Meramec Energy Center Groundwater Model

Ameren Missouri

Meramec Groundwater Model
Project No. 114310

Revision 0
5/9/2019

Meramec Energy Center Groundwater Model

prepared for

Ameren Missouri
Meramec Groundwater Model
St. Louis, Missouri

Project No. 114310

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prepared by

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LIST OF ABBREVIATIONS

Abbreviation	**Term/Phrase/Name**
Burns & McDonnell	Burns & McDonnell Engineering Company, Inc.
Ameren	Ameren Missouri
amsl	above mean sea level
ARM	Absolute Residual Mean
bgs	below ground surface
CCR	Coal Combustion Residuals
cfs	cubic feet per second
cm^3/g	cubic centimeters per gram
CHB	Constant Head Boundary
cm/s	centimeters per second
FDC	Flow Duration Curve
ft.	feet
gpm	gallons per minute
GWPS	Groundwater Protection Standard
HELP	Hydrologic Evaluation of Landfill Performance
K	Hydraulic conductivity
K_d	Distribution coefficient
MEC	Meramec Energy Center
µg/L	Microgram per Liter
MODFLOW	Groundwater flow model developed by McDonald and Harbaugh (1988) with the USGS
MODPATH	Groundwater flow model developed by McDonald and Harbaugh (1988) with the USGS

Abbreviation	**Term/Phrase/Name**
MT3D	Solute transport model developed by Zheng and Wang, (1999)
MSL	Mean Sea Level
ND	Not detected above laboratory reporting limit
NRMS	Normalized Root Mean Square
USGS	U. S. Geological Survey

1.0 INTRODUCTION

The Ameren Missouri (Ameren) Meramec Energy Center (MEC) is located in the far southeast comer of St. Louis County near the confluence of the Meramec and Mississippi Rivers. The MEC was constructed in the relatively flat alluvial valley directly east of the Meramec River and north and west of the Mississippi River. Figure 1-1 shows the location of the approximately 480-acre MEC property (Site) and areas surrounding the MEC. Burns & McDonnell Engineering Company, Inc. (Burns & McDonnell), on behalf of Ameren, developed a groundwater model to be used by Ameren to evaluate current groundwater conditions and potential changes to groundwater conditions related to the management of Coal Combustion Residuals (CCR) surface impoundments at the MEC, including surface impoundment closure strategies and potential groundwater remediation approaches, if needed. This report describes the general site conditions, groundwater model development, model calibration, forward model simulation results and associated assumptions, limitations, and conclusions associated with the groundwater model.

2.0 SITE GEOLOGY AND HYDROGEOLOGY

During construction of the MEC in the 1950s, the site grade was raised as much as 20 feet using imported silty clay fill. Surface impoundments were reportedly constructed by excavating onsite silt and clay soils that were used as fill for plant infrastructure and to construct berms for the surface impoundments (CH2MHILL, 1997). CCR generated at the MEC has been managed in several surface impoundments constructed at the Site, including five active CCR surface impoundment and four surface impoundments considered exempt from CCR groundwater monitoring requirements (see Figure 2-1). The five active CCR surface impoundments include the following:

- Surface Impoundment 492 (approximately 6 acres);
- Surface Impoundment 493 (approximately 6 acres);
- Surface Impoundment 496 (approximately 10 acres);
- Surface Impoundment 498 (approximately 17 acres); and
- Surface Impoundment 489 (approximately 24 acres).

The four surface impoundments considered exempt from CCR groundwater monitoring requirements include the following:

- Surface Impoundment 490 (approximately 23 acres);
- Surface Impoundment 491 (approximately 12 acres);
- Surface Impoundment 494 (approximately 31 acres); and
- Surface Impoundment 495 (approximately 16 acres).

Base elevations of the CCR surface impoundments generally range from approximately 390 to 395 feet above mean sea level (amsl), while CCR has been encountered within the surface impoundments at elevations as low as approximately 387 feet amsl (Golder, 2017).

The MEC property is bounded to the north by wooded and partially developed land, to the south and east by the Mississippi River, to the west by the Meramec River, and to the east by wooded and partially developed land. The typical surface elevation for the developed portions of the MEC property is approximately 420 feet amsl. Surface elevations increase rapidly near bluffs located east of the MEC, with surface elevations ranging from 450 feet amsl to as high as 550 feet amsl on top of the adjacent bluffs (Golder, 2017).

2.1 Geology

The geology underlying the MEC and surrounding area is characterized by the alluvial floodplain deposits along the Meramec and Mississippi River valleys, and the sedimentary bedrock that underlies these alluvial deposits and outcrops to the east of the MEC. The following is a summary of general geologic conditions based on a review of available boring logs and prior summaries of geologic conditions prepared by CH2MHILL (1997) and Golder (2017).

Beneath the fill present near the surface at the Site are interbedded clay, silt, sand, and gravel alluvial deposits that vary based on relative distance from the current Meramec River channel. The alluvial deposits on the eastern portion of the Site generally consist of more fine-grained silty clays, clayey silts, and fine sands while alluvial deposits further to the west closer to the Meramec River consist of more coarse-grained fine to medium sand with clay, silt, and some gravel. The alluvial deposits to the west, closer to the Meramec River, also tend to consist of more coarse-grained sand and some gravel as depth increases. Below these interbedded alluvial deposits is a high plasticity, blueish-gray clay layer that thickens from west to east moving away from the Meramec River and towards the bedrock that forms the boundary of the alluvial deposits to the east. The clay is approximately 5 to 10 feet thick beneath the western portions of the Site and the thickness increase to approximately 60 to 70 feet beneath the eastern portions of the Site. Below this clay layer is a coarse sand and gravel layer up to approximately 10 feet in thickness. This coarse sand and gravel is underlain by a bedrock unit consisting of shale and shaley limestones. The bedrock surface slopes gently to the southeast beneath the Site and then rises sharply at the edge of the Mississippi River valley, outcropping as limestone bluffs along the eastern side of the Site.

2.2 Hydrogeology

The current groundwater monitoring system at the Site includes 12 monitoring wells designated as MW-1 through MW-8, BMW-1, BMW-2, MW-9 (AMW-1), and MW-10 (AMW-2) installed in the uppermost alluvial aquifer. Previously, at least five additional monitoring wells (B-1 through B-6) were installed in the alluvial aquifer on the MEC property in the late 1980s. A review of historical groundwater elevation and Mississippi River elevation data suggests that groundwater elevations in wells located on the eastern portion of the Site and screened in the upper portion of the alluvial aquifer (above approximately 340 feet amsl) are typically higher than those observed in wells located further to the west and exhibit more muted responses to changes in Mississippi River levels.

Based on historical groundwater elevation data collected from upgradient monitoring wells B-1 and B-2, the average groundwater surface elevations for these wells from the late 1980s through the mid-1990s was 411.78 and 400.97 feet amsl, respectively. The average historical groundwater surface elevations reported for downgradient monitoring wells B-4, B-5, and B-6 were approximately 378.4, 379.02, and 378.02 feet amsl, respectively, approximately 20 to 30 feet lower than the average elevations reported for the upgradient wells (B-1 and B-2) (CH2MHILL, 1997). Existing monitoring wells BMW-1 and BMW-2 (locations shown on Figure 2-1) have typically exhibited groundwater elevations that are approximately 5 to 11 feet higher than monitoring wells located further to the west, except for MW-1. Monitoring well MW-1 has consistently exhibited groundwater elevations approximately 10 to 12 feet higher than monitoring wells located further to the south and west (MW-2 through MW-8, MW-9 [AMW-1]), and MW-10 [AMW-2]).

During normal river level conditions, the predominant groundwater flow direction at the Site is from the topographic high atop the bluffs to the northeast, to the southwest towards the Meramec River. Groundwater also flows to south, towards the Mississippi River, on the southern portion of the Site. The hydraulic gradient is greater on the eastern one-third (approximate) of the Site and becomes very flat on the western two-thirds of the Site. Ponding of water in the surface impoundments constructed without liners is reported to influence groundwater elevations and flow directions in the immediate area of the surface impoundments. Groundwater flow direction and gradients can also be influenced by river levels in areas adjacent to the rivers. Reported values for horizontal hydraulic gradients range from 0.001 to 003 feet/foot for monitoring events conducted in 2016 and 2017 (Golder, 2017). Figure 2-2 depicts a generalized cross section of the Site.

3.0 GROUNDWATER FLOW MODEL

Burns & McDonnell has developed a groundwater flow and solute transport model for the MEC. The area covered by the groundwater flow model is shown in Figure 3-1. The purpose of this groundwater model report is to document the model construction, calibration, and results of the modeling effort.

3.1 Technical Approach

The technical approach for constructing a groundwater flow and solute transport model capable of reproducing observed groundwater conditions and predicting the migration of CCR constituents at the MEC consisted of an iterative model development process. The first phase involved construction and calibration of a groundwater flow model. The second phase involved construction and calibration of a solute transport model to simulate transport of select CCR constituents (arsenic, lithium, and molybdenum). The third and final phase of the modeling effort included the simulation of impoundment closure alternatives and an evaluation of these alternatives on groundwater flow conditions and contaminant transport. Details regarding the model construction, along with the data used to develop the model and the primary model assumptions, are presented below.

3.2 Modeling Objectives

The objectives of the groundwater flow and solute transport model construction and analysis were to:

- Consolidate available groundwater elevation and quality data into a numerical framework capable of evaluating closure strategies for the Site.
- Calibrate the model using measured groundwater elevations and measured CCR constituent concentrations to ensure that the model reasonably approximates observed conditions.
- Use the model to predict and evaluate projected groundwater quality conditions resulting from different closure alternatives for the MEC surface impoundments.

3.3 Data Sources

The groundwater model presented within this report was developed using existing data that was collected and interpreted by others. No field investigations or data were collected specifically to support the groundwater modeling effort. The primary data sources used to develop the groundwater flow and solute transport model are:

- United States Geological Survey (USGS): River gauge data for the Meramec and Mississippi Rivers.

- CH2MHILL (1997): Hydrogeologic Assessment of Potential Impacts of Meramec Ash Ponds on Local Groundwater and Surface.
- Woodward Clyde Consultants (1988): Report of Hydrogeological Investigation and Monitoring Well Installation Program.
- Golder (2017, 2018, and 2019): Groundwater monitoring plan and annual groundwater monitoring reports that contain monitoring well installation and testing information, groundwater elevation measurements, potentiometric surface maps, and water quality data.

3.4 Conceptual Model

The geology underlying the MEC Site consists primarily of floodplain deposits of the Mississippi River system and sedimentary bedrock, which outcrops near the north end of the Site. The current site grade is as much as 20 feet above the original ground surface, as the original grade was increased through the placement of imported silty clay fill (CH2MHILL, 1997). The ash ponds were constructed by excavating onsite soils and using those material as construction fill beneath the plant and for the ash pond berms (CH2MHILL, 1997).

The soils below the fill materials at the Site are typical of an alluvial floodplain deposit and consist of interbedded clay, silt, sand, and gravel that generally coarsen with depth. Geologic interpretations presented in the CH2MHILL report (1997) indicate that soils beneath the western portion of the Site consist primarily of silt and sand, while fine silts and clays are primarily found beneath the eastern portion of the property. The following is a summary of the Site geology, as presented in the CH2MHILL report:

> "In general pond ash fill or construction fill extends about 20 to 25 feet below the current site grade (nominally 420 ft. MSL). The fill is underlain by alluvial clayey silt and fine silty sand deposits typically 20 to 40 feet thick (except at the east edge of the site where fine material extends almost to bedrock). As depth increases, the sands in the west part of the Site become coarser-grained and gravelly, with less fines. About 90 feet below grade (approximately 320 ft. MSL) a very stiff, blue-gray, high plastic clay is encountered. The clay is estimated to be about 5 to 10 feet thick in the west but increases to 60 to 70 feet thick at locations beneath the plant. Limestone bedrock is present at depths of about 105-115 feet. A coarse sand and gravel bed, up to 10 feet thick, exists between the limestone and the gray clay."

The shale and limestone bedrock located beneath the unconsolidated alluvial deposits underlying the Site belongs to the Warsaw formation and is upper Mississippian in age (Shannon and Wilson, 1979). The formation consists of shale and shaley limestone.

3.4.1 Hydrogeology

Data collected at the Site indicate that groundwater conditions at the Site are dynamic and are influenced by changes in river stage; however, under normal river stage conditions, the available potentiometric surface maps indicate that groundwater flow at the Site is generally from the topographic high in the northeast (bluffs) towards the southwest (Mississippi and Meramec Rivers). The magnitude and direction of the groundwater gradient were evaluated by Golder (Golder, 2019) and were characterized as follows:

> "the overall net groundwater flow at the Meramec surface impoundments is from the bluffs toward the rivers. Horizontal gradients calculated by the program for the CCR Rule compliance wells (not including background or MW-1) range from 0.0002 to 0.0005 feet/foot with an estimated net annual groundwater velocity of approximately 16 feet per year".

3.4.2 Groundwater Sources and Sinks

Hydraulic sources (inflows) of groundwater to the Site include:

- Recharge from precipitation. This is the primary source of groundwater to the Site.
- Groundwater inflow from bedrock to the northeast (expected to be minimal).
- Inflows from the Meramec and Mississippi Rivers (expected to be minimal except during periods of high streamflow).
- Seepage from the active and unlined surface impoundments.

The hydraulic sink (outflows) of groundwater at the Site is discharge to the Meramec and Mississippi Rivers as baseflow. No pumping wells are located at the Site.

3.5 Groundwater Model Code

The finite difference model code MODFLOW-2000 was used to perform the hydraulic calculations in the groundwater model. MODFLOW is a finite-difference, block-centered model that simulates three-dimensional groundwater flow in saturated porous media. MODFLOW was developed to include a modular structure, allowing different hydrologic systems and stresses to be grouped together to simulate the modeled area.

The solute transport calculations were performed using the MT3DMS model code. MT3DMS is an updated version of the three-dimensional multi-species MT3D model code. MT3DMS includes capabilities for simulating advection, dispersion/diffusion, and chemical reactions of contaminants in groundwater flow systems under general hydrogeological conditions. The solute transport model was constructed to reflect the relatively mobile nature of CCR constituent transport in groundwater at the Site.

3.5.1 Data Processing Software

Construction of the numerical model and the evaluation of model-predicted output were completed using Groundwater Vistas Version 7 (Rumbaugh, 2006). Groundwater Vistas is a pre- and post-processing software package that was used to create standard format MODFLOW file sets from graphically input data.

Model output was evaluated using Groundwater Vistas®, Surfer® Version 15 (Golden Software), ArcMap® 10 (ESRI) and Microsoft Excel. Groundwater Vistas was used when possible to provide contoured model results (model predicted heads and drawdown) and numerical data output. Additional data contouring and evaluation was completed using Surfer. Surfer is a grid-based contouring and three-dimensional surface plotting program. Surfer and ArcMap 10 were used to interpolate the irregularly-spaced, model-predicted data onto regularly spaced grids and to produce contoured results.

3.6 Groundwater Model Construction

The modeled area was selected to include the physical boundaries of the aquifer system that underlies the MEC. Those boundaries include the Meramec River to the west, the Mississippi River to the east, the confluence of the two rivers to the south, and bedrock outcrops to the northeast. The model area is approximately 7,500 feet by 5,500 feet and was discretized using a 100-foot by 100-foot cell size, as shown on Figure 3-1. Once completed, the model grid contained 75 rows, 55 columns, and six layers for a total of 24,750 model cells (17,436 active cells). In addition to the physical boundaries of the aquifer system, the active and unlined surface impoundments were simulated using the MODFLOW river boundary package. Model boundaries are shown on Figure 3-1. Figure 3-2 shows the location of two cross sections that illustrate model layering. The cross sections are shown on Figures 3-3 through 3-4. Model layering was developed based on the boring logs available in the data sources described in Section 3.3.

The primary source of water in the groundwater model is recharge from precipitation. Groundwater recharge rates were initially assigned based on available regional studies, including:

- Illinois State Water Survey Report of Investigation 51 (Groundwater Development in East St. Louis Area, Illinois).
- Water Resources of The St. Louis Area, Missouri (USGS Water Resource Report 30).
- USGS Water-Resources Investigations Report 03-4109.

Recharge into the aquifer system is applied to the uppermost active model layer, meaning if a model cell in layer 1 is dry, recharge would be applied in model layer 2. Final aquifer recharge rates were obtained through model calibration. The primary water sink in the model is outflow to the rivers as baseflow. The degree of interconnection between the rivers and the aquifer (boundary conductance) was adjusted through the model calibration process. Calibration of the MODFLOW model is described below.

3.7 Groundwater Model Calibration

Groundwater level measurements, consisting of synoptic events collected between March 2016 and November 2018, were evaluated for use as potential groundwater model calibration targets. Since groundwater conditions at the Site are highly influenced by river stage, Burns & McDonnell reviewed the flow duration curve (FDC) for the Mississippi River at St. Louis (USGS Gauge 07010000) to evaluate which groundwater monitoring event was most appropriate for simulating "normal" groundwater conditions. The Mississippi River FDC is presented as Figure 3-5. Based on this evaluation, seven of the 12 water level monitoring events were collected during streamflow conditions that are characterized as 75th percentile or higher. These conditions are classified by the USGS as "above normal" streamflow. Of the remaining groundwater level monitoring events, only two were collected during streamflow conditions that were close to the 50th percentile (January and November 2017). Since all groundwater monitoring events other than the January and November 2017 dates were conducted during streamflow conditions that are higher or much higher than normal, only the January and November 2017 water level events are considered representative of normal (or average) groundwater conditions. The November 2017 water level data set was used for groundwater model calibration and is considered appropriate for use in steady state groundwater modeling. Mississippi River streamflow was measured as 176,000 cubic feet per second (cfs) on November 6, 2017 (the groundwater level measurement date).

The November 2017 synoptic water level event that was used to calibrate the groundwater flow model includes water level data from 10 monitoring wells, a measurement of the Mississippi River stage at the Site, and a measurement of the water level in Surface Impoundment 493. The interpreted potentiometric surface, presented in 2017 Annual Groundwater Monitoring Report (Golder, 2018), did not include a water level measurement from monitoring well MW-1. The water level measurements from November 2017 (minus MW-1) were used to calibrate the MODFLOW model. All existing monitoring wells at the Site are screened in either model layer 2 or 3. No monitoring wells that extend deeper into the alluvial aquifer were available for model calibration.

Manual and automated parameter estimation approaches were used to derive reasonable estimates of hydraulic conductivities, anisotropy, and natural recharge rates that produce groundwater elevations close to the observed data. Model calibration results are summarized on Figure 3-6. The average residual in the calibrated model is less than one foot and the scaled or normalized root mean square (NRMS) error is 6.6

percent, which is well below the typical calibration goal for groundwater models (10 percent). The model predicted potentiometric surface is shown on Figure 3-7. The magnitude and direction of the hydraulic gradient shown on Figure 3-7 compares favorably with the contoured potentiometric surface for the November 2017 calibration date (Golder, 2017). A summary of the input parameters for the calibrated model is presented below in Table 3-1.

Table 3-1: Calibrated Groundwater Flow Model Data Input

Model Element	Reported Range	Calibrated Value	Data Source
Hydraulic Conductivity $K_{x,y}$ (feet/day)			
Ash/Fill (Model Layer 1)	3 - 185 (Golder, 2017)	5 - 40	Fetter, C.W. (2000), Calibrated Values
Clayey Silt/Silty Clay (Model Layer 2)		1	Fetter, C.W. (2000), Calibrated Values
Fine/Med Sand (Model Layer 2)		50	Fetter, C.W. (2000), Calibrated Values
Fine/Med Sand (Model Layer 3)		60	Fetter, C.W. (2000), Calibrated Values
Clayey Silt/Silty Clay (Model Layer 3)		1	Fetter, C.W. (2000), Calibrated Values
Clay (Model Layer 4)		0.1	Fetter, C.W. (2000), Calibrated Values
Coarse Sand/Gravel (Model Layer 5)		120	Fetter, C.W. (2000), Calibrated Values
Precipitation Recharge/seepage rate (inches/year)			
Alluvium and active/unlined impoundments[1]	6.3 - 9.9	6.45	ISWS Report of Investigation 51 and USGS Water Resource Report 30
Lined impoundments (489 and 498)		0.25	HELP Model

Notes:
(1) Seepage from the active and unlined impoundments was simulated using the MODFLOW river boundary package.

3.8 HELP Model

The Hydrologic Evaluation of Landfill Performance (HELP) code is a quasi-two-dimensional model developed by the U.S. Army Corps of Engineers that calculates infiltration from a waste management facility based on a representative column of geologic layers. Precipitation, evapotranspiration, runoff, and the geometry and hydrogeologic properties of a layered soil column are input to generate infiltration predictions. The HELP model was used to evaluate how aquifer recharge from precipitation could change as the active impoundments are closed and capped. Results of the HELP modeling are presented below.

Table 3-2: Infiltration through Base Liner (or bottom of ash if no liner)

Model Element	Infiltration as a Percentage of Precipitation
Unimproved Areas	35.32%
Surface Impoundment 489	0.62%
Surface Impoundment 498	0.27%
1 x 10^{-5} cm/s permeability cap (Remaining Unlined Impoundments)	30.67%
1 x 10^{-6} cm/s permeability cap (Remaining Unlined Impoundments)	15.61%
1 x 10^{-7} cm/s permeability cap (Remaining Unlined Impoundments)	1.82%

Notes:
cm/s = centimeters per second

3.9 Fate and Transport Model

A solute fate and transport model was developed by Burns & McDonnell to provide a tool capable of predicting long-term groundwater quality surrounding the MEC. The fate and transport model simulates the potential movement and concentrations of CCR constituents based on the steady state groundwater flow field generated from the MODFLOW model, and conventional solute transport mechanisms. The transport mechanisms simulated by the solute transport model include advection, dispersion, dilution, and adsorption.

3.9.1 MT3DMS Model

MT3DMS is a three-dimensional solute transport model for the simulation of advection, dispersion, and chemical reactions of dissolved constituents in groundwater. The model uses a modular structure similar to that implemented in MODFLOW. The modular structure makes it possible to independently simulate advection, dispersion, sink/source mixing, and chemical reactions without reserving computer memory space for unused options. MT3DMS can be used to simulate changes in concentration of single-species miscible contaminants in groundwater considering advection, dispersion, and some simple chemical reactions. The chemical reactions included in MT3DMS are equilibrium-controlled, linear or non-linear sorption and first-order, irreversible decay or biodegradation. The solute transport model presented in this report used the results of the steady state MODFLOW model as the basis of the groundwater flow field.

3.9.1.1 MT3DMS Solver

The MT3DMS equations were solved using the upstream finite difference method. The finite difference solution was selected over other available solvers because it is computationally efficient for advection dominated systems and because it is mass conservative. MT3DMS includes a mass balance calculation to evaluate the accuracy of the model solution. A low mass-balance error was expected because the upstream finite-difference method starts from a mass-balance equation for each model cell (Zheng and Wang, 1999). For the upstream finite-difference solution, the authors of MT3DMS recommend a mass balance error of “generally much less than 1 percent” (Zheng and Wang, 1999). The mass-balance error observed in the simulations presented within this report was approximately 10^{-3} percent, indicating the numerical solution was valid and stable.

3.9.2 Geochemical Conditions

The key factors controlling the mobility of the modeled CCR constituents (arsenic, lithium, and molybdenum) are groundwater pH, redox conditions, and the presence of competing anions. Chemical data collected from the Site indicate that redox conditions in groundwater are reducing and characterized by high concentrations of dissolved iron. The pH of groundwater at the Site is near-neutral. Under these conditions, it is anticipated that the CCR constituents included in the model (arsenic, lithium, and molybdenum) are mobile in groundwater and little to no attenuation in the mobility of these constituents is expected until groundwater reaches the hyporheic zone, where mixing between shallow groundwater and surface water occurs. As groundwater enters the hyporheic zone, redox conditions are expected to shift from reducing to oxidizing, potentially changing the speciation and solubility of CCR constituents.

3.9.3 Solute Transport Model Conceptualization

As summarized above, the CCR constituents included in the model (arsenic, lithium, and molybdenum) are expected to be mobile in groundwater, with little mobility attenuation occurring in the groundwater system. Under these conditions, the distribution and migration of CCR constituents in groundwater is primarily controlled by advective transport and adsorption/desorption reactions. Absorption/desorption is simulated in MT3D using several equilibrium-controlled sorption isotherms (linear, Freundlich, and

Langmuir), which distribute solutes into aqueous phase or solid phase based on a distribution coefficient (K_d). The groundwater chemical transport model includes the following assumptions:

- The steady state groundwater flow field simulated with the MODFLOW model is a valid average groundwater basis for the transient transport modeling scenario.
- CCR constituents modeled include arsenic, lithium, and molybdenum.
- The CCR constituent concentrations presented by Golder (2017 and 2019) are representative of current conditions in the alluvial aquifer.
- Each surface impoundment is a unique source area.
  - Source concentrations vary by impoundment.
  - Source concentrations were estimated through calibration and are based on the 2017/2018 groundwater sampling results.
  - Source concentration values were constrained during the calibration process based on typical values presented in Electric Power Research Institute (EPRI) *Characterization of Field Leachates at Coal Combustion Product Management Sites: Arsenic, Selenium, Chromium, and Mercury Speciation* (EPRI, 2006).
- Transport mechanisms include:
  - Advection – the primary solute movement mechanism.
  - Dispersion – a scale dependent mechanism.
  - Absorption/desorption – simulated using equilibrium-controlled sorption isotherms.
- CCR constituent concentrations within the alluvial aquifer will not significantly change with time prior to pond closure.
- CCR sources are simulated as concentration applied to recharge.
  - Recharge concentrations represent seepage to groundwater from the surface impoundments.
  - Recharge is applied to the uppermost active model layer; meaning, if a model cell in layer one is dry recharge would be applied in model layer 2.
  - Source concentrations remain constant over time and are not depleted, unless specifically described in a remediation simulation.
- COCs instantly migrate into groundwater.
- Dispersivity coefficients are scale dependent and based on the travel distance of a solute.
  - Longitudinal dispersivity was based on the equations developed by Xu and Eckstein (1995).
  - Horizontal and vertical transverse dispersivity were set equal to 30 percent and 5 percent of longitudinal dispersivity, respectively (Lovanh et.al, 2000).

- Molecular diffusion is assumed to be much smaller than mechanical dispersion and was set to zero (Fetter 1999).

3.9.4 MT3D Calibration

The solute transport calibration was performed using the groundwater flow field generated by the MODFLOW model. No changes were made to the MODFLOW model for the purposes of solute transport model calibration. Solute transport model calibration runs were simulated until model predicted CCR constituent concentrations reached near-equilibrium values.

The solute transport model was calibrated to approximate the average concentration of arsenic, lithium and molybdenum as presented by Golder (2018 and 2019). The source concentration of each CCR constituent was varied to reduce the difference between the modeled and observed average concentration at the monitoring wells. Source concentrations were varied by impoundment to achieve the best reproduction of the CCR constituent distributions in groundwater presented in the 2018 and 2019 Golder reports. Transport model calibration results are summarized in Tables 3-3 through 3-5.

Table 3-3: Model Calibration Results for Arsenic

Monitoring Well	Observed Minimum Concentrations (µg/L)	Observed Average Concentrations (µg/L)	Observed Maximum Concentrations (µg/L)	Model Calculated Concentrations (µg/L)
MW-1	0.4	0.7	1.2	2.6
MW-2	1.3	1.8	2.5	4.0
MW-3	4.6	7.1	8.3	5.0
MW-4	10.5	13.7	15.0	9.0
MW-5	8.0	18.5	22.1	21.4
MW-6	2.3	4.5	8.3	2.2
MW-7	2.1	3.0	4.8	1.5
MW-8	2.1	5.6	6.6	1.8
BMW-1	0.9	1.8	5.5	0.8
BMW-2	0.8	1.4	1.8	0.9
MW-9 (AMW-1)[1]	17.7	17.7	17.7	16.3
MW-10 (AMW-2)[1]	5.5	5.5	5.5	1.2

Notes:
(1) = Well sampled one time
ND = not detected above laboratory reporting limit
µg/L = microgram per Liter

Table 3-4: Model Calibration Results for Lithium

Monitoring Well	Observed Minimum Concentrations (µg/L)	Observed Average Concentrations (µg/L)	Observed Maximum Concentrations (µg/L)	Model Calculated Concentrations (µg/L)
MW-1	5.3	6.2	7.1	5.7
MW-2	3.2	5.9	8.2	5.1
MW-3	3.7	6.7	9.0	4.1
MW-4	20.3	23.2	27.0	10.3
MW-5	18.1	21.6	26.2	66.3
MW-6	123.0	161.5	419.0	148.2
MW-7	37.8	73.8	287.0	120.5
MW-8	26.1	31.0	33.7	28.8
BMW-1	12.0	14.2	16.0	10.3
BMW-2	5.6	7.1	9.3	5.1
MW-9 (AMW-1)[1]	14.2	14.2	14.2	22.2
MW-10 (AMW-2)[1]	38.7	38.7	38.7	10.3

Notes:
(1) = Well sampled one time
ND = not detected above laboratory reporting limit
µg/L = microgram per Liter

Table 3-5: Model Calibration Results for Molybdenum

Monitoring Well	Observed Minimum Concentrations (µg/L)	Observed Average Concentrations (µg/L)	Observed Maximum Concentrations (µg/L)	Model Calculated Concentrations (µg/L)
MW-1	0.8	0.8	0.8	2.2
MW-2	1.2	1.9	2.5	2.6
MW-3	1.9	3.4	5.2	5.0
MW-4	49.7	53.1	56.0	17.9
MW-5	74.4	91.5	105.0	162.0
MW-6	120.0	138.3	163.0	186.0
MW-7	297.0	425.5	717.0	356.0
MW-8	183.0	205.5	229.0	191.0
BMW-1	4.3	5.9	7.2	0.0
BMW-2	0.5	0.5	0.5	0.0
MW-9 (AMW-1)[1]	39.1	39.1	39.1	34.5
MW-10 (AMW-2)[1]	4.3	4.3	4.3	3.2

Notes:
(1) = Well sampled one time
ND = not detected above laboratory reporting limit
µg/L = microgram per Liter

Pore water chemical concentrations were not available to aid in model calibration; therefore, source concentrations were bracketed using EPRI reported values for CCR leachate (EPRI, 2006). The resulting recharge source concentrations for each CCR constituent are presented for each geologic unit or surface impoundment in Table 3-6. A summary of the distribution coefficient (K_d) input parameters for the calibrated model is presented below in Table 3-7.

Table 3-6: Recharge Source Concentrations

Geologic unit or impoundment	Arsenic Concentrations (µg/L)	Lithium Concentration (µg/L)	Molybdenum Concentration (µg/L)
Alluvium/bedrock	2	11	0
489	10	600	1500
498	10	5	10
494/490/493/492/496	10	5	10
491	10	50	450
495	60	50	150

Notes:
ND = not detected above laboratory reporting limit
µg/L = microgram per Liter

Table 3-7: Distribution Coefficients

Parameter	Calibrated Value (cm^3/g)	Data Source
Distribution coefficient		
Arsenic	2	EPRI, 2002
Lithium	0.005	EPRI, 2018
Molybdenum	0.34	EPRI, 2011

Notes:
cm^3/g = cubic centimeters per gram

4.0 SIMULATION OF CLOSURE ACTIVITIES

Following calibration of the solute transport model to observed CCR constituent concentrations, the groundwater flow and solute transport models were modified to evaluate changes in groundwater conditions over a 30-year period following capping and closure of the surface impoundments. Closure activities were simulated by removing the active impoundments from the groundwater model and simulating reduced seepage from the impoundments through the placement of a low permeability cap. Three cap permeability scenarios were evaluated; specifically, a permeability of 1 x 10^{-5}, 1 x $10^{-6,}$ and 1 x 10^{-7} centimeters per second (cm/s).

The following modifications were made to the groundwater and solute transport model to develop the 30-year predictive (forward) model runs:

- Removed all river boundaries that represent surface impoundments that actively store water from the MODFLOW model;
- Modified the recharge/impoundment seepage rate for the two lined impoundments (489 and 498) to reflect the infiltration rates calculated by the HELP model for lined impoundments.
- Adjusted recharge/impoundment seepage rates for the presently unlined impoundments to reflect the reduced seepage (compared to unimproved conditions) estimate developed by the HELP model. The following should be noted:
  - Only the recharge rate was modified. Recharge concentrations were held constant at their calibrated value for the full duration of the 30-year predictive runs.
  - Changes to the recharge rate were only made in areas that overlie a surface impoundment. No changes were made to the recharge rate for areas outside the impoundments.
  - Recharge rates were modified to reflect the reduced seepage/infiltration predicted by the HELP model for different cap permeability values, as described in Section 3.8.

The model recharge zones are shown on Figure 4-1.

4.1 Predicted Future CCR Constituent Concentrations – Impoundment Capping

The results of the 30-year predictive simulations evaluating changes in groundwater conditions following cap placement are described below. Model-predicted CCR constituent concentrations are evaluated two ways: 1) as concentration graphs for each monitoring well at the MEC and 2) as isoconcentration maps. The concentrations presented in this section represent the MT3DMS output concentrations for model layers 2 and 3. These model layers represent the layers of the aquifer system in which the existing monitoring wells are screened. Model-predicted results are presented for two of the three modeled cap permeability scenarios; 1 x 10^{-6} and 1 x 10^{-7} cm/s. Model results did not show a significant change in future groundwater concentrations (compared to current conditions) for the 1 x 10^{-5} cm/s cap scenario and therefore are not included in this report.

4.1.1 Concentration Graphs

Future concentration graphs are presented for each modeled CCR constituent in Appendix A. These concentration graphs illustrate model predicted concentrations at a specific monitoring well location over the course of the 30-year model simulation period. Concentrations are presented based on two closure cap scenarios: 1) 1 x 10^{-6} cm/s cap permeability and 2) 1 x 10^{-7} cm/s cap permeability. Each graph includes the CCR groundwater protection standard (GWPS) for the corresponding CCR constituent as a reference.

4.1.2 Predicted CCR Constituent Distribution

Model-predicted isoconcentration maps are presented for each modeled CCR constituent in Appendix B. These isoconcentration maps illustrate the model-predicted CCR constituent distribution in the alluvial aquifer over the extent of the 30-year model simulation period. Concentrations are presented based on a 1 x 10^{-7} cm/s cap permeability scenario. As stated in the assumptions above, these simulations assume that each impoundment is a unique source area and that the full extent of the impoundment acts as a source of CCR constituents. Source concentrations were held constant over the duration of the model simulation.

4.2 Predicted Future CCR Constituent Concentrations – Impoundment Capping and Remediation

Additional predictive simulations were performed to evaluate the potential impact of implementing groundwater remediation at the Site. These simulations build upon the capping simulations summarized in Section 4.1 by including reduced recharge/seepage concentrations and reduced initial concentrations in groundwater. A summary of the process used to develop this evaluation is presented below:

- As a starting point, used the model described above, with a cap of 10^{-7} cm/s.
- Selected arsenic, lithium, and molybdenum as the CCR constituent to model.
- Reduced initial concentrations in groundwater underlying the impoundment with the highest recharge source concentration for the selected CCR constituent (see Table 3-6) by 25 percent (e.g., initial molybdenum concentrations in groundwater beneath impoundment 489 were reduced by 25 percent). This simulates potential remediation that beneficially impacts the aquifer.
- Simulated future conditions in groundwater over a 30-year period.

Results of the 30-year predictive simulations evaluating the impact of both capping the impoundments and performing groundwater remediation near the impoundment with the highest recharge source concentration for the selected CCR constituent is presented in Appendix C. Model-predicted concentrations are presented in graph form for the monitoring well with the highest average concentration at the MEC for lithium (MW-6) and molybdenum (MW-7). Although MW-5 had the highest average concentration for arsenic at the MEC, the model-predicted concentrations for monitoring well MW-9 are presented in graph form in Appendix C. MW-9 was selected for this assessment because the average arsenic concentration was comparable to MW-5 (see Table 3-3) and more time was required for model predicted concentrations to approach the GWPS at MW-9 than MW-5. The concentrations presented on the graphs in Appendix C represent the MT3DMS output concentrations for model layers 2 and 3.

5.0 SUMMARY AND CONCLUSIONS

Burns & McDonnell developed a groundwater flow and solute transport model to evaluate potential closure and remediation activities at the MEC. The groundwater model was developed and calibrated using groundwater elevation and groundwater analytical data collected from the existing MEC CCR groundwater monitoring system wells in 2016, 2017 and 2018. Forward model simulations were run for the three CCR assessment monitoring constituents (arsenic, lithium, and molybdenum) that have been detected at concentrations above GWPS at the MEC. Forward model simulations were completed for three cap permeability scenarios; specifically, a cap permeability of 1 x 10-5, 1 x 10-6, and 1 x 10-7 cm/s. Forward model simulations were also completed for potential groundwater remediation scenarios that by reducing recharge concentrations and initial groundwater concentrations beneath surface impoundment 489 by 25 percent.

5.1 Conclusions

The following is a summary of notable conclusions resulting from the review of model simulations for the MEC.

- The model simulations indicate that concentrations of arsenic at current CCR monitoring well locations would not attenuate to concentrations that are below the GWPS within approximately 30 years following installation of a cap with a permeability of 1 x 10^{-6} cm/s.

- The model simulations indicate that concentrations of arsenic at current CCR monitoring well locations would attenuate to concentrations that are below the GWPS within approximately 27 years following installation of a cap with a permeability of 1 x 10^{-7} cm/s.

- The model simulations indicate that concentrations of arsenic at current CCR monitoring well locations would attenuate to concentrations that are below the GWPS within approximately 11 years following installation of a cap with a permeability of 1 x 10^{-7} cm/s, and an initial 25 percent reduction in groundwater concentrations simulating potential remediation. A potential remediation model simulation was not completed for a 1 x 10^{-6} cm/s permeability cap.

- The model simulations indicate that concentrations of lithium at current CCR monitoring well locations would attenuate to concentrations that are below the GWPS within approximately 15 years following installation of a cap with a permeability of 1 x 10^{-6} cm/s, and within approximately 14 years following installation of a cap with a permeability of 1 x 10^{-7} cm/s.

- The model simulations indicate that concentrations of lithium at current CCR monitoring well locations would attenuate to concentrations that are below the GWPS within approximately 3.5 years following installation of a cap with a permeability of 1 x 10^{-7} cm/s, and an initial 25 percent reduction in groundwater concentrations simulating potential remediation. A potential remediation model simulation was not completed for a 1 x 10^{-6} cm/s permeability cap.

- The model simulations indicate that concentrations of molybdenum at current CCR monitoring well locations would attenuate to concentrations that are below the GWPS within approximately 12 years following installation of a cap with a permeability of 1 x 10^{-6} cm/s, and within approximately 9 years following installation of a cap with a permeability of 1 x 10^{-7} cm/s.

- The model simulations indicate that concentrations of molybdenum at current CCR monitoring well locations would attenuate to concentrations that are below the GWPS within approximately 5 years following installation of a cap with a permeability of 1 x 10^{-7} cm/s, and an initial 25 percent reduction in groundwater concentrations simulating potential remediation. A potential remediation model simulation was not completed for a 1 x 10^{-6} cm/s permeability cap.

5.2 Limitations

Groundwater and solute transport models are state of the practice tools that are developed to solve complex problems and are thus, by definition, a simplification of the aquifer system. Uncertainties are inherent in all groundwater models and the simplifications built into models result in limitations. The MEC groundwater and solute transport model has been prepared in accordance with generally accepted hydrogeological and engineering practices, and includes the following limitations:

1. CCR constituent sources were simulated as constant concentration sources that do not change with time. This assumption adds significant conservatism to the model-predicted future concentrations of CCR constituents in groundwater presented in this document.
2. The interpretation of CCR constituent concentrations currently in groundwater, which was used to assign initial concentrations in the model, is based on groundwater samples collected from the existing monitoring well network. The interpretation of CCR constituents in groundwater could change if additional wells are added to the monitoring well network.
3. The absence of source water concentration data resulted in the need to extrapolate source concentration values (and locations) through an iterative model calibration process.

4. Groundwater quality samples were only available from monitoring wells that are screened in the uppermost aquifer. No water quality data was available for wells completed in the deeper portions of the aquifer.

Model-predicted CCR constituent concentration magnitude and distribution may change if additional groundwater quality data are collected and used to refine the groundwater flow and solute transport model. Changes to these and other model input parameters could impact the predicted concentrations presented in this report.

6.0 REFERENCES

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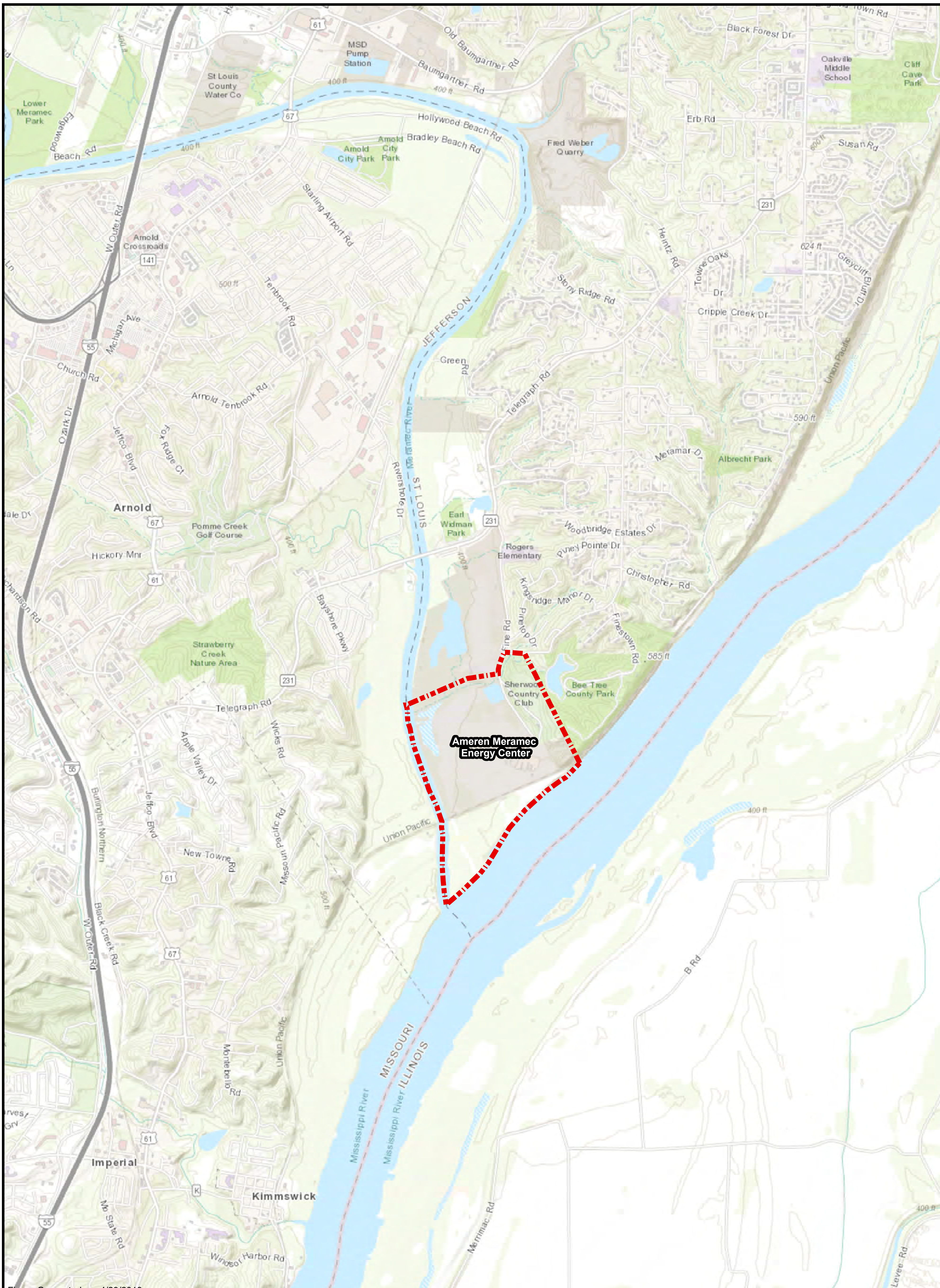
FIGURES



LEGEND

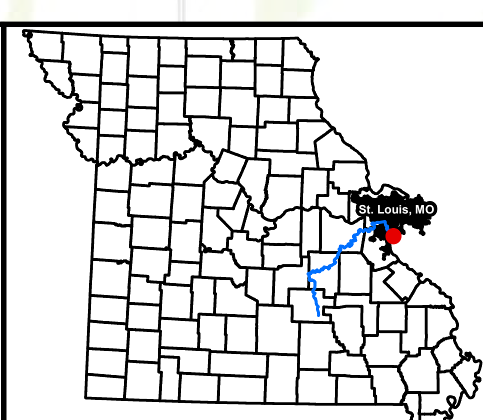
- APPROXIMATE PROPERTY BOUNDARY
- MAJOR METROPOLITAN AREA
- COUNTIES
- MERAMEC RIVER
- SITE

N

NOTES

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

DRAFT

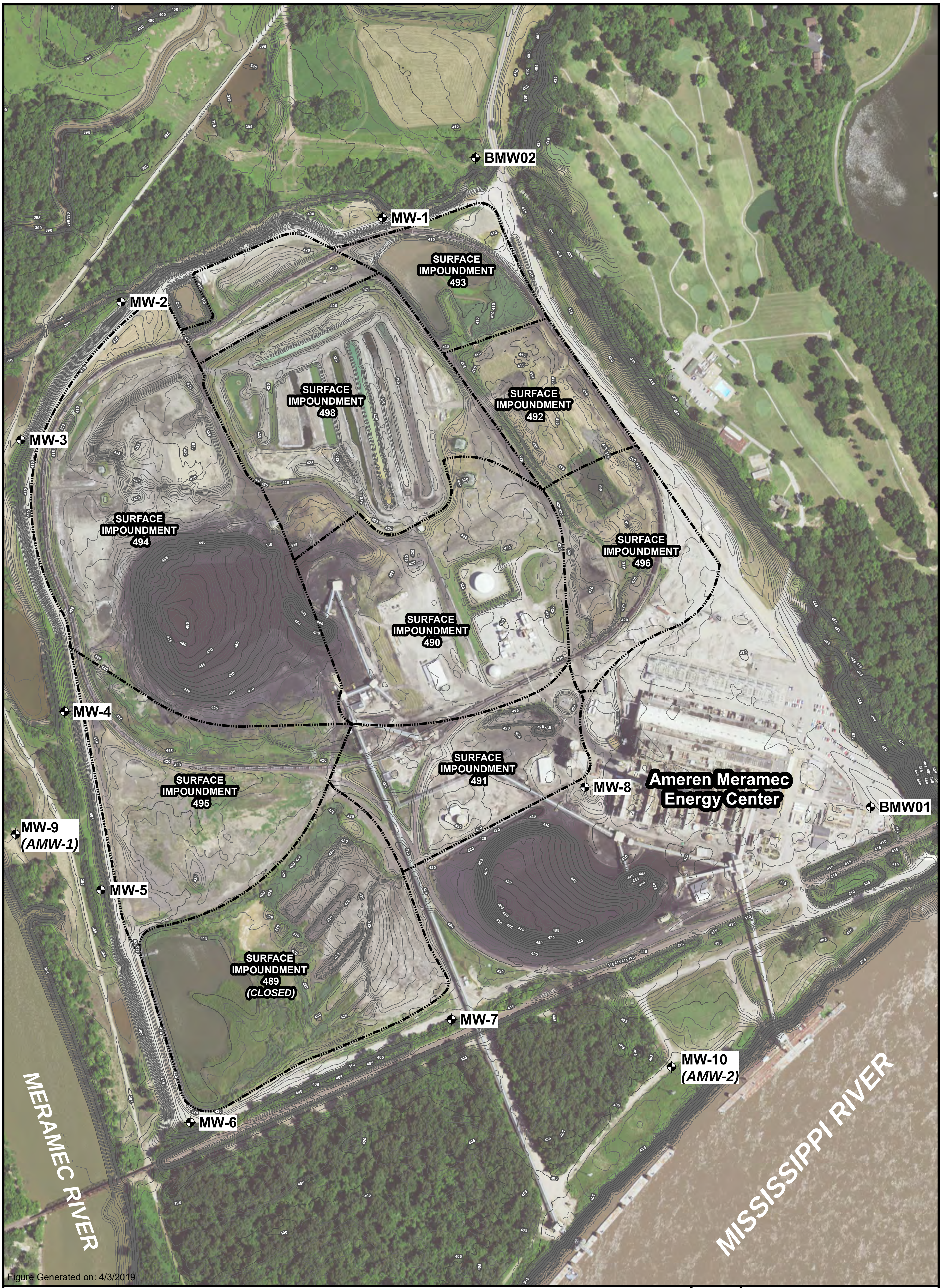


0 1,250 2,500 5,000 Feet

1 " = 2,750 FEET

FIGURE 1-1
SITE TOPOGRAPHIC MAP
AMEREN MERAMEC
ENERGY CENTER
ST. LOUIS, MISSOURI

BURNS & McDONNELL



LEGEND

- MONITORING WELL
- SURFACE IMPOUNDMENT
- MAJOR CONTOURS (5ft)
- MINOR CONTOUR (1ft)

NOTES

MW - MONITORING WELL

1) SURFACE ELEVATION CONTOUR INTERVAL: 1 ft
2) SURFACE IMPOUNDMENT LOCATIONS ARE APPROXIMATE.
3) COORDINATE SYSTEM: NAD 1983 STATE PLANE MISSOURI EAST FPIS - US FEET.
4) AERIAL IMAGE: *Aerial Imagery NAIP 2016*; SOURCE: *ArcGIS Online*; IMAGERY DATE: *5/26/2017*

DRAFT

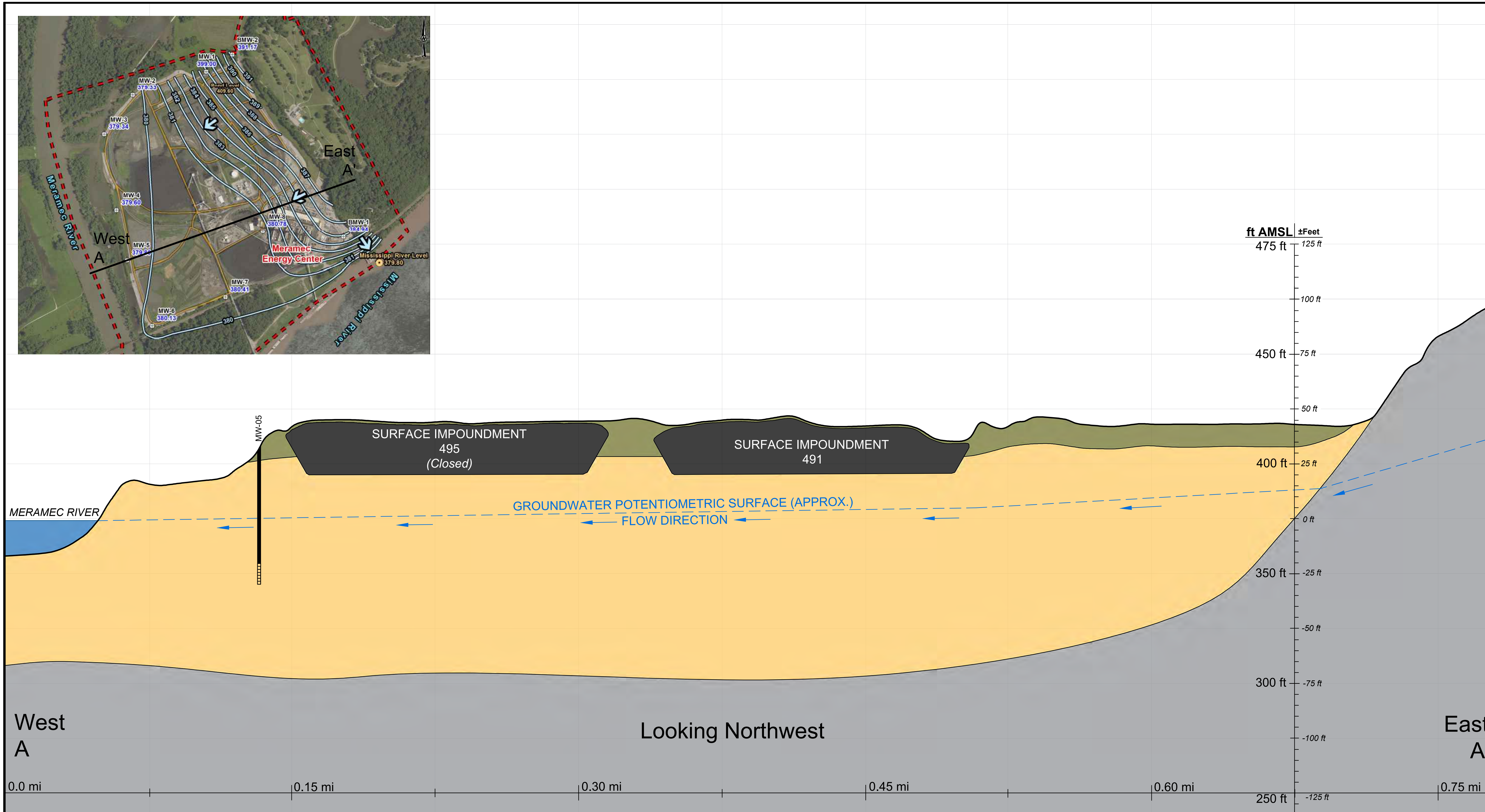
N

0 175 350 700 Feet

1 " = 375 FEET

FIGURE 2-1
SITE FEATURES
AMEREN MERAMEC
ENERGY CENTER
ST. LOUIS, MISSOURI

BURNS & McDONNELL



LEGEND

- CCR SURFACE IMPOUNDMENT
- FILL
- SEDIMENT (SILT, CLAY, COARSE SAND, AND GRAVEL)
- BEDROCK
- MERAMEC RIVER

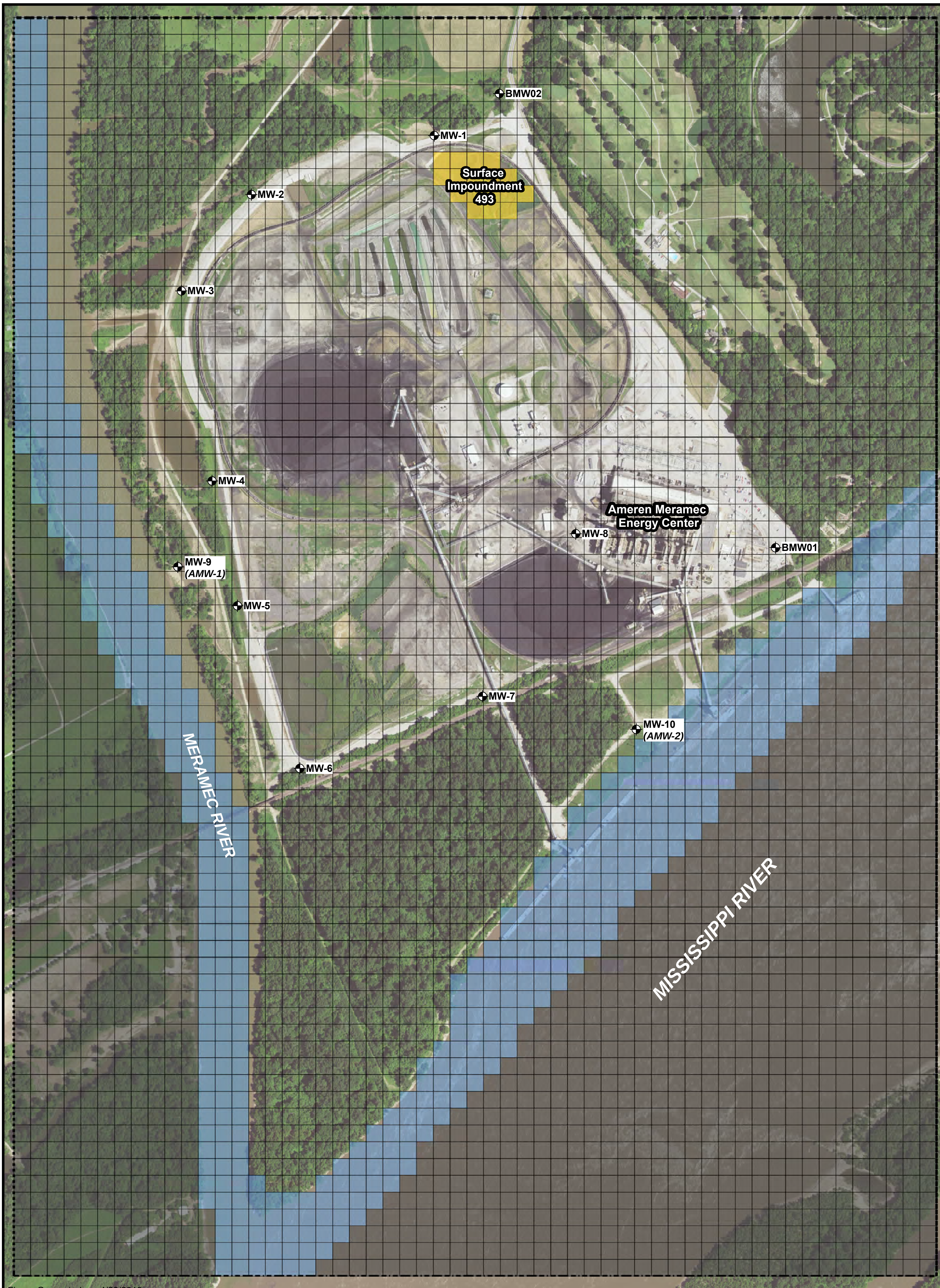
NOTES

1) SURFACE CONTOUR DERIVED FROM GOOGLE EARTH ELEVATION PROFILE (IMAGE FROM 10/16/2018).
2) ALL FEATURE LOCATIONS ARE APPROXIMATE.
3) VERTICAL EXAGGERATION - 6X
4) POTENTIOMETRIC SURFACE BASED ON GROUNDWATER ELEVATIONS RECORDED ON 11/06/2017.
5) POTENTIOMETRIC SURFACE CONTOUR INTERVAL - 1 ft

DRAFT

FIGURE 2-2
CROSS SECTION A-A'
AMEREN MERAMEC
ENERGY CENTER
ST. LOUIS, MISSOURI

BURNS McDONNELL



LEGEND

- MONITORING WELL
- MODEL GRID BOUNDARY
- SURFACE IMPOUNDMENT 493
- MODEL GRID - RIVER
- MODEL GRID - NO FLOW

NOTES

MW - MONITORING WELL

1) GRID DIMENSIONS: 100 ft x 100 ft
2) COORDINATE SYSTEM: NAD 1983 STATE PLANE MISSOURI EAST FIPS 2401 - US FEET
3) SURFACE IMPOUNDMENT 493 SIMULATED AS RIVER BOUNDARY (CONSTANT HEAD).

N

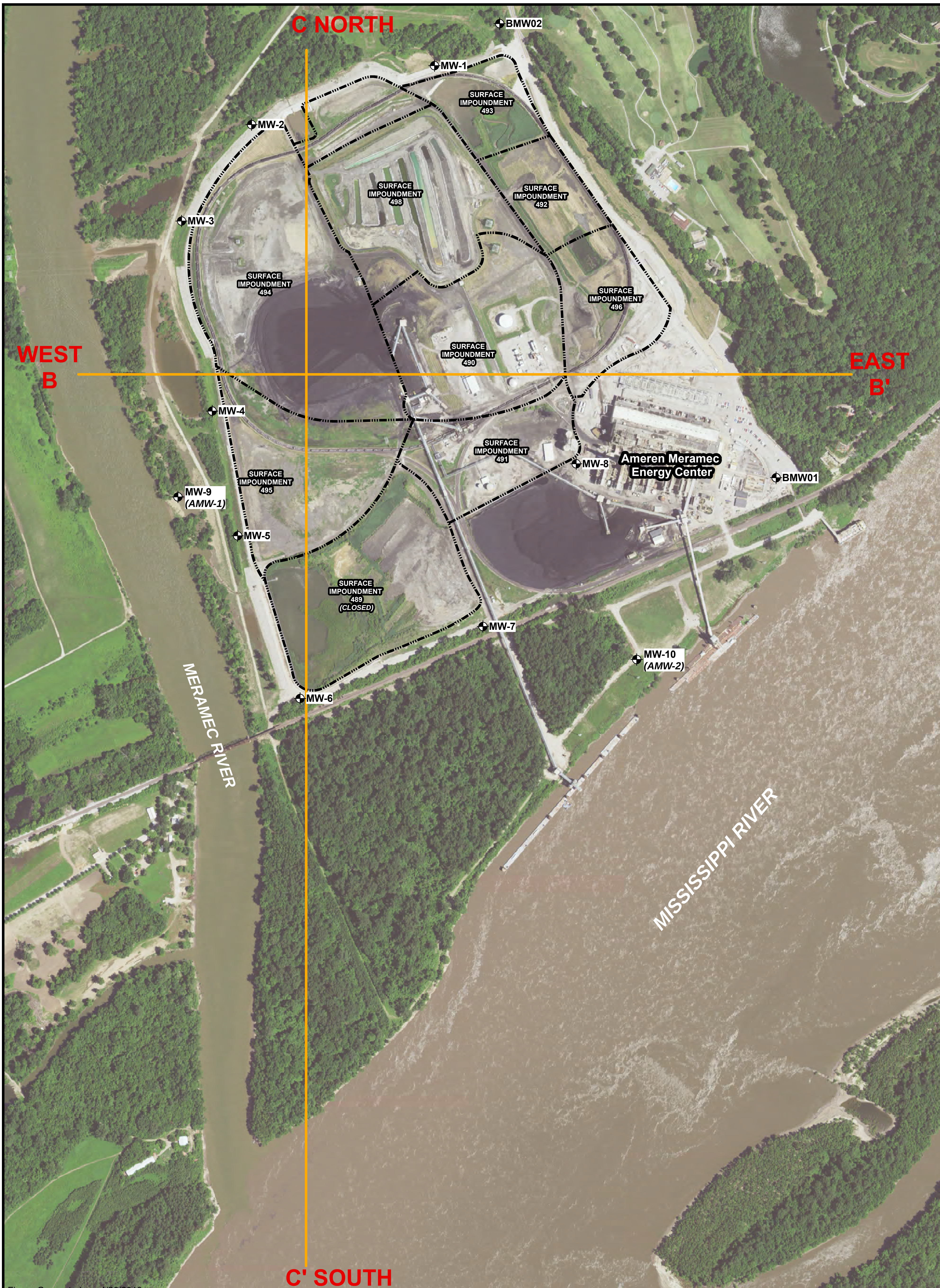
DRAFT

0 250 500 1,000 Feet

1 " = 542 FEET

FIGURE 3-1
MODEL BOUNDARIES
AMEREN MERAMEC
ENERGY CENTER
ST. LOUIS, MISSOURI

BURNS & McDONNELL



LEGEND

- MONITORING WELL
- CROSS SECTIONS
- SURFACE IMPOUNDMENT

NOTES

MW - MONITORING WELL

1) SURFACE IMPOUNDMENT LOCATIONS ARE APPROXIMATE.
2) COORDINATE SYSTEM: NAD 1983 STATE PLANE MISSOURI EAST FIPS 2401 - US FEET

DRAFT

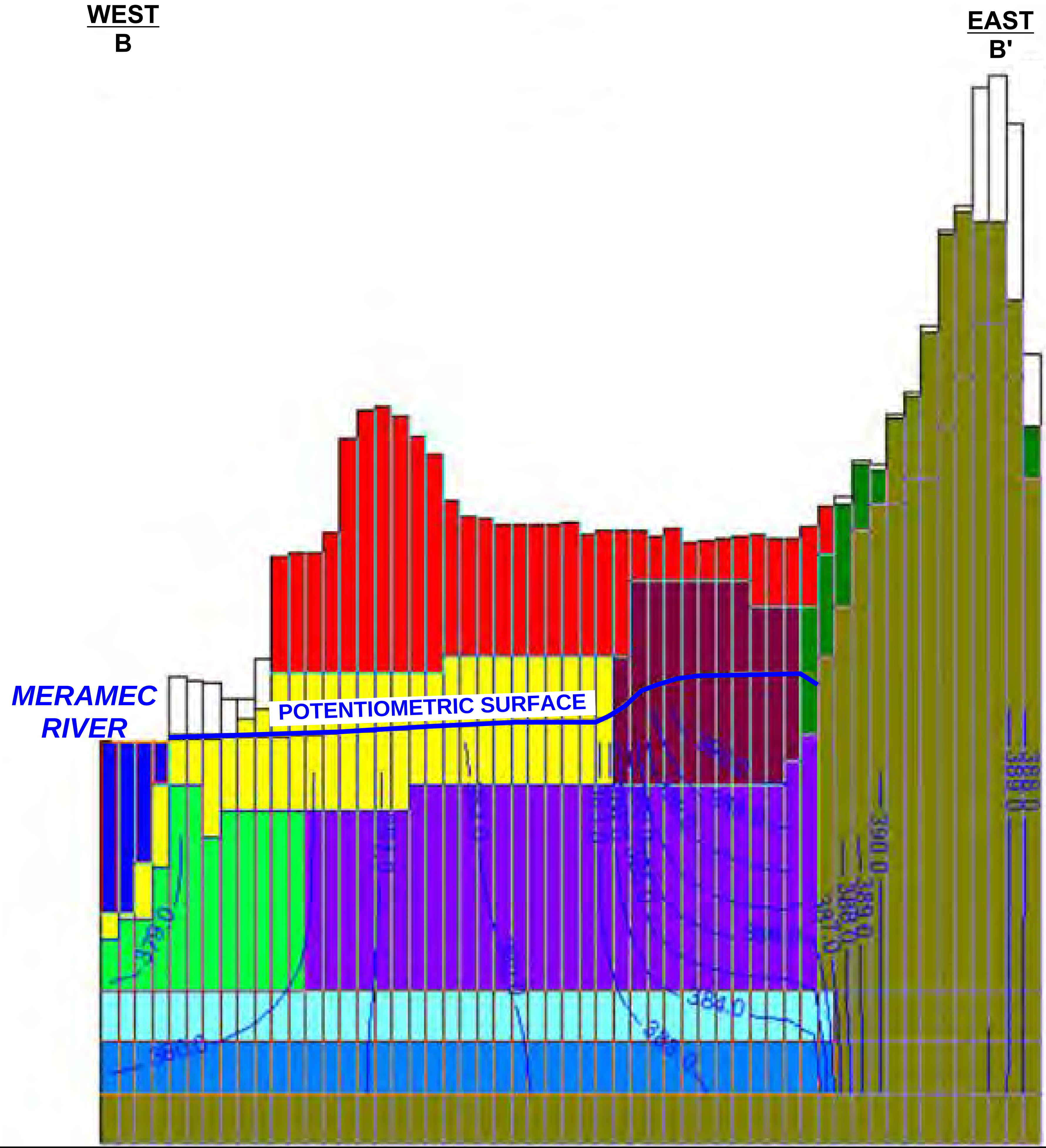
N

0 250 500 1,000 Feet

1 " = 542 FEET

FIGURE 3-2
MODEL CROSS SECTIONS
AMEREN MERAMEC ENERGY CENTER ST. LOUIS, MISSOURI

BURNS & McDONNELL



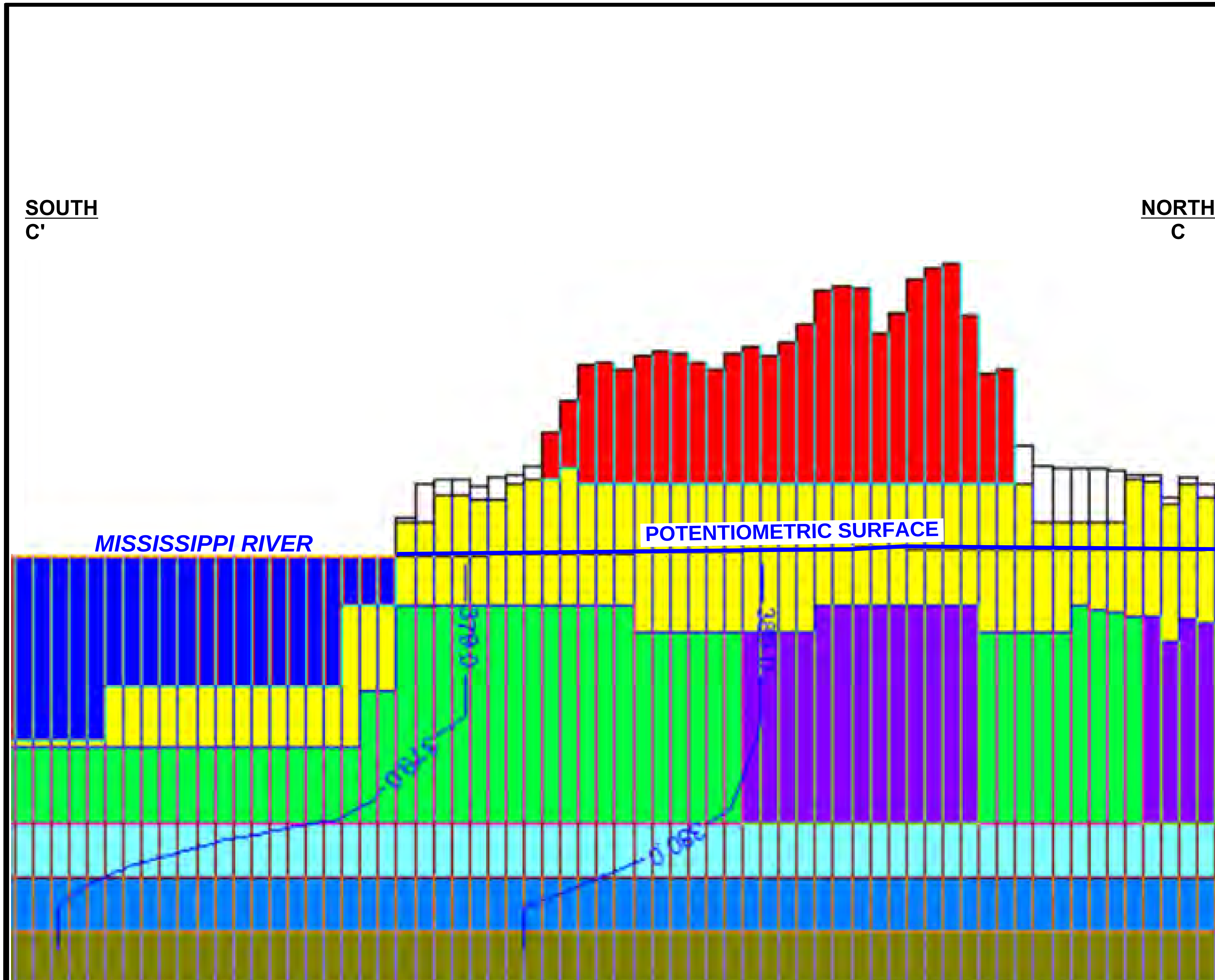
LEGEND

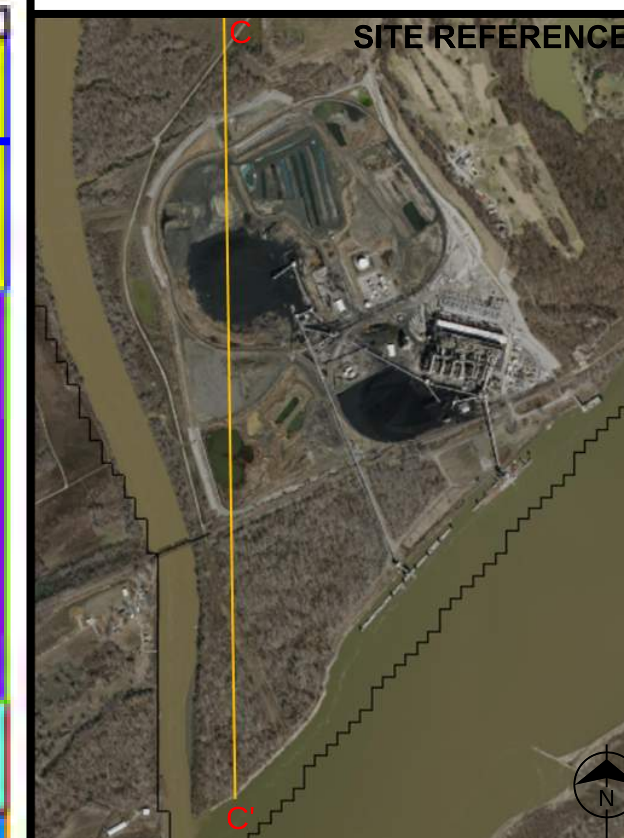
- FILL
- ASH
- SAND - SILTY CLAY
- SAND
- CLAY
- COARSE SAND AND GRAVEL
- BEDROCK

SITE REFERENCE

BURNS McDONNELL

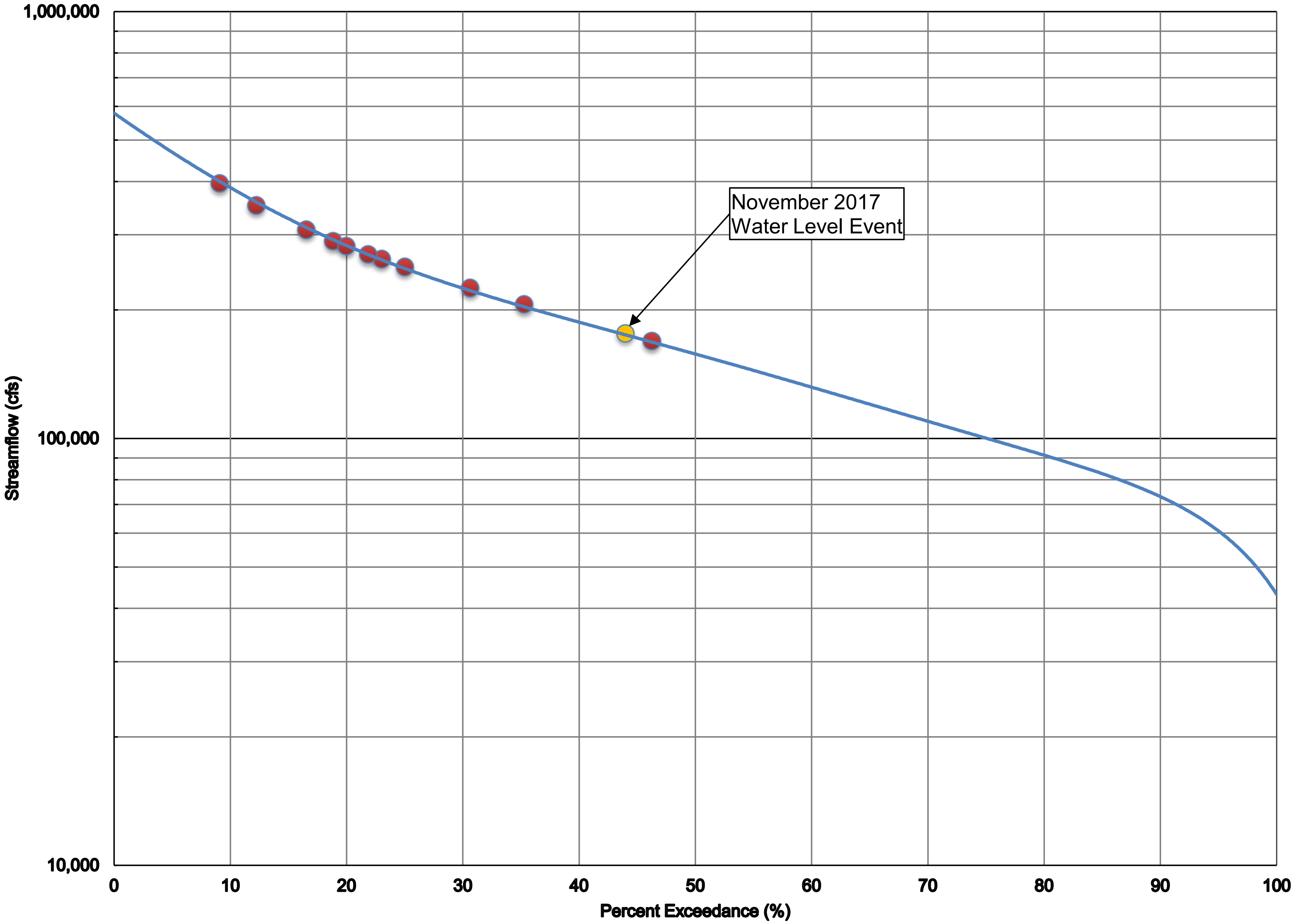
FIGURE 3-3
MODEL CROSS SECTION B-B'
AMEREN MERAMEC
ENERGY CENTER
ST. LOUIS, MISSOURI





BURNS McDONNELL

FIGURE 3-4
MODEL CROSS SECTION C-C'
AMEREN MERAMEC ENERGY CENTER
ST. LOUIS, MISSOURI



LEGEND

Measured Streamflow

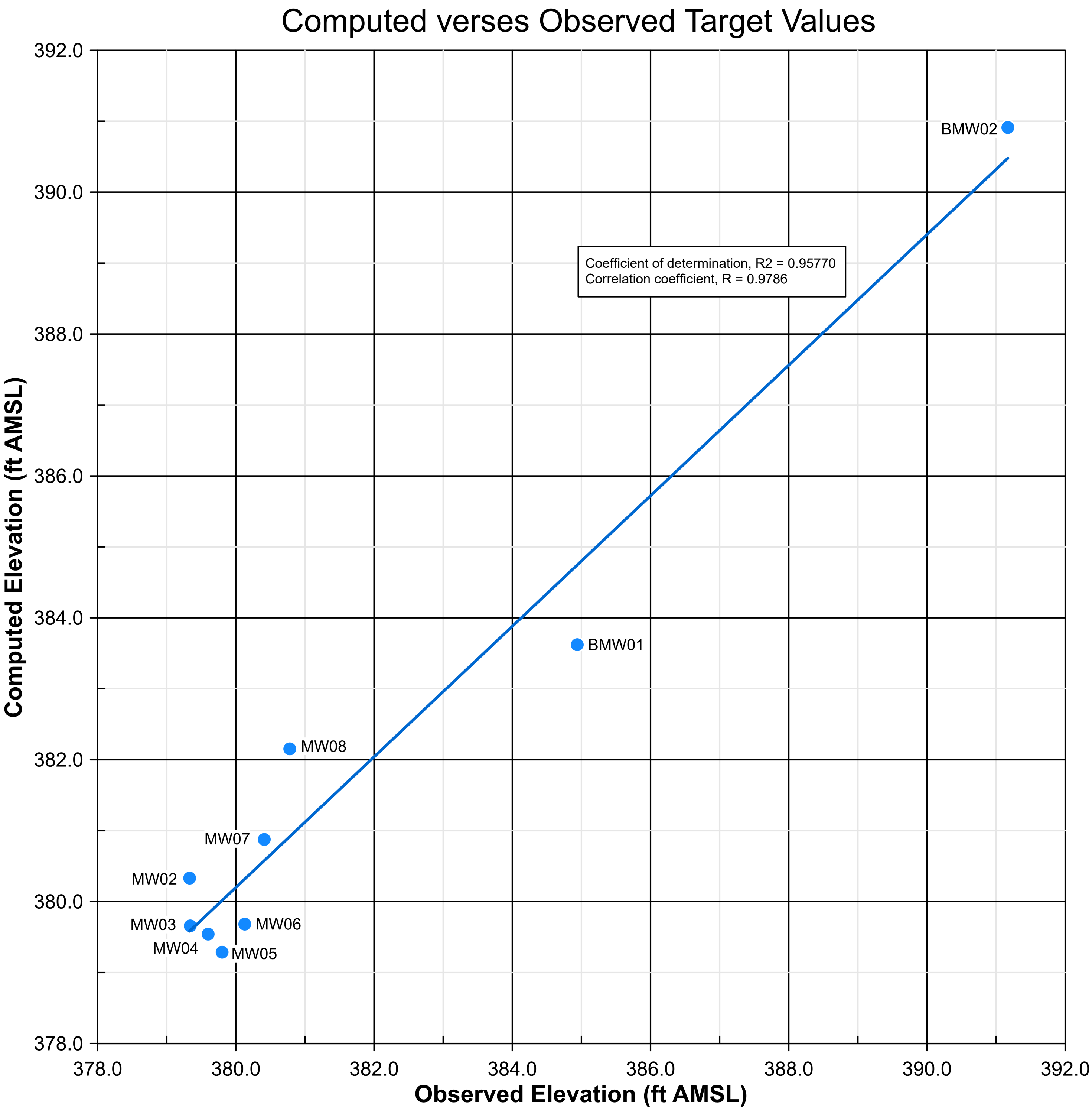
Flow Duration Curve

NOTES

1) This figure illustrates the flow duration curve for the Mississippi River in St. Louis, MO and the measure streamflow for the date where water level measurements were collected at the Site.

FIGURE 3-5
FLOW DURATION CURVE
MISSISSIPPI RIVER AT
ST. LOUIS
USGS GAUGE #07010000

BURNS McDONNELL



LEGEND

- Computed
- Line of zero residuals

STATISTICS

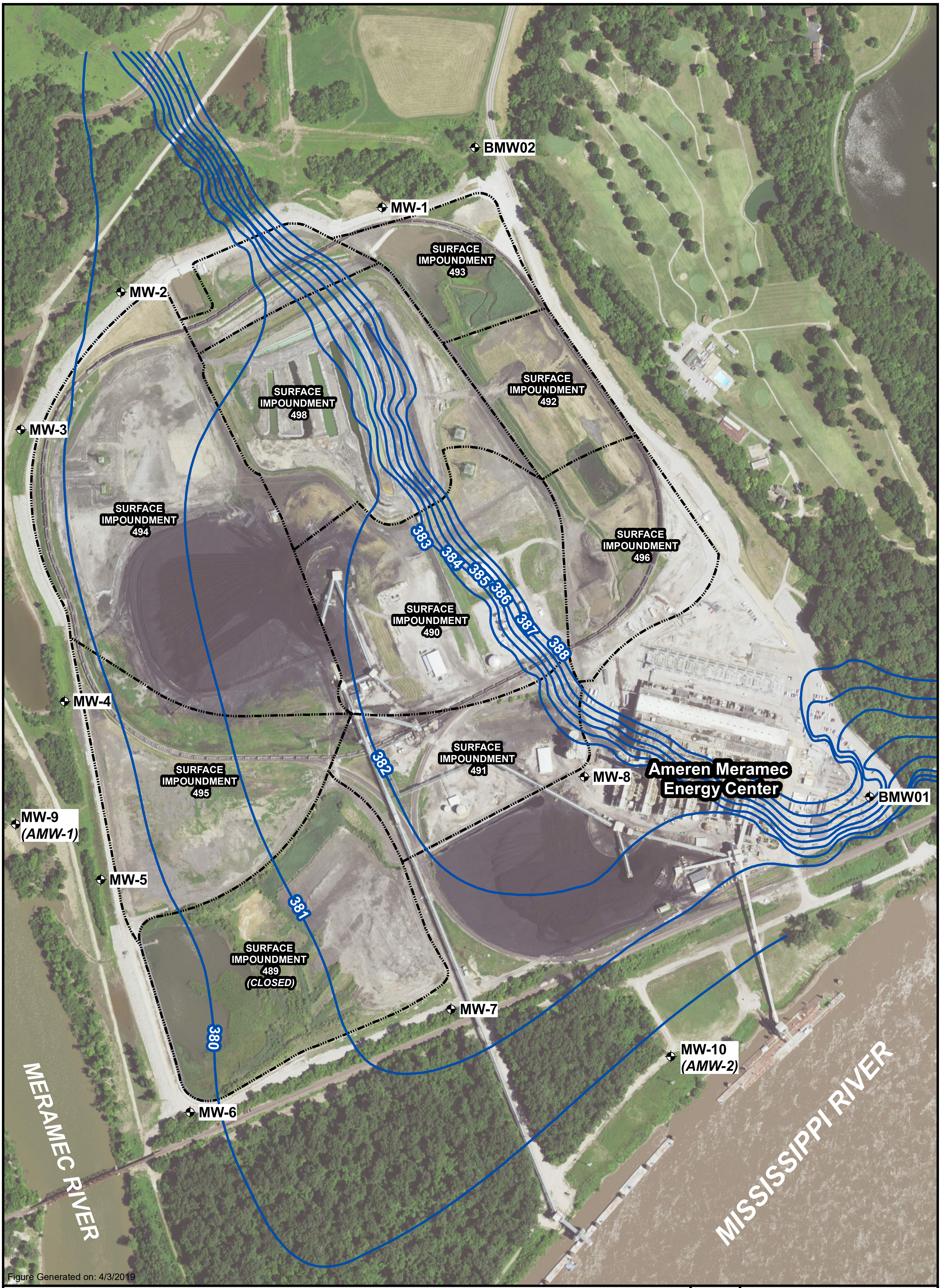
Number of Observations	9
Range in Observations	11.84
Residual Std. Deviation	0.777644
Scaled Residual Std. Deviation	0.065679
Absolute Residual Mean	0.63939
Scaled Absolute Residual Mean	0.054003
Residual Mean	-0.06212
Scaled Residual Mean	-0.00525
RMS Error	0.780122
Scaled RMS Error	0.065889
Sum of Squares	5.477307
Min. Residual	-1.37249
Max. Residual	1.318932

NOTES

1) Observed groundwater elevations were measured on November 6, 2017 (Golder, 2017).
2) Computed groundwater elevations represent the final model calibration.
3) Calibration targets are located in layer 2 or layer 3.

FIGURE 3-6
CALIBRATION RESULTS
AMEREN MERAMEC
ENERGY CENTER
ST. LOUIS, MISSOURI

BURNS McDONNELL



LEGEND

- MONITORING WELL
- POTENTIOMETRIC SURFACE
- SURFACE IMPOUNDMENT

NOTES

MW - MONITORING WELL

1) POTENTIOMETRIC SURFACE CONTOUR INTERVAL: 1 ft
2) POTENTIOMETRIC SURFACE CONTOURS ARE CALCULATED BY THE MODEL.
3) SURFACE IMPOUNDMENT LOCATIONS ARE APPROXIMATE.
4) COORDINATE SYSTEM: NAD 1983 STATE PLANE MISSOURI EAST FPIS 2401 - US FEET

DRAFT

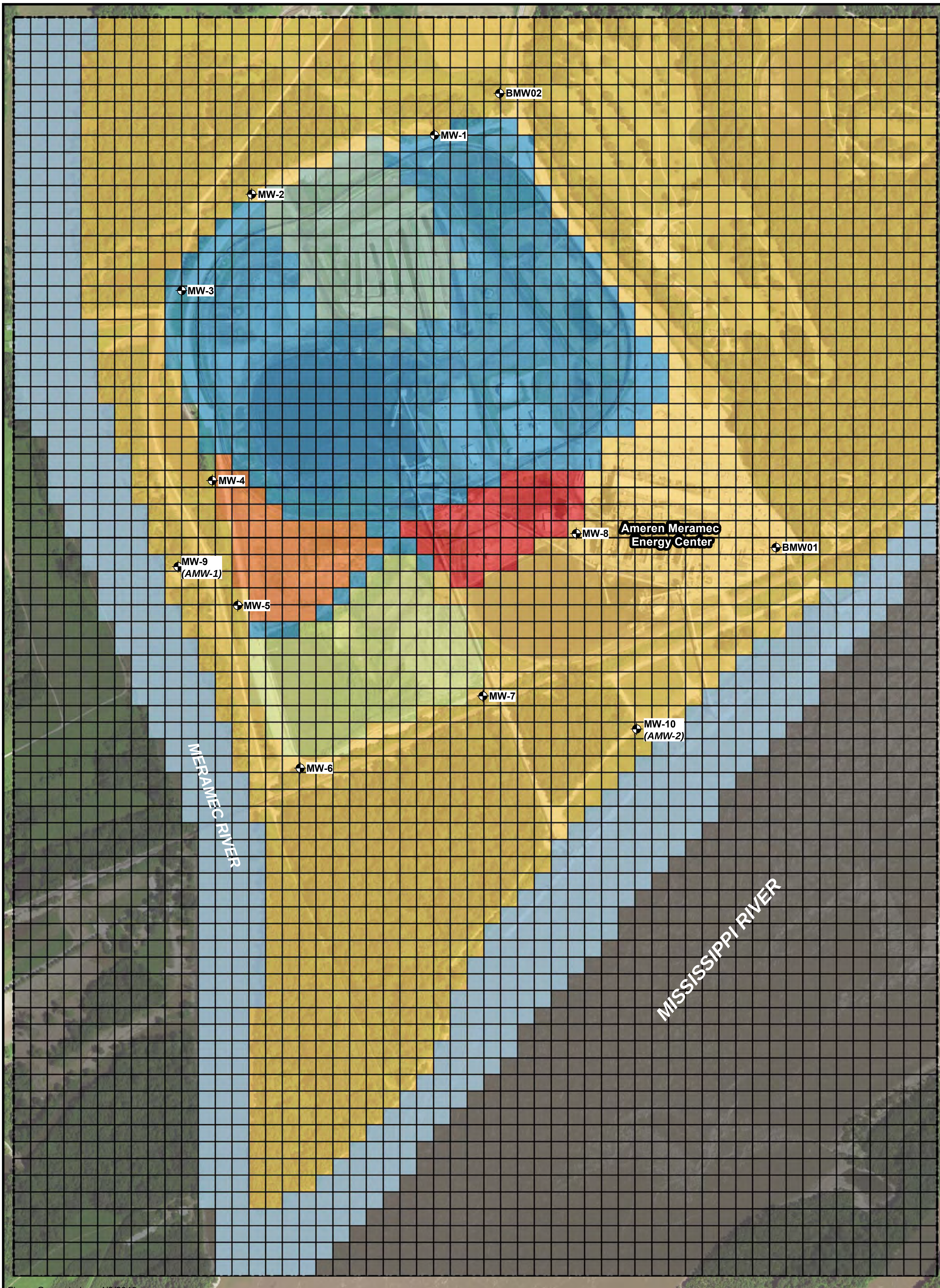
N

0 175 350 700 Feet

1 " = 375 FEET

FIGURE 3-7
POTENTIOMETRIC SURFACE
AMEREN MERAMEC
ENERGY CENTER
ST. LOUIS, MISSOURI

BURNS & McDONNELL.



LEGEND

- MONITORING WELL
- MODEL GRID BOUNDARY
- ALLUVIUM/BEDROCK
- SURFACE IMPOUNDMENT 489
- SURFACE IMPOUNDMENT 498
- SURFACE IMPOUNDMENTS 490/492/493/494/496
- SURFACE IMPOUNDMENT 491
- SURFACE IMPOUNDMENT 495
- MODEL GRID - RIVERS
- MODEL GRID - NO FLOW

NOTES

MW - MONITORING WELL

1) GRID DIMENSIONS: 100 ft x 100 ft
2) COORDINATE SYSTEM: NAD 1983 STATE PLANE MISSOURI EAST FIPS 2401 - US FEET

DRAFT

N

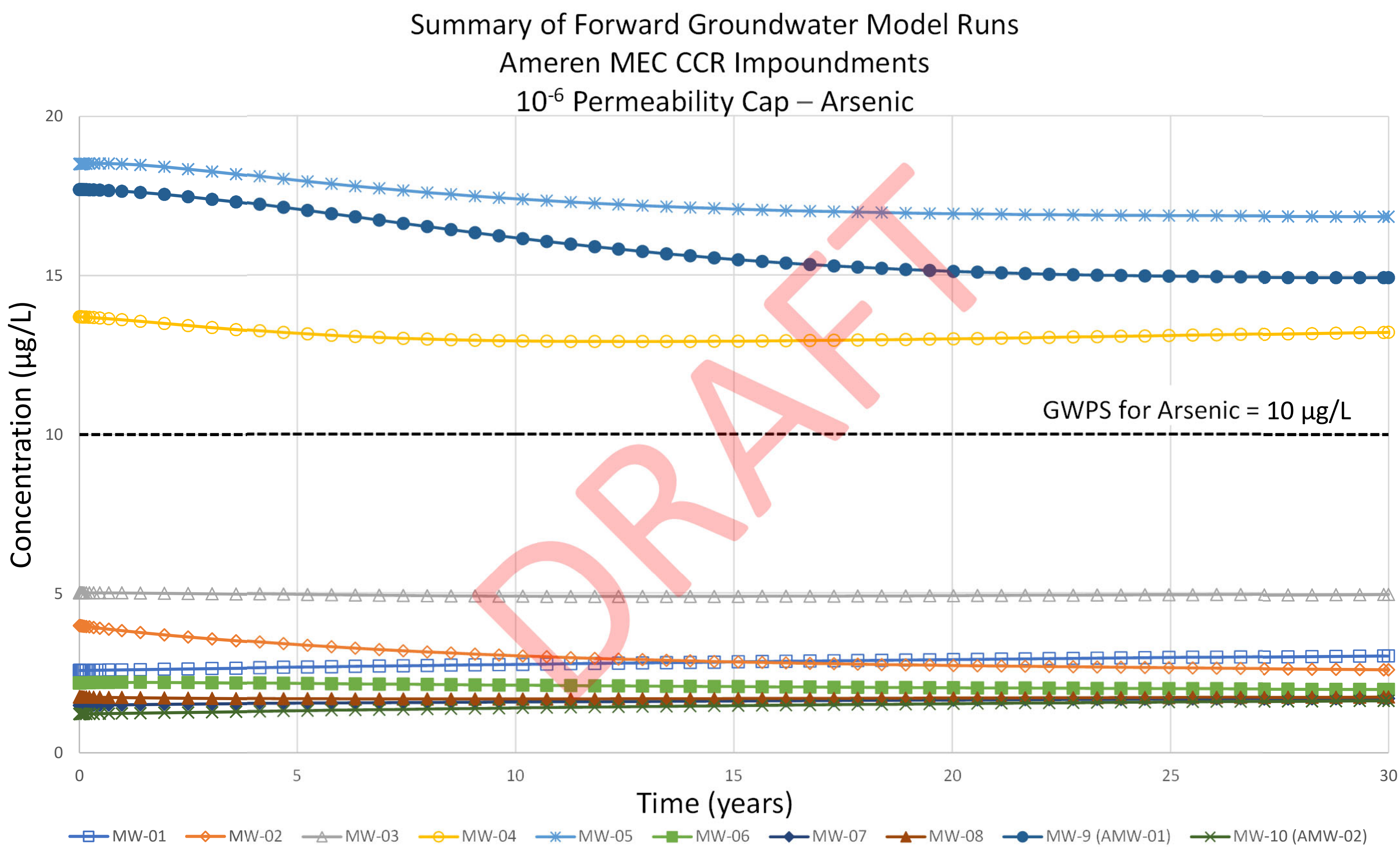
0 250 500 1,000 Feet

1 " = 542 FEET

FIGURE 4-1
MODEL RECHARGE ZONES
AMEREN MERAMEC
ENERGY CENTER
ST. LOUIS, MISSOURI

BURNS & McDONNELL

APPENDIX A – CAPPING SIMULATION CONCENTRATION GRAPHS



Notes:

µg/L = micrograms per Liter

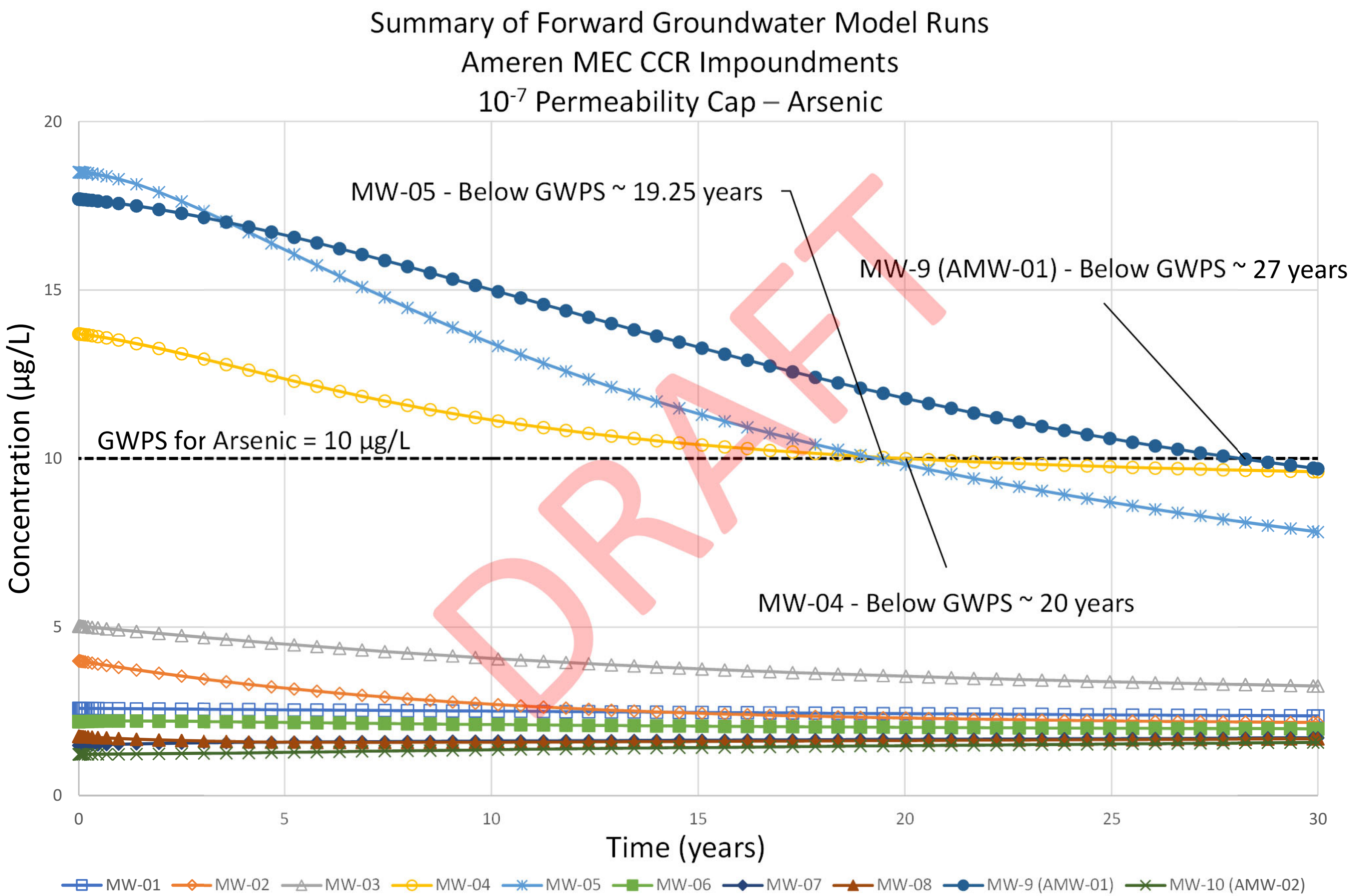
CCR = Coal Combustion Residuals

GWPS = Groundwater Protection Standard

MEC = Meramec Energy Center

BURNS McDONNELL

Figure A-1
Arsenic – 10^{-6} Cap
Meramec Energy Center
Ameren Missouri
St. Louis, Missouri



Notes:

µg/L = micrograms per Liter

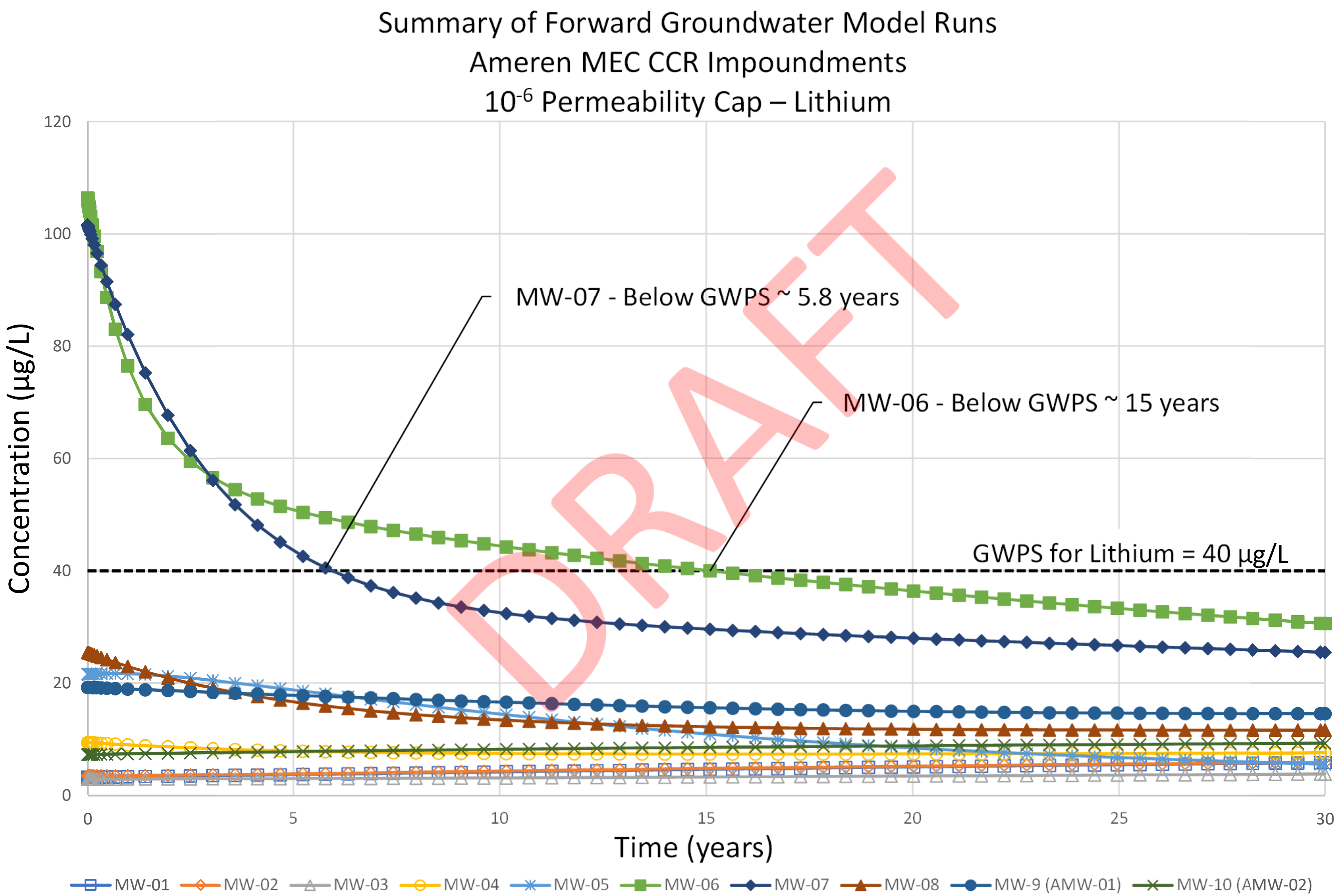
CCR = Coal Combustion Residuals

GWPS = Groundwater Protection Standard

MEC = Meramec Energy Center

BURNS McDONNELL

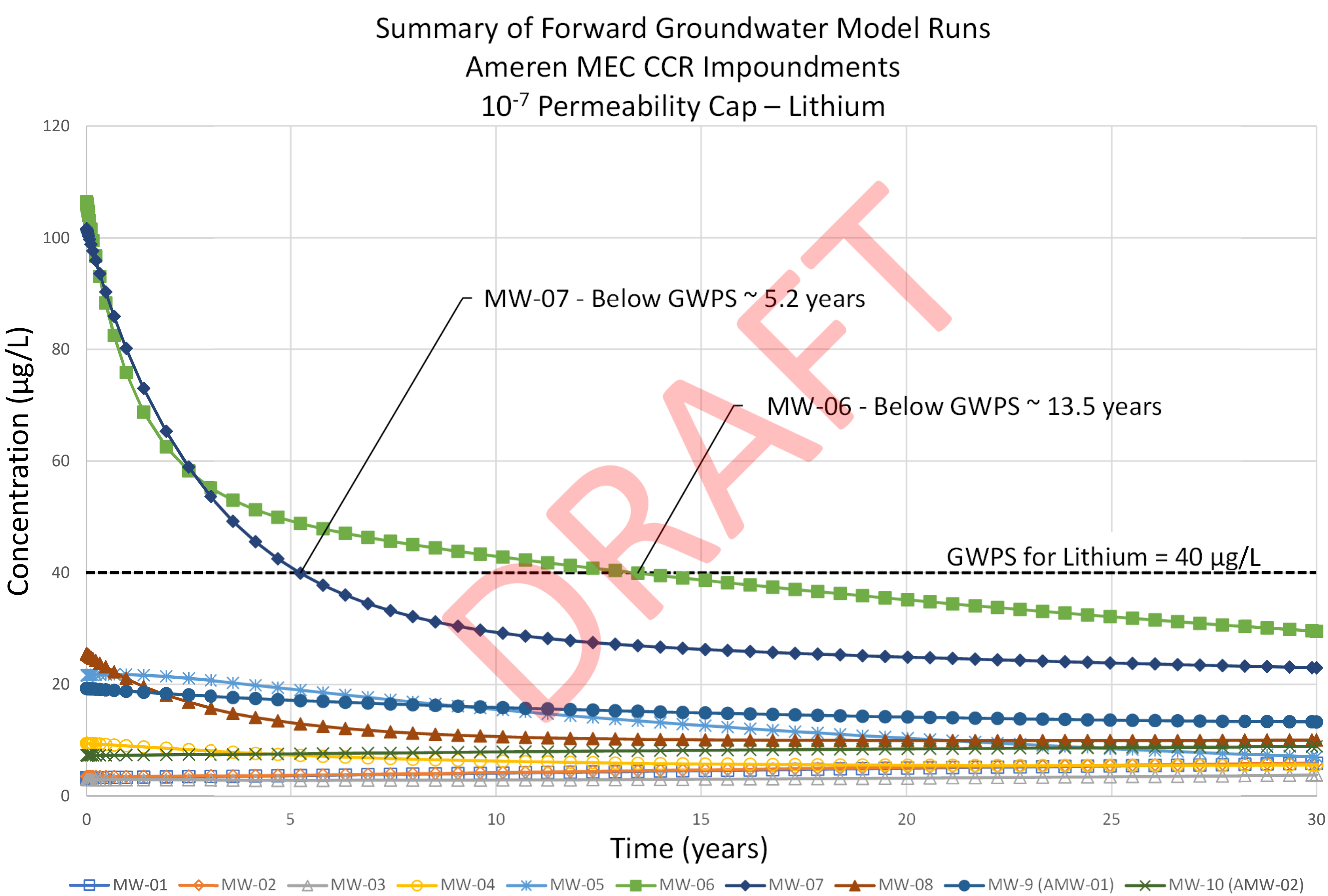
Figure A-2
Arsenic – 10^{-7} Cap
Meramec Energy Center
Ameren Missouri
St. Louis, Missouri



Notes:
µg/L = micrograms per Liter
CCR = Coal Combustion Residuals
GWPS = Groundwater Protection Standard
MEC = Meramec Energy Center

BURNS McDONNELL

Figure A-3
Lithium – 10^{-6} Cap
Meramec Energy Center
Ameren Missouri
St. Louis, Missouri



Notes:

µg/L = micrograms per Liter

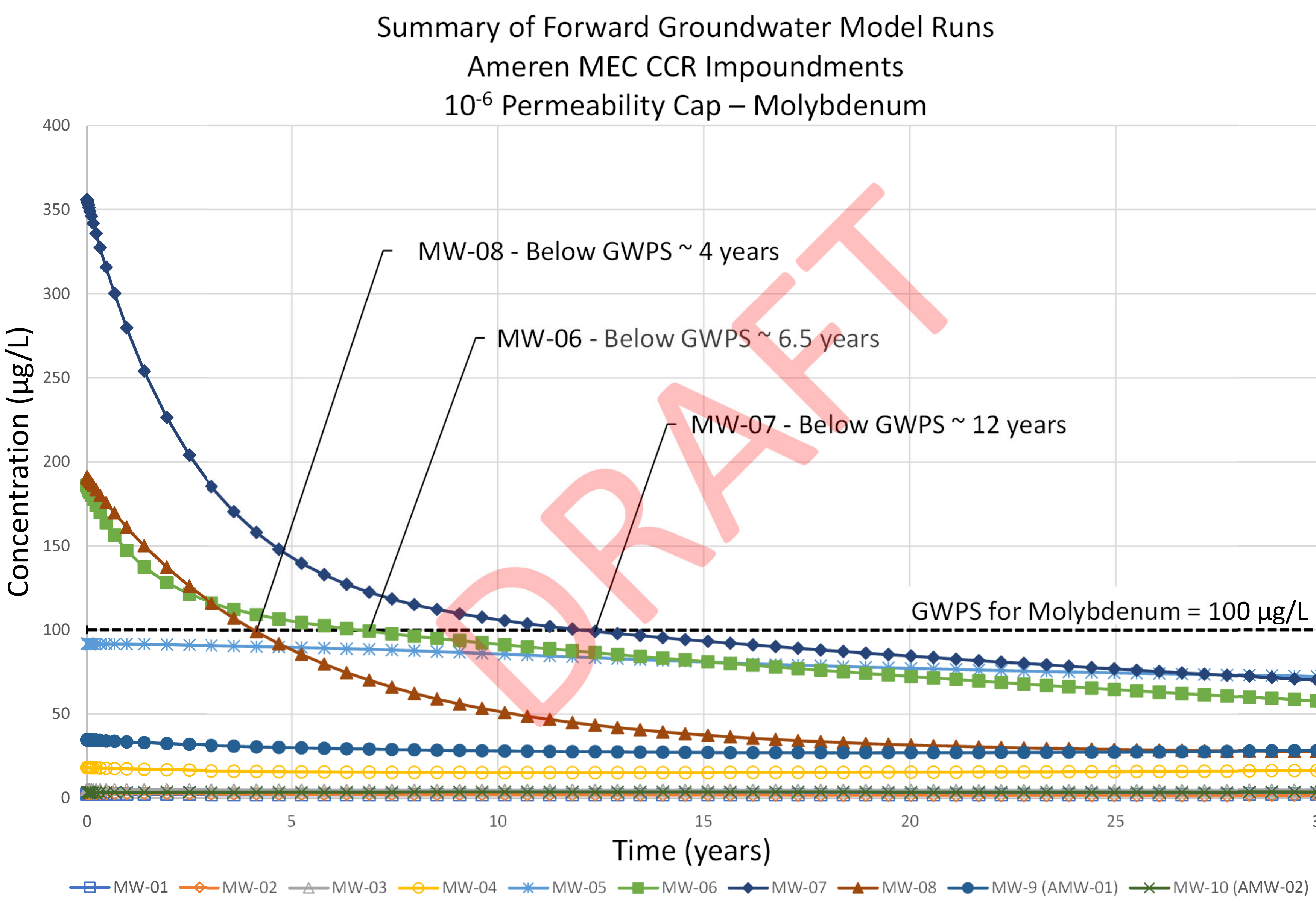
CCR = Coal Combustion Residuals

GWPS = Groundwater Protection Standard

MEC = Meramec Energy Center

BURNS McDONNELL

Figure A-4
Lithium – 10^{-7} Cap
Meramec Energy Center
Ameren Missouri
St. Louis, Missouri



Notes:

µg/L = micrograms per Liter

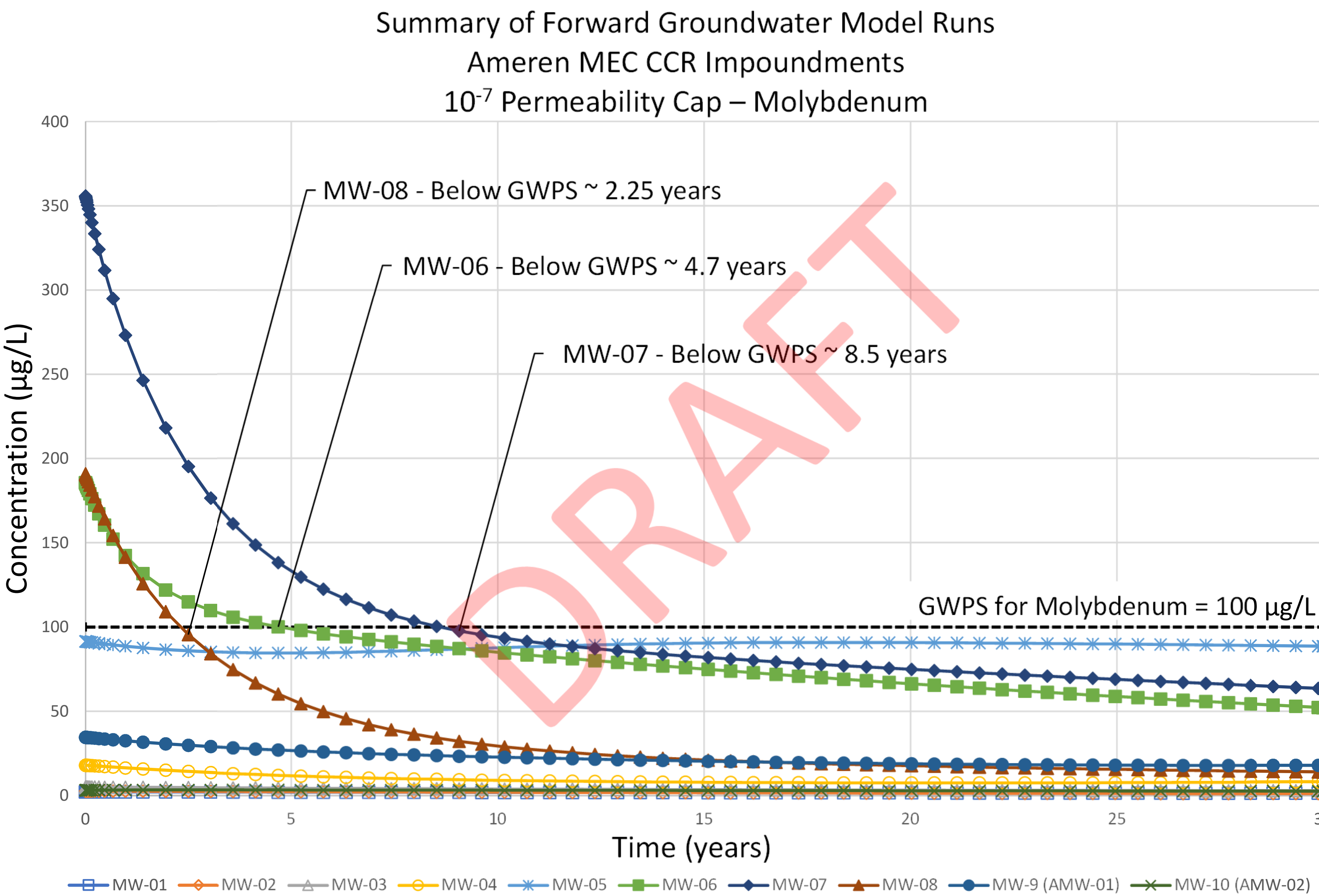
CCR = Coal Combustion Residuals

GWPS = Groundwater Protection Standard

MEC = Meramec Energy Center

BURNS McDONNELL

Figure A-5
Molybdenum – 10^{-6} Cap
Meramec Energy Center
Ameren Missouri
St. Louis, Missouri



Notes:

µg/L = micrograms per Liter

CCR = Coal Combustion Residuals

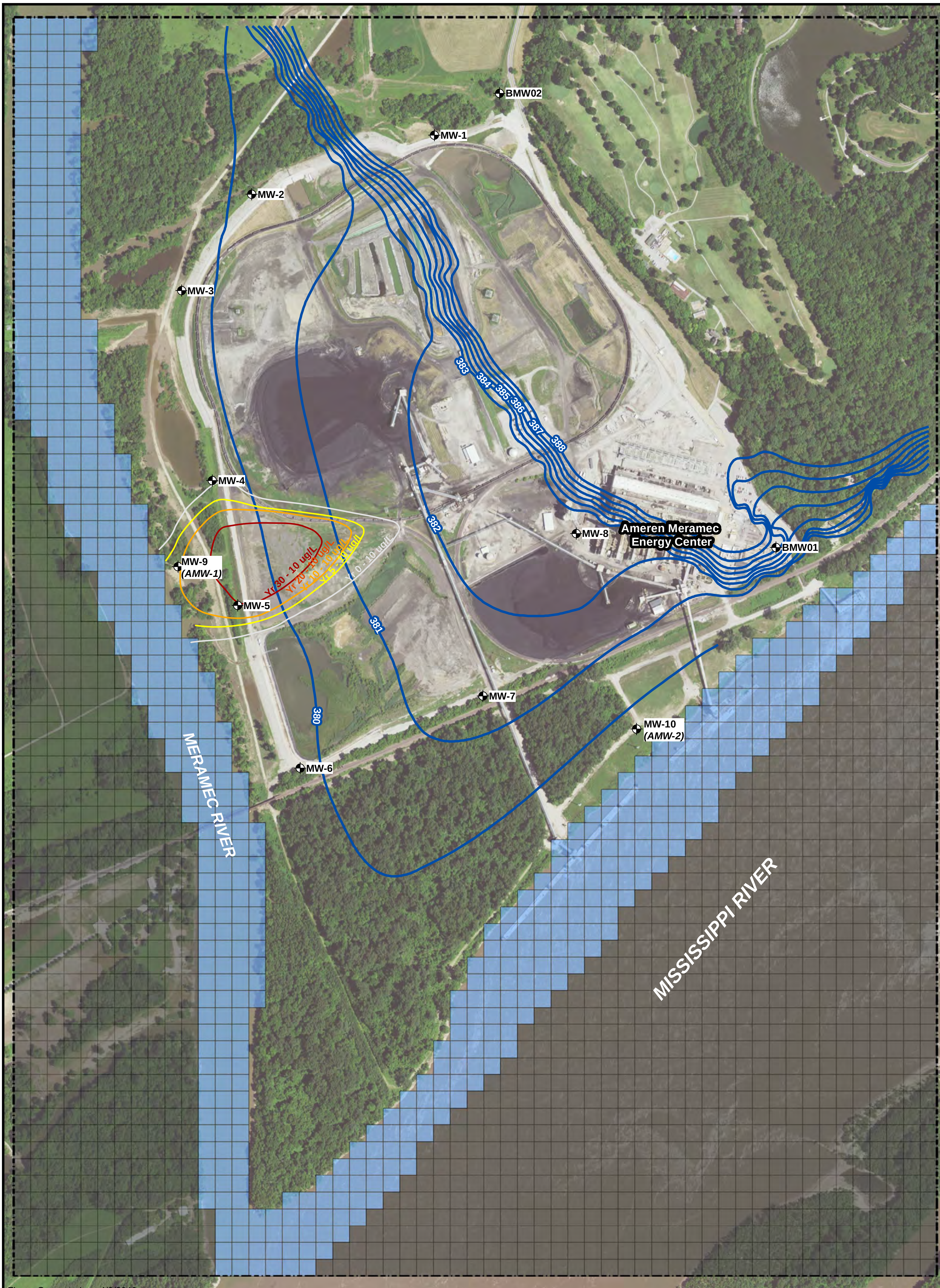
GWPS = Groundwater Protection Standard

MEC = Meramec Energy Center

BURNS McDONNELL

Figure A-6
Molybdenum – 10^{-7} Cap
Meramec Energy Center
Ameren Missouri
St. Louis, Missouri

APPENDIX B – CAPPING SIMULATION ISOCONCENTRATION MAPS



LEGEND

- MONITORING WELL
- ARSENIC - CAP PERMEABILITY (10^{-7} cm/sec) - 0 Year
- ARSENIC - CAP PERMEABILITY (10^{-7} cm/sec) - 5 Year
- ARSENIC - CAP PERMEABILITY (10^{-7} cm/sec) - 10 Year
- ARSENIC - CAP PERMEABILITY (10^{-7} cm/sec) - 20 Year
- ARSENIC - CAP PERMEABILITY (10^{-7} cm/sec) - 30 Year
- POTENTIOMETRIC SURFACE
- MODEL GRID BOUNDARY
- MODEL GRID - RIVERS
- MODEL GRID - NO FLOW

NOTES

ug/L - MICROGRAMS PER LITER
MW - MONITORING WELL
GWPS - GROUNDWATER PROTECTION STANDARD
cm/sec - CENTIMETERS PER SECOND

1) GRID DIMENSIONS: 100 ft X 100 ft
2) POTENTIOMETRIC SURFACE CONTOUR INTERVAL: 1 ft
3) POTENTIOMETRIC SURFACE CONTOURS ARE CALCULATED BY THE MODEL.
4) ARSENIC GWPS - 10.0 ug/L
5) CONCENTRATIONS ARE CALCULATED BY THE MODEL.
6) COORDINATE SYSTEM: NAD 1983 STATE PLANE MISSOURI EAST FPIS 2401 - US FEET

DRAFT

N
0 250 500 1,000
Feet
1 " = 542 FEET

FIGURE B-1
ARSENIC
ISOCONCENTRATION MAP
AMEREN MERAMEC
ENERGY CENTER
ST. LOUIS, MISSOURI

BURNS & McDONNELL

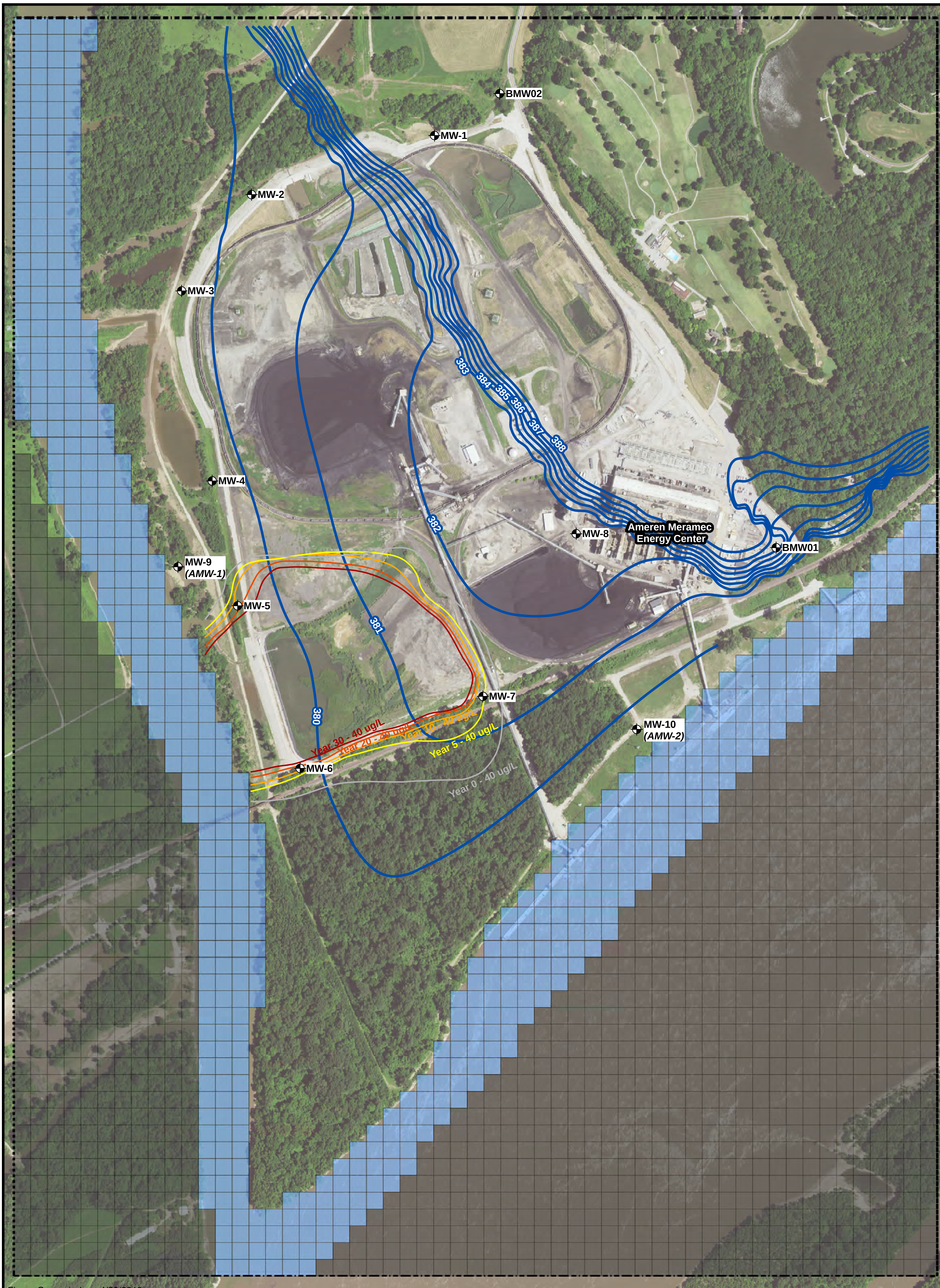


Figure Generated on: 4/29/2019

LEGEND

- MONITORING WELL
- LITHIUM - CAP PERMEABILITY (10^{-7} cm/sec) - 0 Year
- LITHIUM - CAP PERMEABILITY (10^{-7} cm/sec) - 5 Year
- LITHIUM - CAP PERMEABILITY (10^{-7} cm/sec) - 10 Year
- LITHIUM - CAP PERMEABILITY (10^{-7} cm/sec) - 20 Year
- LITHIUM - CAP PERMEABILITY (10^{-7} cm/sec) - 30 Year
- POTENTIOMETRIC SURFACE
- MODEL GRID BOUNDARY
- MODEL GRID - RIVERS
- MODEL GRID - NO FLOW

NOTES

ug/L - MICROGRAMS PER LITER
MW - MONITORING WELL
GWPS - GROUNDWATER PROTECTION STANDARD
cm/sec - CENTIMETERS PER SECOND

1) GRID DIMENSIONS: 100 ft X 100 ft
2) POTENTIOMETRIC SURFACE CONTOUR INTERVAL: 1 ft
3) POTENTIOMETRIC SURFACE CONTOURS ARE CALCULATED BY THE MODEL.
4) LITHIUM GWPS - 40.0 ug/L
5) CONCENTRATIONS ARE CALCULATED BY THE MODEL.
6) COORDINATE SYSTEM: NAD 1983 STATE PLANE MISSOURI EAST FPIS 2401 - US FEET

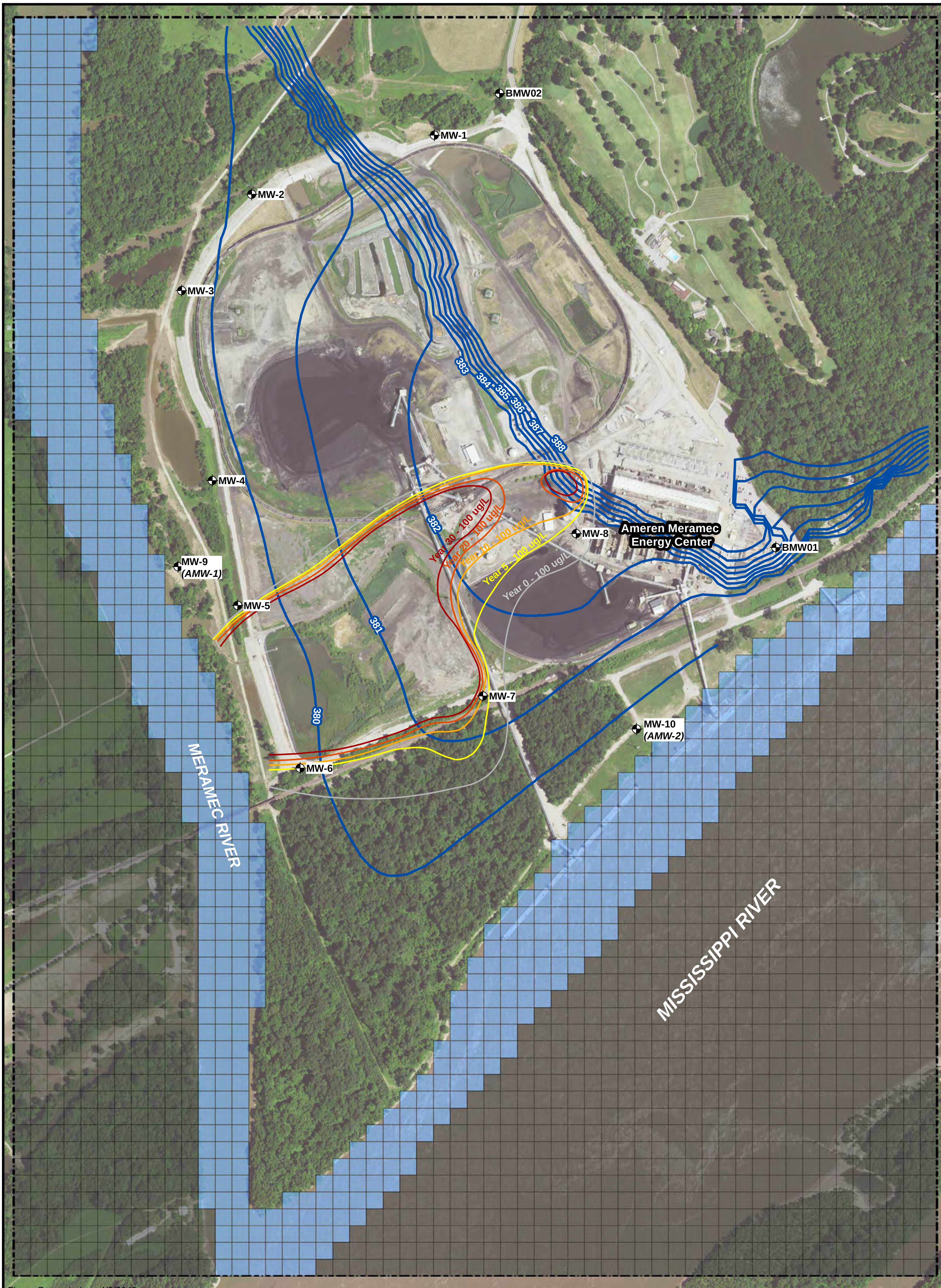
DRAFT

N

0 250 500 1,000
Feet
1 " = 542 FEET

FIGURE B-2
LITHIUM
ISOCONCENTRATION MAP
AMEREN MERAMEC
ENERGY CENTER
ST. LOUIS, MISSOURI

BURNS McDONNELL



LEGEND

- MONITORING WELL
- MOLYBDENUM - CAP PERMEABILITY (10^{-7} cm/sec) - 0 Year
- MOLYBDENUM - CAP PERMEABILITY (10^{-7} cm/sec) - 5 Year
- MOLYBDENUM - CAP PERMEABILITY (10^{-7} cm/sec) - 10 Year
- MOLYBDENUM - CAP PERMEABILITY (10^{-7} cm/sec) - 20 Year
- MOLYBDENUM - CAP PERMEABILITY (10^{-7} cm/sec) - 30 Year
- POTENTIOMETRIC SURFACE
- MODEL GRID BOUNDARY
- MODEL GRID - RIVERS
- MODEL GRID - NO FLOW

NOTES

ug/L - MICROGRAMS PER LITER
MW - MONITORING WELL
GWPS - GROUNDWATER PROTECTION STANDARD
cm/sec - CENTIMETERS PER SECOND

1) GRID DIMENSIONS: 100 ft X 100 ft
2) POTENTIOMETRIC SURFACE CONTOUR INTERVAL: 1 ft
3) POTENTIOMETRIC SURFACE CONTOURS ARE CALCULATED BY THE MODEL.
4) MOLYBDENUM GWPS - 100.0 ug/L
5) CONCENTRATIONS ARE CALCULATED BY THE MODEL.
6) COORDINATE SYSTEM: NAD 1983 STATE PLANE MISSOURI EAST FPIS 2401 - US FEET

DRAFT

N

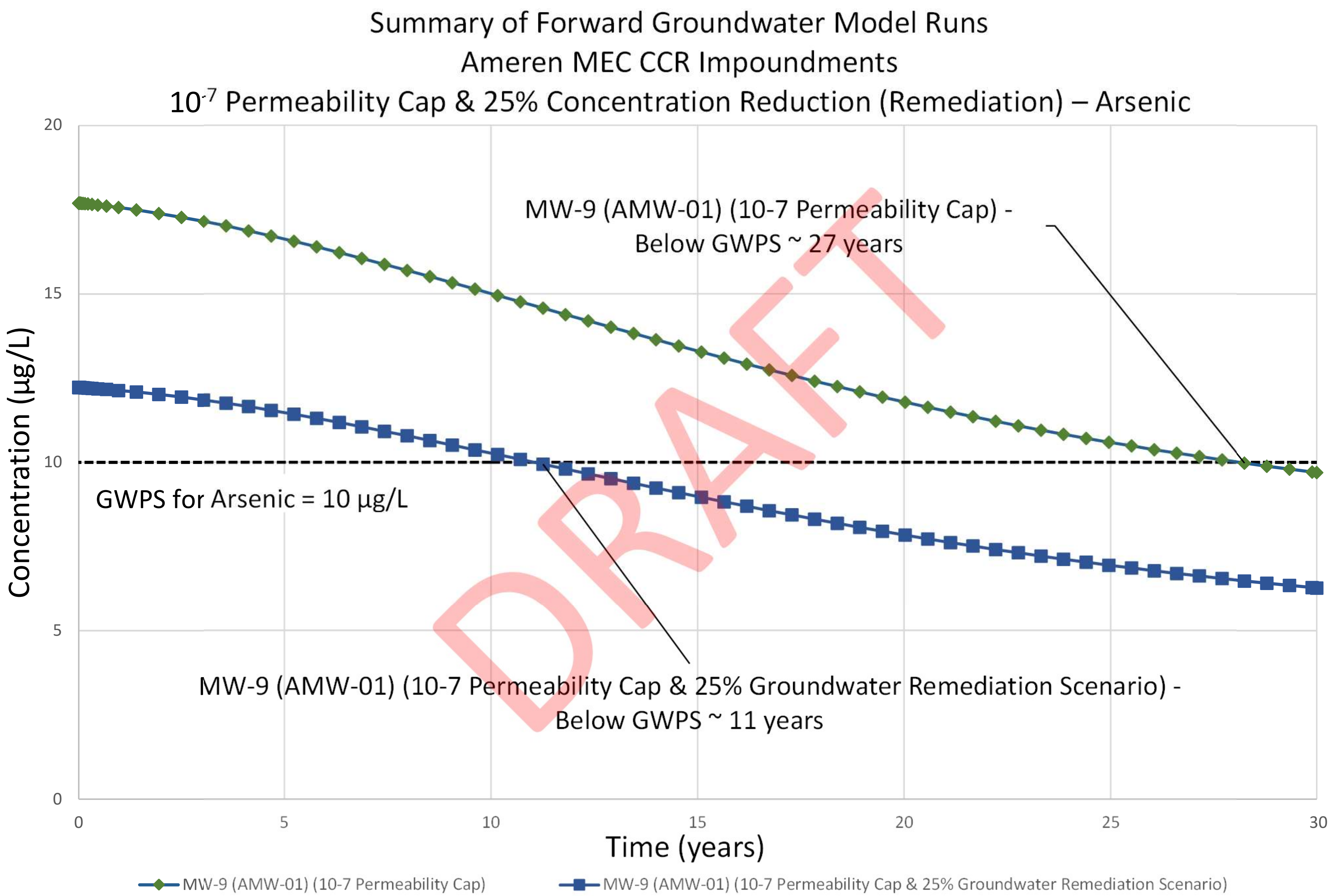
0 250 500 1,000 Feet

1 " = 542 FEET

FIGURE B-3
MOLYBDENUM
ISOCONCENTRATION MAP
AMEREN MERAMEC
ENERGY CENTER
ST. LOUIS, MISSOURI

BURNS & McDONNELL

APPENDIX C – CAPPING AND POTENTIAL REMEDIATION SIMULATION CONCENTRATION GRAPHS



Notes:

µg/L = micrograms per Liter

CCR = Coal Combustion Residual

GWPS = Groundwater Protection Standard

MEC = Meramec Energy Center

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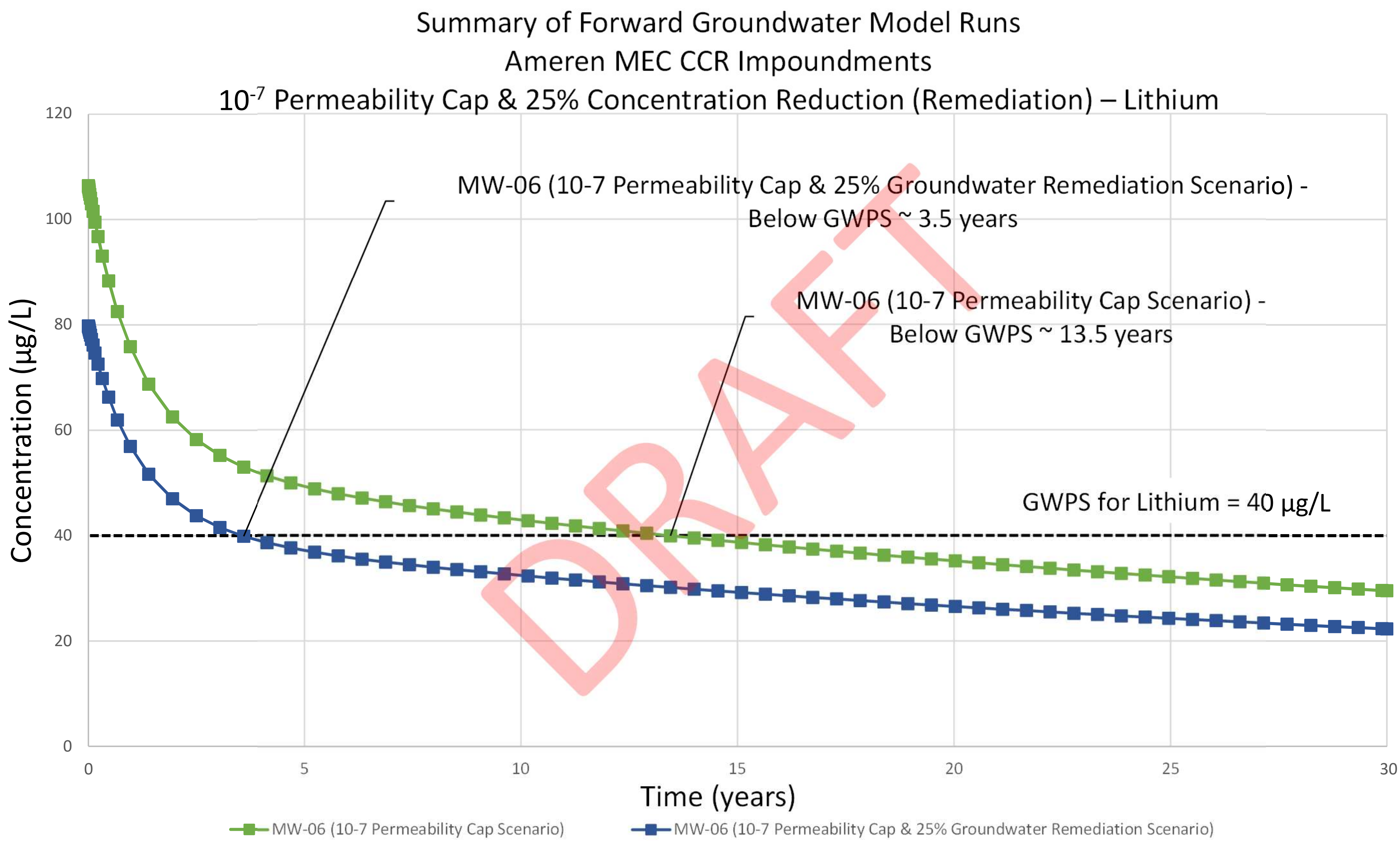
Figure C-1
Arsenic – 10^{-7} Cap &
Groundwater Remediation
Meramec Energy Center
Ameren Missouri



Notes:

µg/L = micrograms per Liter

CCR = Coal Combustion Residuals

GWPS = Groundwater Protection Standard

MEC = Meramec Energy Center

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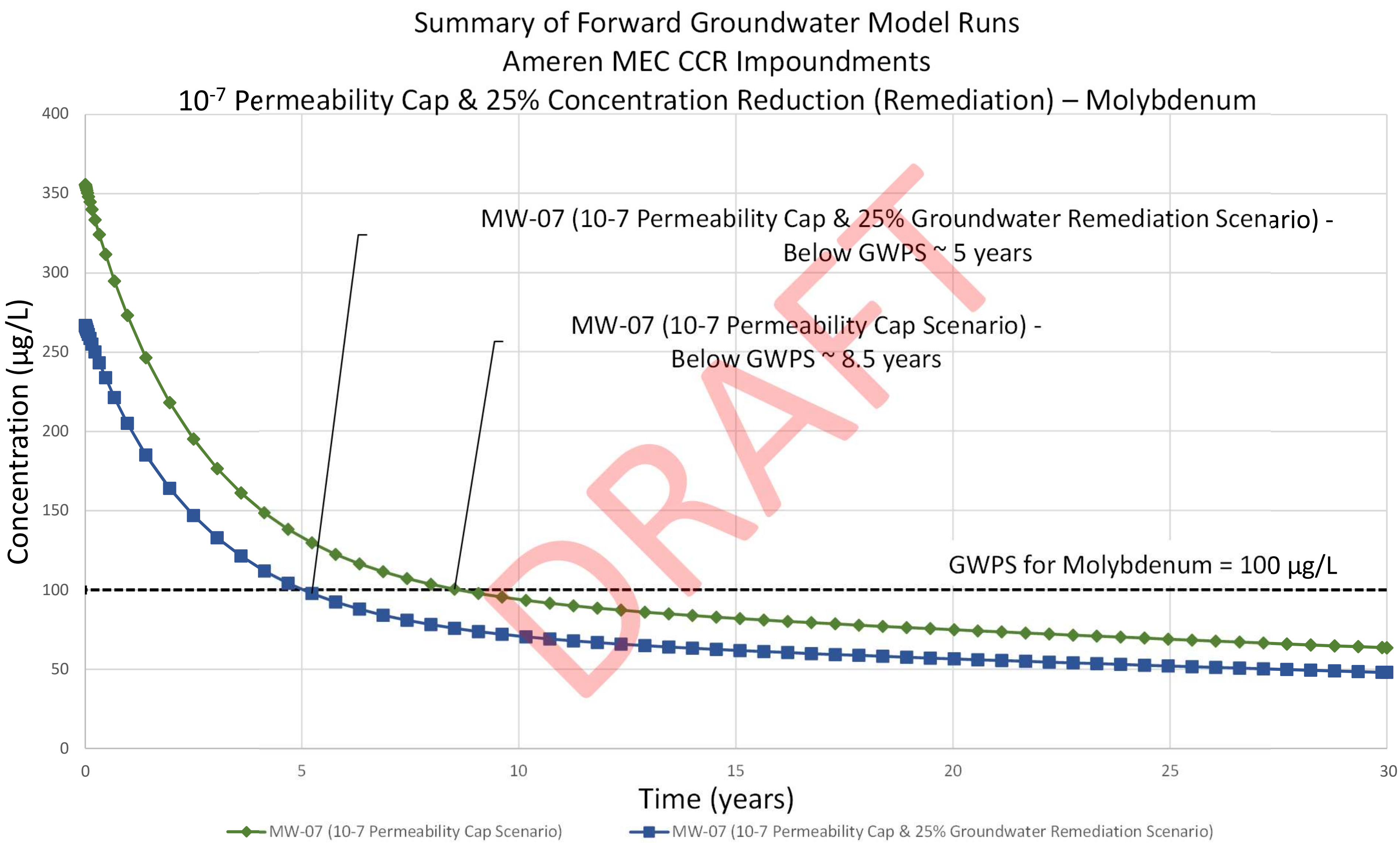
Figure C-2
Lithium – 10^{-7} Cap & Groundwater Remediation
Meramec Energy Center
Ameren Missouri



Notes:

µg/L = micrograms per Liter

CCR = Coal Combustion Residuals

GWPS = Groundwater Protection Standard

MEC = Meramec Energy Center

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Figure C-3
Molybdenum – 10^{-7} Cap & Groundwater Remediation
Meramec Energy Center
Ameren Missouri

AMEREN_00003019

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