TABLE OF CONTENTS

Page

1.0 GROUNDWATER FLOW MODEL OBJECTIVES AND DEVELOPMENT F1-1
- 1.1 Model Software F1-1
- 1.2 Model Components and Structure F1-2
- 1.3 Model Assumptions F1-2
- 1.4 Model Geometry F1-3
- 1.5 Boundary Conditions F1-3
- 1.6 Initial Flow Model Parameters F1-4

2.0 FLOW MODEL CALIBRATION F2-1
- 2.1 Steady-State Calibration F2-1
- 2.2 Steady-State Calibration Results F2-1
- 2.3 Flow Sensitivity Analysis F2-4
  - 2.3.1 Net Recharge F2-4
  - 2.3.2 Horizontal Hydraulic Conductivity F2-5

3.0 PARTICLE TRACKING F3-1
- 3.1 Results of Particle Tracking F3-1

4.0 CONCLUSIONS AND RECOMMENDATIONS F4-1
- 4.1 Conclusions F4-1
- 4.2 Recommendations F4-1

5.0 MODEL USE, LIMITATIONS, AND UNCERTAINTY F5-1
- 5.1 Pumping Rates F5-1
- 5.2 Off-Site Groundwater Pumping F5-1
- 5.3 Future Regional Groundwater Elevation Fluctuations F5-1
- 5.4 Net Recharge Rates F5-1
- 5.5 Hydraulic Conductivity Distribution F5-2

6.0 REFERENCES F6-1

LIST OF TABLES

Page

2-1 Volumetric Water Balance 2-3
2-2 Statistics of Flow Model Sensitivity Runs 2-4

3-1 Particle Tracking Scenarios 3-3

LIST OF FIGURES

(All figures presented at the end of the document)

1-1 Model Domain
1-2 Model Grid
1-3 Model Layer
1-4 Monitoring Well Specifications
1-5 Model Boundary Conditions
1-6 2006 Groundwater Elevation Contours
1-7 Historical Groundwater Elevations (1998 – 2006)
1-8 EarthVision Geologic Model Grid

2-1 Steady State Calibration Results
2-2 Calibrated Horizontal Hydraulic Conductivity Zones
2-3 Simulated versus Observed Groundwater Elevations
2-4 Simulated versus Observed Heads
2-5 Sensitivity Analysis — Recharge
2-6 Sensitivity Analysis — Horizontal Hydraulic Conductivity

3-1 Groundwater Model — Baseline Conditions
3-2 Model Scenario 1 — Near Source Target Zone Groundwater Extraction (20 gpm)
3-3 Model Scenario 2 —Near Source Target Zone Groundwater Extraction (20 gpm) and Injection (25 gpm)
3-4 Model Scenario 3 — Distal Plume Target Zone Groundwater Extraction (20 gpm)
3-5 Model Scenario 4 — Distal Plume Target Zone Groundwater Extraction (25 gpm) and Injection (25 gpm)

1.0 GROUNDWATER FLOW MODEL OBJECTIVES AND DEVELOPMENT

A simplified one-layer, three-dimensional steady-state groundwater flow model was constructed for the Cooper Drum Company Superfund site in South Gate, Los Angeles County, California. This steady-state groundwater model was developed to assist with understanding groundwater flow and evaluation of future remedial alternatives.

This model is not intended for use during detailed remedial design but is a tool for helping to evaluate the general feasibility and relative effectiveness of various remedial alternatives.

Primary groundwater flow model objectives are as follows:

- Build a simplified one layer groundwater flow model that can simulate the recent groundwater flow conditions so that future particle tracking predictions can be conducted.
- Provide sufficient data so that, in the future, a solute transport model can be created that is capable of facilitating future evaluation of the relative effectiveness of various remedial options on upgradient and downgradient concentrations.
- Include sufficient area in the model that is downgradient from the site to facilitate future simulation of contaminant migration toward potential downgradient receptors.
- Provide sufficiently fine grid spacing to allow for future simulation of closely spaced remediation wells at the site.

1.1 Model Software

The groundwater flow model was developed using the Brigham Young University Environmental Modeling Research Laboratory (EMRL) *Groundwater Modeling System* (GMS), Version 6.0 (EMRL, 2006). GMS is a comprehensive graphical user interface (GUI) for performing groundwater simulations. GMS provides a graphical preprocessor/postprocessor interface to several groundwater modeling codes: MODFLOW, MODPATH, MT3DMS, RT3D, FEMWATER, SEEP2D, NUFT, and UTCHEM. The EMRL of Brigham Young University, in partnership with the United States Army Corp of Engineers (USACE) Waterways Experiment Station (WES), developed the GMS interface. The GMS was used to develop a site conceptual hydrogeological model and to convert it into a groundwater flow model. A brief summary of all modeling codes and geological software tools used during this modeling effort are presented below.

EarthVision 7 Geological Model. EarthVision 7 is a three-dimensional (3-D) modeling tool commonly used in oil exploration and, it was used to develop a 3-D geological model. Use of this sophisticated 3-D modeling tool was the most accurate and efficient method for developing the 3-D geologic model and structure of the groundwater model for this site.

MODFLOW Groundwater Flow Model. The computer code selected to model groundwater flow beneath the site was MODFLOW. MODFLOW is a 3-D, cell-centered, finite difference, saturated flow model developed by the United States Geological Survey (USGS) (McDonald and Harbaugh, 1988). GMS provides an interface to the updated version, MODFLOW 2000 (Hill et al., 2000). Based on the information available, the uncertainties in site-specific information, the hydrogeologic complexity of the site, and the modeling objectives, MODFLOW was considered an appropriate groundwater flow code.

MODPATH Particle-Tracking Model. Particle-tracking simulations provide a convenient means of visualizing groundwater flow paths. This is particularly useful for evaluating capture zones around a pumping well and the effects of injection wells. MODPATH was selected as the particle-tracking program for this effort. MODPATH is a 3-D particle-tracking program that enables reverse and forward tracking from sinks (wells) and sources, respectively. MODPATH also was developed by the USGS (Pollock, 1994). GMS has updated the interface for MODPATH to a seamless module that couples with MODFLOW 2000. MODFLOW flow modeling results (direction and rates of groundwater movement) are among the inputs for MODPATH runs.

1.2 Model Components and Structure

The groundwater flow model for Cooper Drum requires the following data:

- Size of model domain;
- Size of model grid (finite-difference discretization);
- Number of model layers;
- Top elevation of model top layer (layer 1);
- Bottom elevation of each model layer;
- Initial heads across model domain (initial condition);
- General heads and conductance at particular model boundaries (boundary condition);
- Horizontal hydraulic conductivity/transmissivity;
- Vertical anisotropy ratio;
- Groundwater recharge rates and distribution;
- Pumping rates for wells;
- Injection rates for wells;
- Definition of time parameters for simulation (steady-state);
- Parameters for output control; and
- Control parameters for the selected solver.

Additional data may be needed if more processes are involved for simulation or if the capacity of the current model must be expanded.

1.3 Model Assumptions

Assumptions are often required for modeling because of the characteristics of governing equations, system complexity, limited availability of measured data, modeling objectives, and constraints of solution methods and computer systems. Because the model was developed for the Cooper Drum groundwater system, several basic assumptions are specific to local conditions. Following are the initial model assumptions.

- Groundwater behaves in accordance with Darcy’s Law;
- Horizontal hydraulic conductivity is isotropic;
- There is no groundwater movement through the base layer of the model; and,

- Groundwater head is vertically uniform within a model layer.

Model assumptions may influence the accuracy and reliability of simulation results. Where possible, fewer simplifying assumptions should be made to provide the appropriate representation of the complex system. The closer the assumptions approximate the groundwater system and field conditions, the more accurately the model will predict the real conditions. However, certain assumptions are deemed necessary to develop a practical model to conduct simulation. The impact of model assumptions may or may not be quantifiable, depending on the characteristics of individual assumptions and the modeling software capability. A reasonable set of assumptions will create a model that is not too complex to be handled by the mathematical techniques, yet is sufficiently detailed to accurately represent the system. The assumptions described are reasonable and practical, based on field conditions and professional judgment. However, as new data become available, some of the initial assumptions could be modified in future upgrades of the model.

1.4 Model Geometry

The model grid extends approximately 2,500 feet in an east to west direction, and approximately 1,650 feet in a north-to-south direction, a total area of 94 acres centering on the Cooper Drum Site, as shown on Figure 1-1. The model is large enough that irregularities along the model edges, caused by a lack of data, do not affect model calculations in the area of interest defined as the Cooper Drum site and 1,300 square feet area surrounding it. The model grid is aligned in a north-south direction, which generally corresponds with the regional groundwater flow direction. The model grid has been refined within the Cooper Drum site to more accurately simulate hydrologic stresses in the area of primary interest. The variable model grid is shown in plan view on Figure 1-2. The variable model grid cell sizes range from 10- by 10-foot cells to 20- by 20-foot cells. The smaller grid spacing was used around areas where the extraction centers and contaminant plumes are located to minimize numerical errors in the flow-and-transport simulations. In addition, the variable grid size allows for finer resolution in areas of steep hydraulic gradients such as near pumping wells. The wider-spaced cells, located far away from the area of Cooper Drum and near the model edges where less computation resolution is needed, require less computer resources during simulations.

In plan view, the domain is spatially discretized into 72 columns in length and 59 rows in width. Vertically, the model extends to a maximum depth of 150 feet below ground surface (bgs), approximately 50 feet mean sea level (msl). An oblique view of the model layer is depicted on Figure 1-3. The model consists of one layer that corresponds to the hydrologic zone currently monitored beneath the site. Figure 1-4 shows monitoring well screen intervals and groundwater elevations for June 2006. The model layer is simulated as an unconfined aquifer. The top of the model layer represents the ground surface, and the bottom approximates the average elevation of the bottom of the Gaspur aquifer in the model domain area. Saturated thickness in the model ranges from approximately 120 feet in the north to 100 feet in the south.

1.5 Boundary Conditions

General Head Boundaries. General head boundaries were specified along the eastern, western northern, and southern perimeters of the model. Figure 1-5 shows the general head boundary conditions for the model. A general head boundary is a leakage boundary, through which a groundwater flux can move either into or out of the model. The general heads on other model perimeters were derived from flow model calibration. The conductance of general head boundary was based on the hydraulic conductivity near the model boundaries and professional judgment. However, the values of the conductance used in general head boundary usually have small effects on simulated groundwater conditions further from the boundaries.

Precipitation. Precipitation affects the net recharge to groundwater. Monthly precipitation data were collected from the Los Angeles Civic Center (LLC) rain gauging station, located in the Los Angeles River Basin of the South Coast Hydrologic Area, near Los Angeles, California. The gauging station is operated by the National Weather Service and the data were obtained electronically from the California Data Exchange Center Website (http://cdec.water.ca.gov/). Precipitation data have been recorded at the station since 1996 (Natural Weather Service, 2005). The average of annual precipitation data were used to assist the estimation of the net recharge within the model domain.

Areal Recharge. Recharge is the influx of water from the ground surface into the aquifer. For the Cooper Drum model domain, the primary mechanism for recharge is assumed to be precipitation. The net recharge rate is set at approximately 10% of the average annual precipitation. Since land use at and around the site is industrial and most areas are covered with buildings and pavement, 10% net recharge is considered to be a reasonable approximation.

Municipal Pumping Conditions. Currently there is no groundwater pumping at the Cooper Drum site. Off-site pumping conditions were not simulated in the Cooper Drum model because they were considered to affect the shallow impacted aquifer beneath the site.

1.6 Initial Flow Model Parameters

Starting Heads. Starting heads were set with water elevation data obtained from the June 2006 groundwater monitoring event. Boundary conditions were set to June 2006 conditions. Starting heads were populated into the model by interpolating available June 2006 groundwater elevations onto the model grid. The 2006 groundwater elevations contours are depicted on Figure 1-6. It should be noted that the starting heads will not affect the final flow solution in steady-state flow simulation as long as it leads to the convergence of a numerical solution. A hydrograph of historic groundwater elevations is provided on Figure 1-7.

Horizontal Hydraulic Conductivity. The spatial distributions of hydraulic conductivity values for the flow model were based on several factors, including site geology, aquifer test results, literature review, and previous groundwater models in the area. The hydraulic conductivity values were categorized into zones (polygons) in the conceptual model based on interpretation of the geologic data into a solid geology model. These hydraulic conductivity values were then mapped onto the numerical groundwater model, and adjusted later in the flow model calibration.

A 3-D geological model was produced to support visualization of the groundwater system at Cooper Drum. This 3-D geological model was developed from lithologic data within the screen intervals of site groundwater wells. Computer modeling of the geology was performed with a 3-D modeling software tool, EarthVision 7, following an interpretation of the lithologic information by a registered professional geologist. EarthVision 7 was used to develop 3-D correlations between the boreholes. The development was accomplished by interpolating numerically coded lithology onto a 3-D grid. The 3-D grid was then filled to produce a solid geologic model and fence diagrams. This method allows for rigorous analysis of the data and the geologic system through any location within the volume. This method saves time because fence diagrams and 3-D models can be viewed on a monitor from several oblique angles prior to printing.

The geologic model was directly imported into GMS. The geology was discretized into separate, independent geological grids. The grids were interpolated to the MODFLOW 2000 grid. The grid was used to enhance the geology in the general Cooper Drum area. The lithologic data was averaged over the total thickness for each MODFLOW 2000 layer. These layer-specific lithologic interpolations were verified by comparing boring logs and cross-sections of the area.

After the lithologic data were interpolated, individual hydraulic conductivity zones were digitized based on the interpolated lithology for each layer. The conductivity zones are refined within and around Cooper Drum because of the extensive amount of lithologic information available from the refined geologic grid. Figure 1-8 shows hydraulic conductivity zones for the entire model domain at the Cooper Drum site.

Values for the hydraulic conductivity zones in this model were derived initially using aquifer test results from previous field investigations (URS Group, Inc. [URS], 2002). These values were compared to literature values (Freeze and Cherry, 1979 and Bear, 1972) to establish initial conductivity ranges for the model. Initial hydraulic conductivity values ranged from 10 to 200 feet/day with the higher conductivity values assigned to the coarser materials. Initial hydraulic conductivities assigned to zones were adjusted during flow model calibration.

Vertical Anisotropy. Vertical leakance is assigned spatially by GMS. Vertical anisotropy ratios were linked to the horizontal hydraulic conductivity zones in the model and were derived from vertical variations between lithologies from the geology model. This approach assumed a relationship between the horizontal and vertical hydraulic conductivities, based on geology.

2.0 FLOW MODEL CALIBRATION

2.1 Steady-State Calibration

The classical iterative calibration process was used: a flow model with specific parameters was run; the simulated groundwater elevations were compared to calibration targets (i.e., groundwater elevations at observation locations); and the model parameters are revised. The process was repeated with revised parameters until the model groundwater elevations adequately simulated the measured groundwater elevation data set. During calibration, the revisions were varied manually, using professional judgment in assigning horizontal hydraulic conductivity and/ or vertical anisotropy values.

Flow calibration criteria, or the acceptable differences between model-predicted (computed) and observed heads (June 2006 groundwater elevations), were selected based on an empirical understanding of the potential errors in measured site groundwater levels. The on-site flow calibration criteria were established at ±1.0 foot at 95% confidence.

Initial estimates for input parameters were selected. The initial general head conductance values are discussed in Section 1.5. Hydraulic conductivity zones where aquifer pumping tests were performed were initially assigned with the calculated hydraulic conductivity values estimated in aquifer pumping test analysis. Hydraulic conductivities for zones in other locations were based on the interpolated geologic model. A reasonable range of values, depending on the lithology, was used based on data obtained from the aquifer pumping tests, literature review, and previous groundwater models for the area.

2.2 Steady-State Calibration Results

A steady-state calibrated groundwater elevation map for the model and calibration targets for the flow model is presented on Figure 2-1. Groundwater elevations for the calibration targets were obtained in June 2006. Calibration is graphically depicted for each target with a colored vertical bar. The center of the target bar corresponds to the observed head. The top of the target corresponds to the observed head plus the calibration target interval (i.e., 1.0 foot). The bottom of the target corresponds to the observed head minus the target interval. The bar color represents the residual (difference between observed and computed heads). If the bar lies entirely within the target interval, the color of the bar is green. If the bar is outside the interval but the residual (difference between observed and computed heads) is less than 200%, the bar is yellow. If the residual is greater than 200%, the bar is red (EMRL, 2006). The residual values for this model were within the calibration target and are shown as green bars (Figure 2-1).

The hydraulic conductivities were adjusted until a satisfactory match between simulated and measured groundwater elevations was achieved. The calibrated horizontal hydraulic conductivity distribution is shown on Figure 2-2. Calibrated horizontal hydraulic conductivity ranged one order of magnitude from 15 to 195 feet/day. These hydraulic conductivities are representative of lithologies that range from silts and sands to gravels. This is also the range used for these lithologies in the model domain.

Determination of when the calibration or the fit between model and reality is acceptable is a subjective judgment. Commonly, the measured and simulated contours are compared. If they are the same relative magnitudes, spacings, and shapes, the model is considered well calibrated. Figure 2-3 shows the simulated (in color) and observed (in black) groundwater elevation map for the model layer.

In addition to the analysis above, several residual error statistics also were calculated to help understand the average error throughout the model domain. Three ways of expressing the average difference between

simulated and measured heads (groundwater elevations) are commonly used (Anderson and Woessner, 1992).

1. The mean error (ME) is the mean difference between measured heads (h_m) and simulated heads (h_s).

$$ME = \frac{1}{n}\sum_{i=1}^{n}(h_m - h_s)_i$$

   where *n* is the number of calibration points. The ME is simple to calculate, but it can be misleading because both negative and positive differences are incorporated in the mean, and they may cancel out the error. Hence, a small ME may not indicate a good calibration, by itself.

2. The mean absolute error (MAE) is the mean of the absolute values of the differences in measured and simulated heads. This value provides a better estimate of the mean error regardless of direction (positive or negative) of the error.

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left|(h_m - h_s)_i\right|$$

3. The root mean squared (RMS) error, or the standard deviation, is the average of the squared differences in the measured and simulated heads. This criterion looks at the average error without considering negative or positive differences. Evaluation of both the ME and MAE helps the modeler understand systematic average error over the model domain, along with the magnitude of that error.

$$RMS = \left[\frac{1}{n}\sum_{i=1}^{n}(h_m - h_s)_i^{\,2}\right]^{0.5}$$

The ME for the model domain was 0.05 foot. The MAE for the model domain was 0.21 foot. The RMS error for the model domain was 0.35 feet. Consequently, the average error across the model domain was about 0.05 feet ±0.35 feet. This is within the calibration target range of ±1.0 foot established prior to initiating calibration. The flow model was therefore considered adequately calibrated to be used to develop a transport model for the site. Figure 2-4 shows the observed heads and simulated heads plotted with the error statistics summary. The RMS error of 0.35 feet is 3.5% of the range of the observed groundwater elevations across the site. This relative flow error (3.5%) is the RMS divided by the range of observed groundwater elevations (10 feet). A 3.5% relative error was well within the predetermined relative flow error criterion of about 10% for the model; therefore, flow calibration is adequate.

Another criterion of model calibration is the correlation between the observed heads and simulated heads referred to as a correlation coefficient (R). R tends to one for perfect predictions (100%), and should be greater than 0.85 (85%).

$$R = \left(\frac{CoVp,o}{\sigma_p \sigma_o}\right)$$

Where:

O	=	i^{th} observed value,
$\bar{o}$	=	mean of observed values,
P_i	=	i^{th} predicted value,
$\bar{p}$	=	mean of predicted values,
n	=	number of pairs of values,
$CoVp,o$	=	$[\Sigma(P-\bar{p})(O-\bar{o})]/[n-1]$,

Where:

$$\sigma_p = \sqrt{\frac{\Sigma(P-\bar{p})^2}{n-1}}$$

$$\sigma_o = \sqrt{\frac{\Sigma(O-\bar{o})^2}{n-1}}$$

For the Cooper Drum model calibration, the correlation coefficient (R) for the observed and simulated heads was calculated as 0.94 or 94 percent. This means that there is a 94% correlation between observed and simulated heads for all of the monitoring well locations used for flow calibration. Monitoring well data (observed heads) and simulated heads used to calculate the correlation coefficient are presented on Figure 2-4.

Volumetric water balance is an important measure of model results. The volumetric water balance can be explained by comparing the total simulated inflows and outflows computed by the model. Inflows are considered groundwater volumes flowing into the model and outflows are flow volumes leaving the model. The difference between total inflow and outflow is divided by either inflow or outflow to yield error in the water balance (Anderson and Woessner, 1992). Ideally, the error in the water balance is less than 0.1% (Konikow and Bredehoeft, 1978). According to Anderson and Woessner (1992), an error of around 1% maybe considered acceptable.

A summary of the calibrated volumetric water balance for this model is shown in Table 2-1. The water balance data indicate that the model has a very low difference between total inflow and outflow (less than 1.73 ft^3/day or 13 gallons/day). The value corresponds to an error yield of 0.0025%, which is significantly below the acceptable water balance error referenced by both Konikow and Bredehoeft (1978) and Anderson and Woessner (1992).

TABLE 2-1

Volumetric Water Balance

	Flow In (ft^3/day)	**Flow Out (ft^3/day)**
Sources/Sinks		
General Heads	65,533.04	-68,452.29
Wells	0	0
Recharge	2,920.97	0
Total Sources/Sink	68,454.01	-68,452.29
Total Flow	68,454.01	-68,452.29
Summary	**In-Out**	**% Difference**
Sources/Sinks	1.73	0.0025
Total	1.73	0.0025

ft^3/day = cubic foot per day

2.3 Flow Sensitivity Analysis

A model response or prediction depends on the governing equations it solves, its mechanisms and structure, and the model parameter values. It is imperative to evaluate how much error is acceptable for a model parameter value and how much uncertainty will be inherent in model predictions, based on the parameters being evaluated. Sensitivity analysis is a means of evaluating model uncertainty by systematically altering the value of one of the model parameters and examining the associated change in the model response.

After flow model calibration, quantitative sensitivity analyses were performed using flow model parameters whose values were uncertain and likely to affect the flow simulation results. The calibrated flow model was used as the baseline simulation, and simulation results of sensitivity runs were compared with that of the baseline simulation at the observation wells.

The flow sensitivity analysis evaluated model uncertainties associated with horizontal hydraulic conductivity and net recharge rate. To quantify the sensitivities of model results to those parameters, ME, MAE, and RMS (or standard deviation) were calculated for observation wells for each sensitivity run.

Sensitivity run results suggested that the flow model is most sensitive to net recharge rates and then horizontal hydraulic conductivity, as shown in Table 2-2. Detailed results of this sensitivity analysis are discussed hereafter.

TABLE 2-2

Statistics of Flow Model Sensitivity Runs

Sensitivity Run	Residual Mean Error	Absolute Mean Error	Standard Deviation	Maximum Change
Net recharge rates reduced by 20%	-0.005	0.005	0.001	0.009
Net recharge rates increased by 20%	0.005	0.005	0.001	0.009
Horizontal hydraulic conductivity reduced by 20%	0.005	0.005	0.003	0.010
Horizontal hydraulic conductivity increased by 20%	-0.003	0.005	0.003	0.007

Notes: Table ordered from most to least sensitive parameters.
All values in feet.

2.3.1 Net Recharge

Changing the net recharge rate affects groundwater flow conditions. Specifically, net recharge introduces downward groundwater flow, increases lateral flow, and can cause water mounding. Consequently, net recharge increases can result in faster lateral and vertical contaminant migration.

Sensitivity analyses were performed with respect to net recharge rates by globally increasing and decreasing the net recharge rates by 20 percent. The sensitivity run results show that with a net recharge increase of 20%, the simulated heads increase by an average value of 0.005 foot at those observation points, with a maximum head increase of 0.009 foot and a standard deviation of 0.001 foot. Similarly, reducing net recharge by 20% resulted in an average decrease of 0.005 foot in heads at those observation points. The maximum head change was 0.009 foot, and the standard deviation of those changes was

0.002 foot. The head changes associated with the net recharge rates increase or decrease by 20%, as shown on Figure 2-5.

2.3.2 Horizontal Hydraulic Conductivity

Hydraulic conductivity is one of the most important parameters of a groundwater flow model. In the horizontal plane, hydraulic conductivity determines the groundwater flow rate in the aquifer and consequently, the rate of contaminant migration. It also determines the rate at which water can be pumped from the aquifer without causing undesirable effects, such as excessive drawdown, and consequently the rate at which dissolved contaminants may be removed from the aquifer.

Sensitivity analyses were performed on horizontal hydraulic conductivities by globally increasing and decreasing horizontal hydraulic conductivities by 20 percent. Sensitivity run results show that when horizontal hydraulic conductivities were increased by 20%, the simulated heads decreased by an average value of 0.003 foot at those observation points, with a maximum head decrease of 0.007 foot and a standard deviation of 0.0013 foot. On the other hand, reducing horizontal hydraulic conductivity by 20% resulted in an average increase of 0.005 foot in heads at those observation points. The maximum increased head was 0.01 foot, and the standard deviation was 0.003 foot. The head changes associated with changes in horizontal hydraulic conductivity are shown on Figure 2-6.

3.0 PARTICLE TRACKING

After the steady-state flow model calibration was successfully completed, particle tracking was performed.

Particles generated using MODPATH may be calculated to travel either forward (downgradient) through the model simulation or backward (upgradient from a specific point, such as an extraction well). Forward-traveling particles provide information about the predicted route of groundwater over the model run. The particle starting locations are selected to predict groundwater migration from specific locations through time. Forward-traveling particles that are captured in an extraction well might not, however, predict the full capture zone for that well. They only predict the travel route for the particles particular starting location. Backward-traveling particles predict where groundwater has traveled to reach a specific location. Particles traveling backward from an extraction well would predict the extent of that well's capture zone. Use of forward- and backward-traveling particles, therefore, depends on the particular questions that are being asked in the modeling effort.

For this model, particles were set to begin upgradient of the site and were expected to travel through the area of groundwater that impacted by the site contaminants of concern (COCs) (trichloroethene [TCE]; cis-1,2-dichloroethene [cis-1,2-DCE]; and 1,4-dioxane [1,4D]). Figure 3-1 includes the 100 microgram per liter (µg/L) composite contour lines for the COCs. TCE in groundwater at concentrations in excess of 10 µg/L is reported to be as far south as McCallum Avenue, based on HydroPunch data collected in March 2007. (URS, 2007)

3.1 Results of Particle Tracking

Predictive Scenarios were conducted to evaluate groundwater capture within the Cooper Drum model (Table 3-1). Figure 3-1 illustrates the current predicted flow regime or initial conditions without the influence of extraction and injection wells. Figures 3-2 through 3-5 show the results of four predictive scenarios for the model using hypothetical extraction and injection wells to influence the particle flow paths. Starting locations for the forward-traveling particles were set along the target area perimeters. Backward-traveling particles are not used for this analysis, because the forward-traveling particles (and their starting locations) are most relevant for evaluating target area capture.

Figures 3-2 and 3-3 show forward-particle tracking with starting locations along the perimeter of the target area footprints, using one near-source extraction well and two near-source injection wells. Figures 3-4 through 3-5 show forward particle tracking with the same starting locations but using two downgradient (distal end of plume) extraction wells and one near source injection well. Particles on the figures are shown as red dots initially (year 0) and then as arrows (year 0 + n years), lines and arrows indicate particle flow paths, and the distance between arrows represents a period of one year.

Figures 3-2 illustrates that predictive capture would occur within the near source target zone (i.e., the COC 100 µg/L composite contour line) using one extraction well with a pumping rate of 20 gallons per minute (gpm). Predicted travel times for particles beginning at the north end of the target zone to the extraction well ranges from approximately two to three years. Particle flow paths to the southwest and northeast, beginning outside of the target zone, remain outside of the area of predicted capture. Figure 3-3 illustrates a reduction of predicted particle travel times to approximately one year with the addition of two injection wells placed north of the near source target zone. The injection well pumping rates are each 25 gpm and the pumping rate at the extraction well is maintained at 20 gpm in this second scenario.

Figure 3-4 illustrates that predictive capture would occur in the distal plume target zone (i.e., the area bounded by the southern extent of the COC 100 µg/L contour on the north and the southern extent of the TCE 10 µg/L contour line on the south) using two extraction wells—each with 20 gpm pumping rates. Particle travel times are approximately 3.5 to 4 years. Figure 3-5 illustrates a reduction of predicted particle travel times to approximately 1 to 2 years with the addition of one injection well placed south of the near source target zone. The injection well and extraction well pumping rates are 25 gpm.

TABLE 3-1

Particle Tracking Scenarios

Scenario	Number of Extraction Wells	Number of Injection Well	Pumping Well Screen Elevation (msl)	Injection Well Screen Elevation (msl)	Extraction Well Pumping Rate (gpm)	Extraction Well Pumping Rate (ft^3/day)	Injection Well Pumping Rate[a] (gpm)	Injection Well Pumping Rate (ft^3/day)
Baseline (Figure 3-1)								
	NA	NA	NA	NA	NA	NA	NA	NA
Near Source (Figures 3-2 and 3-3)								
1	1	NA	50 to 15	50 to 15	20	3,850	NA	NA
2	1	2	50 to 15	50 to 15	25	4,812.5	25	4,812.5
Distal (Figure 3-3)								
3	2	0	30 to -10	NA	20	3,850	NA	NA
Near Source and Distal (Figure 3-4)								
4	2	1	30 to -10	50 to 15	25	4,812.5	25	4,812.5

[a] Rate includes additional 5gpm from SVE System.

ft^3 = cubic feet
gpm = gallons per minute
msl = mean sea level
NA = not applicable
SVE = soil vapor extraction

4.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the model calibration, verification, and sensitivity analyses, this flow model is ready to use as a tool to help manage groundwater cleanup at the Cooper Drum site.

4.1 Conclusions

The model for Cooper Drum site can be used to evaluate a wide variety of pumping scenarios to help predict optimal extraction rates for the future groundwater remediation system. It is worth mentioning that a numerical model is a convenient and cost-efficient tool to mimic site conditions and to provide some otherwise difficult-to-attain insight into the groundwater and plume responses under various natural and man-made conditions. However, any information obtained from modeling contains a certain level of uncertainty, especially for long-term predictions. Section 5.0 discusses uncertainty in greater detail.

The following conclusions may be drawn from the modeling effort.

- The flow component of the groundwater model is adequately calibrated with a 3.5% average relative error between measured and simulated heads across the model domain. Figure 2-3 shows the average head error of the flow component. This figure shows that flow calibration is within the criterion of 10% after adjusting hydraulic conductivity distribution and other parameters in flow model calibration (e.g., recharge, vertical leakance, pumping module, model boundary conditions, and initial flow conditions). Average head errors across the model domain are within ± 1.0 foot of measured groundwater elevations.

Predictions are dependent on model assumptions, including future extraction and injection well pumping, and these predictions could change with changing input assumptions.

4.2 Recommendations

This groundwater flow model should be used to help predict groundwater capture zones and aid the remedial design process. In the future, the model also should be used to help optimize groundwater extraction and injection systems as part of ongoing planning and operation.

Using data from the ongoing Well Monitoring Program, the flow model should be updated annually. This updating frequency should be cost-effective and adequate for testing and improving the model periodically with new site-specific information. Groundwater elevations, contaminant concentrations, extraction well and water supply well pump rates, and precipitation rates should be annually collected and compared with the respective model simulation results so that the fate-and-transport model can be verified. If the differences between the measured groundwater data and the model's predicted results are significant, adjustment and refinement of the model input parameters may be necessary.

The calibrated flow model adheres closely to site-specific data, so that model input parameters are reasonable and appropriate for this site. When model parameters were adjusted during calibration and verification, the modified values were compared to site-specific data, or to literature-reported values when site-specific data were not available. If additional model revisions are deemed necessary, the following items should be considered.

- If groundwater conditions are likely to change in the future (e.g., time-variable pumping, additional remedial measures affecting the groundwater conditions, regional groundwater

rising/declining) the difference between real groundwater condition and the calibrated steady-state flow condition may not be insignificant.

- Consider augmenting the current steady-state model to include a fate and transport model component.
- Further examine and refine recharge rates. This could be part of an annual model update to use more recent values as land uses change and precipitation varies over time.

5.0 MODEL USE, LIMITATIONS, AND UNCERTAINTY

This one-layer steady-state groundwater flow model can be a powerful tool, if used appropriately, to assist in making management decisions for selecting remedial alternatives at the Cooper Drum site. This model can be used to interpret capture zones and to help design future extraction systems at the site. Use of this model is subject to some limitations; like any computer model, it has inherent uncertainty. This does not, however, preclude its use to help make cleanup decisions at Cooper Drum. To the contrary, this model should be used as a tool to assess current conditions and to help implement response actions.

Groundwater models are simplifications of the natural environment and, therefore, have recognized limitations. Hence, some uncertainty exists in the ability of this model to predict groundwater flow. Considerable effort was expended to minimize model uncertainty by using real-world values as model input whenever available and by conducting numerous model runs to calibrate and verify the model. Uncertainty of the model output reflects uncertainties in the conceptual model, the input parameters, and the ability of the mathematical model to simulate real-world conditions adequately.

The model uses steady-state flow conditions. Because flow conditions change over time, the average conditions that the calibrated steady-state model simulates might not always match real conditions closely. The resulting uncertainty is therefore variable, depending on the degree to which actual conditions differ from the calibrated steady-state model.

The use of this model and evaluation of its results should take into account the following potential sources of uncertainty.

5.1 Pumping Rates

Extraction and injection well pumping rates were estimated from previous aquifer pumping tests conducted at the site and were used for the steady-state calibration period. It was assumed that these pumping rates would be representative of future conditions. These estimates will affect predictive model runs. Actual pumping rates should be considered when and if the extraction system is installed at Cooper Drum.

5.2 Off-Site Groundwater Pumping

Off-site groundwater water supply/extraction wells are not included in this model. Pumping from these off-site wells could significantly affect on-site flow regimes and current model input assumptions.

5.3 Future Regional Groundwater Elevation Fluctuations

Long-term groundwater elevations across the site have not been stable; seasonal variations are small but longer term fluctuations of up to 7 feet over an eight-year period have been recorded. Future trends in groundwater elevations (rises or declines) will depend on climate and water supply pumping trends. Use of the model should take these uncertainties into account for the future predictive runs. Also, predictive scenarios should be revised as additional information becomes available.

5.4 Net Recharge Rates

The net recharge rates (or infiltration rates) affect groundwater flow conditions by introducing vertical hydraulic gradients and, thus, affect contaminant transport. Though net recharge cannot be measured, it was estimated after examining related site-specific precipitation data and should be considered an estimated value.

5.5 Hydraulic Conductivity Distribution

The model has been calibrated to within approximately 0.5% of the total groundwater elevation fluctuation across the model domain. The calibrated hydraulic conductivity distribution corresponds to the results of historical aquifer testing across the Site and the interpreted geology. There are areas between these historical tests where hydraulic conductivities have been interpolated. The results from any future aquifer testing (e.g., when new extraction wells are installed and pumping tests are conducted) should be used to refine the hydraulic conductivity distribution in the model and reduce model uncertainty.

6.0 REFERENCES

Anderson, M., and W. Woessner, 1992. *Applied Groundwater Modeling: Simulation of Flow and Advective Transport*. Academic Press, San Diego, California.

Bear, J., 1972. *Dynamics of Fluids in Porous Media*. Dover Publications, New York, New York.

EMRL, 2006. *Groundwater Modeling System*, Version 6.0. Brigham Young University.

Freeze, R., and J. Cherry, 1979. *Groundwater*. Prentice Hall. Upper Saddle River, New Jersey.

Hill, M., E. Banta, A. Harbaugh, and E. Anderman, 2000. *MODFLOW-2000, The U.S. Geological Survey Modular Ground-Water Model; User Guide to the Observation, Sensitivity, and Parameter-Estimation Processes and Three Post-Processing Programs*. Open-File Report 00-184. U.S. Geological Survey. Denver, Colorado.

Konikow, L., and J. Bredehoeft, 1978. Computer Model of 2-D Solute Transport and Dispersion in Groundwater. Techniques of Water-Resources Investigations. B00 7, Ch. C2, United States Geological Survey, 90p.

McDonald, M., and A. Harbaugh, 1988. *A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model*. Book 6, Chapter A1. Techniques of Water-Resources Investigations of the United States Geological Survey. U.S. Geological Survey, Reston, Virginia.

National Weather Service, 2005. Los Angeles, California Annual Rainfall Data. Downloaded from the Internet for Tracy, California, http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?castoc+nca

Pollock, D., 1994. *Users Guide for MODPATH/MODPATH-Plot, Version 3: A Particle Tracking Post-Processing Package for MODFLOW, the U.S. Geological Survey Finite-Difference Ground-Water Flow Model*. U.S. Geological Survey, Reston, Virginia.

URS Group, Inc. (URS), 2002. *Cooper Drum Company Remedial Investigation/Feasibility Study Report*. May.

URS, 2007. *Technical Memorandum: Operable Unit 1 Groundwater Remedy Conceptual Design, Cooper Drum Company Site, South Gate, California.* Draft. May 23.

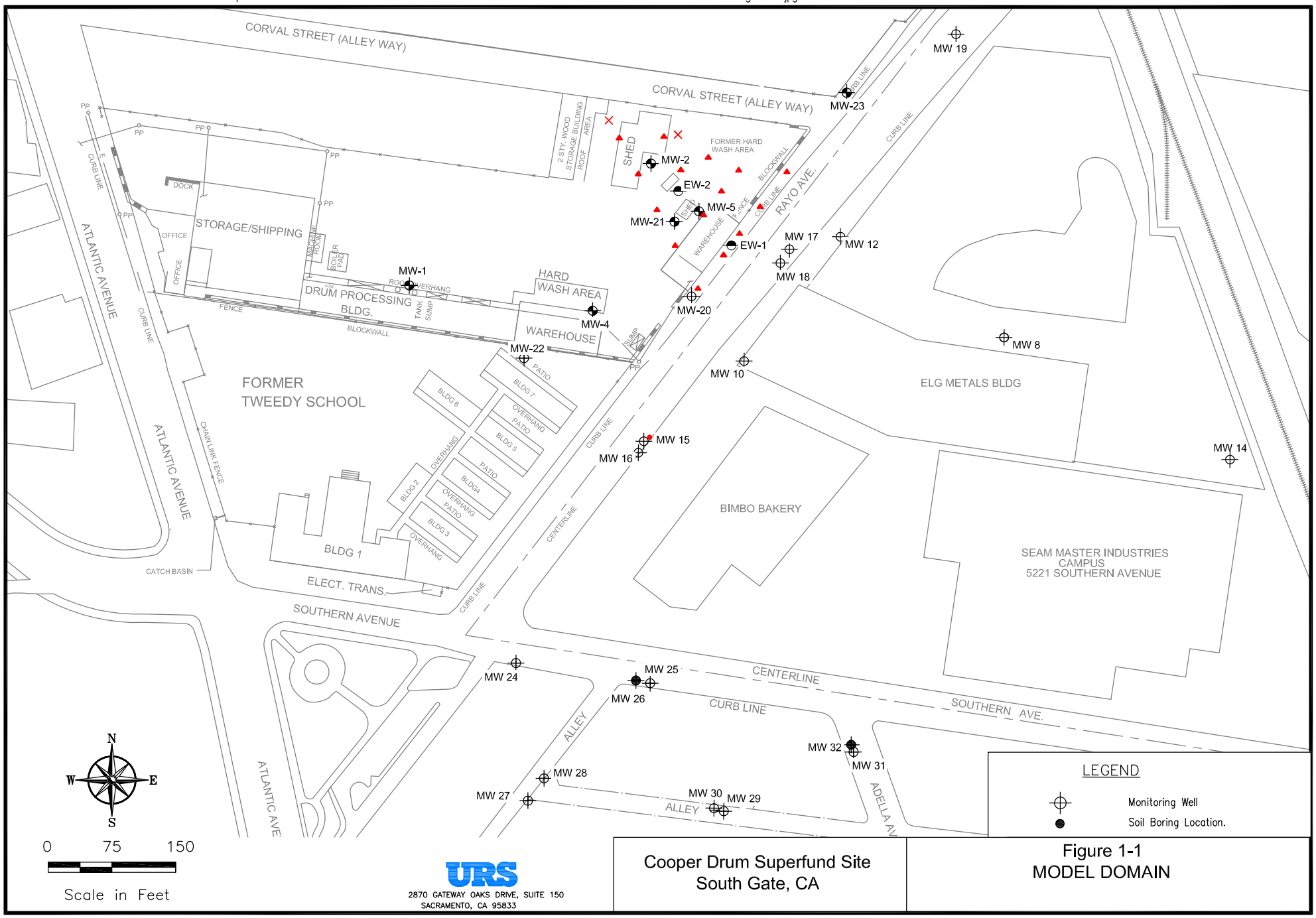
DRAWING: Don-071307-FIG-1-1-MODEL DOMAIN.dwg

DRAWING: T:\current-work files\COOPER-DRUM\Cooper-Drum 20070713\

XREFS: T:\current-work files\COOPER-DRUM\20070404\NEW-BACKGRD2.dwg

IMAGES: Figure 1-2.jpg

PLOT BY: RTAYLOR - Jul 16, 2007 - 1:16:39pm



URS

2870 GATEWAY OAKS DRIVE, SUITE 150
SACRAMENTO, CA 95833

Cooper Drum Superfund Site
South Gate, CA

Figure 1-1
MODEL DOMAIN

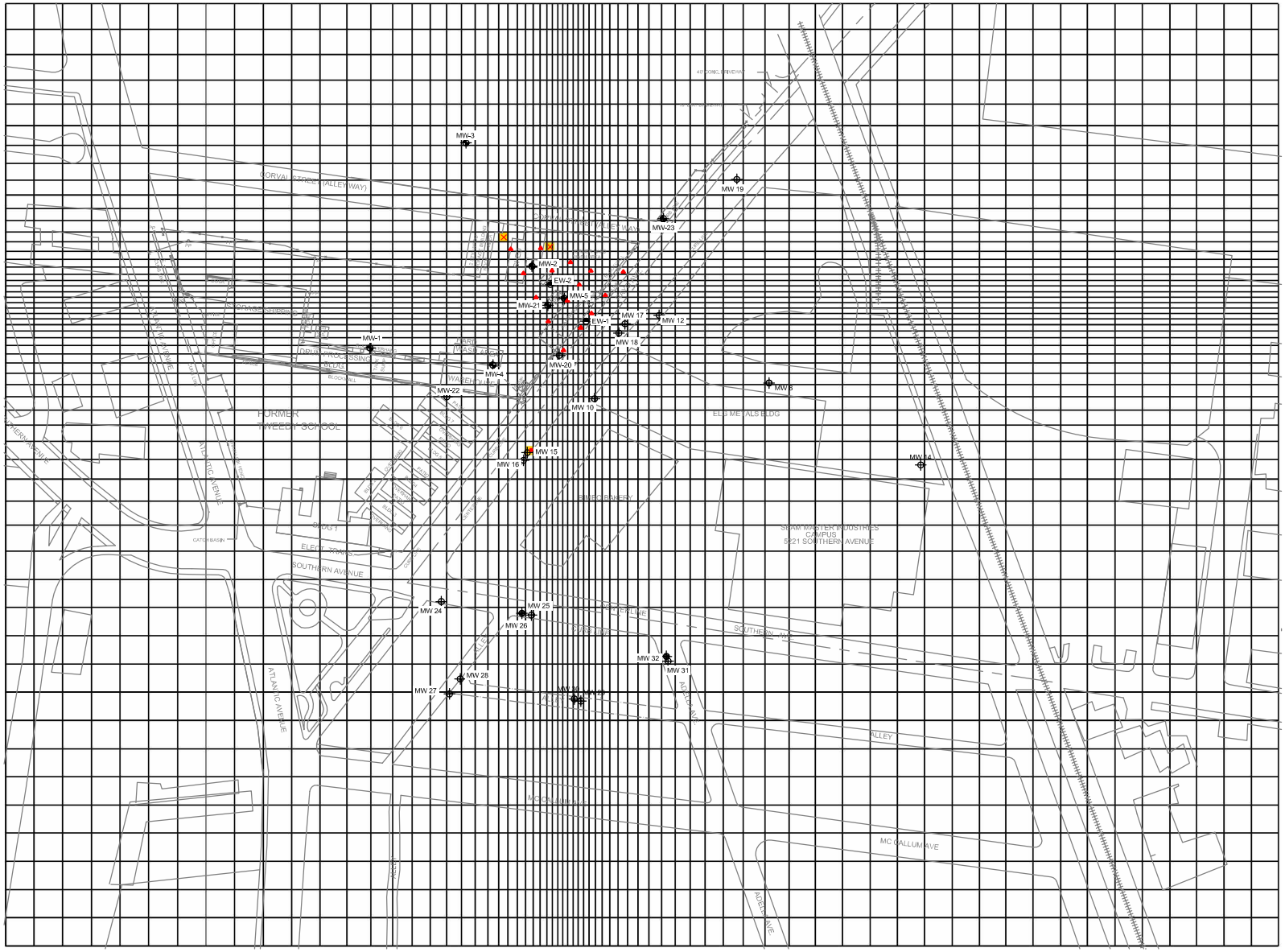
DRAWING: Don-071307-FIG-1-2-MODEL GRID.DWG

XREFS: T:\current-work files\COOPER-DRUM\20070404\NEW-BACKGRD2.dwg

PLOT BY: RTAYLOR - Jul 16, 2007 - 1:18:09pm

DRAWING: T:\current-work files\COOPER-DRUM\Cooper-Drum 20070713\

IMAGES: Figure 1-2.jpg Figure 1-5.jpg Figure 1-5 (GHB).jpg



NOTE: NOT TO SCALE

URS
2870 GATEWAY OAKS DRIVE, SUITE 150
SACRAMENTO, CA 95833

Cooper Drum Superfund Site
South Gate, CA

Figure 1-2
MODEL GRID

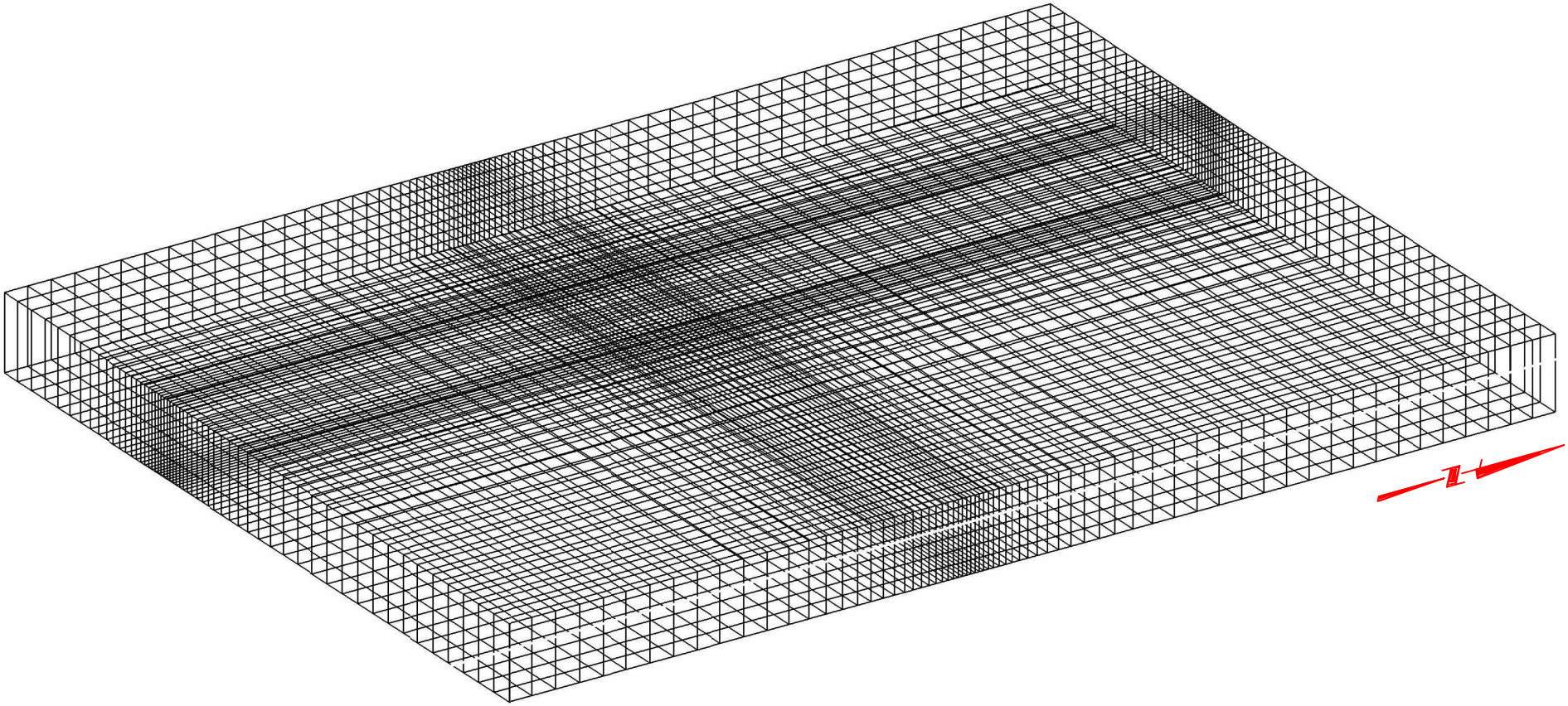
DRAWING: Don-071307-FIG-1-3-MODEL LAYER.dwg

DRAWING: T:\current-work files\COOPER-DRUM\Cooper-Drum 20070713\

XREFS: T:\current-work files\COOPER-DRUM\20070404\NEW-BACKGRD2.dwg

IMAGES: Figure 1-3.jpg

PLOT BY: RTAYLOR - Jul 16, 2007 - 1:19:19pm



VARIABLE GRID SPACING = 10 TO 20 FEET
LAYER THICKINESS = 150 FEET
NOTE : NOT TO SCALE

URS
2870 GATEWAY OAKS DRIVE, SUITE 150
SACRAMENTO, CA 95833

Cooper Drum Superfund Site
South Gate, CA

Figure 1-3
MODEL LAYER

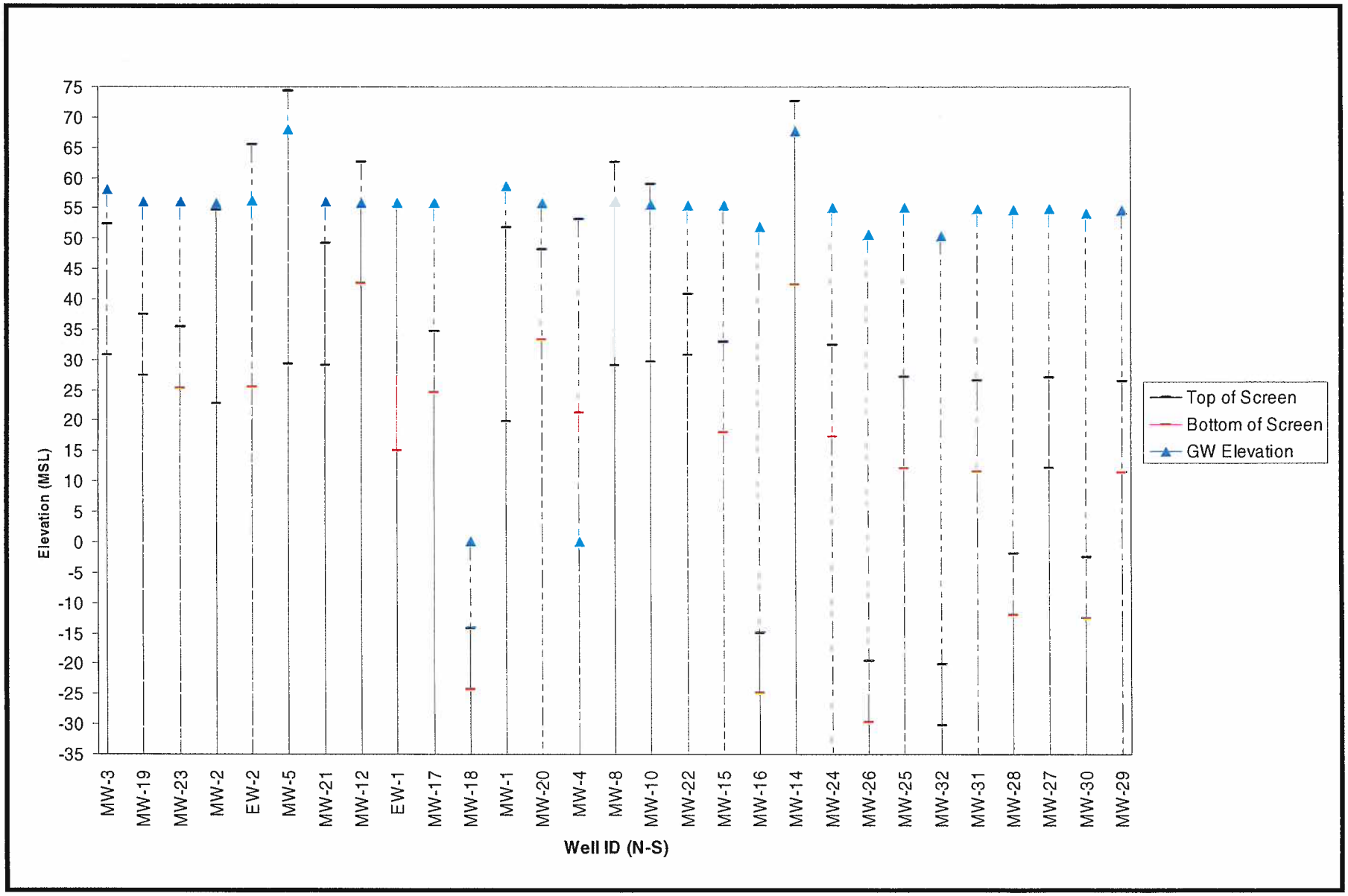


Figure 1-4. Monitoring Well Specifications

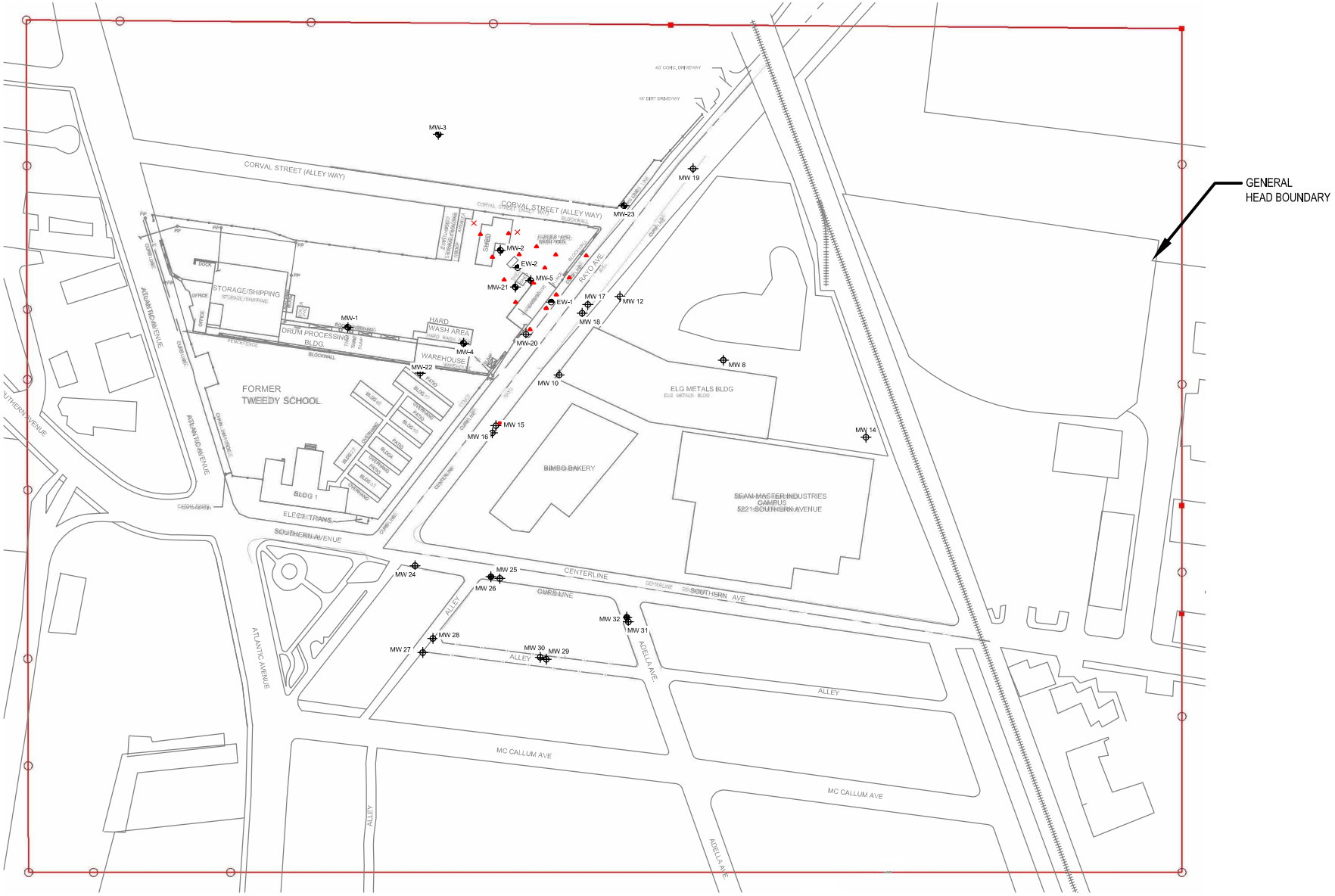
DRAWING: Don-071307-FIG-1-5-MODEL GEN-HED-BNDY.dwg

XREFS: T:\current-work files\COOPER-DRUM\20070404\NEW-BACKGRD2.dwg

PLOT BY: RTAYLOR - Jul 16, 2007 - 1:20:21pm

DRAWING: T:\current-work files\COOPER-DRUM\Cooper-Drum 20070713\

IMAGES: Figure 1-5.jpg Figure 1-5 (GHB).jpg



NOTE: NOT TO SCALE

URS
2870 GATEWAY OAKS DRIVE, SUITE 150
SACRAMENTO, CA 95833

Cooper Drum Superfund Site
South Gate, CA

Figure 1-5
MODEL
GENERAL HEAD BOUNDARY

DRAWING: Don-071307-FIG-1-6-2006-GW-ELEV.dwg XREFS: T:\current-work files\COOPER-DRUM\20070404\NEW-BACKGRD2.dwg PLOT BY: RTAYLOR - Jul 16, 2007 - 1:21:09pm

DRAWING: T:\current-work files\COOPER-DRUM\Cooper-Drum 20070713\ IMAGES: Figure 1-5.jpg Figure 1-5 (GHB).jpg

NOTE:
GROUNDWATER ELEVATIONS ARE SHOWN AS FEET MEAN SEA LEVEL (msl)

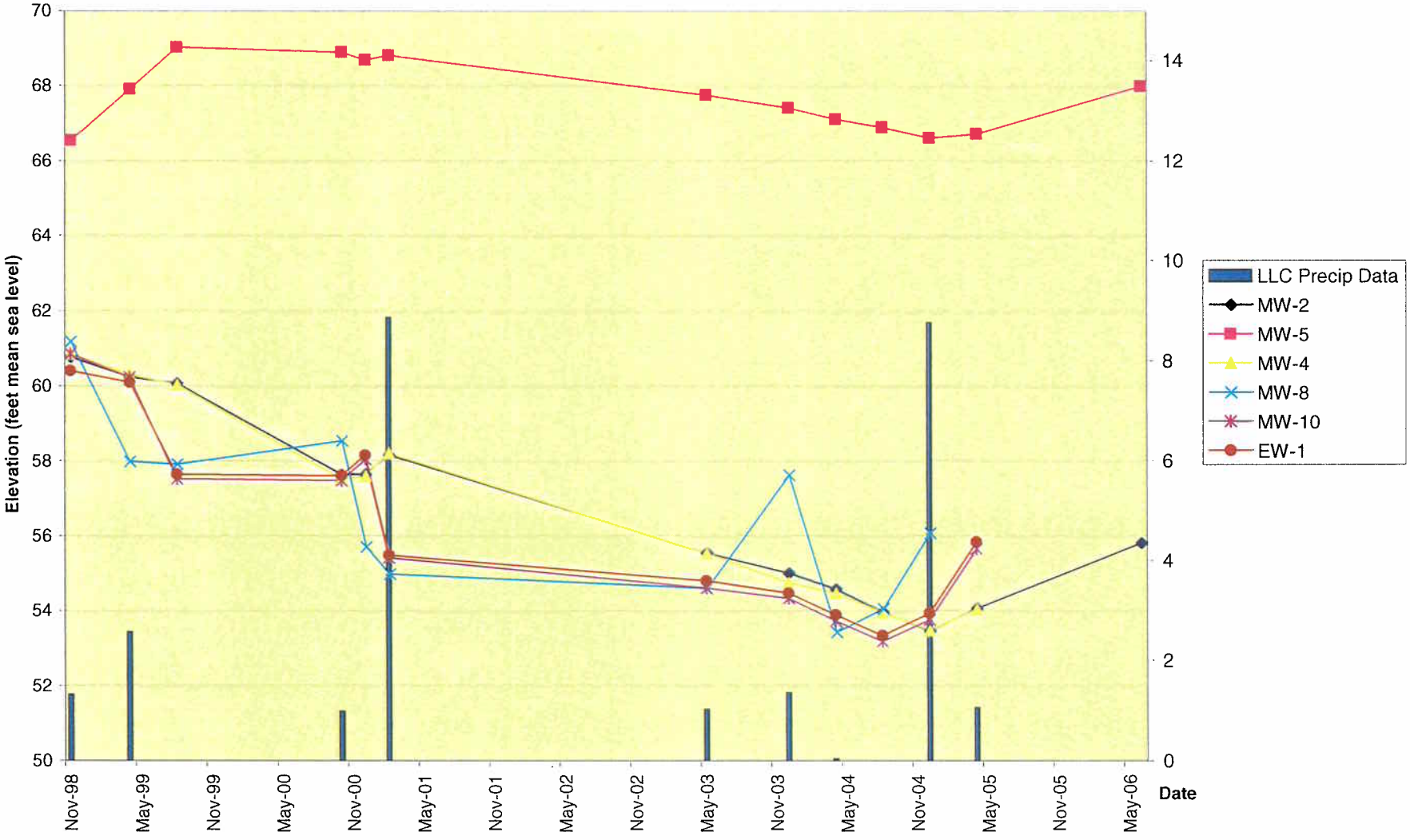
NOTE: NOT TO SCALE

URS
2870 GATEWAY OAKS DRIVE, SUITE 150
SACRAMENTO, CA 95833

Cooper Drum Superfund Site
South Gate, CA

Figure 1-6
2006
GROUNDWATER ELEVATION CONTOURS

1-7 - Historic Groundwater Elevations



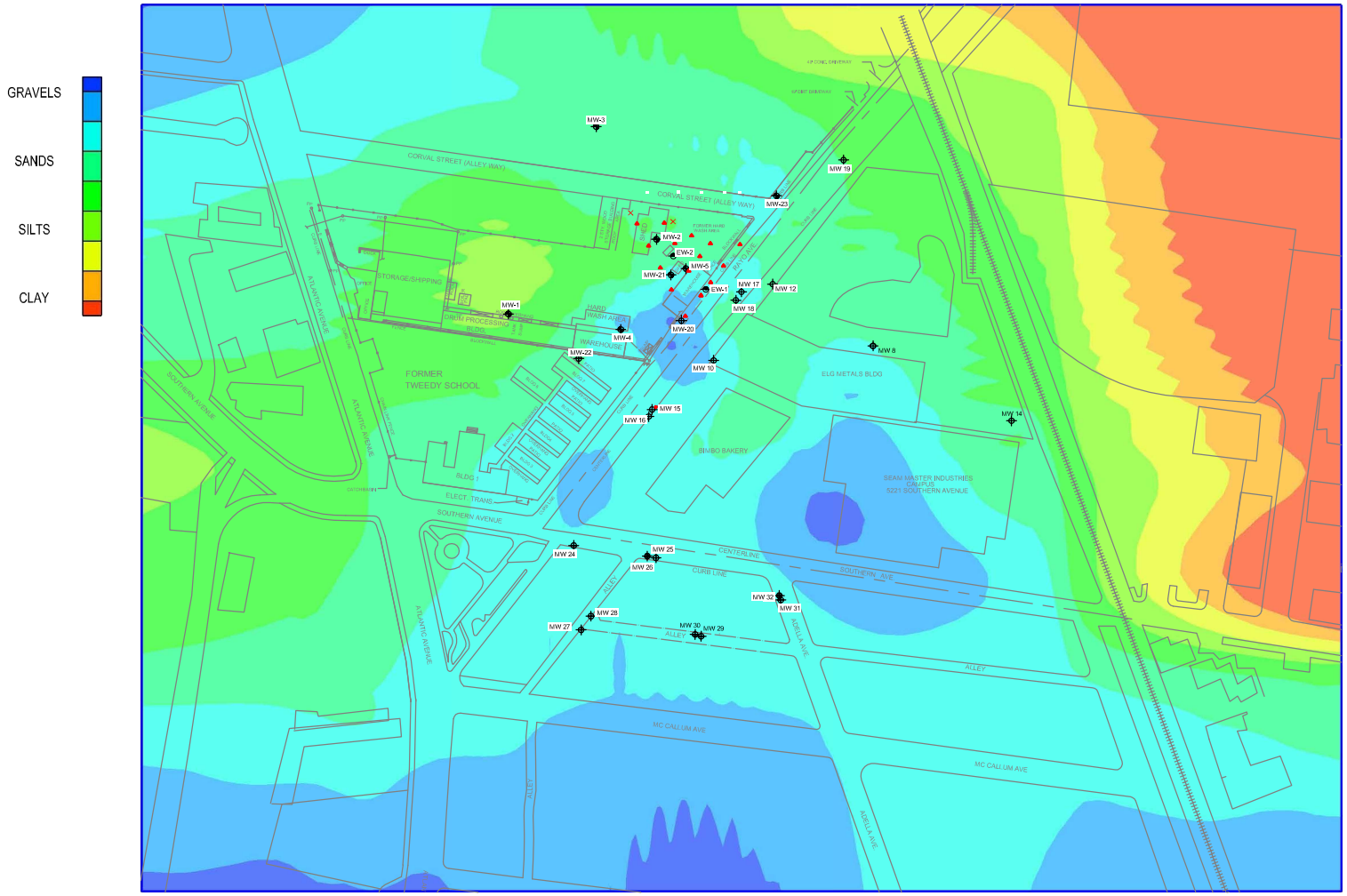
DRAWING: Don-071307-FIG-1-8-EARTH-VISION.dwg

XREFS: T:\current-work files\COOPER-DRUM\20070404\NEW-BACKGRD2.dwg

PLOT BY: RTAYLOR - Jul 16, 2007 - 1:21:57pm

DRAWING: T:\current-work files\COOPER-DRUM\Cooper-Drum 20070713\

IMAGES: Figure 1-7.JPG Figure 1-7 color legend.JPG



NOTE:
MODEL GRID BASED ON SCREEN INTERVAL LITHOLOGY

NOTE: NOT TO SCALE

URS
2870 GATEWAY OAKS DRIVE, SUITE 150
SACRAMENTO, CA 95833

Cooper Drum Superfund Site
South Gate, CA

Figure 1-8
EARTH VISION GEOLOGIC MODEL GRID

DRAWING: Don-071307-FIG-2-1-SSCR.dwg

DRAWING: T:\current-work files\COOPER-DRUM\Cooper-Drum 20070713\

XREFS: T:\current-work files\COOPER-DRUM\20070404\NEW-BACKGRD2.dwg

IMAGES: Figure 2-2.jpg

PLOT BY: RTAYLOR - Jul 16, 2007 - 1:22:57pm

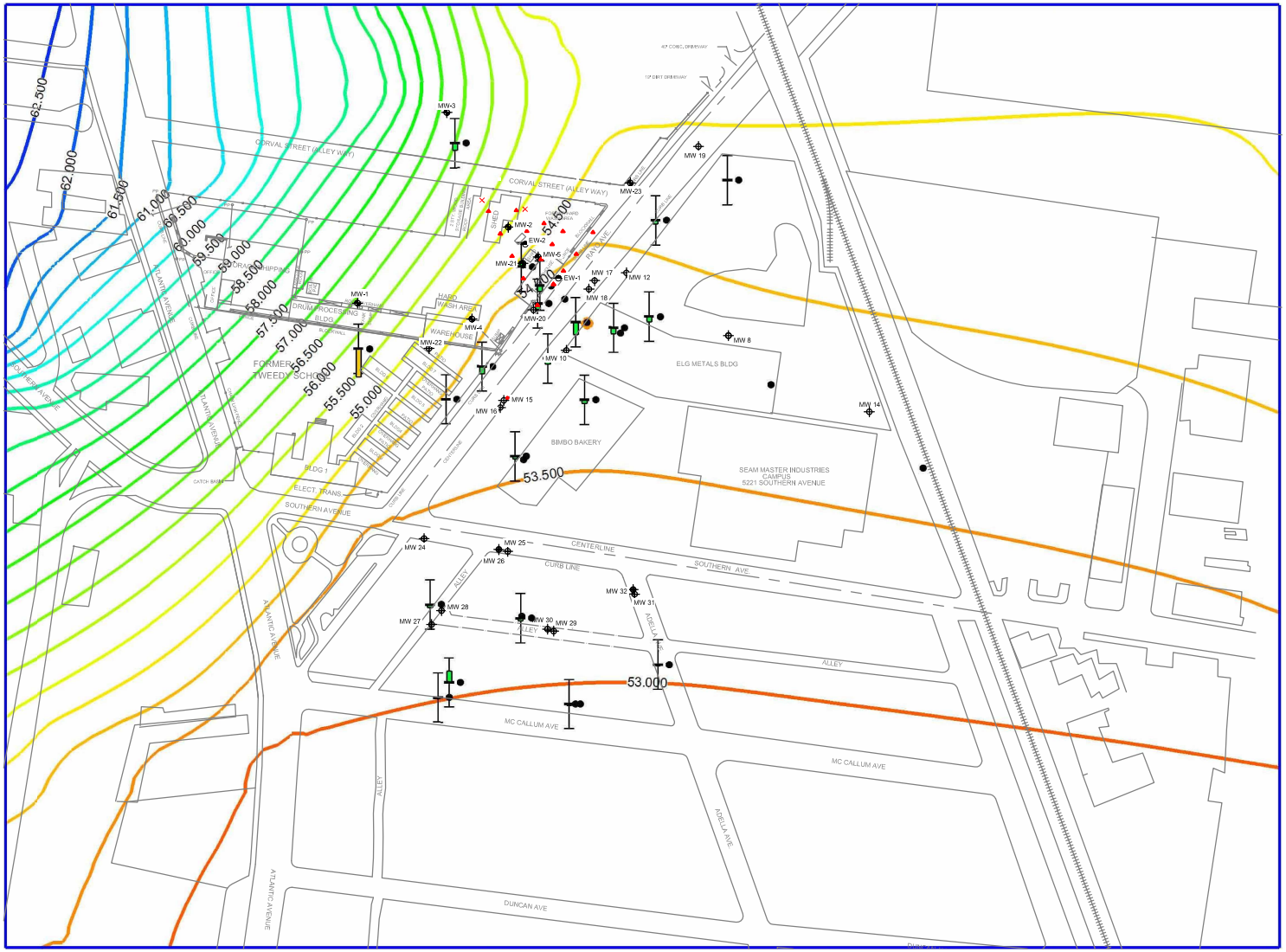
CALIBRATION TARGET

OH - CH — OH + CT / OH / OH - CT

NOTES:
CH = COMPUTED HEAD
CT = CALIBRATION TARGET (± 1 FOOT)
OH = OBSERVED HEAD

COLORED CONTOURS REPRESENT SIMULATED GROUNDWATER ELEVATION (FEET MEAN SEA LEVEL)

NOT TO SCALE



URS
2870 GATEWAY OAKS DRIVE, SUITE 150
SACRAMENTO, CA 95833

Cooper Drum Superfund Site
South Gate, CA

Figure 2-1
STEADY-STATE CALIBRATION RESULTS

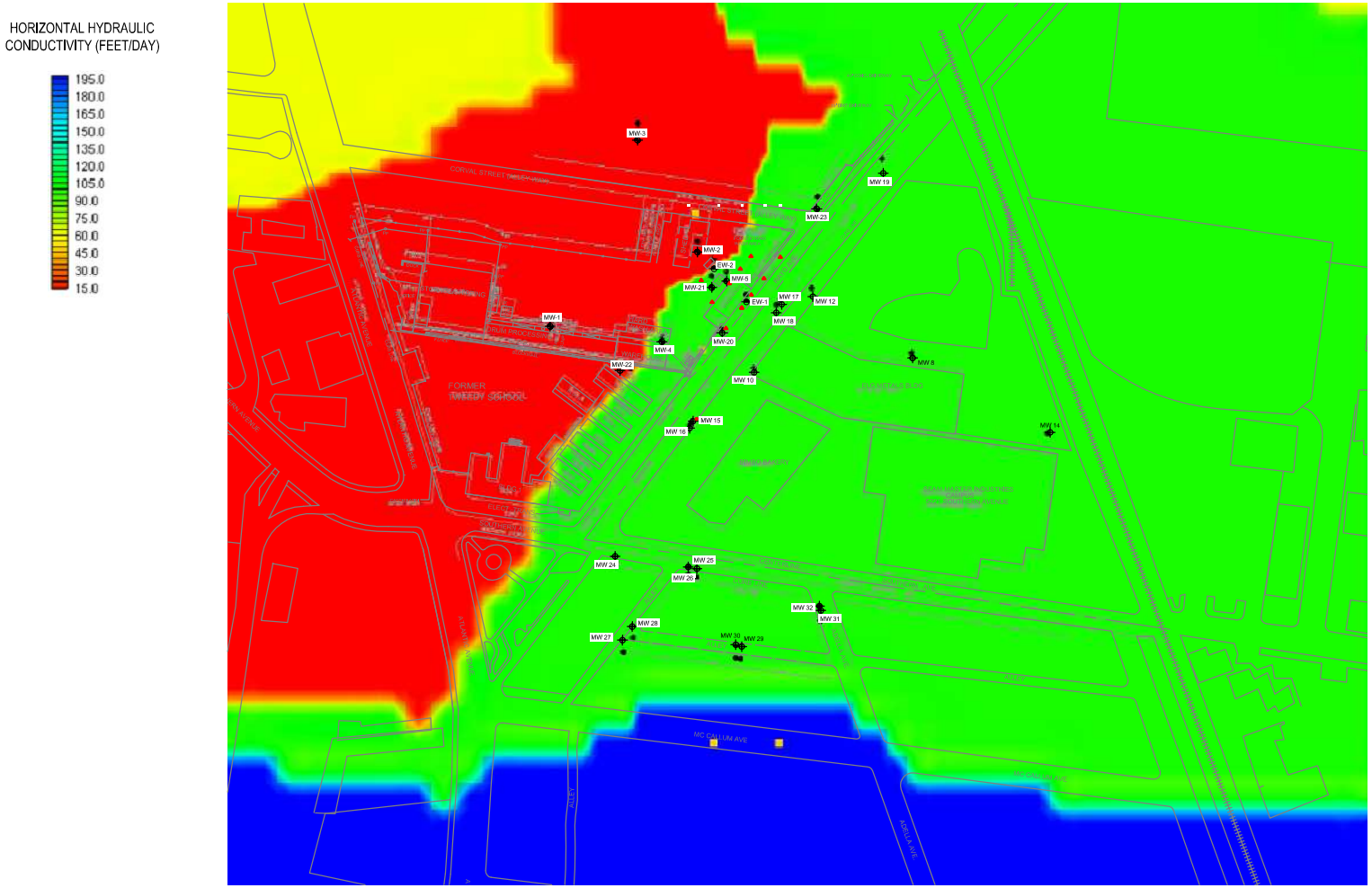
DRAWING: Don-071307-FIG-2-2-CHHCZ.dwg

XREFS: T:\current-work files\COOPER-DRUM\20070404\NEW-BACKGRD2.dwg

PLOT BY: RTAYLOR - Jul 16, 2007 - 1:23:40pm

DRAWING: T:\current-work files\COOPER-DRUM\Cooper-Drum 20070713\

IMAGES: Figure 2-4.bmp Figure 2-4 color legend.bmp



NOTE: NOT TO SCALE

URS
2870 GATEWAY OAKS DRIVE, SUITE 150
SACRAMENTO, CA 95833

Cooper Drum Superfund Site
South Gate, CA

Figure 2-2
CALIBRATED HORIZONTAL HYDRAULIC CONDUCTIVITY ZONES

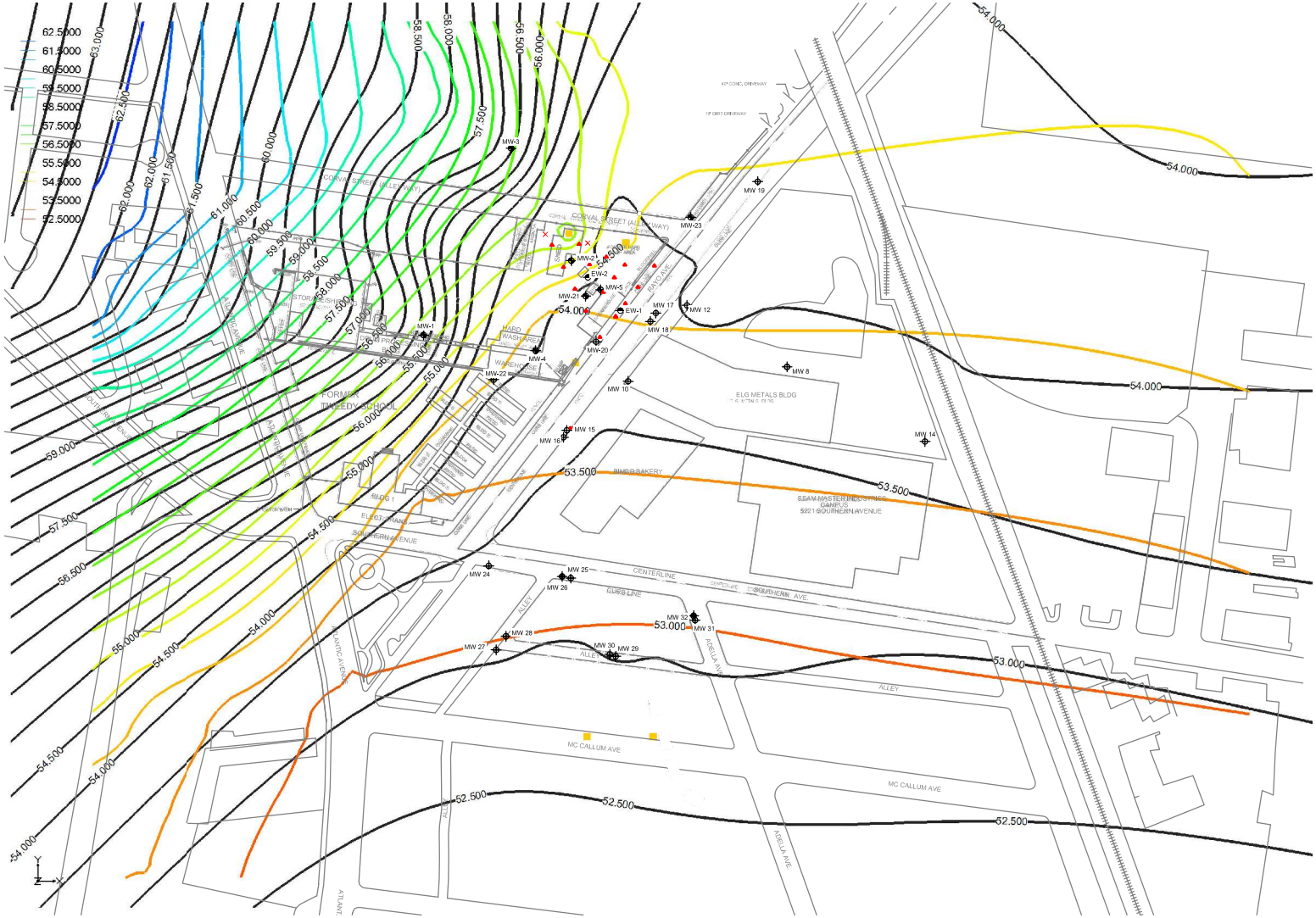
DRAWING: Don-071307-FIG-2-3-SIM-GW-ELEV.dwg

XREFS: T:\current-work files\COOPER-DRUM\20070404\NEW-BACKGRD2.dwg

PLOT BY: RTAYLOR - Jul 16, 2007 - 1:24:28pm

DRAWING: T:\current-work files\COOPER-DRUM\Cooper-Drum 20070713\

IMAGES: Figure 2-3-.jpg



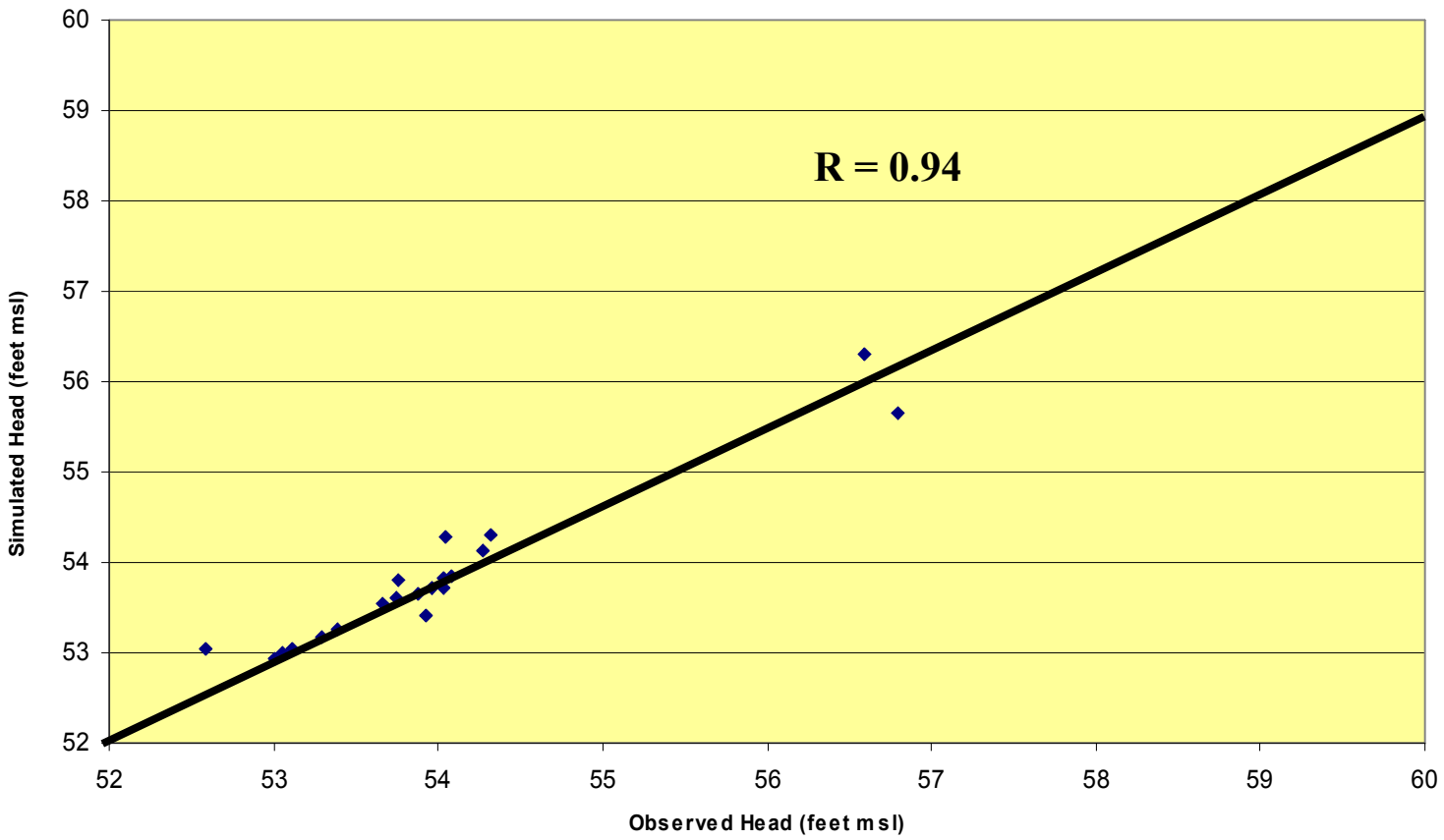
NOTE:
COLORED CONTOURS REPRESENT SIMULATED GROUNDWATER ELEVATION (FEET MEAN SEA LEVEL)

NOT TO SCALE

URS
2870 GATEWAY OAKS DRIVE, SUITE 150
SACRAMENTO, CA 95833

Cooper Drum Superfund Site
South Gate, CA

Figure 2-3
SIMULATED AND OBSERVED GROUNDWATER ELEVATIONS



Error Statistic Summary		
Mean Error (feet)	Mean Absolute Error (feet)	Root Mean Squared (feet)
-0.17	0.23	0.30

Note:
R = correlation coefficient
R = 0.94, indicates a 94% correlation between observed and simulated heads for the monitoring well locations used for flow calibration.

Figure 2-4. Simulated Versus Observed Heads

Figure 2-5 -Changes of Simulated Head at Observation Points
(Compared with baseline simulation)

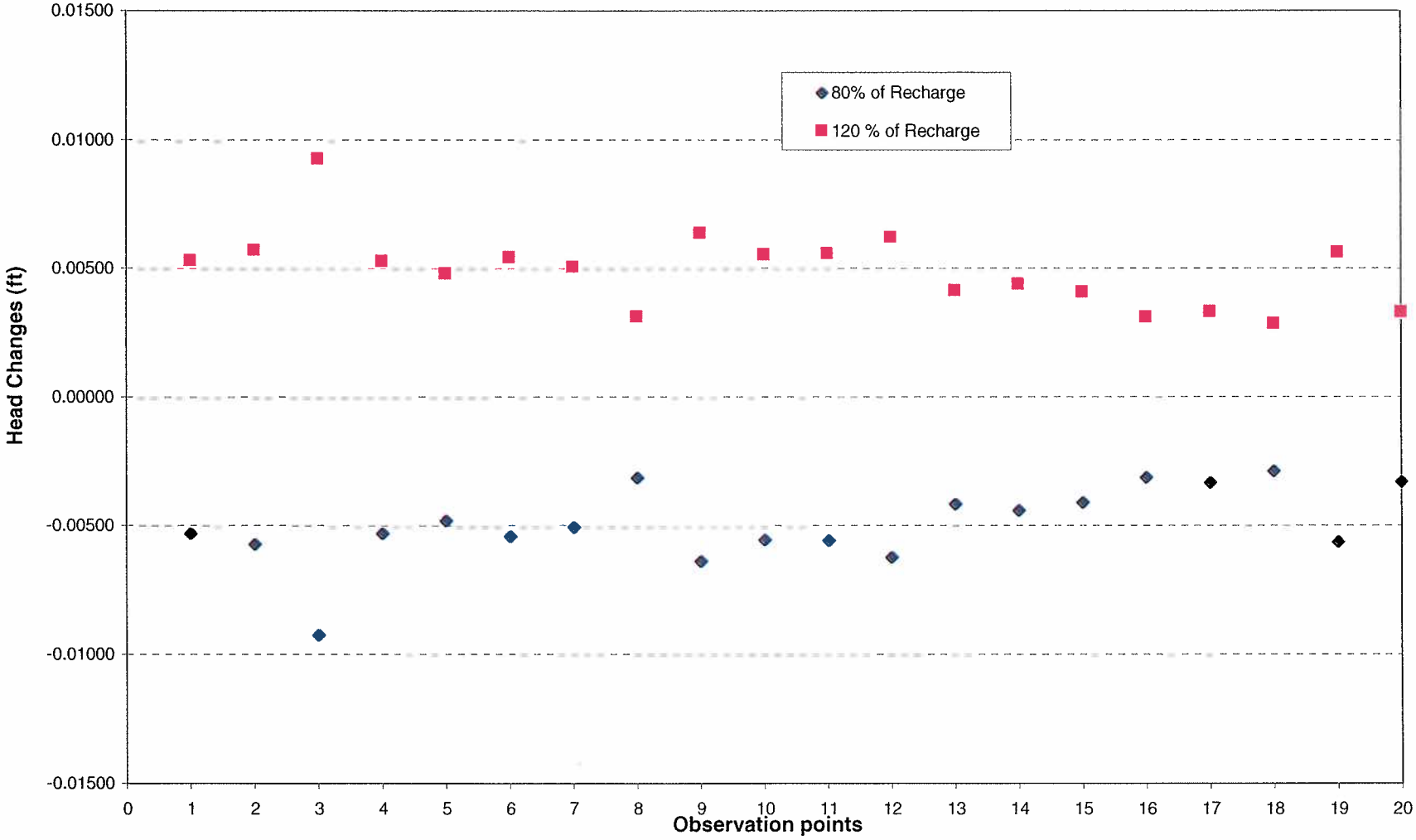
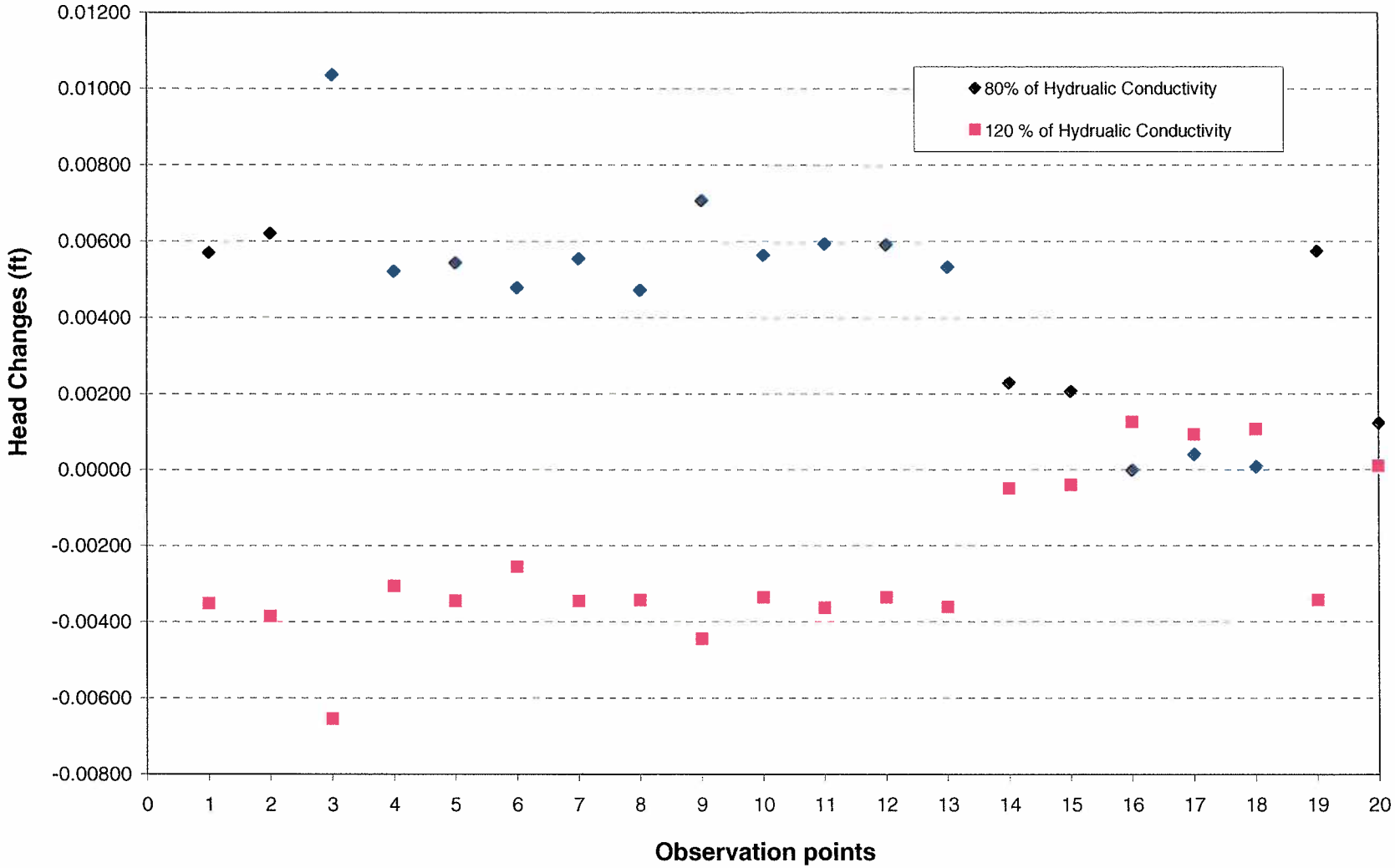
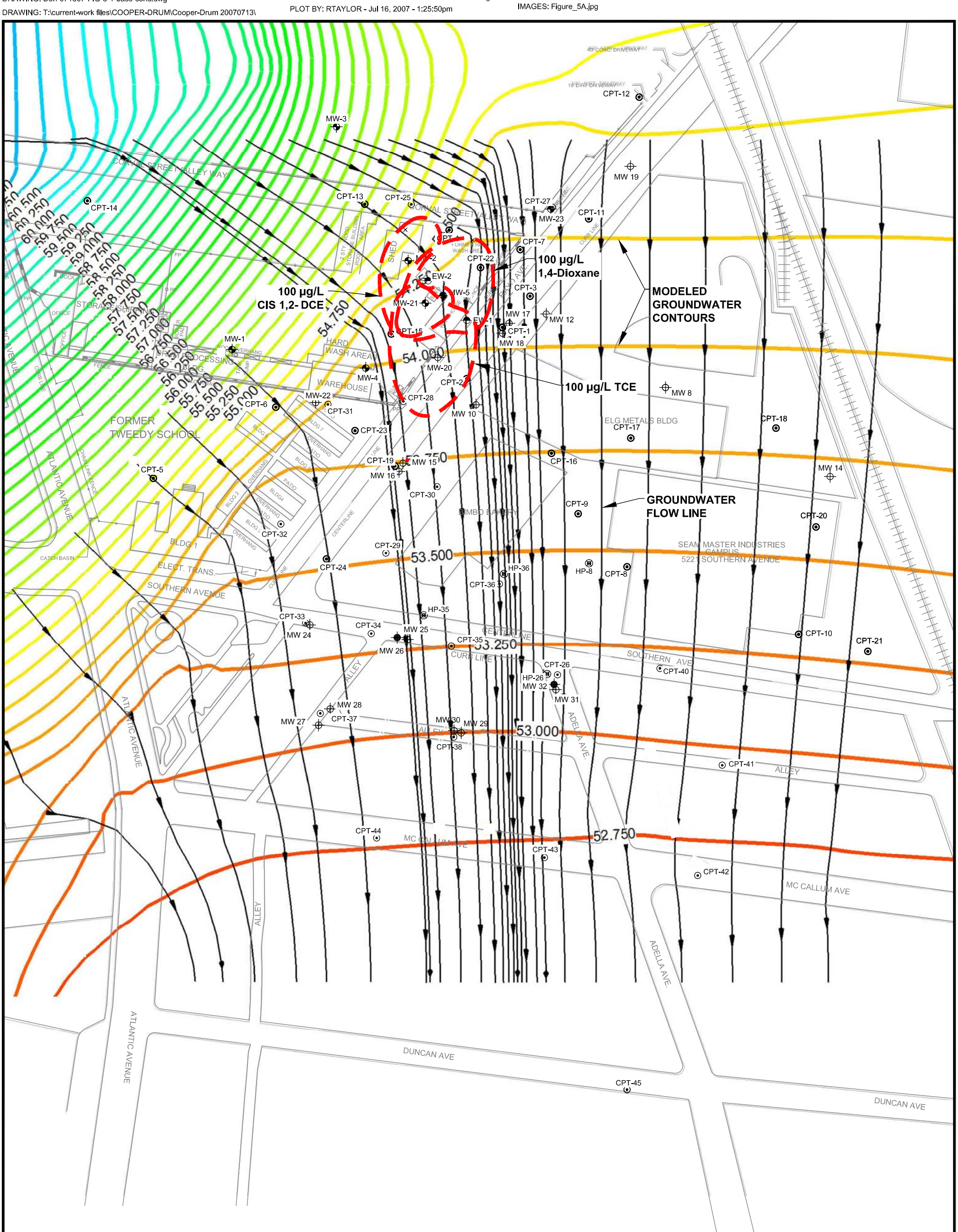


Figure 2-6 - Changes of Simulated Head at Observation Points
(Compared with baseline simulation)



DRAWING: Don-071307-FIG-3-1-base-cond.dwg
DRAWING: T:\current-work files\COOPER-DRUM\Cooper-Drum 20070713\
XREFS: T:\current-work files\COOPER-DRUM\20070404\NEW-BACKGRD2.dwg
PLOT BY: RTAYLOR - Jul 16, 2007 - 1:25:50pm
IMAGES: Figure_5A.jpg



LEGEND

— —	100 ppb Isopeth
–56.75–	Groundwater Elevation
—►	Groundwater Flow Line
⊕	Monitoring Well
●	Soil Boring Location.
TCE	Trichloroethene
DCE	Dichloroethene
µg/L	Micrograms Per Liter

Note:
1. Isopleths From August 2006
2. Distance Between Arrows On Flowline Is One Year.

N W E S

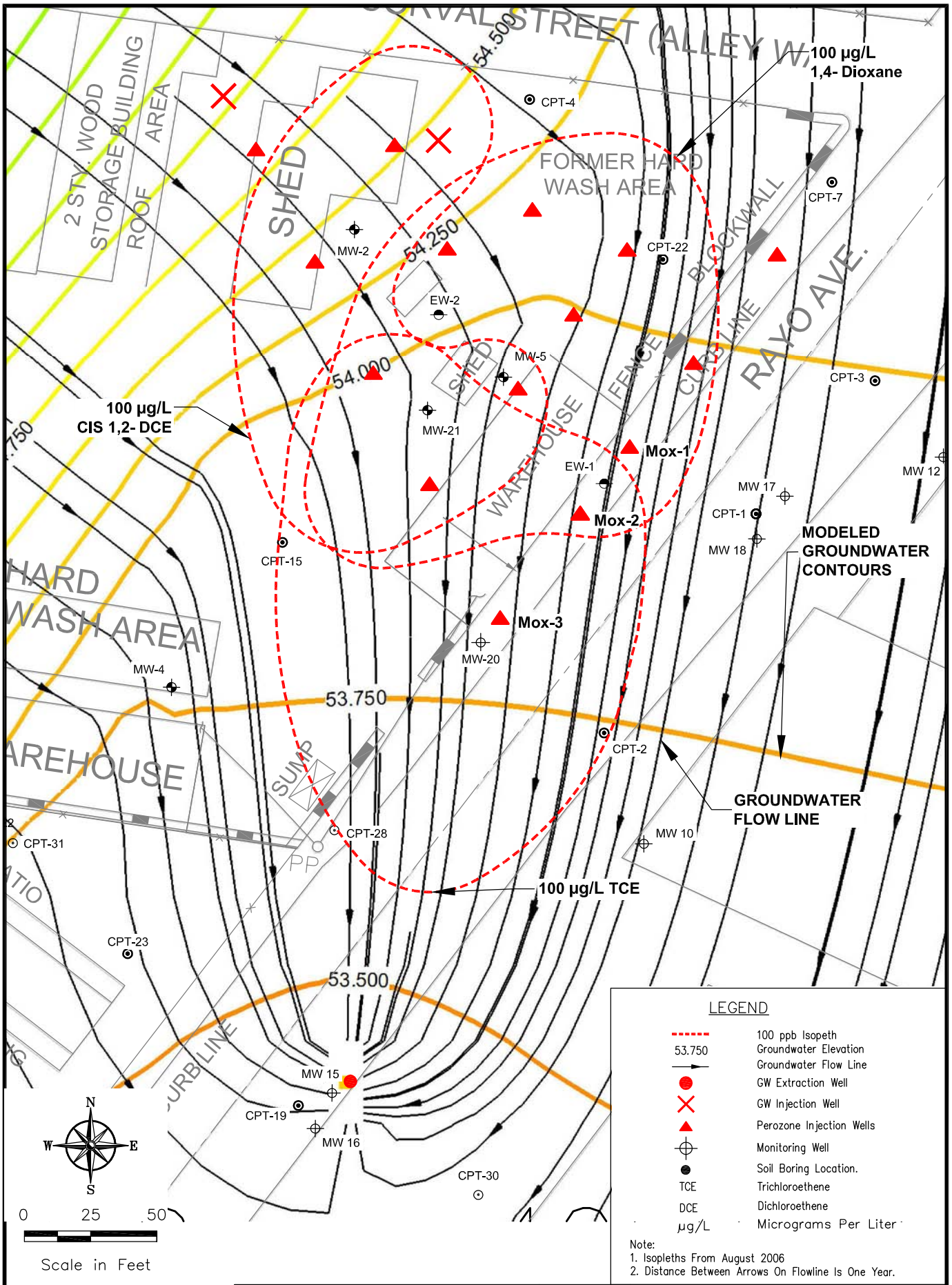
150 75 0 150 300

SCALE IN FEET

URS
2870 Gateway Oaks Dr., Ste. 150
Sacramento, CA 95833-3200
TEL: (916) 679-2000
FAX: (916) 679-2900

Cooper Drum Superfund Site
South Gate, CA

Figure 3-1
GROUNDWATER MODEL
BASELINE CONDITIONS

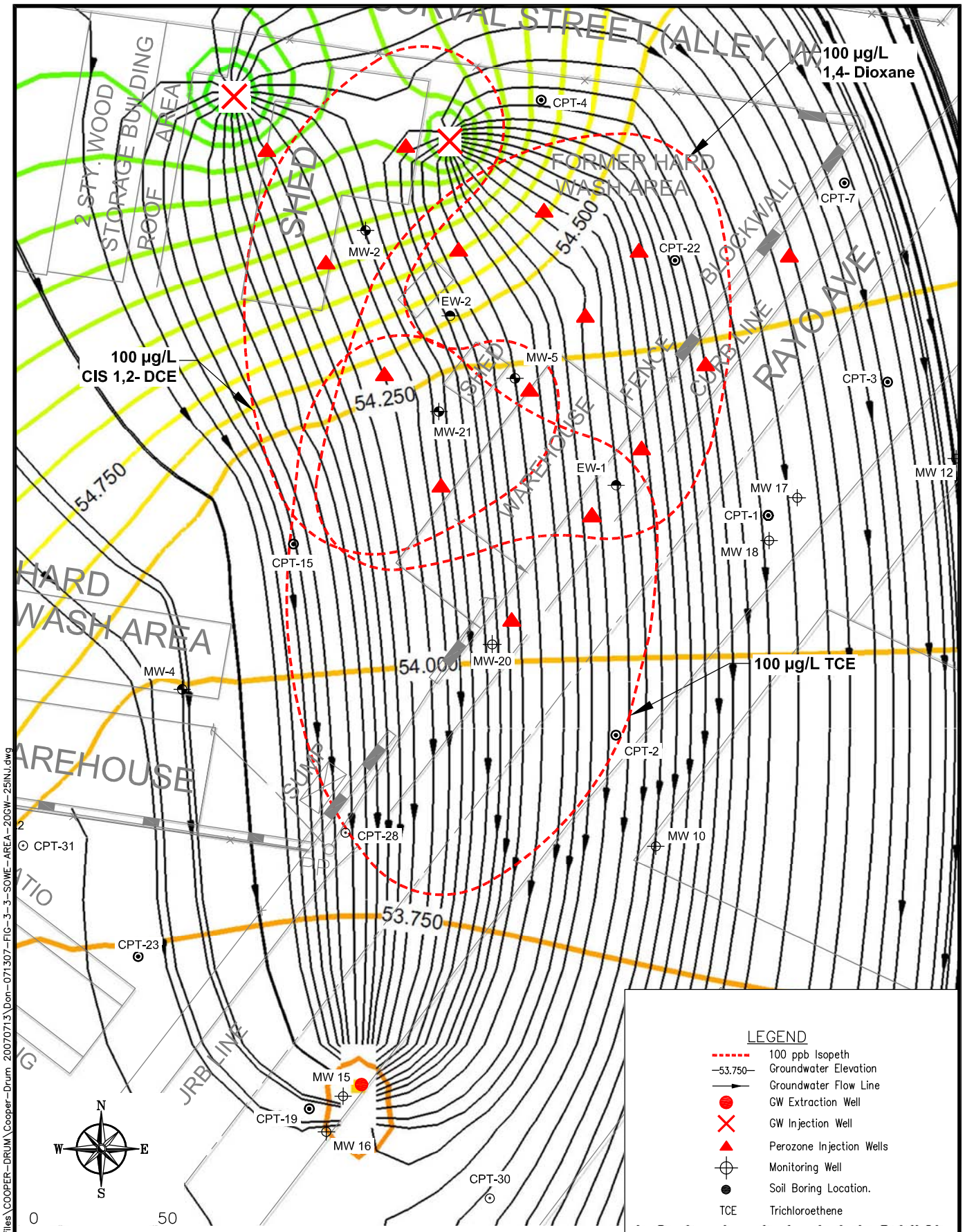


URS
2870 GATEWAY OAKS DRIVE, SUITE 150
SACRAMENTO, CA 95833

Cooper Drum Superfund Site
South Gate, CA

Figure 3-2
MODEL RUN SCENARIO 1
NEAR SOURCE TARGET ZONE
GROUNDWATER EXTRACTION (25 GPM)

PLOT BY: RTAYLOR - Jul 16, 2007 - 1:27:05pm
XREFS: T:\current-work files\COOPER-DRUM\20070404\NEW-BACKGRD2.dwg
IMAGES: Figure 6.jpg Figure-6.jpg
DRAWING: Don-071307-FIG-3-2-SOWE-AREA-REMEDIATION-SYSTEM.dwg
DRAWING: T:\current-work files\COOPER-DRUM\Cooper-Drum 20070713\



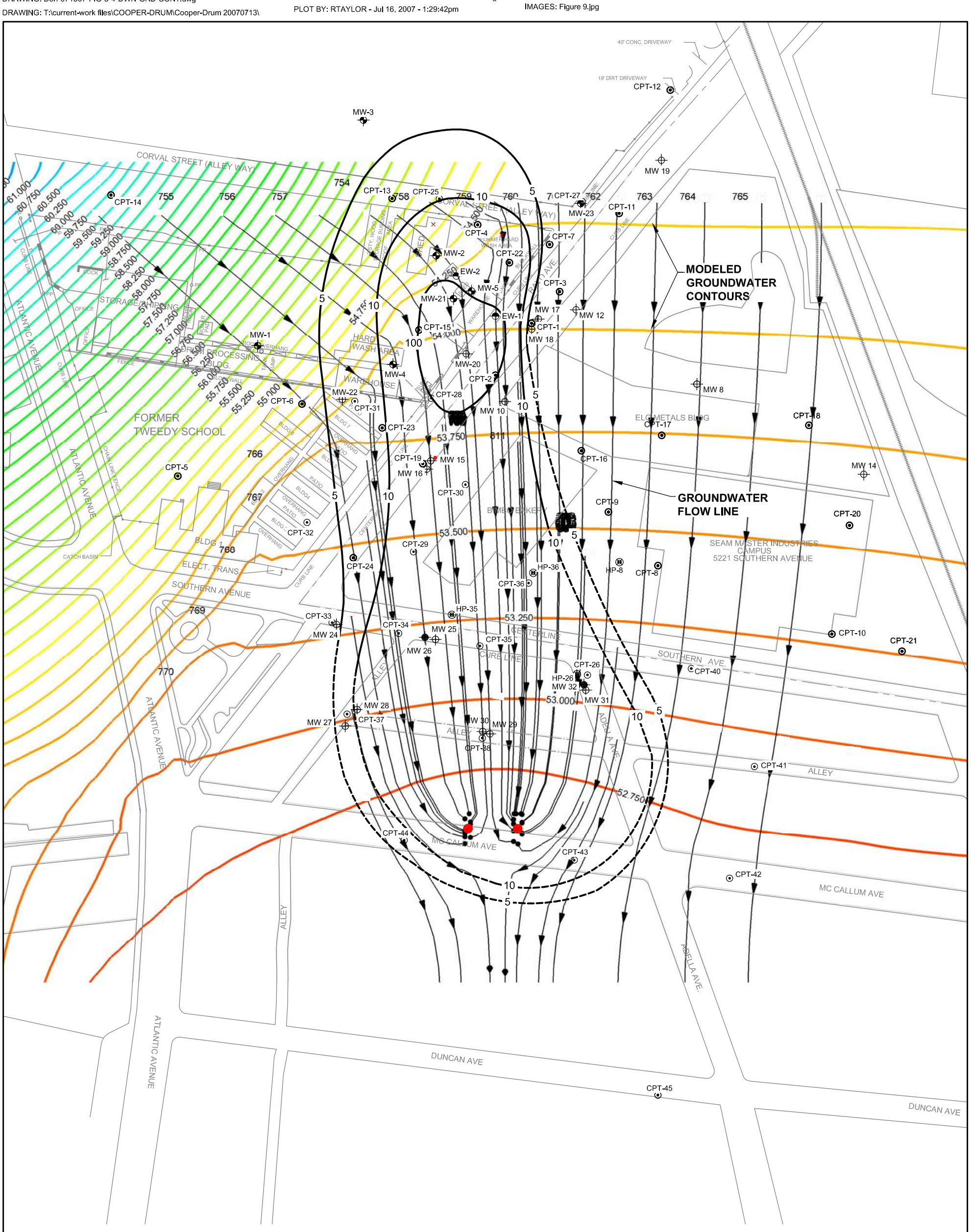
DRAWING: T:\current-work files\COOPER-DRUM\Cooper-Drum 20070713\Don-071307-FIG-3-3-SOWE-AREA-20GW-25INJ.dwg

URS
2870 GATEWAY OAKS DRIVE, SUITE 150
SACRAMENTO, CA 95833

Cooper Drum Superfund Site
South Gate, CA

Figure 3-3
MODEL RUN SCENARIO 2
NEAR SOURCE TARGET ZONE GOUNDWATER EXTRACTION
(25 GPM) AND INJECTION (30 GPM)

DRAWING: Don-071307-FIG-3-4-DWN-GRD-CONT.dwg XREFS: T:\current-work files\COOPER-DRUM\20070404\NEW-BACKGRD2.dwg
DRAWING: T:\current-work files\COOPER-DRUM\Cooper-Drum 20070713\ PLOT BY: RTAYLOR - Jul 16, 2007 - 1:29:42pm IMAGES: Figure 9.jpg



LEGEND

- - - - -	100 ppb Isopeth
–56.75–	Groundwater Elevation
—►	Groundwater Flow Line
●	GW Extraction Well
⊕	Monitoring Well
●	Soil Boring Location.
TCE	Trichloroethene
DCE	Dichloroethene
µg/L	Micrograms Per Liter
CPT	Cone Penetrometer – Test
———	Tce Isoconcentration Contour (Micrograms Per Liter), August 2006
— —	Inferred TCE Concentration From March 2007 CPT/Hyrdo Punch Data

N W E S

150 75 0 150 300

SCALE IN FEET

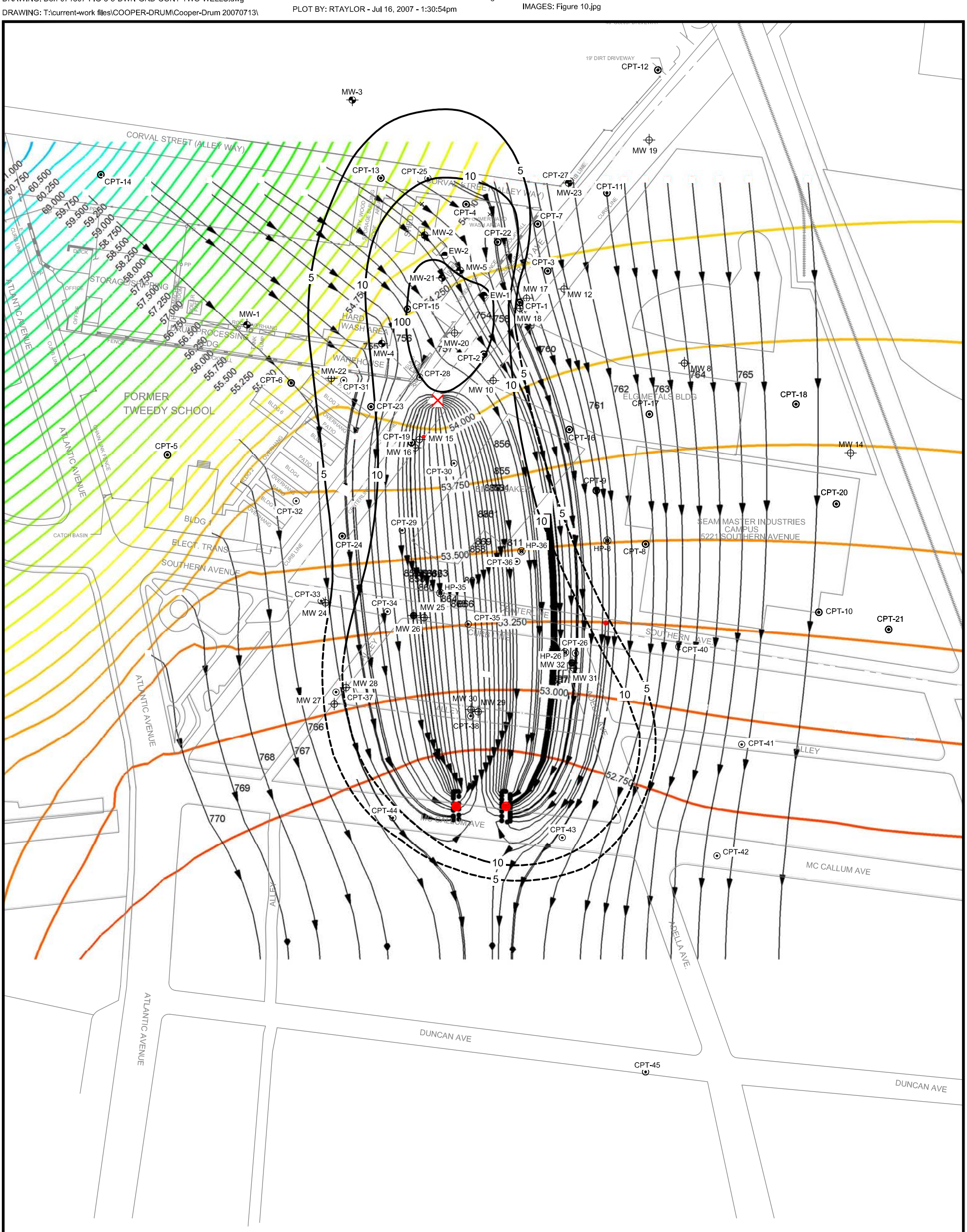
Note:
1. DISTANCE BETWEEN ARROWS ON FLOWLINE IS ONE YEAR.

URS
2870 Gateway Oaks Dr., Ste. 150
Sacramento, CA 95833-3200
TEL: (916) 679-2000
FAX: (916) 679-2900

Cooper Drum Superfund Site
South Gate, CA

Figure 3-4
MODEL RUN SCENARIO 3 - DISTAL PLUME TARGET ZONE
GROUNDWATER EXTRACTION (20 gpm each)

DRAWING: Don-071307-FIG-3-5-DWN-GRD-CONT-TWO-WELLS.dwg XREFS: T:\current-work files\COOPER-DRUM\20070404\NEW-BACKGRD2.dwg
DRAWING: T:\current-work files\COOPER-DRUM\Cooper-Drum 20070713\ PLOT BY: RTAYLOR - Jul 16, 2007 - 1:30:54pm IMAGES: Figure 10.jpg



LEGEND

–56.75 –	Groundwater Elevation
	Groundwater Flow Line
	GW Extraction Well
	GW Injection Well
	Monitoring Well
	Soil Boring Location.
TCE	Trichloroethene
µg/L	Micrograms Per Liter
CPT	Cone Penetrometer – Test
	Tce Isoconcentration Contour (Micrograms Per Liter), August 2006
	Inferred TCE Concentration From March 2007 CPT/Hyrdo Punch Data

Note:
1. DISTANCE BETWEEN ARROWS ON FLOWLINE IS ONE YEAR.

N W E S

150 75 0 150 300
SCALE IN FEET

URS
2870 Gateway Oaks Dr., Ste. 150
Sacramento, CA 95833-3200
TEL: (916) 679-2000
FAX: (916) 679-2900

Cooper Drum Superfund Site
South Gate, CA

Figure 3-5
MODEL RUN SCENARIO 4 DISTAL PLUME TARGET ZONE
GROUNDWATER EXTRACTION
(25 gpm)AND INJECTION (25 gpm)