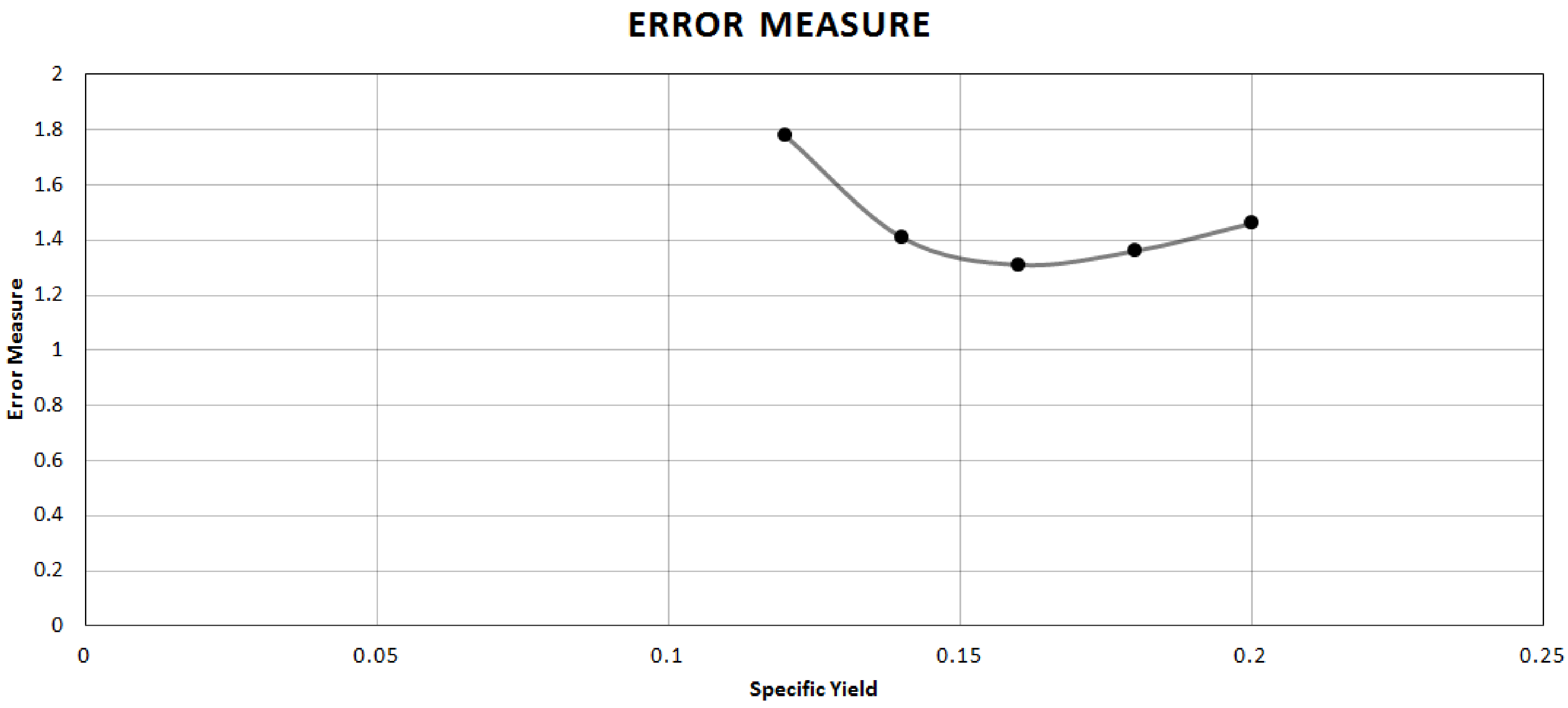

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TO1: Geo-Hydrological Model

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Figure 5-1
Specific Yield Sensitivity Analysis

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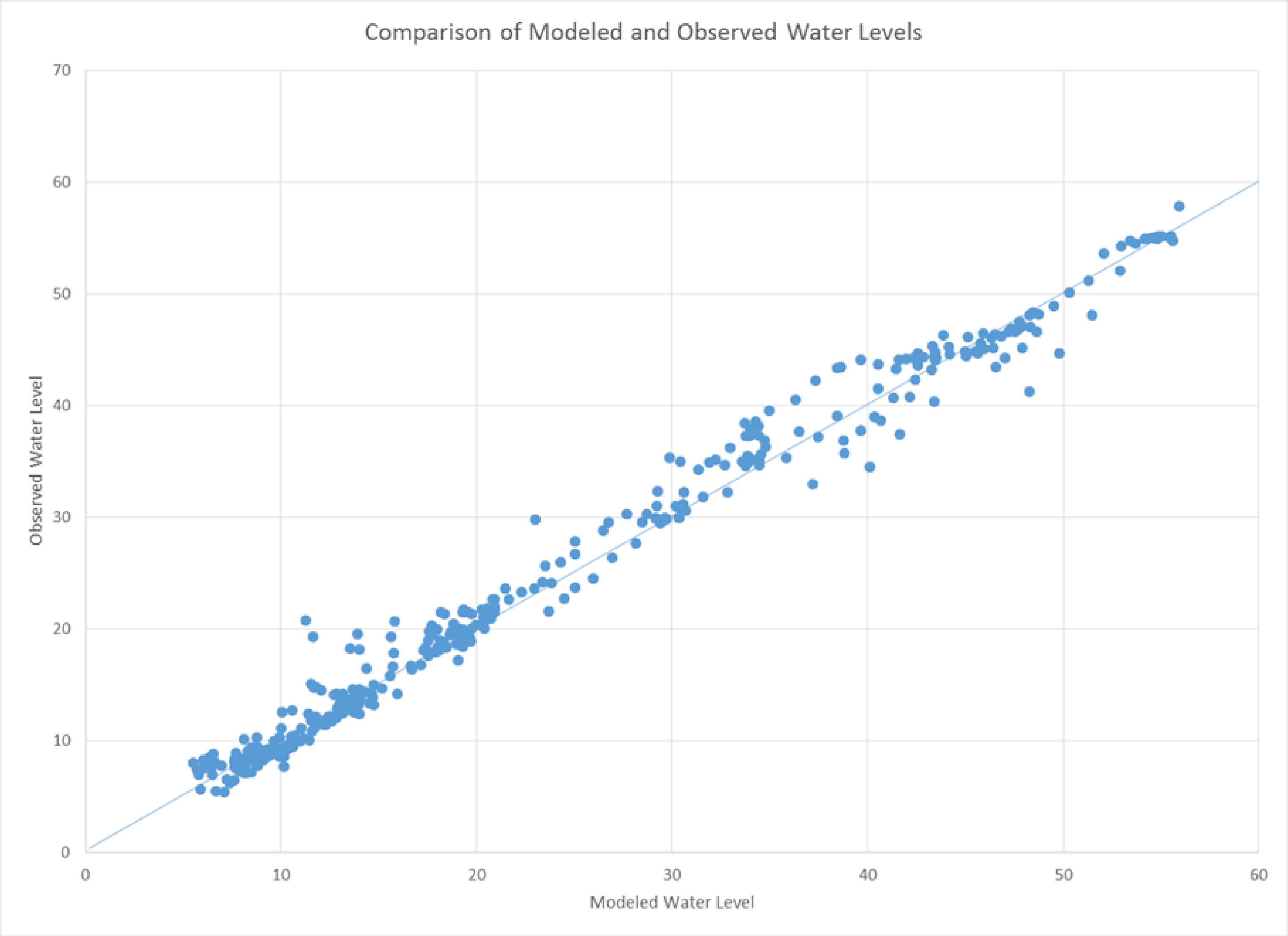

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Figure 5-2

Comparison of Modeled and Field Measured Water Levels During the 2001 to 2002 Calibration Period

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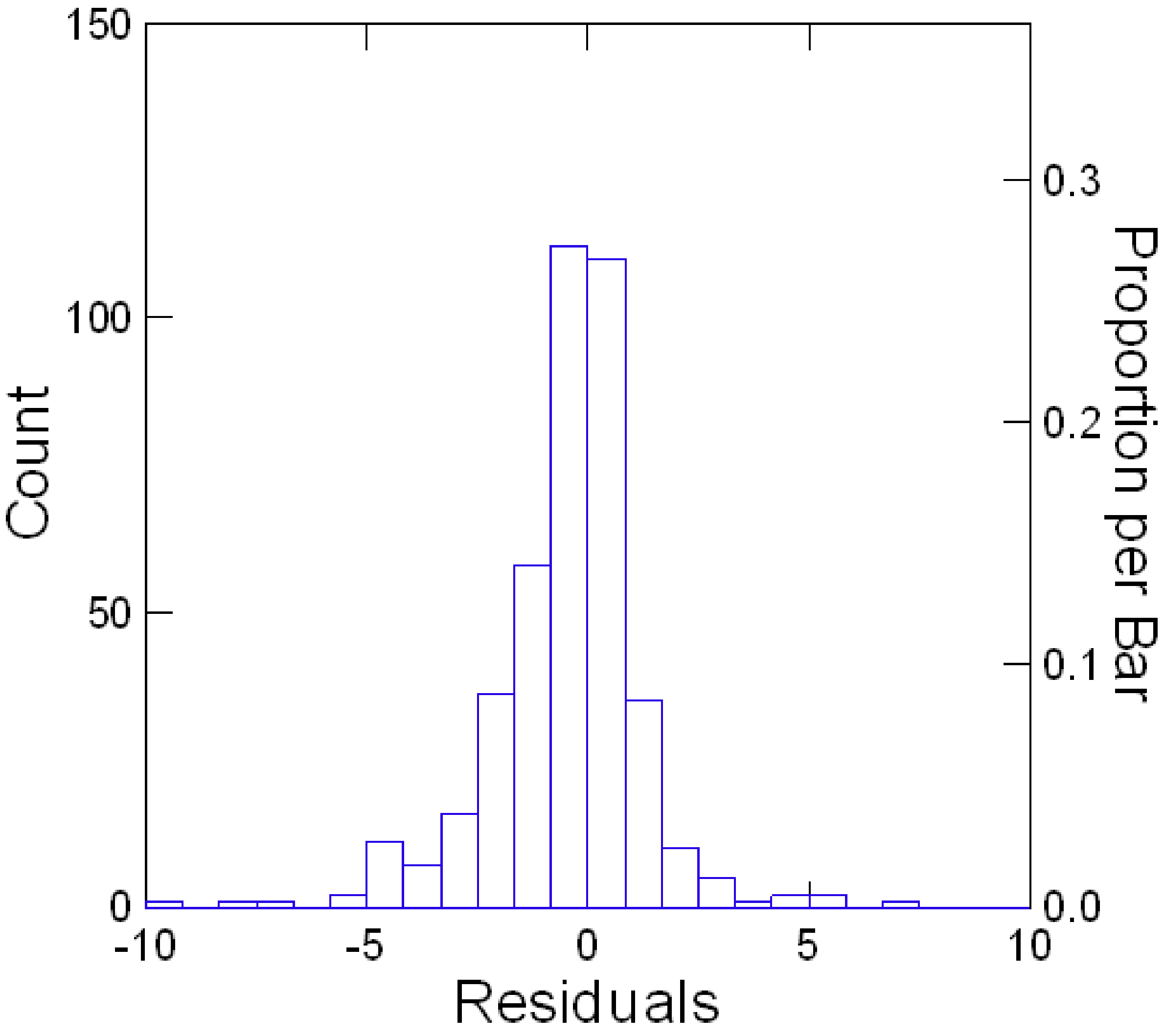

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Figure 5-3
Histogram of Model Residuals

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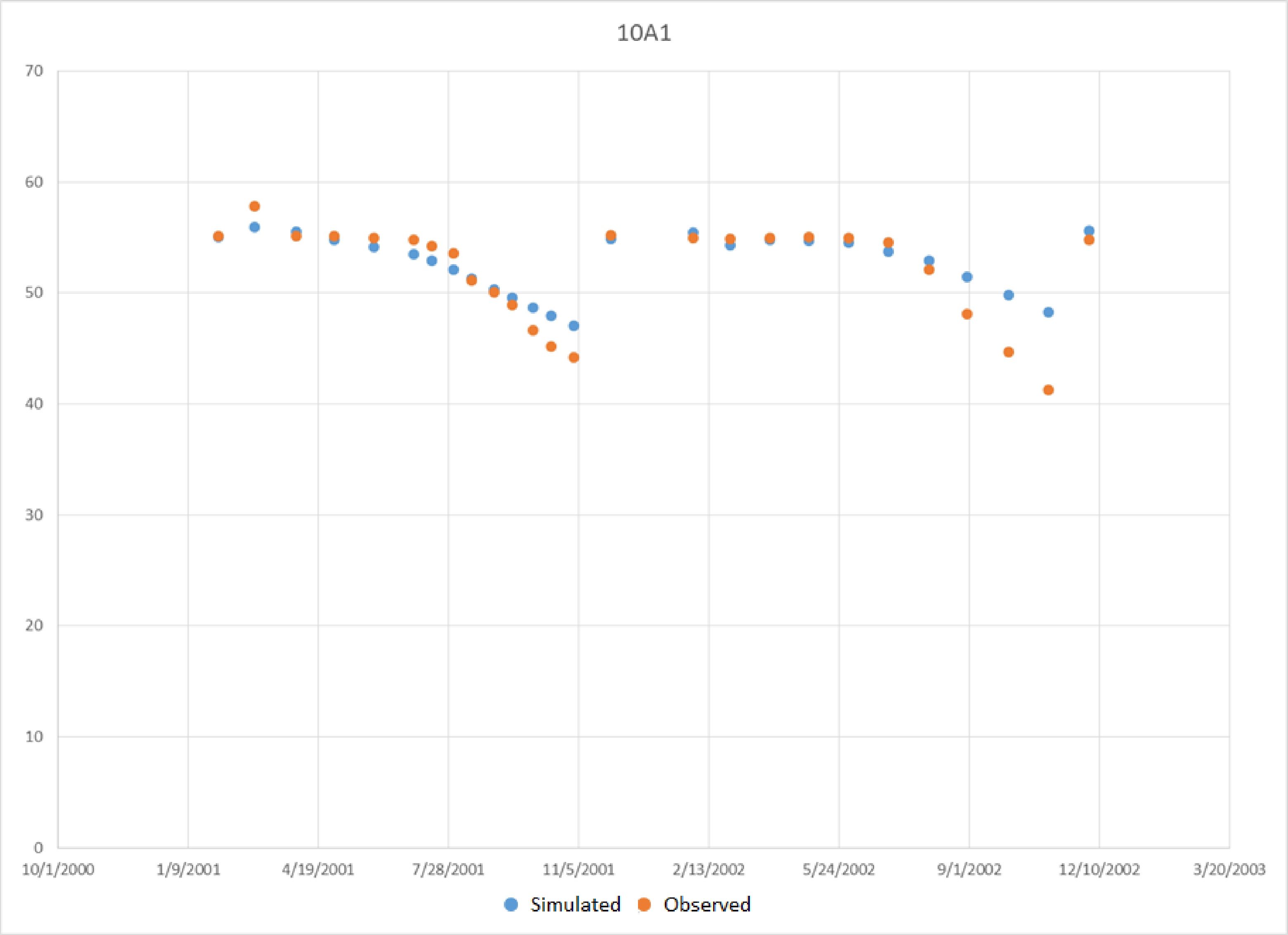

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Figure 5-4
Observed and Modeled Hydrographs at Well 10A1

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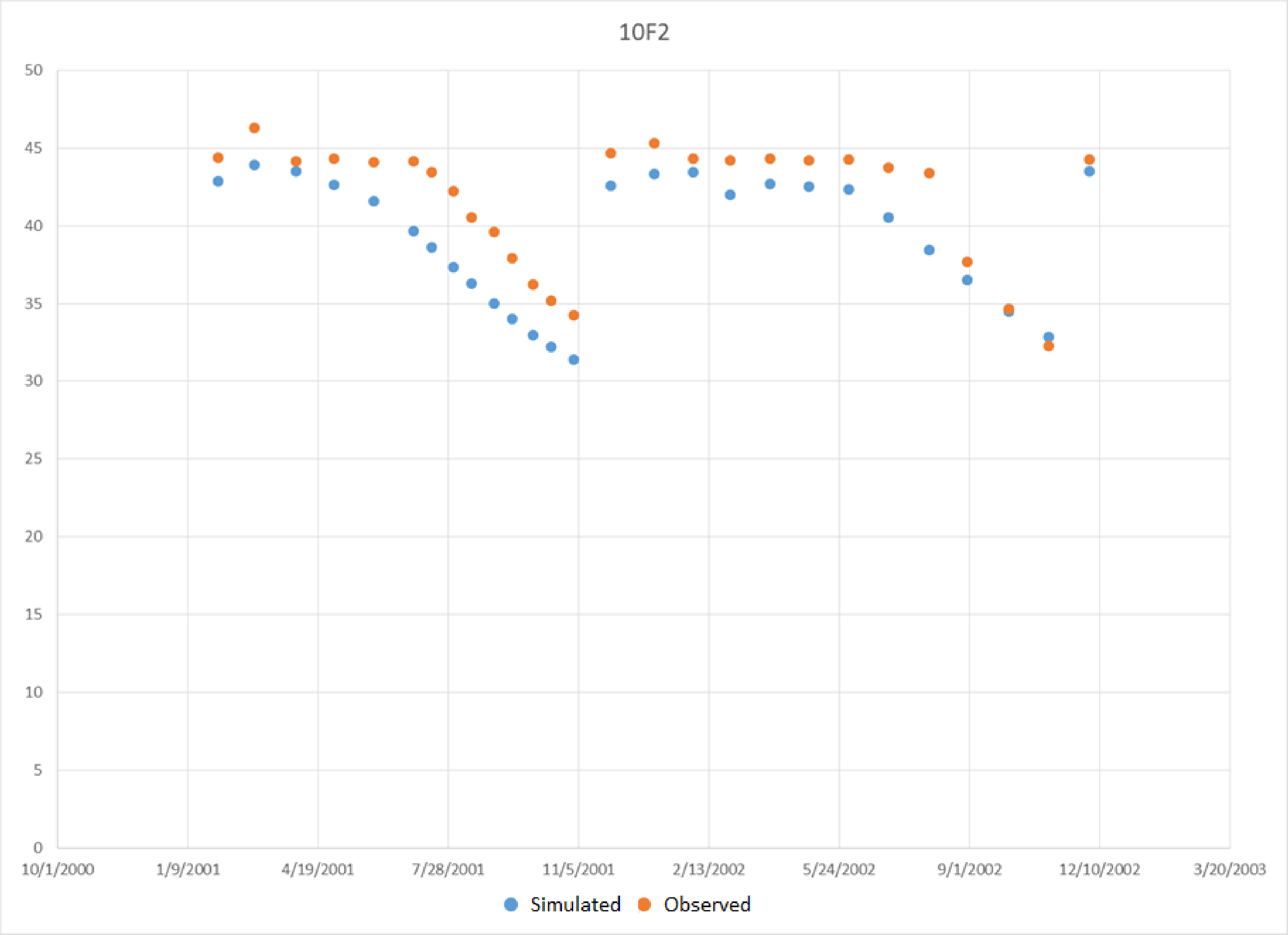

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Figure 5-5

Observed and Modeled Hydrographs at Well 10F2

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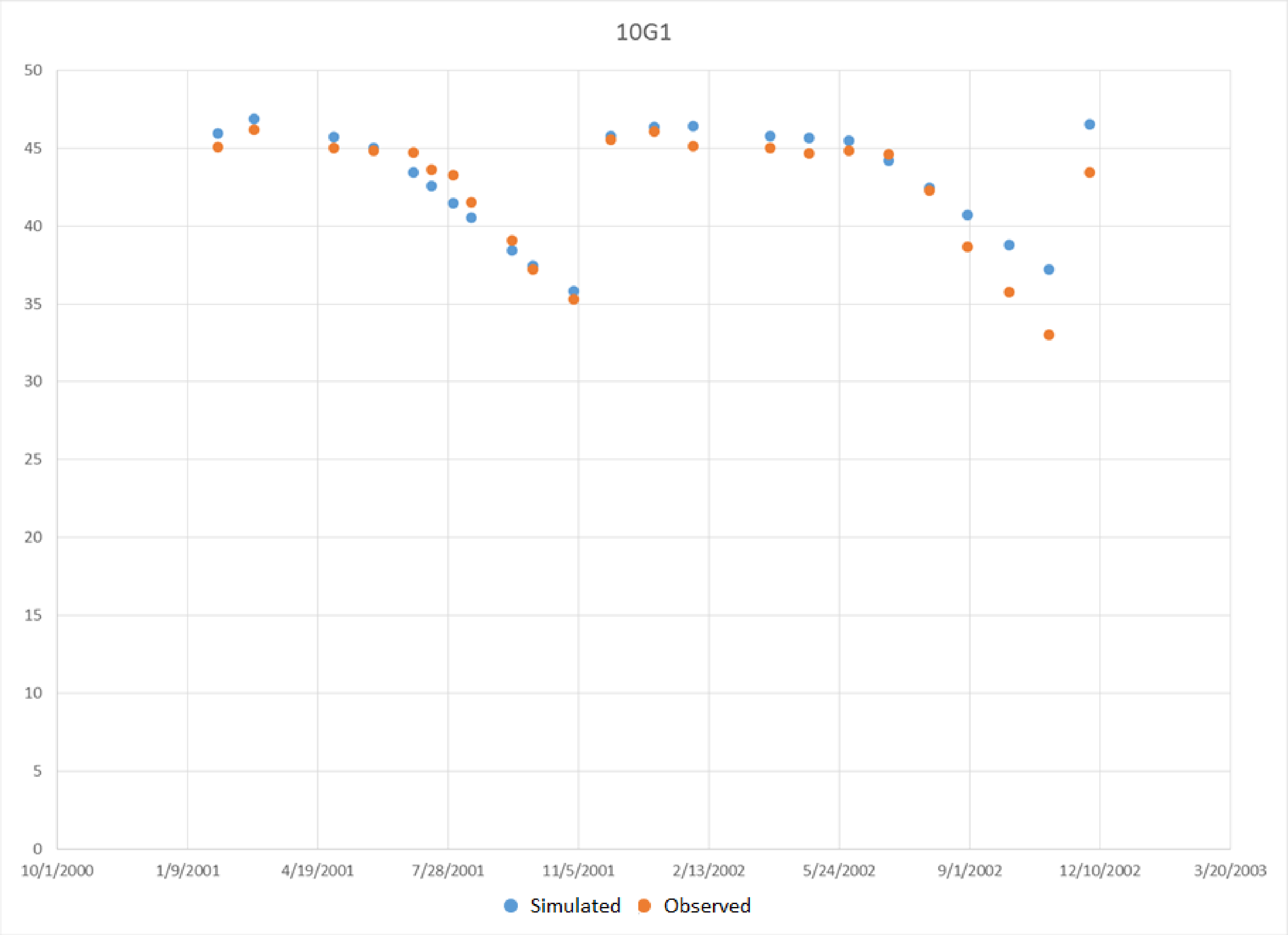

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Figure 5-6

Observed and Modeled Hydrographs at Well 10G1

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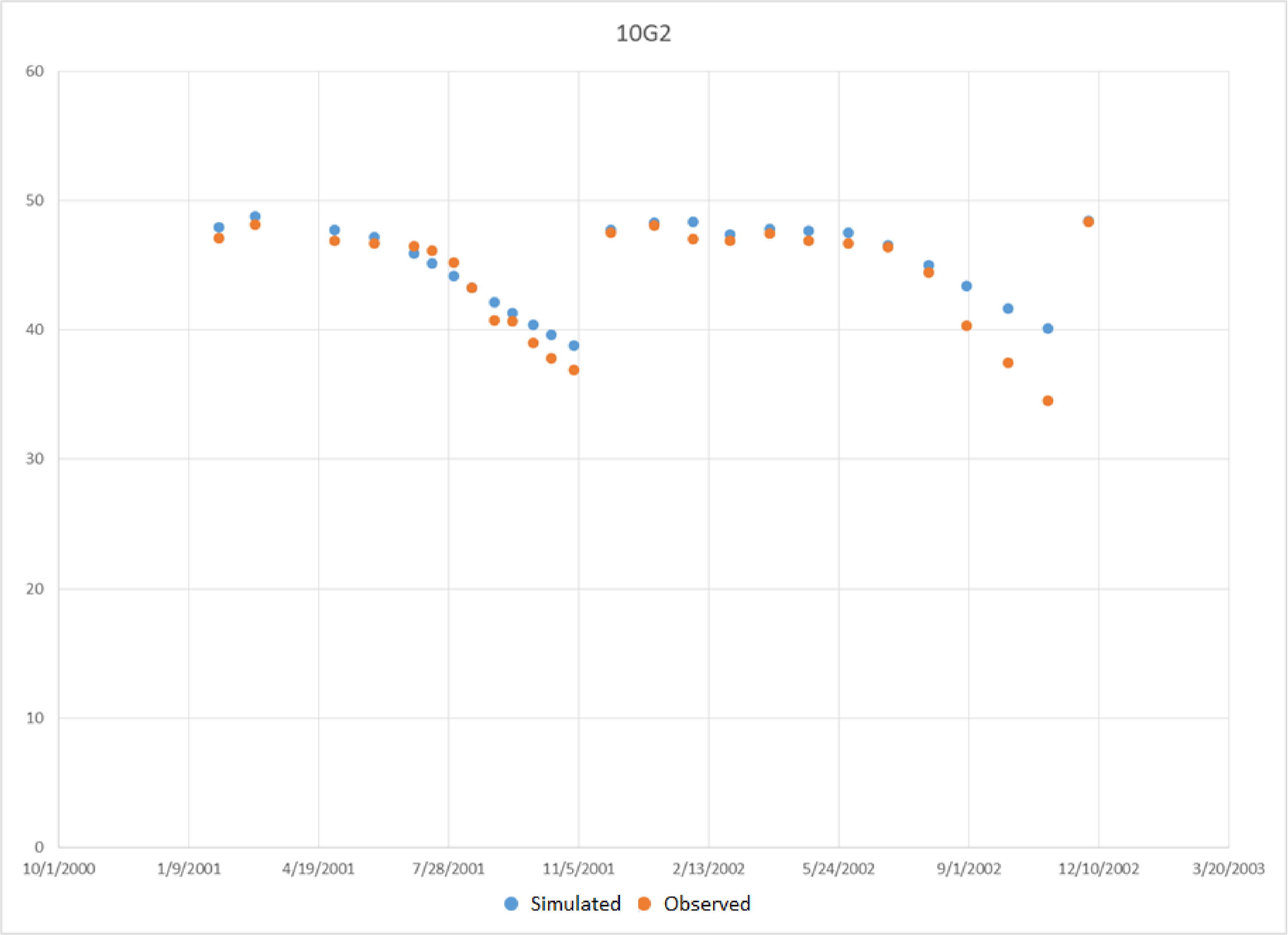

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Figure 5-7
Observed and Modeled Hydrographs at Well 10G2

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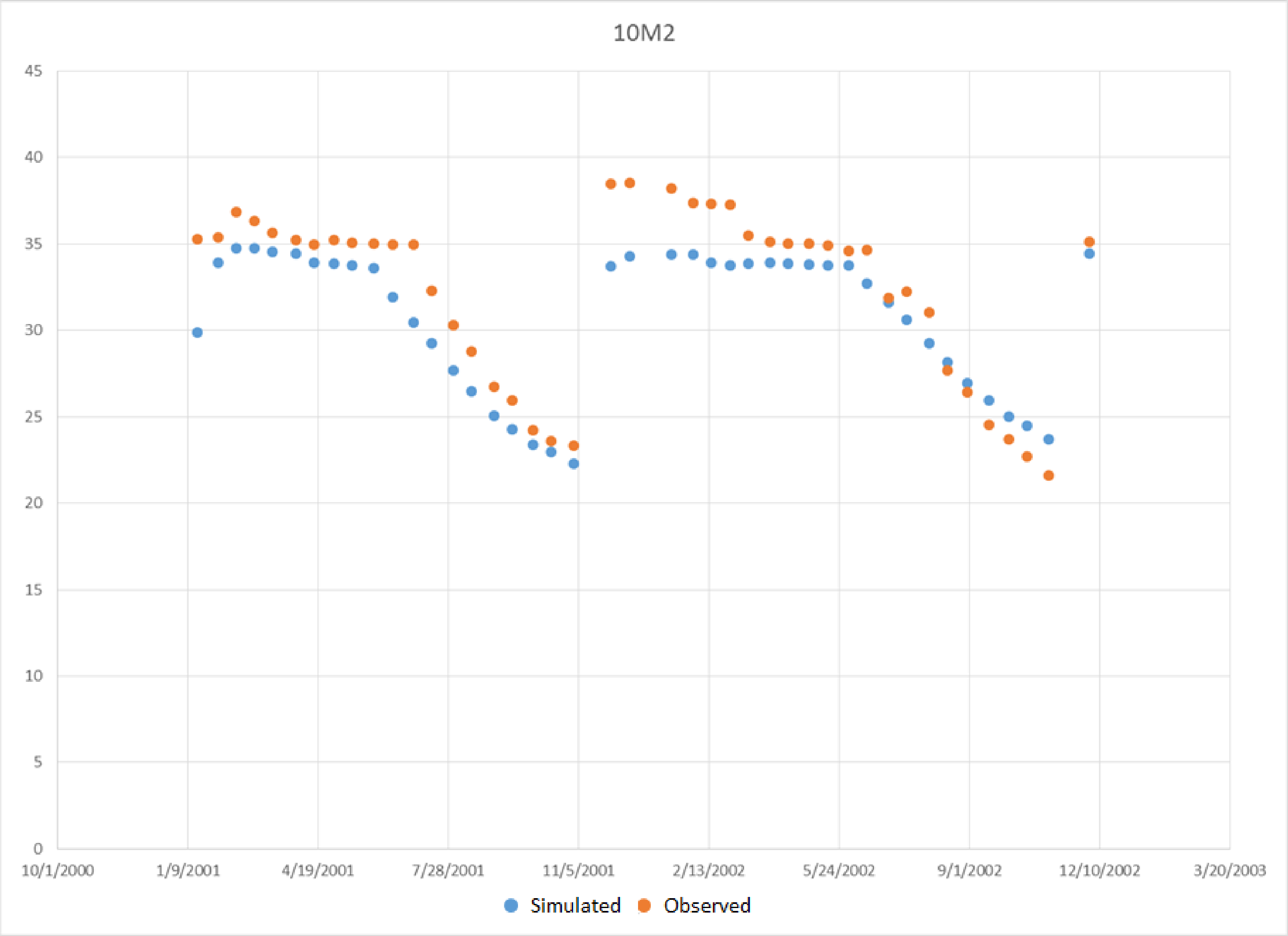

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Figure 5-8
Observed and Modeled Hydrographs at Well 10M2

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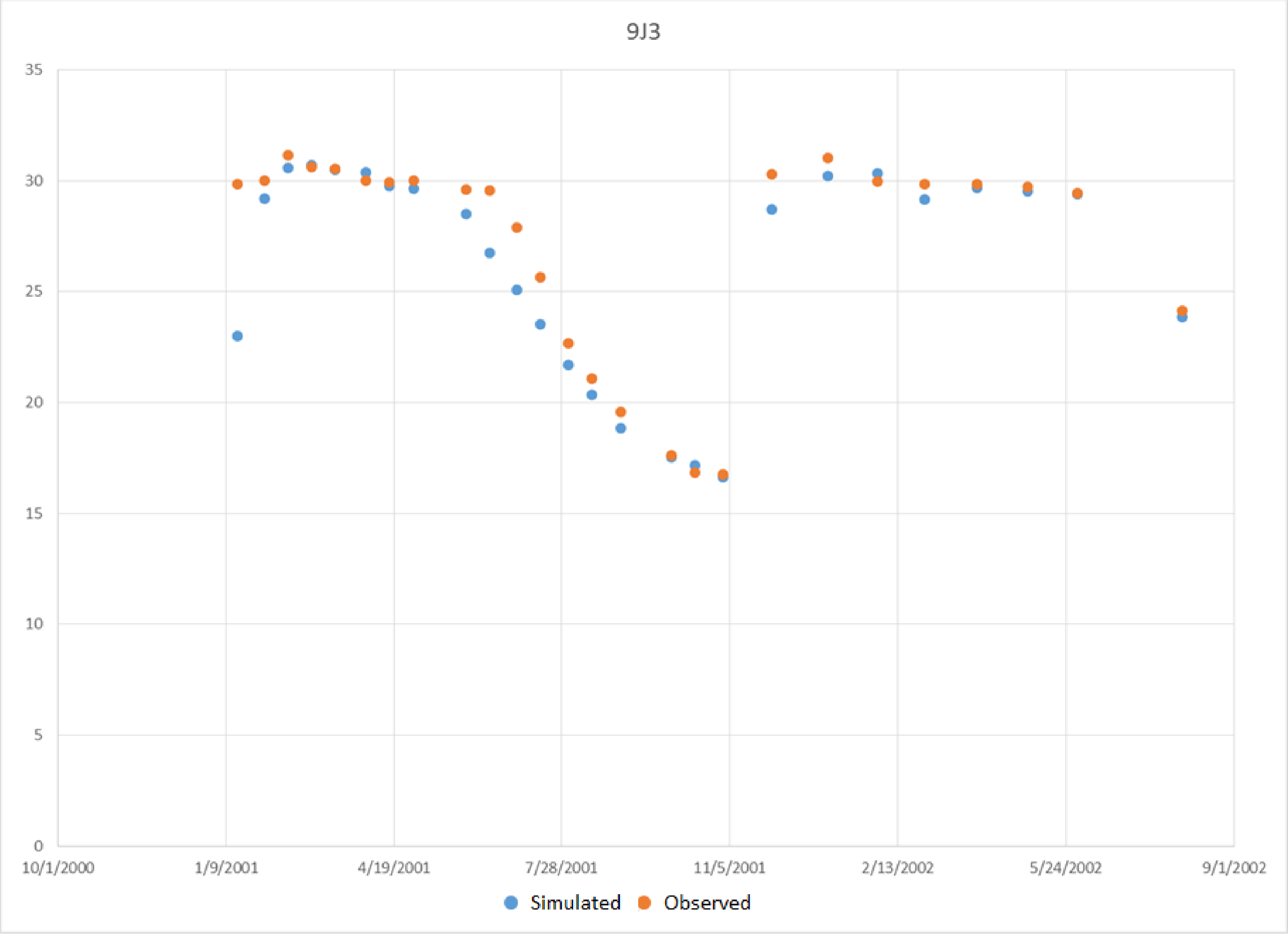

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Figure 5-9
Observed and Modeled Hydrographs at Well 9J3

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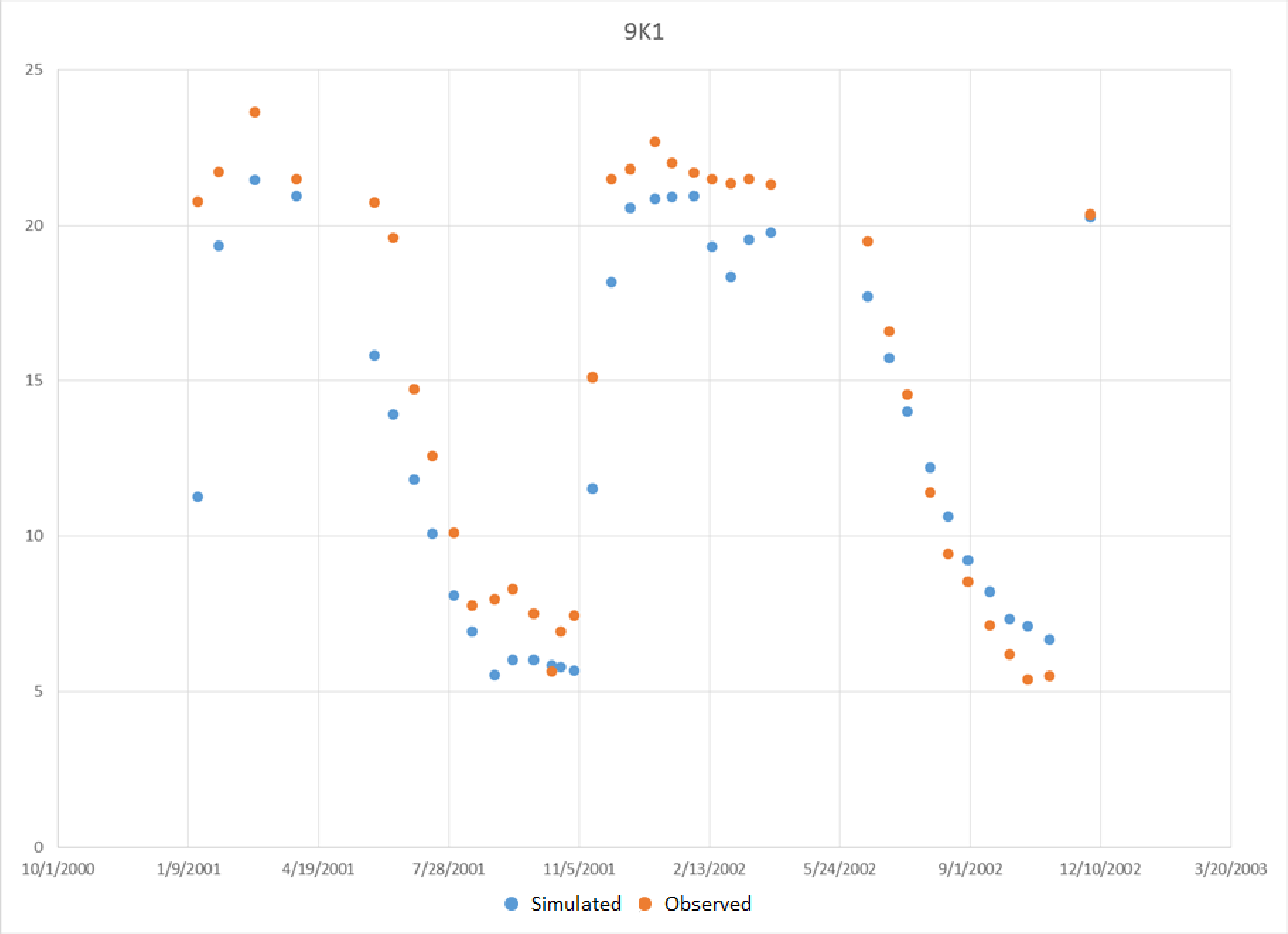

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Figure 5-10
Observed and Modeled Hydrographs at Well 9K1

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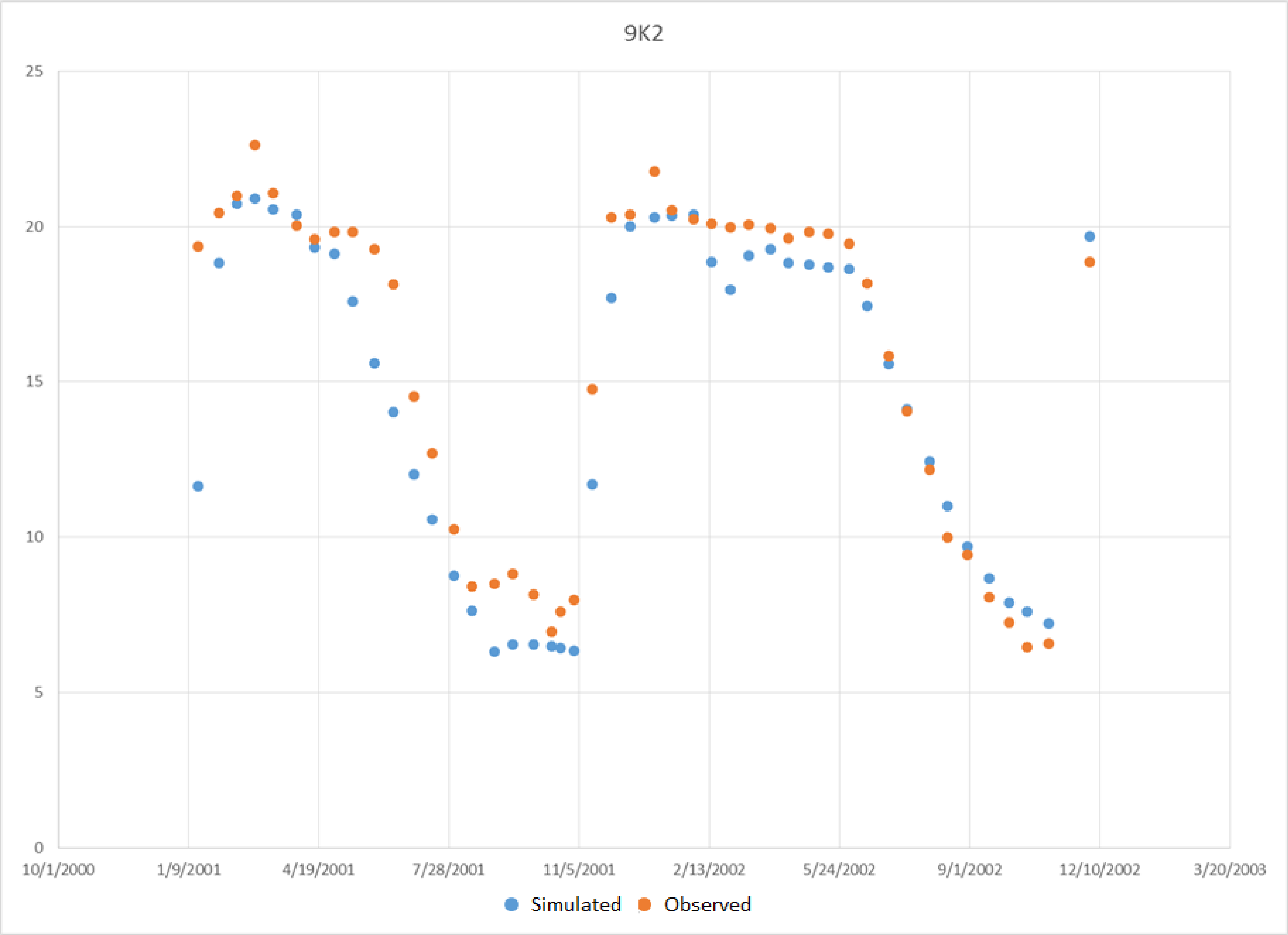

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Figure 5-11
Observed and Modeled Hydrographs at Well 9K2

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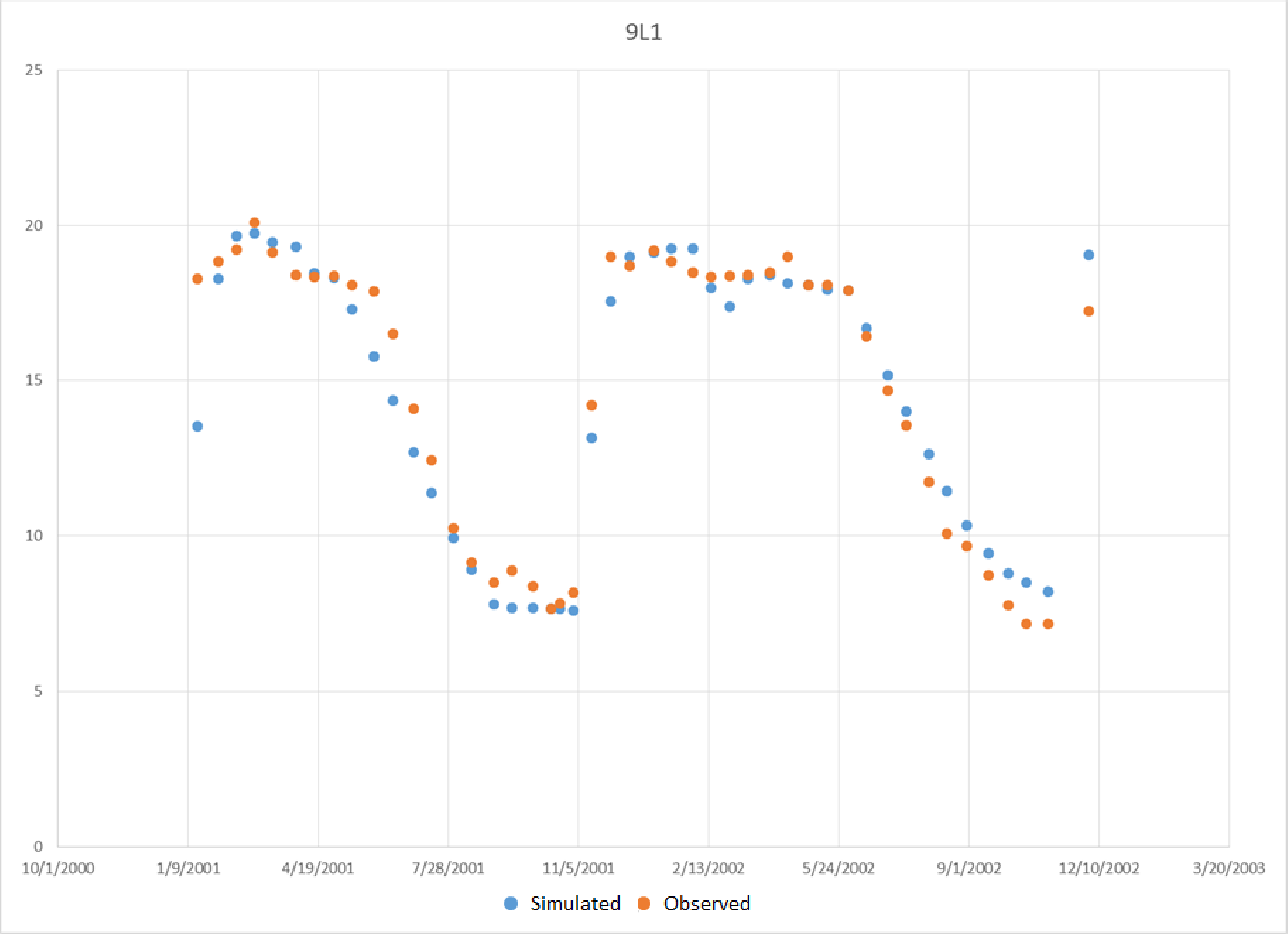

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Figure 5-12
Observed and Modeled Hydrographs at Well 9L1

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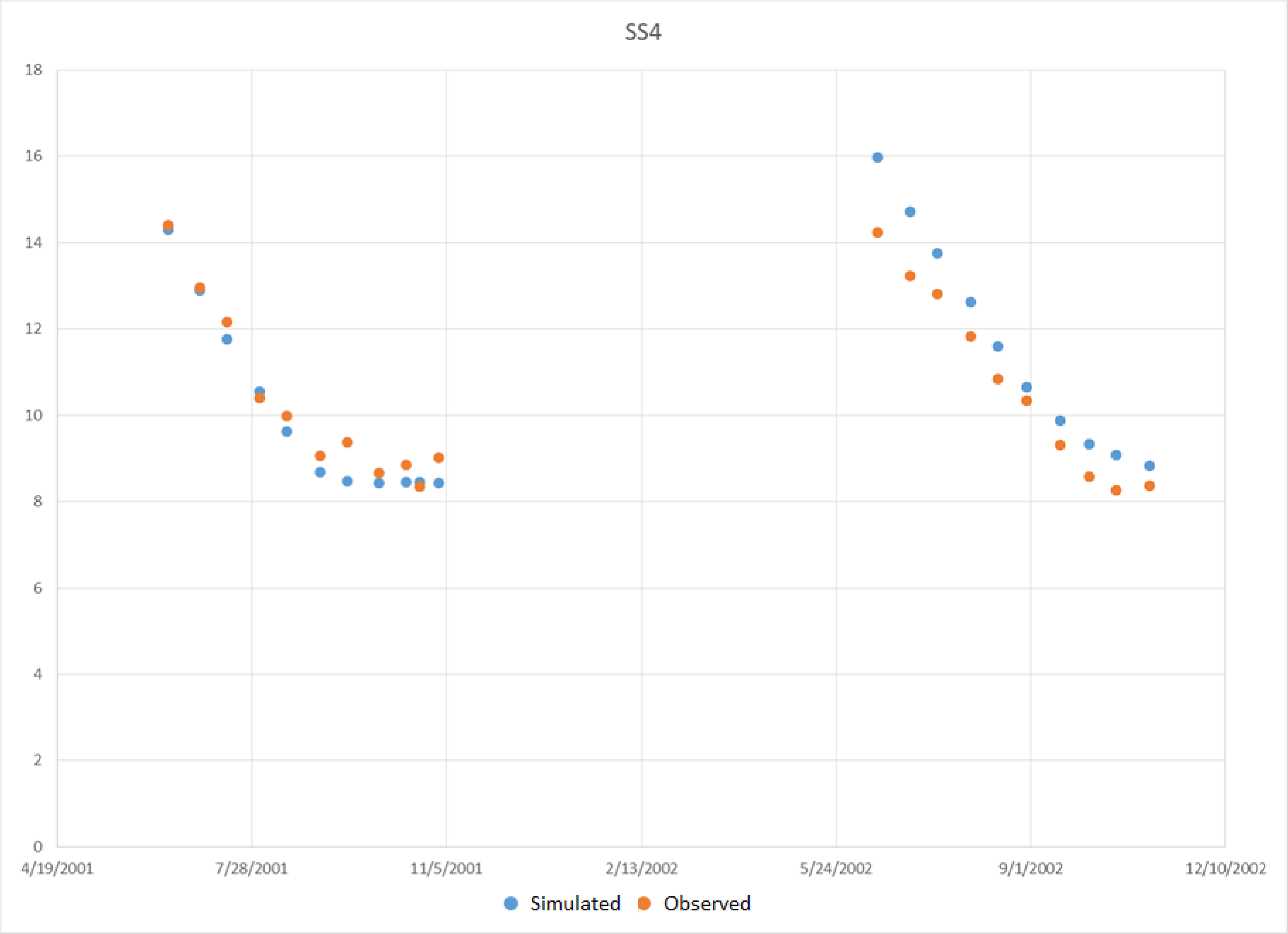

Cambria Emergency Water Supply Project
TO1: Geo-Hydrological Model

Figure 5-13
Observed and Modeled Hydrographs at Well SS4

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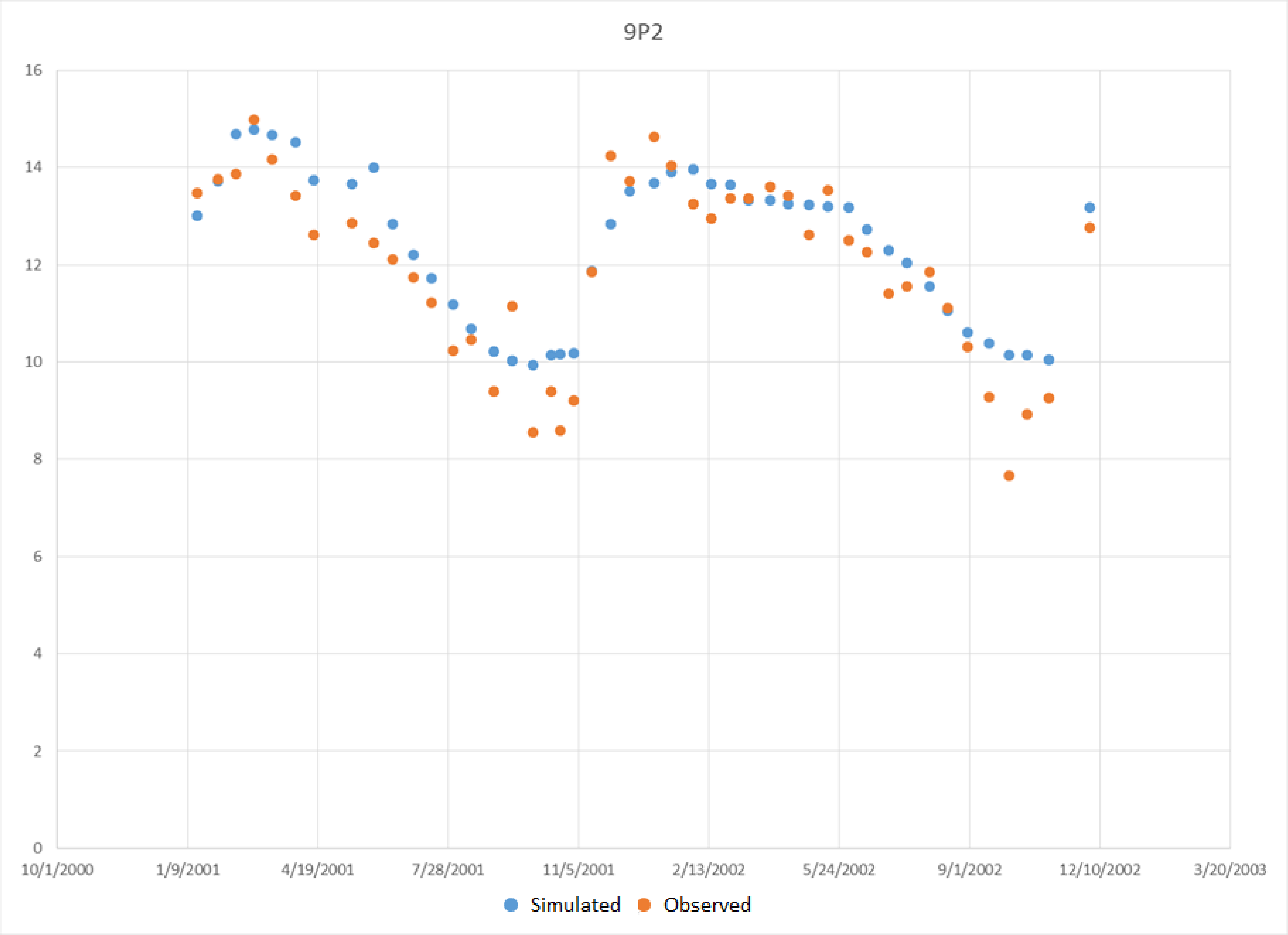

Cambria Emergency Water Supply Project
TO1: Geo-Hydrological Model

Figure 5-14
Observed and Modeled Hydrographs at Well 9P2

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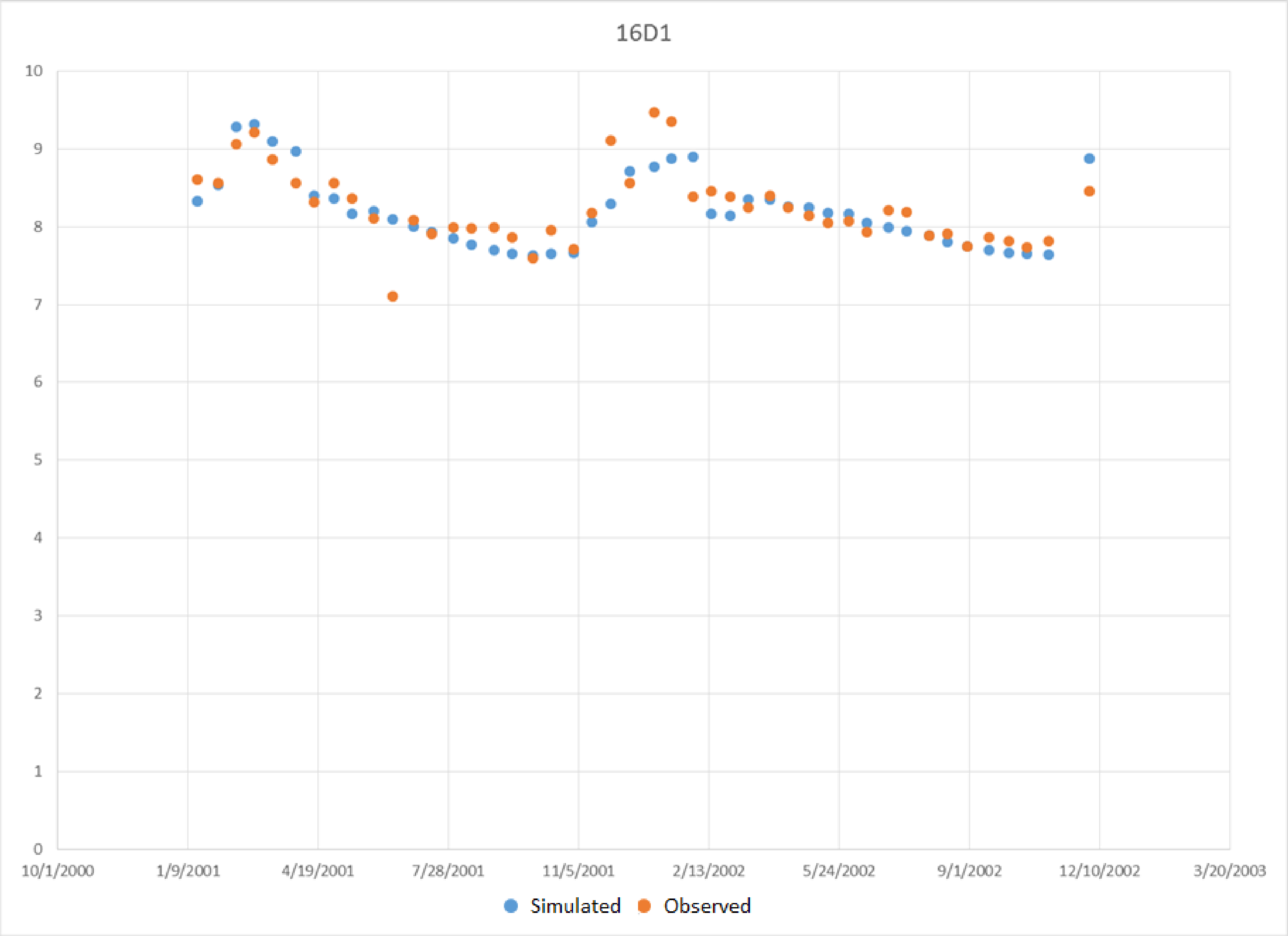

Cambria Emergency Water Supply Project
TO1: Geo-Hydrological Model

Figure 5-15
Observed and Modeled Hydrographs at Well 16D1

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Section 6

Alternatives Analysis

A series of alternatives were defined to address short term emergency water supply for CCSD in the San Simeon basin. These alternatives are focused on development of additional emergency water supply by optimizing recovery of fresh and brackish water in the basin. Currently, significant quantities of fresh water discharge to the ocean. The secondary treated wastewater that is percolated into the aquifer is lost to the ocean or discharges to surface water in the western portion of the basin. A series of simulations were defined to assess the ability to recover additional groundwater and meet requirements for residence time for indirect potable reuse of wastewater affected groundwater in the basin, while also providing for habitat mitigation in the fresh water lagoon.

The assumptions for basin recharge for all of the emergency supply alternatives were identical to allow comparisons to be made. The period incorporated stream flow conditions starting in December 2012 through March 2014 using records from the gaging station in the lower portion of San Simeon Creek. Agricultural pumping rates and return flows were assumed to remain at the rates estimated in the 2007 analysis (Yates, 2007), which were also used during the calibration period. Operational data from CCSD for pumping and percolation pond discharge were obtained from records for the period through February 2014. This simulation period was selected for evaluation of the emergency water supply alternatives since it represents the current drought conditions.

Each of the alternatives will also require disposal of brines from the treatment process. However, brine disposal for the emergency supply alternatives assumes brine evaporation processes from lined ponds and does not interact with the aquifer and is not simulated. Alternatives were simulated using monthly stress periods. The solute transport model tracked the fate of secondary treated waste water and highly treated injected water by simulating movement of a hypothetical tracer compound at a concentration of 100 mg/L. The extent of the tracer over time was assessed by examination of contour maps. The calculated concentrations of the hypothetical tracer at CCSD potable water supply wells was tracked in the model to assess the residence time that the highly treated water remained in the aquifer prior to recovery at the supply wells.

Two sets of emergency water supply alternatives have been considered including two direct potable supply alternatives and two indirect potable reuse alternatives. To qualify for direct potable supply, content of the percolated secondary effluent in the basin water needs to be less than five percent. Otherwise, the basin water will be considered as reclaimed wastewater requiring treatment as it is required for the indirect potable reuse.

For wells that receive recharge from injection of the highly treated basin water, a residence time estimated by modeling needs to be greater than 120 days, which is a safety factor of two over the required field verified residence time of 60 days. The alternatives are described and results of the analysis are presented in following sections. Detailed presentation of simulation results is only presented for the potentially viable alternatives.

6.1 Emergency Alternative 1 (Direct Potable Supply)

This alternative would recover water from the deep portion of the alluvial aquifer for advanced treatment and direct potable supply in the system. This alternative would require that the produced water contain less than five percent water that originated from the percolation ponds. **Figure 6-1** shows the location of the new supply well for this alternative, which would be located on CCSD owned property just east of Van Gordon Creek and in the vicinity of the existing Wells 9N2 and 9N3.

This alternative was simulated using the standard conditions by configuring a new pumping well in only the lower portion of the aquifer and pumping the new supply well at 185 gpm, which would yield 150 gpm after advanced treatment. The design concept for this alternative was to assess the potential for obtaining water from the deeper portion of the aquifer in order to minimize production of secondary treated effluent from the percolation ponds. The existing CCSD well field would be pumped at 260 gpm, for a total potable yield of 410 gpm. Shallow recharge to support the fresh water lagoon would be done by injecting 100 gpm into the shallow aquifer near the upper extent of the lagoon, resulting in a potable water supply of 310 gpm for the CCSD distribution system.

The simulation results indicate that pumping at this location would result in development of significant vertical gradients that would induce movement of the percolated secondary treated wastewater to this well. The natural gradients also indicate that past operations at the percolation ponds have likely impacted these deeper zones, thus the criteria for less than five percent wastewater content will not be met with this alternative.

Figure 6-2 illustrates the movement of percolated wastewater in the groundwater system for a hypothetical tracer injected in the percolating treated wastewater after 270 days. Since the percolation ponds have been operating for several decades, this wastewater is present through the thickness of the aquifer and insufficient isolating strata are present to prevent this downward movement. This alternative is not viable.

6.2 Emergency Alternative 2 (Direct Potable Supply)

This alternative is similar to alternative 1, with the exception that the supplemental production well is sited near the beach area on property that is not controlled by CCSD, as shown on **Figure 6-3**. This supplemental well would also have to be pumped at a higher rate, since the TDS is higher, which will decrease the recovery efficiency of the treatment system. This well would also have to meet the criteria of not producing water with more than a five percent content of the percolated waste water in order for the treated water to be directly used.

The results of this simulation also indicate that significant quantities of waste water are present throughout the aquifer, and operation of the well would induce vertical movement of groundwater from the entire thickness of the aquifer. This alternative is also not viable due to a wastewater content greater than five percent. This well location would also produce very high TDS water, which would result in a lower recovery percentage for treated water. Recent measurements at well 8R3 in the area of this alternative indicates that the groundwater has a TDS of about 5,000 mg/L, and pumping in this area would lead to an increase in TDS.

6.3 Emergency Alternative 3 (Indirect Potable Reuse)

This alternative would pump groundwater near the percolation ponds at a rate of about 500 gpm, use advanced treatment with an estimated 92 percent recovery efficiency and re-inject this water up-gradient of the existing well field. **Figure 6-4** shows the configuration of this alternative. This water would be injected down-gradient of existing irrigation wells and upstream of the CCSD well field to minimize loss of the treated water to other users.

The objective of this alternative is to provide a source of recharge for beneficial use of the secondary treated waste water that would otherwise be lost to the ocean. The simulation results indicated that travel times to the closest CCSD production well will not meet the criteria of 120 days of residence time with an injection well located down-gradient of the irrigation wells. This is due to the short distance available to avoid losses to the irrigation wells and a narrowing of the bedrock valley that result in higher groundwater velocities in this area. The criteria could be met by moving the injection well up-gradient of these irrigation wells, however, this would result in loss of injected water under drought conditions to the irrigation wells when they are pumping. This alternative is potentially viable with a move to a further up-gradient location and resolution of the potential loss of highly treated water to irrigators.

6.4 Emergency Alternative 4 (Indirect Potable Reuse)

This alternative is designed to maximize recovery of the percolated secondary treated wastewater while maintaining a mound to avoid movement of percolated waste water toward the existing well field. This alternative is summarized on **Figure 6-5**. Existing well 9P7, located within the percolation pond area, will be pumped at 710 gpm and will undergo advanced water treatment. A new injection well located between the percolation ponds and the existing CCSD well field will receive 485 gpm, while 100 gpm will be infiltrated near the fresh water lagoon to maintain its viability. Wells SS1 and SS2 would be pumped at 227 gpm each to supply CCSD demands. Well SS3 will not be operational when the basin receives the injected water from the advanced water treatment plant due to its proximity to the recharge well. This conservative assessment assumes that the emergency operations would continue for over a year, assuming that no significant runoff occurs in San Simeon Creek.

Since this alternative meets the selection criteria, detailed simulation results are presented. In order to assess the residence time, a hypothetical tracer was injected with the water at the new injection well location. The areal extent of this tracer was tracked in the model and the simulated tracer concentration in CCSD wells SS1 and SS2 summarized. **Figure 6-6** through **Figure 6-12** show a plan view extent of simulated tracer concentration greater than ten percent of the injected concentration the aquifer at 30 day intervals through 210 days of operations. These figures are a visualization through all of the model layers and represent the maximum extent of the ten percent contour in all of the layers. **Figure 6-13** shows the simulated water level after one year of operations, illustrating the mounding at the injection well with radial flow along the aquifer extent both toward the CCSD supply wells and toward the percolation ponds.

Figure 6-14 shows the simulated breakthrough curve for simulated tracer concentration at wells SS1 and SS2 under pure advective flow conditions. Based on this simulation, the estimated residence time from the injection well to well SS2 is 133 days, which exceeds the criteria time of 120 days, which include the 2 times safety factor over the regulatory target residence time of 60 days. The current draft regulations indicate that with the degree of treatment proposed, a residence time of 60 days, confirmed by a tracer study, will meet the requirements for indirect potable reuse. This alternative has the disadvantage of recirculating a significant quantity of water back to the source well at the percolation ponds where it would be repumped and retreated. Some of this recirculated water would also maintain water levels in the lower basin, which will be beneficial for habitat mitigation at the fresh water lagoon. Approximately 60 percent of the water produced at wells SS1 and SS2 would originate from the injection well during the simulated 1.25 years of operation. The breakthrough curves on Figure 6-14 indicate that half of the water produced at wells SS1 and SS2 would originate from the highly treated water recharged to the basin by between 160 and 200 days for the range of assumptions simulated. The percentage of recovery would increase for longer durations under more extreme drought conditions, as basin inflow decreases. If the emergency alternative is operated for only a period of 3 months, all of the water produced by wells SS1 and SS2 would originate from the basin, since the reinjected water would still be in transit from the recharge well, however, the mounding created at the recharge well would serve to maintain a protective westward gradient, and decrease the rate of water level decline at the production wells.

In order to assess uncertainties in the projections of residence time for this alternative, a series of sensitivity analyses were conducted. The sensitivity analyses included assessing the impact of a significant decline in basin sources of recharge, including native precipitation and lateral boundary inflow. These factors were decreased to half the value used in calibration. The effect of variations in groundwater velocity in the aquifer was assessed by adding the effect of dispersion. As noted earlier, the dispersion process accounts for uncertainties in groundwater velocity associated with small scale variations in the aquifer.

An additional sensitivity simulation decreased the effective porosity and included dispersion. This reasonable worst case simulation included a longitudinal dispersivity of 67 feet and an effective porosity of 0.14. This is a very conservative assessment. Figure 6-14 also shows the simulated tracer breakthrough curves for the base alternative and the three sensitivity simulations. The worst case simulations show that the ten percent breakthrough could occur in less than 120 days with the simulated location of the injection well. The location of the well will be moved slightly down-gradient during preliminary design so that a simulated breakthrough for the worst case simulation is beyond the criteria 120 days.

Maintaining the viability of the fresh water lagoon that is present in the lower reach of San Simeon is an important goal of the project. This viability will be maintained by infiltrating treated water in an area adjacent to the channel on CCSD property to support flow into the upper reach of the lagoon area. A preliminary estimate of 100 gpm was used as a basis to assess the potential for maintaining fresh water in the lagoon area during the drought conditions. The intention of mitigation is to avoid or minimize to the extent feasible negative impacts on the fresh water lagoon.

This fresh water lagoon support was assessed by comparing simulated water levels near the channel and fresh water injection wells to determine the extent to which this injection rate could support discharge to the channel and flow into the lagoon area. The lower extent of the lagoon near the beach has an invert elevation that is below mean sea level, so under extreme drought conditions, this lower reach will maintain a water level near mean seal level (~2.81 feet on the site datum), however, as the quantity of fresh water diminishes, the lagoon will become more saline.

Figure 6-15 shows a comparison of simulated shallow groundwater levels and the channel invert, which indicates that some discharge to the channel will occur for up to a year after commencement of the alternative. This plot assumes that alternative operations would start in late summer 2014. The quantity of water actually entering the channel will diminish over time as the drawdown in the shallow aquifer increases due to the drought and continued pumping of the basin. The rate of decline in water levels increases when irrigation pumping starts around day 300. The permeability of the lagoon deposits is unknown, so it may be necessary to provide increased discharge to the wells or directly to the channel if the drought persists for an extended period. If additional mitigation flow are required, then additional pumping from well 9P7 would be required.

The impact of the emergency operations on movement of brackish water inland from the ocean was assessed using the flow and transport model. A water balance from the simulation is shown on

Figure 6-16, which indicates that a small net discharge to the ocean will occur during the initial year of operations of the emergency alternative as storage is depleting in the basin. This figure also presents the net storage decline in the basin, since pumping will exceed the sources of recharge to the basin. The negative values for ocean outflow indicate a net discharge to the ocean, while the positive rates at month 12 of emergency operations indicate a reversal of flow and inducing a net inflow to the basin from the ocean. Depletions from storage occur through the simulated operating period.

Recent sampling of wells at the site indicated that the total dissolved solids (TDS) in groundwater have been elevated due to probable limited salt water intrusion. The secondary treated wastewater has helped to attenuate the increased TDS of the basin water. A profile of specific conductance was run at well 9P7 at the percolation ponds that indicated a TDS indicative of the treated waste water in the upper 25 feet of the aquifer, with deeper zones indicating possible impacts from limited saltwater intrusion. **Figure 6-17** shows a profile of TDS (primarily estimated based on specific conductance) extending from the beach area to the CCSD well field. A well cluster (9N2/9N3) did not indicate vertical differences in TDS. The values ranged from about 5000 mg/L at well 8R3 near the beach, to a range of 350 to 540 mg/L from the CCSD supply wells. The vertical profile data at 8R3 suggested that the well had been impacted by salt water in the past, either from flow within the aquifer or surface flooding, since the interval below the screen openings showed a TDS of about 23,500 mg/L.

Simulation of the effects of variable density was conducted using the SEAWAT model for this alternative, including the impacts of lower basin recharge, in order to validate the primary simulations using MODFLOW and MT3DMS. These simulations confirmed simulation results that were obtained using the equivalent fresh water head approach. The variable density model did show stratification of high TDS water near the base of the aquifer, however, for the 1.25 year simulated duration of emergency operations, the high TDS water did not migrate inland by a significant distance, and the closest wells near the percolation ponds are not impacted.

The simulations of TDS during operation of the emergency supply alternative was assessed using the equivalent fresh water head approach, since the more compute intensive variable density simulations indicated that this process was not required for the duration of the emergency water supply simulations. The ocean boundary was defined for the simulations as an equivalent fresh water head for each of the zones. Since the density of salt water is higher than for fresh water, as the height of the water column increases, the pressure at depth will be higher in salt water than in fresh water. The current distribution of concentrations of TDS in the aquifer was configured in MT3DMS and the emergency alternative was simulated to assess the water quality that would be produced at well 9P7, which is used as the supply well for the advanced treatment system. This provides a reasonable assessment of water quality since a net outflow to the ocean occurs through most of the simulation period. In order to develop a reasonable estimate of the impact of flow reversals from the ocean toward the 9P7 brackish extraction well, a constant concentration boundary was configured in the model between wells 8R3 and 9N2, with a concentration of 3,000 mg/L, which represents an average between these wells. The current observed data represents a long term average condition during a period when little recharge to the aquifer occurred.

Figure 6-18 shows the simulated TDS concentration at the brackish extraction well 9P7 for the emergency alternative. The simulated TDS at the start is about 800 mg/L, similar to what is observed in the percolated secondary treated wastewater. Over time, the concentration drops, since the capture zone of 9P7 includes up-gradient areas that have groundwater not impacted by either wastewater percolation and eventually recharge water that was injected at RIW1, which has a very low TDS (simulated at 100 mg/L). Flow is induced up-gradient from the west off the ocean. However the higher TDS water that is in this area does not reach 9P7 over the 1.25 year duration of the assumed emergency operations. If emergency operations were to continue into the future with no runoff in San Simeon Creek, then this higher TDS water and eventually sea water would be induced to the area of 9P7. If this extreme drought condition were to occur, the steady-state TDS would be a blend of the percolated waste water, return flows from injection at RIW1 and sea water, with minor basin flow from up-gradient after several years. Under this extreme condition, the TDS could rise as high as 8,500 mg/L when this equilibrium is reached after several years of no stream flow recharging the system.

Based on the simulations, the planned TDS should include a safety factor for design and use a design value of 1200 mg/L to account for uncertainties. If the drought extends into 2017 with no stream flow, then the TDS values will increase, potentially resulting in decreased recovery efficiency from the treatment system.

6.5 Emergency Alternative Recommendation

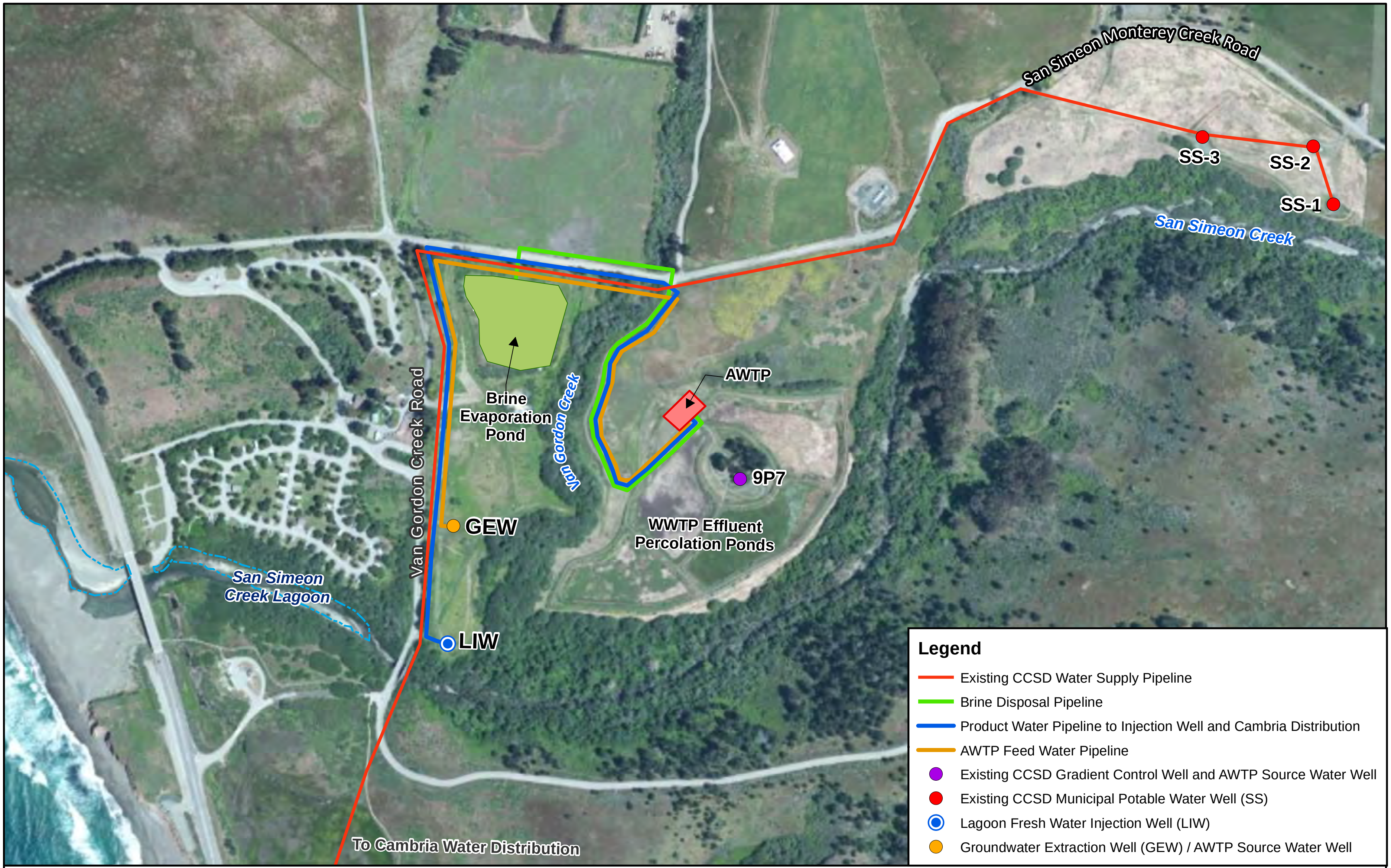
Based on the modeling simulations emergency water supply Alternative 4 is feasible, though there is significant recirculation of the highly treated water. Alternative 3, with a modification to the location of the injection well further up-gradient is also feasible. However, this would require access to property not owned by CCSD.

A key element of this feasibility is the use of an injection well between the CCSD well field and the percolation ponds. Use of this approach allows maintenance of a gradient that protects the well field from impacts from the percolated effluent and brackish water present in the lower basin. Emergency water supply Alternative 4 increases sustainability of the water supply under the current drought conditions, since the previously lost percolated effluent is captured, highly treated, and produced for water supply after appropriate residence time in the aquifer. The brackish water that is pumped from the basin for treatment will be diluted with percolated secondary effluent and a portion of highly treated water that is injected will maintain a protective gradient between the percolation ponds and the potable water well field.

Use of the injection well to create a mound near the freshwater lagoon has limited benefits later in the season as basin water levels are drawn down below the channel invert, precluding discharge of the mounded groundwater to the lagoon. Mitigation would be more effective by discharging the treated water directly in the open channel.

6.7 Conclusions

The modeling analysis indicates that enhancing water supplies for both emergency and long-term conditions is feasible in the San Simeon Creek Basin.



Cambria Emergency Water Supply Project
TO1: Geo-Hydrological Model

Figure 6-1

Emergency Alternative 1 Summary

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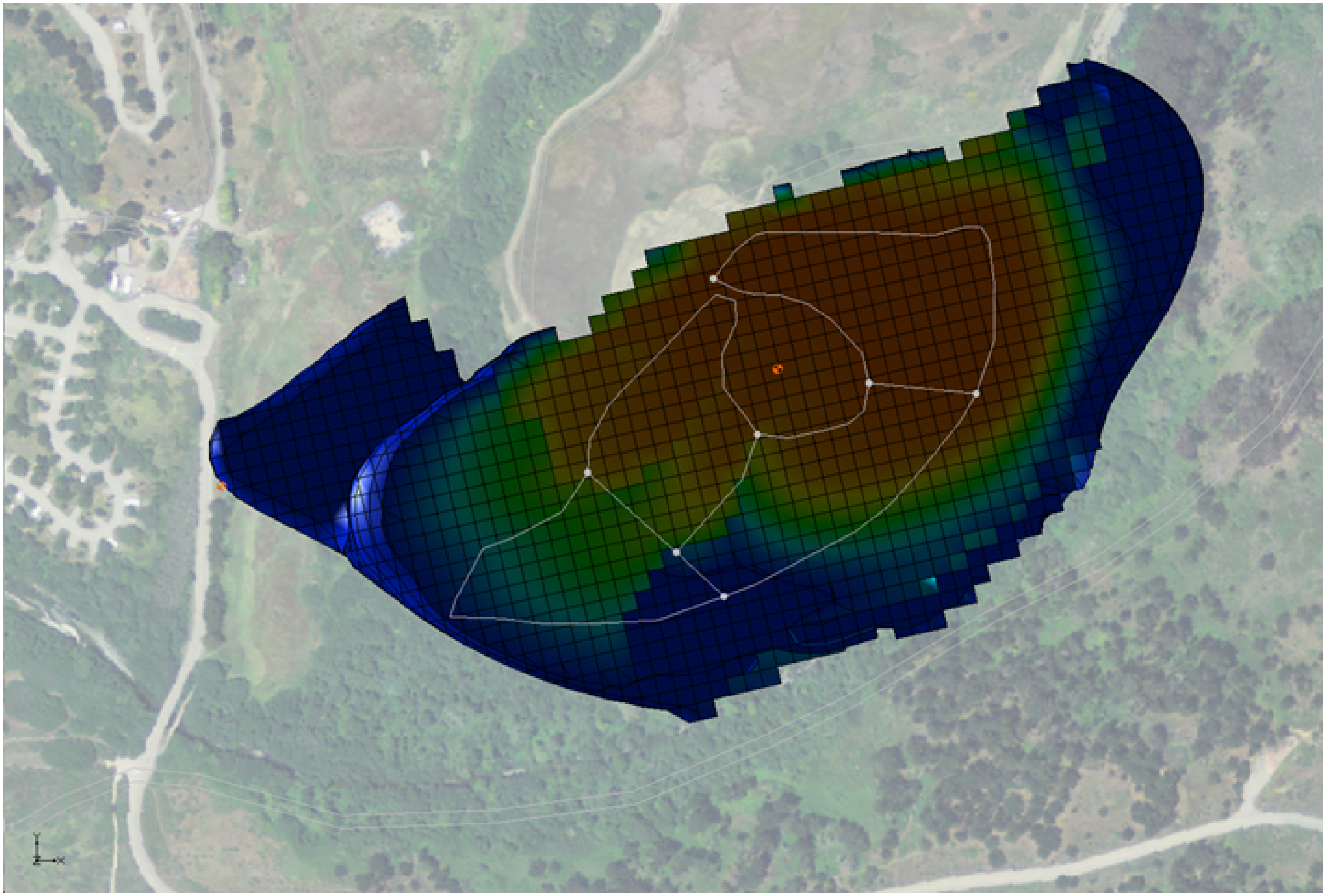

Cambria Emergency Water Supply Project

TO1: Geo-Hydrological Model

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Figure 6-2

Alternative 1: Simulated Extent of Treated Wastewater after 270 days of operation Emergency

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Cambria Emergency Water Supply Project
TO1: Geo-Hydrological Model

Figure 6-3
Emergency Alternative 2 Summary

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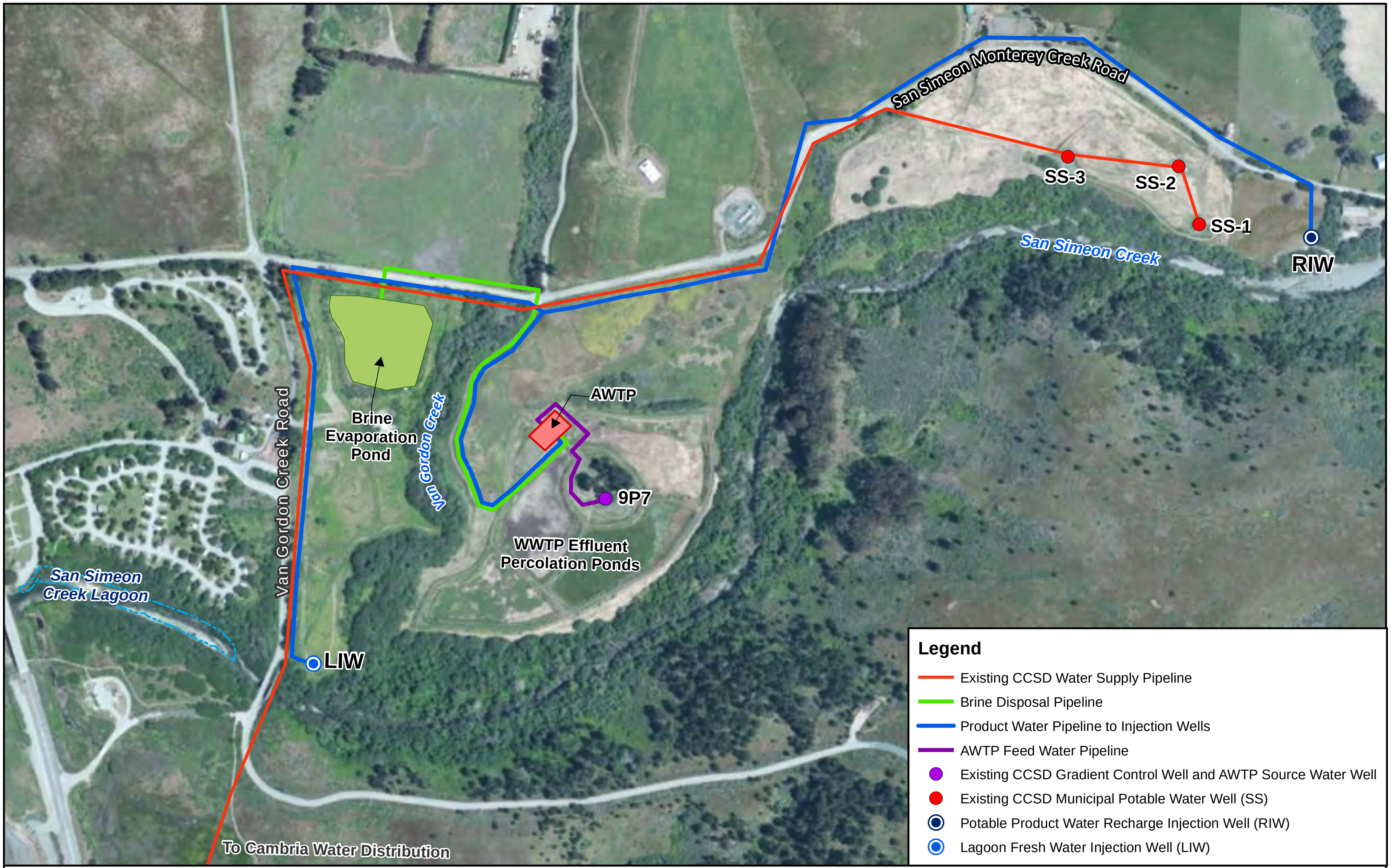

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TO1: Geo-Hydrological Model

Figure 6-4

Emergency Alternative 3 Summary

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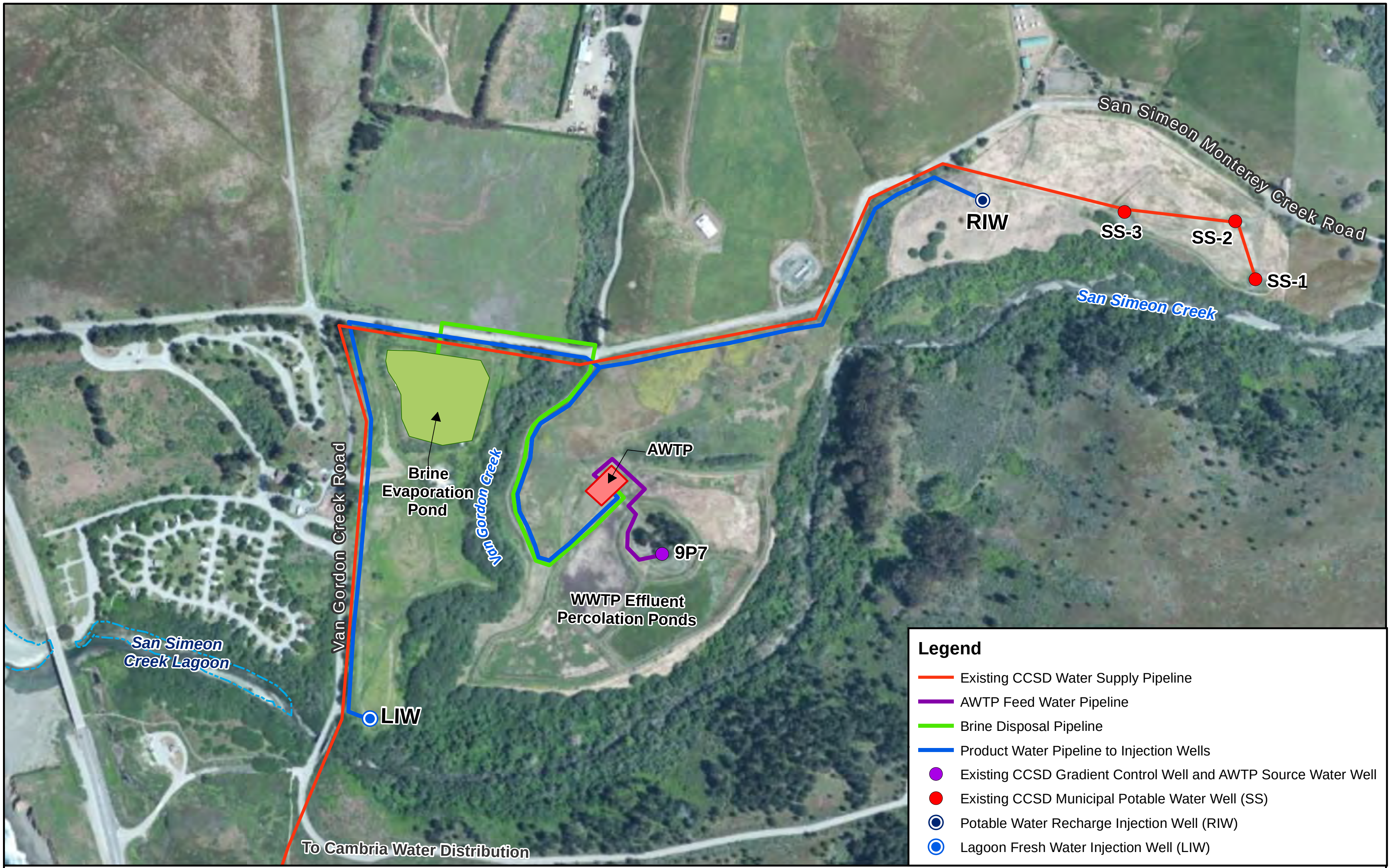

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TO1: Geo-Hydrological Model

Figure 6-5
Emergency Alternative 4 Summary

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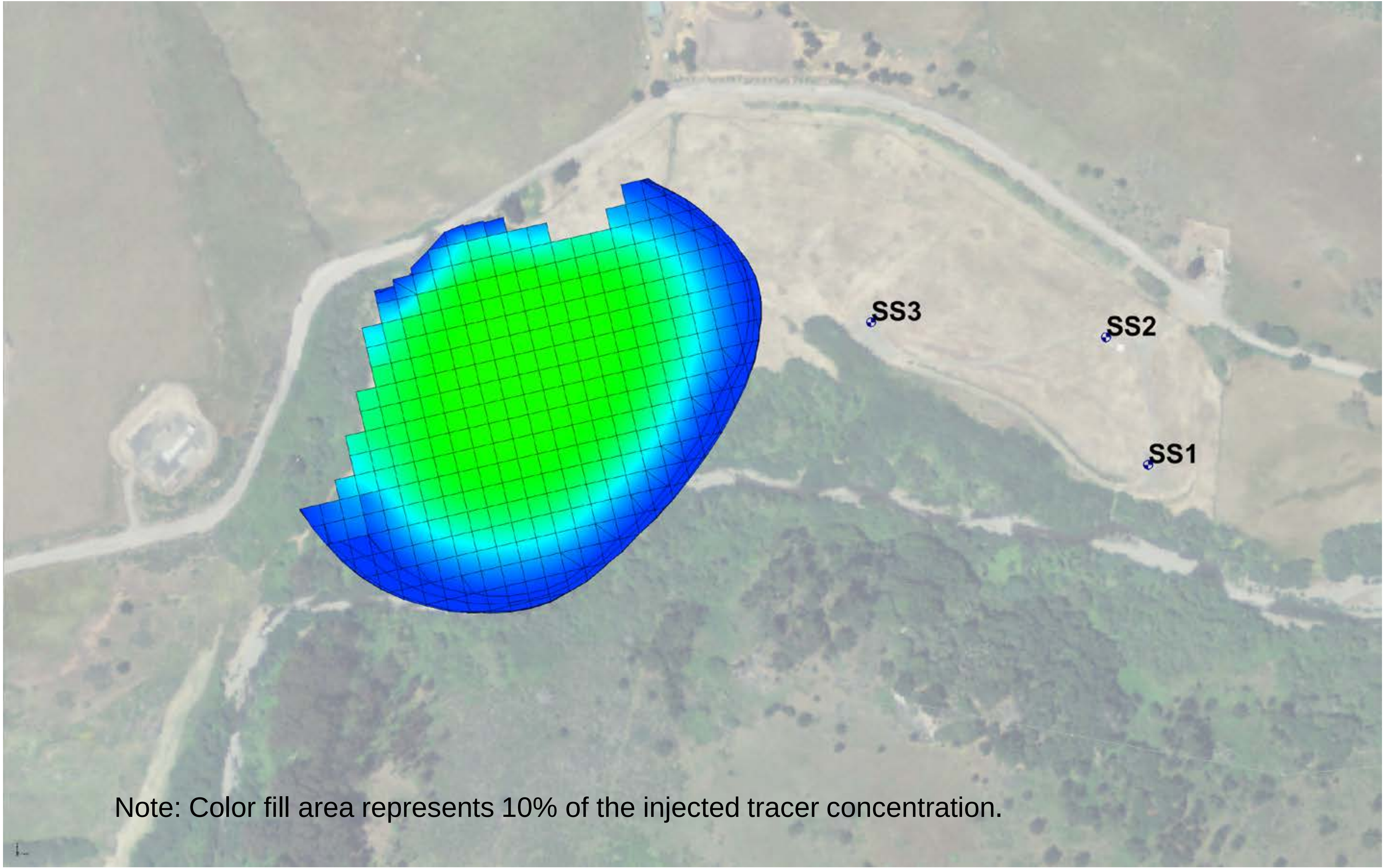

Note: Color fill area represents 10% of the injected tracer concentration.

Cambria Emergency Water Supply Project
TO1: Geo-Hydrological Model

Figure 6-6
Simulated Tracer Extent at 30 Days

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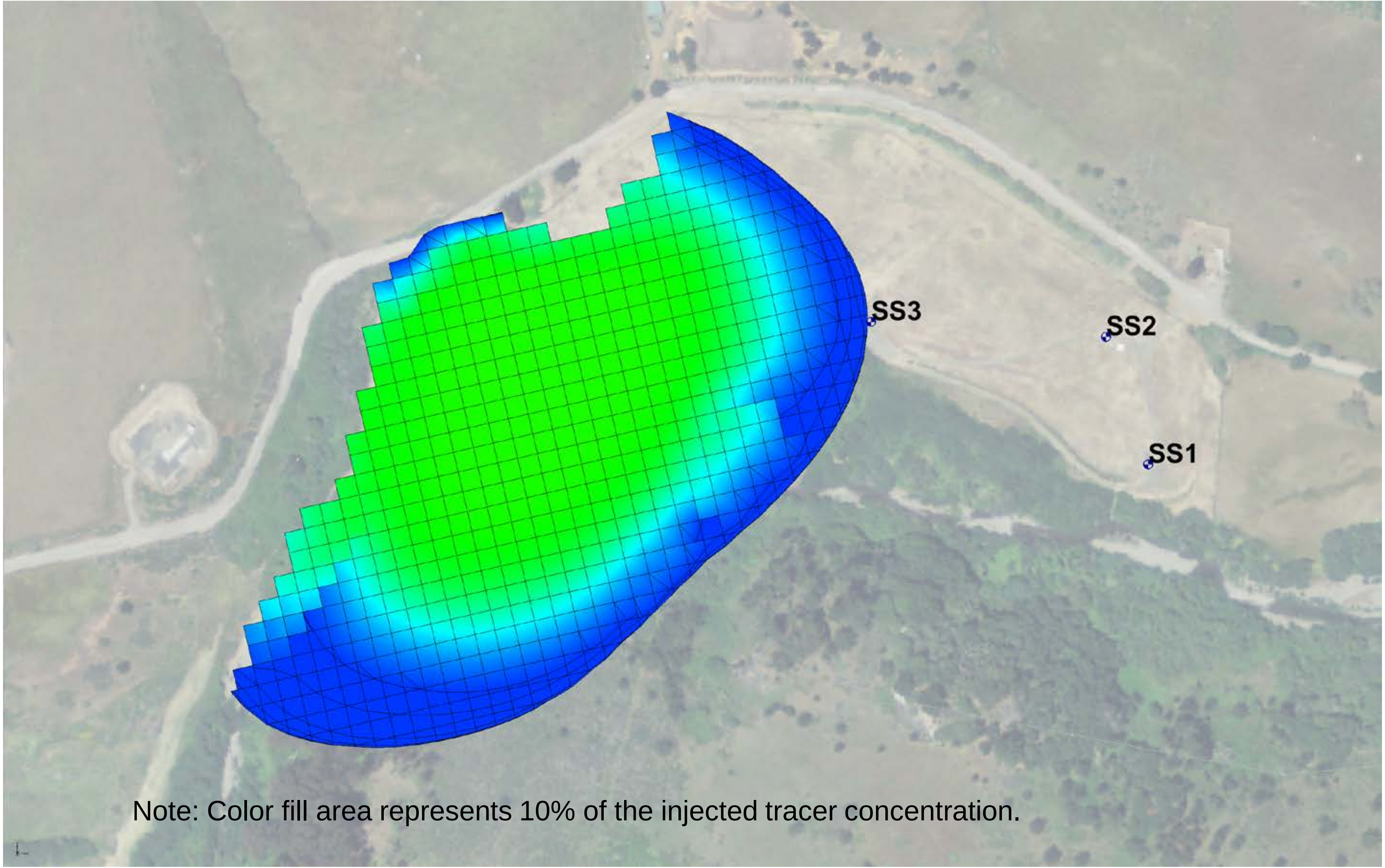

Note: Color fill area represents 10% of the injected tracer concentration.

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TO1: Geo-Hydrological Model

Figure 6-7
Simulated Tracer Extent at 60 Days

CDM Smith

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