Hydrological and Geochemical Processes during Managed Aquifer Recharge with Desalinated Seawater

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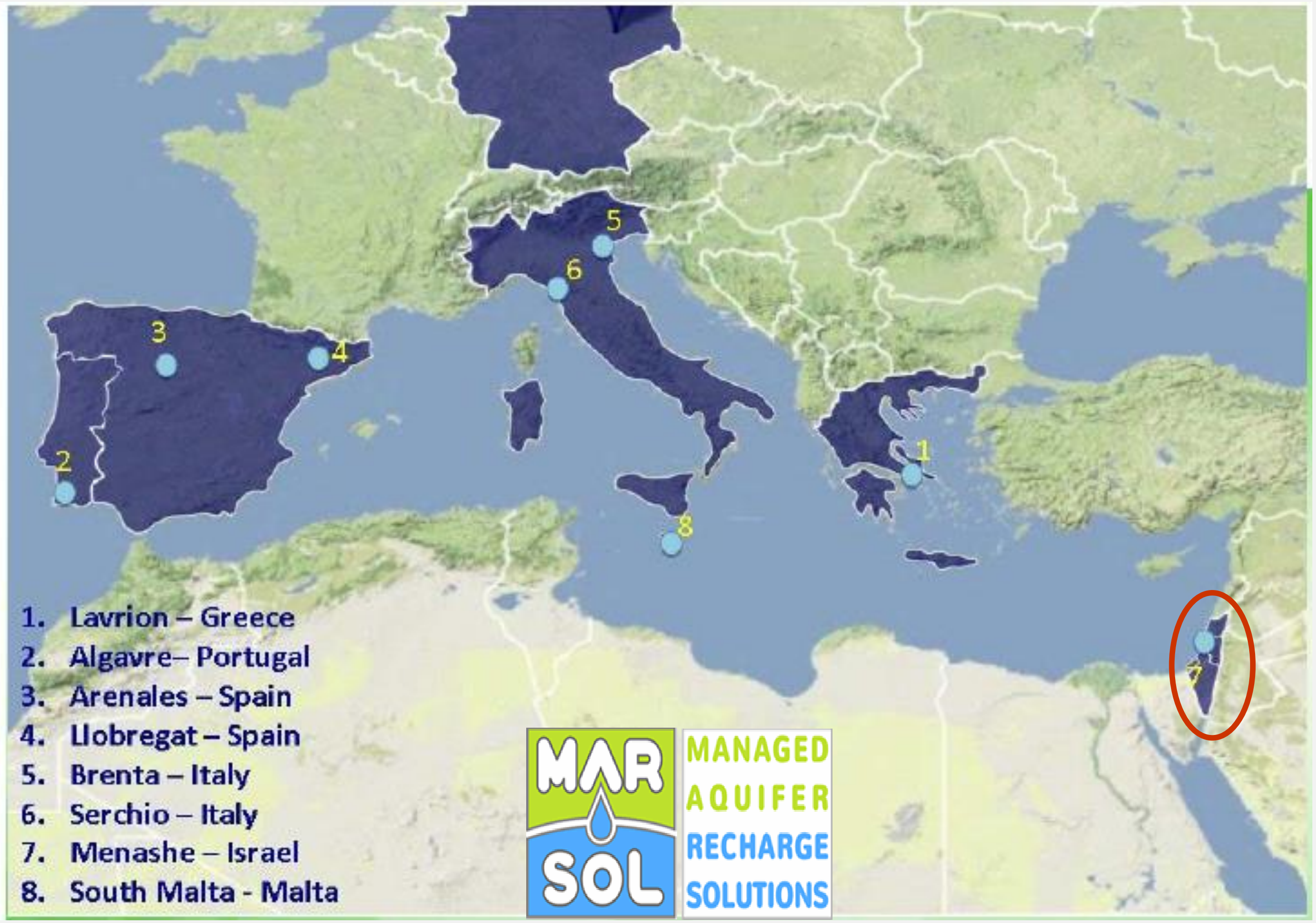
Nitzan I., Katz Y., Guttman Y., Siebner H., Bernstein A., Kurtzman D.

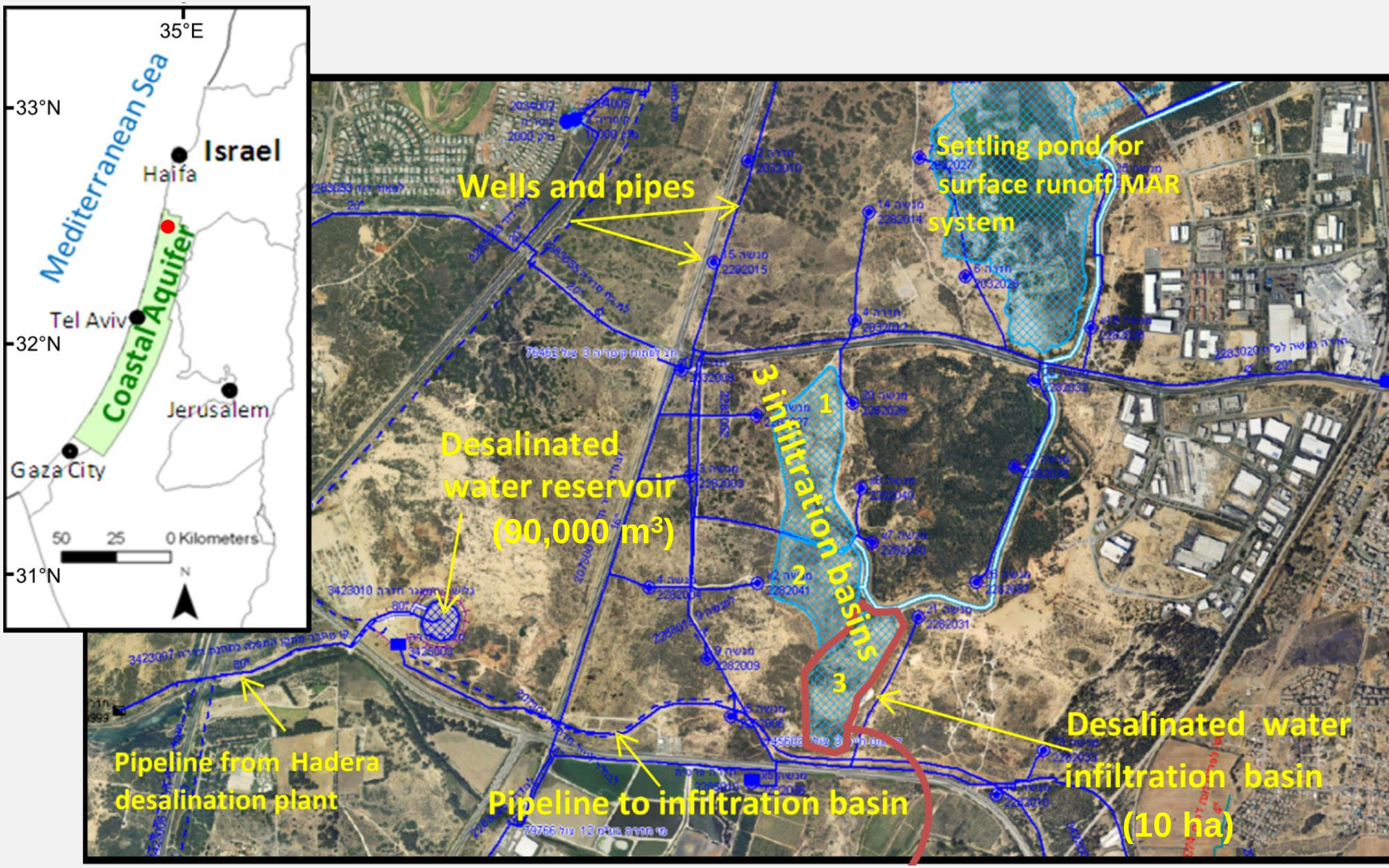
abstract n°1837

25-29th September 2016 43rd IAH congress

The MARSOL project
(WATER-INNO-DEMO - funded by the EU)



Menashe MAR site - overview



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Montpellier, France
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Q: why waste expensive desalinated seawater through MAR?

A: storage capacity

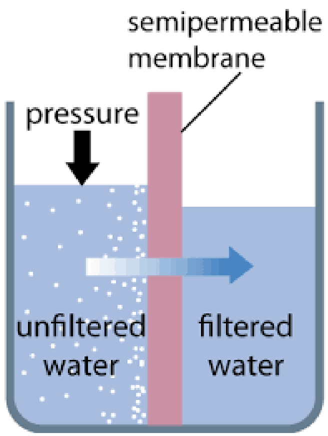
Sometimes, due to operational constraints, it is not possible to supply the desalinated water to the national distribution system, so MAR is the only solution for large scale desalination plants

(at Hadera plant 350,000 to 400,000 m^3/day)

Research question

What processes are expected during MAR of desalinated seawater ?

RO Desalinated Seawater



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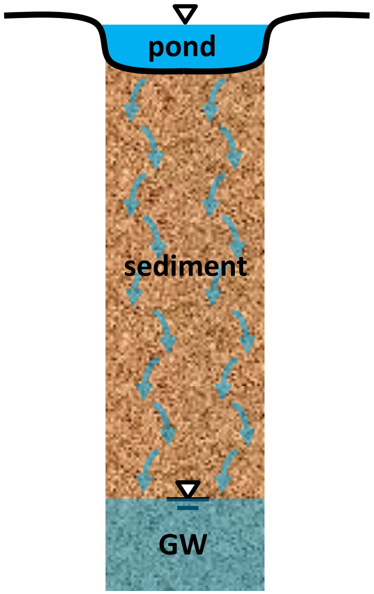
Infiltration pond



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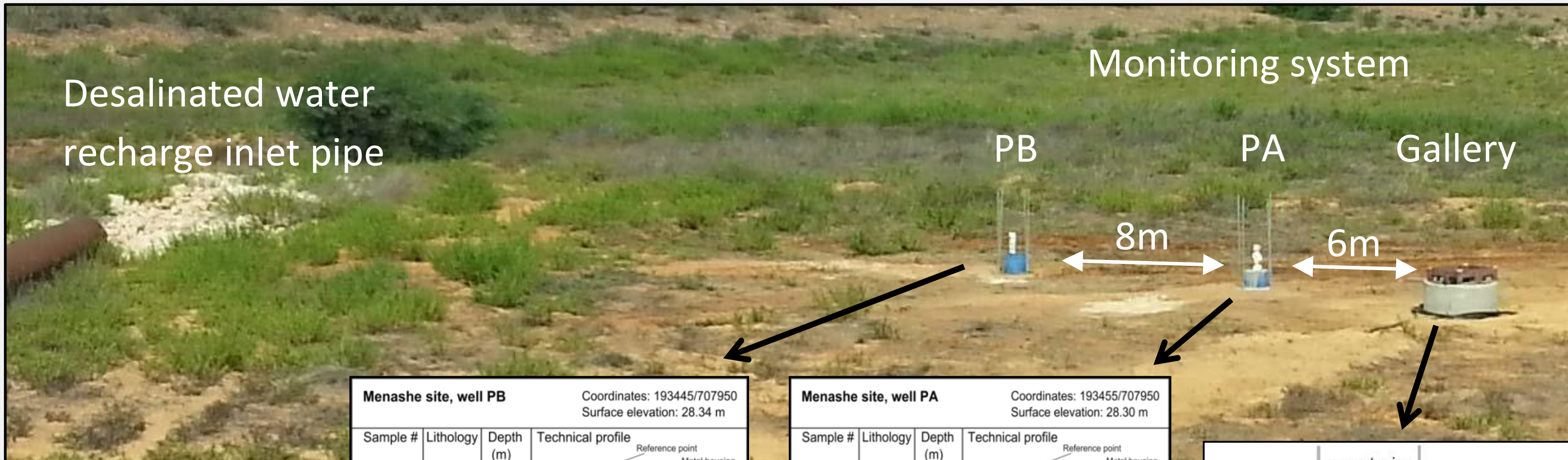
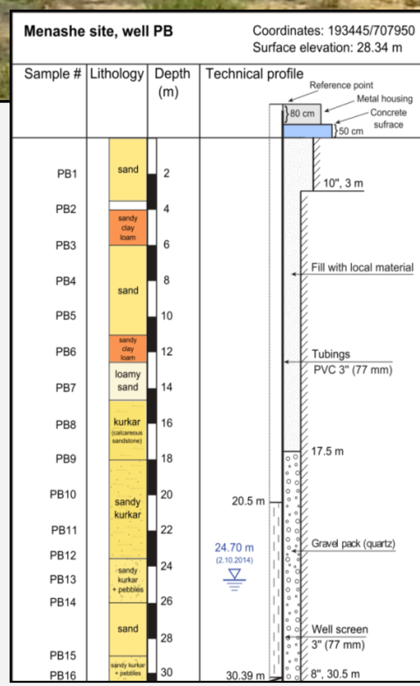
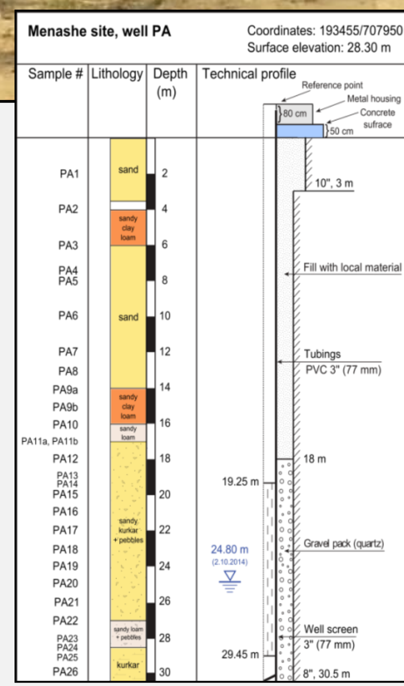
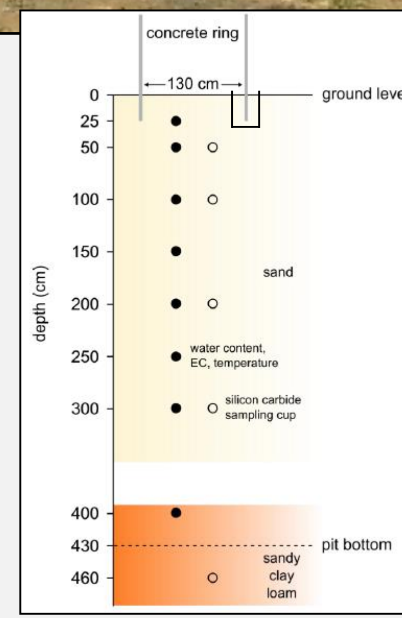
Monitoring system – GW & VZ

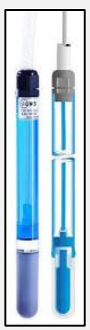








soil sensors



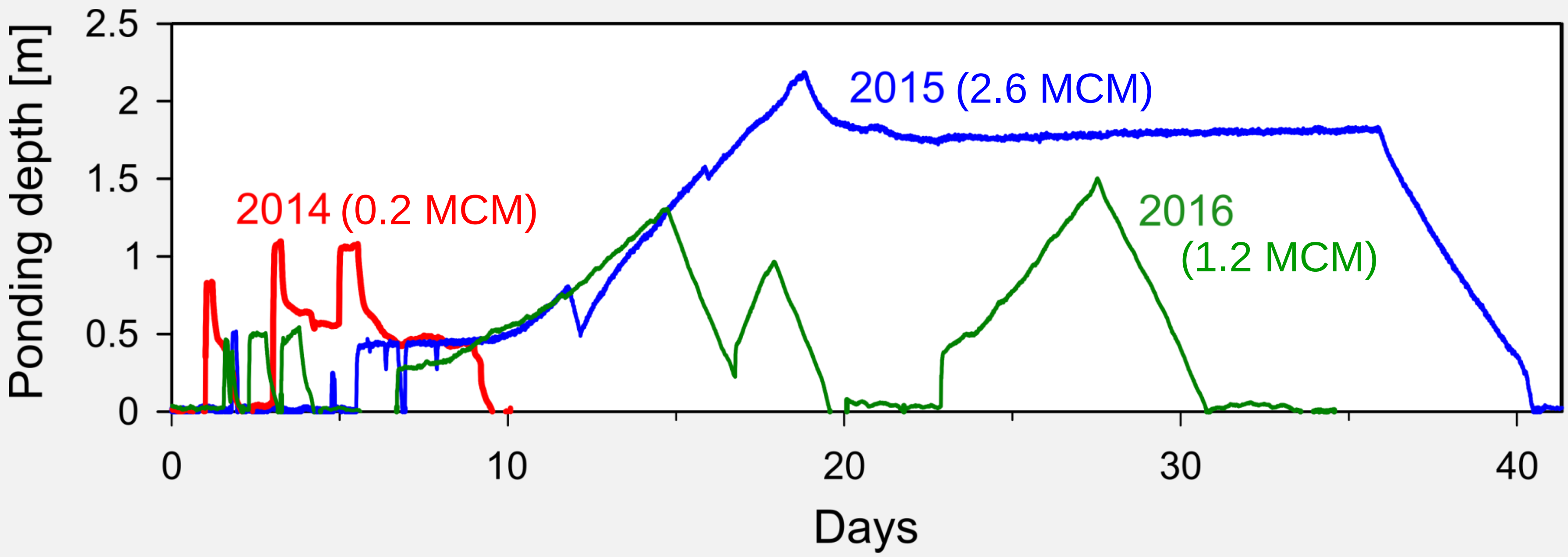
silicon suction cups

CTD Diver

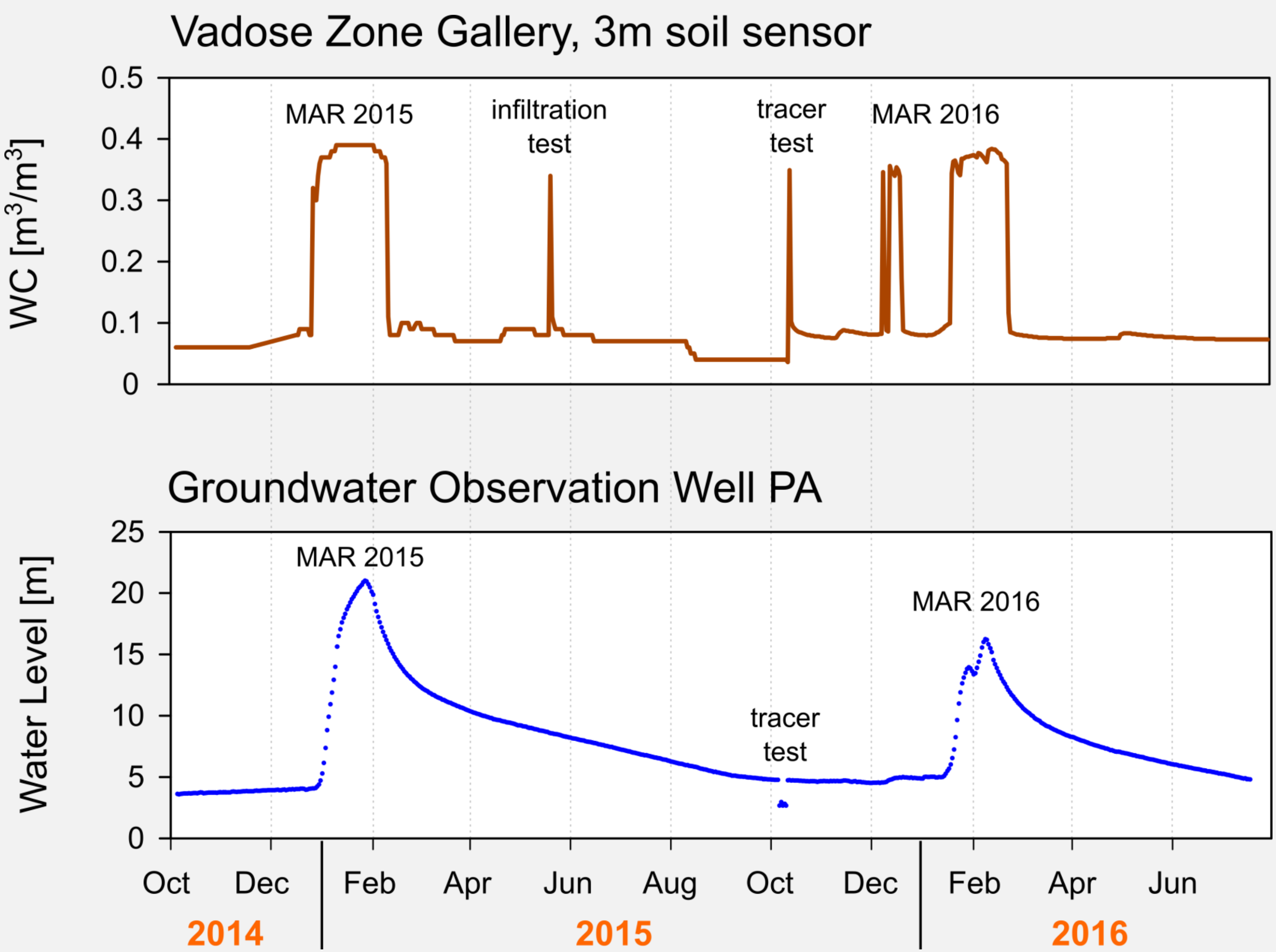
MAR during January 2015 (~$2.6 \cdot 10^6$ m^3)

Hydrological processes

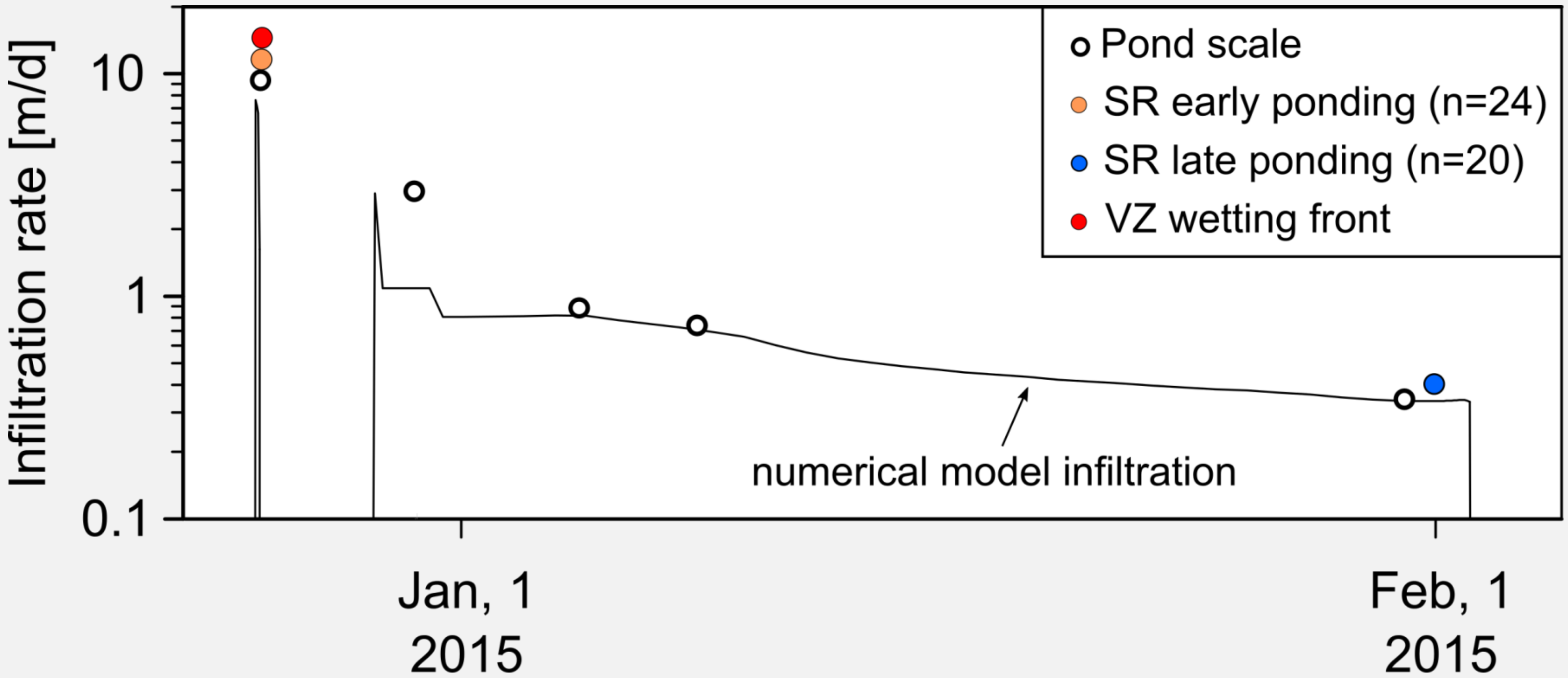
Ponding depth during three MAR events



Monitoring system



Infiltration rates (pond and local scales)



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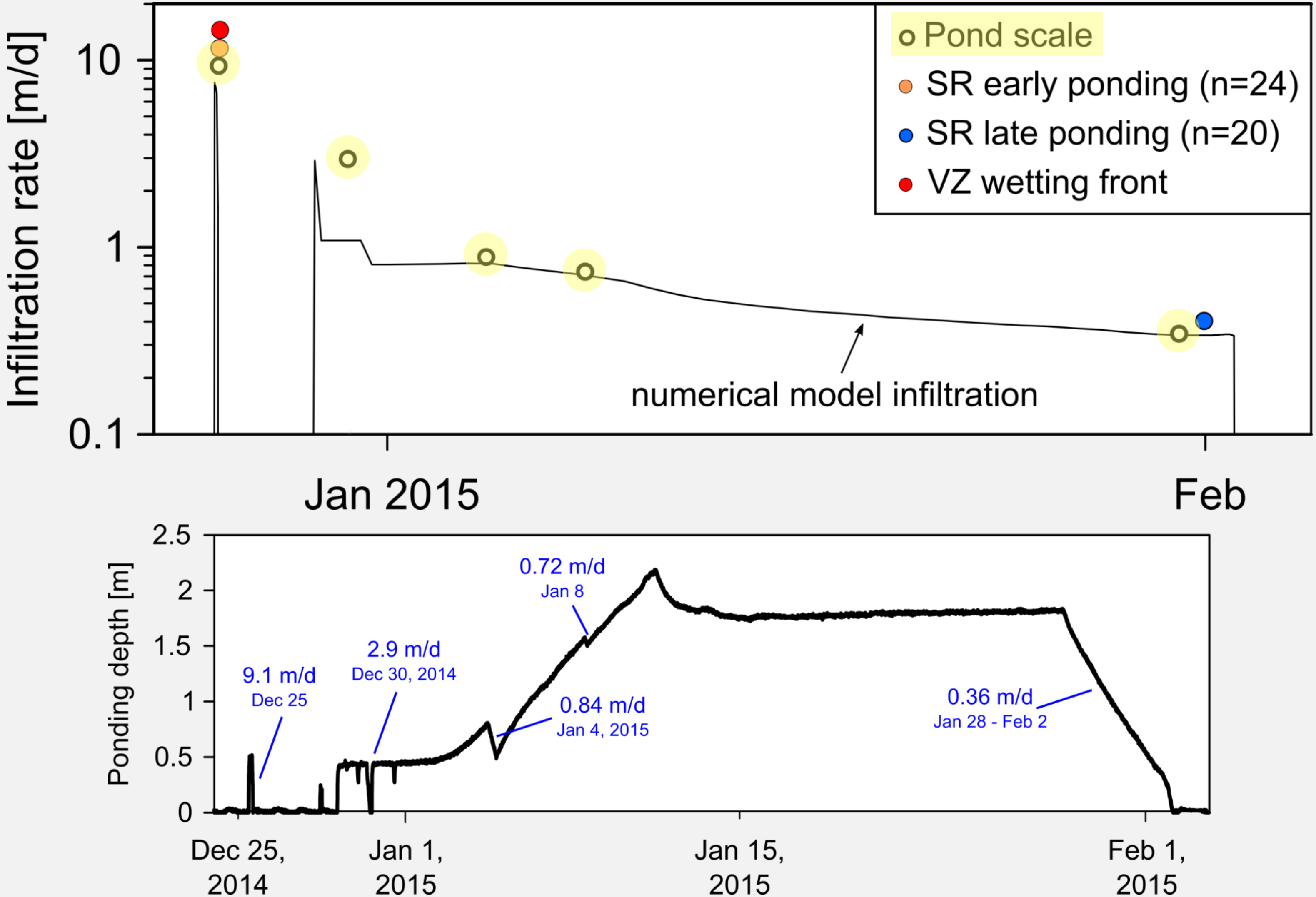

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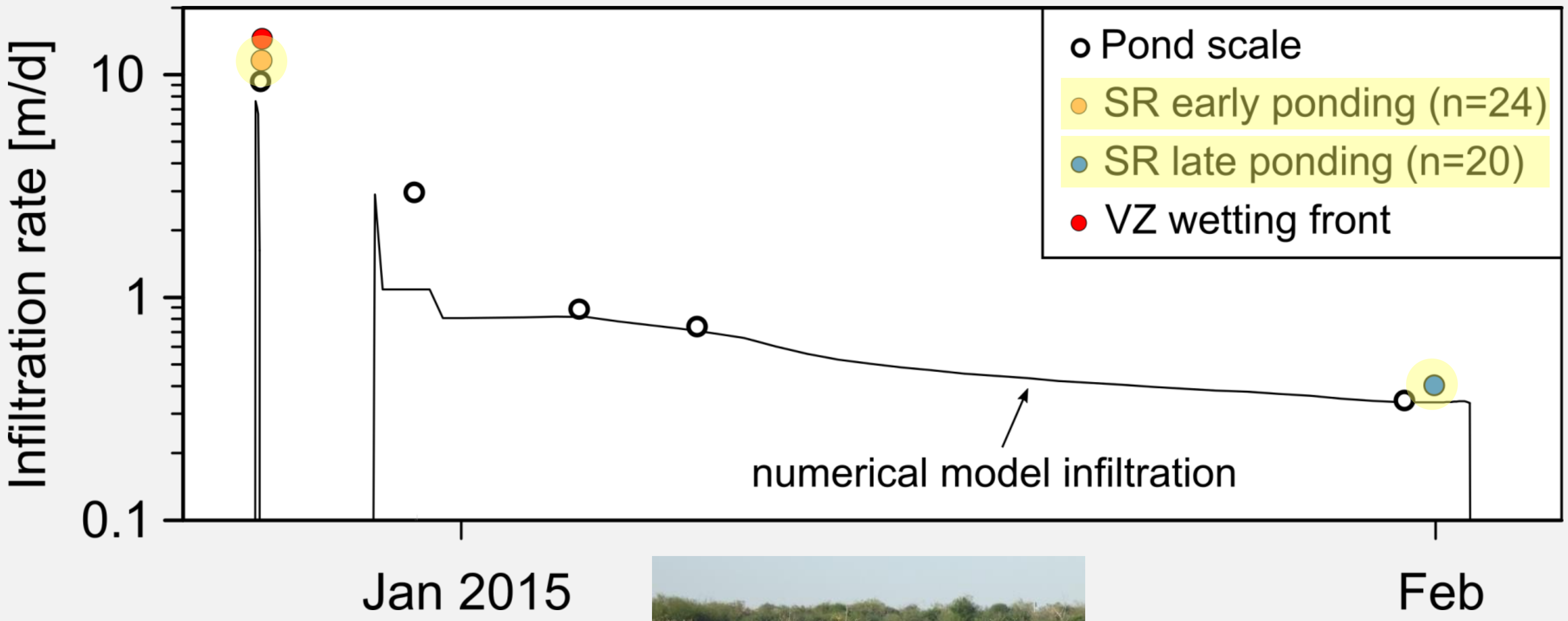

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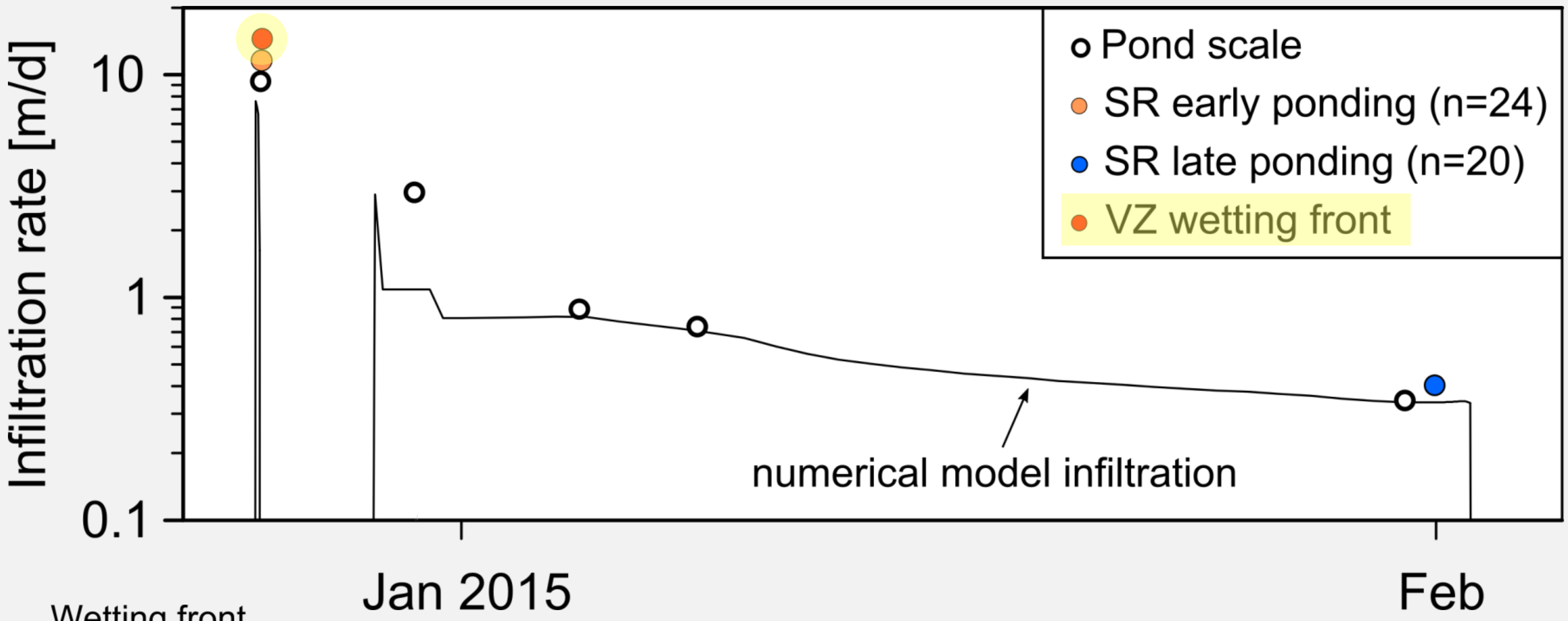
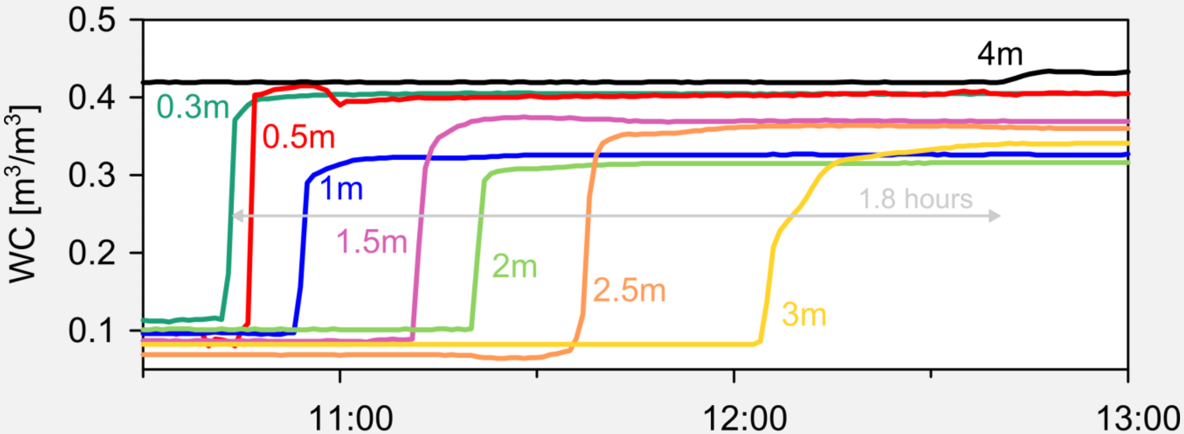
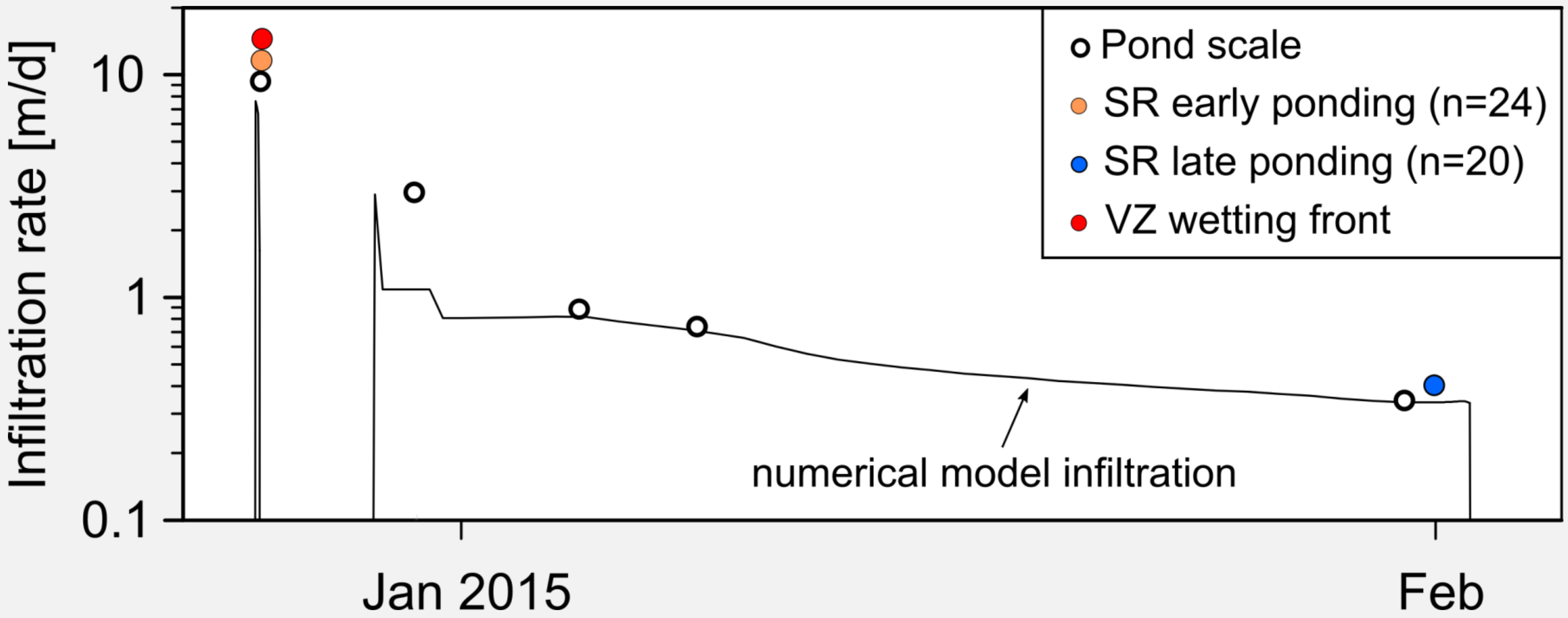


Wetting front



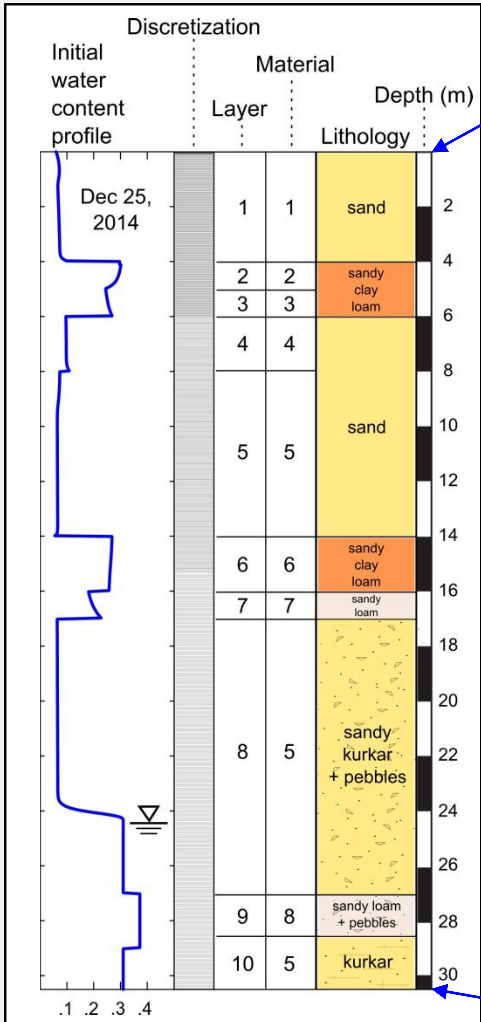
Infiltration rates (pond and local scales)



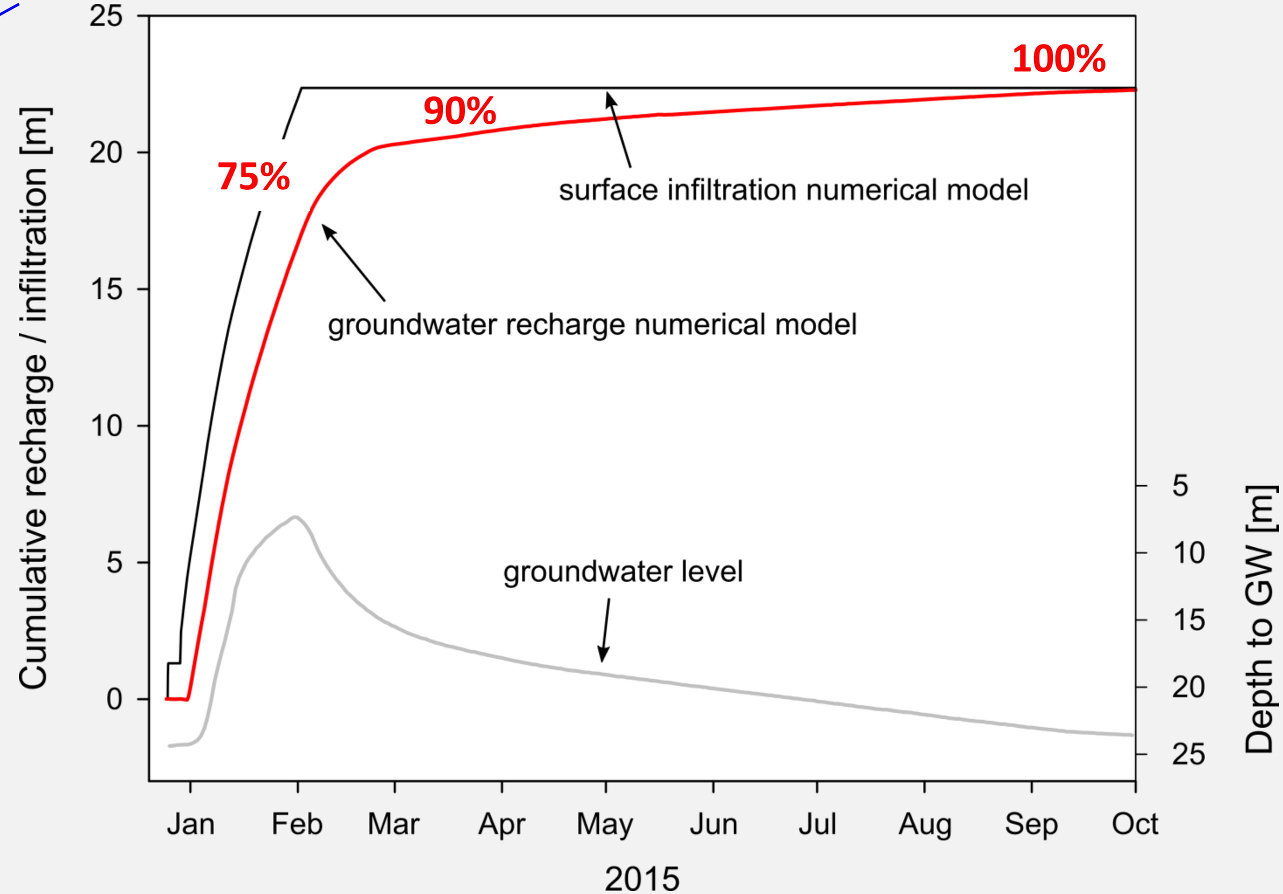
- Similar infiltration rates obtained from all methods
- The decrease in infiltration rates of almost 2 order of mag. is due to low-permeability layers at depths of 4 and 14 m
- Clogging (if any) is less than the impact of the low-permeability layers

Recharge dynamics (numerical model)

BC_{top}: h(t)

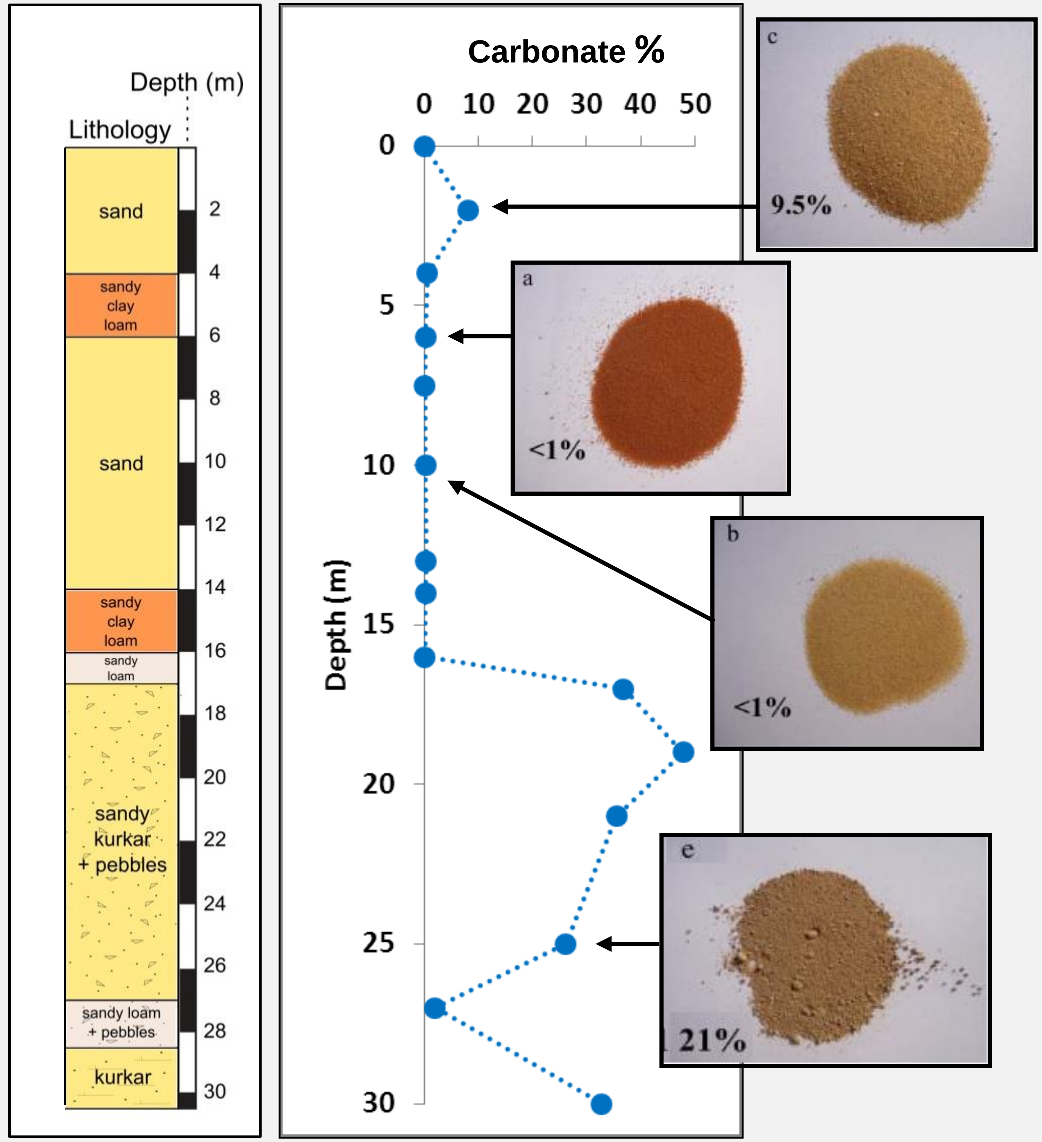


BC_{bot}: h(t)



Geochemical processes

desalinated seawater meets calcareous sediments

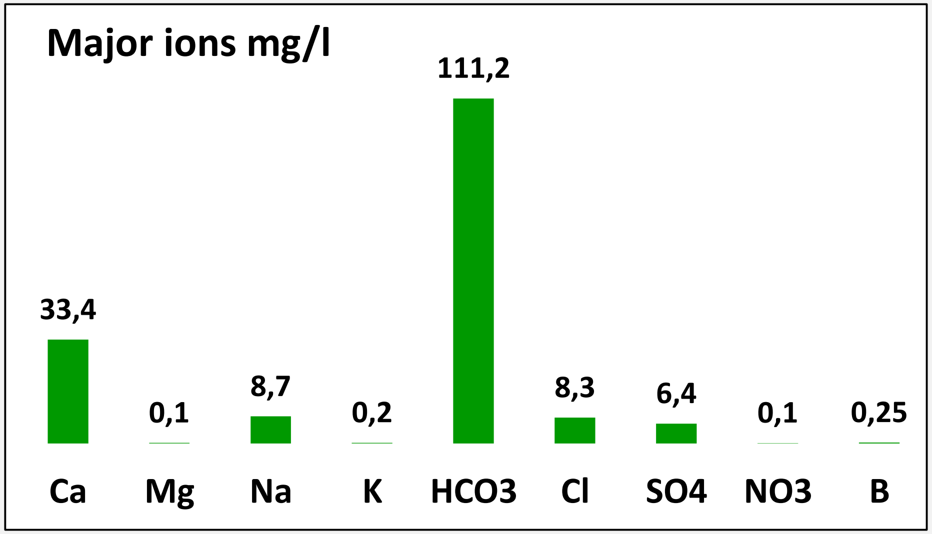


Desalinated seawater

- The RO process operated in the nearby desalination plant removes ~99.9% of the sea salts, leaving the product with practically no bicarbonate, calcium or magnesium.

- The desalination-plant is obliged to remineralize the water to 32 mg/l Ca^{2+} and 80 mg/l HCO_3^-.

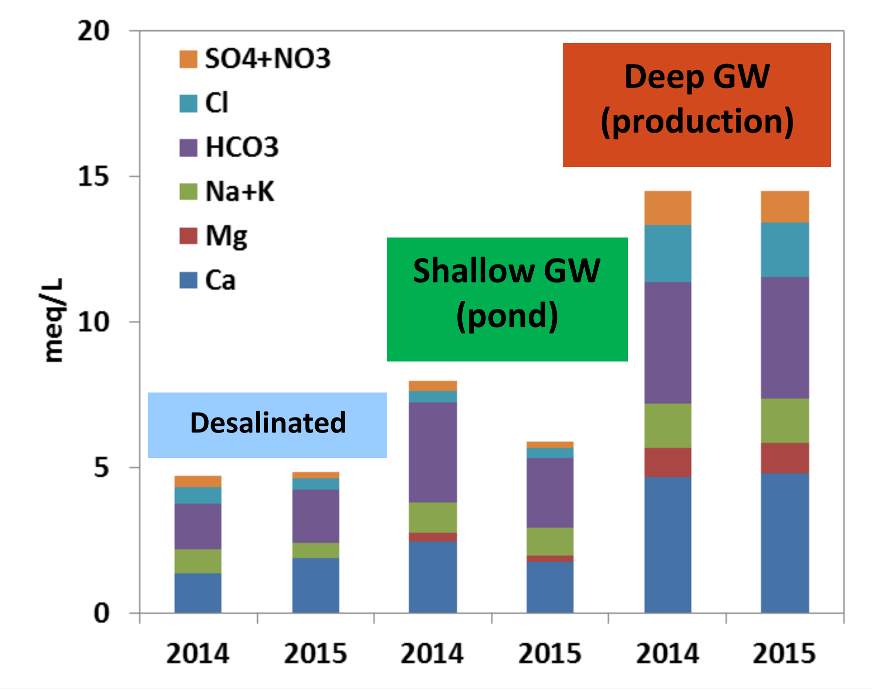
- This is done by dissolving 30 tons of quarry-limestone-gravel every day with acid, and costs about 0.04 EUR/m^3 (~8% of the cost of the final water product).

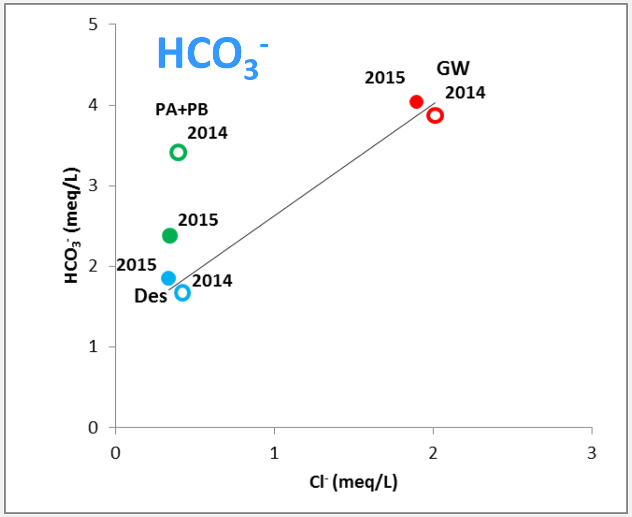


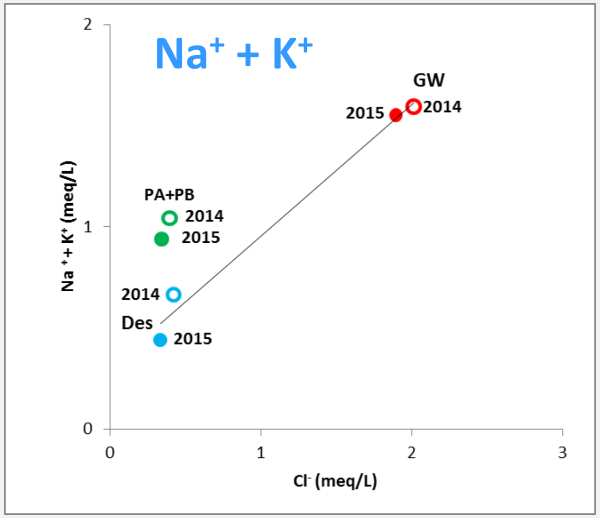
- Mg^{2+} deficiency in the final product of the desalination plants is an unsolved problem.

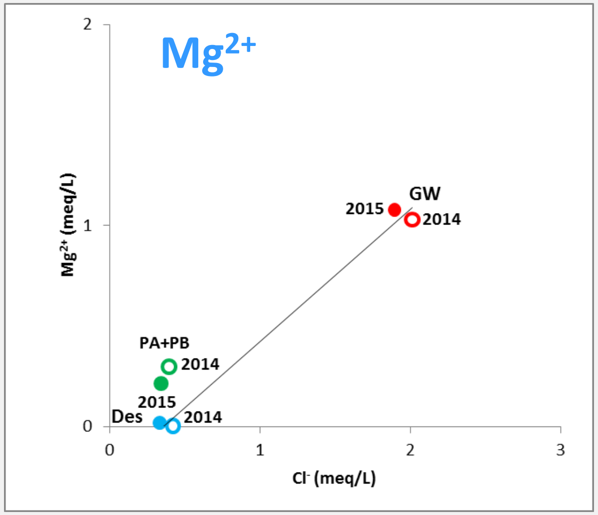
Water composition (3 types)

Shallow groundwater under the pond are not a mix (similar to desalinated water with some ion enrichment)

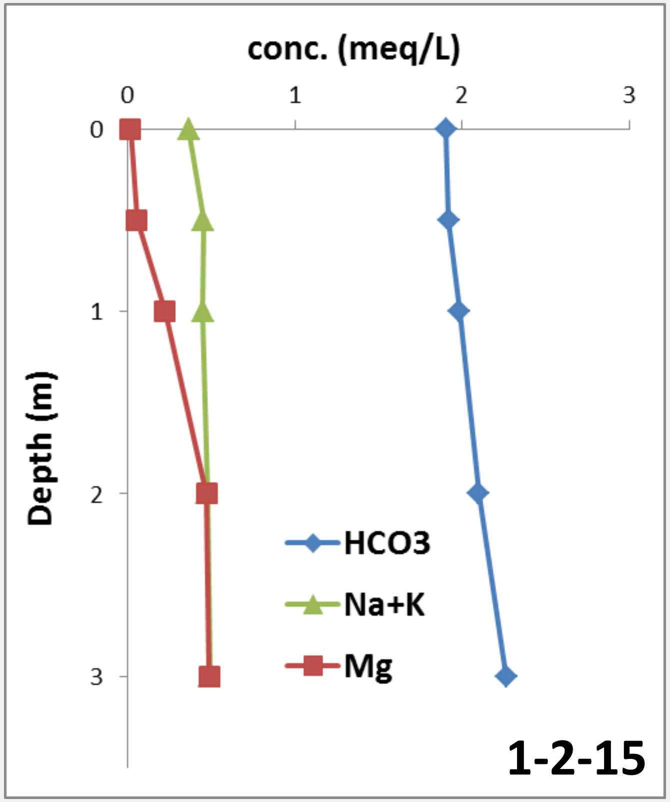






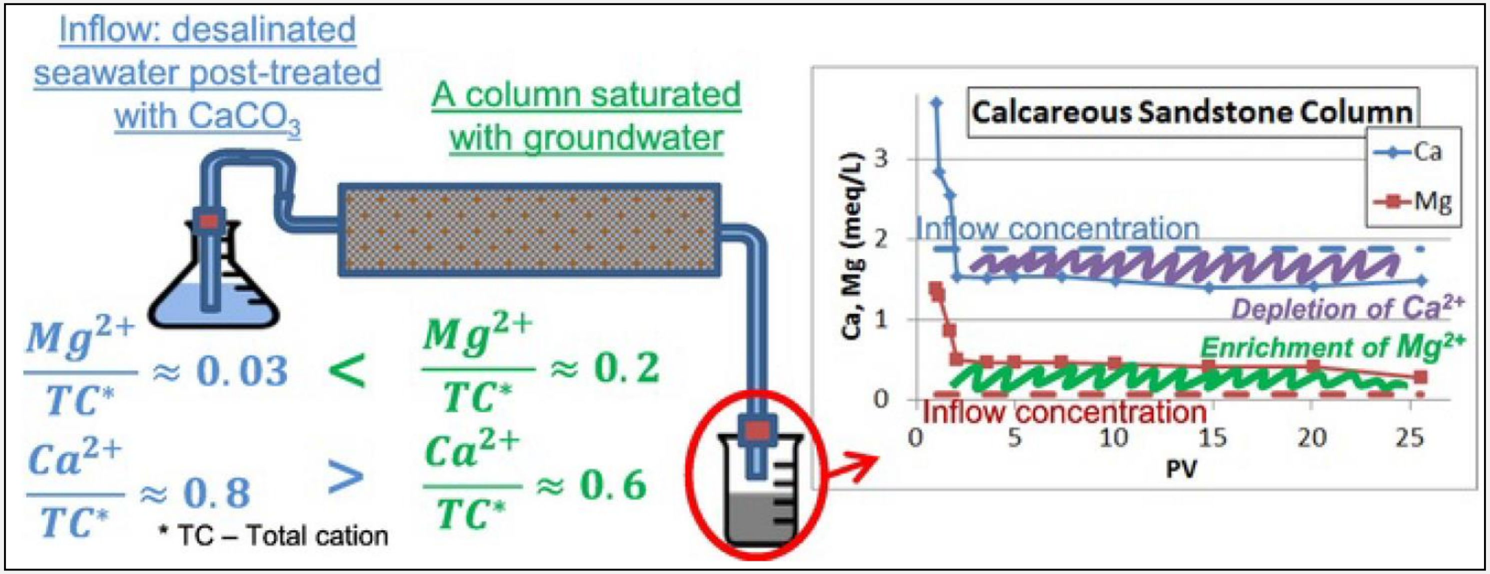


Enrichment is also observed close to the pond surface



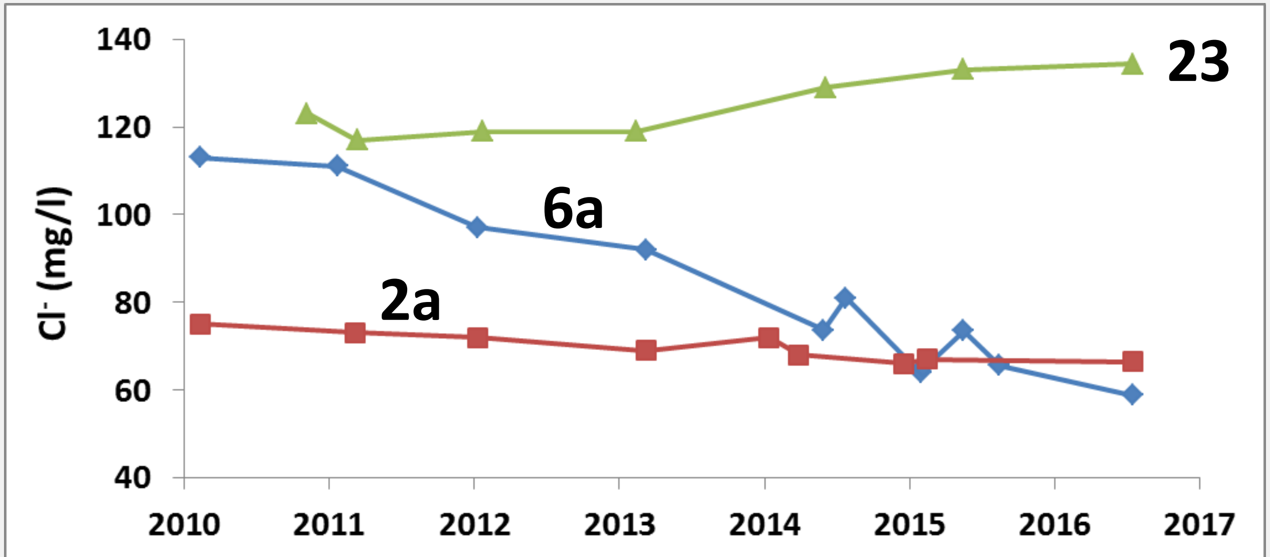
Ion enrichment processes

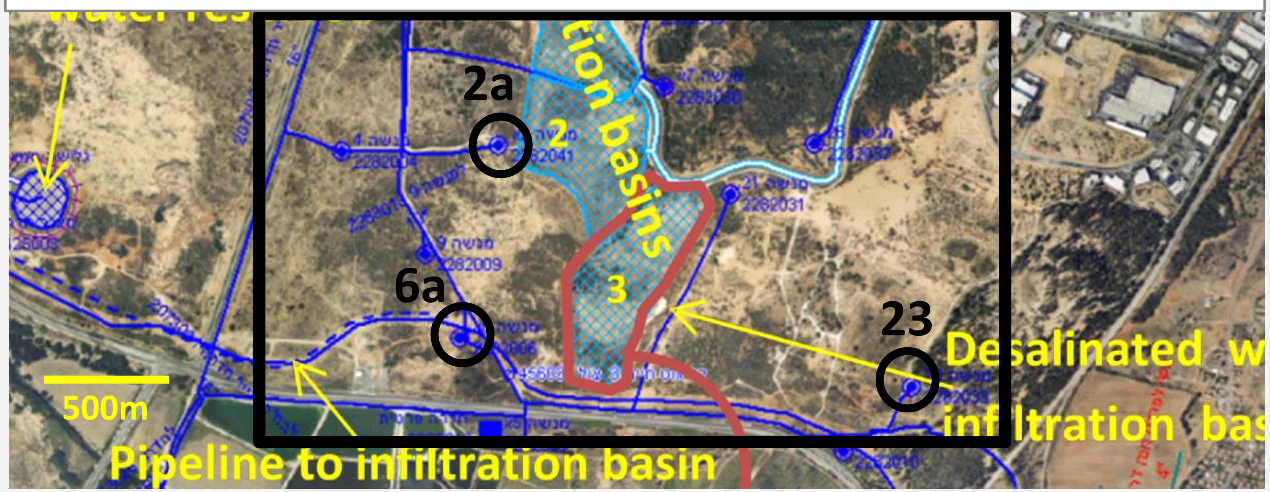
- **Ion exchange (primary): Ca^{2+} for Mg^{2+}**
  (the desalinated seawater are rich with Ca^{2+} due to the lime-dissolution post-treatment)
- **Dissolution (secondary)**



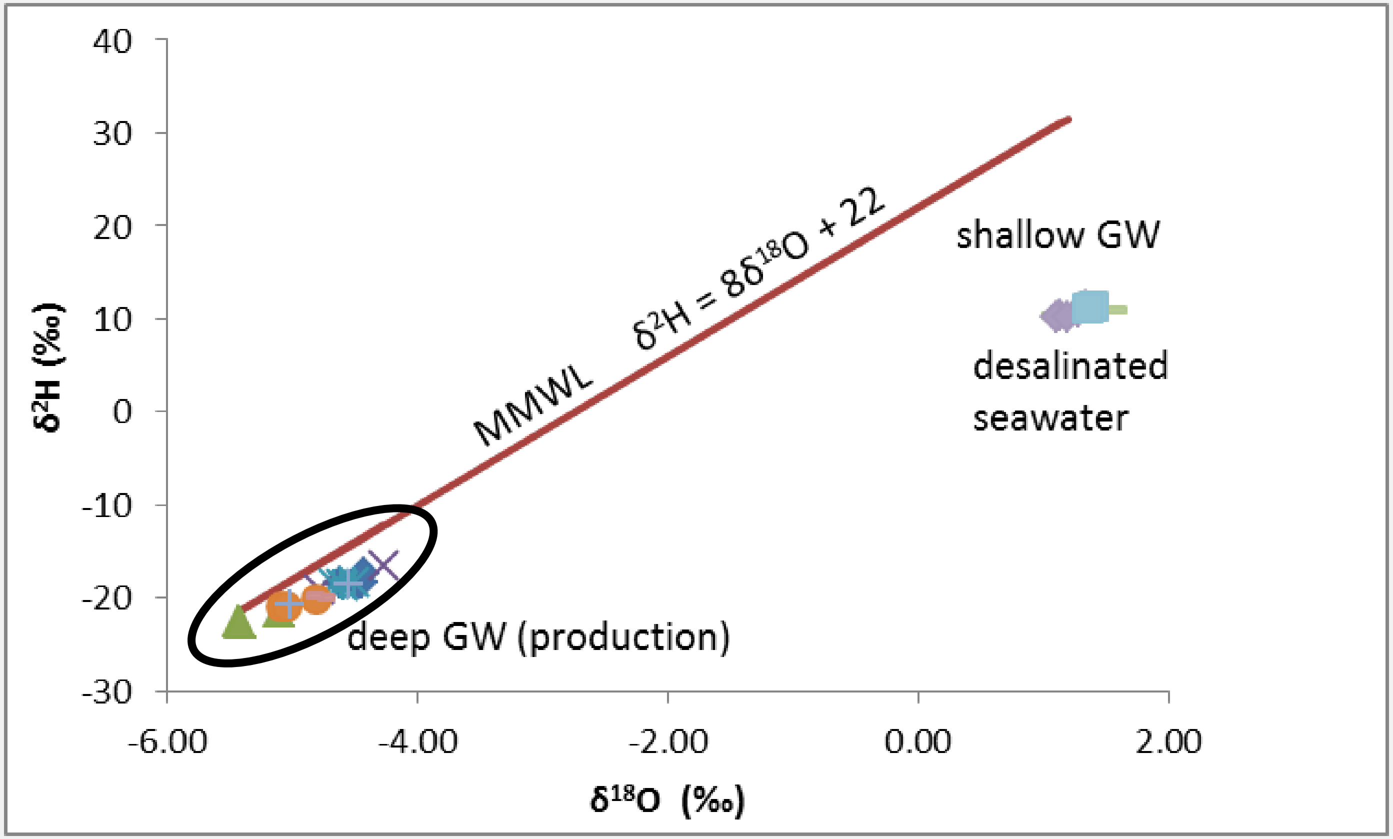
<u>***Ronen-Eliraz et al.*** (in press, *STOTEN*)</u>
Investigating geochemical aspects of managed aquifer recharge by column experiments with alternating desalinated water and groundwater

Mixing with deep groundwater

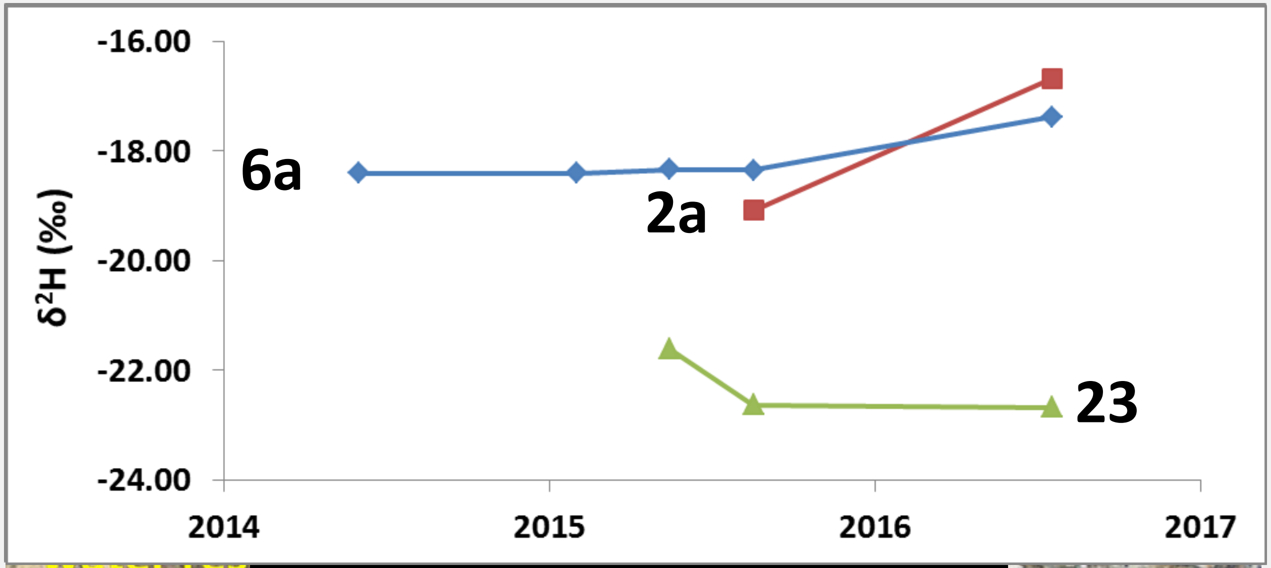


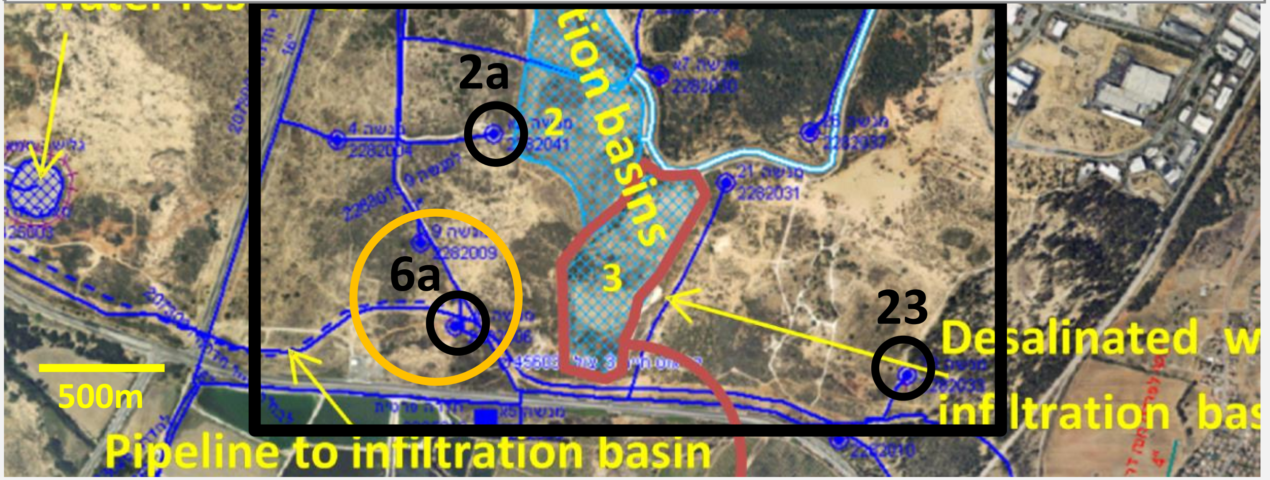


Mixing with deep groundwater



Mixing with deep groundwater





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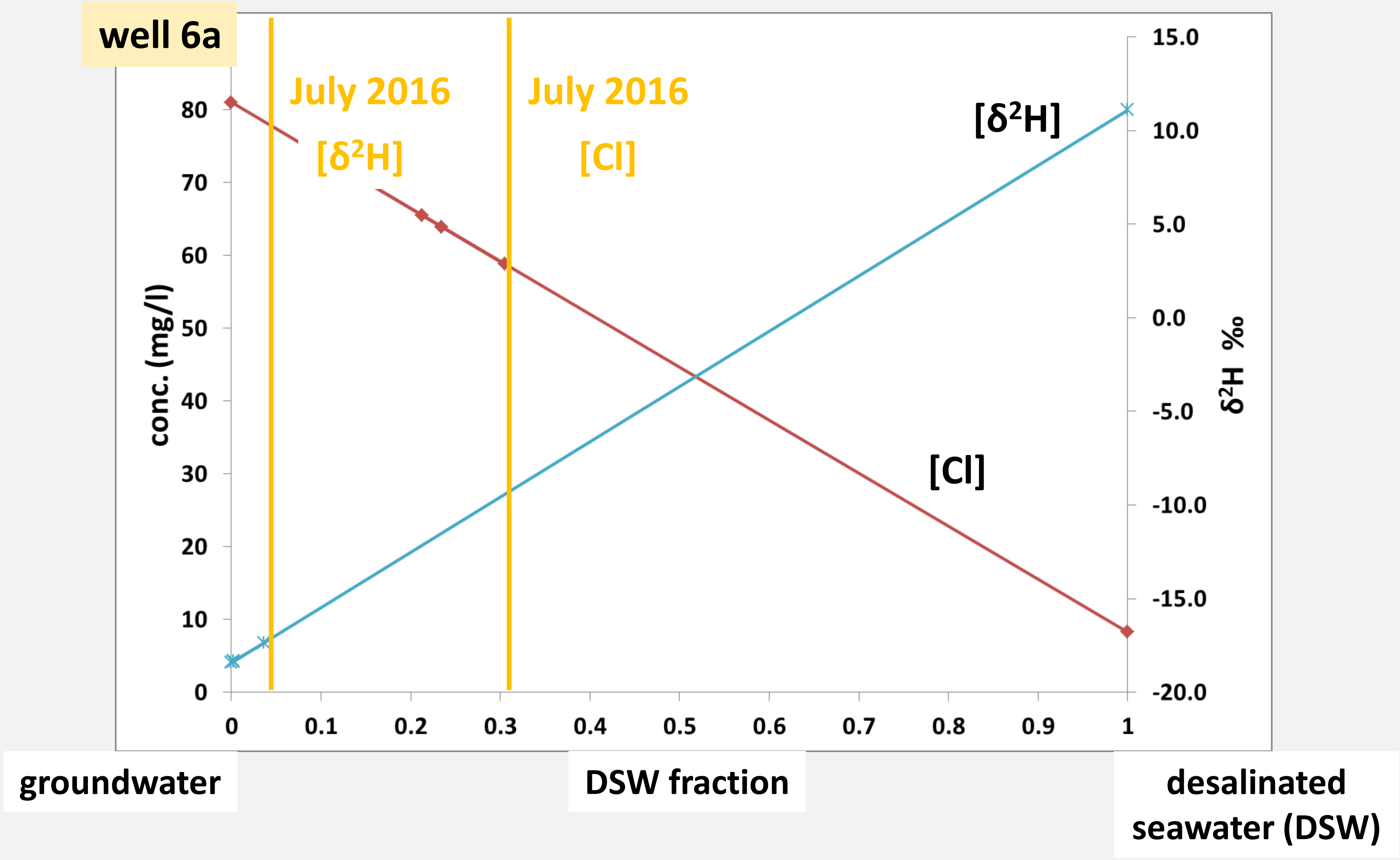
Mixing with deep groundwater - binary mixing?



Summary

- **MAR is the only feasible storage for large scale desalination plants**.
- Monitored infiltration-rates declined by almost two orders of magnitude (from ~10 to ~0.4 m/d) due to the unsaturated zone lithology and not by clogging processes at the pond surface.
- 90% of the infiltrating-water has reached the original water-table depth 2 months after the beginning of MAR.
- The desalinated seawater are enriched with Mg^{2+} by ion exchange during infiltration (Ca adsorbs). The processes is controlled by the high Ca/Mg ratio in the post-treatment desalinated seawater.
- The distinct isotope contrast between desalinated seawater and local GW is a potential tool to evaluate mixing processes at the Menshae MAR site.

Thank you :)

The research leading to these results received funding from the European Union Seventh Framework Program (FP7/2007-2013) under grant agreement no. 619120 (Demonstrating Managed Aquifer Recharge as a Solution to Water Scarcity and Drought – MARSOL).

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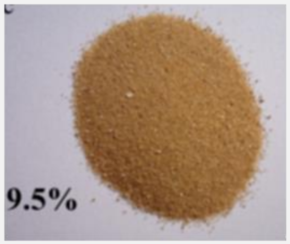
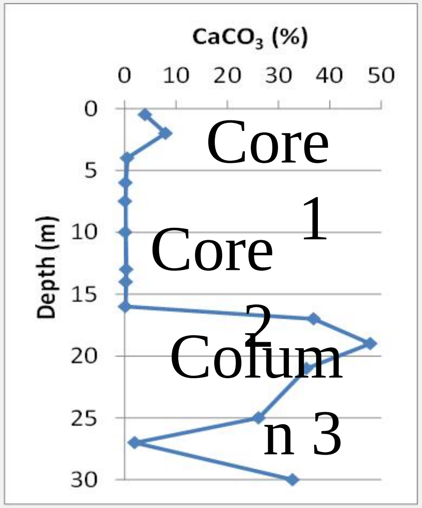
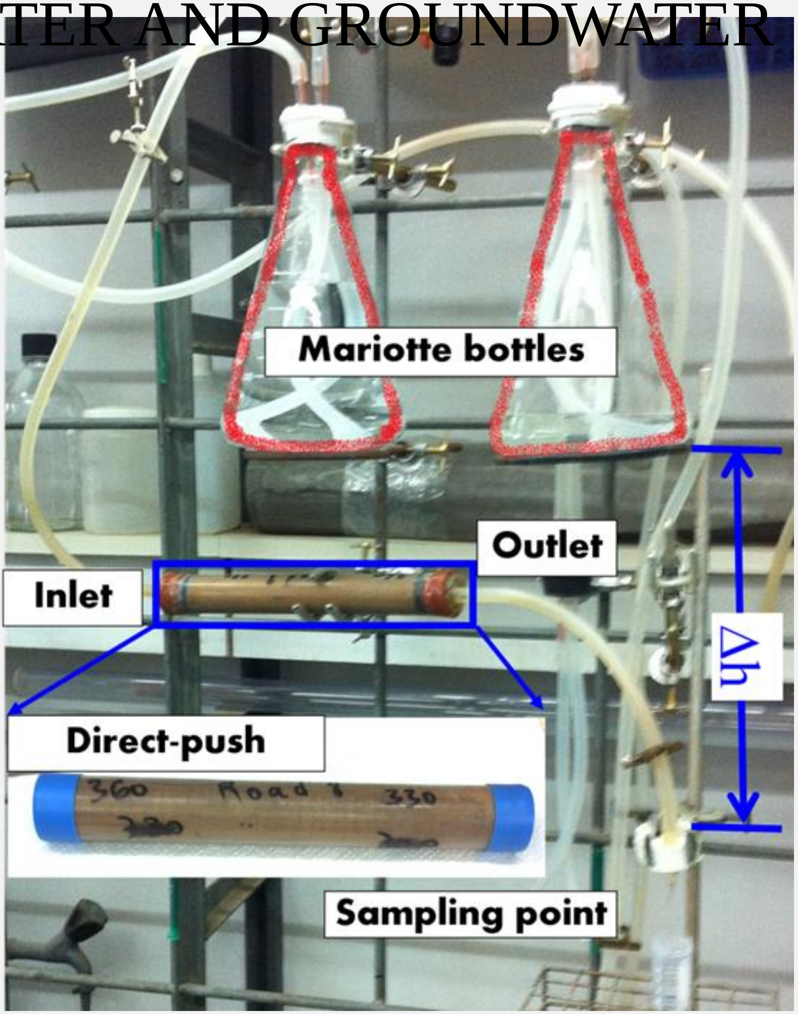
DBPs due to chlorinated desalinated seawater (BGU)

	Sample	THM				Water isotopes	
		$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$	δ^2H (‰)	$\delta^{18}O$ (‰)
Field samples	Well PA					10.861	1.540
	Well PB		+			10.718	1.275
	P-0.5				+	11.499	1.490
	P-1.0					11.185	1.429
	P-2.0		+	+	+	10.746	1.325
	P-3.0		+	+	+	10.818	1.377
Reference values	DSW	Not detected	Not detected	Not detected	Not detected	11.339	1.414
	Well M6	Not analyzed				-18.408	-4.485
	Well M9					-18.475	-4.508

SIMULATING MANAGED AQUIFER RECHARGE BY COLUMN EXPERIMENTS WITH ALTERNATING DESALINATED WATER AND GROUNDWATER

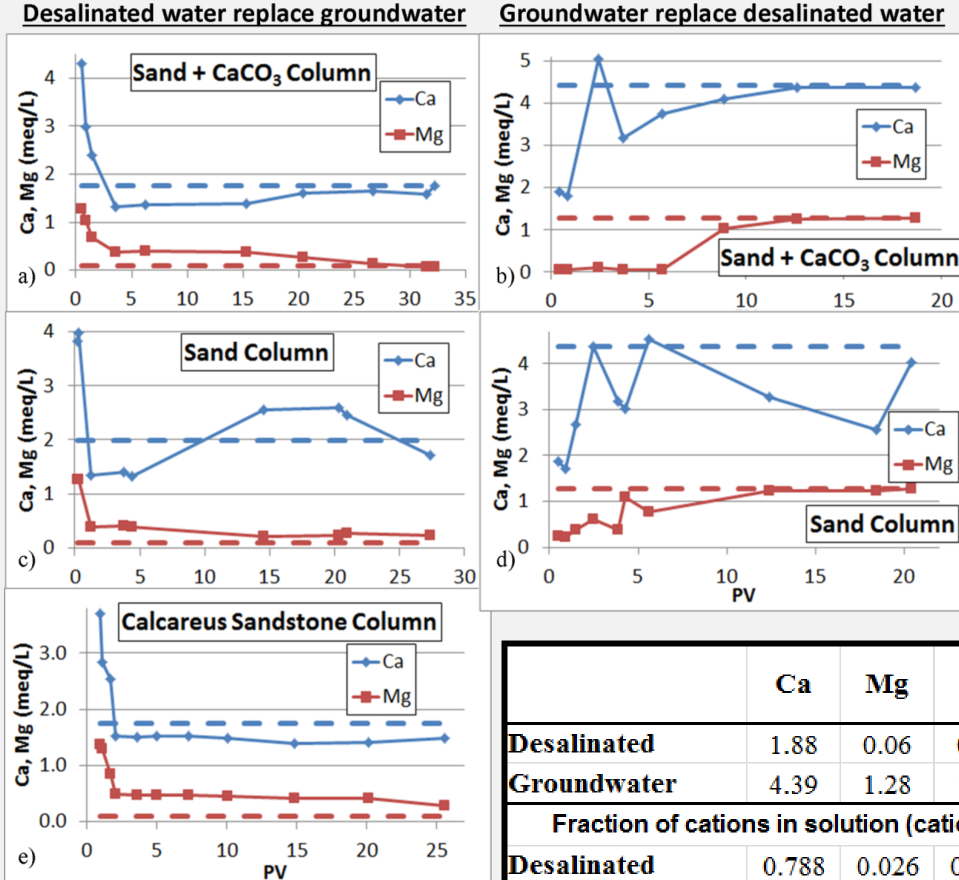


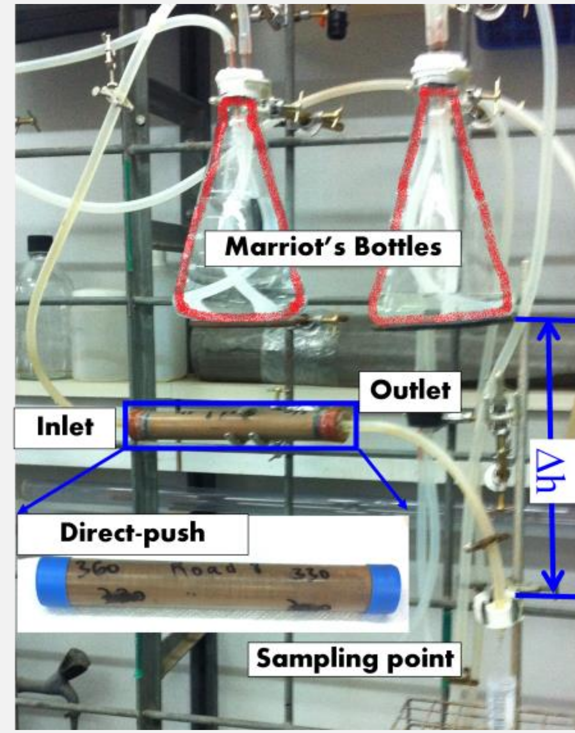




Column experiments

Ronen-Eliraz et al. (in review, *STOTEN*),
Simulating Managed Aquifer Recharge by Column Experiments with Alternating Desalinated Water and Groundwater





	Ca	Mg	Na	K	B	Sum Cation	Ca/Mg	Ca/Na	Ca/K
Desalinated	1.88	0.06	0.41	0.01	0.023	2.39	30	4.6	199
Groundwater	4.39	1.28	1.82	0.05	0.004	7.55	3.4	2.4	89
Fraction of cations in solution (cation/sum of cation):									
Desalinated	0.788	0.026	0.172	0.004	0.010	1			
Groundwater	0.582	0.170	0.241	0.007	0.001	1			
Ratio of fractions:									
GW/DES	0.7	6.6	1.4	1.6	0.1				
DES/GW	1.4	0.2	0.7	0.6	17.9				

מי מייצר מים מותפלים וכמה זה עולה לנו (בשער המתקן)

(מתוך מצגת של החשב הכללי על ההתפלה בישראל)

מתקני התפלה	הרכב הזכיין	כמות מים (מלמ"ש)	תחילת הספקת מים	מחיר המים (₪)
אשקלון V.I.D	I.D.E (50%) VEOLIA (50%)	120	אוגוסט 2005	2.9
פלמחים VIA MARIS	גרניט הכרמל (50%) תה"ל (28%) צינורות המזה"ת (22%)	45 (90 מ-2014)	מאי 2007	3.2
חדרה H2ID	I.D.E (50%) שיכון ובינוי (50%)	127	ינואר 2010	2.6
שורק S.D.L	I.D.E (50%) Hutchison water (50%)	150	סוף 2013	2
אשדוד (תוספת שלי)	מקורות ייזום	100	סוף 2014	2.41

פרמטרים של איכות מים במים המותפלים בישראל (אתר רשות המים)

פרמטר איכות	יחידות	תקנות הבריאות לעם למי שתייה – ערכים מרביים מותרים	ערכים מרביים מותרים (לפי דרישות חוזיות או דרישות משרד הבריאות)				תוצאות בפועל		
			אשקלון	פלמחים	חדרה	שורק ואשדוד	אשקלון	פלמחים	חדרה
כלורידים	מג"ל*	400	20	80	20	20	10-15	30-40	10-15
בורון	מג"ל		0.4	0.4	0.3	0.3	0.2-0.3	0.3-0.4	0.2-0.3
pH	מג"ל	6.5-9.5	7.5-8.5	7.5-8.5	7.5-8.5	7.5-8.5	8.0-8.5	8.0-8.5	8.0-8.5
LSI		---	0.0-0.5	0.0-0.5	0.0-0.5	0.0-0.5	0.0-0.5	0.0-0.5	0.0-0.5
אלקליניוּת ***	מג"ל	---	>40	>40	>80	>80	45-50	40-45	>80
קשיוּת ***	מג"ל	---	80-120	80-120	80-120	80-120	90-110	85-95	80-120
עכירות	יע"ן**	1	<0.5	<0.8	<0.5	<0.5	0.1-0.2	0.1-0.2	0.1-0.2