



Water Resources Research

Supporting Information for

Comparison of travel-time and geostatistical inversion approaches for hydraulic tomography: A synthetic modeling study

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Contents of this file

Figures S1 to S17

Tables S1 to S5

Introduction

The supporting information contains five additional tables ([Tables S1-S5](#)), and seventeen additional figures ([Figs. S1 – S17](#)).

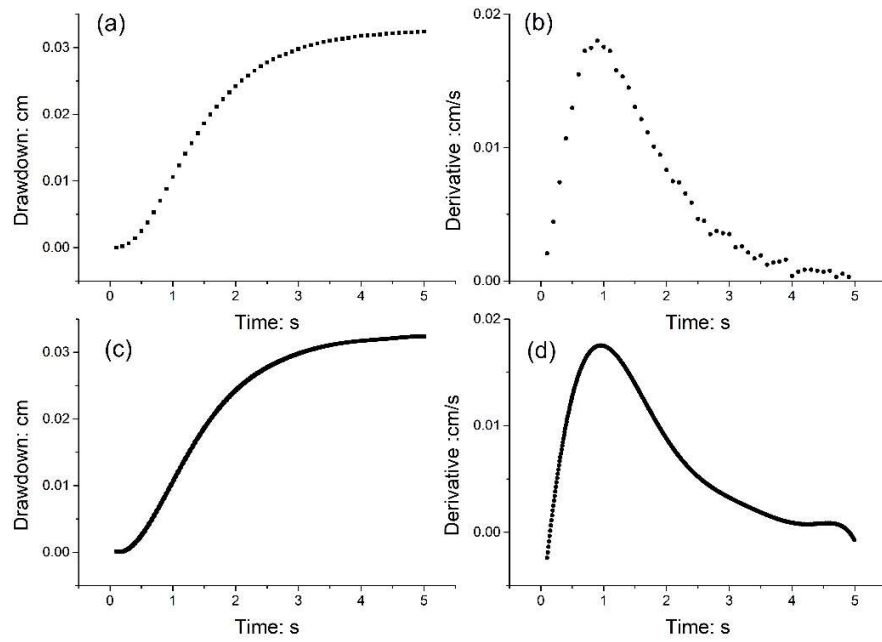


Figure S1. Illustration of hydraulic travel-time: (a) drawdowns at an observation port; (b) derivative of drawdown with respect to time calculated from the original data; (c) drawdowns after polynomial interpolation; (d) derivative of drawdowns with respect to time calculated from the data after polynomial interpolation.

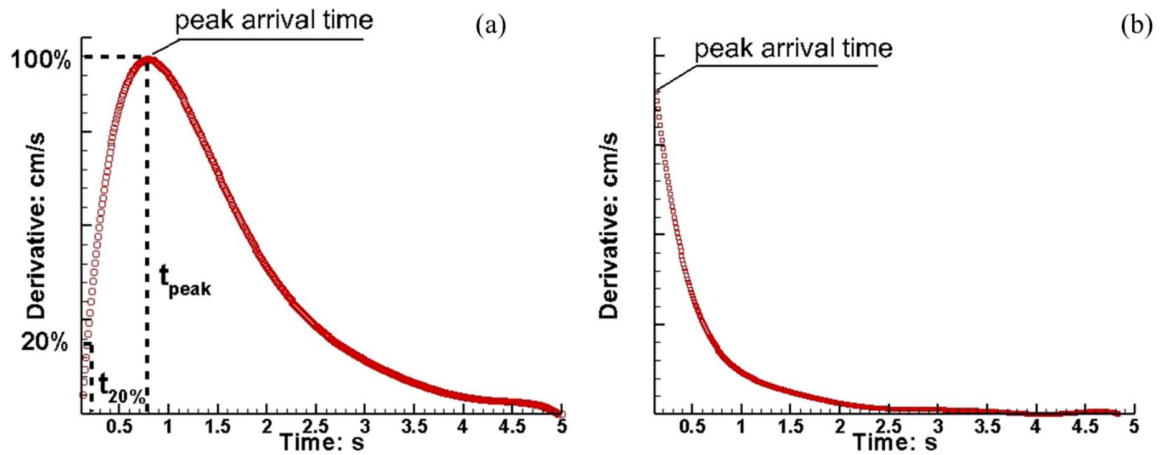


Figure S2. Derivative peak of drawdowns: (a) the common situation; (b) the situation in which the peak arrives at the first observation point.

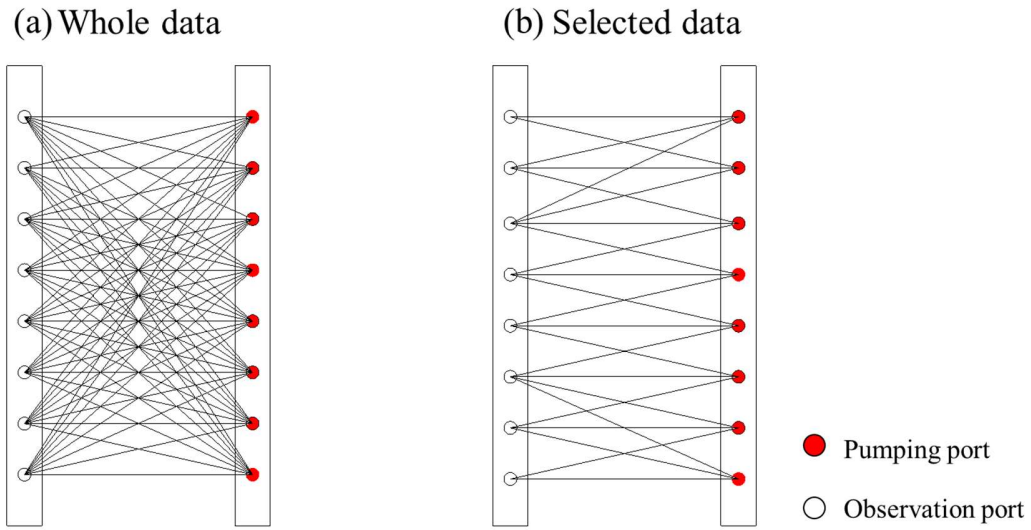


Figure S3. Ray path configurations for two different data sets: (a) whole original data set; and (b) selected data set eliminating source and receiver pairs with large angles.

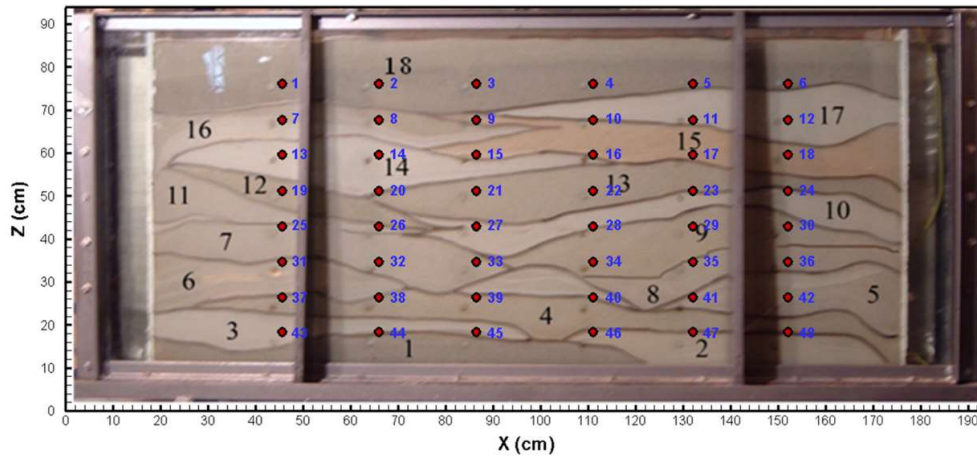


Figure S4. Photograph of the analogue heterogeneous aquifer with layers (black) and port numbers (blue) (Luo et al., 2017). Red circles indicate the 48 ports installed on the aquifer.

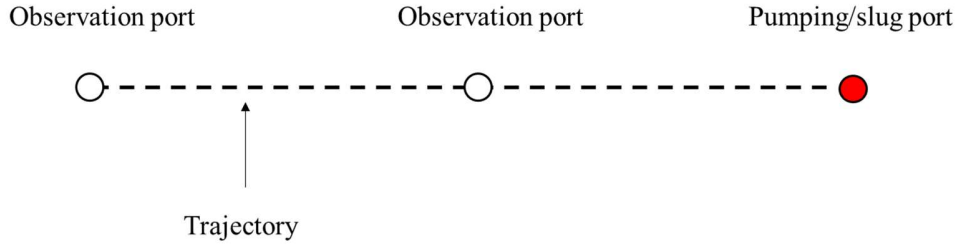


Figure S5. The condition to avoid for TTI.

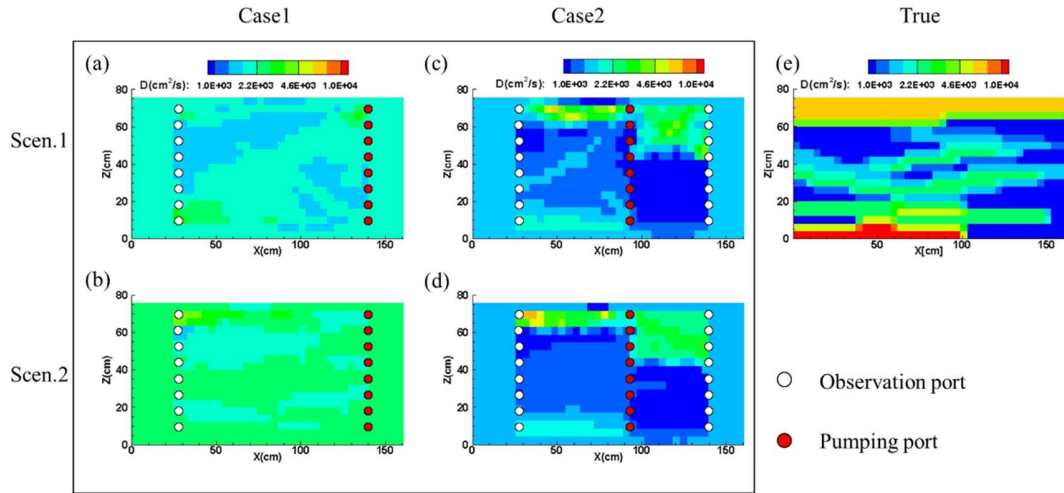


Figure S6. Comparison of reconstructed D tomograms from the TTI approach to the true D distribution: (a) Case 1 Scenario 1; (b) Case 1 Scenario 2; (c) Case 2 Scenario 1; (d) Case 2 Scenario 2; (e) True D . Reconstructed D tomograms use same color scales with True D .

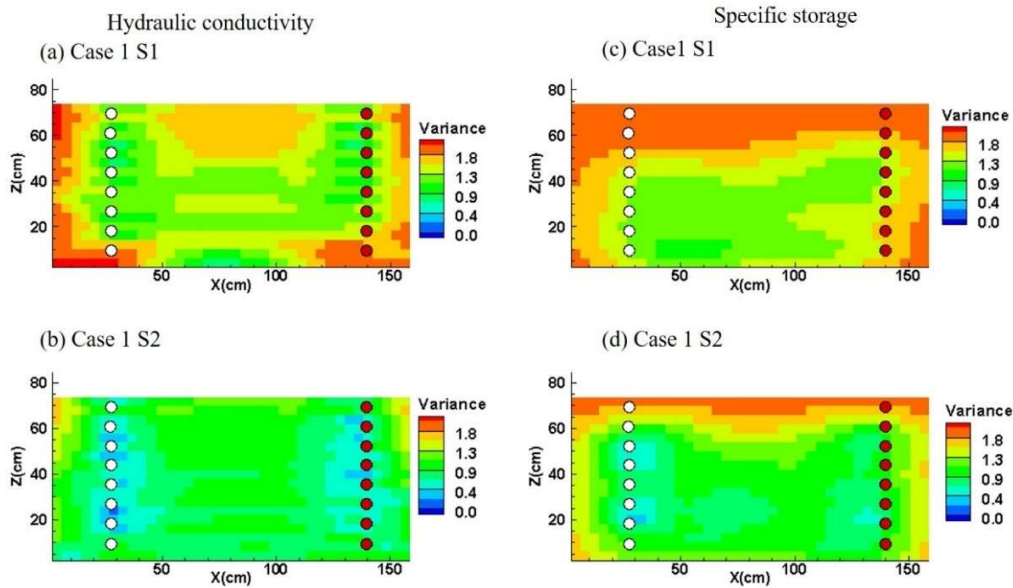


Figure S7. On Case 1, K tomogram variances under: (a) Scenario 1; (b) Scenario 2. On Case 1, S_s tomogram variances under: (c) Scenario 1; (d) Scenario 2.

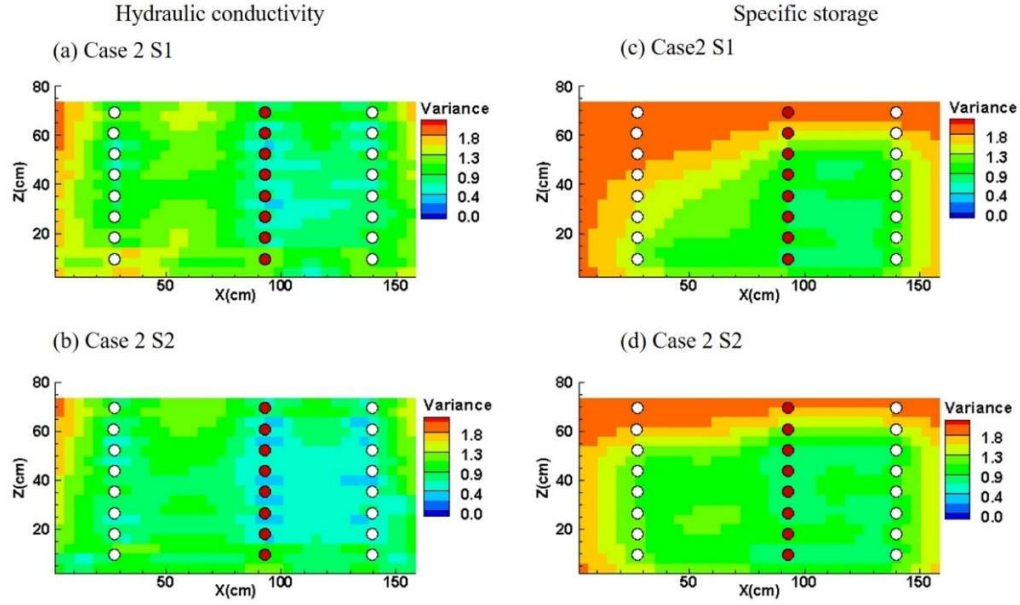


Figure S8. On Case 2, K tomogram variances under: (a) Scenario 1; (b) Scenario 2. On Case 2, S_s tomogram variances under: (c) Scenario 1; (d) Scenario 2.

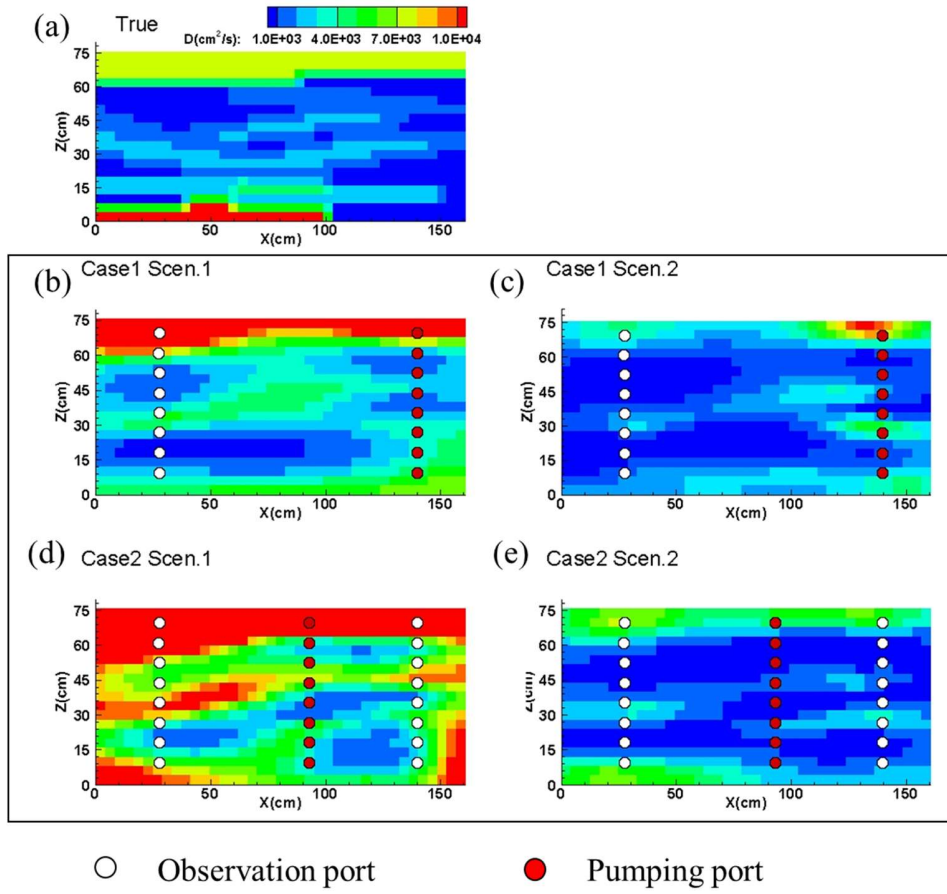


Figure S9. D tomograms from the 'true' model and the geostatistical inversion approach. True model: (a) D tomogram. Calculated D tomograms under: (b) Case 1 Scenario 1; (c) Case 1 Scenario 2; (d) Case 2 Scenario 1; and (e) Case 2 Scenario 2.

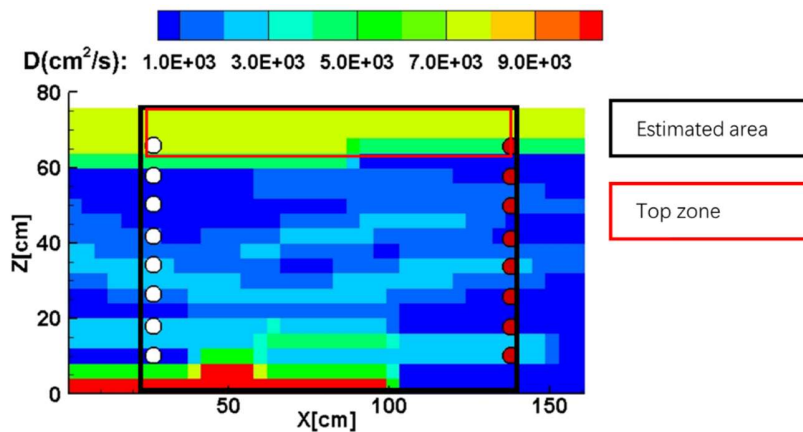


Figure S10. Real D of the true model. The black square is the area of aquifer which is used to compare the TTI and GI approaches. The red square area is the top high D zone of the aquifer.

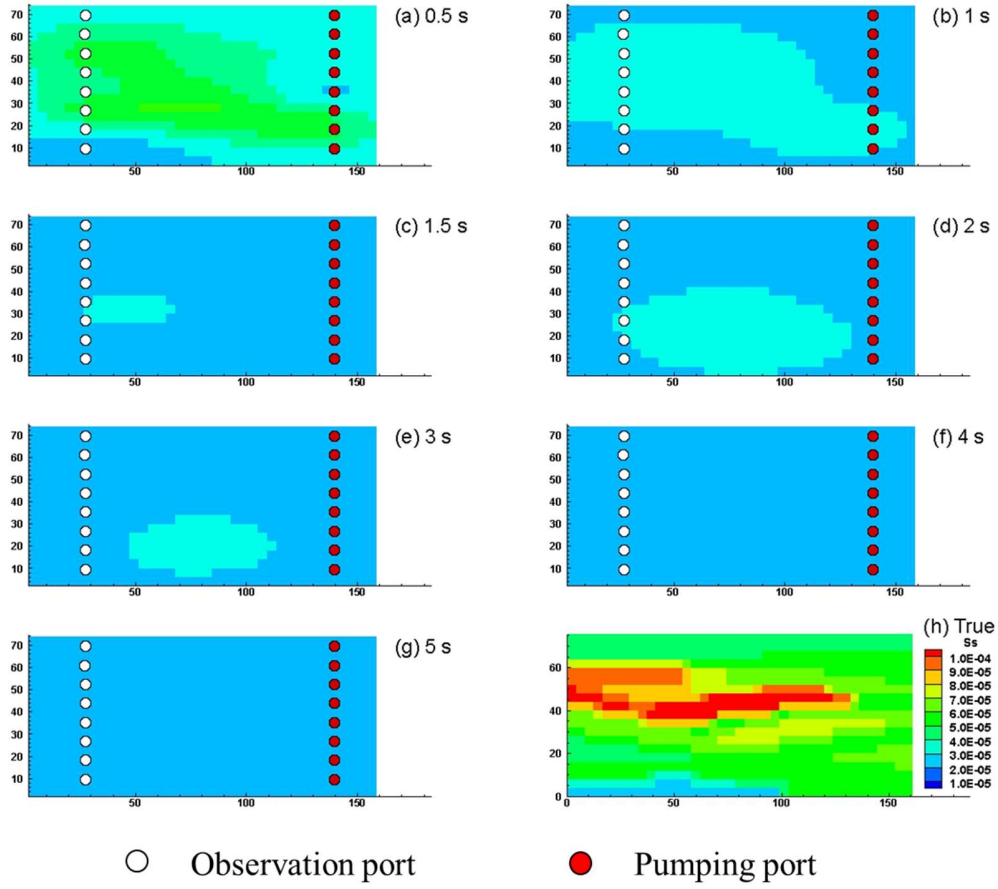


Figure S11 S_s tomograms from 'true' model and the geostatistical inversion approach for Case1 Scenario 1 with data at various times. Estimated S_s tomograms from GI at (a): 0.5 s; (b) 1 s; (c) 1.5 s; (d) 2 s; (e) 3 s; (f) 4 s; (g) 5 s; while (h) is the true S_s .

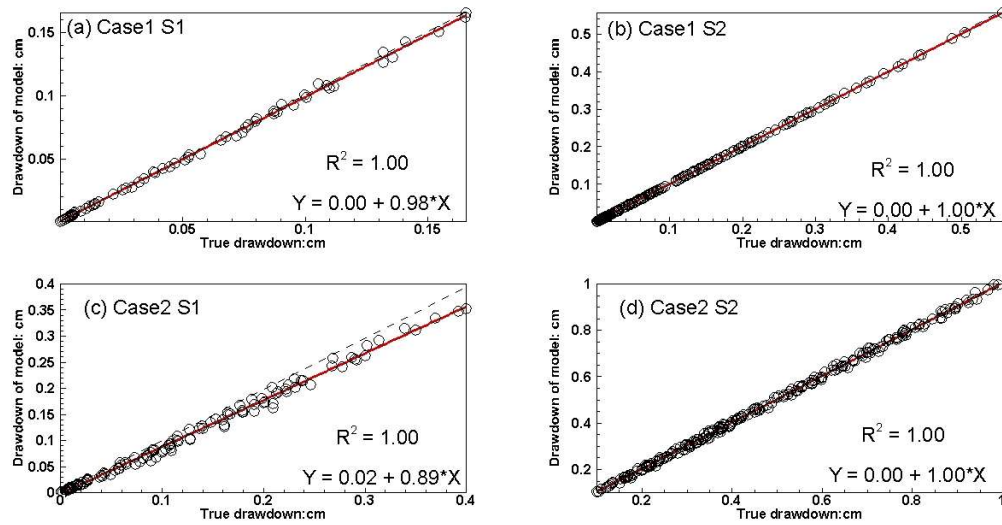


Figure S12. Calibration scatterplots of true drawdowns versus drawdowns simulated by estimated parameters from GI approach under: (a) Case 1 Scenario 1; (b) Case 1 Scenario 2; (c) Case 2 Scenario 1; (d) Case 2 Scenario 2.

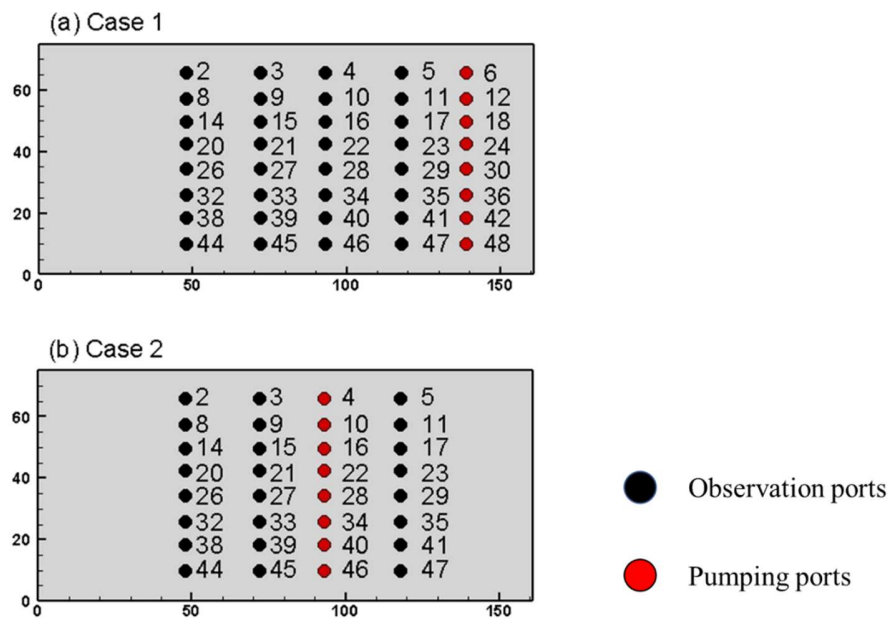


Figure S13. Schematic diagram showing the ports used for model validation on approach one: (1) Case 1; (b) Case 2.

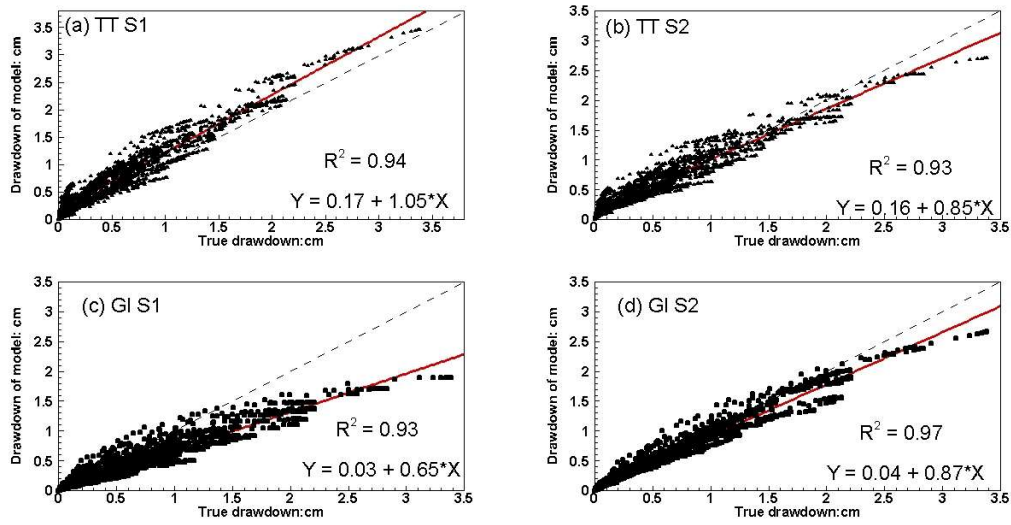


Figure S14. Comparison scatterplots of true drawdowns versus drawdowns simulated by estimated parameters from different models for Case 1 on validation approach one: (a) TTI with scenario 1; (b) TTI with scenario 2; (c) GI with scenario 1; and (d) GI with scenario 2.

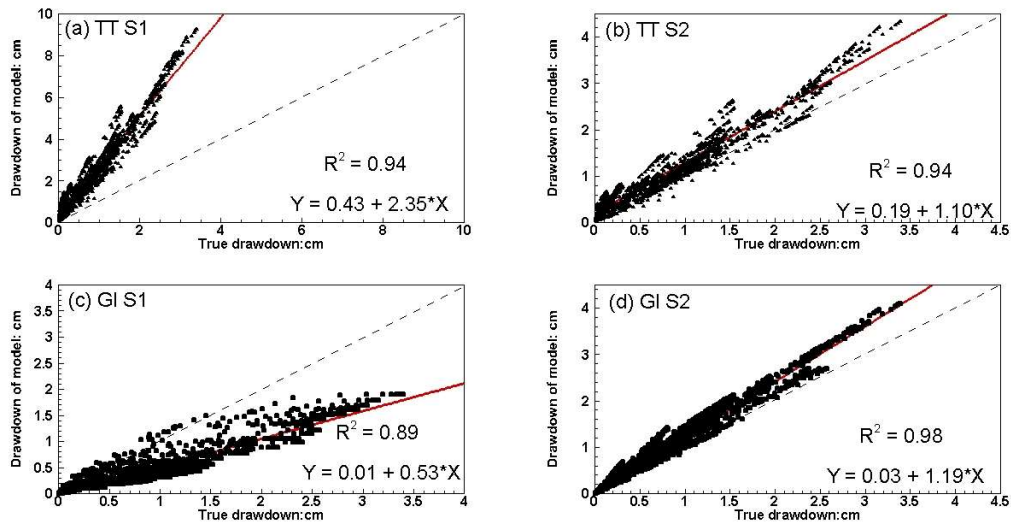


Figure S15. Comparison scatterplots of true drawdowns versus drawdowns simulated by estimated parameters from different models for Case 2 on validation approach one: (a) TTI with scenario 1; (b) TTI with Scenario 2; (c) GI with Scenario 1; and (d) GI with Scenario 2.

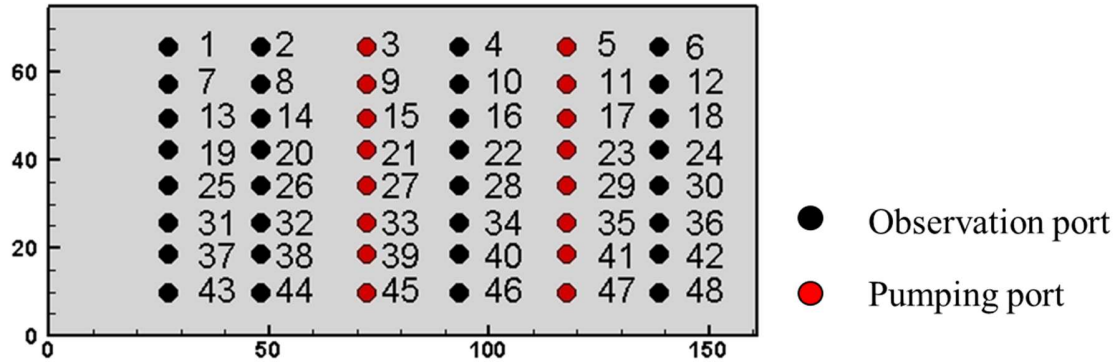


Figure S16. Schematic diagram showing the ports used for model validation for approach two.

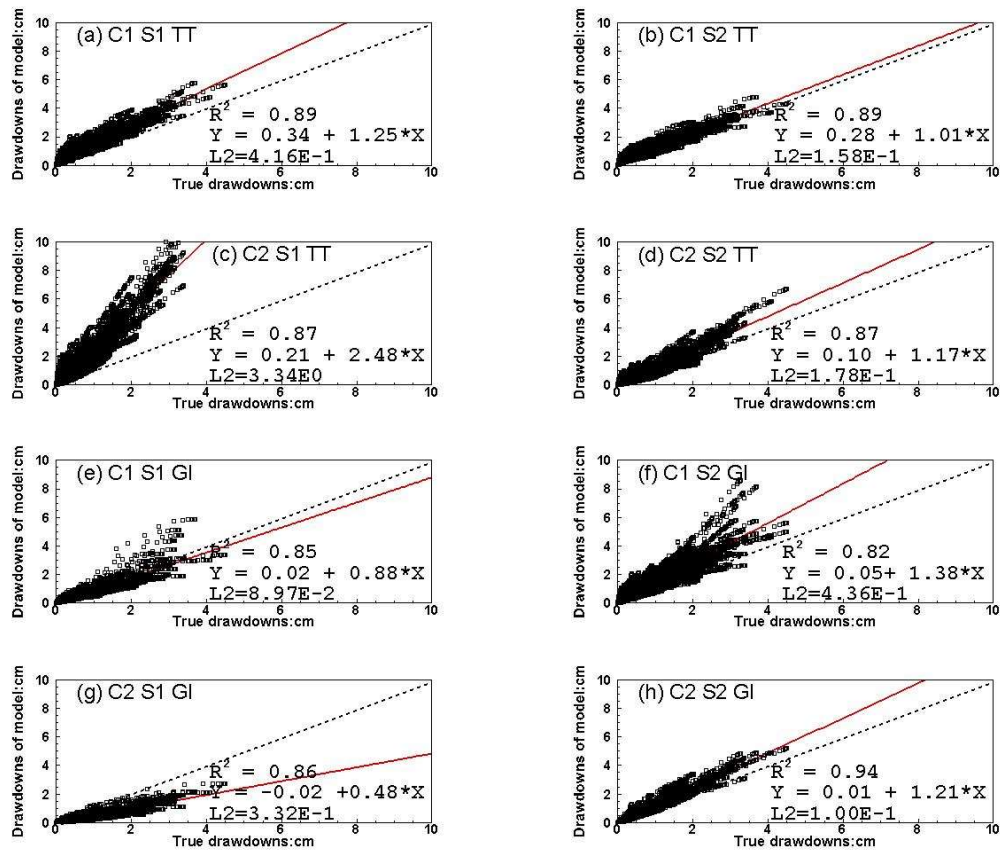


Figure S17. Comparison scatterplots of true drawdowns versus drawdowns simulated by estimated parameters from different models on validation approach two: (a) TTI with Case 1 Scenario 1; (b) TTI with Case 1 Scenario 2; (c) TTI with Case 2 Scenario 1; (d) TTI with Case 2 Scenario 2; (e) GI with Case 1 Scenario 1; (f) GI with Case 1 Scenario 2; (g) GI with Case 2 Scenario 1; (h) GI with Case 2 Scenario 2.

Table S1. Input values of K , S_s , and D for the analogue model.

Layer	K (cm/s)	S_s (/cm)	D (cm ² /s)
1	2.49×10^{-1}	2.39×10^{-5}	1.04×10^4
2	4.50×10^{-2}	5.75×10^{-5}	7.83×10^2
3	1.02×10^{-2}	5.37×10^{-5}	1.90×10^2
4	2.35×10^{-1}	5.03×10^{-5}	4.67×10^3
5	3.08×10^{-2}	6.06×10^{-5}	5.08×10^2
6	5.68×10^{-3}	4.68×10^{-5}	1.21×10^2
7	1.62×10^{-1}	6.68×10^{-5}	2.43×10^3
8	3.87×10^{-2}	5.48×10^{-5}	7.06×10^2
9	1.82×10^{-1}	7.71×10^{-5}	2.36×10^3
10	1.12×10^{-1}	6.69×10^{-5}	1.67×10^3
11	1.66×10^{-2}	5.21×10^{-5}	3.19×10^2
12	1.48×10^{-1}	1.11×10^{-4}	1.33×10^3
13	2.74×10^{-1}	1.23×10^{-4}	2.23×10^3
14	3.10×10^{-2}	8.73×10^{-5}	3.55×10^2
15	1.03×10^{-1}	6.37×10^{-5}	1.62×10^3
16	4.79×10^{-2}	9.30×10^{-5}	5.15×10^2
17	4.11×10^{-2}	5.78×10^{-5}	7.11×10^2
18	3.60×10^{-1}	4.71×10^{-5}	7.64×10^3
Geometric mean	6.78×10^{-2}	6.22×10^{-5}	1.08×10^3

Table S2. summarizes the data criteria used for two scenarios considered by TTI

	Scenario 1		Scenario 2	
	Selecting early travel-time	Constraining angle	Selecting early travel-time	Constraining angle
Case 1	×	×	√	√
Case 2	×	×	×	√

*√used; × abandoned.

Table S3. L_1 and L_2 norms of top high D zone for various cases and scenarios.

	Travel time inversion		Geostatistical inversion	
	L_1	L_2	L_1	L_2
Case 1 Scenario 1	1.48	2.19	0.51	0.36
Case 1 Scenario 2	1.14	1.37	0.61	0.45

Case 2 Scenario 1	1.72	3.01	1.59	2.65
Case 2 Scenario 2	1.68	2.86	0.43	0.22

Table S4. Summary of L_1 and L_2 norms of validation for Cases 1 and 2 on validation approach one.

	Scenario	Method	Validation (drawdown)	
			L1	L2
Case 1	1	TTI	2.03×10^{-1}	6.45×10^{-2}
		GI	1.81×10^{-1}	7.86×10^{-2}
	2	TTI	1.43×10^{-1}	3.19×10^{-2}
		GI	6.88×10^{-2}	1.36×10^{-2}
Case 2	1	TTI	1.51×10^0	3.46×10^{-1}
		GI	3.95×10^{-1}	2.91×10^{-1}
	2	TTI	2.80×10^{-1}	1.20×10^{-1}
		GI	1.42×10^{-1}	7.29×10^{-2}

Table S5. Summary of L_1 and L_2 norms of validation for Cases 1 and 2 on validation approach two.

	Scenario	Method	Validation (drawdown)	
			L1	L2
Case 1	1	TTI	5.18×10^{-1}	4.15×10^{-1}
		GI	1.80×10^{-1}	8.98×10^{-2}
	2	TTI	3.17×10^{-1}	1.58×10^{-1}
		GI	3.52×10^{-1}	4.36×10^{-1}
Case 2	1	TTI	1.26×10^0	3.35×10^0
		GI	4.00×10^{-1}	3.31×10^{-1}
	2	TTI	2.89×10^{-1}	1.77×10^{-1}
		GI	1.90×10^{-1}	1.00×10^{-2}