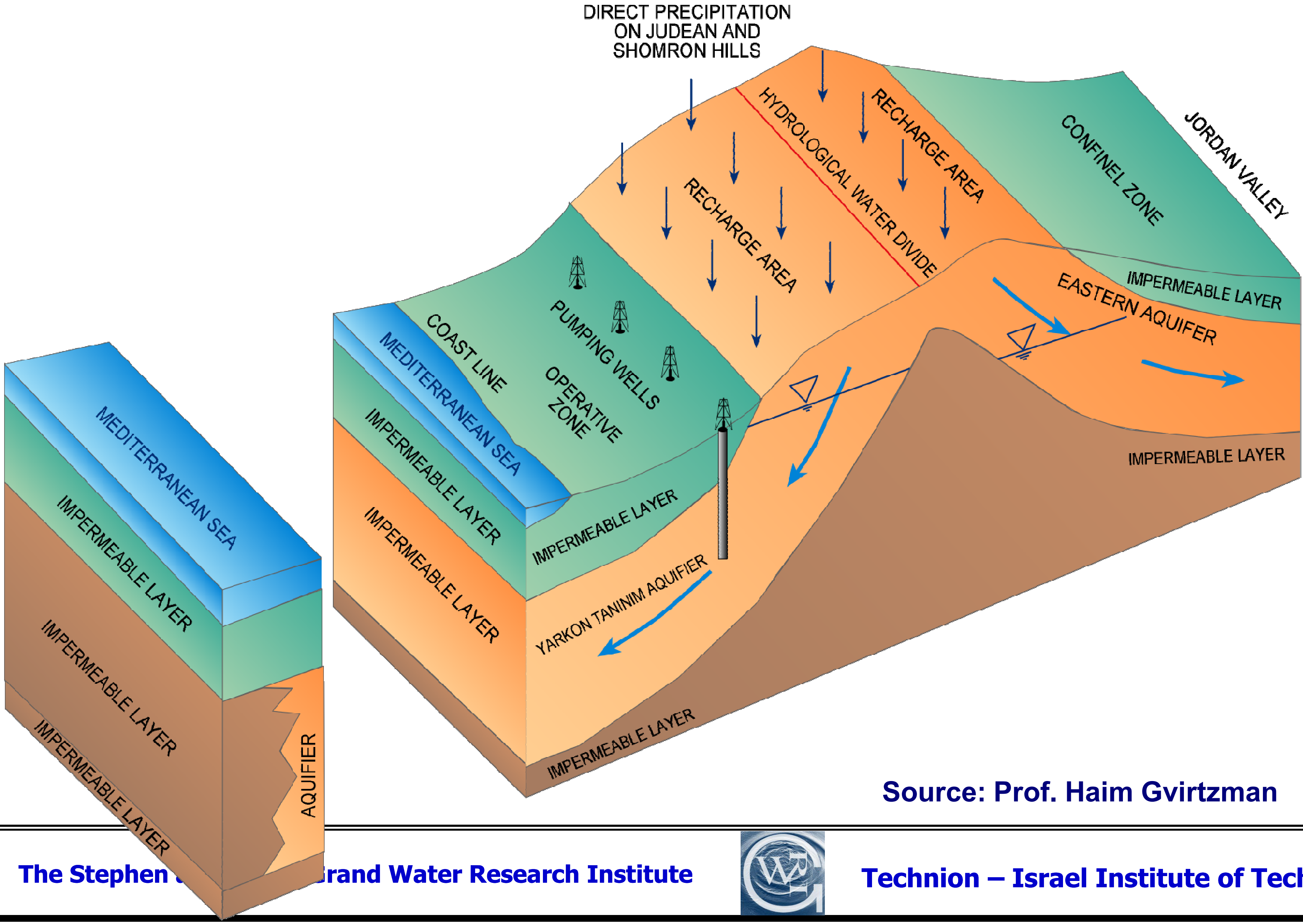
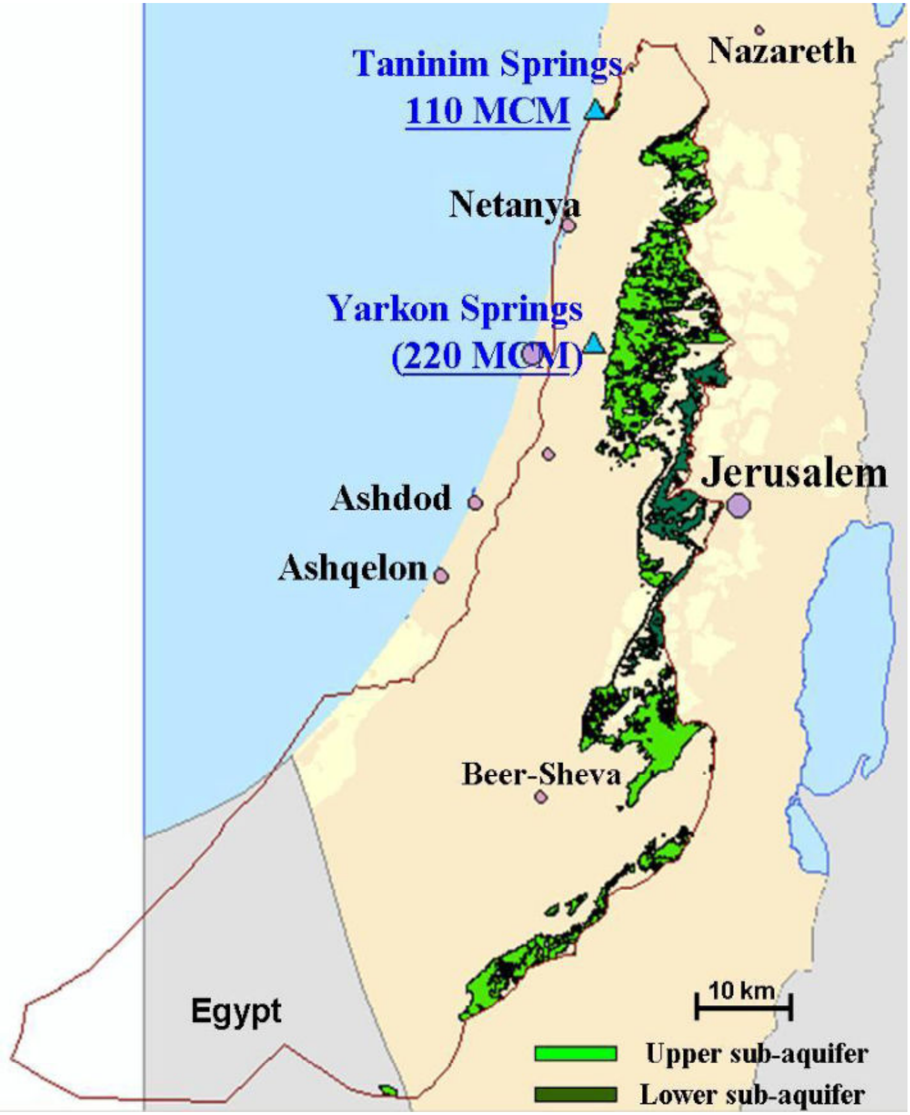
Schematic Cross Section of the Mountain Aquifer in the Judean Mountains Region



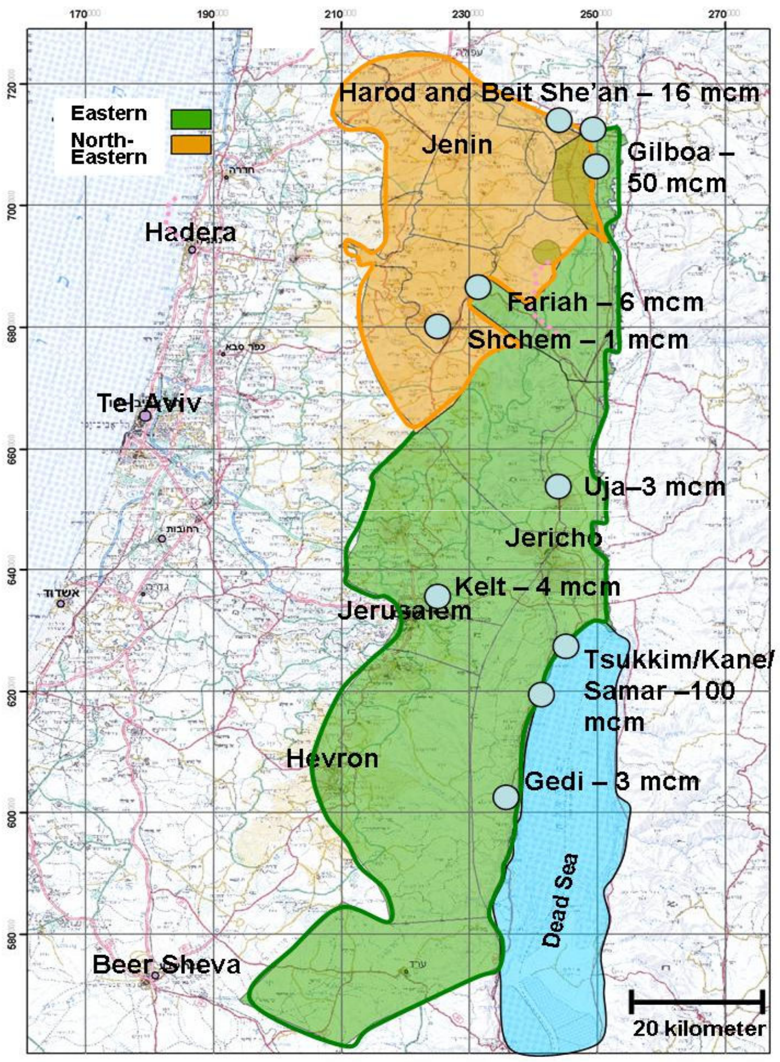
Source: Prof. Haim Gvirtzman

Boundaries and recharge areas of the Western Basin of the Mountain Aquifer, used in a cell model



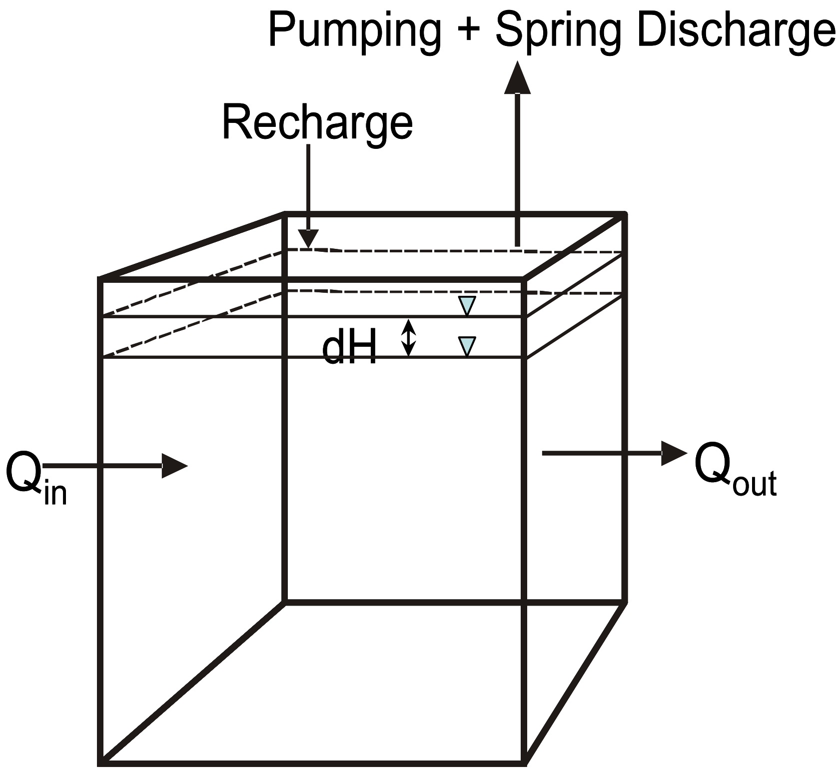
[Source: M. Zilberband, Israel Hydrological Service, 2012]

Boundaries of the Eastern (green) and North-Eastern (ochre) Basins of the of the Mountain Aquifer, used in a cell model



[Source: M. Weiss , Israel Hydrological Service, 2012]

One unit of the Cell Model used by the Israeli Hydrological Service for calculating the annual balance in aquifers



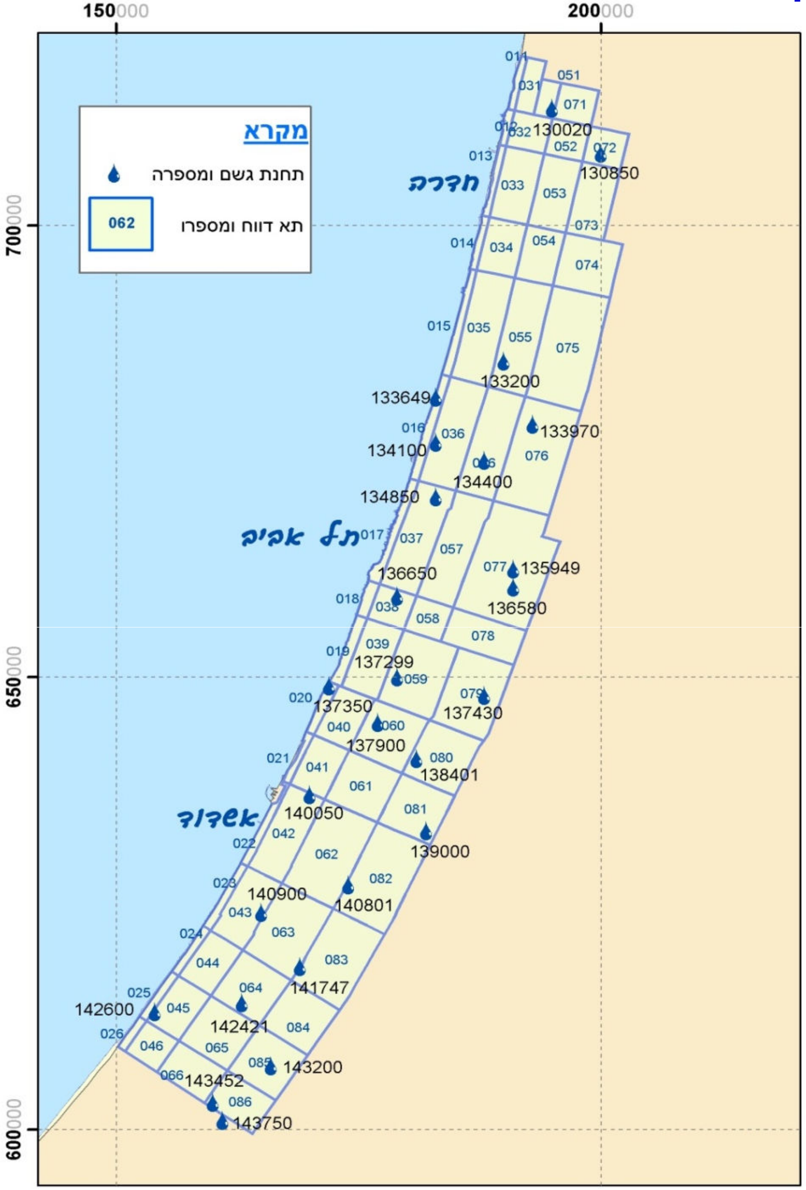
Recharge = A_{Ri}* Rain
Storage Change = A_S* dH

Where:
- Q_{in} - inflow from neighboring cells
- Q_{out} - outflow from neighboring cells
- H - piezometric head
- A_{Ri} - rain-recharge coefficient
- A_S - head-storage coefficient
- $A_{(i-1),i}$ / $A_{i,(i+1)}$ - water exchange coefficients between adjacent cells

$$(\text{Pumping} + \text{Spring Discharge})_i = A_{Ri} * \text{Rain}_i - A_{(i-1),i} * (H_{i-1} - H_i) + A_{i,(i+1)} * (H_i - H_{i+1}) - A_S * (H_i^{t+1} - H_i^{t})$$

[Source: Israeli Hydrological Service, Bachmat Model]

Cell model of the Israeli Coastal Aquifer

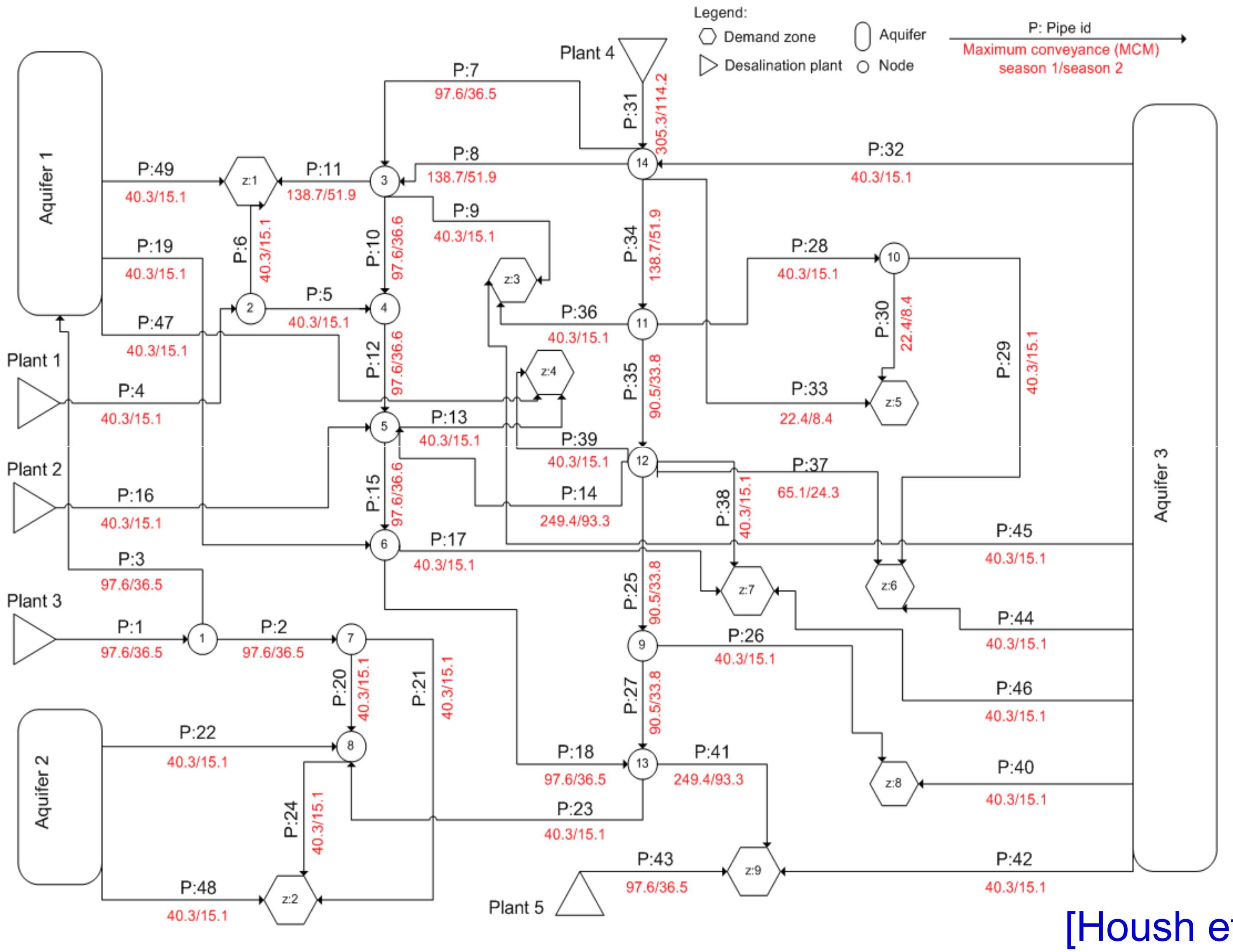


[Source: Y. Livshitz, Israel Hydrological Service. 2012]

Management of Groundwater

- Extensive and continuous monitoring of time-series: precipitation, levels, quality, spring flows
- Water balance models, calculation of the recharge
- Bottom "Red" lines as operational constraints
- Upper operational lines as targets
- Models: from single-cell for single aquifers and the entire storage system, deterministic and stochastic analysis
- Multi-cell models (finite difference, finite element)
- Excellent professionals!

Model of the Israeli National Water System used for optimal operation for 10 years under hydrological uncertainty



[Housh et al., 2012]

Conclusions

- Groundwater provides about 60% of the supply of natural fresh water
- Aquifers are used as storage, jointly with the Sea of Galilee
- Desalination capacity is increasing but the natural sources remains a strategic asset for the country
- Aquifers receive much professional attention regarding their storage, flows and quality
- Polluted aquifer are being remediated and protected
- The Mountain Aquifer is a common resource with the Palestinians

Thank You!