# Appendix I
# Groundwater Model Report



LSCE

Draft

# Fresno County Management Areas A & B Numerical Flow Model Report

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**Prepared for**
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## ABBREVIATIONS & ACRONYMS

| | |
|---|---|
| **AFY** | Acre-feet per Year |
| **BAS** | MODFLOW Basic Package |
| **bgs** | Below Ground Surface |
| **BIS** | UC Davis Basic Irrigation Scheduling |
| **CDEC** | California Data Exchange Center |
| **CIMIS** | California Irrigation Management Information |
| **CVHM** | USGS Central Valley Hydrologic Model |
| **CVP** | Central Valley Project |
| **DIS** | MODFLOW Discretization Package |
| **DWR** | California Department of Water Resources |
| **ET** | Evapotranspiration |
| $ET_0$ | Reference Evapotranspiration |
| **ft** | Feet or foot |
| **ft/d** | feet per day |
| **GHB** | General-Head Boundary |
| **GSP** | Groundwater Sustainability Plan |
| **LAK** | Lake Package |
| **LSCE** | Luhdorff & Scalmanini, Consulting Engineers |
| ***MAE*** | Mean absolute error |
| ***ME*** | Mean error |
| **MNW2** | Multi-Node Well |
| **MODFLOW** | Modular three-dimensional finite-difference ground-water flow model |
| **msl** | Above Mean Sea Level |
| ***NRMSE*** | Normalized Root mean squared error |
| ***RMSE*** | Root mean squared error |
| **SFR** | Streamflow Routing Package |
| **SGMA** | Sustainable Groundwater Management Act |

| | |
|---|---|
| **SUB** | Subsidence Package |
| **UPW** | Upstream Weighting Package |
| **USBR** | United States Bureau of Reclamation |
| **USGS** | United States Geological Survey |

## APPENDICES

Appendix A1 – Observed and Simulated Groundwater Level Elevations of Model Calibration Target Wells

# 1 INTRODUCTION

Analytical and numerical groundwater flow models were developed in a coordinated effort among the six GSP groups in the Delta-Mendota Subbasin (DM Subbasin) using the same methodologies to quantify groundwater conditions for the DM Subbasin and local GSP group areas. A numerical flow model (the model) was developed to simulate surface water and groundwater movement in the geographic extent of the Fresno County Management Areas A and B (FCMA) and adjacent areas. The model utilized data that is described in the "Basin Setting" chapter of the GSP Report (LSCE, 2019) to improve the understanding of hydrologic processes and their relationship to key sustainability metrics within FCMA. This Numerical Model Report has been prepared for Fresno County to summarize the development and calibration of the model, as well as the simulation results of the calibrated model.

Numerical groundwater flow models are structured tools developed to represent the physical hydrological settings and simulate groundwater flow by integrating a multitude of data (e.g. lithology, groundwater levels, surface water features, groundwater pumping, etc.) that compose the conceptualization of the natural geologic and hydrogeologic environment. The model of the FCMA was developed in accordance with the best management practices developed by the California Department of Water Resources (DWR, 2016 and 2017). The modeling approach was developed to effectively quantify key hydrologic processes related to SGMA sustainability indicators that may occur or have occurred in FCMA:

1. Lowering of Groundwater Levels
2. Reduction of Groundwater Storage

The integrated hydrologic model code based on the United States Geological Survey's MODFLOW-NWT (Niswonger et al., 2011) was selected as the modeling platform due to its versatility in simulating crop-water demands in the predominantly agricultural setting and groundwater surface-water interaction characteristics in the Subbasin. The model was calibrated to a diverse set of available historical data using industry standard techniques including trial and error and automated parameter estimation. Model sensitivity was evaluated using a mathematically and statistically robust approach provided in UCODE 2014 (Poeter et al., 2014).

# 2 MODEL CODE

The model codes selected for the flow model are in the public domain and suitable for GSP purposes. Below is a brief description of model codes.

## 2.1 MODFLOW-NWT

MODFLOW-NWT (MF-NWT) is an integrated hydrologic flow model developed by the U.S. Geological Survey (USGS) to evaluate groundwater-surface water interaction and conjunctive use (Niswonger et al., 2011). MF-NWT integrates various processes and packages to enable the robust and dynamic simulation of supply-and-demand agricultural water budgets, surface water, and groundwater flow.

## 2.2 Model Packages

The components utilized in the flow model (model packages) are described below.

***Basic Package:*** The MODFLOW Basic (BAS) package specifies the location of active and inactive model cells and initial heads used at the start of the simulation.

***Discretization Package:*** The MODFLOW Discretization (DIS) package specifies the spatial and temporal model geometry. The spatial discretization includes the row and column spacing and model cell top and bottom elevations. The temporal discretization includes the number and length of model stress periods and timesteps. A MODFLOW stress period is a length of time where specified model stresses are constant. A stress period may be broken up into one or more timesteps for which flow equations are solved.

***Output Control Package:*** The Output Control (OC) package specifies the printing of simulated groundwater heads and volumetric budget.

***Newton Solver:*** The Newton Solver (NWT) package is used to solve the system of hydrologic equations governing groundwater flow and groundwater-surface water interaction. The NWT package is used in models where there are a substantial number of dry cells (hydraulic head is below the cell bottom) within the model.

***Upstream Weighting Package:*** The Upstream Weighting (UPW) package specifies the hydraulic properties within model cells. These include the horizontal hydraulic conductivity, vertical hydraulic conductivity, specific yield and specific storage.

***Subsidence Package:*** The Subsidence (SUB) package is used to simulate changes in groundwater storage and compaction of aquifer systems. The SUB package accounts for storage changes due to the deformation of the aquifer system in confined aquifers, while the UPW package accounts for storage changes due to specific yield and the compressibility of water.

***Multi-Node Well Package:*** The Multi-Node Well (MNW2) package is a head dependent flux boundary condition used to simulate pumping from wells which penetrate multiple model cells vertically.

***Well Package:*** The Well (WEL) package is a head dependent flux boundary condition used to simulate pumping in wells that are completed in one model layer.

***General-Head Boundary Package:*** The General-Head Boundary (GHB) package is a head dependent flux boundary condition used in this model to simulate lateral subsurface flow into and out of the model domain. The flux between a model cell and GHB cell is calculated based on the hydraulic head in the model and GHB cell and conductance specified between them.

***Streamflow Routing Package:*** The Streamflow Routing (SFR) package is used to simulate streams and groundwater-surface water interaction in the model.

***Lake Package:*** The Lake (LAK) package is used to simulate lakes and exchange between lakes and groundwater in the model. The LAK package also allows for interaction with streams within the model domain.

## 2.3 Parameter Estimation

Parameter estimation was conducted using UCODE 2014 (Poeter et al., 2014). UCODE is a parameter estimation code that calculates model parameter which minimize the model error (i.e., difference between observed data and simulated values). This is achieved using modified Gauss-Newton iteration (Marquardt-Levenberg method) which minimizes the least squares objective function value *(Sb).*

As part of the parameter estimation process, the sensitivity of the simulated values is calculated (Hill and Tiedman, 2007). The sensitivity of all (or groups) of simulated parameters are summarized by the “composite scaled sensitivity” (CSS). The CSS is used to determine which parameters are most sensitive (those with higher CSS influence the model results to a greater degree) and provides a statistically robust approach to model sensitivity analysis (Hill and Tiedman, 2007).

# 3 DISCRETIZATION

The discretization of the model describes the spatial extent of the modeled area, the model layering, model cell size, and the temporal element of the model. The discretization of the model focused on creating a model structure that would allow the model to simulate groundwater conditions on a scale of subareas that larger than approximately 100 acres within a subbasin with sufficient detail and resolution that is balanced by the length of time (run time) for each model run.

## 3.1 Spatial Discretization and Model Layering

The groundwater model domain includes an approximately 388 square mile rectangular portion of the western San Joaquin Valley encompassing parts of Delta-Mendota (157 sq. mile), Madera (117 sq. mile), Kings (79 sq. mile), Westside (33 sq. mile) and Chowchilla (2 sq. mile) subbasins (**Figure 3-1**). The model domain boundary was located at a minimum distance of about two miles to south and southwest sides from FCMA boundaries, and six miles to other sides. This buffer zone allows to identify hydrological interactions between FCMA and adjacent subareas under various simulated conditions. The model domain was discretized onto an orthogonal finite difference grid composed of 245 rows, 228 columns and 9 layers (**Figure 3-2**). Each grid cell is a 440 ft x 440 ft square. The top elevation of the model was based on the land surface as determined by a 10-meter digital elevation model developed by the USGS. The bottom of the model domain was initially set as the base of post-Eocene continental deposits and base of fresh water taken from the Central Valley Hydrologic Model (Faunt, et al., 2009).

Vertical discretization of 9 layers was primarily determined by the location and extent of lacustrine deposits including the A- Clay, B-Clay and Corcoran Clay (Croft and Gordon, 1968; Croft 1972). Model layers 1 and 2 represent the uppermost unconfined portions (shallow zone) of the upper aquifer deposited above the A-Clay where present. Model layer 1 is used to assign boundary conditions representing major natural surface water features and its thickness ranges from about 12 to 40 feet. Thickness of Layer 2 ranges from about 33 to 102 feet. Layer 3 is used to represent the A-clay or A-clay equivalent and is approximately to 18 ft thick. The top elevation of Layer 3 was estimated based on the top elevation of the A-clay, which generally occurs between 20 and 80 ft, above mean sea level (msl) or up to 125 ft bgs as determined by DWR Well Completion Reports, geophysical logs, and land surface elevations (**Figure 3-3**). Beyond the extent of the A-clay, the top of layer 3 follows the slope of the land surface. The deep zone of the upper aquifer is represented by model layers 4 through 6. Layers 4 and 6 represent the upper and lower portions of the deep zone, extending from the bottom of the A-clay or A-clay equivalent to the top of the Corcoran Clay. Layer 5 is about 20 ft thick and is used to represent the C-clay or C-clay equivalent, which bisects the deep zone in some areas, where this clay is present (**Figure 3-4**).The thickness of the deep aquifer zone as represented by model layers 4 and 6 range from about 80 to 455 ft.

Layer 7 is used to represent the Corcoran Clay which ranges in thickness from approximately 8 to 90 ft in areas where this clay exists. The thickest portion of the Corcoran Clay is in the northwestern portion of the model domain and it thins to the southeastern portion of the domain(. The thickness of this layer was estimated from available DWR Well Completion Reports and geophysical logs available throughout the model domain. The depth to the top of the Corcorcan Clay in the model domain ranges from 190 to 560 ft, bgs. Layers 8 and 9 are used to represent the lower aquifer that underlies the Corcoran Clay (**Figure 3-5**). Layer 8 extends from the bottom of the Corcoran Clay to a thickness of about 195 to 685 ft (elevation of 700 ft below sea level or the maximum presumed depth of groundwater pumping). Layer 9 is included as a buffer between the bottom of layer 8 and the bottom of the model domain and may intersect the base of fresh water in some areas. Layer 9 ranges from 5 to 460 ft thick (-705 ft to -1160 ft, msl) and dips to the southwest. The bottom elevation of layer 9 corresponds to the bottom of layer 8 in the CVHM (Faunt et al., 2009). The minimum, maximum and mean thicknesses of model layers are given in **Table 3-1**.

Model layers in MODFLOW-NWT can be assigned as either confined (storage coefficient and transmissivity do not vary) or unconfined (storage coefficient and transmissivity dependent on saturated thickness). Model layers 1 through 6 are designated as unconfined while layers 7 through 9 are designated as confined.

**Table 3-1: Thicknesses of Model Layers**

| Layer Number | Within Entire Model Domain (ft) | | | Within FCMA (ft) | | |
|---|---|---|---|---|---|---|
| | Minimum | Maximum | Mean | Minimum | Maximum | Mean |
| **1** | 12 | 40 | 34 | 16 | 37 | 31 |
| **2** | 33 | 102 | 54 | 43 | 102 | 86 |
| **3** | 17 | 19 | 18 | 18 | 19 | 18 |
| **4** | 68 | 122 | 91 | 91 | 122 | 94 |
| **5** | 20 | 21 | 20 | 20 | 20 | 20 |
| **6** | 11 | 323 | 153 | 170 | 305 | 203 |
| **7** | 8 | 89 | 40 | 22 | 60 | 41 |
| **8** | 246 | 684 | 464 | 249 | 396 | 366 |
| **9** | 5 | 464 | 270 | 323 | 451 | 372 |

## 3.2 Temporal Discretization

The groundwater model was used to calculate a water budget over three different time periods: historic (2003-2012), current (2013), and projected (2014-2070). The historic period was selected to meet the minimum 10-year GSP requirement and the current water year of 2013 was selected based on the availability of data for other GSP groups in the Subbasin and it follows the historic water budget period. Two model runs were developed for the projected period; a baseline run with comparable historic conditions, and a modified version of the baseline run that incorporated climate change factors provided by DWR (**DWR, 2018**) on rainfall, evapotranspiration, and streamflow.

Historic, current, and projected simulation periods were divided into 120, 12, and 684 monthly stress periods, respectively. Specified conditions such as groundwater pumpage, precipitation, evapotranspiration, surface water flows, surface water deliveries, and general head boundary conditions remain constant within each stress period and vary between stress periods. Each stress period is divided evenly into two timesteps where the flow equations are solved by the model.

# 4 BOUNDARY CONDITIONS

Boundary conditions specified in the model are general head conditions (groundwater levels immediately outside of the model domain), groundwater pumping, surface water flows (streams, canals and lakes) and recharge of groundwater from rainfall, irrigation water and artificial recharge facilities. Actual data were used to develop boundary conditions for the 2003 through 2017 period.

Climatic observations of 1979 through 2017 and 1965 through 1978 were sequentially used to represent expected conditions of 2018 through 2056 and 2057 through 2070, respectively (**Table 4-1**). General head conditions and surface water deliveries for irrigation observed in representative historical water years (2010, 2011 and 2013 for average, wet and dry years, respectively) were assigned to corresponding type of water years in 2018-2070 period. Water year types were determined using the San Joaquin River Index (SJR Index) developed by DWR (http://cdec.water.ca.gov/water_supply.html). Available annual land use data were used to estimate irrigation water demands when needed during 2000-2012 period, and 2013 land use data were used for this estimation for 2013 and later years. Water year types in simulation periods are given in **Tables 4-1 and 4-2**.

**Table 4-1: Water Year Types in Delta-Mendota Subbasin for Historic and Current Simulation Periods**

| Year | SJR Index | Year Type |
|---|---|---|
| 2003 | Below Normal | Normal |
| 2004 | Dry | Dry |
| 2005 | Wet | Wet |
| 2006 | Wet | Wet |
| 2007 | Critical | Dry |
| 2008 | Critical | Dry |
| 2009 | Below Normal | Normal |
| 2010 | Above Normal | Normal |
| 2011 | Wet | Wet |
| 2012 | Dry | Dry |
| 2013 | Critical | Dry |



**Table 4-2: Water Year Types in Delta-Mendota Subbasin for Projected Simulation Period**

| Projected Year | Corresponding Historic Year | SJR Index | Year Type |
|---|---|---|---|
| 2014 | 2014 | Critical | Dry |
| 2015 | 2015 | Critical | Dry |

| | | | |
|---|---|---|---|
| 2016 | 2016 | Dry | Dry |
| 2017 | 2017 | Wet | Wet |
| 2018 | 1979 | Above Normal | Normal |
| 2019 | 1980 | Wet | Wet |
| 2020 | 1981 | Dry | Dry |
| 2021 | 1982 | Wet | Wet |
| 2022 | 1983 | Wet | Wet |
| 2023 | 1984 | Above Normal | Normal |
| 2024 | 1985 | Dry | Dry |
| 2025 | 1986 | Wet | Wet |
| 2026 | 1987 | Critical | Dry |
| 2027 | 1988 | Critical | Dry |
| 2028 | 1989 | Critical | Dry |
| 2029 | 1990 | Critical | Dry |
| 2030 | 1991 | Critical | Dry |
| 2031 | 1992 | Critical | Dry |
| 2032 | 1993 | Wet | Wet |
| 2033 | 1994 | Critical | Dry |
| 2034 | 1995 | Wet | Wet |
| 2035 | 1996 | Wet | Wet |
| 2036 | 1997 | Wet | Wet |
| 2037 | 1998 | Wet | Wet |
| 2038 | 1999 | Above Normal | Normal |
| 2039 | 2000 | Above Normal | Normal |
| 2040 | 2001 | Dry | Dry |
| 2041 | 2002 | Dry | Dry |
| 2042 | 2003 | Below Normal | Normal |
| 2043 | 2004 | Dry | Dry |
| 2044 | 2005 | Wet | Wet |
| 2045 | 2006 | Wet | Wet |
| 2046 | 2007 | Critical | Dry |
| 2047 | 2008 | Critical | Dry |
| 2048 | 2009 | Below Normal | Normal |
| 2049 | 2010 | Above Normal | Normal |
| 2050 | 2011 | Wet | Wet |
| 2051 | 2012 | Dry | Dry |
| 2052 | 2013 | Critical | Dry |
| 2053 | 2014 | Critical | Dry |
| 2054 | 2015 | Critical | Dry |
| 2055 | 2016 | Dry | Dry |

| | | | |
|---|---|---|---|
| 2056 | 2017 | Wet | Wet |
| 2057 | 1965 | Wet | Wet |
| 2058 | 1966 | Below Normal | Normal |
| 2059 | 1967 | Wet | Wet |
| 2060 | 1968 | Dry | Dry |
| 2061 | 1969 | Wet | Wet |
| 2062 | 1970 | Above Normal | Normal |
| 2063 | 1971 | Below Normal | Normal |
| 2064 | 1972 | Dry | Dry |
| 2065 | 1973 | Above Normal | Normal |
| 2066 | 1974 | Wet | Wet |
| 2067 | 1975 | Wet | Wet |
| 2068 | 1976 | Critical | Dry |
| 2069 | 1977 | Critical | Dry |
| 2070 | 1978 | Wet | Wet |

## 4.1 General Head Boundary Condition

Flow model requires that the hydraulic heads immediately outside the model boundary (general head) are specified for all stress periods. These general head conditions affect the subsurface flow into and out of the model domain. Assigned general head values varied spatially (both laterally and vertically) and temporally. They were estimated using publicly available historical groundwater level data and data that LSCE had received from local entities.

Initial (i.e., at the beginning of flow simulation) hydraulic heads within the model domain, which are required to simulate flow in subsequent stress periods, were taken from the results of a calibrated model that simulated flow in the same area.

## 4.2 Groundwater Pumping

Groundwater is extracted to make up the estimated irrigation demand of crops that is not met by surface water and precipitation in each GSA zone. In addition, GSAs that belongs to MPG extracts groundwater to transfer to other GSAs in MPG (transfer pumping). Reliable information on location and construction of existing groundwater pumping wells in FCMA and some adjacent local entities was available. This information was used to place model wells, including the model layers where each well was screened. An approximately one-mile grid of virtual wells was used to simulate groundwater pumping in areas where sufficient information on existing wells was not available. Screen depths of virtual wells in different localities were determined after evaluating available well completion reports.

The same set of model wells (both actual and virtual wells) were used in historical, current and projected simulations. The model did not have pumping wells in Mendota Wildlife Area.

### 4.2.1 Known Pumping

For the simulations of historic and current periods, known groundwater pumping (for irrigation and transfer) was assigned to known wells in areas where relatively reliable records of pumping were available on monthly basis. In addition to MPG lands, these areas included portions of the CCID, Columbia Canal Company, New Columbia Ranch, and Meyers Farms.

### 4.2.2 Estimation of Unknown Pumping

For areas where groundwater pumping data was not available for historic and current simulation periods, required amount of groundwater for irrigation was estimated employing a water budget approach. Crop water demand of a model cell ($D_{crop}$) is equal to the product of effective crop coefficient of the cell ($KC_{cell}$) and reference evapotranspiration ($ET_0$). The amount of groundwater required to satisfy the crop water demand that was not met by precipitation and surface water deliveries was then calculated assuming an irrigation efficiency of 80%. Estimated groundwater demand of each model cell was then assigned to the nearest well to the centroid of that cell, provided that the well and model cell are located within the same local entity.
Total transfer pumping volume of the FCMA was set constant at 11,440 AFY throughout the projected period, and it was distributed between wells similar to the actual distribution in 2014-2016 period. This value was obtained after considering the annual transfer pumping average of 21,053 AFY contributed by all Mendota Pool Group entities (**USBR & WWD, 2018**), and historical contribution ratios by FCMA and FWD. Furthermore, extraction of water from Meyers Water Bank was active only during dry years of the projected period at a rate of 7,175 AFY.

Below is a brief description of parameters used to estimate the groundwater demand for irrigation.

#### ***Precipitation***

Rainfall data was specified at each model cell for each stress period within each simulation period. Monthly precipitation data for the 1980-2017 period was taken from the PRISM Climate Group at Oregon State University (http://prism.oregonstate.edu/) at a spatial resolution of 2km x 2km. Precipitation values for the 1965-1979 period was taken from representative water years selected from the 1980-2017 period. Representative years were identified by comparing the total annual precipitations of recorded at Mendota and Madera rain gages (California Data Exchange Center Station ID “MEN” and “MDR”, respectively) for the two periods. The PRISM data was gridded and assigned to model cells based on whether the center of the model cell falls within each PRISM precipitation data cell (**Figure 4-1**).

### *Surface Water Deliveries*

Imported water is used for irrigation in Coehlo Family Trust area in FCMA. Furthermore, Mendota Wildlife Area (MWA) receives surface water from Central Valley Project (CVP) through Mendota Pool and San Luis Canal. Imported surface water received by the entities located within the model domain through CVP were obtained from monthly delivery data published by USBR Central Valley Operations (https://www.usbr.gov/mp/cvo/deliv.html). Entities that partially fall within the model domain was assigned a portion of the delivered water volume based on the area located within the model domain. Surface water deliveries observed in representative water were assigned to corresponding type of water years in 2018-2070 period.

### *Land Use*

Estimation of irrigation water demand for the historic period (2003-2012) was based on land surface characteristics that existed in this period on annual basis, while that for the current and projected periods was based on land surface characteristics of 2013. Land surface characteristics of the model domain were established after reviewing several land use data sources (DWR land use surveys - Fresno County 2000, Eastern Fresno County 2009, Land IQ 2014) and satellite imageries obtained from USDA National Agricultural Statistics Service (NASS) and Google Earth. Irrigated and non-irrigated lands were determined using the DWR land use descriptions and visual observation of Google Earth satellite imageries (**Figures 4-2 and 4-3**).

### *Reference Evapotranspiration*

For a given stress period of the simulation (a period of one month), one reference evapotranspiration ($ET_0$) value was used for the entire model domain. This value was estimated from data available from two weather stations managed by the California Irrigation Management Information System (CIMIS). Monthly $ET_0$ of the model domain was set at that measured at Firebaugh/Telles station (Station ID 7) for the period of 1982 – 1991, and at the average of values measured at Westlands (Station ID 105) and Firebaugh/Telles stations for the 1992 – 2017 period. For the years prior to 1982, monthly $ET_0$ values were estimated using Fresno County monthly ET (from NOAA - Station ID USC00043261) based on simple linear regressions between NOAA data and CIMIS data.

### *Crop coefficients*

The crop coefficient of a particular landcover type can vary with time as a function of growth stage of crops. Crop coefficients for different land surface characteristics, including non-irrigated lands such as bare ground, barren/fallow lands and natural vegetation, were calculated based on the UC Davis Basic

Irrigation Scheduling (BIS) application developed by Snyder et al. (2000, 2008) at monthly frequency. Values for the crops that were not provided in the BIS were taken from Allen et al. (1998), if available. For the remaining crops, values were approximated based on comparable crops available in BIS or Allen et al. (1998). For model cells that contained multiple landcover types, an area-weighted crop coefficient ($KC_{cell}$) was calculated.

Evapotranspiration of a model cell calculated using $KC_{cell}$ was used to estimate the evapotranspiration and deep percolation components of precipitation. In order to determine the water demand of irrigated crops, an "effective crop coefficient" was calculated by setting the crop coefficient to zero for non-irrigated landcover types (e.g., fallow lands, pasture) and non-irrigated months of irrigated crops (e.g., time between the end of one growing season and the start of next growing season of a crop).

## 4.3 Areal Recharge

Areal recharge in the model was simulated using the Recharge (RCH) Package. Components of recharge that were simulated included recharge from precipitation, irrigation, and recharge facilities in the Meyers Water Bank, New Columbia Ranch, and Terra Linda Farms.

Precipitation that exceeds the crop water demand of a model cell at a given stress period was assumed to percolate to groundwater (i.e., no surface runoff from precipitation). It was also assumed that 20% of applied irrigation water and 30% of any known surface water supplies that exceeded irrigation demand during a particular stress period percolates into groundwater aquifers.

Water is diverted to Meyers Farm recharge ponds (Meyers Water Bank) and Terra Linda Recharge Canal via the pool during wet years. Meyers Water Bank receives Central Valley Project (CVP) water allocated to Meyers Farm by the San Luis Water District (SLWD), which is delivered to the pool via DMC, and subsequently drawn into the ponds. Percolated water is stored in the shallow aquifer and extracted through shallow wells during dry years. Terra Linda Recharge Canal receives flood flows from the Kings River (via James Bypass/ Fresno Slough). Monthly pond infiltration volumes during historical and current periods were estimated from reported monthly diversions to ponds/canal after adjusting for 4% evaporation. Monthly infiltration volumes for the projected period were estimated based on reported historical data. Surface water delivered to Meyers Recharge Ponds during the projected period was consistent with that of surrogate years (2010, 2011, 2013). Water diversion to Terra Linda Recharge Canal was active only when the total annual rainfall at the Madera rain gage (California Data Exchange Center Station ID "MDR") exceeded 10 inches during projected period. Assigned diversion volumes were consistent with reported diversions of 2011.

## 4.4 Groundwater-Surface Water Interaction

Surface water features were simulated using a combination of the Streamflow Routing (SFR) and Lake (LAK) packages. The SFR package routes the flow between adjacent stream cells, as well as calculates the flow between the stream and underlying aquifer at each model cell. Major streams and canals that were simulated using the SFR package include the SJR, Delta Mendota Canal, Chowchilla Bypass, James Bypass and other major canals that divert water from the Pool (**Figure 4-4**). Flow and stage in these streams and canals were simulated based on known inflow and canal diversion data.

The LAK package was used in conjunction with the SFR package to simulate stage, volume, as well as exchanges between groundwater and surface water within the Mendota Pool and Fresno Slough. Lake bed hydraulic properties were based on previous estimates of seepage amounts from the Pool (KDSA and LSCE, 2000). In the northern branch of the Pool, the assigned lake bed conductance was slightly higher than the Fresno Slough portion of the Pool, because lake bed sediments are likely coarser due to influence from the San Joaquin River. In the northern branch of the Pool, the lake bed conductance was 0.02 ft/per day compared to 0.002 ft/per day in the Fresno Slough branch of the Pool.

### 4.4.1 Stream flow data

The primary surface water features located within the model domain are the San Joaquin River (SJR), Mendota Pool (the Pool), Delta Mendota Canal (DMC), Fresno Slough, James Bypass, Chowchilla Bypass, and other major irrigation canals divert water from the Pool. The Pool receives surface water from the SJR, DMC, and flood flows of Kings River via James Bypass/ Fresno Slough. Furthermore, pumped groundwater is also discharged into the Pool by the MPG and others for exchange and for irrigation of lands adjacent to the Pool using the Pool as a conveyance. Under normal conditions, flow of the Fresno Slough is to the south from the Pool. During flood events of the Kings River, flood flows are directed north into the Fresno Slough portion of the Pool creating a northerly flow. The primary canals that convey water from the northern end of the Pool are the CCID Main Canal, CCID Outside Canal, Firebaugh Intake Canal, and Columbia Canal. Several parties divert water from the southern end of the Pool via Lateral 6 and Lateral 7 canals.

Flow of the SJR measured downstream of Gravelly Ford (USGS #11253058) was used to simulate the flow along its path to the Pool. Any excess flood water beyond the capacity of the SJR is diverted through the Chowchilla Bypass at the SJR bifurcation. The flow between the bifurcation and the Pool is simulated after accounting for diversions, which are measured at the gaging station located downstream of the Chowchilla Bypass intake (USGS #11253115). Flow from the pool to SJR downstream of the Mendota Dam was calculated internally by the groundwater model based on the stage in the Pool and elevation of the Mendota Dam. Flow of James Bypass that is measured near San Joaquin (USGS #11253500, CDEC Station ID - JBP) was used to calculate its flow that enters the Pool. Flow of the DMC was specified based on data available from the San Luis Delta Mendota Water Authority (SLDMWA). Diversions from the Pool to the Firebaugh Canal, CCID Outside Canal, CCID Main Canal, and Columbia Canal were specified based monthly diversion volumes provided by the USBR.

## 4.5 Initial Conditions

Initial conditions define the state of the aquifer system at the beginning of the simulation period. For the historical period of the model, the initial conditions were representative of groundwater elevations existed in October 2002 (i.e, beginning of the water year 2003) within the model domain. Initial conditions were developed for the shallow and deep zones of the upper aquifer (**Figures 4-5 and 4-6**), as well as for the lower aquifer (**Figure 4-7**) using simulation results of a previously developed and calibrated flow model (LSCE, 2018). Available measured groundwater level data of Fall 2002 were compared with simulated water levels for accuracy. Starting times of current and projected simulations were selected in such a way that their initial conditions could be taken from results of the historic and current simulations, respectively.

# 5 AQUIFER PROPERTIES

The hydraulic properties of an aquifer system, primarily the hydraulic conductivity and storage coefficients, control the groundwater flow and storage in it. Hydraulic conductivity is a measure of the ability of a material to transmit water through it. The volume of water which an aquifer can release or take into storage given a unit change in hydraulic head is defined as the storativity (for a confined aquifer) or specific yield (for an unconfined aquifer) of that aquifer.

While aquifer tests were used (where available) to quantify these parameters, values for these parameters are most often assigned using generally acceptable values for the sediment textures or the type of aquifer that is present, and where possible constrained using what limited aquifer test data may be available. In addition, analysis of seasonal variations in groundwater levels, subsurface geology, and well construction features were used in estimating the type of aquifer and storage coefficient in the absence of aquifer test data. Shallow wells that have minimal seasonal variations likely have high storage coefficients (specific yield). Deep wells that have large variations in seasonal water levels likely have low storage coefficients (storativity or specific storage).

## 5.1 Hydraulic Conductivity

Hydraulic conductivity within the model domain was developed following a three-step process and assigned to model cells using the Upstream Weighting (UPW) package. The first step was to utilize the texture analysis methods and data employed by the USGS in developing the CVHM groundwater model (USGS, 2009) to create a geostatistical representation of textures related to the percent of coarse-grained sediments that are present. The second step was to revise the geostatistical representation to more accurately reflect known and estimated depositional trends in the area of the model domain. Thirdly, textures were converted to hydraulic conductivities based on available aquifer test data (65 total tests for the shallow and deep zones within the model domain), CVHM values assigned within the model domain, and a review of literature values. This three-step process provided a comprehensive method for producing a reasonable representation of the distribution of hydraulic conductivity which incorporates lithologic data from relatively abundant DWR Well Completion Reports into a regional geologic framework. Hydraulic conductivities were adjusted as part of the calibration process within ranges of values associated with the observed aquifer materials.

## 5.2 Storage Properties and Aquifer Compaction

Aquifer storage properties and aquifer compaction were simulated using a combination of the Subsidence (SUB) and Upstream Weighting (UPW) packages. The UPW package was used largely to simulate storage changes at the water table. The SUB package was used to simulate aquifer compaction and storage changes occurring in the confined aquifer system.

In an unconfined system, the change in groundwater storage is largely controlled by the specific yield. The specific yield is a dimensionless storage coefficient equal to the ratio of water which an aquifer will yield due to gravity-driven drainage compared to the total bulk aquifer volume. The specific yield is approximately equal to the porosity of a bulk aquifer unit minus some volume of water which remains trapped in the pore spaces due to capillary forces. It is not uncommon for an unconfined aquifer to yield 20 to 30 percent of its total volume in water.

In a confined system, the amount of water a unit volume of aquifer releases or takes up per unit change in hydraulic head is determined by the specific storage. Since the porous medium in a confined aquifer is always saturated, changes in groundwater storage due to changes in hydraulic head are determined by the compressibility/expandability of the pore spaces leading to deformation of the aquifer skeleton and (to a lesser extent) the compressibility of water. Deformation of the aquifer skeleton can occur either elastically (recoverable) or inelastically (permanent) and is dependent on the composition of the aquifer material and the amount of stress (effective stress) within the aquifer. Inelastic deformation occurs when the effective stress within the fine-grained material in an aquifer system exceeds the maximum effective stress leading to permanent changes in the arrangement of grains and is represented by an inelastic specific storage. Elastic deformation occurs when the maximum effective stress is not exceeded and is represented using an elastic specific storage.

The specific yield and compressibility of water were specified in the UPW package. Values for specific yield were assigned to unconfined layers following a review of the CVHM model values used within the model domain and adjusted during model calibration. The compressibility of water ($1.4 \times 10^{-6}$/ft) estimated from previous studies (Faunt et al, 2009), was scaled with respect to the porosity of each model layer and assigned to all model layers as a specific storage.

The SUB package solves for changes in compaction and groundwater storage based on changes in the hydraulic head, the preconsolidation stress (or preconsolidation head in the SUB package), and coefficients governing the elastic and inelastic skeletal storage (Hoffman et al., 2003). The elastic and inelastic skeletal storage properties were assigned in the SUB package. The elastic skeletal specific storage coefficients were estimated for fine- and coarse-grained materials and weighted by the respective fine- and coarse-grained volume fraction for each model layer. The inelastic skeletal specific storage coefficient for each model layer was calculated based on the volume fraction of fine-grained material multiplied by the inelastic specific storage. Initial specific storage values for fine- and coarse-grained materials were estimated from those reported in Faunt et al. (2009) and adjusted during model calibration to extensometer data collected from the Yearout and Fordel extensometers. Preconsolidation head input values were determined from the CVHM preconsolidation head simulations and assigned to each model cell at the beginning of the model simulation period. In instances where the initial groundwater head assigned in the MPG model is less than the preconsolidation head simulated in CVHM, the SUB Package assumed the preconsolidation head is equal to the lower of the two values.

# 6 MODEL CALIBRATION

Model calibration involves the adjustment of input parameters within the constraints of the conceptual model to best represent the hydrogeologic system being simulated. The groundwater flow model was calibrated largely by manually adjusting assigned aquifer parameters to achieve an agreeable fit between simulated and observed water levels at wells located in the model domain. Regional trends in simulated groundwater flow direction also compared to observed trends to qualitatively evaluate model performance. The flow model was calibrated for the period from 2000 through 2013 comparing measured groundwater levels and stream flow with simulation results.

## 6.1 Calibrated Parameter Values

Model calibration focused primarily on adjusting assigned aquifer properties within the model domain. Parameters modified during model calibration process included:

- Aquifer horizontal and vertical hydraulic conductivity
- Elastic and inelastic skeletal storage and specific yield coefficients
- Streambed and lakebed hydraulic conductivity

### 6.1.1 Calibrated Aquifer Hydraulic Conductivity

The horizontal hydraulic conductivity values in the model were adjusted within ranges consistent with observed data and interpretation of aquifer materials. Hydraulic conductivity data from aquifer tests and specific capacity were also used to constrain the range of hydraulic conductivity values. The final calibrated horizontal hydraulic conductivity values ranged from 1.7 x $10^{-3}$ ft/day in the Corcoran clay (model layer 7) to 490 ft/day in layer 3 (**Table 6-1**). Final calibrated vertical hydraulic conductivity values were from approximately one to two orders of magnitude less than the horizontal hydraulic conductivity and ranged from 2.5 x 10-4 ft/day in the Corcoran clay to approximately 50 ft/day in model layers 3, 4, and 6. Calibrated vertical hydraulic conductivity in the A and C clays was 1.7 x $10^{-3}$ ft/day. West of the Fresno Slough, the vertical hydraulic conductivity of the A-Clay was increased to 1.0 x $10^{-2}$ ft/day to better reflect results from well completion reports which suggest that the A-Clay is less continuous in this area. The distribution of final hydraulic conductivity values in the shallow and deep zones of the upper aquifer, lower aquifer and confining layers is presented in **Figures 6-1 through 6-9**.

**Table 6-1: Calibrated Hydraulic Conductivity values in ft/day**

| Parameter | Model Layer(s) | Entire Model Domain (ft/day) | | | FCMA (ft/day) | | |
|---|---|---|---|---|---|---|---|
| | | Minimum | Maximum | Average | Minimum | Maximum | Average |
| Horizontal K | 1,2 | 5.5 X $10^{-1}$ | 2.3 X $10^{2}$ | 9.4 X $10^{1}$ | 4.6 X $10^{1}$ | 2.1 X $10^{2}$ | 8.4 X $10^{1}$ |
| Horizontal K | 3 | 5.4 X $10^{-2}$ | 4.9 X $10^{2}$ | 9.6 X $10^{1}$ | 5.4 X $10^{-2}$ | 1.0 | 2.9 X $10^{-1}$ |
| Horizontal K | 4 | 4.9 X $10^{1}$ | 2.2 X $10^{2}$ | 1.3 X $10^{2}$ | 4.9 X $10^{1}$ | 1.8 X $10^{2}$ | 8.0 X $10^{1}$ |
| Horizontal K | 5 | 3.8 X $10^{-1}$ | 1.0 X $10^{1}$ | 3.7 | 3.8 X $10^{-1}$ | 4.1 X $10^{-1}$ | 3.9 X $10^{-1}$ |
| Horizontal K | 6 | 2.6 X $10^{1}$ | 3.3 X $10^{2}$ | 1.6 X $10^{2}$ | 4.5 X $10^{1}$ | 2.1 X $10^{2}$ | 1.0 X $10^{2}$ |
| Horizontal K | 7 | 1.7 X $10^{-3}$ | 1.7 X $10^{-3}$ | 1.7 X $10^{-3}$ | 1.7 X $10^{-3}$ | 1.7 X $10^{-3}$ | 1.7 X $10^{-3}$ |
| Horizontal K | 8,9 | 8.1 | 1.0 X $10^{2}$ | 4.3 X $10^{1}$ | 1.1 X $10^{1}$ | 7.1 X $10^{1}$ | 2.5 X $10^{1}$ |
| Vertical K | 1,2 | 8.4 X $10^{-2}$ | 3.5 X $10^{1}$ | 1.4 X $10^{1}$ | 7.0 | 3.2 X $10^{1}$ | 1.3 X $10^{1}$ |
| Vertical K | 3 | 1.7 X $10^{-3}$ | 5.1 X $10^{1}$ | 1.0 X $10^{1}$ | 1.7 X $10^{-3}$ | 1.0 X $10^{-1}$ | 2.6 X $10^{-2}$ |
| Vertical K | 4 | 1.1 X $10^{1}$ | 4.9 X $10^{1}$ | 2.7 X $10^{1}$ | 1.1 X $10^{1}$ | 3.8 X $10^{1}$ | 1.8 X $10^{1}$ |
| Vertical K | 5 | 1.7 X $10^{-3}$ | 1.3 X $10^{0}$ | 4.2 X $10^{-1}$ | 1.7 X $10^{-3}$ | 1.7 X $10^{-3}$ | 1.7 X $10^{-3}$ |
| Vertical K | 6 | 4.1 | 5.2 X $10^{1}$ | 2.5 X $10^{1}$ | 7.2 | 3.3 X $10^{1}$ | 1.7 X $10^{1}$ |
| Vertical K | 7 | 2.5 X $10^{-4}$ | 2.5 X $10^{-4}$ | 2.5 X $10^{-4}$ | 2.5 X $10^{-4}$ | 2.5 X $10^{-4}$ | 2.5 X $10^{-4}$ |
| Vertical K | 8,9 | 1.5 | 1.9 X $10^{1}$ | 8.0 | 2.0 | 1.3 X $10^{1}$ | 4.8 |
| Vertical K (A Clay) | 3 | 1.7 X $10^{-3}$ | 1.7 X $10^{-3}$ | 1.7 X $10^{-3}$ | 1.7 X $10^{-3}$ | 1.7 X $10^{-3}$ | 1.7 X $10^{-3}$ |
| Vertical K (C Clay) | 5 | 1.7 X $10^{-3}$ | 1.7 X $10^{-3}$ | 1.7 X $10^{-3}$ | 1.7 X $10^{-3}$ | 1.7 X $10^{-3}$ | 1.7 X $10^{-3}$ |

### 6.1.2 Calibrated Streambed and Lakebed Hydraulic Conductivity

The hydraulic conductivity of the streambed for the San Joaquin River (SJR) and large irrigation canals was adjusted within a probable range of values to match observed discharge in the SJR and hydraulic heads in observation wells near the river and canals.

Calibrated vertical hydraulic conductivity of SJR streambed was 0.25 ft/day while that of the other canals was 5.0 x $10^{-3}$ ft/day (Table XX). Lakebed hydraulic conductivity was estimated by comparing the net seepage from the Pool and Fresno Slough to values previously estimated by KDSA and LSCE (2000). A value of 2.0 x $10^{-3}$ ft/day was used in the Fresno Slough branch of the Pool (**Table 6-2**). The SJR branch of the Pool was assigned a larger value of 2.0 x $10^{-2}$ ft/day to better match observed water levels in shallow wells in the area and because it is presumed that coarser sediments are present in this portion of Pool as compared to the Fresno Slough branch of the Pool, thereby resulting in a larger value.

**Table 6-2: Calibrated Streambed and Lakebed Hydraulic Conductivity Values**

| Surface Water Feature | Hydraulic Conductivity (ft/day) |
|---|---|
| San Joaquin River | $2.5 \times 10^{-1}$ |
| Canals | $5.0 \times 10^{-3}$ |
| Mendota Pool | $2.0 \times 10^{-3}$ to $2.0 \times 10^{-2}$ |

### 6.1.3 Calibrated Storage Coefficients

Storage coefficients assigned to the models included specific yield and inelastic and elastic specific storage. The values for these parameters were adjusted to match observed water levels and compaction above the Corcoran Clay. Calibrated specific yield ranged from 0.18 to 0.31 (**Table 6-3**). Elastic skeletal specific storage assigned to fine-grained material was $1.0 \times 10^{-6}$ per foot while elastic skeletal specific storage assigned to coarse-grained material was $5.5 \times 10^{-6}$ per foot. Inelastic skeletal specific storage was $1.6 \times 10^{-4}$ per foot. Calibrated inelastic specific storage was consistent with values assigned in previous studies (Faunt et al., 2009). Elastic specific storage values were greater than those used in CVHM in order to match observed compaction at extensometer sites, however, water levels in confined layers were not sensitive to this change.

**Table 6-3: Calibrated Aquifer Storage Coefficient Values**

| Parameter | Layer(s) | Calibrated Value |
|---|---|---|
| Specific Yield | 1,2,3 | 0.24 – 0.31 |
| Specific Yield | 4 | 0.18 |
| Specific Yield | 5 | 0.18 – 0.29 |
| Specific Yield | 6 | 0.20 |
| Specific Storage - Elastic (per ft) | 7 | $1.0 \times 10^{-05}$ |
| Specific Storage - Elastic (per ft) | 8,9 | $8.8 \times 10^{-06}$ |
| Specific Storage - Inelastic (per ft) | 7 | $1.6 \times 10^{-04}$ |
| Specific Storage - Inelastic (per ft) | 8,9 | $1.2 \times 10^{-04}$ |

## 6.2 Model Calibration Targets

The groundwater flow model was calibrated to measured groundwater level elevations, streamflow, and compaction above the Corcoran Clay.

### 6.2.1 Groundwater Levels

A total of 6,403 measured groundwater levels at 117 dedicated monitoring and production wells were used as the primary source of information used to calibrate the groundwater flow model. Sources of water level data include wells monitored by the MPG and other entities such as the USGS, DWR, and USBR. While an effort was made to rely on observations from wells screened in only discrete intervals in one model layer, wells screened over two model layers were used in some cases where available data were limited. Observations are generally concentrated near FCMA and surrounding areas where well construction information and consistent records of water level measurements were available for the calibration period (**Figures 6-10, 6-11, and 6-12**). The water level data was predominantly available for wells constructed in the shallow and deep zones of the upper aquifer, while a limited amount of data was available for the lower aquifer. This resulted in the model calibration effort focusing on the upper aquifer while less focus was provided to the lower aquifer.

### 6.2.2 Streamflow

The simulated values of flow from the pool to SJR downstream of the Mendota Dam were compared with measured flow at the USGS stream gage at San Joaquin River near Mendota Dam (USGS #11254000) for calibration (**Figure 4-4**).

### 6.2.3 Subsidence

The compaction data collected at two extensometers in the Mendota area; the Fordel extensometer located west of the Fresno Slough and the Yearout Ranch extensometer located east of the Slough, were used to calibrate the simulated compaction of the flow model (**Figure 6-13**). Both extensometers monitor compaction above the Corcoran Clay, the top of which was encountered at depths of 418 and 428 ft at the Fordel and Yearout Ranch sites, respectively.

### 6.2.4 Evaluation of Calibration

Model calibration was evaluated through four common statistics used to characterize model fit. These include the mean error (ME), mean absolute error (MAE), Root Mean Squared Error (RMSE), and the Normalized RMSE (NRMSE).

The mean error (ME), or model bias, is a measure of the overall tendency of the model to over-predict (-) or under-predict (+) measured values (Belitz and Phillips, 1993; Anderson and Woessner, 1992). The mean absolute error (MAE) is a measure of model accuracy calculated as the average magnitude of the error between observed and simulated values (Anderson and Woessner, 1992). The root mean square error (RMSE) is also a common measure of model accuracy quantifying the standard error (Anderson and Woessner, 1992). The normalized root mean squared error (NRMSE) is calculated to account for the scale dependency of the RMSE and is a measure of the RMSE divided by the range of observations (Anderson and Woessner, 1992).

Flow model calibration statistics are given in **Table 6-4**. Figure **6-14** shows the simulated vs observed groundwater levels at model calibration target wells, while the timeseries data of simulated and observed water level (groundwater level calibration hydrographs) are presented in **Appendix A1**. **Figure 6-15** shows observed and simulated values of SJR flow downstream of Mendota Dam. Observed and simulated compaction above the Corcoran Clay at Fordel and Yearout Ranch Extensometers are shown in **Figures 6-16 and 6-17**, respectively.

### Table 6-4: Groundwater Flow Model Calibration Statistics

| Aquifer Depth Zone | Number of Wells | Number of Observations | ME (ft) | MAE (ft) | RMSE (ft) | NRMSE |
|---|---|---|---|---|---|---|
| Shallow | 64 | 4,110 | -4.5 | 8.5 | 10.5 | 7.8% |
| Deep | 46 | 2,038 | -2.5 | 10.1 | 13.1 | 9.8% |
| Lower | 6 | 255 | -7.9 | 15.5 | 22.2 | 14.8% |
| All | 116 | 6,403 | -4.0 | 9.3 | 12.0 | 6.2% |

# 7 MODEL UNCERTAINTY AND LIMITATIONS

Any groundwater flow model is a simplification of the natural environment, and therefore has recognized limitations. For this reason, some uncertainty exists in the ability of any numerical model to completely represent the groundwater flow in the natural environment. Considerable effort was expended to minimize model uncertainty by using measured values as model inputs whenever available, and by conducting numerous quality assurance and quality control assessments of data that were available of various sources.

Where availability of data is limited (spatially or temporally) to develop model input parameter datasets, conservative values were chosen for input parameters with high uncertainty. This is no warranty expressed or implied that this modeling study has considered or addresses all hydrogeological, hydrological, environmental, geotechnical or other characteristics and properties associated with the subject model domain and the simulated system. The finding and conclusions of this study are focused on a Subbasin-scale, and representation of site-scale conditions in the model may be approximate. The flow and transport models were developed in a manner consistent with the level of care and skill normally exercised by professionals practicing under similar conditions in the area.

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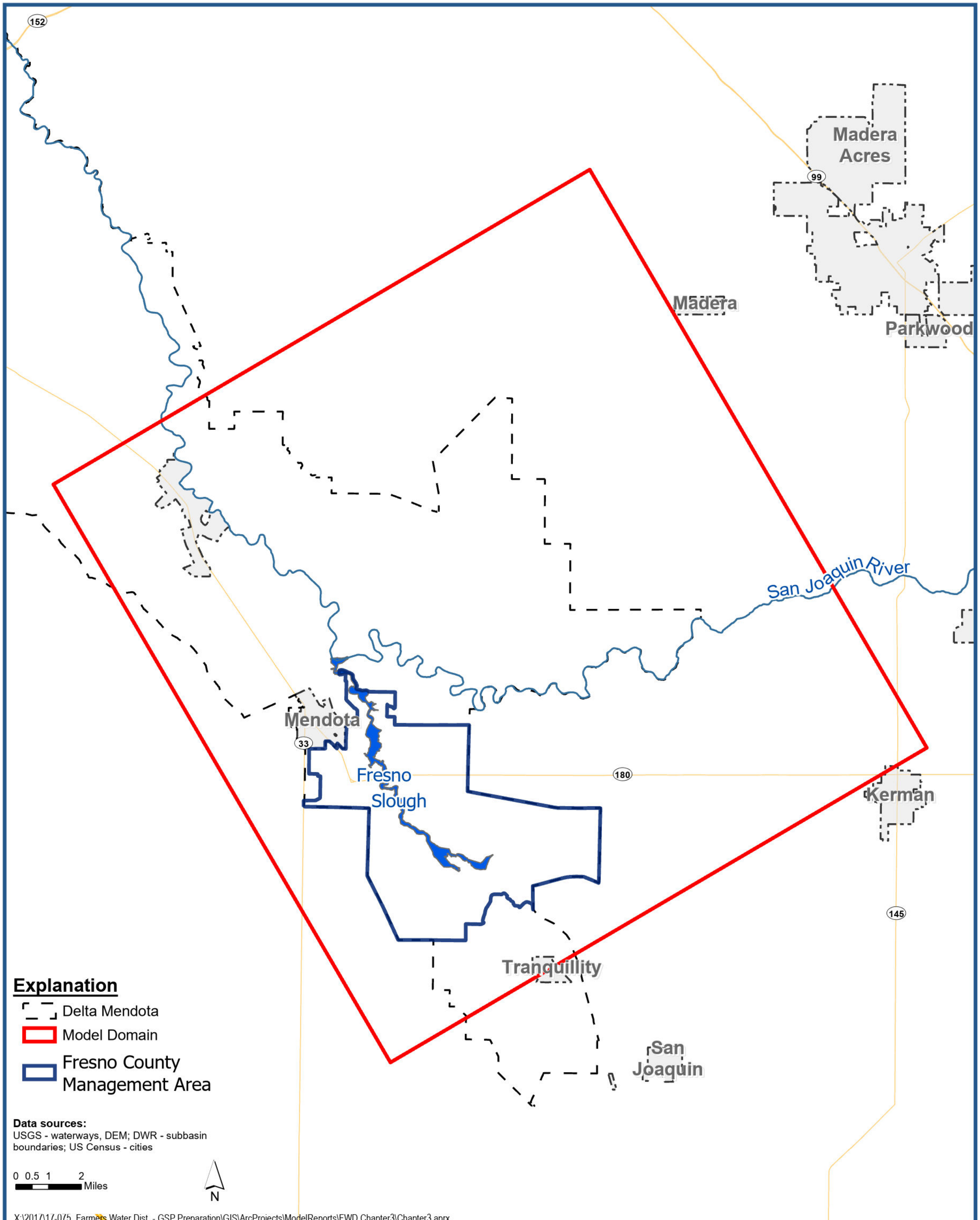


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**Primary Study Area and Extent of Model Domain**

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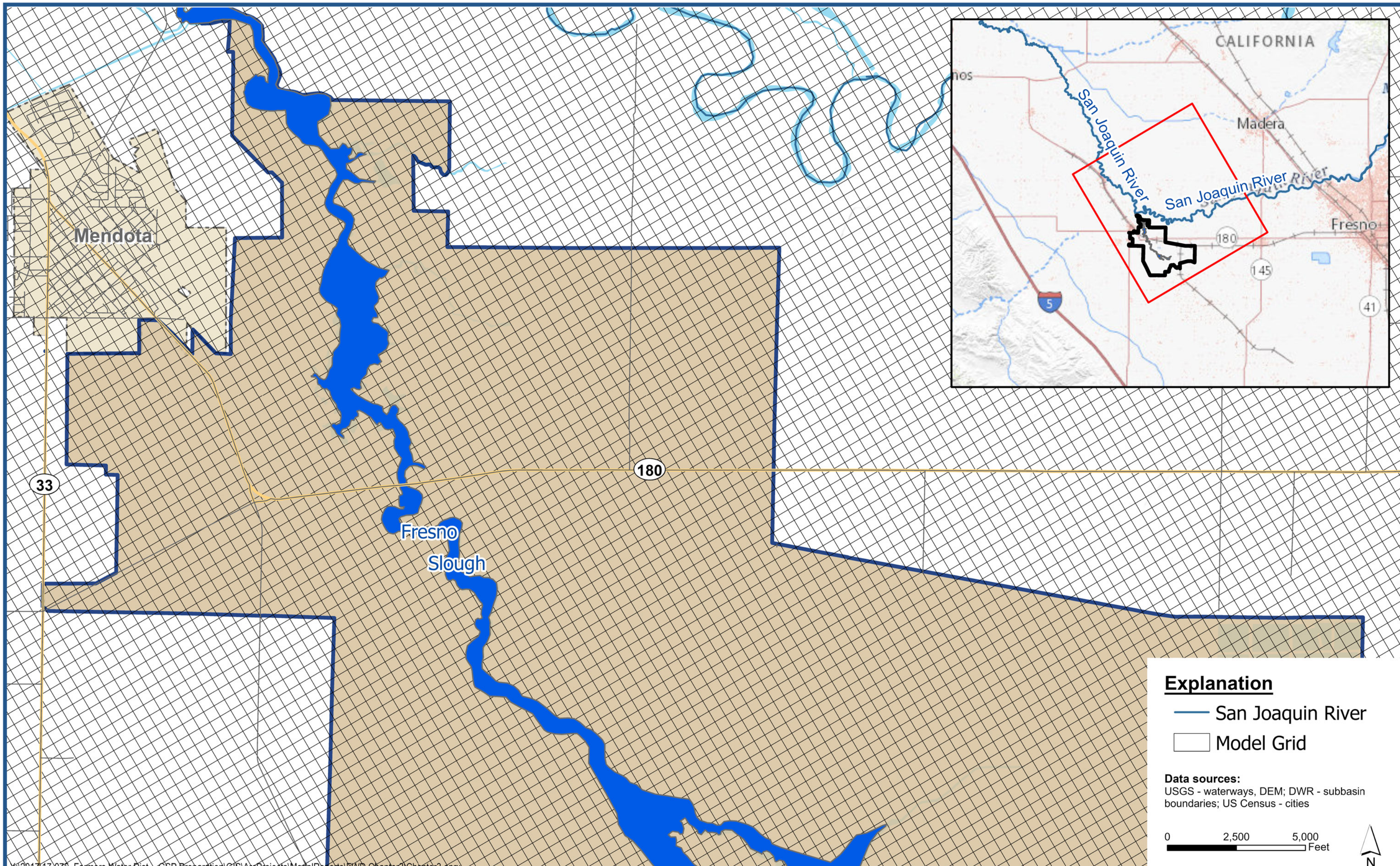
**Figure 3-1**

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**Groundwater Flow Model Domain and Grid Spacing**

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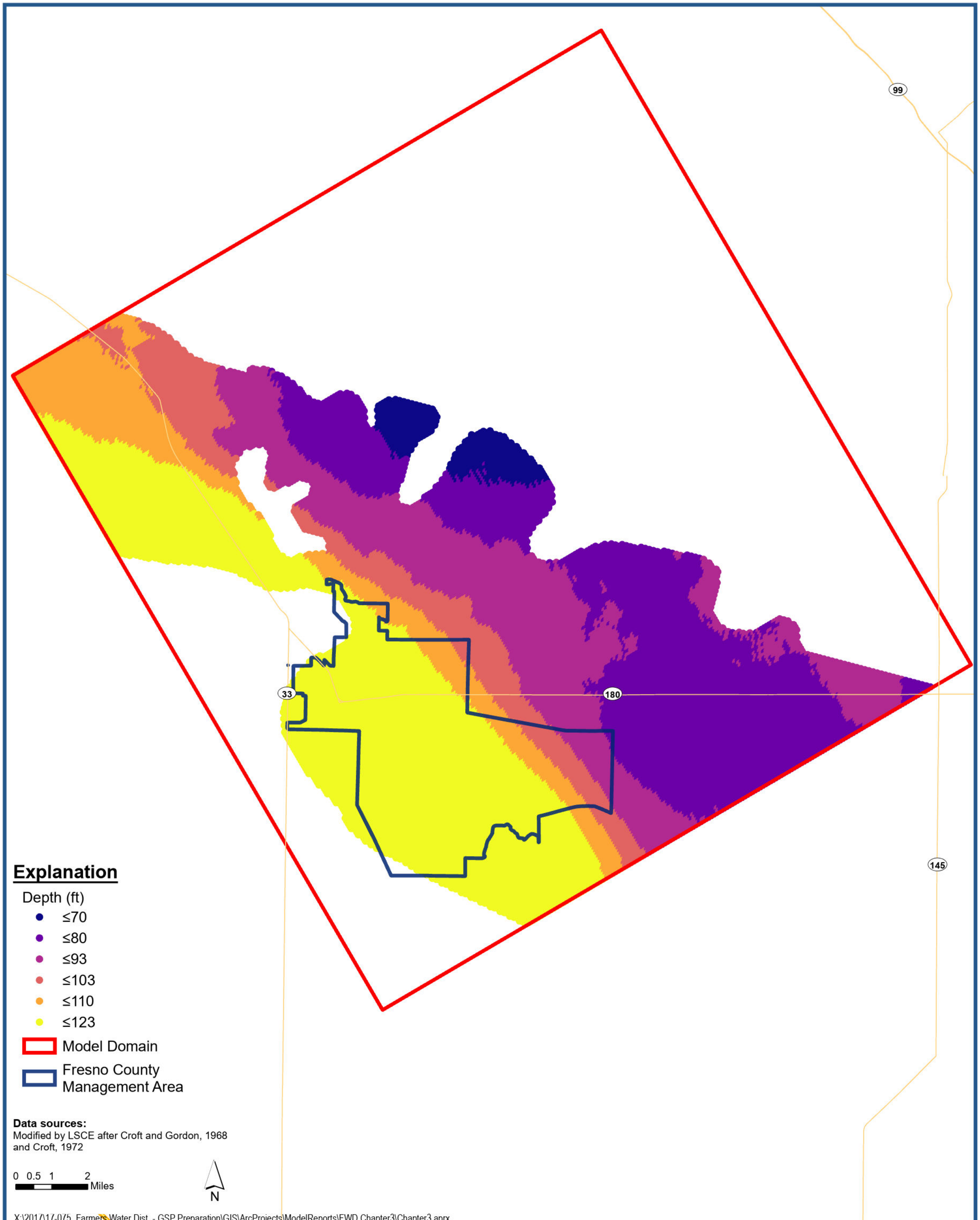
*County of Fresno*

**Figure 3-2**

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**Approximate Extent and Depth of the A-Clay**

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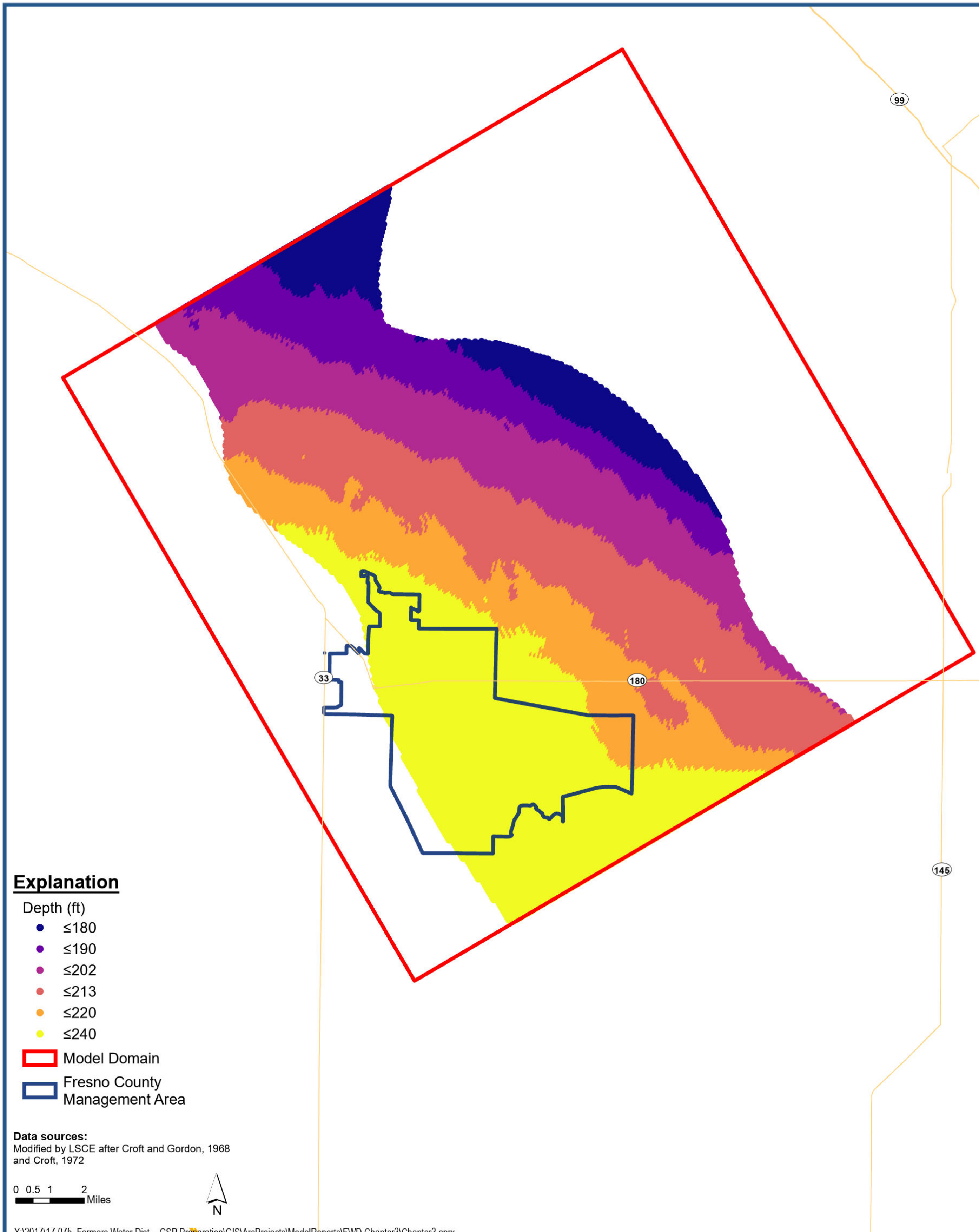
**Figure 3-3**

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**Approximate Extent of and Depth to the C Clay**

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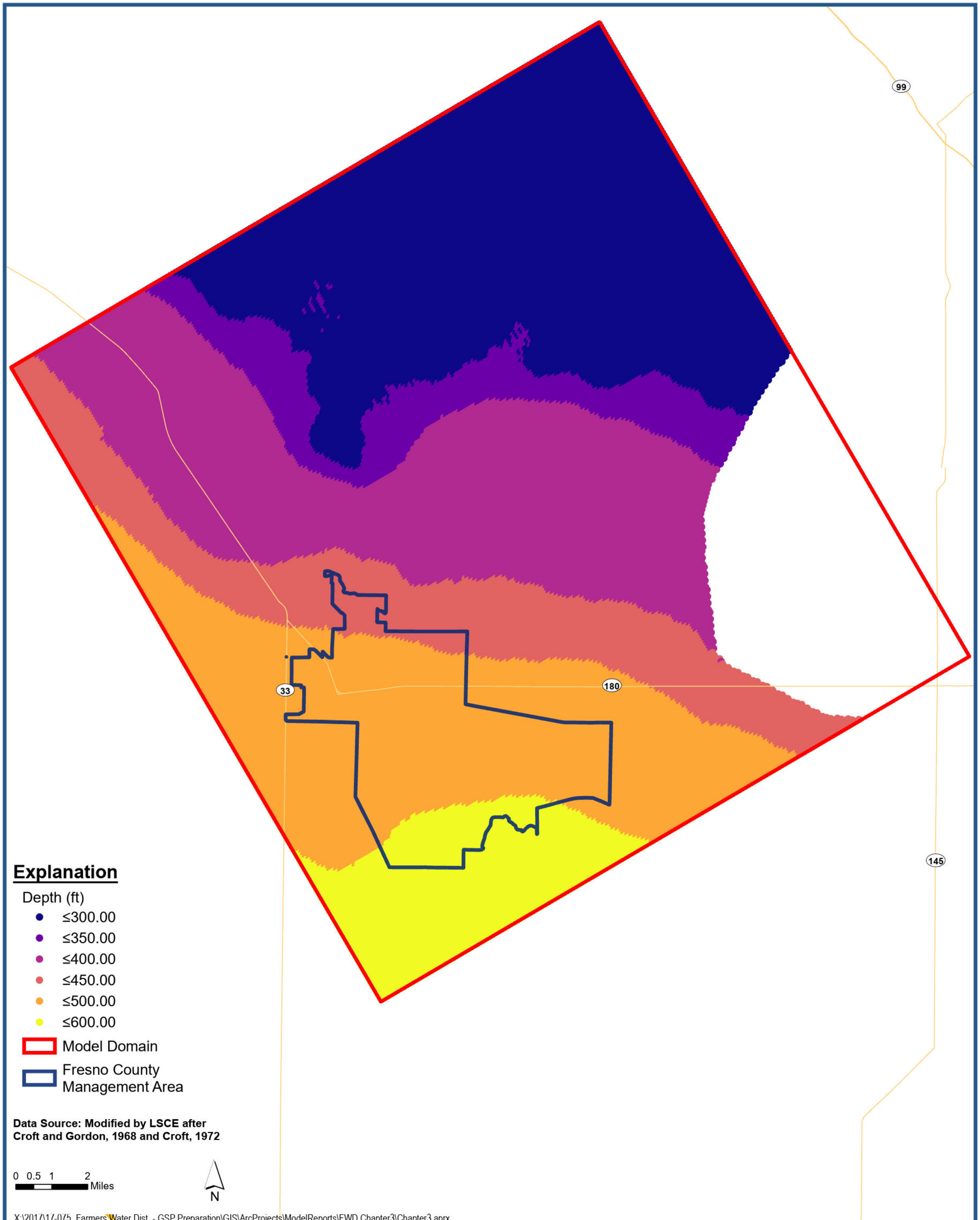
**Figure 3-4**

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**Approximate Extent of and Depth of the Corcoran Clay**

**Figure 3-5**

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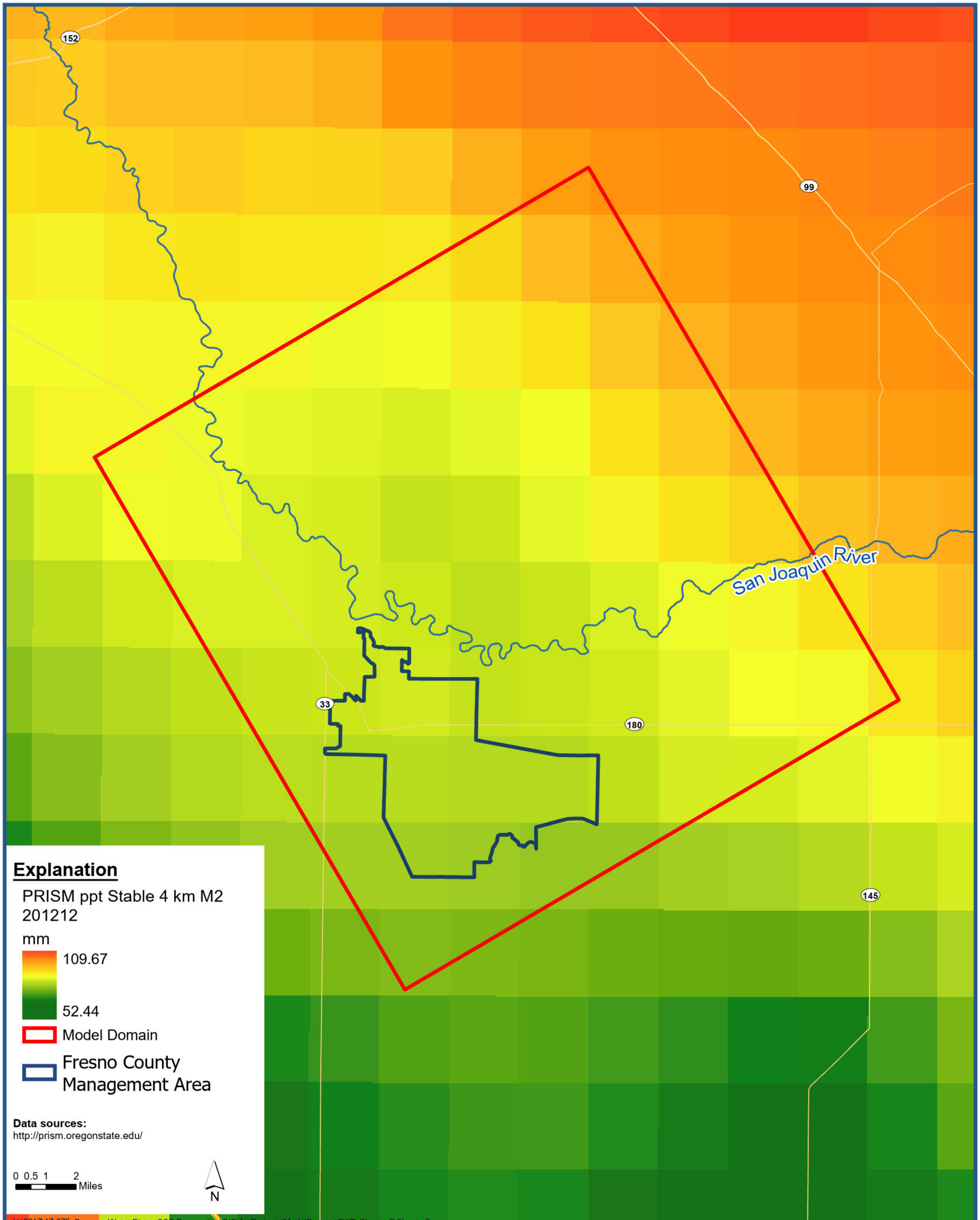


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**Assigned Precipitation from PRISM Data for December 2010**

**Figure 4-1**

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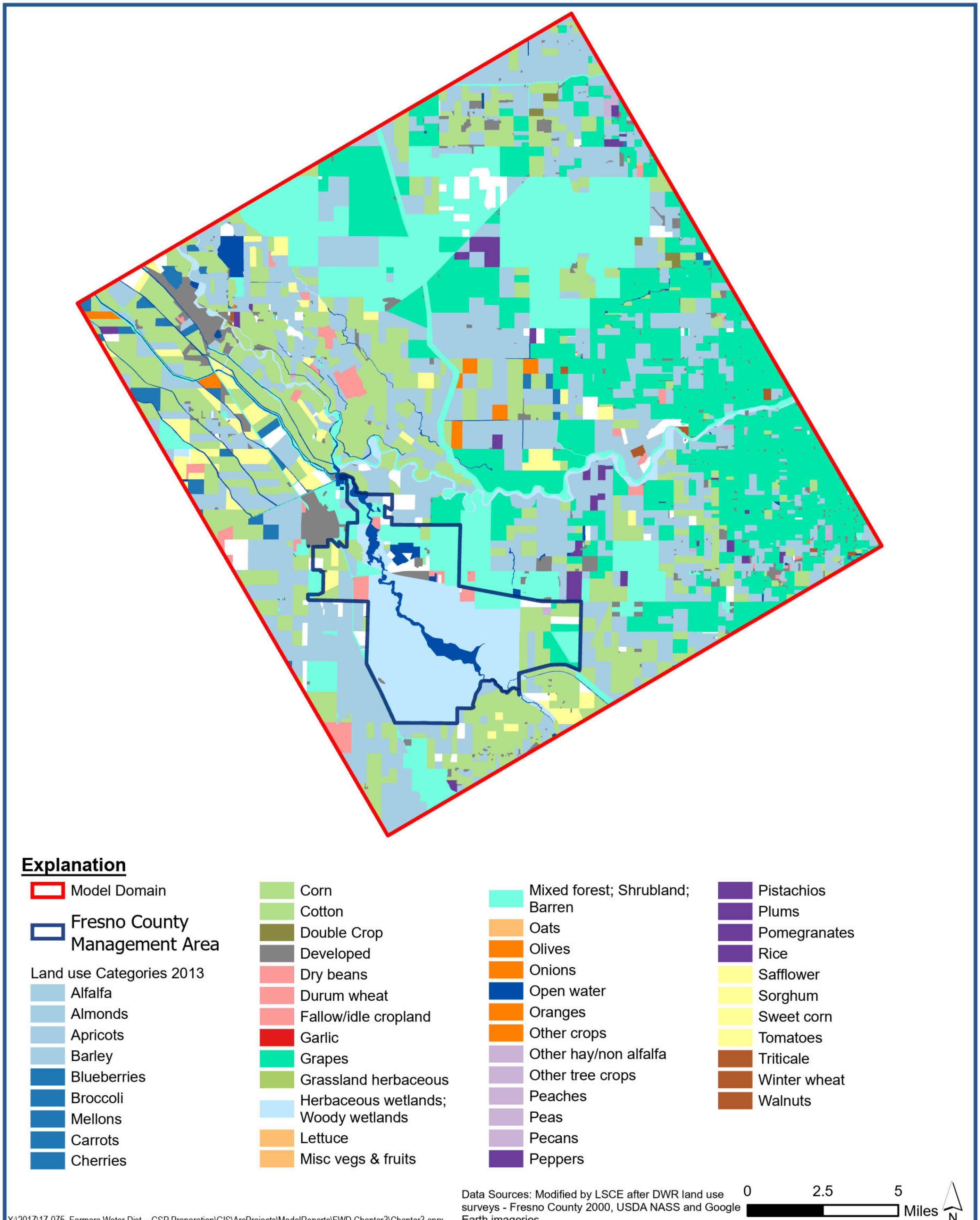


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**Land Use in the Model Area; 2003**

**Figure 4-2**

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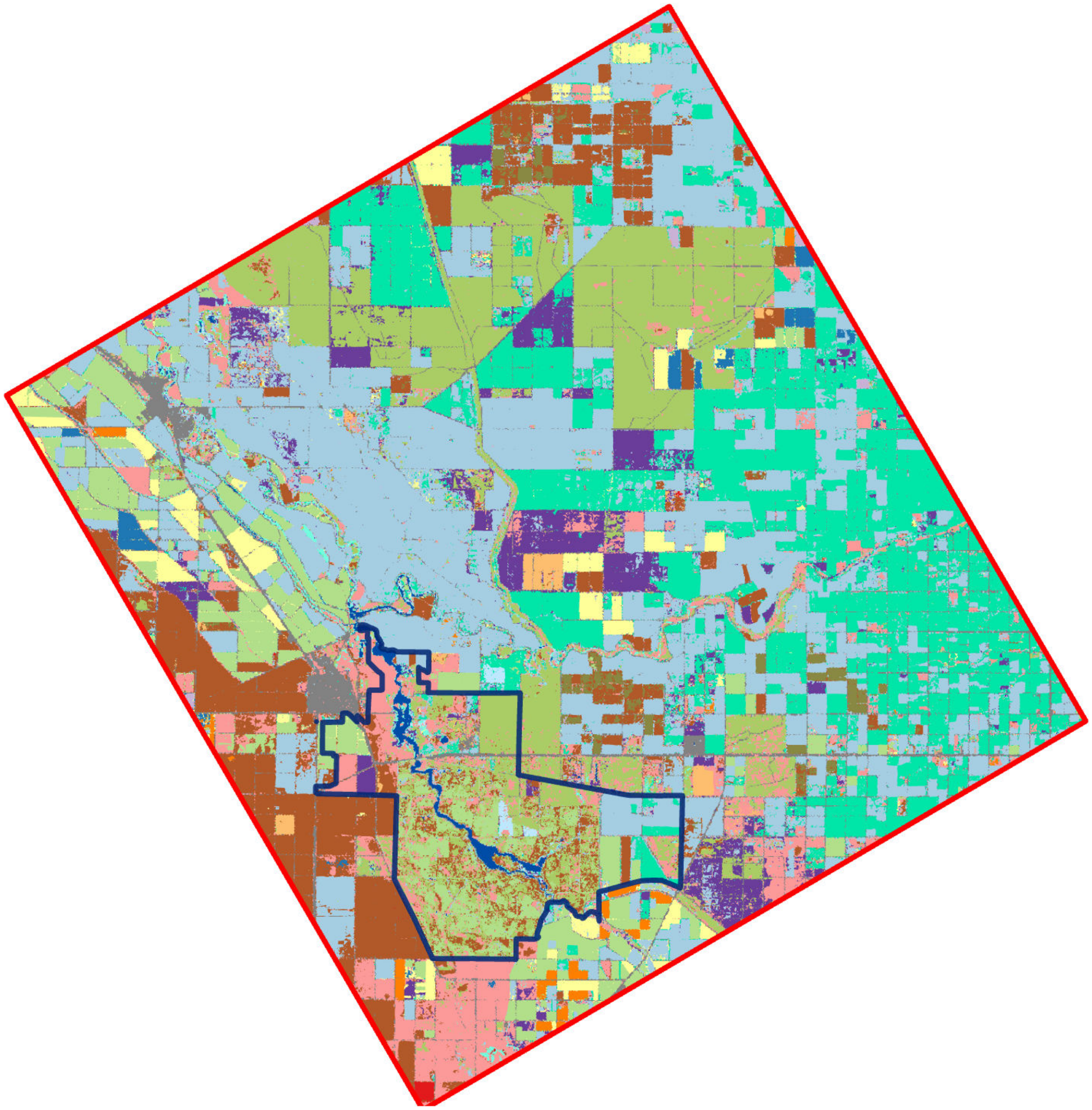

**Explanation**

- Model Domain
- Fresno County Management Area

Land use Categories 2013

- Alfalfa
- Almonds
- Apricots
- Barley
- Blueberries
- Broccoli
- Mellons
- Carrots
- Cherries
- Corn
- Cotton
- Double Crop
- Developed
- Dry beans
- Durum wheat
- Fallow/idle cropland
- Garlic
- Grapes
- Grassland herbaceous
- Herbaceous wetlands; Woody wetlands
- Lettuce
- Misc vegs & fruits
- Mixed forest; Shrubland; Barren
- Oats
- Olives
- Onions
- Open water
- Oranges
- Other crops
- Other hay/non alfalfa
- Other tree crops
- Peaches
- Peas
- Pecans
- Peppers
- Pistachios
- Plums
- Pomegranates
- Rice
- Safflower
- Sorghum
- Sweet corn
- Tomatoes
- Triticale
- Winter wheat
- Walnuts

Data Sources: Modified by LSCE after DWR land use surveys - Fresno County 2000, Eastern Fresno County 2009, Land IQ 2014, USDA NASS and Google Earth imageries

0 2.5 5 Miles N

X:\2017\17-075 Farmers Water Dist. - GSP Preparation\GIS\ArcProjects\ModelReports\FWD Chapter3\Chapter3.a

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**Land Use in the Model Area ; 2013**

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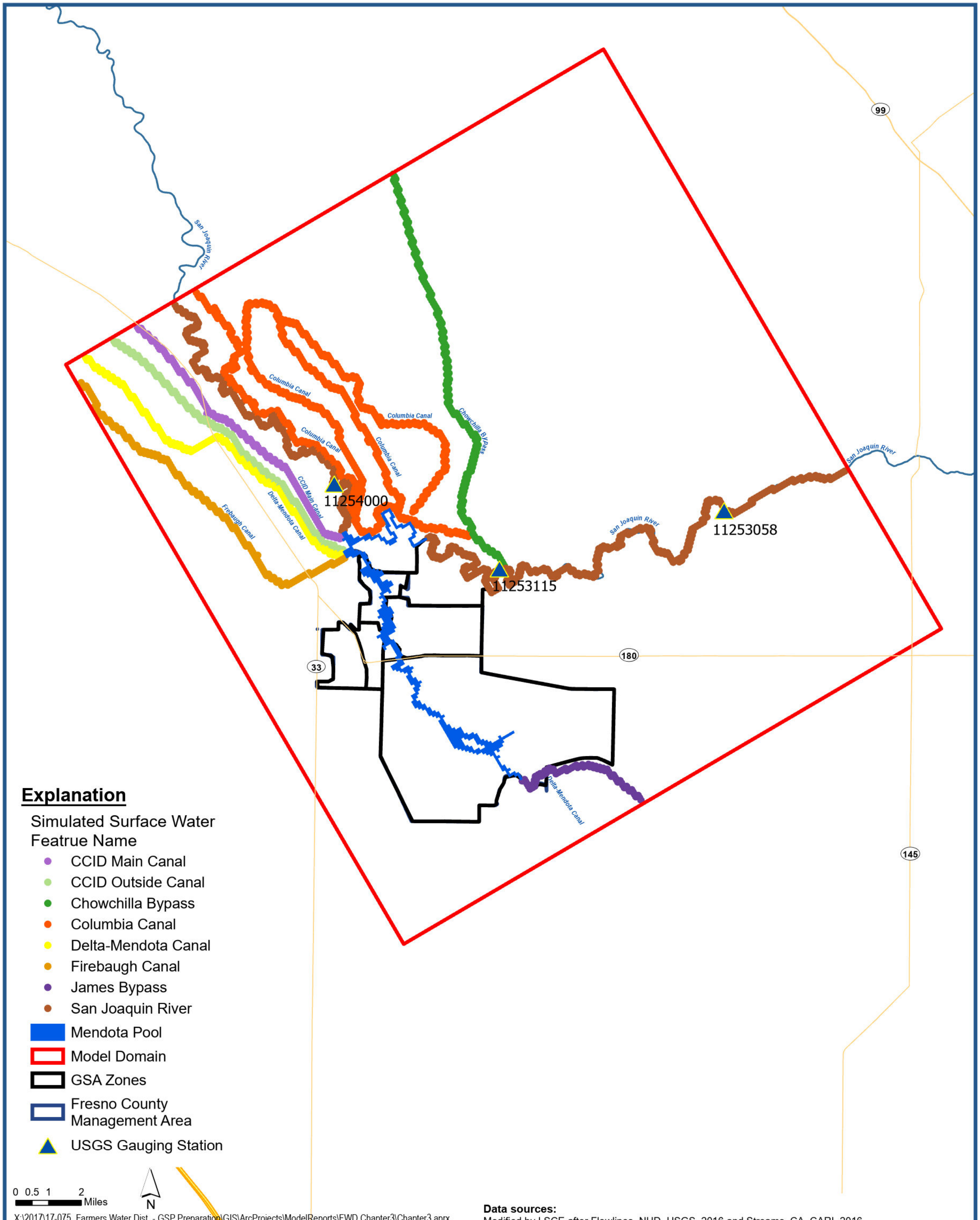
**Figure 4-3**

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**Streams, canals and Mendota Pool that were Simulated in the Flow Model**

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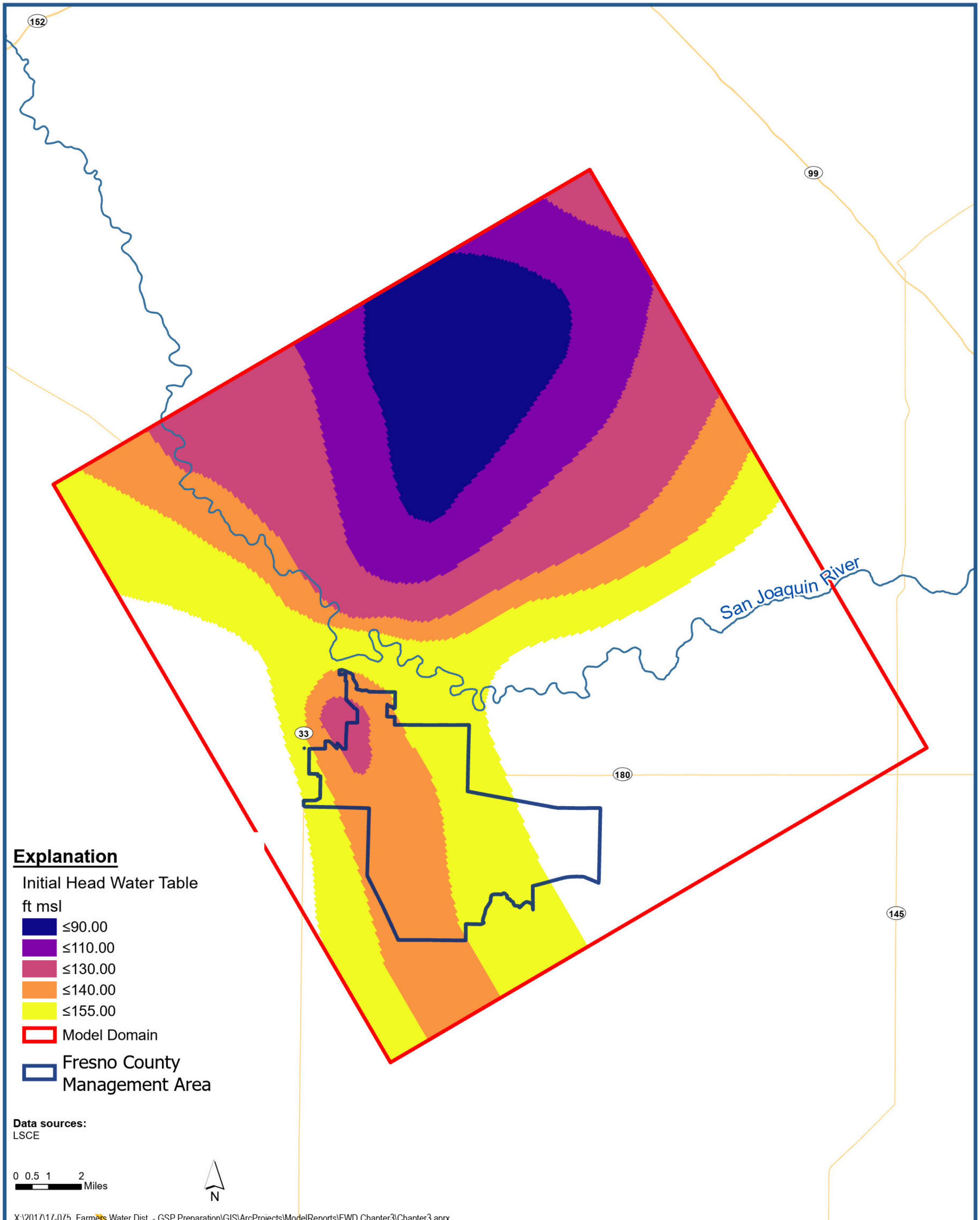
**Figure 4-4**

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**Water Table Initial Heads**

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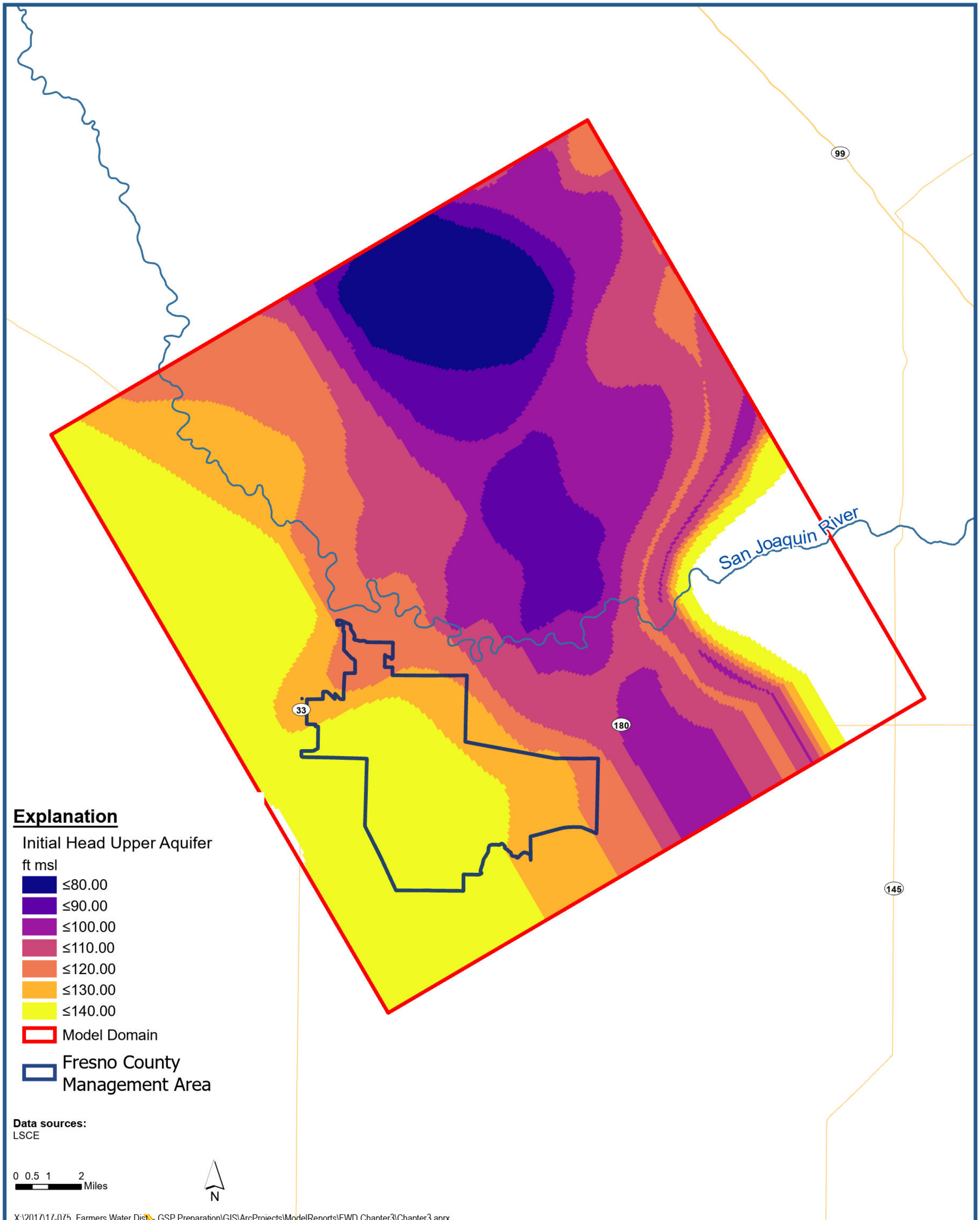
**Figure 4-5**

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**Upper Aquifer Initial Heads**

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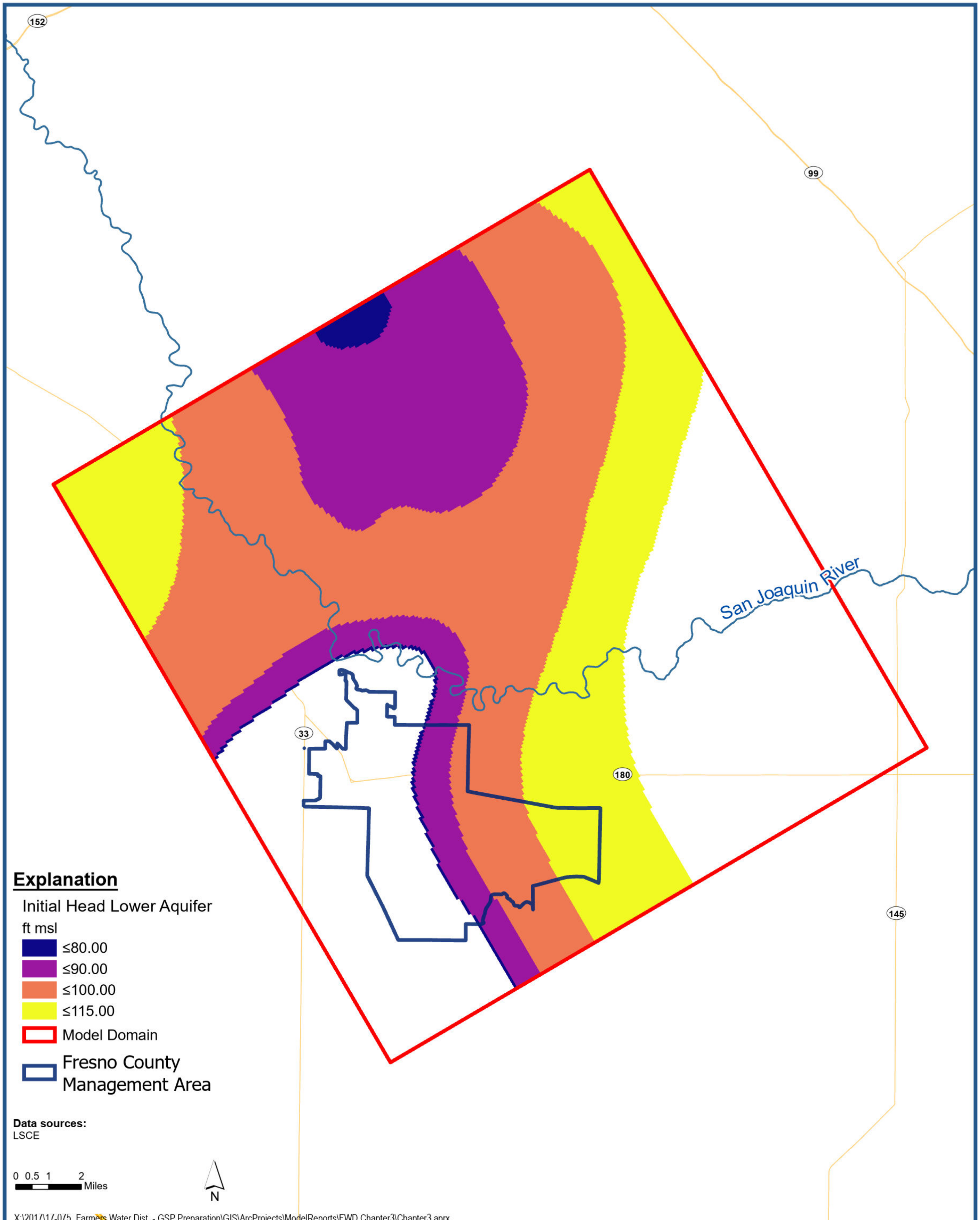
**Figure 4-6**

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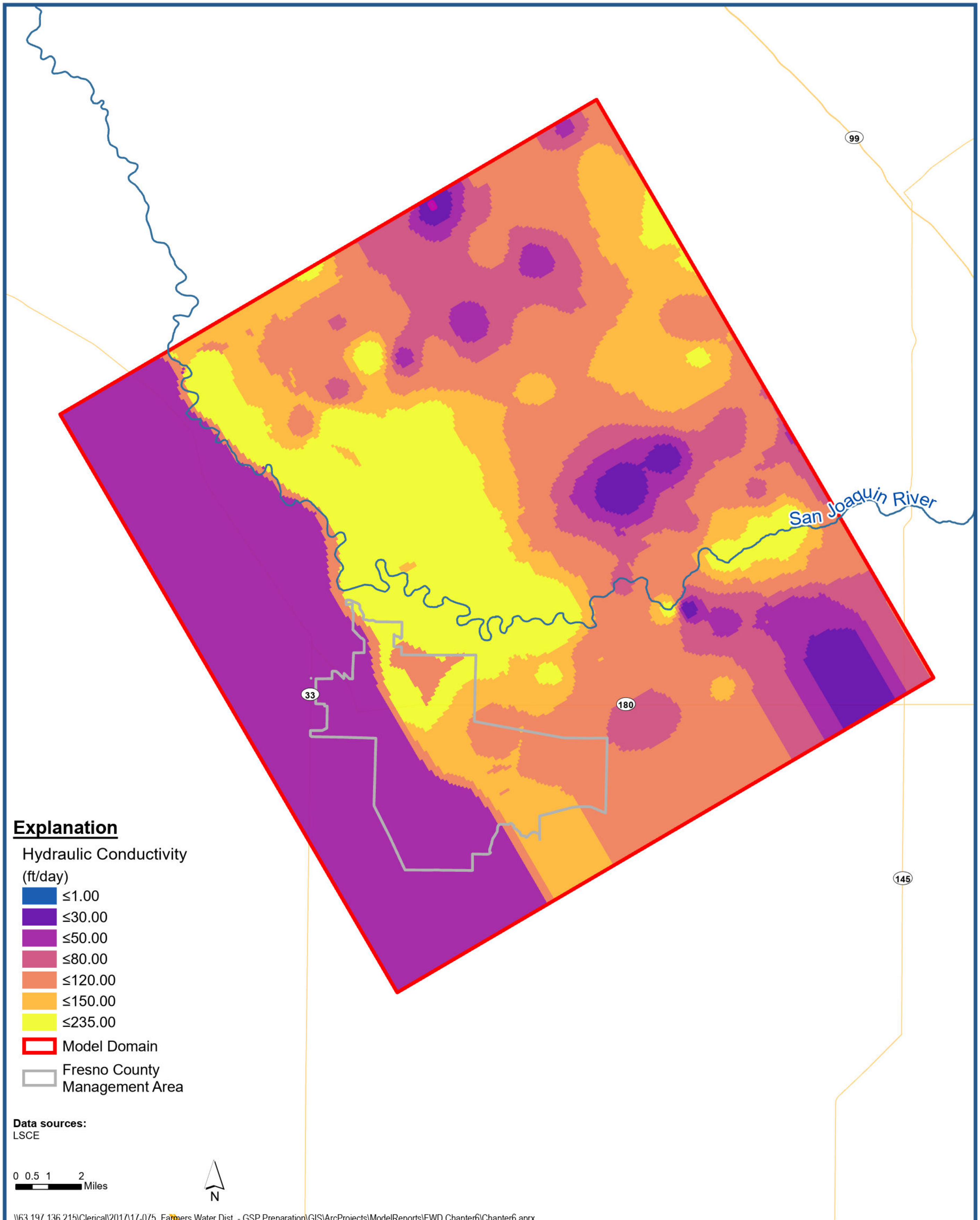
**Lower Aquifer Initial Heads**

**Figure 4-7**

*Groundwater Sustainability Plan*
*County of Fresno*

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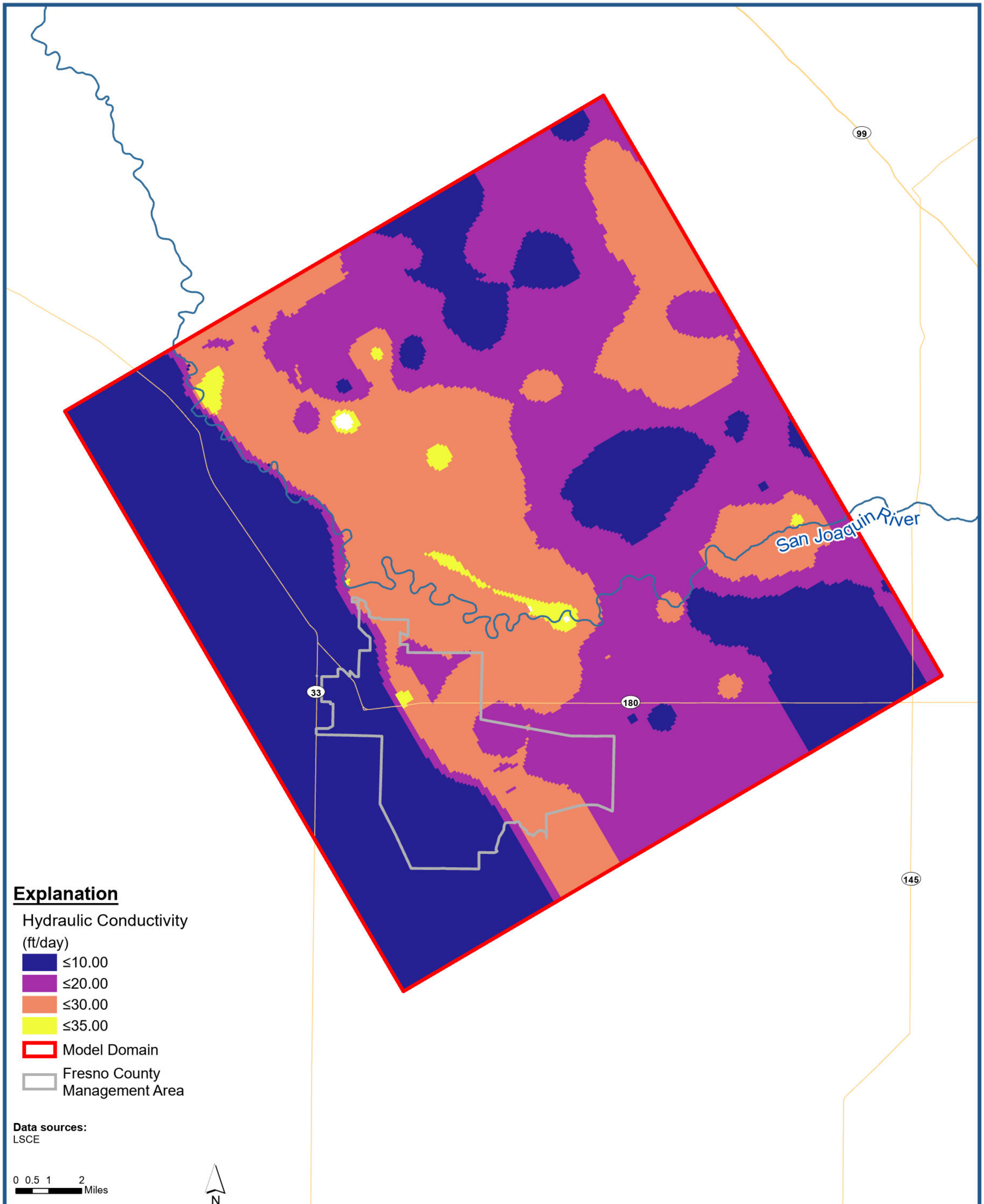
**Horizontal Hydraulic Conductivity Assigned to the Upper Aquifer Shallow Zone**

*Groundwater Sustainability Plan*
*County of Fresno*

**Figure 6-1**

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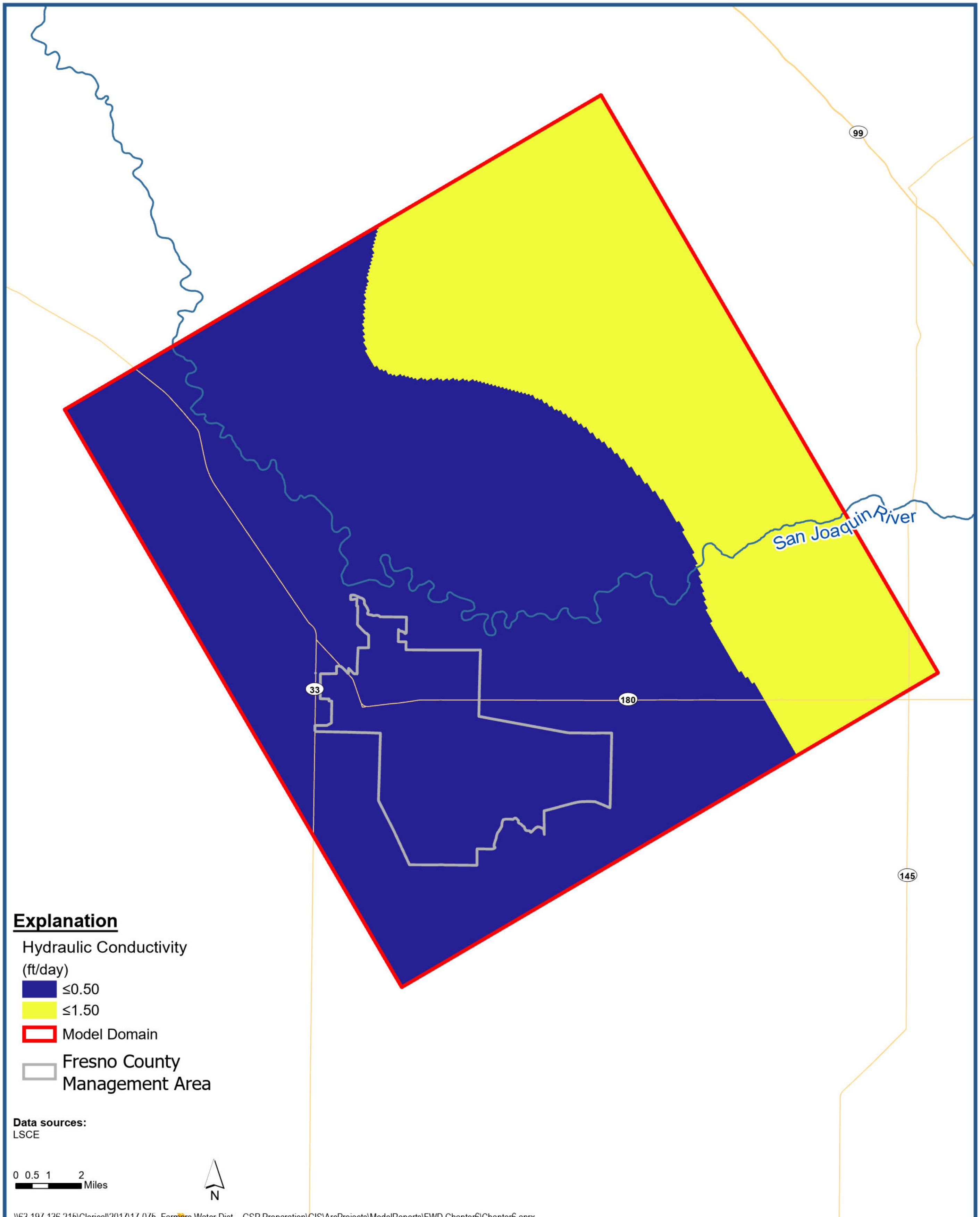
**Vertical Hydraulic Conductivity Assigned to the Upper Aquifer Shallow Zone**

*Groundwater Sustainability Plan*
*County of Fresno*

**Figure 6-2**

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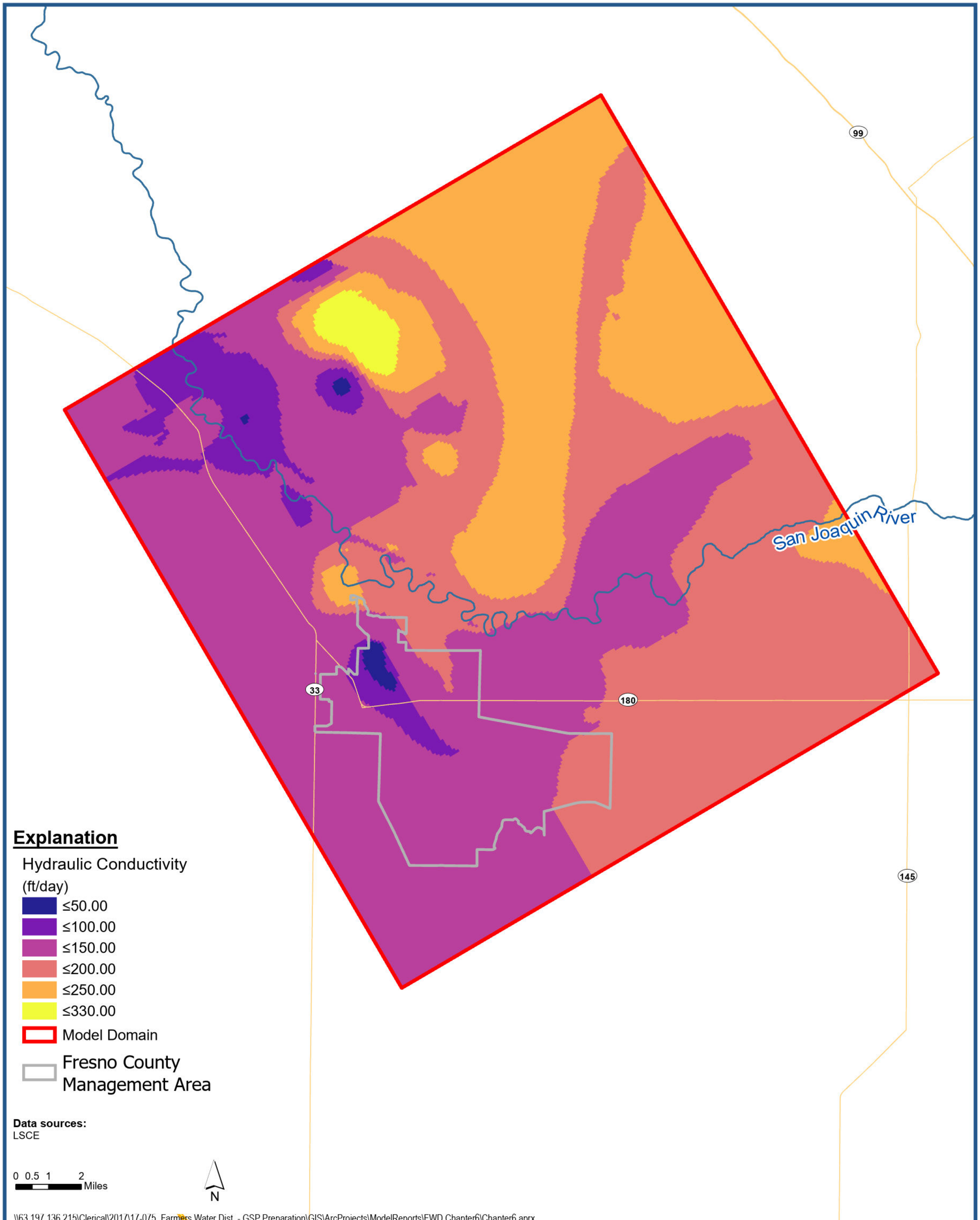
**Vertical Hydraulic Conductivity Assigned to the C Clay**

*Groundwater Sustainability Plan*
*County of Fresno*

**Figure 6-4**

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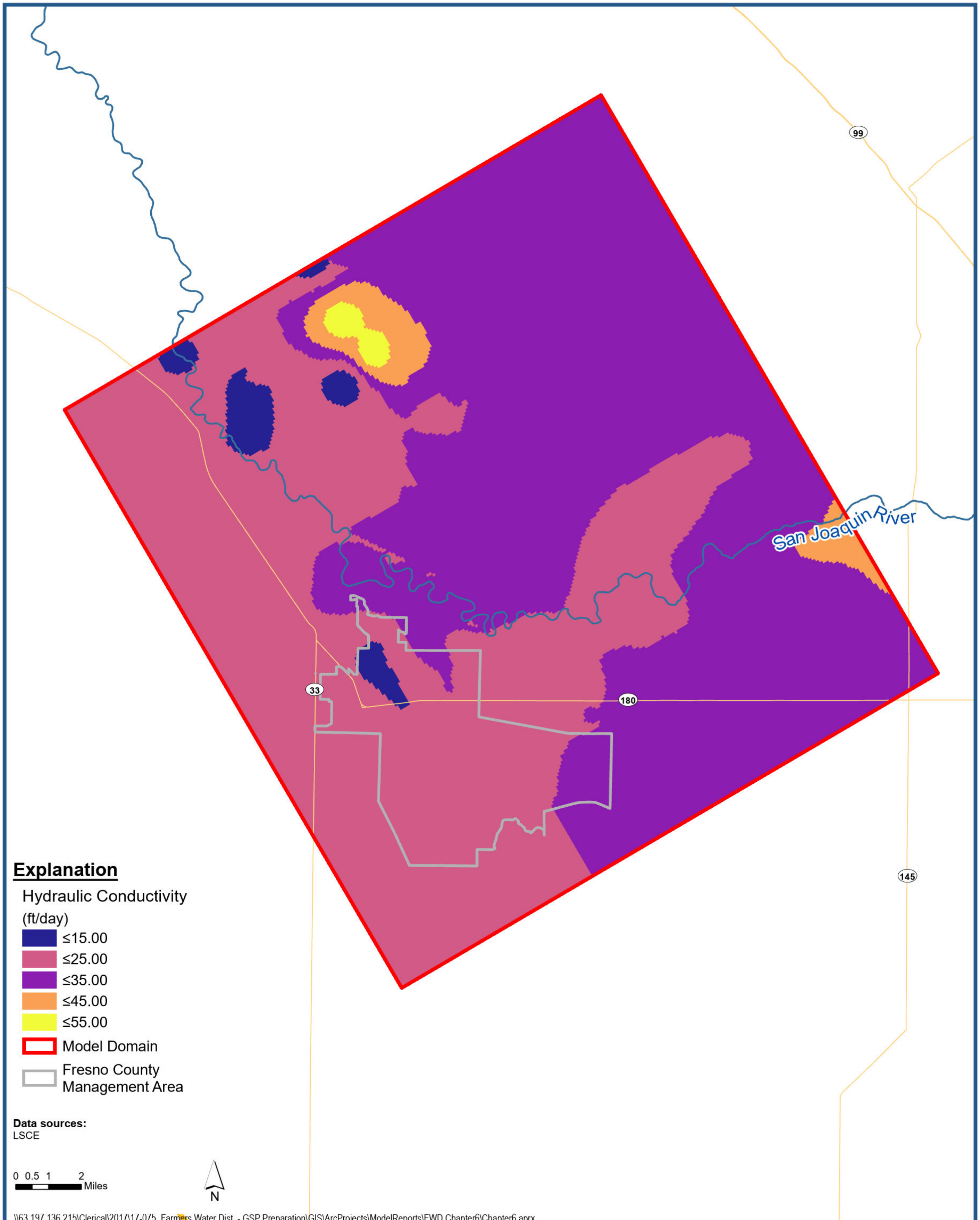
**Horizontal Hydraulic Conductivity Assigned to the Upper Aquifer Deep Zone**

*Groundwater Sustainability Plan*
*County of Fresno*

**Figure 6-5**

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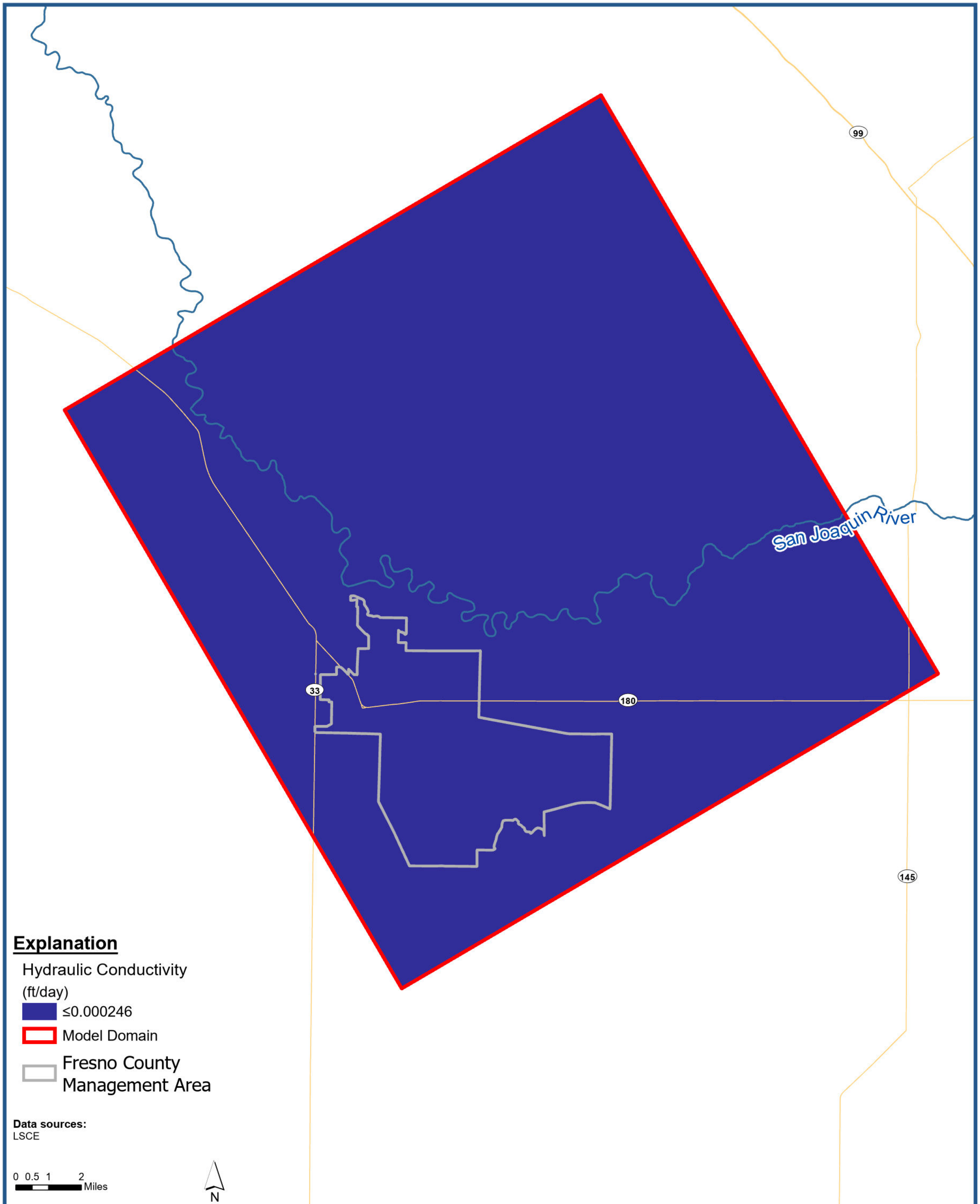
**Vertical Hydraulic Conductivity Assigned to the Upper Aquifer Deep Zone**

*Groundwater Sustainability Plan*
*County of Fresno*

**Figure 6-6**




\\63.197.136.215\Clerical\2017\17-075 Farmers Water Dist. - GSP Preparation\GIS\ArcProjects\ModelReports\FWD Chapter6\Chapter6.aprx

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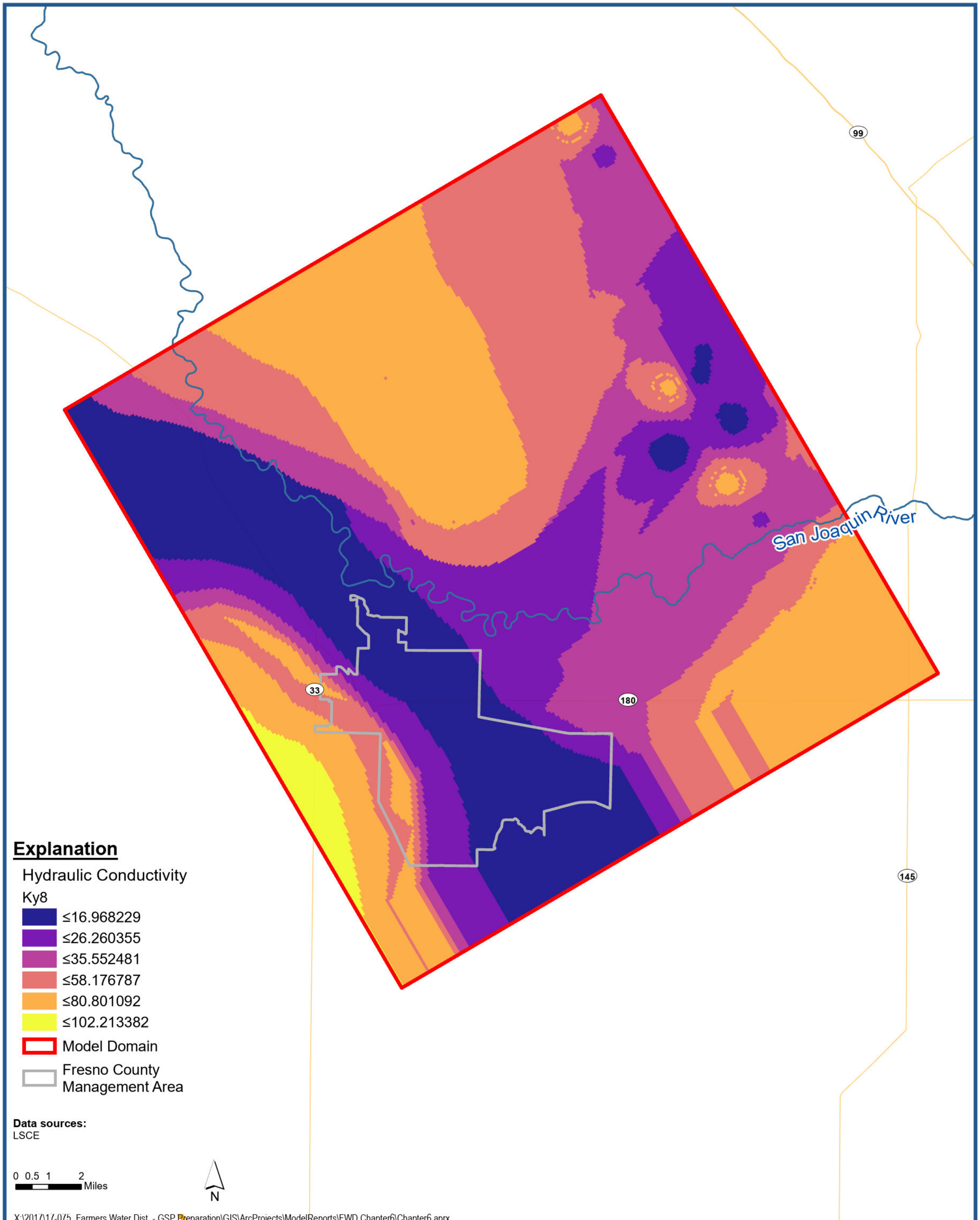
**Vertical Hydraulic Conductivity Assigned to the Corcoran Clay**

*Groundwater Sustainability Plan*
*County of Fresno*

**Figure 6-7**

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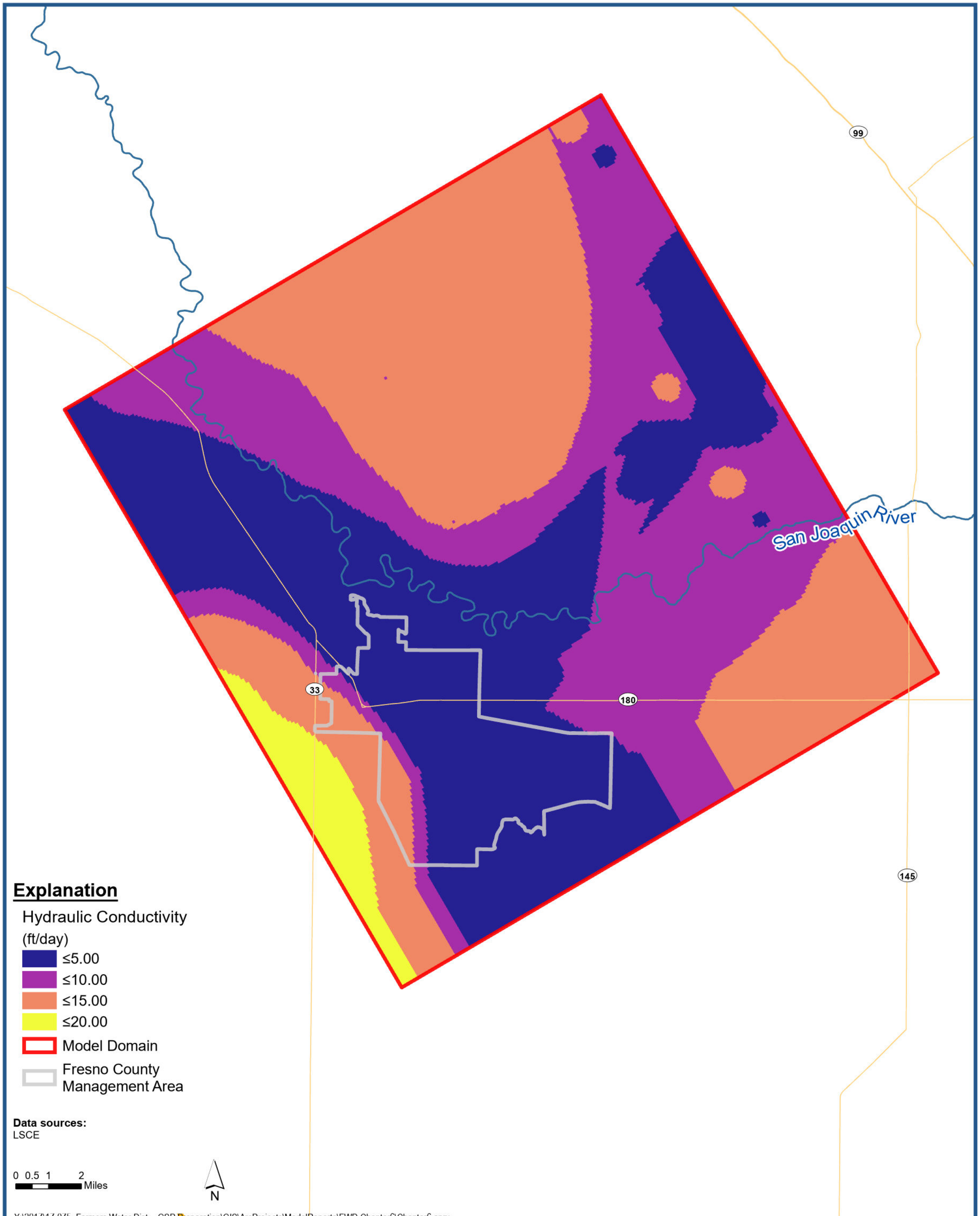
**Horizontal Hydraulic Conductivity Assigned to the Lower Aquifer**

*Groundwater Sustainability Plan*
*County of Fresno*

**Figure 6-8**

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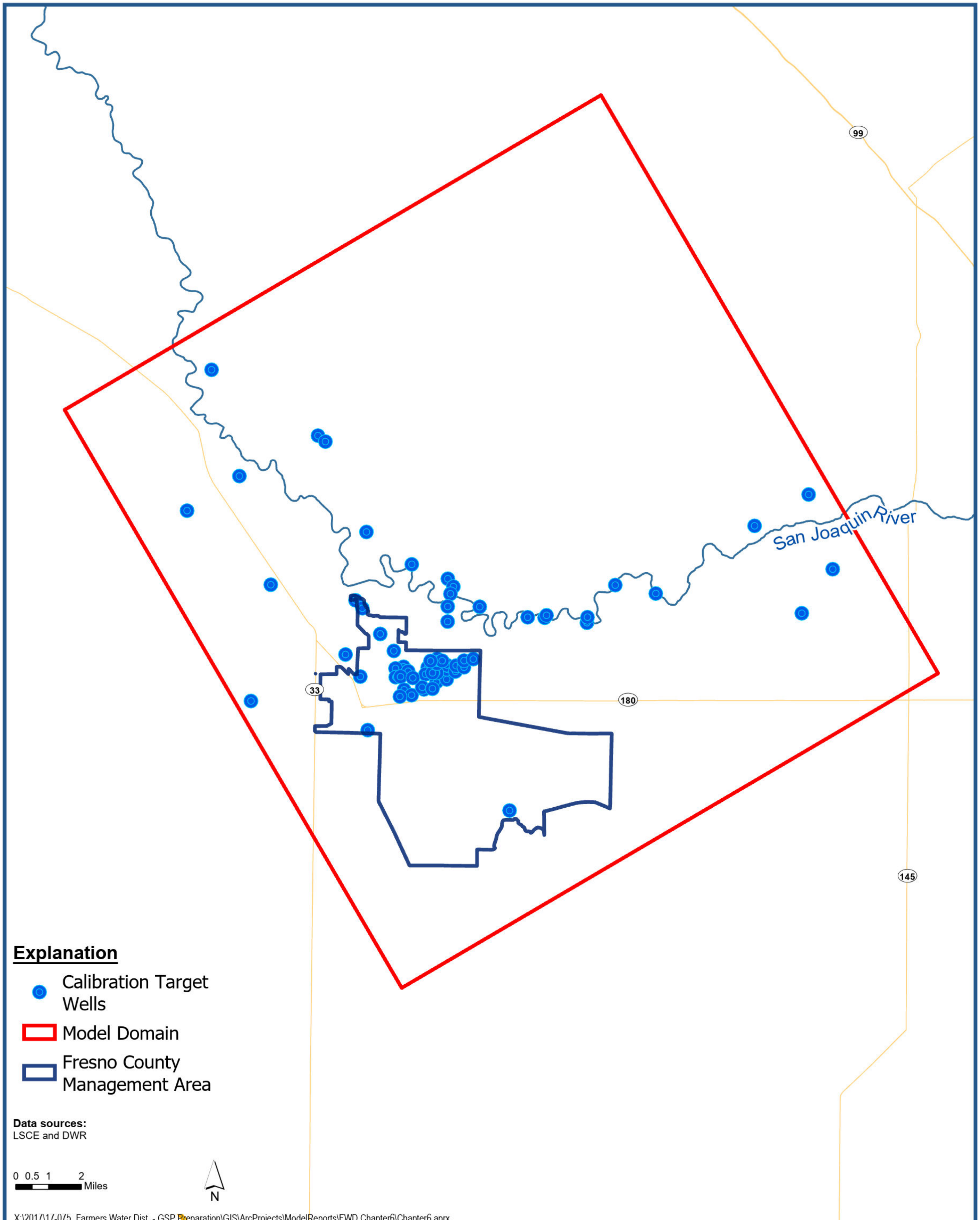
**Vertical Hydraulic Conductivity Assigned to the Lower Aquifer**

*Groundwater Sustainability Plan*
*County of Fresno*

**Figure 6-9**

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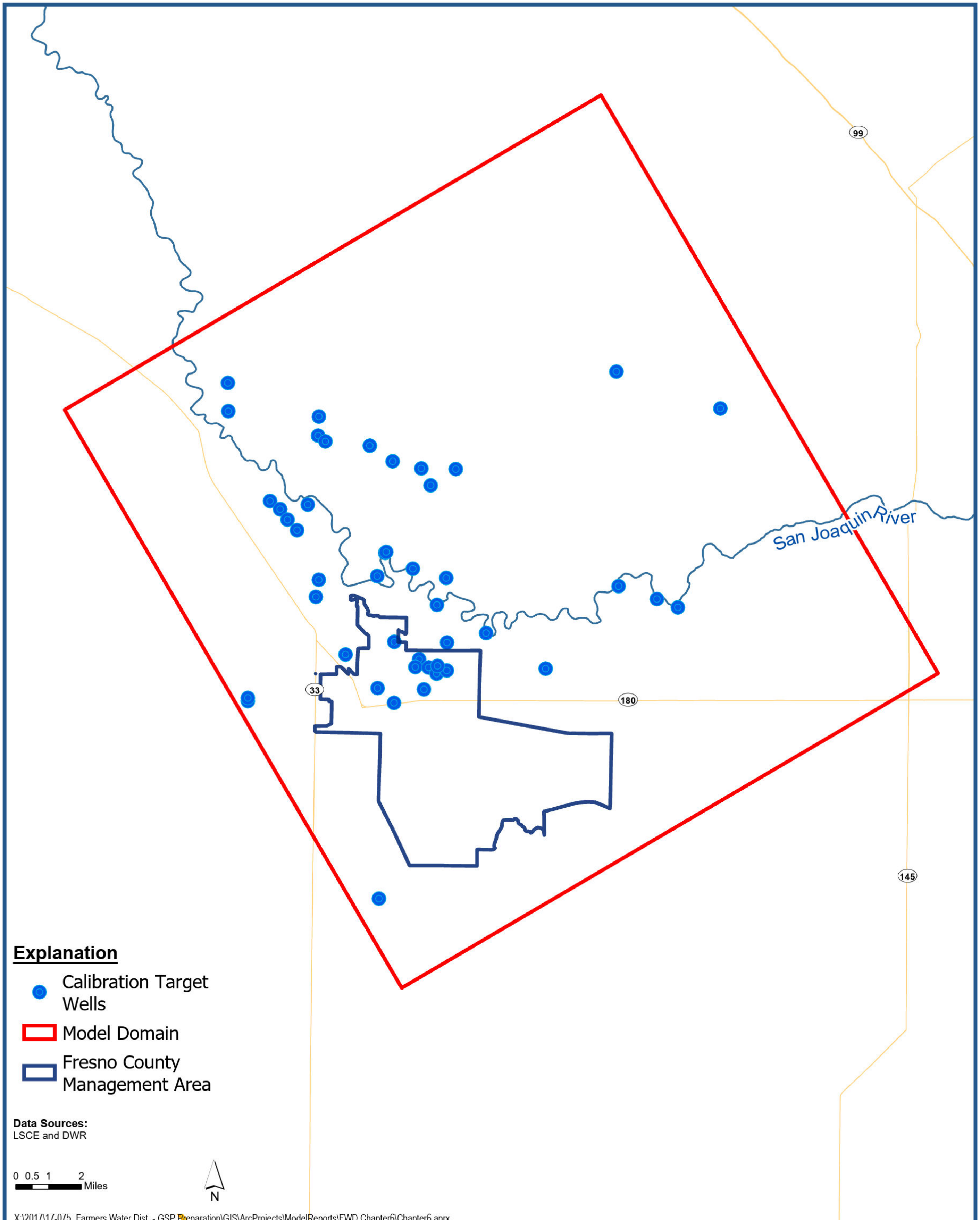
**Locations of Upper Aquifer Shallow Zone Wells Used for Model Calibration**

*Groundwater Sustainability Plan*
*County of Fresno*

**Figure 6-10**

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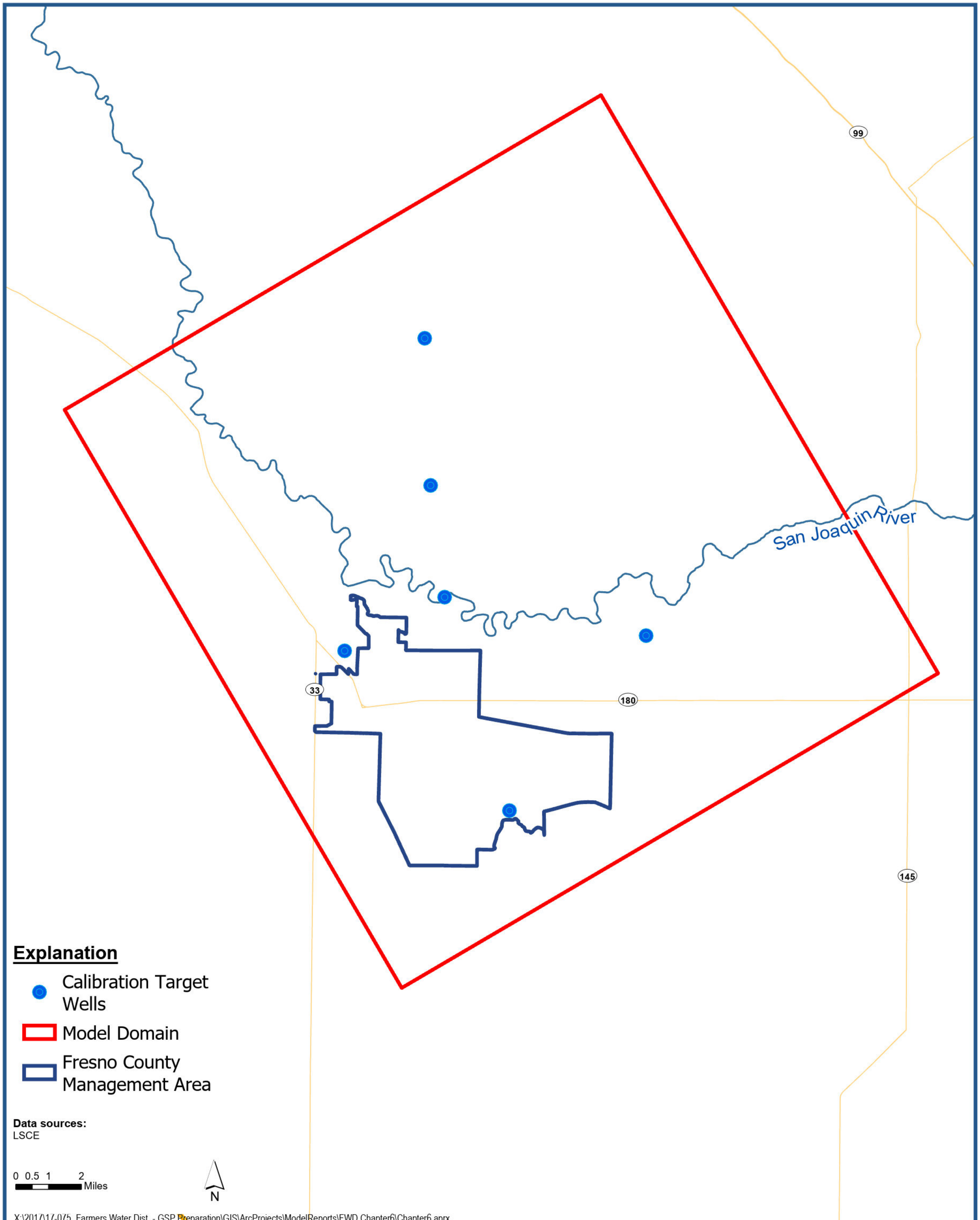
**Locations of Upper Aquifer Deep Zone Wells Used for Model Calibration**

*Groundwater Sustainability Plan*
*County of Fresno*

**Figure 6-11**

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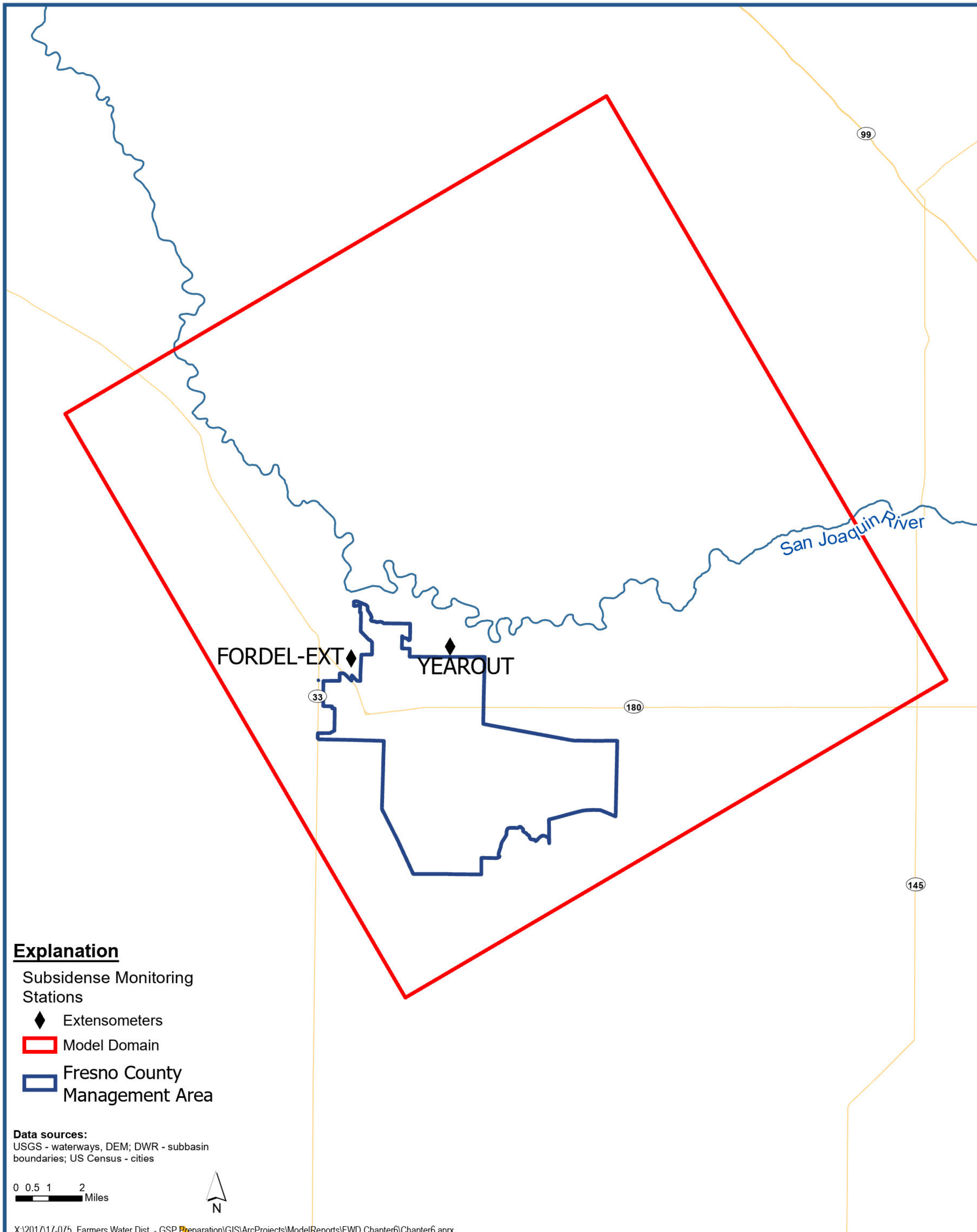
**Locations of Lower Aquifer Wells Used for Model Calibration**

*Groundwater Sustainability Plan*
*County of Fresno*

**Figure 6-12**

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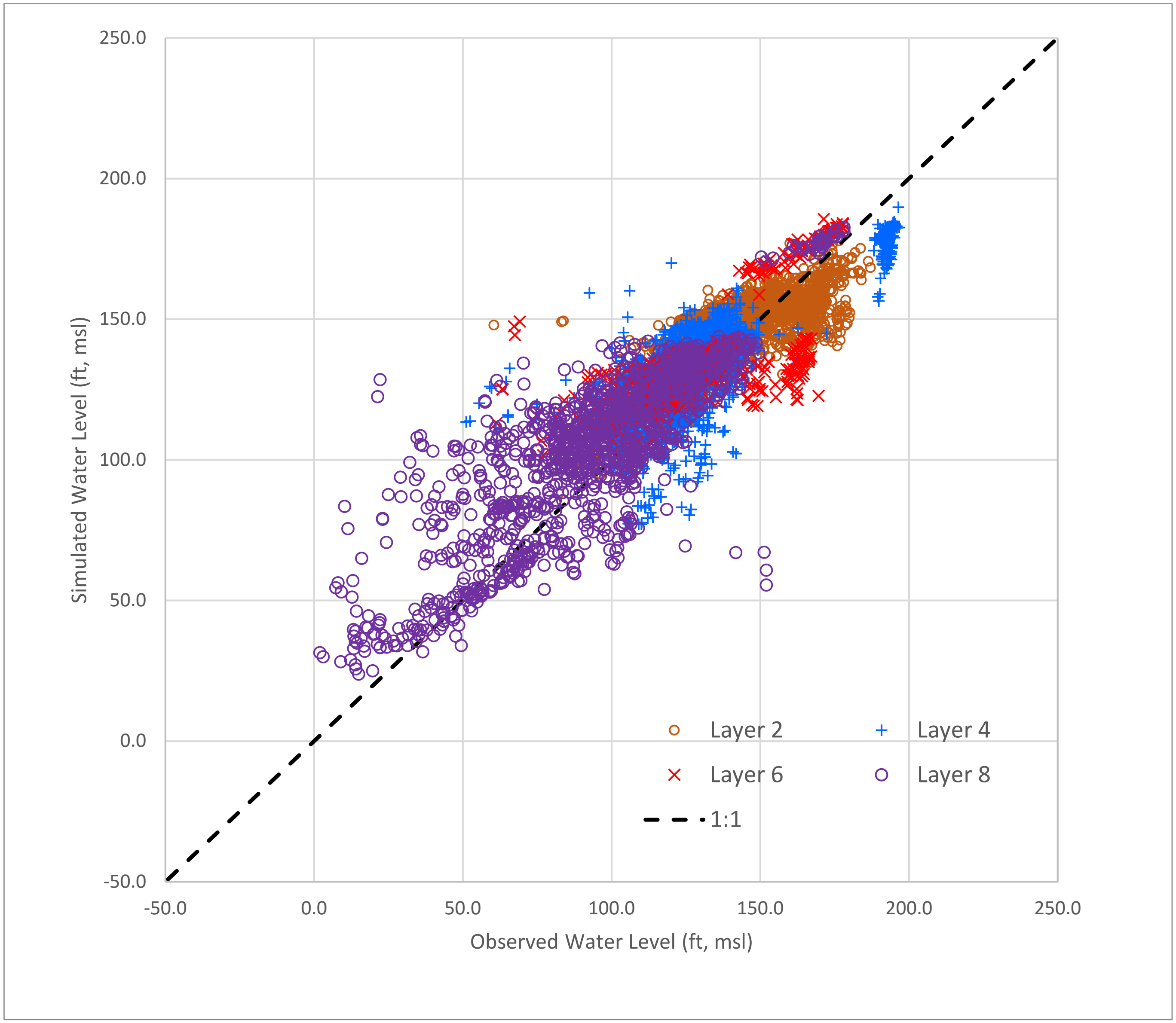
**Location of Subsidence and Compaction Observations Used in Model Calibration**

*Groundwater Sustainability Plan*
*County of Fresno*

**Figure 6-13**

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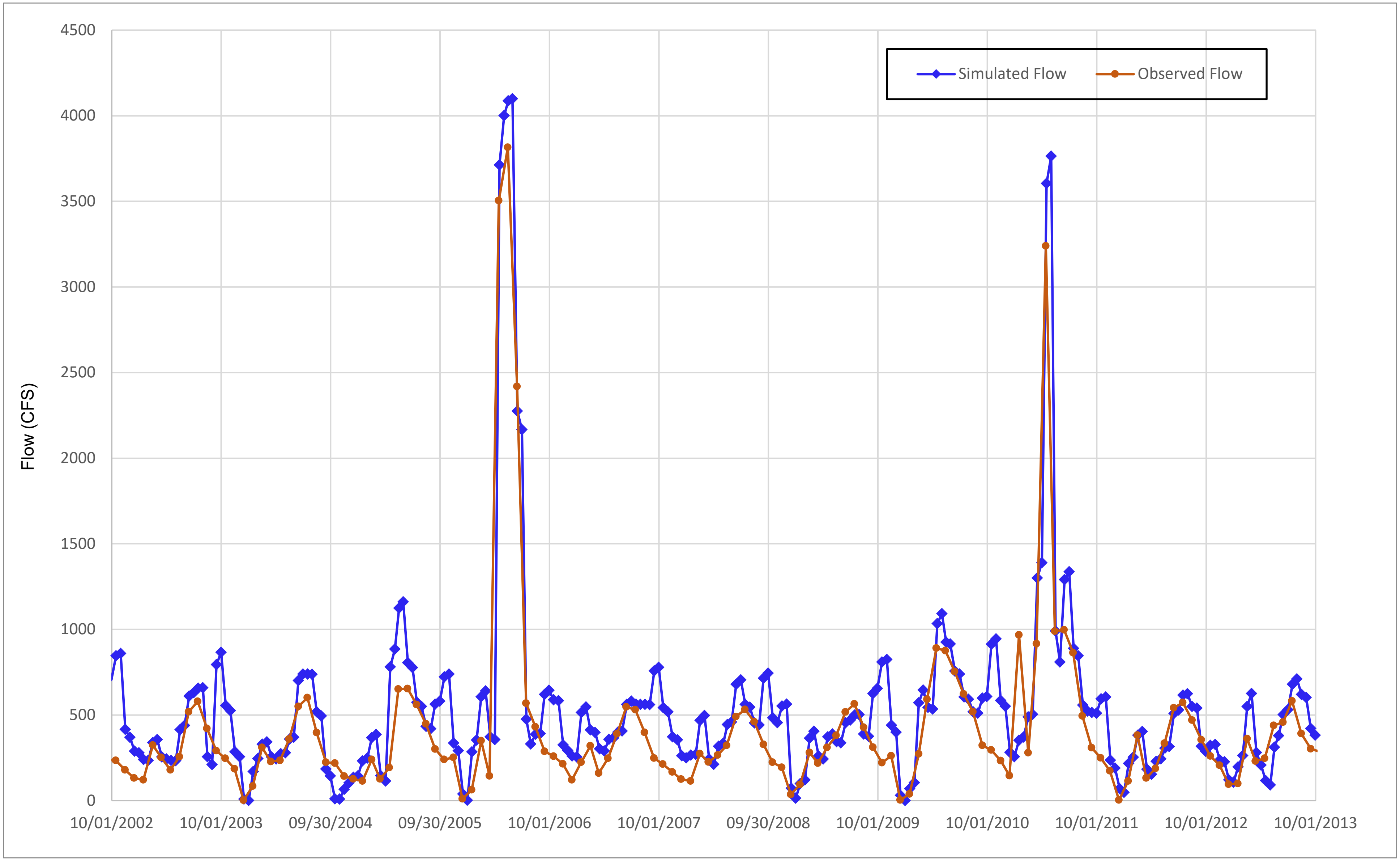
**Simulated vs Observed Groundwater Level Elevations of Model Calibration Target Wells**

*Groundwater Sustainability Plan*
*County of Fresno*

**Figure 6-14**

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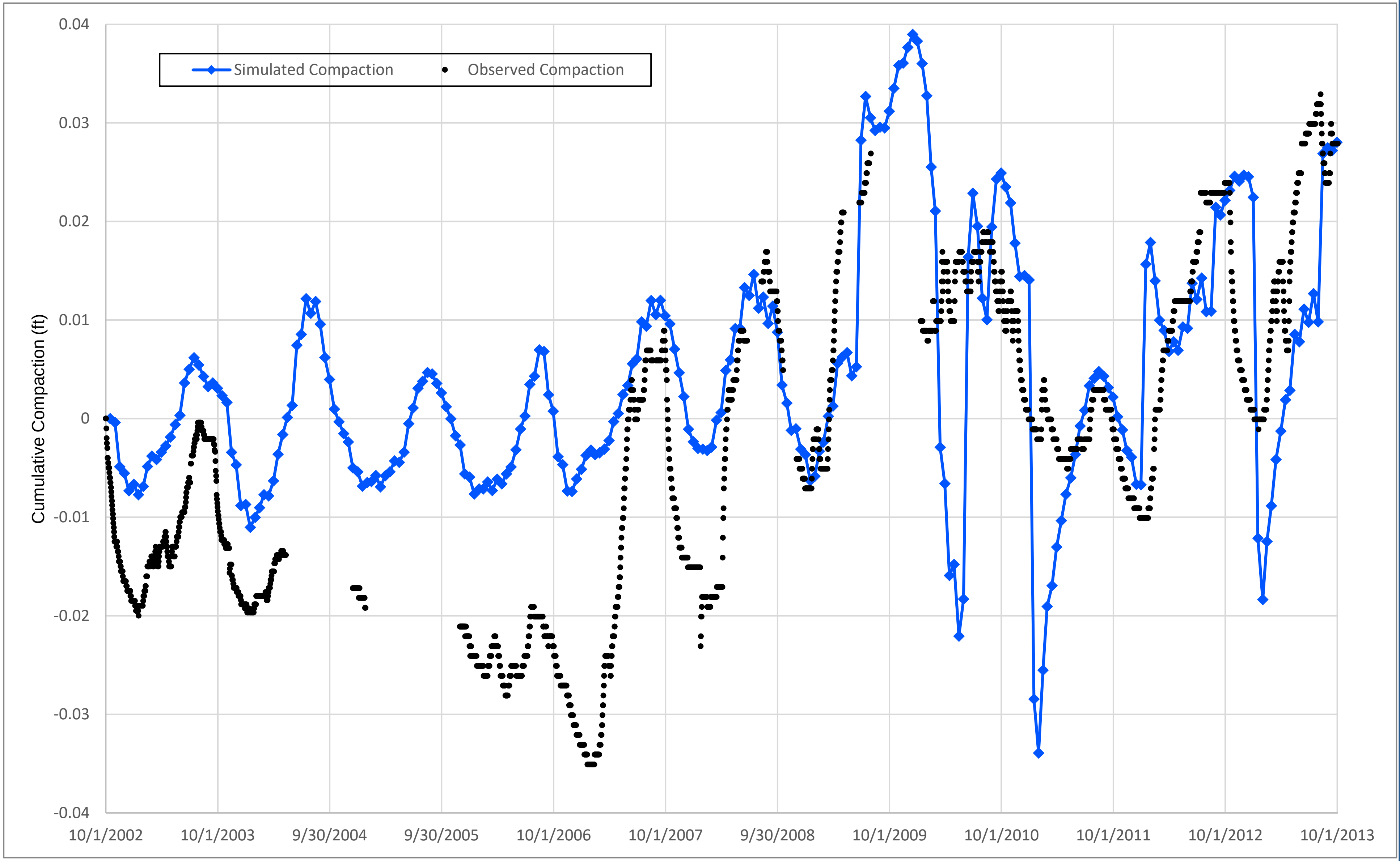
**Observed and simulated flow of the San Joaquin River downstream of the Mendota Dam**

*Groundwater Sustainability Plan*
*County of Fresno*

**Figure 6-15**

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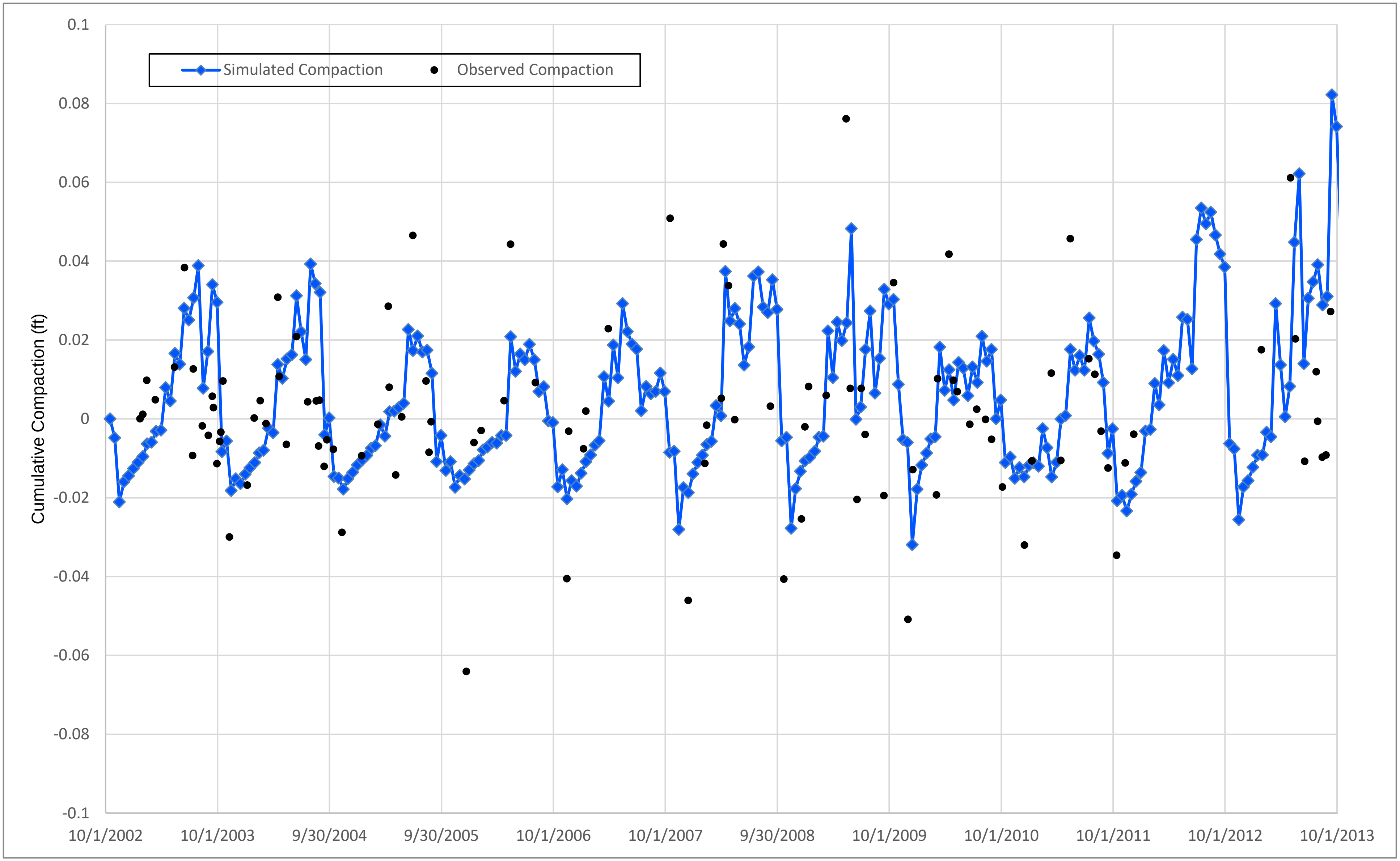
**Observed and Simulated Compaction above the Corcoran Clay at Fordel Extensometer**

*Groundwater Sustainability Plan*
*County of Fresno*

**Figure 6-16**

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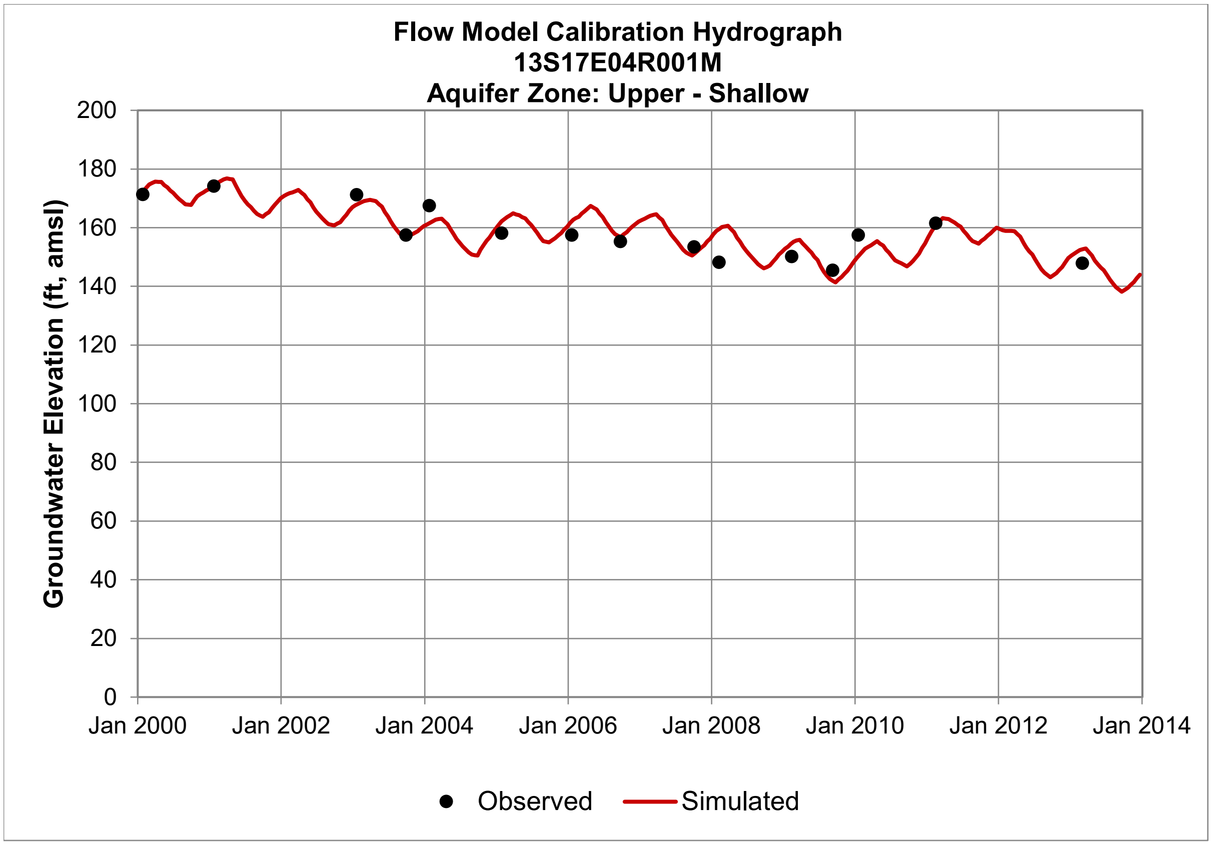
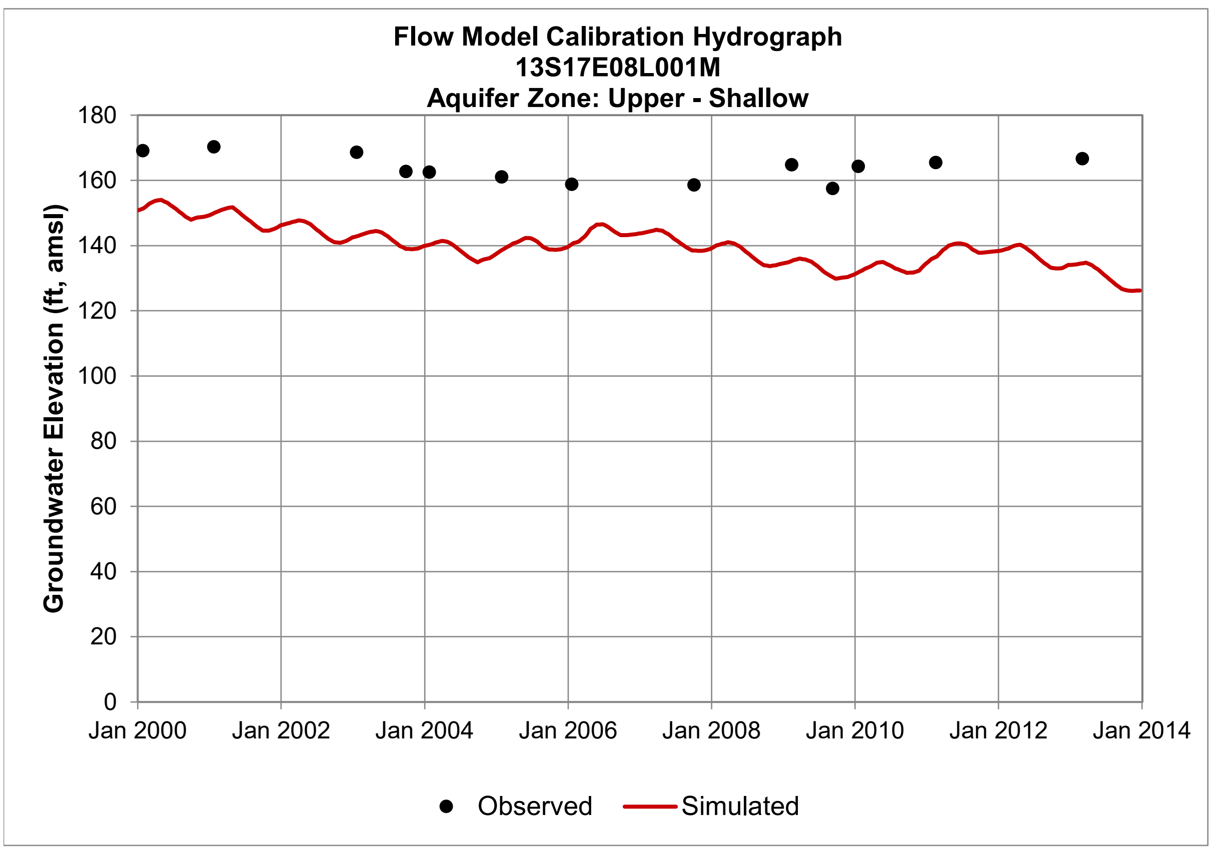
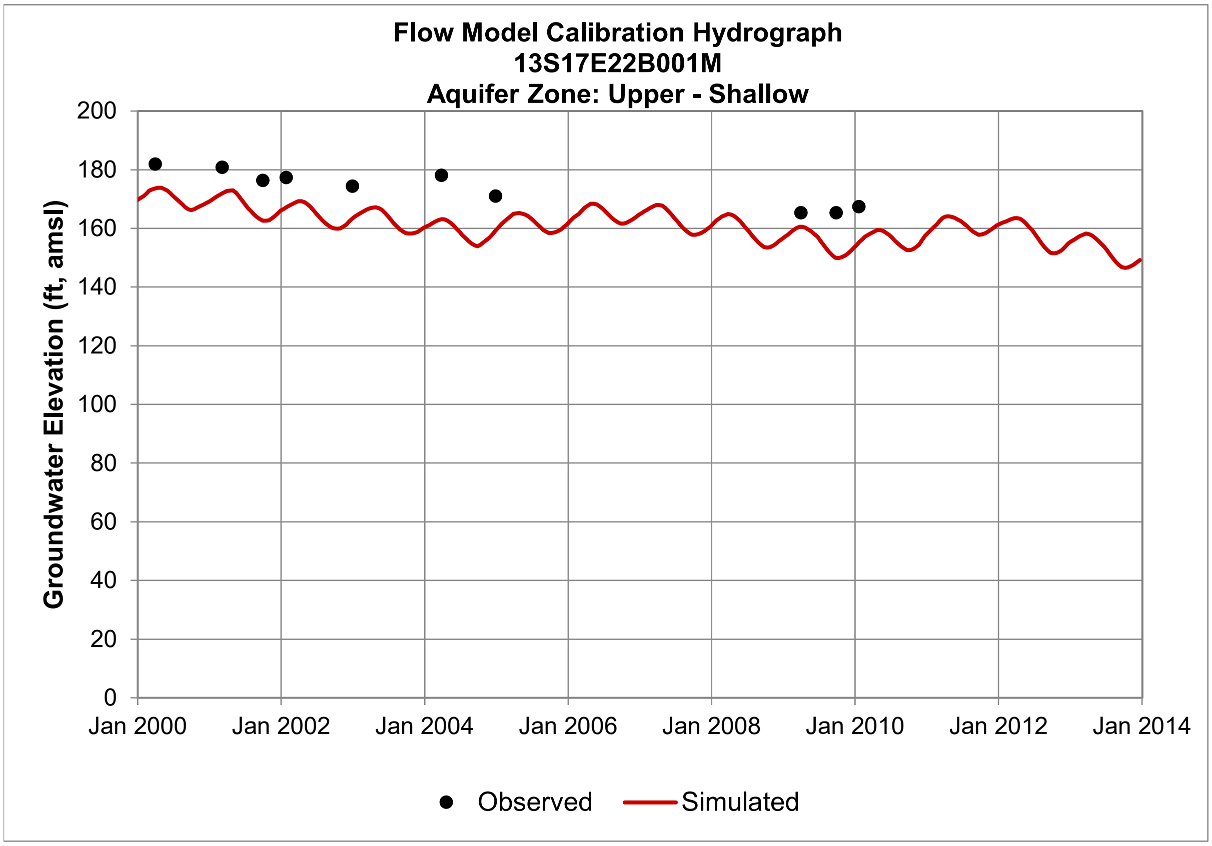
**Observed and Simulated Compaction above the Corcoran Clay at Yearout Ranch Extensometer**

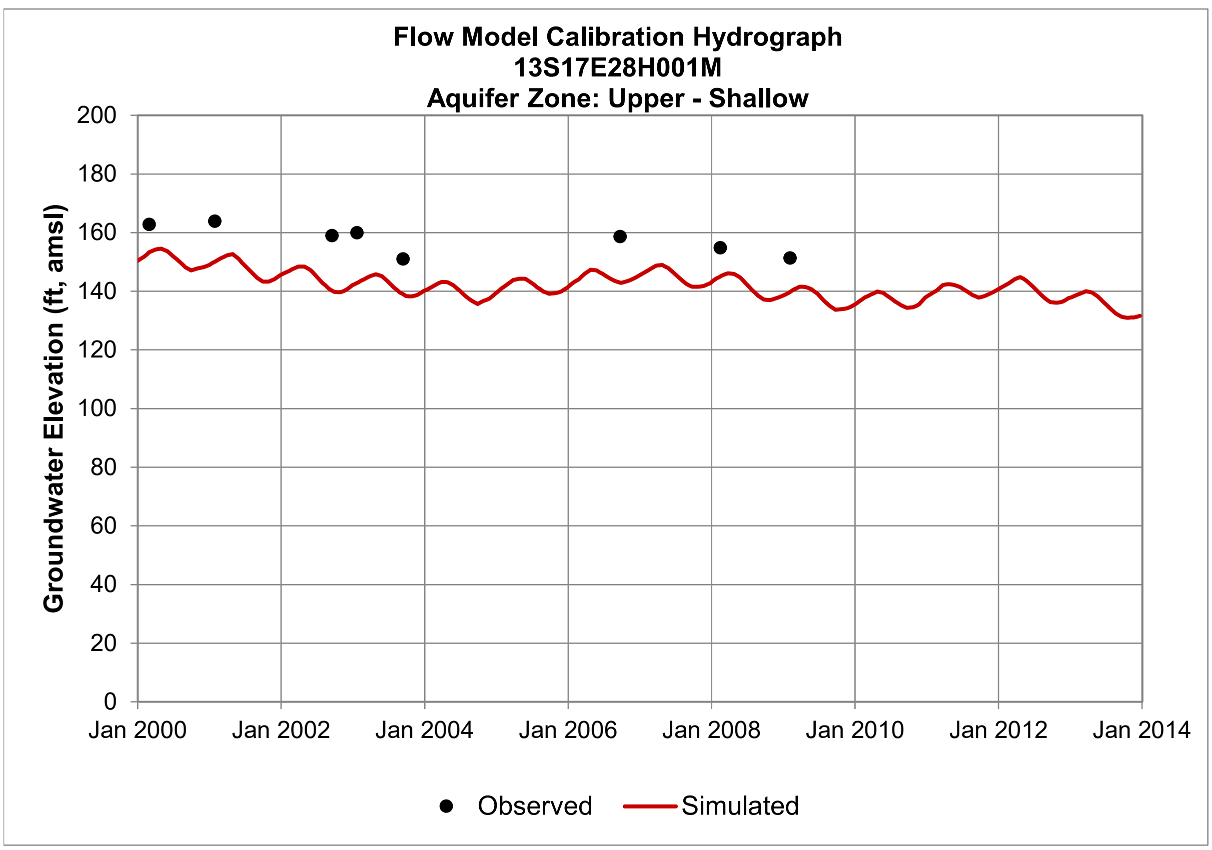
*Groundwater Sustainability Plan*
*County of Fresno*

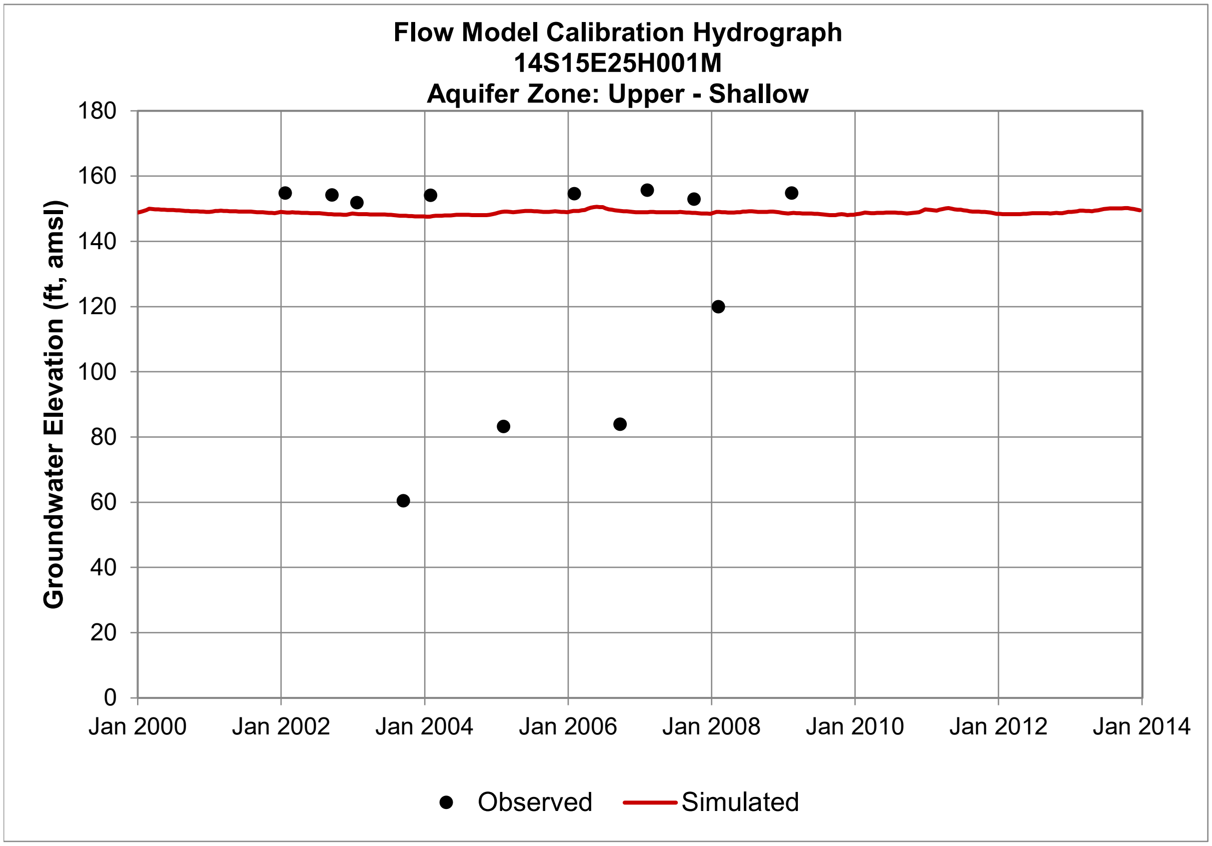
**Figure 6-17**


Flow Model Calibration Hydrograph
13S17E04R001M
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
0
20
40
60
80
100
120
140
160
180
200
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
13S17E08L001M
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
0
20
40
60
80
100
120
140
160
180
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
13S17E22B001M
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
200
180
160
140
120
100
80
60
40
20
0
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
13S17E28H001M
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
200
180
160
140
120
100
80
60
40
20
0
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
14S15E25H001M
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
0
20
40
60
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100
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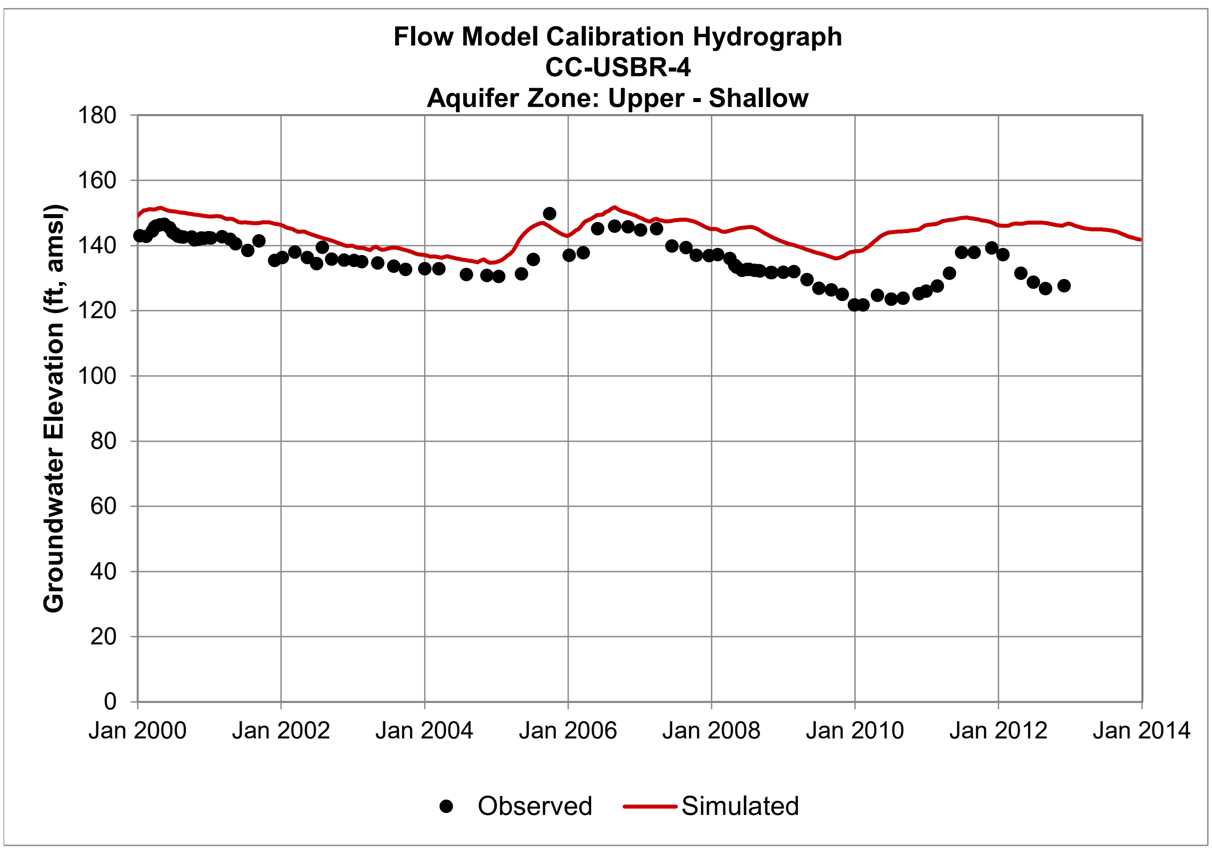
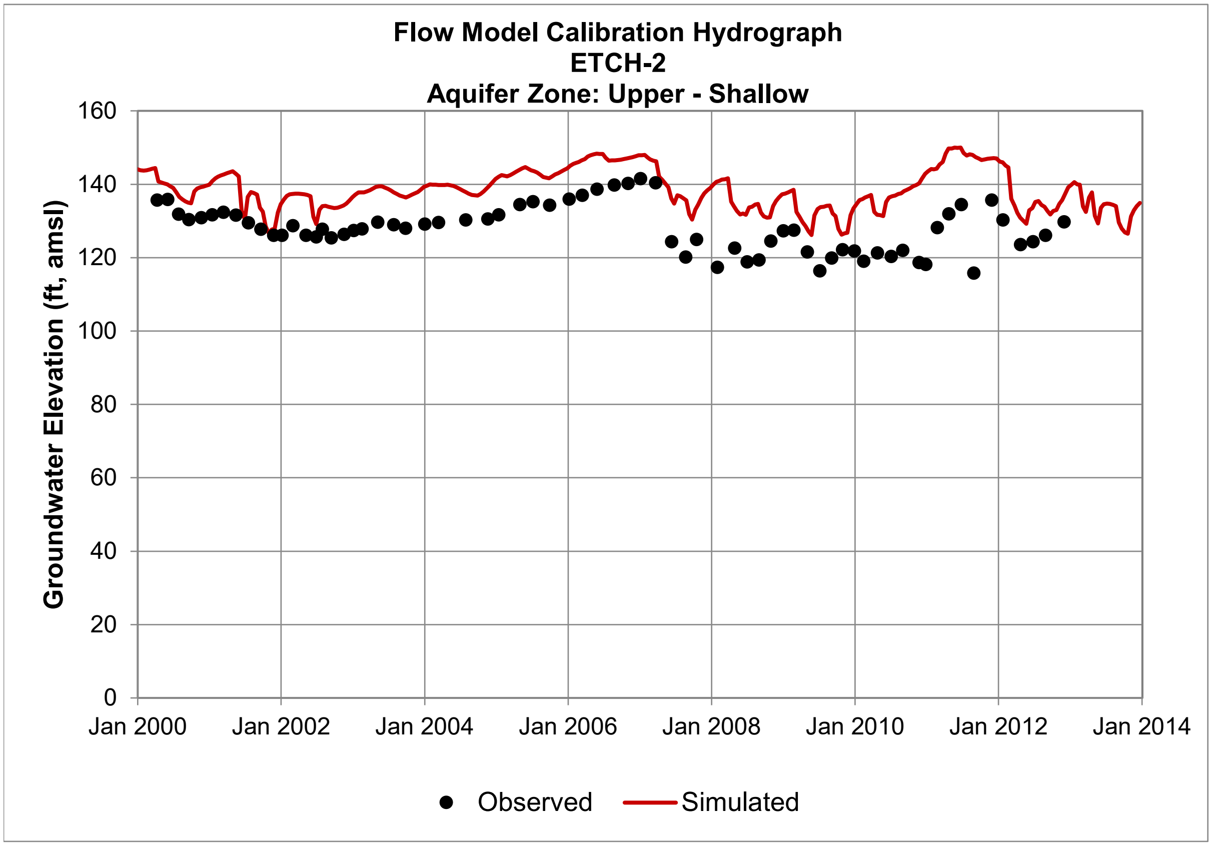
140
160
180
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
CC-USBR-4
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
0
20
40
60
80
100
120
140
160
180
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
ETCH-2
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
0
20
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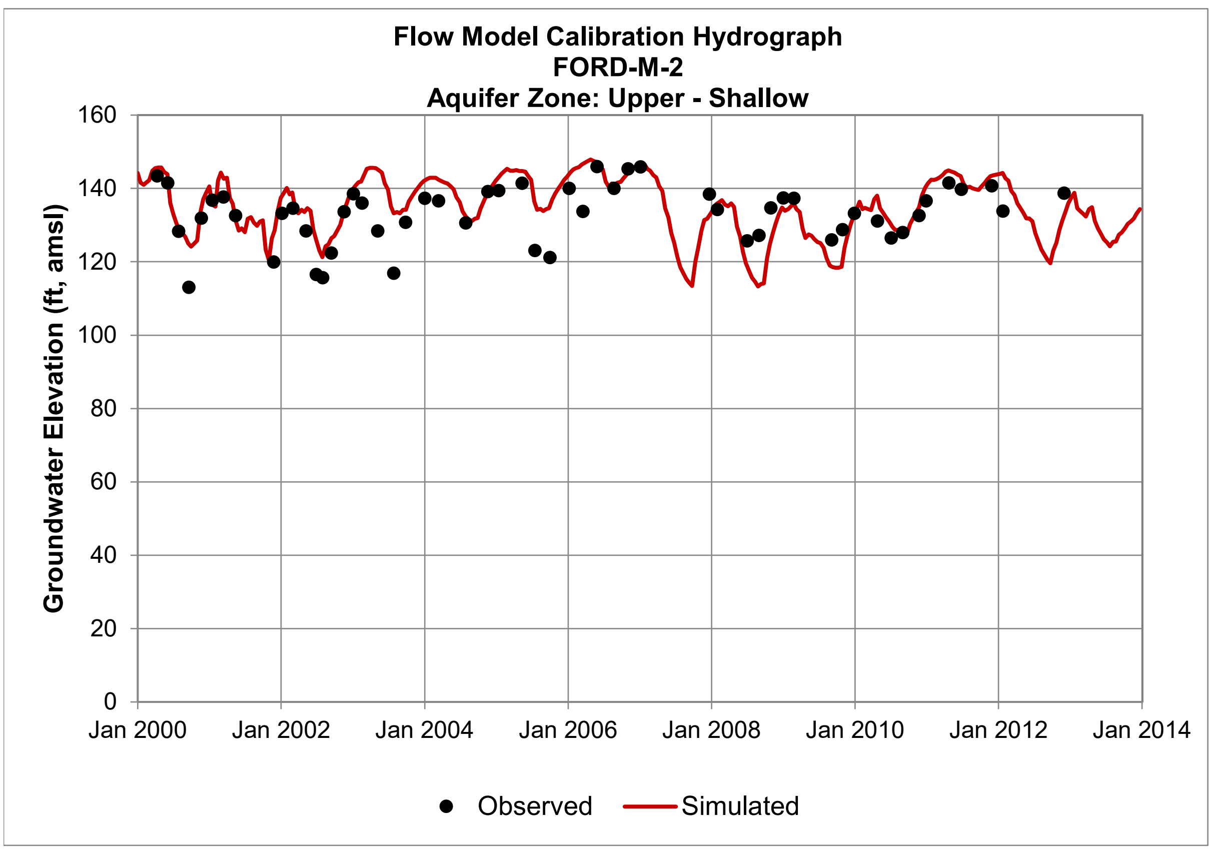
60
80
100
120
140
160
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
FORD-M-2
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
0
20
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60
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100
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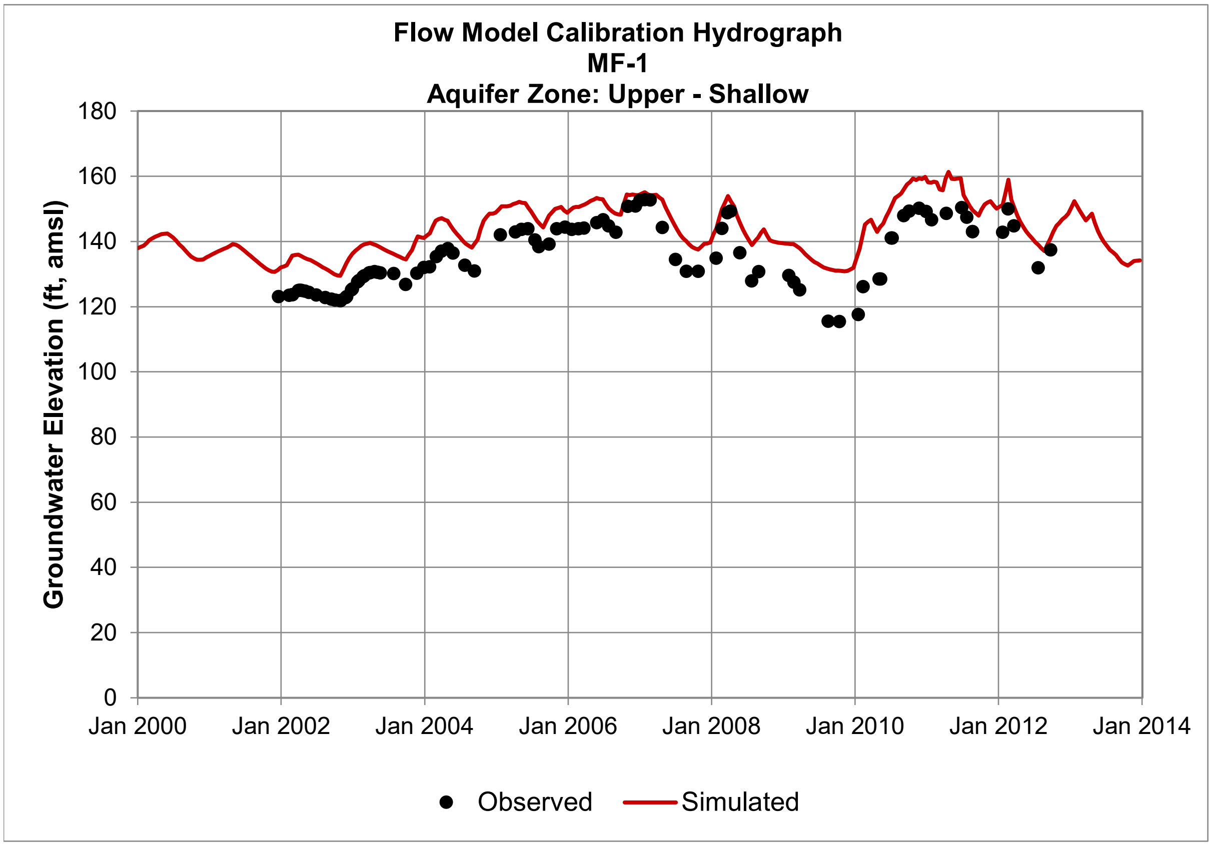
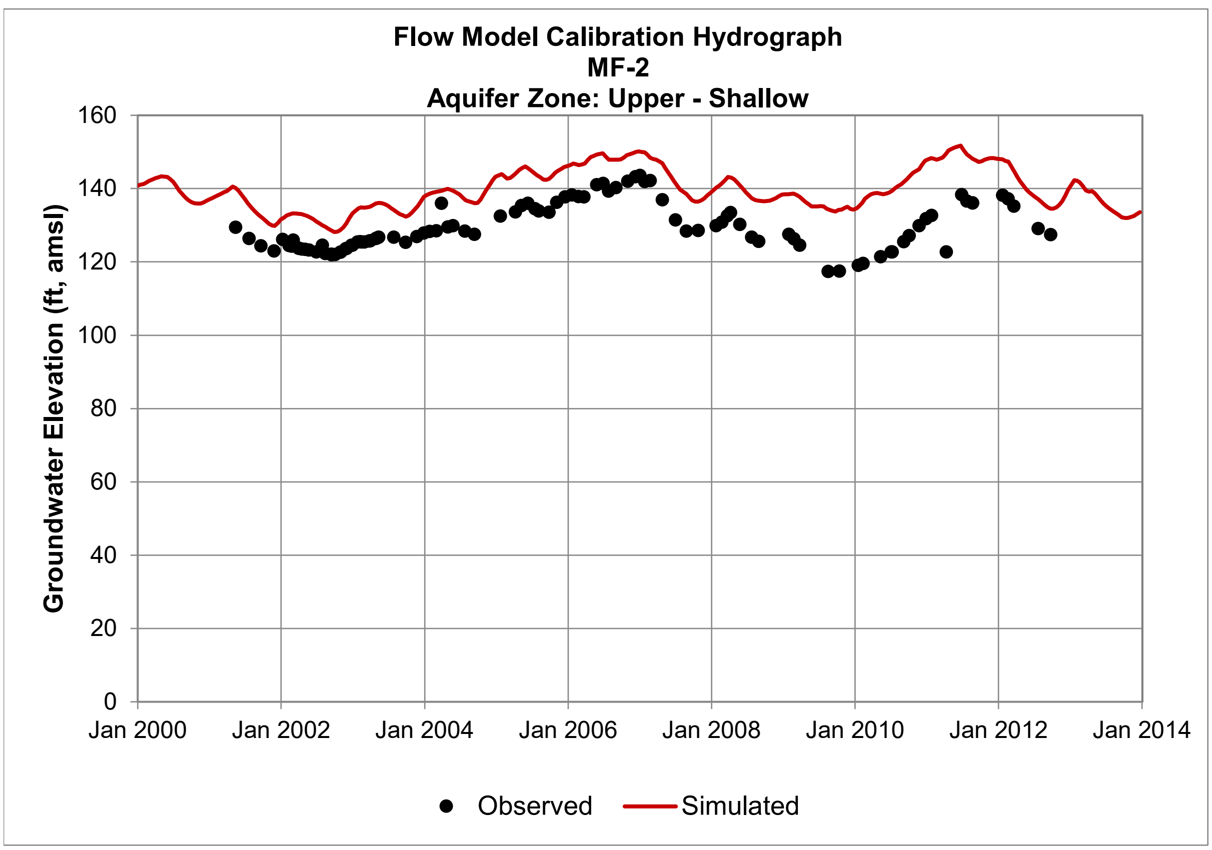
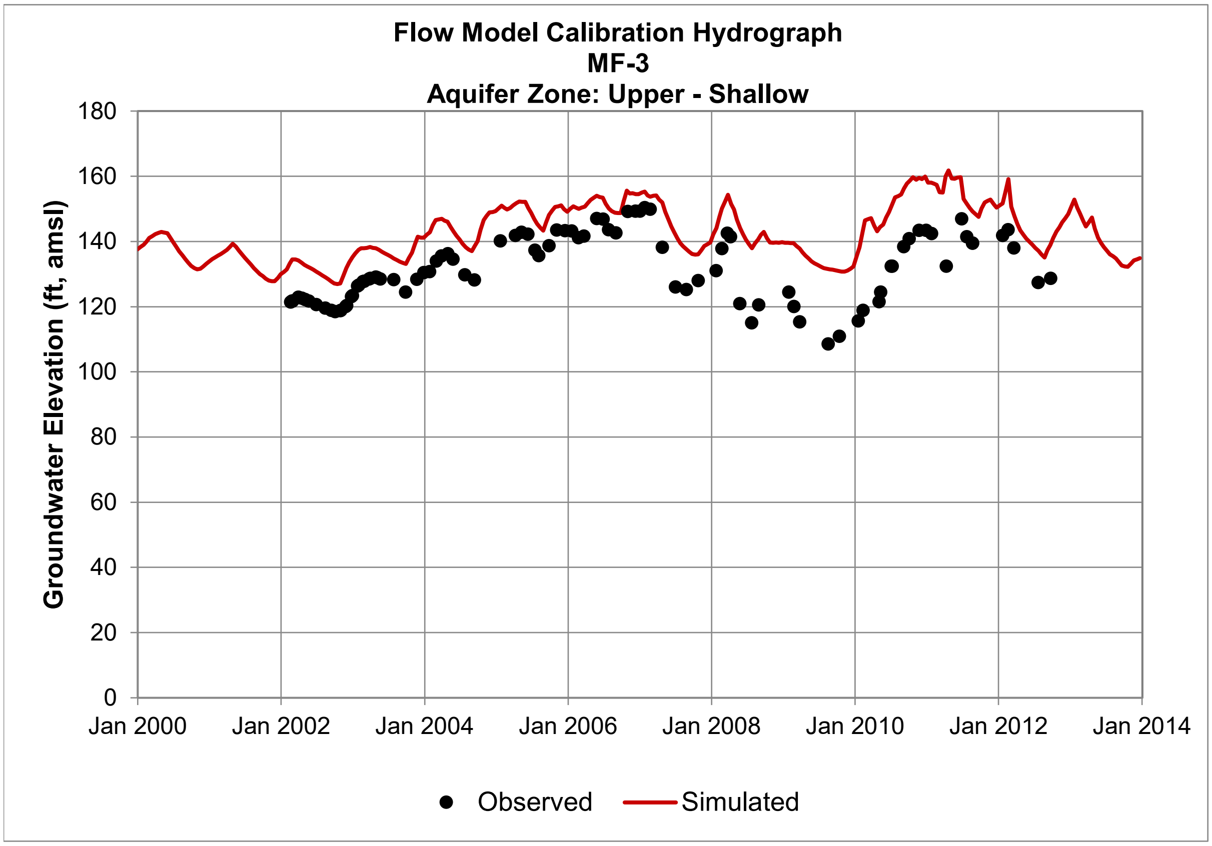
140
160
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
MF-1
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
0
20
40
60
80
100
120
140
160
180
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
MF-2
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
0
20
40
60
80
100
120
140
160
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
MF-3
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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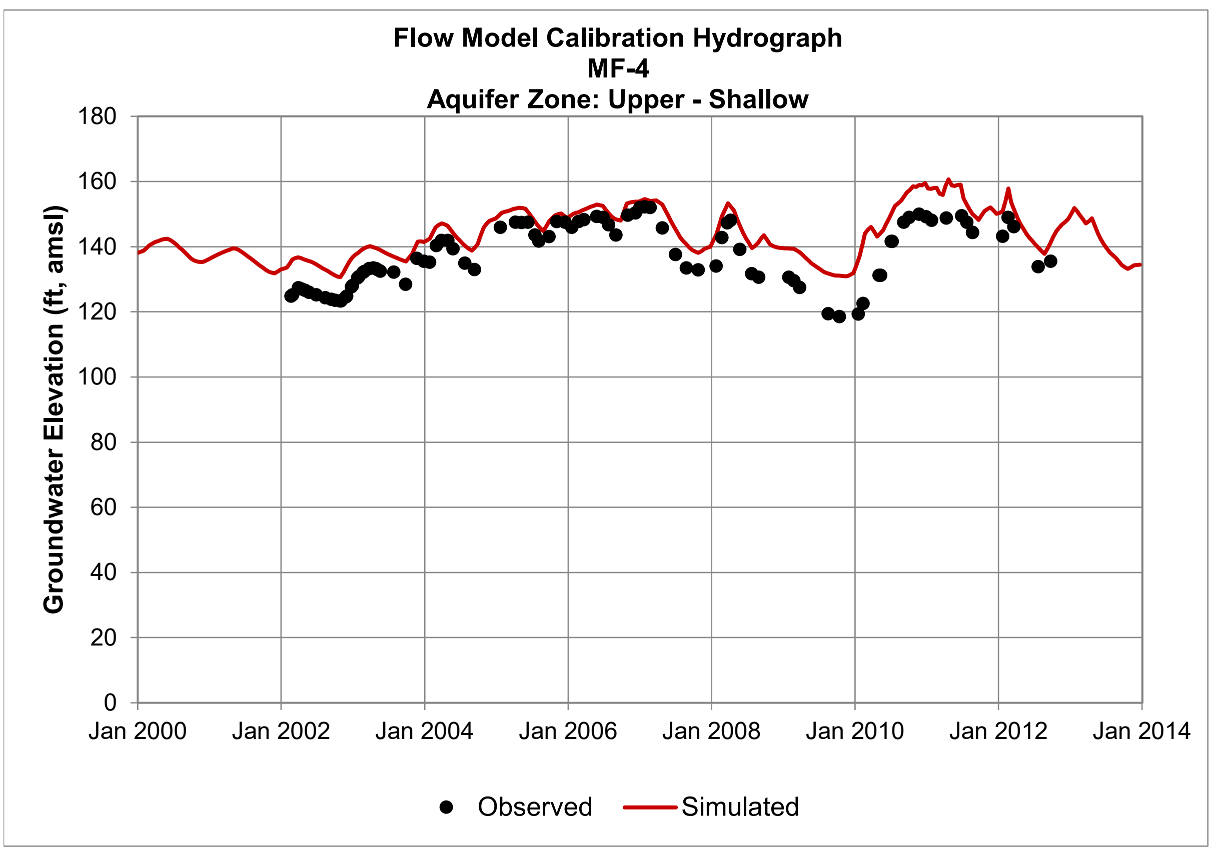
20
40
60
80
100
120
140
160
180
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
MF-4
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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60
80
100
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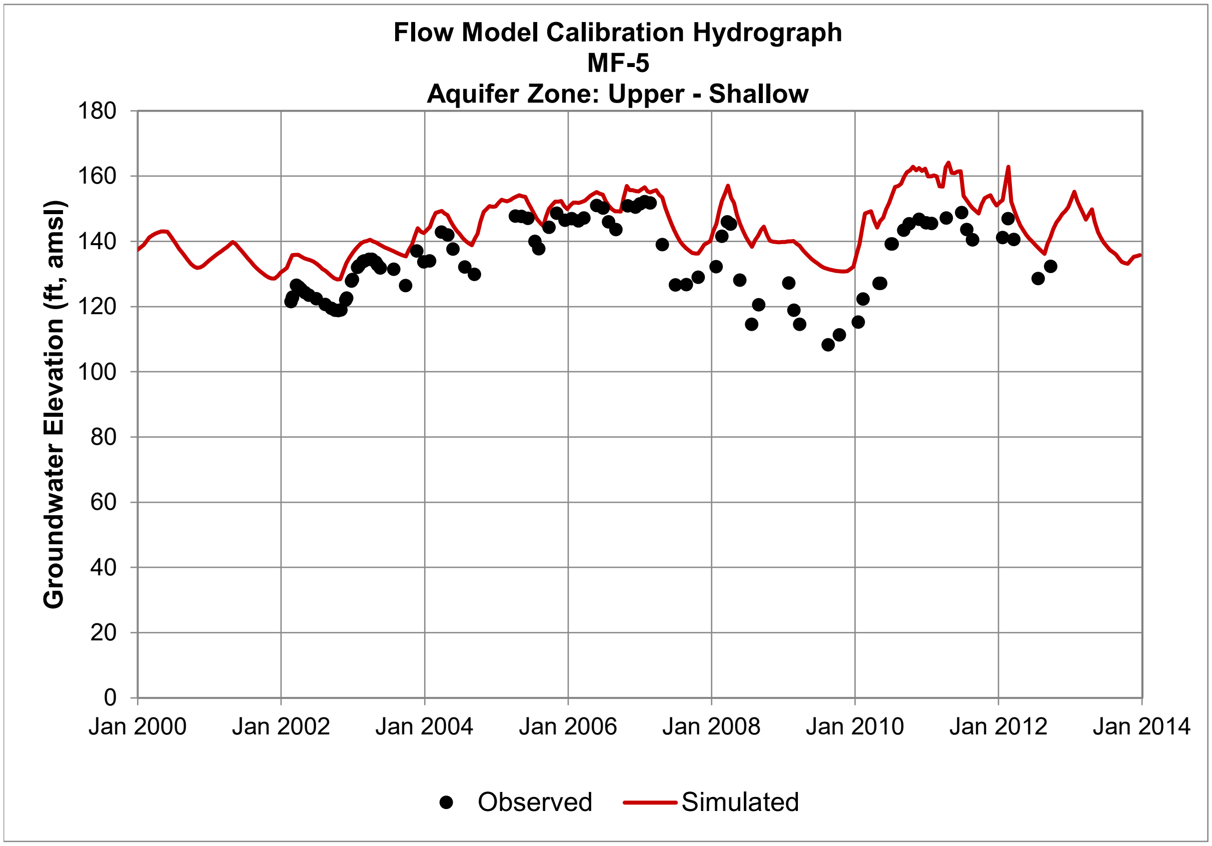
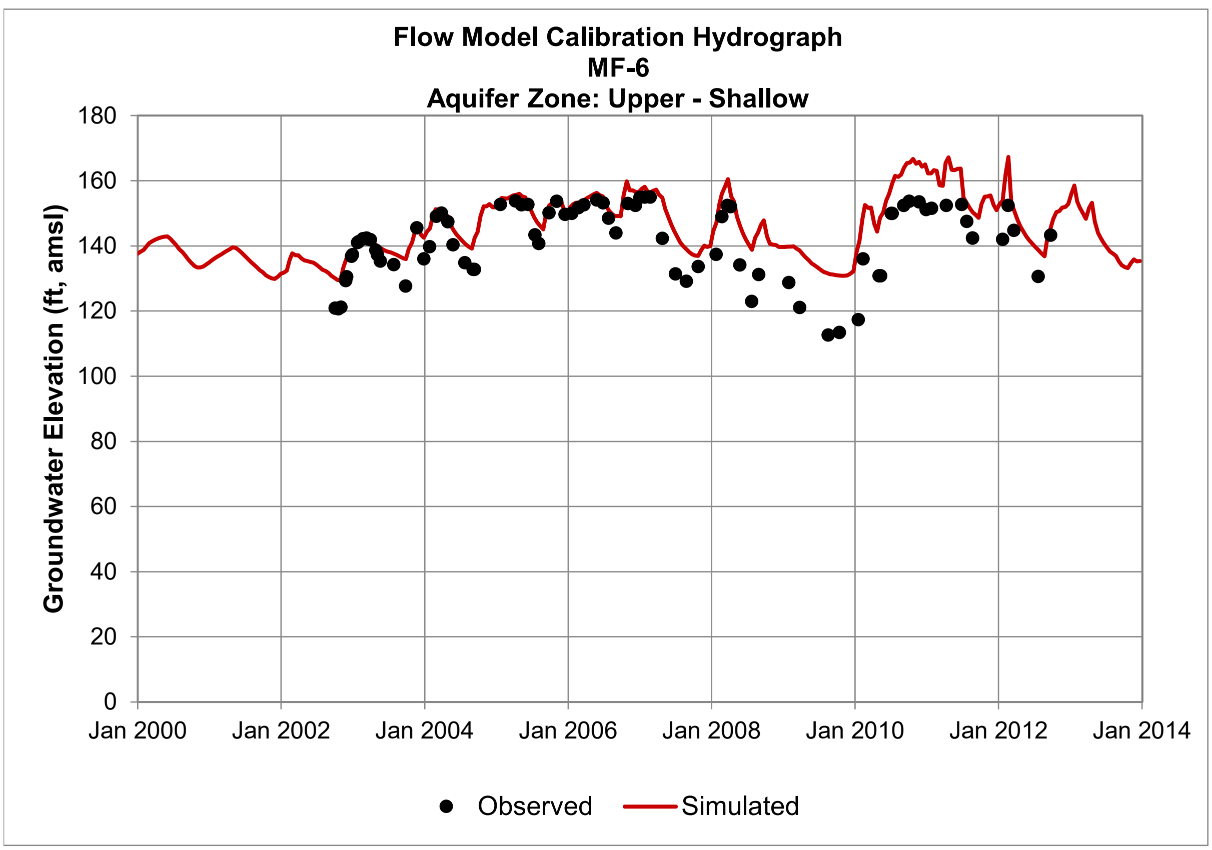
140
160
180
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
MF-5
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
180
160
140
120
100
80
60
40
20
0
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
MF-6
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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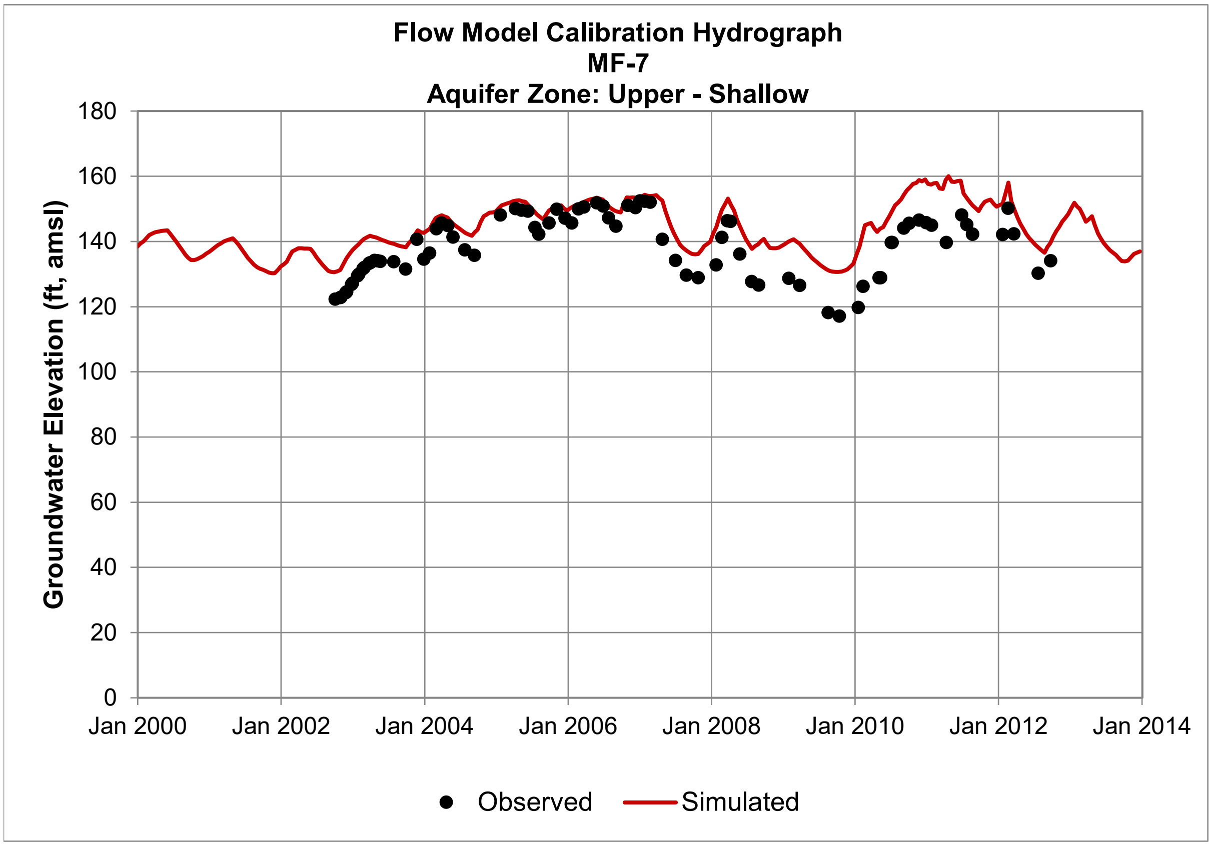
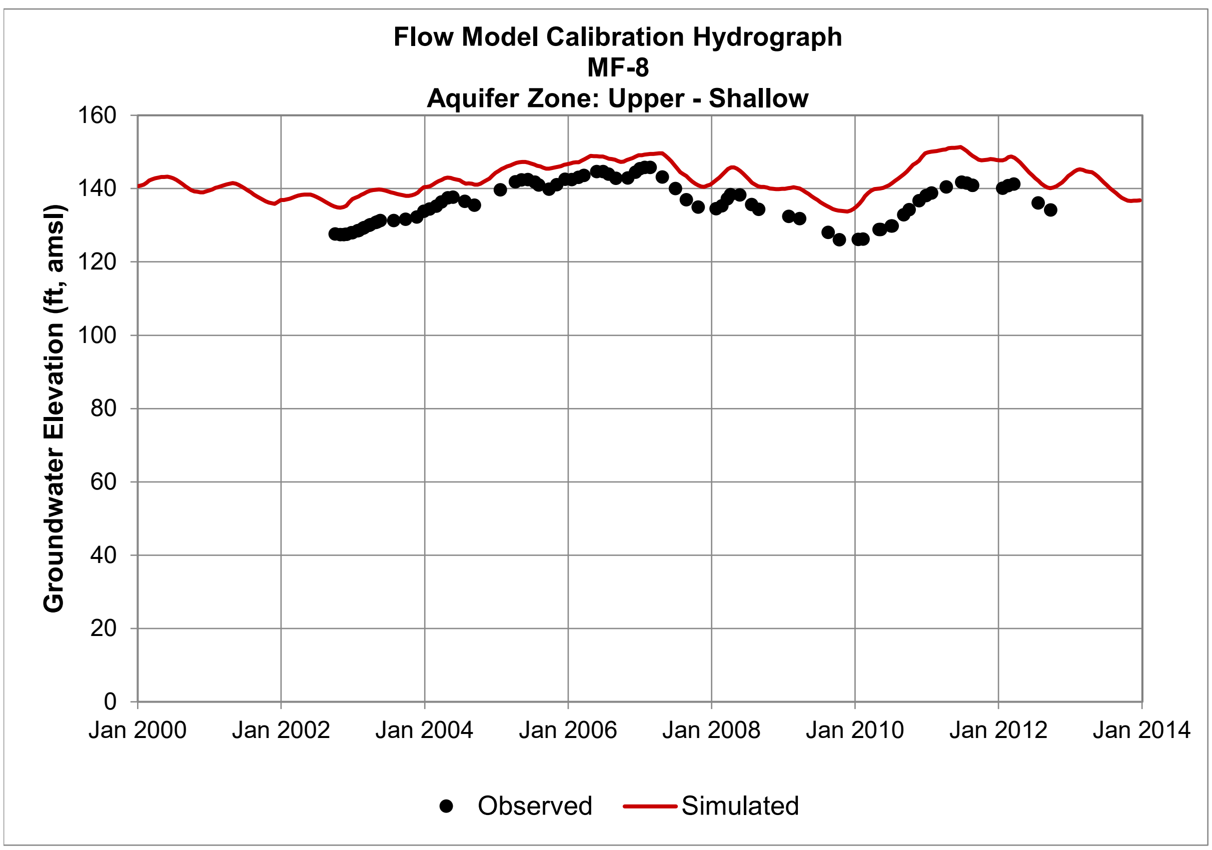
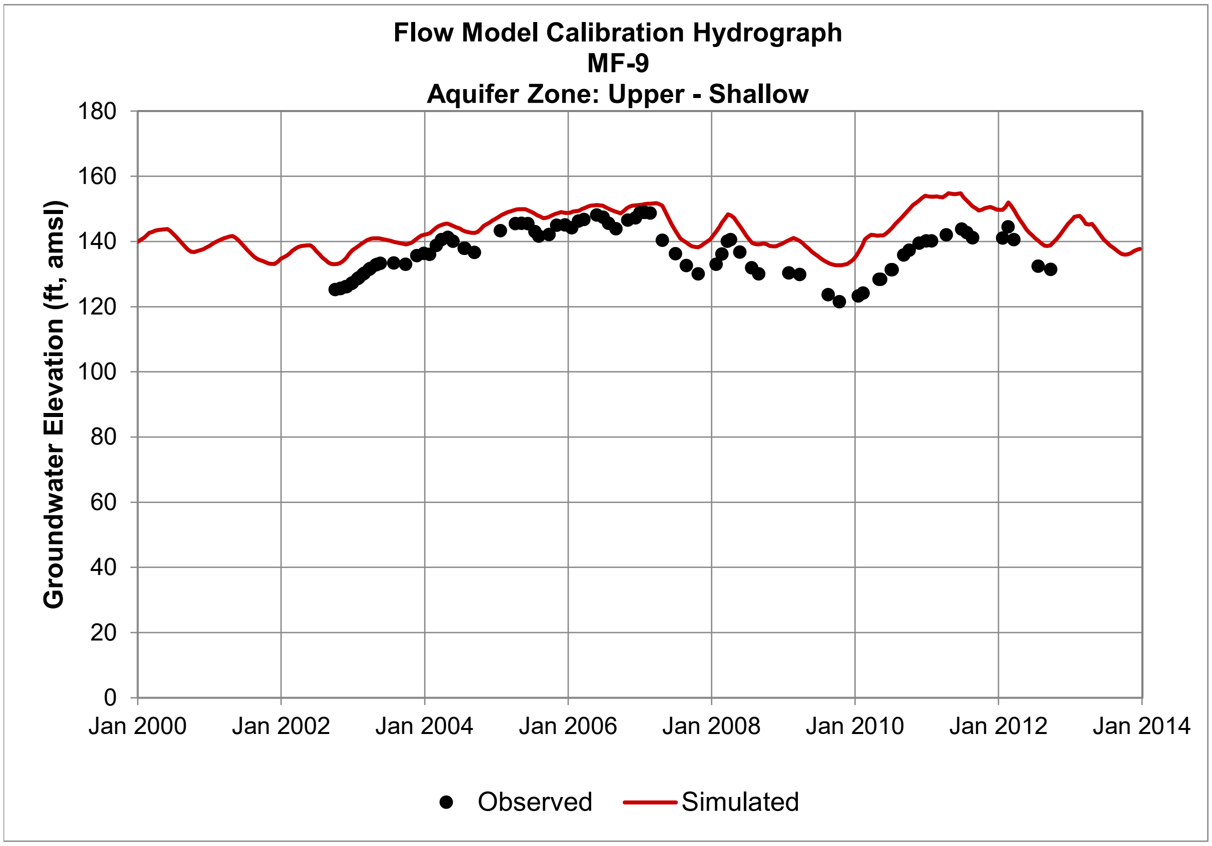
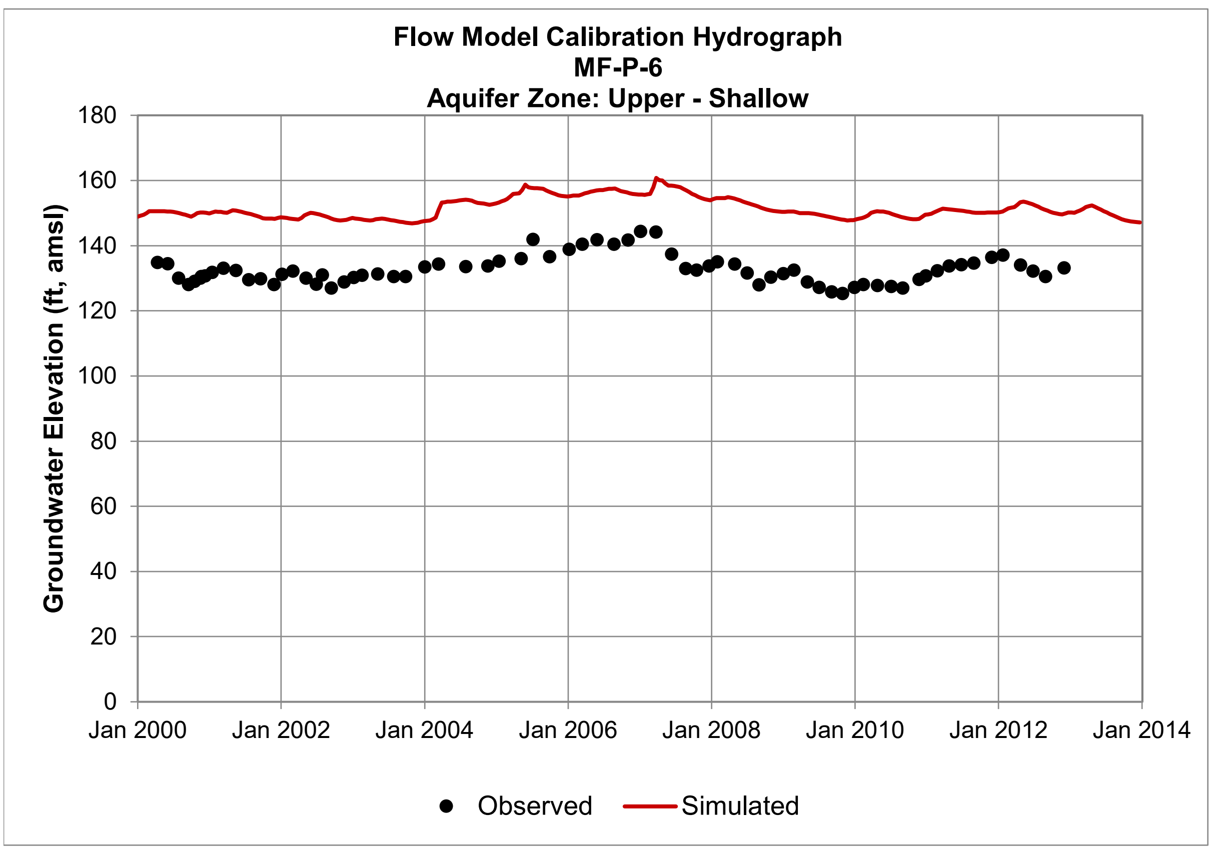
160
140
120
100
80
60
40
20
0
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
MF-7
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
180
160
140
120
100
80
60
40
20
0
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
MF-8
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
160
140
120
100
80
60
40
20
0
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
MF-9
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
180
160
140
120
100
80
60
40
20
0
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
MF-P-6
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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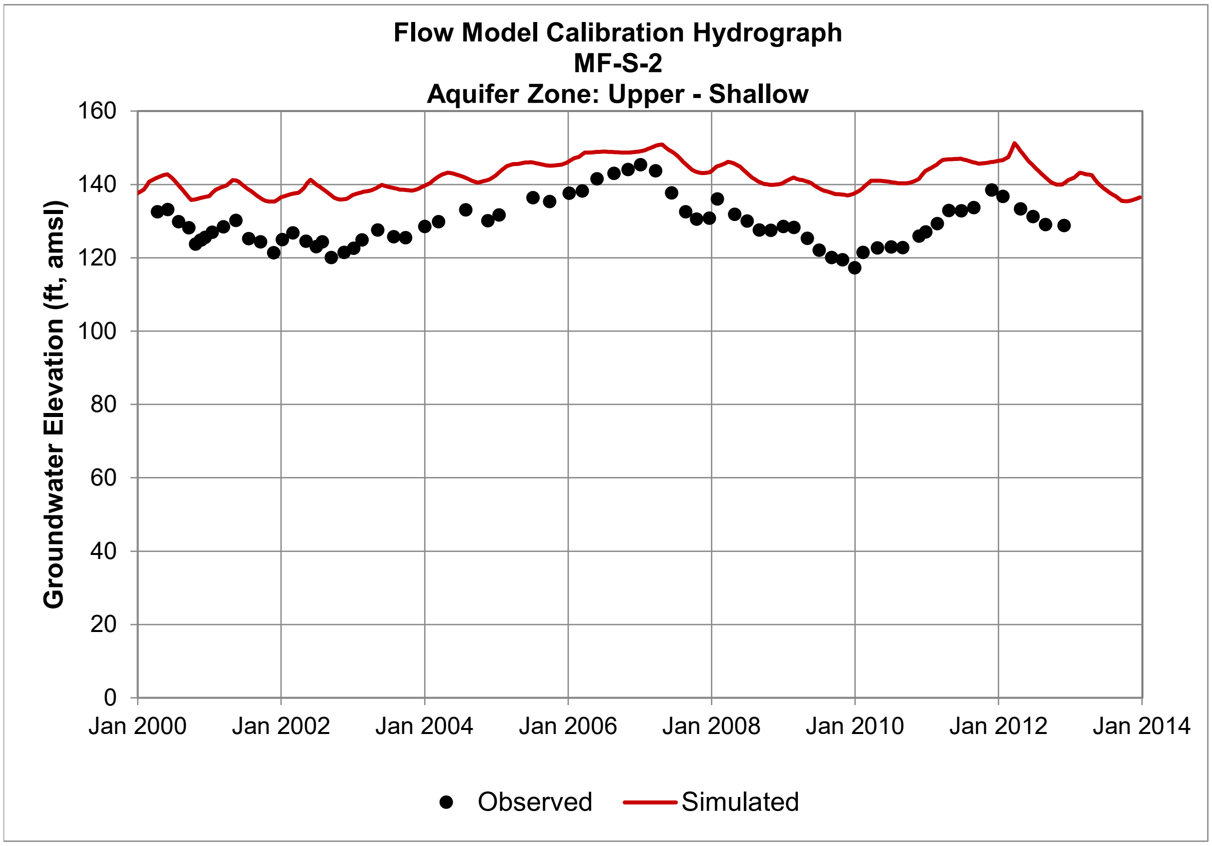
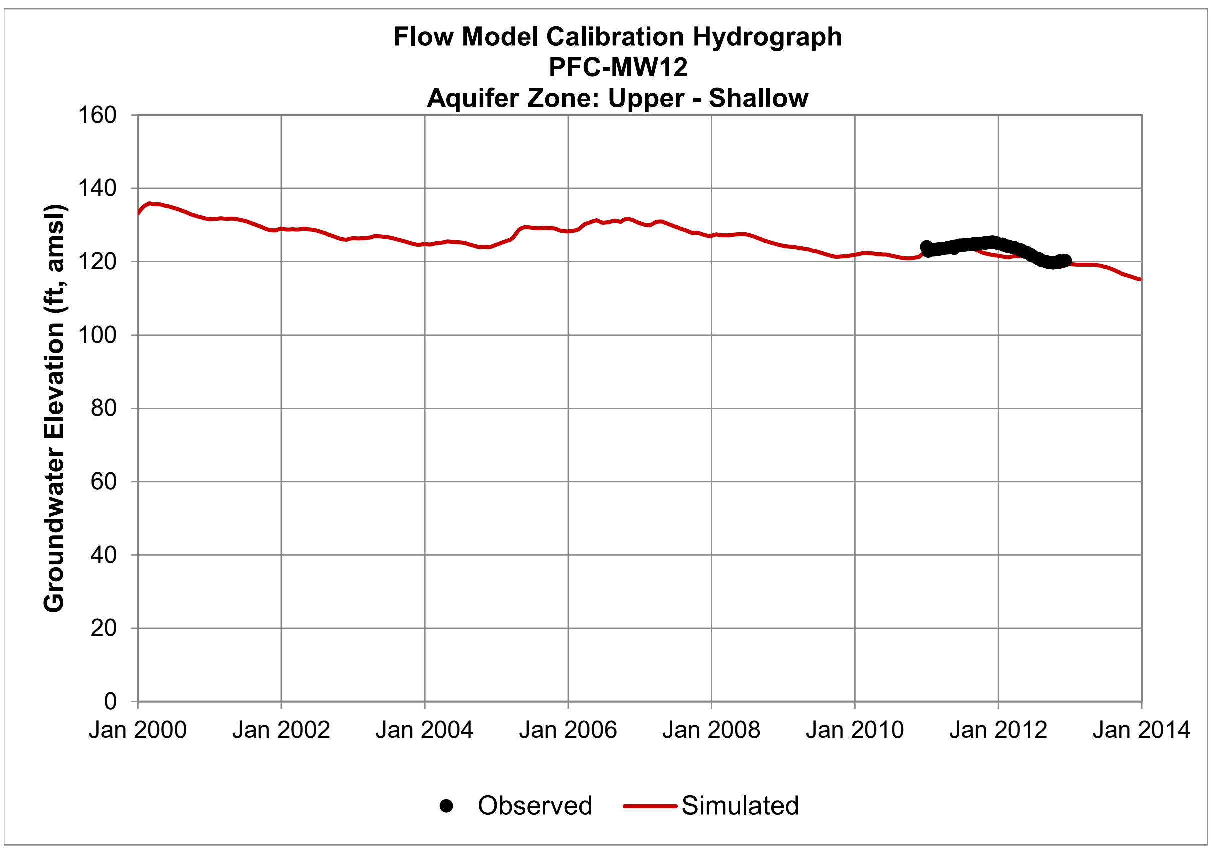
160
140
120
100
80
60
40
20
0
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
MF-S-2
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
160
140
120
100
80
60
40
20
0
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
PFC-MW12
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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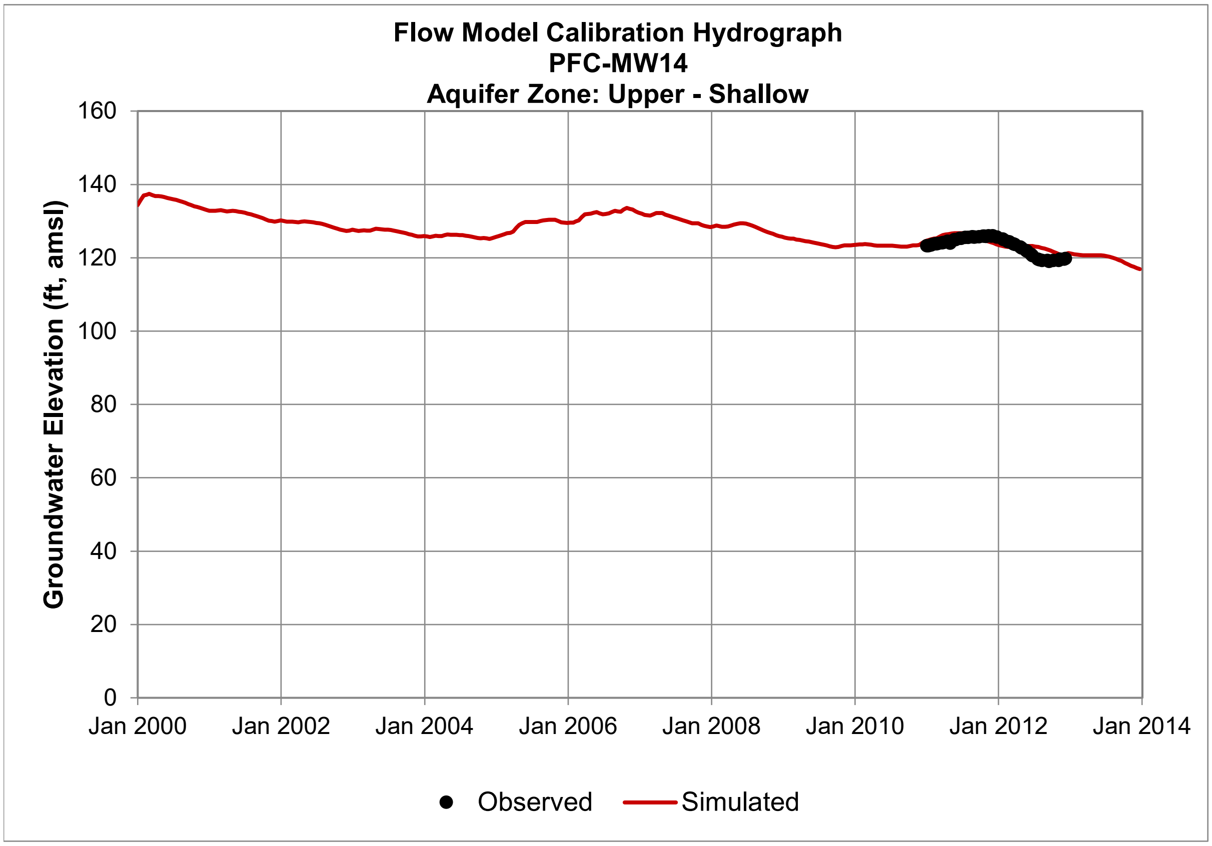
140
120
100
80
60
40
20
0
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
PFC-MW14
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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140
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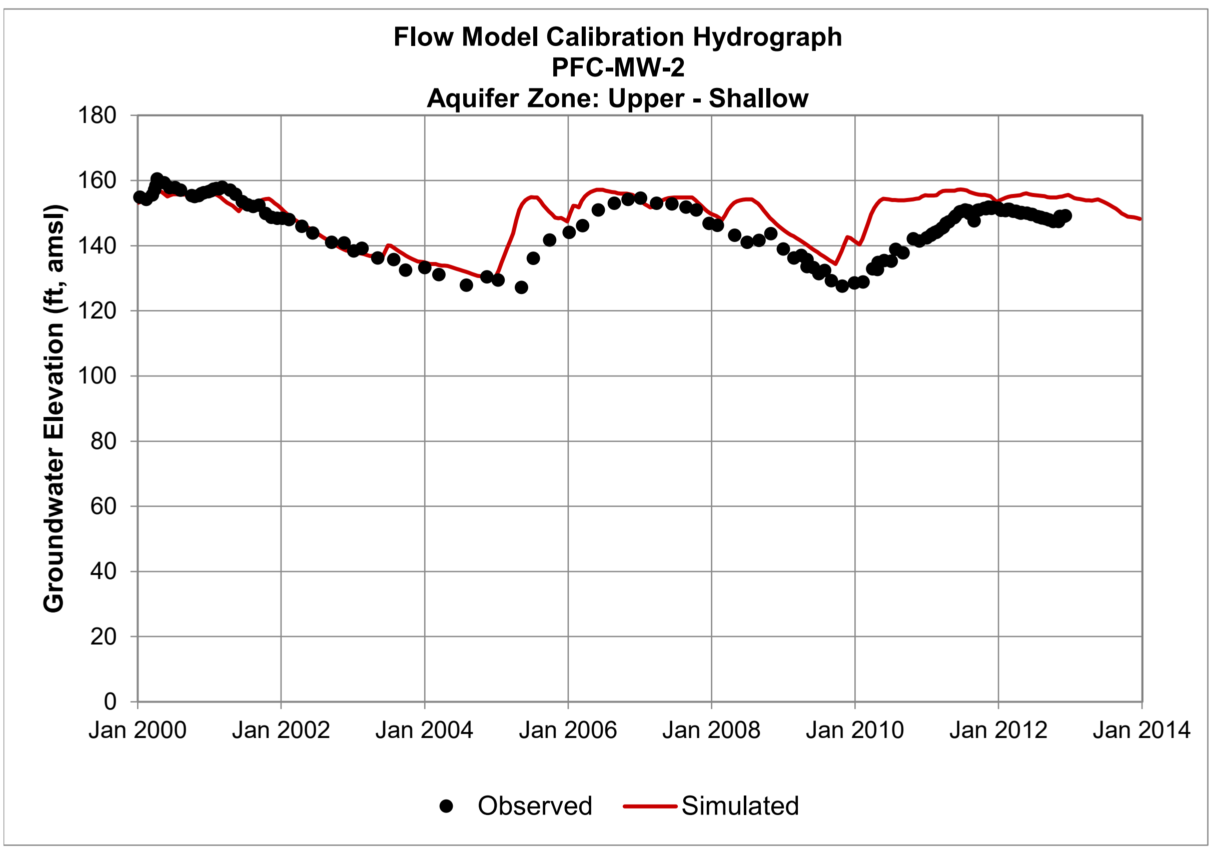
20
0
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
PFC-MW-2
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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160
140
120
100
80
60
40
20
0
Jan 2000
Jan 2002
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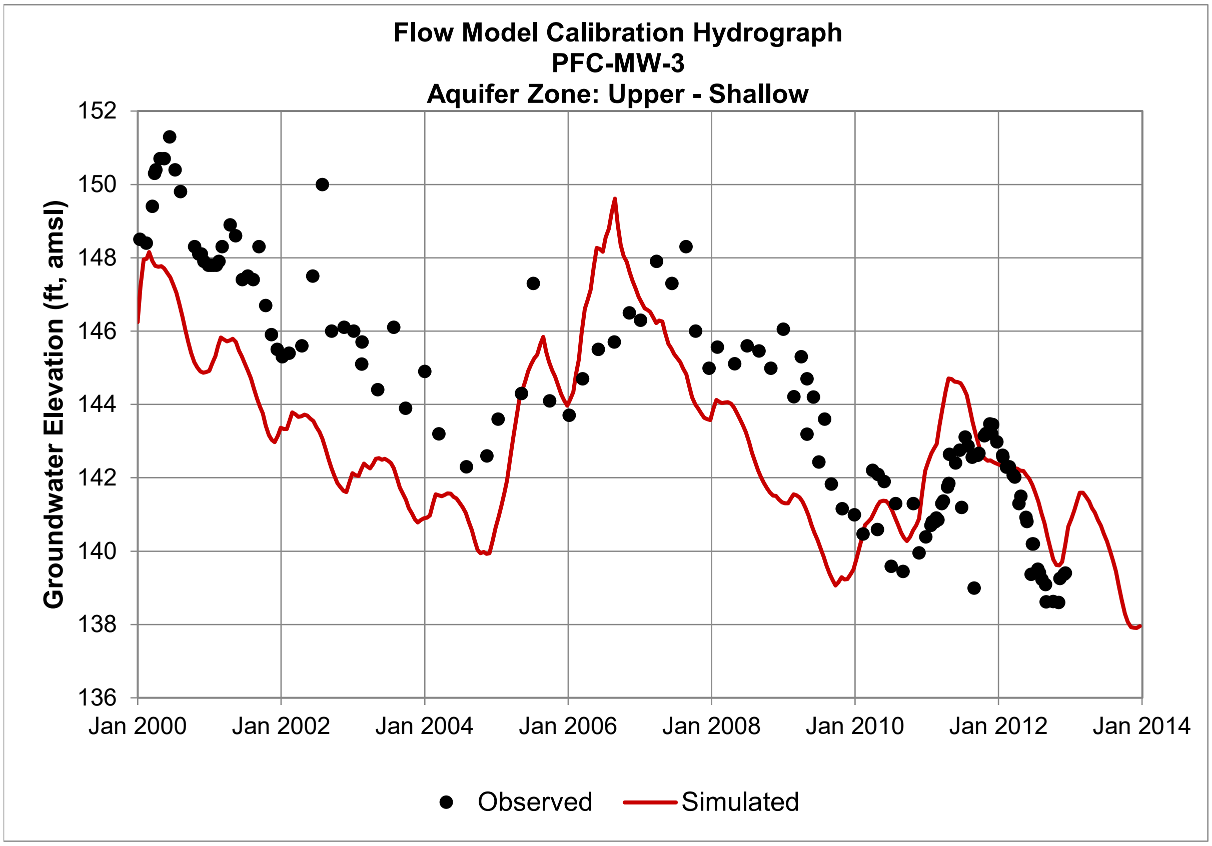
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
PFC-MW-3
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
152
150
148
146
144
142
140
138
136
Jan 2000
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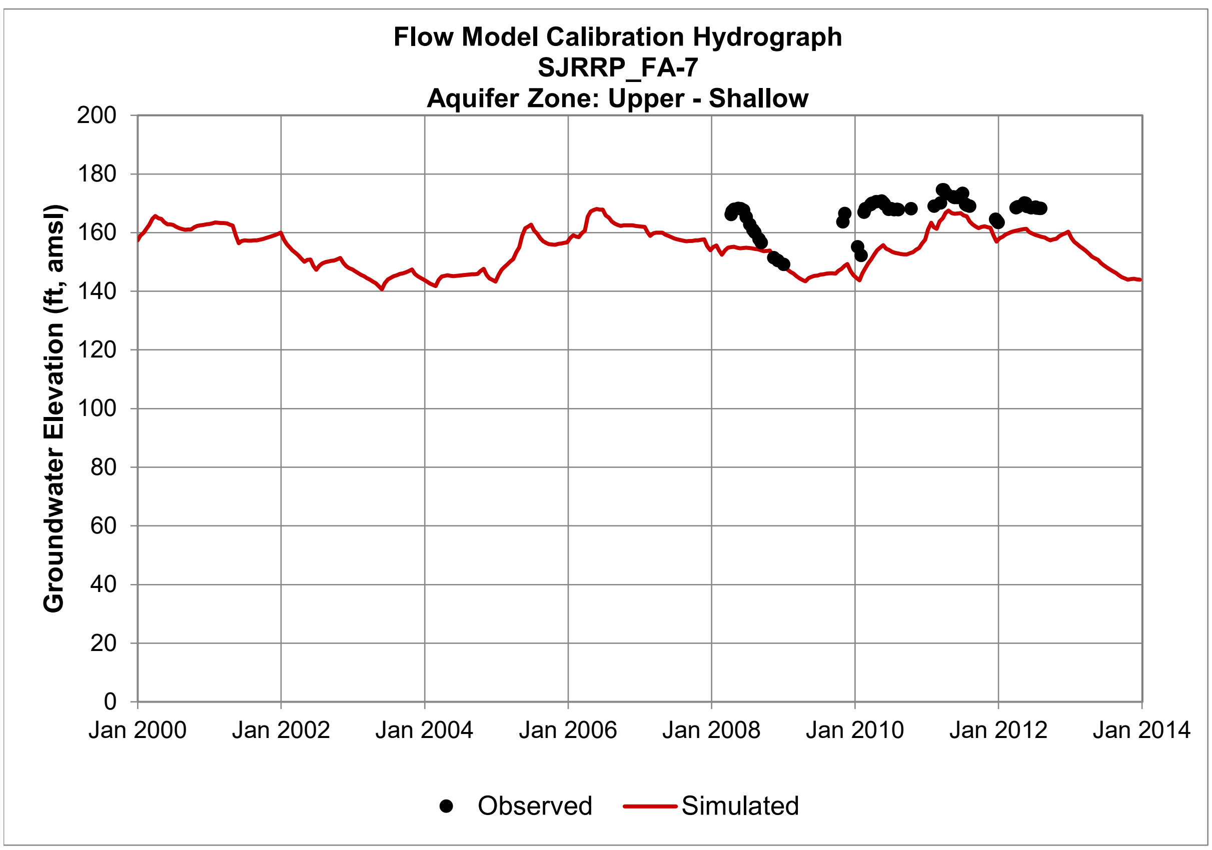
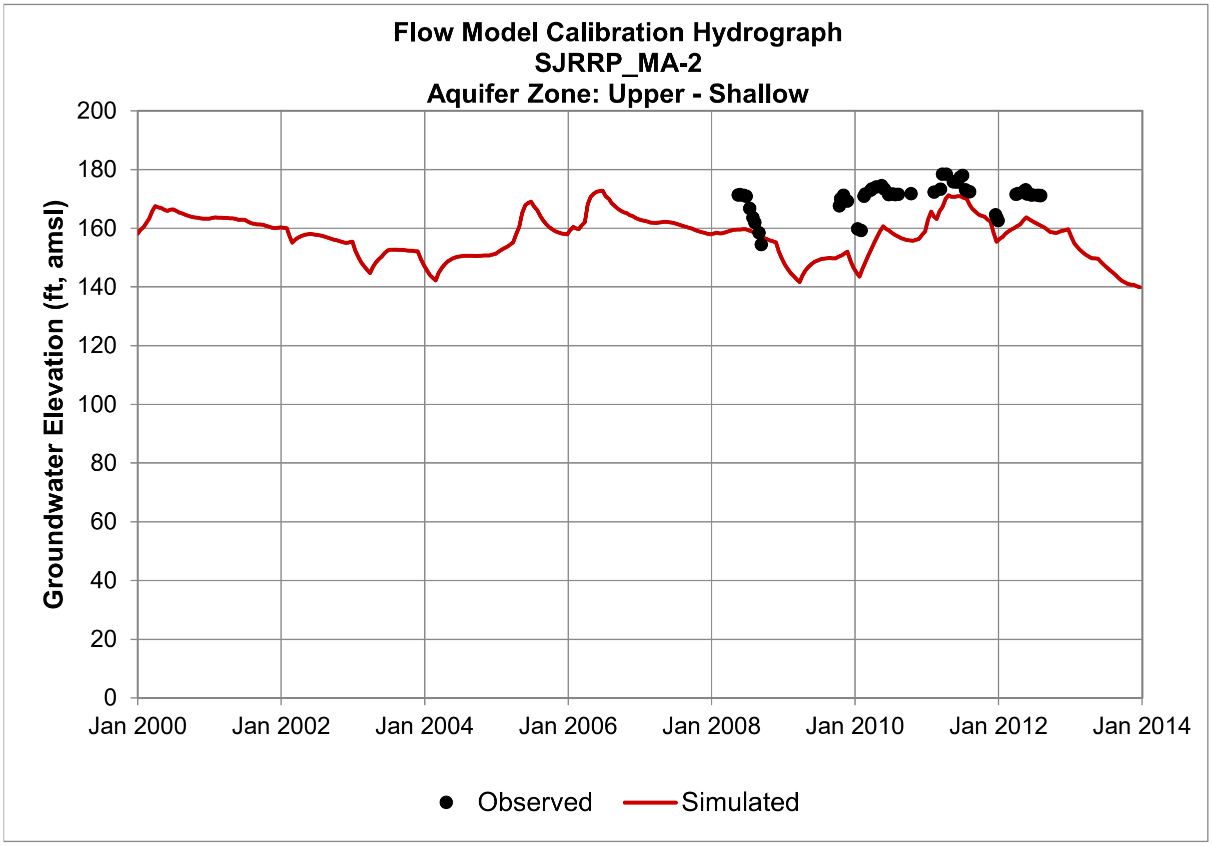
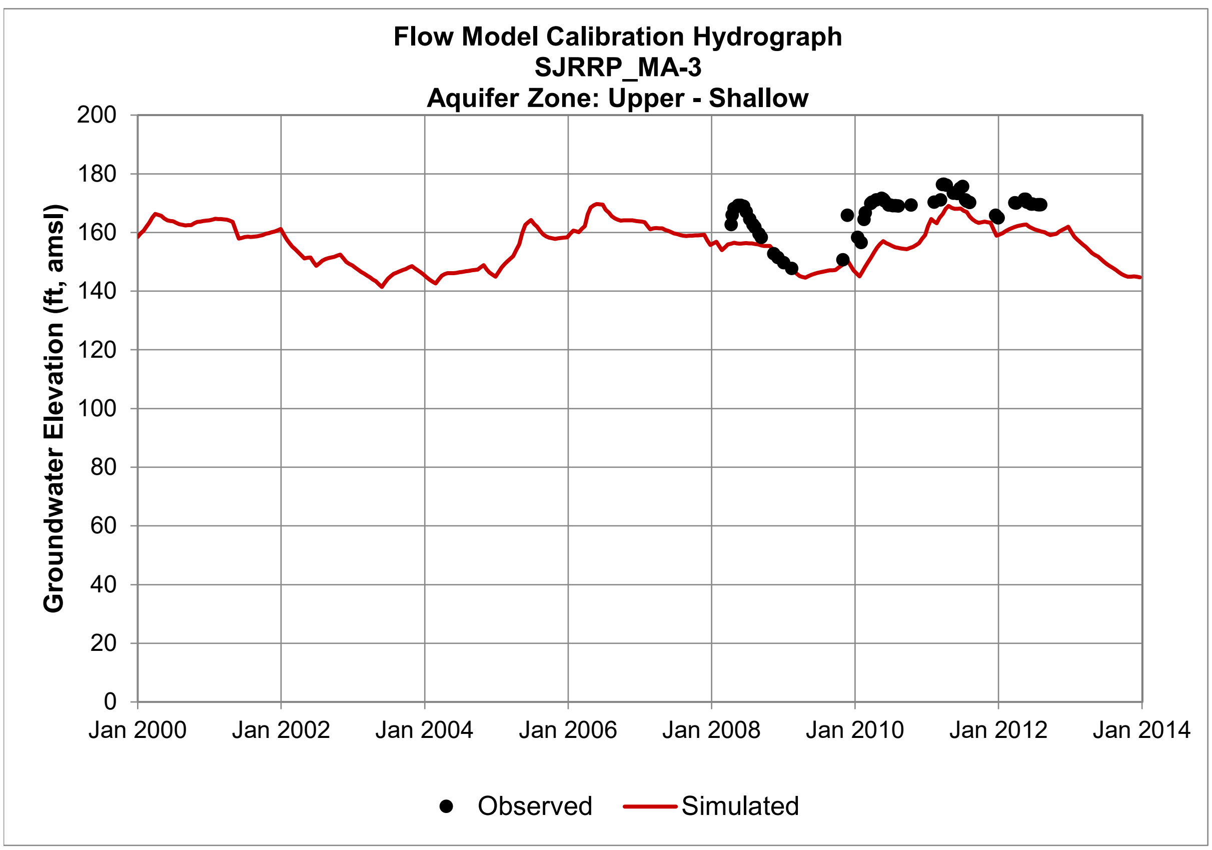
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
SJRRP_FA-7
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
200
180
160
140
120
100
80
60
40
20
0
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
SJRRP_MA-2
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
200
180
160
140
120
100
80
60
40
20
0
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
SJRRP_MA-3
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
200
180
160
140
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40
20
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Jan 2000
Jan 2002
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Jan 2008
Jan 2010
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Observed
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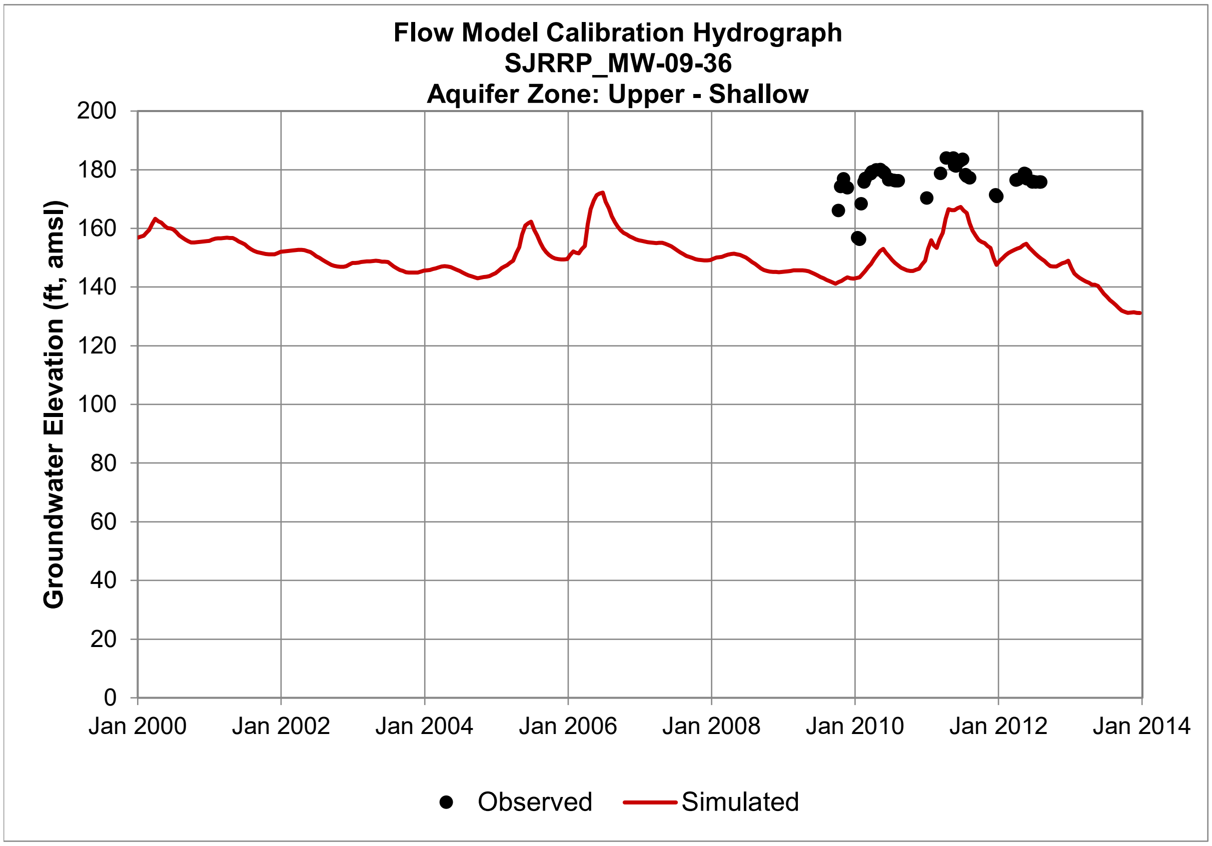
Flow Model Calibration Hydrograph
SJRRP_MW-09-36
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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180
160
140
120
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Jan 2002
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Observed
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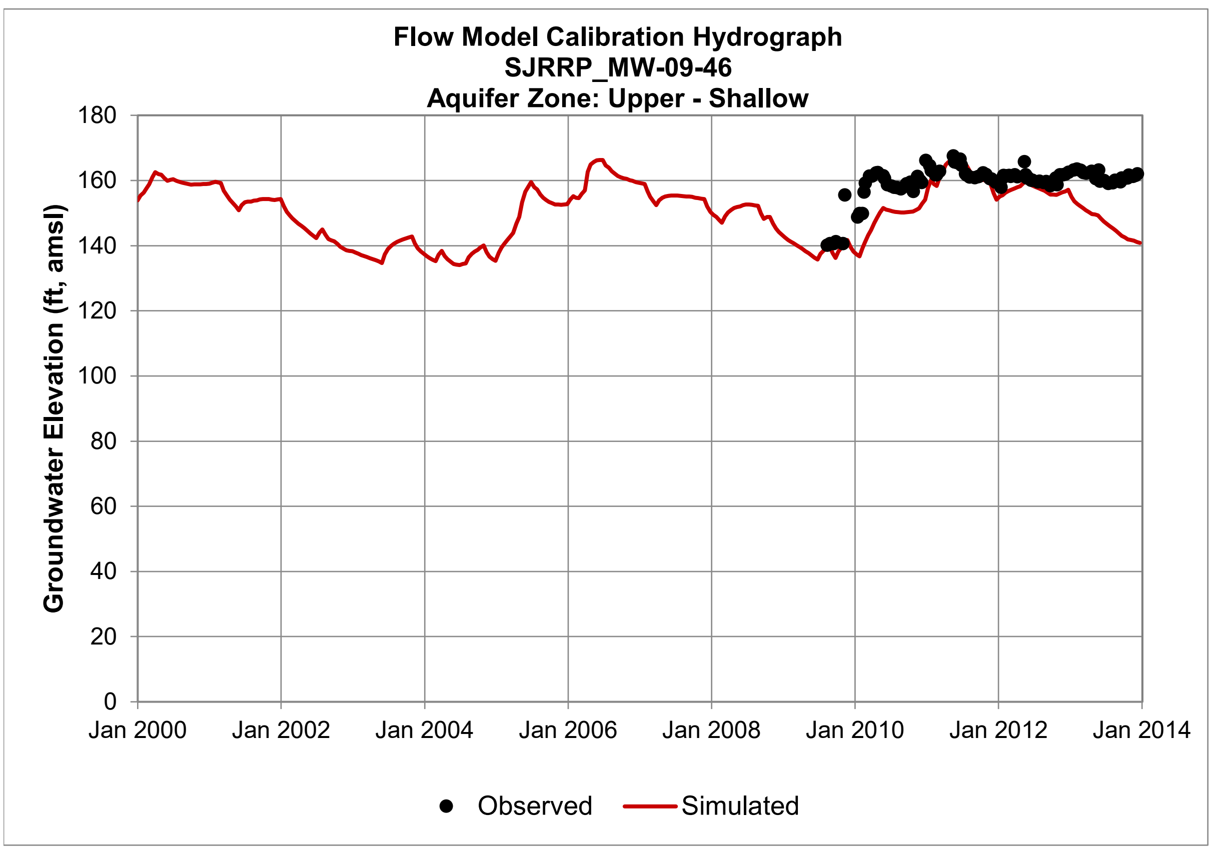
Flow Model Calibration Hydrograph
SJRRP_MW-09-46
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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160
140
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20
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Jan 2000
Jan 2002
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Observed
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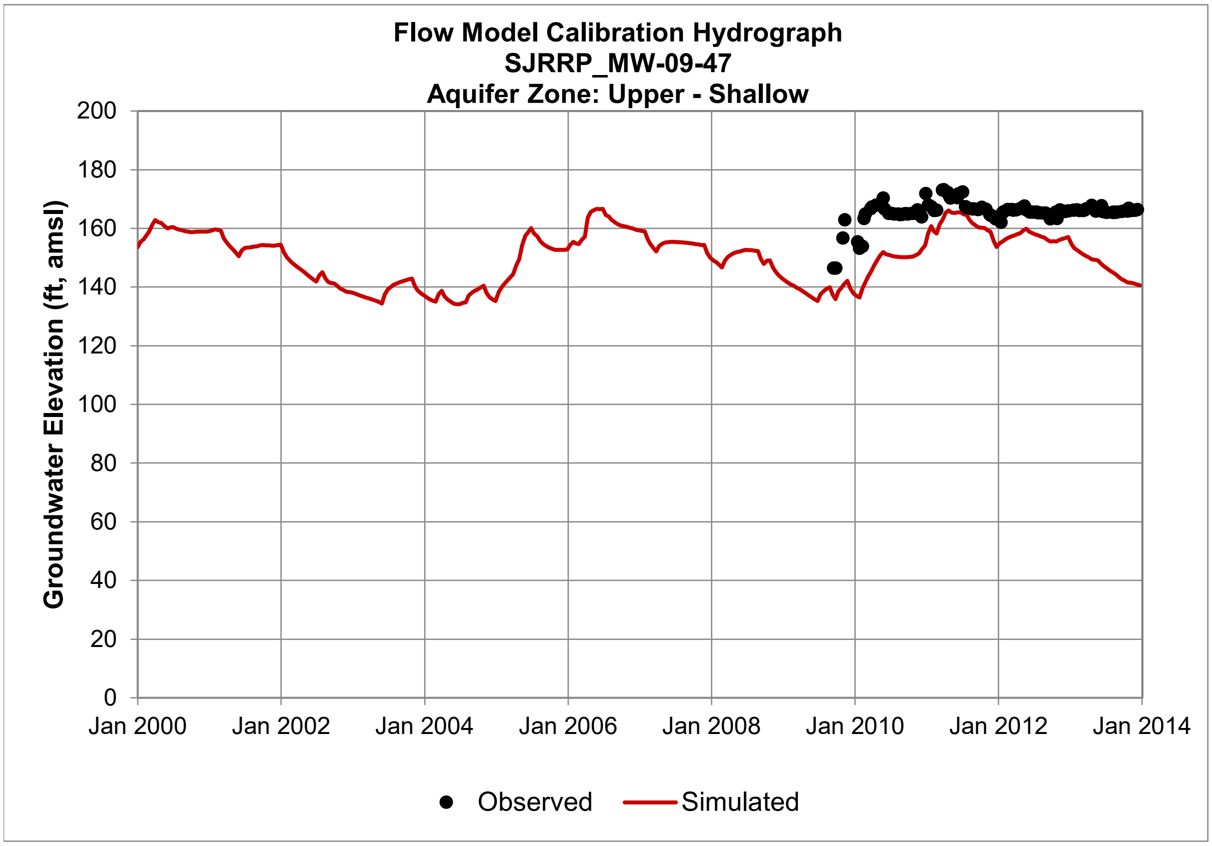
Flow Model Calibration Hydrograph
SJRRP_MW-09-47
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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180
160
140
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Jan 2010
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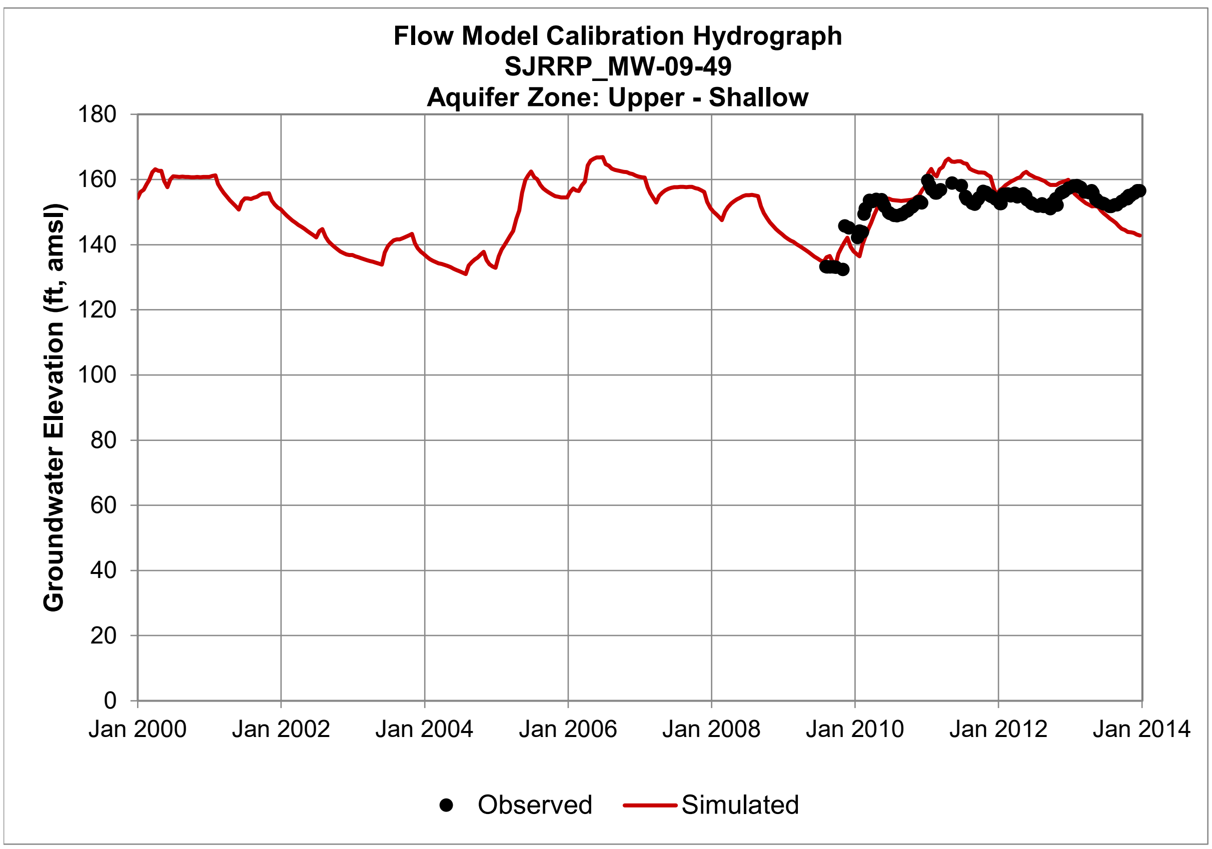
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
SJRRP_MW-09-49
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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160
140
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Jan 2010
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Jan 2014
Observed
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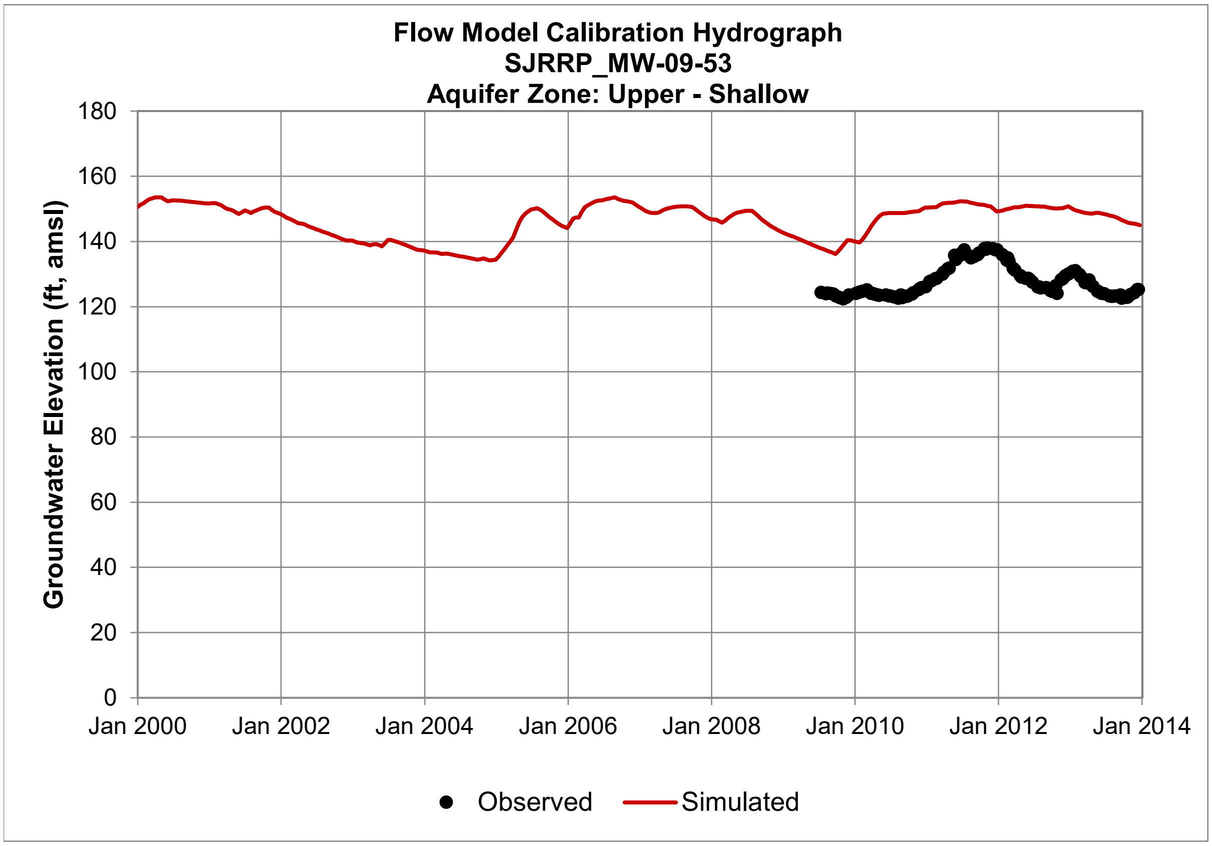
Flow Model Calibration Hydrograph
SJRRP_MW-09-53
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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160
140
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Jan 2006
Jan 2008
Jan 2010
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Jan 2014
Observed
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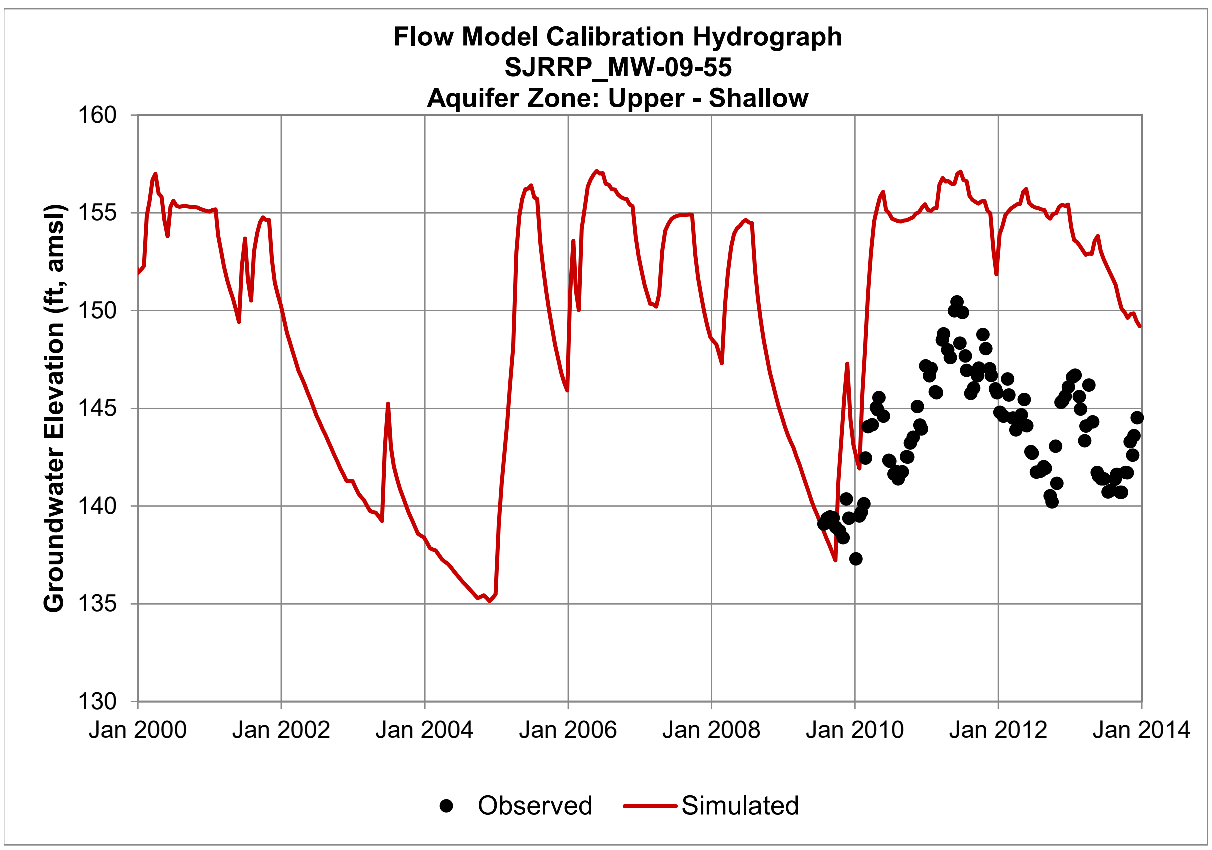
Flow Model Calibration Hydrograph
SJRRP_MW-09-55
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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135
130
Jan 2000
Jan 2002
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Jan 2006
Jan 2008
Jan 2010
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Jan 2014
Observed
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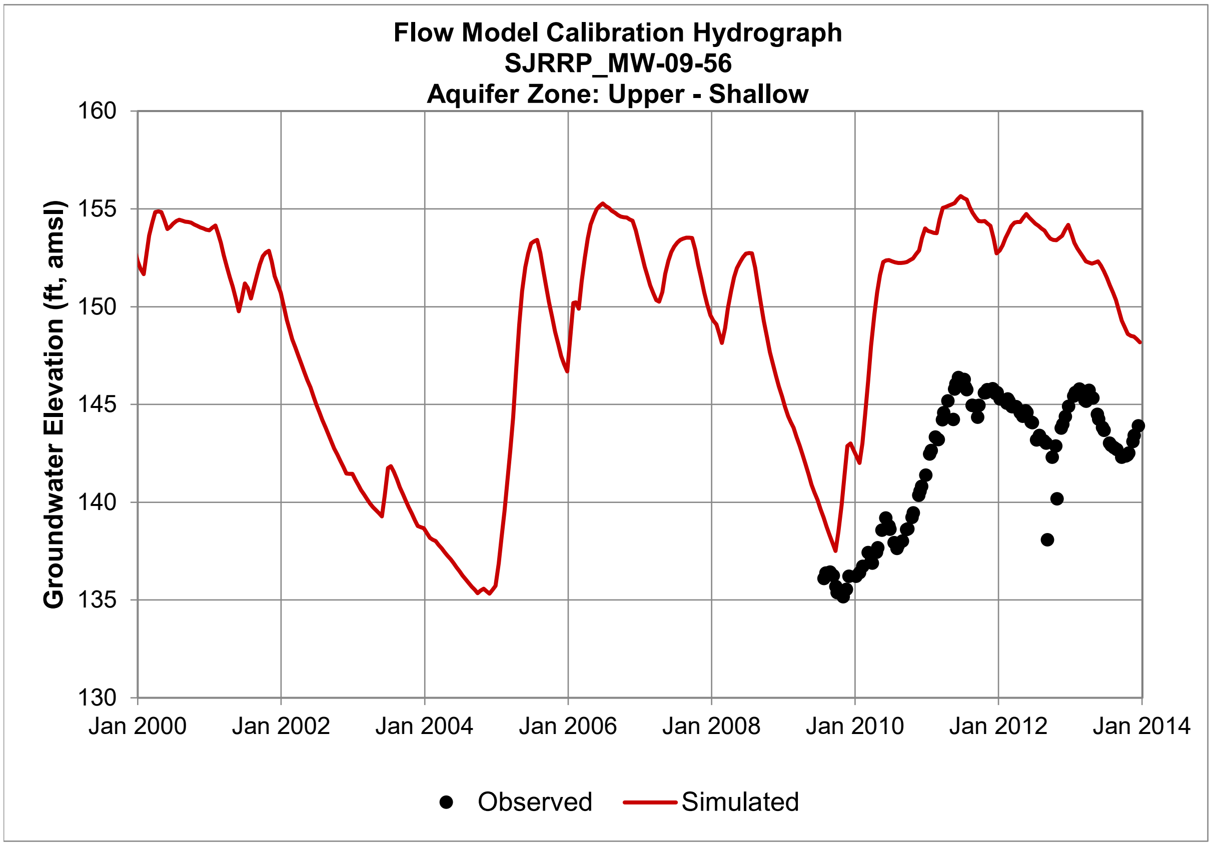
Flow Model Calibration Hydrograph
SJRRP_MW-09-56
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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135
130
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Jan 2014
Observed
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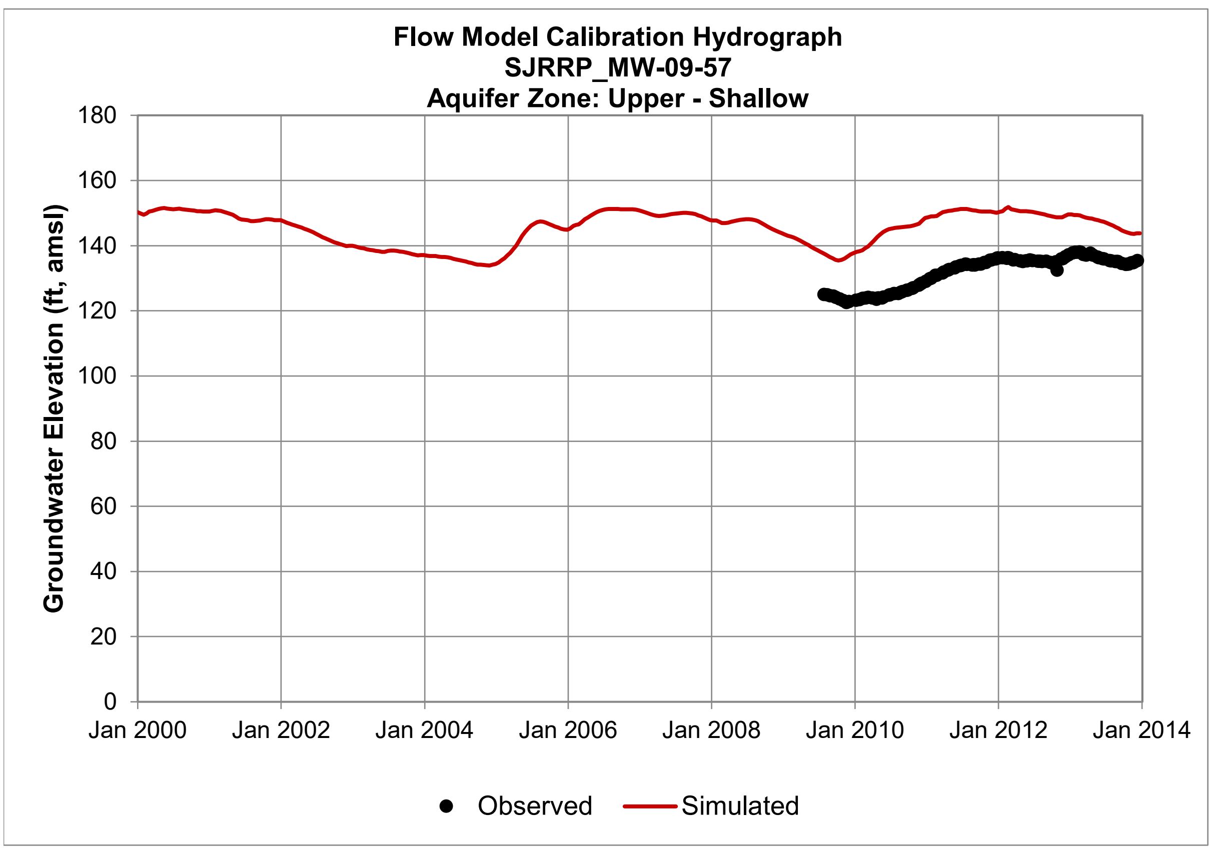
Flow Model Calibration Hydrograph
SJRRP_MW-09-57
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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160
140
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Jan 2006
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Jan 2014
Observed
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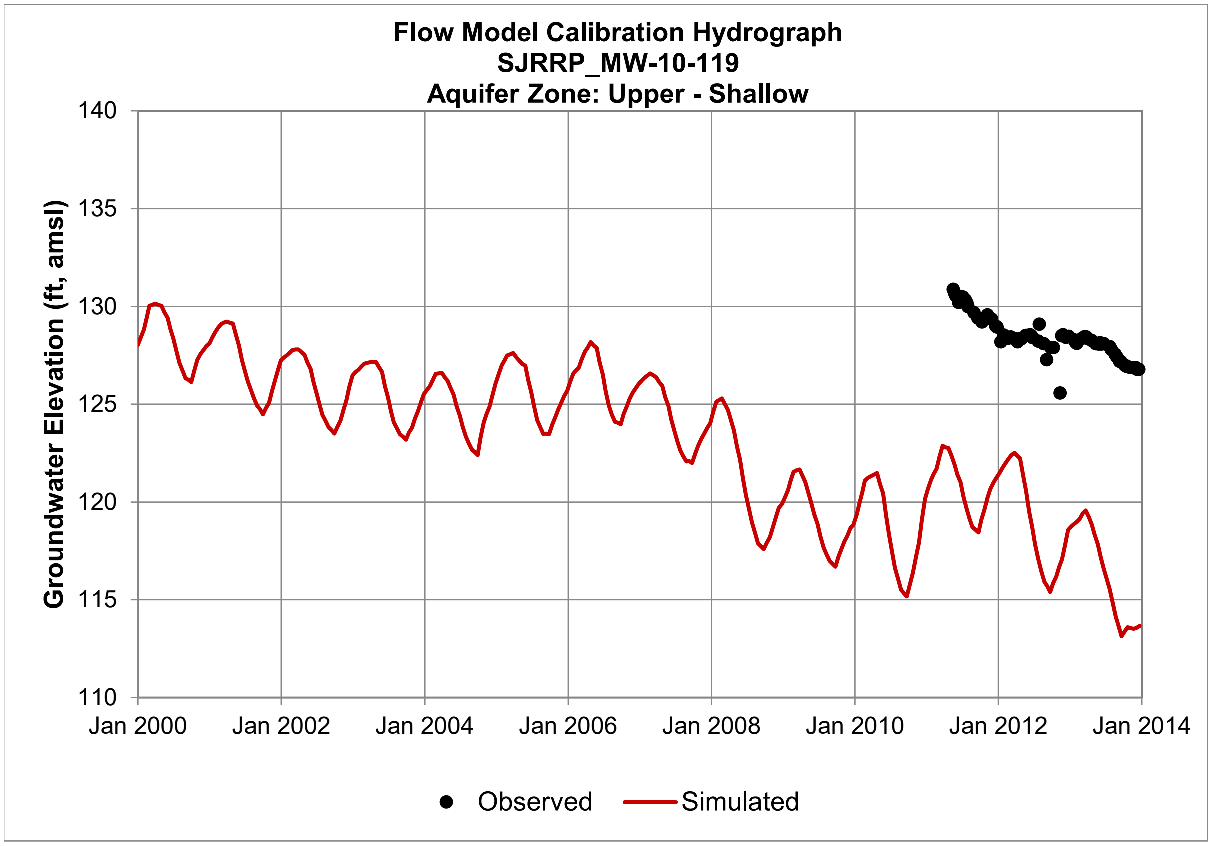
Flow Model Calibration Hydrograph
SJRRP_MW-10-119
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
140
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115
110
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Jan 2006
Jan 2008
Jan 2010
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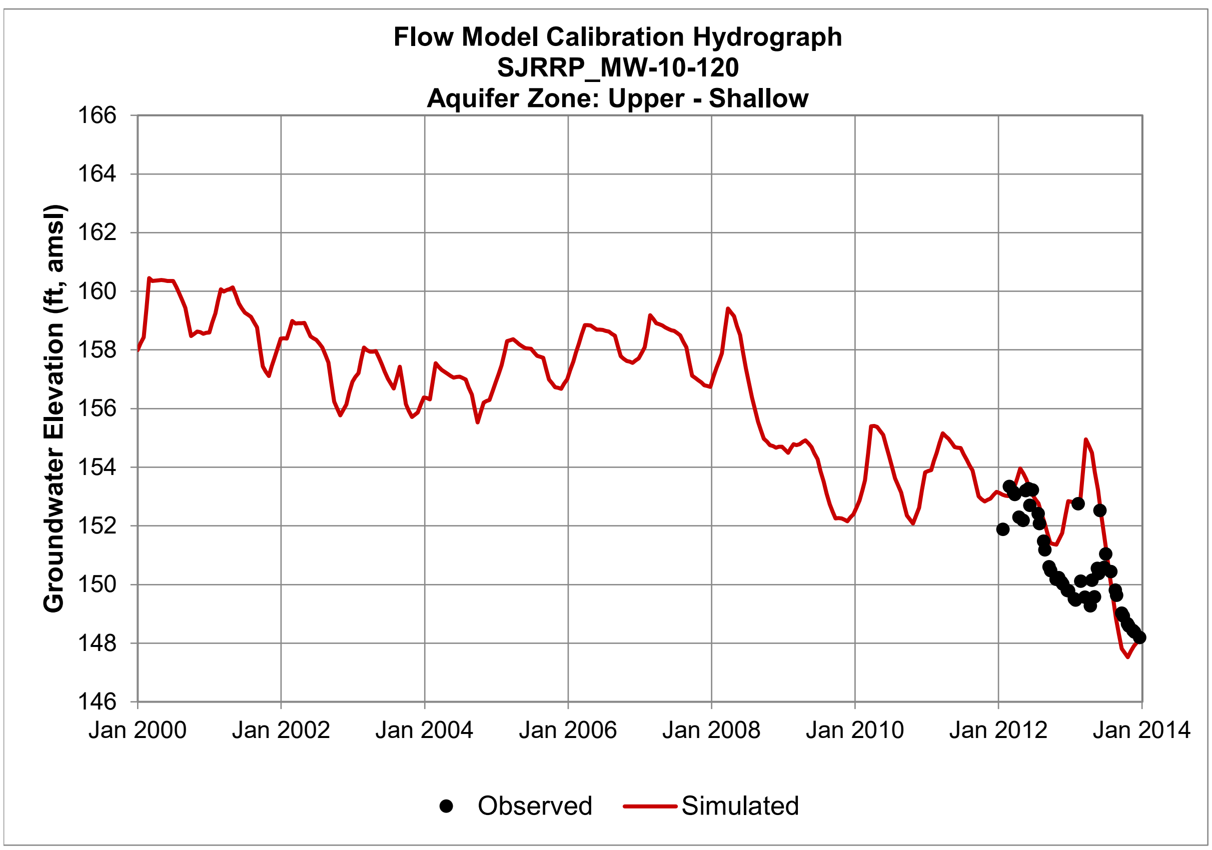
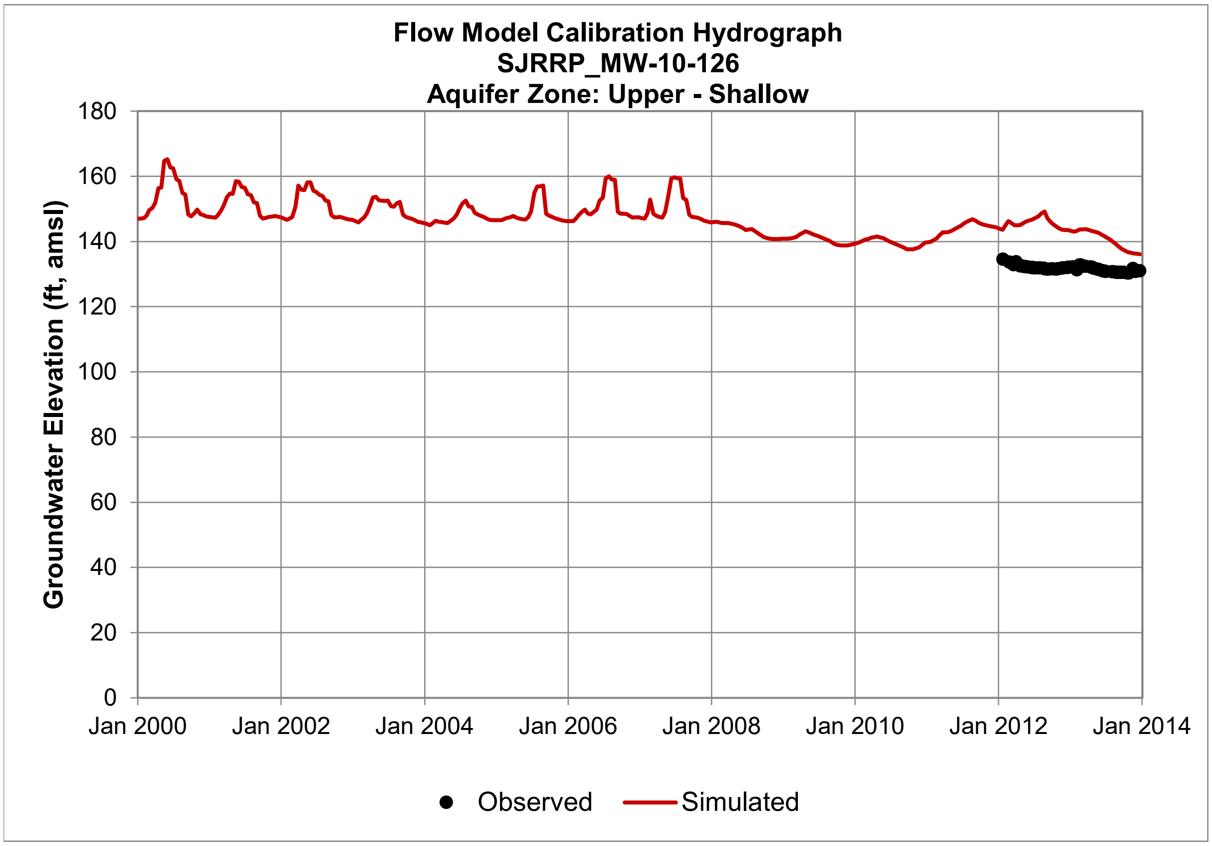
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
SJRRP_MW-10-120
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
166
164
162
160
158
156
154
152
150
148
146
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
SJRRP_MW-10-126
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
180
160
140
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80
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40
20
0
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Jan 2002
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Jan 2008
Jan 2010
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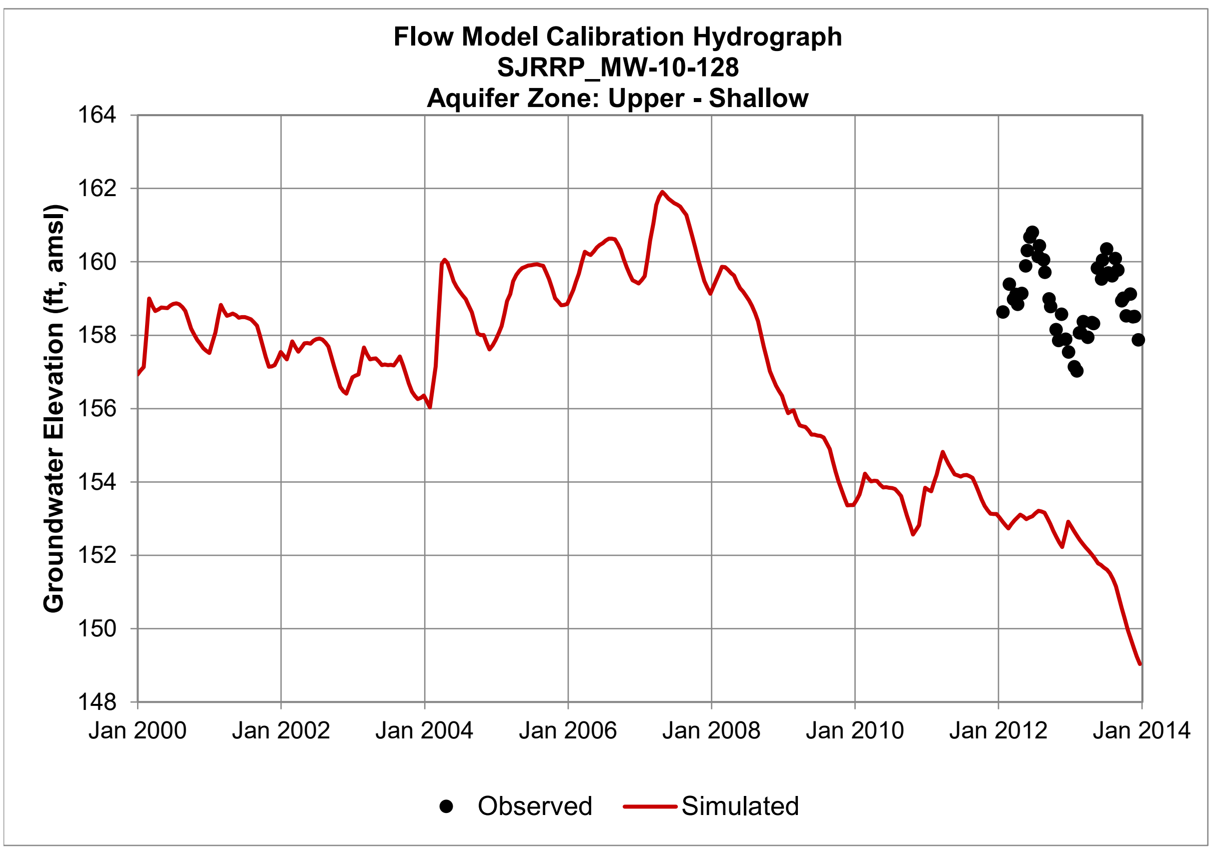
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
SJRRP_MW-10-128
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
164
162
160
158
156
154
152
150
148
Jan 2000
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Jan 2010
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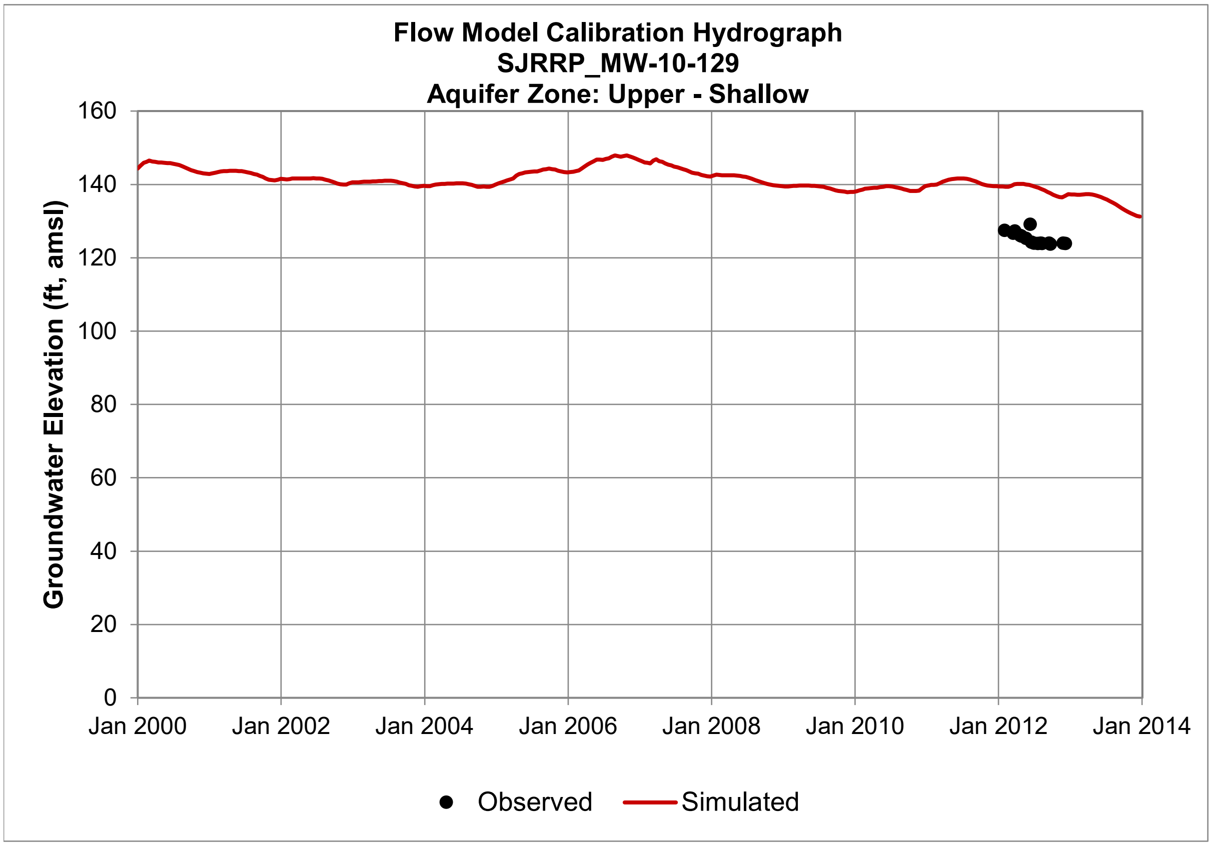
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
SJRRP_MW-10-129
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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140
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20
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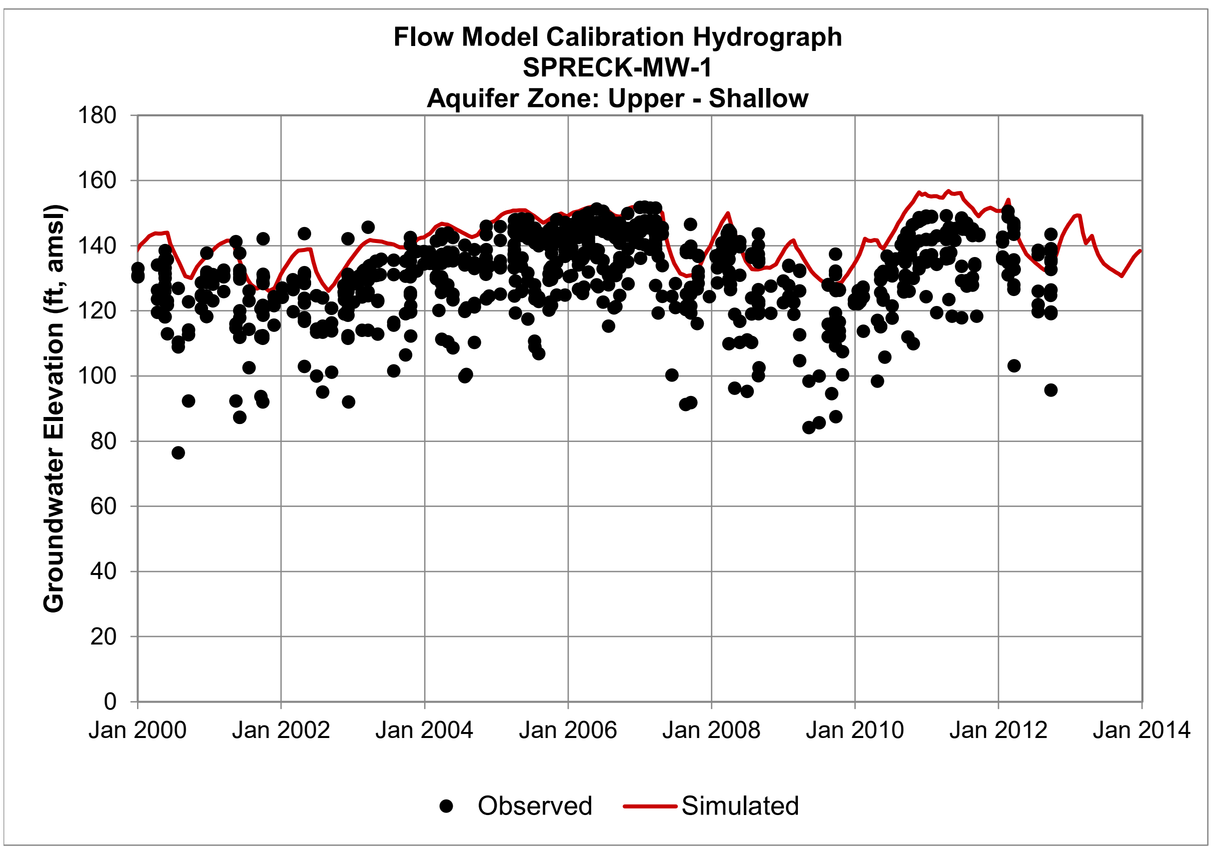
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
SPRECK-MW-1
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
180
160
140
120
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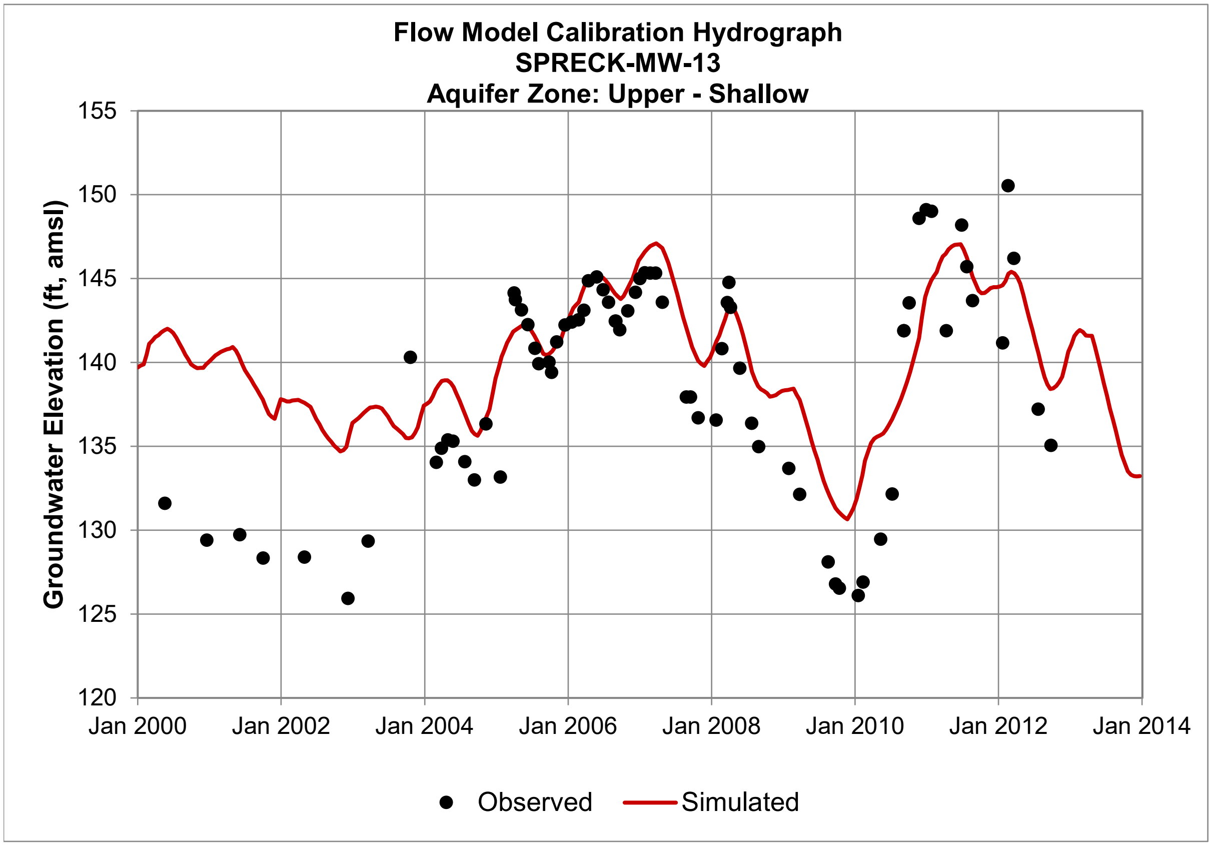
80
60
40
20
0
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
SPRECK-MW-13
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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125
120
Jan 2000
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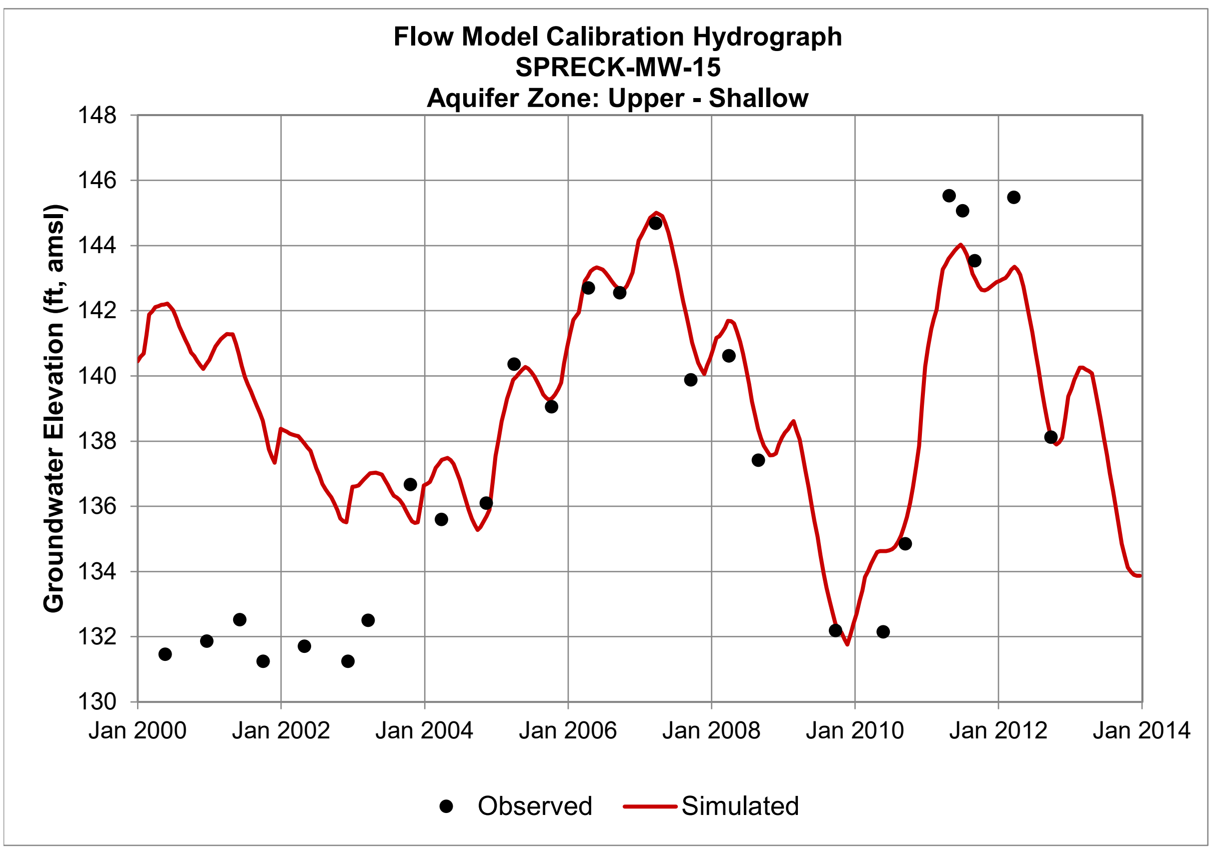
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
SPRECK-MW-15
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
148
146
144
142
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134
132
130
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Jan 2008
Jan 2010
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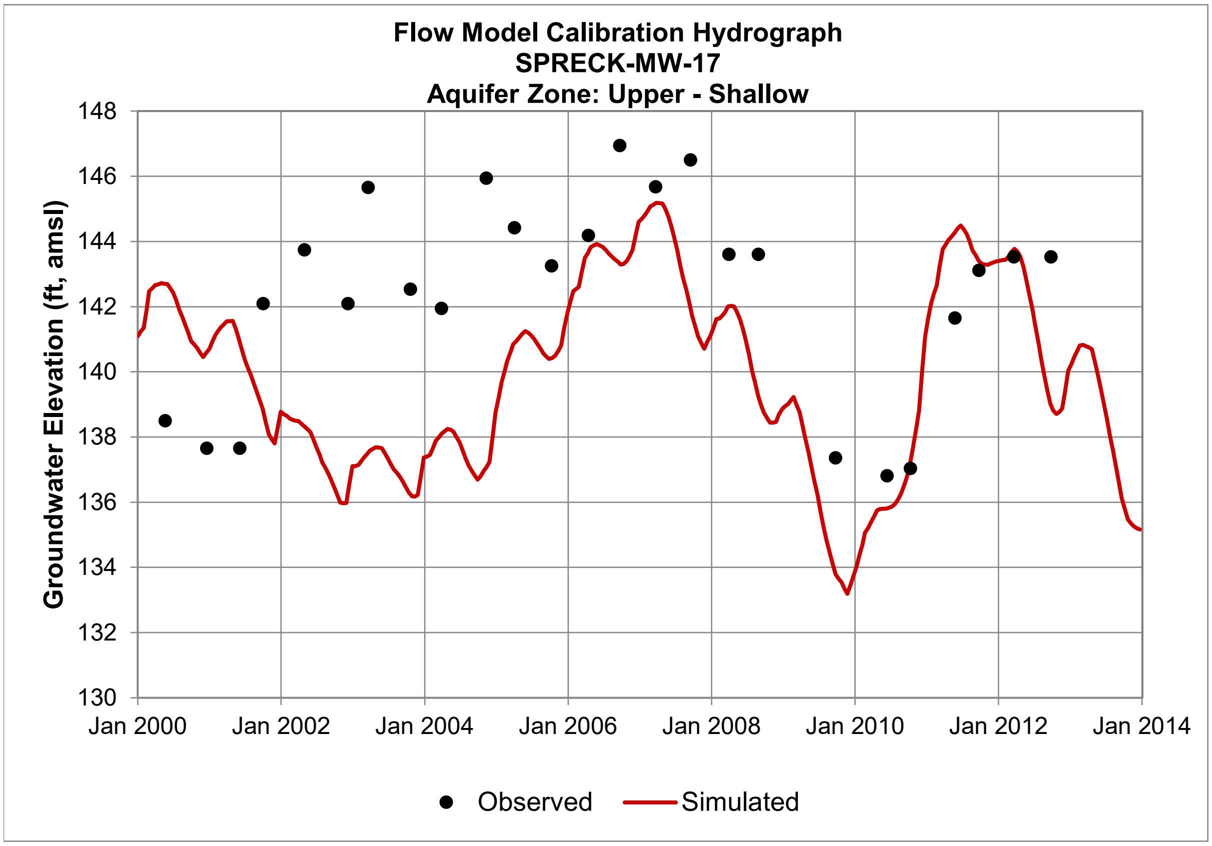
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
SPRECK-MW-17
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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146
144
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Jan 2008
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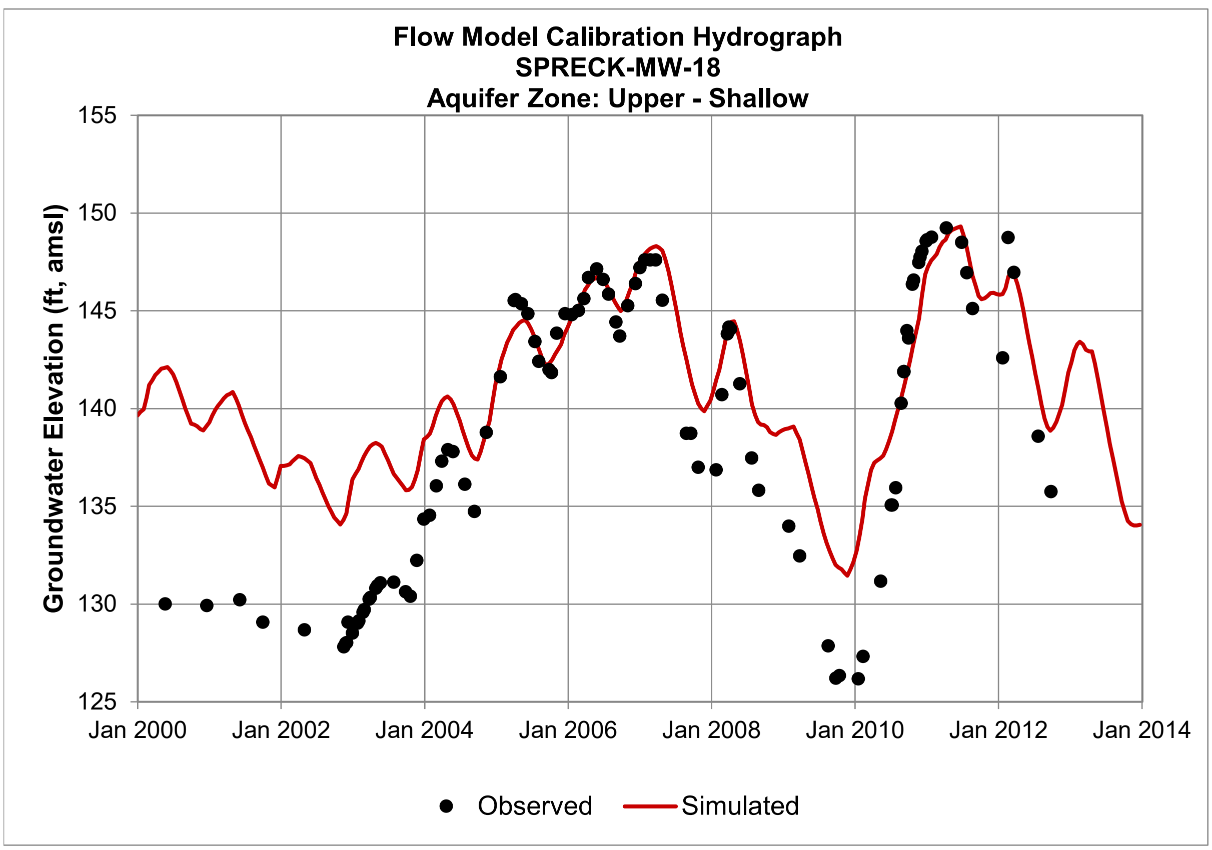
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
SPRECK-MW-18
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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130
125
Jan 2000
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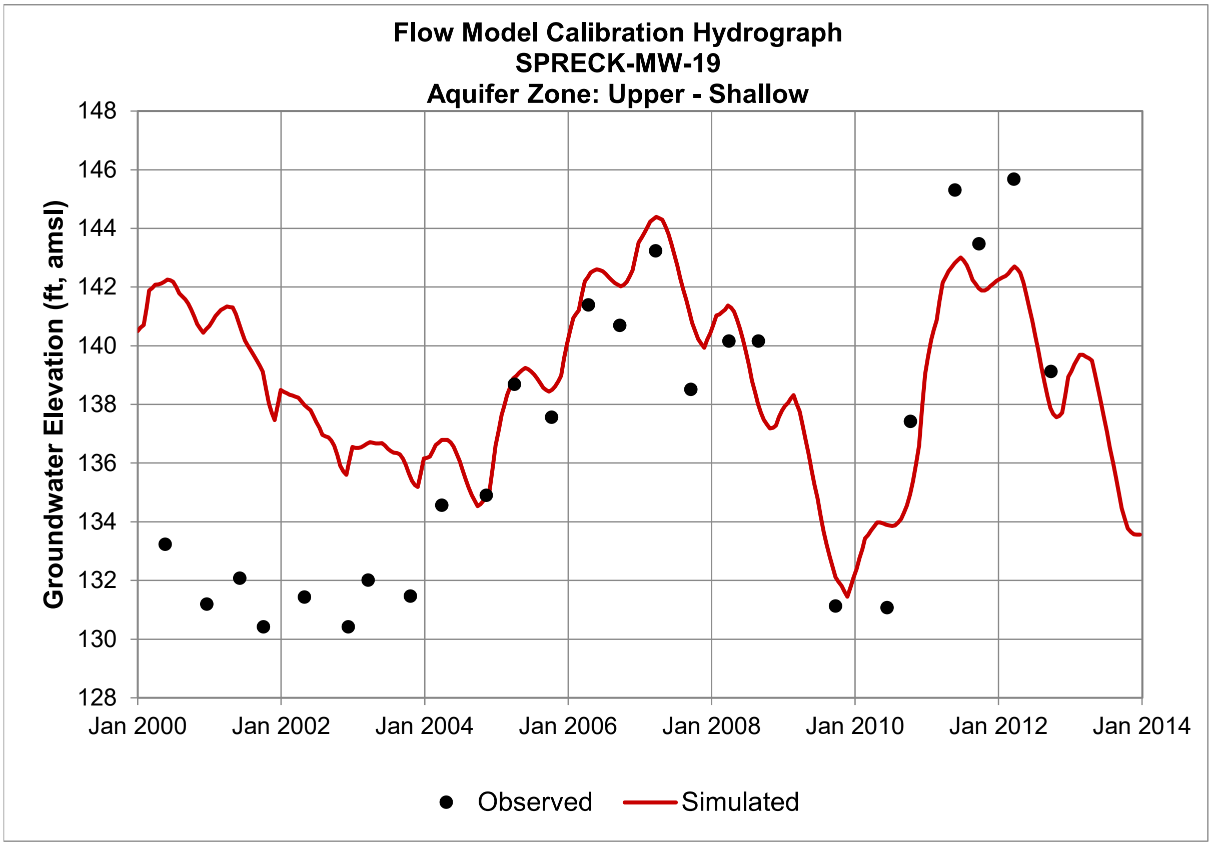
Observed
Simulated


Flow Model Calibration Hydrograph
SPRECK-MW-19
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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146
144
142
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130
128
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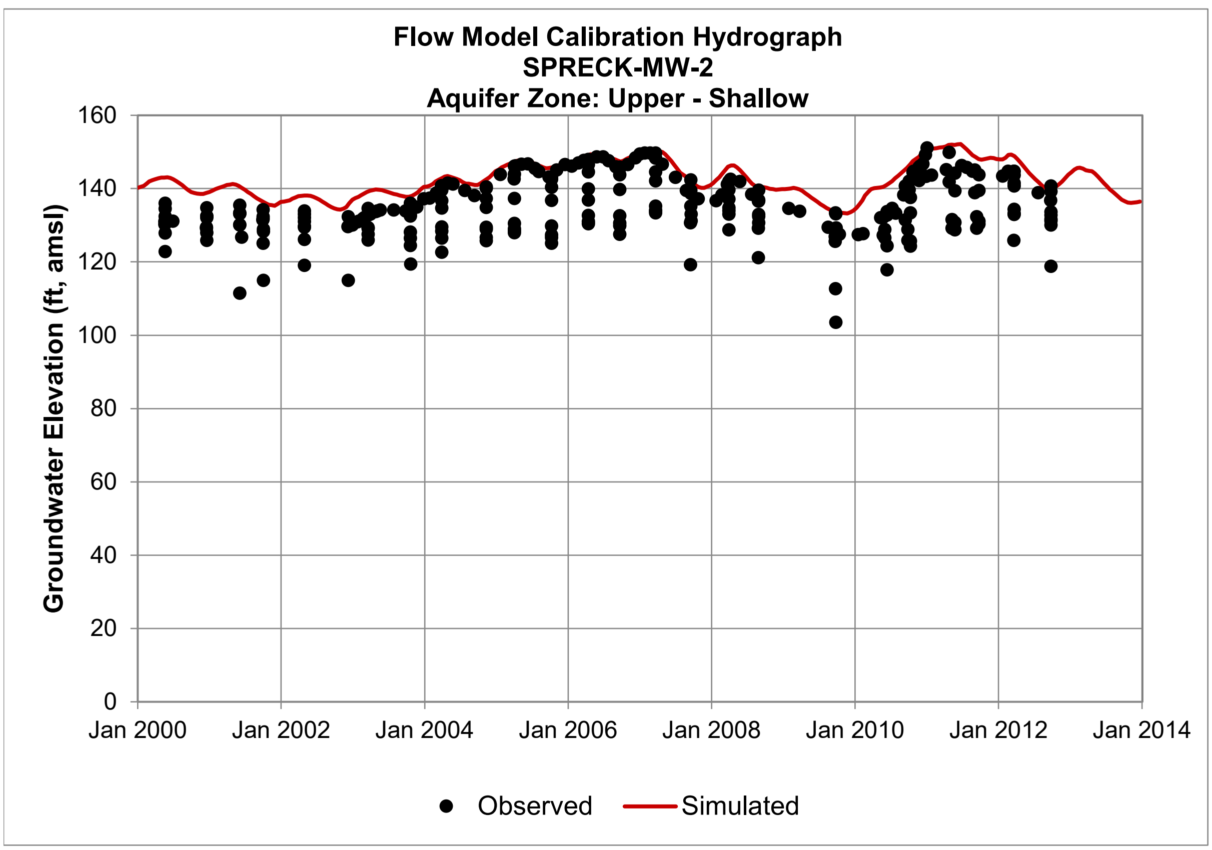
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
SPRECK-MW-2
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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140
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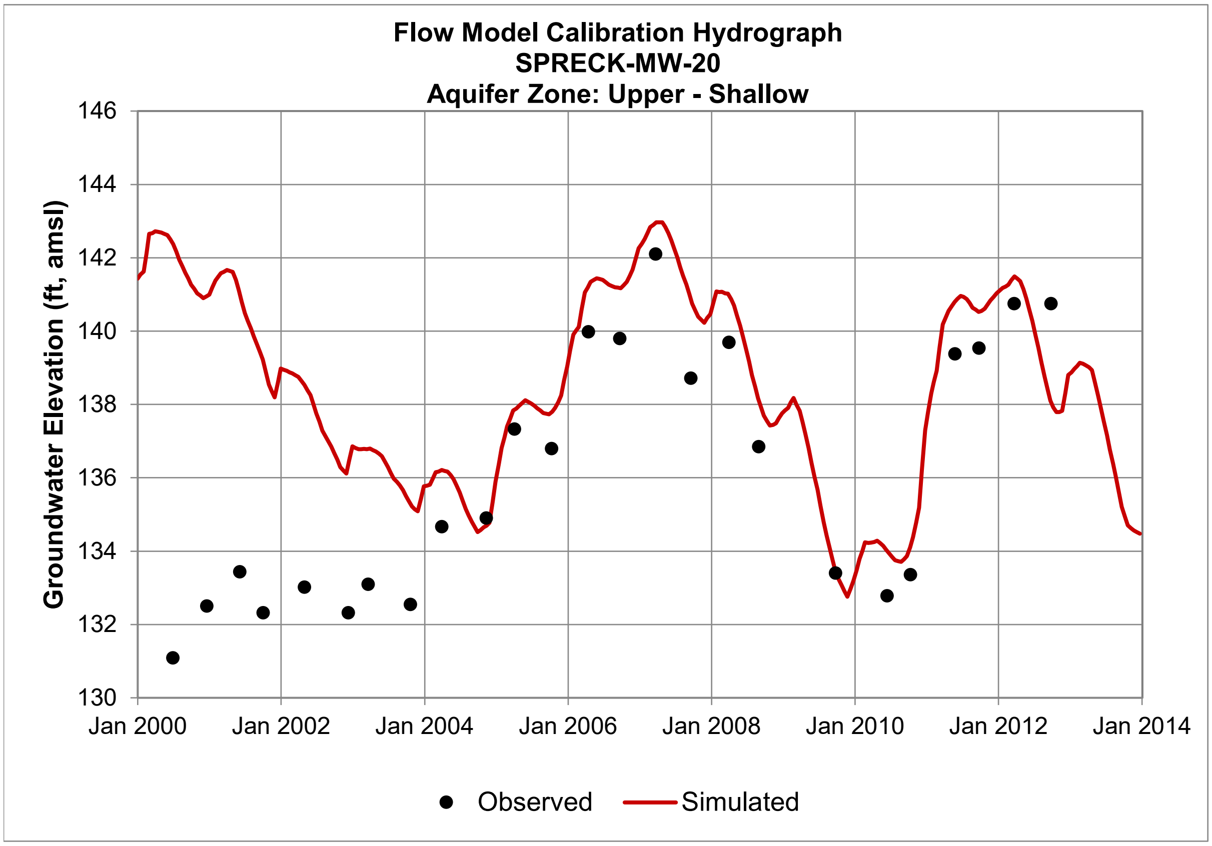
Observed
Simulated


Flow Model Calibration Hydrograph
SPRECK-MW-20
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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144
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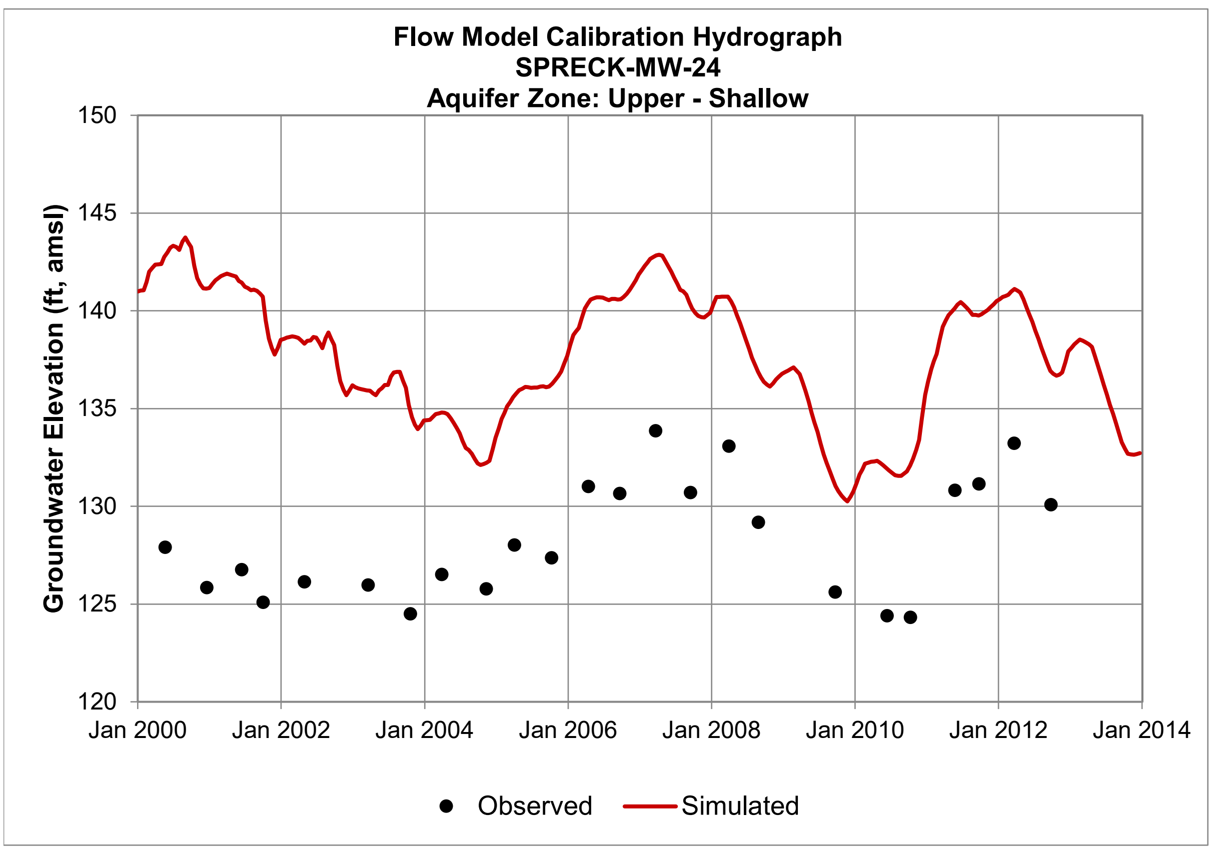
Observed
Simulated


Flow Model Calibration Hydrograph
SPRECK-MW-24
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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125
120
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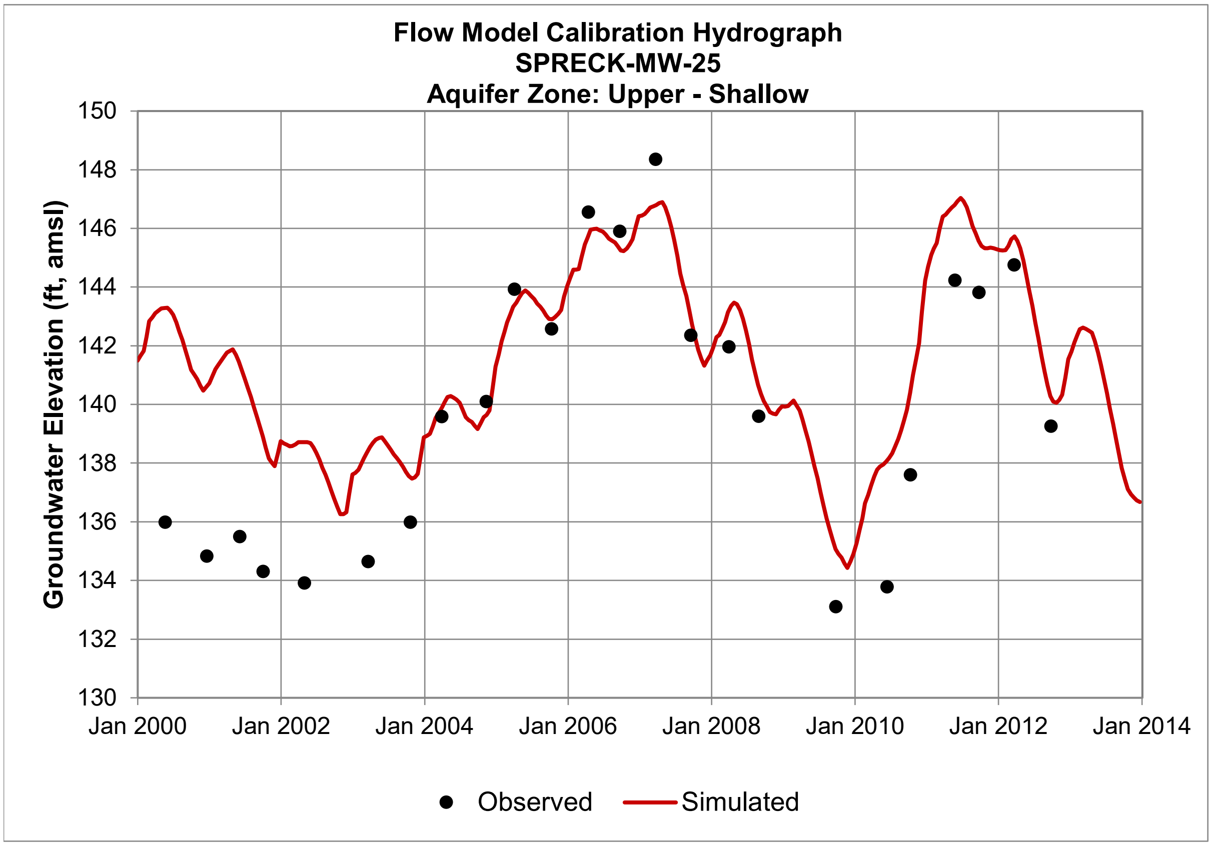
Observed
Simulated


Flow Model Calibration Hydrograph
SPRECK-MW-25
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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146
144
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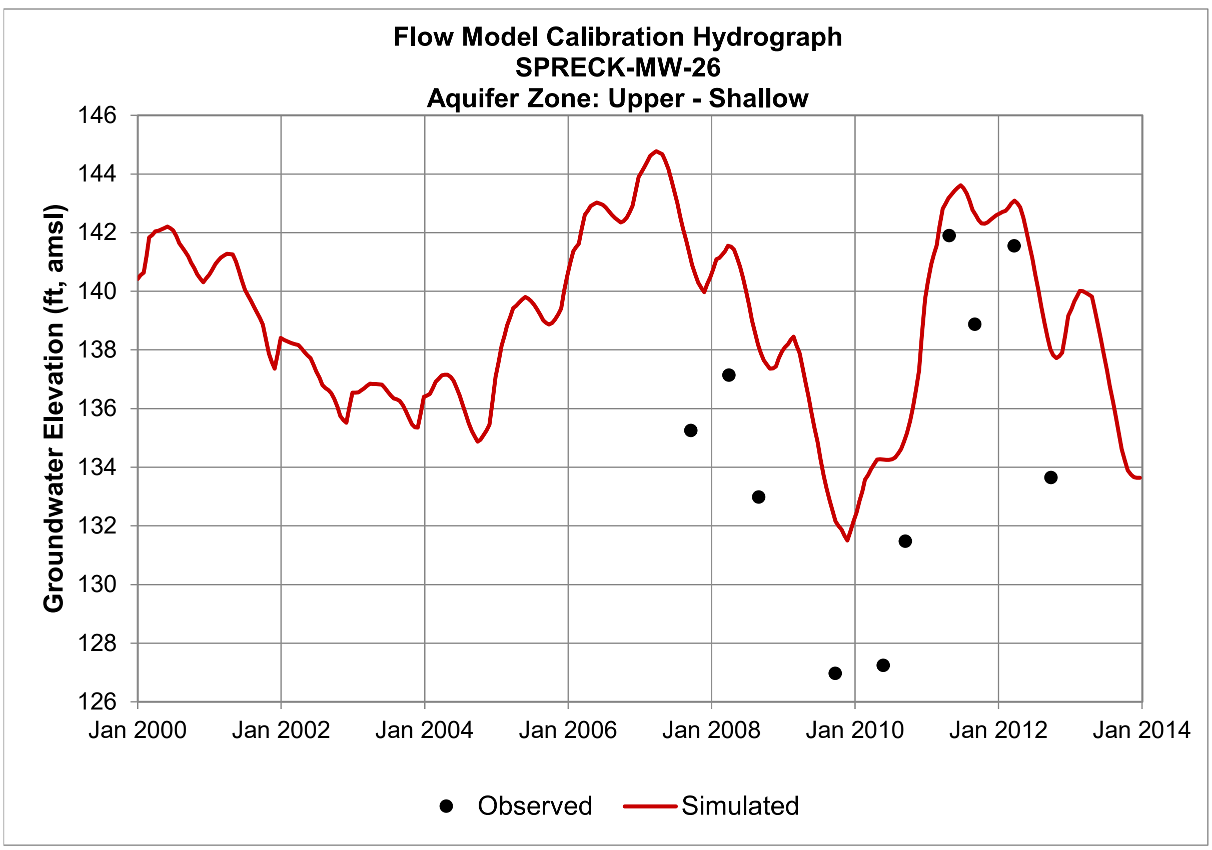
Flow Model Calibration Hydrograph
SPRECK-MW-26
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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142
140
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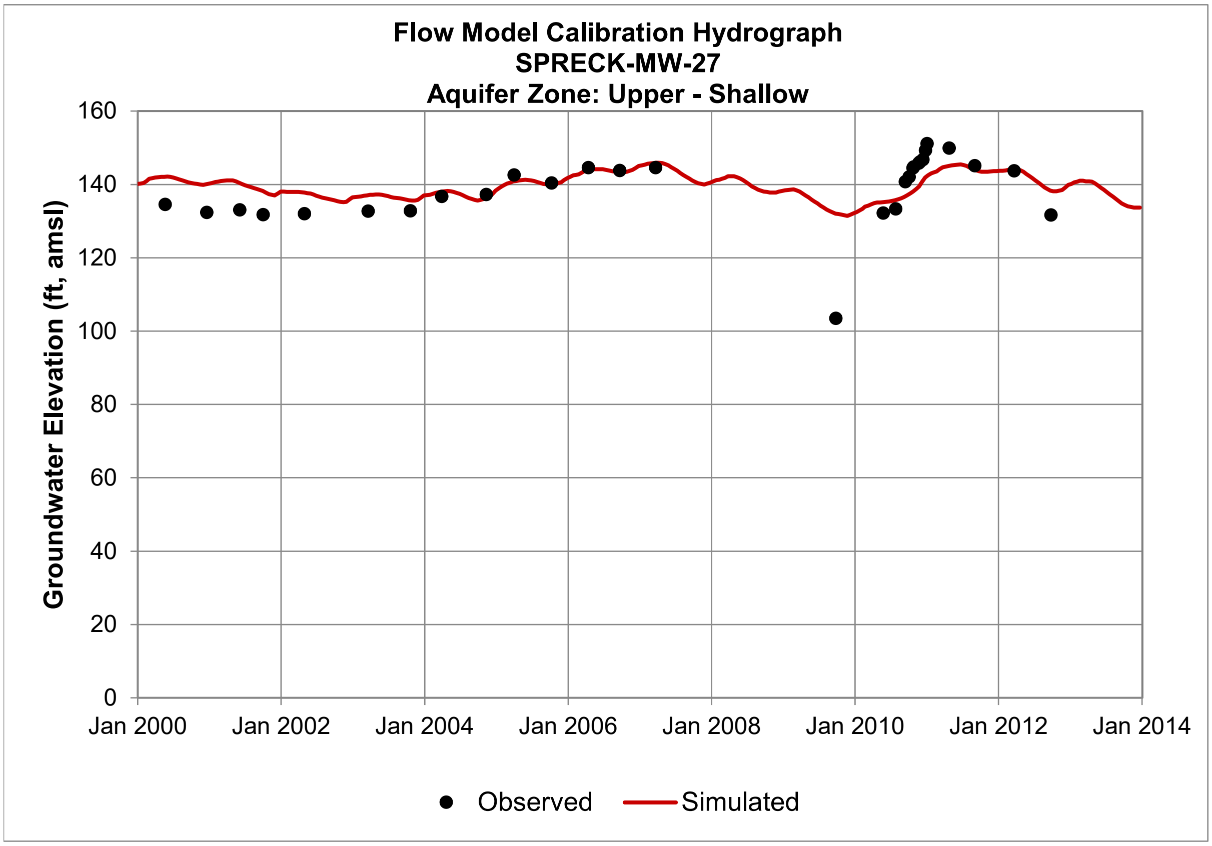
Flow Model Calibration Hydrograph
SPRECK-MW-27
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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Observed
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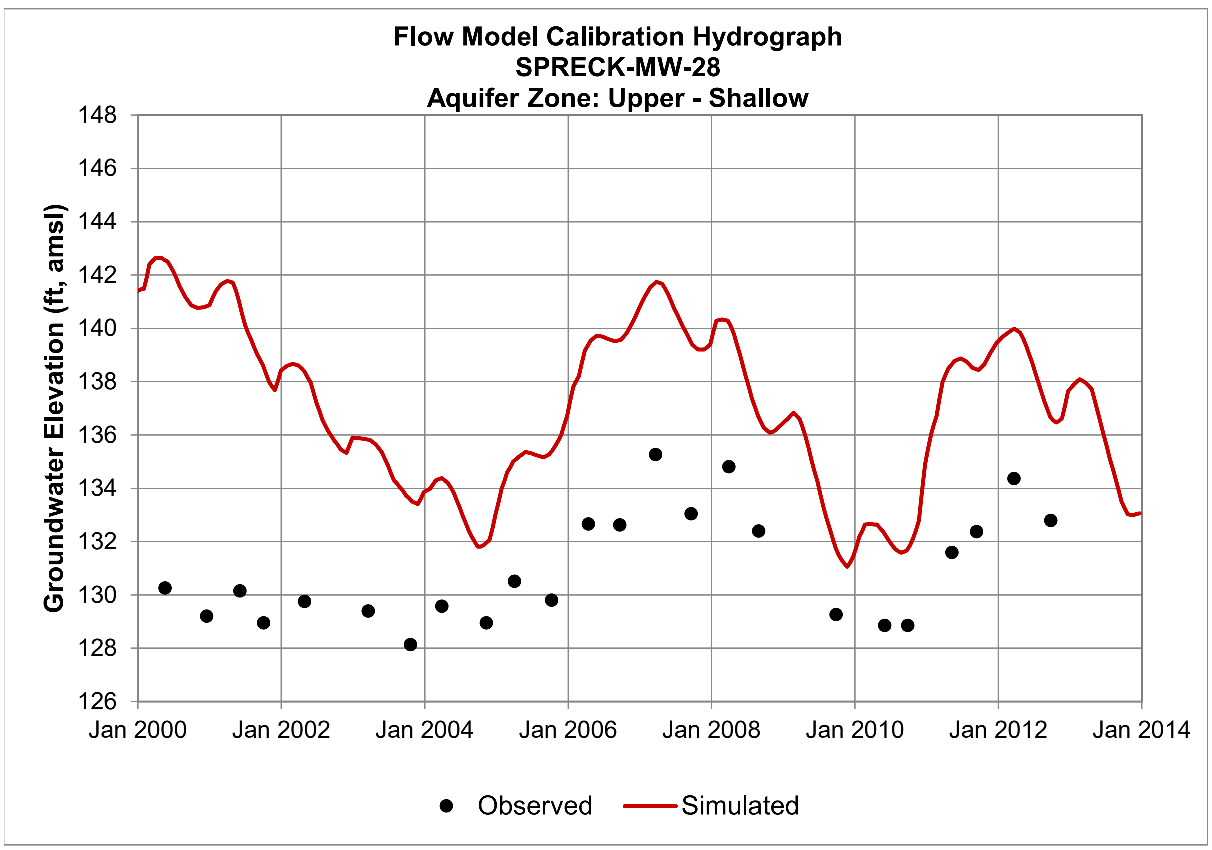
Flow Model Calibration Hydrograph
SPRECK-MW-28
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
148
146
144
142
140
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Jan 2000
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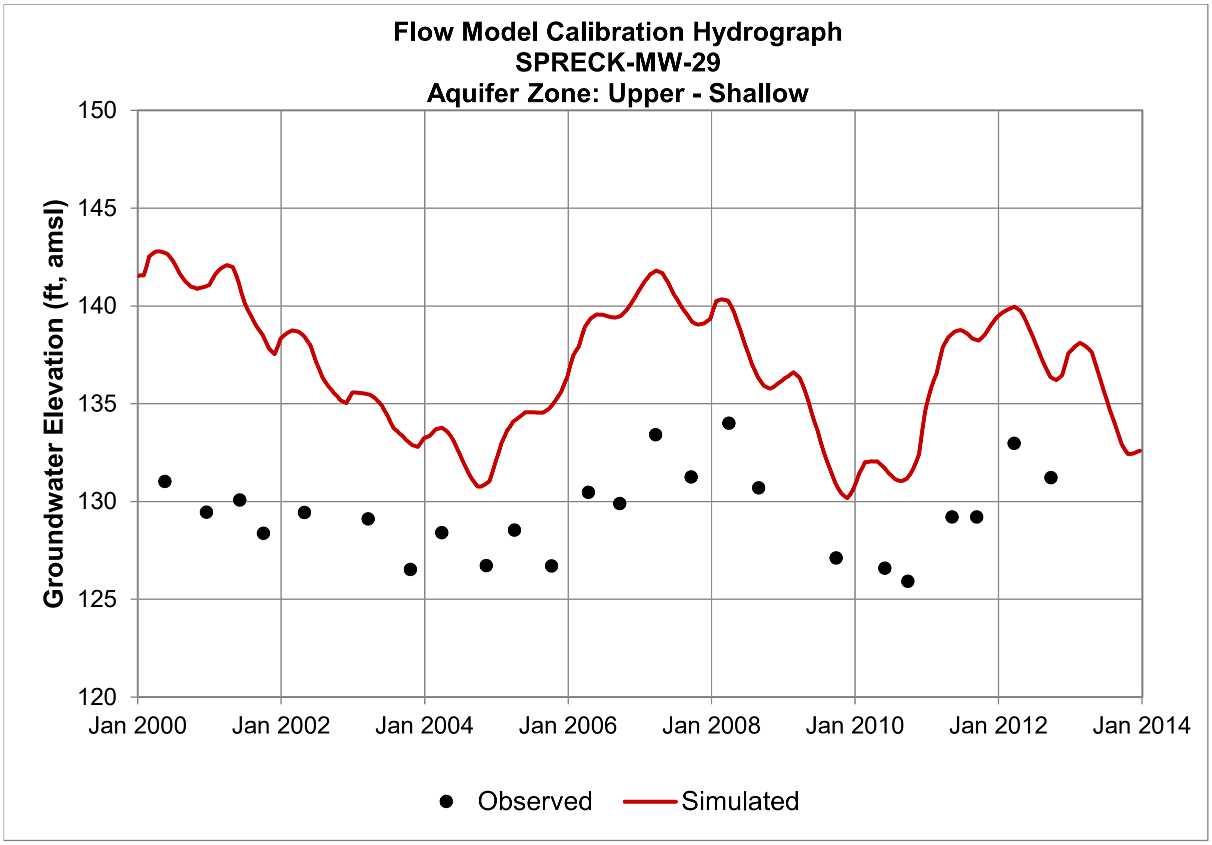
Observed
Simulated


Flow Model Calibration Hydrograph
SPRECK-MW-29
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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145
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125
120
Jan 2000
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Observed
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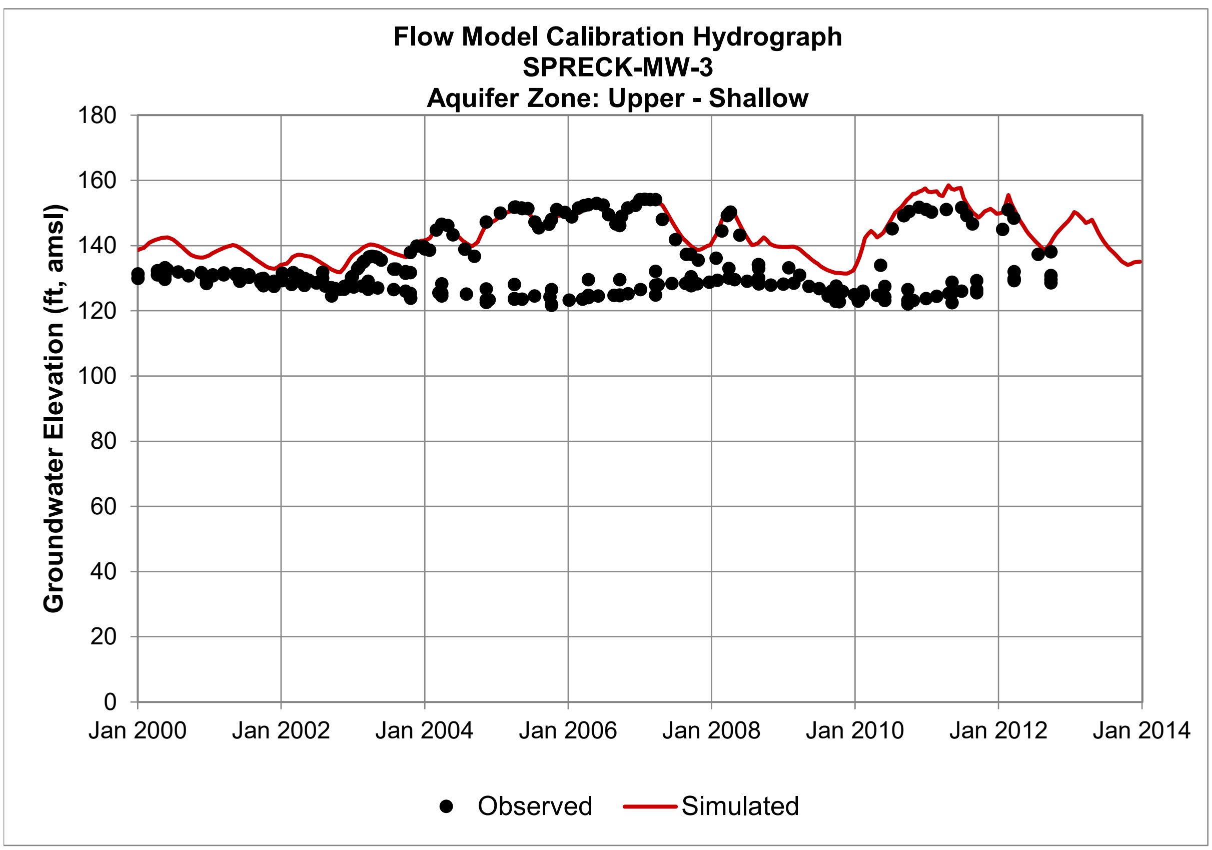
Flow Model Calibration Hydrograph
SPRECK-MW-3
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
180
160
140
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Jan 2000
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Jan 2008
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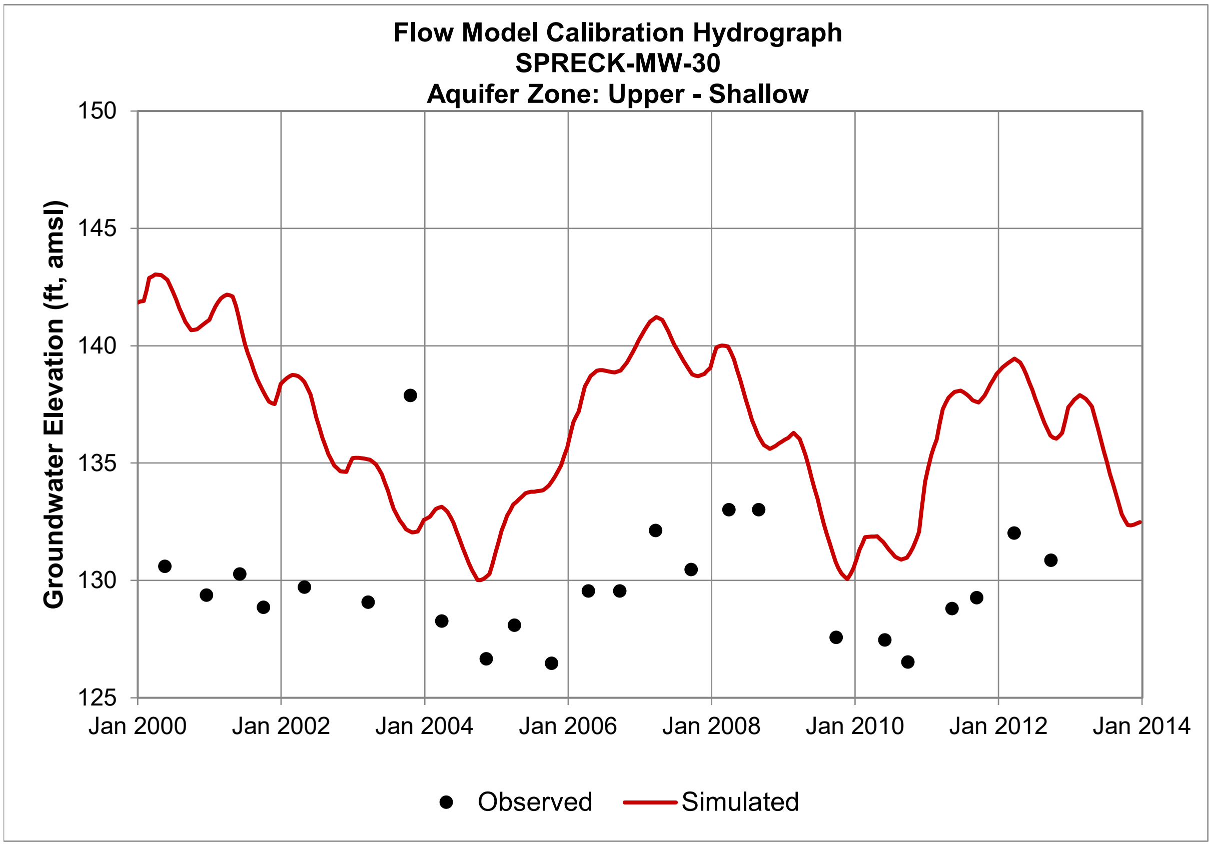
Observed
Simulated


Flow Model Calibration Hydrograph
SPRECK-MW-30
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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Jan 2000
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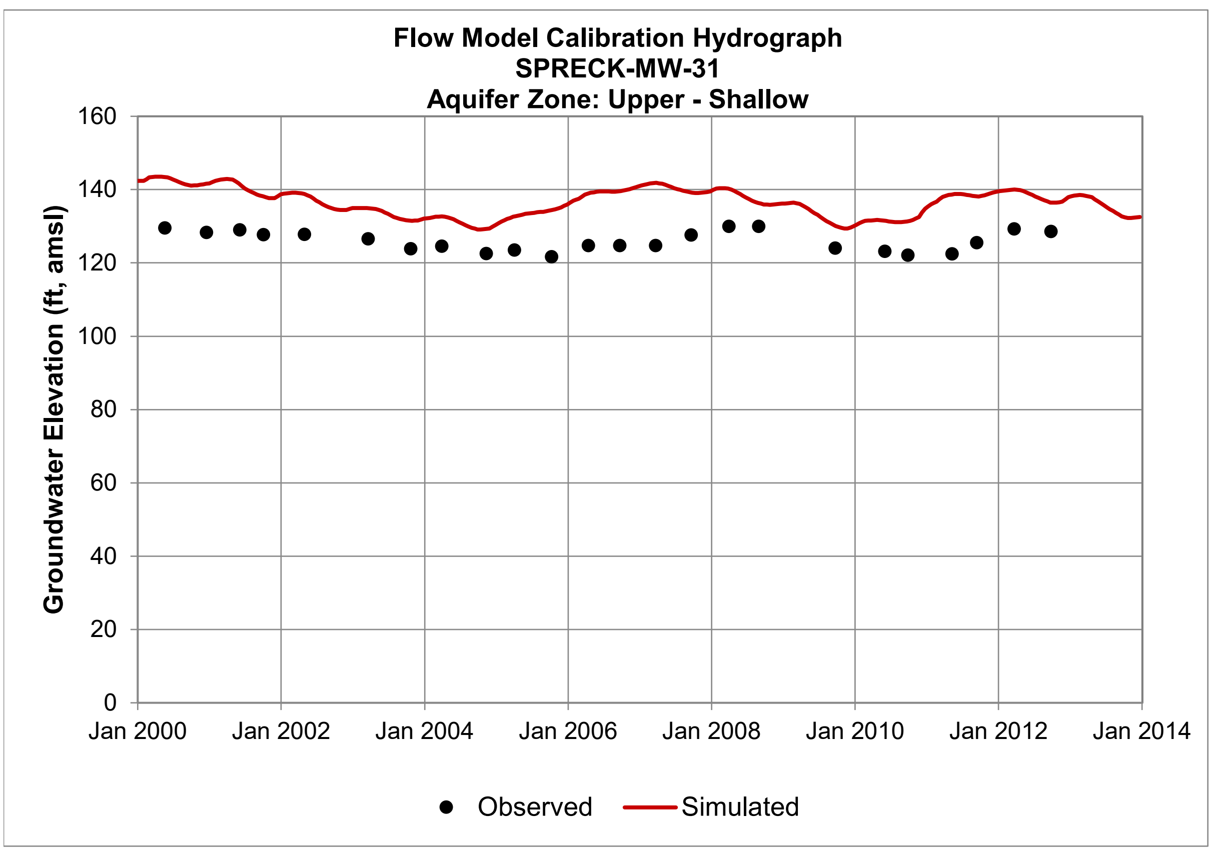
Observed
Simulated


Flow Model Calibration Hydrograph
SPRECK-MW-31
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
160
140
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Jan 2000
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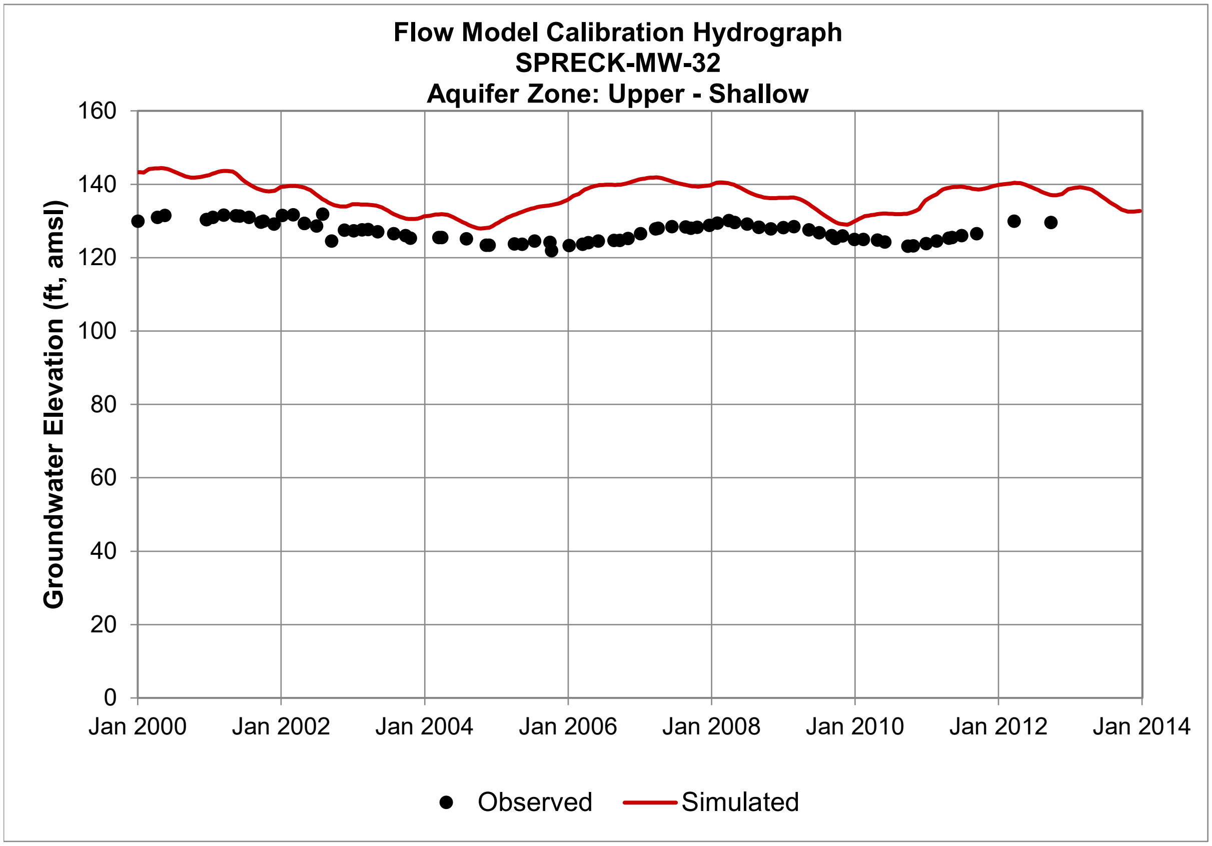
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
SPRECK-MW-32
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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Jan 2000
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Jan 2008
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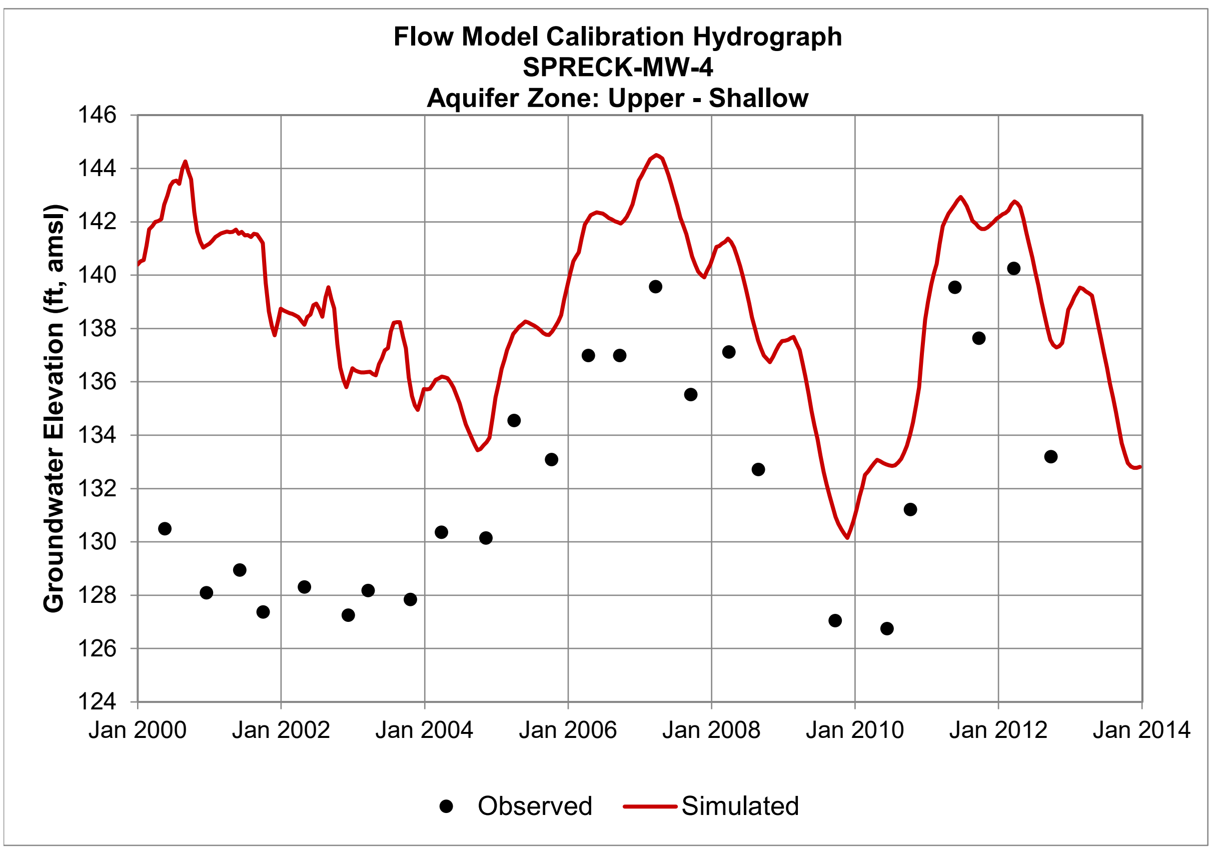
Observed
Simulated


Flow Model Calibration Hydrograph
SPRECK-MW-4
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
146
144
142
140
138
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124
Jan 2000
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Jan 2012
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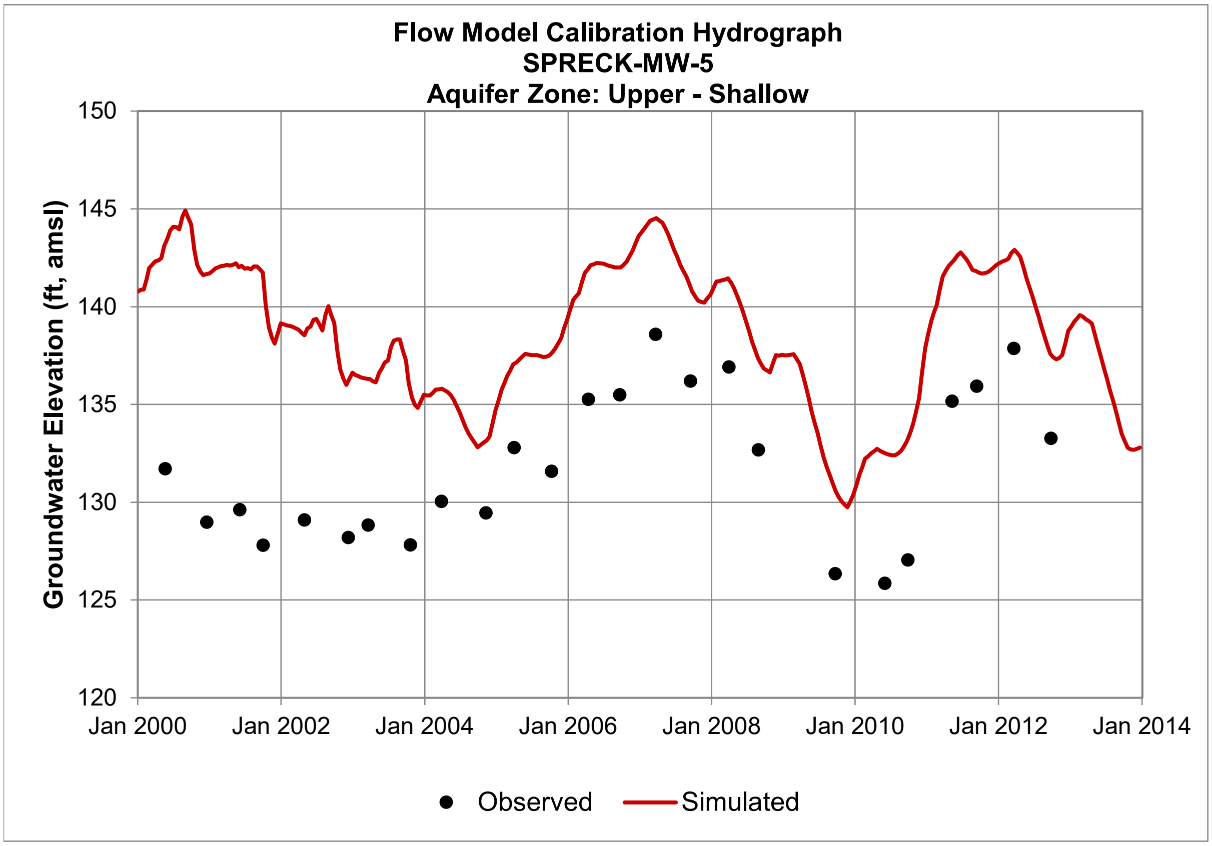
Observed
Simulated


Flow Model Calibration Hydrograph
SPRECK-MW-5
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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125
120
Jan 2000
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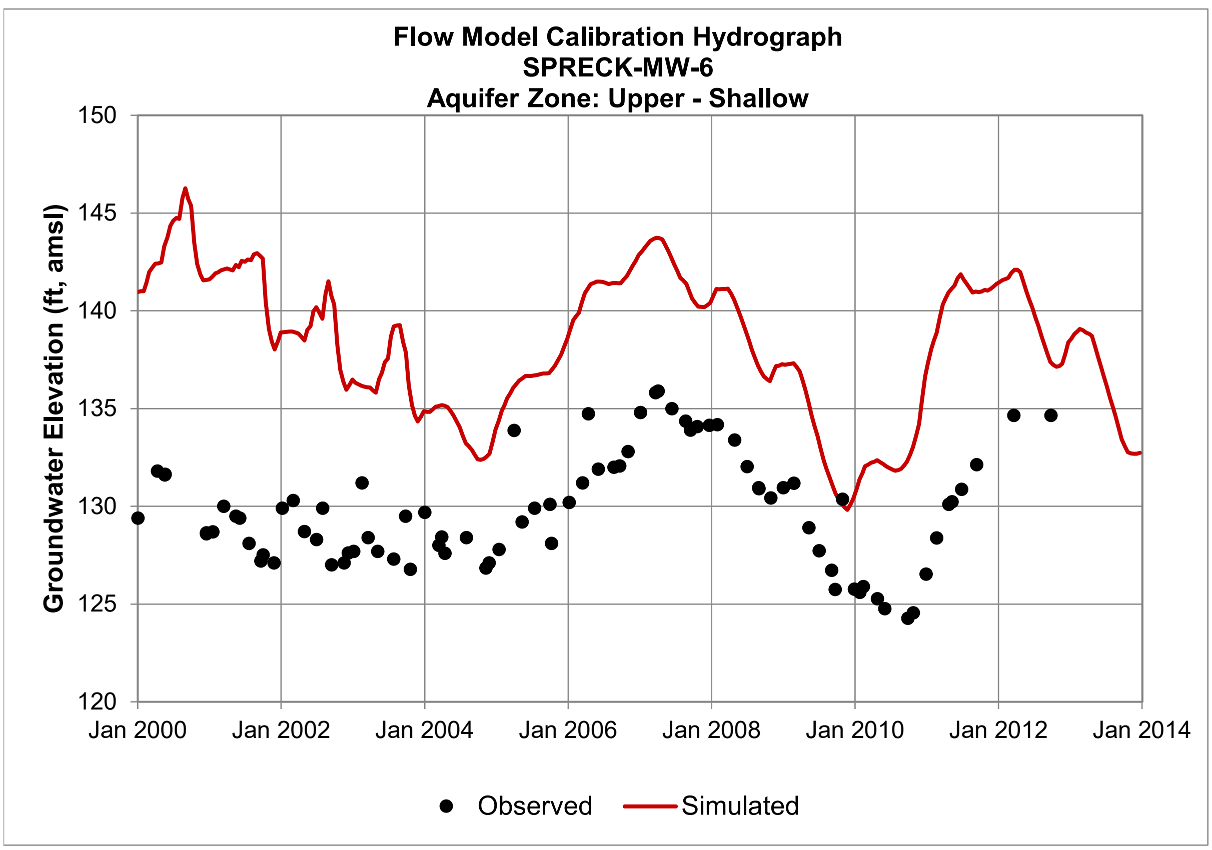
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
SPRECK-MW-6
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
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125
120
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
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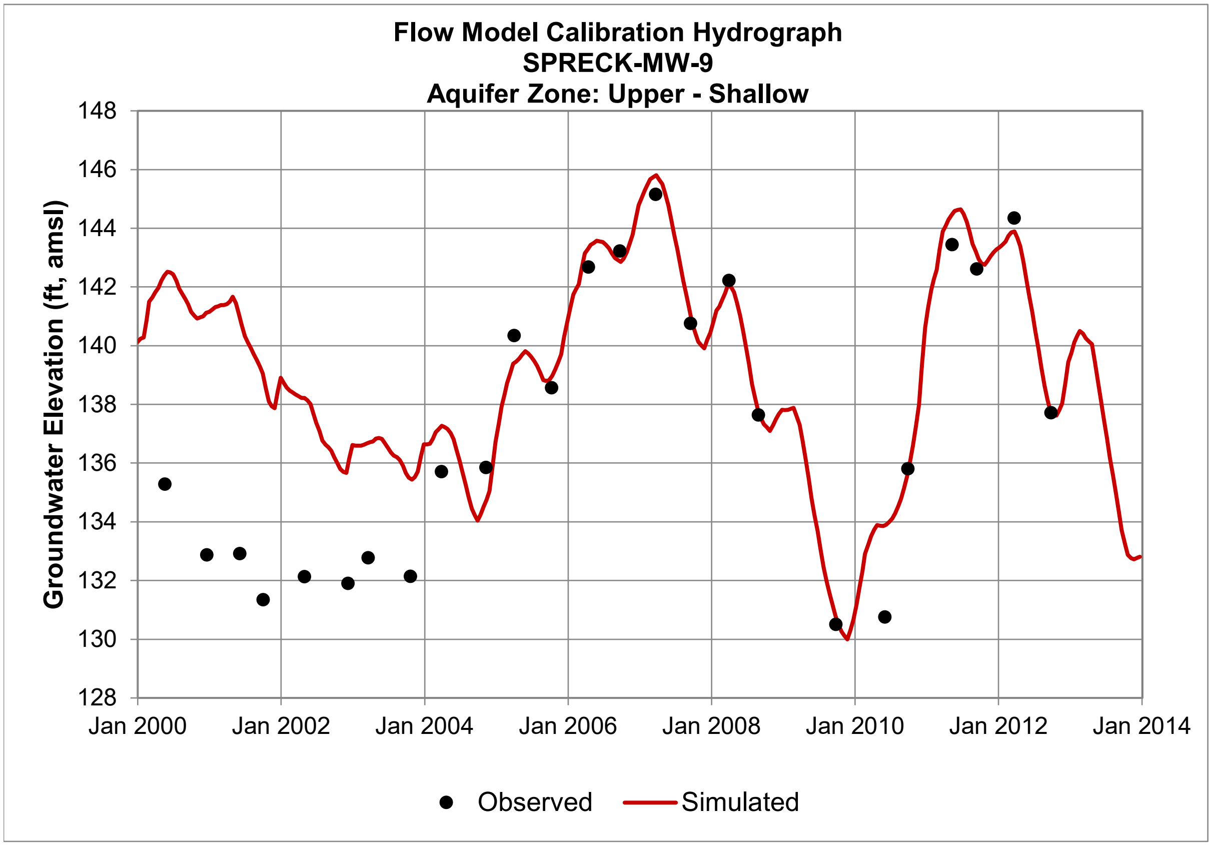
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
SPRECK-MW-9
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
148
146
144
142
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130
128
Jan 2000
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Jan 2012
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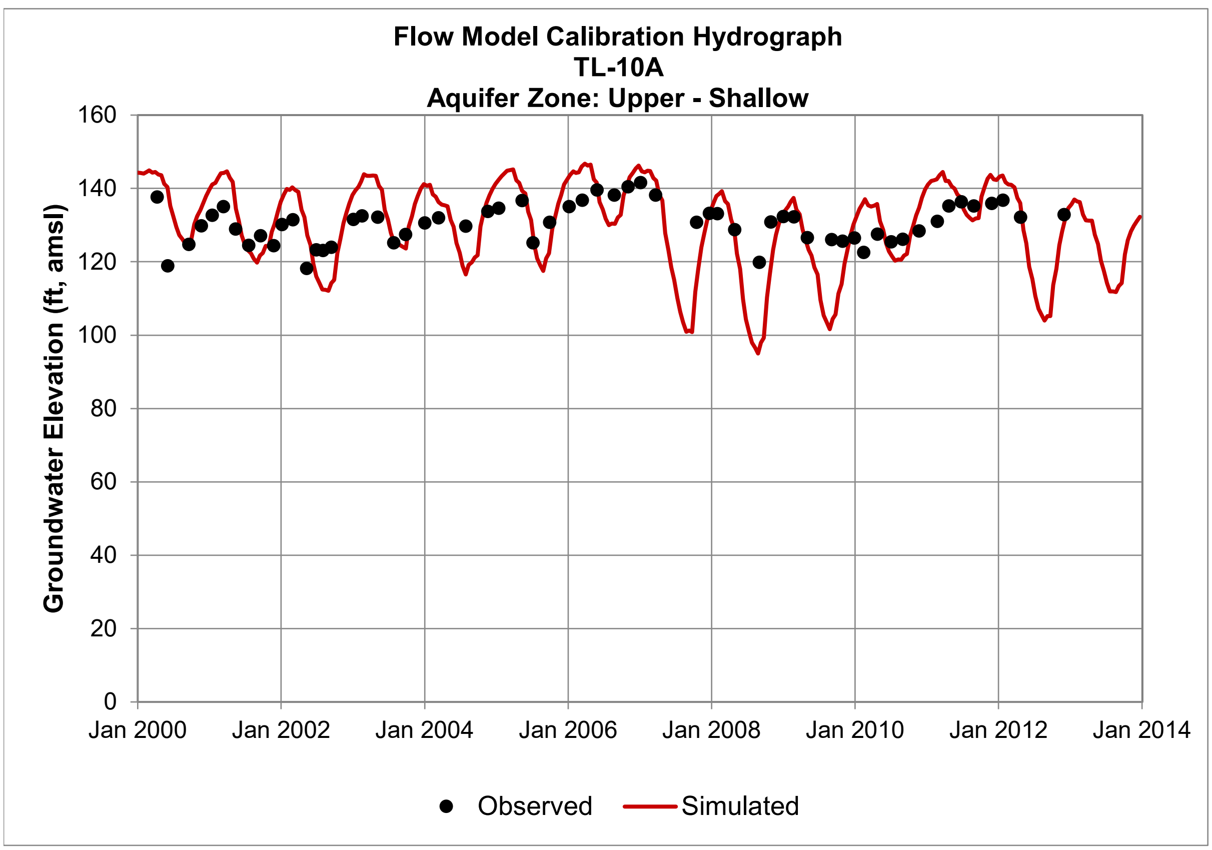
Observed
Simulated


Flow Model Calibration Hydrograph
TL-10A
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
160
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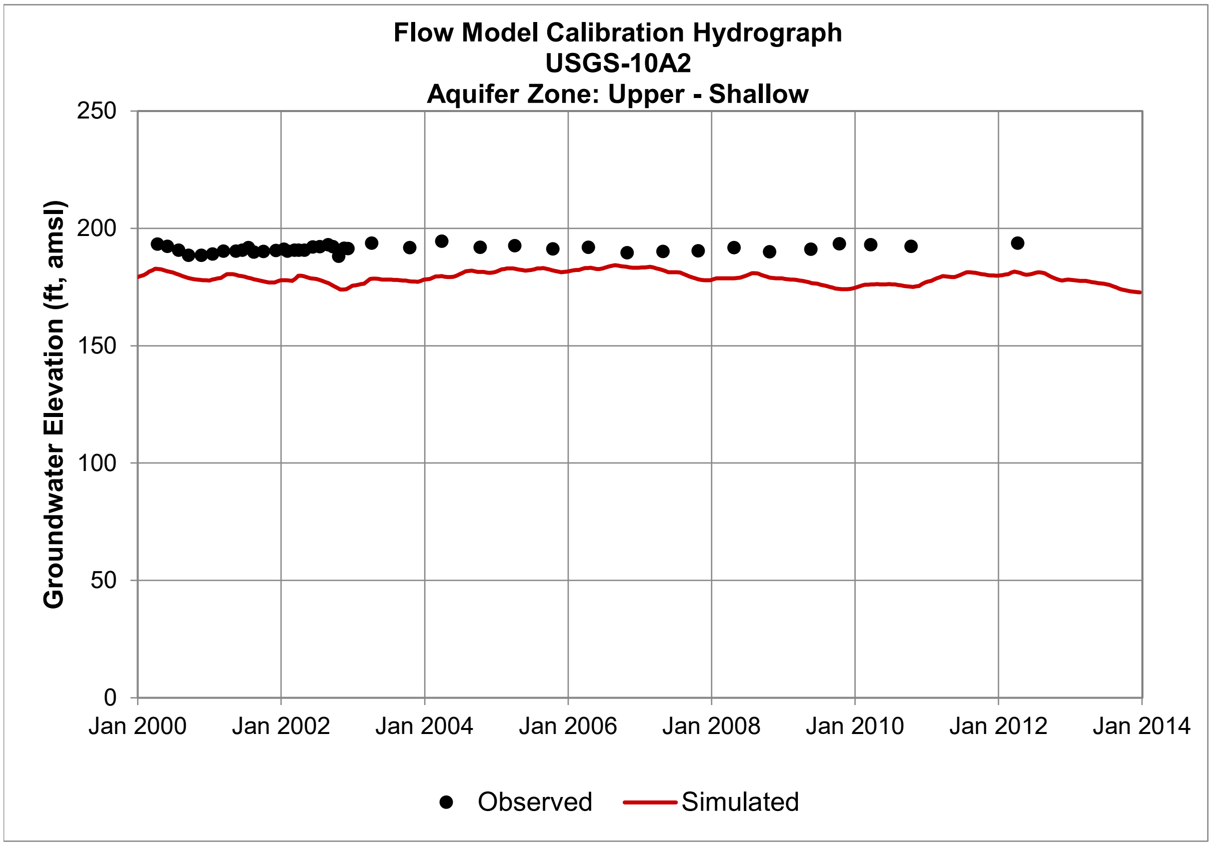
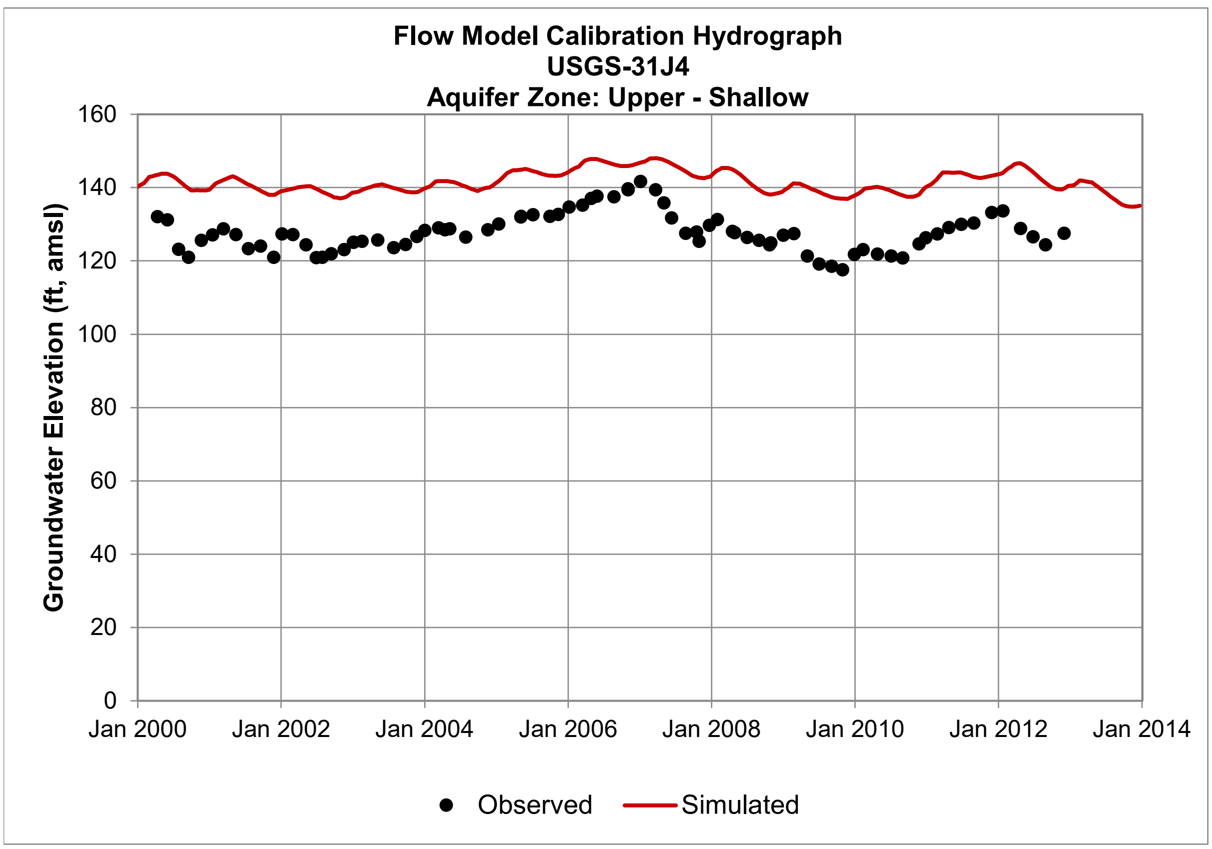
Observed
Simulated


Flow Model Calibration Hydrograph
USGS-10A2
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
250
200
150
100
50
0
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
USGS-31J4
Aquifer Zone: Upper - Shallow
Groundwater Elevation (ft, amsl)
160
140
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20
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Jan 2000
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Jan 2004
Jan 2006
Jan 2008
Jan 2010
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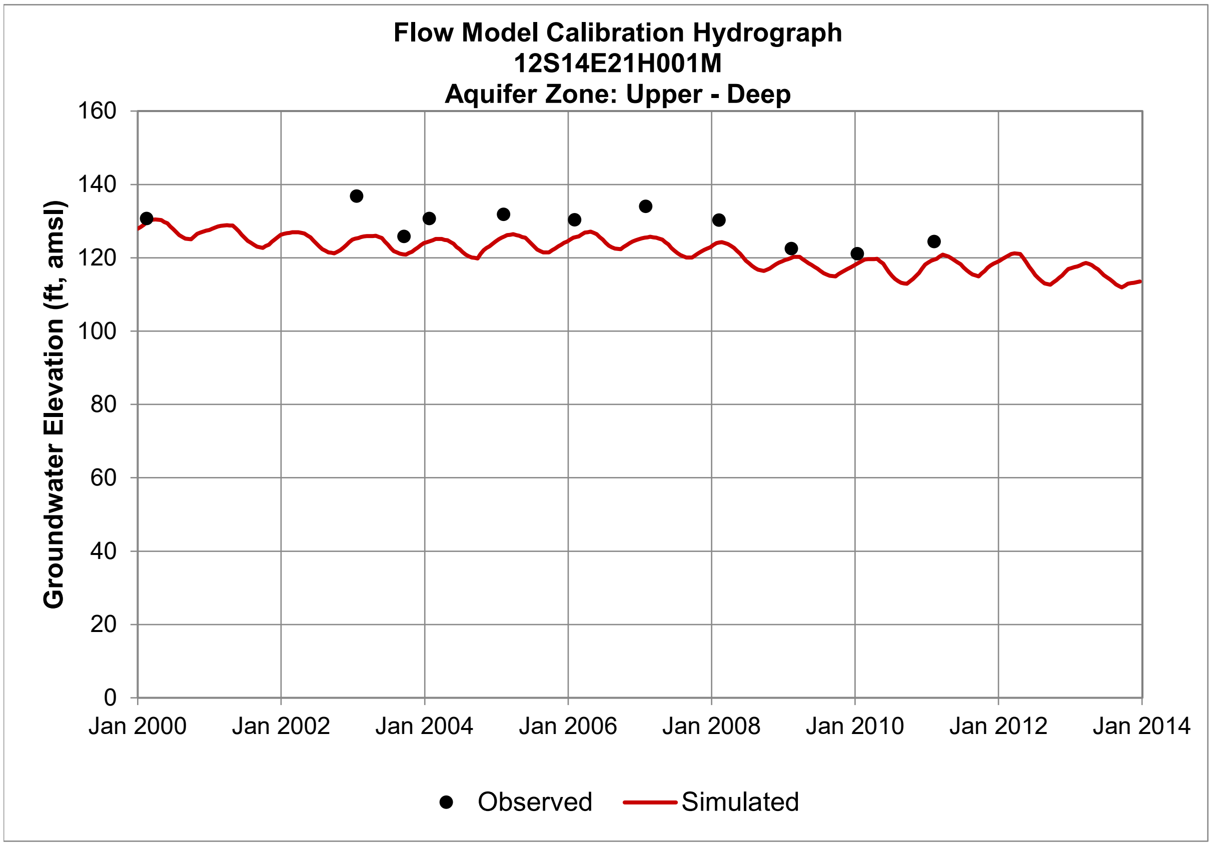
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
12S14E21H001M
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
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140
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40
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Jan 2006
Jan 2008
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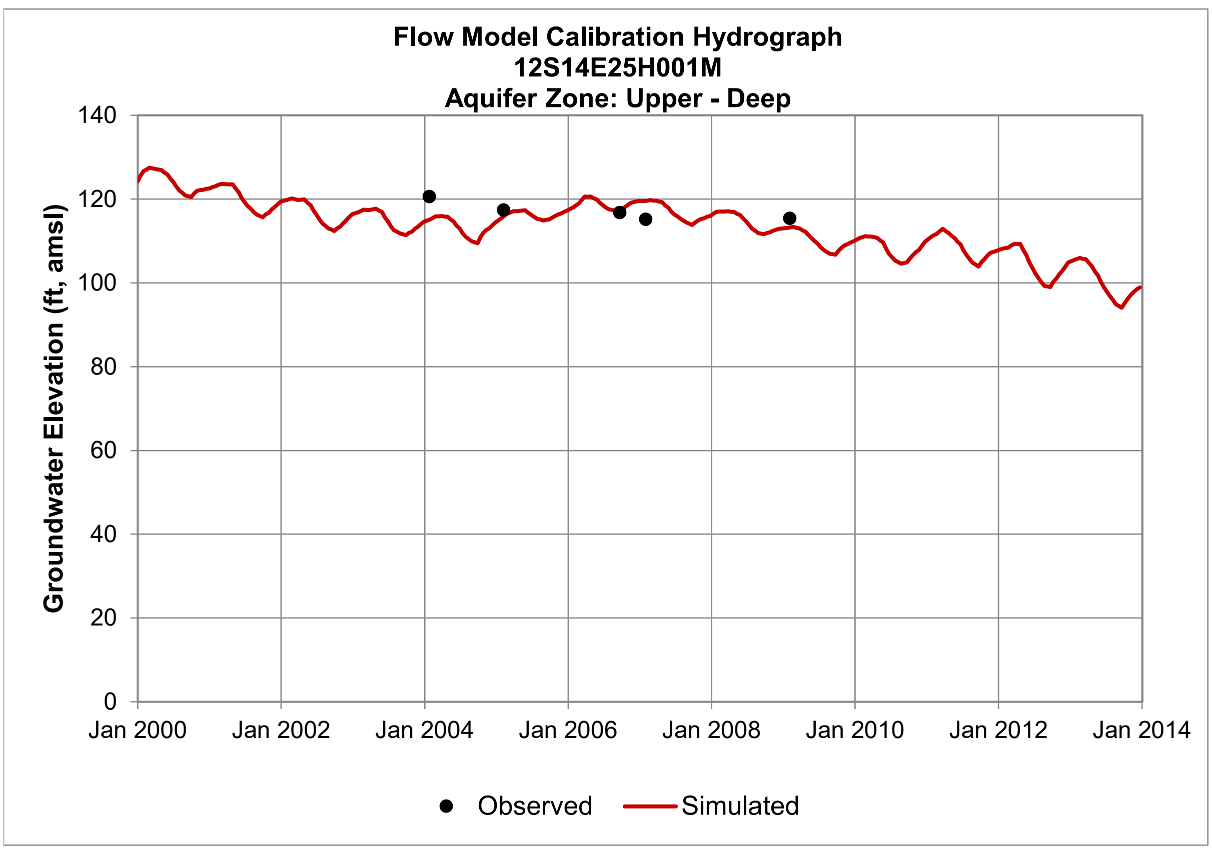
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
12S14E25H001M
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
140
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Observed
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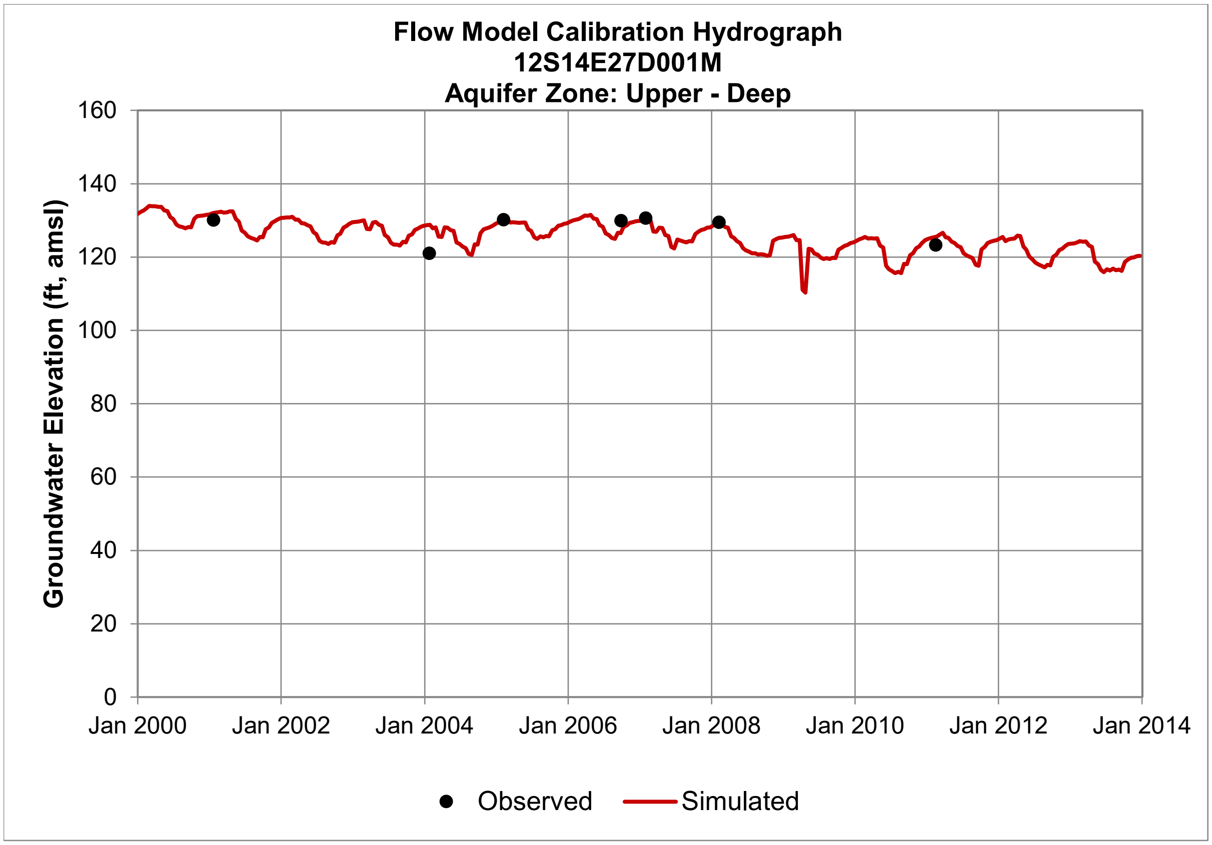
Flow Model Calibration Hydrograph
12S14E27D001M
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
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140
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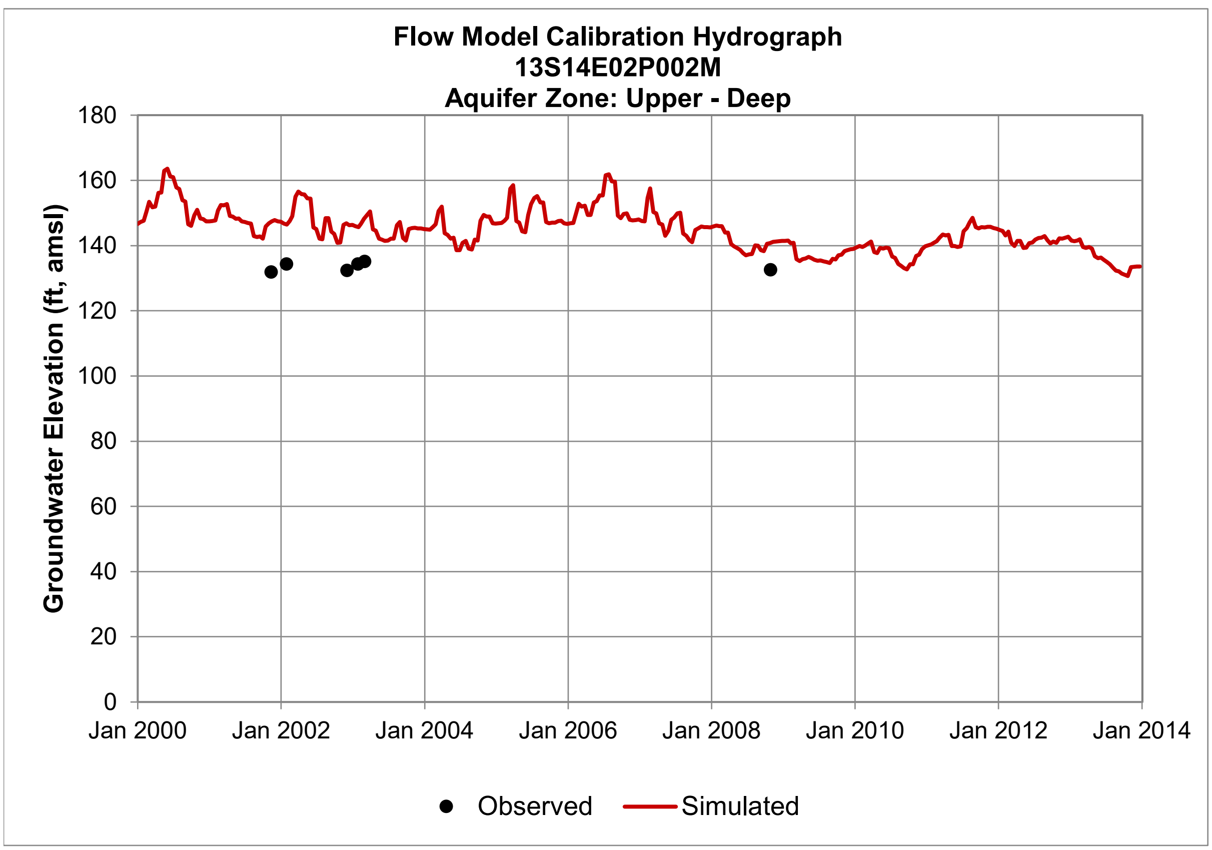
Flow Model Calibration Hydrograph
13S14E02P002M
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
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Observed
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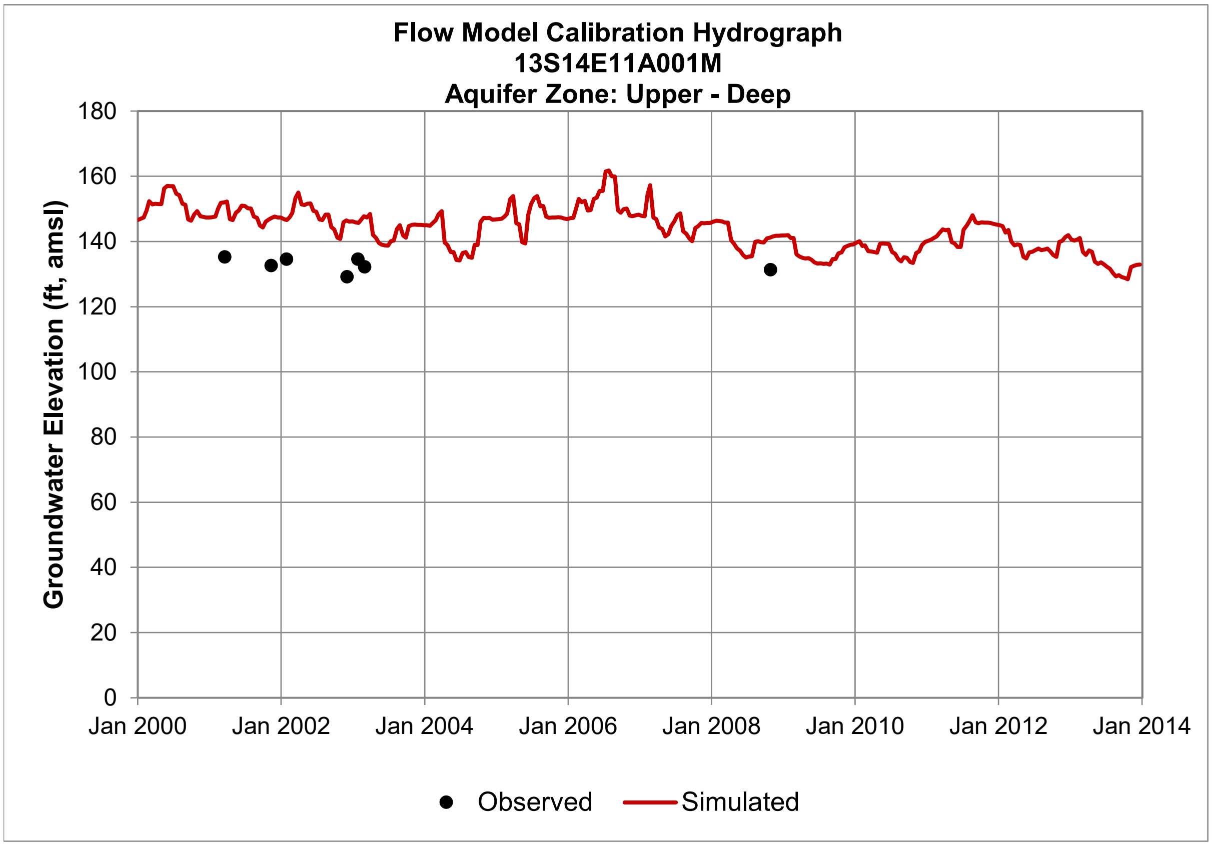
Flow Model Calibration Hydrograph
13S14E11A001M
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
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160
140
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Observed
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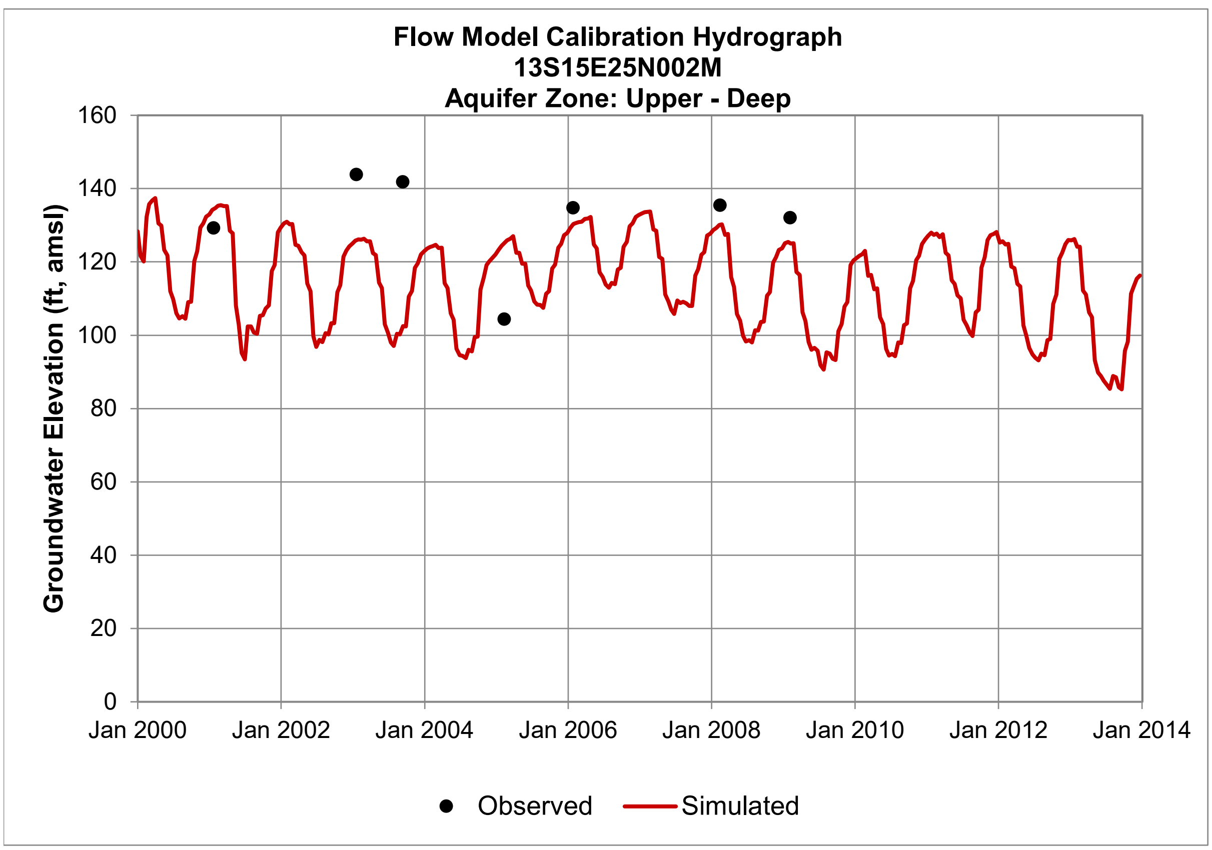
Flow Model Calibration Hydrograph
13S15E25N002M
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
160
140
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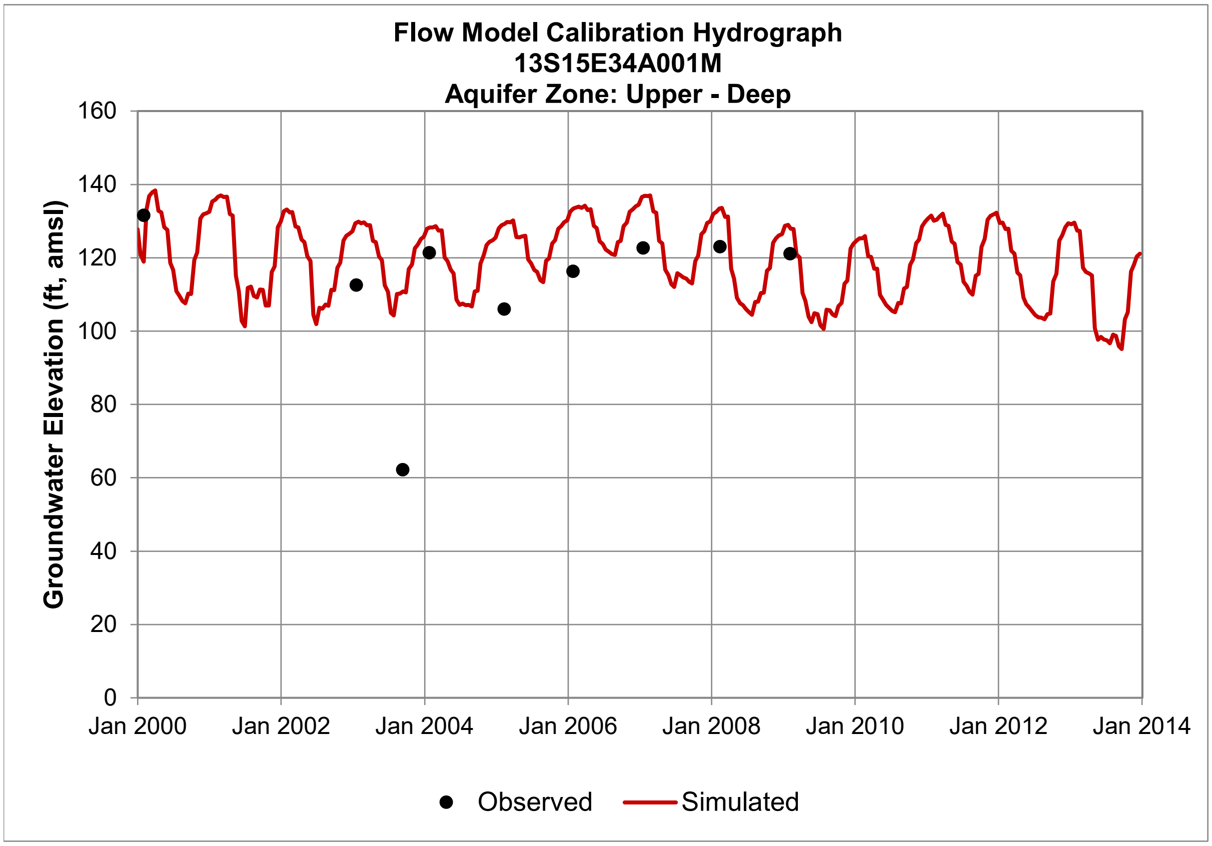
Flow Model Calibration Hydrograph
13S15E34A001M
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
160
140
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Observed
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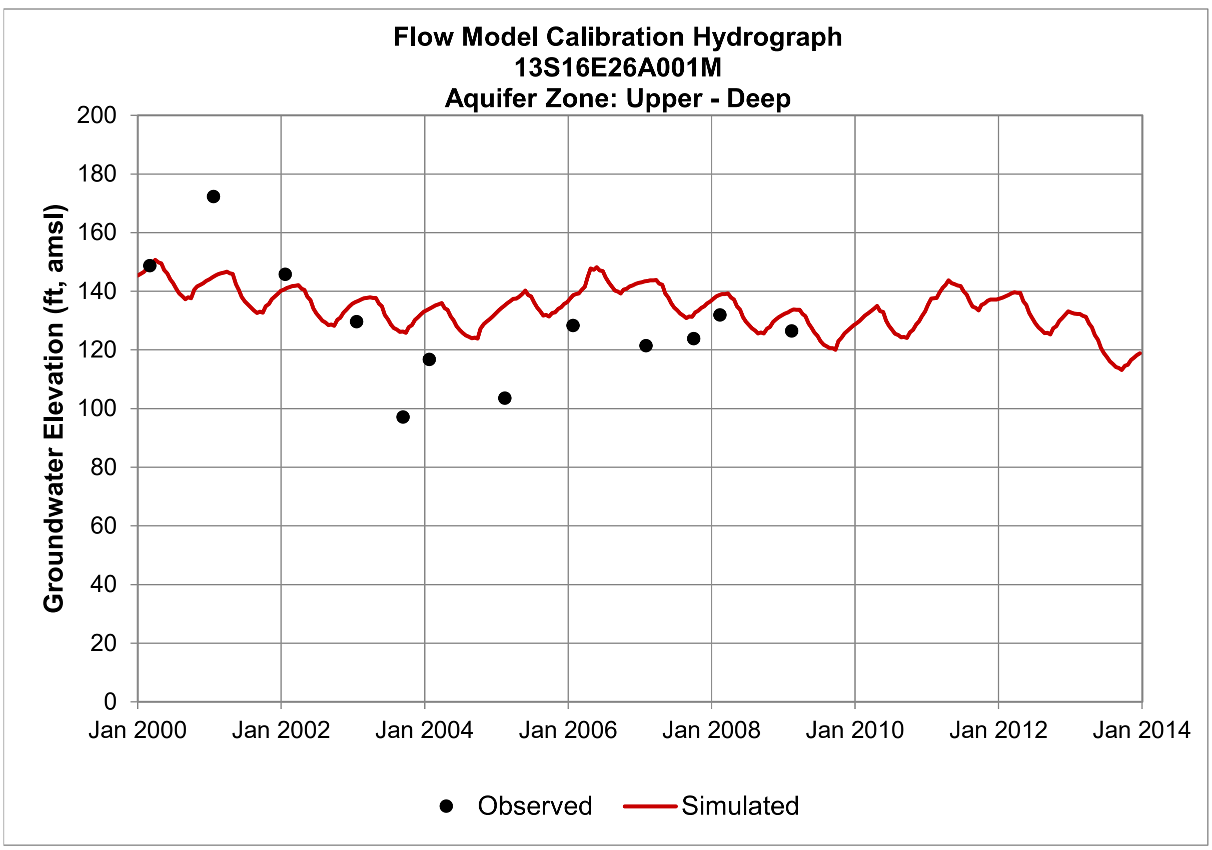
Flow Model Calibration Hydrograph
13S16E26A001M
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
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180
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140
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Observed
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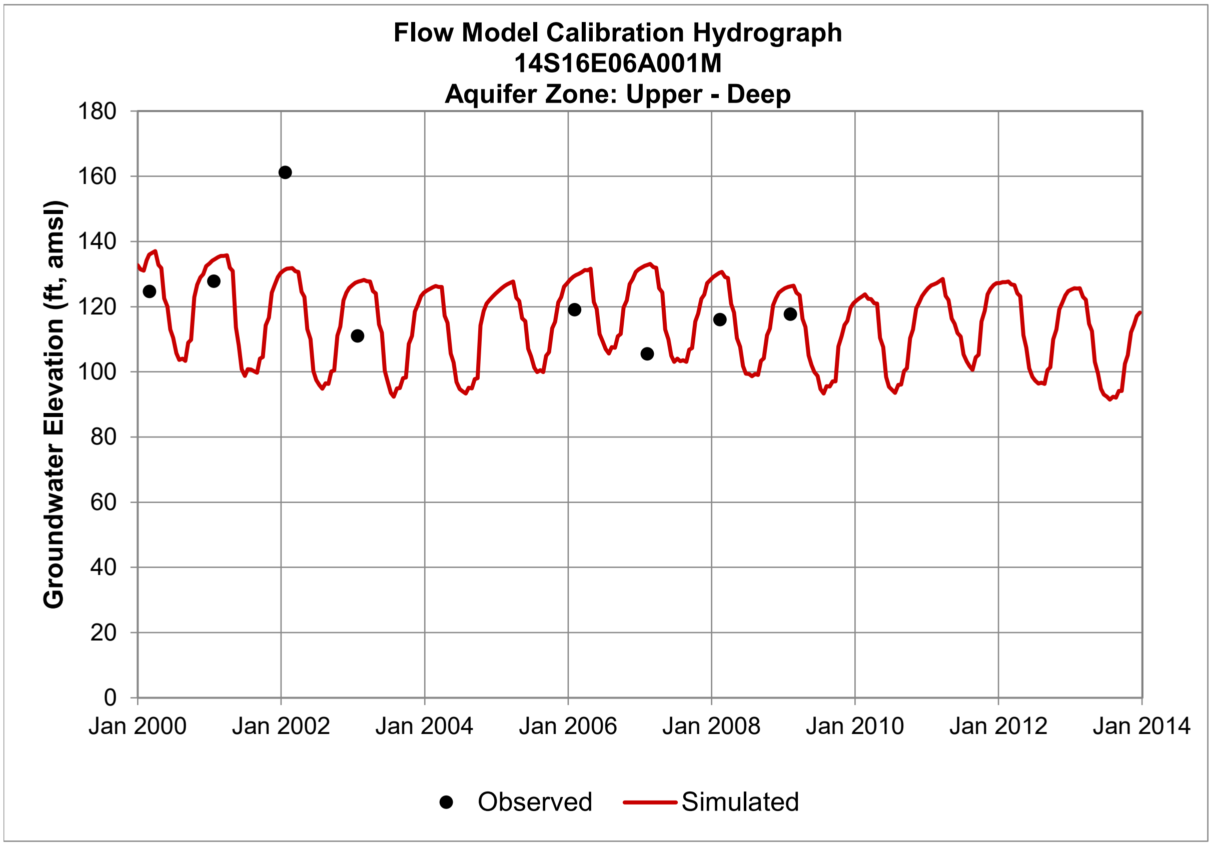
Flow Model Calibration Hydrograph
14S16E06A001M
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
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160
140
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Jan 2014
Observed
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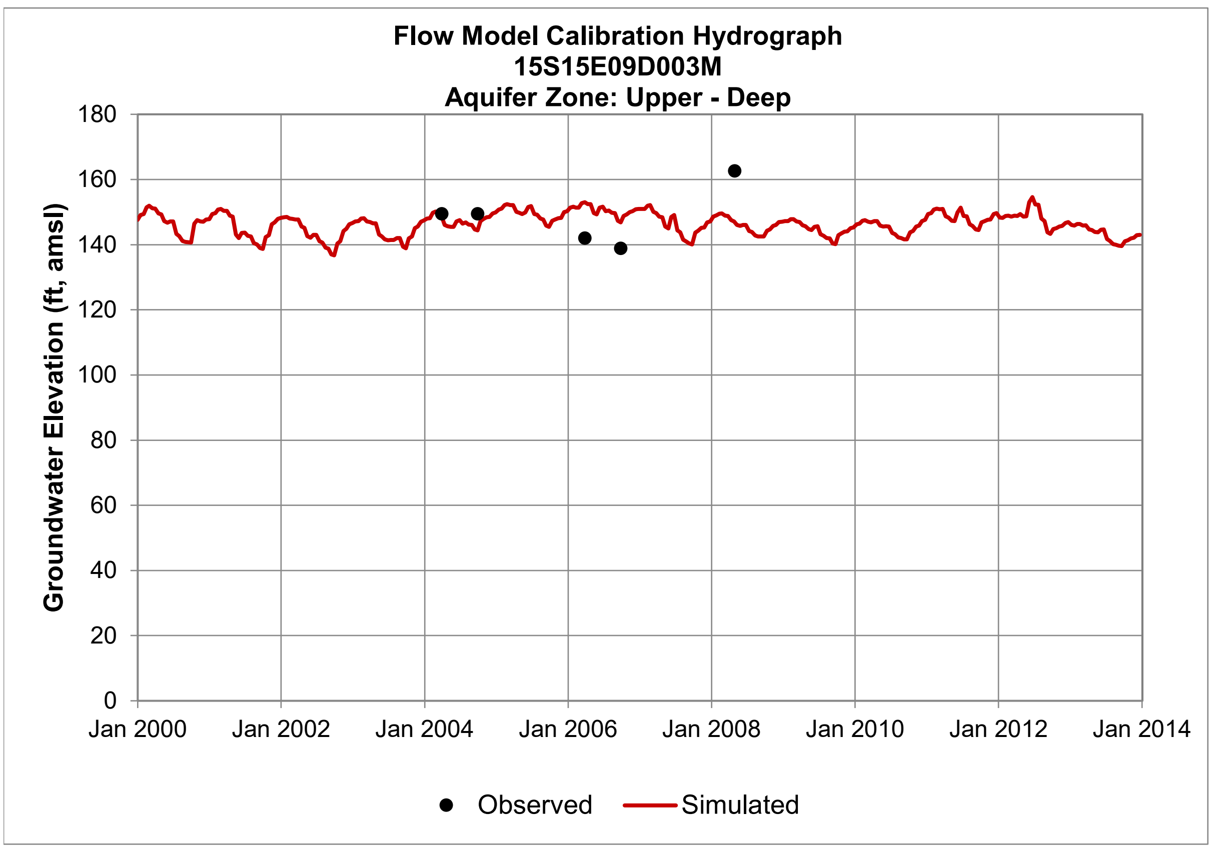
Flow Model Calibration Hydrograph
15S15E09D003M
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
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Observed
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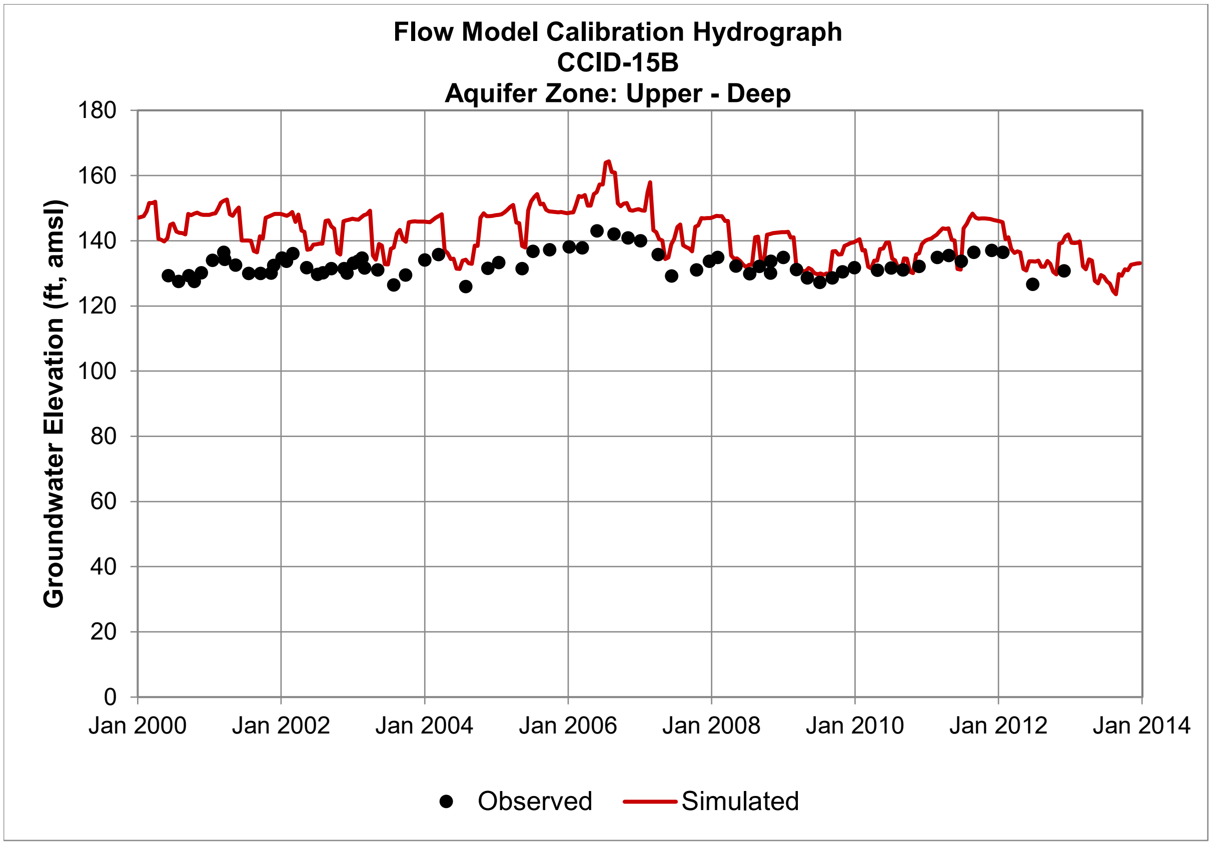
Flow Model Calibration Hydrograph
CCID-15B
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
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160
140
120
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20
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Jan 2008
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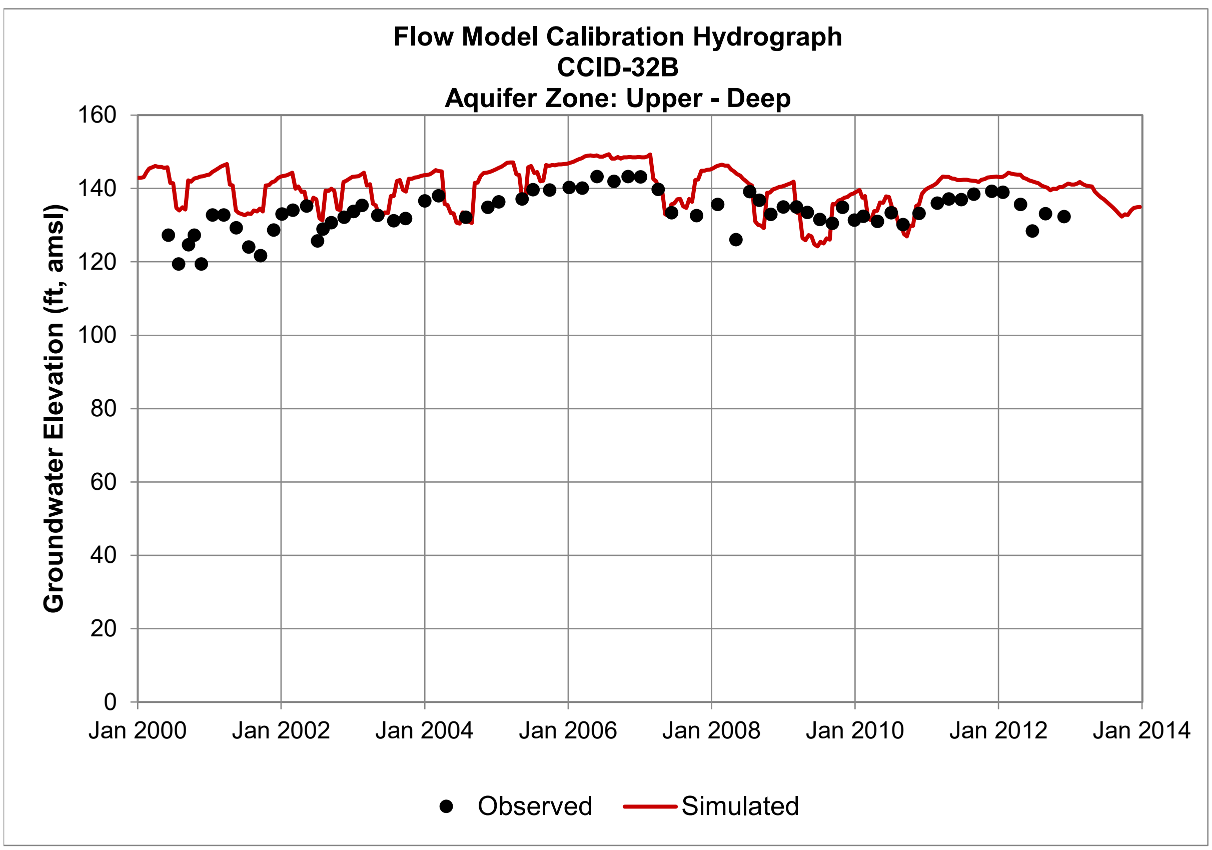
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
CCID-32B
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
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Jan 2000
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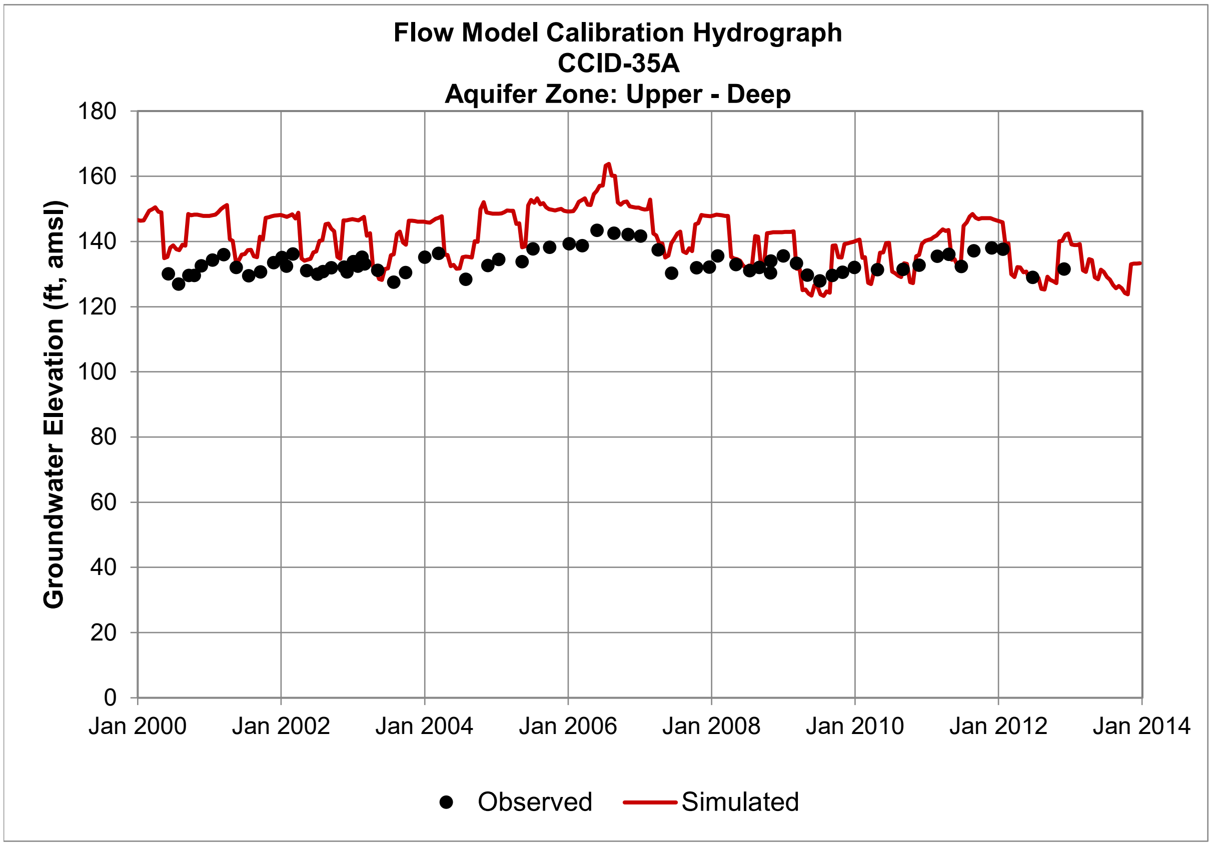
Observed
Simulated


Flow Model Calibration Hydrograph
CCID-35A
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
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40
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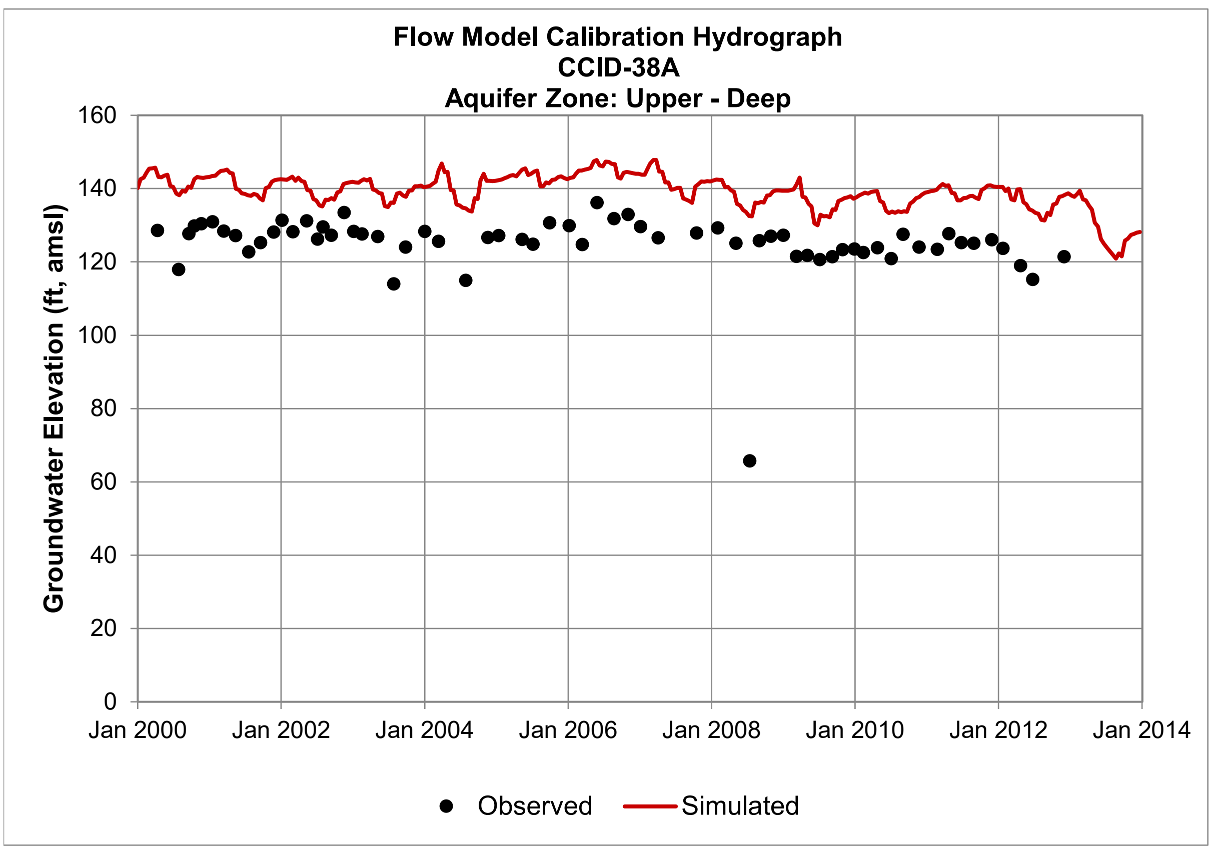
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
CCID-38A
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
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20
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140
160
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
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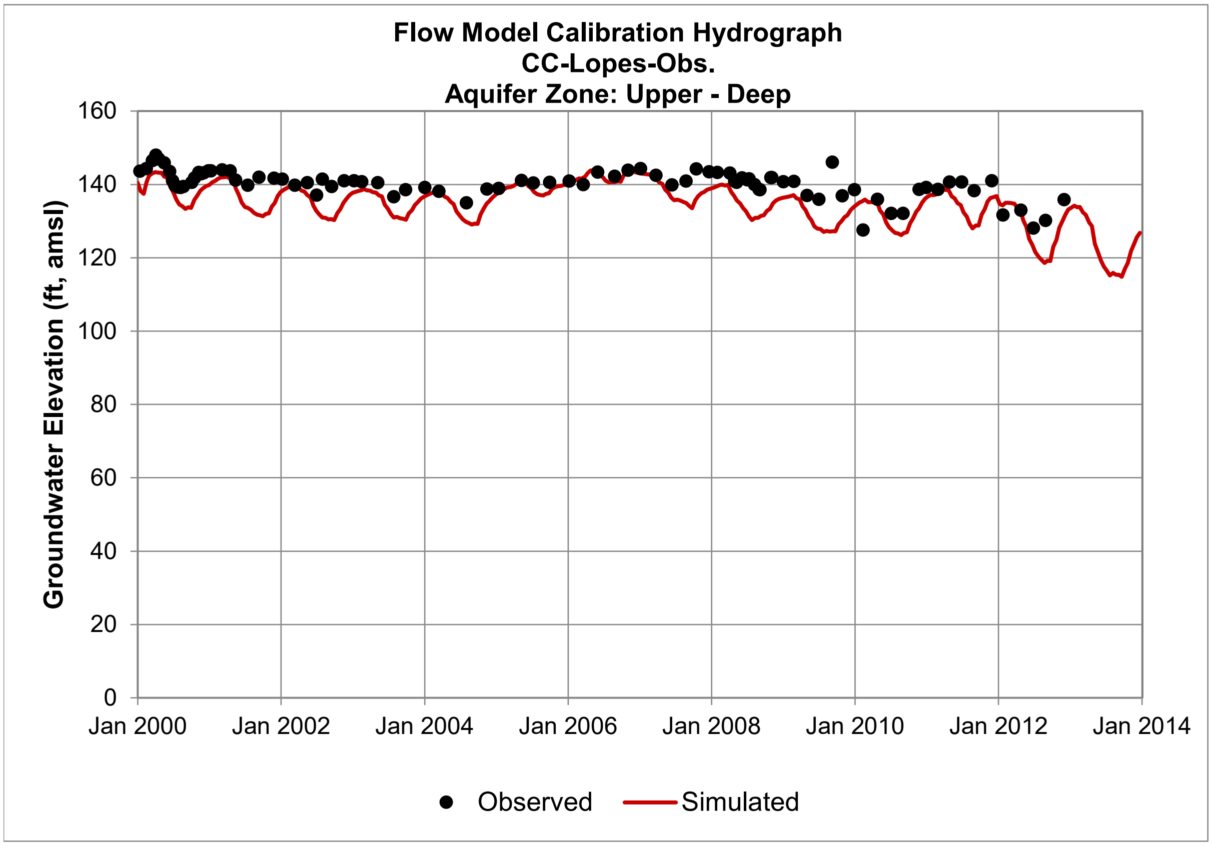
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
CC-Lopes-Obs.
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
0
20
40
60
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100
120
140
160
Jan 2000
Jan 2002
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Jan 2006
Jan 2008
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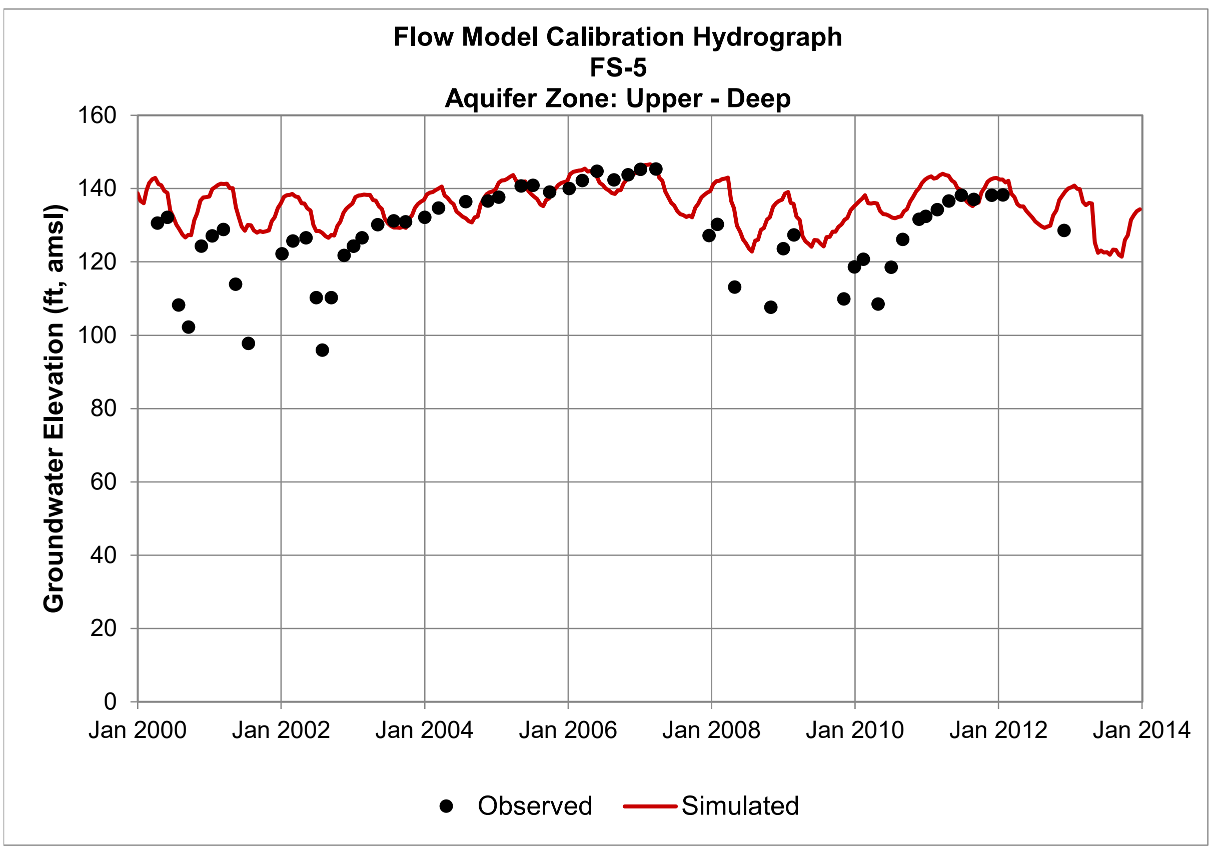
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
FS-5
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
0
20
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80
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120
140
160
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Jan 2004
Jan 2006
Jan 2008
Jan 2010
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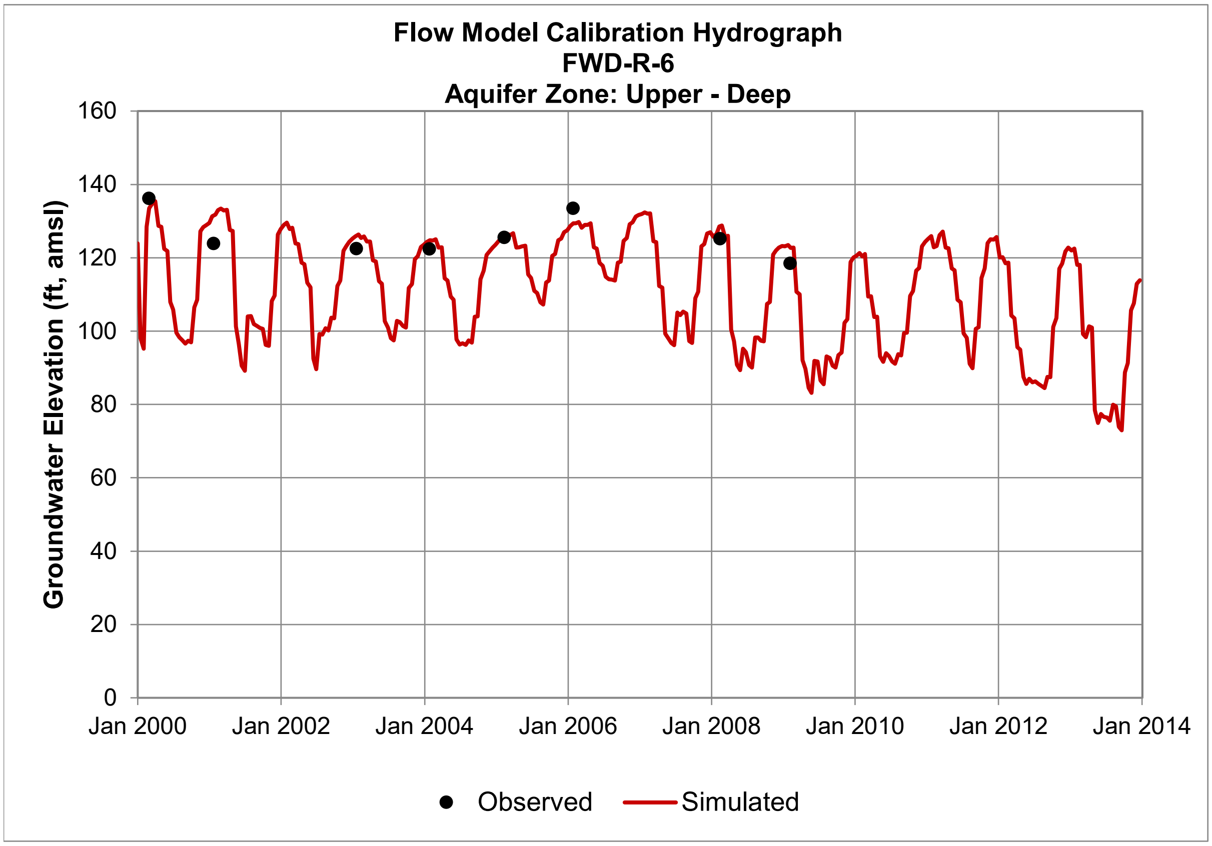
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
FWD-R-6
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
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20
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140
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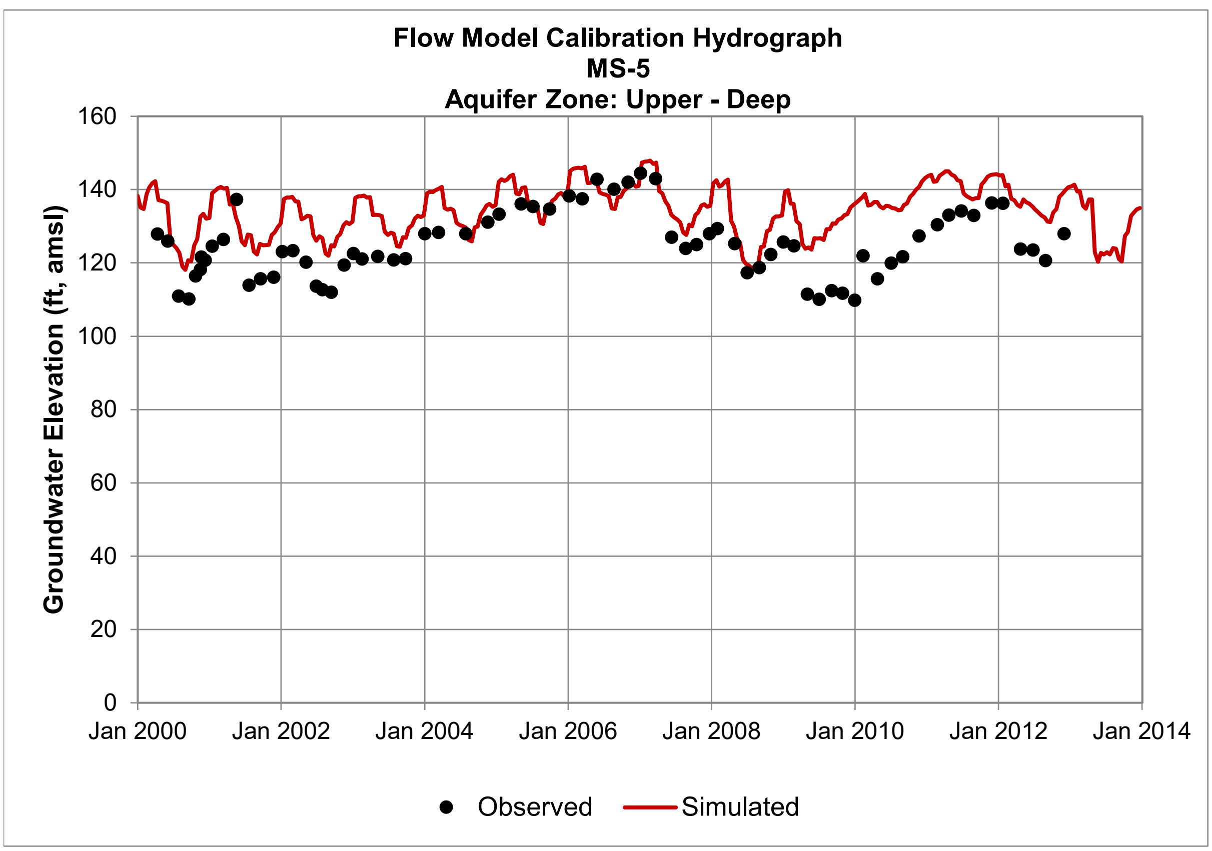
Observed
Simulated


Flow Model Calibration Hydrograph
MS-5
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
0
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140
160
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Observed
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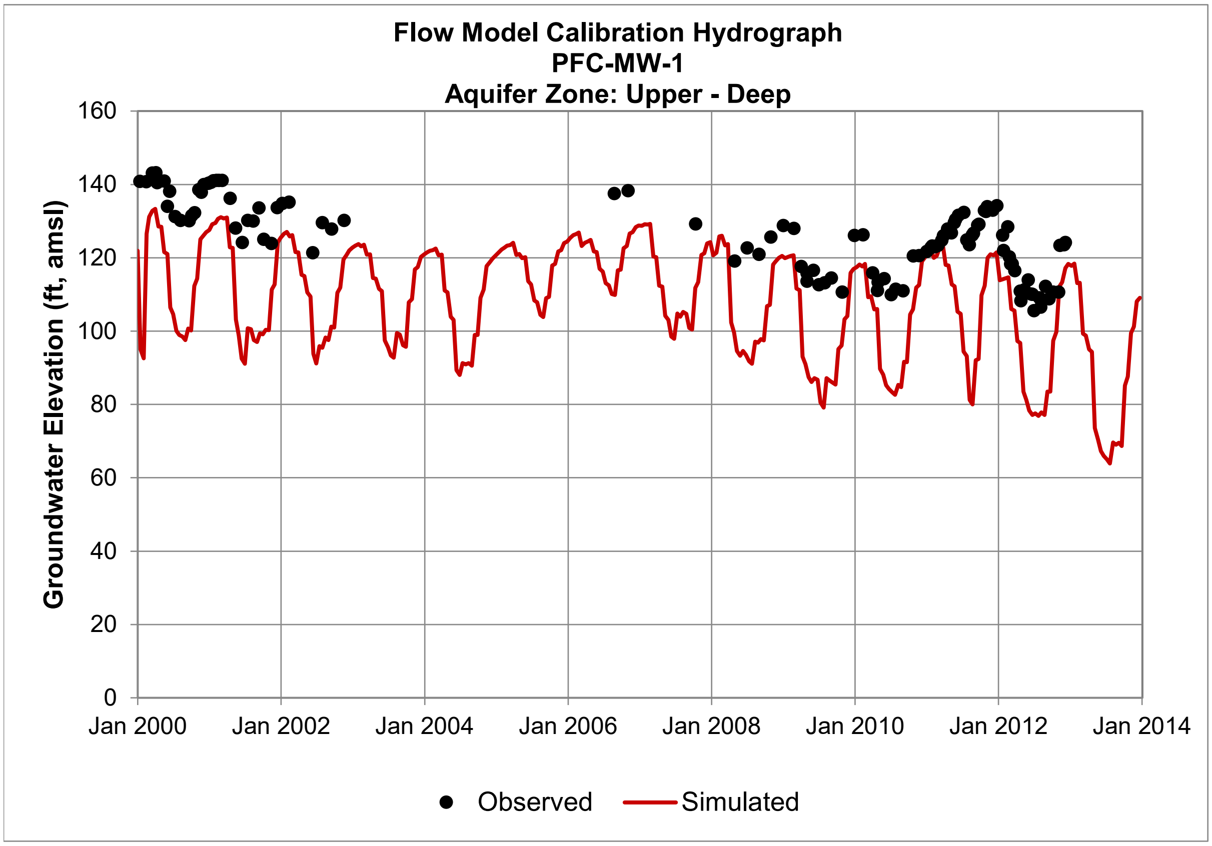
Flow Model Calibration Hydrograph
PFC-MW-1
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
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Jan 2008
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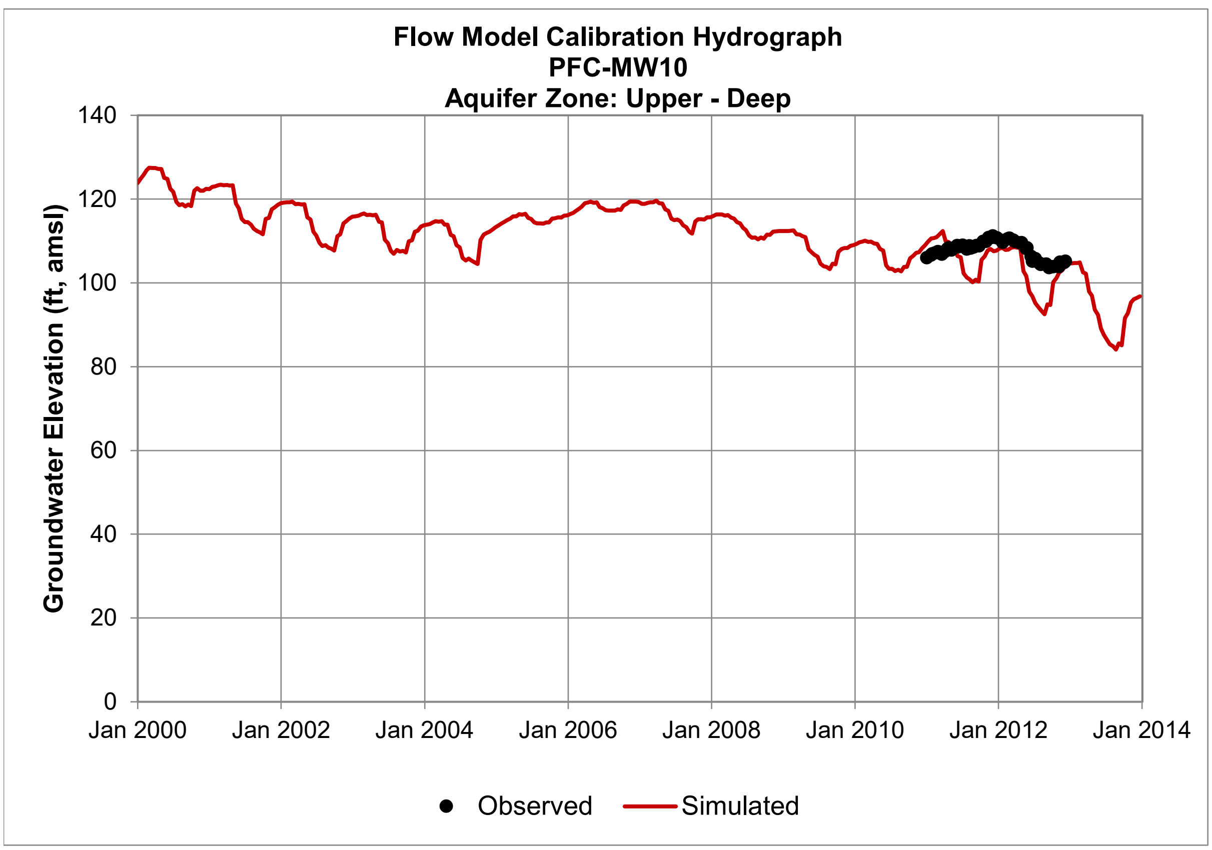
Observed
Simulated


Flow Model Calibration Hydrograph
PFC-MW10
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
140
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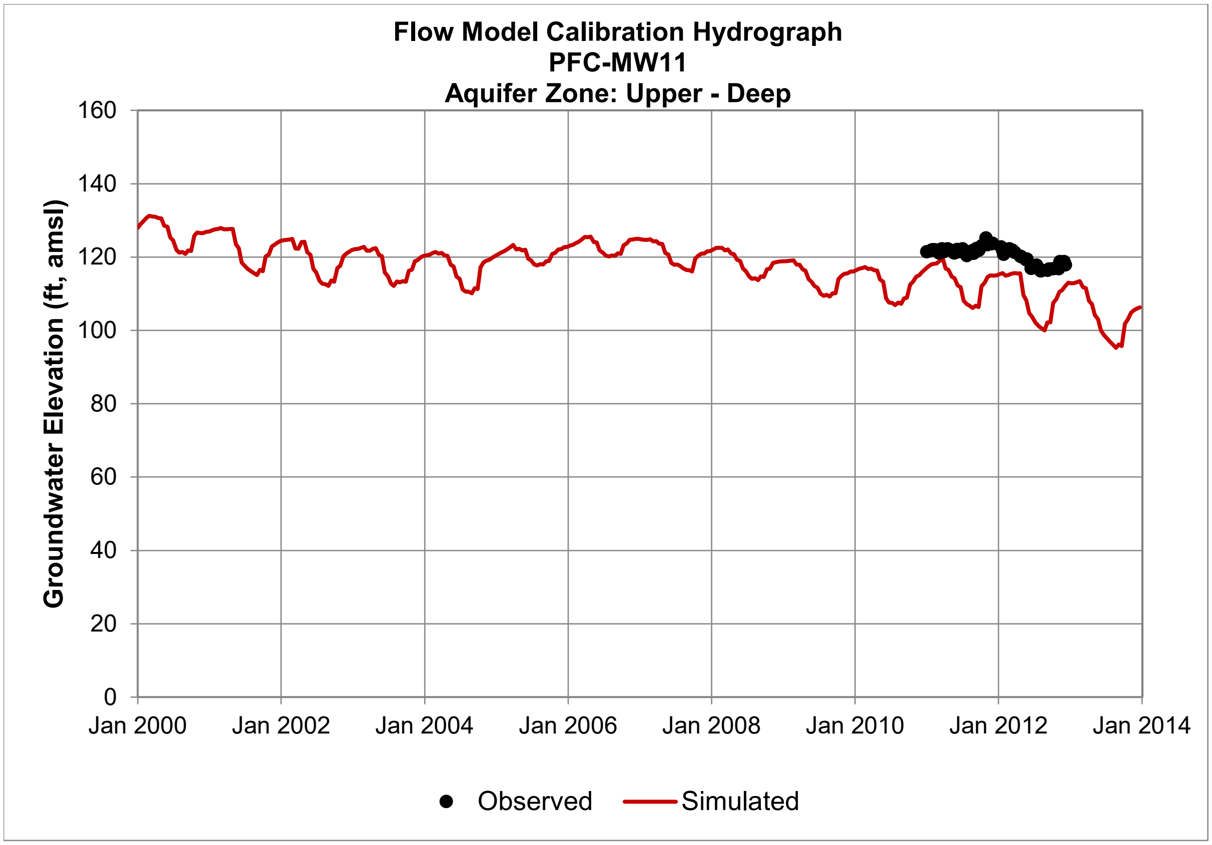
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
PFC-MW11
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
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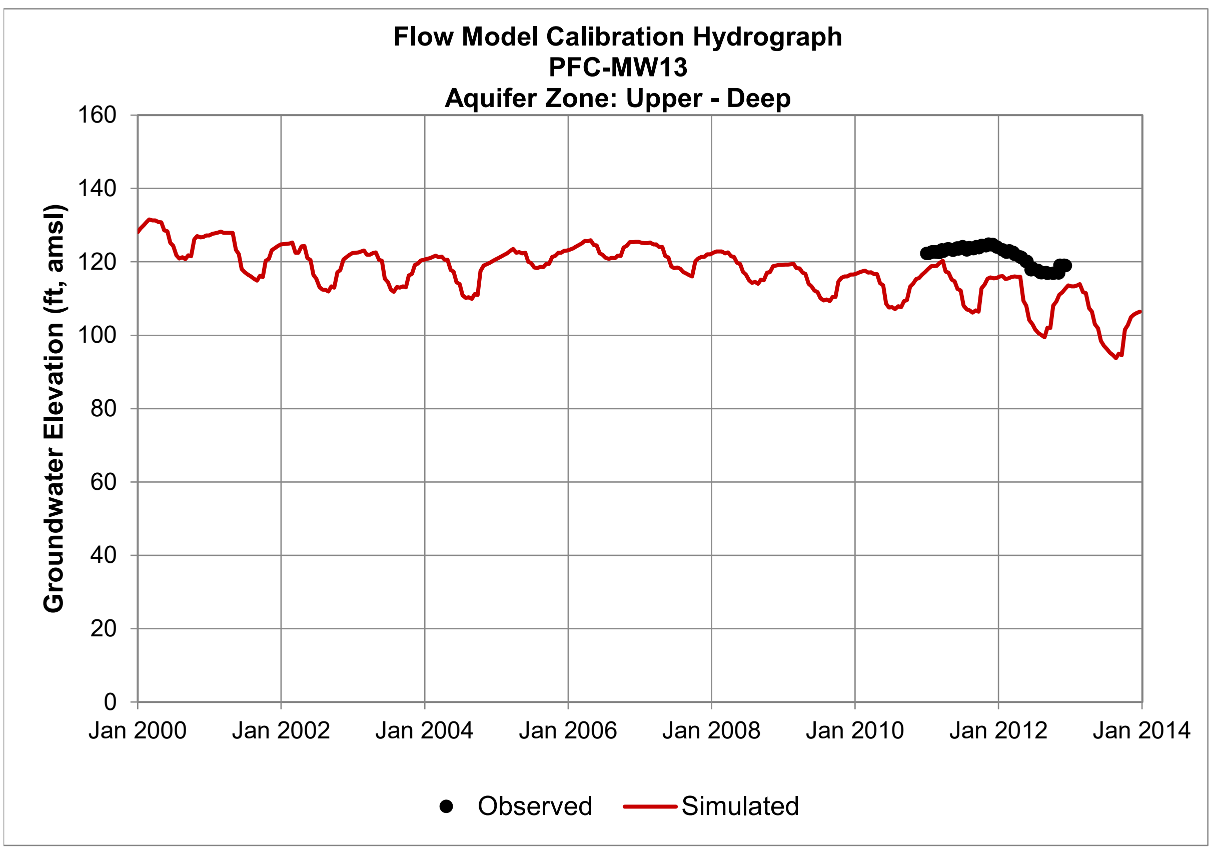
Observed
Simulated


Flow Model Calibration Hydrograph
PFC-MW13
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
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Observed
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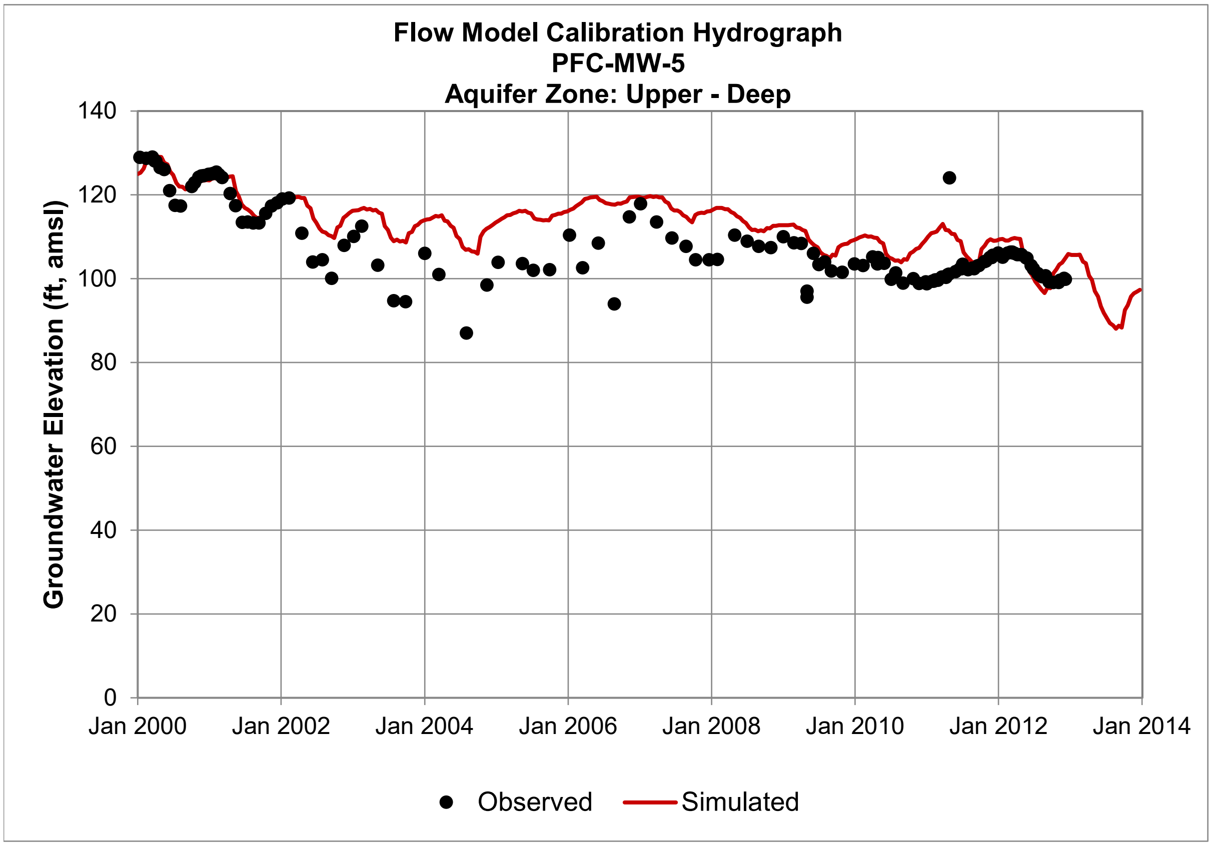
Flow Model Calibration Hydrograph
PFC-MW-5
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
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Observed
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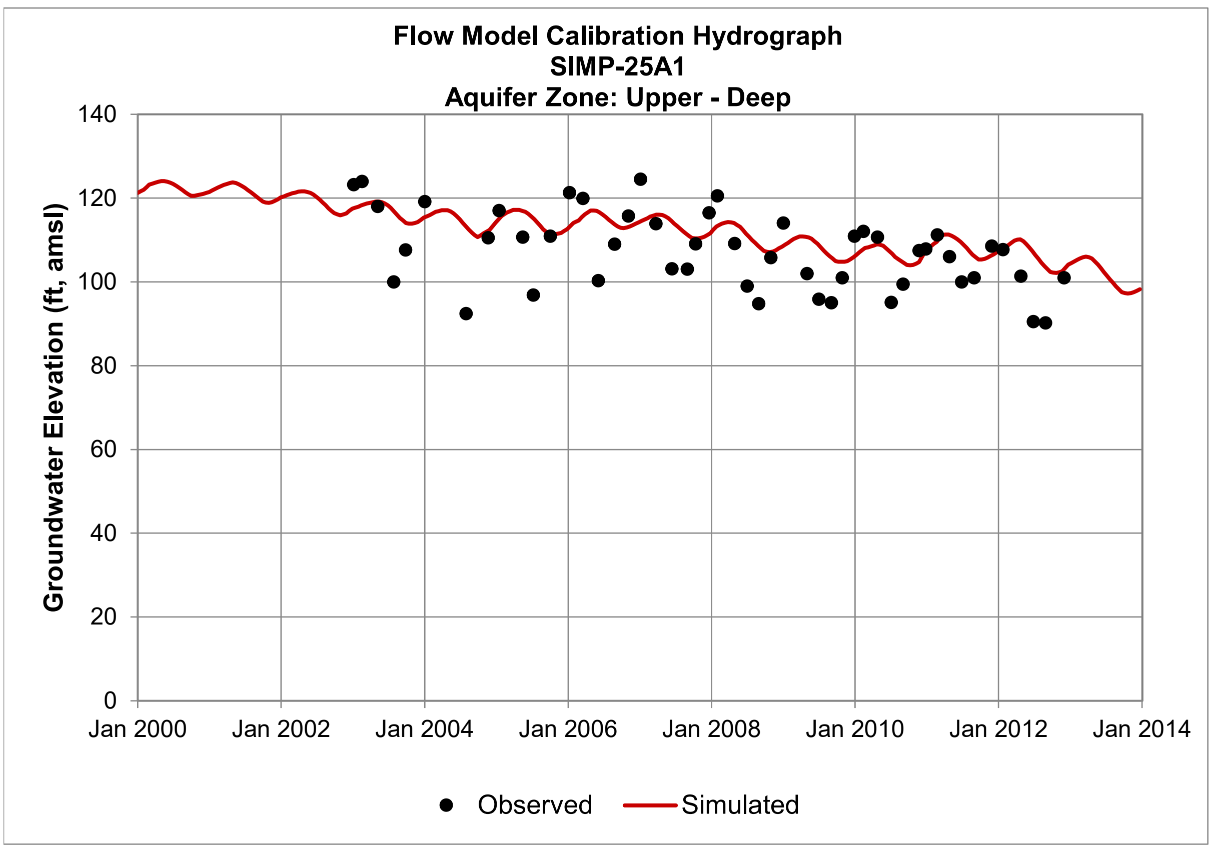
Flow Model Calibration Hydrograph
SIMP-25A1
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
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Observed
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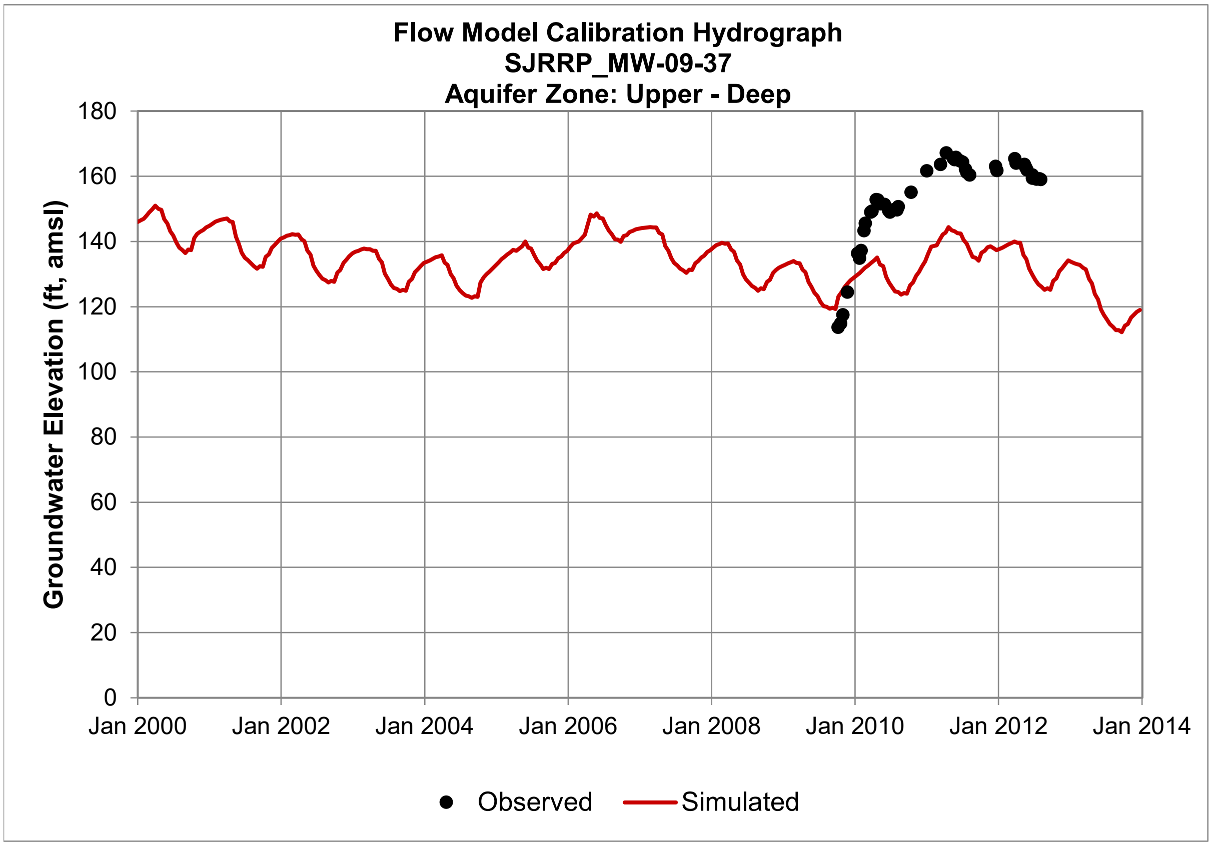
Flow Model Calibration Hydrograph
SJRRP_MW-09-37
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
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Observed
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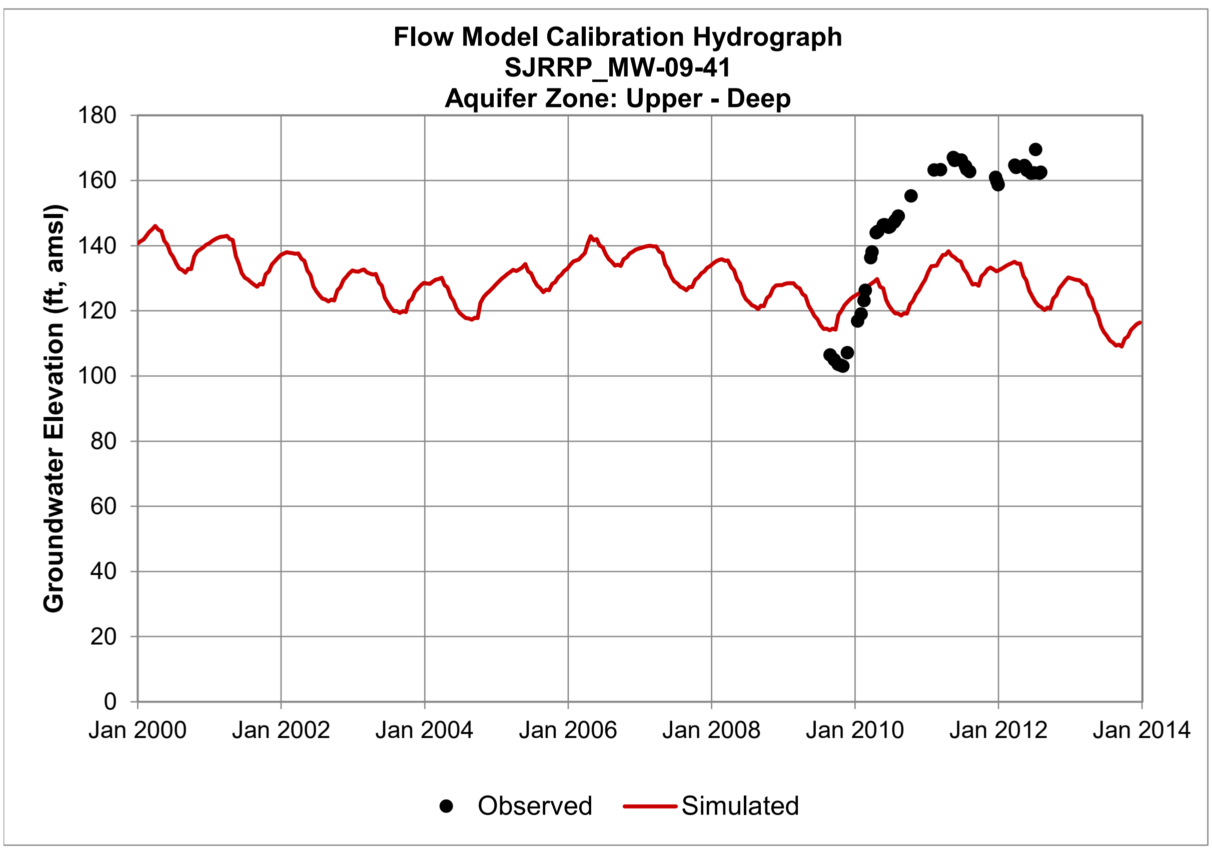
Flow Model Calibration Hydrograph
SJRRP_MW-09-41
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
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Observed
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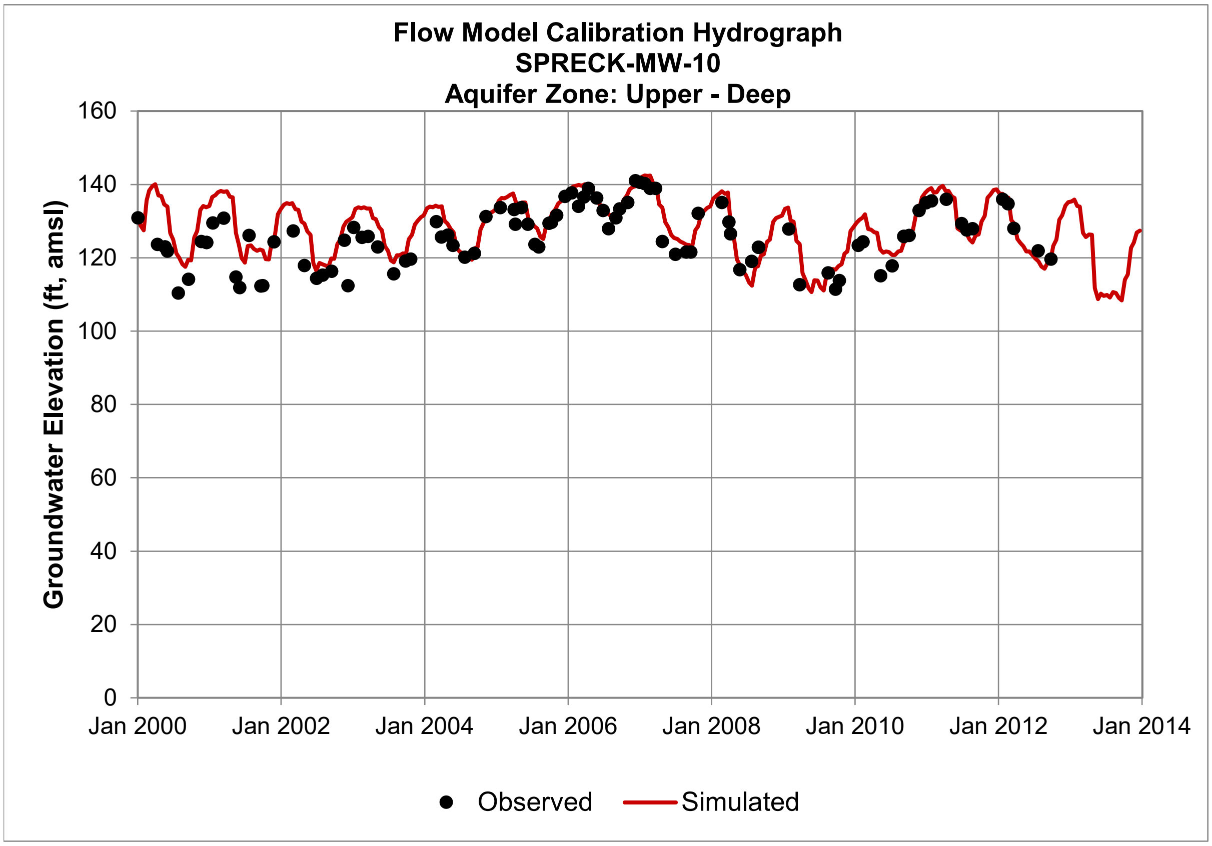
Flow Model Calibration Hydrograph
SPRECK-MW-10
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
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160
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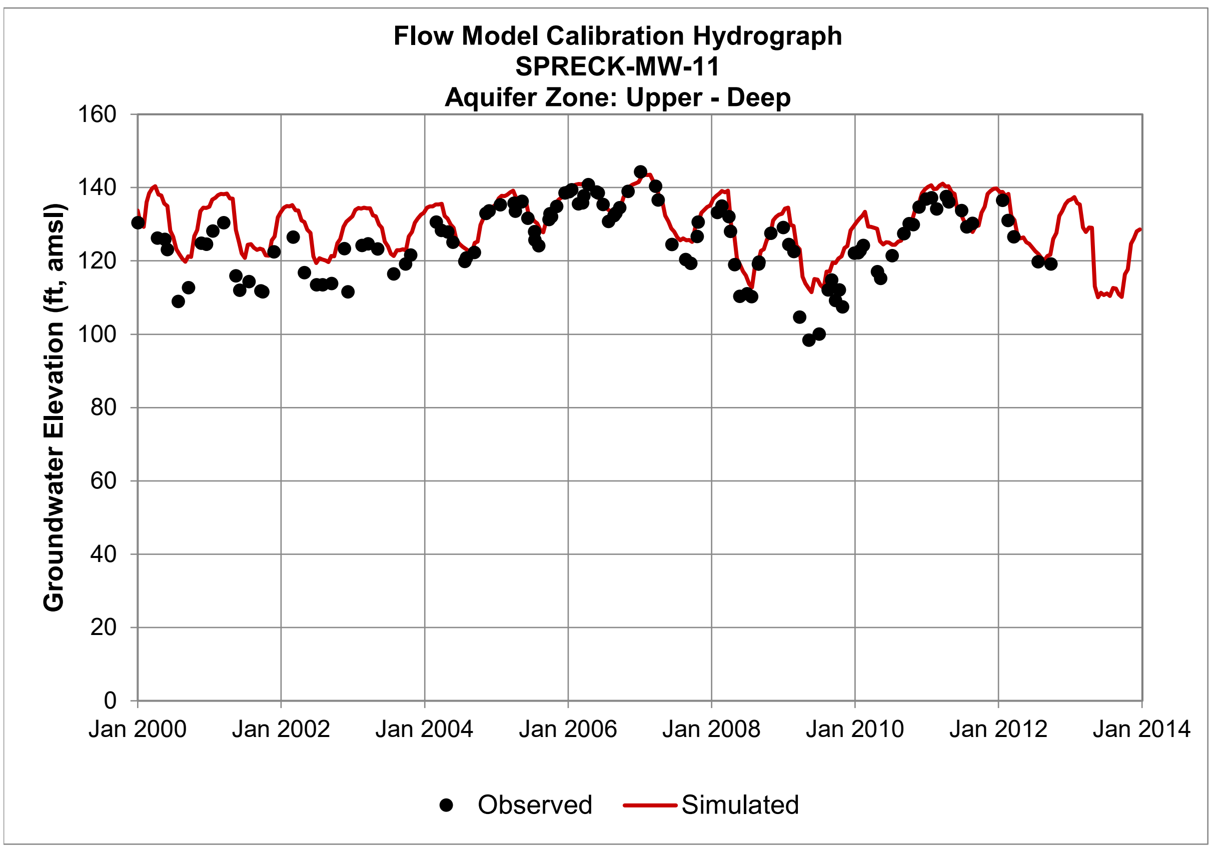
Observed
Simulated


Flow Model Calibration Hydrograph
SPRECK-MW-11
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
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Jan 2000
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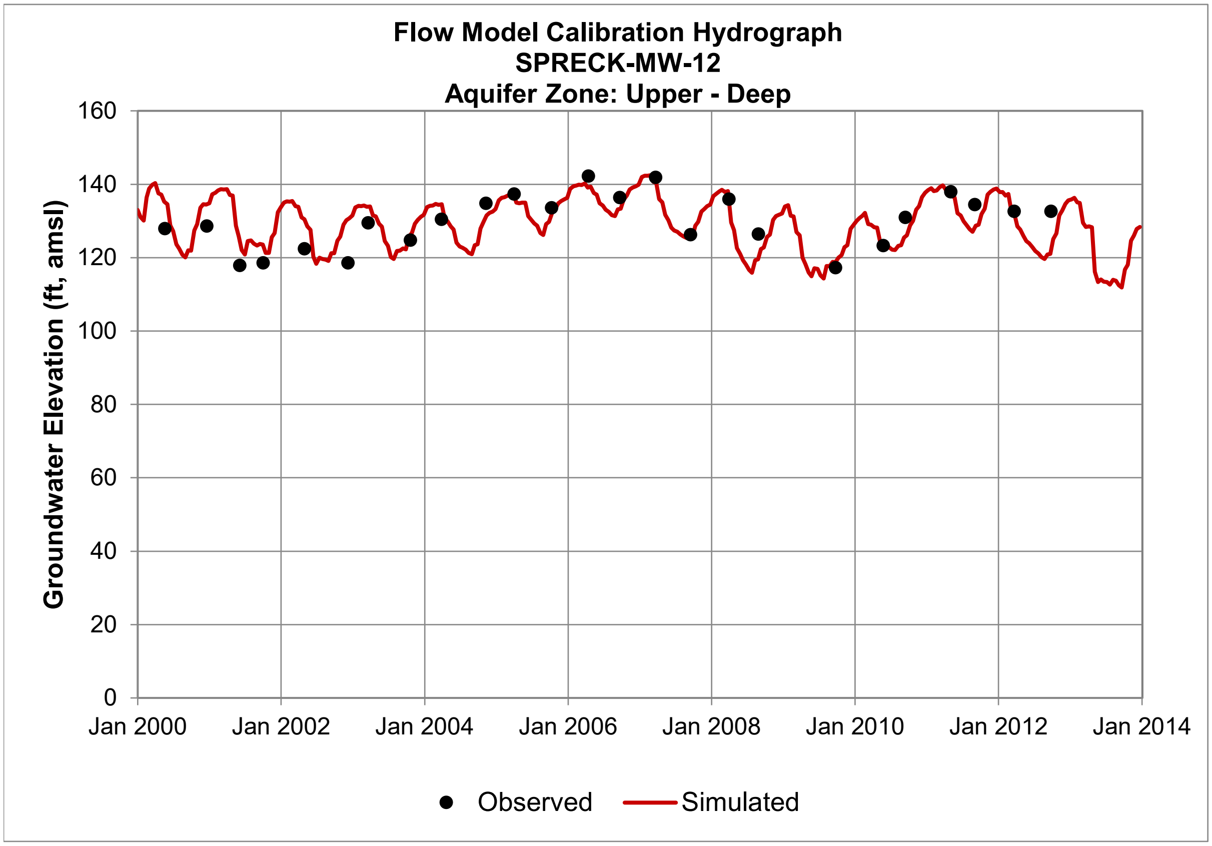
Observed
Simulated


Flow Model Calibration Hydrograph
SPRECK-MW-12
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
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Jan 2000
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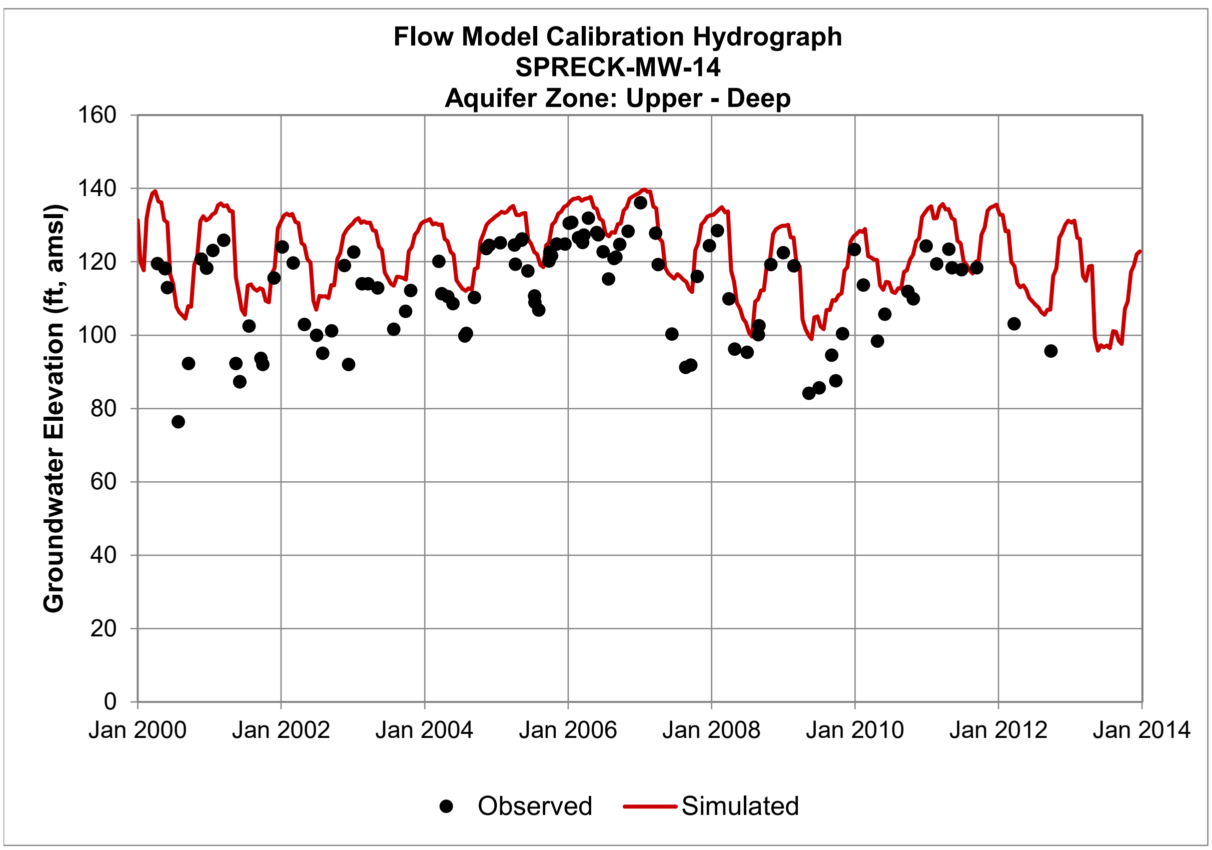
Observed
Simulated


Flow Model Calibration Hydrograph
SPRECK-MW-14
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
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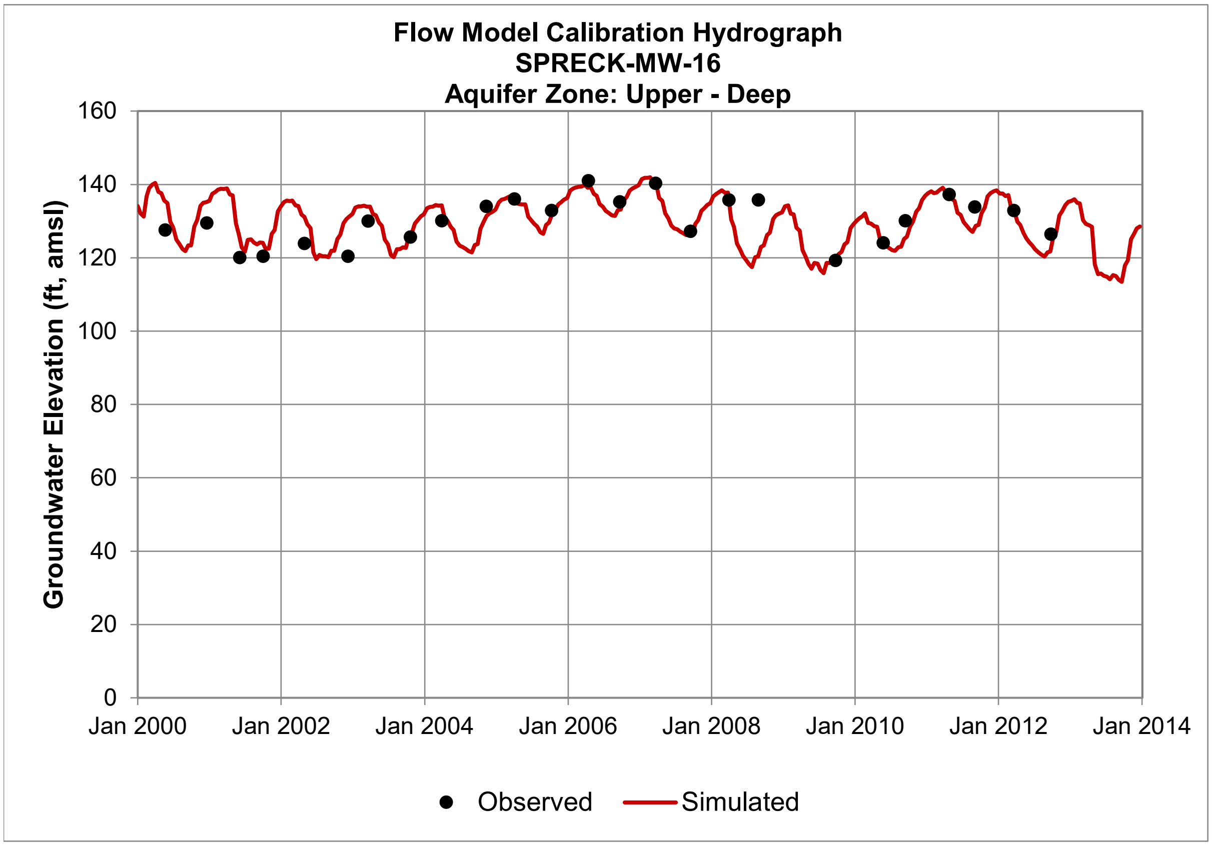
Observed
Simulated


Flow Model Calibration Hydrograph
SPRECK-MW-16
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
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Jan 2000
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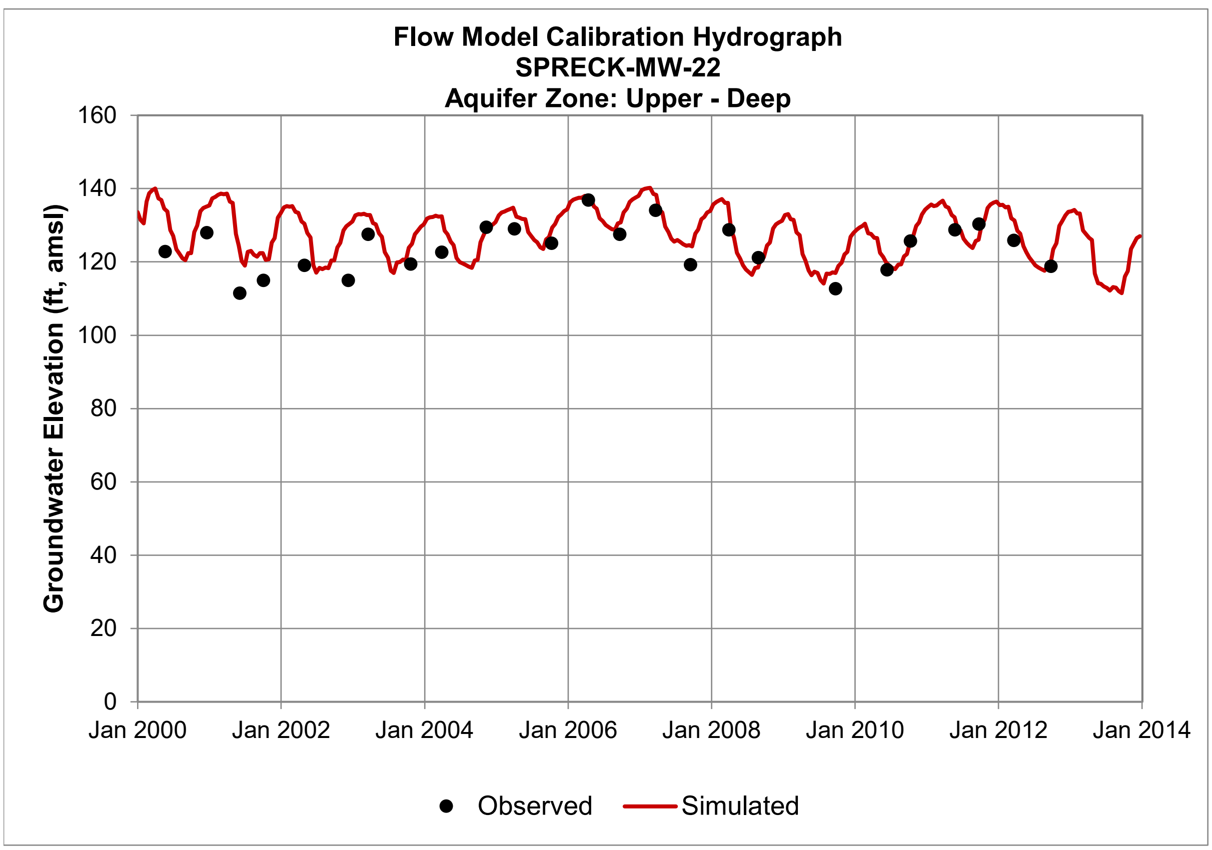
Observed
Simulated


Flow Model Calibration Hydrograph
SPRECK-MW-22
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
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160
Jan 2000
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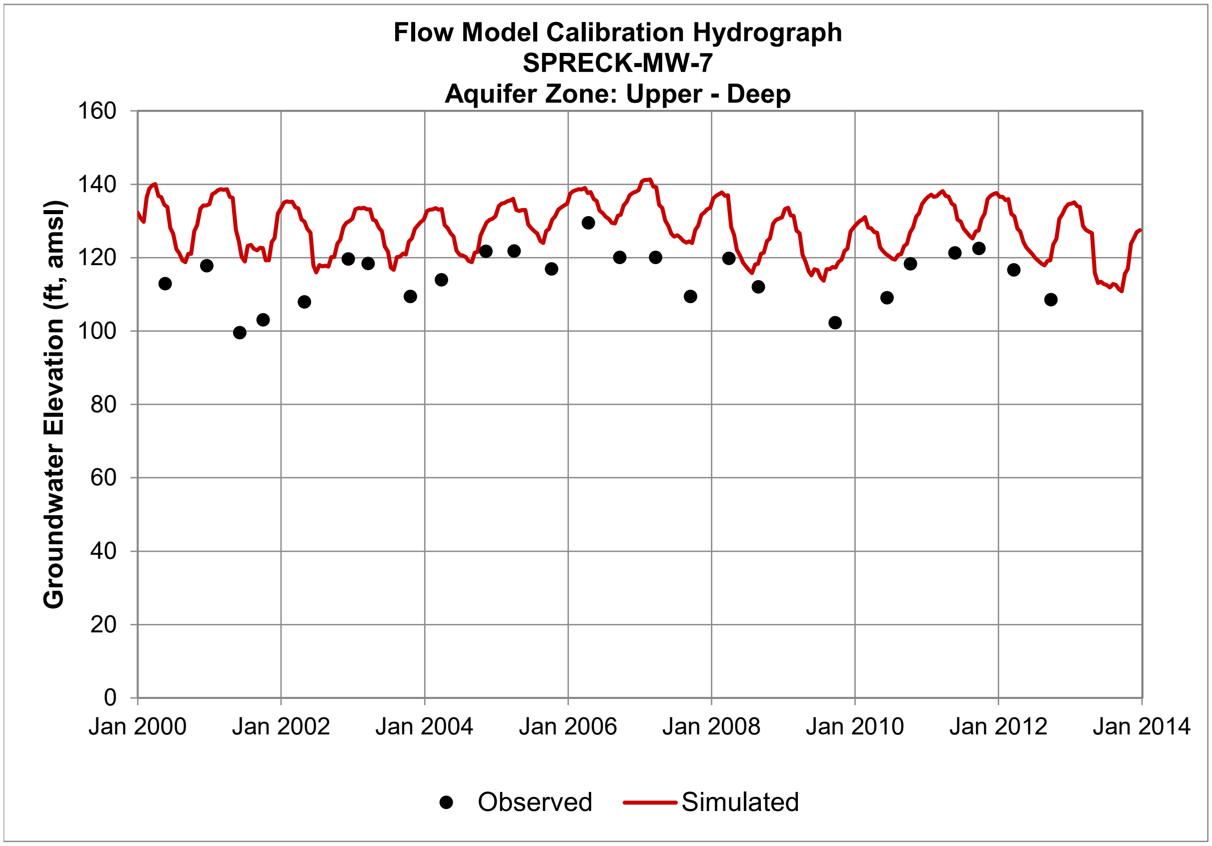
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
SPRECK-MW-7
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
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140
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0
Jan 2000
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Jan 2006
Jan 2008
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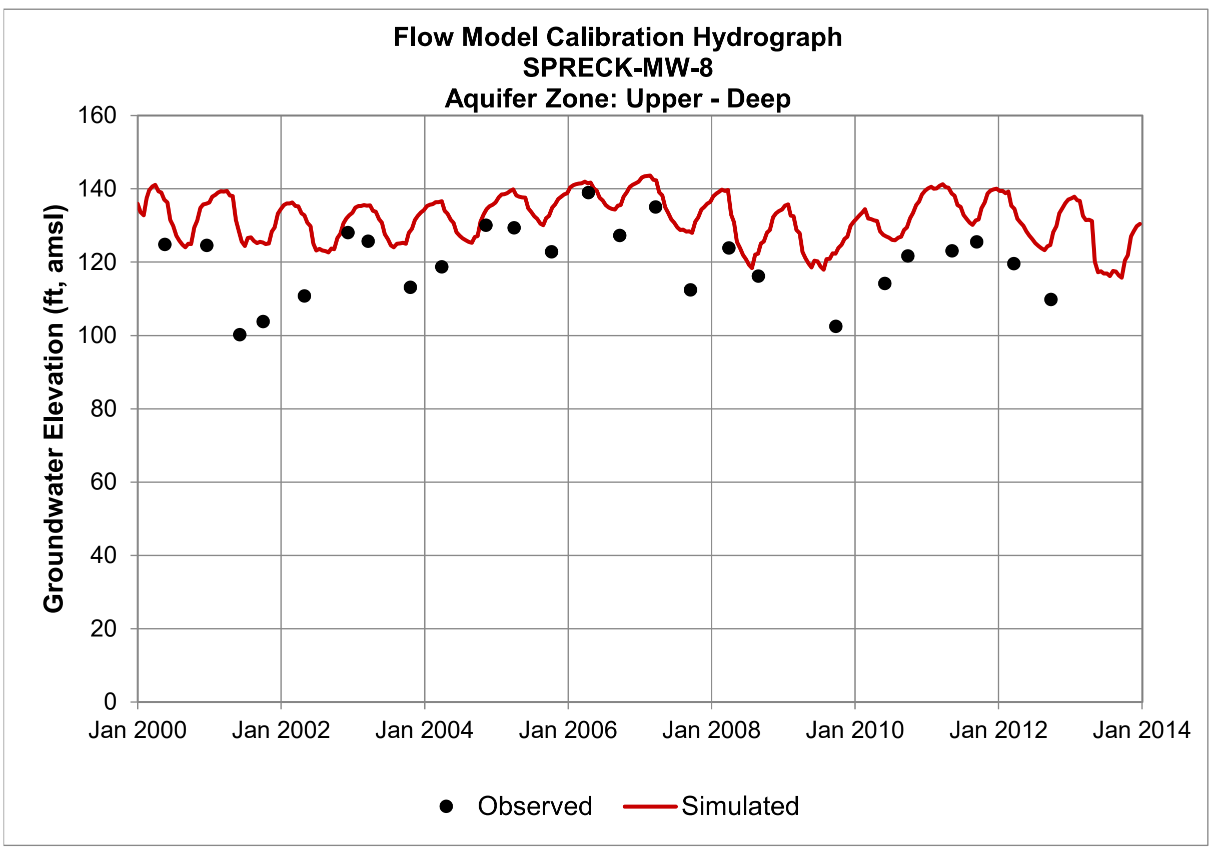
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
SPRECK-MW-8
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
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140
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Jan 2000
Jan 2002
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Jan 2006
Jan 2008
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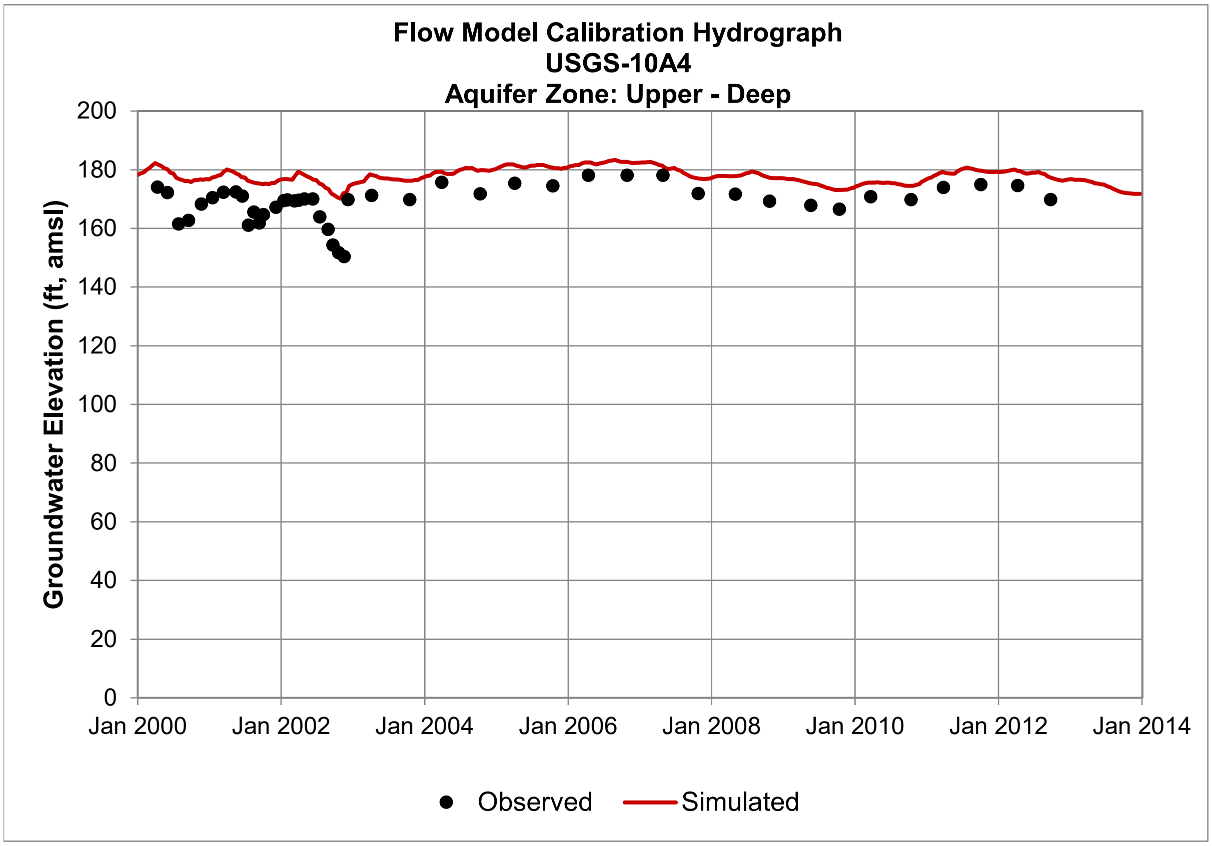
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
USGS-10A4
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
0
20
40
60
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160
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Jan 2000
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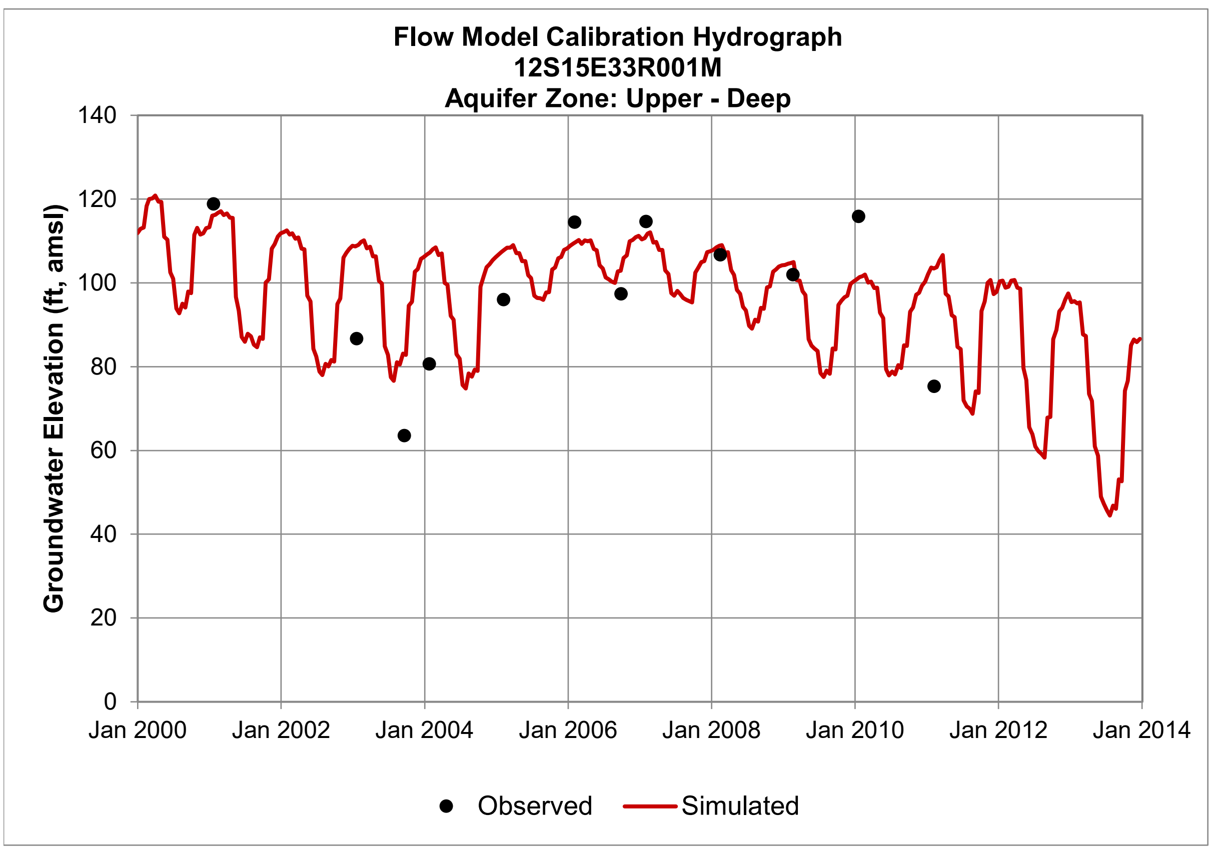
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
12S15E33R001M
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
0
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Jan 2000
Jan 2002
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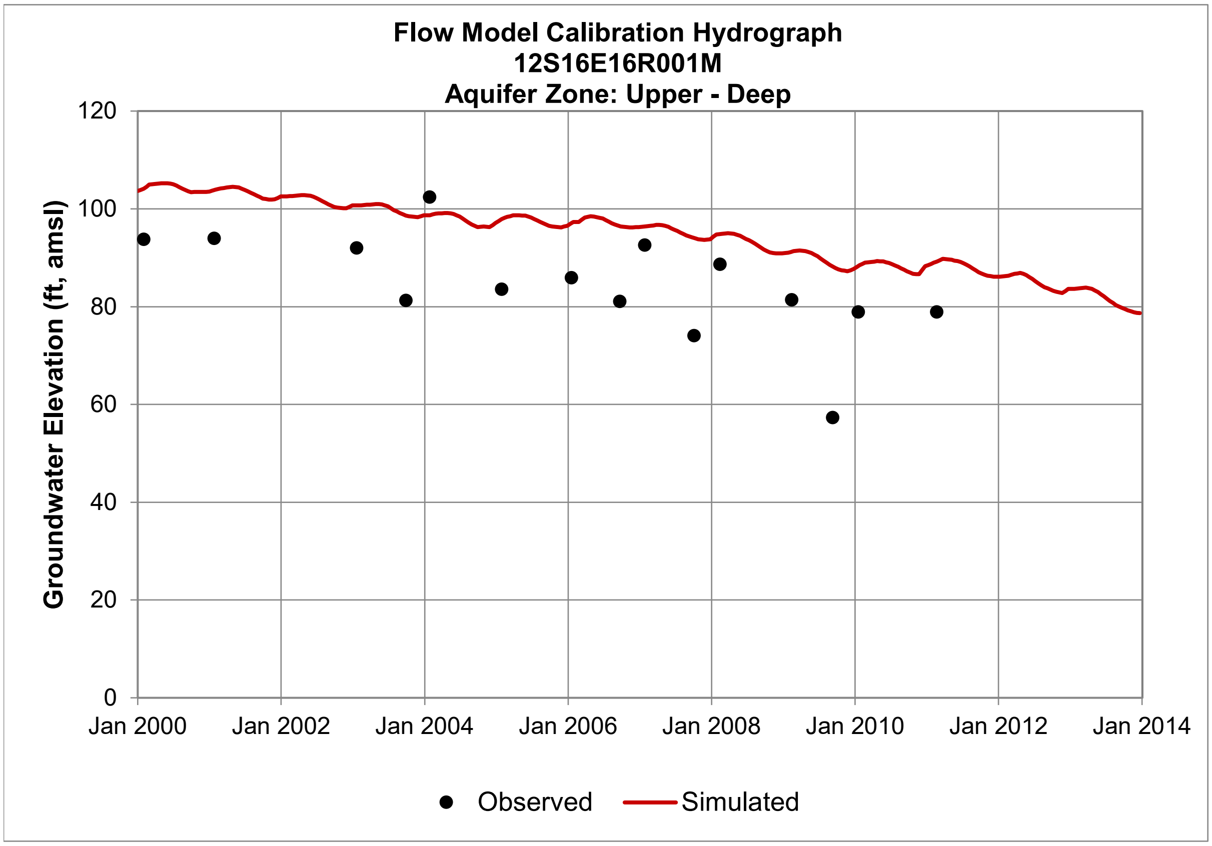
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
12S16E16R001M
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
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Jan 2000
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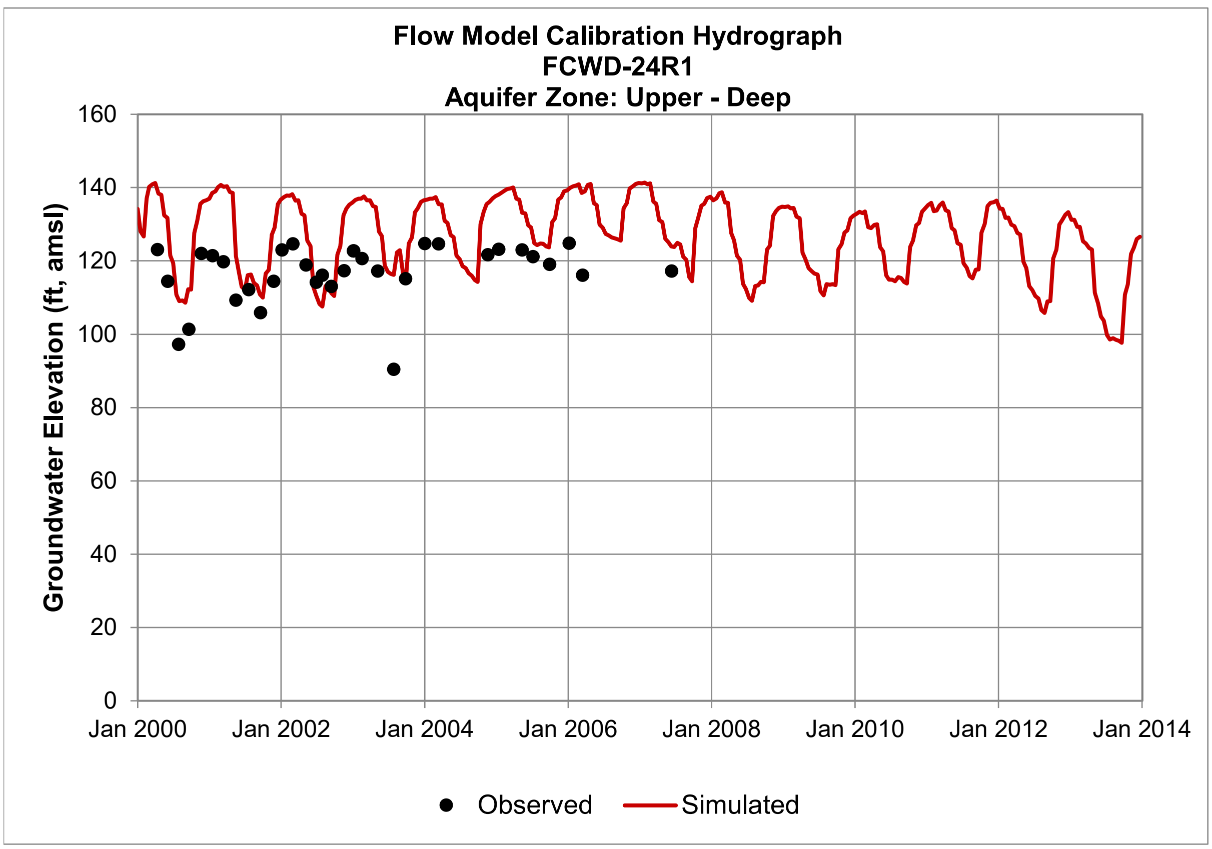
Observed
Simulated


Flow Model Calibration Hydrograph
FCWD-24R1
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
0
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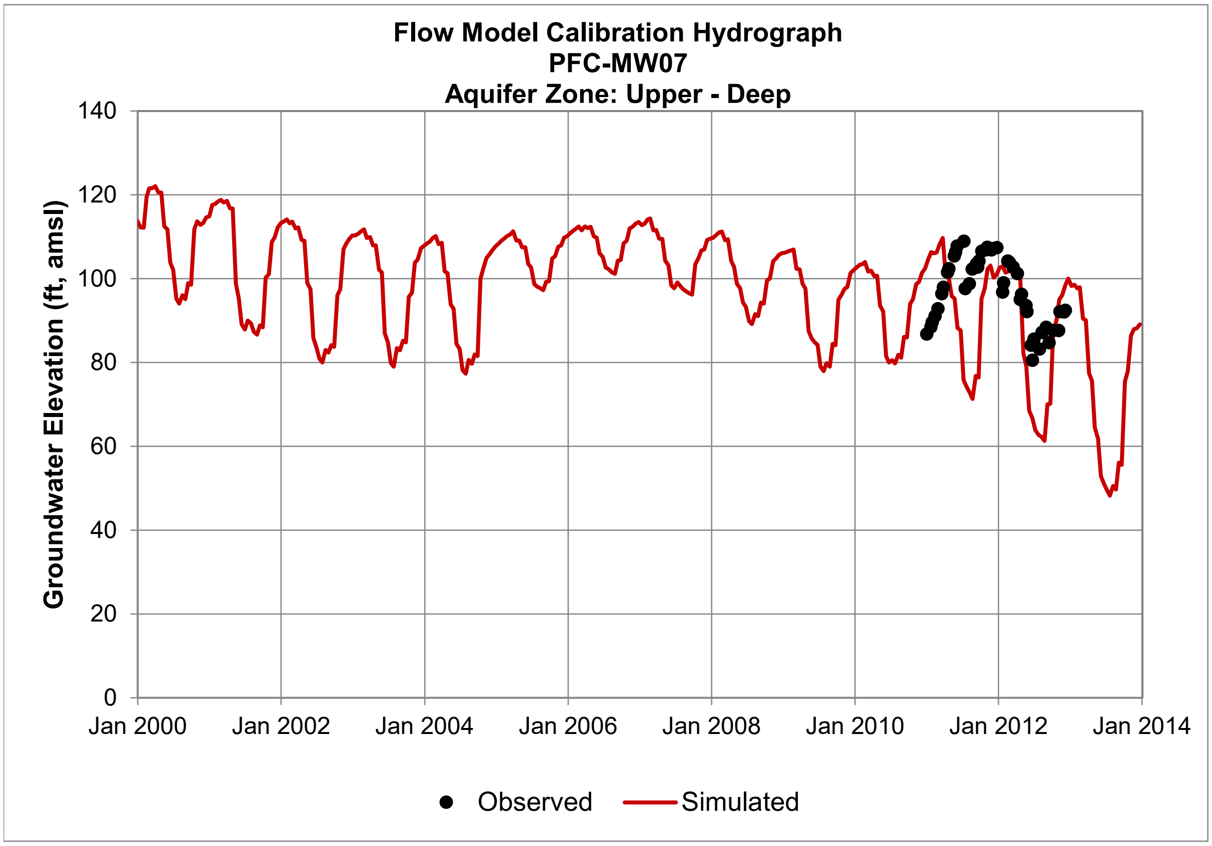
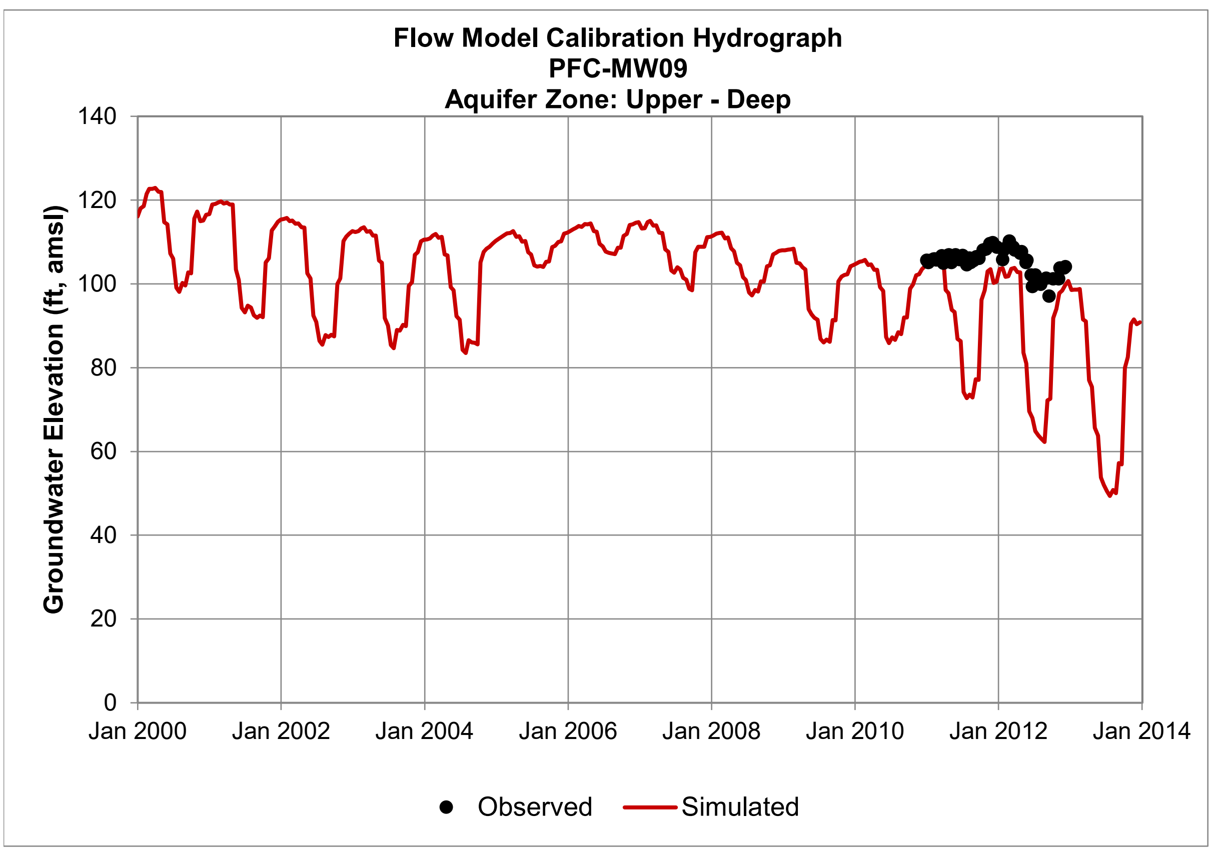
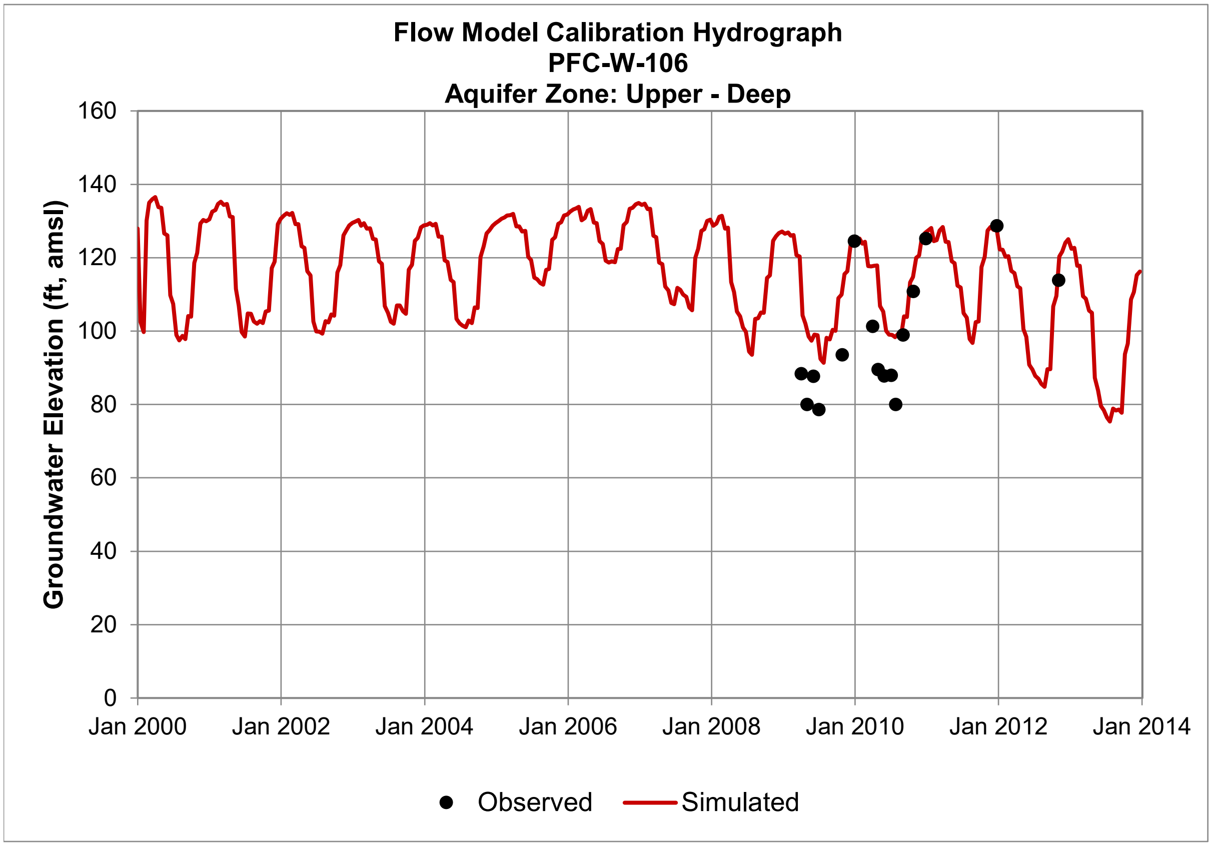
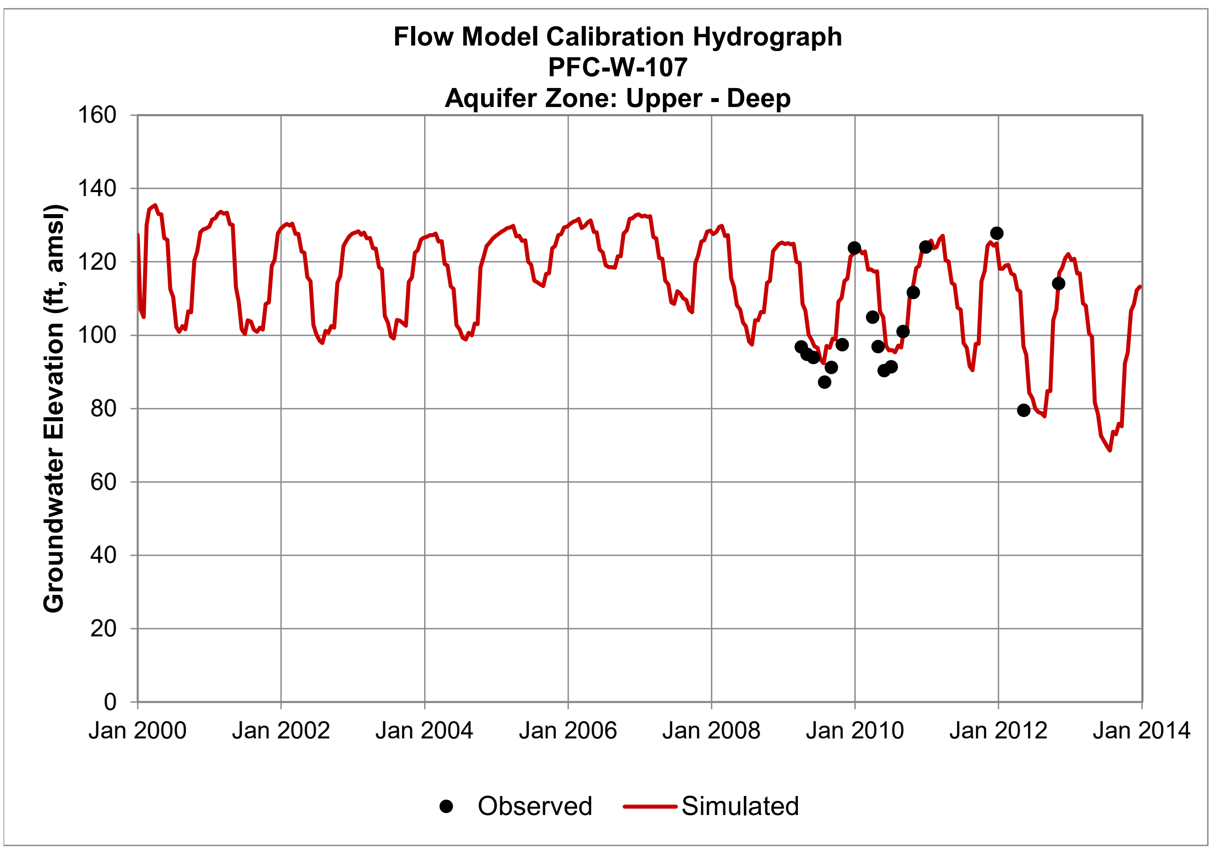
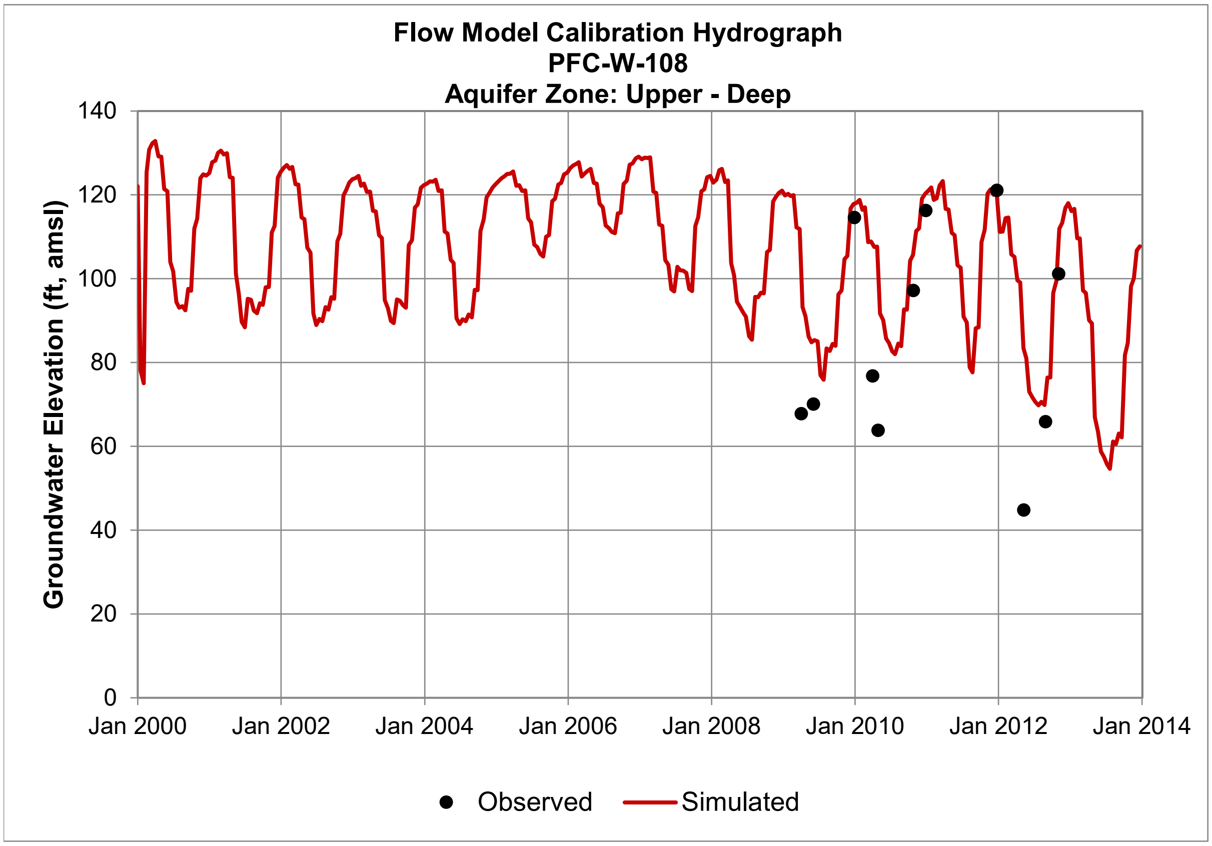
40
60
80
100
120
140
160
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated

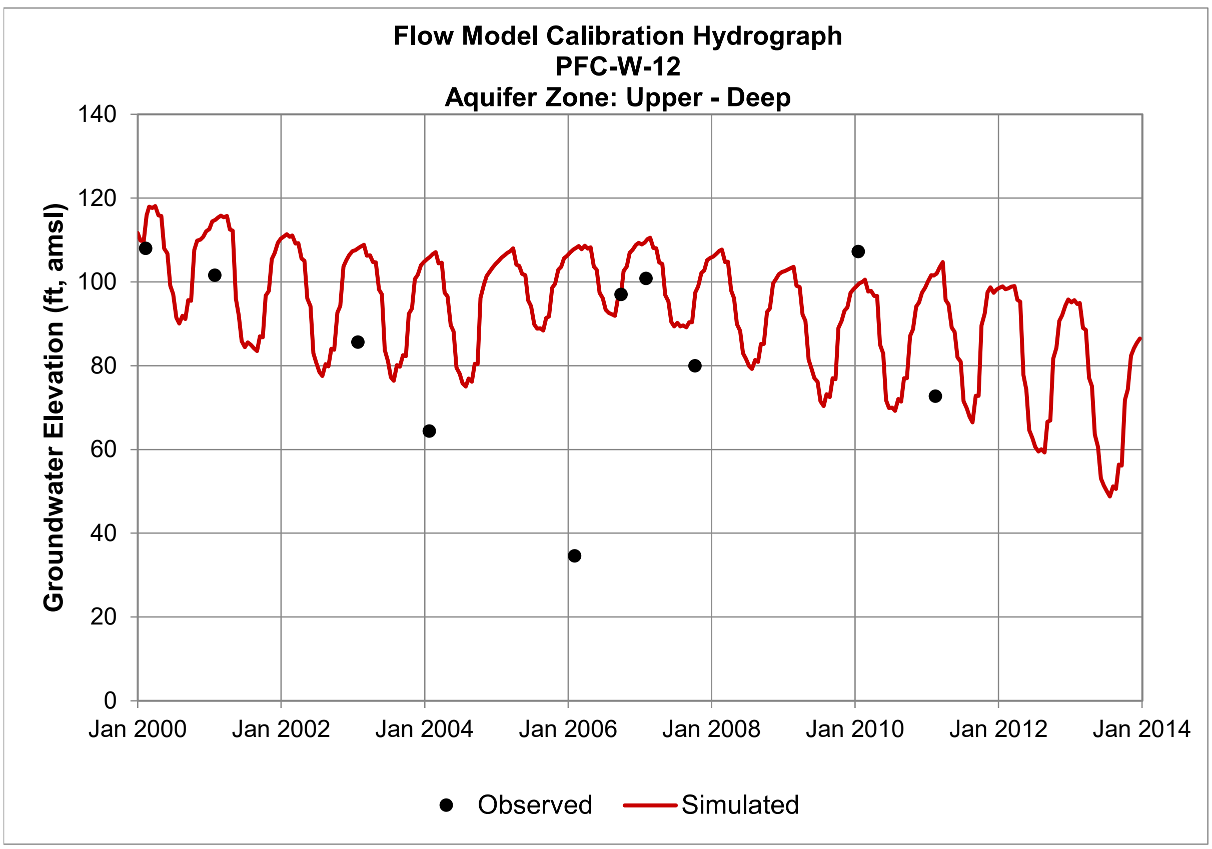

Flow Model Calibration Hydrograph
PFC-MW07
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
140
120
100
80
60
40
20
0
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated

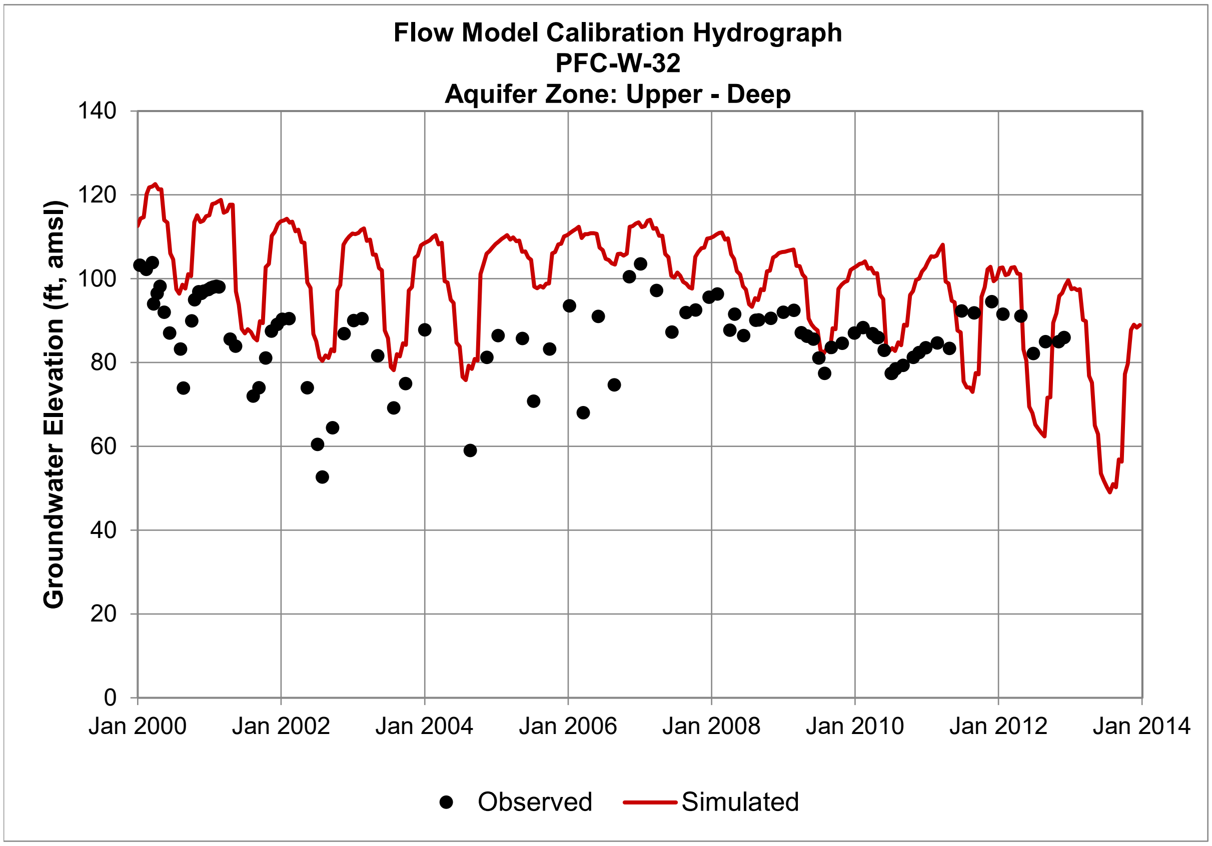

Flow Model Calibration Hydrograph
PFC-MW09
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
140
120
100
80
60
40
20
0
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated

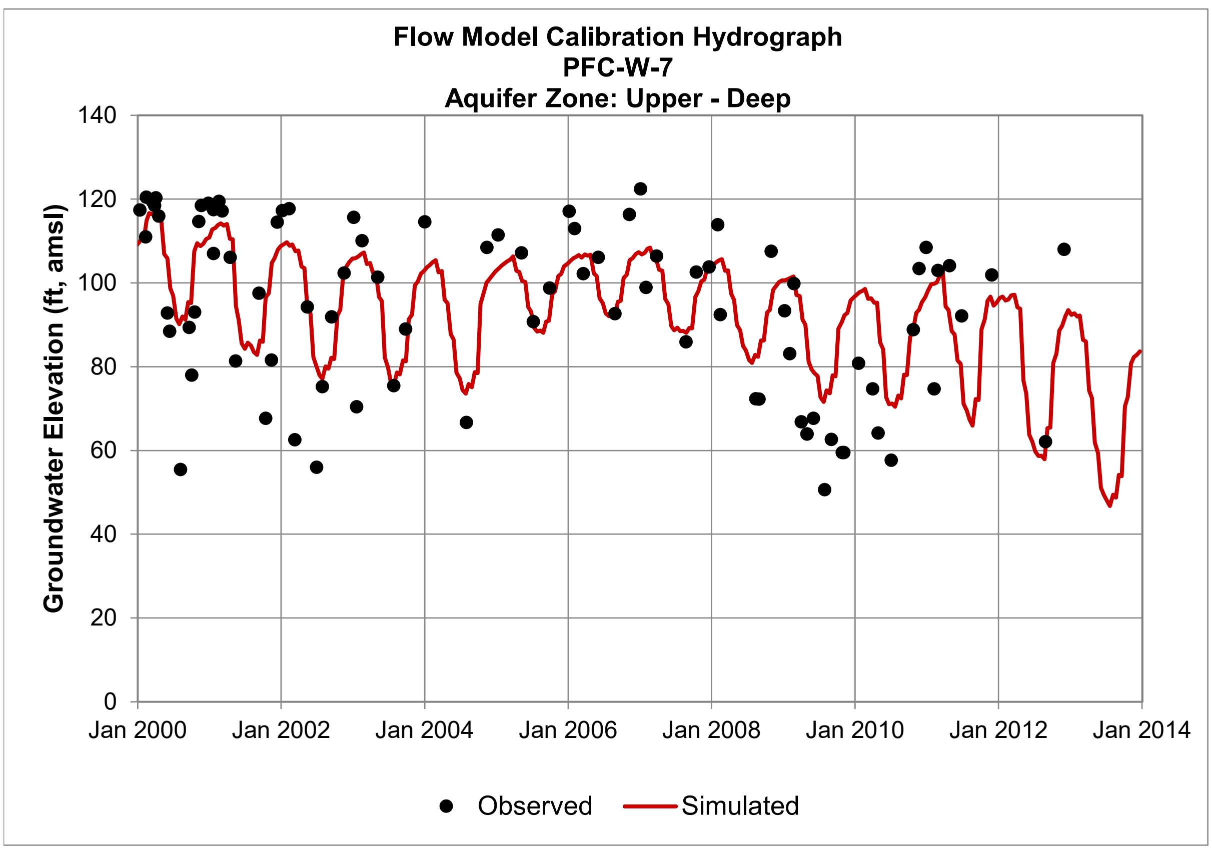

Flow Model Calibration Hydrograph
PFC-W-106
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
160
140
120
100
80
60
40
20
0
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated

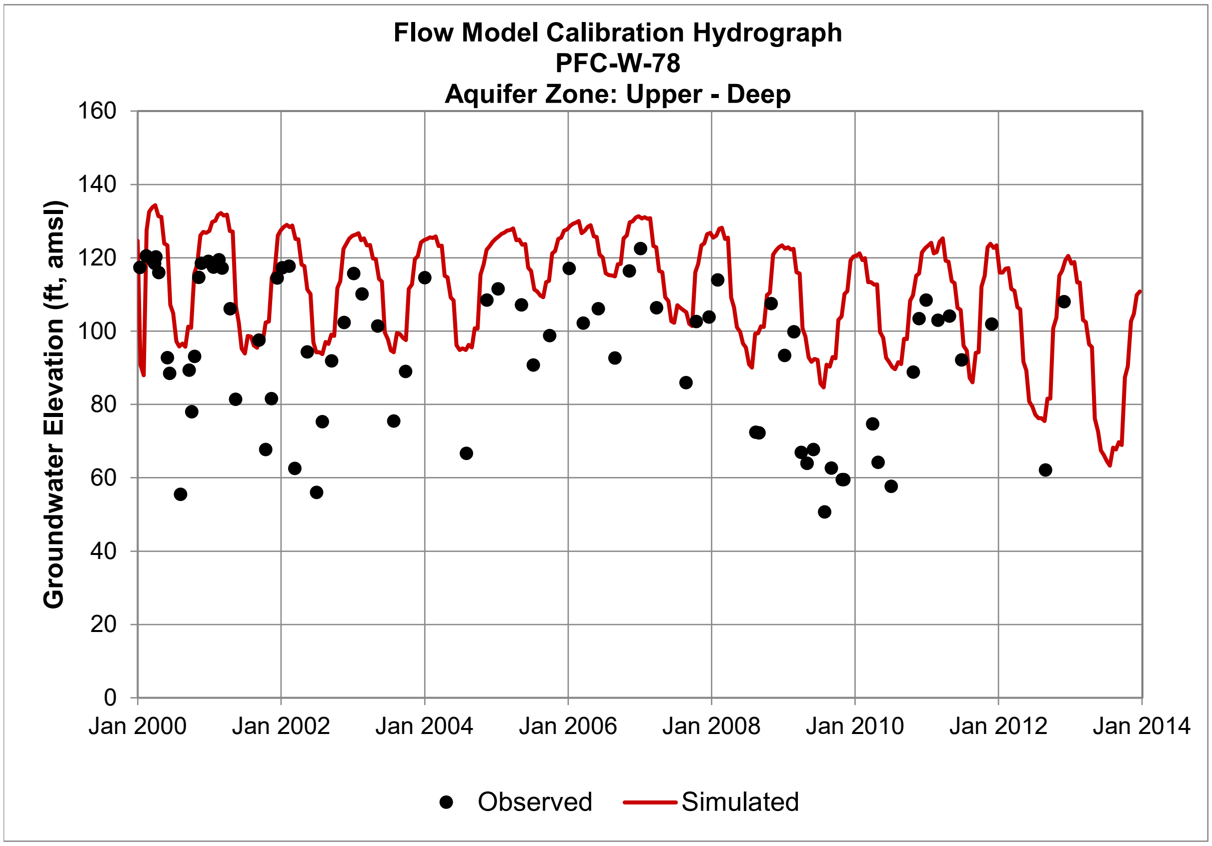

Flow Model Calibration Hydrograph
PFC-W-107
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
160
140
120
100
80
60
40
20
0
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated

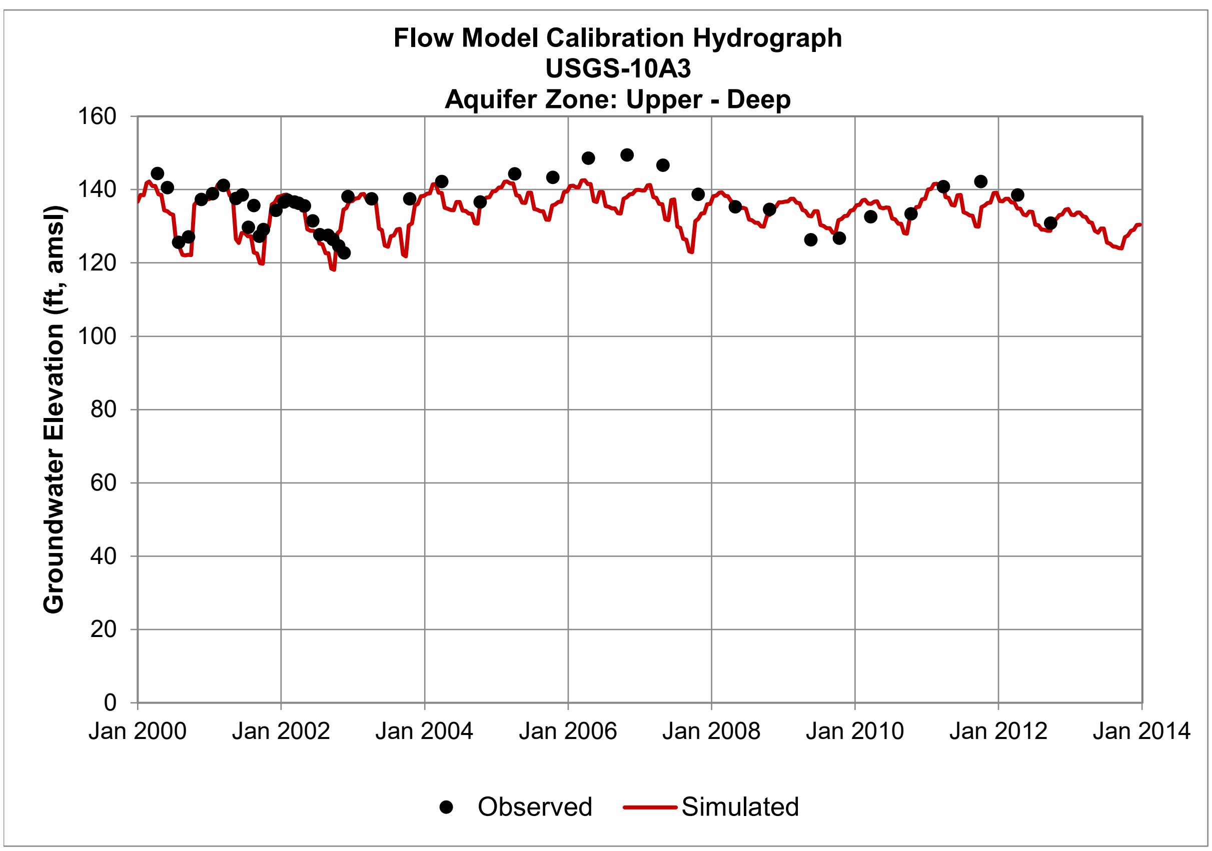

Flow Model Calibration Hydrograph
PFC-W-108
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
0
20
40
60
80
100
120
140
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated

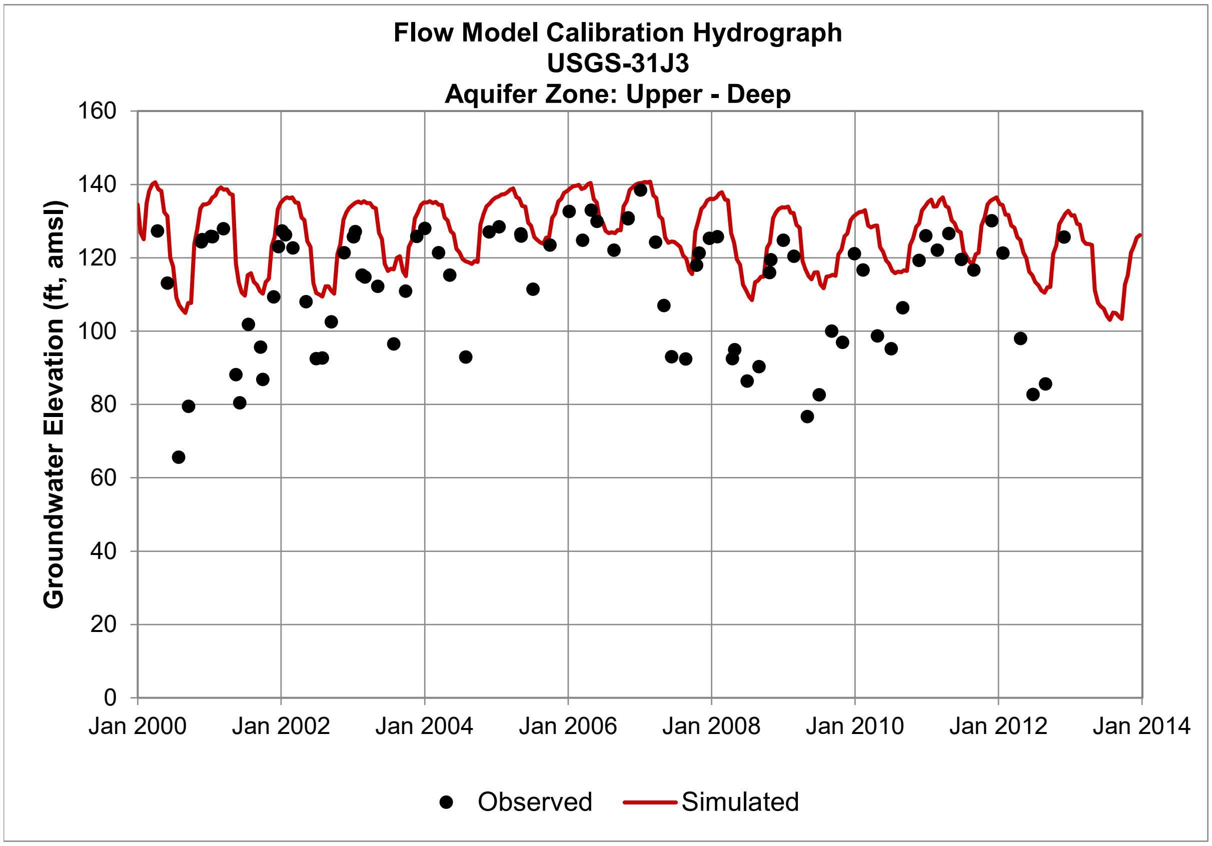

Flow Model Calibration Hydrograph
PFC-W-12
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
0
20
40
60
80
100
120
140
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated

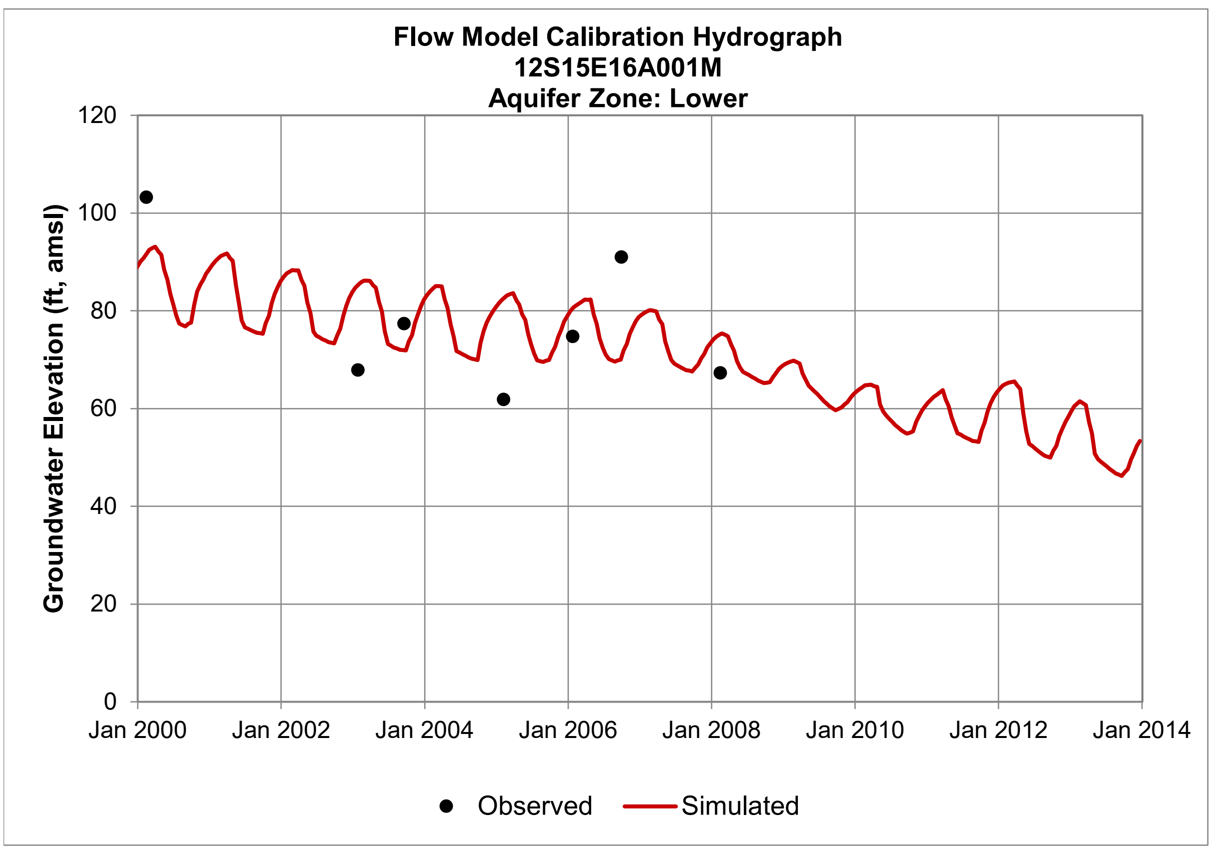

Flow Model Calibration Hydrograph
PFC-W-32
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
0
20
40
60
80
100
120
140
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated

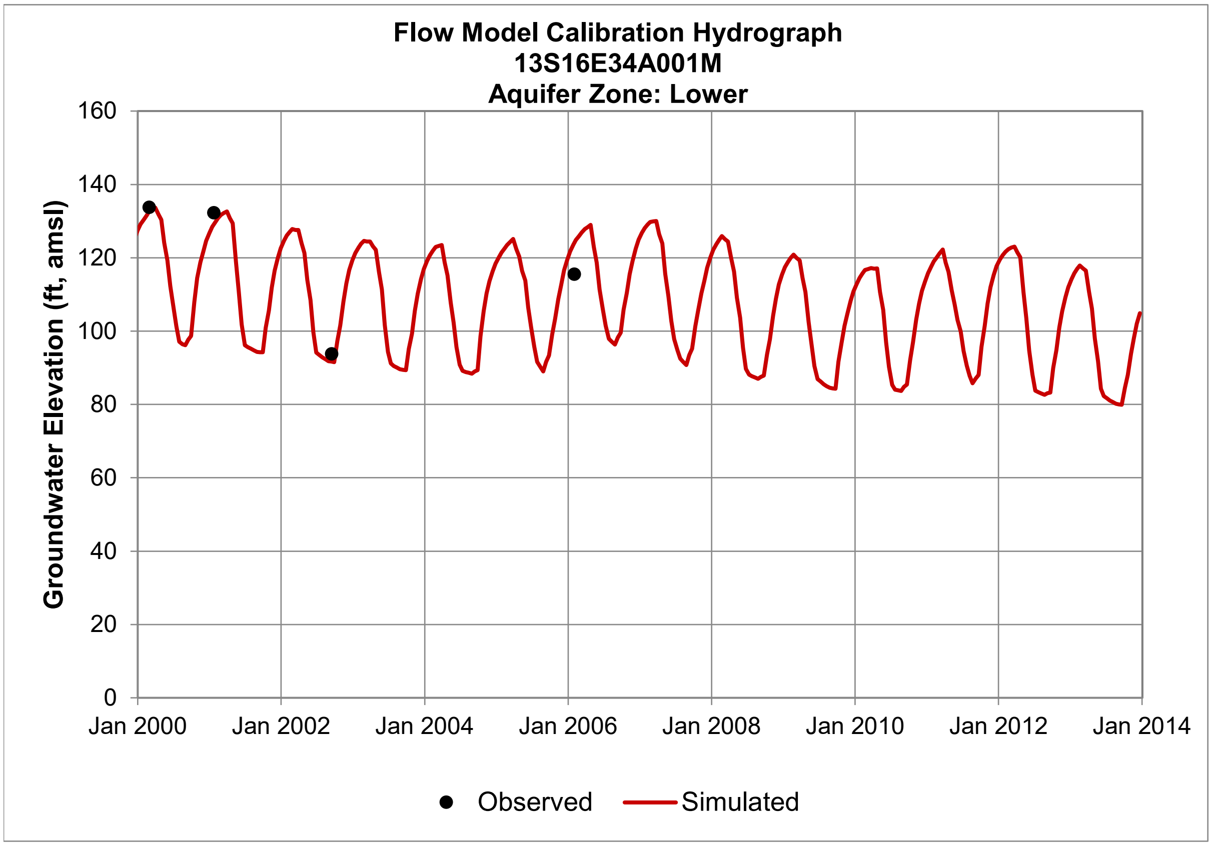

Flow Model Calibration Hydrograph
PFC-W-7
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
0
20
40
60
80
100
120
140
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated

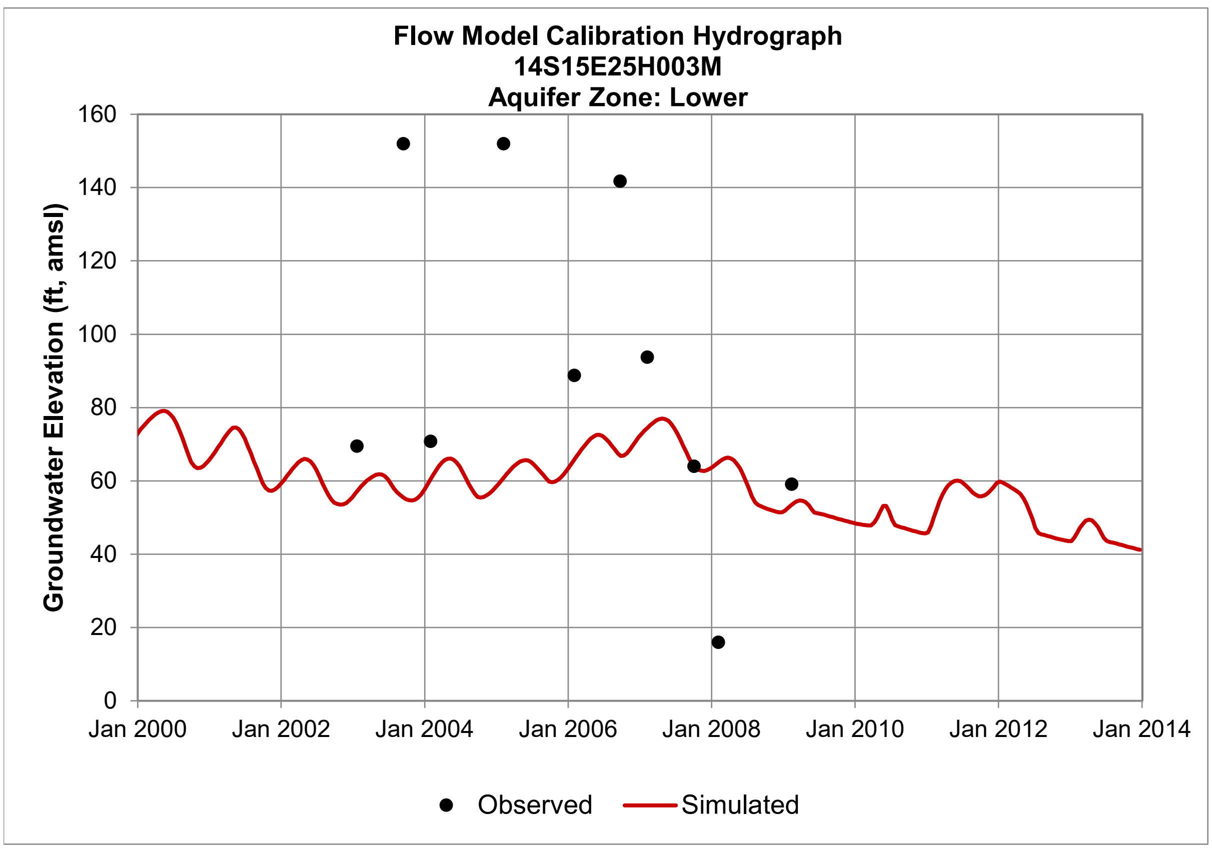

Flow Model Calibration Hydrograph
PFC-W-78
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
0
20
40
60
80
100
120
140
160
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated

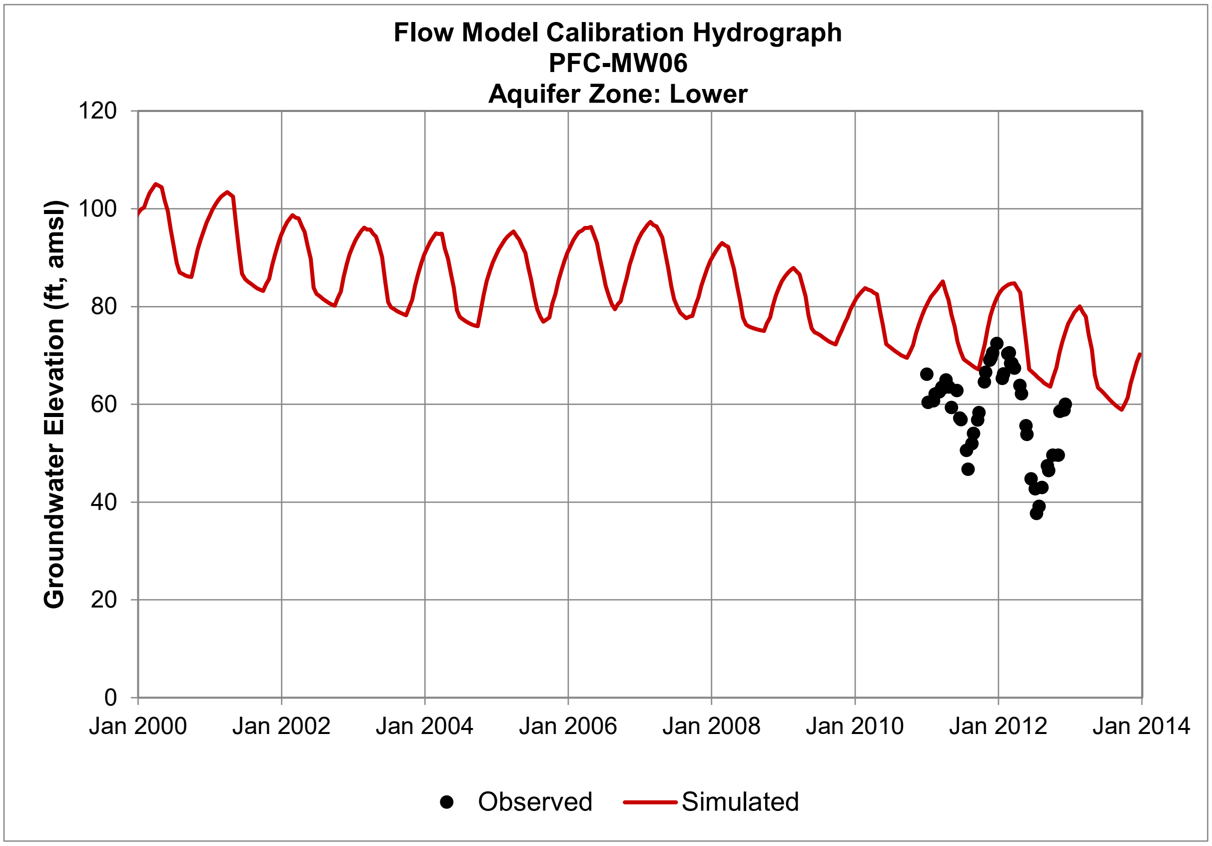

Flow Model Calibration Hydrograph
USGS-10A3
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
0
20
40
60
80
100
120
140
160
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
USGS-31J3
Aquifer Zone: Upper - Deep
Groundwater Elevation (ft, amsl)
0
20
40
60
80
100
120
140
160
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
12S15E16A001M
Aquifer Zone: Lower
Groundwater Elevation (ft, amsl)
0
20
40
60
80
100
120
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
13S16E34A001M
Aquifer Zone: Lower
Groundwater Elevation (ft, amsl)
160
140
120
100
80
60
40
20
0
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
14S15E25H003M
Aquifer Zone: Lower
Groundwater Elevation (ft, amsl)
160
140
120
100
80
60
40
20
0
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
PFC-MW06
Aquifer Zone: Lower
Groundwater Elevation (ft, amsl)
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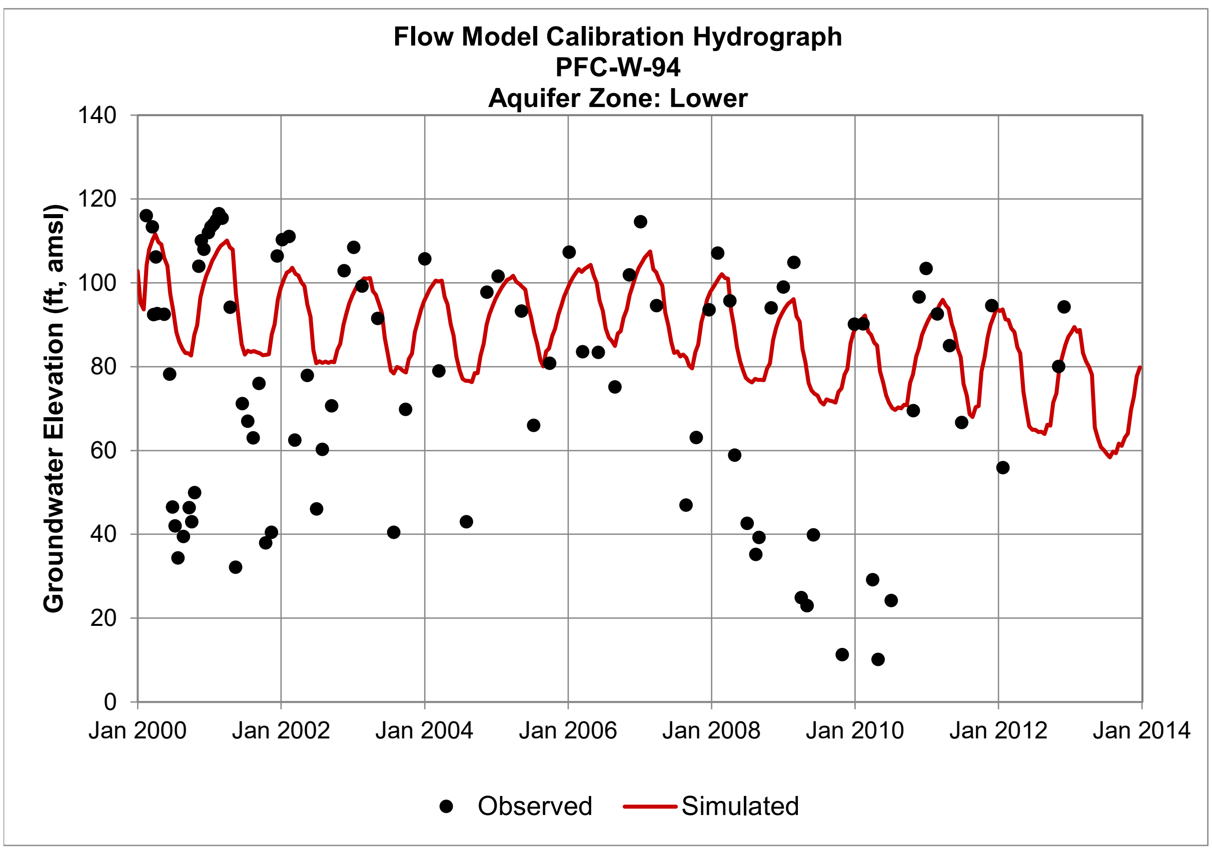
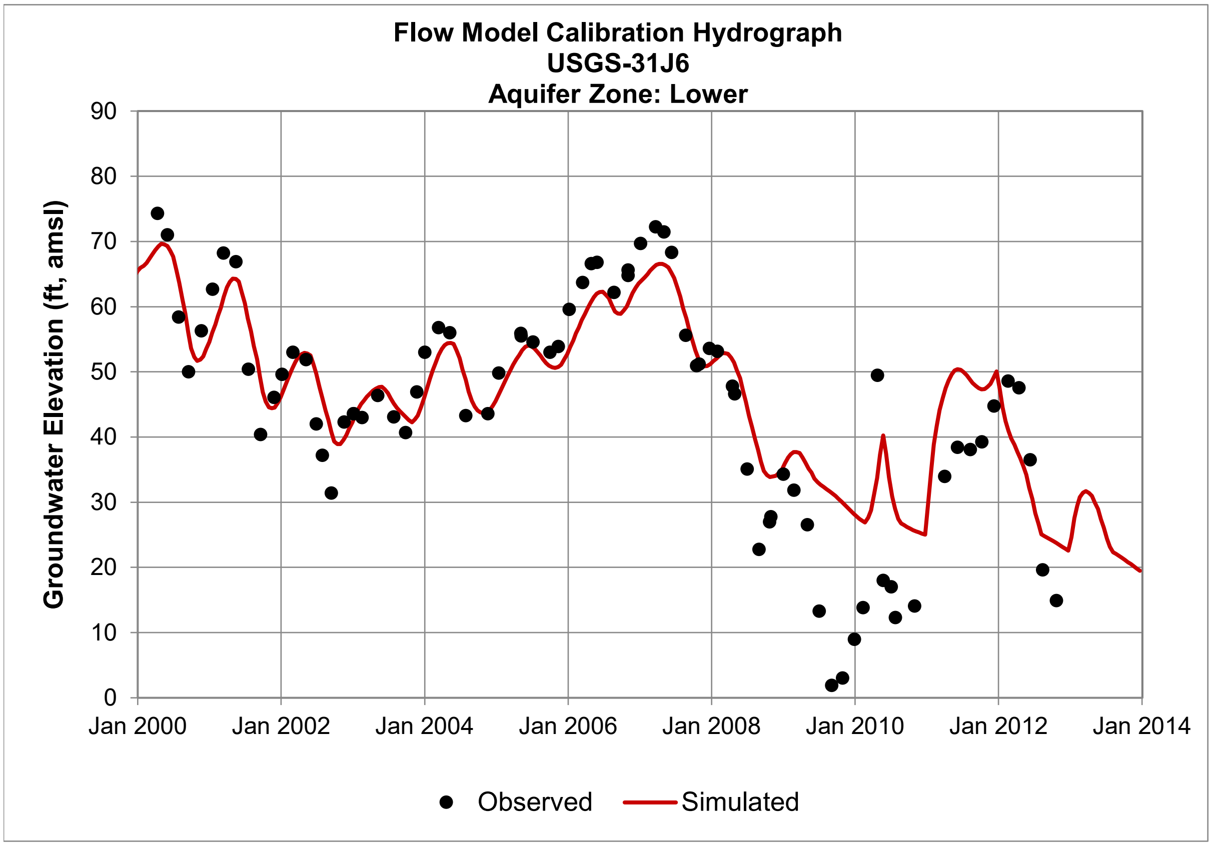
20
40
60
80
100
120
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
PFC-W-94
Aquifer Zone: Lower
Groundwater Elevation (ft, amsl)
0
20
40
60
80
100
120
140
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated


Flow Model Calibration Hydrograph
USGS-31J6
Aquifer Zone: Lower
Groundwater Elevation (ft, amsl)
0
10
20
30
40
50
60
70
80
90
Jan 2000
Jan 2002
Jan 2004
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Observed
Simulated