GROUNDWATER MODELING REPORT FOR KENNECOTT UTAH COPPER CORPORATION SOUTH FACILITIES GROUNDWATER PLUME SOUTHWESTERN JORDAN VALLEY, UTAH

REVISED FLOW AND TRANSPORT MODEL SOUTHWESTERN JORDAN VALLEY, UTAH

NOVEMBER 2000
(Revised: August 2003)

KENNECOTT UTAH COPPER CORPORATION

(This page intentionally left blank)

TABLE OF CONTENTS

EXECUTIVE SUMMARY .... **ii**

1.0 Introduction **1**

1.1 Background 1

1.2 Modeling Codes 2

2.0 Modeling Approach **2**

2.1 Purpose and Scope 2

2.2 Current Model Status 2

2.3 Head-Dependent Western Boundary 3

2.4 Eastern Boundary Model Expansion 4

2.5 Revised Model Calibration 5

2.5.1 Steady-State Calibration 5

2.5.2 Transient-State Calibration 6

2.5.3 Model Sensitivity 7

3.0 CURRENT MODELING RESULTS **7**

3.1 Current Bingham Creek Groundwater Remediation Scenario 7

4.0 LIMITATIONS OF THE MODELING **9**

5.0 CONCLUSIONS **9**

6.0 REFERENCES **12**

LIST OF TABLES

Table 1: Modeling Extraction Rates for KUCC Production Wells 3

Table 2: Steady-State Flow Model Calibration Results 6

Table 3: Extraction Rates for the Proposed Remedial Strategy 8

LIST OF FIGURES

Figure 1: Flow model study area location map 1

Figure 2: Evaluation zones for comparing head-dependent vs. specified flux boundaries. 4

Figure 3: Revised model's expanded eastern boundary 4

Figure 4: Current modeling scenario well placement locations 8

ATTACHMENTS:

Figures 5-8: Time series charts for the revised model transient calibration at selected locations

Figures 9-12: Sulfate and draw down plots for current remedial modeling scenario for 30 and 50 years

EXECUTIVE SUMMARY

As part of additional studies related to a Remedial Investigation and Feasibility Study (RI/FS) of groundwater in the southwestern Jordan Valley (KUCC 1998), Kennecott Utah Copper Corporation (KUCC) has continued optimization of its groundwater flow and transport model while investigating possible remedial strategies for the Bingham Creek groundwater plume. This includes continual updating of model parameters and data in order to allow KUCC to more accurately analyze groundwater flow and contaminant migration.

KUCC has made improvements to the original flow and transport model used in the RI/FS investigations, including incorporation of a head-dependent (general head) boundary along the western edge of the model that replaced the constant flux boundary used in the original model. Also, the eastern model boundary was expanded from the Jordan River east to the base of the Wasatch Mountains. Updated field data were also incorporated into the current flow and transport model.

KUCC's current expanded sub-regional model of the southwestern Jordan Valley is bounded by the Oquirrh and Traverse mountains on the west and south and by the Wasatch Mountains and approximately 6000 South Street on the east and north. The model contains a grid of 94 rows and 136 columns, with variably sized cells and eight vertical layers.

The model incorporates recharge to the principal and shallow unconfined aquifers from the following sources:

- precipitation
- bedrock aquifer
- irrigation canals
- irrigated fields, lawns and gardens
- stream and channel fill
- reservoirs and evaporation ponds.

Discharge sources include extraction from wells, evapotranspiration and head-dependent boundaries (KUCC 1998).

KUCC recalibrated the expanded model for steady and transient states in the same manner as in the RI/FS study. The steady state simulated hydrologic conditions in 1965. The transient state simulated the period 1966-1998, and included annual stress periods. Calibration variables were adjusted within reasonable ranges, as determined from data collected from the RI/FS and other work. The calibration process is considered successful when a reasonable match is made between observed and modeled conditions for the years being simulated.

The calibrated model closely matched observed water-level declines, estimated flow exchange to the Jordan River, computed flows through the northern and eastern boundaries, sulfate concentrations and vertical hydraulic gradients throughout the modeled area. It is therefore considered to be a useful tool for predicting flow and contaminant transport for the SWJV.

Many potential remedial responses have been investigated with the updated flow and transport model since the publication of the RI/FS. The primary remedial strategy involves increased

extraction between the region of the acid extraction well ECG1146 and the sulfate extraction wells K109/B2G1193. All scenarios have used combined West Jordan municipal pumping rates of 2500 gallons per minute (gpm) for their four production wells W420, W361, W363 and W387 while Riverton municipal pumping was increased to 3500 gpm. West Jordan and Riverton municipal wells were changed in the model to more closely resemble seasonal pumping by incorporating extraction over a six-month period for each year and off for the other six-months. K109 and B2G1193 were pumped at constant rates of 1000 and 500 gpm respectively for all scenarios. Other KUCC extraction wells incorporated in the model include the Lark production well LTG1139 (average extraction of 250 gpm), sulfate extraction well LTG1147 (average extraction of 500 gpm). KUCC acid extraction well ECG1146 and four other proposed acid wells were modeled with varied pumping rates and durations, always totaling 2500 gpm combined (additional scenarios for acid pumping extraction between 2500 to 4000 gpm were investigated, but not included in this report). The north shoulder well was assumed to be off for these simulations.

1.0 INTRODUCTION

1.1 Background

The expanded predictive model was developed to provide a tool for better estimation of regional groundwater flow and contaminant transport as part of the continuing studies for the Kennecott Utah Copper Corporation (KUCC) Remedial Investigation and Feasibility Study (RI/FS) of groundwater in the southwestern Jordan Valley, Utah. The area of the expanded RI/FS model is shown in Figure 1.

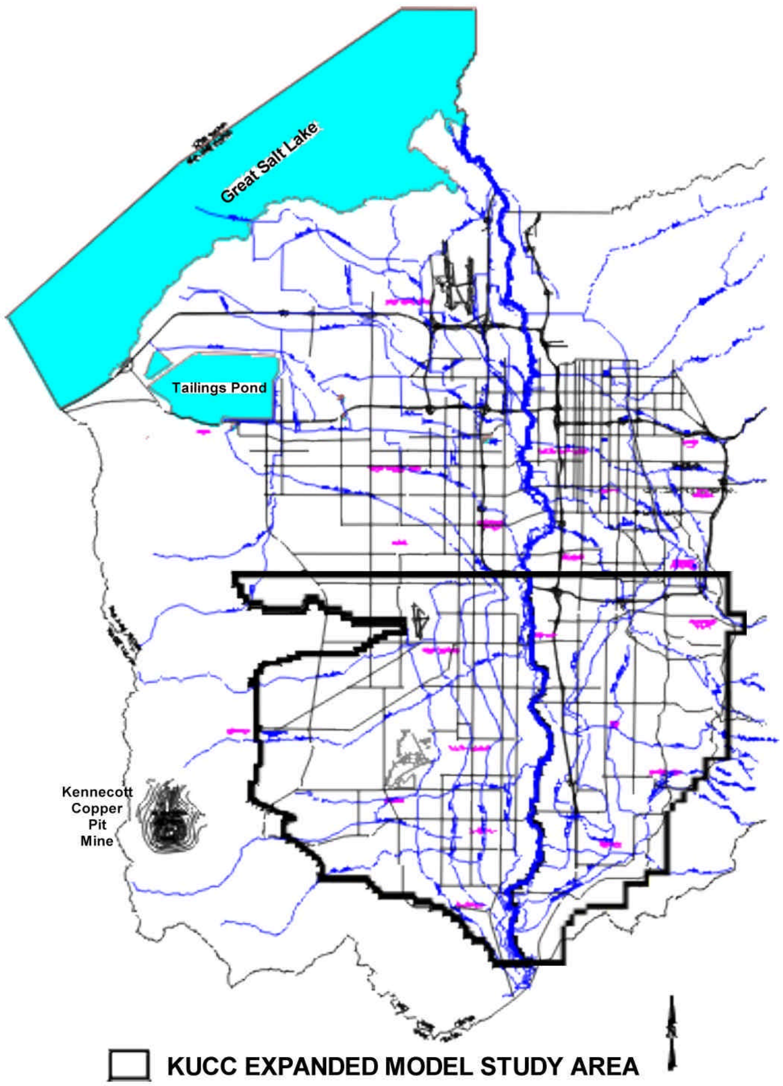


Figure 1: Expanded predictive flow model location map

1.2 Modeling Codes

The groundwater flow model was developed using the finite difference, modular, three-dimensional groundwater flow model MODFLOW (McDonald and Harbaugh 1988) coupled with MT3D (Zheng 1996), which is a three-dimensional transport code. MODFLOW was developed by the U.S. Geological Survey to approximate flow within a groundwater flow system. MT3D is a transport model that combines groundwater flow with the physical aspects of contaminant transport, including advection, dispersion and chemical reactions.

2.0 MODELING APPROACH

2.1 Purpose and Scope

The purpose of this report is to summarize the changes and updates incorporated into the KUCC South Facilities expanded flow and transport model since publication of the KUCC South Facilities RI/FS in 1998.

The primary reason for continuing to update the KUCC flow and transport groundwater model in this region is that comparison of current field conditions with 1996 data shows that the Bingham Canyon groundwater contamination has migrated. In order to provide a better estimation for possible containment scenarios within the model, updates to the model data need to be continually incorporated to provide higher confidence possible for modeling remedial actions.

This report focuses on the main issues of concern raised by the RI/FS Technical Review Committee (TRC) about the original RI/FS model including: the use of an upgradient constant-flux boundary, the Jordan River as a groundwater flow divide, the lack of a transport code capable of simulating density-driven flow and changes in the lengths of the stress periods to more accurately simulate seasonal well pumping. These previous modeling limitations were discussed in the RI/FS as well as in the modeling reports included in the RI/FS appendices.

2.2 Current Model Status

The current model has undergone the following major changes since March 1998:

1) Incorporation of an upgradient head-dependent boundary along the western margin
2) Expansion of the model's eastern boundary to extend from the Jordan River (previously modeled as a groundwater flow divide) to the base of the Wasatch Mountains
3) Change of simulation stress periods to six months to better emulate seasonal pumping
4) Integration of new data to provide the most recent and accurate information.

In addition, construction of a three-dimensional finite grid using the model code FEMWATER (developed by George T. Yeh) is underway. In addition, FEMWATER will provide a means to incorporate possible effects of density-driven flow for the acid portion of the Bingham Creek groundwater plume.

2.3 Head-Dependent Western Boundary

The specified-flux boundary was replaced by a head-dependent (or "general head") boundary along the model's western margin. This was done because a model with a fixed flux is likely to over-predict the effectiveness of containment scenarios in transport simulations.

Evaluation of the new head-dependent boundary involved assessing:

- horizontal exchange through the northern head-dependent boundary
- flow comparisons for the Jordan River reaches
- potentiometric surfaces
- drawdown maps
- calibration statistics.

Horizontal flow exchange (in versus out of the model) were compared to Hely and others (1971), as well as USGS and the previous KUCC model. Jordan River flow was investigated simultaneously with horizontal exchange to achieve a balanced representation between these two parameters. Evaluation of potentiometric maps, flow directions and drawdown for both the steady-state and transient calibrations yielded no notable problems.

The following table outlines the statistics of the current model's head-dependent western boundary. The zones mentioned in Table 1 are superimposed on model layer 3 and shown in Figure 2.

Table 1. Western Specified Flux Boundary vs. the Current Head-Dependent Boundary.

	Specified Flux Flow into the Model (cubic feet per day)	Head-Dependent (Percent Difference vs. Specified Flux)	
		Year 1	**Year 50**
Zone 1 (Layer 3)	729,972	-6.9	-2.2
Zone 2 (Layer 3)	269,500	1.8	11.7
Zone 3 (Layer 3)	292,994	4.1	5.0
Zone 1 (Layer 4)	187,960	4.5	56.8
Zone 2 (Layer 4)	70,190	5.7	13.5
Zone 3 (Layer 4)	195,510	7.5	17.2

The results of these comparisons show that as drawdown in the western portion of the model increases, flow into the model from this boundary also increased due to the increased gradient as expected compared to the characteristics of the original constant flux boundary.

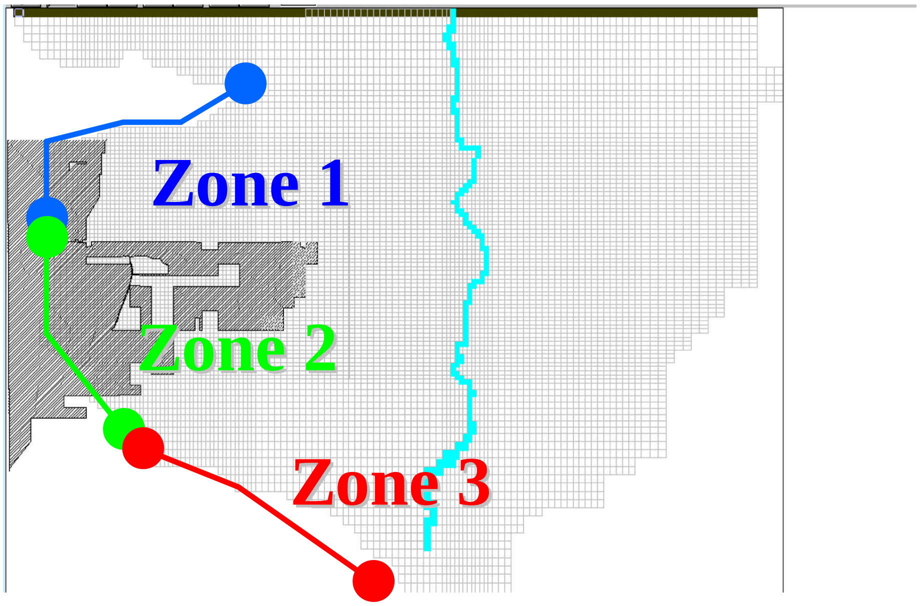


Figure 2: Evaluation zones for flow used in comparing head-dependent vs. specified flux boundaries

2.4 Eastern Boundary Model Expansion

Following incorporation of the head-dependent western boundary, the next step in updating the original RI/FS model involved expanding the model's eastern boundary from the Jordan River to the base of the Wasatch Mountains. This increased the number of columns in the model from 104 to 136. Figure 3 shows a comparison of the original eastern margin compared to the revised model.

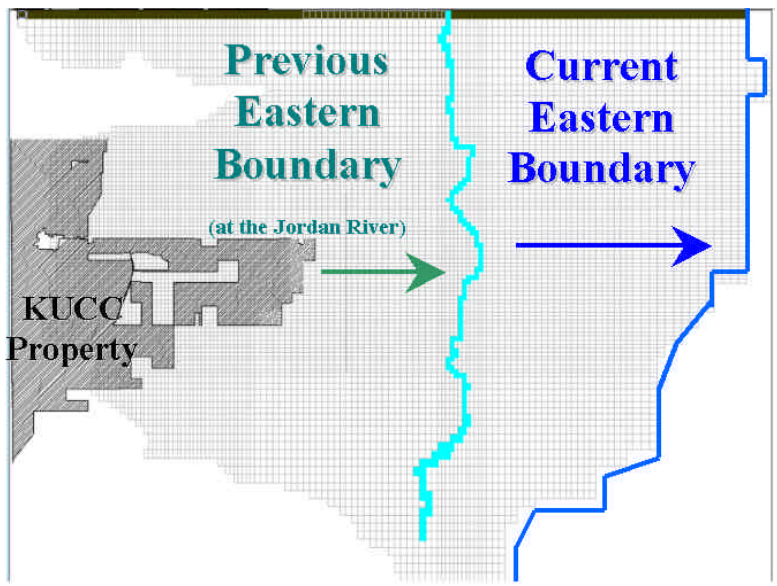


Figure 3: Revised model's expanded eastern boundary

Evaluation of the revised model following expansion of the eastern boundary involved assessing:

- horizontal exchange through the northern head-dependent boundary
- flow comparisons for the Jordan River reaches
- potentiometric surfaces
- drawdown maps
- calibration statistics.

Recalibration of the expanded model was done upon completion of model expansion as discussed in Section 2.5.

2.5 Revised Model Calibration

The KUCC model was calibrated for steady-state and transient-state conditions. Calibration of the model was completed in the same manner as in the original RI/FS. This involved an iterative process between steady and transient calibrations because of a shortage of data describing the steady-state condition of the aquifer. The calibration process focused on adjusting calibration variables to produce a reasonable match with observed water levels and estimated recharge and discharge sources within the principal and unconfined aquifers. The following sections describe steady- and transient-state calibrations for the revised KUCC model.

2.5.1 Steady-State Calibration

The steady-state calibration was directed towards achieving a reasonable match with the available measured water levels, estimated discharge to the Jordan River and the component of flow through the general-head boundaries. Vertical gradients were not considered during steady-state calibration due to the absence of data for comparison. The main parameters used as calibration variables were conductance and head values for incorporation of the western head-dependant boundary. Other calibration variables in the steady-state calibration also were investigated, including horizontal and vertical hydraulic conductivity, and areal and bedrock recharge. Irrigation and lawn watering seepage, irrigation canals seepage, river boundary parameters were not used as calibration variables. Much of the calibration process focused on the effects in the revised model due to differences in inflow from the head-dependent western margin.

Throughout the calibration process, results from each model run were compared with the available measured water levels found in the KUCC model domain. For the steady-state calibration, a total of 32 observation sites were available, all of which were located in the principal aquifer in layers 3 and 4. Data were not available within the study area for the water table within the shallow unconfined aquifer; data from the original RI/FS model were used as the default. The shallow unconfined aquifer could only be analyzed by evaluating the groundwater contribution to the Jordan River.

For each model run, a statistical analysis of the observed versus computed water levels was conducted to determine the accuracy of the simulation. Three methods were used for determining the level of accuracy. The first method involved calculating the mean of the residuals. This provides a measure of the bias of the distribution, indicating whether the simulation was over- or under-estimating the water table as a whole. The second method involved the calculation of the root mean square or standard deviation of the residuals, which provides a measure of the squared differences in measured and computed water levels. The third method involved calculating the standard error between the observed and computed values. The standard error calculates the mean of the absolute values of the residuals. This provides a more realistic measure of the average difference between the observed and computed values.

Calibration targets for the observed versus computed heads were established by evaluating several parameters in each area of the model domain. The horizontal gradient was considered to be the most critical due to the steep water table along the western edge of the model domain. Flows from the shallow unconfined aquifer discharging to the Jordan River were also addressed in the steady-state calibration.

Another calibration target set for the steady-state calibration involved accurately representing flow through the northern model boundary. Flows through this boundary could not be independently calculated due to a lack of data concerning the geometry of the aquifer and the associated aquifer properties. The only basis for calibration was a comparison with the USGS model. This comparison was undertaken by comparing the total flow discharging from the model with the percentage leaving the northern boundary. A calibration target of ± 5 percent of the computed values of the USGS model was determined to be acceptable for calibration.

Results of the steady-state calibration for 32 modeling points comparing the original RI/FS modeling results to the current head-dependent expanded model are shown in Table 2. Calibration data was very comparable to results seen from the original RI/FS modeling calibration.

Table 2. Steady-State Flow Model Calibration Results (data in feet).

	Original RI/FS Model	Revised Model
Average Mean Error	NA	7.1
Average Mean Absolute Error	11.2	11.4
Root Mean Squared Error	14.5	14.7
Single Max. Difference Lower than Measured	37.0	26.9
Single Min. Difference Higher than Measured	32.0	45.3

2.5.2 Transient-State Calibration

The transient-state calibration relied predominately on matching the observed water level changes that have occurred within the SWJV from 1965 to 1998 with the original RI/FS modeling results. Extreme water-level declines have occurred within the modeled area due to excessive pumping of groundwater for municipal and industrial needs. The transient-state model also focused on estimating the leakage rates from the former Large Bingham Reservoir located at the mouth of Bingham Canyon. Groundwater discharge to the Jordan River, flow through the northern boundary and vertical gradients were also examined throughout the transient-state calibration. Parameters treated as calibration variables included horizontal and vertical hydraulic conductivity, specific yield, storage coefficient and the recharge to the aquifer from the Large Bingham Reservoir.

Throughout the transient-state calibration, any changes made to the hydraulic conductivity fields required the steady-state simulation to be rerun. The transient-state calibration was used to identify problems with the steady-state calibration that could not be identified previously due to lack of data for describing the steady-state condition. Specific yield and storage coefficient estimates generated from the aquifer pump tests provided initial estimates for material types found within the study area. These values were modified in some situations to provide a better match with observed conditions. Model-computed results were compared to observed conditions through development of hydrographs for various locations throughout the study area. The calibration process provided the ability to examine the overall response of the model to a range of values for the parameters being considered as variables. The transient-state calibration concluded when a reasonable match was observed between computed and measured values. Figures 5-8 (see Attachments) are time series graphs for a sample of the 32 locations by which the transient simulations were judged. The simulations were compared versus observed data, the USGS model and the original RI/FS model.

2.5.3 Model Sensitivity

Classifications of previous sensitivity analyses for the original RI/FS model were followed and showed that parameters fit into three groups; sensitive, moderately sensitive and insensitive. Model parameters termed as sensitive included areal recharge, bedrock recharge and the horizontal hydraulic conductivity representing the principal aquifer. Increasing or decreasing the magnitude of the parameters termed as sensitive caused the model to produce erroneous results. The model responded by over- or under-predicting the water-level elevation or computing unacceptable discharge values to the Jordan River. Model parameters termed as moderately sensitive included specific yield, storage coefficient and the vertical hydraulic conductivity representing the principal aquifer. Modifying the magnitude of these parameters caused computed values to slightly deviate from observed conditions. Model parameters termed as insensitive included riverbed conductance, horizontal hydraulic conductivity of the shallow unconfined aquifer and vertical hydraulic conductivity of the shallow unconfined aquifer. When modifications were made to these parameters, computed results did not deviate from the observed conditions. This response indicates that a range of values are likely acceptable, along with exemplifying the potential for a non-uniqueness solution.

3.0 CURRENT MODELING RESULTS

3.1 Current Bingham Creek Groundwater Remediation Scenario

The current expanded head-dependent model has been used primarily to investigate possible remedial strategies for the Bingham Creek groundwater plume. Predictive modeling runs for 50 years have been investigated.

Table 3. Extraction Rates for the Proposed Remedial Strategy.

Well *(For ID/location, see attached figures)*	**Model Layer***	**Pumping Rate (gpm)**	**Years**
Acid Well (ECG1146)	4	1250	0-5
New Acid Well #1	4	750	6-15
New Acid Well #2	4	1250	0-30
New Acid Well #3	4	Varied †	6-50
New Acid Well #4	4 (50%), 5 (50%)	Varied ††	15-50
K109	4	167	0-50
K109	5	667	0-50
K109	6	166	0-50
B2G1193	4	65	0-50
B2G1193	5	435	0-50

* **Layer 3 is approximately 0 – 150 feet below the groundwater table**
Layer 4 is approximately 150 - 300 feet below the groundwater table
Layer 5 is approximately 300 – 450 feet below the groundwater table
Layer 6 is approximately 450 – 650 feet below the groundwater table
† **Varied Pumping: Years 6-30, 500 gpm; Years 31-50, 1250 gpm**
†† **Varied Pumping: Years 16-30, 750 gpm; Years 31-50, 1250 gpm**

Placement of these wells is shown below in Figure 4.

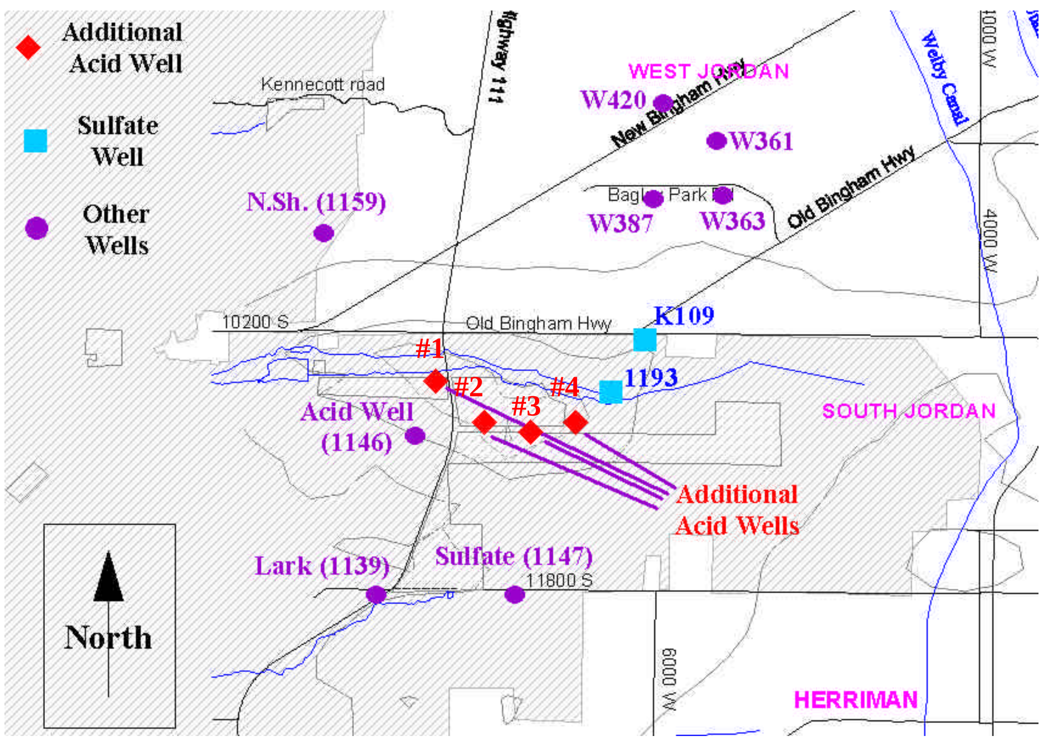


Figure 4: Current modeling scenario well placement locations

KUCC extraction at wells K109 and B2G1193 (K60 replacement well) and ECG1146 (Acid Well) are listed in Table 3 for the most current remediation strategy in coordination with the proposed Natural Resource Damage plan. Additional KUCC pumping in this scenario included Lark production well LTG1139 pumping 250 gpm (from model layers 5, 6 and 7) and the sulfate extraction well LTG1147 pumping 500 gpm (from model layers 5 and 6). Extraction rates at the KUCC wells for this scenario were assumed to remain operative year-round for predictive model simulations.

All scenarios have used identical combined West Jordan municipal pumping of 2500 gallons per minute (gpm) from production wells W420, W361, W363 and W387. West Jordan municipal wells were changed in the current expanded model to more closely resemble seasonal pumping by incorporating extraction over a six-month period for each year and off for the remaining months. Riverton municipal pumping was increased to average 5600 acre-feet per year (afy) (3500 gpm) and like the West Jordan municipal wells, was also changed to mimic seasonal pumping. K109 and B2G1193 were pumped at constant rates of 1000 and 500 gpm respectively for all scenarios.

Additionally, model-simulated pumping in the Zone B plume was incorporated into the aforementioned modeling scenarios. The extraction in this zone was distributed between model layers 3 and 4 at seven individual well locations (see attached figures). Wells number 1 through 6 were assigned pumping rates of approximately 235 gpm each, and the seventh well was assigned pumping of 1200 gpm for a total of 2610 gpm (about 4200 afy). Pumping at these locations was designed to balance containment and contraction of the Zone B sulfate plume with regard to minimizing drawdown of the groundwater table.

4.0 LIMITATIONS OF THE MODELING

The hydrogeologic system in this area is complex and can only be approximated in the modeling. As a result, techniques directed toward smoothing and weighting collected data were required to incorporate the actual properties found within the groundwater system as described in the RI report (KUCC 1998).

The KUCC model is currently being updated to model variable density groundwater flow. Changes in plume movement due to density-driven flow could have a notable effect on any numerically modeled remediation system.

5.0 CONCLUSIONS

The KUCC model has been revised as part of the continuing effort to provide an improved means for analysis of flow and contaminant transport in the SWJV. This model incorporated previous hydrologic investigations and modeling studies related to the study area along with the data gathered by KUCC personal and consultants for the RI/FS. As with the previous RI/FS modeling, the revised model was developed and calibrated using the finite difference, modular, three dimensional groundwater flow model MODFLOW (McDonald and Harbaugh, 1988). Following calibration, the flow model was coupled with the contaminate transport code MT3D (Zheng 1996) to simulate the movement of sulfate, particularly focusing in the area of Bingham Creek.

The model was calibrated for steady-state and transient-state conditions in the same manner as the original RI/FS model. The steady-state simulations were developed to represent conditions in

1965. The transient-state simulation represents conditions from 1966-1998 with the results of the steady-state calibration being used for initial conditions.

The revised KUCC southwestern Jordan Valley model was represented with a variable space grid comprised of 104 rows by 136 columns. Cells sizes ranged from 500 ft by 500 ft in the vicinity of the Bingham Reservoir sulfate plume and Jordan River to 1000 ft by 1224 ft at the southern edge of the model domain.

The revised model has the same vertical layer distribution as the original RI/FS model. The aquifer was divided into 8 layers. Layer 1 represented the shallow unconfined aquifer located in the eastern part of the study area. Layer 2 represented the confining layer, separating the shallow unconfined and principal aquifer, and layers 3-8 represented the principal aquifer. The model incorporated specified flux cells to represent: seepage from irrigation canals, areal precipitation, infiltration of unconsumed irrigation water from fields, lawns and gardens, seepage from the Bingham Creek reservoir and KUCC evaporation ponds, and underflow at Bingham Canyon, Butterfield Canyon and the Jordan Narrows. Industrial, municipal, stock and domestic wells were also represented with specified flux cells. Head-dependent flux boundaries were incorporated at the northern model boundary and the Jordan River to simulate flow into and out of the model domain at these locations. The specified flux boundary was replaced in the revised model by a head-dependant boundary for a more accurate representation of bedrock recharge along that margin.

Steady-state calibration involved matching computed and observed conditions for the following: 1) water levels, 2) discharge to the Jordan River, and 3) discharge through the northern model boundary. The calibration process involved varying the head-dependent western margin parameters within probable ranges until a reasonable match with the above-mentioned conditions was achieved between Hely and others (1971), USGS and KUCC data. The results of the steady-state calibration showed a reasonable match was achieved for water levels throughout the model domain. Calibration of discharge to the Jordan River was shown to be in line with estimates made by Hely and others (1971), but slightly lower overall discharge than the USGS model. Discharge through the northern boundary was observed to be in line with computed values in the USGS model and other estimates.

The transient-state calibration relied on matching the following: water-level changes, discharge to the Jordan River, discharge through the northern boundary, and vertical hydraulic gradients throughout the model domain. Hydrographs of computed water levels were found to match observed water-levels changes through most of the modeled area. Discharge to the Jordan River provided a reasonable match with previous estimates, but was found to slightly over predict computed values from the USGS model. Model computed vertical hydraulic gradients matched the observed directions and provided a reasonable match with the observed magnitude of the gradient.

Classifications of previous sensitivity analyses for the original RI/FS model were followed and showed that parameters fit into three groups; sensitive, moderately sensitive and insensitive. Model parameters termed as sensitive included areal recharge, bedrock recharge and the horizontal hydraulic conductivity representing the principal aquifer. Model parameters termed as insensitive included riverbed conductance, horizontal hydraulic conductivity of the shallow unconfined aquifer and vertical hydraulic conductivity of the shallow unconfined aquifer.

Overall, the revised KUCC model shows improvements to the original RI/FS model including an expanded modeling area and improvements in the parameters for the western margin bedrock recharge. The model closely simulated observed water-level declines, estimated discharge to the Jordan River, computed flows through the northern boundary, and vertical hydraulic gradient throughout the modeled area. It is therefore considered to be an improved tool for predicting flow and contaminant transport for the Jordan Valley.

6.0 REFERENCES

Hely, A. G., Mower, R. W., and Harr, C. A., 1971, Water resources of Salt Lake County, Utah: State of Utah Department of Natural Resources Technical Publication No. 31.

Kennecott Utah Copper Corporation (KUCC), 1998, Final draft remedial investigation report for Kennecott Utah Copper south facilities groundwater plume, south Jordan Valley, Utah: Version B, March, variously paged.

McDonald, M.G., and Harbaugh, A.W., 1988, A modular three-dimensional finite-difference groundwater flow model: U.S. Geological Survey Techniques of Water Resources Investigation, book 6.

Zheng, C., 1996, MT3D a modular three dimensional transport model for simulation of advection, dispersion, and chemical reactions of contaminants in groundwater systems: S. S. Papadopolus and Assoc., Inc.

Attachments

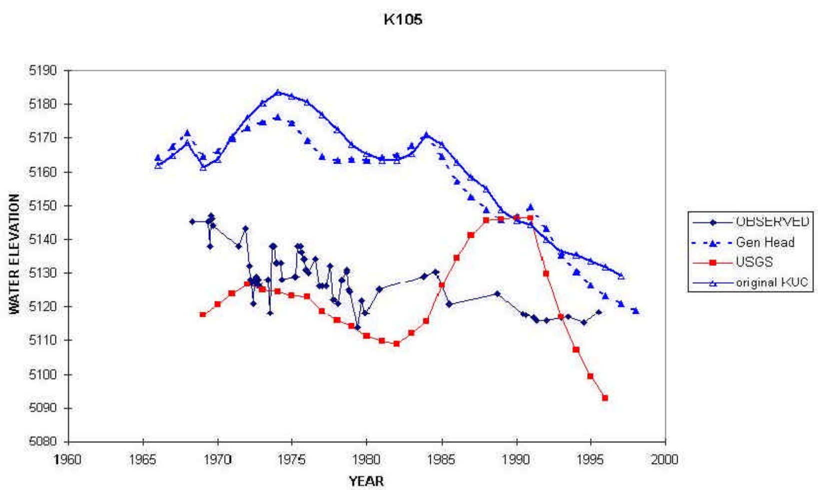


Figure 5. Transient calibration comparison at well K105.

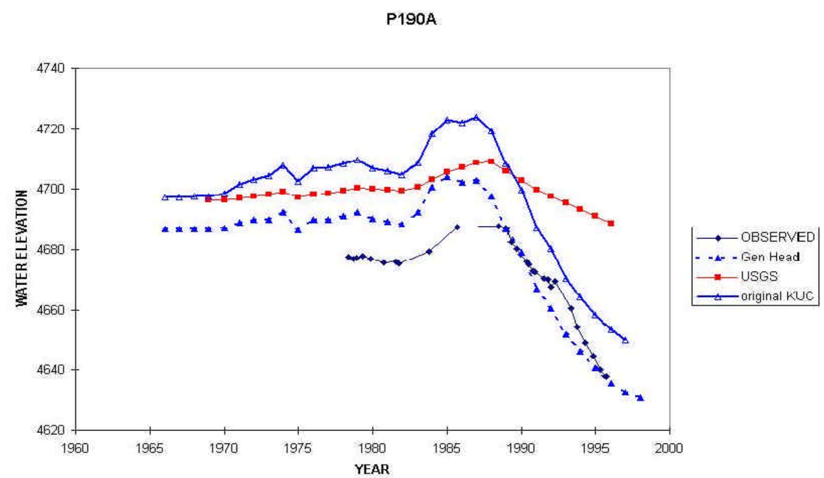


Figure 6. Transient calibration comparison at location P190A.

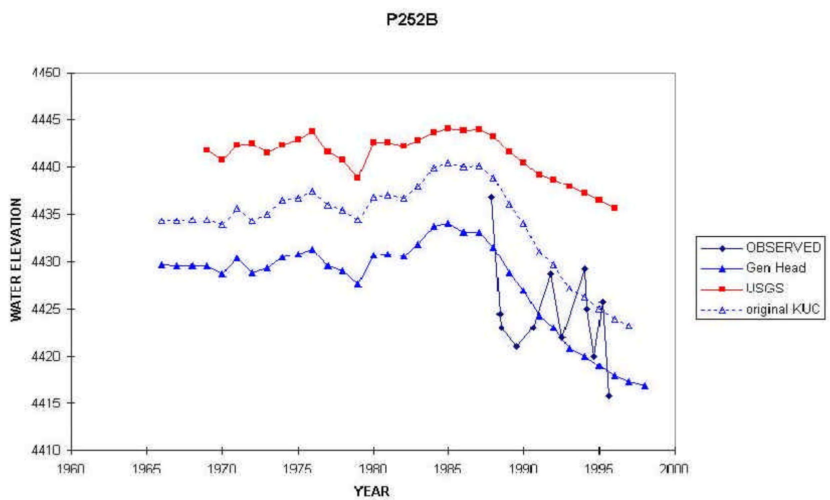


Figure 7. Transient calibration comparison at well P252B.

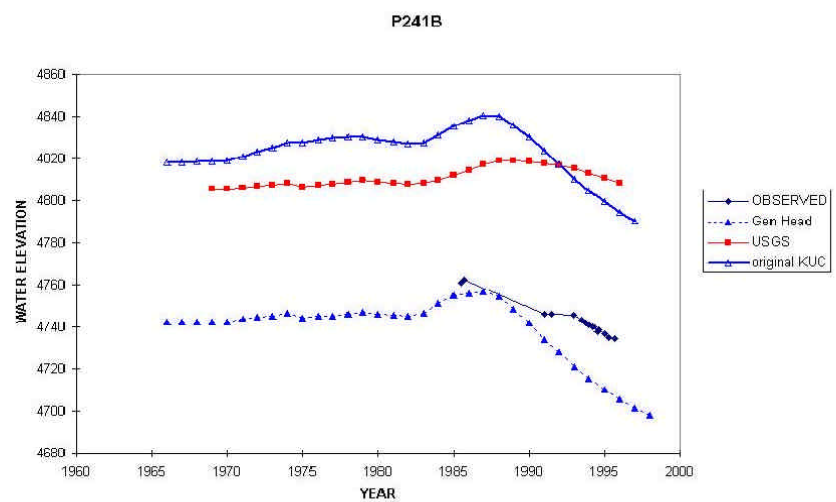
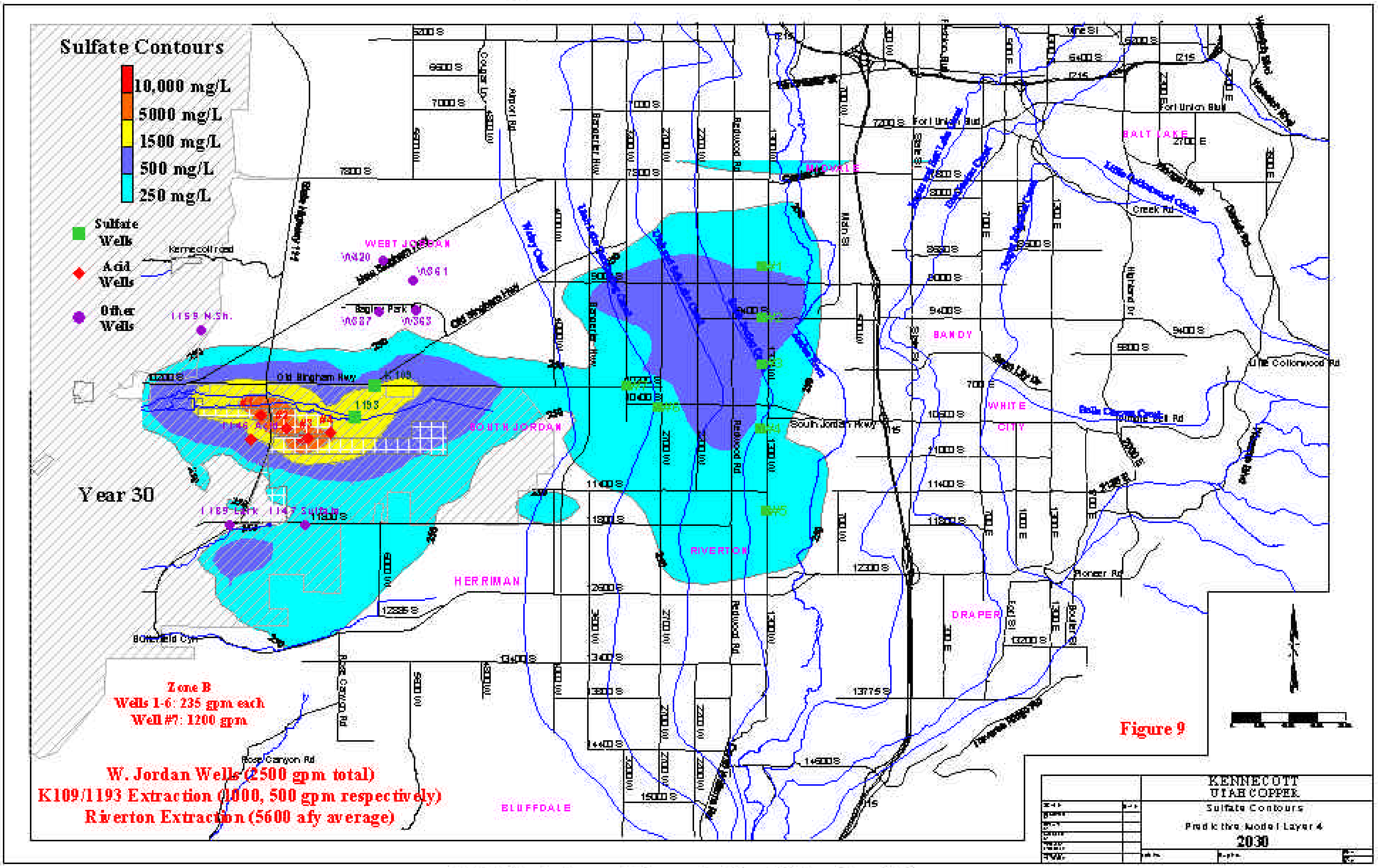


Figure 8. Transient calibration comparison at location P241B.

2500 gpm maximum Acid Extraction--Layer 4



Acid Containment Scenario (4 additional wells)

Figure 9. Predictive model sulfate values for the current acid containment scenario in year 2030.

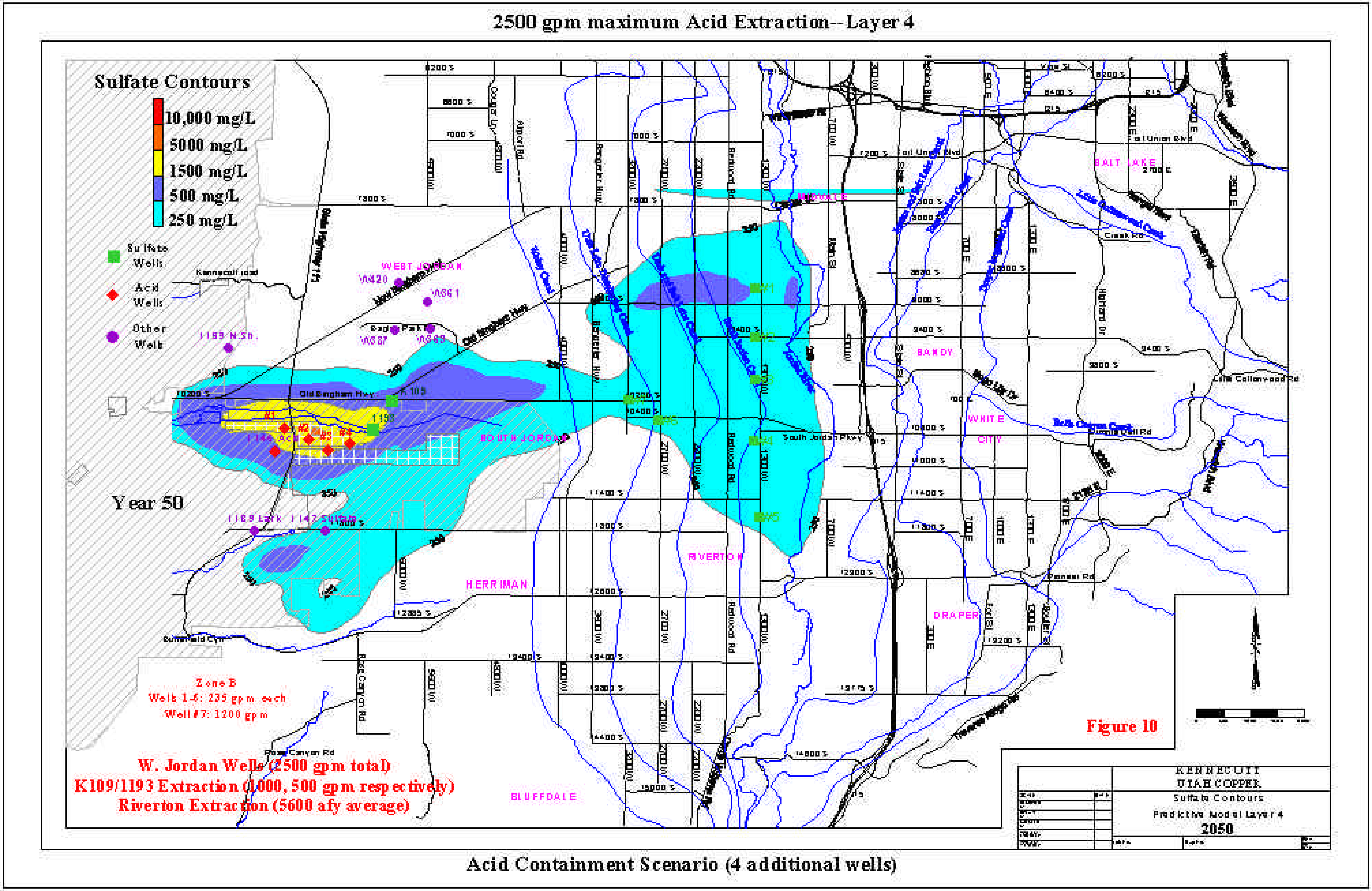


Figure 10. Predictive model sulfate values for the current acid containment scenario in year 2050.

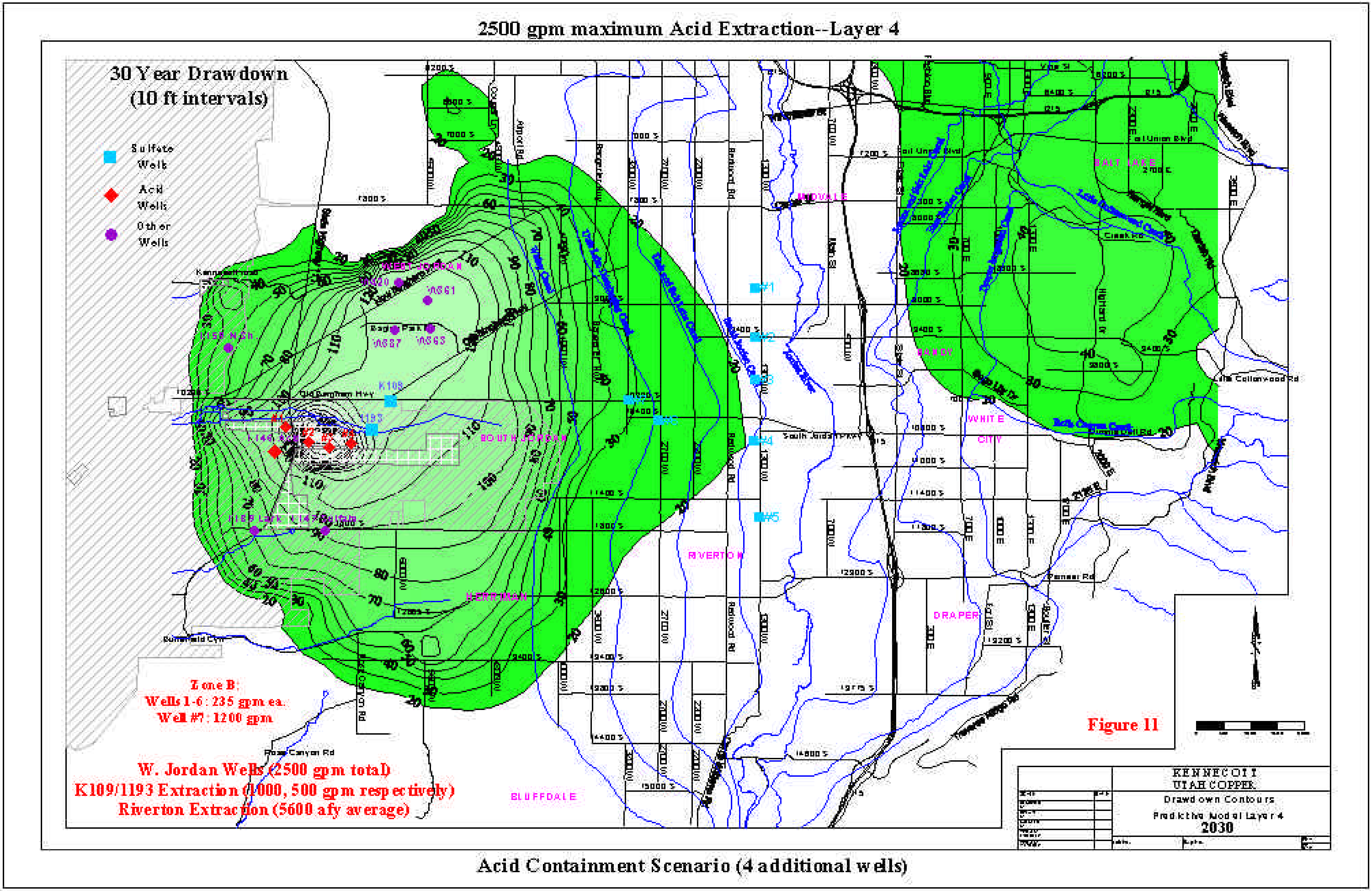


Figure 11. Predictive model draw down values for the current acid containment scenario in year 2030.

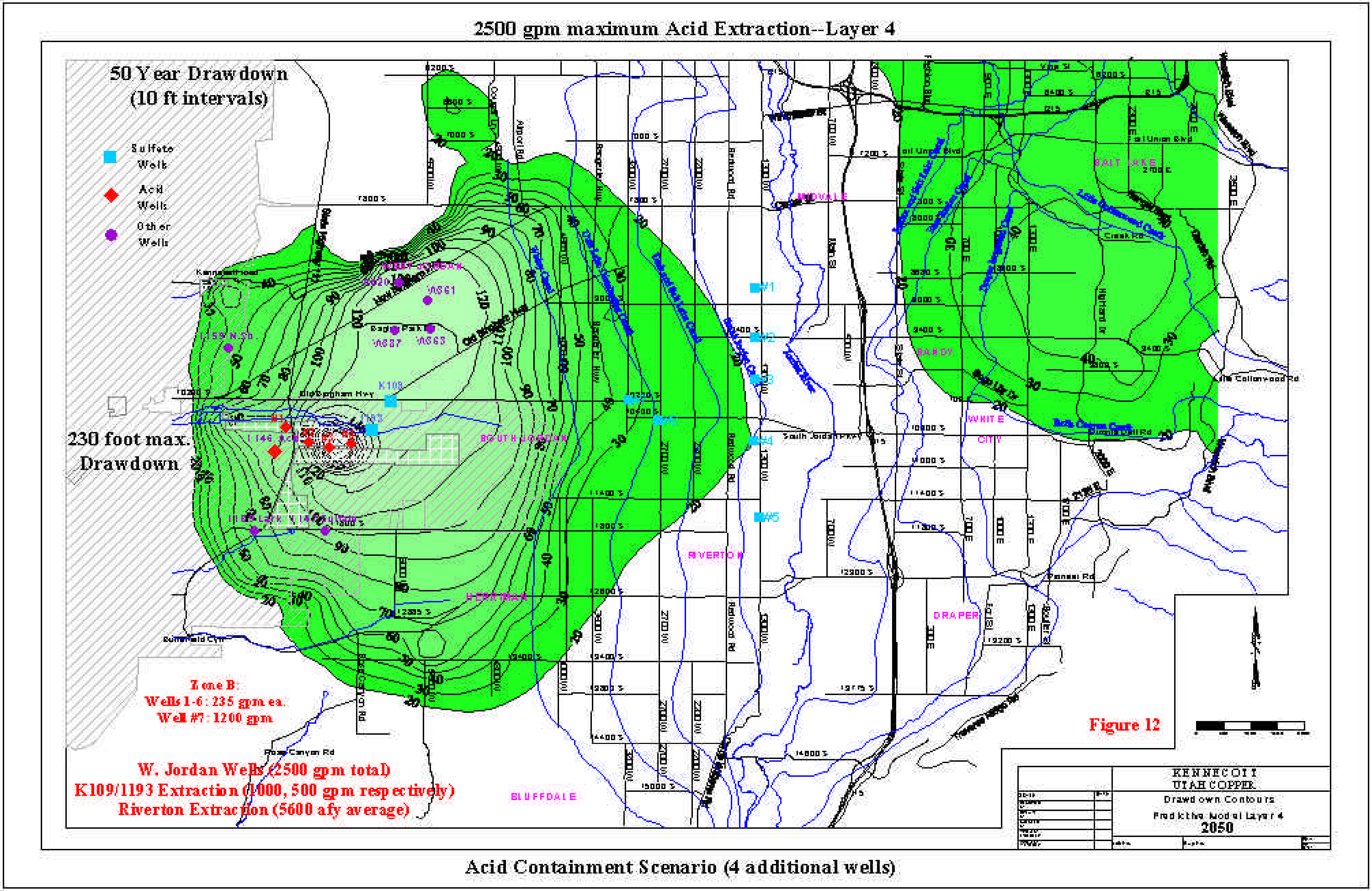


Figure 12. Predictive model draw down values for the current acid containment scenario in year 2050.