APPENDIX I

NUMERICAL MODEL FOR
SIMULATION OF GROUNDWATER FLOW AND SULFATE TRANSPORT
IN THE VICINITY OF THE PHELPS DODGE SIERRITA TAILING IMPOUNDMENT

TASK 4 OF AQUIFER CHARACTERIZATION PLAN

REVISION 1

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TASK 4 OF AQUIFER CHARACTERIZATION PLAN
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Prepared for:

PHELPS DODGE SIERRITA, INC.
6200 West Duval Mine Road
Green Valley, Arizona

Prepared by:

HYDRO GEO CHEM, INC.
51 West Wetmore Road
Tucson, Arizona 85705
(520) 293-1500

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLES

FIGURES

FIGURES (Continued)

APPENDICES

1. INTRODUCTION

A numerical groundwater flow and sulfate transport model was developed for the region surrounding the Phelps Dodge Sierrita, Inc. (PDSI) Tailing Impoundment (PDSTI) (Figure I.1). The model, referred to as the PDSI Regional-Scale Model (PDSIRM), was developed for Task 4 of the Work Plan (Hydro Geo Chem, Inc. (HGC), 2006) and represents basin fill aquifer conditions in the vicinity of the PDSTI for the period from 1940 to 2006. The model will be used to predict future conditions associated with potential mitigation actions being considered in the Feasibility Study to develop a Mitigation Plan pursuant to the Work Plan. The goals of the PDSIRM are to:

- Calibrate to measured groundwater levels and sulfate distributions within the model domain (1940 to 2006).
- Understand the current groundwater flow and sulfate transport dynamics at different locations near the PDSTI.
- Predict future groundwater levels and sulfate distributions in the vicinity of the PDSTI under various mitigation alternatives.

The PDSIRM is intended to be a tool for evaluating potential mitigation alternatives for the sulfate plume, where the sulfate plume is defined by aqueous sulfate concentrations in excess of 250 milligrams per liter (mg/L) that result from seepage from the PDSTI. Any use of the PDSIRM outside of this intended use may require additional aquifer characterization and model refinement.

This report describes the model development and calibration. Section 2 summarizes the conceptual site model that was the basis for model construction, Section 3 discusses model code selection; Section 4 provides details on model construction, including model discretization, boundary conditions, sources and sinks, and initial model parameterization; Section 5 discusses model calibration for the steady state (1940) and transient (1941 to 2006) simulations; Section 6 discusses the results of a sensitivity analysis; and Section 6 discusses the strengths and limitations of the PDSIRM. Predictive simulations using the PDSIRM will be conducted as part of the Feasibility Study.

2. CONCEPTUAL SITE MODEL

The numerical model was constructed to reflect the conceptual model of the hydrostratigraphy, sulfate sources and distribution, and sulfate transport mechanisms. The conceptual site model is summarized below, and a more detailed discussion of the conceptual model is provided in Section 3 of the main body of the Aquifer Characterization Report (ACR).

2.1 Hydrostratigraphy

The conceptual model of hydrostratigraphy of the basin fill aquifer was developed based on classification and comparison of material types intercepted in boreholes and is shown in Appendix G of the ACR. The basin fill consists of coarse-grained sediment, primarily sand and gravel, with a considerable amount of variation in material types with depth and laterally. In the vicinity of the sulfate plume, the general stratigraphic sequence consists of an upper, middle, and lower zone. The upper zone of basin fill is between 200 and 600 feet thick, is predominately unsaturated, and contains sand and gravel with a high proportion of silt and clay either as discrete layers or as mixtures with the sand and gravel. The middle zone is predominately sand and gravel. Silt and clay can be locally present in the middle zone, but they do not form a significant percentage of the middle zone. The middle zone extends to bedrock in some portions of the aquifer. Where the middle zone does not extend to bedrock, it is underlain by a lower zone of basin fill that contains greater amounts of silt and clay, a lack of gravel, zones of moderate induration, and increased calcium carbonate.

In general, hydraulic conductivities range between 5 and 50 feet per day (ft/day) in the upper and middle zones of the basin fill and are generally lower in the lower zone of the basin fill (see Appendix H of the ACR). There is also a general tendency for hydraulic conductivity to increase slightly from south to north, with the highest hydraulic conductivities in the northern portion of the plume (e.g., CW-7 and MO-2007-2).

The bedrock is significantly less permeable than the overlying basin fill aquifer. Hydraulic tests of existing shallow bedrock wells at the Sierrita Mine indicate that bedrock hydraulic conductivities are typically one to more than four orders of magnitude lower than for the basin fill. The highest hydraulic conductivities estimated from tests in bedrock wells are typically less than 1 ft/day, and range to as low as about 0.00001 ft/day. In contrast, hydraulic conductivities measured in the basin fill have a mean of 20 ft/day and range up to 120 ft/day (see Figure 6 and Appendix A of the ACR). Because even the highest bedrock conductivity estimates, presumably representative of more fractured rock, are significantly lower than typical basin fill conductivities, the bedrock cannot be a significant source of, or conduit for sulfate migration to the basin fill even if elevated concentrations of sulfate are present in the bedrock.

2.2 Sulfate Sources and Distribution

The primary known source of sulfate is gravity drainage of the pore water (seepage) from the PDSTI to the underling basin fill aquifer. A second source of sulfate is groundwater in the bedrock upgradient of the tailing impoundment; however, the contribution of sulfate by bedrock recharge is likely very minor compared to the seepage from the PDSTI because of the low permeability of bedrock. Potential sources of sulfate outside the PDSTI may be the tailing impoundments at other mines and recharge from the Santa Cruz River. Work conducted for the Aquifer Characterization Plan identified a zone of sulfate in excess of 100 mg/L along the Santa Cruz River channel. Groundwater monitoring indicates no commingling between the plume originating from the PDSTI and the sulfate-bearing water along the Santa Cruz River channel at this time (see Appendix B of the ACR).

The lateral distribution of sulfate in the basin fill aquifer is shown in Figure 4 of the ACR, and the extent of the sulfate plume as defined by the 250 mg/L contour is shown on Figure 1 of the ACR. Within the plume, elevated sulfate generally occurs throughout the thickness of the saturated basin fill aquifer, although the lateral and vertical distributions of sulfate on the margins of the plume can be influenced by local-scale aquifer heterogeneities and hydraulic conditions.

2.3 Sulfate Transport

Once introduced to the basin fill aquifer, sulfate is transported at the average groundwater flow velocity because it is a conservative ion and does not attenuate through adsorption or precipitation at the concentrations and conditions observed in the study area. The direction and velocity of groundwater flow and sulfate transport are determined by the prevailing hydraulic gradients and hydraulic properties of the basin fill aquifer.

Sulfate-bearing seepage is intercepted through groundwater pumping within the interceptor wellfield. Currently, sulfate capture is most effective in the southern portion of the interceptor wellfield. Sulfate capture is incomplete in the northern portion of the interceptor wellfield. The impacted groundwater that is not intercepted at the interceptor wellfield flows easterly and mixes with the northerly flowing regional groundwater in the basin fill aquifer near Green Valley. The mixing of the high sulfate water originating in the PDSTI with the northerly flowing regional groundwater in the central part of the basin causes the plume to turn northward and creates a sharp front at the eastern plume boundary (ACR, Figure 4). Locally, groundwater flow and sulfate transport can be influenced by geologic heterogeneities, groundwater pumping, and recharge.

3. NUMERICAL MODEL SELECTION

MODFLOW-SURFACT version 3.0 (HydroGeologic, Inc., 1996) is the numerical code used for the PDSIRM groundwater flow and sulfate transport simulations. MODFLOW-SURFACT is based on the widely used United States Geological Survey modeling program, MODFLOW (McDonald and Harbaugh, 1988). The MODFLOW-SURFACT program incorporates several additional modules into the MODFLOW framework that are designed to increase model robustness and improve its ability to simulate complex hydrologic processes. Some advantages of MODFLOW-SURFACT that are particularly beneficial for a three-dimensional model such as the PDSIRM include:

- Improved ability to manage cell wetting and drying using a variably saturated formulation with "pseudo-soil functions". This feature is essential in a transient, multi-layer model where upper layers may de-saturate, then re-wet, as the result of pumping and recharge.

- Automatic allocation of pumping withdrawals from each layer in wells that are screened over multiple layers. This feature provides for a more correct representation of pumping.

- Automatic and adaptive time-stepping and output control. This feature increases the flexibility and efficiency of the numerical solver by adjusting the solver time stepping based on the complexity of the problem.

- Improved matrix solver. This feature adds efficiency and robustness over the standard MODFLOW solvers.

Sulfate transport was simulated in MODFLOW-SURFACT using the Total Variation Diminishing (TVD) implicit scheme. The TVD scheme constrains the solution domain of a system of partial differential equations so that values of local minima do not decrease and values of local maxima do not increase with time. This ensures that numerical solutions are physically correct and mass conserving.

Model construction and the execution of the MODFLOW-SURFACT code were performed using Groundwater Vistas, Version 4 (Environmental Simulations, Inc., 2000) software package. Groundwater Vistas provides a visual interface for assembly, execution, and viewing of the MODFLOW family of codes.

4. MODEL CONSTRUCTION

The PDSIRM is designed to simulate the major hydrogeologic processes that influence groundwater flow and sulfate transport in the region of the PDSTI. These include regional groundwater flow, groundwater pumping, natural and artificial recharge, and evapotranspiration. A variety of sources were consulted during model development to quantify these processes. Principal sources of information included the following:

- Reports of previous groundwater flow and transport models in the vicinity of PDSTI (Travers and Mock, 1984; Hanson and Benedict, 1994; Mason and Bota, 2006; Errol L Montgomery and Associates (ELMA), 1994, 2007a).
- Arizona Department of Water Resources (ADWR).
- Water providers in the vicinity of PDSTI (e.g., Community Water Company (CWC), Farmers Investment Company (FICO)).
- Hydrogeologic information collected or compiled by HGC as part of the Aquifer Characterization Plan.
- Hydrogeologic information assembled and/or reevaluated from prior investigations (e.g., ELMA, 1987, 1995, 2007b).
- Information provided by PDSI, including sulfate concentration and groundwater level databases.

All information was synthesized under the context of the site conceptual model, discussed in Section 3 of the main body of the ACR. The conceptual model and the modeling objectives provided the basis for the construction of the PDSIRM, including the spatial and temporal extents; discretization and layering of the model domain; boundary conditions; groundwater and sulfate sources and sinks; and initial aquifer properties.

4.1 Spatial and Temporal Extents

The active portion of the PDSIRM domain covers an area of approximately 100 square miles (260 square kilometers (km^2)) (Figure I.2). The active model region extends from just above West Arivaca Road on the south (Universal Transverse Mercator (UTM) 3510500) to just below Pima Mine Road on the north (UTM 3540000). From the PDSTI this region extends east about 8.5 miles (13.5 km). The area of primary emphasis for the PDSIRM is the area in the vicinity of PDSTI, including the areas surrounding the current extent of the sulfate plume. The area of primary emphasis incorporates the area bounded by about UTM 3519700 on the south to UTM 3531900 on the north and from the no flow boundary on the west to approximately UTM 503700 on the east (Figure I.2). This area of primary interest extends approximately 1,000 feet or more beyond the northern and eastern extents of the sulfate plume. Further, the area of primary interest corresponds to other modeling efforts for the PDSTI (e.g., ELMA, 1994, 2007a) and has been the focus of the aquifer characterization conducted as part of the Work Plan and reported in the ACR. Aquifer characteristics, including hydraulic properties and hydrogeologic units, outside of the area of emphasis are less characterized and, therefore, are less certain. The domain outside of the area of emphasis has less significance to simulation of sulfate plume migration because it is distant from the plume and potential mitigation actions that will be simulated to develop the Mitigation Plan. The aquifer region outside the area of primary emphasis is included in the model to reduce the sensitivity of flow and transport simulations within the area of emphasis on assumed boundary conditions.

The temporal domain of the PDSIRM is divided into three simulation periods: steady-state (1940), historic (1941 – 2007), and predictive (2007 and beyond). The steady-state simulation of the year 1940 establishes initial groundwater levels for the PDSIRM before significant groundwater development in the area. During and prior to 1940, the Upper Santa Cruz Basin is believed to have been in a state of “dynamic equilibrium” (Mason and Bota, 2006), meaning that groundwater withdrawals matched groundwater inflows, and water levels had no long-term fluctuations. Groundwater levels from the steady-state simulation were used as the initial heads for a transient simulation of groundwater flow and sulfate transport for the period from 1941 to 2006 (historic simulation). The final heads from the historic simulation will be used as the initial heads for the predictive simulations.

4.2 Discretization

The model domain is discretized into 215 rows, 162 columns, and 3 layers (Figure I.3). Rows are oriented west to east and columns are oriented north to south. Grid cell widths and lengths range from 100 meters (m) to 400 m. The coarsest grid cell spacing (400 m by 400 m) occurs in the southern, northern, and eastern positions of the model domain, peripheral to the area of emphasis. The finest grid cell spacing (100 m by 100 m) is centered in the area of primary emphasis (Figure I.3). Placing the largest grid cells in the periphery of the model domain and decreasing the grid cell size within the area of primary interest reduced computation requirements without compromising spatial resolution within the area of primary interest. (Figure I.3).

A three-layer model was used to represent the upper, middle, and lower zones of the basin-fill aquifer that were identified during aquifer characterization (ACR, Section 3.2.1). The three model layers are of equal thickness at a given location, with the thickness of each layer varying according to the aquifer thickness at each location. Information collected as part of the Aquifer Characterization Plan shows a coarser-grained, higher permeability zone at intermediate depths in several locations (ACR, Appendices D, E, G, and F). Results of pumping tests at nested wells (ACR, Appendix E) and depth-specific inflow velocity profiling at ESP-2 and ESP-4 wells (ACR, Appendix C) also suggest an intermediate-depth zone of relatively higher hydraulic conductivities. Layer 2 of the model generally corresponds to what was identified as the intermediate-depth zone during aquifer characterization. The top of the upper model layer (Layer 1) corresponds to the ground surface, and the bottom of the lower layer (Layer 3) corresponds to the bedrock elevation, as estimated during aquifer characterization (Section 3.3.1 of ACR and ACR, Appendix A).

4.3 Boundary Conditions

The model has two types of boundary conditions: no flow and specified head and concentration (Figure I.4). No flow cells are inactive grid cells that do not permit groundwater flow or solute transport into, or out of, the cell. Specified head and concentration boundaries are grid cells that are maintained at specified values during a stress period (defined as one year for the PDSIRM) but can vary from one stress period to another.

4.3.1 No Flow Boundaries

No flow conditions are assigned along the model boundary at locations that represent the outer edges of the basin fill aquifer (Figure I.4) and along the bottom of the lowermost layer, representing the bedrock surface. No flow cells are considered to be outside of the model domain and represent a natural barrier to flow and transport. No flow boundaries specified at the southeastern portion of the domain correspond to the pinching out of the aquifer against the Santa Rita Mountains; those specified at the western edge of the model domain correspond to the pinching out of the aquifer against the Sierrita Mountains. Note that natural recharge along these mountain ranges was accounted for by specifying recharge to the cells immediately interior to the no flow boundaries where mountain front recharge is believed to occur (see Section 4.4.1). The no flow cells on the western edge of the model also included the pit areas of the Asarco Mission Mine and the Twin Buttes Mine which are mainly located in bedrock and which are not of primary interest for this modeling effort. Although the Twin Buttes Mine pit area was not included in the active model domain, groundwater flow into the Twin Buttes Mine pit was accounted for by specifying a constant negative groundwater flux in active cells immediately adjacent to the Twin Buttes Mine pit (ACR Section 3.4.3).

The no-flow boundary representing the aquifer bedrock surface was created from the bedrock elevation database that was developed as part of the Aquifer Characterization Plan (ACR, Appendix A). This database includes drilling data from boreholes that are located in the southern Tucson basin and that either penetrated bedrock or deep basin fill. Information sources for borehole data were the ADWR 35- and 55-series imaged records databases, the PDSI well database, PDSI borehole data, and a report by Steffen, Robertson, and Kirsten (SRK) (1985b). Bedrock elevation data were translated into a bedrock surface grid using the software package Surfer®. For the purpose of model stability, the total thickness of each layer of the PDSIRM was kept to a minimum of 30 m (98 feet). This stipulation required depressing bedrock elevations along the portions of the model boundaries where the basin fill aquifer pinched out against the rise of the mountain fronts. Bedrock elevations were lowered beneath portions of the PDSTI; however no bedrock elevations under the IW wellfield were lowered. The model sensitivity to the bedrock elevation adjustments could not be formally evaluated because the adjustments were required for model stability. Any effects of the adjustments likely were compensated during calibration of hydraulic conductivities.

4.3.2 Specified Head and Concentration Boundaries

Specified head and concentration boundaries are located along the south, north, and eastern boundaries of the model (Figure I.4). These boundaries occur within, rather than at the margins of, the basin-fill aquifer. Very little groundwater level data exists along these domain boundaries. Therefore, for the period from 1940 to 1999, the values of the specified heads were initially based on a regional groundwater flow model constructed by Mason and Bota (2006) (referred to hereafter as the ADWR model). Although the ADWR model heads are simulated rather than measured, they provide a reasonable starting point for the calibration of the specified head values because they are based on a large-scale, calibrated, model of the Tucson Basin.

The initial specified boundary heads were created by digitizing the AWDR model results from each stress period (1940 to 1999). Because the ADWR model uses 0.5 mile (approximately 805 m) grid spacing, boundary heads between the ADWR grid cells were interpolated. For the period from 2000 to 2006, specified boundary heads along the north boundary were projected from groundwater level measurements made during the first and third quarters of 2007 and from the hydraulic gradients inferred from those measurements (ACR, Appendix B). The values of the specified boundary heads were adjusted during model calibration to better match historic groundwater levels measured near the specified head boundary locations.

Sulfate concentrations are also prescribed along the specified head boundaries. The specified concentration boundary conditions prescribe the sulfate concentration for groundwater flowing into the model domain. Any prescribed concentrations at outflow boundaries are ignored, and concentrations at outflow cells are determined by the code. The boundary concentrations were estimated using data from recent water quality sampling events (ACR, Appendix B). Sulfate concentrations ranging from three to 100 mg/L are specified along the southern boundary, with the highest concentrations along the Santa Cruz River channel, and the lowest concentrations near the western mountain front. A sulfate concentration of 30 mg/L is specified along the eastern boundary, and a concentration 75 mg/L is specified along the northern boundary. A water quality survey conducted in the early 1980s by the Pima Association of Governments (PAG) shows a similar spatial distribution of sulfate concentrations (PAG, 1983); therefore, the specified boundary concentrations are constant during the simulation.

4.4 Groundwater Sources and Sinks

Sources of groundwater in the PDSIRM domain are mountain front recharge, river and agricultural recharge, seepage from tailing impoundments, and artificial recharge. Groundwater sinks include pumping wells, evapotranspiration (ET), and the Twin Buttes Mine pit. All sources and sinks were modeled as transient processes, meaning that values of a specified source or sink could change throughout the simulation. MODFLOW-SURFACT uses the stress period concept for transient simulations. All processes are constant during a user-specified stress period, but can change step-wise between stress periods. The constant stress period time in the PDSIRM is one year. Sources or sinks are modeled using annual averages. Figures I.5 and I.6 show the spatial distribution of recharge sources for two representative years, 1980 and 2006, respectively.

4.4.1 Mountain Front Recharge

Mountain front recharge is the contribution from mountains to the groundwater recharge in the basin fill aquifer, including infiltration from surface sources (i.e., precipitation, streamflow) and subsurface inflow from adjacent bedrock. Mountain front recharge is included along the western edge of the PDSIRM domain (Sierrita Mountains) and along the southeastern corner of the domain (Santa Rita Mountains). Initial estimates of mountain front recharge were taken from the ADWR model, which is based on recharge estimates from Hanson and Benedict (1994). The ADWR model assumed mountain front recharge to be constant in time. The volumetric recharge rates in the ADWR model corresponding to the southeastern recharge zone in the PDSIRM and the western recharge zones north and south of the PDSTI are 2,100 acre-feet per year (ac-ft/yr) along the southeastern mountain front (Santa Rita Mountains) and 7,900 (ac-ft/yr) along the western portion of the domain (Sierrita Mountains) (Table I.1). Both of these volumetric rates are equivalent to approximately 200 gallons per minute per mile (gpm/mi). The mountain front recharge is uniformly distributed as areal recharge rates (volume/area/time) to the grid cells in Layer 1 (uppermost model layer) that are immediately inside the no flow boundary cells along the respective west and southeast fronts. A mass balance for the simulated mountain front recharge was computed to verify that the sum of the areal rates totaled the volumetric rates applied in the ADWR model.

Spatially uniform mountain front recharge rates are unlikely along the entire range of the Sierrita Mountains. The pits at the Twin Buttes Mine and PDSI Mine likely capture some mountain front recharge. Farther south, the Demetrie Wash, which runs southeast from the PDSI mill area across the southwest side of the PDSTI, likely provides greater recharge rates near the area of PDSTI than the uniform rates based on the estimates of Hanson and Benedict (1994). Little information is available to quantify the capture in the Twin Buttes pit or the contribution from the Demetrie Wash; however, consideration of these features was used to guide model calibration. For example, mountain front recharge was removed along the mountain front adjacent to and to the north of Twin Buttes Mine and was increased in the proximity of Demetrie Wash (Section 4.4 and Table I.1).

4.4.2 River and Agricultural Recharge

River recharge is defined as infiltration from the Santa Cruz River that replenishes the basin-fill aquifer, and agricultural recharge is defined as water that is applied to crops in excess of consumptive use and evaporation demand. The rates and spatial distribution of river and agricultural recharge in the PDSIRM were taken from the ADWR model. River recharge in the ADWR model is based on reports by Gallagher (1979), Keith (1981), and Webb and Betancourt

(1990) as compiled in Hanson and Benedict (1994). Agricultural recharge in the ADWR model was estimated as the product of the total volume of water used for irrigation and an irrigation inefficiency coefficient. Mason and Bota (2006) determined the spatial distribution of agricultural recharge from a number of sources, including the location of irrigation grandfathered rights and crop survey data. The ADWR model lumps the rates for river recharge and agricultural recharge because agricultural land use is centered along the Santa Cruz River. Therefore, these two sources of inflow are not distinguished from each other.

Annual river and agricultural recharge in the ADWR model increases during the period from 1940 to 1960 from about 15,000 acre-feet (ac-ft) to about 30,000 ac-ft. The increase in recharge rates generally corresponds to a decline in groundwater levels due to pumping. After 1960, annual river and agricultural recharge gradually decreases to between about 15,000 and 20,000 ac-ft/yr. The decrease is reflective of increased irrigation efficiency and urbanization of farmland (Mason and Bota, 2006). River and agricultural recharge from the ADWR model was apportioned in the PDSIRM by rediscretizing the spatial distribution of recharge in the ADWR model to match the finer grid cell spacing in the PDSIRM. The refined distribution for each stress period was then imported into the PDSIRM. The extents of recharge are much wider than the channel widths of the Santa Cruz River (Figures I.5 and I.6). The wide extent accounts for the agricultural recharge component.

The ADWR model runs only through 1999. The value of river and agricultural recharge in the PDSIRM after 1999 was set at about 15,400 ac-ft/yr, which is near the recharge volumes in the mid-1990's. Using the recharge value from the mid-1990s to approximate recharge from

2000 to 2006 is more appropriate than using a longer-term average because recharge from agriculture has declined as agricultural lands have been converted to residential developments. A comparison of the ADWR model annual recharge volumes and the recharge volumes used in the calibrated PDSIRM is shown in Figure I.7.

4.4.3 Seepage from Tailing Impoundments

Recharge due to seepage from tailing impoundments is included for the PDSTI, Esperanza Tailing Impoundment (ETI), and the Twin Buttes Tailing Impoundment (TBTI) (Figures I.5 and I.6). Seepage from Asarco Mission Mine Tailing Impoundments 7 and 8, for which estimates were not readily available, was not included in the model. Because these impoundments are adjacent to the northern model boundary, the affects of seepage from these impoundments were assumed to be accounted for in the adjacent specified head boundary to the north.

4.4.3.1 Phelps Dodge Sierrita Tailing Impoundment

PDSTI has been in operation since 1970 (Reed & Associates, 1986). Initial seepage rates for the PDSTI were taken from a water budget study conducted for the PDSTI (ELMA, 2007b). The water budget estimates the historical hydraulic loading to, and seepage from, the PDSTI using PDSI milling and slurry composition data; yearly satellite images of tailing impoundment extent and wetness; on-site pan evaporation correlated with pan evaporation estimates from nearby weather stations (to extend the period of record); historical climatological data; and moisture retention characteristics measured from soil cores taken at PDSTI. The estimated seepage rates, reported in Table I.2 and Figure I.8, show initially high seepage rates (about 10,000 ac-ft/yr) that gradually decrease through the late 1980s and then increase again in the early 1990s. The cumulative seepage volume through the PDSTI is estimated to be 252,406 ac-ft as of the end of 2006. The highest estimated seepage rate through the PDSTI (11,507 ac-ft/yr) occurred in 1972, and the lowest seepage rate through the PDSTI (2,241 ac-ft/yr) occurred in 1988. Adjustments to the seepage rate estimates were allowed during model calibration, and seepage rates in the calibrated model were about 30 to 35 percent higher than the estimates in ELMA (2007b) (Section 4.4, Table I.2). The need to increase the estimated PDSTI seepage rates for calibration does not necessarily indicate that seepage is higher, but that flow beneath the PDSTI from all the water sources needed to be increased to calibrate to measured groundwater levels and sulfate concentrations. Uncertainties in several hydrologic parameters and processes may have contributed to the need to increase the PDSTI seepage rates in the calibrated model. These parameters and processes may include mountain front recharge, bedrock underflow, aquifer and/or bedrock permeability's, and seepage from the PDSTI and ETI.

The modeled areal extent of seepage from the PDSTI increases with time, consistent with the growth of the PDSTI, as shown in images used in the development of the water budget for the PDSTI (ELMA, 2007b). These images indicate that the seepage area in the early stages of PDSTI development was concentrated toward the southeastern portion of the present-day impoundment, and gradually grew to encompass the full north-south extent of the PDSTI. The tailings construction and drainage is represented in the model by gradually increasing the recharge area of the PDSTI with time, with recharge focused on the lower half of the impoundment during the 1970's and early 1980's. After 1985, the majority of the present-day impoundment was developed, and the modeled recharge area of the PDSTI is constant after 1985. Based on the analysis of tailing samples taken from the PDSTI (ELMA, 2007b), the physical and hydrologic properties of the tailing material at the PDSTI have no substantial spatial variations. Therefore, recharge rates for the PDSTI recharge areas are spatially uniform in the model.

PDSI data show that sulfate concentrations in samples collected from the PDSTI reclaim pond between 1980 and 2006 range from less than 1,600 mg/L to as high as about 2,800 mg/L, with an average concentration of 1,956 mg/L (ELMA, 2007b). The upper concentration of sulfate in seepage is limited by its solubility, which can vary over a wide range depending on the factors such as the water temperature and other ions present in the groundwater (Snoeyink and Jenkins, 1980; Hendry et al., 1986). Nevertheless, the average sulfate concentration in the samples from the reclaim pond provides a reasonable starting estimate of the average sulfate concentration in the PDSTI seepage. The sulfate concentrations measured from samples taken from the reclaim pond have no apparent trend with time, so a constant concentration of 1,956 mg/L was specified in the PDSTI seepage water. Adjustments of this parameter were allowed during model calibration; although, a concentration of 1,956 mg/L is used in the calibrated model (Table I.1).

4.4.3.2 Esperanza Tailing Impoundment

The ETI was in operation from 1959 to 1981. High and low estimates for seepage from the ETI were estimated using a water budget methodology similar to that used for the PDSTI (ELMA, 2007c). The high and low values account for uncertainties in evaporation estimates. The calibrated model uses the high seepage estimates. These seepage volumes range from about 2,200 ac-ft/yr to about 1,000 ac-ft/yr. No tailing was delivered to the ETI during 1972 and between September 30, 1977 and February 1, 1978 (Reed & Associates, Inc., 1986). Consequently, the water balance shows no seepage for the years 1972 and 1978 (Table I.2, Figure I.8), although some seepage from the ETI probably did occur during these years due to drain-down from the previous years' applications. Drain-down seepage was not estimated in the water budget for the ETI. Therefore, the water allocation for the 1971 to 1972 and 1977 to 1978 will have some inaccuracies; although, the total water applied and total seepage over these periods balances the water budget. Any inaccuracies in the timing of water allocation during the two years do not impact the model results (Section 5).

The model recharge area for the ETI is 250 acres and is assumed to be constant with time. The ETI recharge area is positioned in the model slightly south of the actual ETI location to account for the appearance of a southeasterly overland drainage pattern that is visible in historic images and that may have channeled some infiltration to the south of the ETI. No water quality samples from ETI seepage are available, and the concentration of the seepage in ETI is specified to be the same as for the PDSTI.

4.4.3.3 Twin Buttes Tailing Impoundment

The Twin Buttes Mine operated from 1965 to 1983. Seepage rates from the TBTI are taken from a groundwater flow and transport model of the PDSTI vicinity (ELMA, 1994, 2007a), which was based on estimates given by SRK (1986). These seepage estimates are 4,100 ac-ft/yr from 1970 through 1976; 7,900 ac-ft/yr from 1977 though 1979; 4,720 ac-ft/yr from 1980 through 1982; and 1,360 from 1983 through 1985. The model assumes that no seepage occurs after 1985 (Figure I.8). The seepage area for the TBTI was specified as 1,900 acres and was constant with time. Seepage rates from the TBTI were not adjusted in the calibrated model.

Solute transport from the TBTI was not considered because the focus of the model is the sulfate plume from the PDSTI. Sufficient information was unavailable to provide a reliable calibration of sulfate transport from TBTI.

4.4.4 Artificial Recharge

Artificial recharge in the PDSIRM domain includes infiltration basins operated by Robson-Ranch Quail Creek (RRQC). The RRQC underground storage facility (ADWR facility number 71-58139.001) includes twelve basins, nine of which are currently in operation (Pima County, 2007). The facility is located directly south of the Green Valley Waste Water Treatment Plant (GVWWTP) and receives effluent from GVWWTP as its source for recharge water (Pima County, 2007). The RRQC facility is permitted to store up to 2,240 acre-feet annually (ADWR, 2006). In 2006, RRQC recharged an estimated 1,619 acre-feet. Recharge amounts for years prior to 2006 are based on estimates of annual recharge using RRQC recharge reports and population projections (ELMA, 2007a). The modeled recharge from the RRQC facility linearly increases from 100 acre-feet in 1970 to 1,619 ac-ft by 2006. These recharge estimates were not adjusted during model calibration.

4.4.5 Pumping

Groundwater withdrawal by pumping is the major groundwater sink in the PDSTI region. Pumping information was taken from several sources: the ADWR model, information reported in ELMA (2007a), ADWR databases, well surveys, and local water providers. These sources are explained below, and tables of well locations and pumping volumes used in the model are provided in Appendix I.1.

The AWDR model provides pumping estimates for the entire Tucson AMA during the period from 1940 to 1999. Between 1940 and 1960, few pumping records exist, and the pumping rates for this period are based on power consumption records and crop distribution surveys (Anderson, 1972). Because these pumping estimates are not based on user records, their accuracy is uncertain (Dale Mason, personal communication, August 6, 2007). Between 1960 and 1984 more user records exist; however, many of the pumping rates and locations are still based on the estimates of Anderson (1972) using energy and crop data as well as on estimates made by Travers and Mock (1984). Pumping estimates for the period from 1940 to 1984 are assigned cadastral coordinates, but do not necessarily correspond to individual well locations. Beginning in 1984, all non-exempt well owners (i.e., well owners pumping more than 35 gallons per minute [gpm]) have been required to report annual pumping amounts to ADWR per AMA regulations. Therefore estimates of pumping rates and locations are more accurate after 1984. Although the early-time pumping rates are uncertain, they were not adjusted during model calibration because (1) the rates have already been applied in previous calibrated models and (2) treating pumping as a calibration parameter would likely add a high level of non-uniqueness to the model calibration. The effects of the early-time pumping rates are dampened as the model simulation moves forward in time when pumping rates are more certain.

Pumping information for the period from 1971 to 2003 for PDSI wells and other wells located within the area of emphasis was obtained from pumping files used in a prior model (ELMA, 2007a). These pumping data were developed using ADWR databases, PDSI databases, and pumping rates reported by SRK (1986). Prior to 1979, few records were available, and pumping rates for 1971 to 1978 were estimated from the 1979 pumping rates.

ADWR records that were consulted to obtain pumping information were the Groundwater Site Inventory (GWSI) database, the ADWR 55-series Well Registry, and annual pumping reports submitted to ADWR by water rights owners. In these databases, and other sources of pumping records, only the annual total is reported. The average daily pumping rate was estimated by dividing the total pumping amount by the number of days in the year.

Well locations were determined from a variety of sources. Locations for CWC wells were provided by CWC, and locations for wells GV-01 and GV-02 at the GVWWTP were provided by Pima County. Other well locations within the area of emphasis, except for wells imported from the ADWR model, were determined from surveys conducted in 2007 by AMEC Infrastructure, Inc., or by AZTEC Land Surveying, Inc. Spatial coordinates for wells located on the periphery of the model domain were obtained from the ADWR GWSI database and the 55-series Well Registry.

Pumping information from the various sources was incorporated into the PDSIRM as follows:

- For the period from 1940 to 1970, pumping estimates from the ADWR model were applied exclusively. Well locations were converted from ADWR row and column coordinates to equivalent coordinates in the PDSIRM. Because the ADWR model used 0.5-mile grid spacing, wells could only be located to the nearest 0.5 mile (2,640 feet).

- For the period from 1971 to 1983, pumping rates from ELMA (2007a) were applied in the PDSIRM. Locations for the wells were taken from the HGC well location database. For wells not included in ELMA (2007a), locations and pumping rates were taken from the ADWR model, as was done for the period from 1940 to 1960.

- For the period from 1984 to 2006, pumping rates were applied from ELMA (2007a) or from the ADWR database for wells and/or years not included in the ELMA (2007a).

Figure I.9 shows the annual pumping totals for all the wells in the PDSIRM domain using the above pumping data. Pumping increases from about 12,500 ac-ft/yr in 1940 to a maximum of nearly 133,500 ac-ft/yr in 1976. After 1976, pumping totals begin to decrease to between 60,000 ac-ft/yr and 75,000 ac-ft/yr by 1985. Reduced agricultural pumping is the primary reason for the decrease in pumping after the mid-1970s (Mason and Bota, 2006). Pumping rates were not adjusted during model calibration.

MODFLOW-SURFACT can automatically allocate flow from each layer penetrated by a well based on aquifer properties and well screened intervals. For pumping obtained from the ADWR model, no information on screened intervals is available, and these wells are assumed to be fully screened over all three layers. Information on screened-intervals is taken from ELMA (2007a) for the wells included in that model. For all other wells, well-construction data is taken from the ADWR 55-series Well Registry. Some of the registry records contained detailed well construction information, while other records provided few details other than the total well depth. If screened intervals were not given in the image records, the screened interval is assumed to equal the total depth of well penetration into the aquifer.

4.4.6 Evapotranspiration

ET estimates are taken from the ADWR model, which are based on the rates and spatial distribution of Hanson and Benedict (1994). The spatial distribution of the ET zones in the AWDR model was digitized and imported into the PDSIRM. These ET zones are located near the Santa Cruz River. The potential ET rates range from 0.0023 ft/d to 0.03 ft/d with a uniform extinction depth of 25 feet. The potential ET rate is assumed constant throughout the simulation period, although the actual ET rate decreased with time due to the decline in groundwater levels. ET rates were not adjusted during model calibration.

4.4.7 Twin Buttes Mine Pit

The Twin Buttes Mine pit is not expected to have a major influence on the hydraulics of the basin-fill aquifer, although it may function as a weak groundwater sink (SRK, 1985a). A constant inflow of approximately 250 gpm is estimated to enter the east face of the pit at the intersection of the bedrock and the basin fill (Harold Metz (Twin Buttes Properties, Inc.), personal communication with Ned Hall (PDSI), November 16, 2007). This observation suggests that the pit does act as a sink for groundwater from the basin fill aquifer. The influence of the Twin Buttes pit is represented in the PDSIRM by including a constant negative groundwater flux at the west model boundary near the area of the pit with a total outflow rate of approximately 250 gpm.

4.5 Initial Aquifer Parameterization

Aquifer parameters include saturated hydraulic conductivity, storage coefficient, specific yield, effective porosity, and dispersivity. Initial estimates of these parameters, with the exception of dispersivity, were based on the calibrated parameters in the ADWR model and field measurements or data evaluations made as part of the Aquifer Characterization Plan. Dispersivity was estimated by model calibration. Initial and final aquifer parameters and ranges are summarized in Table I.1.

4.5.1 Saturated Hydraulic Conductivity

The saturated hydraulic conductivity (Ksat) describes the rate at which groundwater can flow under a given hydraulic gradient. Within the area of emphasis, the initial estimates of Ksat were based on information collected during the Aquifer Characterization Plan, including lithologic logs from drilling activities, pumping tests, and depth-specific sampling and inflow profiling. In addition to pumping tests conducted as part of the Aquifer Characterization Plan, hydraulic properties data for previous pumping and slug tests were compiled and evaluated (ACR, Appendix A and E). These previous tests were conducted in the IW, BW, PZ, MH, Duval, FICO, and GV wells. The evaluation of the pumping tests show a wide range in horizontal Ksat values, from less than 1 ft/d to over 100 ft/d. Estimated horizontal Ksat values were relatively higher (approximately 30 to 118 ft/d) in the area northeast of PDSTI (wells MO-2007-1, MO-2007-2, M-25, MH-26, and CW-7); whereas estimated horizontal Ksat values were relatively low (less than 1 ft/d) in the deepest wells of the well nests located east of the south half of PDSTI (MH-13, MO-2007-5, MO-2007-6). The drilling activities, pumping tests, and inflow profiling conducted as part of the Aquifer Characterization Plan do provide evidence that the aquifer is more permeable at intermediate depths in the vicinity of Green Valley; however, the increase in permeability is small (ACR, Appendix E and H). Vertical Ksat values were typically estimated to be less than 1 ft/d in hydraulic tests conducted as part of the Aquifer Characterization Plan (ACR, Appendix E). Initial values of vertical Ksat in the PDSIRM were set at 0.2 ft/d.

In the area outside the focus of the Aquifer Characterization Plan, the initial Ksat values were based on the calibrated Ksat values used in the ADWR model. Although the layer elevations in the ADWR model do not coincide with those of the PDSIRM the differences in layer thicknesses were neglected for the estimate of initial Ksat values. The calibrated Ksat values from the ADWR model are vertically stratified, with the highest Ksat values in the upper layer (Layer 1) and the lowest values in lowest layer (Layer 3). Because only a transmissivity is specified for Layer 3 of the ADWR model, an equivalent Ksat was calculated based on the bedrock in the PDSIRM and the top of the Layer 3 in the ADWR model. Ksat values in the ADWR model range from 2 ft/d to about 300 ft/d in Layer 1, 1 ft/d to 139 ft/d in Layer 2, and from less than 1 ft/d to about 15 ft/d in Layer 3. The distribution of ADWR Ksat value was condensed into several representative intervals ranging from 1 ft/d to 50 ft/d Values greater than 50 ft/d in the ADWR model were typically in isolated areas and were assigned values equal to the adjacent cells. Vertical Ksat for each of the zones was assigned a value equal to about 10 to 30 percent of the horizontal Ksat value. The resulting Ksat distribution was then rediscretized to match the PSDIRM domain and imported into the PSDIRM. The initial Ksat values and distributions were varied during model calibration to improve the match between simulated and measured groundwater levels (Section 4.4 and Table I.1).

4.5.2 Storage Coefficient and Specific Yield

The storage coefficient (S) and specific yield (Sy) define how changes in hydraulic head affect aquifer storage of groundwater. In particular, the value of Sy describes the drainability of an unconfined aquifer and is of more importance for the PDSIRM. Initial values for S and Sy, are taken from the ADWR model. The value of S for was uniform at 0.0001. The values for Sy are spatially variable, ranging from 0.05 to 0.16. During model calibration, the values for Sy were allowed to vary between 0.02 and 0.22. This range of values for Sy is consistent with the range reported in Fetter (2001). The range of Sy values in the calibrated model was from 0.08 to 0.20. The value of S was not adjusted during model calibration (Table I.1).

4.5.3 Effective Porosity

The effective porosity (θs) is the fraction of the total pore volume of aquifer matrix through which groundwater actively flows. Therefore, the solute transport velocity is influenced by the effective porosity. The initial value for θs was 0.25 and was spatially uniform throughout the model domain. Values of θs were adjusted between 0.2 and 0.3 during model calibration (Table I.1).

4.5.4 Dispersivity

Dispersivity (α) is a parameter that accounts for hydrodynamic dispersion. As a result of hydrodynamic dispersion, some groundwater travels faster, and some slower, than the average groundwater velocity at a particular location. This causes “spreading” of a solute at the margins of a plume by allowing some solute to travel faster and some slower than the average transport velocity. Values of α increase with increasing media heterogeneity and have been observed to be “scale-dependent”, generally increasing with solute transport distance (Gelhar, 1993). Evaluation of the sulfate plume morphology, especially for the margins of the plume, based on water quality sampling data for the first and third quarters of 2007 (ACR, Appendix B) indicates very little plume dispersion has occurred. Therefore, with the exception of directly underneath the PDSTI, the values of longitudinal, transverse, and vertical dispersivity were initially set to zero in the PDSIRM and did not need to be adjusted for calibration. This allows all modeled plume dispersion to be accounted for by the variation in aquifer properties and by any numerical dispersion inherent in the transport solution. Under the PDSTI, the vertical dispersivity is 65 feet, while longitudinal and transverse dispersivities are zero. This high vertical dispersivity beneath the PDSTI is used to facilitate movement of sulfate in the PDSTI recharge to the lower model layers, consistent with the conceptual model of sulfate migration in the PDSTI.

4.6 Initial Conditions

The initial groundwater levels for the transient (1941 to 2006) model were taken from the calibrated steady-state model. Initial sulfate concentrations were specified to follow the trends observed in the background water quality samples collected in 2007 (ACR, Appendix B): lower concentrations (> 5 mg/L to 30 mg/L) near the basin margin and a higher concentration (80 mg/L) in the middle of the basin, along the Santa Cruz River.

5. MODEL CALIBRATION

Model calibration is the process of adjusting the model input parameters to achieve reasonable matches between simulated groundwater levels and sulfate concentrations with measured values. Model calibration of groundwater levels was first conducted for a steady-state model representing conditions in 1940. Calibration of groundwater levels and sulfate concentrations was then performed for a transient model representing the period from 1941 to 2006. The calibration methodology and calibration results for the steady-state and transient simulations are discussed below.

5.1 Calibration Criteria

During model calibration, input parameters were systematically adjusted to improve the match between measured and simulated groundwater levels and sulfate concentrations. Improvement was judged both quantitatively and qualitatively. The differences between measured and simulated values (referred to as residuals) provided a quantitative evaluation of model calibration at specific "target" locations (i.e. locations where data of measured values existed). For the 1940 steady-state simulation, calibration targets were taken from those used to calibrate the ADWR model. Calibration targets for the years from 1941 through 2005 were taken from the PDSI database, ELMA (2007a), PAG (1983), Environmental Resource Consultants (ERC) (1996) and from the ADWR model. Calibration targets for the end of the year 2006 were the actual groundwater levels measured by HGC for groundwater sampling during the first and third quarters of 2007. The first and third quarters were used because groundwater monitoring during these two quarters was the most extensive, with measurements at key locations not included in previous sampling events. These two quarters also show the differences in groundwater levels during the winter versus the summer.

A qualitative assessment of model calibration was conducted by mapping the spatial distribution of residuals and by comparing groundwater level and sulfate concentration contours created from the simulated and from measured values. Mapping residuals helped to detect spatial bias in errors, and the contour maps helped to evaluate how well the simulated groundwater levels and sulfate concentrations compared to field measurements on a large scale.

The historic groundwater levels sometimes showed variations of several feet or more within a given year and from one year to the next. Groundwater levels measured by HGC between first quarter and third quarter, 2007 could also vary several feet between measurements taken at the same location. The intra-annual variations possibly reflect increased pumping during the summer months. Simulation of these intra-annual water level fluctuations was not practical because pumping information could only be obtained as annual totals and because sub-annual stress periods would further increase simulation processing times. Therefore, simulated groundwater levels that were between target values for a given year were taken as a satisfactory match.

5.2 Calibration Methodology

Model calibration initially began for the 1940 steady-state simulation. The 1940 simulation had relatively little pumping and few calibration targets compared to the calibration years in the transient simulation. Therefore, many of the stresses and groundwater level measurements that aid in the calibration of aquifer parameters were not present in the steady-state simulation and much of the parameter estimation could only be accomplished during the calibration of the transient model. Consequently model calibration proceeded iteratively between the steady-state model and the transient model until the most satisfactory solution was reached for both.

5.3 Calibration Results

Both the initial values of parameters and their spatial distributions were varied during model calibration to better match measured groundwater levels and sulfate concentrations. The final calibrated parameter values and ranges are provided in Table I.1. Figures I.10 to I.12 show the spatial distribution of Ksat values in the three model layers, and Figure I.13 shows the spatial distribution of Sy values, which is the same in all layers.

5.3.1 Groundwater Calibration

A good agreement was achieved between measured groundwater levels and the simulated groundwater level contours for the steady-state (1940) calibration (Figure I.14), and no spatial bias is apparent in the residuals between measured and simulated values (Figure I.15).

Therefore, the calibrated steady-state model is believed to provide a reasonable initial condition for the transient groundwater flow simulation.

Simulated groundwater level contours are compared with the measured groundwater levels from the first and third quarter 2007 sampling events in Figure I.16 and Figure I.17. Contour maps of measured water level elevations for the first and third quarters of 2007 are in Appendix B and Figure 5 of the ACR, respectively. The simulated groundwater level contours demonstrate several important features of the potentiometric field estimated from measured groundwater levels, including:

- The steep hydraulic gradient emanating westward from the PDSTI, and the abrupt turn to the north of the flow field immediately downgradient (east) of the PDSTI.
- The curvature of the groundwater contours across the center of the basin.
- The groundwater level trough and flattening of the hydraulic gradient in the northwest portion of the model domain and the groundwater level rise in the northeast portion of the model domain.

Simulated groundwater contours and measured water levels show the greatest differences in the north part of the model domain in the vicinity of the apparent groundwater level trough east of the Twin Buttes Mine. The trough is defined by water levels that dip easterly from the Twin Buttes Mine, westerly from the vicinity of the Santa Cruz River near and north of Duval Mine Road, and northerly from Green Valley. The trough is evident in both the first and third quarter 2007 groundwater sampling events and appears to be a persistent feature shown to varying degrees by groundwater level maps for 1966 (Davidson, 1973) and 1982 (PAG, 1983; Murphy and Hedley, 1984). The trough in water level contours implies a zone of convergent groundwater flow toward the northwest portion of the model domain. The differences between simulated and measured water levels in the northern portion of the model could be due to differences between assumed and actual values for hydraulic properties, groundwater pumping, or recharge. Improved simulation of the groundwater levels in northern model areas would require further aquifer characterization and refinement of the conceptual model beyond the area of emphasis.

Simulated versus measured groundwater levels for all groundwater level targets used in the transient simulation are shown in Figure I.18. Highlighted in the figure are the targets for the 2007 sampling events. A similar comparison is made in Figure I.19 for the area of emphasis (inner rectangle in Figure I.2). Overall, the simulated versus measured points follow the one-to-one line, showing the ability of simulated results to match measured groundwater levels across the entire model domain. The upward deviation from the one-to-one line at the lower groundwater elevations is due to the difficulty in simulating the groundwater level depression in the northwest part of the model domain.

Appendix I.2 includes hydrographs of measured and simulated groundwater levels at several wells (refer to Figure I.2 for well locations). These hydrographs are representative of the calibration at different areas of the model domain and provide the following observations:

- Although measured groundwater levels in the southern part of the model domain show large fluctuations, the simulated results approximate the median behavior and show a particularly good match with recent measurements (Appendix I.2, Figures I.2.1 to I.2.4).

- Groundwater level time-series for wells immediately down-gradient of the PDSTI, along the IW-wellfield, show a general agreement between simulated and measured, although the absolute values can differ by several feet (Appendix I.2, Figures I.2.5 to I.2.7). Most discrepancies appear to be caused by the inability of the model to simulate steep hydraulic gradients at sub-grid locations.

- About one mile east of the PDSTI, the simulated results match the average behavior of measured points; however, individual wells can have periods where the simulated results deviate from the measured points (Appendix I.2, Figures I.2.8 to I.2.12). The reasons for the deviations are uncertain, but because the deviations at different wells show no systematic variations, they do not indicate a modeling bias in the area east of the PDSTI.

5.3.2 Sulfate Concentration Calibration

Simulated sulfate concentration contours are compared with measured sulfate concentrations from the third quarter 2007 sampling events in Figure I.20. The third quarter 2007 sampling event is used for comparison even though the model simulation was conducted only through the end of 2006 because the third quarter event provides sulfate concentration measurements at several key locations surrounding the PDSTI that were not obtainable in previous sampling events. The simulated sulfate concentration contours shown in Figure I.20 represent concentrations averaged over the upper and middle layers. These layers represent the primary flow and transport zones near the PDSTI because the permeabilities in these layers are generally higher than in the lowermost layer. The simulated sulfate concentrations in each of the three layers are shown in Figure I.21. In general, the extent of the sulfate plume is greater in the upper layer than in the lowermost layer. Appendix I.3 provides chemographs of the simulated and measured sulfate concentrations at several locations near the edge and within the interior of the plume where a time series of sulfate concentrations are available and where large changes in sulfate concentrations have occurred (Figures I.3.1 to I.3.7 of Appendix I). The simulated sulfate concentrations for these chemographs are averaged over the upper two model layers because this approximates the typical screened intervals for the wells where actual sulfate concentrations were measured. The time series of measured concentrations in these chemographs includes measurements through the third quarter of 2007, which is beyond the simulation period. Measurements outside of the simulation period are shown as solid symbols.

The sulfate contours in Figure I.20 and the chemographs in Appendix I.3 illustrate the strengths of the transport model in representing several important features of the plume as inferred from the following water quality measurements:

- The general shape of the sulfate plume is represented, including a broad base near the PDSTI and a thinner leading edge (Figure I.20).
- The arrival time of the plume is accurately simulated at several key locations along the eastern edge of the plume (Appendix I.3, Figures I.3.1 and I.3.2).
- The northward advance of the plume is represented (Appendix I.3, Figures I.3.3 to I.3.4).
- Concentrations in the plume interior are generally well represented (Appendix I.3, Figures I.3.5 to I.3.7).

While the model reproduces the general characteristics of the sulfate plume, it is unable to match measured concentrations at every location. In particular, the simulated sulfate distribution does not match the higher sulfate concentrations measured in 2007 at the deeper wells at MO-2007-5 located at the southeastern portion of the sulfate plume. The high sulfate concentrations measured in 2007 at the MO-2007-5 wells may represent residual concentrations from a retreating plume rather than an advancing plume. This hypothesis is supported by: (1) historic measurements at CW-3 that show sulfate concentrations declining between the late 1980's and present and (2) the determination that the southern portion of the IW wellfield is now operating effectively to cut off seepage that would contribute to the southeastern portion of the plume.

The simulated plume when averaged over the upper two layers also slightly over predicts the northern extent of the plume, as inferred by water quality measurements made in 2007. The over prediction results from the model's difficulty in simulating the sharpness of the sulfate plume at its northern extent, where sulfate concentrations rapidly decrease from about 1,400 mg/L at M-20 to about 20 mg/L at the corresponding depth in MO-2007-1. This may lead to a conservative prediction (i.e., earlier arrival of predicted than measured) at the northern extent of the plume.

The inability of the model to match the sharpness of the plume front and concentrations at some point locations is likely due to aquifer heterogeneities that cannot be adequately captured in the model (e.g., localized contrasts in permeability and porosity and anisotropies in aquifer properties). These heterogeneities cannot be detected using practical aquifer characterization methods, nor can they be simulated by a regional-scale numerical model constructed with spatial zone-wise homogeneity and temporal period-wise uniformity. Therefore, the model cannot replicate aquifer heterogeneities and processes that vary at spatial and temporal scales finer than the model discretization, and the model has practical limits on its ability to predict concentrations at point locations and where rates of sources and sinks for groundwater and sulfate can change quickly, such as near the PDSTI (Section 7). However, the calibration results demonstrate that the model accurately simulates the key trends and attributes of groundwater flow and sulfate migration, giving confidence that the model can be used as a predictive tool for evaluating mitigation alternatives.

5.4 Adjustments During Model Calibration

Several adjustments to initial parameters were made during model calibration to achieve better matches between simulated and measured groundwater levels and sulfate concentrations. Table I.1 provides a comparison of initial and final parameters and ranges. The major adjustments that were made during model calibration include the following:

- A higher Ksat zone (Ksat = 36 to 89 ft/d) was created in the western portion of the model domain, extending north of PDSTI, and the specified heads along the northern boundary were lowered where the boundary intersects the higher Ksat zone.
- Mountain front recharge along the northwestern portion of the model domain (beginning at approximately the Twin Buttes Mine) was decreased and the mountain front recharge within the area of the PDSTI was increased (Section 3.4.1).
- Seepage rates in the PDSTI were increased approximately 30 to 35 percent from the rates estimated in ELMA (2007b). The need to increase the PDSTI seepage rates does not necessarily indicate that seepage is higher, but that flow beneath the PDSTI from all the water sources needed to be increased for model calibration.

The area east of the Twin Buttes Mine has a persistent zone of depressed groundwater levels, indicative of convergent groundwater flow. The means selected to simulate the depressed groundwater levels was to increase Ksat values in a zone trending north from the Twin Buttes Mine area to the northern model boundary (Figures I.11 to I.13). The Ksat values in this zone range from 36 ft/d to 89 ft/d. Although the Ksat values of the higher Ksat zone are consistent with measured Ksat values at several locations north and northeast of the PDSTI (e.g., MO-2007-02, CW-7, MH-26), the northern extent of this zone is unknown. Estimated Ksat values at some wells in the area do not corroborate (e.g., Ksat values at many of the Twin Buttes wells range from about 10 to 20 ft/d; ELMA (1987, 1995)). Therefore, establishing the higher

Ksat zone in the model and extending it to the northern model boundary is speculative, but was needed to match water level measurements in the area (PAG, 1983; ACR, Appendix B).

Mountain front recharge was adjusted as a means of lowering groundwater levels in the northwest portion of the model domain and increasing groundwater levels in the southern portion of the model domain. The changes are consistent with hydrologic features. The Twin Buttes pit likely intercepts much of the mountain front recharge in the Twin Buttes area, and mountain front recharge was set to zero after 1970 from about the Twin Buttes area to the north boundary. The Demetrie Wash may increase mountain front recharge in the vicinity of the PDSTI, and mountain front recharge was increased from about 195 ac-ft/yr/mile to about 280 ac-ft/yr/mile for about a four-mile in the general vicinity of the PDSTI.

The increases in the PDSTI seepage rates were necessary to better match groundwater levels and sulfate concentrations. As stated in Section 3.4, the increases may reflect inherent uncertainties in the seepage estimates and/or uncertainties in the model conceptualization and parameterization of other hydraulic properties and processes that contribute to flow beneath the PDSTI.

6. SENSITIVITY ANALYSIS

A sensitivity analysis was conducted for the transient (1941 to 2006) model. The objective of the sensitivity analysis was to understand the relative influence that the calibrated values of model parameters have on the simulation results.

6.1 Sensitivity Analysis Procedure

The sensitivity of the simulation results to changes in the values of model input parameters was evaluated by systematically varying parameter values and comparing the ensuing simulation results with those of the calibrated model. The values of the following parameters were adjusted as part of the sensitivity analysis:

- Saturated hydraulic conductivity (horizontal and vertical)
- Storage coefficient
- Specific yield and porosity (varied simultaneously)
- Evapotranspiration
- River recharge
- Mountain front recharge
- Seepage from the PDSTI (rate and concentration)
- Seepage from the ETI (rate and concentration)

Model sensitivity simulations were performed by varying the values of the parameter being tested while keeping the values of the other parameters constant at their final calibration values. For the parameter being tested, a simulation was run with the parameter values uniformly increased by 25 percent, followed by a simulation run with the parameter values uniformly decreased by 25 percent. The sensitivity analysis was limited to uniformly adjusting a single input parameter (i.e., multiple parameters were not simultaneously varied and a parameter was adjusted by the same percentage at all locations). For each simulation, the root mean square residual (RMSR) and mean arithmetic residual (MAR) between measured and simulated target values for the first quarter 2007 sampling event were computed and compared with the RMSR and MAR for the final calibration simulation. MAR and RMSR are defined as follows:

$$MAR = \frac{\sum_{i=1}^{n}(C_i - T_i)}{n} \qquad [1]$$

$$RMSR = \frac{\sqrt{\sum_{i=1}^{n}(C_i - T_i)^2}}{n} \qquad [2]$$

Where:

C_i = residual between the calibrated model simulation and measure values for target i

T_i = residual between the test simulation and measure values for target i

n = number of targets

Sensitivity was then evaluated as the arithmetic difference between the MAR (ΔMAR) for the calibration and test simulations, and the relative percent difference in the root mean square error (ΔRMSE) between the two simulations. The value (positive or negative) of ΔMAR indicates the average direction that the parameter change moved the groundwater levels and sulfate concentrations. The value of ΔRMSE indicates the average magnitude of that change and provides a relative measure of the least to the most sensitive parameter.

6.2 Sensitivity Analysis Results

Table I.3 summarizes the results of the sensitivity analysis. For groundwater levels at the 2007 target locations, the model is most sensitive to changes in Ksat and increases in the seepage rate in the PDSTI. Groundwater levels at target locations are influenced more by decreases in the PDSTI seepage rate than by increases in the seepage rate. Groundwater levels at target locations are moderately influenced by changes in specific yield, river recharge, and mountain front recharge. Changes in the storage coefficient, evapotranspiration, and the seepage rate in the ETI have relatively little influence on groundwater levels at the 2007 target locations.

Sulfate concentrations at the 2007 target locations are most sensitive to increases in the concentration of the seepage in the PDSTI. The sulfate concentrations are also moderately to highly sensitive to increases in the seepage rate in the PDSTI and decreases in the specific yield/porosity because these parameters affect the mass loading of sulfate and/or the rate of the sulfate plume migration. Seepage in the ETI has a modest influence on simulated sulfate concentrations. The sulfate concentrations at the 2007 target locations are less sensitive to changes in other parameters.

7. SUMMARY AND CONCLUSIONS

The results of the model calibration for the historic simulation of groundwater levels and sulfate concentrations show the abilities of the PDSIRM to simulate the groundwater flow and sulfate plume migration within the vicinity of the PDSTI. The simulated groundwater level trends and the overall shape of the simulated groundwater levels are similar to observed trends, indicating the essential components of the aquifer hydraulics are represented. Likewise, the general shape and extents of the simulated sulfate plume matches the observed plume, demonstrating that the factors influencing plume movement are incorporated in the model construction. The time-series data (Appendices I.3) indicate that the model is capable of matching the sulfate concentrations and sulfate plume arrival at key locations.

The calibration results provide confidence in the ability of the PDSIRM to serve as a tool for predicting groundwater flow and sulfate transport in the vicinity of the PDSTI. To appropriately use this tool, however, the strengths and limitations of the model should be understood. For example, although the bulk migration of the sulfate plume is well represented, the time-series data (Appendix I.3) show that the model cannot be expected to perfectly match all measurements at particular locations. This limitation is inherent to numerical models constructed from finite characterization data and that simplify process complexities and spatial/temporal heterogeneities. Some of the strengths and limitations of the PDSIRM are discussed below.

7.1 Model Strengths

For the purposes of developing alternatives for sulfate plume mitigation down-gradient of PDSTI, this model provides several advantages over other groundwater flow and transport models developed for the region near the PDSTI. These advantages include the following:

- Large spatial extents of the model domain that reduce the influence of boundary conditions within the area of the plume.
- Long temporal extent, beginning in 1940 when the aquifer is considered to be in "dynamic equilibrium", minimizes the influence of initial aquifer conditions on future simulations.
- Integration of the most comprehensive datasets on aquifer characteristics (e.g., Ksat values and bedrock elevations).
- Calibration to both groundwater level and sulfate concentration measurements, including measurements taken as part of the Aquifer Characterization Plan.

The strengths of the PDSRIM provide confidence in simulated predictions for groundwater levels and sulfate distributions in the area surrounding PDSTI.

7.2 Model Limitations

Numerical models are an approximation of reality. As with all numerical models, the applicability and predictive ability of the PDSIRM has limits. These limitations should be understood when using the PDSIRM. Important limitations of the PDSIRM include: spatial and temporal uncertainty and spatial and temporal averaging.

7.2.1 Spatial and Temporal Uncertainty

Information on aquifer characteristics and groundwater levels used for conceptual model development and model calibration decreases away from the area of emphasis. The specified-head boundaries at the north, east, and south of the model are supported by relatively few measurements. Measurements of aquifer properties and hydrogeologic units are also sparse near the model boundaries, and projection of layer elevations outside the area of emphasis is uncertain. Consequently, the confidence in model predictions decreases away from the area of emphasis, the area immediately downgradient of the PDSTI.

The model's predictive ability farther forward in time will be partly dependent on the accuracy of projected sources and sinks. Forecasts of aquifer stresses such as pumping and recharge rates and their spatial distributions can be uncertain the farther they are projected, and differences between the forecast and actual conditions can lead to inaccuracies in model predictions.

7.2.2 Spatial and Temporal Averaging

All finite-difference and finite-element codes discretize heterogeneous and continuous processes and parameters into blocks (or nodes) of constant values. For aquifer systems of relatively uniform properties and for finely discretized models, the effect of discretization will be minimal. For heterogeneous systems with time-variable processes (pumping, river and agricultural recharge, artificial recharge, etc.), such as in the Green Valley area, model predictions will be increasingly unable to match point-scale values even though they may satisfactorily represent average behavior. The discrepancies between point measured values and the model block averages may be important in areas of steep gradients, such as across the PDSI Interceptor Wellfield and at the margin of the plume.

The model also averages continuously changing or episodic temporal processes into discrete constant-in-time values. Such processes include seasonal river recharge and pumping that are simulated as average daily values based on a yearly total. Closely matching groundwater levels may be difficult due to temporal averaging, although simulated values should be within, or near, the range of measured values for a given simulation time period (one year for the PDSIRM).

7.3 Conclusion

The intended use of the PDSIRM is for evaluation of the effectiveness and preliminary design of mitigation actions (HGC, 2006). As with all models, the PDSIRM provides a simplistic conceptualization of a more complex natural system; however the PDSIRM is appropriately constructed and calibrated for its intended use. The model is constructed to include the geologic features of the aquifer and the principle stresses that affect groundwater levels and sulfate transport, and the model is calibrated to match the general distribution of the present groundwater levels and sulfate plume. When appropriately used, the PDSIRM can be an effective tool to evaluate the effects of various mitigation actions to be considered in the Feasibility Study.

8. REFERENCES

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TABLES

TABLE I.1
Initial and Calibrated Model Parameters

Parameter or Process	Unit	Initial Value or Range	Final Value or Range	Sources for Initial Values
Horizontal Saturated Hydraulic Conductivity (Ksat)	ft/d	1.0 - 50	1.3 - 89	Mason and Bota (2006), ACR, Appendices A, E
Vertical Ksat	ft/d	0.2 - 3.0	0.2 - 4.1	ACR, Appendices E
Storage Coefficient (S)	ft/ft	0.0001	0.0001	Mason and Bota (2006)
Specific Yield (Sy)	ft/ft	0.1	0.08 - 0.20	Fetter (2001)
Effective Porosity (θse)	ft^3/ft^3	0.25	0.20 - 0.30	Fetter (2001)
Dispersivity, α_L, α_T, α_V	ft	0, 0, 0	0, 0, 0 - 65	ACR, Appendix B, model calibration
Total River + Agricultural Recharge	ac-ft/yr	14,400 - 29,900	14,600 - 37,600	Mason and Bota (2006)
Western Mountain Front Recharge	ac-ft/yr	7,900	7,700	Mason and Bota (2006)
Southeastern Mountain Front Recharge	ac-ft/yr	2,100	2,600	Mason and Bota (2006)
Concentration in PDSTI Seepage	mg/L	1,956	1,956	ELMA (2007b)

Notes:

ft/d = feet per day
ft /ft = feet per feet
ft^3/ft^3 = cubic feet per cubic feet
ac-ft/yr = acre-feet per year
mg/L = milligrams per liter

TABLE I.2
Seepage Estimates for Tailing Impoundments

	SEEPAGE (ac-ft/yr)	
YEAR	**Sierrita Tailing Impoundment[a]**	**Esperanza Tailing Impoundment[b]**
1959	---	1,735
1960	---	2,312
1961	---	1,920
1962	---	1,906
1963	---	1,817
1964	---	1,548
1965	---	1,481
1966	---	1,639
1967	---	2,190
1968	---	2,155
1969	---	2,013
1970	---	1,738
1971	9,389	1,499
1972	11,507	0
1973	10,470	1,363
1974	9,388	2,556
1975	7,873	1,542
1976	9,114	1,457
1977	8,823	1,009
1978	10,664	0
1979	5,852	1,422
1980	6,149	2,273
1981	7,095	2,720
1982	2,482	---
1983	6,599	---
1984	5,131	---
1985	6,051	---
1986	2,508	---
1987	2,498	---
1988	2,241	---
1989	3,341	---
1990	10,664	---
1991	10,507	---
1992	9,271	---
1993	9,987	---
1994	7,587	---
1995	6,601	---
1996	5,327	---
1997	5,119	---
1998	6,072	---
1999	7,893	---
2000	9,356	---
2001	10,024	---
2002	2,859	---
2003	6,065	---
2004	4,655	---
2005	5,777	---
2006	7,467	---
Total	**252,406**	**38,294**

Notes:

[a] Errol L. Montgomery & Associates [ELMA] (2007b)

[b] High seepage estimates from ELMA (2007c)

ac-ft/yr = acre-feet per year

TABLE I.3
Results of Sensitivity Analysis

		Groundwater Levels		Sulfate Concentration	
Parameter	**Parameter Adjustment**	**ΔMAR (ft)**	**ΔRMSR (%)**	**ΔMAR (mg/L)**	**ΔRMSR (%)**
Horizontal Hydraulic Conductivity	+ 25	-9.60	10.6%	-11.7	2.92%
	- 25	13.1	13.4%	19.2	2.92%
Vertical Hydraulic Conductivity	+ 25	0.15	0.08%	1.89	0.31%
	- 25	-0.04	-0.08%	-3.08	-0.16%
Storage Coefficient	+ 25	-0.01	-0.01%	0.01	0.00%
	- 25	0.01	0.01%	0.00	0.00%
Specific Yield/Porosity	+ 25	-5.33	0.18%	64.1	-0.76%
	- 25	4.83	5.18%	-68.6	13.2%
Evapotranspiration	+ 25	0.00	0.00%	-0.03	0.01%
	- 25	-0.04	-0.05%	0.03	0.0%
River Recharge	+ 25	-4.12	2.08%	2.63	-0.25%
	- 25	6.46	4.15%	-5.21	4.15%
Mountain Front Recharge	+ 25	-5.54	3.23%	5.03	-1.60%
	- 25	-5.55	3.23%	5.02	-1.60%
PDSTI Seepage Rate	+ 25	-9.29	1.31%	-49.1	10.7%
	- 25	9.15	18.6%	56.9	0.53%
Concentration in PDSTI Seepage	+ 25	0.00	0.00	-80.4	41.2%
	- 25	0.00	0.00	80.3	-4.72%
ETI Seepage Rate	+ 25	-0.33	-0.08%	-7.85	3.36%
	- 25	0.39	0.12%	7.93	-3.26%
Concentration in ETI Seepage	+ 25	0.00	0.00%	61.0	7.96%
	- 25	0.00	0.00%	9.33	-4.84%

Notes:

ΔMAR = Change in Mean Arithmetic Error between calibrated model and sensitivity simulation

ΔRMSR = Change in Root Mean Square Error between calibrated model and sensitivity simulation

PDSTI = Phelps Dodge Sierrita Tailing Impoundment

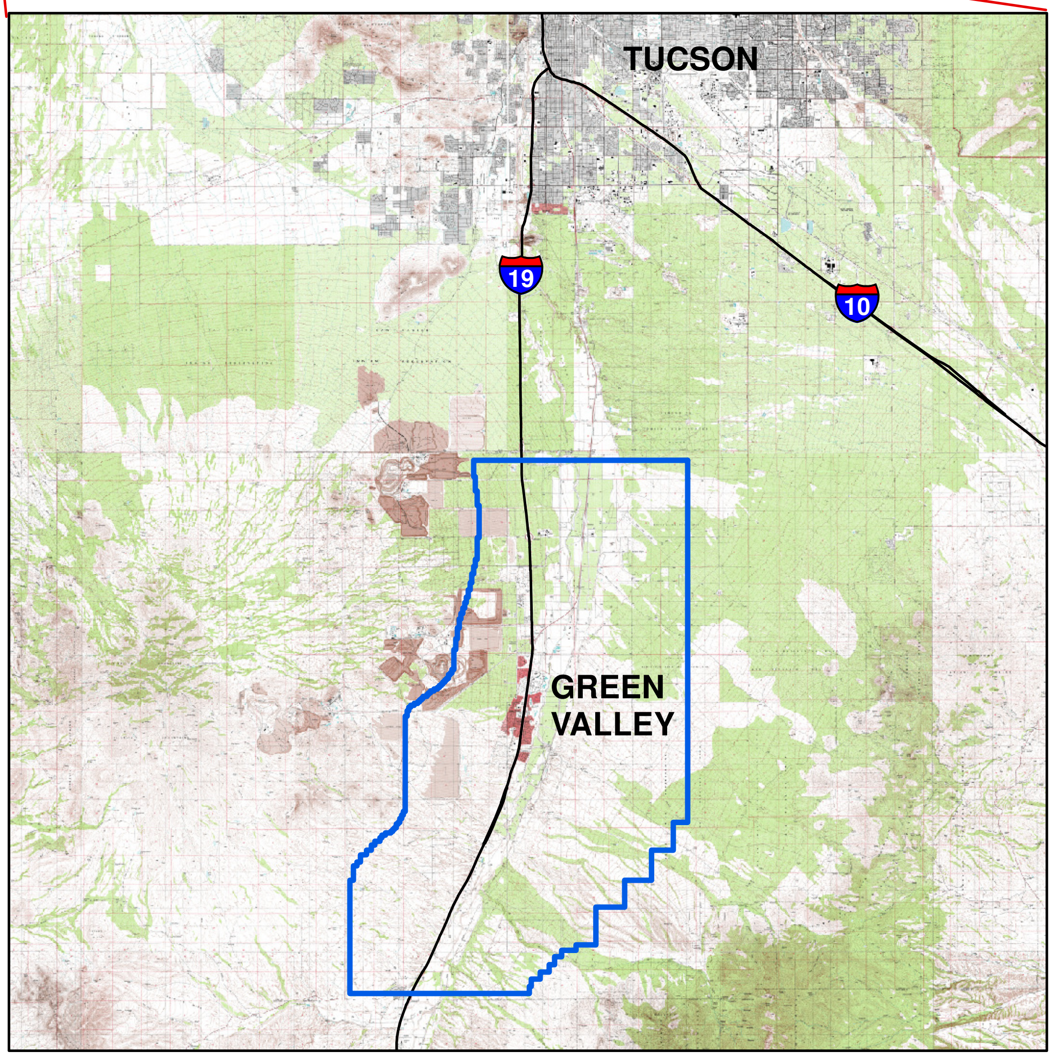
ETI = Esperanza Tailing Impoundment

ft = feet

mg/L = millligrams per liter

% = percent

FIGURES



Legend

Model Extents

0 1 2 3 4 5 Miles

PROJECTION:
UTM Zone 12N NAD83

N

HYDRO GEO CHEM, INC.

SITE LOCATION					
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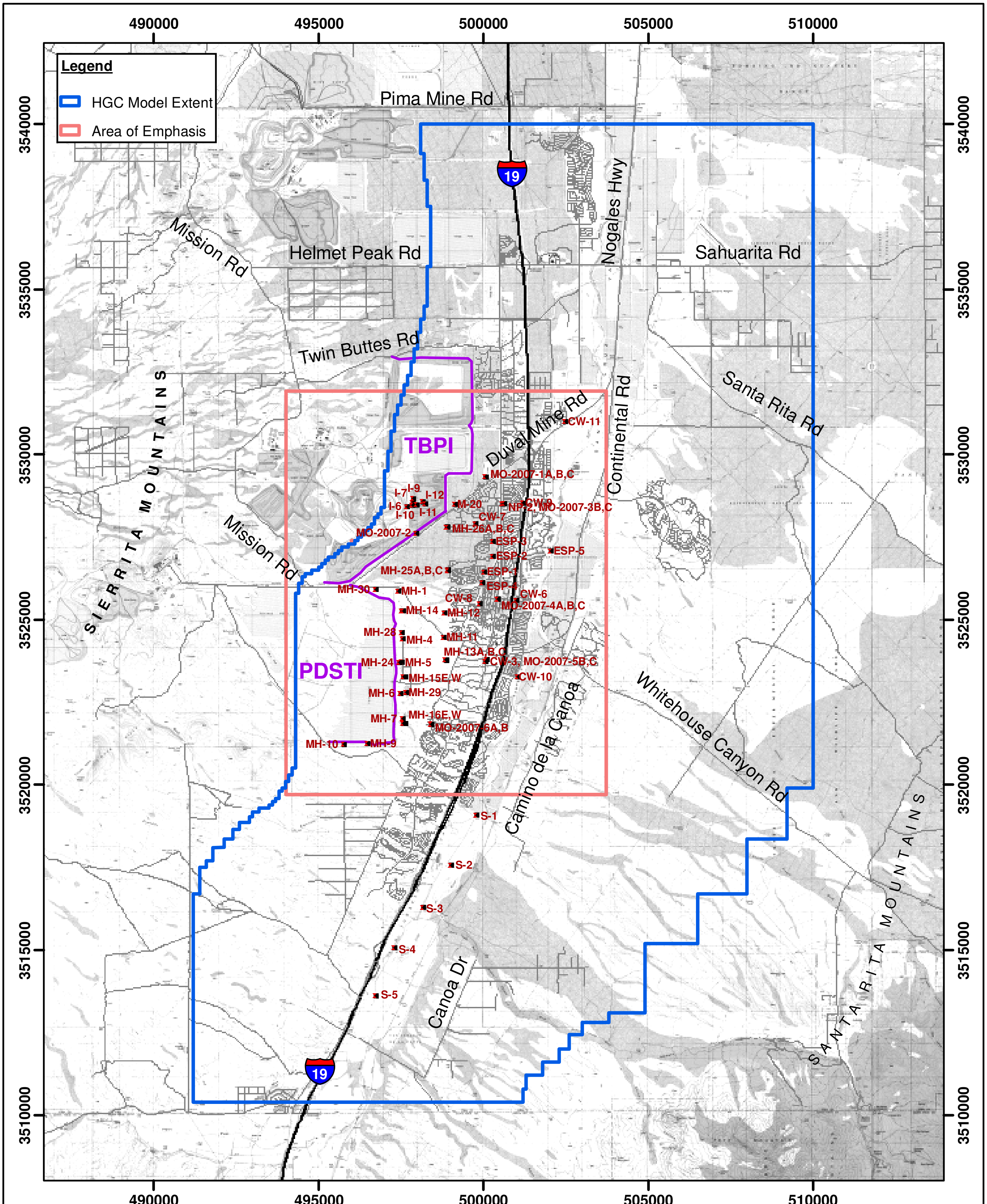

0 6,500 13,000 Feet

PROJECTION:
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MODEL EXTENTS AND WELL LOCATIONS

Approved	Date	Author	Date	File Name	Figure
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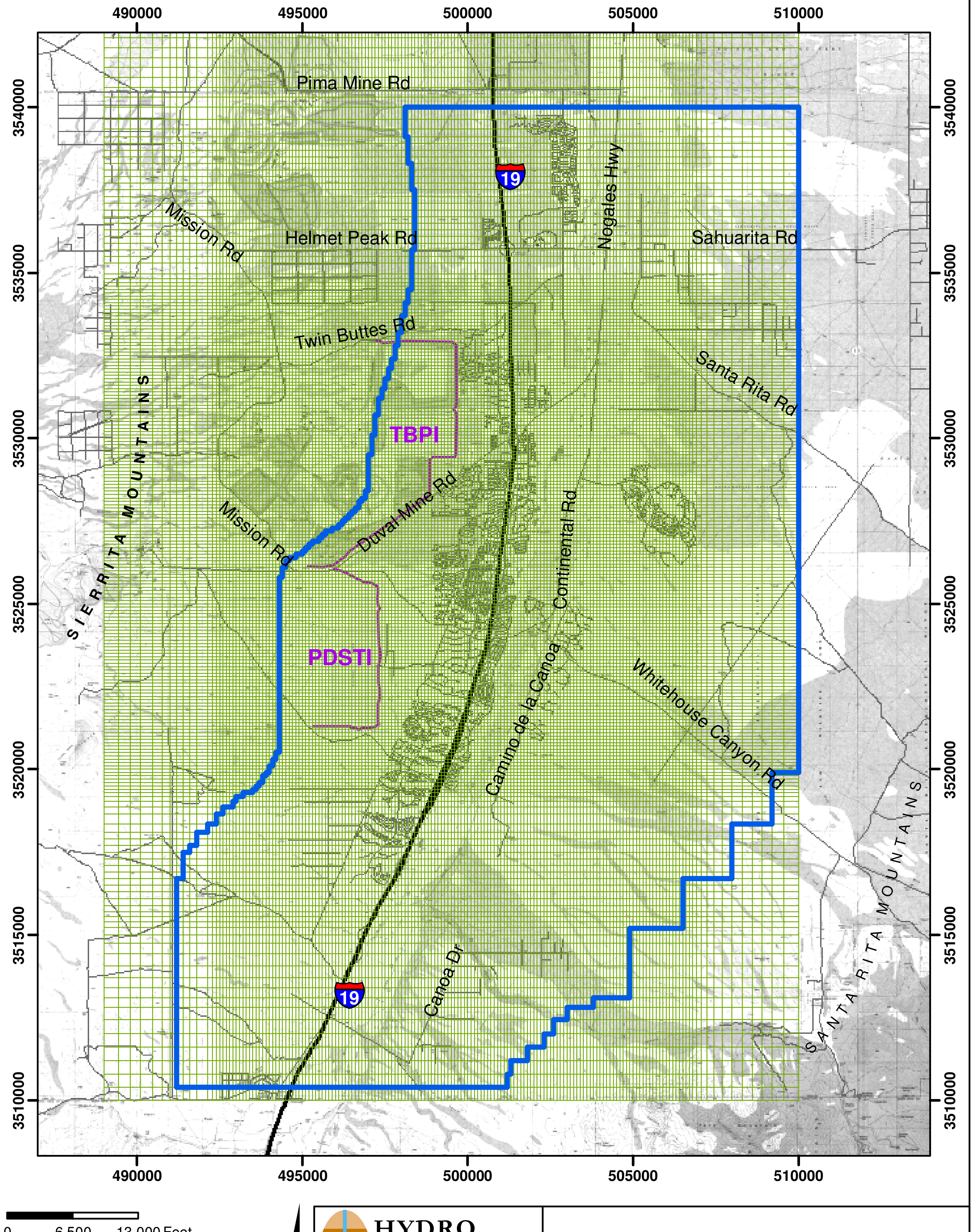

PROJECTION:
UTM Zone 12N NAD83

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MODEL DISCRETIZATION

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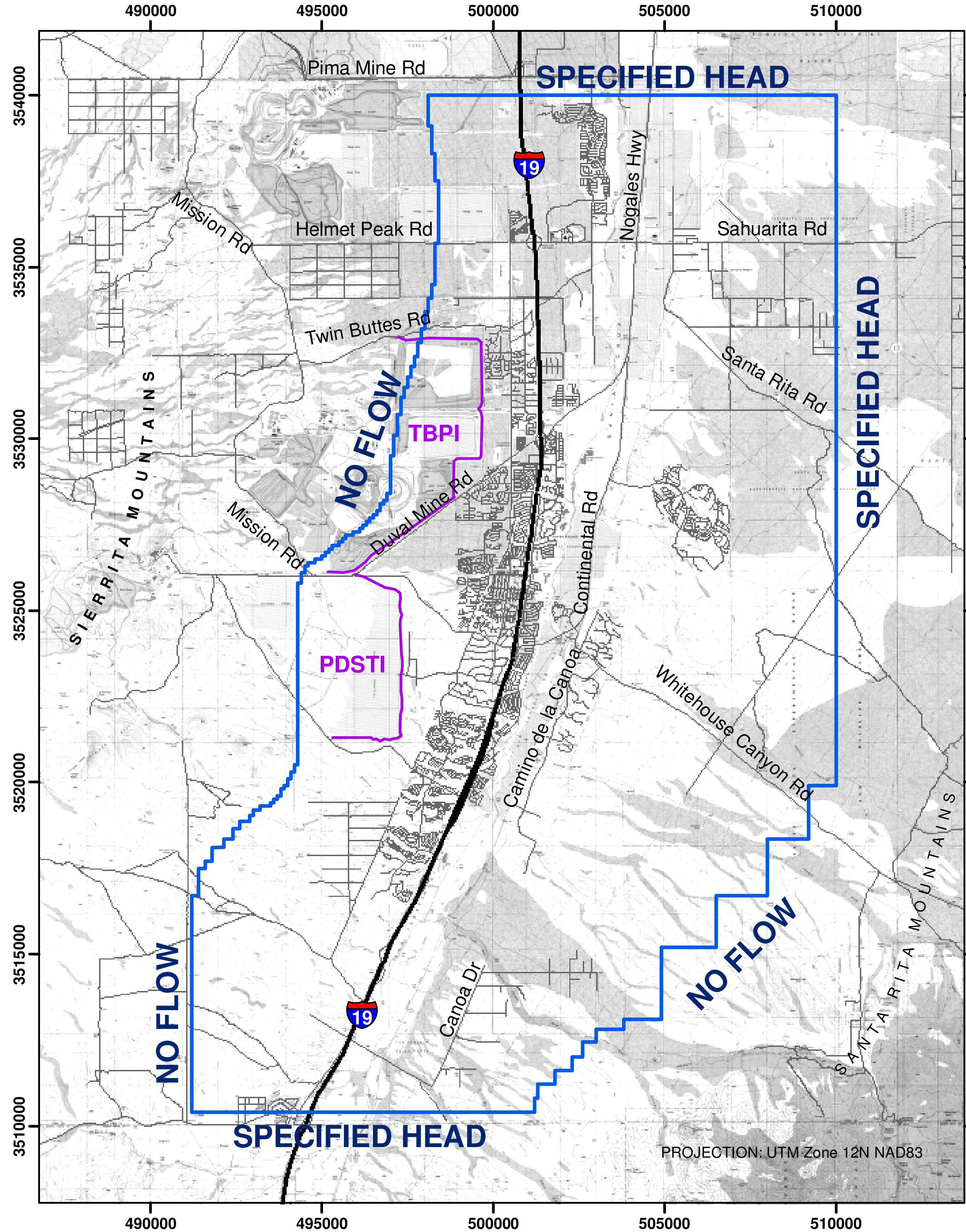

PROJECTION:
UTM Zone 12N NAD83

HYDRO GEO CHEM, INC.

MODEL BOUNDARY CONDITIONS

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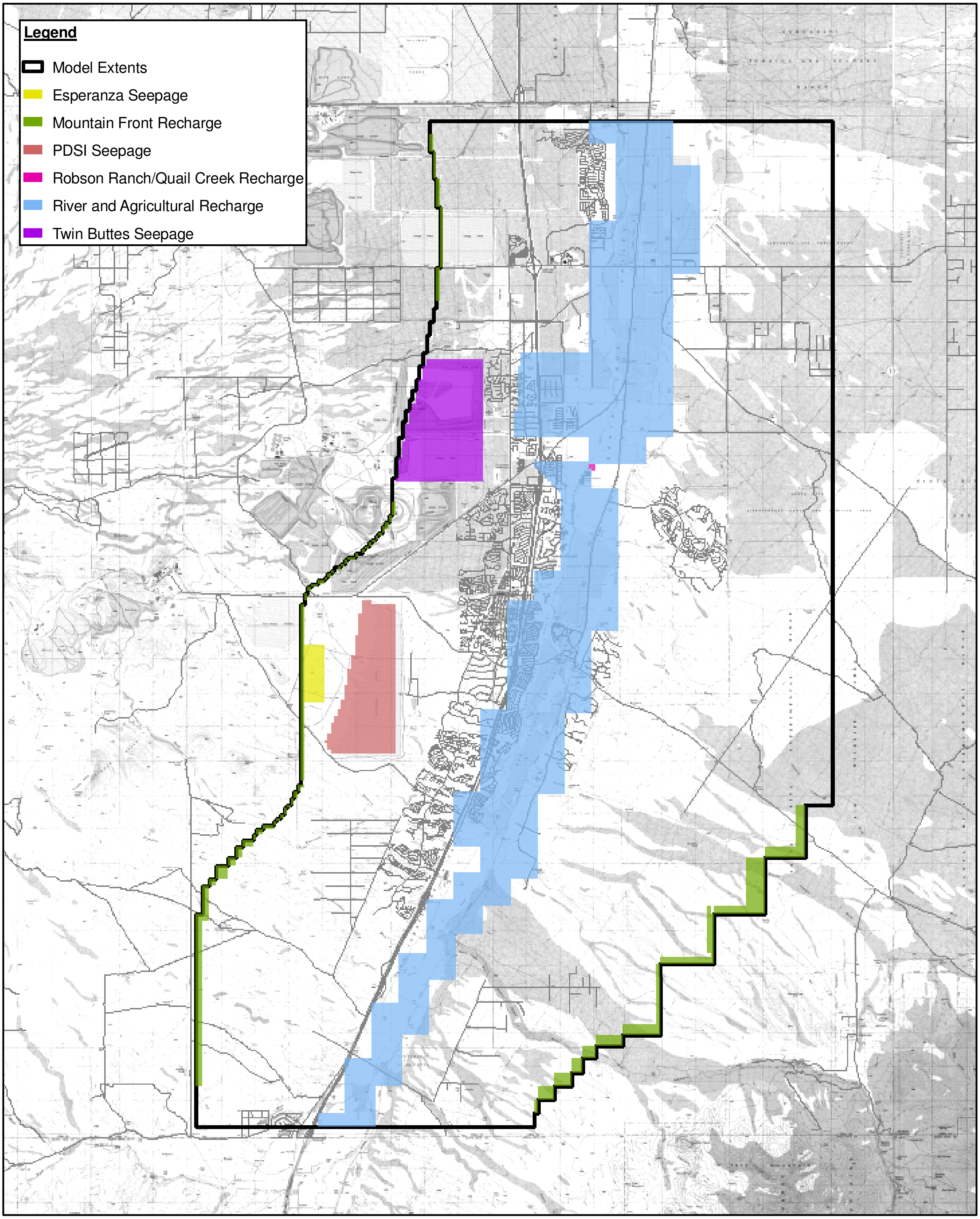

0 6,500 13,000 Feet

PROJECTION:
UTM Zone 12N NAD83

N

HYDRO GEO CHEM, INC.

MODEL RECHARGE ZONES FOR 1980

Approved	Date	Author	Date	File Name	Figure
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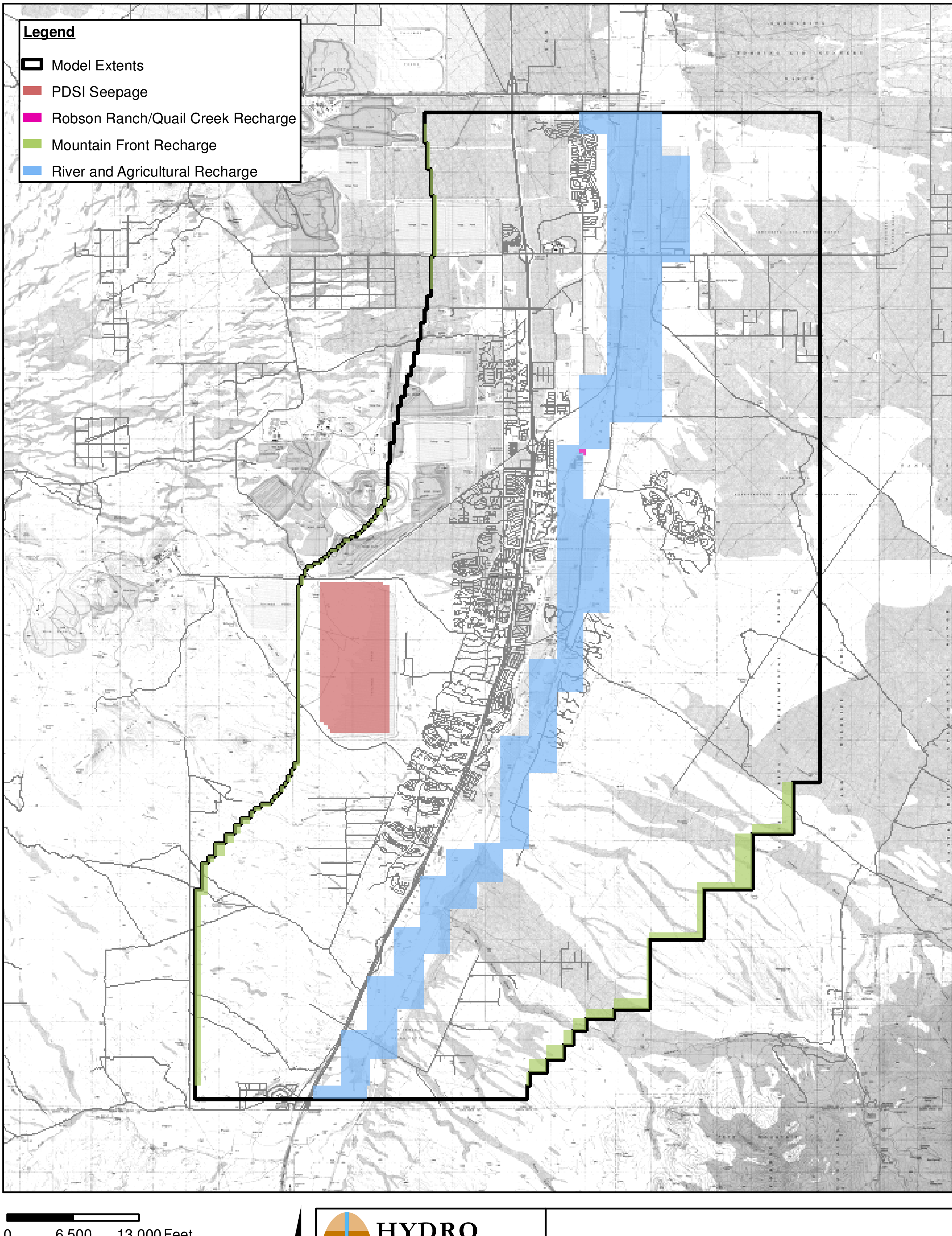

PROJECTION:
UTM Zone 12N NAD83

HYDRO GEO CHEM, INC.

MODEL RECHARGE ZONES FOR 2006

Approved	Date	Author	Date	File Name	Figure
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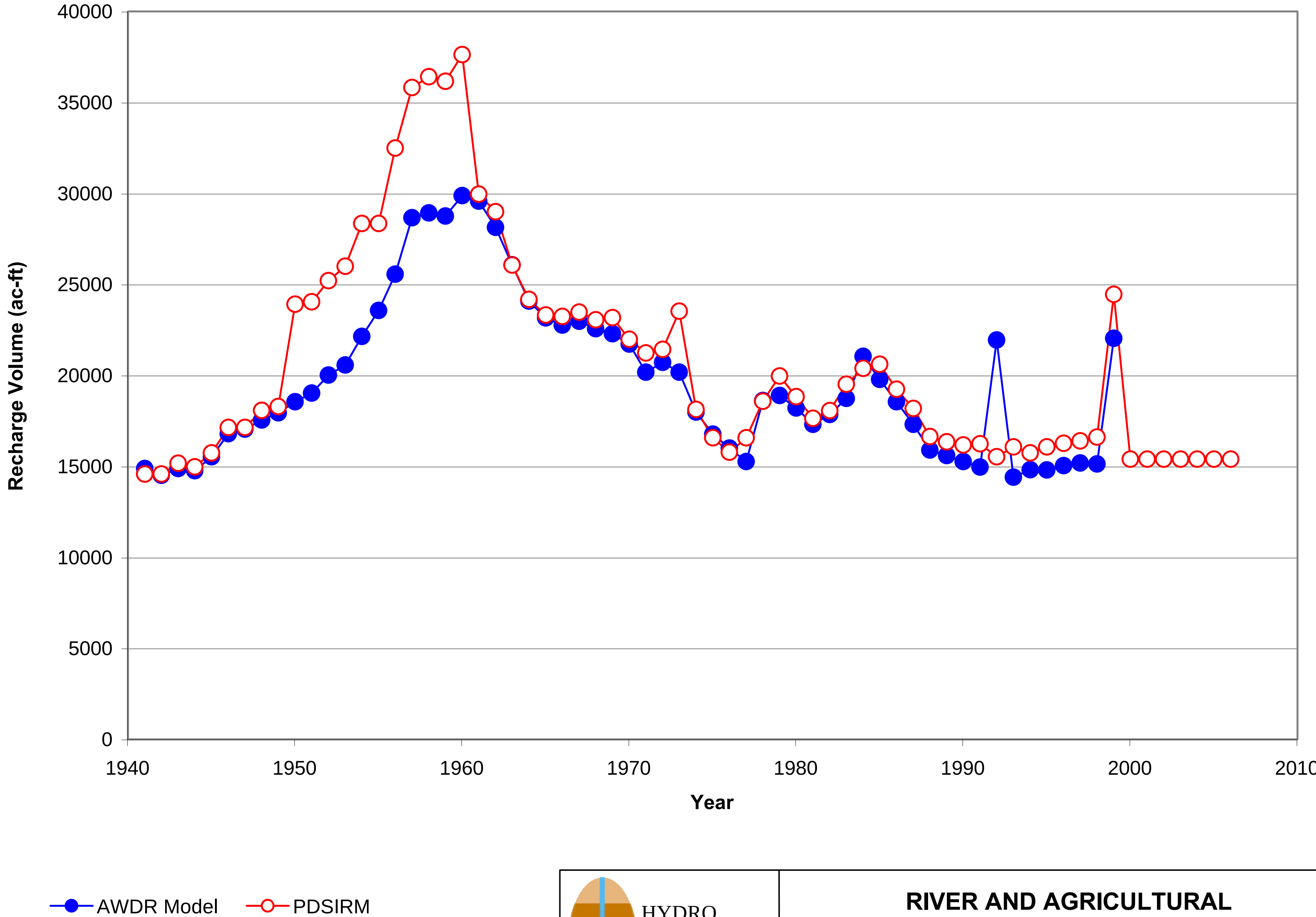

HYDRO GEO CHEM, INC.

RIVER AND AGRICULTURAL RECHARGE VOLUMES

APPROVED	DATE	FIGURE
NWH	11/17/2007	**I.7**

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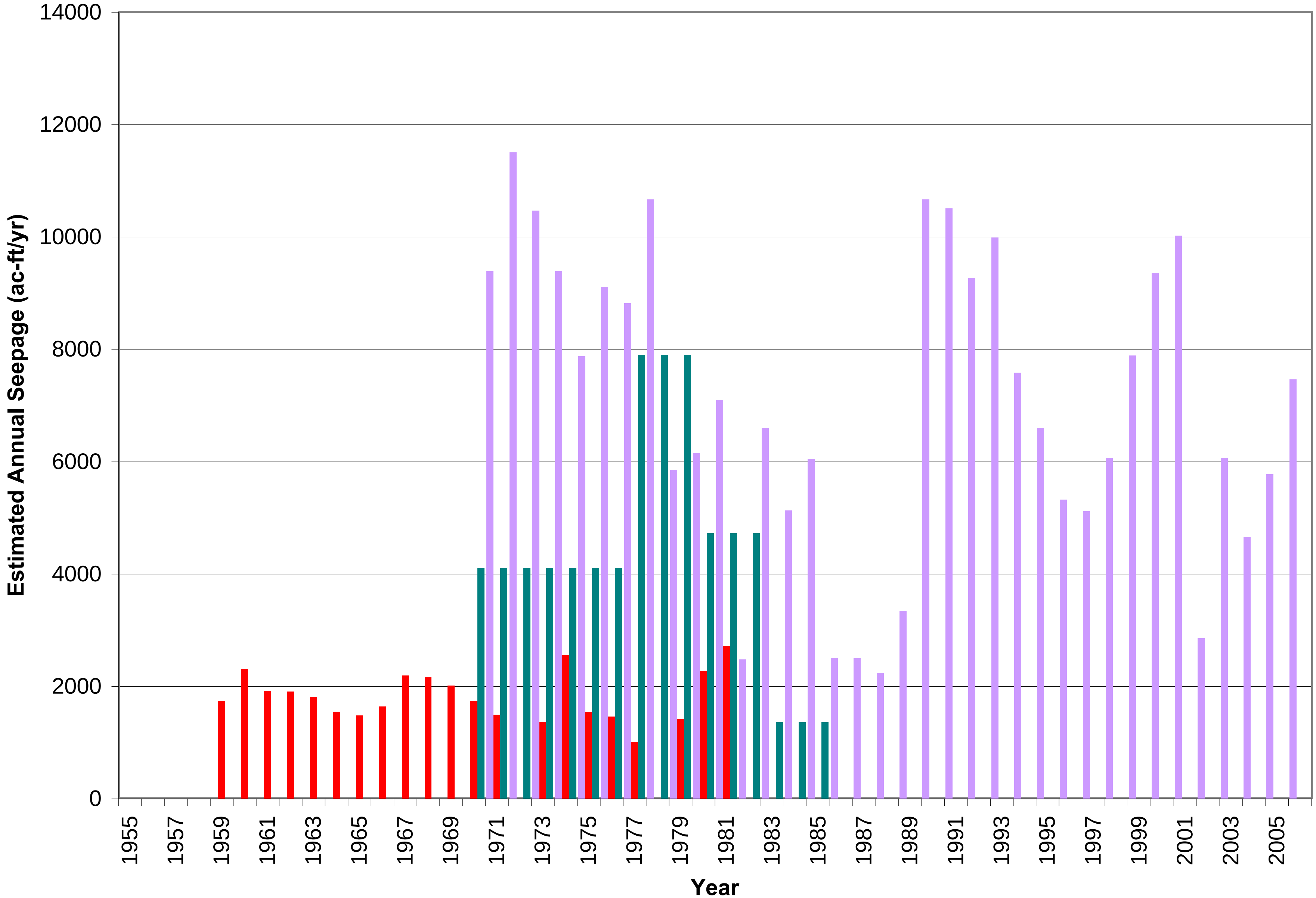
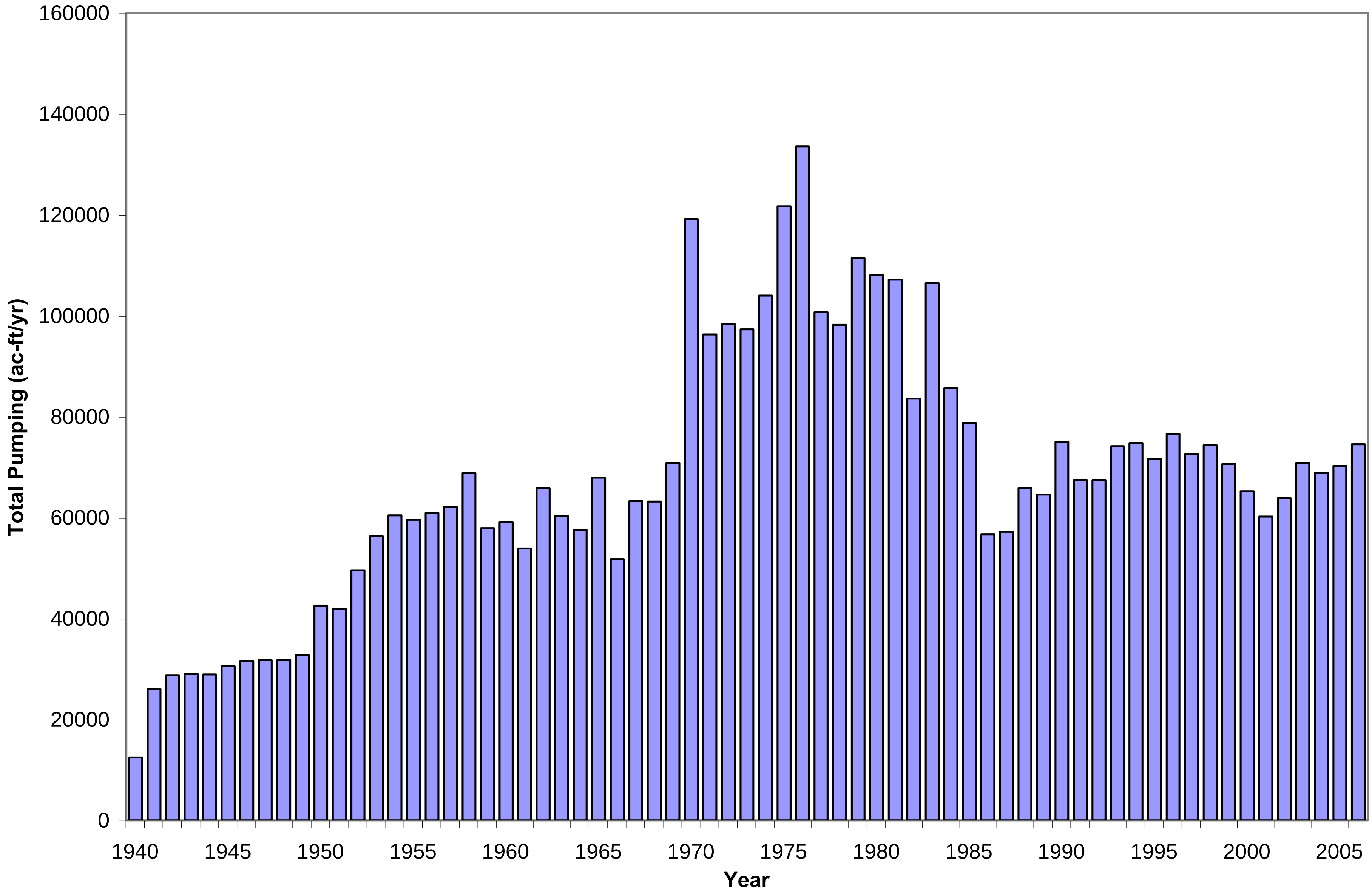


HYDRO GEO CHEM, INC.

SEEPAGE RATE ESTIMATES FOR TAILING IMPOUNDMENTS

APPROVED	DATE	FIGURE
NWH	11/17/2007	**I.8**

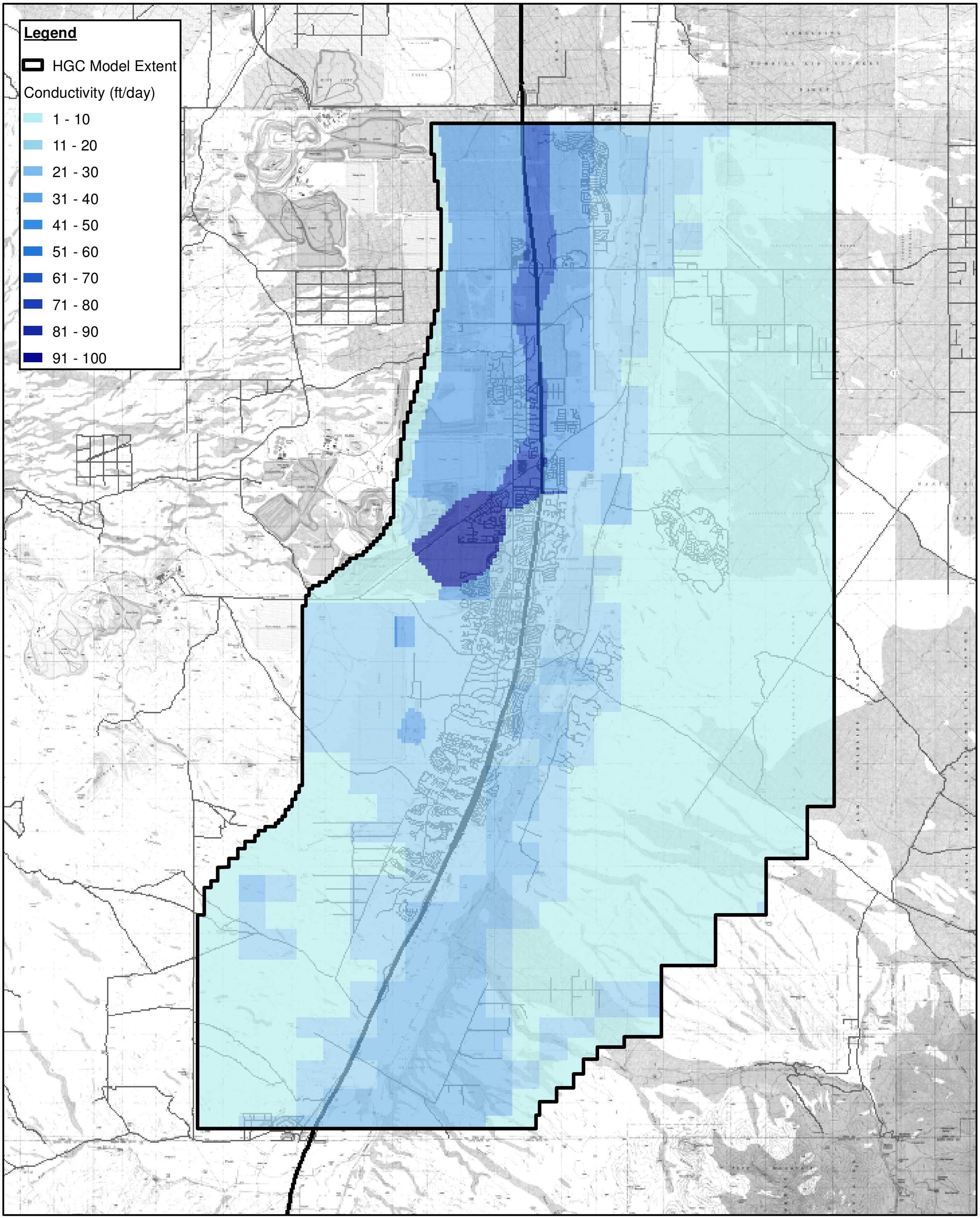


HYDRO GEO CHEM, INC.

TOTAL PUMPING IN MODEL DOMAIN (1940 - 2006)

APPROVED	DATE	FIGURE
NWH	11/17/2007	**I.9**

H:\78300\78314 Numerical Model\Report\PDSIRM_figures.xls: F9 Ptotals



0 6,500 13,000 Feet

PROJECTION:
UTM Zone 12N NAD83

N

HYDRO GEO CHEM, INC.

SATURATED HYDRAULIC CONDUCTIVITY DISTRIBUTION IN MODEL LAYER 1

Approved	Date	Author	Date	File Name	Figure
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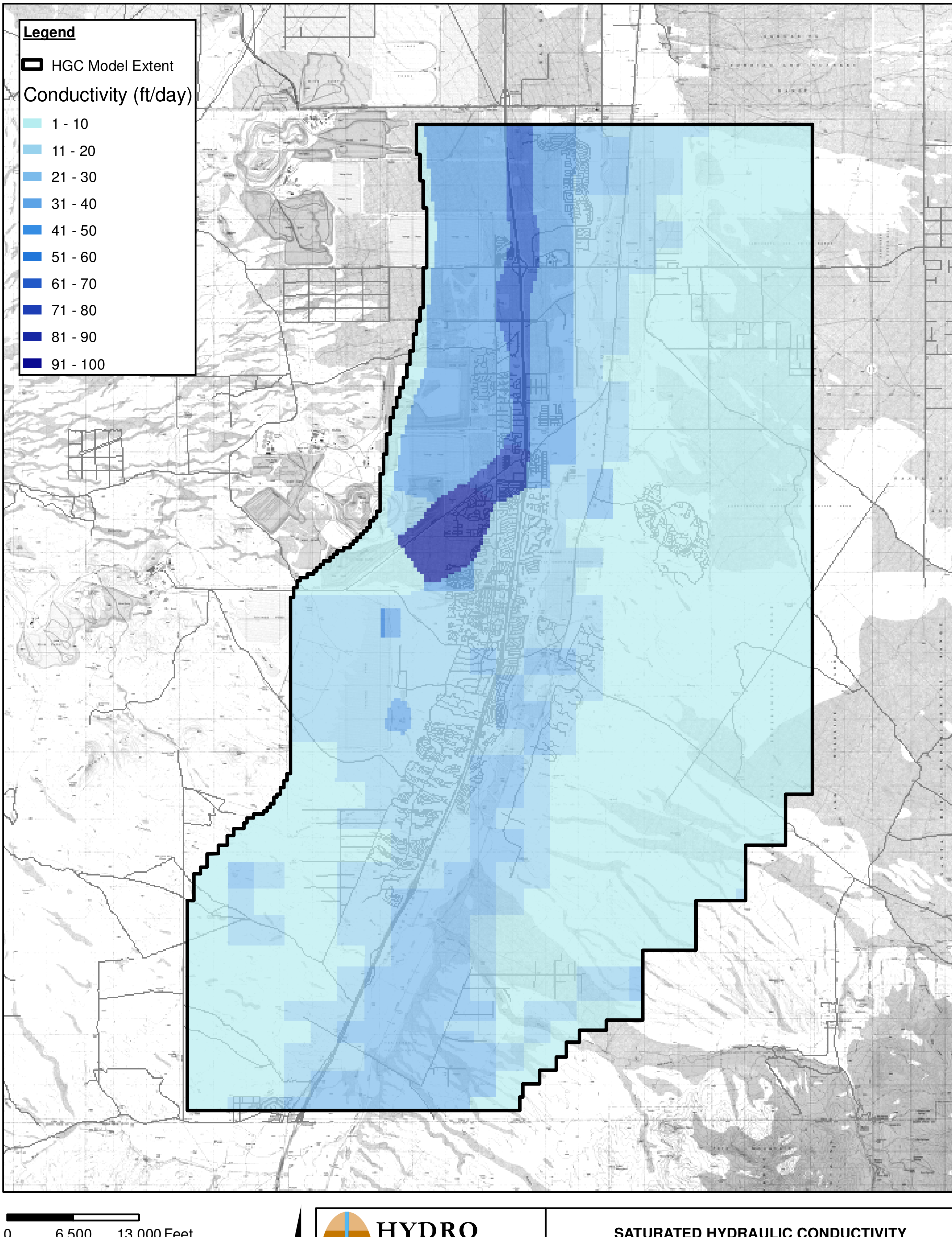

PROJECTION:
UTM Zone 12N NAD83

HYDRO GEO CHEM, INC.

SATURATED HYDRAULIC CONDUCTIVITY DISTRIBUTION IN MODEL LAYER 2

Approved	Date	Author	Date	File Name	Figure
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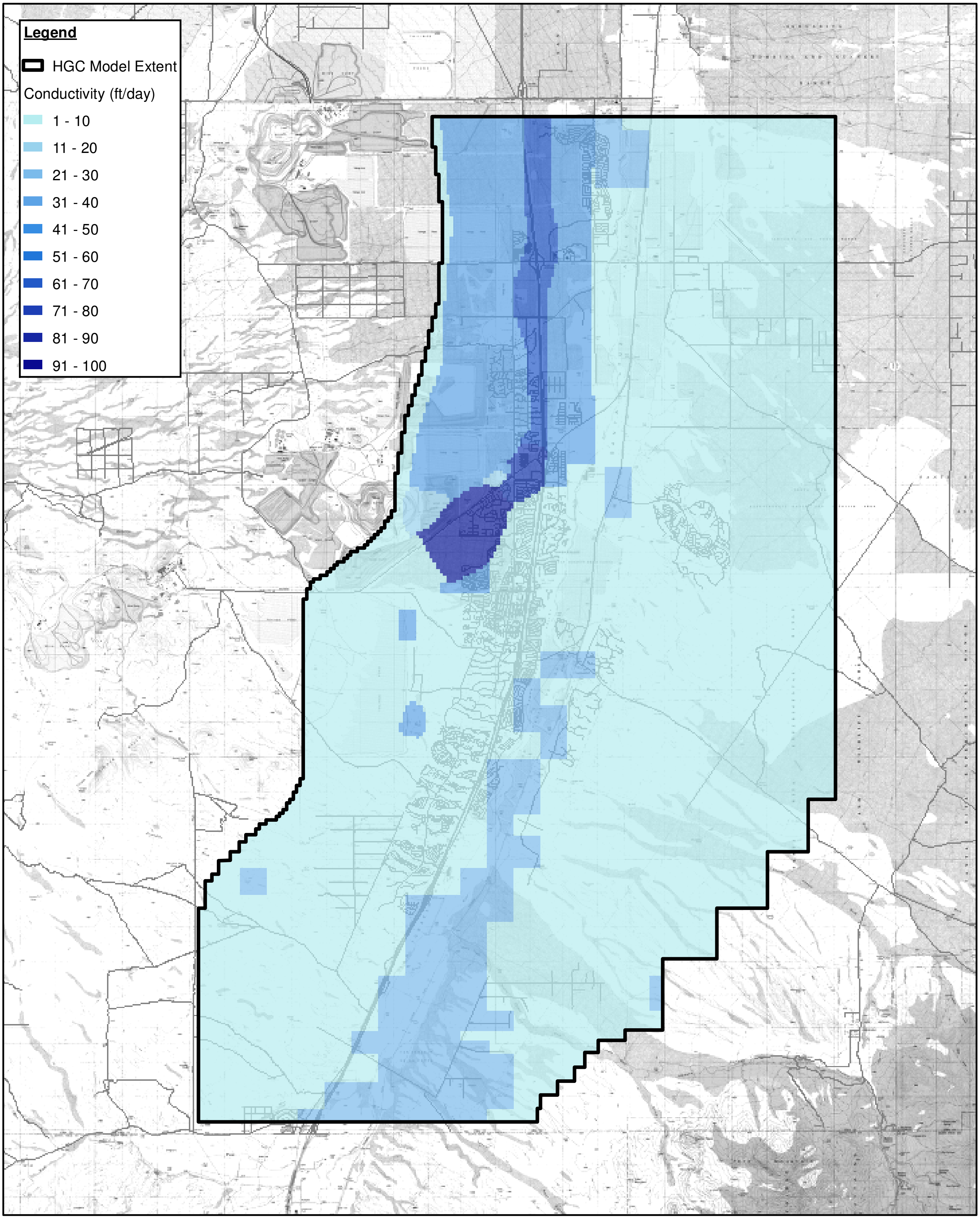

0 6,500 13,000 Feet

PROJECTION:
UTM Zone 12N NAD83

N

HYDRO
GEO
CHEM, INC.

SATURATED HYDRAULIC CONDUCTIVITY DISTRIBUTION IN MODEL LAYER 3

Approved	Date	Author	Date	File Name	Figure
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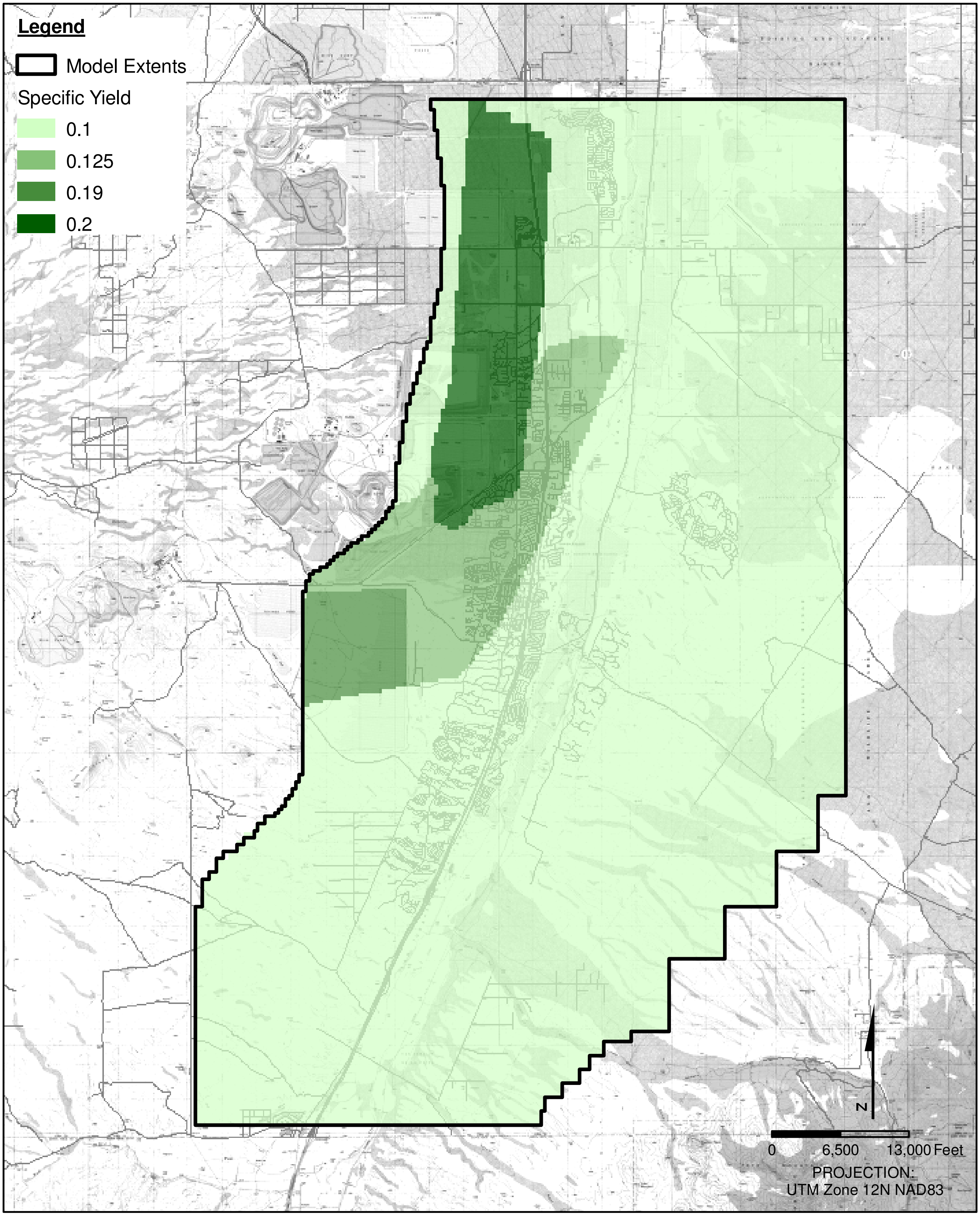

HYDRO GEO CHEM, INC.

SPECIFIC YIELD DISTRIBUTION IN MODEL DOMAIN

Approved	Date	Author	Date	File Name	Figure
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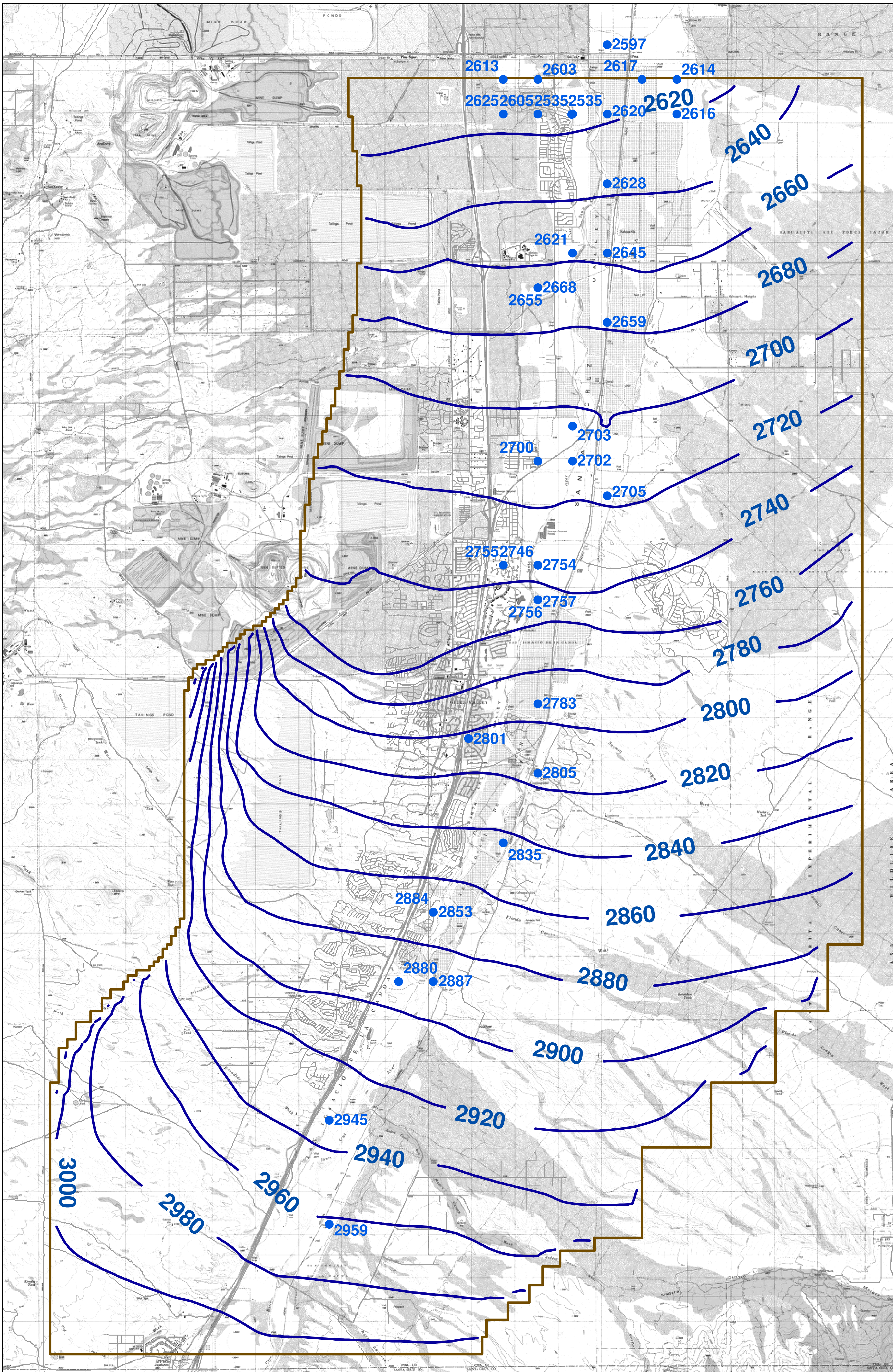

Legend

- 1940 Measured Data
- Simulated Groundwater Contours
- Model Extents

0 3,500 7,000 Feet

PROJECTION:
UTM Zone 12N NAD83

N

HYDRO GEO CHEM, INC.

SIMULATED GROUNDWATER LEVEL CONTOURS WITH MEASURED DATA FOR 1940 STEADY-STATE SIMULATION

Approved	Date	Author	Date	File Name	Figure
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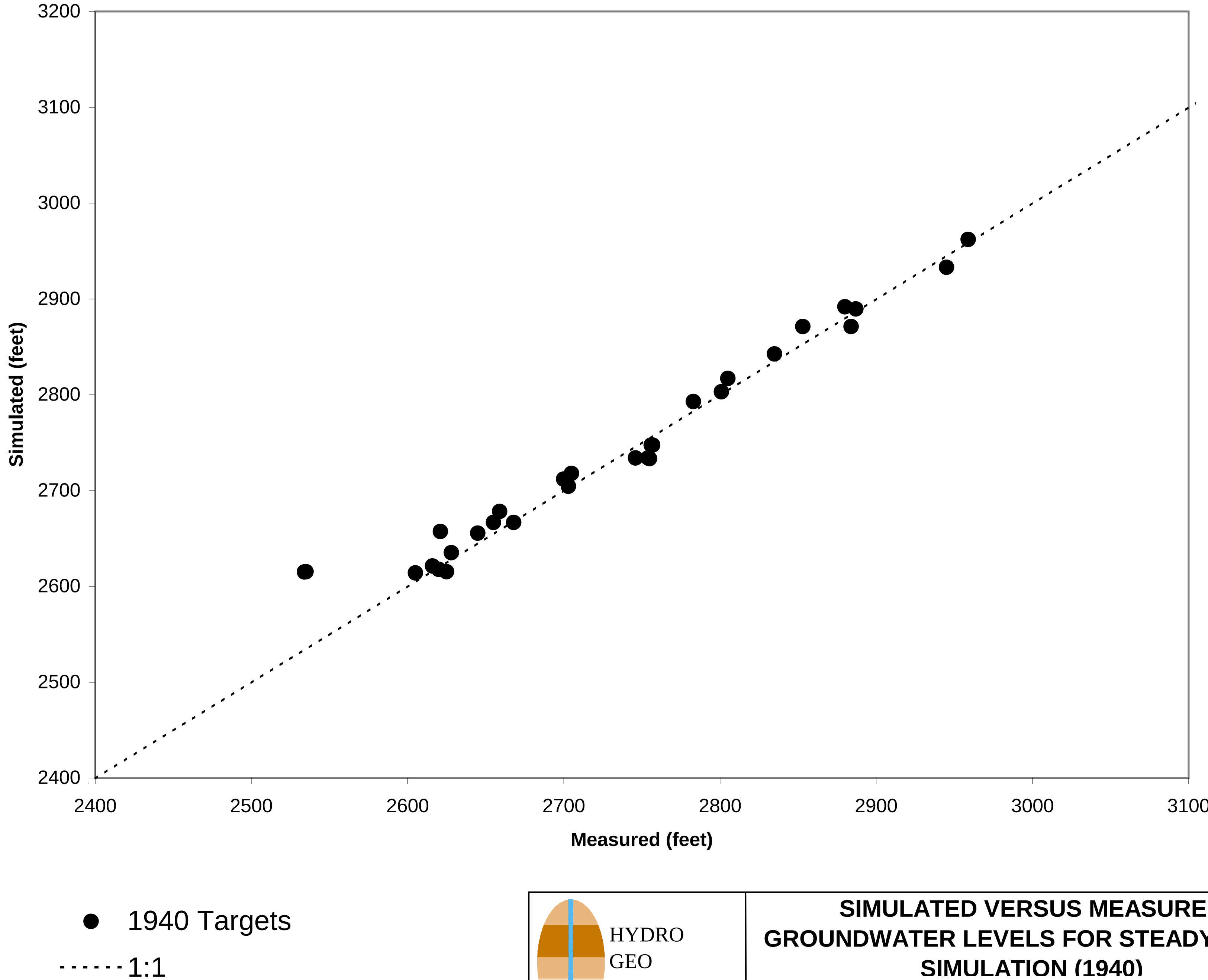

HYDRO GEO CHEM, INC.

SIMULATED VERSUS MEASURED GROUNDWATER LEVELS FOR STEADY-STATE SIMULATION (1940)

APPROVED	DATE	FIGURE
NWH	11/21/2007	I.15

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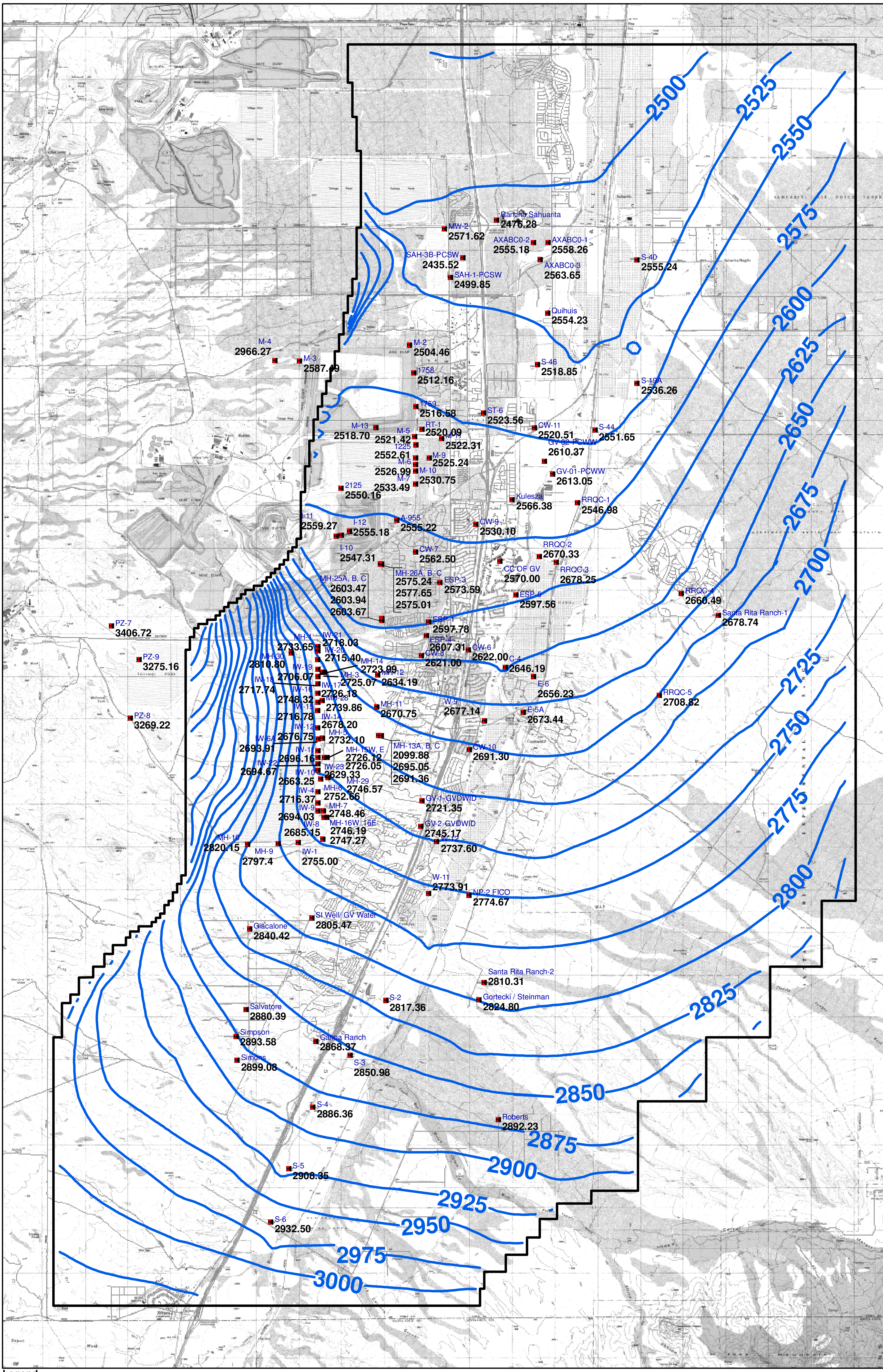

Legend

M-2 Well Location & Identifier

2504.46 Measured Groundwater Elevation (ft amsl)

Simulated Groundwater Contours

Model Extents

0 3,500 7,000 Feet

PROJECTION:
UTM Zone 12N NAD83

N

HYDRO GEO CHEM, INC.

SIMULATED GROUNDWATER LEVEL CONTOURS FOR THE END OF 2006 WITH MEASURED GROUNDWATER LEVELS FROM FIRST QUARTER 2007

Approved	Date	Author	Date	File Name	Figure
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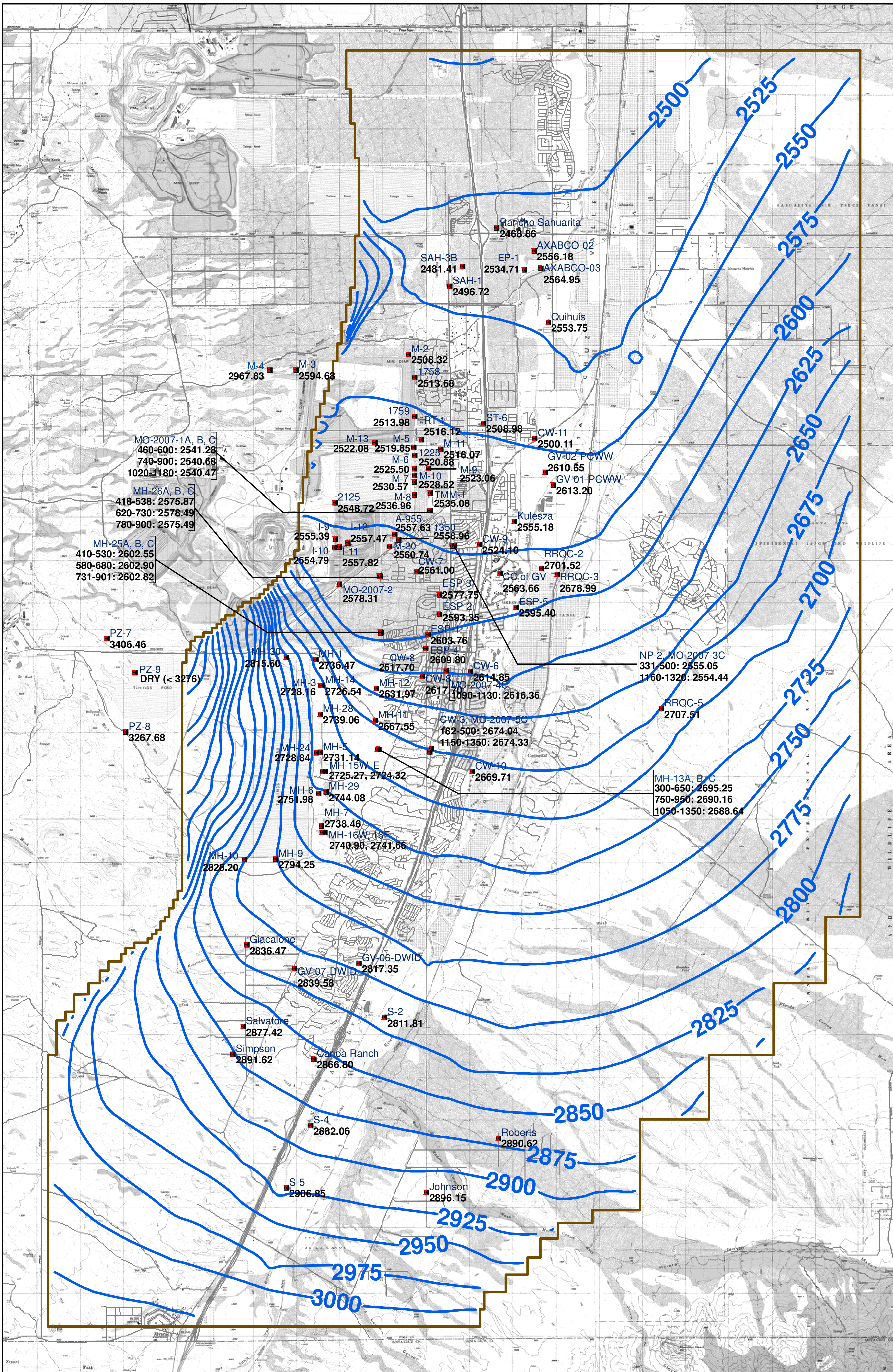

Legend

M-2 Well Location & Identifier

2504.46 Measured Groundwater Elevation (ft amsl)

Simulated Groundwater Contours

Model Extents

0 3,500 7,000 Feet

PROJECTION:
UTM Zone 12N NAD83

N

HYDRO GEO CHEM, INC.

SIMULATED GROUNDWATER LEVEL CONTOURS FOR THE END OF 2006 WITH MEASURED GROUNDWATER LEVELS FROM THIRD QUARTER 2007

Approved	Date	Author	Date	File Name	Figure
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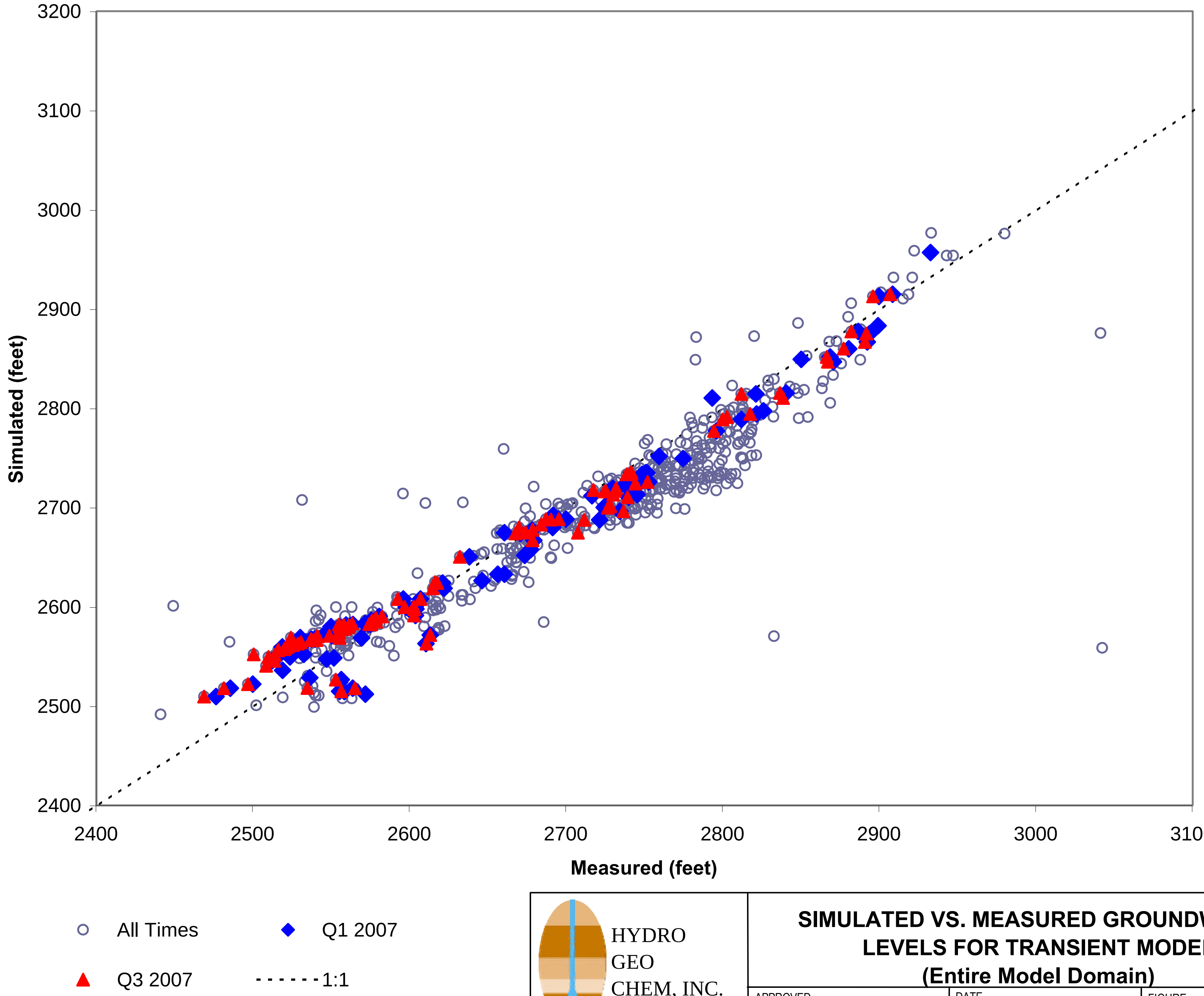
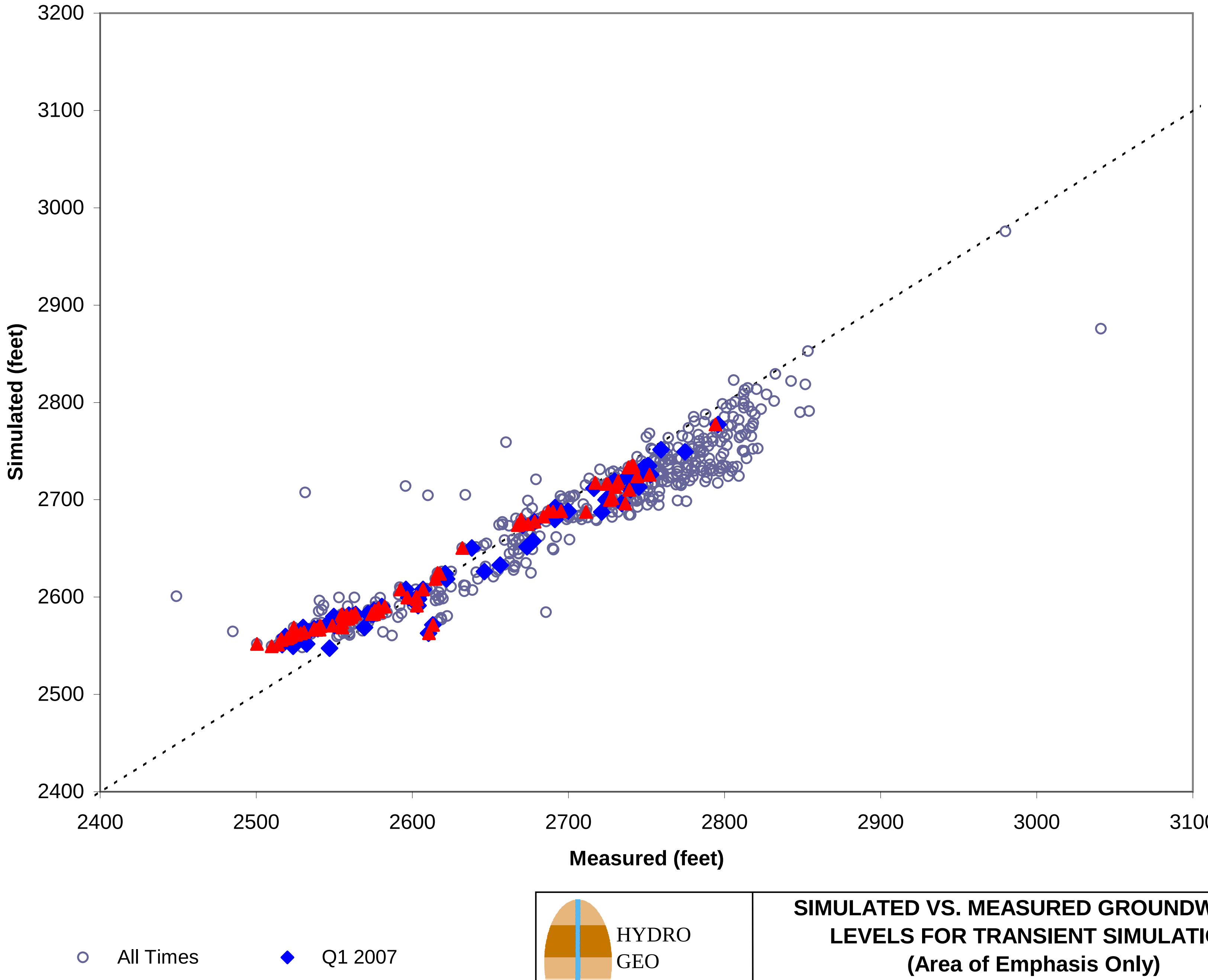


HYDRO GEO CHEM, INC.

SIMULATED VS. MEASURED GROUNDWATER LEVELS FOR TRANSIENT MODEL (Entire Model Domain)

APPROVED	DATE	FIGURE
NWH	11/21/2007	**I.18**



HYDRO GEO CHEM, INC.

SIMULATED VS. MEASURED GROUNDWATER LEVELS FOR TRANSIENT SIMULATION (Area of Emphasis Only)

APPROVED	DATE	FIGURE
NWH	11/21/2007	**I.19**

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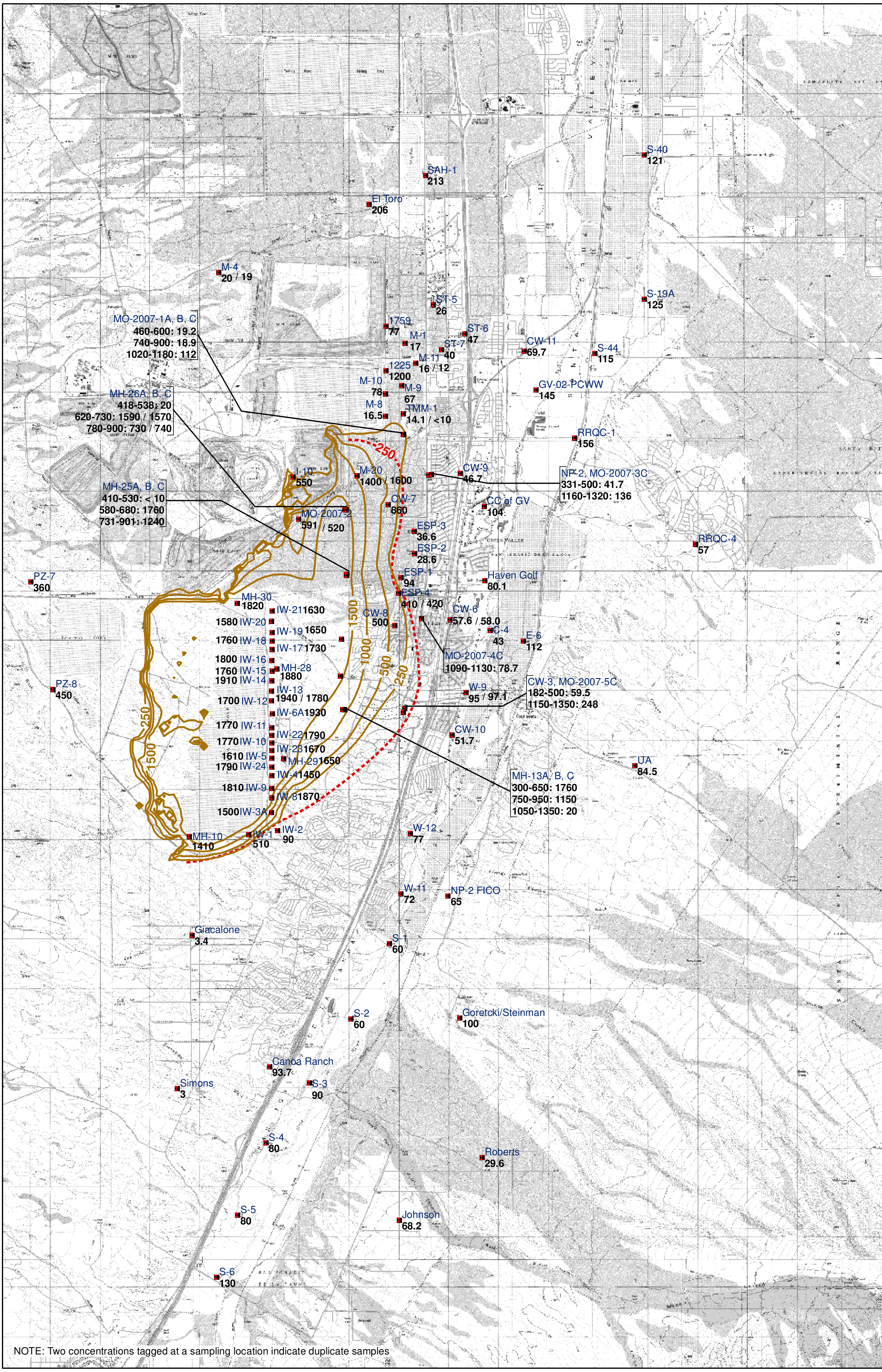

NOTE: Two concentrations tagged at a sampling location indicate duplicate samples

Legend

- M-1 Well Location & Identifier
- 17 Sulfate Concentration (mg/L)
- Screen (ft bgs): Sulfate Concentration (mg/L)
- Simulated Sulfate Contours
- Measured 250 mg/L Sulfate Contour

0 3,000 6,000 Feet

PROJECTION:
UTM Zone 12N NAD83

N

HYDRO GEO CHEM, INC.

SIMULATED AVERAGE SULFATE CONCENTRATION CONTOURS FOR THE END OF YEAR 2006 WITH MEASURED SULFATE CONCENTRATIONS FROM THIRD QUARTER 2007

Approved	Date	Author	Date	File Name	Figure
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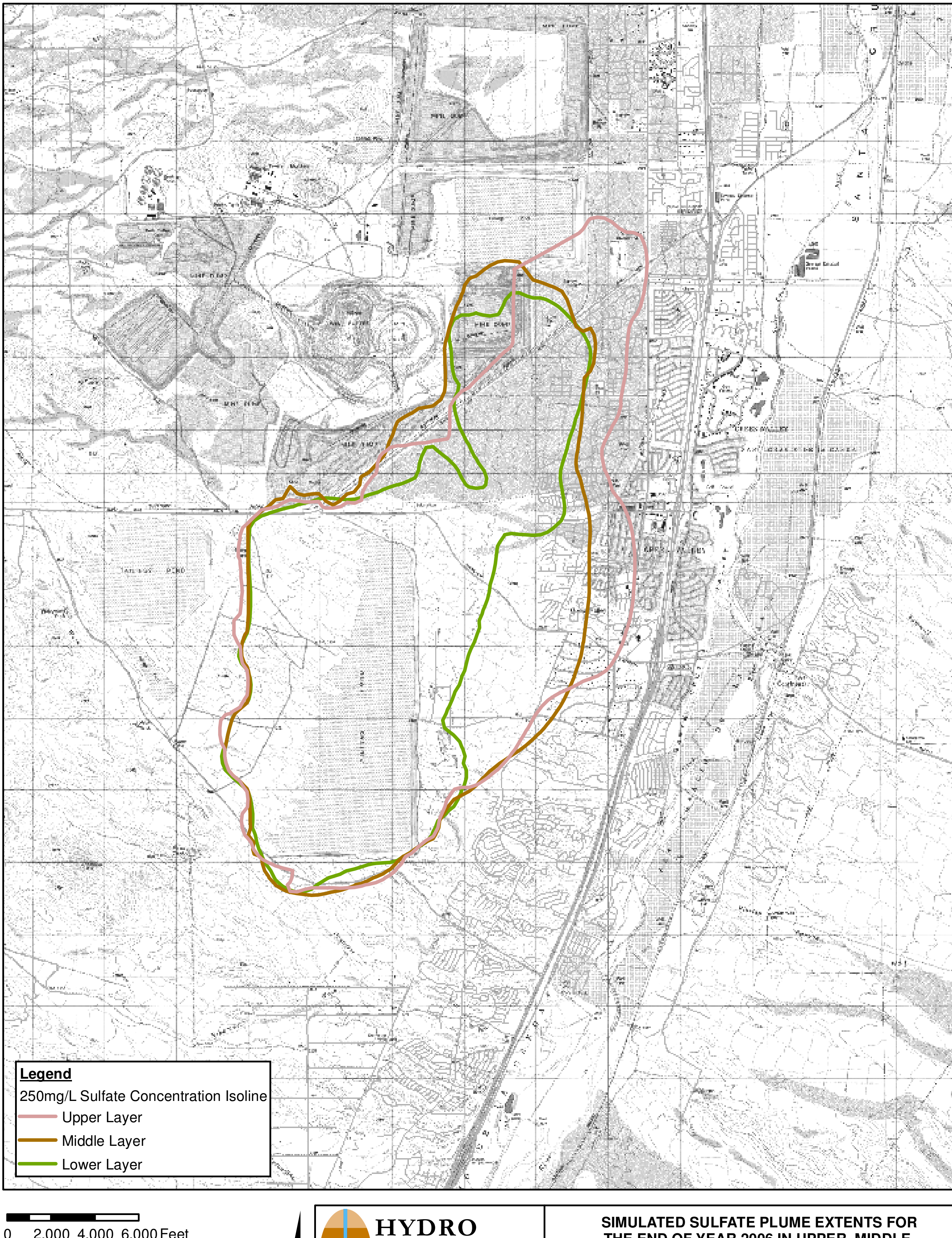


PROJECTION:
UTM Zone 12N NAD83

HYDRO GEO CHEM, INC.

SIMULATED SULFATE PLUME EXTENTS FOR THE END OF YEAR 2006 IN UPPER, MIDDLE, AND LOWER MODEL LAYERS

Approved	Date	Author	Date	File Name	Figure
NWH	01/22/09	RAM	01/22/09	78301421G	I.21

APPENDIX I.1

WELL LOCATIONS AND PUMPING RATES

TABLE I.1.1
Well Locations and Pumping Rates for Steady-State (1940) Simulation

UTM83E	UTM83N	Pumping Rate (gpm)
496051	3511005	15
496051	3511810	15
496051	3512615	15
496855	3511005	15
496855	3511810	15
496855	3512615	15
497660	3515029	15
497660	3515833	15
498465	3515029	15
498465	3515833	15
500879	3519857	68
500879	3522271	155
500879	3523075	316
500879	3524685	93
500879	3525489	93
500879	3526294	78
500879	3527099	62
500879	3530318	16
501683	3522271	155
501683	3524685	93
501683	3525489	93
501683	3526294	78
501683	3527099	78
501683	3529513	16
501683	3530318	16
502488	3524685	78
502488	3525489	78
502488	3526294	78
502488	3527099	78
502488	3527904	101
502488	3528686	101
502488	3542388	62
502415	3543192	62
503293	3524685	78
503293	3525489	78
503270	3526294	78
503293	3527099	78
503293	3527904	101

TABLE I.1.1
Well Locations and Pumping Rates for Steady-State (1940) Simulation

UTM83E	UTM83N	Pumping Rate (gpm)
503293	3528708	101
503293	3542388	62
503293	3543192	62
504097	3529513	93
504097	3530318	93
504097	3531927	868
504097	3532732	336
504074	3535950	310
504097	3537560	139
504097	3538364	279
504097	3539169	174
504097	3539974	174
504097	3542388	62
504097	3543192	62
504902	3529513	93
504902	3530318	93
504902	3533536	336
504902	3535146	310
504902	3537560	139
504902	3539169	174
504902	3539974	174
504902	3542388	62
504902	3543192	62
505707	3536755	558
505707	3537560	78
505707	3538364	78
506511	3537560	78
506511	3538364	78

Notes:
Well locations and pumping rates from ADWR Model (Mason and Bota, 2006)
UTM83E = Universal Transverse Mercator, North American Datum 1983, East
UTM83N = Universal Transverse Mercator, North American Datum 1983, North
gpm = gallons per minute

TABLE I.1.2
Well Locations and Pumping Rates for
Transient Simulation, taken from ADWR Model (Mason and Bota, 2006)

Well ID	UTM83E	UTM83N	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
ANAMAX	502488	3531123	0	0	0	0	0	0	0	0	0	0	0	337	479	479	479	479	479	0	0	0	0	0	0	0	595	421	105	0	574	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANAMAX MINING COMPANY	502488	3532732	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANAMAX MINING COMPANY	502488	3534341	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1830	604	176	171	521	1839	2246	1601	2710	1940	547	1643	1365	923	0	799	874	816	604
COT:SC-024 A	508121	3538365	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	628	661	668	612	338	495	285	451	534	536	380	207
CYPRUS PIMA ASSOCIATES	503293	3539974	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	505	0
CYPRUS/DUVAL	500074	3521467	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	306	1684	1193	1298	1379	1404	1417	1499	1995	2505	2802	2505	0	0	0	0	0	0	0	0	0	0	0	0	0
D-15-13 15DCA	500074	3534341	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	296	296	296	296	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-16-13 34AAB - ASARCO	500074	3539974	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	44	44	317	723	1034	428	673	506	1268	1599	1126	750	1050	1057	285	218	303	419	358	0	0	0	0	0
D-16-13 35A	501683	3539974	0	0	0	0	0	0	0	0	0	0	0	0	53	53	53	53	53	386	407	407	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-16-13 35AAA & 35ABB ASARCO	501683	3539974	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1168	946	1131	561	206	231	1149	949	1127	436	886	0	730	594	424	410	905	1393	1385	1250
D-16-13 35BBB & BAB MISSION	500879	3539974	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	544	2412	1984	609	1309	760	1014	1399	1723	1130	1157	1193	2275	2076	0	2001	1728	2209	2429	1211	1863	1853	1671
D-16-13 36 ASSIGNED USGS	502488	3539169	0	56	56	56	56	56	0	0	0	84	80	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	534	0	0	0	0	0	0	0	0
D-16-13 36 ASSIGNED USGS	502488	3539974	0	56	56	56	56	56	0	0	0	84	80	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-16-13 36 ASSIGNED USGS	503293	3539169	0	56	56	56	56	56	0	0	0	84	81	81	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-16-13 36 ASSIGNED USGS	503293	3539974	0	0	0	55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-16-13 36A - 3 WELLS	503293	3539974	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3897	0	3547	3301	3661	0	1277	0	0	2864	0	0	0	3001	992	0	14
D-16-13 36A - 4 WELLS	500074	3536755	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1917	0	0	0	0
D-16-13 36A - CYPRUS PIMA	503293	3539974	0	0	0	0	0	0	0	0	0	0	0	0	0	121	243	243	243	366	385	385	386	1399	1399	1399	986	3825	0	0	0	0	0	3503	0	1913	2148	0	619	0	0	0	1184	655	16
D-16-13 36A 5 C-P	501683	3539974	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4384	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-16-13 36A ASSIGNED USGS	503293	3539974	0	49	49	49	0	49	0	0	0	74	61	61	0	0	0	0	76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	737	393	10
D-16-13 36CBC - CYPRUS-PIMA	502488	3539169	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1082	935	1242	0	150	0	0	0	0
D-16-13 36DDD - CYPRUS-PIMA	503293	3539169	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	660	732	701	255	473	713	333	0	0	0	0	0	0	0
D-16-14 32A	506511	3539974	0	43	2	23	23	23	0	0	0	0	0	0	0	87	87	87	446	93	98	98	103	103	103	103	103	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-16-14 32B	505707	3539974	0	23	23	23	23	23	45	45	45	107	131	151	71	159	159	159	159	61	65	65	68	68	68	68	68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-16-14 32C	505707	3539169	0	23	23	23	23	23	45	45	45	107	131	151	0	88	88	88	88	31	33	33	34	34	34	34	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-13 01A	503293	3538365	0	26	26	26	26	26	38	38	38	113	0	301	176	528	528	528	528	325	325	325	402	435	435	435	435	268	0	0	0	0	0	0	2647	0	0	2983	861	0	0	1975	0	0	0
D-17-13 01A - CYPRUS-PIMA	503293	3538365	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	733	0	779	807	2453	816	0	0	0	715	0	1916	1022	27
D-17-13 01B	502488	3538365	0	26	26	26	26	26	38	38	38	113	0	0	0	178	178	178	178	109	109	109	135	147	147	147	147	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-13 01C	502488	3537560	0	26	26	26	26	26	38	38	38	113	0	304	178	355	355	355	355	219	219	219	271	293	293	293	293	0	0	0	0	0	0	0	0	0	0	0	0	0	0	484	0	0	0
D-17-13 01D	503293	3537560	0	26	26	26	26	26	38	38	38	113	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-13 02A - 3 WELLS	501683	3538365	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2591	2914	2358	2195	2433	2329	1544	1573	1776	2371	1352	650	1296	0	0	0	0
D-17-13 02A - CYPRUS-PIMA	501683	3538365	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	650	0	0	0	0	0
D-17-13 02B - CYPRUS	500879	3538365	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	971	786	732	811	776	515	645	790	457	0	0	432	0	0	0	0
D-17-13 10A - CYPRUS-PIMA	500074	3536755	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	786	732	811	776	515	524	299	790	457	0	0	0	0	0	0
D-17-13 12A	503293	3536755	0	70	70	70	70	70	56	56	56	112	126	126	0	726	726	726	726	311	311	311	311	317	317	317	317	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-13 12B	502488	3536755	0	70	70	70	70	70	55	55	55	110	126	126	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-13 12C	502488	3535951	0	69	69	69	69	69	55	55	55	110	126	126	0	0	0	0	0	0	0	0	0	0	0	0	635	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-13 12D	503293	3535951	0	70	70	70	70	70	56	56	56	112	126	126	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-13 13A - ANAMAX(?)	503293	3535146	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	443	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-13 13B - ANAMAX(?)	502488	3535146	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	443	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-13 17DDD - DUVAL	496855	3534341	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	537	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-13 22A	500074	3533537	0	0	0	0	0	0	0	0	0	0	0	0	28	28	28	28	28	62	62	62	62	170	170	170	170	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-13 22B	499269	3533537	0	0	0	0	0	0	0	0	0	0	0	0	28	28	28	28	28	62	62	62	62	170	170	170	170	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-13 22C	499269	3532732	0	0	0	0	0	0	0	0	0	0	0	0	28	28	28	28	28	62	62	62	62	170	170	170	170	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-13 22D	500074	3532732	0	0	0	0	0	0	0	0	0	0	0	0	28	28	28	28	28	62	62	62	62	170	170	170	170	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-13 23A	501683	3533537	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	70	108	108	108	108	248	248	248	248	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-13 23B	500879	3533537	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	70	108	108	108	108	248	248	248	248	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-13 23C	500879	3532732	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	70	108	108	108	108	248	248	248	248	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-13 23D	501683	3532732	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	70	110	110	110	110	250	250	250	250	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-13 24A	503293	3533537	0	0	0	0	0	282	28	56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-13 24B	502488	3533537	0	0	282	282	0	282	28	28	28	155	244	279	126	126	126	126	126	248	248	248	248	280	280	280	280	393	1010	898	466	521	483	241	65	153	540	0	0	0	0	0	0	0	0
D-17-13 24C	502488	3532732	0	0	0	0	0	0	0	26	26	139	208	237	108	108	108	108	108	211	211	211	211	237	237	237	237	0	0	0	0	0	0	0	0	0	540	566	434	426	494	568	608	480	507
D-17-13 24D	503293	3532732	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1998	0	0	0	0	0	0	540	0	0	0	0	0	0	0	0
D-17-13 25A	503293	3531927	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1156	0	0	2187	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-13 25B - ANAMAX	502488	3531927	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1156	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-13 25CCD - ANAMAX	503293	3531123	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	105	0	2028	0	0	0	0	1901	2664	0	0	0	0	0	0	0
D-17-13 25CDD - ANAMAX	502488	3531123	0	0	0	0	0	0	0	0	0	0	0	64	91	91	91	91	91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-13 35A	501683	3530318	33	36	36	36	36	36	84	84	84	89	530	530	324	324	324	971	971	683	683	683	675	865	76	118	154	0	89	450	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-13 35B	500879	3530318	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-13 35C	500879	3529513	33	73	73	73	73	73	167	167	167	179	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-13 35D	501683	3529513	33	36	36	36	36	36	84	84	84	89	0	531	647	647	647	647	647	455	455	455	502	273	76	59	77	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-13 36A	503293	3530318	0	0	0	0	0	0	0	0	0	21	68	77	196	196	196	196	196	161	322	322	412	326	251	124	225	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-13 36B	502488	3530318	0	0	0	0	0	0	0	0	0	21	68	77	196	196	196	196	196	161	161	161	234	179	108	31	112	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-13 36C	502488	3529513	0	0	0	0	0	0	0	0	0	21	68	77	195	195	195	195	195	162	162	162	235	326	243	124	229	0	1406	742	1248	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-13 36D	503293	3529513	0	0	0	0	0	0	0	0	0	21	76	76	196	196	196	196	196	161	161	161	234	326	257	125	281	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-14 05A ASSIGNED USGS	506511	3538365	108	23	23	23	23	23	0	0	0	0	0	0	0	88	88	88	88	31	33	33	34	34	34	34	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-14 05B	505707	3538365	108	78	78	78	78	78	78	78	78	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-14 05C	505707	3537560	107	77	77	77	77	77	77	77	77	108	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-14 05D	506511	3537560	108	77	77	77	77	77	77	77	77	0	0	124	206	206	206	206	206	144	144	144	130	78	78	78	78	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-14 17B	505707	3535146	0	0	0	0	0	0	0	0	0	236	103	118	78	78	78	78	78	78	78	78	82	82	82	82	82	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-14 17D	506511	3534341	0	0	0	0	0	0	0	0	0	0	0	118	80	157	157	157	157	157	157	157	166	166	166	166	166	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-14 29	505707	3531123	61	44	44	44	44	44	44	44	44	0	45	45	90	178	178	178	178	178	178	178	188	188	188	188	188	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-14 29 ASSIGNED USGS	505707	3531927	61	45	45	45	45	45	45	45	45	0	45	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-14 29A ASSIGNED USGS	506511	3531927	61	45	45	45	45	45	45	45	45	0	44	44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-14 29D ASSIGNED USGS	506511	3531123	61	45	45	45	45	45	45	45	45	0	45	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-14 30D	504902	3531123	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	267	267	281	257	257	257	257	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-14 31A	504902	3530318	82	59	59	59	59	59	59	59	59	0	18	20	8	8	8	8	8	6	6	6	7	7	7	7	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-14 31B	504097	3530318	82	59	59	59	59	59	59	59	59	0	0	0	0	141	189	189	189	158	158	158	166	166	166	166	166	0	288	390	518	221	182	239	169	0	0	188	0	0	0	0	0	0	0
D-17-14 31C	504097	3529513	81	58	58	58	58	58	58	58	58	0	0	117	46	46	46	46	46	38	38	38	40	40	40	40	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-17-14 31D	504902	3529513	81	58	58	58	58	58	58	58	58	0	85	98	39	39	39	39	39	32	32	32	34	34	34	34	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-18-13 01A	503293	3528709	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1120	1059	1359	627	781	1074	891	345	839	622
D-18-13 01B	502488	3528709	335	587	587	587	587	587	272	272	272	620	440	503	276	276	276	276	276	394	394	394	336	0	0	111	125	0	64	307	308	55	63	70	32	37	375	39	39	39	0	0	0	0	0
D-18-13 01C	502488	3527904	665	448	448	448	448	448	269	269	269	612	0	498	273	273	273	273	273	390	390	390	336	782	434	328	370	1199	423	617	612	2198	1960	2151	2079	1120	1059	1359	1365	781	1074	891	1051	981	726
D-18-13 01CCC Community Wtr	502488	3527904	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	340	35	35	35	652	0	0	0	0
D-18-13 01D	503293	3527904	0	0	0	0	0	0	272	272	272	620	440	503	276	276	276	276	276	394	394	394	336	388	441	332	374	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-18-13 02A	501683	3528709	0	45	45	45	45	45	69	69	69	0	343	392	552	552	0	0	552	158	158	158	144	311	311	311	311	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-18-13 02B	500879	3528709	0	46	46	46	46	46	69	69	69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-18-13 02C	500879	3527904	0	46	46	46	46	46	68	68	68	0	0	0	0	0	552	552	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-18-13 02D	501683	3527904	0	45	45	45	45	45	69	69	69	1359	343	785	1104	1104	1104	1104	1104	315	315	315	287	623	623	623	623	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-18-13 10AAC & ADC	500074	3527099	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	510	2195	1543	1681	1786	1819	1835	1941	1995	1109	1241	1109	0	0	0	0	0	0	0	0	0	0	0	0	0
D-18-13 11B	500879	3527099	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	123	123	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-18-13 11C	500879	3526295	0	0	0	0	0	0	0	0	0	909	488	558	558	558	558	558	558	203	203	203	185	241	241	362	362	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-18-13 11D	501683	3526295	0	252	252	252	756	756	845	845	845	455	494	565	565	565	565	565	565	205	205	205	187	244	244	244	244	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-18-13 13B	502488	3525490	654	336	336	336	336	336	0	0	343	343	521	595	397	397	397	397	397	210	210	210	191	171	171	171	171	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-18-13 13C	502488	3524685	0	0	0	0	337	337	344	344	344	344	521	595	794	794	794	794	794	420	420	420	383	342	513	513	513	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-18-13 13D	503293	3524685	629	324	324	324	324	324	688	688	344	344	521	596	397	397	397	397	397	210	210	210	191	171	171	171	171	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-18-13 14B	500879	3525490	313	339	339	339	339	339	489	489	489	677	0	822	925	925	925	925	925	720	720	720	656	890	890	890	890	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-18-13 14C	500879	3524685	378	409	409	409	409	409	590	590	590	815	410	468	351	351	351	351	351	273	273	273	249	338	338	338	338	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-18-13 34D	500074	3519857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1818	1821	1251	681	1223	1405	1505	1188	1256
D-18-14 06A	504902	3528709	0	0	0	0	0	0	76	76	76	154	156	156	156	156	156	156	156	156	156	156	156	156	156	156	156	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-18-14 06B	504097	3528709	0	0	0	0	0	0	78	78	78	156	155	155	155	155	155	155	155	155	155	155	155	155	155	155	155	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-18-14 06C	504097	3527904	0	0	0	0	0	0	77	77	77	156	156	156	156	156	156	156	156	156	156	156	156	156	156	156	156	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-18-14 06D	504902	3527904	0	0	0	0	0	0	77	77	77	156	155	155	155	155	155	155	155	155	155	155	155	155	155	155	155	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-18-14 08A	506511	3527099	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	566	318	394	591	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-19-13 03ACC - DUVAL	500074	3519053	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	768	1270	1704	1052	1371	1243	2720	2484	1890	1704	1559	1475	484	782
D-19-13 04C	497660	3518248	0	0	0	0	0	0	0	0	0	0	0	0	89	89	89	89	89	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-19-13 04D	498465	3518248	0	0	0	0	0	0	0	0	0	0	0	0	88	88	88	88	88	88	88	88	88	88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-19-13 09C	497660	3516639	0	233	233	233	233	233	233	233	233	233	350	350	1050	1050	1050	1050	1050	350	350	350	186	186	186	186	186	700	256	860	888	420	0	0	37	53	0	0	0	0	0	0	0	0	0
D-19-13 10ADA - DUVAL	498465	3517443	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2183	0	0	0
D-19-13 10ADA - DUVAL	499269	3517443	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1137	0	0	0	0	2239	0	0	0	0	0	0	0	0
D-19-13 10ADA - DUVAL	500074	3517443	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1804	1889	1732	1834	0	2267	2142	2050	2127	0	2066	660	1095
D-19-13 16/DUVAL	497660	3515834	0	130	130	130	130	130	130	130	130	130	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1605	2546	2832	2869	2894	3325	3022	2942	2876	2668	3003	2843	908	1506
D-19-13 16A	498465	3515834	0	130	130	130	130	130	130	130	130	130	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-19-13 16B	498465	3515029	0	132	132	132	132	132	132	132	132	132	1039	1039	1646	1646	1646	1646	1646	520	520	520	276	597	597	597	597	534	419	464	658	260	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE I.1.2
Well Locations and Pumping Rates for
Transient Simulation, taken from ADWR Model (Mason and Bota, 2006)

Well ID	UTM83E	UTM83N	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
D-19-13 16C	497660	3515029	0	130	130	130	130	130	130	130	130	130	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-19-13 17DDD - DUVAL	496855	3515029	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1702	2286	1863	2089	2379	2418	1438	2466	2189	2010	1903	608	1009
D-19-13 20A	496855	3514225	0	64	64	64	64	64	64	64	64	128	385	385	385	385	385	385	385	257	257	257	136	136	136	136	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-19-13 20B	496051	3514225	0	64	64	64	64	64	64	64	64	128	381	381	381	381	381	381	381	424	424	424	225	135	135	135	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2302	0	0	0
D-19-13 20C/DUVAL	496051	3513420	0	64	64	64	64	64	64	64	64	128	385	385	385	385	385	385	385	341	341	341	181	136	136	0	136	286	537	389	732	1550	1994	2217	2042	2144	2617	2992	0	0	147	0	0	0	0
D-19-13 20D	496855	3513420	0	65	65	65	65	65	65	65	65	128	385	385	385	385	385	385	385	257	257	257	136	136	136	0	136	0	0	0	0	0	0	0	0	0	0	0	2301	2694	2279	0	2178	696	1155
D-19-13 21B	497660	3514225	0	0	0	0	0	0	0	0	0	0	286	286	477	477	477	477	477	0	0	0	0	152	152	152	152	0	182	625	648	312	0	0	0	0	0	0	0	0	27	31	33	26	29
D-19-13 21C	497660	3513420	0	0	0	0	0	0	0	0	0	0	0	146	242	242	242	242	242	0	0	0	0	78	78	78	78	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-19-13 29A	496855	3512615	41	60	60	60	60	60	60	60	60	117	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-19-13 29B	496051	3512615	42	58	58	58	58	58	58	58	58	117	233	233	233	233	233	233	233	155	155	155	82	82	82	82	82	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-19-13 29C	496051	3511811	42	58	58	58	58	58	58	58	58	117	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	906	495	929	1110	1458	1836	1912	1837	1602	2829	2569	2222	2100	1924	1575	1491	642	965
D-19-13 29D	496855	3511811	41	58	58	58	58	58	58	58	58	117	0	236	236	236	236	236	236	158	158	158	168	168	168	168	168	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-19-13 32	496855	3511006	0	233	233	233	233	233	233	233	233	467	233	233	467	429	0	0	0	233	233	233	124	288	288	288	288	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D-19-13 32B	496051	3511006	0	0	0	0	0	0	0	0	0	0	0	0	233	233	0	0	0	117	117	117	62	144	144	144	144	306	434	201	296	470	288	365	264	268	199	280	198	0	0	0	0	0	0
D-19-13-31AD	495246	3511006	81	88	176	176	176	176	0	0	242	233	448	663	795	795	795	795	795	567	767	767	407	443	443	443	443	410	343	601	296	397	228	249	328	285	180	0	489	453	608	698	747	590	624
D-19-13-31BC	494441	3511006	81	173	173	173	173	173	0	0	124	117	512	583	489	489	489	489	489	501	501	501	266	288	288	288	288	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DUVAL CORPORATION	498465	3516639	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FARMERS INVESTMENT CO	500074	3521467	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	637	442	815	616	392	485	198	451	272	624	463	0	0	0	0	0	0	0	0	0	0	0	0	0
FARMERS INVESTMENT CO	503293	3524685	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	63	57	57	57	57	57	83	57	57	61	61	63	65	65	65	65	36	0	0	0	0	0	0	0
FARMERS INVESTMENT CO	503293	3531123	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	208	1406	1191	1521	1413	1139
FICO - D-16-14 31A	504902	3539974	0	0	0	0	0	0	0	0	0	0	38	30	89	89	89	89	89	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-16-14 31B	504097	3539974	0	0	0	0	0	0	0	0	0	0	38	30	90	90	90	90	90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-16-14 31C	504097	3539169	0	832	832	790	790	790	1116	1058	1058	319	346	274	451	451	451	451	451	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-16-14 31D	504902	3539169	0	814	814	773	773	773	0	0	0	319	38	30	451	451	451	451	451	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-17-13 13A	503293	3535146	0	0	0	0	0	0	0	0	0	214	220	350	553	553	553	553	553	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-17-13 13D	503293	3534341	0	268	536	509	509	509	160	152	152	214	223	176	279	279	279	279	279	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-17-13 24ACC	503293	3533537	0	0	0	0	0	0	0	0	100	360	754	558	252	252	252	252	252	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-17-13 25ABB ADD	503293	3531927	0	112	112	106	106	106	279	264	264	165	145	100	380	380	380	380	380	841	506	401	484	567	595	513	632	818	850	579	738	463	653	513	576	477	718	1012	627	758	838	727	928	863	695
FICO - D-17-13 25CDC	502488	3531123	0	108	108	103	103	103	0	0	255	159	0	0	0	0	0	0	0	996	430	570	781	622	619	537	710	667	610	686	681	679	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-17-14 05CDA	505707	3537560	0	0	0	0	0	0	0	0	0	0	0	124	207	207	207	207	207	589	545	502	389	382	324	168	250	335	382	345	313	186	60	50	80	51	353	493	192	211	241	294	376	350	281
FICO - D-17-14 06BCB	504097	3538365	450	276	276	263	263	263	262	248	248	0	219	174	326	326	326	326	326	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-17-14 06CCC	504097	3537560	568	279	279	265	265	265	265	251	251	0	250	174	326	326	326	326	326	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-17-14 06DDD(?)	504902	3537560	574	429	135	564	536	536	530	502	502	0	656	520	652	652	652	652	652	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-17-14 07A	504902	3536755	271	147	147	140	140	140	0	0	0	277	223	177	177	177	177	177	177	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-17-14 07B	504097	3536755	267	146	146	139	139	139	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-17-14 07C	504097	3535951	271	148	148	141	141	141	0	0	0	0	222	177	177	177	177	177	177	355	231	218	341	310	358	249	290	113	226	226	355	268	281	225	269	284	140	552	417	279	337	473	605	562	453
FICO - D-17-14 07D	504902	3535951	271	147	147	140	140	140	560	530	530	346	224	177	177	177	177	177	177	614	682	404	418	392	397	360	411	413	512	340	438	396	388	335	386	321	20	639	509	577	496	413	528	490	395
FICO - D-17-14 08BDD	505707	3536755	0	0	0	0	0	0	0	0	0	0	0	294	294	294	294	294	294	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-17-14 08CAD	505707	3535951	1965	0	0	0	0	0	610	1157	1157	700	424	294	294	294	294	294	294	976	425	422	329	298	214	343	575	531	449	262	337	424	229	114	159	109	107	0	0	0	0	0	0	0	0
FICO - D-17-14 18ADC	504902	3535146	1297	707	707	671	671	671	617	584	584	416	756	525	700	700	700	700	700	1286	1448	1194	1303	1461	1012	878	974	1123	1090	926	1428	852	801	662	1020	1051	1142	1210	895	763	826	750	958	891	717
FICO - D-17-14 18DAD	504902	3534341	1092	595	595	565	565	565	623	591	590	1329	675	535	714	714	714	714	714	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-17-14 19ABC	504902	3533537	524	286	286	272	270	272	272	258	258	393	402	319	297	297	297	297	297	564	405	290	262	273	262	185	207	239	293	175	206	265	211	241	322	163	82	0	0	0	0	0	0	0	0
FICO - D-17-14 19CBD	504097	3532732	653	357	357	339	337	339	339	321	321	420	477	379	354	354	354	354	354	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-17-14 30	504097	3531927	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-17-14 30ACD	503055	3532226	0	0	0	0	0	0	0	0	0	66	0	376	319	479	479	479	479	0	0	267	313	296	185	1161	1326	0	483	1167	1577	1453	1145	824	1176	1365	1609	1293	691	764	764	837	1069	994	800
FICO - D-17-14 30ACD	504902	3531927	0	0	0	0	0	0	0	0	0	3	0	37	32	47	47	47	47	0	0	23	27	26	16	101	115	0	42	101	137	126	100	72	102	119	140	112	60	66	66	73	93	86	70
FICO - D-17-14 30BBB	504097	3531927	0	1633	1633	1551	1551	1551	1551	1469	1469	69	0	207	869	869	869	869	869	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-17-14 30BCC BDD	504097	3531927	0	0	0	0	0	0	0	0	0	384	0	0	176	352	320	352	352	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-17-14 30CDD	504097	3531123	0	0	0	0	0	0	0	0	0	69	0	0	0	0	0	177	177	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-18-13 12A	503293	3527099	0	228	228	217	217	217	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-18-13 12B	502488	3527099	0	228	228	217	217	217	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-18-13 12C	502488	3526295	0	226	226	215	215	215	861	815	815	1065	744	592	788	788	788	788	788	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-18-13 12D	503293	3526295	0	228	228	217	217	217	0	0	0	0	0	591	394	394	394	394	394	1851	24	454	354	426	384	178	255	178	210	242	290	208	51	0	0	0	503	319	384	230	466	307	337	313	252
FICO - D-18-13 13ABC	503293	3525490	0	95	0	0	618	618	654	620	620	405	757	601	802	802	802	802	802	608	707	597	513	792	705	592	942	490	545	328	981	688	930	888	790	947	505	922	741	904	1013	811	889	826	665
FICO - D-18-13 23BAD	501393	3523933	0	0	0	0	0	0	0	0	0	0	330	263	263	263	263	263	263	1959	1074	568	0	0	420	485	756	330	404	397	733	642	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-18-13 23CCB	500879	3523076	1660	906	906	861	861	861	0	0	0	959	669	530	532	532	532	532	532	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-18-13 24BBB	501393	3523933	0	0	0	0	0	0	220	209	209	136	227	158	315	315	315	315	315	210	1054	798	860	818	691	651	661	776	881	598	882	636	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-18-13 26AAD 26ABB	501683	3522271	0	0	0	0	0	0	579	548	548	578	636	505	505	505	505	505	505	691	559	322	164	234	216	184	263	132	252	97	329	206	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-18-13 26CCD	500879	3521467	0	0	0	0	0	0	602	571	571	602	732	581	581	581	529	529	529	277	443	388	200	361	262	303	314	257	223	191	278	309	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-18-13 2BCA	500879	3522271	1531	1670	1670	1587	1587	1587	530	502	502	530	644	512	512	512	512	512	512	1461	1145	918	603	711	464	497	628	141	561	449	595	573	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-18-13 34ACA	500074	3520662	319	490	490	465	465	465	166	158	158	825	787	624	1129	1129	1129	1129	1129	2236	1160	1027	799	786	719	467	668	277	485	387	686	577	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-18-13 35BAB	500879	3520662	0	0	0	0	0	0	793	752	752	1228	380	303	303	303	303	303	303	708	499	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-18-13 35CBA	500879	3519857	0	0	0	0	0	0	0	0	0	0	382	605	605	605	605	605	605	139	271	236	377	334	292	379	379	229	258	204	335	293	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO - D-19-13 03B	499269	3519053	0	200	200	190	190	190	190	180	180	117	250	200	399	399	399	399	399	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO: B-01	504097	3534341	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	285	314	220	209	233	23	0	0	0	0	0	0	0	0
FICO: B-02	504097	3531123	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	387	346	346	316	282	308	305	186	231	61	0	0	0	0
FICO: E-02	501683	3522271	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	324	224	153	97	236	210	160	276	151	166	198	244	247	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO: E-04	502488	3525490	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	864	683	378	474	497	441	299	365	435	446	464	477	548	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO: E-06	501680	3524946	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	767	526	273	517	284	235	428	575	561	509	484	687	746	563	316	705	446	440	412	294	399	254	378	414	384	310
FICO: S-02	504902	3537560	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	367	334	243	238	201	256	311	352	347	502	337	459	371	116	0	0	0	0	0	0	0	0	0	0	0	0
FICO: S-08	504097	3538365	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	583	249	338	401	429	372	319	311	113	259	260	267	205	131	69	72	88	0	0	0	0	0	0	0	0	0
FICO: S-10	504097	3537560	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	385	109	186	293	422	457	432	408	388	455	335	319	232	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO: S-17	495246	3529513	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	387	118	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO: S-19	504841	3532023	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	556	438	226	329	388	285	196	159	129	144	115	265	369	373	342	217	382	291	486	335	204	79	147	142	137	132
FICO: S-24	504097	3532732	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	737	588	404	512	488	433	350	300	439	575	300	349	467	453	356	415	439	414	257	198	201	183	80	103	95	77
FICO: S-25	502233	3533248	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	29	25	40	31	39	36	29
FICO: S-25	503037	3533248	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	545	399	397	425	446	332	282	369	208	481	416	247	361	335	167	110	170	69	438	560	476	762	580	741	688	554
FICO: S-26	503293	3535146	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	390	180	293	410	459	534	423	459	182	453	454	449	360	220	301	237	276	249	0	0	0	0	0	0	0	0
FICO: S-27	504097	3532732	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	637	422	287	281	311	291	227	279	305	298	224	293	245	162	114	123	82	58	0	0	0	0	0	0	0	0
FICO: S-28	504902	3536755	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	416	412	308	465	219	151	149	136	116	181	123	180	213	151	79	79	62	5	0	0	0	0	0	0	0	0
FICO: S-30	504902	3539974	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	419	326	345	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO: S-33	503859	3532226	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	70	40	64	93	110	80	55	45	36	41	32	75	104	105	96	61	108	82	137	95	57	22	41	40	39	37
FICO: S-35	503293	3531927	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1211	849	610	791	992	795	702	761	498	820	908	597	986	506	562	552	654	311	285	147	98	145	256	327	303	245
FICO: S-36	505707	3536755	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	617	452	454	404	405	402	358	434	442	427	342	440	548	233	347	215	241	227	61	148	184	240	230	294	273	220
FICO: S-37	504097	3539169	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	268	466	439	448	264	340	0	0	0	68	352	240	233	271	272	243	143	9	0	0	0	0	0	0
FICO: S-38	503293	3535146	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	247	135	260	307	419	302	221	338	130	337	289	72	135	96	119	131	149	0	0	0	0	0	0	0	0	0
FICO: S-39	504902	3531927	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	486	390	496	399	447	334	40	140	119	514	228	296	134	139	173	123	96	0	0	0	0	0	0	0	0	0
FICO: S-41	502488	3531123	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	215	181	144	137	40	53	30	116	59	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO: S-42	505707	3536755	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	69	176	253	3434	298	235	370	364	267	237	252	296	210	135	256	98	0	0	0	0	0
FICO: S-43	503009	3537068	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	253	460	462	530	513	474	496	454	394	388	167	336	430	399	322
FICO: S-43	503813	3537068	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	175	319	321	369	356	330	345	315	274	270	116	234	299	278	224
FICO: S-44	503859	3530811	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1171	1097	656	831	961	580	741	689	555
FICO: S-45	504834	3532831	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	195	1295	1522	937	1009	939	647	828	769	619
FICO: S-46	502647	3532239	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	371	1705	1336	725	677	435	685	876	813	655
FICO: S-48	504987	3537067	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	577	527	318	382	486	506	647	601	485
FICO: S-49	504793	3538083	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	79	488	382	246	288	533	406	519	482	388
FICO: S-50	504991	3538695	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	522	257	257	173	387	254	325	302	243
FICO: S-51	503017	3535471	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1285	1458	678	494	1011	877	1121	1042	839
FICO: S-52	504790	3535663	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	427	346	335	290	388	445	569	529	426
FICO: S-53	503453	3532635	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1131	1425	855	917	1216	900	1149	1068	860
FICO: S-55	502062	3531858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	316	404	375	302
FICO: S-56	505213	3534443	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	376	481	447	360
FICO: W-05	504902	3539169	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	254	293	229	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FICO: W-06	504097	3539169	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	710	483	396	519	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TUCSON, CITY OF	507316	3538365	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	176	613	529	530	561	512	335	388	477	400	361	318	367	179	302

Notes

UTM83E = Universal Transverse Mercator, North American Datum 1983, East

UTM83N = Universal Transverse Mercator, North American Datum 1983, North

No pumping specified after 1983
All pumping units in gallons per minute (gpm)

Well ID	ADWR Registration	UTM83E	UTM83N	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
11caa	801179	501186	3526788	0	0	0	0	0	0	0	0	0	0	0	0	0	1	55	36	69	38	46	54	53	46	42	58	46	42	35	42	31	28	37	48	37	19	0	0
25cbd	634348	492757	3531386	23	23	23	23	23	23	23	23	23	23	22	18	16	15	19	1	12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
AN1	608518	502595	3527990	2325	2325	2325	2325	1131	1131	1131	1131	1131	1131	1266	1248	166	10	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AN-2(RRQC2)	608519	503457	3529250	1548	1548	1548	1548	1131	1131	1131	1131	1131	1131	1189	1221	126	0	0	0	0	0	0	0	1	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0
AN-4(RRQC1)	608521	503457	3527990	0	0	0	0	1131	1131	1131	1131	1131	1131	1279	664	58	69	60	3	0	0	0	0	0	0	94	156	0	0	0	0	261	266	334	378	384	362	326	357
C1	624008	503353	3529320	50	50	50	50	50	50	50	50	50	50	47	39	35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C4	624010	501760	3525384	1332	1332	1332	1332	1332	1332	1332	1332	1332	1332	1247	1033	922	854	823	1160	932	710	783	756	922	911	852	833	1167	817	987	840	914	888	757	794	808	908	921	1113
CCofGV	501760	501635	3527876	484	484	484	484	484	484	484	484	484	484	453	376	335	311	280	375	336	339	389	324	396	379	364	388	440	453	408	378	377	353	340	393	371	289	117	54
CEMEX	607815	505129	3540303	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	77	178	194	251	343	162	73	0	245	277
Colgate	639904	509408	3532606	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
ContSD39	601769	504049	3522942	0	0	0	0	0	0	0	0	0	0	0	0	0	22	10	0	0	11	9	7	7	7	0	0	0	0	0	6	17	1	2	2	2	2	2	3
Cox	604432	508795	3534015	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2	2	3	2	2	0	2	2	7	3	3	2	3	4	3	2	2	2	2	2	2	2
Cox	627079	508795	3534015	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	2	5	5	3	0	3	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CSD39	638581	504049	3522942	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	9	0	0	0	0	0	8	7	7	9	9	0	0	0	0	0	0	0	0	0
CW3	627483	500048	3523810	137	137	137	137	137	137	137	137	137	137	212	175	157	145	142	5	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CW5	627484	501234	3522497	0	0	0	0	187	187	187	187	187	187	175	145	129	120	275	223	269	284	293	224	268	287	254	290	316	309	199	139	131	89	85	105	0	0	0	0
CW6	627485	500891	3525794	420	420	420	420	420	420	420	420	420	420	393	326	291	269	276	404	353	348	319	366	311	352	336	388	439	248	371	342	103	326	401	418	221	295	252	183
CW7	502546	499660	3528094	0	0	0	0	0	0	0	0	0	0	0	511	456	423	285	408	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CW8	543600	499799	3525661	300	300	300	300	300	300	300	300	300	300	300	300	300	0	0	0	0	0	0	0	0	0	0	0	9	428	453	517	623	677	527	723	713	426	1	1
CW9	588121	501072	3528741	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	202	396	551	304
Davis_Robert	516216	507647	3533428	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	20	25	21	23	0	0	0	0	0	0	0	0	0	0	0	0	0
E10A	086931	502452	3523995	43	43	43	43	43	43	43	43	43	43	40	33	30	27	27	38	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E11A	624018	502092	3527822	468	468	468	468	468	468	468	468	468	468	439	363	324	300	325	191	100	245	296	294	304	373	294	339	298	246	341	332	378	330	305	284	446	496	501	445
E12	624019	500635	3520347	490	490	490	490	490	490	490	490	490	490	459	380	339	314	341	447	325	202	199	183	190	232	221	263	242	228	249	176	171	163	183	144	146	126	287	0
E13	624020	503122	3526403	1131	1131	1131	1131	1131	1131	1131	1131	1131	1131	1058	877	783	725	882	968	609	528	620	698	714	766	621	725	700	697	768	637	735	667	664	612	705	828	261	48
E15	624022	500333	3518794	0	0	0	0	0	0	0	0	0	0	0	0	0	409	319	390	391	276	261	296	289	306	287	440	474	266	302	237	252	247	260	305	487	527	543	587
E16	624023	503328	3525727	701	701	701	701	701	701	701	701	701	701	656	544	486	450	573	624	404	395	436	464	471	457	404	411	436	354	430	388	423	387	400	395	467	469	427	429
E3A	624011	502198	3523933	649	649	649	649	649	649	649	649	649	649	607	503	449	416	405	390	315	344	368	380	443	476	449	486	513	385	386	427	470	172	405	311	433	496	494	521
E5A	624012	502184	3524332	522	522	522	522	522	522	522	522	522	522	488	404	361	334	283	125	103	209	92	57	59	59	58	65	81	97	105	104	134	147	157	192	194	200	197	272
E6	624013	502425	3525169	554	554	554	554	554	554	554	554	554	554	519	430	384	355	351	476	305	258	278	292	337	314	298	283	272	280	312	244	249	372	308	354	351	332	347	402
E7	624014	503086	3525553	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	1	1	1	1	1	4	6	9	8	5	7	7	9	10	10	11	9	1	1	1
E8	624015	502374	3525166	208	208	208	208	208	208	208	208	208	208	195	162	144	133	172	234	243	196	146	193	172	236	216	230	219	197	253	209	190	181	169	180	186	209	198	0
E9	624016	500862	3521222	274	274	274	274	274	274	274	274	274	274	256	213	190	176	214	153	68	162	162	156	214	171	166	236	166	186	215	164	135	43	121	136	242	343	204	147
ESP1	623102	499970	3526449	828	828	828	828	828	660	543	103	277	431	266	33	0	0	0	0	0	0	0	0	4	7	12	151	13	20	0	0	0	0	0	0	0	21	272	173
ESP2	623103	500242	3526925	414	414	414	414	414	330	271	51	139	216	133	17	0	0	0	0	3	38	8	71	173	7	92	172	22	1	0	0	0	0	1	0	7	143	308	367
ESP3	623104	500234	3527377	828	828	828	828	828	660	543	103	277	431	266	33	0	0	0	43	1	10	9	56	47	0	0	0	0	0	0	0	0	0	0	1	0	44	259	598
ESP4	623105	499917	3526133	828	828	828	828	828	660	543	103	277	431	266	33	0	0	0	1	6	305	71	81	436	783	211	380	1	14	1	5	0	0	1	0	12	45	0	0
FICO623990	623990	505931	3536661	0	0	0	0	0	0	0	0	0	0	0	0	0	124	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Granite	801075	503396	3531617	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
Grant	801401	496059	3518416	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1
GV1	603428	499813	3522254	664	664	664	664	664	664	664	664	664	664	621	515	460	426	352	442	471	454	664	499	693	666	694	570	754	661	841	504	806	611	612	615	793	793	730	730
GV2	603429	499786	3521654	355	355	355	355	355	355	355	355	355	355	332	276	246	228	407	478	434	458	739	689	556	572	559	0	672	798	595	879	659	768	800	939	754	754	780	780
GVINV_625711	625711	501568	3526181	690	690	690	690	690	690	690	690	690	690	646	535	478	442	445	445	448	240	266	235	192	205	241	276	220	255	232	223	274	260	237	226	221	193	204	198
GVINV_625712	625712	501600	3526400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	200	199	177	244	229	195	146	192	198	184	163	183	181	160	198	191	182	192	152
Hoogerwerk_RL	601910	509871	3532610	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	1	1	0	0	0	0
I10	608525	497798	3528469	0	0	0	0	1068	1068	1068	1068	1068	1131	1131	1131	1131	429	336	2	0	0	28	686	869	750	1081	815	803	919	173	1503	390	690	817	674	553	0	0	0
I11	608524	497919	3528485	0	0	0	0	1068	1068	1068	1068	1068	1131	1131	1131	1131	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I12	608523	498110	3528578	0	0	0	0	1068	1068	1068	1068	1068	1131	1131	1131	1131	926	865	10	36	127	597	1006	977	960	947	866	844	0	758	338	470	138	5	55	210	0	0	0
I13	087309	498195	3528505	0	0	0	0	1068	1068	1068	1068	1068	1131	1131	1131	1131	1297	972	153	1	95	885	817	1157	1061	877	624	0	0	0	0	0	0	0	0	0	0	0	0
I7	608528	497807	3528531	0	0	0	0	0	0	0	0	0	0	0	0	0	0	622	4	0	0	590	846	667	740	338	188	671	667	517	348	172	19	0	0	0	0	0	0
I9	608526	497823	3528672	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	56	109	0	0	0	50	145	73	11	1	24	28	63	14	0	0	0	0
IW1	623129	496906	3521278	0	0	0	0	0	0	0	0	686	941	425	486	604	678	768	643	720	647	441	336	0	0	0	253	18	0	3	141	683	447	79	234	412	392	403	365
IW10	508237	497370	3523122	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	363	259	331	442	302	571	297	595	781	729	205	295	564	672	252	0	480	178	114	351	256
IW11	508235	497371	3523429	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	699	806	442	718	499	471	579	467	458	632	65	365	58	165	494	5	839	495	596	581	289
IW12	545555	497365	3523970	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	45	200	305	299	338	126	64	214	138	79	135
IW13	545556	497364	3524167	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	58	24	64	0	0	13	0	73	31	23
IW14	545557	497367	3524373	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	188	178	137	156	89	129	0	84	94	90
IW15	545558	497373	3524567	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	112	92	90	102	14	0	17	22	29	41
IW16	545559	497371	3524783	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	49	31	0	0	0	0	0	0	0	9
IW17	545560	497374	3525003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	205	169	134	95	66	67	0	83	28	9
IW18	545561	497374	3525170	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	128	80	55	37	0	0	0	50	2	8
IW19	545562	497374	3525343	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	51	189	256	264	229	135	0	0	170	195	182
IW2	623130	497485	3521361	0	0	0	0	0	0	0	0	621	1031	729	513	513	710	769	469	777	524	630	309	813	851	673	436	249	333	98	322	460	631	812	321	417	734	712	594
IW20	545563	497365	3525569	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	169	94	111	121	42	115	162	88	78	76
IW21	545564	497375	3525773	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	218	219	106	172	130	242	217	86	160	156
IW22	200554	497370	3523274	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	300	261	490
IW23	200555	497369	3522971	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	150	136	212
IW24	200556	497372	3522634	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	175	241	415
IW3	623131	497366	3521723	0	0	0	0	0	0	0	0	526	1049	691	287	623	659	730	510	800	687	652	439	718	666	804	537	605	85	259	454	634	754	856	667	486	0	0	0
IW3A	201732	497366	3521723	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	344	713	411
IW4	623132	497372	3522466	0	0	0	0	0	0	0	0	431	913	870	485	540	625	731	491	300	395	400	383	204	663	645	688	482	636	579	473	494	524	221	448	19	519	171	249
IW5	623133	497370	3522815	0	0	0	0	0	0	0	0	0	154	490	352	265	248	453	294	823	690	776	703	815	524	1002	1196	1094	1032	510	649	639	83	2	52	517	423	15	127
IW6A	545565	497381	3523709	0	0	0	0	0	0	0	0	0	0	375	207	223	0	0	0	0	0	0	0	0	0	0	0	0	45	79	0	169	269	141	54	4	153	135	122
IW7	623135	496428	3521307	0	0	0	0	0	0	0	0	0	0	55	42	49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IW8	508238	497368	3522021	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	652	430	712	769	421	835	784	525	705	580	497	277	216	125	318	231	758	585	845	704	463
IW9	508236	497370	3522208	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	275	347	340	327	431	457	470	297	210	108	0	0	0	2	1	5	116	251	74	293
Jensen_RD	801393	504908	3544834	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	3	3	4	3	3	4	3	3	3	4	5	4	3	3	4	4	4	4	4	4
Jurs	801442	496055	3519512	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	10	5	5	5	5	20	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Kiewit	583888	504190	3530600	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	127	0	0	0
Lamb	628534	505340	3535044	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	1	1	1	1	2	5	5	5	2	2	2	2	2	2	2	2	2
Lawyers	608599	504207	3527782	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
LosArboles	524178	502573	3533448	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	32	36	42	497	45	44	38	32	31	32	29	32	33	32	28	29
LosArboles	610277	502467	3533753	0	0	0	0	0	0	0	0	0	0	0	0	0	19	164	18	23	25	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M10	607790	501144	3539879	0	0	0	0	0	0	0	0	0	0	0	0	0	640	1178	660	404	600	1461	1840	1683	676	1572	1693	1876	1964	1842	1780	1861	1824	756	1760	1547	1416	459	1325
M11	607791	501957	3540492	0	0	0	0	0	0	0	0	0	0	0	0	0	774	509	300	142	730	927	1246	1565	1138	750	977	1197	976	1476	1421	1387	1684	1110	390	0	117	1287	997
M12	529538	502754	3540495	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	235	785	905	945	1087	893	1236	1243	1085	743	995	301	269	375	368	618

TABLE I.1.3
Well Locations and Pumping Rates for
Transient Simulation, Taken from Various Sources[a]

Well ID	ADWR Registration	UTM83E	UTM83N	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
M13	611139	503350	3540498	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	107	521	611	507	703	608	726	643	590	759	790	452	257	487	241	724
M14	532046	502554	3539883	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	473	533	833	911	645	849	648	922	799	659	361	307	409	293	717
M6	607787	500542	3540494	0	0	0	0	0	0	0	0	0	0	0	0	0	517	671	673	926	781	872	378	346	630	434	176	84	137	241	346	0	0	0	0	0	0	0	0
M7	607788	500947	3540494	0	0	0	0	0	0	0	0	0	0	0	0	0	514	832	649	949	970	532	134	205	796	479	500	205	0	0	0	0	0	0	0	0	0	0	0
M8	607789	501351	3540493	0	0	0	0	0	0	0	0	0	0	0	0	0	524	125	801	878	660	471	794	753	576	568	593	614	510	417	0	0	0	0	0	0	0	0	0
Madera_Highlands	624019	503285	3526162	0	0	0	0	0	0	0	0	0	0	0	0	0	93	101	132	96	60	59	184	191	232	221	263	243	229	249	176	171	164	183	144	0	0	0	0
NP1	605899	501004	3529211	81	81	81	81	81	81	81	81	81	81	76	63	56	52	32	32	35	41	39	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NP2	624028	500929	3519541	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	2	4	0	6	0	4	6
NP2	605898	500909	3520046	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	27	25	20	22	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OcotilloCommunity	801309	498963	3511412	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	1	1	1	2	7	4	4	8	5	12	12	20	22	7	8	11	14	10	11	11	11
Olivas	801154	503396	3531213	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	10	10	6	3	6	6	4	3	2	0	0	1	0	1	1	1	1	1	1	1	1
P1	611138	503152	3540091	0	0	0	0	0	0	0	0	0	0	0	0	0	48	48	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PDSI	611140	503554	3539892	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
PDSI	611745	503553	3540095	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poole	801975	495659	3519508	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	3	2	2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0
QCWC_No13	608522	504788	3528380	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	2	7	13	21	9	8	9	27	23	59	61	84	119	73	139	164
RchoSah_WC	611144	502752	3537471	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	133	116	85	31	242	298	534
RT1	504946	499811	3530971	0	0	0	0	0	0	0	0	0	0	0	539	1688	2232	2294	58	0	0	0	0	0	0	0	0	796	1609	1748	1716	1610	1092	1495	1091	1069	0	0	0
S1	623111	499931	3518793	0	0	0	0	0	0	0	0	0	0	0	0	0	1232	947	1683	1566	1332	1446	862	1663	1038	787	1704	1002	1408	1776	668	748	1583	1350	964	1740	1164	1883	1443
S12	623981	505183	3535660	0	0	0	0	0	0	0	0	0	0	0	0	0	661	805	891	706	637	722	712	661	686	579	620	590	677	591	536	642	664	639	624	580	603	780	871
S19	623982	504841	3532023	0	0	0	0	0	0	0	0	0	0	0	0	0	642	1077	1113	797	657	877	847	887	867	758	855	659	866	842	660	786	772	736	795	832	915	847	938
S2	623112	499133	3517459	0	0	0	0	0	0	0	0	0	0	0	0	0	2145	2025	1072	271	2028	1674	1851	2329	1267	2425	1914	2158	2569	1973	892	608	1288	1210	600	1672	1327	1409	1172
S22	623983	503660	3531621	0	0	0	0	0	0	0	0	0	0	0	0	0	432	434	458	308	277	273	270	351	322	501	404	351	302	288	221	76	305	319	262	374	448	388	466
S25	623985	503037	3533248	0	0	0	0	0	0	0	0	0	0	0	0	0	519	815	906	810	880	873	634	785	880	205	818	808	754	778	705	683	875	750	795	777	700	828	944
S29	623986	503806	3535671	0	0	0	0	0	0	0	0	0	0	0	0	0	308	376	361	299	296	236	255	347	311	275	223	233	200	242	204	207	391	305	317	377	363	363	407
S3	623113	498136	3516037	0	0	0	0	0	0	0	0	0	0	0	0	0	2318	1638	1735	1585	1671	1554	1593	1929	1123	1342	1294	1251	1809	1070	1192	1309	2147	1797	83	657	1994	1495	1640
S31	623987	505995	3537476	0	0	0	0	0	0	0	0	0	0	0	0	0	313	357	304	278	256	280	241	341	338	308	305	289	265	223	214	140	44	0	0	0	106	127	218
S33	623988	503859	3532226	583	583	583	583	583	583	583	583	583	583	630	522	466	432	433	458	308	276	273	270	351	322	501	403	351	301	288	221	76	305	319	262	832	406	405	344
S4	623114	497344	3514807	0	0	0	0	0	0	0	0	0	0	0	0	0	1821	1434	822	1797	1420	1567	1653	2039	1524	1224	1374	1031	976	1534	1583	1947	2405	2200	884	2764	2444	2400	2423
S40	623991	505004	3534851	0	0	0	0	0	0	0	0	0	0	0	0	0	847	967	999	854	758	845	683	762	897	813	841	788	818	813	685	769	876	750	666	728	771	675	713
S43	623993	503813	3537068	0	0	0	0	0	0	0	0	0	0	0	0	0	527	517	526	356	520	477	458	506	370	503	461	587	539	548	513	453	575	604	515	526	618	598	539
S44	623994	503859	3530811	0	0	0	0	0	0	0	0	0	0	0	0	0	831	1062	1135	892	747	819	936	977	882	797	867	895	939	980	890	895	1180	985	1033	1029	1175	1024	1163
S45	623995	504834	3532831	0	0	0	0	0	0	0	0	0	0	0	0	0	1246	1263	1526	1150	950	1077	1056	1139	1141	1014	1062	989	1032	834	915	1062	1092	1030	862	1030	1098	999	1012
S46	623996	502647	3532239	0	0	0	0	0	0	0	0	0	0	0	0	0	354	508	765	803	352	770	573	811	847	533	720	696	773	606	614	438	395	571	993	756	557	501	616
S48	623997	504987	3537067	0	0	0	0	0	0	0	0	0	0	0	0	0	547	530	439	451	413	343	404	443	444	407	433	424	406	396	369	391	406	368	294	344	443	429	436
S49	623998	504793	3538083	0	0	0	0	0	0	0	0	0	0	0	0	0	407	254	213	342	329	328	347	358	371	333	255	245	253	245	206	253	243	247	245	238	334	292	292
S5	623115	496561	3513401	0	0	0	0	0	0	0	0	0	0	0	0	0	754	2577	1425	538	151	1404	1831	1835	1107	1309	2720	2568	2476	2137	2268	2648	1867	2118	1152	4	2642	2793	2840
S50	623999	504991	3538695	0	0	0	0	0	0	0	0	0	0	0	0	0	259	396	353	154	124	0	0	0	0	0	82	88	0	0	0	0	0	0	0	0	0	90	157
S51	624000	503017	3535471	0	0	0	0	0	0	0	0	0	0	0	0	0	340	484	792	870	786	825	709	843	824	653	1001	850	791	820	712	804	891	718	544	753	888	895	832
S52	624001	504790	3535663	0	0	0	0	0	0	0	0	0	0	0	0	0	354	393	385	264	296	359	873	841	865	659	352	354	344	357	323	357	379	387	358	360	403	316	302
S52A	534992	504806	3534853	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36	55	45	45	51	65	67	74	66	70	65	66	31	35
S53	624002	503453	3532635	0	0	0	0	0	0	0	0	0	0	0	0	0	1186	1268	1343	1102	1092	1100	1076	1060	1175	961	985	911	852	790	785	880	819	826	791	833	986	861	1240
S54	624003	503069	3531047	1338	1338	1338	1338	1338	1338	1338	1338	1338	1338	1252	1037	926	857	933	661	716	724	557	63	0	530	733	970	1077	982	852	784	740	872	742	397	692	1091	1081	774
S55	624004	502062	3531858	668	668	668	668	668	668	668	668	668	668	625	518	462	428	456	826	1014	876	1054	828	1050	1110	988	1082	1137	1035	944	1000	875	1021	1095	780	1033	1118	1093	1148
S56	624005	505213	3534443	0	0	0	0	0	0	0	0	0	0	0	0	0	353	315	381	163	275	216	235	262	262	285	309	280	237	213	214	74	301	253	322	427	358	281	307
S6	623116	496371	3511992	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2357	791	1459	879	1212	1192	1884	935	1653	2544	3279	2955	2480	3146	3038	1898	2585	3128	1167	1458	2269	2593
Sahuarita	534039	506745	3536662	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	8	10	10	9	10	7	8	8	19	20	15	17	17	21
Sahuarita	611142	502953	3538272	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	85	184	354	212	312	181
SahVal_WC	607626	503052	3536369	0	0	0	0	0	0	0	0	0	0	0	0	0	16	17	20	20	15	0	14	15	14	15	16	16	17	20	20	19	21	17	19	17	17	18	18
SC14A	619888	507765	3542928	0	0	0	0	0	0	0	0	0	0	0	0	0	429	358	382	376	334	375	312	261	254	71	273	378	4	0	0	0	0	0	0	0	0	0	0
SC20A	619894	508167	3542318	0	0	0	0	0	0	0	0	0	0	0	0	0	499	429	469	393	265	413	393	432	311	96	269	348	328	341	404	184	462	496	408	0	0	0	0
SC21A	619895	506972	3542521	0	0	0	0	0	0	0	0	0	0	0	0	0	352	414	387	351	327	268	358	305	209	190	288	402	432	442	407	323	342	437	404	0	0	0	0
SC23A	619897	506943	3538481	0	0	0	0	0	0	0	0	0	0	0	0	0	526	555	447	468	448	452	381	481	427	331	391	546	467	502	450	488	407	451	382	0	0	0	0
SC24A	619898	507953	3538486	0	0	0	0	0	0	0	0	0	0	0	0	0	544	329	335	528	416	445	437	433	272	0	289	402	386	399	402	199	432	464	396	466	430	416	0
Schulz_J	622106	504900	3544035	0	0	0	0	0	0	0	0	0	0	0	0	0	3	5	1	5	7	9	0	12	16	14	26	16	21	26	47	40	39	13	16	14	14	14	14
Sedgwick_C	801127	505200	3542928	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	3	0	0	0	5	3	0	0	22	66	11	0	32	16	1	0	0	0
Smith	640149	509102	3533110	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	2	2	2	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Spafford_Jack	602952	495920	3518583	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
ST5	608531	500619	3531941	0	0	0	0	0	0	87	87	87	87	81	67	60	56	59	0	67	60	47	46	55	43	56	142	157	156	93	113	147	103	93	165	36	80	54	17
ST6	608530	501248	3531353	0	0	0	0	73	73	73	73	73	73	68	57	50	47	60	0	50	61	93	78	81	92	95	36	31	52	121	100	43	64	26	56	24	23	19	19
ST7	566940	500778	3531036	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	78	107	150	86	240	196	243	329
SUS	605342	501863	3535970	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0	0	76	0	0	0	0	0	0
SUS	605344	501863	3535970	0	0	0	0	0	0	0	0	0	0	0	0	0	37	37	38	39	42	56	35	45	41	48	0	33	23	52	62	70	0	0	83	82	96	96	95
ValVerde	803064	502386	3531830	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	3	0	4	3	4	5	4	4	0	4	6	0	5	5	6	6	5	5	4	5	3
ValVerdeSub	603835	502489	3531323	0	0	0	0	0	0	0	0	0	0	0	0	0	15	19	1	12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	2	2	2
VVDN_WC	602019	501674	3532142	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	28	0	21	32	25	35	32	37	47	43	48	53	50	42	45	43	51	48	47	44	41
W11	624025	499969	3520085	13	13	13	13	13	13	13	13	13	13	12	10	9	8	186	690	744	502	548	494	524	486	549	767	541	401	488	407	462	568	501	494	177	198	186	181
W12	624026	500156	3521299	921	921	921	921	921	921	921	921	921	921	862	715	638	590	601	744	628	545	611	644	758	737	747	0	599	562	691	462	568	557	610	602	718	669	698	575
W9	624024	501271	3524132	856	856	856	856	856	856	856	856	856	856	802	664	593	549	616	613	558	411	608	614	659	604	468	685	692	555	718	569	682	506	545	453	539	530	587	520

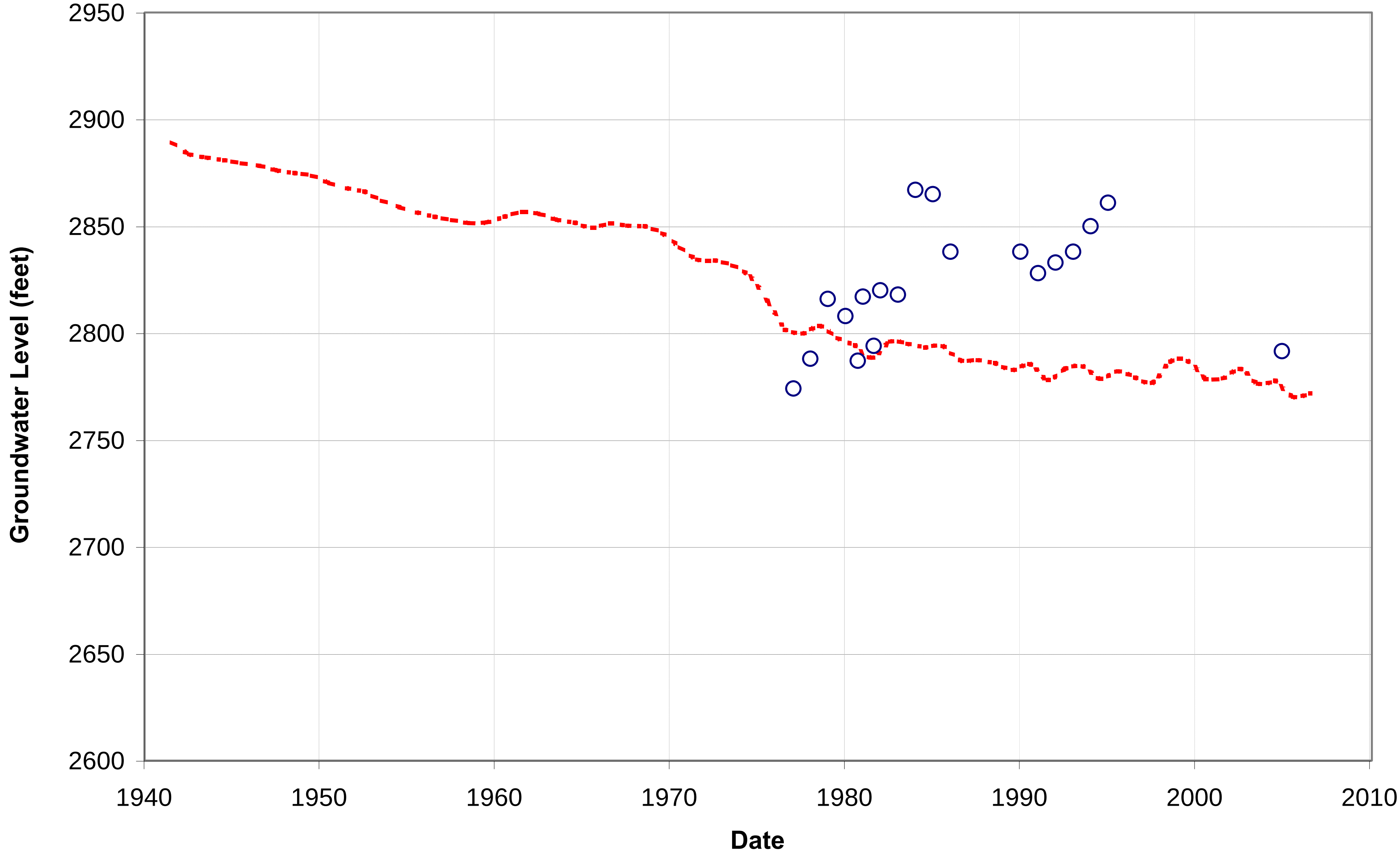
Notes
[a] Arizona Department of Water Resources (ADWR) 55 Well Registry and Groundwater Site Inventory (GWSI), ELMA (2007a)

UTM83E = Universal Transverse Mercator, North American Datum 1983, East

UTM83N = Universal Transverse Mercator, North American Datum 1983, North
No pumping specified from 1941 to 1970
All pumping units in gallons per minute (gpm)

APPENDIX I.2

MEASURED AND SIMULATED HYDROGRAPHS AT SELECT WELLS

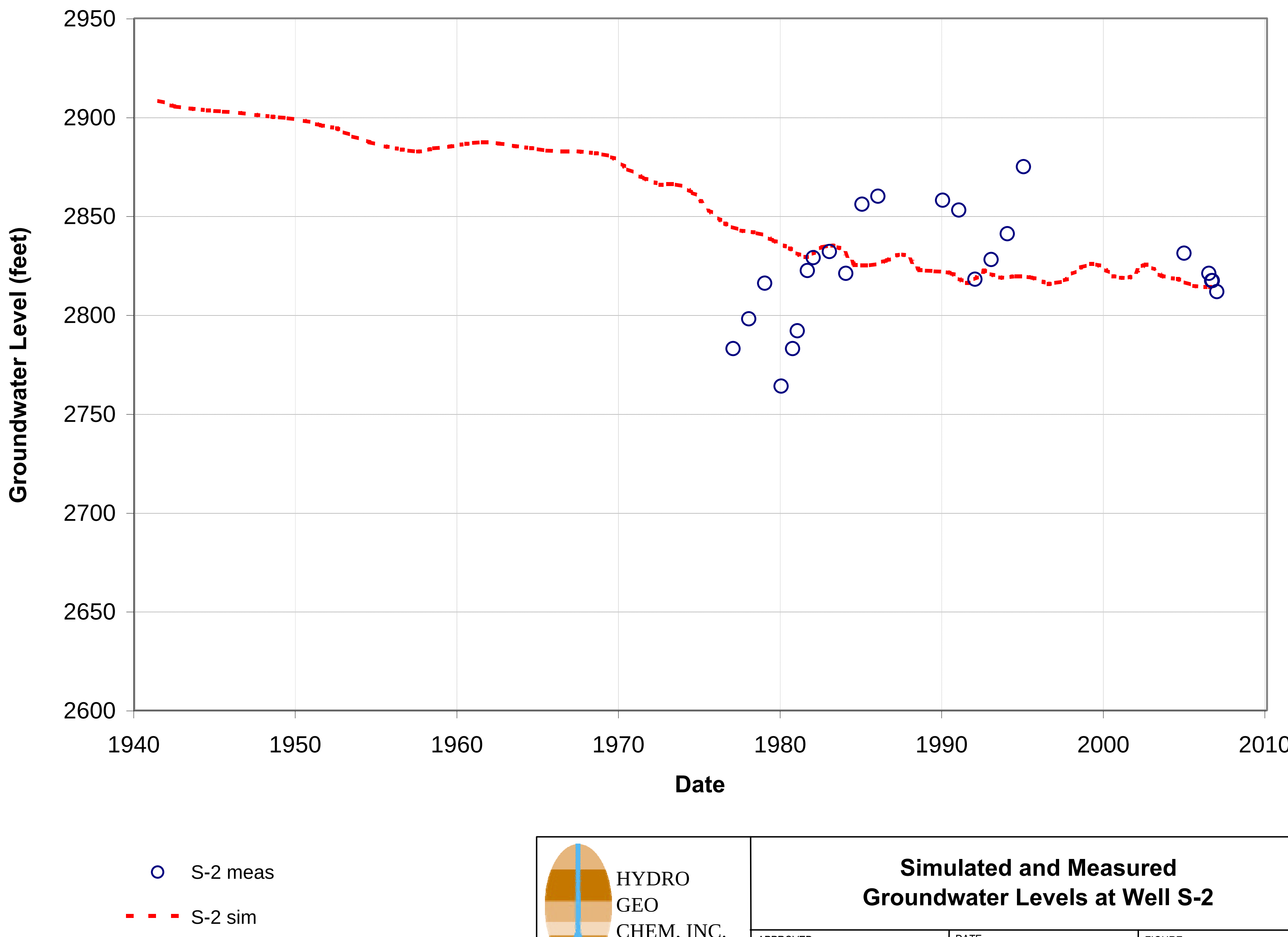


HYDRO GEO CHEM, INC.

Simulated and Measured Groundwater Levels at Well S-1

APPROVED	DATE	FIGURE
NWH	11/20/2007	I.2.1

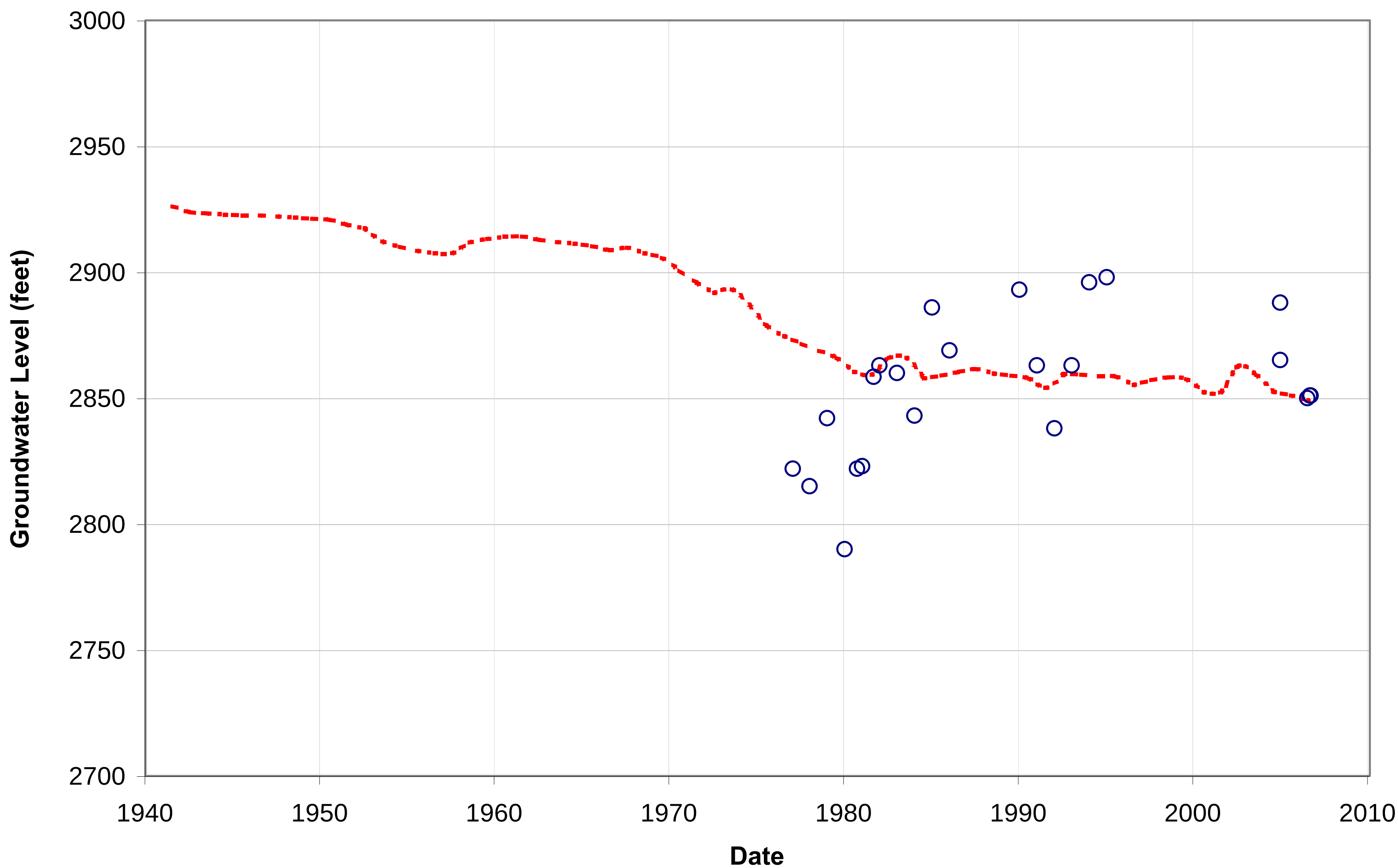
H:\78300\78314 Numerical Model\HGC Model\calibration\TimeSeries3.xls: S1G



HYDRO GEO CHEM, INC.

Simulated and Measured Groundwater Levels at Well S-2

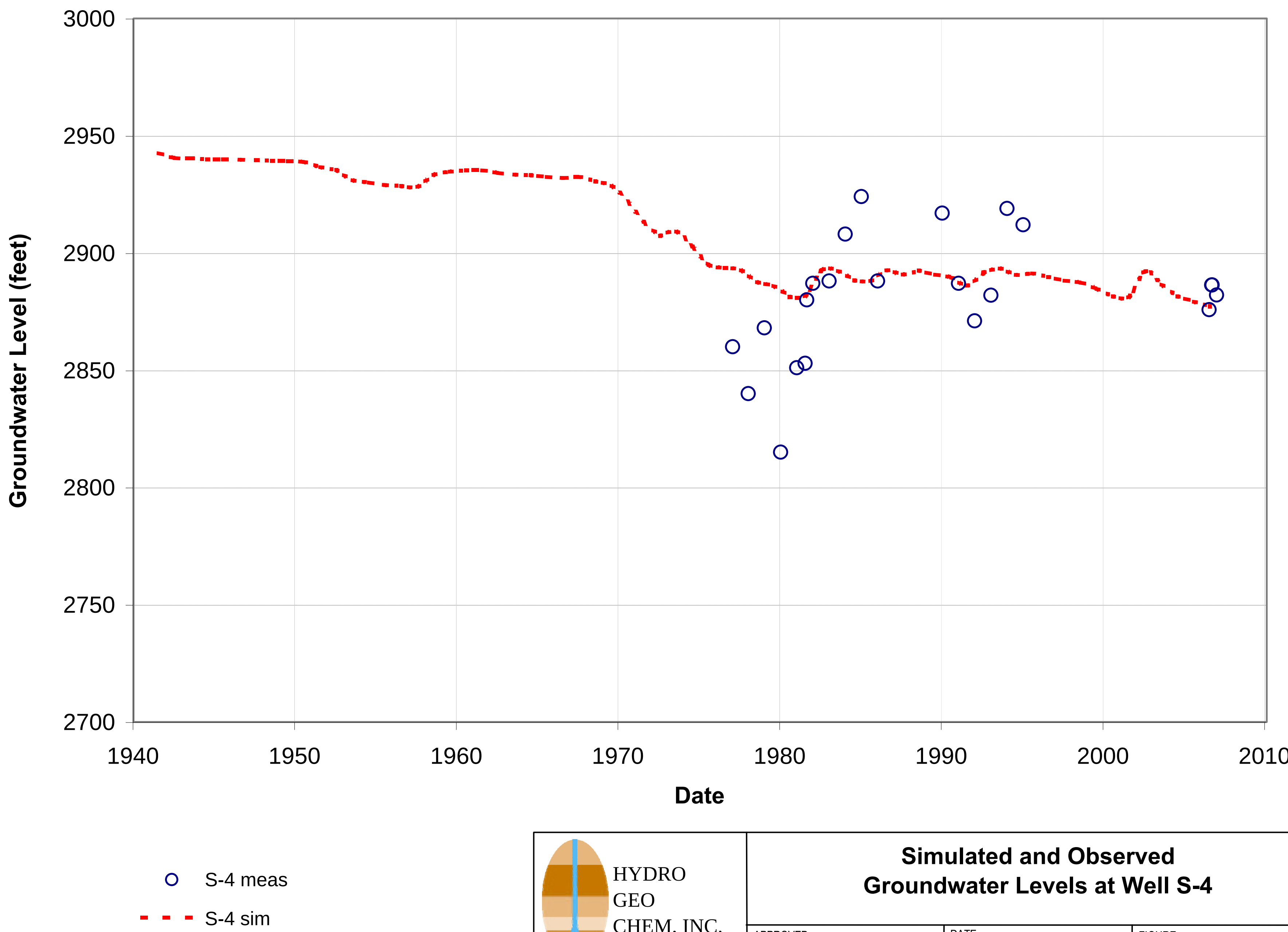
APPROVED	DATE	FIGURE
NWH	11/20/2007	I.2.2



HYDRO GEO CHEM, INC.

Simulated and Measured Groundwater Levels at Well S-3		
APPROVED NWH	DATE 11/20/2007	FIGURE I.2.3

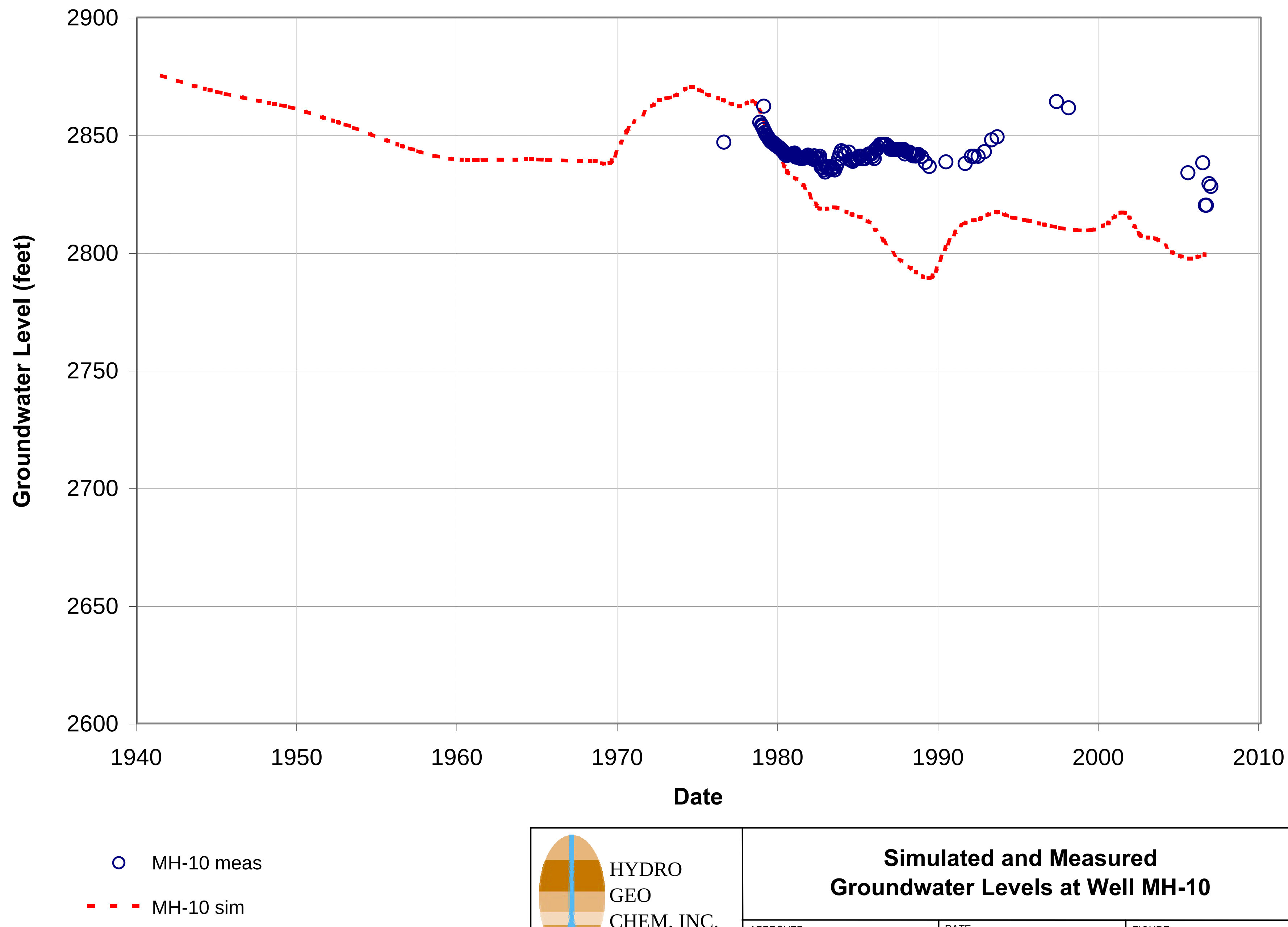
H:\78300\78314 Numerical Model\HGC Model\calibration\TimeSeries3.xls: S3G



HYDRO
GEO
CHEM, INC.

Simulated and Observed
Groundwater Levels at Well S-4

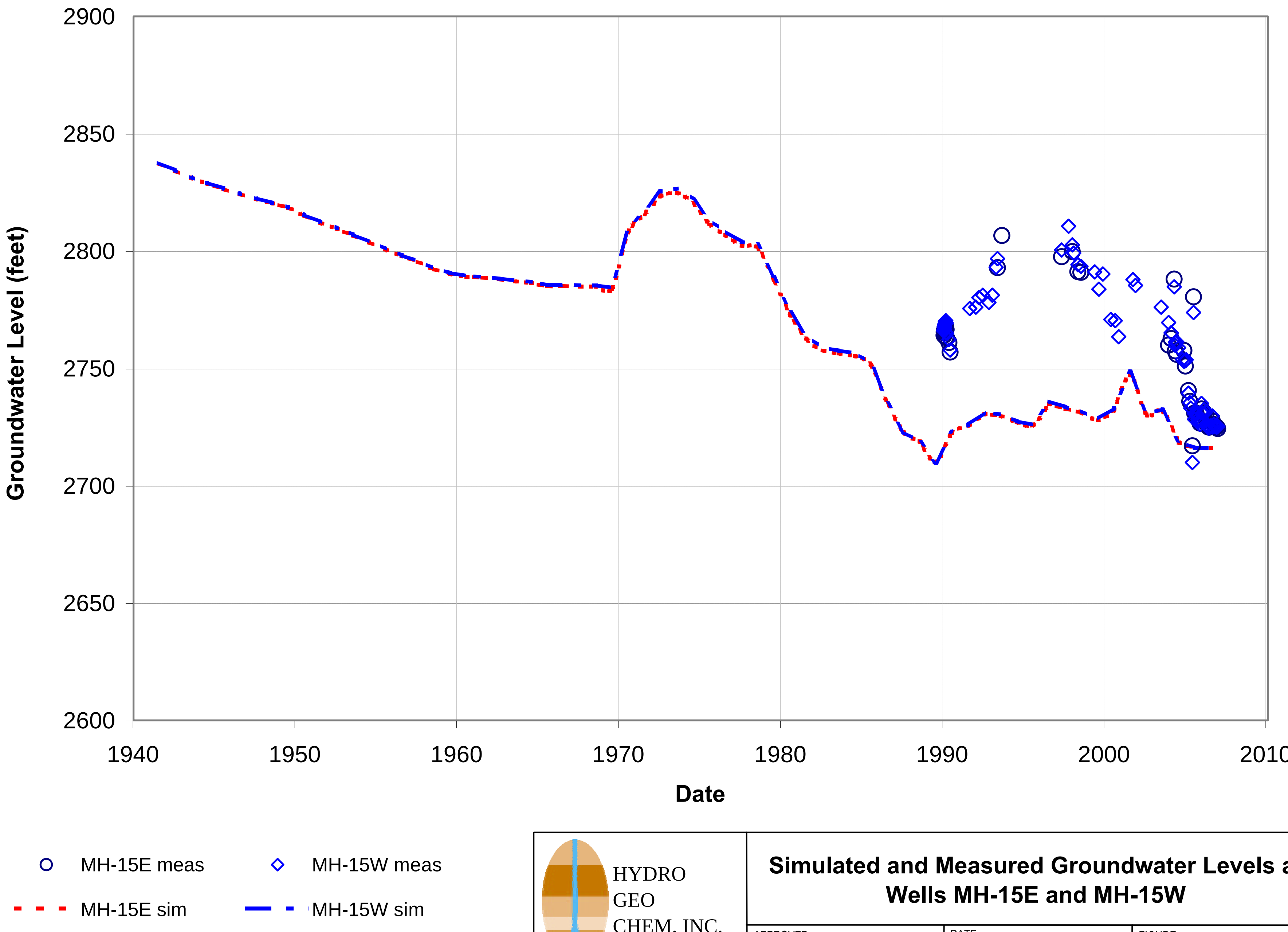
APPROVED	DATE	FIGURE
NWH	11/20/2007	I.2.4



HYDRO GEO CHEM, INC.

Simulated and Measured Groundwater Levels at Well MH-10		
APPROVED NWH	DATE 11/20/2007	FIGURE I.2.5

H:\78300\78314 Numerical Model\HGC Model\calibration\TimeSeries2.xls: MH10G

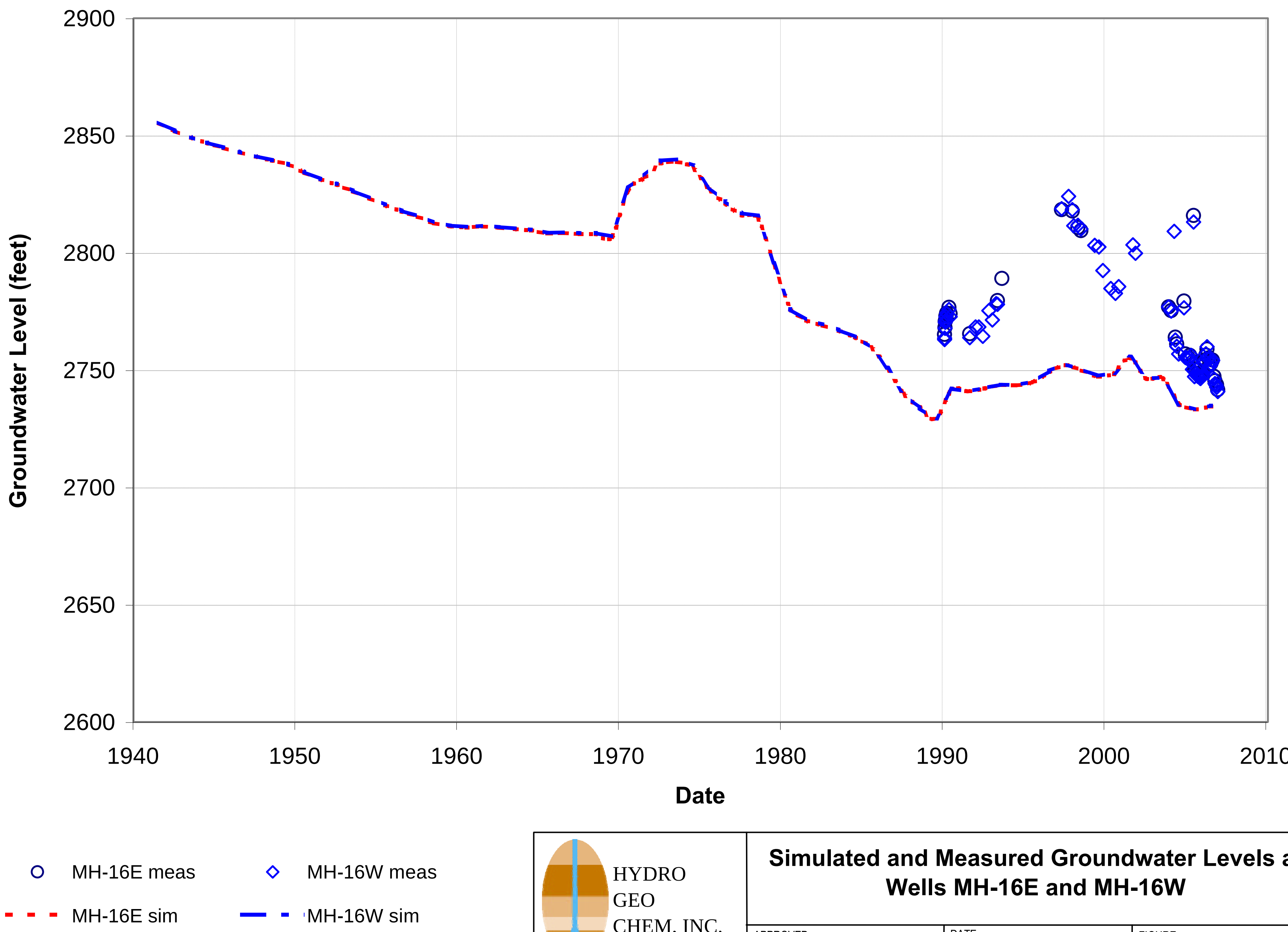


HYDRO GEO CHEM, INC.

Simulated and Measured Groundwater Levels at Wells MH-15E and MH-15W

APPROVED	DATE	FIGURE
NWH	11/20/2007	I.2.6

H:\78300\78314 Numerical Model\HGC Model\calibration\TimeSeries2.xls: MH15G

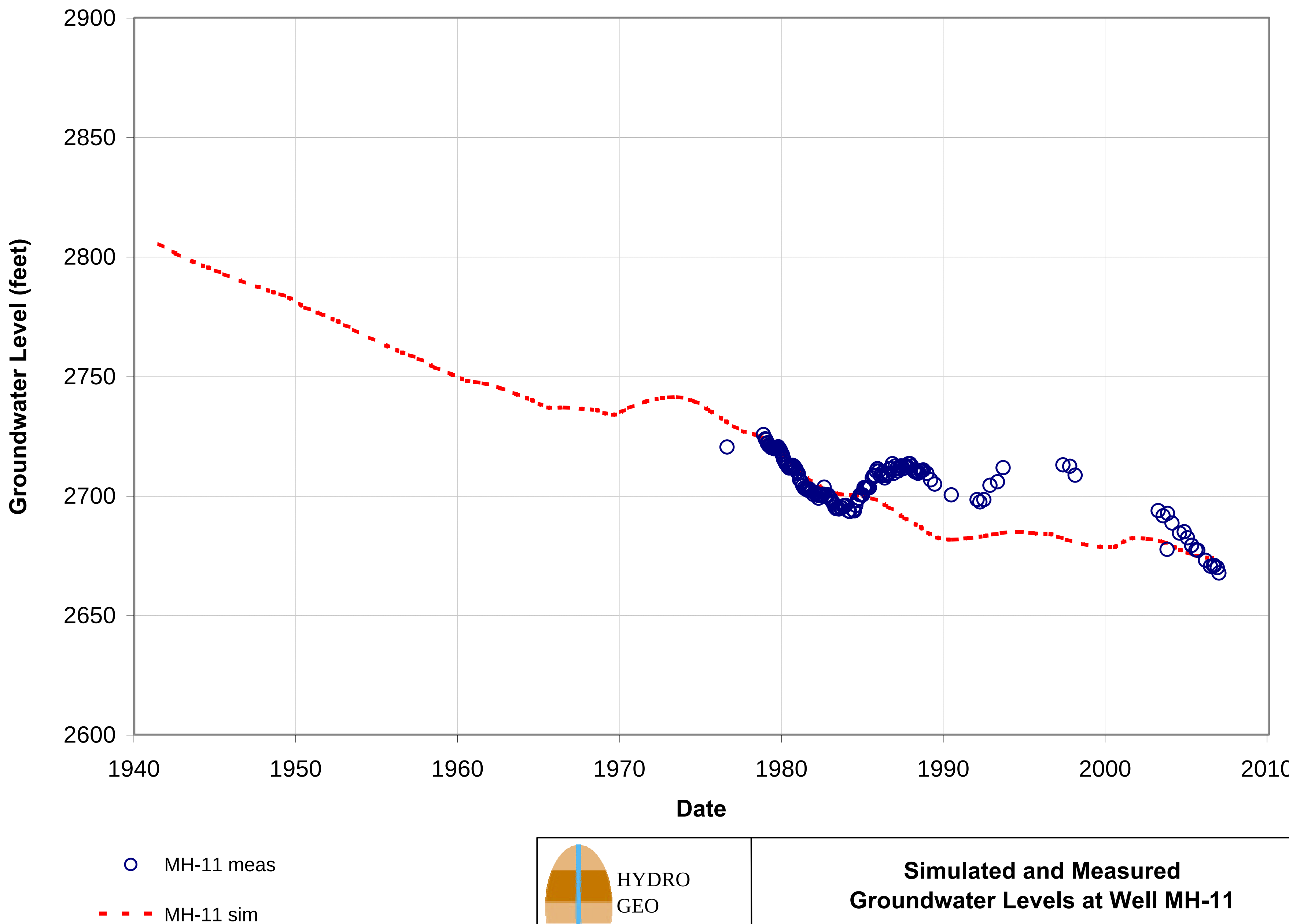


HYDRO GEO CHEM, INC.

Simulated and Measured Groundwater Levels at Wells MH-16E and MH-16W

APPROVED	DATE	FIGURE
NWH	11/20/2007	I.2.7

H:\78300\78314 Numerical Model\HGC Model\calibration\TimeSeries2.xls: MH16G

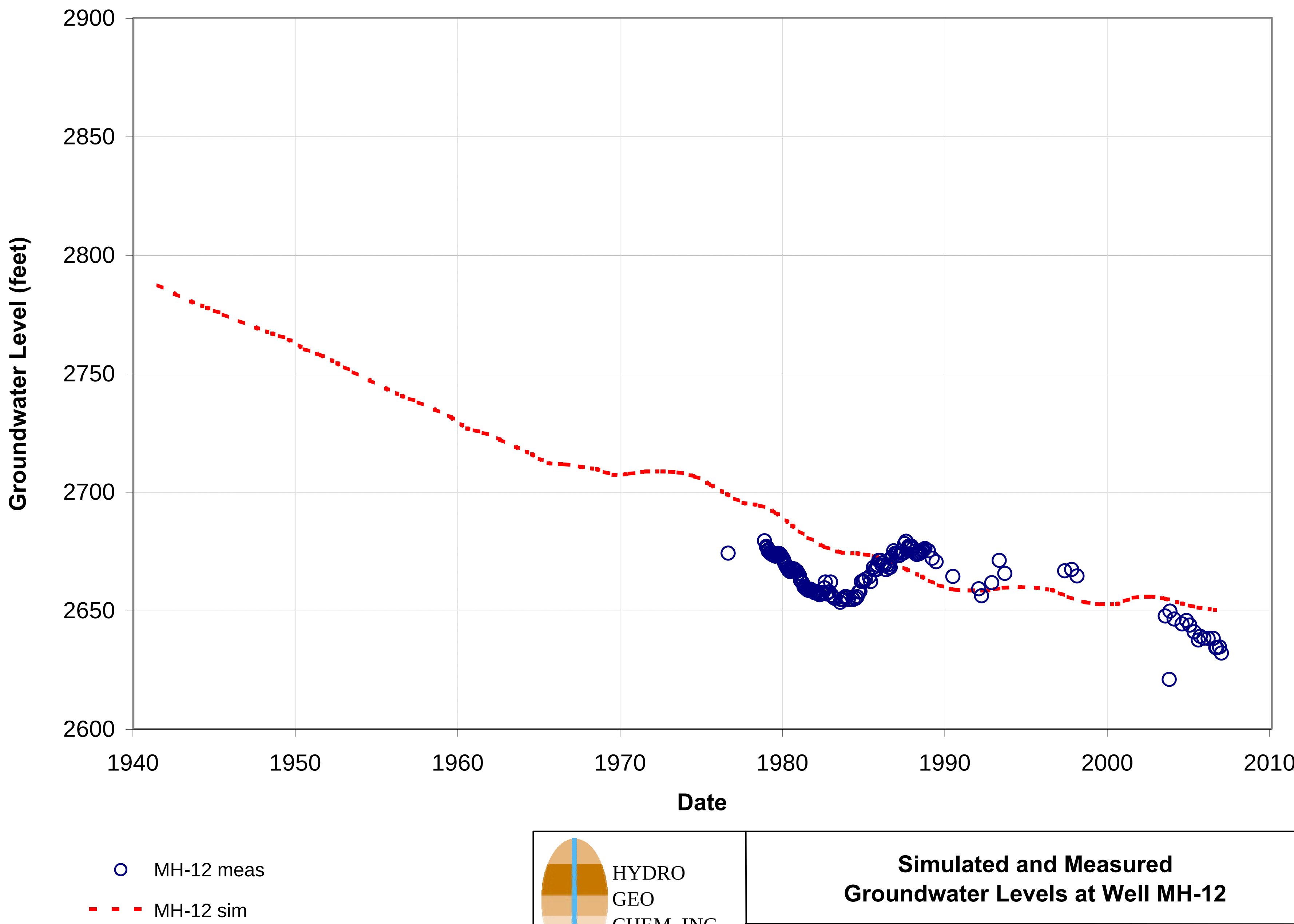


HYDRO
GEO
CHEM, INC.

Simulated and Measured Groundwater Levels at Well MH-11

APPROVED	DATE	FIGURE
NWH	11/20/2007	I.2.8

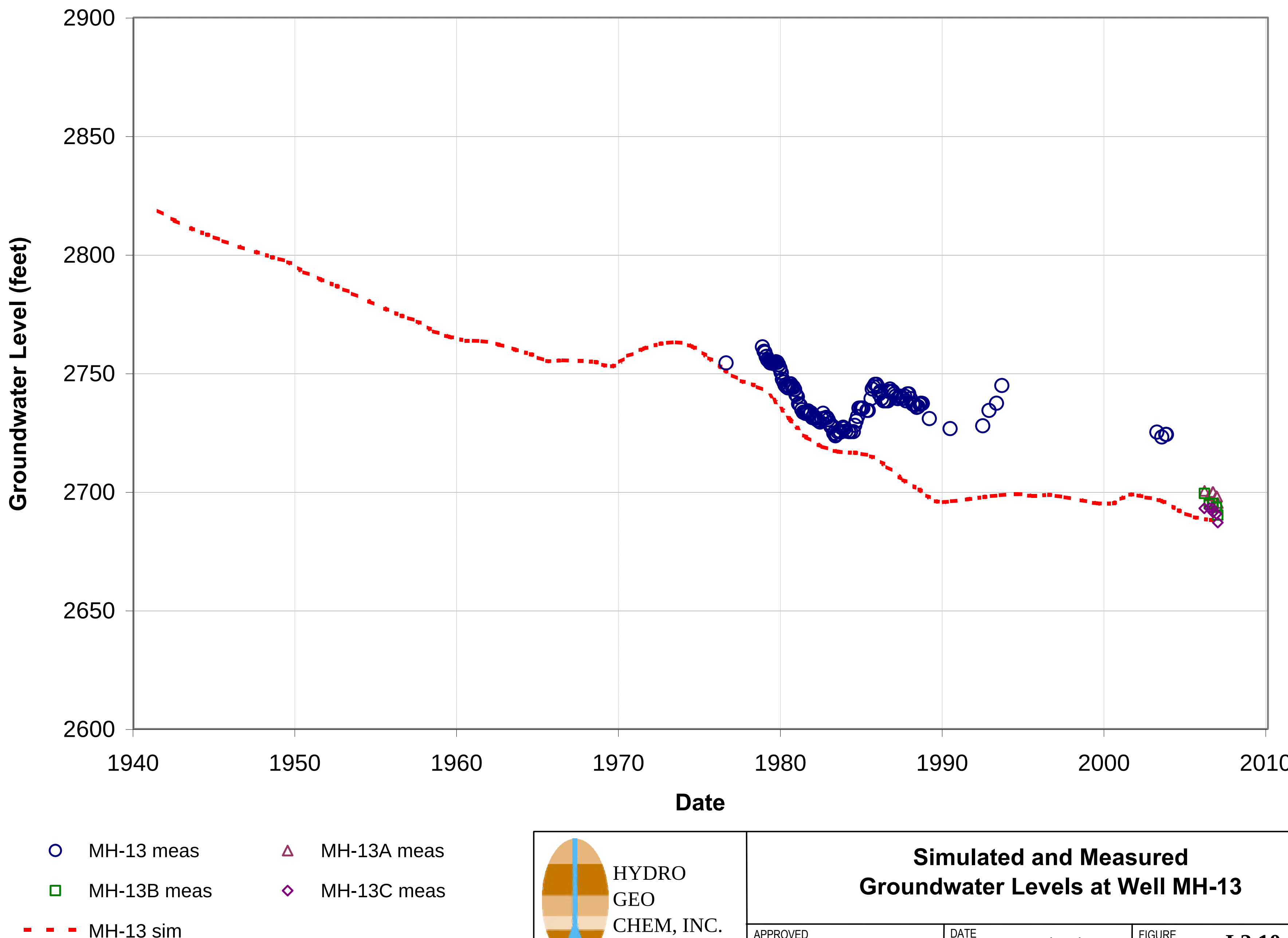
H:\78300\78314 Numerical Model\HGC Model\calibration\TimeSeries2.xls: MH11G



HYDRO GEO CHEM, INC.

Simulated and Measured Groundwater Levels at Well MH-12

APPROVED	DATE	FIGURE
NWH	11/20/2007	I.2.9

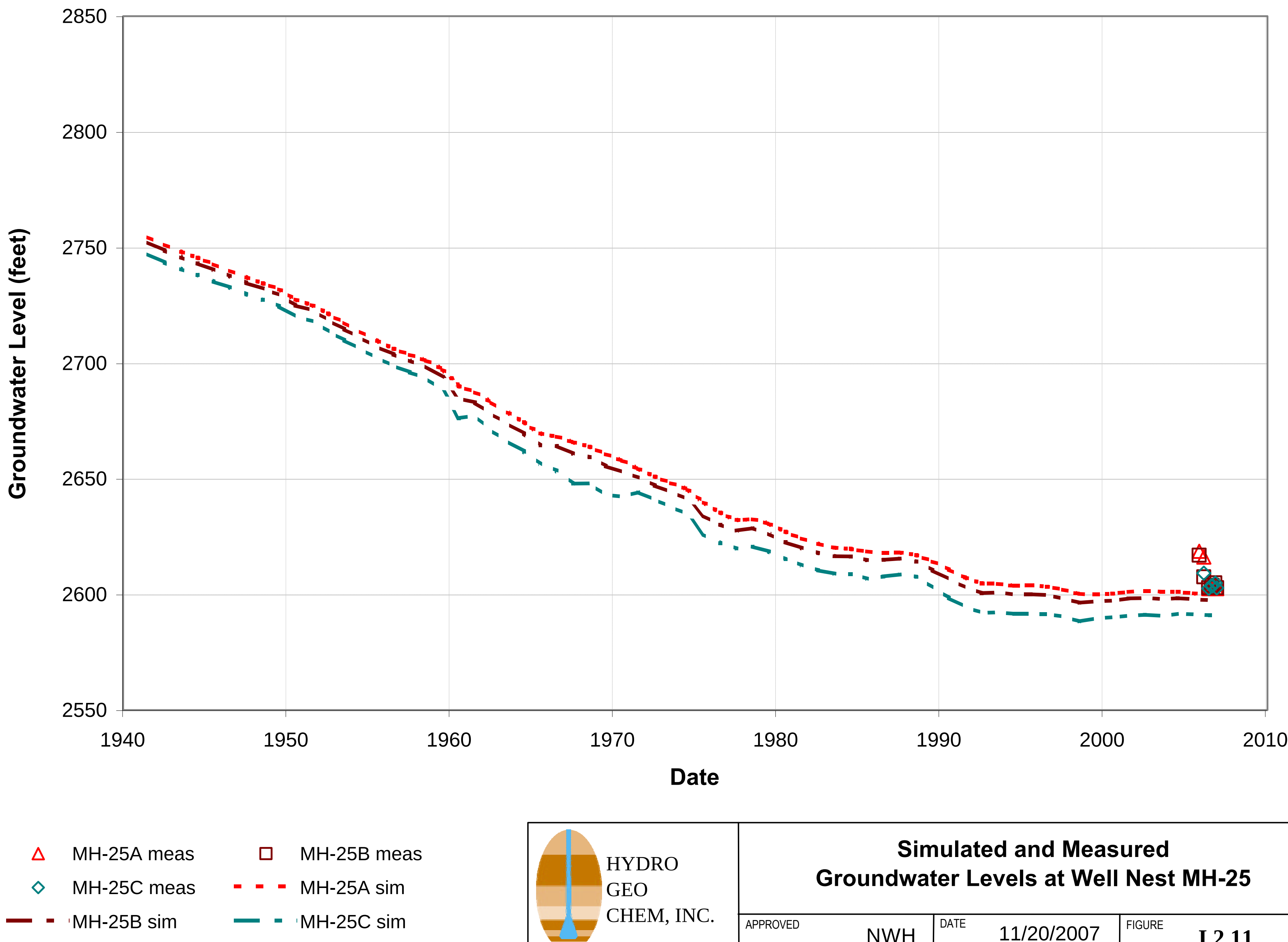


HYDRO GEO CHEM, INC.

Simulated and Measured Groundwater Levels at Well MH-13

APPROVED	DATE	FIGURE
NWH	11/20/2007	I.2.10

H:\78300\78314 Numerical Model\HGC Model\calibration\TimeSeries2.xls: MH13G



HYDRO
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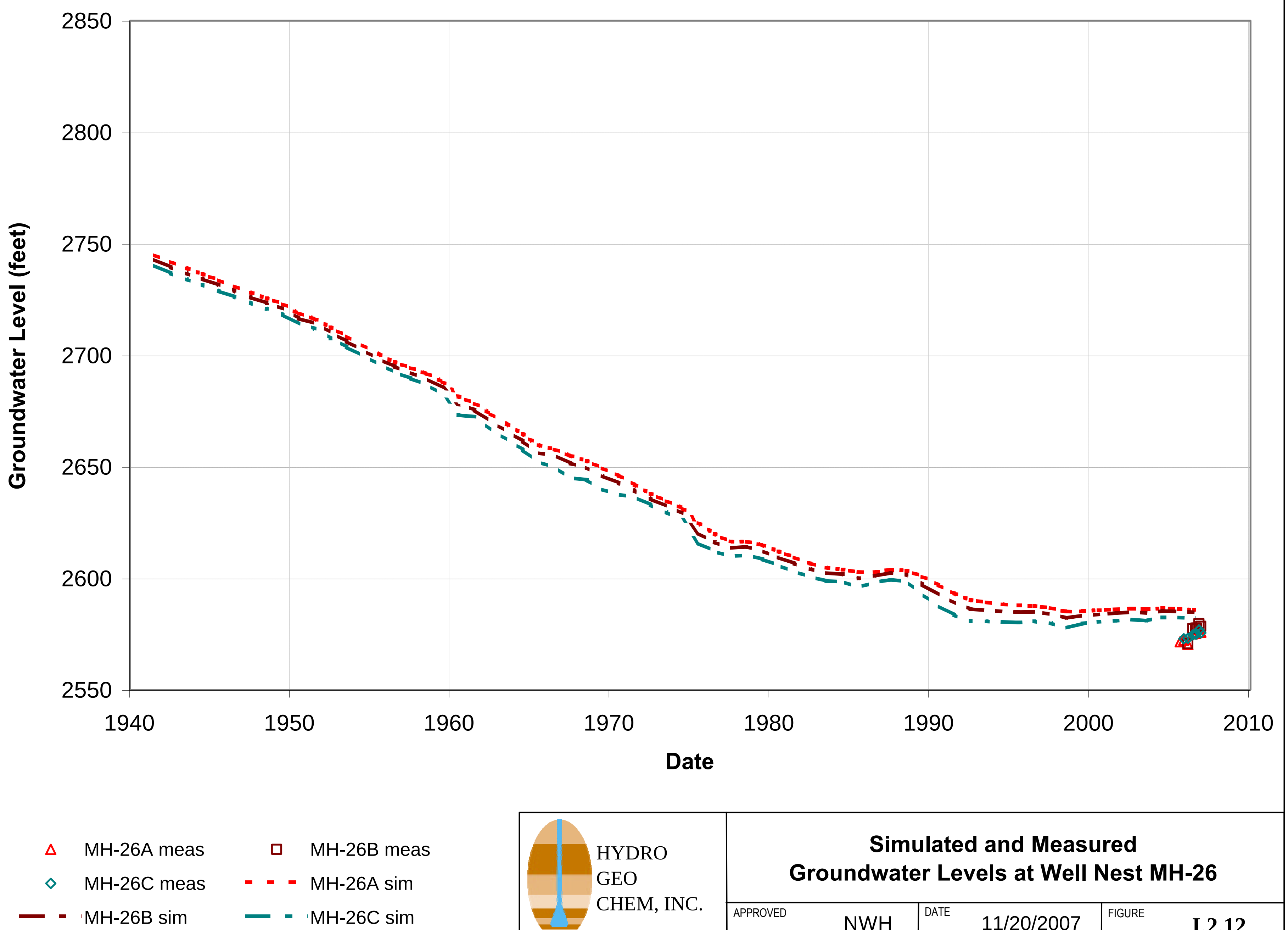
CHEM, INC.

Simulated and Measured Groundwater Levels at Well Nest MH-25

APPROVED	DATE	FIGURE
NWH	11/20/2007	I.2.11

H:\78300\78314 Numerical Model\HGC Model\calibration\TimeSeries2.xls: MH25G



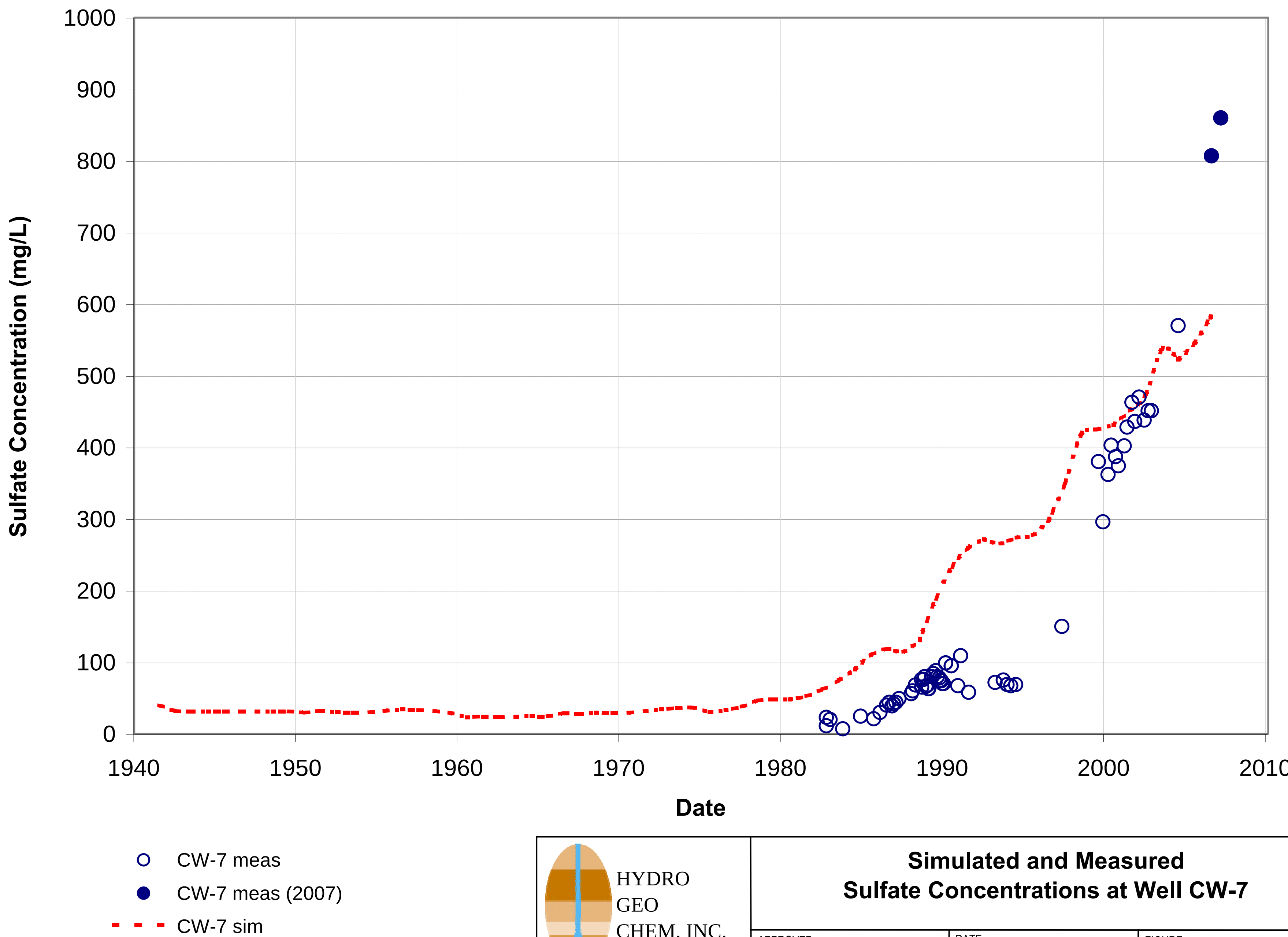
HYDRO GEO CHEM, INC.

Simulated and Measured Groundwater Levels at Well Nest MH-26		
APPROVED NWH	DATE 11/20/2007	FIGURE I.2.12

H:\78300\78314 Numerical Model\HGC Model\calibration\TimeSeries2.xls: MH26G

APPENDIX I.3

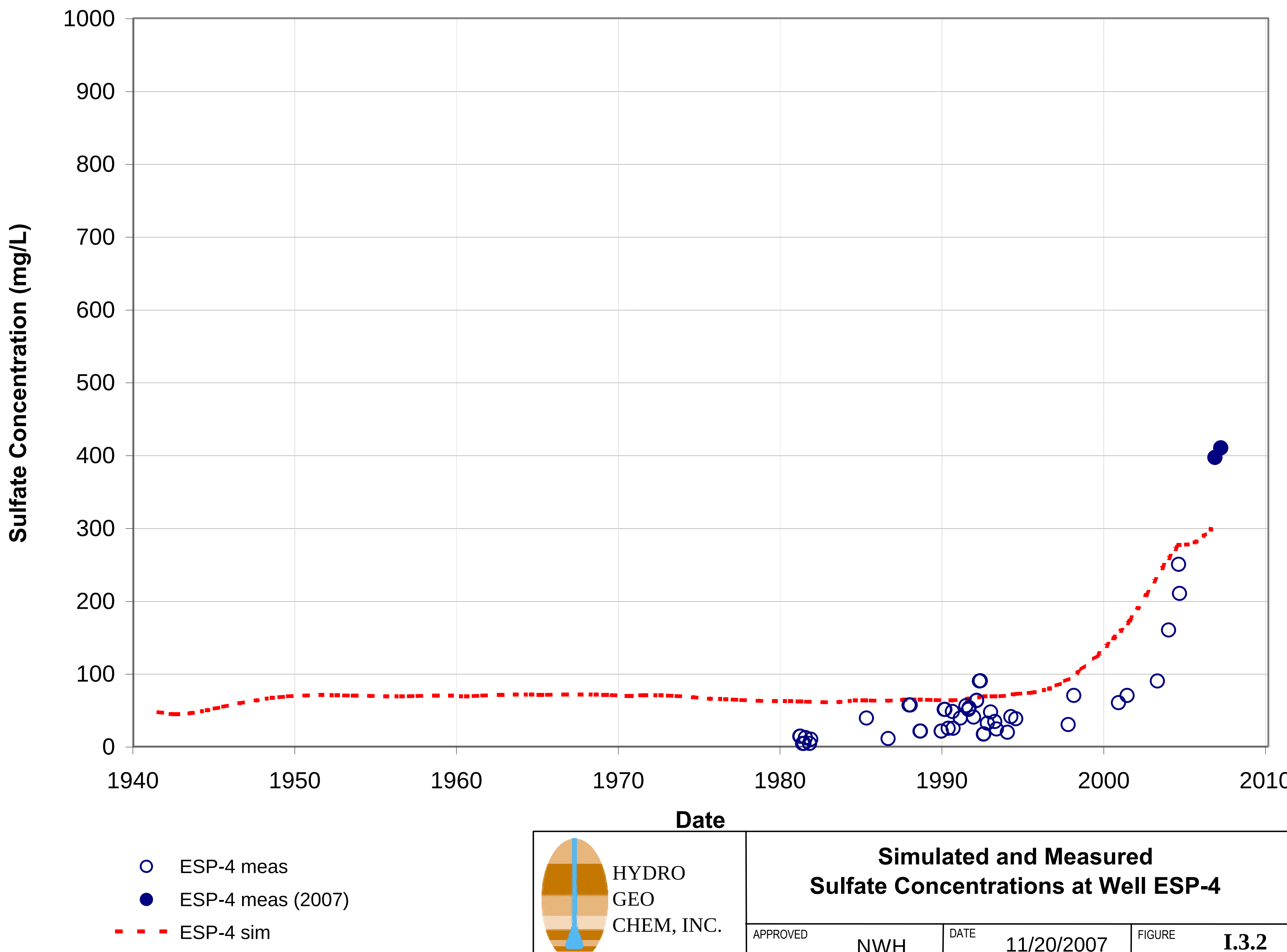
MEASURED AND SIMULATED CHEMOGRAPHS AT SELECT WELLS



HYDRO
GEO
CHEM, INC.

Simulated and Measured
Sulfate Concentrations at Well CW-7

APPROVED	DATE	FIGURE
NWH	11/20/2007	I.3.1

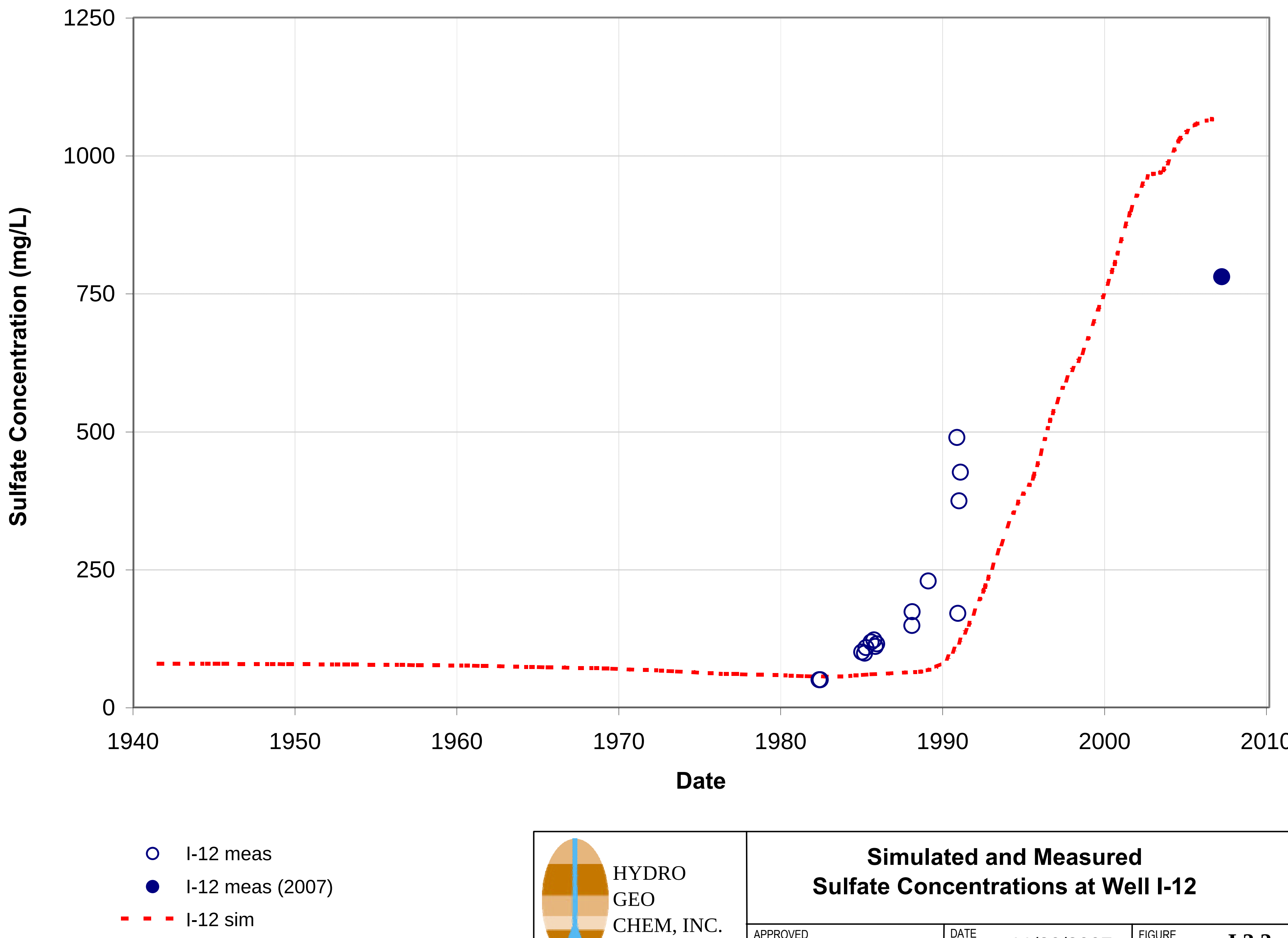


HYDRO GEO CHEM, INC.

Simulated and Measured Sulfate Concentrations at Well ESP-4

APPROVED	DATE	FIGURE
NWH	11/20/2007	I.3.2

H:\78300\78314 Numerical Model\HGC Model\calibration\TimeSeries.xls: ESP4S

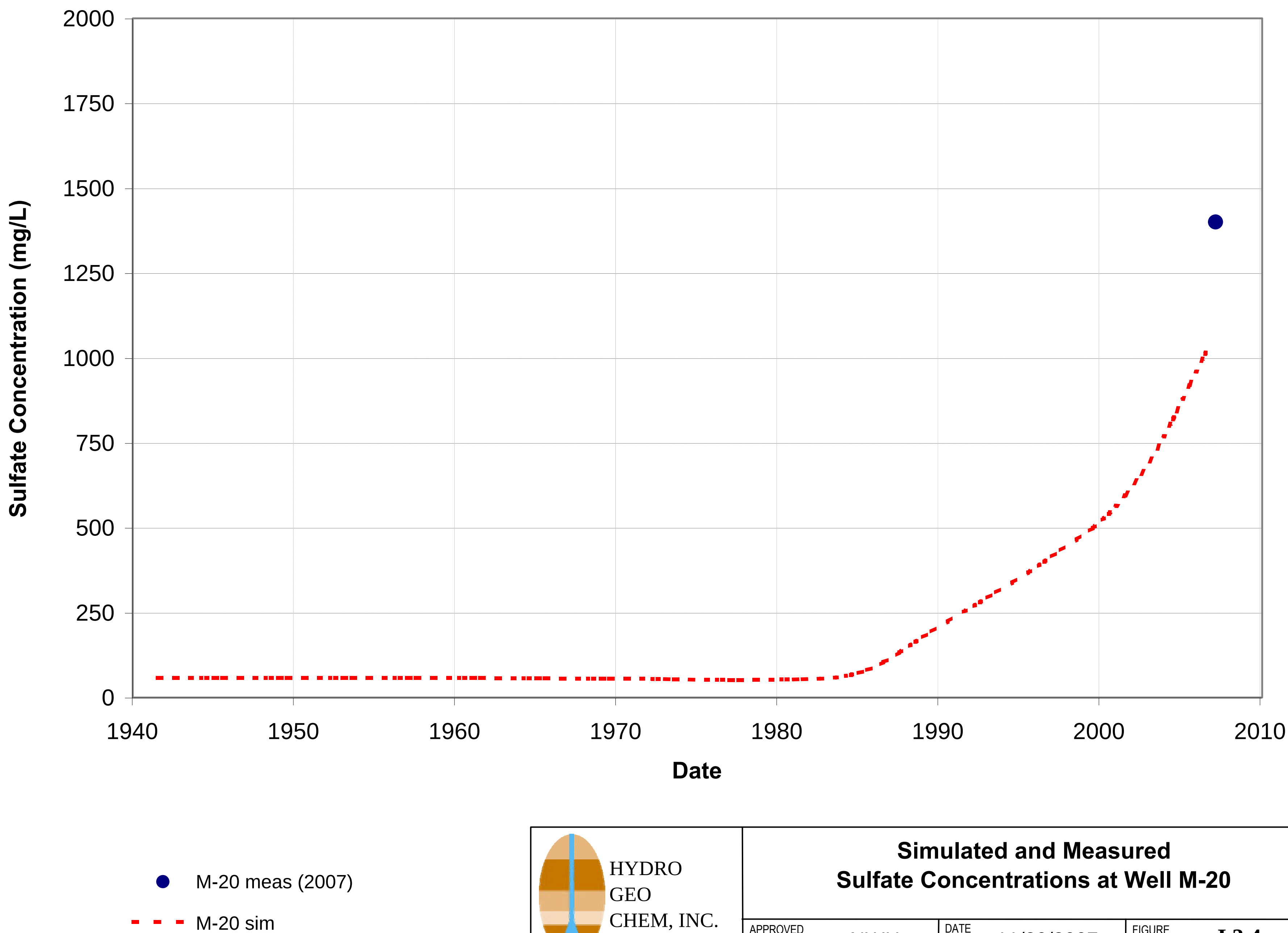


HYDRO GEO CHEM, INC.

Simulated and Measured Sulfate Concentrations at Well I-12

APPROVED	DATE	FIGURE
NWH	11/20/2007	I.3.3

H:\78300\78314 Numerical Model\HGC Model\calibration\TimeSeries.xls: I12S

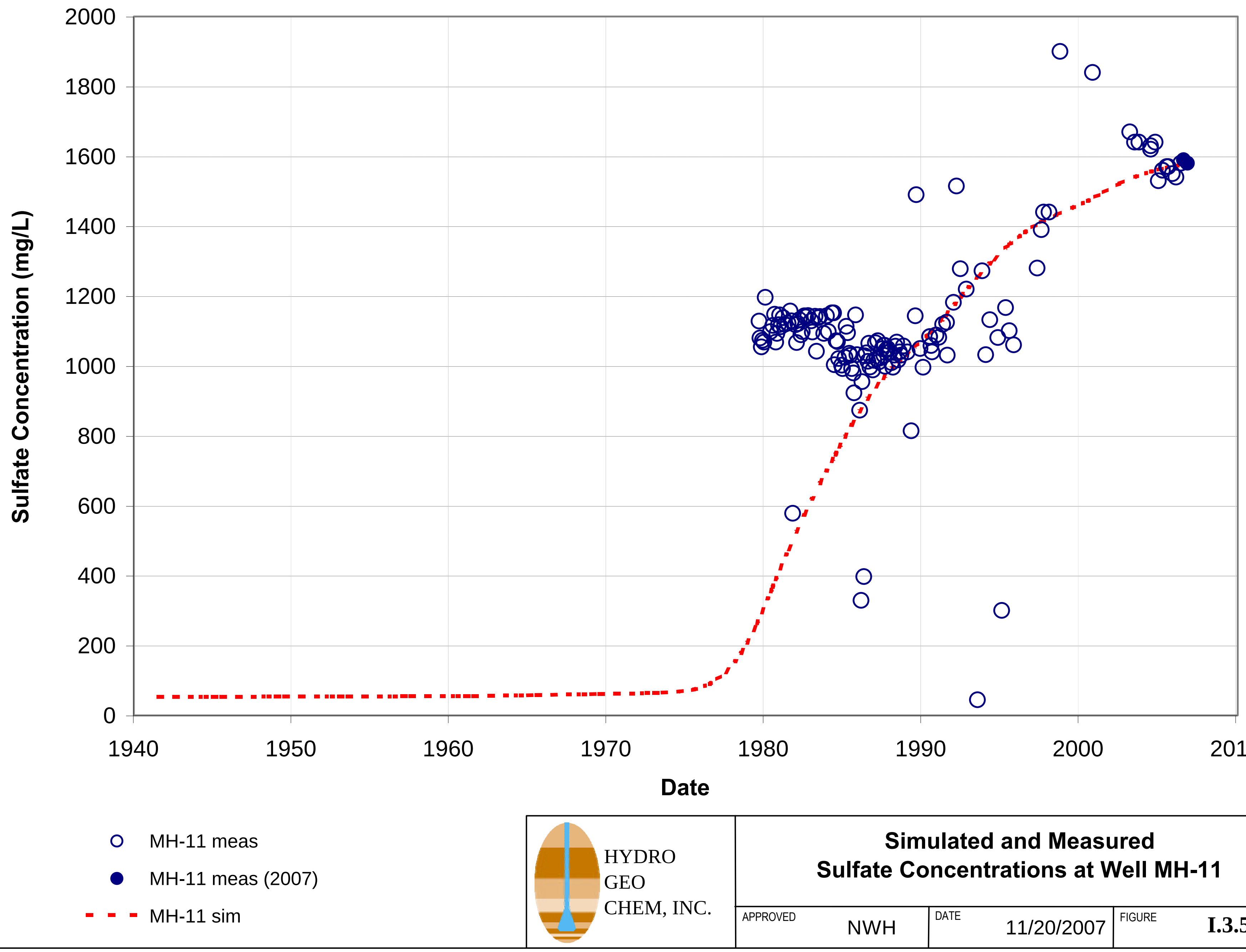


HYDRO GEO CHEM, INC.

Simulated and Measured Sulfate Concentrations at Well M-20

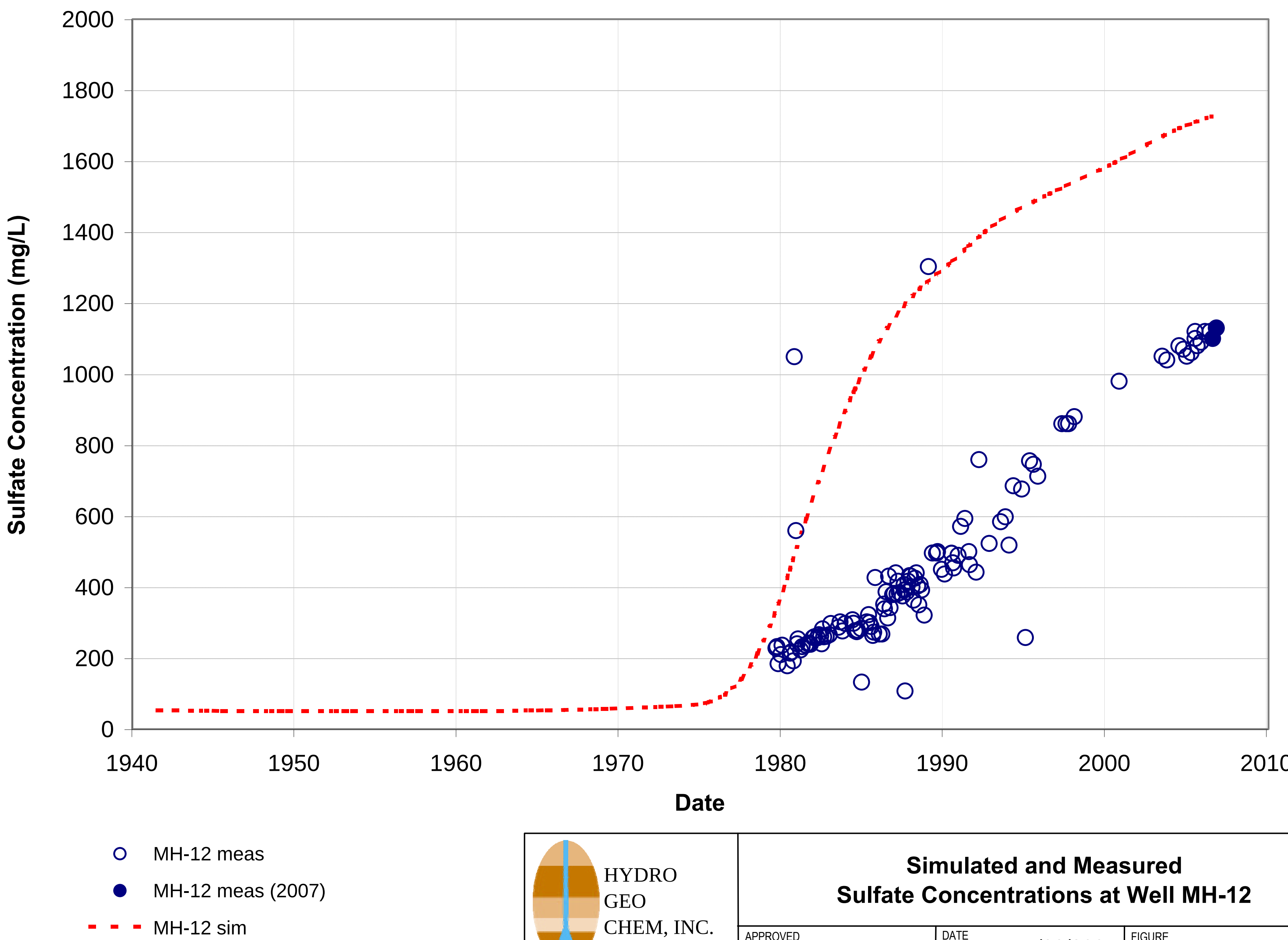
APPROVED	DATE	FIGURE
NWH	11/20/2007	I.3.4

H:\78300\78314 Numerical Model\HGC Model\calibration\TimeSeries3.xls: M20S



HYDRO GEO CHEM, INC.	Simulated and Measured Sulfate Concentrations at Well MH-11		
	APPROVED NWH	DATE 11/20/2007	FIGURE I.3.5

H:\78300\78314 Numerical Model\HGC Model\calibration\TimeSeries2.xls: MH11S

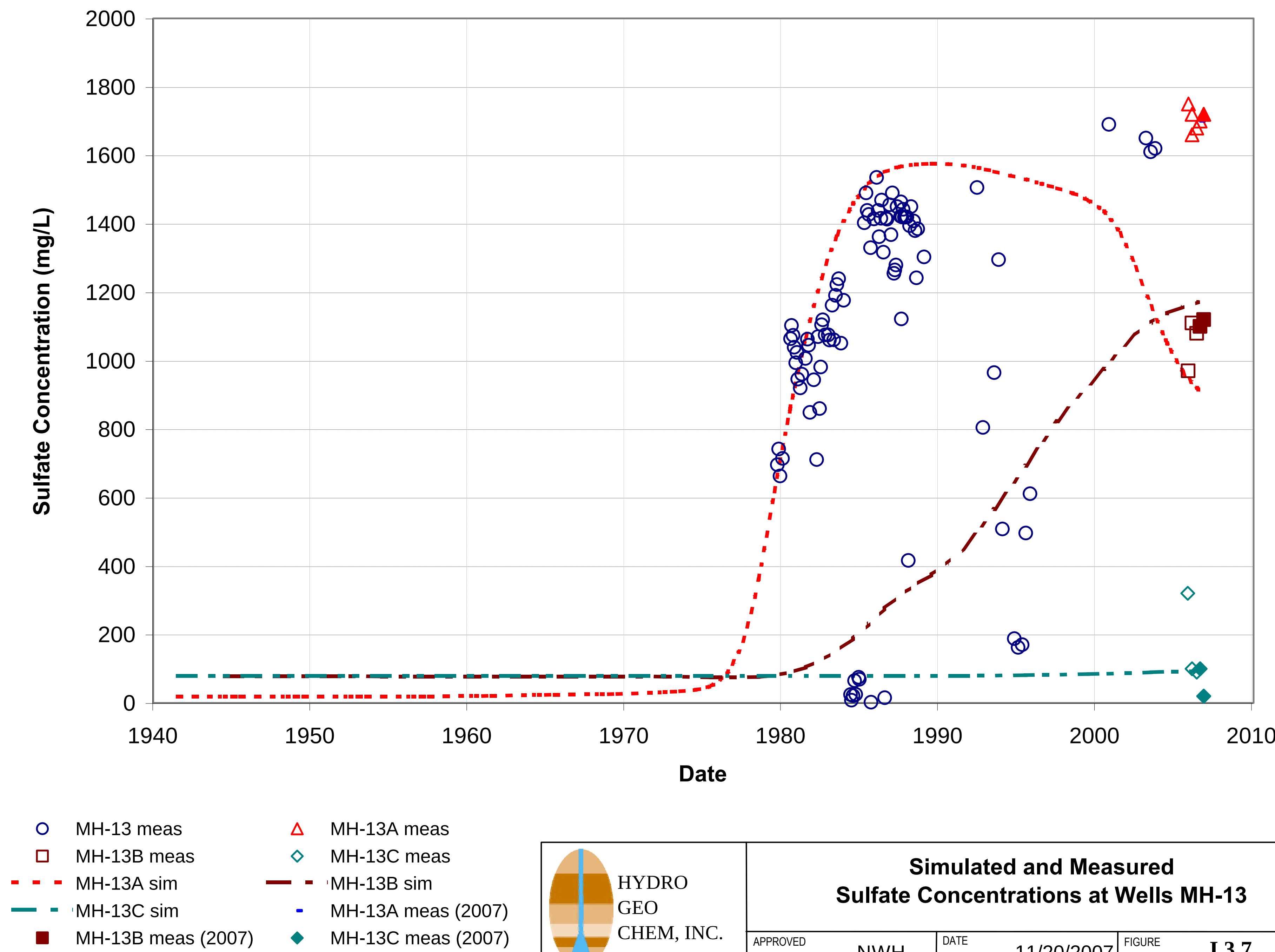


HYDRO GEO CHEM, INC.

Simulated and Measured Sulfate Concentrations at Well MH-12

APPROVED	DATE	FIGURE
NWH	11/20/2007	I.3.6

H:\78300\78314 Numerical Model\HGC Model\calibration\TimeSeries2.xls: MH12S



HYDRO GEO CHEM, INC.

Simulated and Measured Sulfate Concentrations at Wells MH-13		
APPROVED NWH	DATE 11/20/2007	FIGURE I.3.7

H:\78300\78314 Numerical Model\HGC Model\calibration\TimeSeries2.xls: MH13S