NUMERICAL SIMULATIONS OF GROUNDWATER AND SURFACE WATER

2025 - 23 Vears O



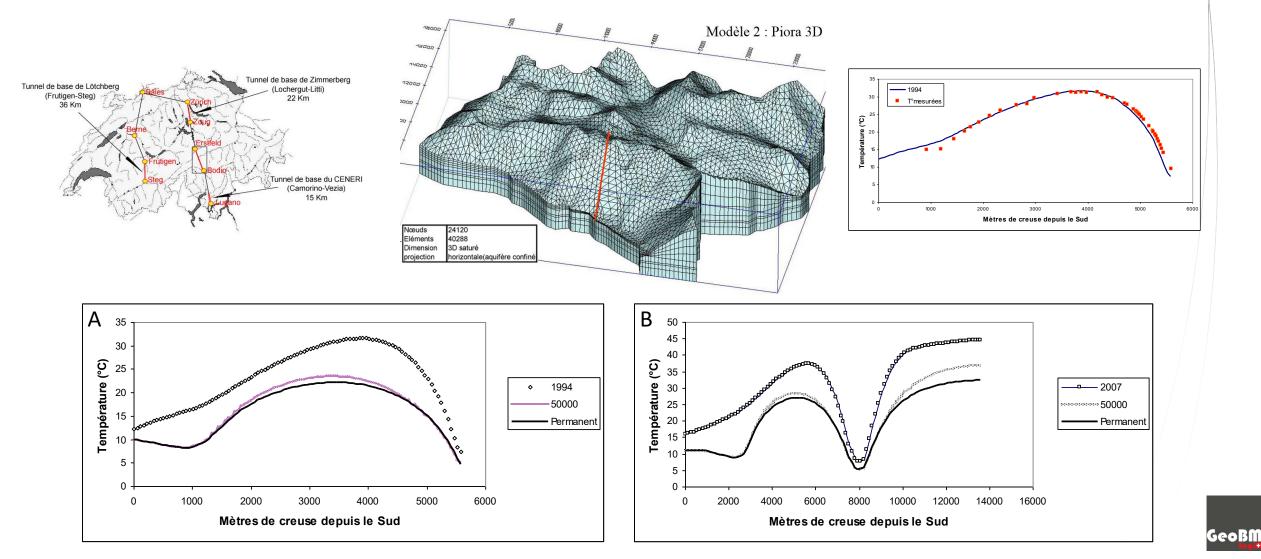
Dr Boris Matti, MAI 2025

FLOW, THERMAL and MASS TRANSPORT MODELS

Type of Models and Objectives	References
Flow and thermal at the level of the Alpine massif	Piora gallery, Gothard Base Tunnel (TI, CH)
Flow and hydro-mechanical coupling of landslides	La Frasse (VD, CH)
Flow and thermal for the study of heat pumps	Sion Hospital and SUVA (VS, CH), San Vittore (GR, CH), Migros Aigle (VD, CH), Osogna (TI, CH), Giubiasco (TI, CH), Cadempino (TI, CH), Stabio (TI, CH)
Flow for the mining sector , sustainability study of water resources, pumping strategy and long-term groundwater drawdown with regional impact study	As Suq, Ad Duwahyi and Humaymah Gold mines (KSA)
Flow at urban scale for construction of metro lines or tunnels	Riyadh (KSA), Doha (QA), Pian Magadino Tunnel (TI, CH)
Flow at the urban scale for dewatering, drawdown and water table control	Dubaï DEWA (UAE) , DIP and BESIX (UAE), Beach Well System (Brunei), Hassya (UAE), Emaar (UAE), Shuraya Island (KSA)
Flow at the peri-urban scale for drawdown water table control	Dubaï AL MAKTOUM INTERNATIONAL AIRPORT (UAE)
Flow and mass transport for environmental studies impact, incl. pumpings	Beach Well System (Brunei), NEOM Development (KSA), Trojena catchment (KSA)
Flow at an urban/regional scale for the study of the water resources and manage/recharged aquifer project	Kabul (AF), Saq and Dawadmi Aquifers (KSA), Wilaya El Menia (Algeria), Niger (NIGER)
Flow at a local scale with coupling of surface water and groundwater for aquifer recharge study	Kabul (AF), Wadi Al Alb (KSA), Al Ghat (KSA), Bishah (KSA)
Flow and mass transport at a regional scale for the study of the reinjection of treated sewage effluent (TSE) and storage in hypersaline environments	Lusail, ECS, Messaimeer Graveyard, Al Rayyan Stadium (Doha, Qatar), Aquifer Storage and Recovery (ASR) (QATAR), NEOM Development (KSA)
Flow and mass transport at a local scale for the study of the interactions between lake water and aquifer	Maroggia (TI, CH)
Flow for geotechnical studies, dewatering estimations, sheet piling, retention basin	Koweit, BESIX (UAE), Bégnins (VD, CH), Stazione di pompaggio-ARM (TI, CH), IDA Vacallo (TI, CH), IDA Giubiasco (TI, CH)

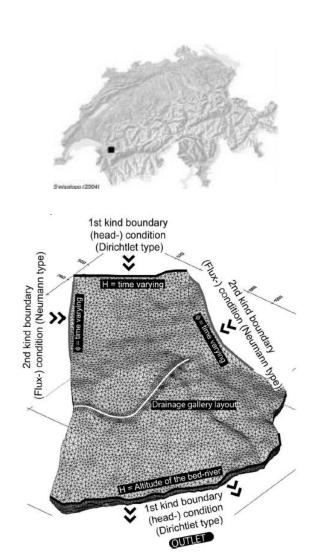
CASE 1 PIORA – ALPTRANSIT (TI, CH) – 3D HYDRO-THERMAL (2001-2002)

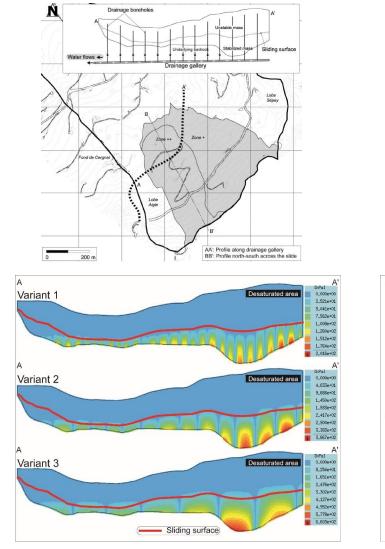
<u>Objectives</u>: To calibrate a 3D hydro-thermal model of the Gotthard massif and to estimate the temperatures during the drilling of the Alptransit base tunnel. Approach point: La Piora gallery.

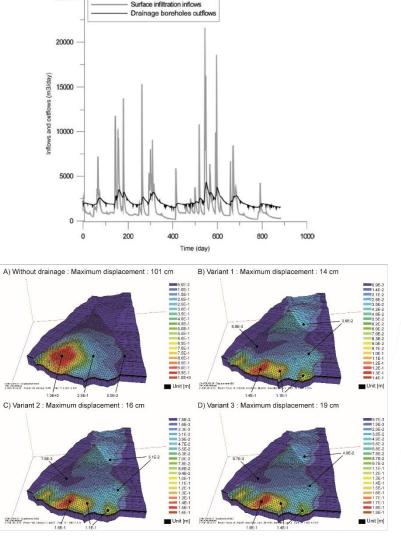


CASE 2 LA FRASSE LANDSLIDE (VD, CH) – 3D FLOW AND HYDRO-MECHANICAL COUPLING (2005-2008)

<u>Objectives</u>: To calibrate a 3D flow model (hydro-mechanical coupling) of the Frasse landslide to design the drainage gallery (by sub-vertical gravity drains), to estimate the outflows (drain contribution) and the residual movements.

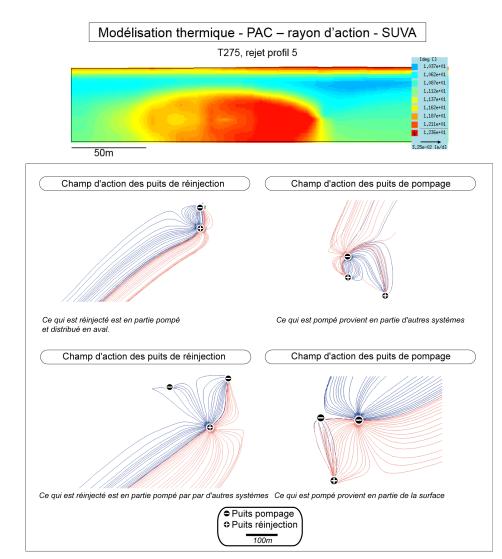






CASE 3 SION HOSPITAL AND SUVA (VS, CH) – 3D HYDRO-THERMAL (2007)

<u>Objectives</u>: To calibrate a 3D hydro-thermal model of the Rhone aquifer to assess the thermal potential of the aquifer and to study the feasibility of additional heat pump systems. Study of thermal interferences and thermal plume path.



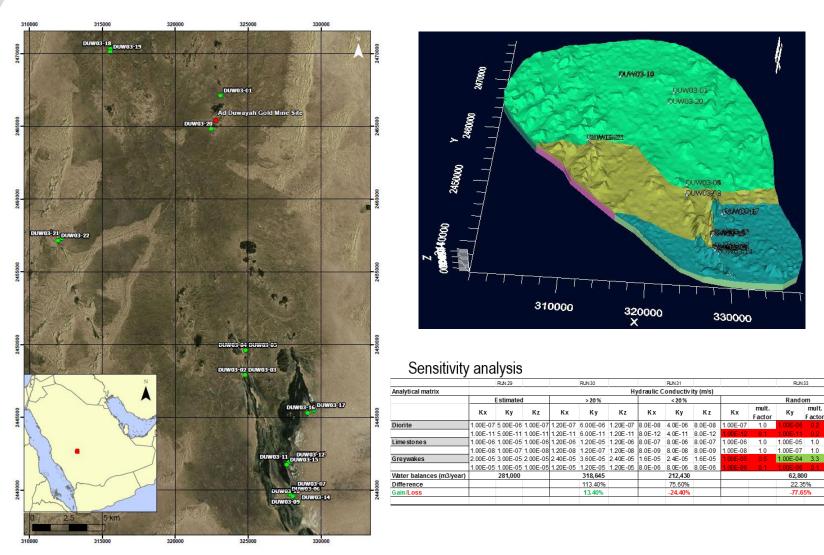
Bilan thermique en automne		Bilan thermique en hiver	
Flux entrant par la face amont	2.87E+11 [J.j ⁻¹]	Flux entrant par la face amont	3.42E+11 [J.j ⁻¹]
Flux entrant avec les précipitations	3.20E+11 [J.j ⁻¹]	Flux entrant avec les précipitations	4.73E+11 [J.j ⁻¹]
Flux entrant par le Rhône	2.70E+10 [J.j ⁻¹]	Flux entrant par le Rhône	1.73E+10 [J.j ⁻¹]
Flux géothermique à la base	4.61E+10 [J.j ⁻¹]	Flux géothermique à la base	4.64E+10 [J.j ⁻¹]
Flux sortant par la face aval	- 4.81E+11 [J.j ⁻¹]	Flux sortant par la face aval	- 4.59E+11 [J.j ⁻¹]
Flux sortant par le sommet	- 2.95E+11 [J.j ⁻¹]	Flux sortant par le sommet	- 2.47E+11 [J.j ⁻¹]
Flux sortant par exfiltration vers le Rhône	- 9.19E+11 [J.j ⁻¹]	Flux sortant par exfiltration vers le Rhône	- 9.11E+11 [J.j ⁻¹]
Puits de prélèvement ICHV PAC	- 8.20E+09 [J.j ⁻¹]	Puits de prélèvement ICHV PAC	
Puits de réinjection ICHV PAC	8.39E+09 [J.j ⁻¹]	Puits de réinjection ICHV PAC	
Puits de prélèvement SUVA PAC	- 5.85E+10 [J.j ⁻¹]	Puits de prélèvement SUVA PAC	- 4.61E+10 [J.j ⁻¹]
Puits de réinjection SUVA PAC	4.58E+10 [J.j ⁻¹]	Puits de réinjection SUVA PAC	4.00E+10 [J.j ⁻¹]
Total	- 1.14E+12 [J.j ⁻¹]	Total	- 7.44E+11 [J.j ⁻¹]
Bilan thermique en été		Bilan thermique au printemp s	
Bilan thermique en été Flux entrant par la face amont	5.77E+11 [J.j ⁻¹]	Bilan thermique au printemps Flux entrant par la face amont	7.72E+11[J.j ⁻¹]
-	5.77E+11 [J.j ⁻¹] 7.60E+11 [J.j ⁻¹]		7.72E+11[7.j ⁻¹] 6.06E+11 [7.j ⁻¹]
Flux entrant par la face amont		Flux entrant par la face amont	
Flux entrant par la face amont Flux entrant avec les précipitations	7.60E+11 [J.j ⁻¹]	Flux entrant par la face amont Flux entrant avec les précipitations	6.06E+11 [J ;j-1]
Flux entrant par la face amont Flux entrant avec les précipitations Flux entrant par le Rhône	7.60E+11 [J.j ⁻¹] 9.14E+11 [J.j ⁻¹]	Flux entrant par la face amont Flux entrant avec les précipitations Flux entrant par le Rhône	6.06E+11 [7 j ⁻¹] 1.11E+12 [7 j ⁻¹]
Flux entrant par la face amont Flux entrant avec les précipitations Flux entrant par le Rhône Flux géothermique à la base	7.60E+11 [J.j ⁻¹] 9.14E+11 [J.j ⁻¹] 6.58E+10 [J.j ⁻¹]	Flux entrant par la face amont Flux entrant avec les précipitations Flux entrant par le Rhône Flux géothermique à la base	6.06E+11 [7.j ⁻¹] 1.11E+12 [7.j ⁻¹] 6.56E+10 [7.j ⁻¹]
Flux entrant par la face amont Flux entrant avec les précipitations Flux entrant par le Rhône Flux géothermique à la base Flux sortant par la face aval	7.60E+11 [J.j ⁻¹] 9.14E+11 [J.j ⁻¹] 6.58E+10 [J.j ⁻¹] - 4.85E+11 [J.j ⁻¹]	Flux entrant par la face amont Flux entrant avec les précipitations Flux entrant par le Rhône Flux géothermique à la base Flux sortant par la face aval	6.06E+11 [J _j ⁻¹] 1.11E+12 [J _j ⁻¹] 6.56E+10 [J _j ⁻¹] - 3.93E+11[J _j ⁻¹]
Flux entrant par la face amont Flux entrant avec les précipitations Flux entrant par le Rhône Flux géothermique à la base Flux sortant par la face aval Flux sortant par le sommet	7.60E+11 [J.j ⁻¹] 9.14E+11 [J.j ⁻¹] 6.58E+10 [J.j ⁻¹] - 4.85E+11 [J.j ⁻¹] - 1.26E+12 [J.j ⁻¹]	Flux entrant par la face amont Flux entrant avec les précipitations Flux entrant par le Rhône Flux géothermique à la base Flux sortant par la face aval Flux sortant par le sommet	6.06E+11 [J _j ⁻¹] 1.11E+12 [J _j ⁻¹] 6.56E+10 [J _j ⁻¹] - 3.93E+11[J _j ⁻¹] - 1.24E+12 [J _j ⁻¹]
Flux entrant par la face amont Flux entrant avec les précipitations Flux entrant par le Rhône Flux géothermique à la base Flux sortant par la face aval Flux sortant par le sommet Flux sortant par exfiltration vers le Rhône	7.60E+11 [J.j ⁻¹] 9.14E+11 [J.j ⁻¹] 6.58E+10 [J.j ⁻¹] - 4.85E+11 [J.j ⁻¹] - 1.26E+12 [J.j ⁻¹] - 2.21E+11 [J.j ⁻¹]	Flux entrant par la face amont Flux entrant avec les précipitations Flux entrant par le Rhône Flux géothermique à la base Flux sortant par la face aval Flux sortant par le sommet Flux sortant par exfiltration vers le Rhône	6.06E+11 [7 j ⁻¹] 1.11E+12 [7 j ⁻¹] 6.56E+10 [7 j ⁻¹] - 3.93E+11[7 j ⁻¹] - 1.24E+12 [7 j ⁻¹] -2.94E+10 [7 j ⁻¹]
Flux entrant par la face amont Flux entrant avec les précipitations Flux entrant par le Rhône Flux géothermique à la base Flux sortant par la face aval Flux sortant par le sommet Flux sortant par exfiltration vers le Rhône Puits de prélèvement ICHV PAC	7.60E+11 [J,j ⁻¹] 9.14E+11 [J,j ⁻¹] 6.58E+10 [J,j ⁻¹] - 4.85E+11 [J,j ⁻¹] - 1.26E+12 [J,j ⁻¹] - 2.21E+11 [J,j ⁻¹] - 8.51E+10 [J,j ⁻¹]	Flux entrant par la face amont Flux entrant avec les précipitations Flux entrant par le Rhône Flux géothermique à la base Flux sortant par la face aval Flux sortant par le sommet Flux sortant par exfiltration vers le Rhône Puits de prélèvement ICHV PAC	6.06E+11 [J _j ⁻¹] 1.11E+12 [J _j ⁻¹] 6.56E+10 [J _j ⁻¹] - 3.93E+11[J _j ⁻¹] - 1.24E+12 [J _j ⁻¹] -2.94E+10 [J _j ⁻¹] -4.68E+10 [J _j ⁻¹]
Flux entrant par la face amont Flux entrant avec les précipitations Flux entrant par le Rhône Flux géothermique à la base Flux sortant par la face aval Flux sortant par le sommet Flux sortant par exfiltration vers le Rhône Puits de prélèvement ICHV PAC Puits de réinjection ICHV PAC	7.60E+11 $[J_ij^{-1}]$ 9.14E+11 $[J_ij^{-1}]$ 6.58E+10 $[J_ij^{-1}]$ - 4.85E+11 $[J_ij^{-1}]$ - 1.26E+12 $[J_ij^{-1}]$ - 2.21E+11 $[J_ij^{-1}]$ - 8.51E+10 $[J_ij^{-1}]$ 9.66E+10 $[J_ij^{-1}]$	Flux entrant par la face amont Flux entrant avec les précipitations Flux entrant par le Rhône Flux géothermique à la base Flux sortant par la face aval Flux sortant par le sommet Flux sortant par exfiltration vers le Rhône Puits de prélèvement ICHV PAC Puits de réinjection ICHV PAC	6.06E+11 [J _j ⁻¹] 1.11E+12 [J _j ⁻¹] 6.56E+10 [J _j ⁻¹] - 3.93E+11[J _j ⁻¹] - 1.24E+12 [J _j ⁻¹] -2.94E+10 [J _j ⁻¹] 4.68E+10 [J _j ⁻¹] 5.97E+10 [J _j ⁻¹]

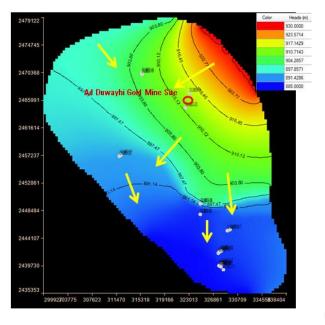


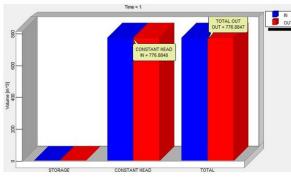
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CASE 4 AD DUWAHYI GOLD MINE (KSA)- 3D FLOW (2013-2014)

Objectives: To calibrate a 3D flow model of the aquifer related to the Ad Duwahyi Gold Mine (KSA). Water resources sustainability study and long-term strategy.







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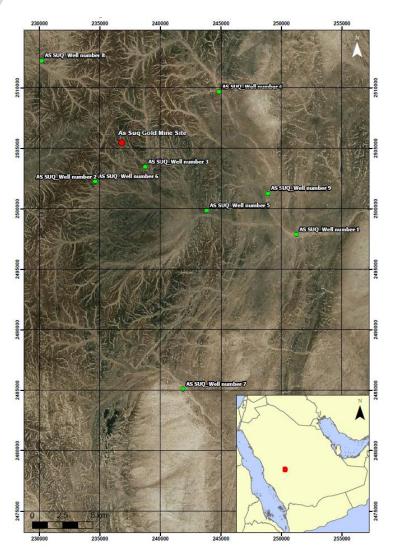
Facto

Global water budget of around 770 m3/day, i.e. around 281,000 m3/year

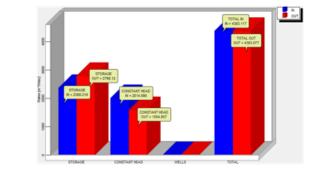
MODFLOW

CASE 5 AS SUQ GOLD MINE (KSA)- 3D FLOW (2013-2014)

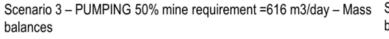
<u>Objectives</u>: To calibrate a 3D flow model of the aquifer related to the Ad Suq Gold Mine (KSA). Sustainability study of water resources and long-term pumping strategy.

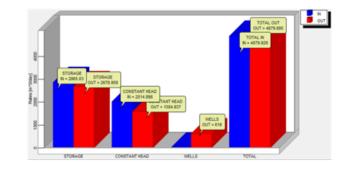


Scenario 1 – WITHOUT WELL – Mass balances



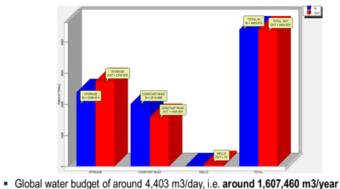
Global water budget of around 4,383 m3/day, i.e. around 1,600,000 m3/year



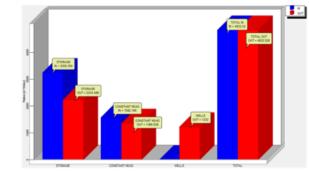


Global water budget of around 4,880 m3/day, i.e. around 1,781,200 m3/year

Scenario 2 - ACTUAL PUMPING=75 m3/day - Mass balances



Scenario 4 – PUMPING 100% mine requirement =1,232 m3/day – Mass balances



Global water budget of around 4,832 m3/day, i.e. around 1,763,680 m3/year



MODFLOW

CASE 6 HUMAYMAH GOLD MINE (KSA)- 3D FLOW (2013-2014)

<u>Objectifs du problème</u>: To calibrate a 3D flow model of the aquifer realted to the Humaymah Gold Mine (KSA). Water resources sustainability, long-term mining strategy, dewatering/groundwater drawdown and regional impact.

5.79E-07

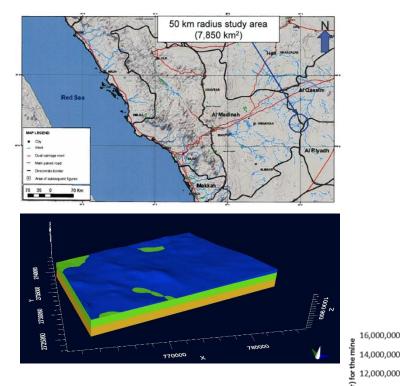
1.18E-

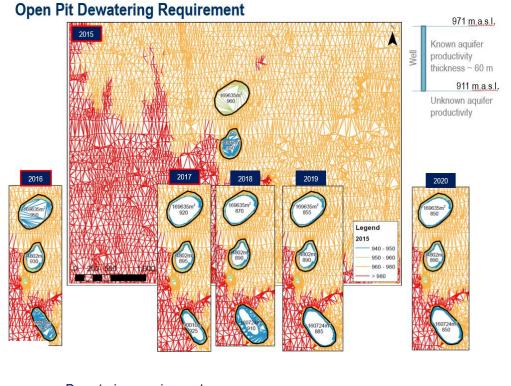
★ 8.10E-★ 8.91E-

2.66E-

- 1.88E-

- 6.38E-





		oring	requiremen	1
7	DEWA	enno	requirement	11
/	001101			

2015	2016	2017	2018	2019	2020
m3/year	m3/year	m3/year	m3/year	m3/year	m3/year
/?	2,000,656	2,509,155	4,205,299	4,867,929	5,107,045
m3/day	m3/day	m3/day	m3/day	m3/day	m3/day
-	5,481.25	6,874.40	11,521.37	13,336.79	13,991.90
	m3/year / ? m3/day	m3/year m3/year /? 2,000,656 m3/day m3/day	m3/year m3/year m3/year /? 2,000,656 2,509,155 m3/day m3/day m3/day	m3/year m3/year m3/year m3/year / ? 2,000,656 2,509,155 4,205,299 m3/day m3/day m3/day m3/day	m3/year m3/year m3/year m3/year /? 2,000,656 2,509,155 4,205,299 4,867,929 m3/day m3/day m3/day m3/day m3/day

2014 2015 2016 2017 2018 2019 2020 Years

10,000,000

8,000,000

6,000,000

4,000,000

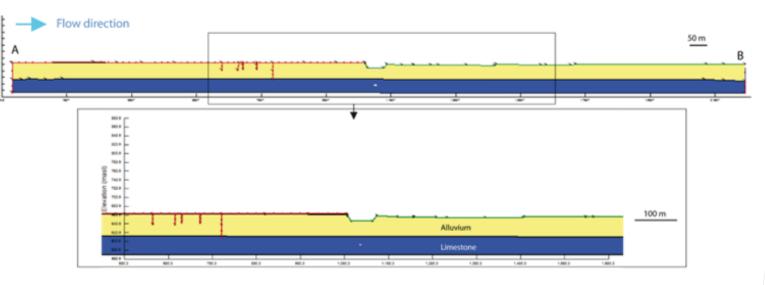
2,000,000



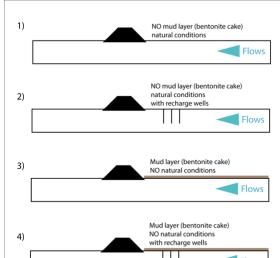
CASE 7 WADI AL ALB (KSA) FORCED RECHARGE - 2D FLOW (2014)

Objectives: To calibrate a 2D flow model of the Wadi Al Alb (KSA) aquifer to assess the potential for seasonal recharge by forced recharge combining retention dam and gravity wells.





Modeling Scenarios



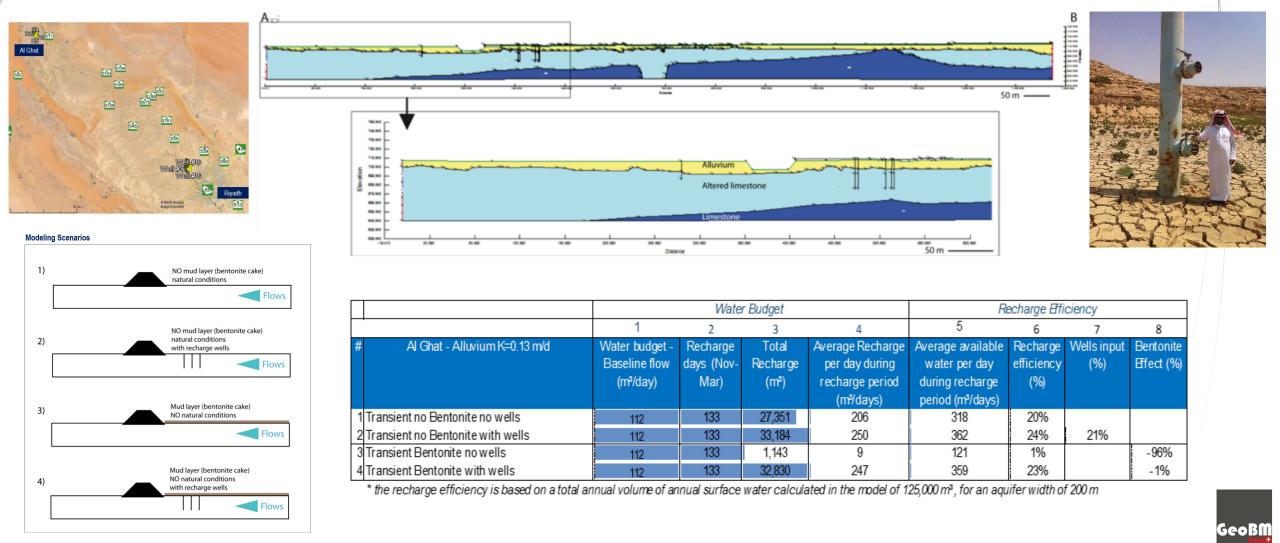
		Water Budget				Recharge Efficiency			
		1	2	3	4	5	6	7	8
#	Al Alb	Water budget -	Recharge	Total	Average Recharge	Average available	Recharge	Wells input	Bentonite
		Baseline flow	days (Nov-	Recharge	per day during	water per day	efficiency	(%)	Effect (%)
		(m³/day)	Mar)	(m³)	recharge period	during recharge	(%)		
					(m%days)	period (m³/days)			
1	Transient no Bentonite no wells	3,928	133	1,368,245	10,288	14,216	33%		
2	Transient no Bentonite with wells	3,928	133	1,563,809	11,758	15,686	37%	14%	
3	Transient Bentonite nowells	3,928	133	61,000	459	4,387	1%		-96%
4	Transient Bentonite with wells	3,928	133	1,324,347	9,957	13,885	32%		-15%

* the recharge efficiency is based on a total annual volume of annual surface water calculated in the model of 4,200,000 m³, for an aguifer width of 200 m

SEEPW

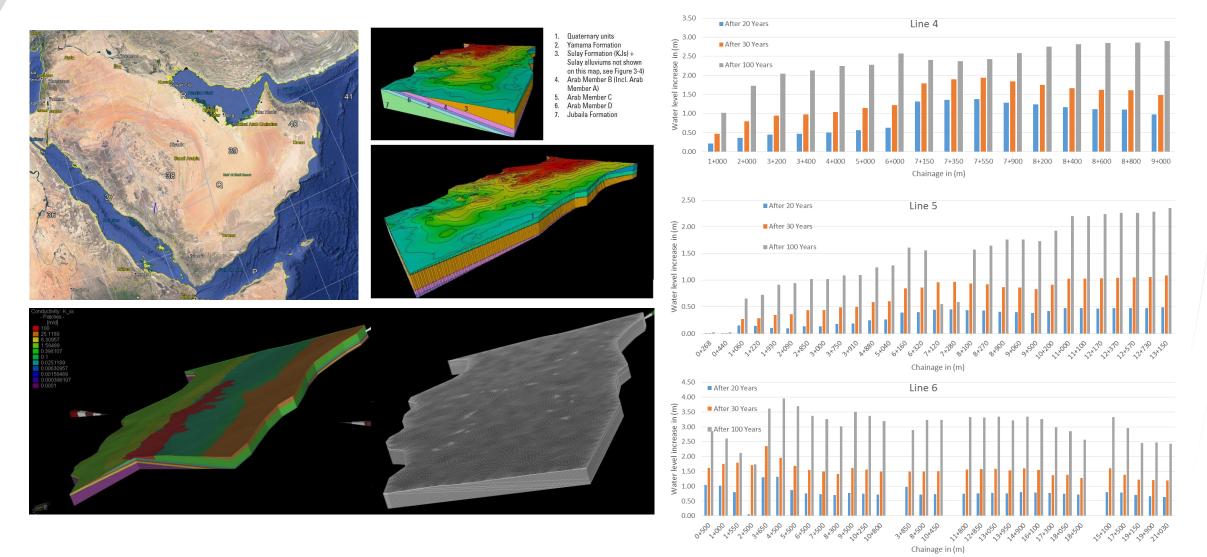
CASE 8 WADI AL GHAT (KSA) FORCED RECHARGE – 2D FLOW (2014)

<u>Objectives</u>: To calibrate a 2D flow model of the Wadi Al Ghat (KSA) aquifer to assess the potential for seasonal recharge by forced recharge combining retention dam and gravity wells.



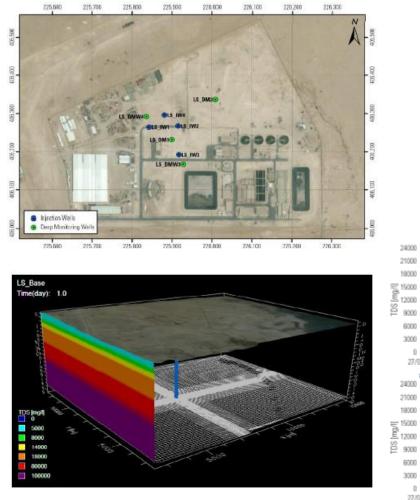
CASE 9 RIYADH METRO REGIONAL MODEL – 3D FLOW (2014-2015)

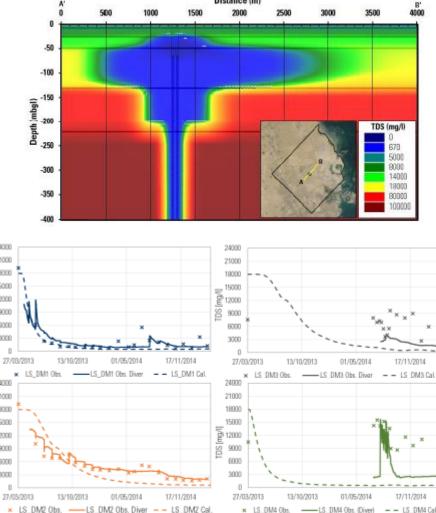
<u>Objectives</u>: To calibrate a 3D flow model of the Riyadh aquifers (KSA) to assess the flow conditions and water table elevation during the construction of the various metro lines.

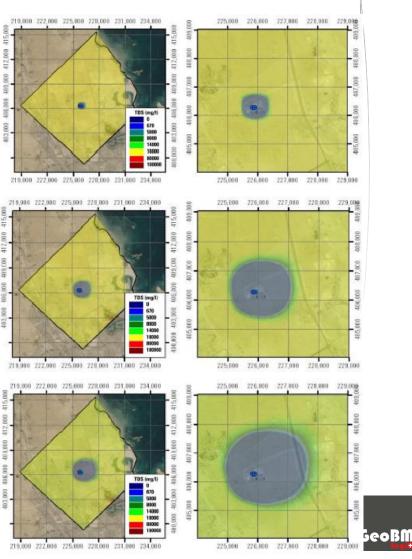


CASE 10 TSE REINJECTION LOCAL MODEL FOR LUSAIL (DOHA) – 3D FLOW - MASS TRANSPORT (SALINITY) (2015)

<u>Objectives</u>: To calibrate a 3D flow-mass transport model at Lusail in the industrial zone of Doha, for the study of the reinjection of treated sewage effluents (TSE) in the hypersaline aquifer.

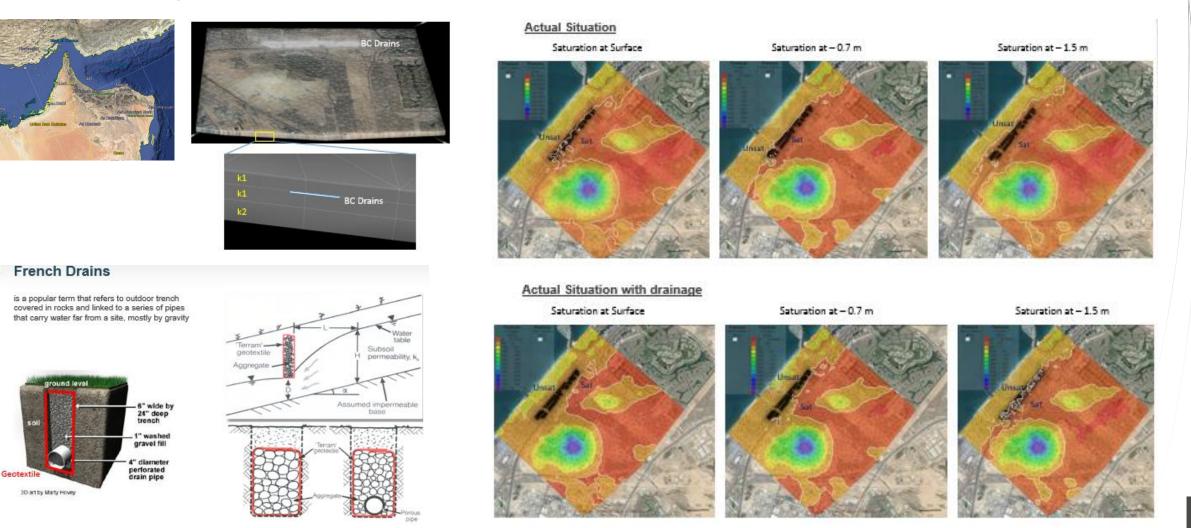






CASE 11 DUBAÏ "DEWA" FRENCH DRAIN DEWATERING – 3D FLOW (2016)

<u>Objectives</u>: To calibrate a 3D flow model of Dubai's coastal aquifers to design a permanent French drain system to control the groundwater levels.

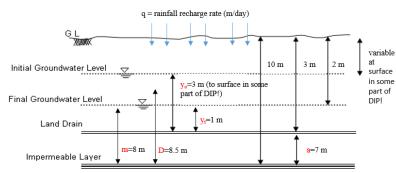


GeoßM

CASE 12 DUBAÏ "DIP" FRENCH DRAIN DEWATERING – 3D FLOW (2016)

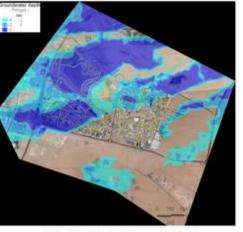
<u>Objectives</u>: To calibrate a 3D flow model of Dubai's coastal aquifers to design a permanent French drain system to control the groundwater levels.





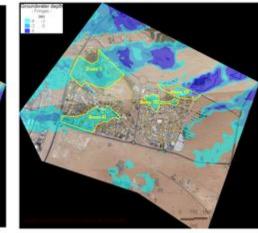
steady state conditions - Actual without dewatering

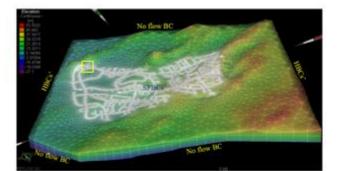
steady state conditions - with dewatering



Construction Priority – phase I

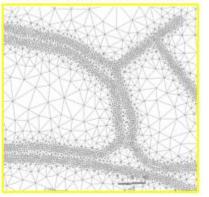
Additional Land Drains required in phase II

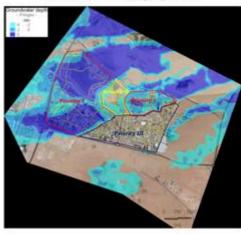




3 layers Total mesh elements: 1,733,724 Total of nodes: 1,156,004 Phreatic type toping an unconfined aquifer

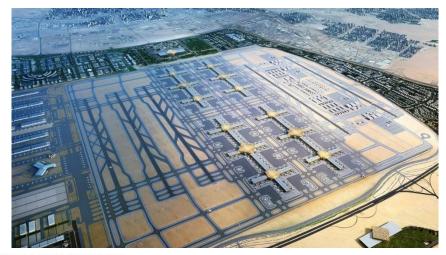
Mesh refinement at land drains



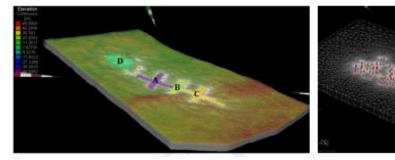


CASE 13 DUBAI "AL MAKTOUM INTERNATIONAL AIRPORT" DEWATERING – 3D FLOW (2018)

<u>Objectives</u>: To calibrate a 3D flow model for the future AI Maktoum international airport (Dubai, UAE) to design the dewatering deep wells system to control the water table during the excavation and construction stages.

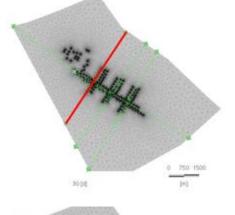


Dewatering Wells Network



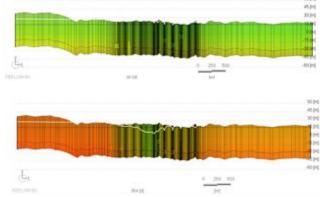
A total of 200 dewatering wells have been imported into the model. As indicated, 4 dewatering Section have been defined:

- Section A contains 77 wells
- Section B 53 wells
- Section C 53 wells and
- Section D 17 wells

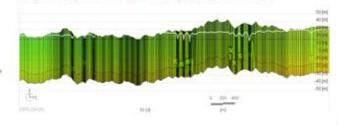


30 [4]

Transversal Profile #4 - Section A



Longitudinal profile #5 - All Sections - profile 1 after 30 days

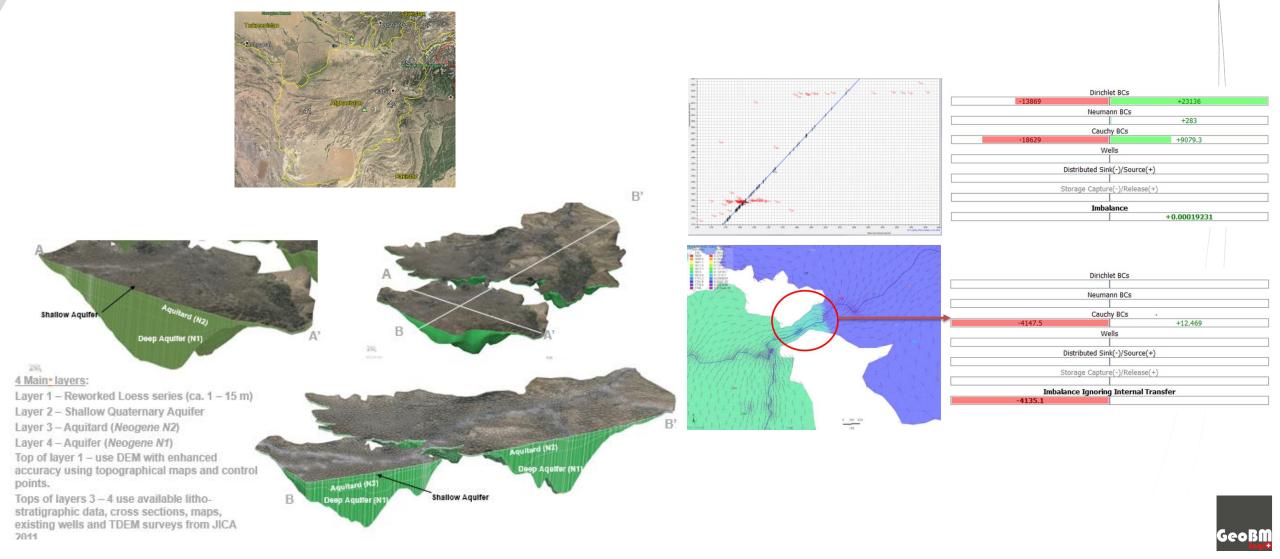


Inflo	ws rates in m³/d	Inflows r	ates per well in m³/d
Section A	2280.00	Section A	30 (pump capacity = 1.23m ³ /h)
Section B	1870.00	Section B	35 (pump capacity = 1.47 m ³ /h)
Section C	4160.00	Section C	78 (pump capacity = 3.27 m ³ /h)
Section D	1350.00	Section D	79 (pump capacity = 3.31 m ³ /h)
Total:	<u>9660.00</u>	Average	56 (pump capacity = 2.32 m ³ /h)



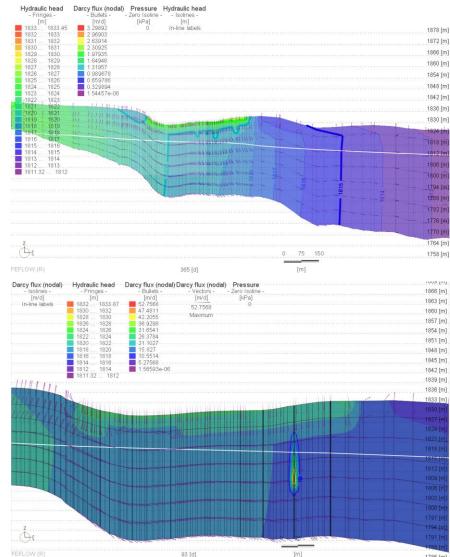
CASE 14 KABUL AQUIFER MANAGED RECHARGE – 3D FLOW (2017-2019)

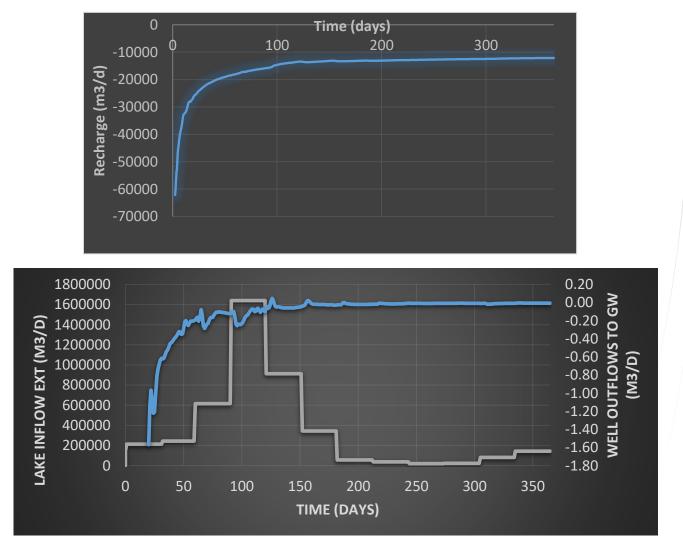
<u>Objectives</u>: To calibrate a 3D flow model of the regional aquifer of the city of Kabul (Afghanistan) for the study of the water availability and regional analyses of water resources.



CASE 15 KABUL AQUIFER MANAGED RECHARGE – 3D FLOW (2017-2019)

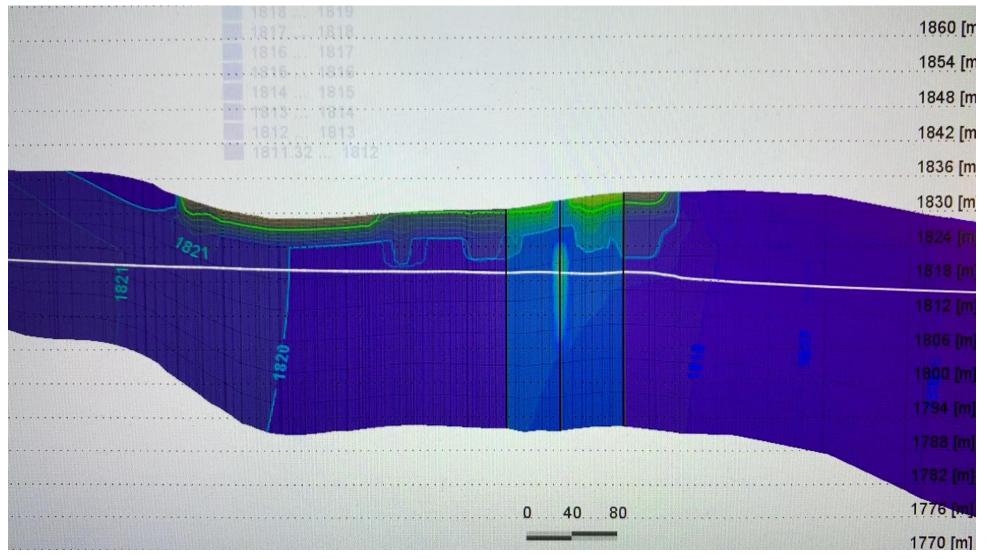
<u>Objectives</u>: To calibrate local 3D flow models at each forced recharge pilot site, with surface water (retention ponds) / groundwater coupling using IfmLake Module (FEFLOW plug-in).





CASE 16 KABUL AQUIFER MANAGED RECHARGE - 3D FLOW (2017-2019)

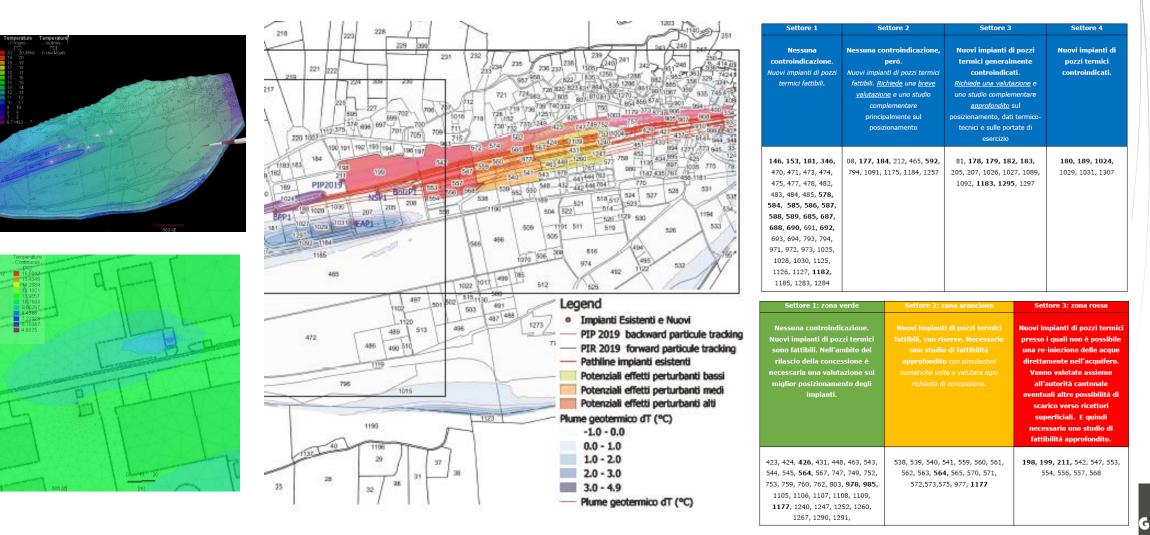
<u>Objectives</u>: To calibrate local 3D flow models at each forced recharge pilot site, with surface water (retention ponds) / groundwater coupling using IfmLake Module (FEFLOW plug-in).



-EFLOW

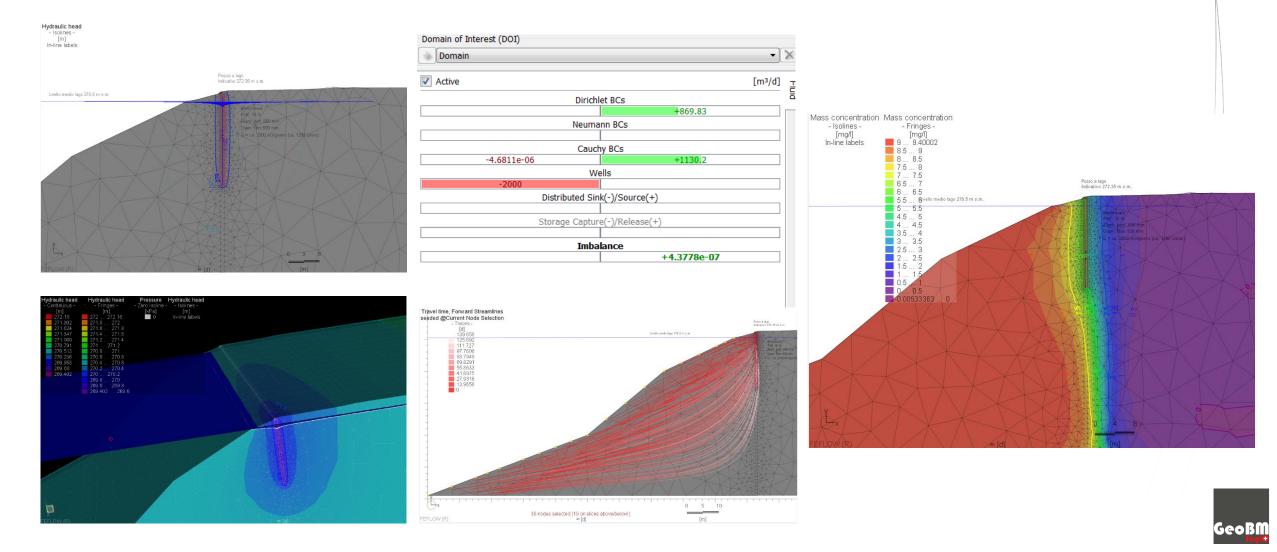
CASE 17 SAN VITTORE (GR, CH) HEAT PUMPS – 3D HYDRO-THERMAL (2017-2019)

<u>Objectives</u>: To calibrate a 3D hydro-thermal model of the San Vittore (GR) aquifer for the assessment of the thermal seasonal effect of heat pumps, and the study of the sustainable use of the thermal resources.



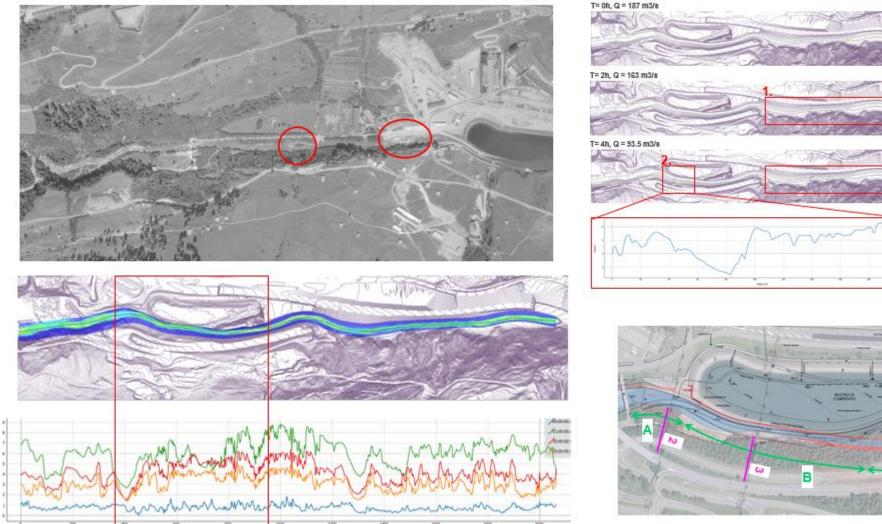
CASE 18 MAROGGIA LAKE-PUMPING-CONTAMINATION – 3D FLOW (2019)

<u>Objectives</u>: To calibrate a pseudo-3D flow model of the coastal aquifer of Maroggia (TI) and the municipality well to assess the aquifer/lake contribution and the impacts of possible pollution (mass transport).



CASE 19 RIVIERE TICINO (TI) DIKE EVALUATION – 2D FLOW (2017)

<u>Objectives</u>: To calibrate a 2D flow model of the Ticino river in Airolo (TI, CH) to study sediment transport related to several fluvial redevelopment options.



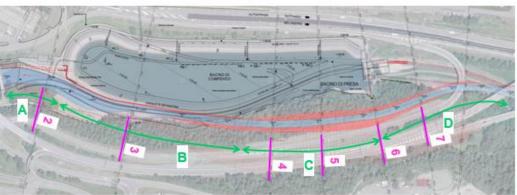


T= 6h, Q = 46.7 m3/8





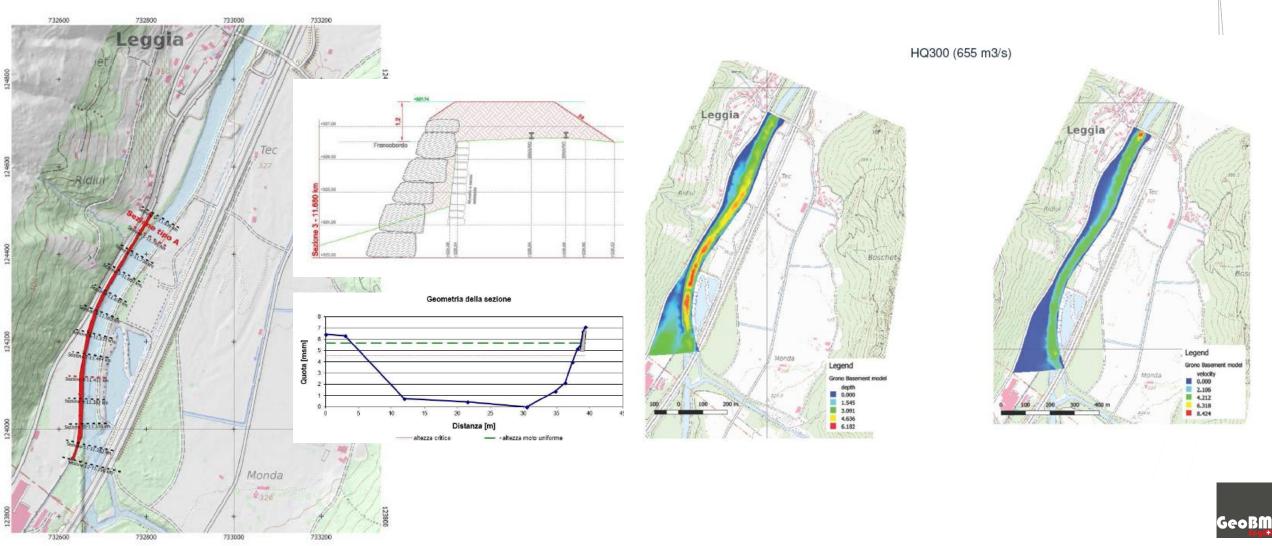
- → <u>Pto. 1</u>: Depositi a valle (già dopo 2h)
- → Pto. 2: Depositi nel tratto di riprofilo (dopo 4h)
- → Pto. 3: Depositi a monte (dopo 6h)



BASEMENT

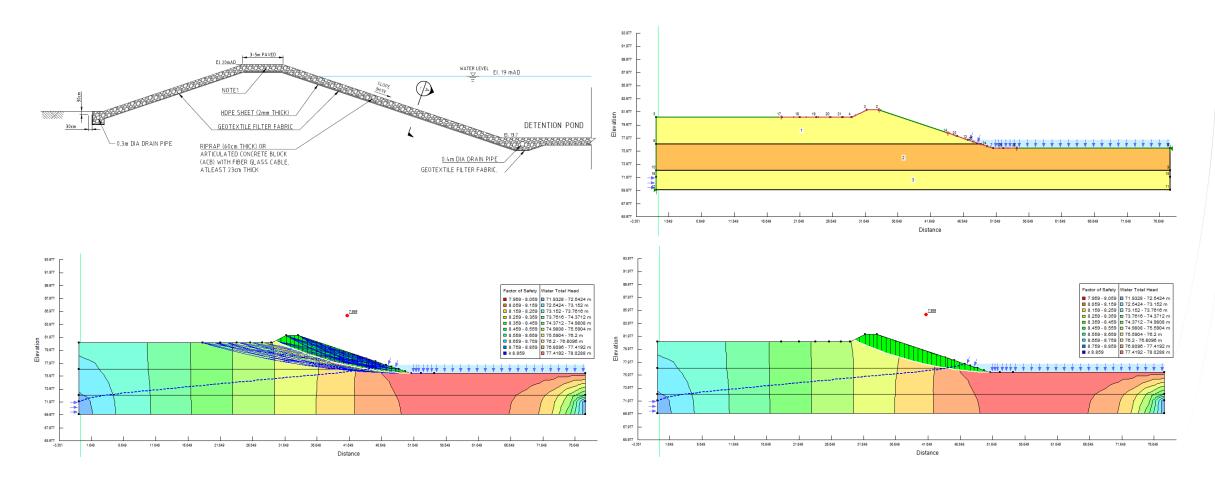
CASE 20 MOESA (GR, CH) RIVER DIKE STABILITY EVALUATION – 2D FLOW (2018)

<u>Objectives</u>: To calibrate a 2D flow model of the Moesa (GR, CH) river to study sediment transport related to several fluvial redevelopment options and dike stability studies.



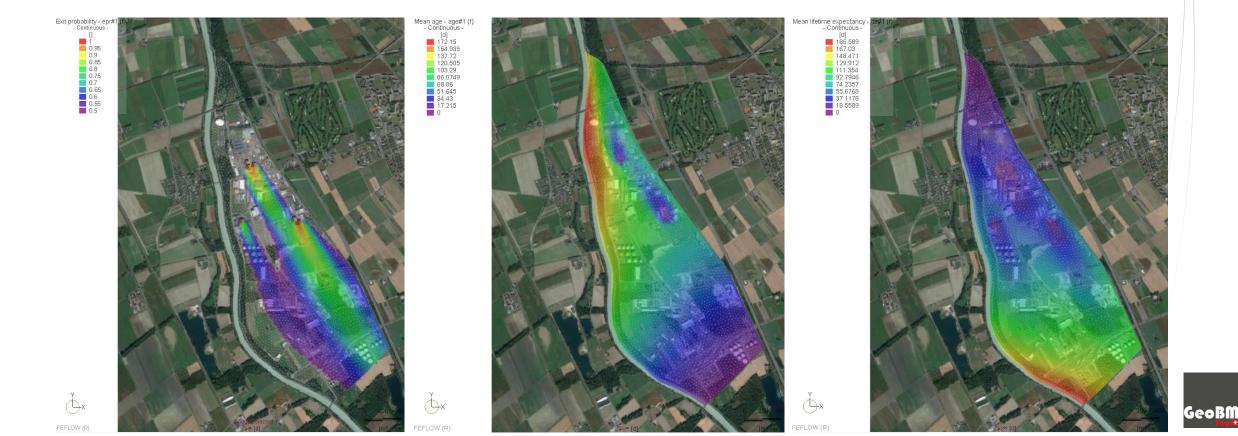
CASE 21 RETENTION POND IN KOWEIT – 2D FLOW (2019)

<u>Objectives</u>: Design of retention pond including bank stability calculation and seepage analyzes. Program: GEOSTUDIO, SEEPW + SLOPE.



CASE 22 HEAT PUMPS – MIGROS, CH – 3D HYDRO-THERMAL (2020)

<u>Objectives</u>: To calibrate a 3D hydro-thermal model for the feasibility study of thermal exploitation by pumping the water table of the Rhône within the framework of the CC CHABLAIS CENTER 2020 project. The system must allow the production of heat and cold. In addition to the flow steady-state solutions towards a well described by Dupuit's analytical solution, the statistical distribution of the random variable 'age' of the groundwater has been modeled using the classical advection-dispersion equation for the transport of a conservative and non-reactive tracer.



CASE 23 KABUL AQUIFER MANAGED RECHARGE – INJECTION WELL – 3D FLOW (2020)

Objectives: To calibrate local 3D flow models for each pilot site related to deep wells forced recharge.

A

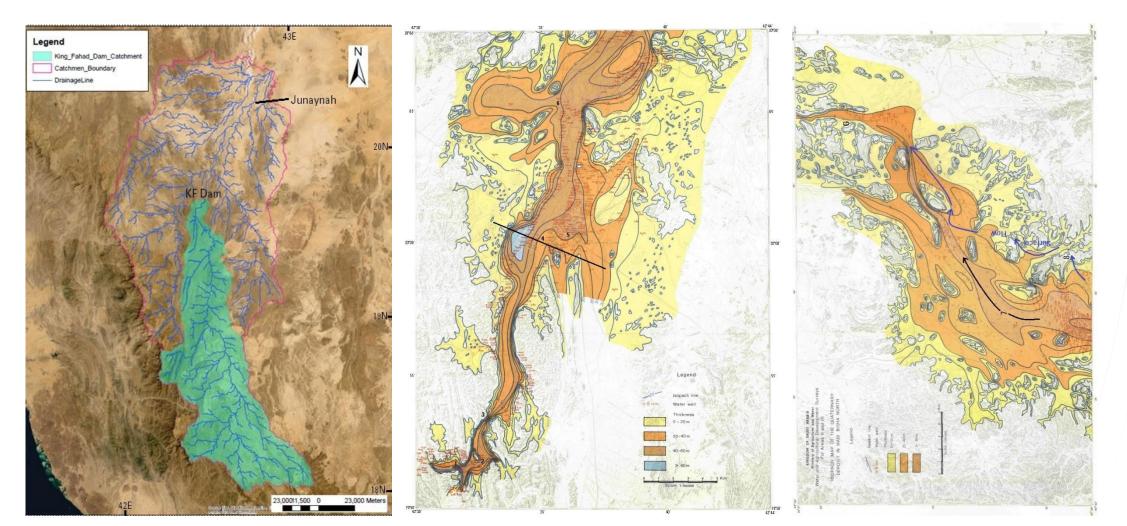
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Figure 8: A) Numerical mesh at Badem Bagh (MAR Site 4) with (B) mesh refinement details at the infiltration borehole

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CASE 24 AQUIFER RECHARGE – WADI BISHA KSA- 3D FLOW (2020)

<u>Objectives</u>: To calibrate a 3D flow model to identify the optimal way to distribute the water stored behind the King Fahad Dam, by determining the groundwater balance of the area, chiefly recharge sources and amounts, as well as the amount of water leaving the system naturally and additional discharge through man made abstractions.



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CASE 25 SHEET PILES STUDY- BÉGNINS, CH - 2D FLOW (2020)

<u>Objectives</u>: To calibrate a vertical 2D digital flow model and identify the interactions between a sheet piles wall and the Césille water resources.

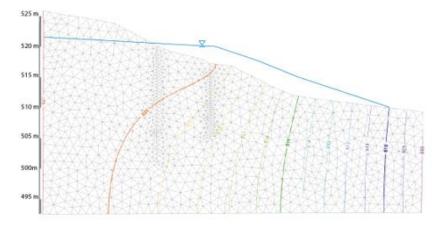
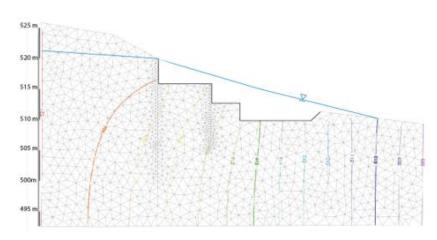
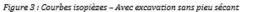


Figure 2 : Courbes isopièzes - Situation actuelle





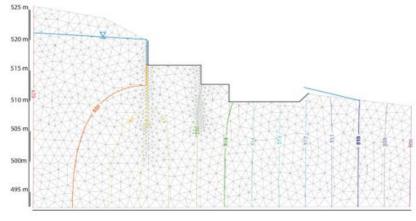
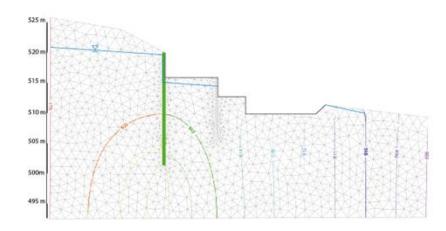
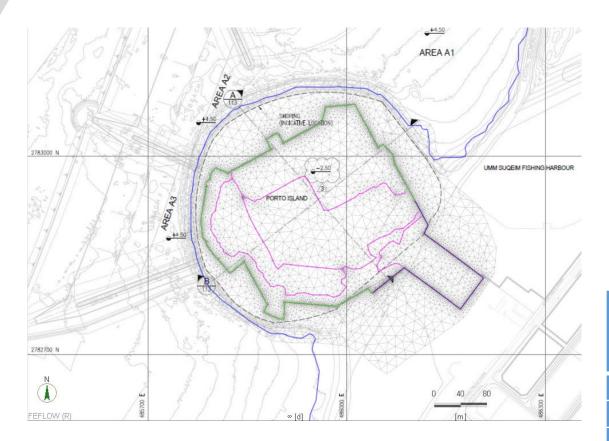


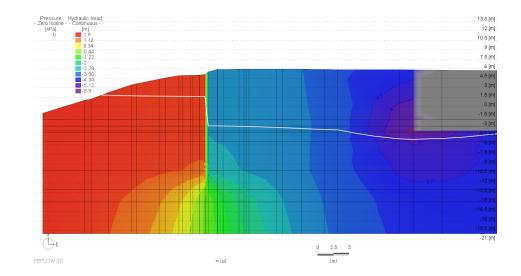
Figure 4 : Courbes isopièzes - Avec excavation et pieux sécants 13 mètres



CASE 26 WATER TABLE DRAWDOWN – DUBAI (UAE) – 3D FLOW (2020)

Objectives: To calibrate a 3D flow model for enabling works construction dewatering.



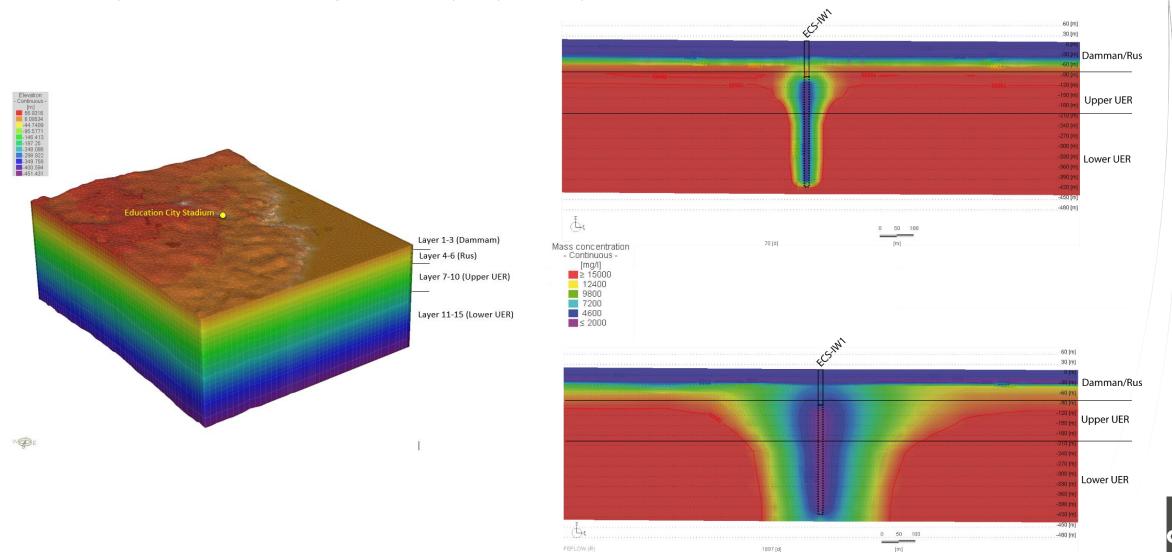


Scenario	Description	Permeabi	lity (m³/s)	Dewatering Level	requirements	dewatering (m³/day) based nodeling
		Sand	Sandstone		Shoring	No shoring
1a	Tender	2.50E-06	2.50E-06	Tender	517	706
1b	Permeability		2.502-00	EI001	526	725
1c	Tender Permeability – Contractor- Assessed	1.20E-04	1.00E-05	E1001	5,071	20,283
2a	Post-award			Tender	6,866	64,073
2b	permeability (pumping test)*	4.10E-04	1.00E-05	EI001	7,053	65,821

GeoßM

CASE 27 TSE RECHARGE at ECS, Messaimeer Graveyard, Al Rayyan Stadium (Doha, Qatar) – 3D FLOW – MASS TRANSPORT (SALINITY) (2020-21)

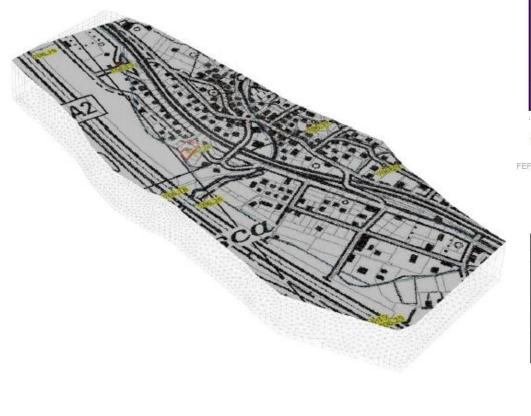
<u>Objectifs du problème</u>: To calibrate a 3D flow-mass transport (salinity) model for different areas in Doha, for the study of the reinjection of treated sewage effluents (TSE) in the hypersaline aquifer.

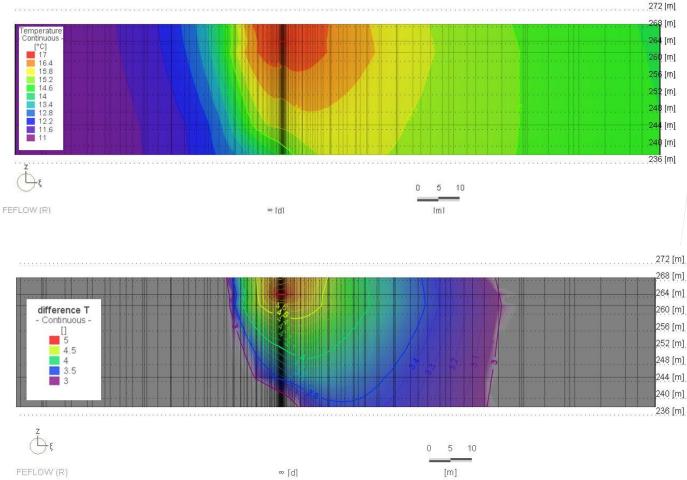


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CASE 28 OSOGNA HEAT PUMP (TI, CH) – 3D HYDRO-THERMAL (2017-2019)

Objectives: To calibrate a 3D hydro-thermal model to evaluate the extension (impact) of the thermal plume with time.

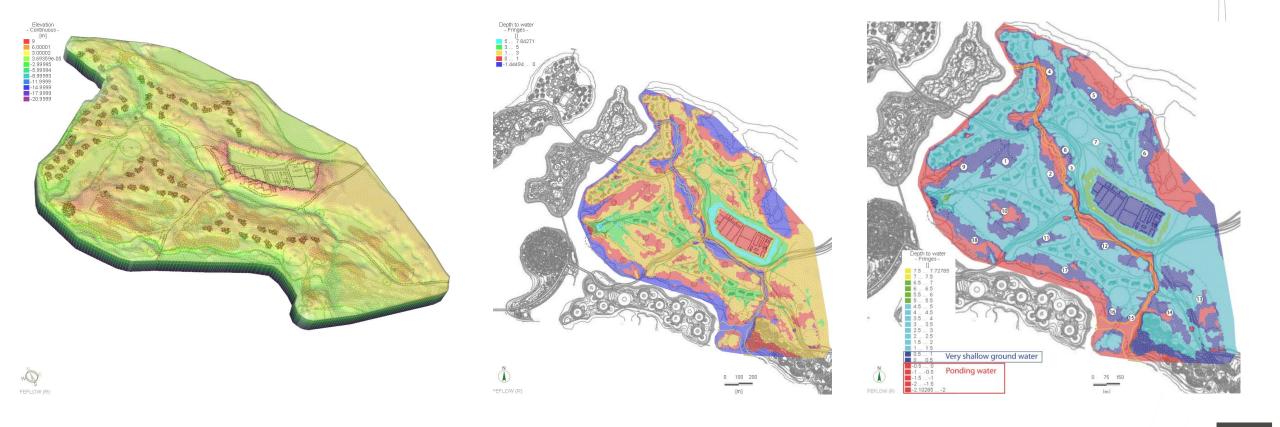






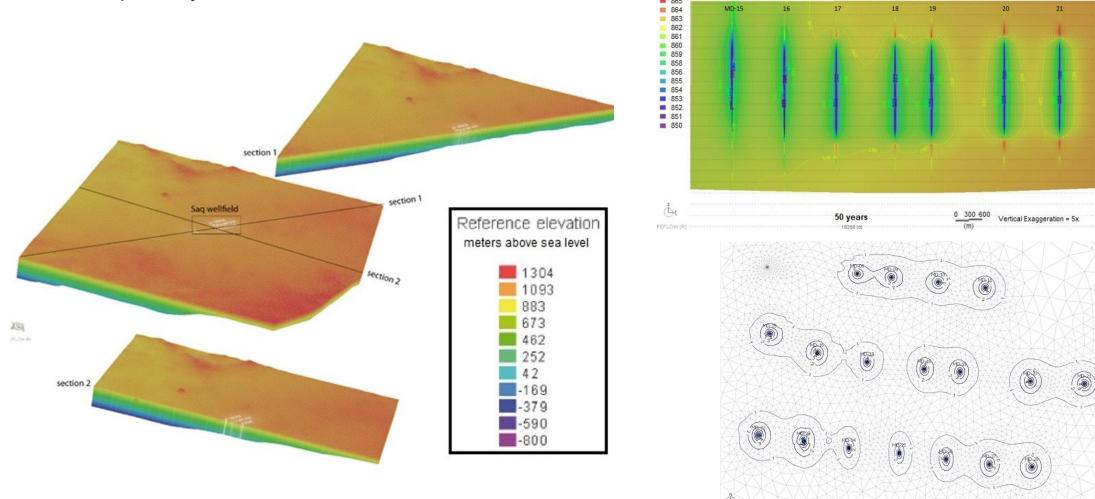
CASE 29 SHURAYRAH GOLF CLUBHOUSE, KSA- 3D FLOW (2021-2024)

<u>Objectives</u>: To calibrate a 3D groundwater model for the future SHURAYRAH GOLF CLUBHOUSE (KSA) to current conditions and used to generate depth-to-groundwater maps for MHWS, 2020 baseline, and 2070 projections. A +0.9 m design water level was also assessed and adopted for future drainage and recharge planning. to assess groundwater conditions and risks related to high water levels across Shurayrah Island.



CASE 30 AQUIFER MANAGEMENT – THE GREAT SAQ WELL FIELD (KSA) – 3D FLOW – (2021-2022)

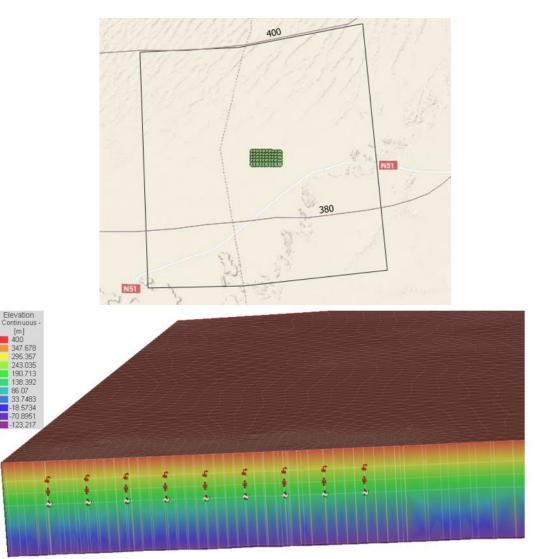
<u>Objectives</u>: To calibrate a 3D hydro model to assess water-supply sustainability via water balances, to predict groundwater level drawdown for 50 years and 100 years and to assess the sensitivity of the model to factors that are imperfectly known.



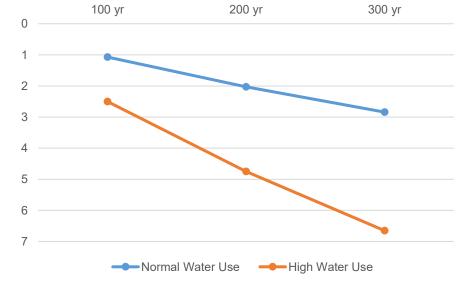
CASE 31 AQUIFER MANAGEMENT – 3D HYDRO- WILAYA EL MENIA, (ALGERIA) - (2022-2023)

Objectives: To calibrate a 3D hydro model to assess the quality and quantity of water available for commercial use

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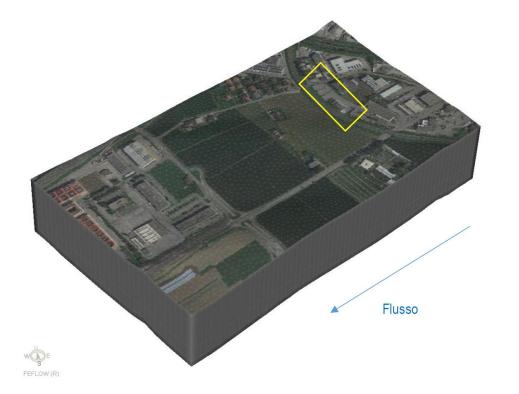


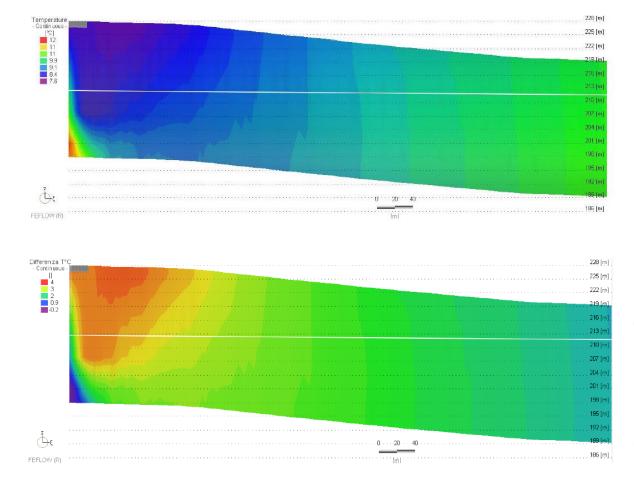
		100 yr	200 yr	300 yr	100 yr	200 yr	300 yr
Normal	Low	1.07	2.03	2.84	4.9	6.3	7.3
Normal	Normal	0.48	1.08	1.58	3.6	5.2	6
Normal	High	0.33	0.76	1.15	3.42	4.26	5.26



CASE 32 GIUBIASCO HEAT PUMP (TI, CH) – 3D HYDRO-THERMAL (2022)

Objectives: To calibrate a 3D hydro-thermal model to evaluate the extension (impact) of the thermal plume with time.



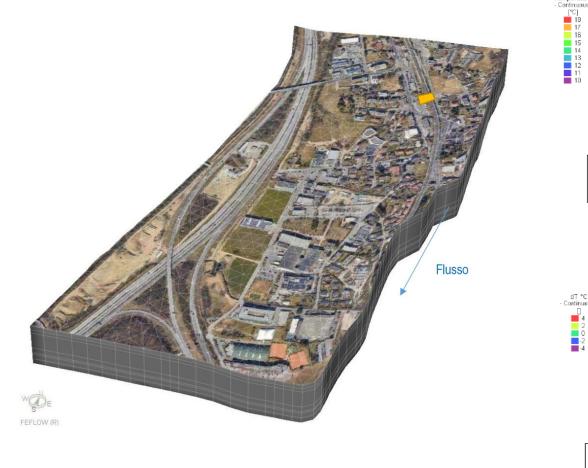


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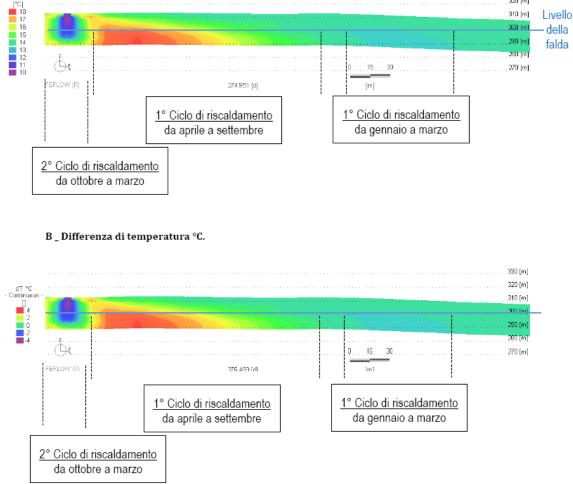
CASE 33 CADEMPINO HEAT PUMP (TI, CH) – 3D HYDRO-THERMAL (2023)

Objectives: To calibrate a 3D hydro-thermal model to evaluate the extension (impact) of the thermal plume with time.

Temperature



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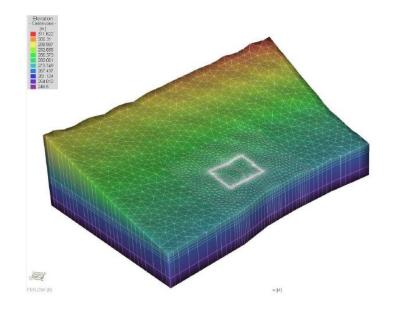
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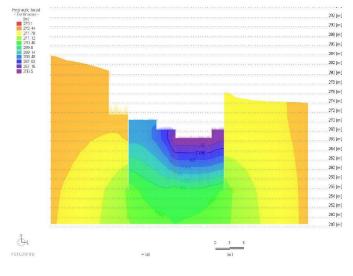
320 [m]

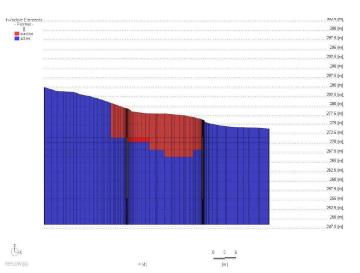
310 [m]

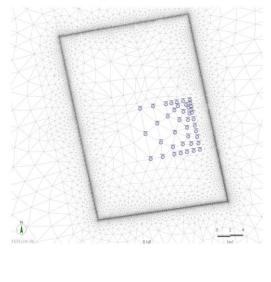
CASE 34 WATER TABLE DRAWDOWN – Stazione di pompaggio-ARM (TI, CH) – 3D FLOW (2023)

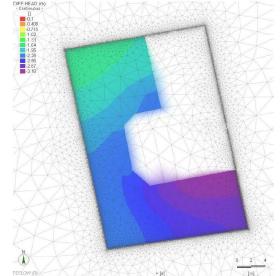
Objectives: To calibrate a 3D flow model for enabling works construction dewatering.





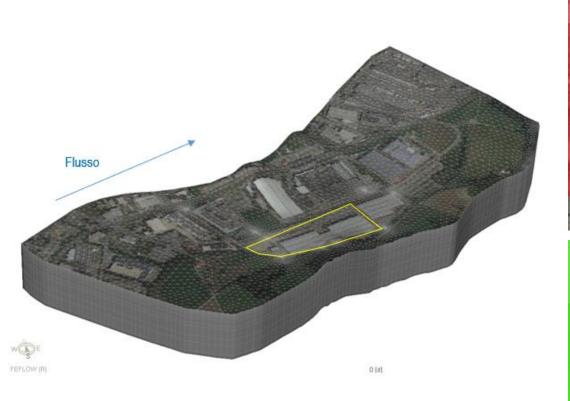


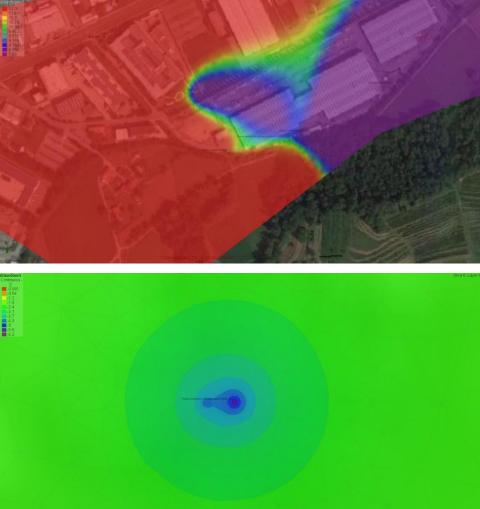




CASE 35 STABIO HEAT PUMP (TI, CH) – 3D HYDRO-THERMAL (2023)

Objectives: To calibrate a 3D hydro-thermal model to evaluate the extension (impact) of the thermal plume with time.



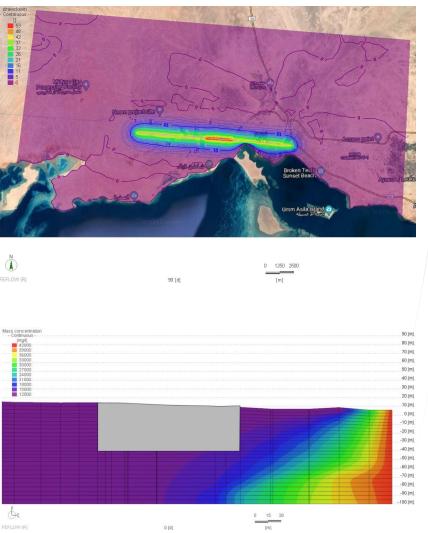




CASE 36 FLOW and SALINITY MODEL – The Spine development at NEOM, on the Red Sea Coast of Saudi Arabia (KSA) – 3D FLOW – MASS TRANSPORT (SALINITY) (2022-23)

<u>Objectives</u>: to undertake 3D groundwater numerical modelling for the assessment of groundwater level and quality (salinity) impact at parts of The Line and The Spine development, at NEOM, on the Red Sea Coast of Saudi Arabia, for the Lots 5 to 7. .

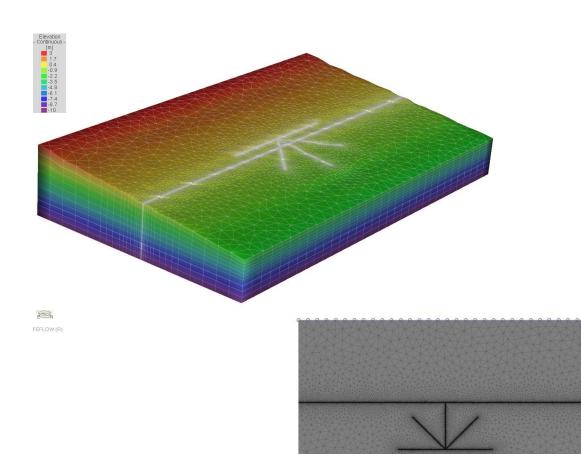


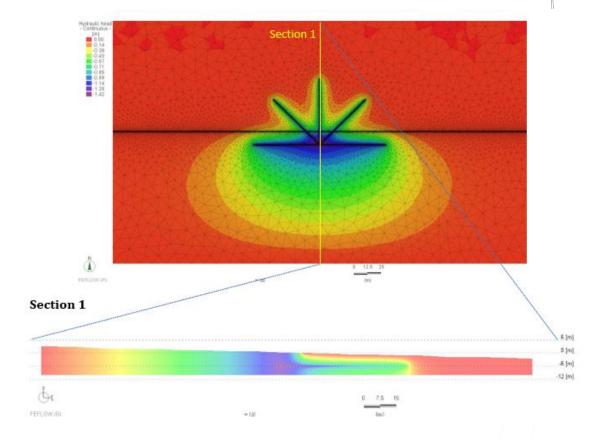


GeoBM

CASE 37 BRUNEI BEACH WELL SYSTEM – BRUNEI – 3D FLOW (2023)

<u>Objectives</u>: To calibrate a 3D flow model to simulate two (2) beach well layouts and to determine which simulated layout would be able to provide mostly 350 m3/hr with an acceptable drawdown of maximum – 4 meters.





GeoßM

CASE 38 TROJENA CATCHMENT STUDY - KSA - 3D FLOW (2023-24)

Objectives: A 3D conceptual groundwater model for the site has been developed to gauge the baseline conditions, and as a tool in understand potential future changes in groundwater conditions.

14/11/2023 14/12/2023

14/10/2023

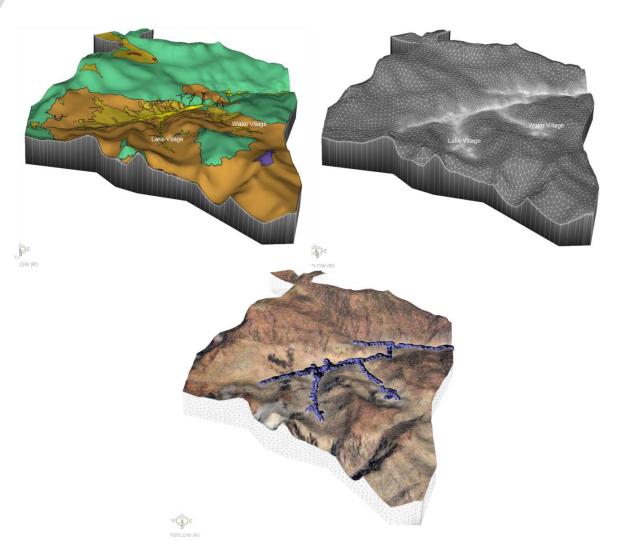
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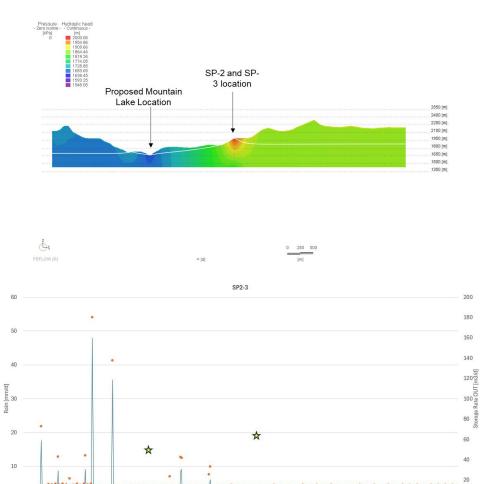
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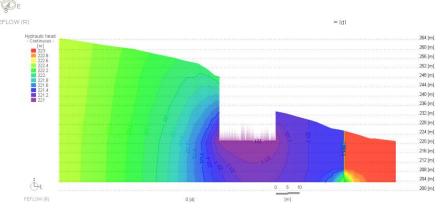
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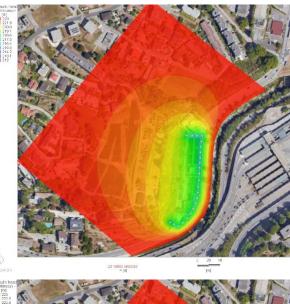
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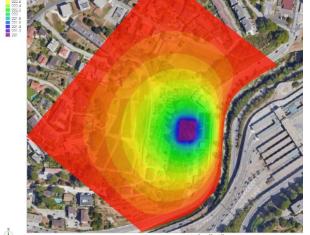
CASE 39 WATER TABLE DRAWDOWN – SEAWAGE TREATMENT PLANT "IDA-VACALLO" (TI, CH) – 3D FLOW (2024)

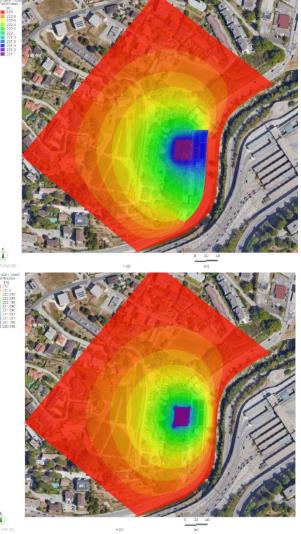
<u>Objectives</u>: To calibrate a 3D flow model to analyze of solutions for lowering groundwater levels in a 21x30m excavation area with a 3m variation. This includes estimating inflows into the excavation pit and proposing alternatives.







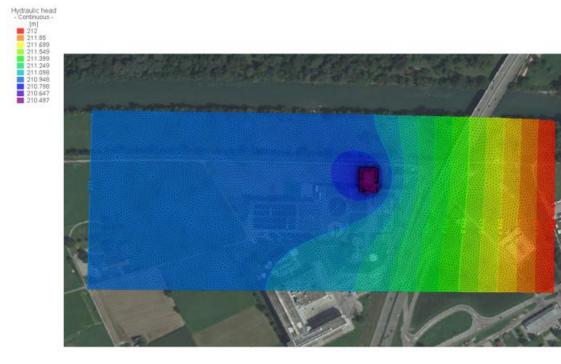




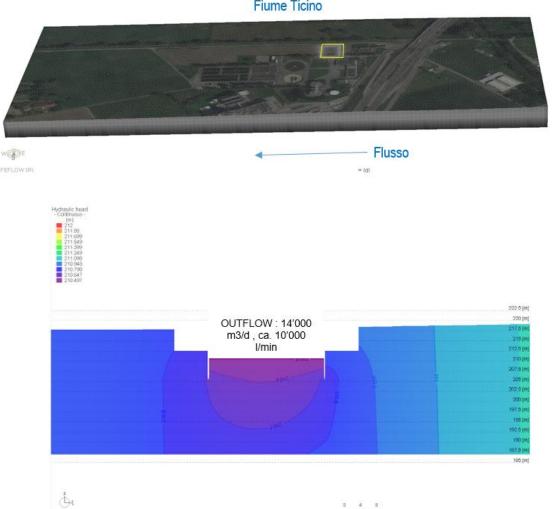


CASE 40 WATER TABLE DRAWDOWN – SEAWAGE TREATMENT PLANT "IDA-GIUBIASCO" (TI, CH) – 3D FLOW (2024)

<u>Objectives</u>: To calibrate a 3D flow model to analyze of solutions for lowering groundwater levels in a 21x30m excavation area with a 3m variation. This includes estimating inflows into the excavation pit and proposing alternatives.



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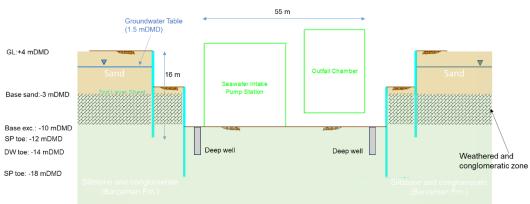


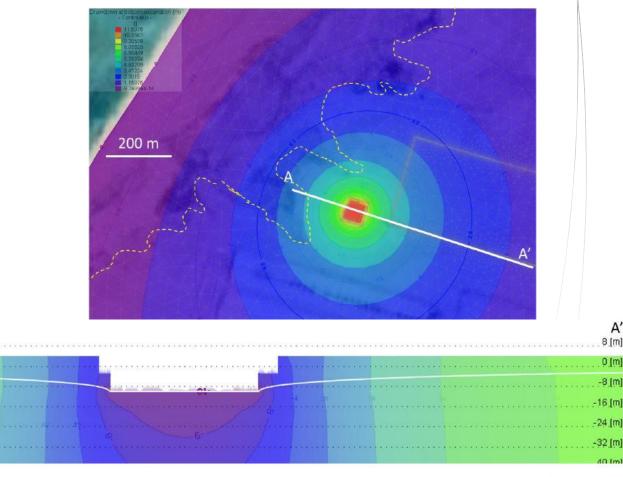
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CASE 41 WATER TABLE DRAWDOWN – HASSYAN IWP - DUBAI (UAE) – 3D FLOW (2020)

<u>Objectives</u>: To calibrate a 3D flow model to assess potential impacts of construction dewatering on groundwater levels at the sensitive habitat.



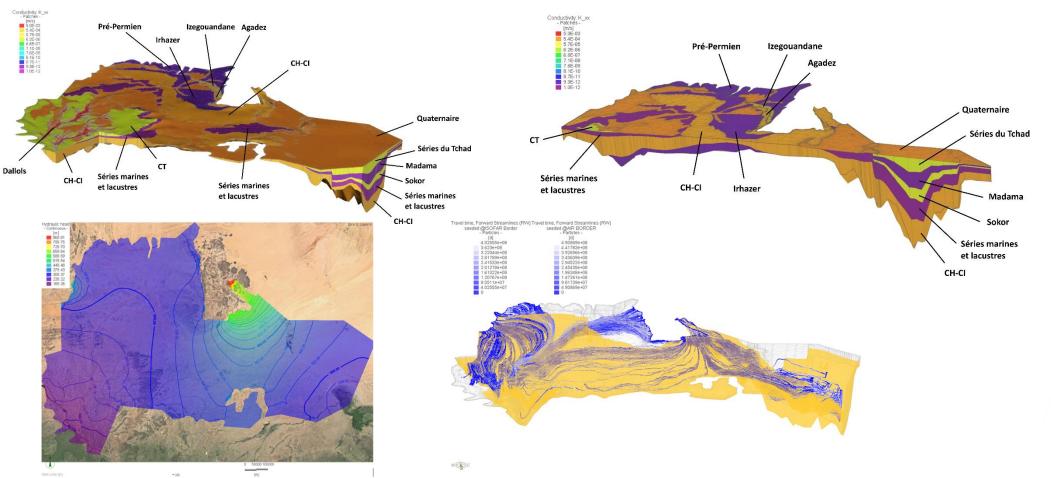




CASE 42 WATER Sustainability – NIGER – 3D FLOW (2023)

<u>Objectives</u>: 3D numerical model FEFLOW is designed to evaluate the groundwater balance on the scale of the entire two sedimentary basins East and West of Niger.

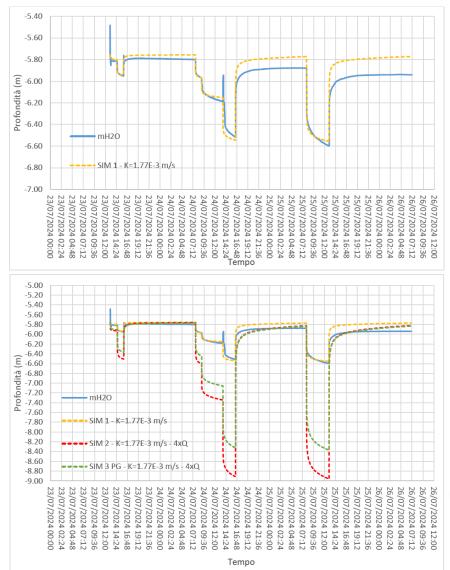
This involves integrating the geological structure of the country and the complex distribution of the different aquifers into a 3D digital mesh, and evaluating both recharge sources and discharge points, with emphasis on natural processes.



CASE 43 STABIO HEAT PUMP (TI, CH) – 3D HYDRO-THERMAL (2024-2025)

<u>Objectives</u>: To calibrate a 3D hydro-thermal model to evaluate the water sustainability and extension (impact) of the thermal plume with time.

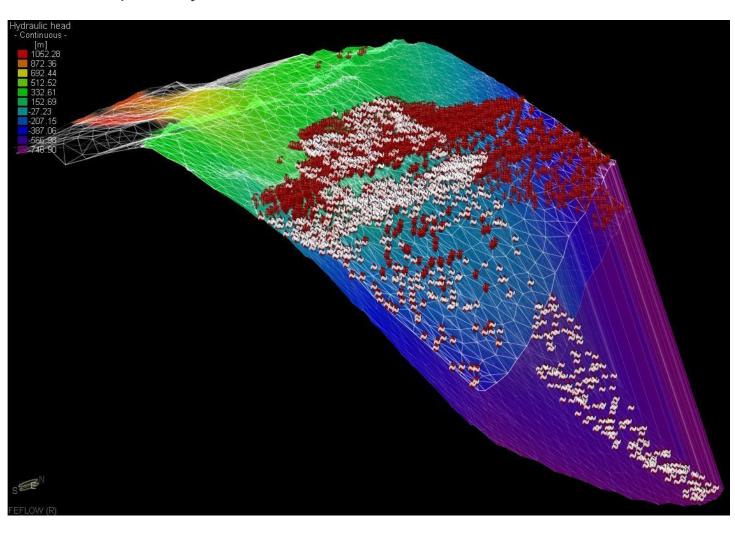


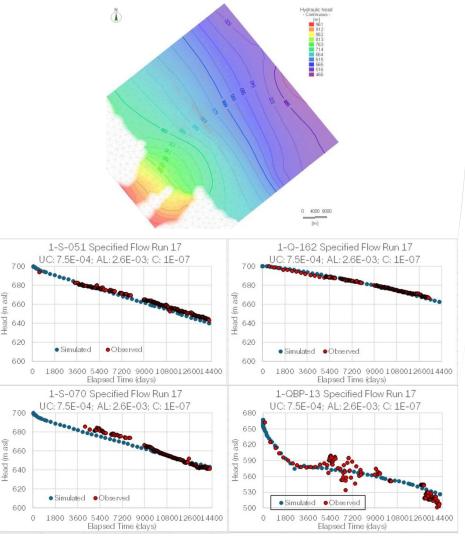


GeoßM

CASE 44 AQUIFER MANAGEMENT – THE GREAT SAQ/DAWADMI WELL FIELD (KSA) – 3D FLOW – (2024)

<u>Objectives</u>: To calibrate a 3D hydro model to assess water-supply sustainability via water balances, to predict groundwater level drawdown for 50 years and 100 years and to assess the sensitivity of the model to factors that are imperfectly known.



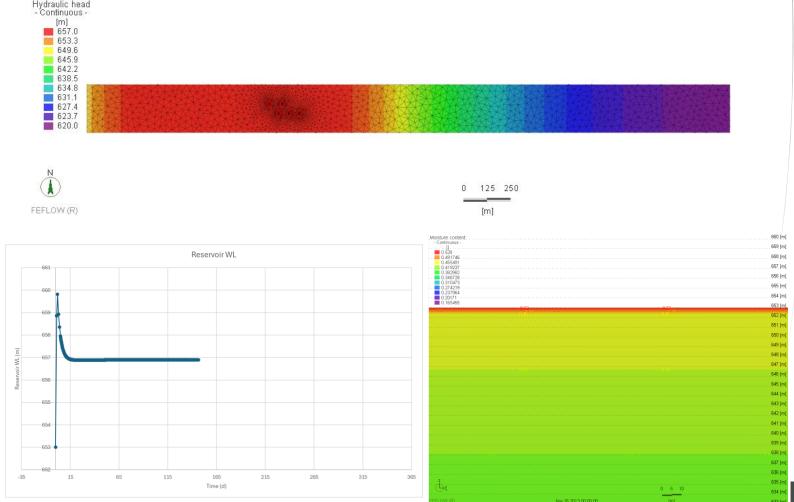


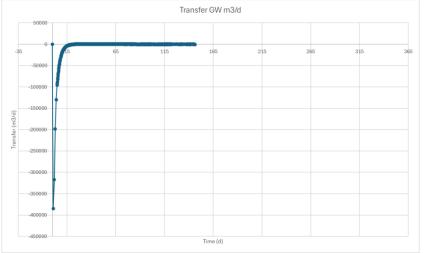
GeoßM

CASE 45 WADI AL ALB (KSA) FORCED RECHARGE – 3D FLOW (2024)

<u>Objectives</u>: To calibrate a 3D flow model of the Wadi Al Alb (KSA) aquifer to assess the potential for seasonal recharge by forced recharge combining retention dam and gravity wells. Using FEFFLOW IFM-Lake module



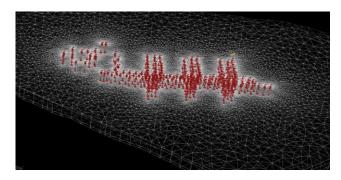


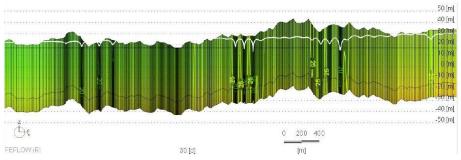


-EFLOW

CASE 46 DUBAI "AL MAKTOUM INTERNATIONAL AIRPORT" DEWATERING – 3D FLOW (2024-2025)

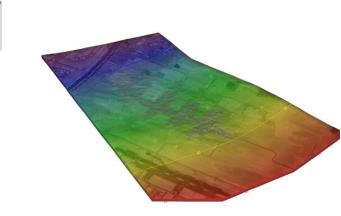
<u>Objectives</u>: To calibrate a 3D flow model for the future AI Maktoum international airport (Dubai, UAE) to design the dewatering deep wells system to control the water table during the excavation and construction stages.







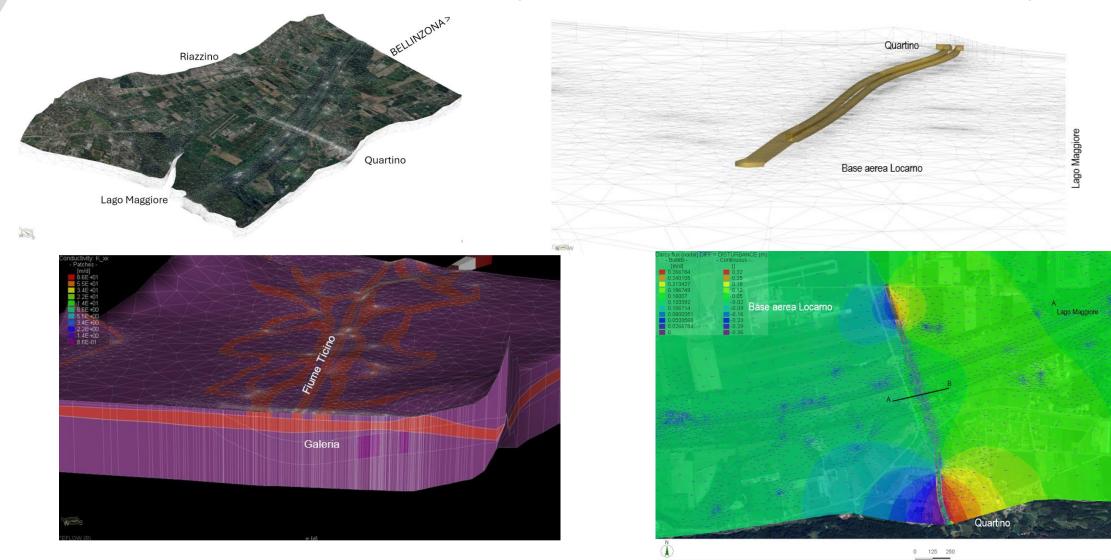






CASE 47 PROGETTO COBELLO – PIAN MAGADINO TUNNELING (TI, CH) – 3D FLOW (2025)

<u>Objectives</u>: To calibrate a 3D flow model to analyze the hydraulic impact of the future tunnel crossing the Magadino Plain, with particular focus on the effects on groundwater and the protected area of the Bolle di Magadino.



CASE 48 DUBAI "EMAAR" GROUNDWATER CONTROL – FRENCH DRAINS – 3D FLOW (2025)

<u>Objectives</u>: To calibrate a 3D flow model of Dubai's coastal aquifers to design a permanent French drain system to control the groundwater levels

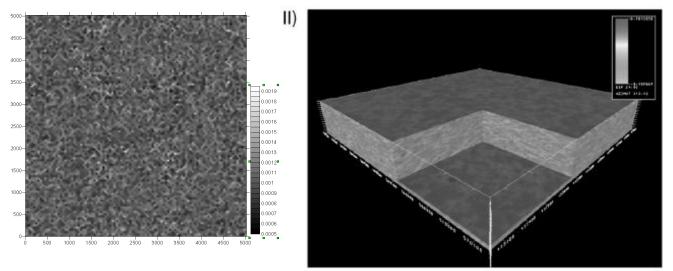
3D HETEROGENEOUS MEDIUM GENERATION with Hydro_Gen

The approach is	based	on random
spatial functions	Υ	

The spatial distribution of the physical property (i.e. permeability k) is random and correlated in space

The permeability k varies spatially according to a stationary lognormal law (Freeze (1975) and Gelhar (1993)) where Y follows a normal distribution with mean μ and variance σ 2.

-	12					depth (m)	
1)	x-coordinate	y-coordinate	altitude	K measured	LOG K	from	to
LF2	569675.20	133689.40	984.30	1.60E-05	-4.80	-12.00	-13.50
				8.70E-06	-5.06	-31.50	-34.50
				1.40E-04	-3.85	-68.50	-69.00
	2			2.30E-04	-3.64	-83.00	-83.50
LF3	569574.80	133434.90	946.67	5.50E-05	-4.26	-49.00	-50.00
P302	569659.60	133659.70	980.25	5.00E-05	-4.30	-56.00	-57.00
		10000000000000		5.00E-05	-4.30	-129.00	-140.00
1301	569623.60	133661.90	984.21	2.00E-05	-4.70	-34.00	-36.00
	0			6.00E-03	-2.22	-51.00	-53.00



Grid dimension (m)		Model dimension (m)			Statistical parameters			Correlation lengths			
dx	dy	dy	dimX	dimY	dimZ	Covariance type	Variance	Mean	λx (m)	λy (m)	λz (m)
10	10	10	1050	1050	-160	Exponential	1.08	-4.69	10	50	2