Phase II Response Report of Vivek Bedekar, PhD, PE

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December 12, 2025

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Acronyms

% Percent

AFY Acre-feet per year

BCM	Basin Characterization Model
ET	Evapotranspiration
IWV	Indian Wells Valley
IWVGA	Indian Wells Valley Groundwater Authority
MBR	Mountain block recharge
MFR	Mountain front recharge

Executive Summary

I have been retained by Murphy & Evertz LLP to review the Indian Wells Valley Groundwater Authority (IWVGA) Model and the associated opinions provided by Dr. Todd Kincaid, P.G. dated August 8, 2025.

There are a number of shortcomings in the IWVGA Model. The model is unresponsive to the intermittent groundwater head increases seen in the measured data. The intermittent high precipitation events that cause groundwater levels to rise are not represented in the IWVGA Model.

The IWVGA Model uses unreasonably high specific storage values. These values are neither supported by scientific literature nor by site-specific measurements obtained using aquifer tests. The large specific storage values that are associated with fine-grained materials do not correlate to the horizontal hydraulic conductivity and specific yield in the model and are spatially represented in areas characterized by coarse-grained material. Unreasonably high specific storage values compensate for lower inflow into the model. A no-pumping scenario was simulated to assess whether inflows in the model are reasonable. The IWVGA Model failed to show the expected outcome, that is to represent pre-development conditions characterized by surface water discharges and increased evapotranspiration (ET), suggesting that the overall inflow to the model is low.

The large specific storage property is associated with confined storage; however, these values are high even in shallow layers where unconfined conditions are expected. Re-running the IWVGA Model with reasonable specific storage numbers within the shallow model layer and also within deep layers clearly showed that groundwater levels substantially decrease in the IWVGA Model indicating that the model lacks inflows needed to represent observed groundwater levels.

Overall, the utility of the IWVGA Model is limited because of unreasonably large specific storage values caused by the less recharge and missing intermittent high-intensity recharge. The IWVGA Model in its current state should not be used for estimating safe yield or for predictive purposes. Recalibration is recommended to make this model usable. All aquifer properties should be within a plausible range and appropriate inflow rates should be considered to improve the IWVGA Model.

REPORT

Section 1.
Background

I was retained by Murphy & Evertz LLP to review the Ramboll Model that simulates conditions in the Indian Wells Valley (IWV) groundwater basin. I wrote an affirmative report dated August 11, 2025 (Bedekar, 2025), in which I reviewed the numerical groundwater model developed by Ramboll, including model development and calibration. The model is documented by Ramboll (2025), and the associated model files were produced in April 2025.

In this responsive report, I have reviewed the "Expert opinion of Dr. Todd Kincaid, P.G. regarding the safe yield of the principal aquifer in the Indian Wells Valley Groundwater Basin," dated August 8, 2025 (Kincaid, 2025). The focus of my review was limited to the model evaluation presented by Kincaid (2025). Additionally, I reviewed the Indian Wells Valley Groundwater Authority Model (IWVGA Model) to compare and contrast the Ramboll Model and the IWVGA Model, in order to form my responsive opinions presented in the next section. The IWVGA Model is documented by Rybarski and Bacon (2025) and the model files I reviewed were received in April 2025.

Section 2.
Responsive Opinions

This section presents my opinions in response to the modeling review presented by Kincaid (2025). The IWVGA Model was labeled as GSP-GWM-2025 by Kincaid (2025). My review of the IWVGA Model also forms the basis of the responsive opinions as presented here. Below is a summary of my opinions followed by an elaborate discussion.

- Responsive Opinion 1: Observed groundwater levels rise as a result of wet-year recharge.
- Responsive Opinion 2: No-pumping simulation indicates deficiencies in recharge implemented in the IWVGA Model.
- Responsive Opinion 3: High IWVGA Model aquifer storage properties compensate for a smaller recharge estimate.
- Responsive Opinion 4: The IWVGA Model is incorrectly calibrated.

2.1 Responsive Opinion 1: Observed groundwater levels rise as a result of wet-year recharge.

A number of observations show an intermittent increase in groundwater levels following large precipitation events. The increase in groundwater levels is observed only in a few wells, the magnitude of change varies over time, and the occurrence of increases in water levels in some cases lags the precipitation events by up to three years. One set of multi-level observation wells (25S/38E25J01, 25S/38E25J02, and 25S/38E25J03) co-located in space and screened at different depths (shallower, intermediate, and deeper, respectively), is used here for illustrative purposes. Figure 2-1 shows the location of these wells.

Figure 2-2 presents the time-series of annual total inflow to the basin as simulated by the Ramboll Model and compares that against observation data. The annual inflow rates are reproduced from Figure 6-3 of my affirmative report. The observed groundwater level data show an intermittent increase in groundwater levels corresponding to the high-precipitation events in 2005, 2010, 2017, and 2023. It is also noted that the precipitation events in 2017 and 2023 resulted in a significant snowpack as simulated by the Basin Characterization Model (BCM), while the 2005 and 2010 precipitation did not result in a large snowpack. Consequently, the increase in groundwater level for well 25S/38E25J01 was observed in relatively quick succession after the large precipitation in 2005 and 2010, as compared to a lagged increase in 2017. Similarly, 25S/38E25J02, which is deeper than 25S/38E25J01, shows lagged increase in water level. The deepest of the three observation wells, 25S/38E25J03, only shows a response to the 2017 precipitation event. It is possible that the effect of 2023 precipitation may lead to a delayed increase in groundwater levels that is not plotted in Figure 2-2 and may only be observed when data become available for periods beyond those shown.

The pumping rates in the vicinity of these observations were reviewed to ensure that the increase in water levels was not caused by decreased pumping (pumping in the area was constant) and that the increase in groundwater level is appropriately attributed to inflows.

It is important to note that the increase in groundwater levels is not observed in all observation wells, implying the existence of preferential flow paths as mountain front/block recharge (MFR/MBR) enters the valley. The inflow occurring from different watersheds is not uniform in space, and different watersheds may provide different rates at different times. No monitoring wells are located close to where MFR/MBR is expected to enter the valley. The distance between the edge of the alluvial basin and the monitoring wells explains the lagged signal. Considering these aspects, it is difficult to correlate one set of hydrographs with simulated MFR/MBR emanating from specific areas. Further field data and analyses may be needed to ascertain the source of the water causing groundwater levels to increase.

The two models are compared to assess which model simulates the intermittent groundwater increase observed in the data. Figure 2-3 compares the observed data with the Ramboll Model, and Figure 2-4 compares the data with the IWVGA Model. The Ramboll Model displays an intermittent increase resulting from the corresponding increases in the inflow to the model. The simulated values do not represent the time-lagged nature of the MFR/MBR and therefore result in a larger and earlier increase than the observed data suggests. In contrast, the IWVGA Model does not show any response or any increase in groundwater heads.

These differences in the two models (intermittent increase in observed data simulated by the Ramboll Model and not represented by the IWVGA Model) are seen in Figures 11 through 14 of the Kincaid (2025) report. These observations contradict the assessment provided by Kincaid (2025) that the IWVGA Model “is a more reliable predictive tool.” On the contrary, the lack of response in groundwater levels in the IWVGA Model indicates that the key input – intermittent high inflow rates from MFR/MBR – is missing in the IWVGA Model.

2.2 Responsive Opinion 2: No-pumping simulation indicates deficiencies in recharge implemented in the IWVGA Model.

In my affirmative report, I presented the results of a no-pumping simulation using the Ramboll Model. The experimental result demonstrates that the Ramboll Model is robust in representing conditions that are consistent with historical pooling that occurred during pre-development conditions.

A similar no-pumping simulation was performed using the IWVGA Model by switching off groundwater withdrawal in the model. The resulting discharge locations of water are shown in Figure 2-5. The result of this simulation shows a substantially smaller area of surface water discharge than expected.

Further analysis was undertaken to determine the change in other boundary conditions caused by zero pumping. The results are presented in Table 2-1. The Ramboll Model for the period 1987 – 2022 shows that one-third of decreased pumping results in increased groundwater storage and two-thirds of the reduced pumping results in surface drainage or evapotranspiration (ET) discharge. The IWVGA Model shows that only 9% of reduced pumping results in increased surface drainage or ET discharge, while the majority of reduced pumping (91%) results in increased groundwater storage. Similar results were observed even when the full duration of the simulation was considered.

The lack of surface water discharge in the IWVGA Model when pumping was shutoff indicates low estimated recharge in the IWVGA Model.

2.3 Responsive Opinion 3: High IWVGA Model aquifer storage properties compensate for a smaller recharge estimate.

The aquifer storage properties used in the IWVGA Model are unreasonable. The high confined storage values used in the IWVGA Model compensate for the lower recharge estimate. This opinion is supported by multiple lines of evidence, as discussed in detail in the following subsections.

2.3.1 Scientific Literature

The aquifer storage properties, particularly the specific storage values associated with confined storage used in the IWVGA Model, are on the high end of the spectrum of specific storage values suggested in scientific literature. Figure 2-6 provides a comparison of specific storage values used in the two models and also shows a compilation of the range of specific storage values for different aquifer materials in scientific literature (Chowdhury et al., 2022).

The storage properties used for 40% of the aquifer materials (exceeding 4×10^{-4} m^{-1}) in the IWVGA Model incorrectly suggests that IWV is predominantly comprised of fine-grained sediments. The texture analyses (Figure 5-2 of my affirmative report) show that although the valley consists of fine-grained material in the China Lake area, the majority of the sediments are coarse-grained. The range of values used by McGraw et al. (2016) (10^{-4} to 10^{-7} m^{-1}) is also consistent with the Ramboll Model, and contradicts the values used in the IWVGA Model. The specific storage values used by the IWVGA Model are inconsistent with the scientific literature and the conditions in the IWV.

2.3.2 Storativity and Correlation with Other Aquifer Properties

Aquifer storativity was calculated for both models – the Ramboll Model and the IWVGA Model. Storativity accounts for aquifer thickness because it is calculated by multiplying the specific storage and the aquifer thickness as represented in the model. The individual storativity numbers were then correlated with other aquifer properties – specific yield and horizontal hydraulic conductivity. Figure 2-7 shows the relationship between storativity and horizontal hydraulic conductivity, and between storativity and specific yield for both models. No significant trends are seen in the Ramboll Model. The highest storativity values are associated with lower conductivity values, indicating consistency with fine-grained materials. The IWVGA Model, on the other hand, shows unreasonable relationships. High conductivity values associated with high storativity values are contradictory. Similarly, high specific yield associated with high storativity (derived from specific storage values) also demonstrates inconsistency between aquifer properties in the IWVGA Model.

Figure 2-8 presents site-specific storativity values for IWV that were published by Heintz (2020). A majority of the values used in the IWVGA Model, compared to the values estimated by Heintz (2020), are larger by one to two orders of magnitude.

2.3.3 Spatial Distribution

Figure 2-9 shows the distribution of specific storage values used in the IWVGA Model. The patterns are inconsistent with the distribution of sediments in the valley. There are also inconsistencies within the model across different layers, with Layer 2 showing smoothly varying values in specific zones whereas all other zones have a uniform value, which is indicative of targeted calibration. Model Layer 2 shows the largest specific storage values and is aligned with the areas of pumping wells, contradicting the nature of alluvial deposits in the area that support production wells. The distribution of specific storage values contradicts other aquifer properties (specific yield and hydraulic conductivity) as shown in Figures 2-10 and 2-11 and also demonstrated in Figure 2-7. The number of zones, their shapes, and the contrasting values within and across these zones are not realistically plausible and indicate that the aquifer properties were overfit during model calibration.

Figure 2-12 compares the total storativity between the two models. Storativity was calculated using specific storage multiplied by layer thickness and integrated over all model layers. Figure 2-12 clearly shows that the areas where most of the pumping occurs are characterized by unrealistically high storativity in the IWVGA Model, while the Ramboll Model uses reasonable values in the valley. These values are comparable with the specific yield values and are two to three orders of magnitude greater than the site-specific values presented in Figure 2-8. The use of unrealistic and unreasonable parameter values limits the usability of the IWVGA Model for safe yield estimation and for predictive purposes.

2.3.4 Contribution of Confined Storage to Groundwater Depletion

Groundwater depletion is comprised of change in storage within unconfined and confined systems. Calculations were performed for both models to account for the different storage components separately. It was found that the contribution of confined storage accounts for 20–30% of the total storage depletion as simulated by the Ramboll Model, while confined storage accounts for 50–60% of the total storage depletion in the IWVGA Model. The confined storage contribution simulated by the IWVGA Model is unreasonable. The representation of specific storage has a significant effect on model performance, calibration, and reliability for safe yield assessment.

2.4 Responsive Opinion 4: The IWVGA Model is incorrectly calibrated.

The assessment by Kincaid (2025) that the IWVGA Model (referred to in the report as GSP-GWM-2025) is a more reliable predictive tool is inaccurate. The comparison between the two models presented in Table 3 of Kincaid (2025) shows very similar calibration statistics–residual mean, average residual mean, and root mean square error. Both models use zones to calibrate the model, and most of the calibration is based on fixed boundary conditions, including recharge, and changing aquifer properties and flow barrier properties to match historical data. The difference between the two models, however, is how the calibration was achieved. As mentioned in my affirmative report, in addition to the goodness-of-fit, it is critical to review the calibration parameters to ensure that the values that were calibrated remain within a plausible range. I found that the parameters used by the Ramboll Model were reasonable; however, the parameters used in the IWVGA Model, particularly the storage parameters, are questionable. The spatial distribution of aquifer properties and the unreasonably high specific storage appear to be a result of overfitting of parameters during model calibration. This approach of overfitting parameters limits the usability of the IWVGA Model for safe yield estimation and for predictive purposes.

As discussed in the previous opinion, the confined storage parameters used in the IWVGA Model are high. My assessment is that the specific storage values are unreasonably high in the IWVGA Model to compensate for the lower recharge rates. I performed two simulations to assess the effects of changing specific storage values to more reasonable values as discussed previously. Figure 2-13 shows the segmented scatterplots for the unmodified IWVGA Model and the two simulations with different specific storage values.

In the first simulation, the values of specific storage in Layer 1, which is the top-most layer, were decreased. Specific storage values in Model Layer 1 are typically irrelevant, as the shallowest layer in IWV is unconfined. This change results in the average error increasing from 5 feet (ft) to 10 ft. That is a significant change and indicates poor calibration resulting from the use of incorrect specific storage in Layer 1.

In the second simulation, specific storage values greater than 10^{-4} ft^{-1} were decreased to 10^{-5} ft^{-1}. This is a reasonable specific storage value and changes the average error to 33 ft. The simulated water levels show a steeper declining trend as compared to the observed water levels. This highlights that with reasonable specific storage values, a larger recharge is needed to match the rate at which groundwater levels are declining in the basin. The lack of reasonable calibration of the IWVGA Model has a direct effect on safe yield assessment. Given that the larger specific storage numbers mask the lower recharge values, the IWVGA Model is expected to provide a lower estimate of safe yield.

Section 3.
Summary and Recommendations

The IWVGA Model exhibits several key deficiencies that limit its reliability. Observed intermittent rises in groundwater levels following precipitation events are not reproduced, indicating that episodic recharge is not represented in the model. The model also relies on unrealistically high specific storage values that are inconsistent with published literature and with aquifer-test results. These values are spatially assigned in coarse-grained areas where such storage characteristics are not expected, and they appear to compensate for insufficient inflow. A no-pumping simulation further demonstrated that the model does not reproduce expected pre-development conditions such as surface water discharge and increased ET, confirming that inflows are inadequately represented in the IWVGA Model. Additionally, excessively high confined storage values were assigned even in shallow, unconfined layers, and test runs with more reasonable storage parameters showed that the model cannot reproduce measured groundwater levels without significantly increasing inflows.

Given these limitations, the IWVGA Model should not be used for estimating safe yield or for predictive analyses in its current form. Recalibration is necessary, including applying realistic aquifer properties within plausible ranges, ensuring consistency between aquifer storage and hydraulic conductivity. The model should incorporate appropriate inflow rates and explicitly represent intermittent recharge to align simulated groundwater responses with observations. Implementing these corrections is essential to improve model performance and make it suitable for safe yield evaluations.

Section 4.
References

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FIGURES

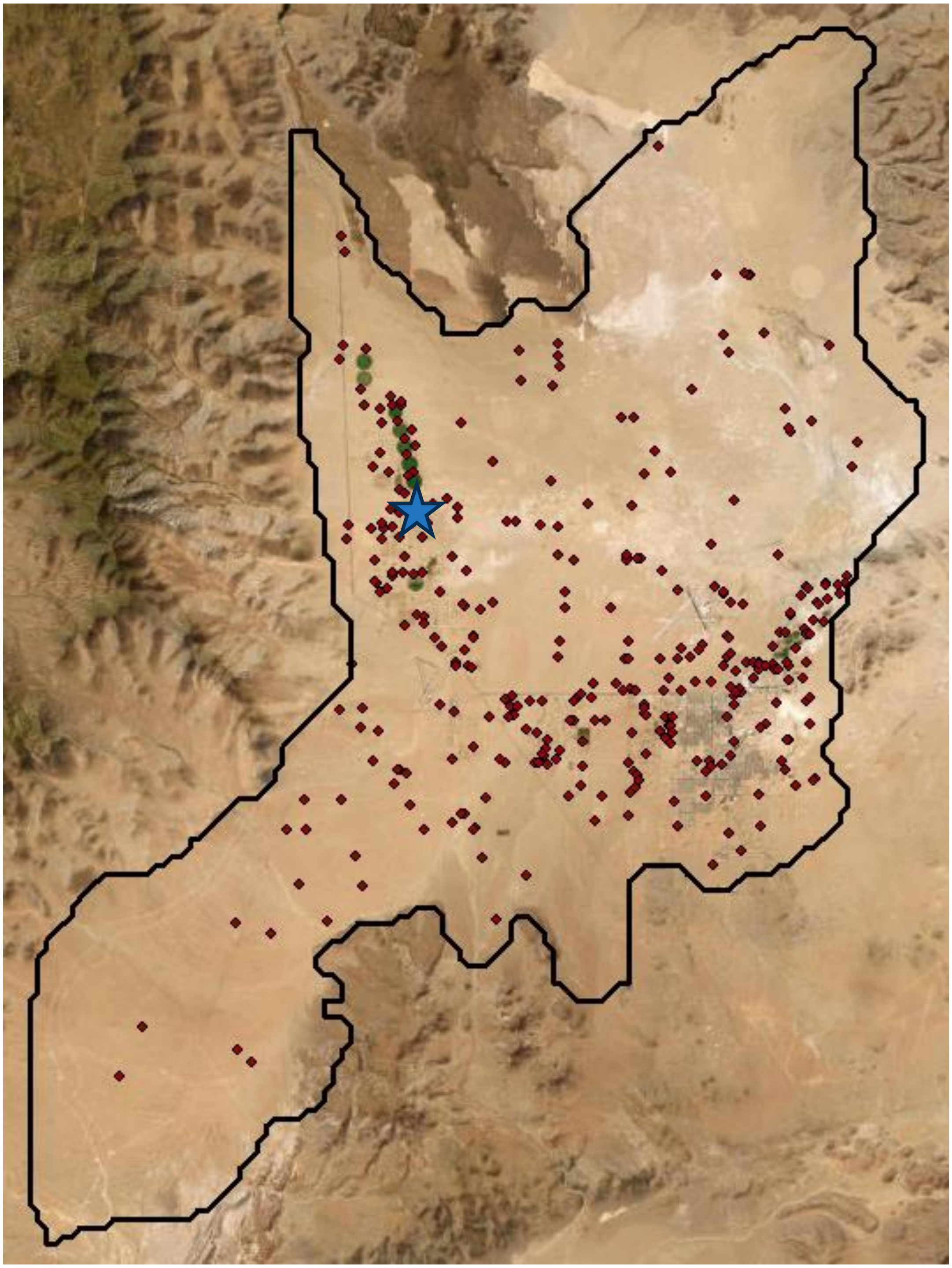


Figure 2-1: Location of observation wells. The blue star represents the location of multi-level wells 25S/38E25J01, 25S/38E25J02, and 25S/38E25J03.

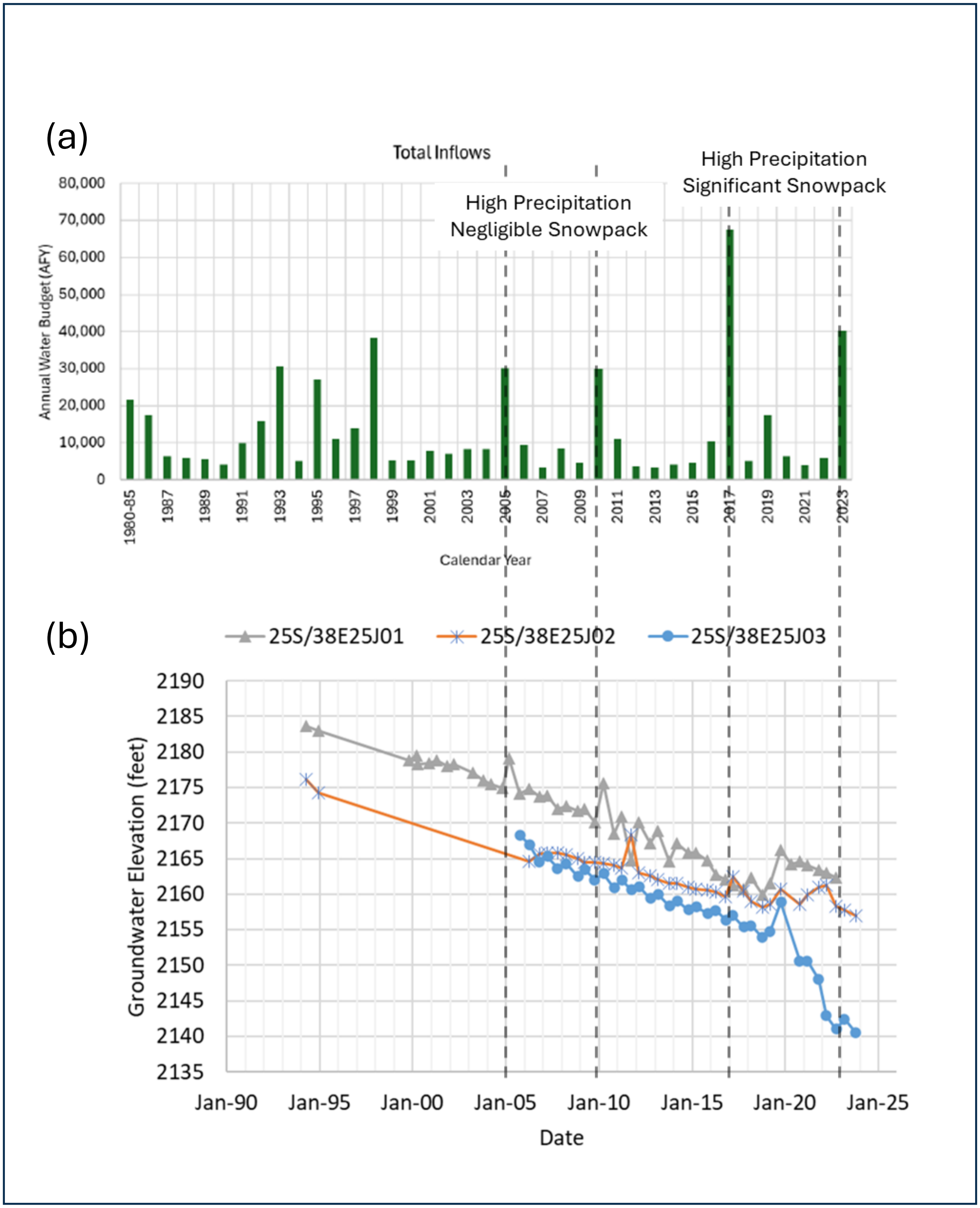


Figure 2-2: Time-series plots comparing: (a) total inflows specified in the Ramboll Model; and (b) groundwater levels observed at a set of multi-level monitoring wells.

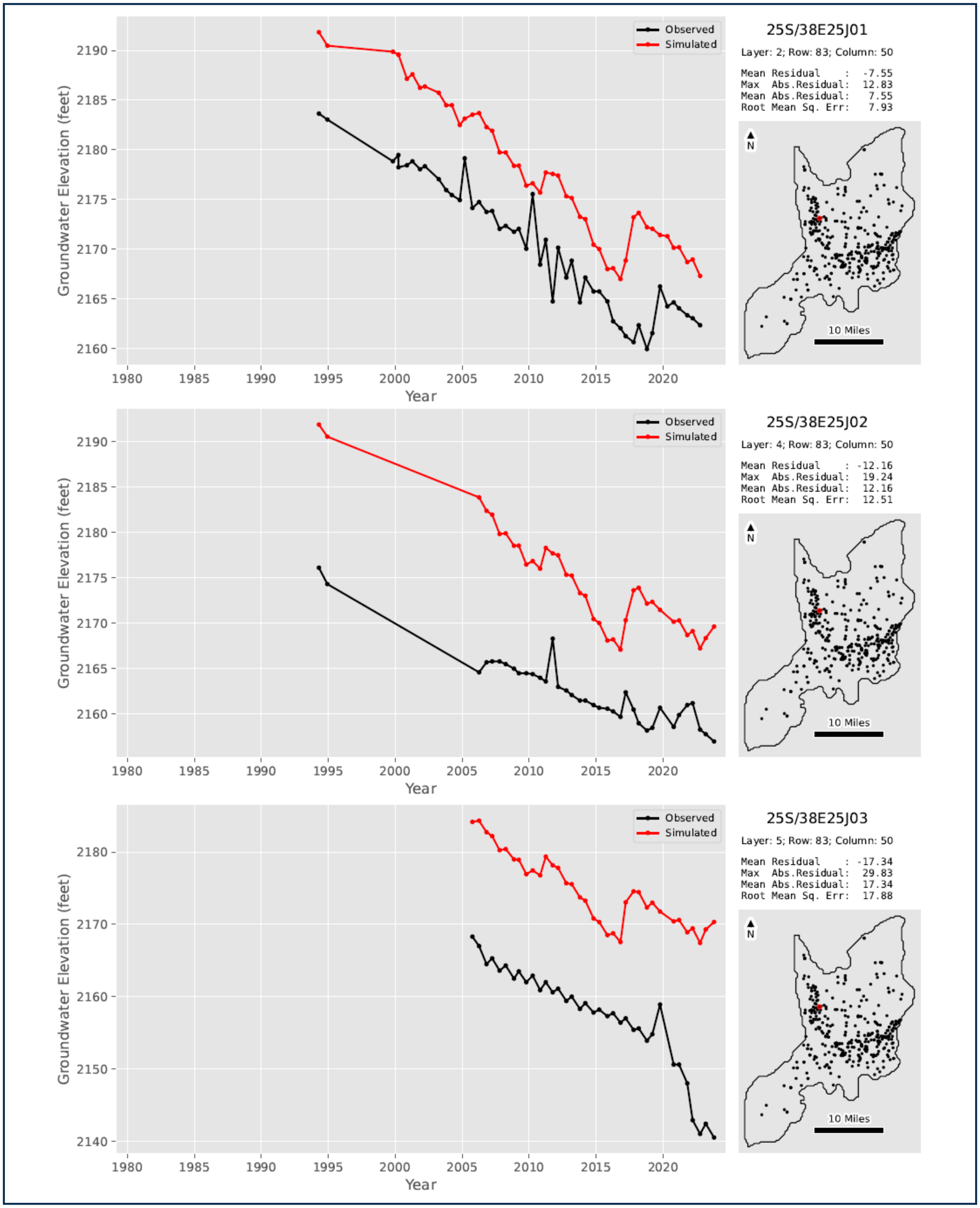


Figure 2-3: Time series data illustrating intermittent increase in groundwater levels comparing simulated values generated by the Ramboll Model.

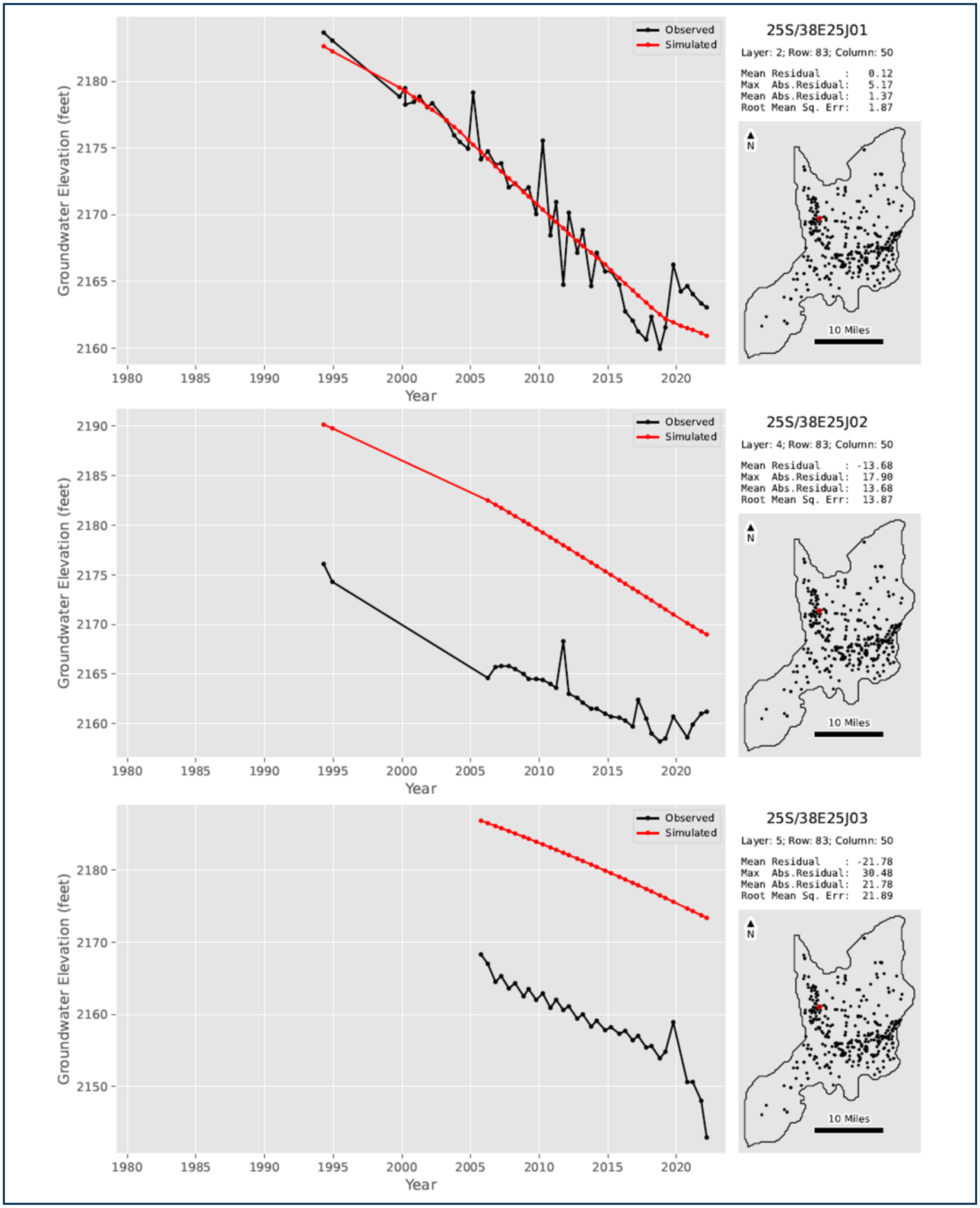


Figure 2-4: Time series data illustrating intermittent increase in groundwater levels comparing simulated values generated by the IWVGA Model.

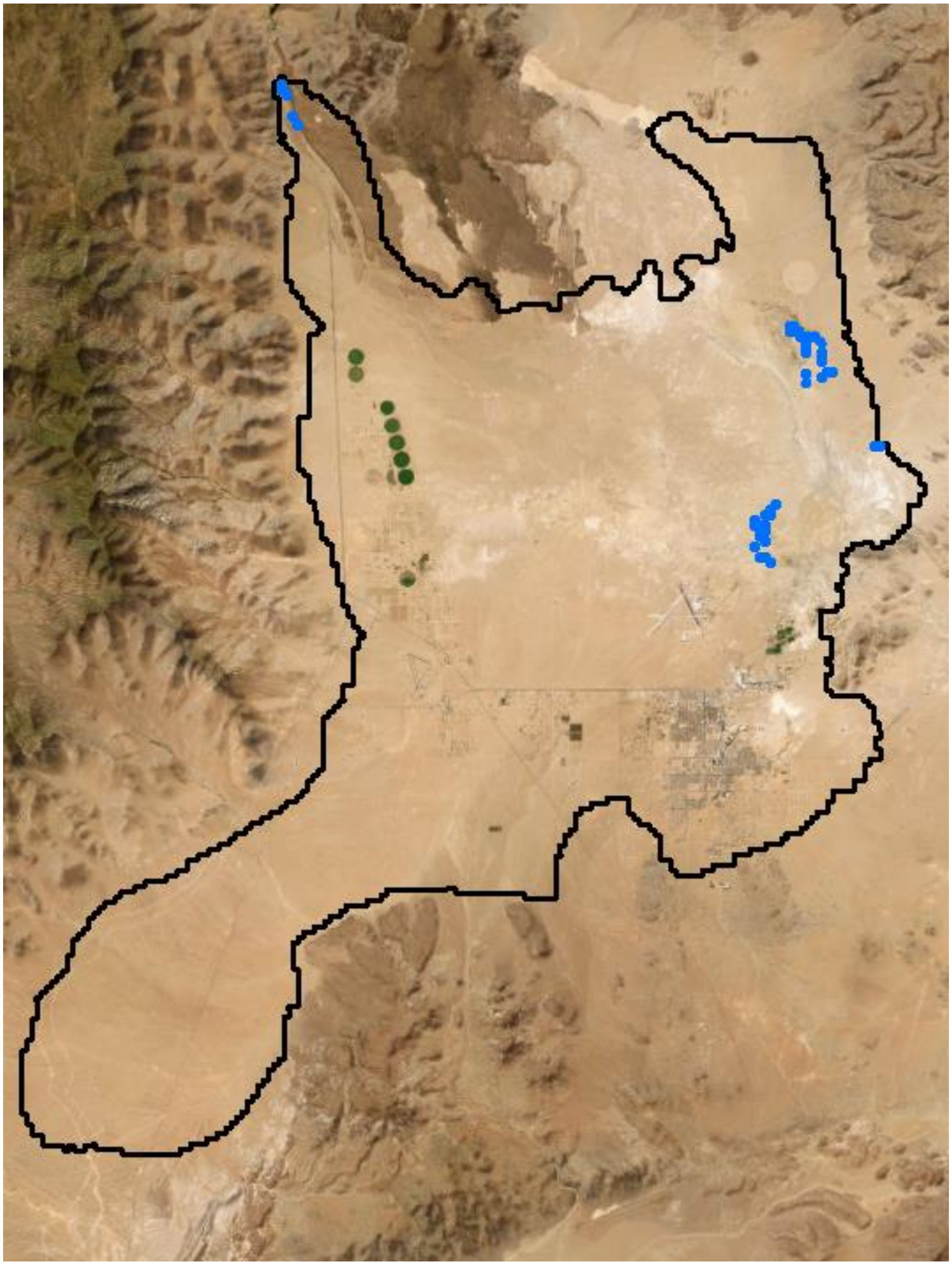


Figure 2-5: Map showing the discharge locations of water under no-pumping conditions using the IWVGA Model.

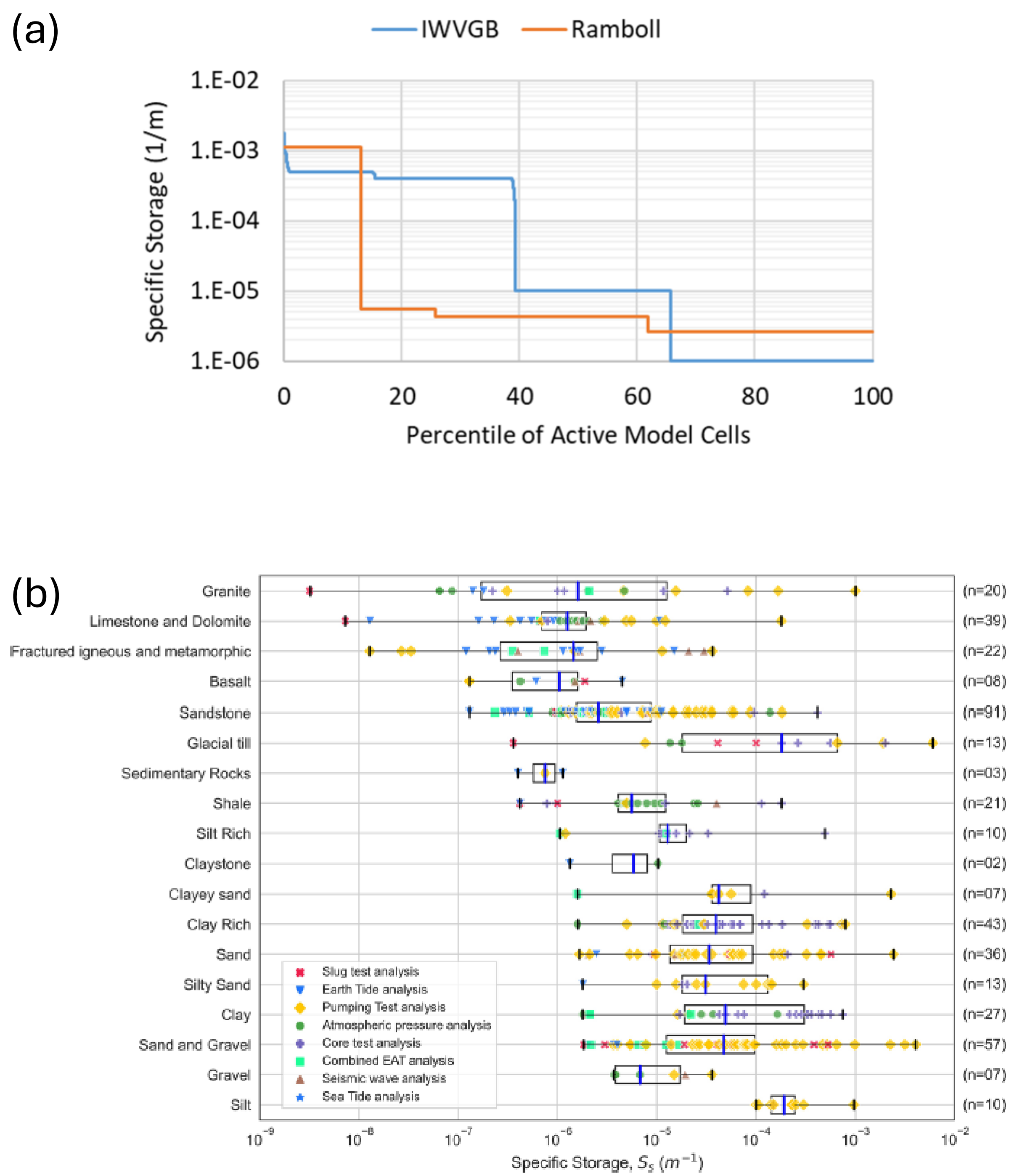


Figure 2-6: Specific storage values: (a) exceedance plots comparing the Ramboll Model and the IWVGA Model; and (b) literature values (reproduced from Chowdhury et al., 2022).

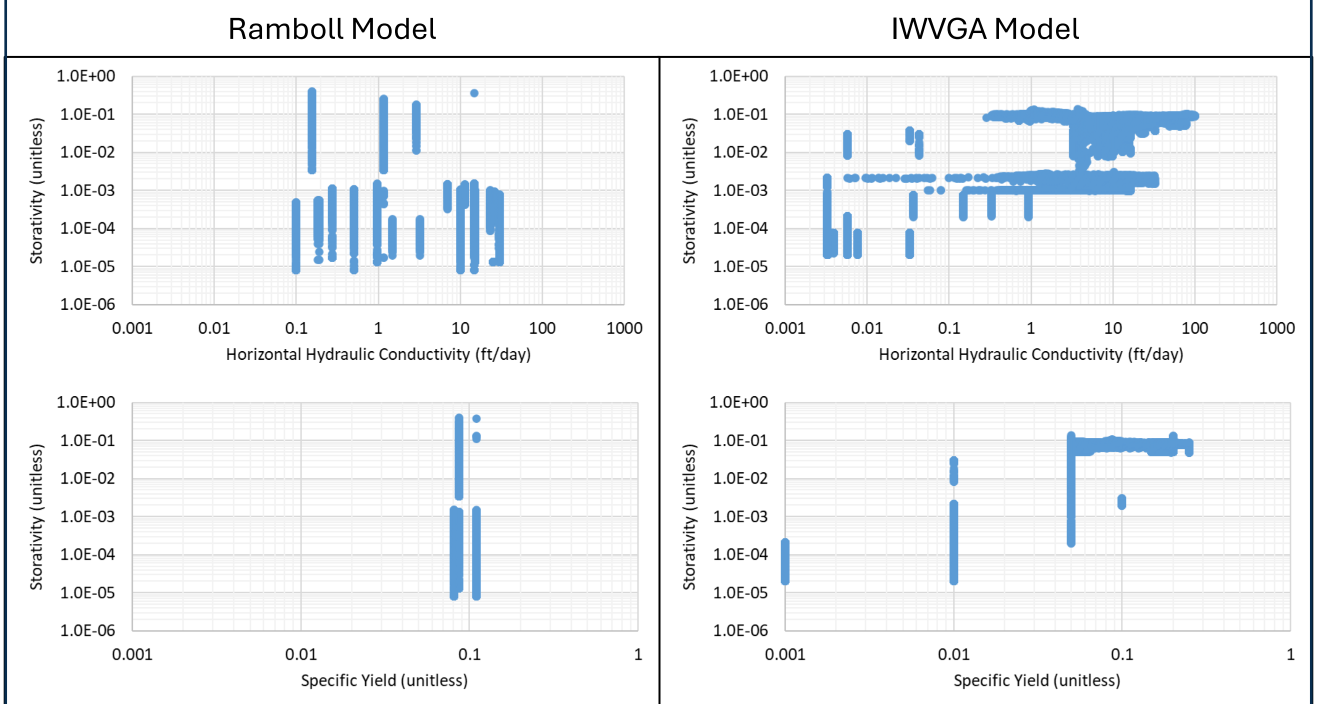


Figure 2-7: Correlation between aquifer parameter values in the Ramboll Model and the IWVGA Model.

Table 5. Calculated transmissivity, hydraulic conductivity, and storativity from the IWVWD Well 10 constant-rate pumping test.

Method	Transmissivity [gpd/ft]	Hydraulic Conductivity[A] [ft/day]	Storativity	Figure (Appendix A)
Theis (1935) Distance-drawdown (24 hours)	58,750	13.83	0.00313	A-1
Theis (1935) Distance-drawdown (4 days)	62,530	14.72	0.00537	A-2
Cooper and Jacob (1946) Time-drawdown				
Well 9A	83,866	19.74	0.00057	A-3
Well 8	88,054	20.73	0.00099	A-4
Cooper and Jacob (1946) Time-recovery				
Well 9A	79,551	18.73	0.00045	A-5
Well 8	82,429	19.40	0.00090	A-6
Theis (1935) Type-curve				
Well 9A	95,074	22.34	0.00040	A-7
Well 8	103,425	24.34	0.00072	A-8

[A]Saturated thickness of 568 ft is assumed and represents the interval between the static water level and the total depth in Well 10.

Table 10. Calculated transmissivity, hydraulic conductivity, and storativity from the Quist Ranch 21 hr pumping test.

Method	Transmissivity [gpd/ft]	Hydraulic Conductivity[A] [ft/day]	Storativity	Figure (Appendix B)
Theis (1935) Distance-drawdown	84,530	66.48	0.0019	B-1
Cooper and Jacob (1946) Time-drawdown 26S39E35G02	171,603	135.0	0.00076	B-2
Cooper and Jacob (1946) Time-recovery 26S39E35G02	148,690	116.9	0.00073	B-3
Theis (1935) Time-recovery 26S39E35G01	93,213	73.31	N/A	B-4
Theis (1935) Type-curve 26S39E35G02	167,988	132.1	0.00085	B-5

N/A = Not applicable; Theis (1935) recovery cannot solve for storativity.
[A]Saturated thickness of 170 ft is assumed and represents the interval between the static water level and the total screened depth in 26S39E35G01.

Table 11. Calculated transmissivity, hydraulic conductivity, and storativity from the Quist Ranch 48 hr pumping test.

Method	Transmissivity [gpd/ft]	Hydraulic Conductivity[A] [ft/day]	Storativity	Figure (Appendix C)
Theis (1935) Distance-drawdown	62,808	37.32	0.0032	C-1
Cooper and Jacob (1946) Time-drawdown 26S39E35G01	196,506	116.8	0.00093	C-2
Cooper and Jacob (1946) Time-recovery 26S39E35G01	161,231	95.81	0.00076	C-3
Theis (1935) Time-recovery 26S39E35G02	34,314	20.39	N/A	C-4
Theis (1935) Type-curve 26S39E35G01	196,149	116.6	0.0012	C-5

N/A = Not applicable; Theis (1935) recovery cannot solve for storativity.
[A]Saturated thickness of 225 ft is assumed and represents the interval between the static water level and the total screened depth in 26S39E35G02.

Figure 2-8: Site-specific values of storativity based on long-term aquifer tests in the IWV. The tables are reproduced from Heintz (2020).

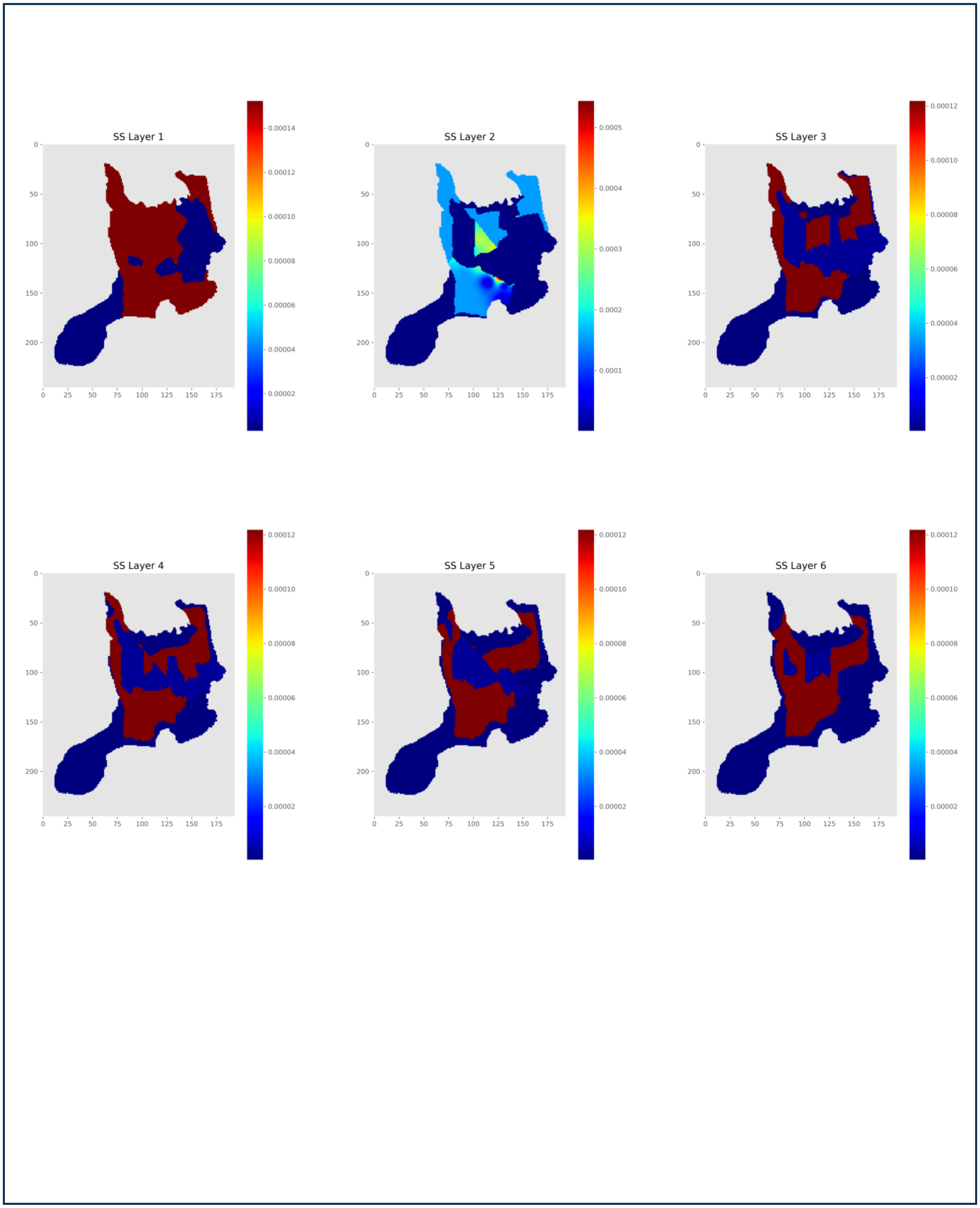


Figure 2-9: Specific storage values used by IWVGA Model. The units displayed on the maps are ft^{-1}.

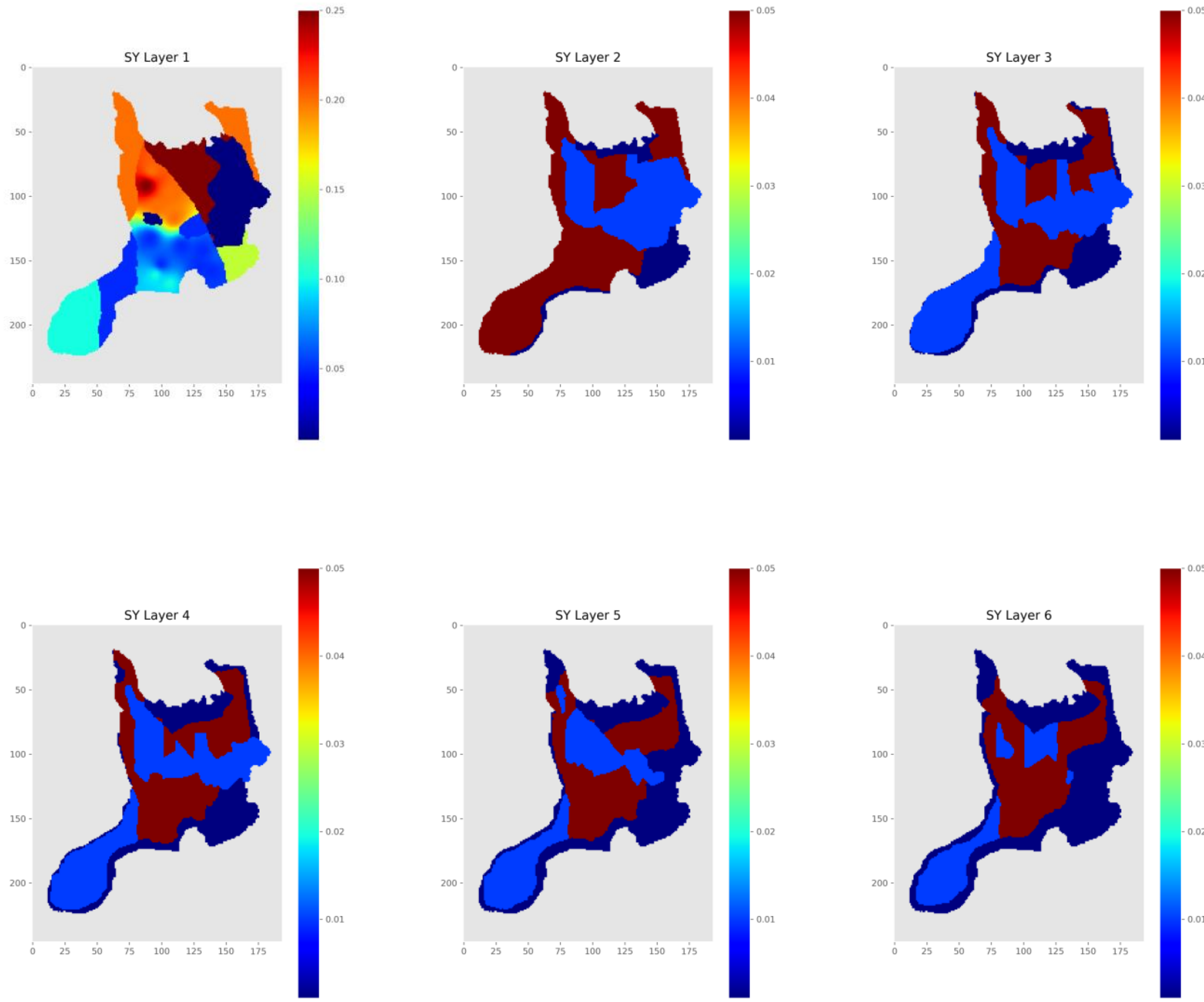


Figure 2-10: Specific yield values used by IWVGA Model.

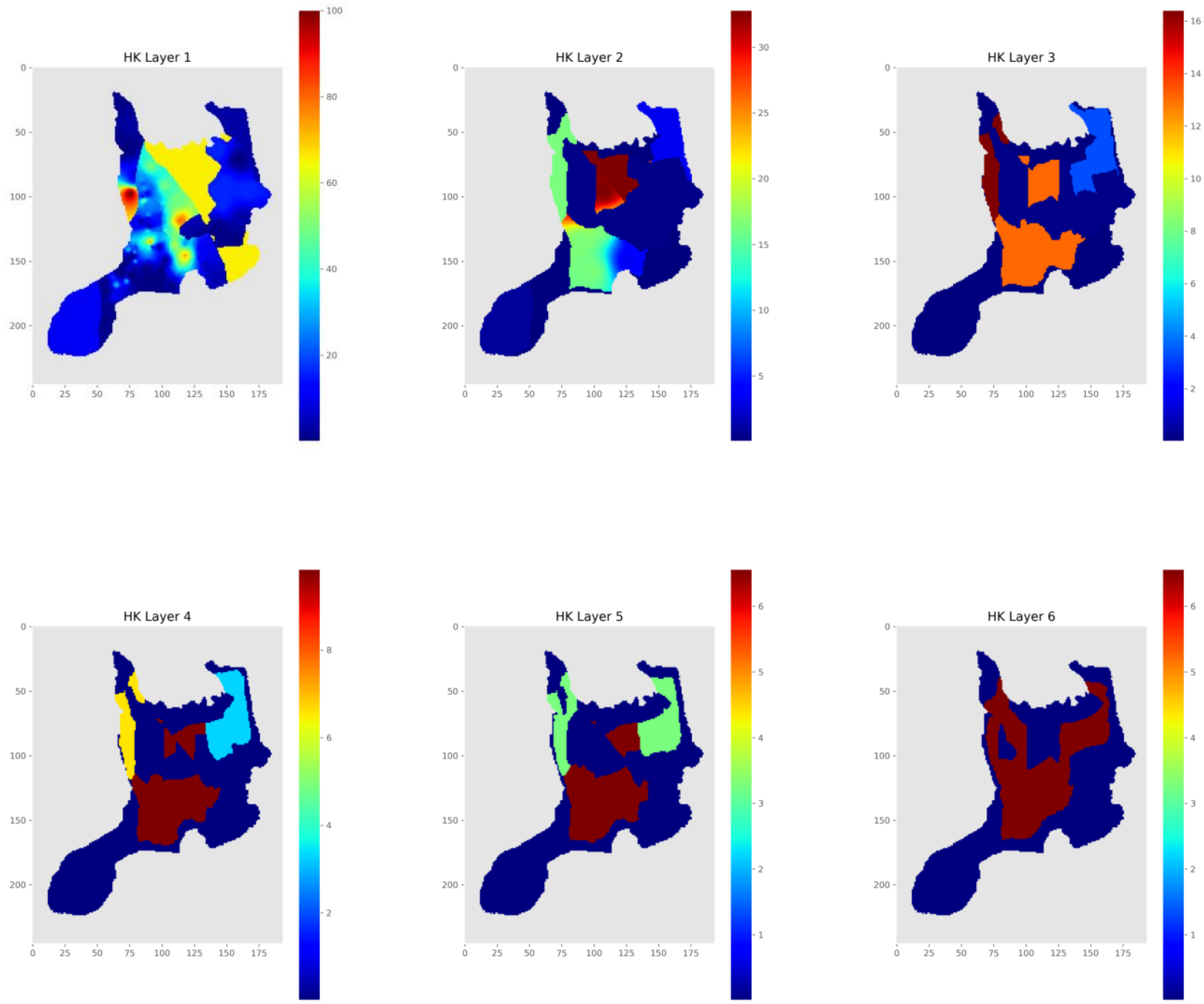


Figure 2-11: Horizontal hydraulic conductivity values used by IWVGA Model. The units displayed on the maps are ft/day.

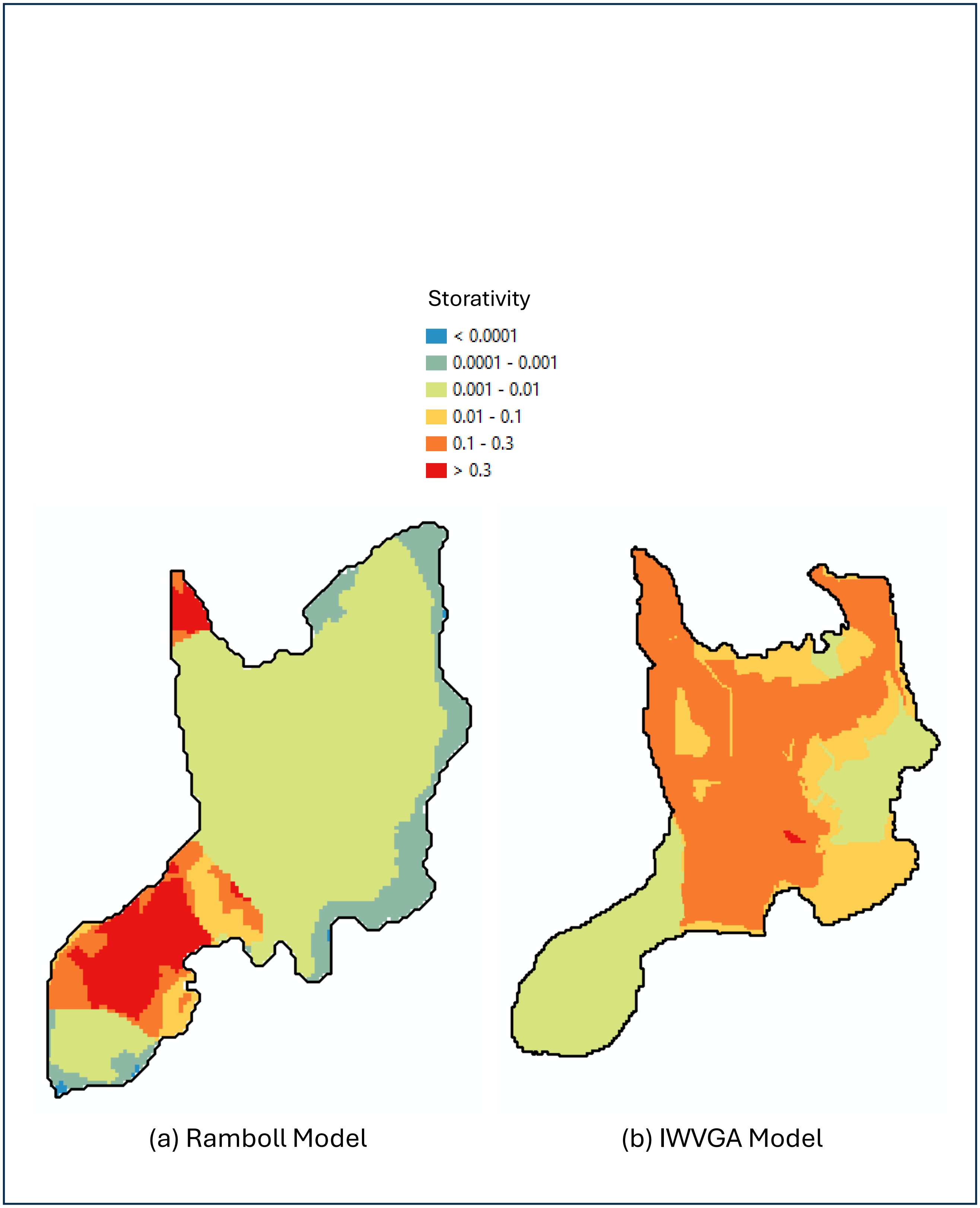
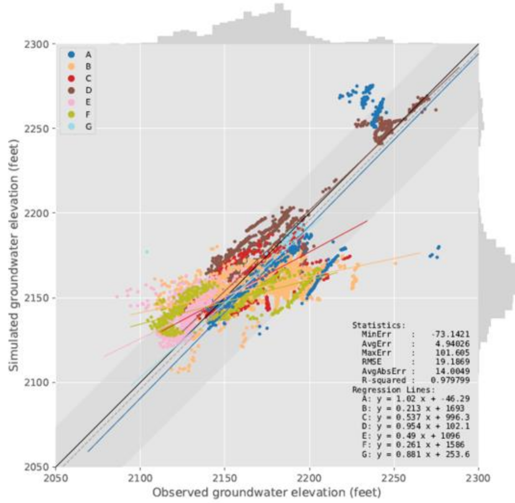
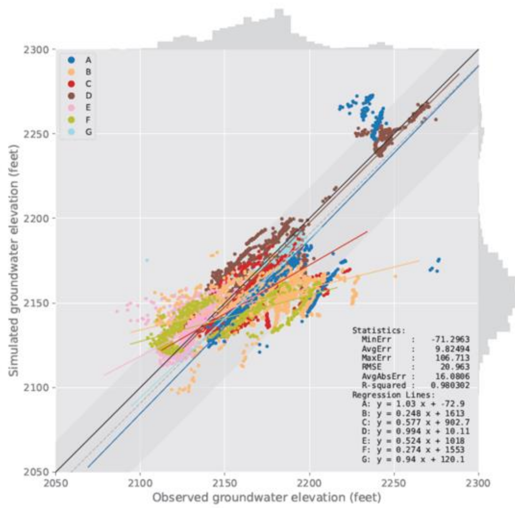


Figure 2-12: Storativity as represented by: (a) the Ramboll Model; and (b) the IWVGA Model.

IWVGA Model



IWVGA Model with layer 1 specific storage reduced



IWVGA Model with specific storage values greater than 10^{-4} ft^{-1} decreased to 10^{-5} ft^{-1}

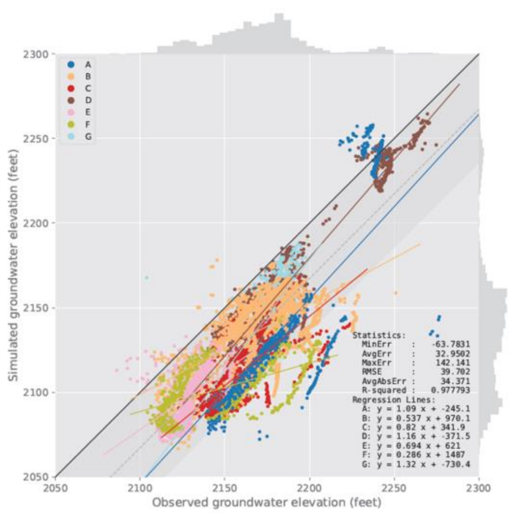


Figure 2-13: Effects of changing specific storage to reasonable values in the IWVGA Model.

TABLES

Term	Ramboll Model		IWVGA Model	
	Rate (AFY)	Percent Distribution	Rate (AFY)	Percent Distribution
Pumping Decrease	-24,149		-25,868	
Storage Increase	8,197	33.2	23,472	90.7
GW ET Increase	252	1.0	1,662	6.4
Surface Drainage/ET Increase	16,205	65.7	705	2.7
GHB Increase	0	0.0	28	0.1

Table 2-1: Change in boundary condition flows for the period 1987-2022 for the no-pumping simulation with the Ramboll Model and the IWVGA Model.