The anthropogenic impact of cross-borders water resources development on the water quality of the Jordan River

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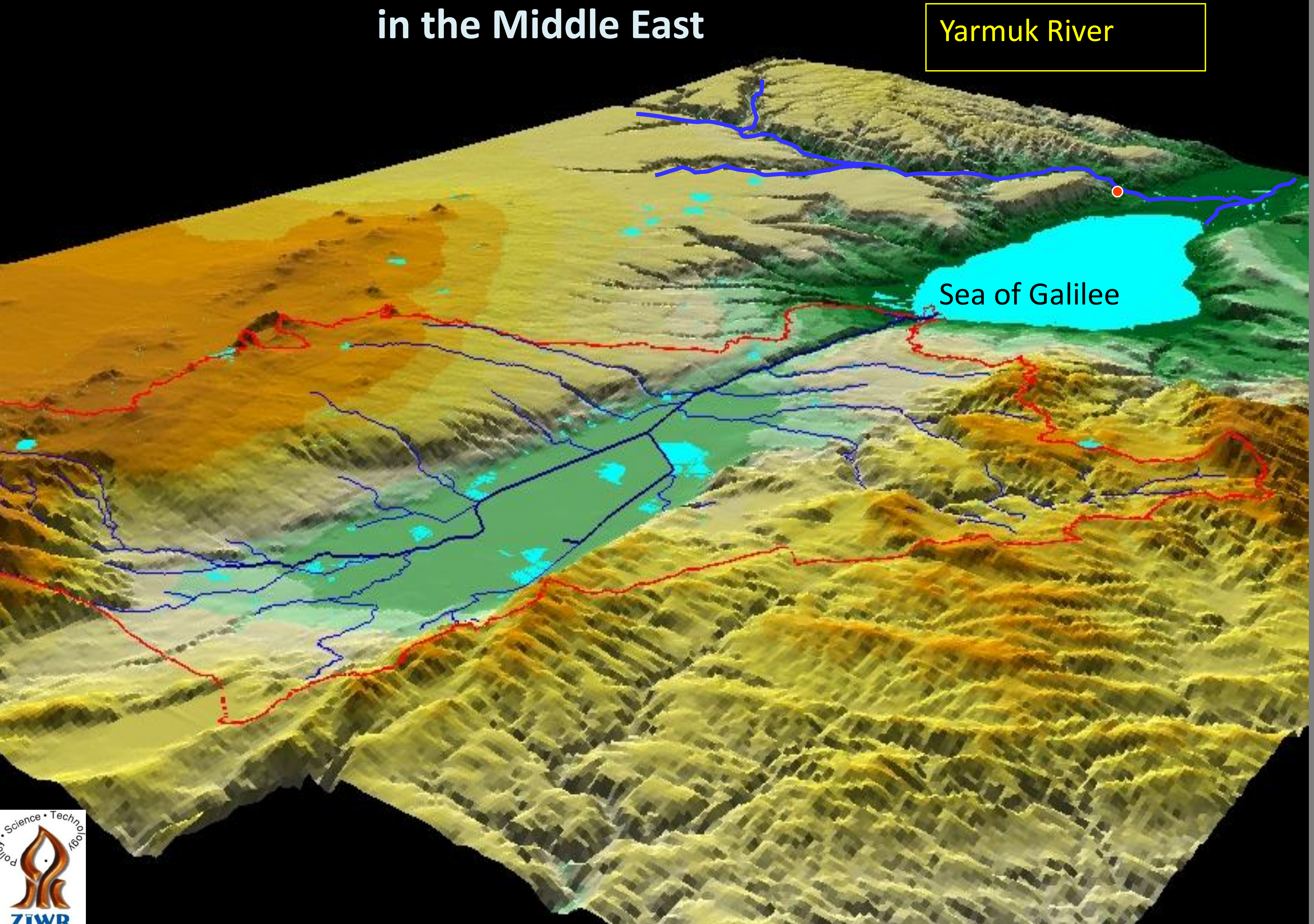
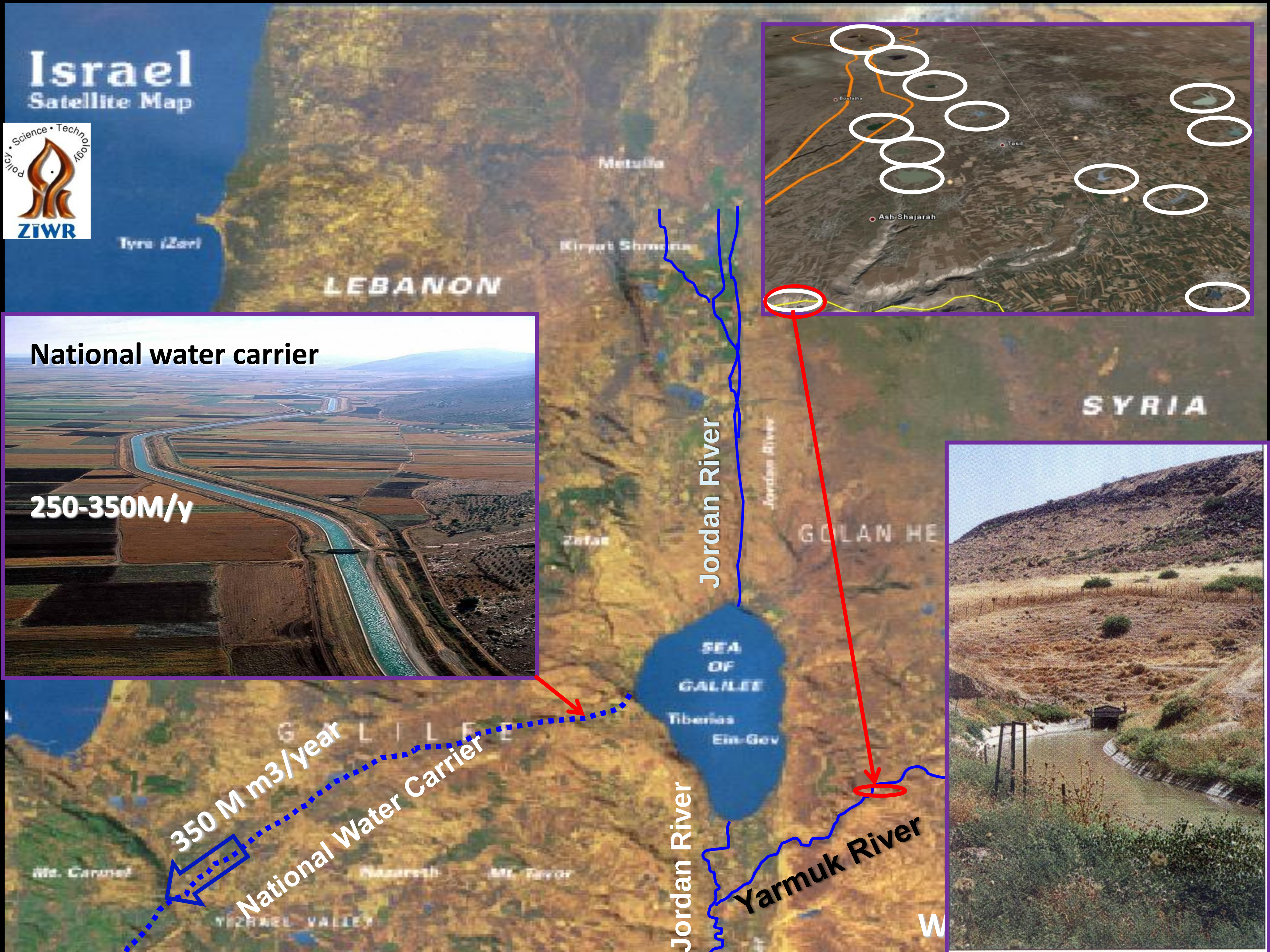
The Sea of Galilee - The only natural fresh water reservoir in the Middle East



Science • Technology • Policy
ZIWR

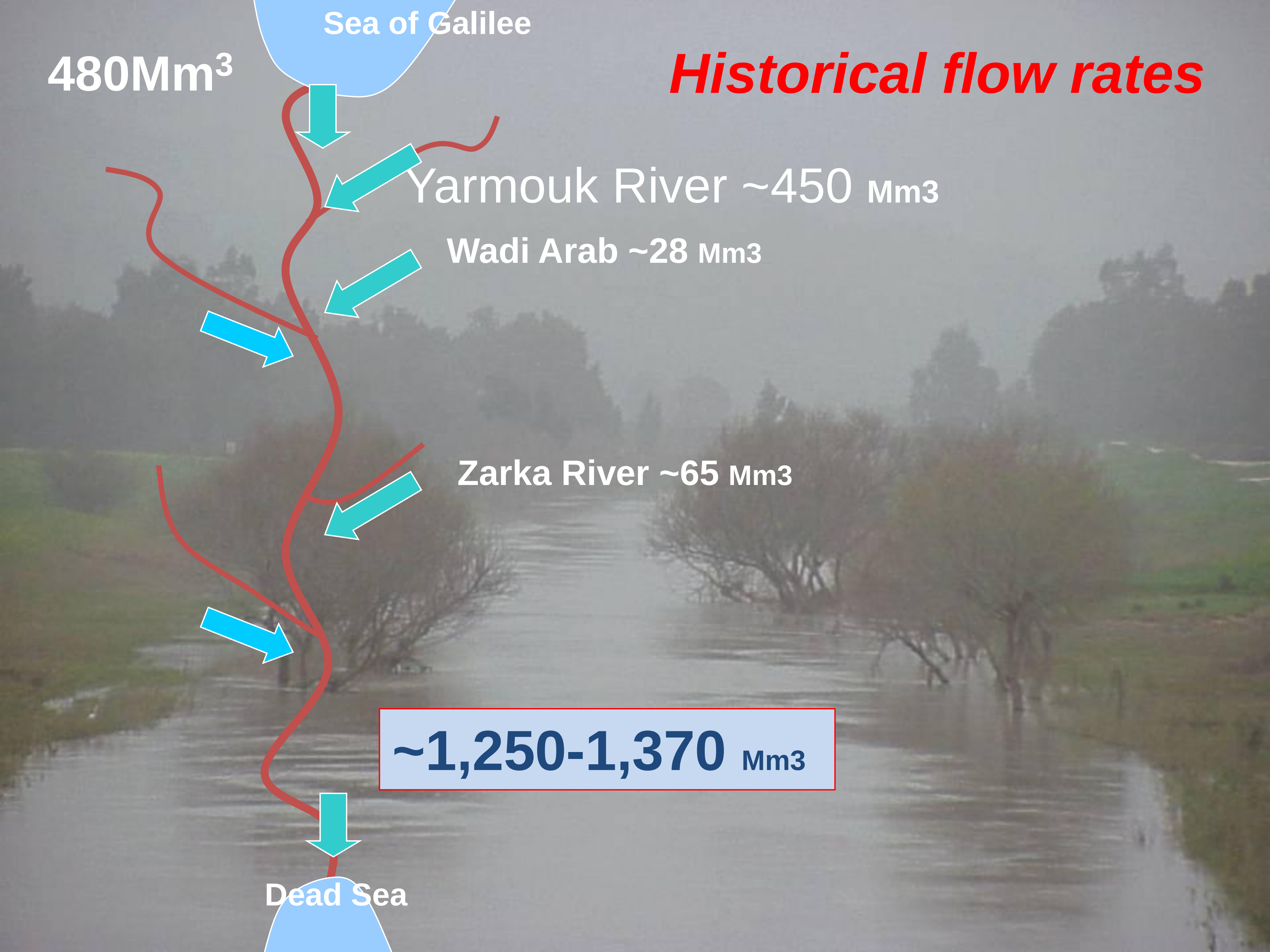
The Jordan River basin is a cross-borders trans-boundary basin shared by Lebanon, Syria, Jordan, Palestinian Authority and Israel.

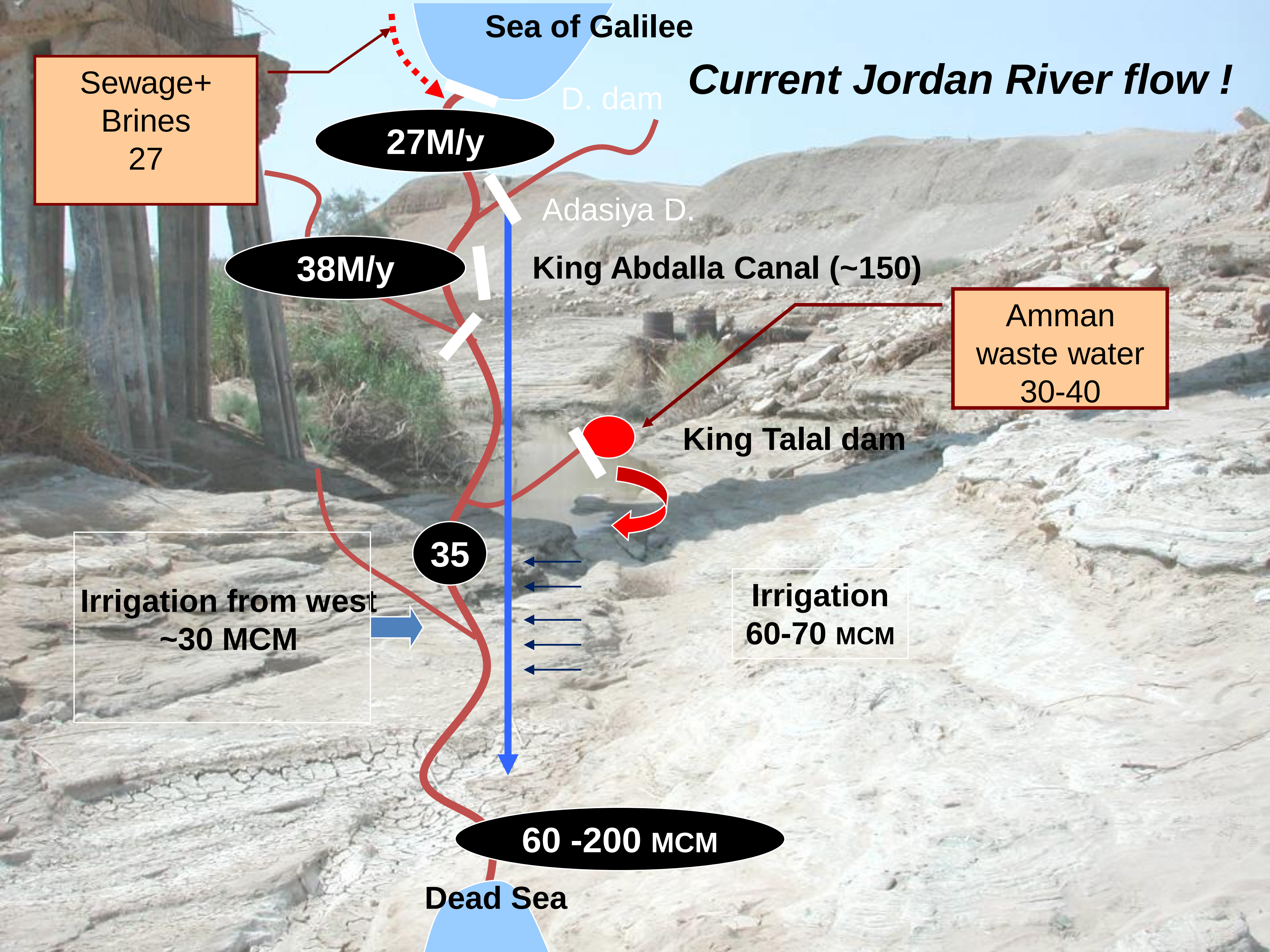
Water Budget



Israel
Satellite Map
Policy • Science • Technology
ZIWR
Metulla
Tyre (Zor)
Kiryat Shmona
LEBANON
SYRIA
National water carrier
250-350M/y
Tasil
Ash Shajarah
Jordan River
Jordan River
GOLAN HE
Zefat
SEA OF GALILEE
Tiberias
Ein-Gev
GALILEE
350 M m3/year
National Water Carrier
Mt. Carmel
Nazareth
Mt. Tavor
YIZRAEL VALLEY
Jordan River
Yarmuk River
W

The Jordan Valley Basin


Historical flow rates
Sea of Galilee
480Mm3
Yarmouk River ~450 Mm3
Wadi Arab ~28 Mm3
Zarka River ~65 Mm3
~1,250-1,370 Mm3
Dead Sea


Sea of Galilee
Current Jordan River flow !
Sewage+
Brines
27
D. dam
27M/y
Adasiya D.
38M/y
King Abdalla Canal (~150)
Amman
waste water
30-40
King Talal dam
35
Irrigation from west
~30 MCM
Irrigation
60-70 MCM
60 -200 MCM
Dead Sea

Water Sources & Water Quality of the Lower Jordan River

Identifying & Quantifying the Current Sources !

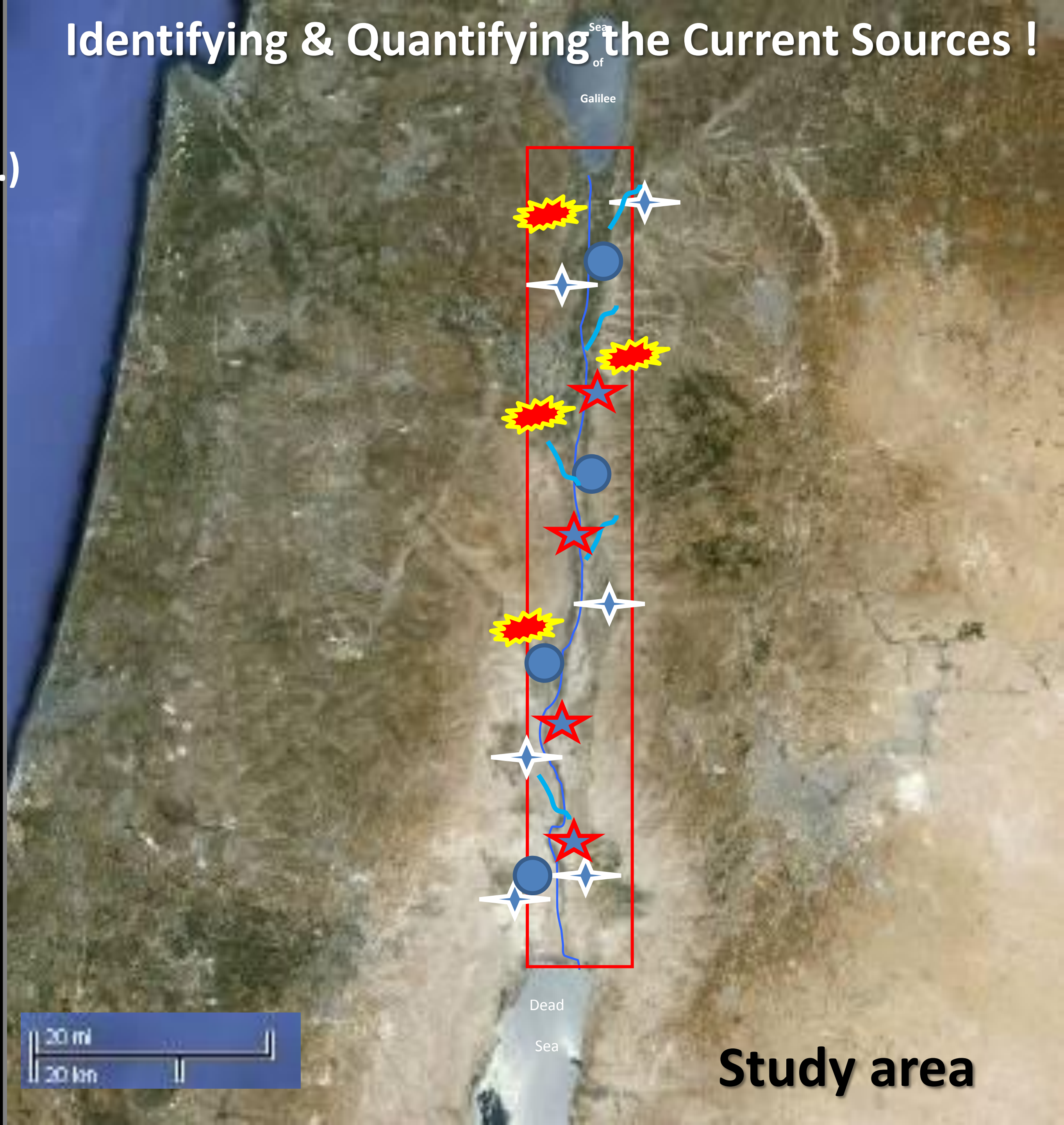
Effluents (industrial, domestic, fish ponds etc.)

Irrigation-subsurface return flow (drains)

Springs

Streams

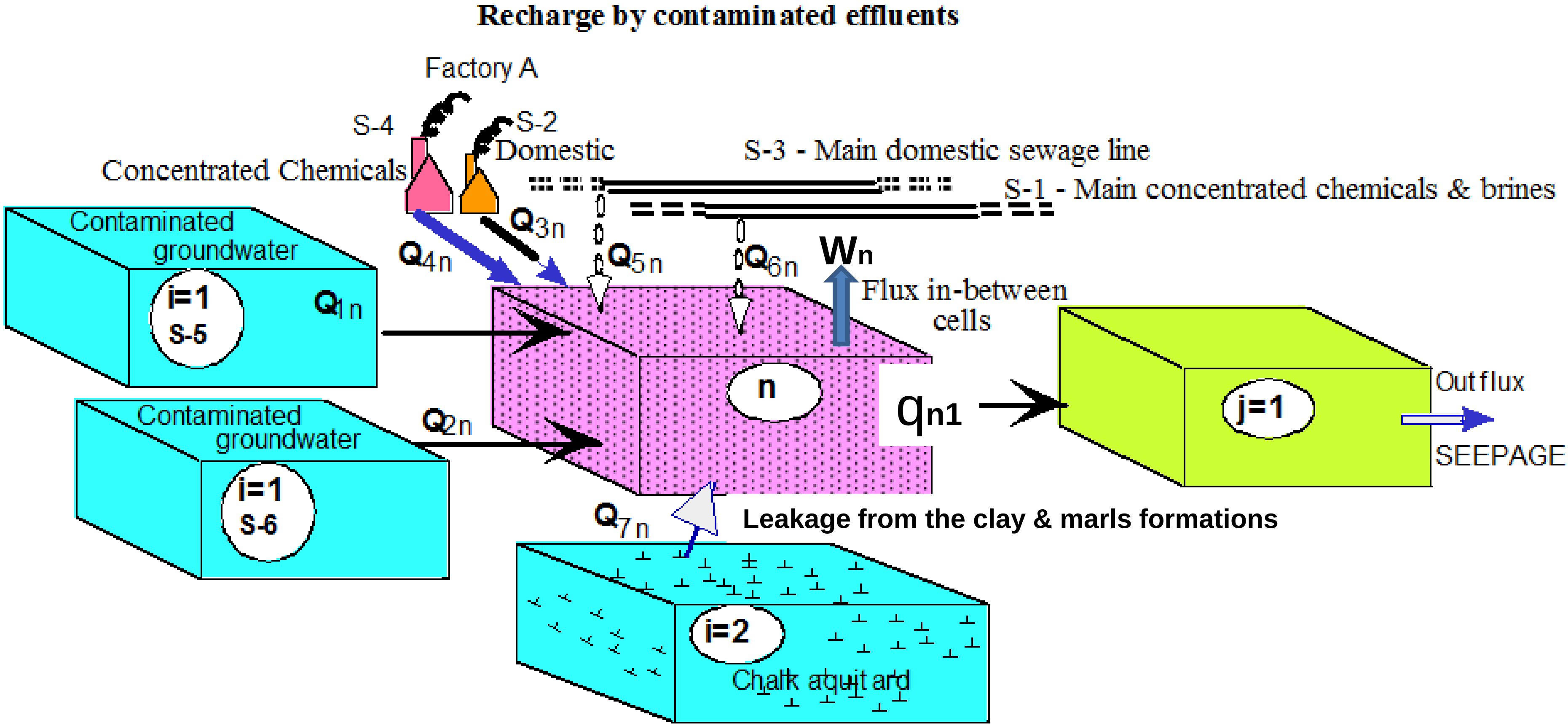
Seepage from shallow aquifers



Study area

The Mixing Cells Modeling (MCM) concept

Water Balance Expression

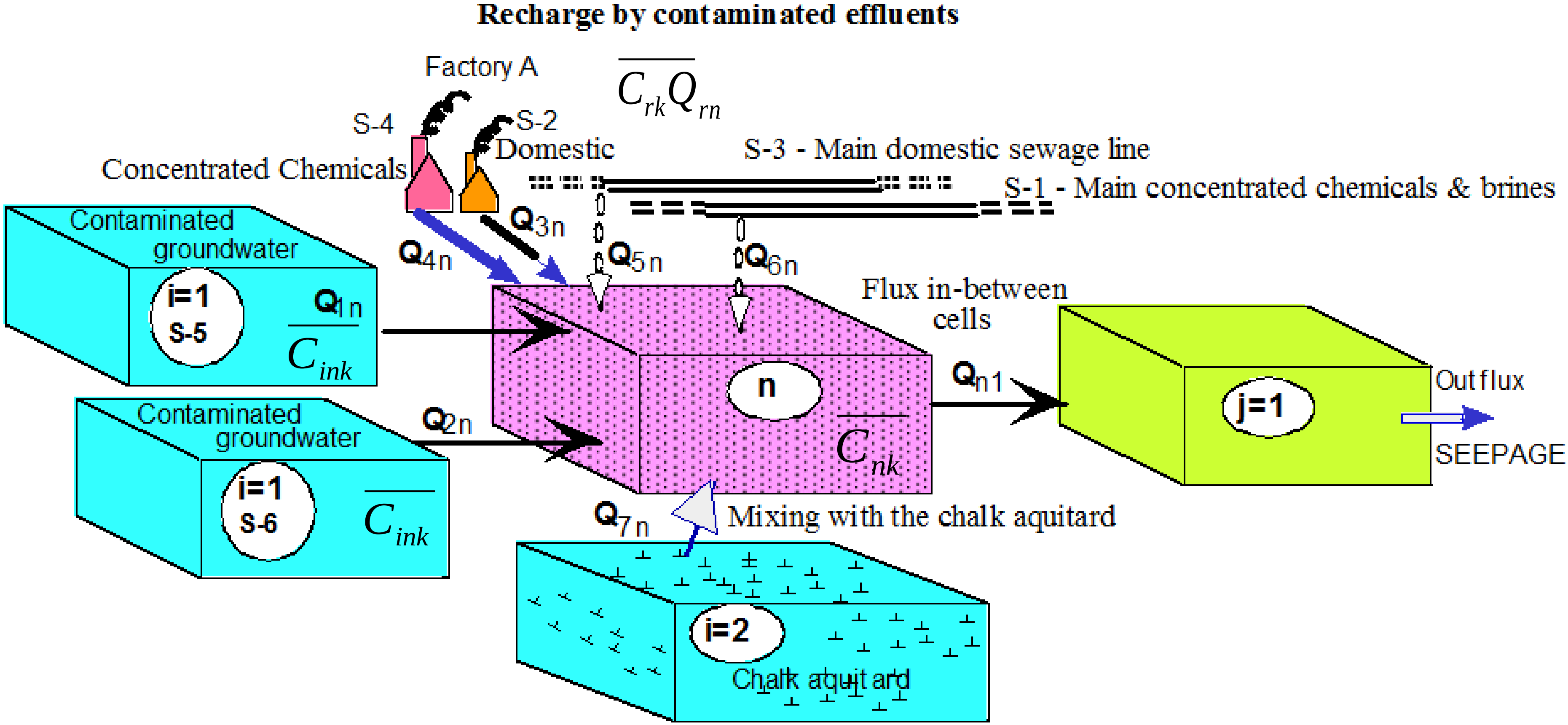


$$(1) \qquad \sum_{r=1}^{R_n} Q_{rn} + \sum_{i=1}^{I_n} q_{in} - \sum_{j=1}^{J_n} q_{nj} - W_n - S_n = 0$$

$$(2) \qquad \sum_{r=1}^{R_n} \overline{Q}_{rn} + \sum_{i=1}^{I_n} \overline{q}_{in} - \sum_{j=1}^{J_n} \overline{q}_{nj} - \overline{W}_n - \overline{S}_n = \varepsilon_n$$

All potential sources are identified

Mass Balance Expression



$$(3) \quad \sum_{r=1}^{R}\overline{C_{rk}Q_{rn}} + \sum_{i=1}^{I}\overline{C}_{ink}\,\overline{q}_{in} - \overline{C}_{nk}\left[\sum_{j=1}^{J}\overline{q}_{nj} + \overline{W}_{n} - \overline{S}_{n}\right] = \varepsilon_{nk}$$

Every source is designated by a unique hydro-chemical composition

$$
\begin{aligned}
&\sum_{r=1}^{R_n} \overline{Q}_{rn} + \sum_{i=1}^{I_n} \overline{q}_{in} - \sum_{j=1}^{J_n} \overline{q}_{nj} - \overline{W}_n = \varepsilon_n \\
&\sum_{r=1}^{R} \overline{C_{rk_1} Q_{rn}} + \sum_{i=1}^{I} \overline{C}_{ink_1} \overline{q_{in}} - \overline{C}_{nk_1} \left[\sum_{j=1}^{J} \overline{q}_{nj} + \overline{W}_n + \overline{S}_n \right] = \varepsilon_{nk_1} \\
&\sum_{r=1}^{R} \overline{C_{rk_2} Q_{rn}} + \sum_{i=1}^{I} \overline{C}_{ink_2} \overline{q_{in}} - \overline{C}_{nk_2} \left[\sum_{j=1}^{J} \overline{q}_{nj} + \overline{W}_n + \overline{S}_n \right] = \varepsilon_{nk_2} \\
&\sum_{r=1}^{R} \overline{C_{rk_3} Q_{rn}} + \sum_{i=1}^{I} \overline{C}_{ink_3} \overline{q_{in}} - \overline{C}_{nk_3} \left[\sum_{j=1}^{J} \overline{q}_{nj} + \overline{W}_n + \overline{S}_n \right] = \varepsilon_{nk_3} \\
&\vdots \qquad\qquad \vdots \qquad\qquad \vdots \qquad\qquad \vdots \\
&\sum_{r=1}^{R} \overline{C_{rK} Q_{rn}} + \sum_{i=1}^{I} \overline{C}_{inK} \overline{q_{in}} - \overline{C}_{nK} \left[\sum_{j=1}^{J} \overline{q}_{nj} + \overline{W}_n + \overline{S}_n \right] = \varepsilon_{nK}
\end{aligned}
\tag{4}
$$

Water Balance Expression

Mass Balance Expressions

$$(5)\quad \underline{\underline{C}}_n \underline{X}_n + \underline{P}_n = \underline{E}_n$$

$$(6)\quad \underline{\underline{C}}_n = \begin{bmatrix} 1, & 1, & \cdots, 1, & 1, & 1, & \cdots, 1, & -1, & \cdots, -1 \\ \bar{C}_{r_1nk_1}, & \bar{C}_{r_2nk_1}, & \cdots, \bar{C}_{Rnk_1}, & \bar{C}_{i_1nk_1}, & \bar{C}_{i_2nk_1}, & \cdots, \bar{C}_{Ink_1}, & -\bar{C}_{nk_1}, & \cdots, -\bar{C}_{nk_1} \\ \bar{C}_{r_1nk_2}, & \bar{C}_{r_2nk_2}, & \cdots, \bar{C}_{Rnk_2}, & \bar{C}_{i_1nk_2}, & \bar{C}_{i_2nk_2}, & \cdots, \bar{C}_{Ink_2}, & -\bar{C}_{nk_2}, & \cdots, -\bar{C}_{nk_2} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \bar{C}_{r_1nK}, & \bar{C}_{r_2nK}, & \cdots, \bar{C}_{RnK}, & \bar{C}_{i_1nK}, & \bar{C}_{i_2nK}, & \cdots, \bar{C}_{InK}, & -\bar{C}_{nK}, & \cdots, -\bar{C}_{nK} \end{bmatrix}_{[(K+1)\bullet(R_n+I_n+J_n)]}$$

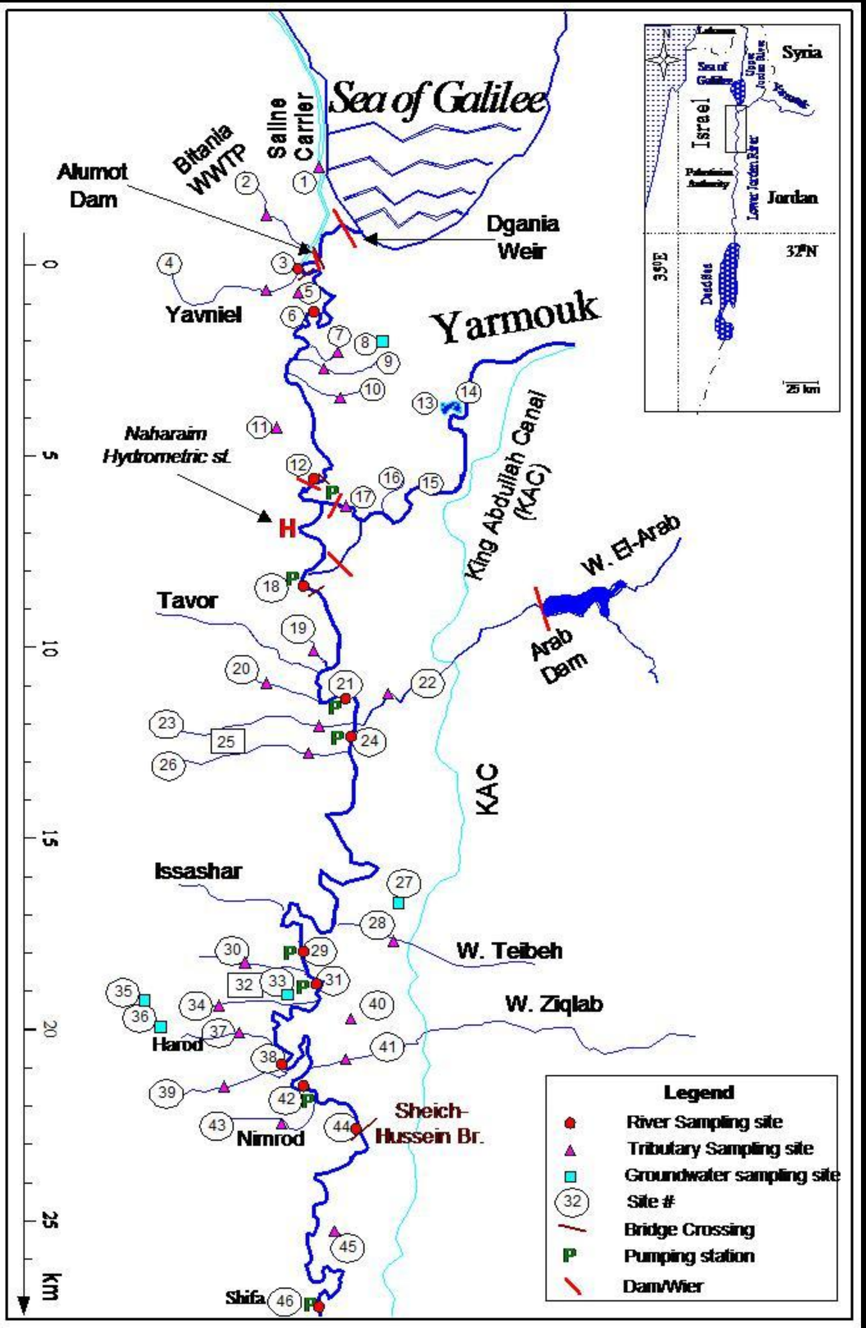
$$(7)\quad \underline{X}_n = \begin{bmatrix} \bar{Q}_{r_1} \\ \bar{Q}_{r_2} \\ \vdots \\ \bar{Q}_{R_n} \\ \bar{q}_{i_1} \\ \bar{q}_{i_2} \\ \vdots \\ \bar{q}_{I_n} \\ \bar{q}_{nj_1} \\ \bar{q}_{nj_2} \\ \vdots \\ q_{nJ_n} \end{bmatrix}_{[(R_n+I_n+J_n)\bullet 1]}$$

$$(8)\quad P_n = \begin{bmatrix} \bar{W}_n + \bar{S}_n \\ \bar{C}_{nk_1}\bar{W}_n + \bar{S}_n \\ \bar{C}_{nk_2}\bar{W}_n + \bar{S}_n \\ \bar{C}_{nk_3}\bar{W}_n + \bar{S}_n \\ \vdots \\ \bar{C}_{nK}\bar{W}_n + \bar{S}_n \end{bmatrix}_{[(K+1)\bullet 1]}$$

$$(9)\quad E_{\underline{n}} = \begin{Vmatrix} \varepsilon_n \\ \varepsilon_{nk_1} \\ \varepsilon_{nk_2} \\ \varepsilon_{nk_3} \\ \vdots \\ \varepsilon_{nK} \end{Vmatrix}_{[(K+1)\bullet 1]}$$

$$(10)\quad J = \sum_{n=1}^{N} \left[\underline{E}^T \underline{\underline{\Phi}} \underline{E}_n\right] = \sum_{n=1}^{N} \left[(\underline{\underline{C}}_n \underline{X}_n + \underline{P}_n)\Phi(\underline{\underline{C}}_n \underline{X}_n + \underline{P}_n)\right]$$

Sampling stations (north)



Hydro-chemical & Isotopes Data

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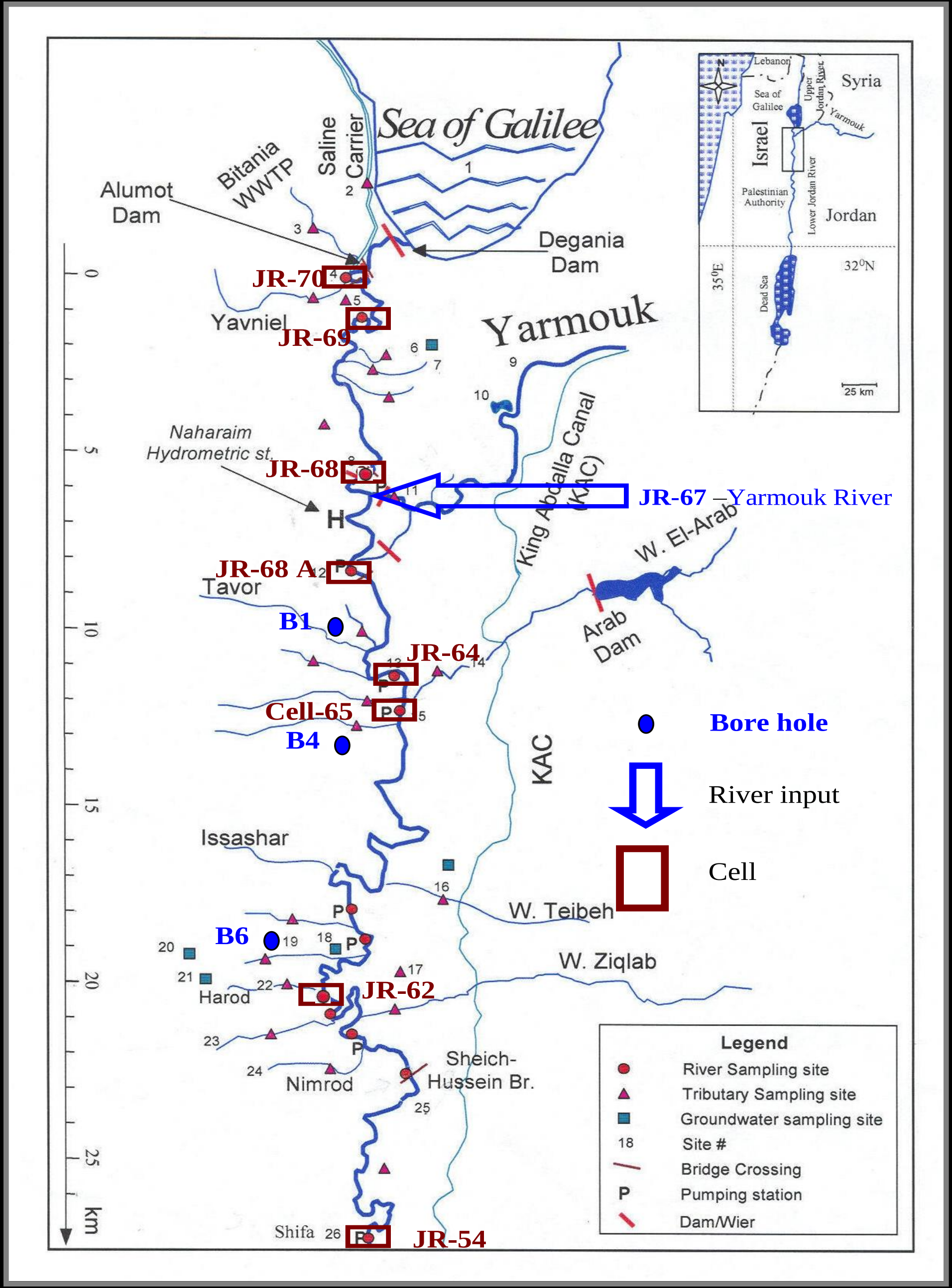
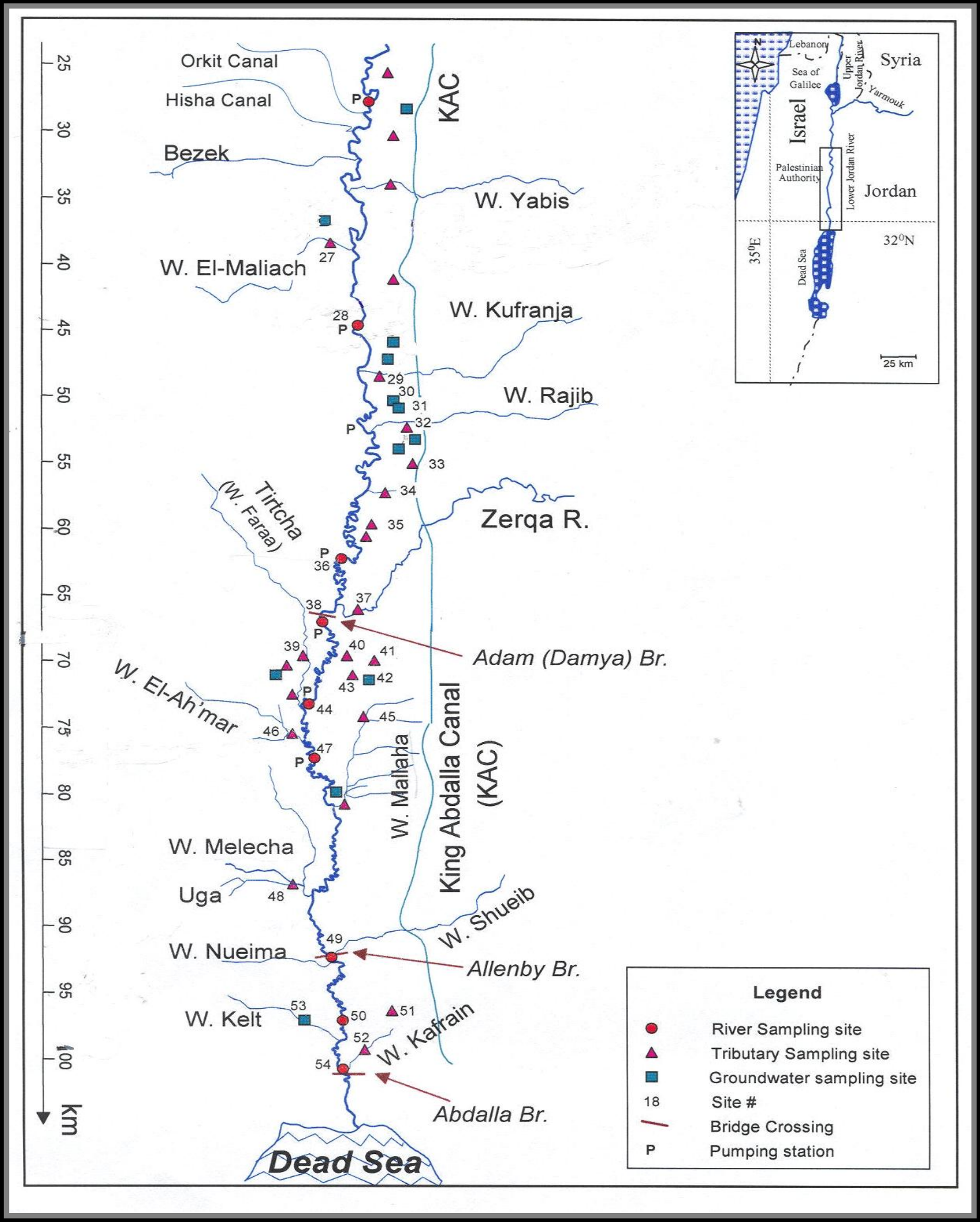
Duke University, NC USA

Efrat Farber
Ben Gurion University, Israel

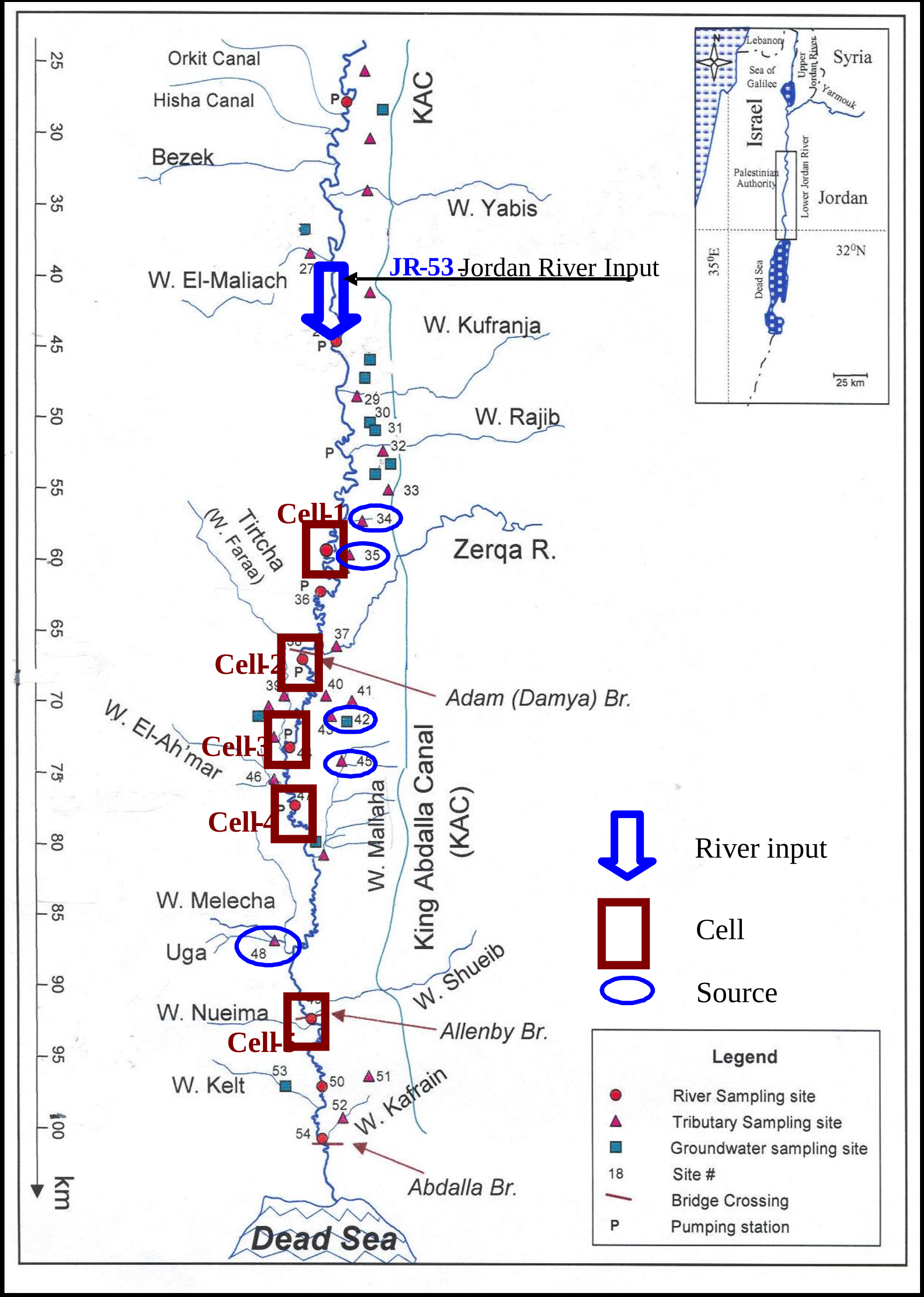
Modeling (north)



Sampling stations (south)



Modeling (south)

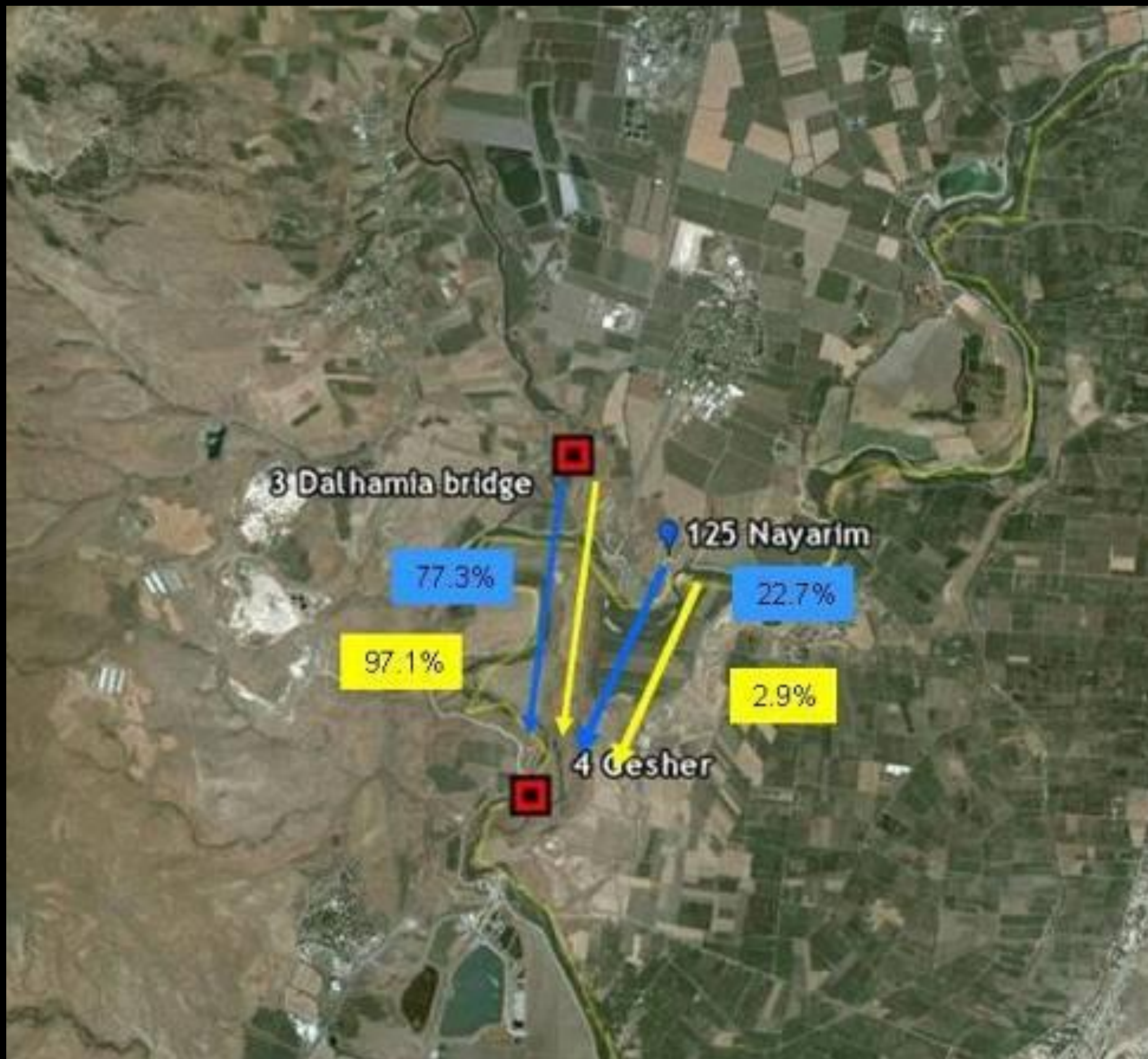


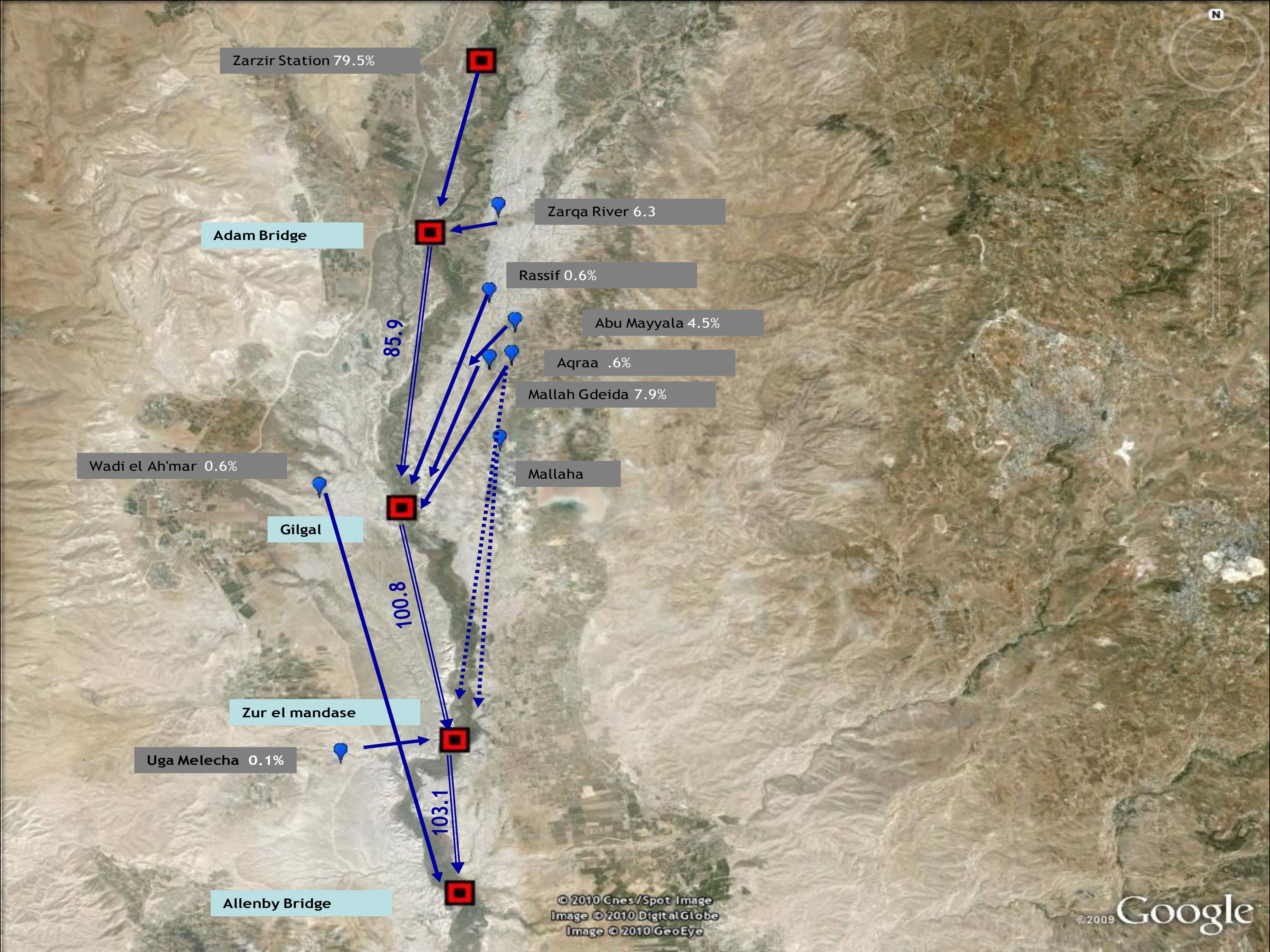
MCM Results for single compartments/segments along the Lower Jordan Valley

Average hydro-chemical and isotopic data for the winter (September 2000-February 2001) and summer (March 2001-August 2001).

Cell 1: Results for the upper Jordan River at Alumot dam- Alumot Bridge

Cell	Source	winter 00-01		summer 01	
		%cell inflow	% diff.	%cell inflow	% diff.
Cell_4	Gesher		1.60%		3.32%
	Cell_3	77.3		97.2	
	W.Surf.Inflow_125 - Naharayim	22.7		2.93	





Zarzir Station 79.5%
Zarqa River 6.3
Adam Bridge
Rassif 0.6%
Abu Mayyala 4.5%
85.9
Aqraa .6%
Mallah Gdeida 7.9%
Mallaha
Wadi el Ah'mar 0.6%
Gilgal
100.8
Zur el mandase
Uga Melecha 0.1%
103.1
Allenby Bridge
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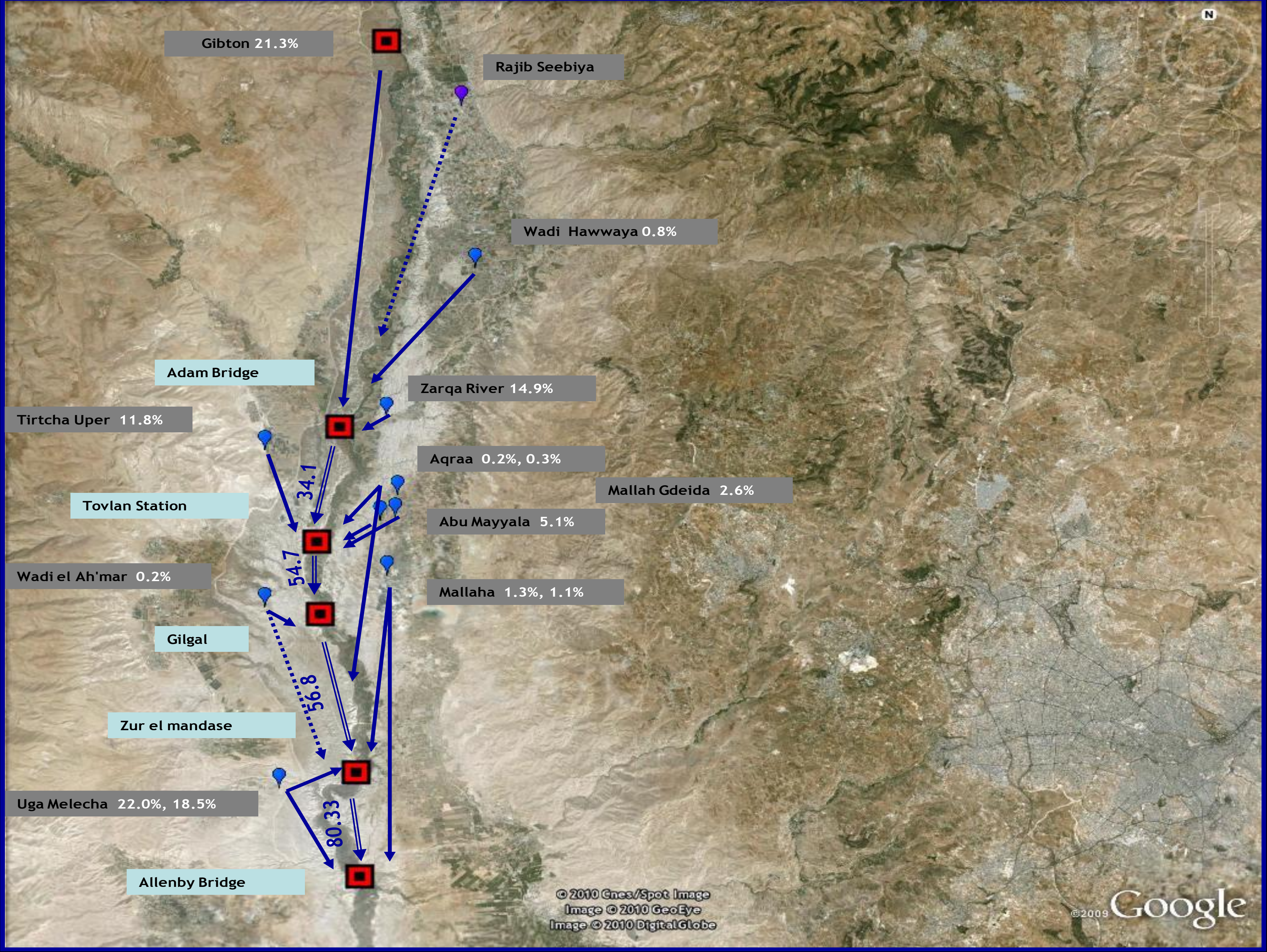

Gibton 21.3%
Rajib Seebiya
Wadi Hawwaya 0.8%
Adam Bridge
Zarqa River 14.9%
Tirtcha Uper 11.8%
Aqraa 0.2%, 0.3%
34.1
Mallah Gdeida 2.6%
Tovlan Station
Abu Mayyala 5.1%
54.7
Wadi el Ah'mar 0.2%
Mallaha 1.3%, 1.1%
Gilgal
56.8
Zur el mandase
Uga Melecha 22.0%, 18.5%
80.33
Allenby Bridge
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The *MCMsf* Model enabled to assess the current fluxes and discharge of water sources along the Jordan River !

Thank you for your attention

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