APPENDIX E

GROUNDWATER MODELING RESULTS

APPENDIX E
McLAREN TAILINGS ABANDONED MINE SITE
GROUNDWATER MODEL

Prepared for:

Montana Department of Environmental Quality
Mine Waste Cleanup Bureau
P. O. Box 200901
Helena, Montana 59620

Engineering Services Contract DEQ/MWCB Number 407038
Task Order Number 21

Prepared by:

Pioneer Technical Services, Inc.
P.O. Box 3445
Butte, Montana 59702

April 16, 2009

MONTANA
MICHAEL W.
BORDUIN
13834 PE
LICENSED
PROFESSIONAL ENGINEER

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

1.0 MCLAREN TAILINGS ABANDONED MINE SITE GROUNDWATER MODEL

This appendix provides a summary of the McLaren Tailings Abandoned Mine Site (Site) groundwater model, including the model setup, calibration, groundwater budget, considerations for site-specific conditions, transient simulations, the evaluation and optimization of the 60% Construction Dewatering Design, and the recommended sequence of phased construction dewatering and tailings excavation.

2.0 MODEL SETUP

The primary objective of the groundwater model is to evaluate and optimize the construction dewatering design. In order to do this, the groundwater model must provide a reasonable approximation to conditions at the Site. The groundwater model was constructed utilizing industry standard software and available data. During the construction of the computer model, consideration was given to the model extent, material layers, streams and drains, recharge, and evapotranspiration. To evaluate the time frame of the construction dewatering and the effect of changing seasons, the steady state model was utilized to build a transient model, in which three years of seasonal effects were evaluated.

2.1 SOFTWARE

Two software packages were utilized to simulate groundwater conditions at the Site. The core software that simulates groundwater flow is MODFLOW® 2000. This software is a three-dimensional finite-difference groundwater flow model developed by the United States Geological Survey (USGS). This core software is manipulated by the graphical user interface (GUI) Groundwater Modeling System (GMS®). Both MODFLOW® 2000 and GMS® are industry standard software.

2.2 AVAILABLE DATA

Available data for the construction of the groundwater model include the 2008 Site pumping test (Table E-1), groundwater elevations from the Bureau of Reclamation (BOR) provided in the *Response Action Report for the McLaren Tailings Site, Cooke City, Montana* (BOR, 1994), monthly climate summary from the Western Regional Climate Center (WRCC), and borehole logs and stream flow measurements from the Montana Bureau of Mines and Geology (MBMG) report *MBMG-23 Final Report, Acid Mine Drainage Control – Feasibility Study, Cooke City, Montana* (*MBMG-23 McLaren Feasibility Study*) (MBMG, 1975). Regional hydrogeology is described by the Montana Bureau of Mines and Geology (MBMG, 1999) and stratigraphic sections describing subsurface geology are provided by the Bureau of Reclamation (BOR, 1990).

2.3 MODEL DOMAIN

To adequately simulate the Site and the representative hydrogeologic conditions, the boundary of the model, or model domain, was extended a significant distance in all directions away from the Site (Figure E-1). The downgradient and upgradient boundaries of the model are located approximately 0.35 miles and 0.65 miles, respectively, from the Site. The north and south model boundaries are located up on the valley walls, approximately 0.4 miles and 0.2 miles, respectively, from the Site. Given the technical scope and resources available for the project, the model boundaries did not incorporate the entire Soda Butte Creek hydrologic basin. With the boundary locations described above, the size of the model is approximately 1.2 miles in length (along the axis of Soda Butte Creek) by 0.8 miles in width (perpendicular to Soda Butte Creek) (Figure E-1).

2.4 GRID

To estimate groundwater flow, MODFLOW 2000® utilizes a grid that consists of three-dimensional rectangular cells. Each cell represents a finite portion of the aquifer, and groundwater flow within each cell is estimated based on the cell dimensions and the hydraulic properties that have been assigned to it. Multiple layers of cells with different dimensions and hydraulic properties can be assembled together to represent multiple layers of material (i.e., tailings overlying alluvium, which in turn is overlying bedrock) (Figure E-2).

Because the grid is made up of rectangular cells, the model is generally more accurate if one axis of the grid is oriented in the same direction as the general direction of groundwater flow. With the McLaren Tailings Abandoned Mine Site groundwater model, one axis of the model grid was oriented along the axis of the valley bottom (Figure E-2).

The model accuracy is also generally improved by utilizing smaller cell sizes; however, too many cells in the model prevents the model from running in a time-efficient manner. In order to improve the model accuracy and reduce model run times, the model grid was "refined", where smaller cells were utilized in the area of interest (McLaren Tailings Abandoned Mine Site) and larger grid cells were utilized for the remainder of the model (Figure E-2).

2.5 MATERIAL LAYERS

Within the model domain, three primary hydrogeologic materials were identified, which include tailings, alluvium/colluvium (alluvium), and bedrock. These three materials were simulated within the groundwater model as three layers, with tailings as Layer 1, alluvium as Layer 2, and bedrock as Layer 3 (Figure E-2 and Figure E-3). While the thickness and extent of the tailings (Layer 1) has been well defined through the numerous site investigations, the thickness of the alluvium and the location of the alluvium/bedrock contact is subject to greater uncertainty. Nevertheless, as the objective of the construction dewatering system is to dewater the tailings and the upper two feet of the alluvium, the thickness of the alluvium and location of the contact between the alluvium and bedrock does not appear to be as critical.

To estimate the thickness of the alluvium and the location of the bedrock underneath the Site (Figure E-3), a combination of borehole logs and groundwater surface maps were utilized. These records likely indicate the original location of the Soda Butte Creek channel before it was moved to the current location to the north of the Site. The borehole logs from the pumping well utilized during the 2008 aquifer test (PW-01), wells 24a and 24b (MBMG, 1975), and boreholes DH89-3 through DH-89-7, DH-89-10, DH-89-11 located along the southern border of the tailings (MBMG, 1990) provide the thicknesses of the alluvium (from 10.5 feet to 50 feet) and depth to bedrock. In addition to these borehole logs, groundwater surface maps were utilized to locate a high conductivity zone underneath the tailings. For the purposes of this construction dewatering design, this high conductivity zone is assumed to be the original location of Soda Butte Creek (MBMG, 1975) and as such, the original channel would have characteristics of a greater hydraulic conductivity and greater alluvial thickness. Within the model, this original channel was simulated in Layer 2 as a thicker portion of Layer 2 with a hydraulic conductivity of 120 feet per day (ft/day) (Figure E-4).

In a similar manner, the estimated bottom of alluvium was utilized as the top of the bedrock. The location of the top of bedrock beneath much of the Site is not well documented; therefore the top of bedrock was estimated using available borehole records. Bedrock outcroppings are present at the southwest corner of the Site, and along the valley sidewalls above the Site. Using these general locations, the top of bedrock was estimated and utilized as the top of Layer 3. For uniformity, the thickness of Layer 3 was assumed to be 400 feet.

2.6 FLUX ACROSS BOUNDARIES

While the north, west, and east boundaries must all account for groundwater flux across each boundary, the south model boundary was located along a topographic divide. By placing the model boundary at this location, groundwater flow from the south is a direct function of the quantity of recharge and the drainage area. Unlike the north, west, and east boundaries, the south boundary is not an artificial flux boundary.

While the north boundary is an assigned flux boundary and includes Miller Creek, the flux was minimized by purposefully locating the boundary along a bedrock plateau. Only flux through Miller Creek has been simulated.

General flux values along the west and east boundaries have been estimated through Darcy's law, as shown in Equation 1.

$$\mathbf{Q = K{*}i{*}A} \qquad \mathbf{(1)}$$

Where:

Q = Volume of flux in cubic feet per day (ft^3/day);

K = Hydraulic conductivity in ft/day;
i = Hydraulic gradient in feet per foot (unitless); and
A= Cross sectional area of the aquifer (ft^2).

Using Darcy's law, flux into the groundwater model through the north and east boundaries, and flux out of the groundwater model through the west boundary, have been estimated and are shown in Table E-2. To apply the boundary fluxes shown in Table E-2, a series of wells were placed at the west, north, and east boundaries, and utilized to add or remove the appropriate quantity of flux across each boundary (Figure E-5).

2.7 STREAM

Soda Butte Creek, the only continually flowing surface water body at the Site, historically varies in flow from less than 0.2 cubic feet per second (cfs) during baseflow conditions to over 100 cfs during high flow conditions (MBMG, 1975). These same historical records of high flow conditions near the Site illustrate regions of the creek where significant gains and losses occur (MBMG, 1975). The most dramatic loss in streamflow from these historical records occurs as the creek approached the Site from the northeast, where the slope of the creek flattens out and the width increases significantly. Based on measurements collected June 21, 1975, the creek lost approximately 6 cfs, or nearly 20 percent of its total flow. During the same investigation, a significant gain in flow occurs once the creek flows around the northern boundary of the Site and starts to turn back to the south. At this point, where the creek wraps around the northwest corner of the Site, the historical investigation noted a gain of nearly 5 cfs, or a 15 percent gain. With these significant gains and losses in such a short area, it is obvious that significant exchanges of water occur between Soda Butte Creek and the underlying groundwater aquifer.

Because Soda Butte Creek is a continually flowing surface water body, it was modeled with the MODFLOW® stream package (Figure E-6). The stream package creates stream channels with a specific width, sinuosity, slope, conductance, stream bed thickness, stage elevation, and Manning's roughness coefficient (n).

Stream conductance (c_s) is determined by Equation 2:

$$\mathbf{C_s = L * w * K_v * b} \qquad \textbf{(2)}$$

Where:

C_s = Stream conductance;
L = Stream reach length (ft);
w = Stream width (ft);
b= Thickness of streambed (ft); and
K_v = Vertical hydraulic conductivity (ft/day)

Because Soda Butte Creek has been surveyed, the actual shape of the creek was utilized in the model (the creek sinuosity was set to 1.0).

The stream package calculates flow within the channel based on the Manning's equation and gains or losses to the aquifer based on the conductance value. The stream package was used over the MODFLOW river package due to the additional ability to specify sinuosity and roughness within the channel. A stream width of 10 to 20 feet was assigned to Soda Butte Creek within the model.

To determine the n-value of Soda Butte Creek, the visual roughness of the creek channel was compared to the illustrations provided in *Roughness Characteristics of Natural Channel* (Barnes, 1987). Based on this comparison, a roughness coefficient of 0.05 was selected and utilized for the majority of Soda Butte Creek, with the exception of the flat, slow section just to the northeast of the Site. For this section, a roughness coefficient of 0.03 was utilized.

To simulate seasonal flow variations in Soda Butte Creek and Miller Creek, monthly streamflow measurements from *MBMG-23 McLaren Feasibility Study* (MBMG, 1975) were utilized. Between these recorded streamflow measurements and observations of the location of groundwater in nearby test pits in 2008, it appears that during baseflow conditions Soda Butte Creek is largely disconnected from the groundwater aquifer. During high flow conditions, however, the connectivity of Soda Butte Creek appears to shift drastically and the creek appears to lose a large quantity of water at the northeastern portion of the Site (MBMG, 1975). The location where this large quantity of water is lost from Soda Butte Creek is the same location where the creek channel was first diverted to the north of the Site. Because these locations coincide, it is believed that during high flow conditions, a large quantity of streamflow is lost to the original Soda Butte Creek channel and flows underneath the Site. To simulate significant streamflow loss during high flow conditions, the conductivity of the bottom of the stream channel was varied transiently so that the conductance of the stream bottom was low during baseflow months and high during peak runoff months.

Because Soda Butte Creek loses a significant amount of water to groundwater during high flow season, Soda Butte Creek and its connection to groundwater play a significant role in the construction dewatering effort.

2.8 DRAINS

Intermittent or ephemeral drainages are simulated in MODFLOW 2000® through the utilization of "drains". The surface water features in the Site that are intermittent or ephemeral include Miller Creek, the seeps along the toe of the tailings dam face, the man-made drain along the southern boundary of the Site, and the secondary channel located to the west of the Site and south of Soda Butte Creek (Figure E-7). All of these surface water features were simulated with the MODFLOW® drain package. A drain is very effective at intercepting groundwater that has risen to the surface during high flow and removing the water from the model. In this manner, the drain package is able to simulate this rapid removal of excess groundwater during high flow and remain relatively inactive during baseflow conditions.

The drain package creates channels that have a specified shape, slope, and conductance through the bottom of the drain. Once water enters a drain from the model, the water is removed entirely from the model and does not contribute to downgradient surface water flows. The conductance value of a drain (C_D) is calculated as:

$$\mathbf{C_D = L * w * K_v} \qquad \textbf{(3)}$$

Where:

C_D = Drain conductance;
L = Drain reach length (ft);
w = Cell width (ft); and
K_v = Vertical hydraulic conductivity (ft/day).

The width of the drain is defaulted to the width of the model cell that the drain passes through.

2.9 RECHARGE AND EVAPOTRANSPIRATION

Recharge refers to how and when precipitation returns to groundwater, while evapotranspiration refers to the removal of water from groundwater by the combined processes of evaporation and usage by vegetation (transpiration).

To simulate recharge to the Site groundwater model, precipitation data were utilized from the Western Regional Climate Center (WRCC) Station 241995. Precipitation data have been collected in Cooke City from November 1, 1967 to December 31, 2007 and the "Period of Record Monthly Climate Summary" was utilized. Because a large portion of the precipitation that falls on the Site is in the form of snow, and typically does not begin to melt until March, precipitation from November through February was not immediately applied to the model. Instead, precipitation quantities from the colder months were accumulated and then applied uniformly from March through June.

While recharge was directly simulated, evapotranspiration was simulated by only applying a fraction of the recharge. It was assumed that in the extreme climate of Cooke City, evaporation plays very little role in the removal of water from groundwater. Based on this reasoning, the entire quantity of recharge was applied to the groundwater model.

2.10 TRANSIENT SIMULATION

The transient groundwater model adds the component of time to the steady state groundwater model. The purpose of building a transient Site groundwater model is primarily to estimate the time required for the Construction Dewatering Design to remove groundwater from the tailings and the underlying alluvium. A secondary objective of the transient simulation is to determine how the model responds to seasonal changes in the Cooke City area.

The total length of time simulated within the transient model was three years. This duration was selected because it is the estimated length of time that will be required to excavate the Site.

3.0 MODEL CALIBRATION

Because the construction dewatering system will be designed utilizing the McLaren groundwater model, ensuring that the model is approximating true groundwater conditions is required. For this reason, several calibration methods were implemented, which include the following:

- Steady State Model Calibration, including
  - Groundwater head calibration (Figure E-8);
  - Hydraulic gradient calibration (Figure E-9);
  - Pumping test calibration (Figure E-10); and
- Transient calibration with seasonal response (Figure E-11);

Each of the four calibration methods are discussed in this section.

3.1 STEADY STATE MODEL CALIBRATION

The steady state model calibration helps to confirm that the groundwater model is a reasonable representation of groundwater conditions at the Site.

3.1.1 Groundwater Elevation Calibration

The first portion of the steady state model calibration is the comparison of groundwater elevation measurements (observed heads) to what the groundwater model computes (computed heads). The observed heads utilized to calibrate the McLaren Tailings Abandoned Mine Site groundwater model include measurements from wells, piezometers, and seeps that are located in and around the Site.
Each groundwater installation has been represented as an observation point within the groundwater model (Figure E-8). The series of these observation points utilized a total of 22 wells and seeps measured during the 2008 McLaren Tailing Abandoned Mine Site pumping test, 42 test pits with general groundwater elevations. For purposes of this calibration section, the 22 field measurements from wells and seeps and 42 groundwater elevations from the test pits were utilized in the comparison of computed versus observed head values provided in Figure E-8.

At the end of each steady-state model run, the computed heads are compared to the observed, and the cumulative difference between all observed heads and computed heads are summarized with three types of statistics: mean error, mean absolute error, and root mean squared error. The difference of the three error summaries is summarized below:

Mean error (ME) is defined in Equation 4 as:

$$ME = \frac{1}{n}\sum_{i=1}^{n}(h_c - h_o)_i \qquad \textbf{(4)}$$

Where:

n is the number of observations;
h_c is the computed value; and
h_o is the observed value.

Mean absolute error (MAE) is defined as:

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left|h_c - h_o\right|_i$$

Root mean squared (RMS) error is defined as:

$$RMS = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(h_c - h_o)_i^2}$$

Mean error of the steady-state McLaren Tailing Abandoned Mine Site groundwater model was –1.14 feet, mean average error was 5.48 feet, and root mean squared error was 6.34 feet over 64 observation points (Figure E-8). Within Figure E-8, the error at each observation point is plotted as a tiny bar graph comparing computed versus observed head values.

3.1.2 Hydraulic Gradient Calibration

In addition to the groundwater elevation calibration, the groundwater model was calibrated to match the observed groundwater contours from September 30, 2008. This calibration is very similar to the groundwater elevation calibration, with the exception that instead of matching the water table at a finite amount of points, an effort is made to match the entire water table.

The results of the hydraulic gradient calibration are shown in Figure E-9. In Figure E-9 the observed groundwater contours (solid blue lines) are compared to the computed groundwater contours (dashed blue lines). As can be observed from Figure E-9, the groundwater contours in the central portion of the Site are far apart, indicating either relatively thicker alluvium or a higher hydraulic conductivity. In addition, the groundwater contours in the vicinity of the Site tailings dam are very close together, indicating either a lower hydraulic conductivity or a reduction in the thickness of the alluvium.

During the calibration of the hydraulic gradient, several modifications were made. To match the groundwater table in the center of the Site, a very high alluvial hydraulic conductivity of 2,400 ft/day was assigned in this region (increased from 120 ft/day). This high hydraulic conductivity was necessary to match the observed groundwater contours, but does not match the contours exactly. It should be noted that the highest conductivity noted during the pumping test was 120 ft/day, therefore it is likely that the shallow groundwater gradient is caused by deeper alluvium at this location.

To match the steeper groundwater contours at the Site tailings dam, the alluvial hydraulic conductivity in this region was dropped to 0.5 ft/day (from an initial 120 ft/day), which significantly improved the match of hydraulic gradient in this area.

3.1.3 Pumping Test Calibration

The final calibration utilizing the steady state version of the model is the calibration of the pumping test. As summarized in Section 3.4.4 of the main report, a 24-hour pumping test was conducted on October 1, 2008. Because this pumping test demonstrates how the aquifer responds to dewatering on a small scale, it is appropriate to reproduce this same pumping test within the groundwater model.

In Table E-3, the observed drawdown measurements over 24 hours at 12 different observation wells and piezometers are compared to the computed drawdown in the steady state model. This comparison shows relatively good agreement in the model at the pumping well, and fair agreement in the observation points. The groundwater model overestimated the drawdown at two locations (PW-01 and PZ-01S), but underestimated the drawdown at the rest of the points by approximately one-third to one-half (Table E-3).

The pumping test calibration demonstrates that the groundwater model responds similarly to the measured response to the pumping test; however, it underestimates the drawdown response. Based on this comparison, it can be shown that the groundwater model is conservative in its response to dewatering, meaning that the model will likely overestimate the time that it will take to successfully dewater the Site.

3.2 TRANSIENT CALIBRATION WITH SEASONAL RESPONSE

As mentioned previously, the transient groundwater model adds the component of time to the steady state groundwater model. The total length of time simulated within the transient model is three years, as shown on Figure E-11. In this figure, the dashed line represents a repeating pattern of groundwater fluctuation in monitoring well W-3 in the year 1990. Monitoring well W-3 has been completed in the alluvium, and the groundwater fluctuation observed at this well during one year (15 feet) demonstrates the characteristically large seasonal fluctuation in groundwater observed at the Site.

In comparison, the computed groundwater elevation at monitoring well W-3 is shown as a solid line with small circles representing each 30 days of simulation. Several observations can be made from comparing the observed groundwater fluctuation to the computed groundwater fluctuation. First, the computed groundwater fluctuation increases and decreases every season by approximately four feet. This is significantly less than the 15 feet observed at the actual well. The model generates a smoothed depiction of the rapid transient changes in water elevations. A second observation from the comparison of observed and computed heads is the evident lag time between the observed and computed data. As can be seen on Figure E-11, the heads computed by the model start rising sooner than the heads observed in W-3. In addition, the rate of increase and decrease shown by the groundwater model is significantly slower. In comparing the lag time between the observed and computed data, it appears that the water in the groundwater model is rising sooner than in the observed Site aquifer, but the rate of rise and decline is much slower.

Based on the Transient calibration with seasonal response, it can be seen that the groundwater model does respond to seasonal changes in groundwater flow. The response shown by the model emulates approximately 30 percent of the observed fluctuation, and the fluctuation occurs at a slower rate. Because the computed fluctuation of groundwater is lower and the seasonal response time is slower, it appears likely that storage may be a factor. Additional storage in the bedrock aquifer and in the alluvium will mute the seasonal response, reducing the seasonal groundwater fluctuation and extending the response time of the fluctuation. Because the model appears to account for more storage, the model may be more conservative in the quantity of water available in the groundwater system that will be removed during construction dewatering.

4.0 GROUNDWATER BUDGET

The groundwater budget refers to the total quantity of water entering and leaving the model (through flux boundaries, precipitation, streams, and drains). One feature of a fully functional groundwater model is that the quantity of water entering the model should agree very closely with the quantity of water leaving the model. Volumes of groundwater entering and leaving the model via flux boundaries, precipitation, etc. are summarized in Table E-4, and the bottom line in this table demonstrates a very close agreement between the total volume entering and leaving the model, with less than -0.05 percent (%) difference. In total, over three years of model run time, approximately 211 million cubic feet (cf), or approximately 1,000 gallons per minute (gpm) of water enters and leaves the groundwater model.

4.1 <u>TYPICAL GROUNDWATER QUANTITIES UNDERNEATH MCLAREN TAILINGS ABANDONED MINE SITE</u>

In preparation of evaluating different construction dewatering scenarios, the rate of groundwater entering the alluvium beneath the Site was determined. This rate is important because it defines the quantity of water typically flowing underneath the Site, and provides a general estimate of the total quantity of water that will need to be routinely removed from the alluvium underneath the construction site in order to maintain an effectively dewatered construction site.

To further guide the construction dewatering efforts, groundwater flowing underneath the Site was divided into six separate zones, as shown in Figure E-12. By creating these six zones, each zone could be approached individually and evaluated based on the applicability for the utilization of different types of construction dewatering techniques.

The flux across each zone is provided in Table E-5. By comparing Figure E-12 and Table E-5, regions with significantly more flow can be identified and designed accordingly.

5.0 CONSIDERATIONS FOR CONSTRUCTION DEWATERING SYSTEM

During the development of the construction dewatering system, several considerations were made, including the following:

- Seasonal groundwater fluctuations;
- Inadequate materials stability;
- Effectiveness of a cutoff wall (sheet piling);
- Efficiency of dewatering wells;
- Number and location of dewatering wells;
- Removal of groundwater storage;
- Winter operations;
- Quantity of water requiring treatment;
- Quantity of water requiring sediment removal; and
- Sequence of tailings excavation.

In particular, during the groundwater model setup and evaluation of the dewatering system, it was observed that two of these conditions within the Site increase the difficulty of the construction dewatering effort. These conditions are the seasonal groundwater fluctuations and inadequate materials stability. In the design of the construction dewatering system, seasonal groundwater fluctuations were accounted for through year-round pumping and by including additional pumping capacity in the system. Inadequate materials stability have been accommodated through minimizing open excavations to the tailings removal itself, and utilizing "closed" dewatering techniques such as dewatering wells and cutoff walls. Additional details on these conditions have been provided below.

5.1 SEASONAL GROUNDWATER FLUCTUATION

Changing seasons at the Site provide significant changes in groundwater flow and elevation, and are a large consideration in the construction dewatering design. Due to the large quantities of snowfall received in the winter, the rapid melting of snow in the spring, and the location of the Site in the upper part of the Soda Butte Creek drainage, groundwater fluctuation at the Site typically vary from 12 to 15 feet. To accommodate this extra volume, the construction dewatering design has been set up to accommodate fluctuating groundwater volumes.

The primary method of accommodating seasonal groundwater fluctuation is through the year-round pumping of groundwater. Historically groundwater elevations have started to rise at the beginning of April and begin to steadily decline in August and September.

5.2 INADEQUATE MATERIALS STABILITY

As mentioned previously, the stability of the saturated tailings are poor, and therefore, the utilization of dewatering trenches has been ruled out. In addition to the poor stability of the tailings, the material located to the southwest of the Site has very poor saturated stability, and therefore this location is also a poor candidate for a dewatering trench.

Another area where materials stability is of primary concern is in the area downgradient of the tailings dam. Materials in this area are highly saturated from seeps along the toe of the tailings dam, and also excavation in this area is not recommended until the majority of the Site is dewatered and a significant portion of the material removed from the area behind the tailings dam. Because this area will likely be drier as a result of the construction dewatering effort, it is recommended that this area be dewatered and excavated after the tailings behind the tailings dam have been removed.

5.3 EFFECTIVENESS OF A DEWATERING TRENCH

Two locations exist at the Site where the material stability appears to be appropriate and a dewatering trench would be highly effective. The first location is at the northeast portion of the Site where the creek flattens out significantly, and the second location is downstream of the tailings dam, where the installation of dewatering wells does not appear to be feasible.

The first location evaluated for a dewatering trench, at the northeastern portion of the Site, appeared to be ideal because of its location just downgradient of where significant quantities of water are lost by Soda Butte Creek during high flow conditions (MGMB, 1975). These losses are thought to occur because the original Soda Butte Creek channel historically existed at this location, and it is likely that high flow from the current Soda Butte Creek infiltrates to the original channel and subsequently flows directly underneath the Site. Cutting off this additional flow would significantly reduce the quantity of groundwater that would have to be pumped from within the tailings.

Through the evaluation of the dewatering trench, it was determined that this would be a very effective location. The alluvium present at this location is very conductive and the trench could likely be constructed to be deep enough to intercept most of the losses from Soda Butte Creek during high flow conditions.

The drawback to constructing a dewatering trench in this location is that it will occupy a significant amount of space in a construction area that is already space-constricted. In addition, the hazard of having a deep trench that will be partially filled with groundwater is significant, both from the perspective of a construction site and one of the main haul roads passing nearby to the dewatering trench. The close proximity to Cooke City, where residents may advertently or inadvertently enter the trench (wherein significantly different groundwater depths will be encountered, along with potential ice conditions) is also very hazardous.

Based on the space requirements of the construction site and the relative hazard posed by constructing a dewatering trench at this location, it was instead decided to evaluate alternate dewatering methods, including a cutoff wall and dewatering wells.

The second location evaluated for a dewatering trench is at the toe of the tailings dam. This location was considered for a dewatering trench because it is very wet during almost all times of the year, the ability to construct dewatering wells in this location is poor, and almost all of the groundwater flowing underneath the Site also flows through this location.

During the evaluation of dewatering this location, it appears to be beneficial to leave the excavation of these tailings toward the end of that work. Dewatering the Site should have some effect on drying this area out for at least a portion of the year. In addition, it was recommended that the water from the treatment and settling ponds not be discharged upstream of this location, so as not to pump the same water twice. Based on this evaluation, it is recommended that once the southern portion of the Site is dewatered and subsequently removed, dewatering will be initiated through the construction of a dewatering trench by deepening the main seep drainage located at the toe of the Site tailings dam. Deepening the main seep drainage into a dewatering trench and excavating a sump at the east terminus of the trench (at the same location where the main seep currently daylights from the tailings dam), the groundwater gradient in this area would effectively be reversed, and the losses from Soda Butte Creek to the dewatering trench would be minimized. In this manner, groundwater can be effectively captured in this area and circulated through the treatment and settling ponds before being discharged to Soda Butte Creek. Because the dewatering trench will be located in an existing seep, flows entering the dewatering trench from Soda Butte Creek during high flow conditions may need to be restricted. To limit these contributions of surface water from Soda Butte Creek, it is recommended that the trench be appropriately protected from accumulating additional surface water flows through the installation of a protective dike, plug, or other appropriate measure.

5.4 EFFECTIVENESS OF A CUTOFF WALL (SHEET PILING)

Because of inadequate material stability for dewatering trenches, the next best option is the installation of a cutoff wall (sheet piling) with associated dewatering wells located upgradient of the cutoff wall. In evaluating the Site, two locations were evaluated for locating a cutoff wall, and one location was selected.

5.4.1 Northeast Portion of McLaren Tailing Abandoned Mine Site

The first location evaluated for a cutoff wall is at the northeast portion of the Site, at the same location evaluated for a dewatering trench. This first location was previously evaluated (BOR, 1990) for alluvial sediment depth and content. In this investigation, three boreholes (DH89-1, DH89-1, and DH89-3) were drilled to the alluvium/bedrock contact. All of the boreholes encountered somewhat different materials, and the depth to bedrock along this alignment was determined to range from 36.2 feet to greater than 50 feet. The materials intercepted by these three boreholes ranged from tailings to "silt with sand" to boulders approximately 2.6 feet in diameter.

Based on the evaluation, it was decided that the construction of a cutoff wall at this first location would not be cost effective and the relative effectiveness would be questionable. The location would not be cost effective because of the excessive and unknown depth to bedrock (>50 feet) and also the large cobbles and boulders present would increase the difficulty of installation. The general effectiveness of the cutoff structure would likely be significantly reduced by the uneven bedrock surface and the large cobbles and boulders present in the alluvium. The uneven bedrock surface would not allow the cutoff wall to fully contact the bedrock and would leave large gaps underneath the cutoff wall for groundwater to flow through. The large boulders would also limit the depth to which the cutoff wall could be installed, and could even cause an inadvertent breach in the seams of the cutoff wall. For these reasons, a cutoff wall was removed from consideration at this location and the primary method of groundwater removal was left to dewatering wells.

5.4.2 Southwest Portion of McLaren Tailing Abandoned Mine Site

The second location evaluated for a cutoff wall is at the southwest portion of the Site, just to the south of the treatment and settling ponds. Even though the groundwater model indicated that this area could be effectively dewatered with wells alone, four additional considerations required that this location be evaluated as a candidate for a cutoff structure. These considerations include the following:

1. Significant quantities of water coming from this hillside;
2. Relatively shallow alluvial depth at this location that would likely limit the effectiveness of dewatering wells alone;
3. Necessity to excavate tailings at this location before the treatment and settling ponds were constructed;
4. Structural requirement that the area underneath the treatment and settling ponds be dry before the ponds were constructed; and
5. Uncertainty as to if the water is emanating from discrete locations, and where there locations might be.

In addition to the above conditions, this location has some advantages that make it more ideal for a cutoff wall than the first location. These location advantages include the following:

1. Relatively shallow depth to bedrock;
2. Significantly easier driving conditions (smaller sediment sizes) than in the northeast portion of the Site; and
3. Ability to key the cutoff wall into the nearby rock outcrop to the west.

Based on these groundwater conditions and location advantages, it was recommended that a cutoff wall be installed at this location in conjunction with a series of upgradient dewatering wells. The length of the proposed cutoff wall is 910 feet and is based upon the apparent length of frequently saturated hillside, as well as incorporating locations of any apparent slumps that may have been caused by seeps and/or excessive spring runoff.

5.5 EFFICIENCY OF DEWATERING WELLS

The dewatering wells at the Site have been separated into two different types, including 30 to 60 gpm wells and 100 to 200 gpm wells. Every aspect of these two different types of wells has been based on the types and depth of alluvium these wells will be completed in and the associated productivity.

5.6 NUMBER AND LOCATION OF DEWATERING WELLS

Four larger 100 to 200 gpm wells will be located along a central east-west axis of the Site. Because these wells will be completed in the original Soda Butte Creek alluvium, the productivity of the alluvium is anticipated to be relatively high and the thickness of the alluvium is anticipated to be 40 to 50 feet. Because the alluvium is so conductive, these four wells will have the most effect on groundwater levels within the Site. One of the larger wells will operate year-round and three of the larger wells will only be operated from early April to the end of December. The effluent from these wells will be treated appropriately.

Approximately 15 smaller wells (30 to 60 gpm) are located around the perimeter of the Site, and are anticipated to be poorer producers. The main reason for the reduced productivity is that they are located in alluvium that is relatively less conductive and also not as thick as the alluvium near the center of the Site. There are significantly more smaller wells because each well is not as productive as the larger wells and the effect of each well is not as wide-reaching as the larger wells. These 15 wells will be effective as a unit in keeping groundwater from entering the Site. Because all of the 30 to 60 gpm wells will be completed on the upgradient boundary of the Site, they are not anticipated to pump contaminated groundwater and will be operational year-round.

5.7 REMOVAL OF STORAGE

Typically, construction dewatering consists of two stages of groundwater removal. The first stage is characterized by an initial higher flow rate which deals with removing the initial storage volume (storage flow rate), and the second stage is characterized by a second, lower flow rate which represents the quantity of groundwater flowing through the aquifer itself (construction flow rate). To accommodate the initial storage flow rate, the Site construction dewatering design has been sized to pump approximately 900 to 1,000 gpm. This additional flow capacity is also necessary for the higher flow rate that is anticipated during runoff conditions from April until July.

Because the storage volume will have to be removed before effective tailings dewatering can occur, it is recommended that for optimal dewatering of the McLaren Tailings, the storage volume be removed only once at the beginning of the project. Following the initial removal of the storage volume, it is recommended that groundwater pumping continue through the winter, and increase to accommodate spring runoff conditions. In this manner, the storage volume is not allowed to build up again during the winter and effective dewatering of the tailings will occur year-round.

5.8 FEASIBILITY OF WINTER OPERATIONS

Winter at Cooke City is characterized by temperatures below freezing and large quantities of snowfall. Because the construction dewatering system will need to be operational at the beginning of April to remove significant amounts of seasonally rising groundwater and the settling ponds would need to be clear of snow and ice during this portion of the year to start operation, it was decided that the system (groundwater dewatering system and settling pond) would be operated year-round.

To operate in the winter, the assumption was made that only the groundwater from the perimeter of the Site would be pumped through the sediment detention ponds. The entire construction dewatering system has been designed with the effort of intercepting as much groundwater as possible before it flows beneath the Site. The groundwater pumped during the winter could be discharged through both sediment detention ponds and allowed to gravity flow to Soda Butte Creek.

Once groundwater begins rising in early April, additional wells within the center of the Site will be activated and the water effectively treated in the already flowing sediment detention ponds. The anticipated timeframe during each construction year that these additional wells would be operated and the effluent water treated would be from early April until the end of December.

Because the construction dewatering system will be operational year round, all of the water pumped by the dewatering wells will need to remain below the frost line until it reaches the dewatering control building and subsequently discharged to the treatment and settling pond. Each dewatering well will need to be set up with a pitless adapter located below the frost line and pipes that cross underneath haul roads will need to be protected from frost by placing sections of blueboard insulation just above the discharge pipeline and the haul road.

An additional benefit of year-round operations is realized in that the alluvium underneath the Site will be dewatered all the time and water in the tailing will have an extended amount of time (approximately 2.5 years) in which to drain.

6.0 EVALUATION OF CONSTRUCTION DEWATERING DESIGN UTILIZING THE GROUNDWATER MODEL

The groundwater model was utilized to evaluate and optimize the Construction Dewatering Design. To assist in the evaluation, the list of considerations developed in Section 5.0 and a set of 14 criteria were developed to assess the efficiency, cost effectiveness, and feasibility of each design (Table E-6).

The Construction Dewatering Design was evaluated and optimized by configuring the components of the design within the groundwater model, including the location, depth, and pumping rate of each groundwater dewatering well, and the location, efficiency, and length of the cutoff wall. The components were then evaluated with a three-year simulation to determine the ability of the design to effectively dewater the tailings.

The following text provides the evaluation of the 60% Construction Dewatering Design. Components of this evaluation include the following: a set of 14 criteria to assess the efficiency, cost-effectiveness, and feasibility; a summary of four iterations conducted to evaluate and optimize the Construction Dewatering Design; the recommended Construction Dewatering Design; and a proposed sequence of tailings excavation.

6.1 CRITERIA FOR EFFICIENCY, COST EFFECTIVENESS, AND FEASIBILITY

To guide the evaluation and optimization of the Construction Dewatering Design, a set of 14 criteria were developed to rate the relative efficiency, cost effectiveness, and feasibility of the design, as follows:

1. What is the quantity of groundwater pumped during winter and summer operations?
2. Does groundwater need to be treated during winter operations?
3. How much groundwater needs to be treated during summer operations?
4. Does the design violate any of the considerations for the Construction Dewatering System (Section 5.0)?
5. What is the possibility of a portion of the tailings not being effectively dewatered?
6. How much reserve capacity is available for groundwater treatment and sediment settling?
7. Does the design contain expectations for conditions that have not been confirmed by site investigations?
8. What is the potential for the system freezing during winter operations and what are the consequences?
9. How easily can the system be adapted to the growing size of the tailings excavation and the shrinking size of the groundwater dewatering system?
10. Can portions of the system be shut down without shutting down the entire dewatering system?
11. Does the system account for localized dewatering deeper pockets of saturated tailings?
12. How well does the system account for heterogeneous conditions, including localized seeps and upwelling groundwater?

13. Can a cost-effective substitution be made for any of the physical components?
14. Does the system rely too heavily on any one component that if it fails, will shut down the entire dewatering system?

6.2 EVALUATION AND OPTIMIZATION OF THE CONSTRUCTION DEWATERING DESIGN

Because the primary goal of the Construction Dewatering Design is to dewater the groundwater tailings, changes to the Construction Dewatering Design first considered site-specific conditions and then modifying a portion of the design to more effectively meet the 14 criteria for efficiency, cost-effectiveness, and feasibility.

The Construction Dewatering Design utilizes a series of dewatering wells, one cutoff wall, and a dewatering trench and sump added at the toe of the tailings dam.

6.2.1 Design Simulations

To evaluate and optimize the Construction Dewatering Design, a series of four simulated designs have been utilized. Each of the simulated designs utilize common design elements, including larger dewatering wells near the center of the Site, smaller wells around the edges, a cutoff wall located along the southwestern boundary, and a dewatering trench and sump for dewatering below the tailings dam. A complete summary of each design simulation has been provided in Table E-6 and a summary of the primary differences between each simulated design is provided in the following text.

In addition to the total quantity of water produced from the Construction Dewatering Design, the effect of varying pumping rates during the summer and winter were evaluated. As determined from the design simulations, it was determined that year-round pumping was most effective at lowering the groundwater elevation in the tailings.

6.2.1.1 Design Simulation 1

Design Simulation 1 focused on one large set of four dewatering wells located in the middle of the Site and one small set of five dewatering wells paired with a cutoff wall located along the southeastern edge of the Site. The total winter and summer pumping rate of Design Simulation 1 is 550 gpm, with 400 gpm from within the tailings. Advantages of this design are simplicity (small number of wells) and a low pumping rate. Limitations of Design Simulation 1 are the requirements for treatment during the wintertime, incomplete dewatering of the tailings, and poor ability to adapt to undocumented point water and dewater localized tailings pockets. For these reasons, the design was further optimized in Design Simulation 2.

6.2.1.2 Design Simulation 2

Design Simulation 2 modifies Design Simulation 1 with two of the four larger wells taken offline in the winter and a cluster of five smaller wells added in the northeast quadrant of the tailings. The total summer pumping rate of Design Simulation 2 is 700 gpm, with 400 gpm from within the tailings. This rate is reduced in the wintertime to 500 gpm with 200 gpm from within the tailings. Advantages of this design are lower winter treatment rate, decreased the reliance on the set of four large dewatering wells located in the middle, and better ability to adapt to undocumented point water sources and dewater localized tailings pockets. Because this design still requires treatment for 200 gpm of groundwater in the wintertime, the design was further optimized in Design Simulation 3.

6.2.1.3 Design Simulation 3

Design Simulation 3 modified Design Simulation 2 with three of the four larger wells taken offline in the winter with one in operation and a cluster of five smaller wells added in the north central quadrant of the tailings. The total summer pumping rate of Design Simulation 3 is 850 gpm, with 400 gpm from within the tailings, and reduced to 400 gpm in the winter with 100 gpm requiring treatment. Advantages of this design are lower winter treatment rate, decreased the reliance on the set of four large dewatering wells located in the middle, and better ability to adapt to undocumented point water sources and dewater localized tailings pockets. Because this design still requires treatment for 100 gpm of groundwater in the wintertime, the design was further optimized in Design Simulation 4.

6.2.1.4 Design Simulation 4

Design Simulation 4 modified Design Simulation 3 with all larger central wells taken offline in the winter, one of the smaller wells in the northeast quadrant converted to a larger capacity well (150 gpm), and one larger sized well (60 gpm) added in the east quadrant of the Site. The total summer pumping rate of Design Simulation 4 has been increased to 930 gpm, while the volume from within the tailings is approximately 300 gpm. Pumping volumes in the wintertime have been increased by 50 gpm to 450 gpm with no water requiring treatment. Advantages of this design are no winter treatment requirement, a significant decrease in the reliance on the set of the large dewatering wells located in the middle (one large central well was removed from the design), and improved ability to adapt to undocumented point water sources and localized tailings pockets. This design fulfills the requirement of eliminating treatment of water in the wintertime, however has added many additional dewatering wells and an additional quantity of clean groundwater must be pumped. Design Simulation 4 appears to be a reasonable balance between no wintertime treatment and increased number of pumping wells.

6.2.2 Conclusions of the Design Simulations

In the evaluation of the Construction Dewatering Design, it was noted that a much greater efficiency is realized when the system operates year-round. This introduces difficulty into the design because treatment of groundwater during the wintertime is a significant expense and also a significant feasibility issue. In order to meet the primary objective and provide the most efficient dewatering system, a secondary objective for the system is to operate during the wintertime and also require no groundwater treatment. The results of the four design simulations demonstrate that operating the dewatering system during the winter without treating the water require increased pumping rates from the perimeter of the Site. By increasing the quantity of water pumped from the perimeter of the Site, Design Simulation 4 was able to reduce the total treated groundwater in the winter to zero, thus meeting the secondary objective.

Because only Design Simulation 4 met the secondary objective, the recommended Construction Dewatering Design is Design Simulation 4. Besides meeting the secondary objective, advantages of this design include a high degree of adaptability in dewatering localized pockets of tailings and accommodate point water sources. Disadvantages of Design Simulation 4 are the increased number of pumping wells. The additional cost to install and maintain the additional pumping wells will likely offset the cost effectiveness of not treating groundwater in the wintertime.

7.0 RECOMMENDED CONSTRUCTION DEWATERING DESIGN

The recommended Construction Dewatering Design, based on Design Simulation 4 in the previous section, is shown on Figure E-13.The layout of the Construction Dewatering Design consists of a total of 19 wells, one cutoff wall, and one dewatering trench and sump. To take advantage of site-specific conditions, a series of larger wells have been designed to pump from 60 to 200 gpm and a series of smaller wells have been designed to pump approximately 30 gpm. The anticipated flow rate for each of the 19 wells has been provided on Figure E-13.

7.1 SUGGESTED SEQUENCE OF PHASED DEWATERING AND TAILINGS EXCAVATION

Based on the results of the groundwater model, the Construction Dewatering Design for the Site would be most effective with a three-phase approach to divide the dewatering effort into defined stages of sequential tailings dewatering and removal. This sequence allows for lengthy dewatering of some of the more difficult areas, and diverts the focus of the initial tailings excavation effort to removing unsaturated tailings or tailings that are readily dewatered.

In Phase 1, the majority of the tailing are dewatered and tailings located within the southern half of the Site would be excavated. Tailings located downgradient of the Site tailings dam toe would not be removed or even dewatered during Phase 1. Once the material behind the Site tailings dam has been suitably dewatered and a significant portion removed, Phase 2 would initiate dewatering and enable the removal of the southern portion of tailings located downstream of the Site tailings dam. It appears to be advantageous to delay Phase 2 because the area below the Site dam is typically very saturated and difficult to work in. By allowing Phase 1 dewatering to operate, this area may become drier and subsequently more workable.

After the completion of Phase 2, Soda Butte Creek would be relocated to its new location. With the creek moved downgradient of these tailings, the losses from the existing Soda Butte Creek channel will not contribute water to the remaining tailings located along the northern boundary of the Site (just to the south of the existing Soda Butte Creek). By waiting until Soda Butte Creek is relocated, these tailings should be easier to dewater and the excavation efficiency of these tailings should improve.

The proposed sequence of tailings excavation is outline on Sheet 12 of the Construction Drawings in Appendix G of this McLaren Tailings Abandoned Mine Site Reclamation Design Report.

Excavation as outlined will provide the fully saturated tailings the maximum amount of time available to dewater and the tailings along the northern portion of the Site will be excavated after Soda Butte Creek has been moved to its restored location.

8.0 REFERENCES

Barnes, 1987. Roughness Characteristics of Natural Channels.

BOR, 1994. Response Action Report for the McLaren Tailings Site, Cooke City, Montana.

BOR, 1990. Subsurface Exploration for the McLaren Tailing Site, Cooke City, Montana.

MBMG, 1975. MBMG-23 Final Report, Acid Mine Drainage Control – Feasibility Study, Cooke City, Montana.

MBMG, 1999. Hydrogeology of the upper Soda Butte Creek Basin, Montana Bureau of Mines and Geology: Report of Investigation 7. 1999.

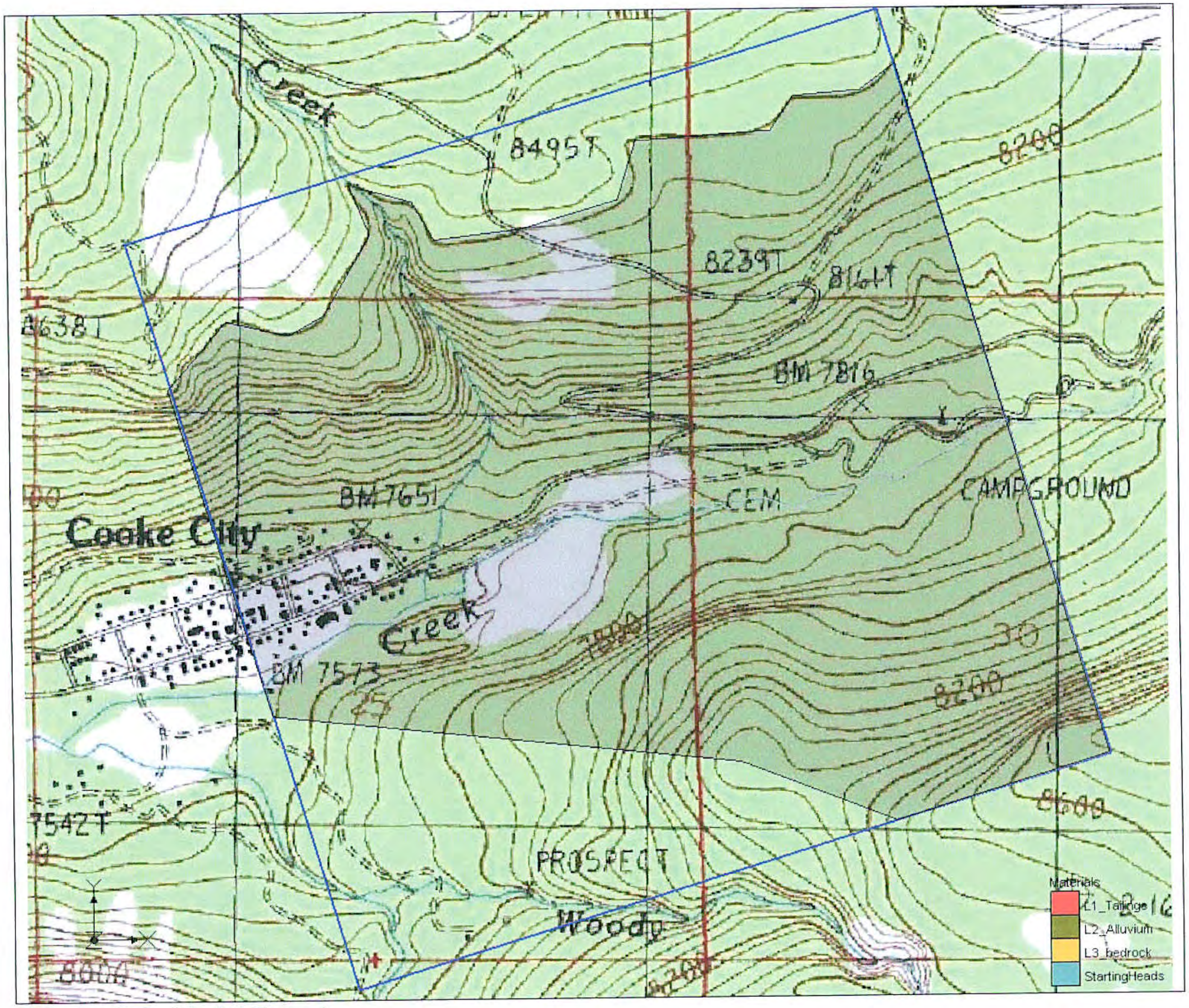


Figure E-1: Model Extent

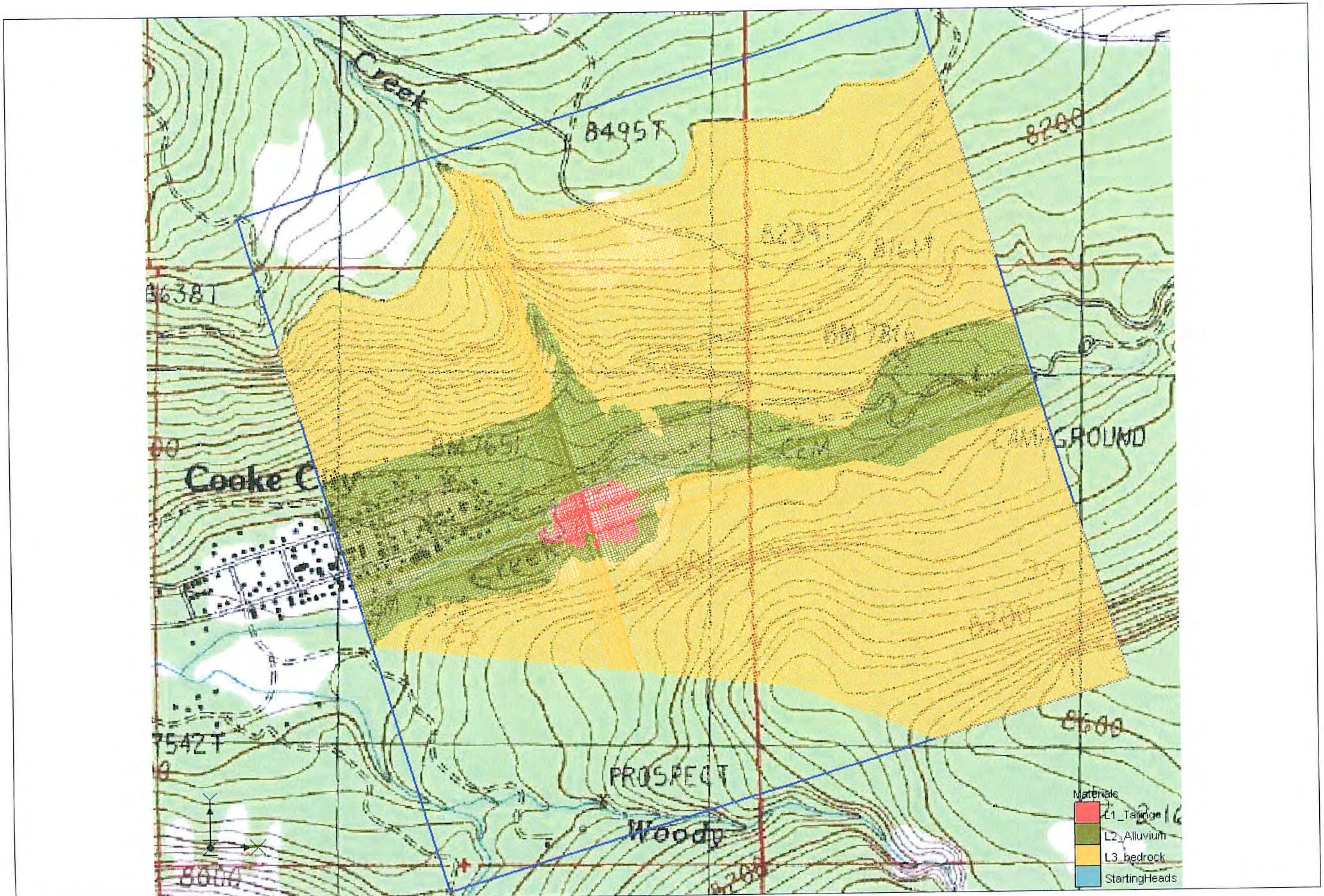


Figure E-2: Map View, Model Grid and Material Layers

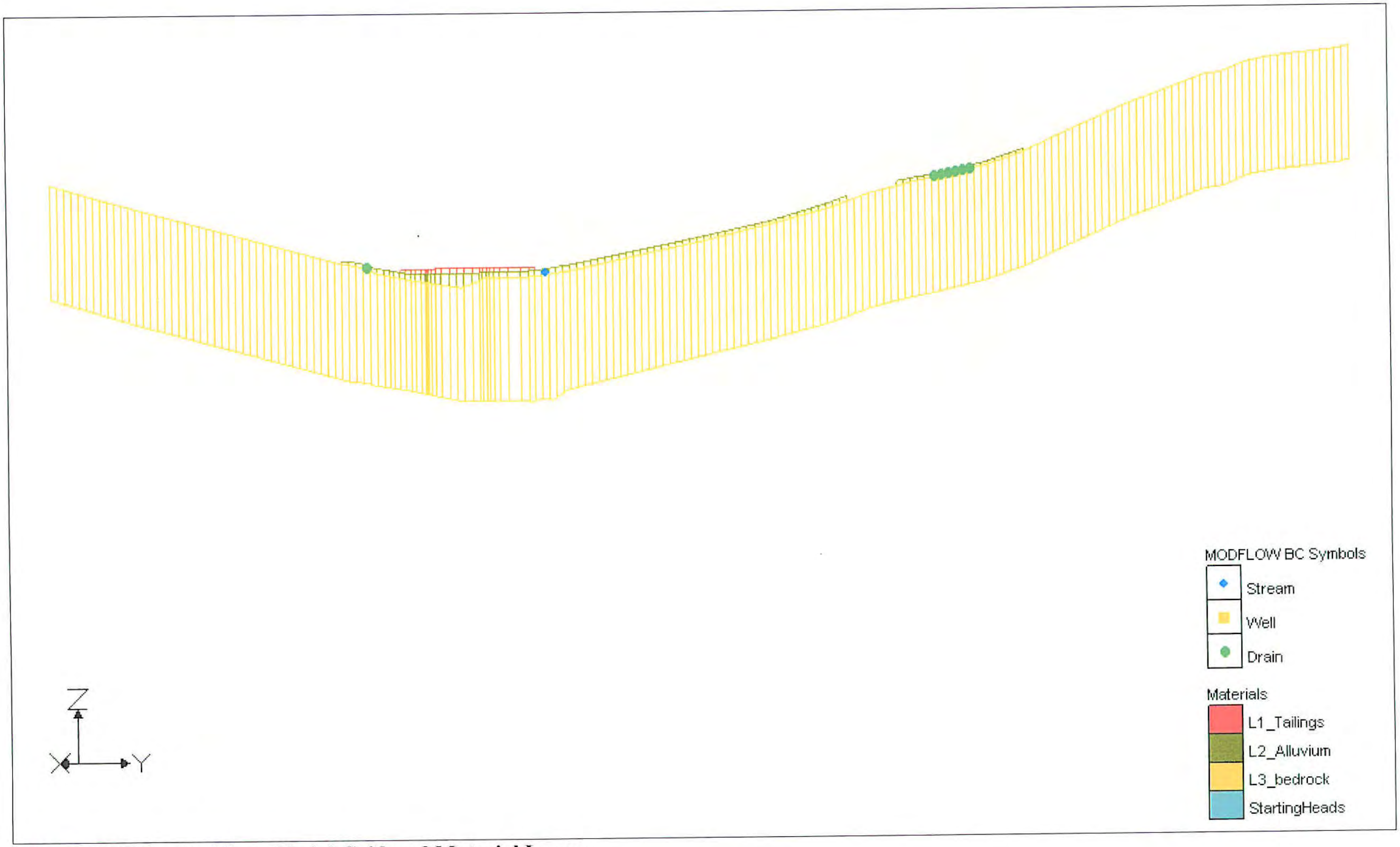


Figure E-3: Profile View, Model Grid and Material Layers

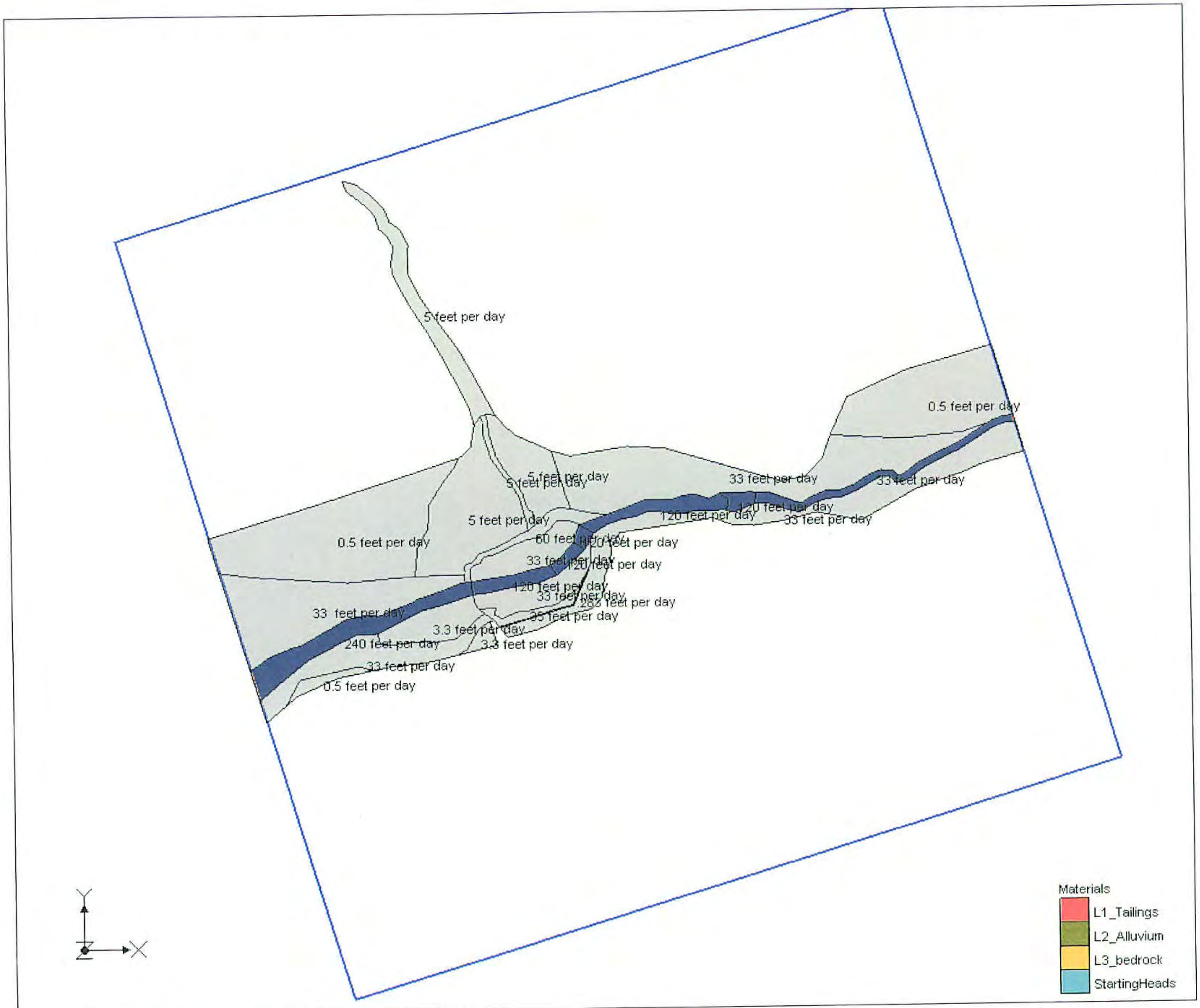


Figure E-4: Layer 2 Hydraulic Conductivity

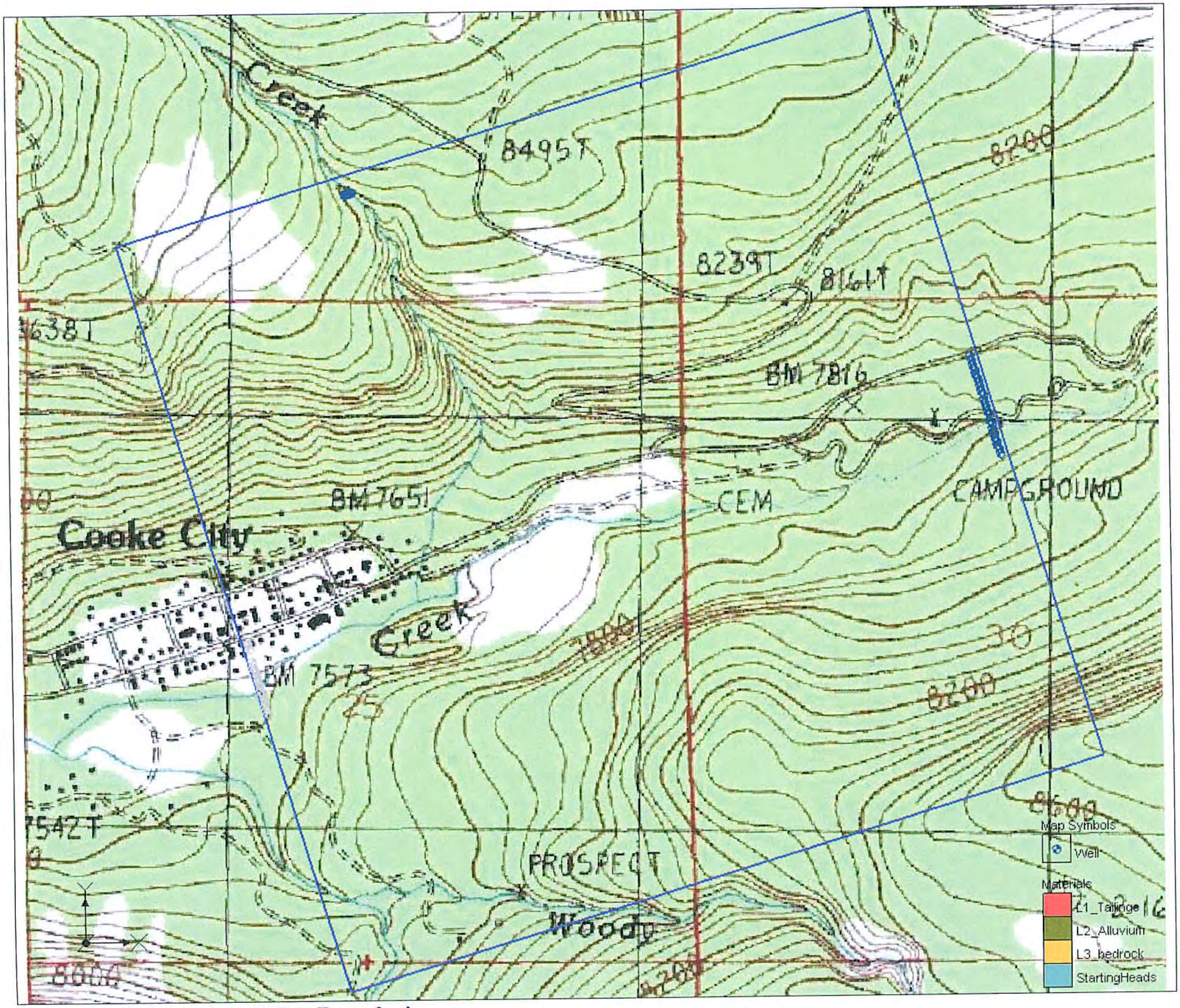


Figure E-5: Location of Flux Boundaries

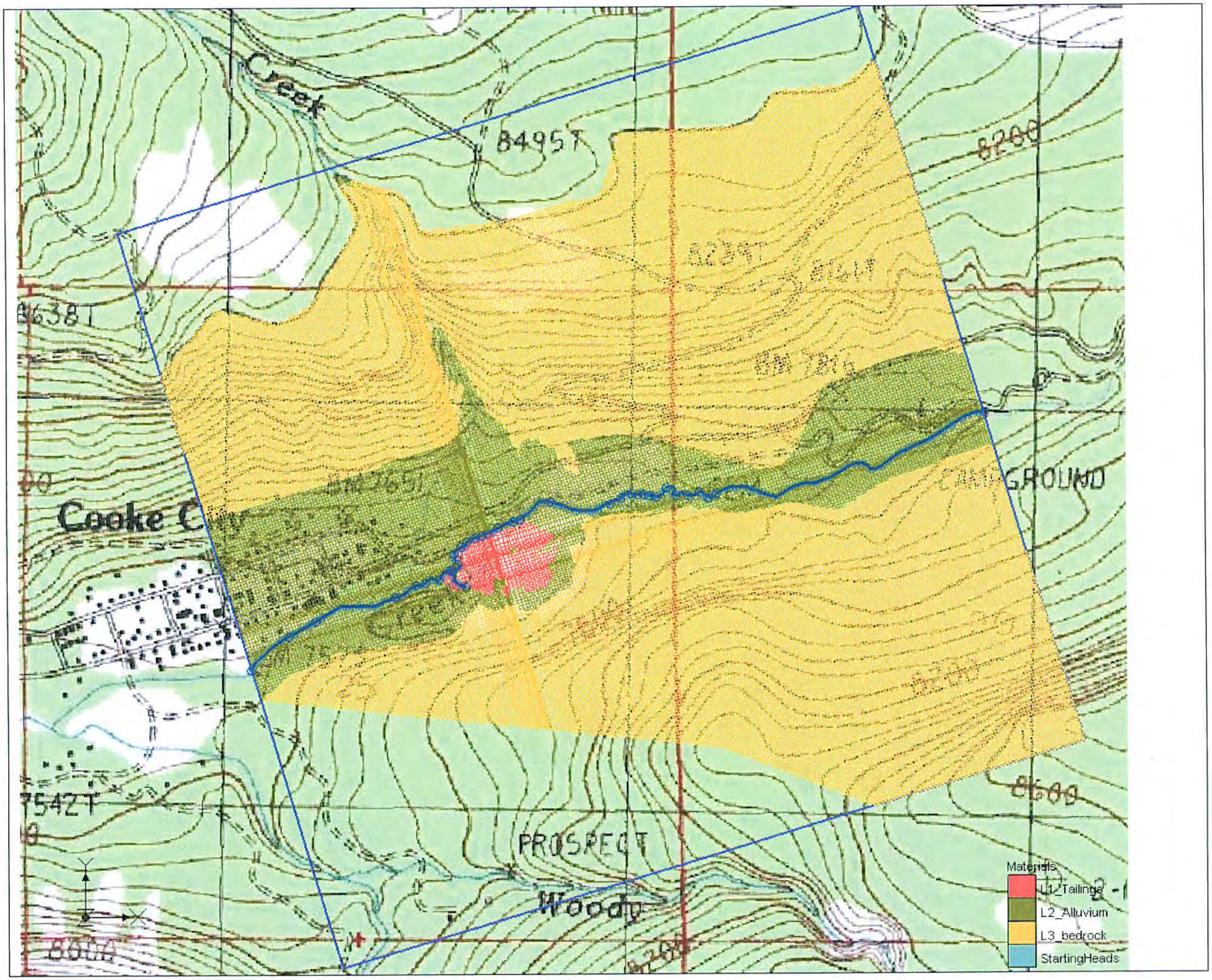


Figure E-6: Soda Butte Creek

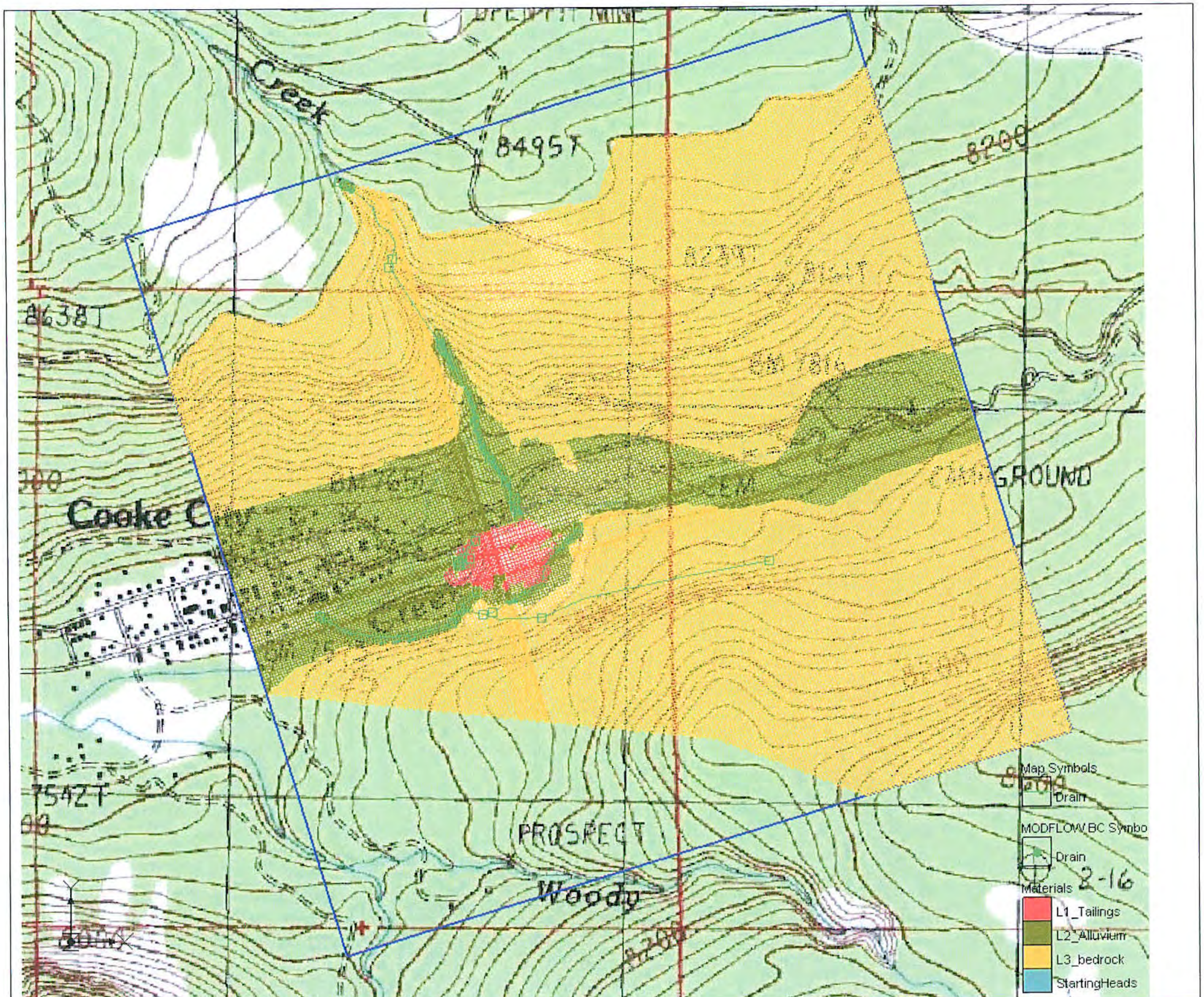


Figure E-7: Drains

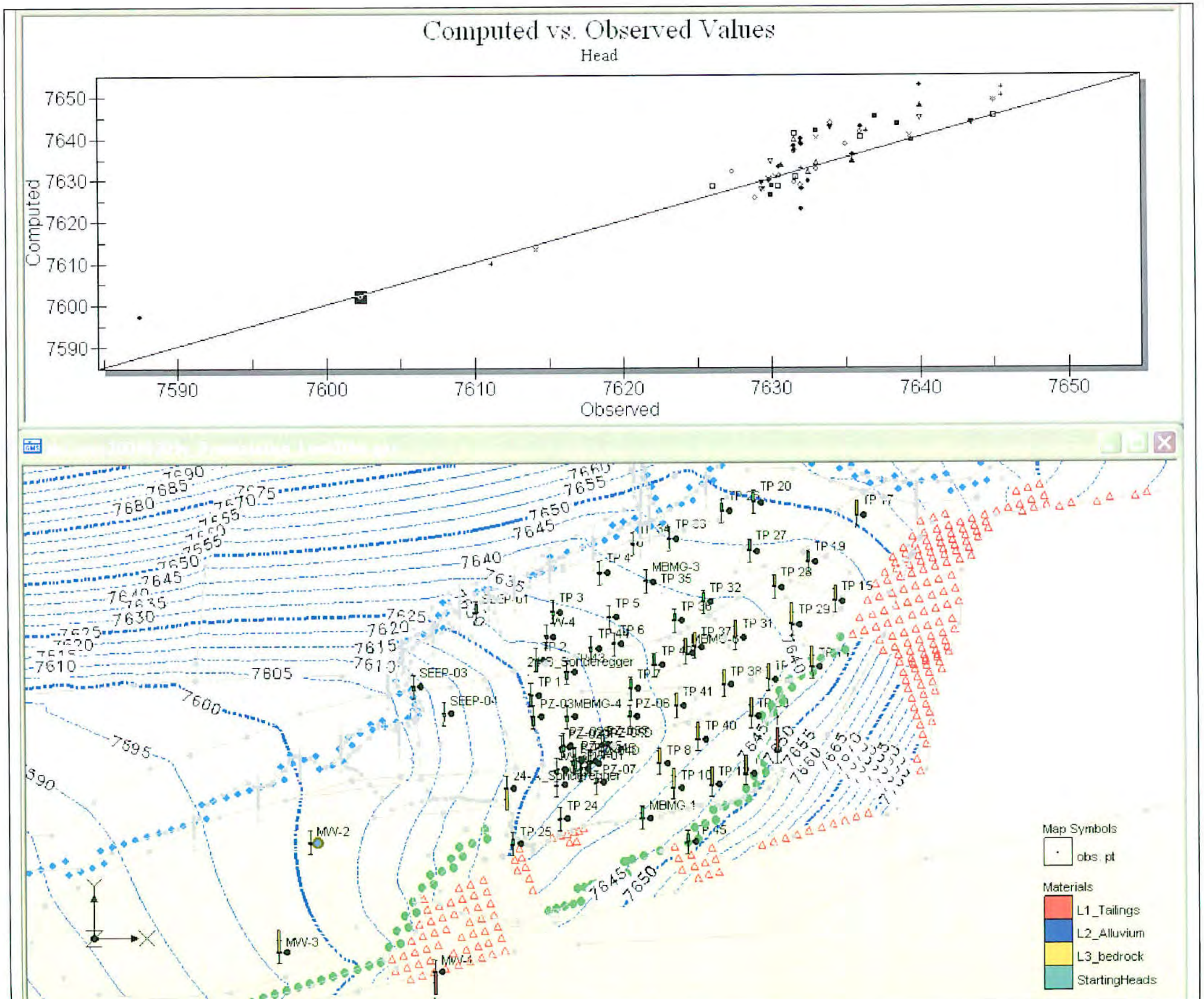


Figure E-8: Groundwater Head Calibration

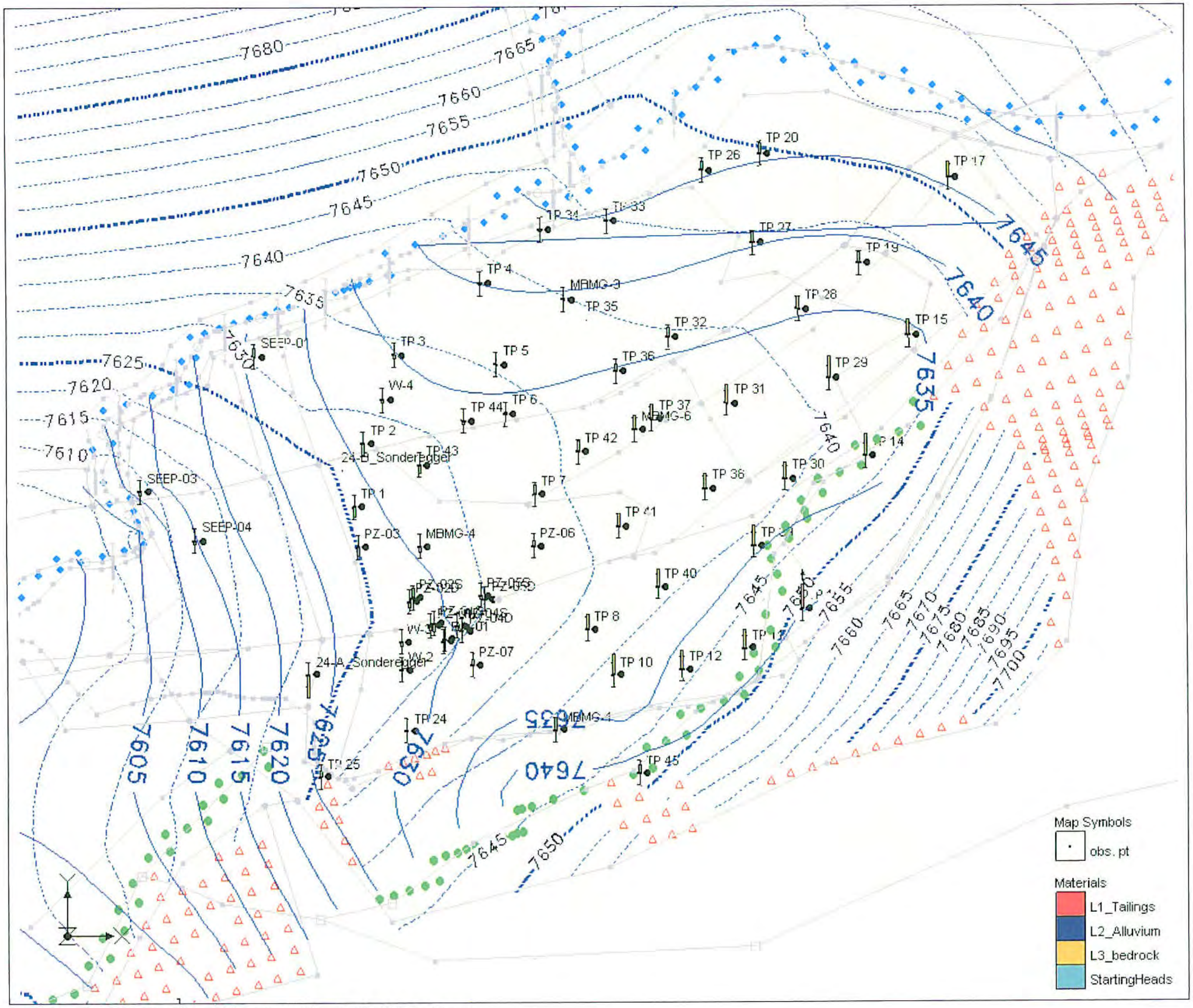


Figure E-9: Hydraulic Gradient Calibration

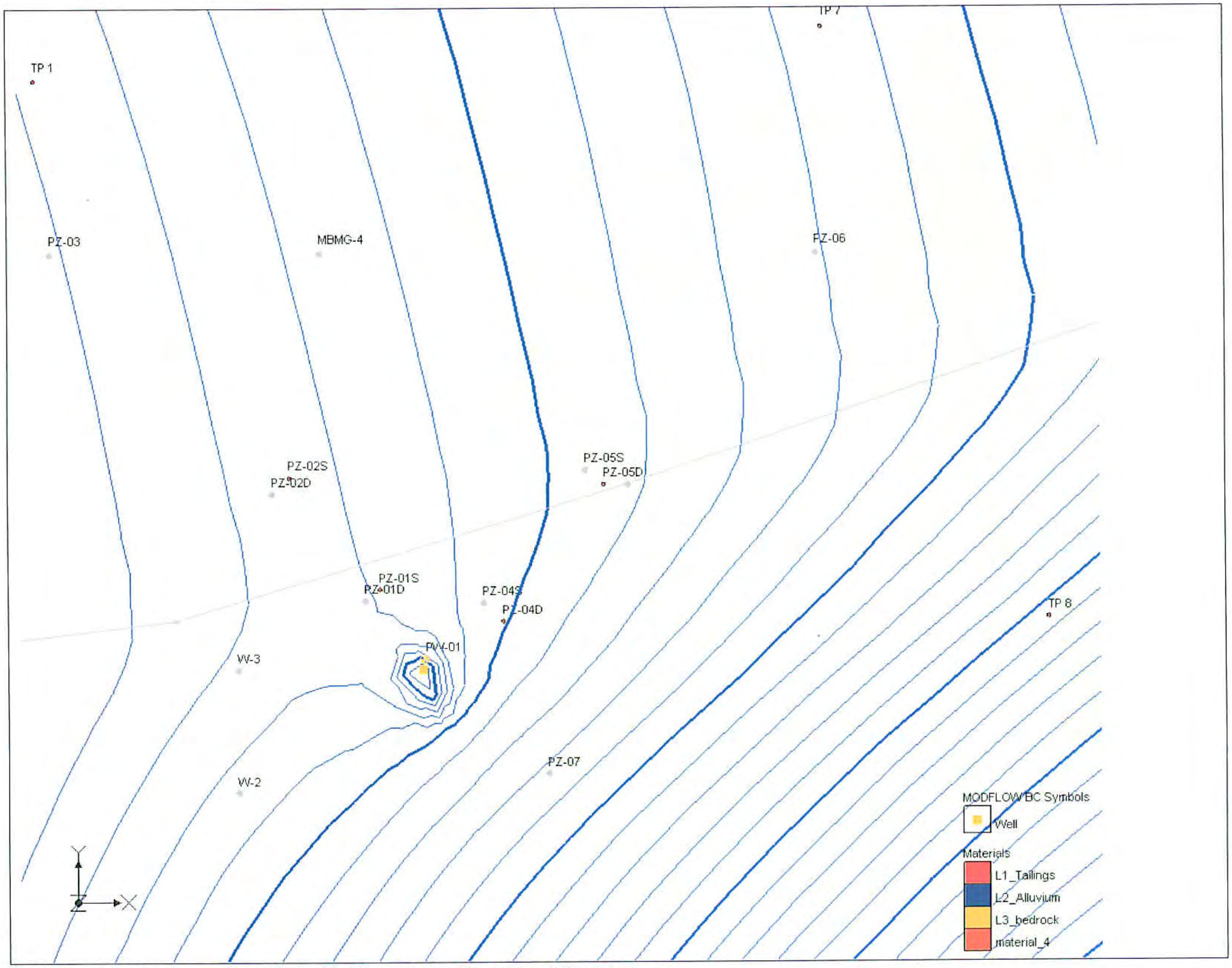


Figure E-10: Pumping Test Calibration, One-Foot Contours

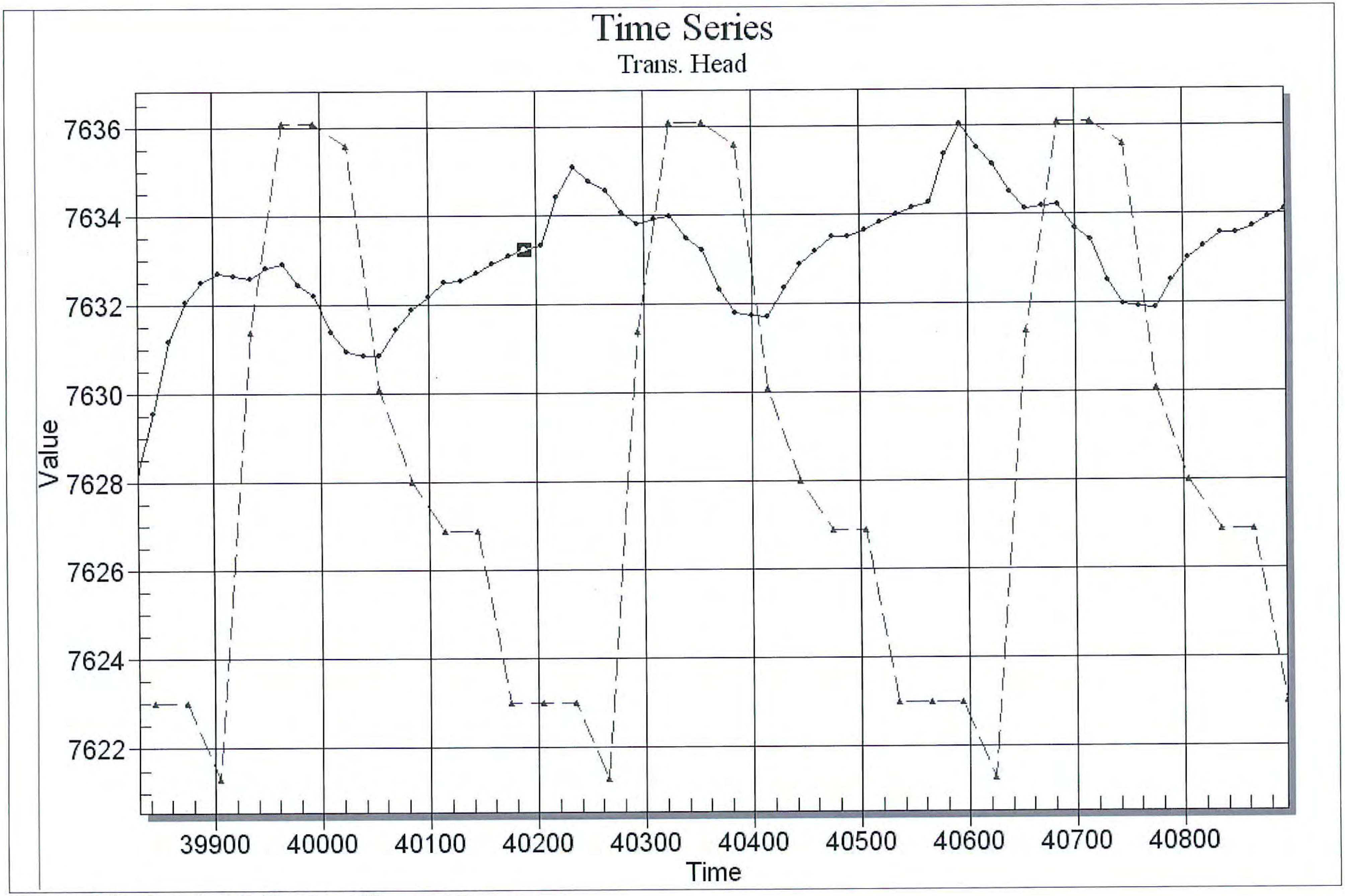


Figure E-11: Transient Calibration of Seasonal Response

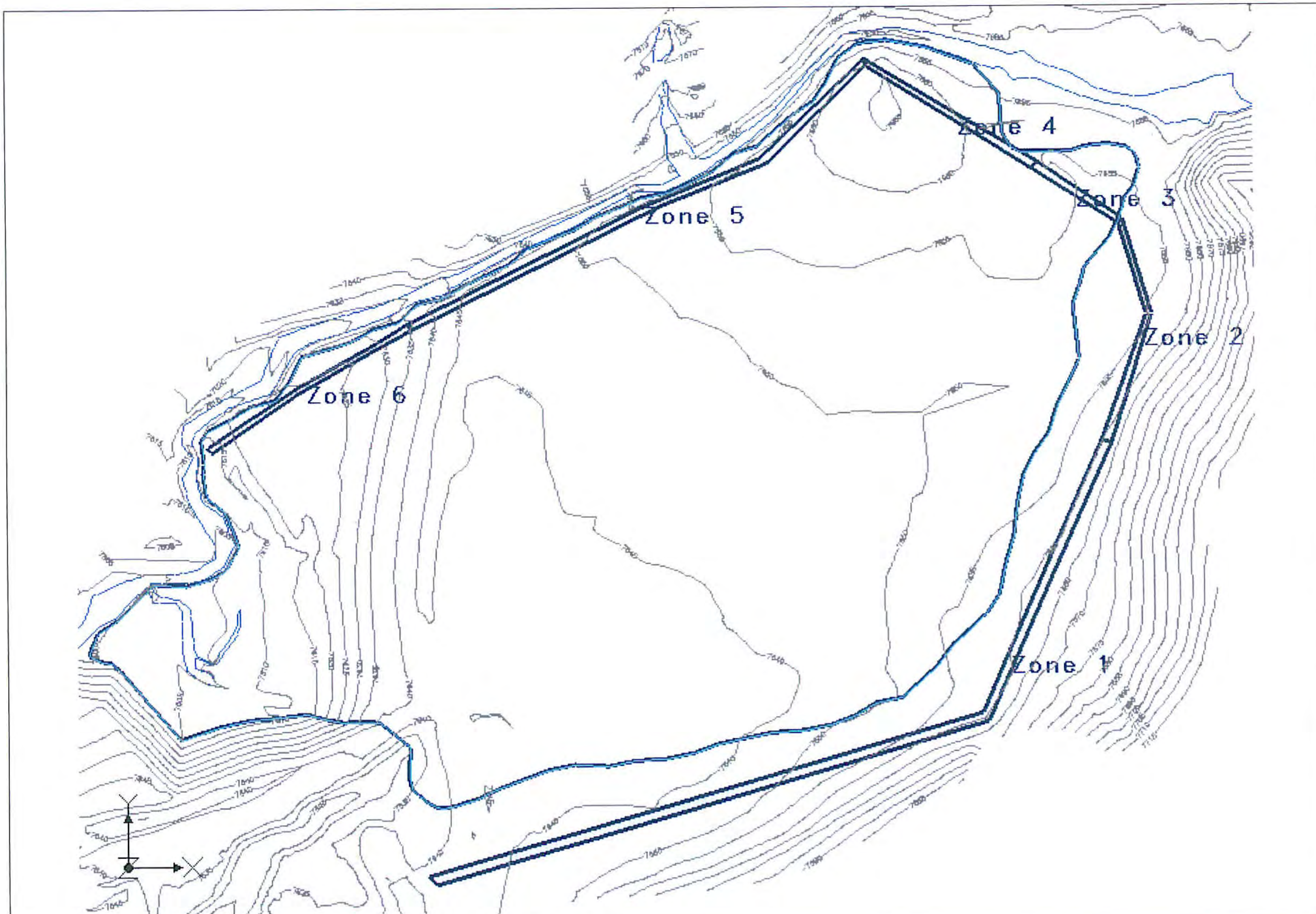
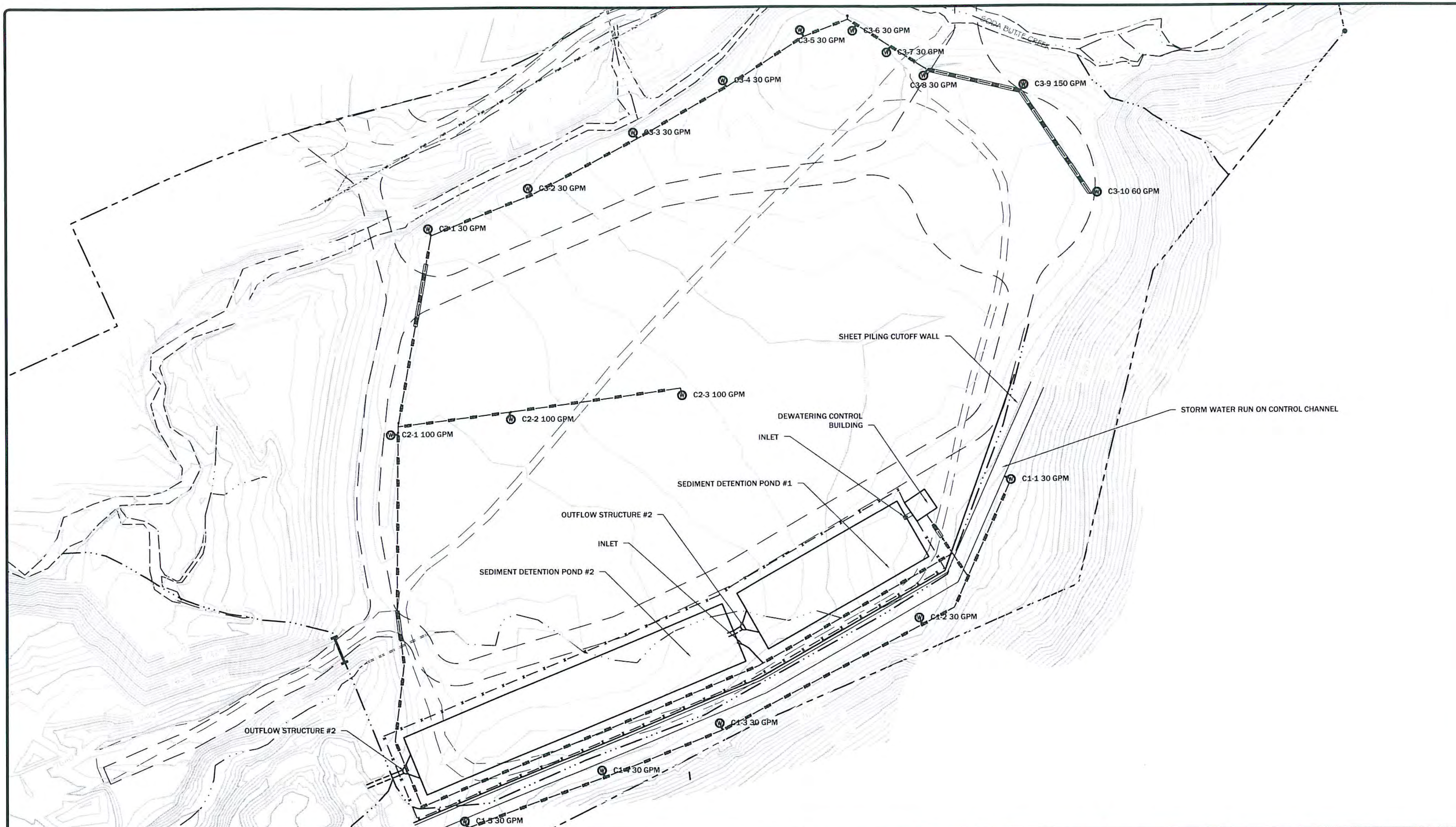


Figure E-12: Six Groundwater Flux Zones, McLaren Tailings



N

PROJECTION: TRANSVERSE MERCATOR
ZONE: MONTANA
DATUM: MSP NAD83 NAVD88
UNITS: FEET
SOURCE: PIONEER

SCALE IN FEET
0 50 100

FIGURE E-13

CONSTRUCTION DEWATERING SYSTEM

PIONEER TECHNICAL SERVICES, INC.
Butte, Helena, Anaconda

DATE: 4/15/09

\\Srvw2k\clientdata1$\DEQ\McLaren\2009\Drawings\Figures\Draft Design\MCLAREN-DFT-F106-09.dwg, 4/16/2009 12:12:25 PM

TABLE E-1: McLaren Tailings Abandoned Mine Site Aquifer Parameters

Location	Completion	Parameters for the Alluvial Aquifer				Parameters for the Tailings Aquifer				Fit Quality (Poor, Average, Excellent)
		T (ft^2/day)	b (ft)	K (ft/day)	S (unitless)	T (ft^2/day)	b (ft)	K (ft/day)	S (unitless)	
PW-01*	Both	350	10.5	33	0.00068	0.46	16	0.029	N/A	poor
PZ-01D	Alluvial	351	10.5	33	0.000068	0.32	16	0.020	N/A	excellent
PZ-02D	Alluvial	1177	10.5	112	0.00064	0.04	16	0.0023	N/A	good
PZ-03	Alluvial	1303	10.5	124	0.0039	0.016	16	0.00101	N/A	good
PZ-04D	Alluvial	351	10.5	33	2.8E-06	0.04	16	0.0025	N/A	good
PZ-05D	Alluvial	910	10.5	87	0.000182		16		N/A	good
PZ-06	Alluvial	789	10.5	75	0.0061		16		N/A	good
PZ-07	Alluvial	301	10.5	29	9.5E-06		16		N/A	good
AVERAGE	Alluvial	740		66	0.00146	0.174		0.0065	N/A	
PZ-01S	Tailings	631	10.5	60	N/A	0.072	16	0.0045	0.120	good
PZ-02S	Tailings	1012	10.5	96	N/A	0.072	16	0.0045	0.0128	excellent
PZ-04S	Tailings	839	10.5	80	0		16		0.046	excellent
PZ-05S	Tailings	862	10.5	82	N/A	0.072	16	0.00451	0.0092	good
AVERAGE	Tailings	836		80		0.07		0.0045	0.047	
OVERALL AVERAGE		**775**		**74**	**0.00146**	**0.090**		**0.0056**	**0.047**	

*: Due to the poor fit quality of the pumping well (PW-01), aquifer parameters from this location were not utilized in the overall average.

TABLE E-2: McLaren Tailings Abandoned Mine Site Flux Boundaries

Location	K (ft/day)	Width (ft)	Depth (ft)	area (ft^2)	i	Q (ft^3/day)	Q (gpm)	Number of Wells
East Boundary (Flux In)								
Layer 2	0.5	180	10	1,800	0.27	240	1.2	15
	33	230	10	2,300	0.029	2,219	12	7
	120	65	15	975	0.029	3,421	18	2
Layer 3	0.5	200	400	80,000	0.267	10,667	55	15
	20	200	400	80,000	0.029	46,784	243	15
North Boundary (Flux In)								
Layer 2	5.0	90.0	20.0	1800.0	0.1	1,304	7	7
Total In						**64,635**	**336**	
West Boundary (Flux Out)								
Layer 2	33	200	20	4,000	0.021	2,794	15	3
	33	170	30	5,100	0.021	3,562	19	4
	240	235	48	11,163	0.021	56,698	295	6
Layer 3	0.5	200	400	80,000	0.27	10,667	55	21
	20.0	200	400	80,000	0.029	46,784	243	3
Total Out						**120,504**	**626**	

TABLE E-3: Pumping Test Calibration

	Head Drawdown		Difference
Location	Observed	Computed	Feet
PW-01	6.4	6.86	(0.46)
PZ-01S	0.25	0.59	(0.34)
PZ-01D	2.9	0.66	2.24
PZ-02S	0.41	0.26	0.15
PZ-02D	0.8	0.22	0.58
PZ-03	0.4	0.16	0.24
PZ-04S	0.47	0.86	(0.39)
PZ-04D	2.4	0.96	1.44
PZ-05S	0.34	0.21	0.13
PZ-05D	0.96	0.23	0.73
PZ-06	0.32	0.15	0.17
PZ-07	1.98	0.91	1.07

TABLE E-4: McLaren Tailings Abandoned Mine Site Groundwater Model Budget

	Flux			
	ft^3/3 years	ft^3/1 year	ft^3/day	gpm
IN				
Storage	5,141,127	1,713,709	4,760	25
Constant Head	-	-	-	-
Wells	18,378,758	6,126,253	17,017	88
Drains	-	-	-	-
Recharge	187,207,760	62,402,587	173,341	900
Stream Leakage	7,458	2,486	7	0
Total In	210,735,103	70,245,034	195,125	1,014
OUT				
Storage	1,571,252	523,751	1,455	8
Constant Head	-	-	-	-
Wells	44,248,444	14,749,481	40,971	213
Drains	7,196,629	2,398,876	6,664	35
Recharge	-	-	-	-
Stream Leakage	157,814,480	52,604,827	146,125	759
Total Out	210,830,805	70,276,935	195,214	1,014
In-Out	(95,702)	(31,901)	(89)	(0.46)
Percent Discrepancy	**-0.05%**			

TABLE E-5: Zone Budget

Zone	Construction Phase	Flux* (ft^3/day)	Flux* (gpm)
1	1	31,957	166
2	1	11,166	58
3	1	29,070	151
4	1	15,979	83
5	1	29,840	155
6	2	15,594	81
Total Phase 1		**118,011**	**613**
Total		**133,604**	**694**

* : The volumes provided here are estimates directly from the model and therefore show a level of accuracy that is not realistic to expect during construction dewatering.

TABLE E-6: Simulated Designs

Design	Component	Number of Wells	Location	Pumping Rate (ea) (gpm)		Total Flow Rate (Criteria [C-] 1)		Winter Treatment?	Total Treated Flow Rate (C-3)		Violated any Considerations?	Portion of Tailings not Effectively Dewatered?	Reserve Capacity (Treatment/Sediment Ponds)	Unrealistic Expectations?	Potential for Freezing?	System Adaptability	Portions of System be Shut Down?	Ability to Dewater Localized Tailings Pockets?	Accommodate Point Water Sources?	Cost Effective Substitutions?	System Rely on One Component too Heavily?
				Summer	Winter	Summer	Winter	(C-2)	Summer	Winter	(C-4)	(C-5)	(C-6)	(C-7)	(C-8)	(C-9)	(C-10)	(C-11)	(C-12)	(C-13)	(C-14)
1	Large Wells	4	Central	100	100																
	Intermediate Wells	-		-	-																
	Small Wells	5	Southwest	30	30																
	Cutoff Wall		Southwest			550	550	Yes	400	400	Yes- Winter Ops	Yes- north	400/950	Yes- winter ops	Low	Fair (along central wells)	Yes (central wells)	Poor	Southwest - excellent All other locations - poor	Yes - Winter Ops very costly, look at reducing treated winter water to 0	Yes- central wells are key to majority of dewatering
2	Large Wells	2	Central	100	100																
		2	Central	100	-																
	Intermediate Wells	-		-	-																
	Small Wells	5	Southwest	30	30																
		5	Northeast	30	30																
	Cutoff Wall		Southwest			700	500	Yes	400	200	Yes- Winter Ops	Yes- north-central	400/800	Yes- winter ops	Low	Good (along central and northeast wells)	Yes (central wells and northeast wells)	Fair	Southwest - excellent Northeast - good All other locations - poor	Yes - Winter Ops very costly, look at reducing treated winter water to 0	Yes- central wells are less important, but still vital to majority of dewatering, but less so than Design 1
3	Large Wells	1	Central	100	100																
		3	Central	100	-																
	Intermediate Wells	-		-	-																
	Small Wells	5	Southwest	30	30																
		5	North	30	30																
		5	Northeast	30	30																
	Cutoff Wall		Southwest			850	550	Yes	400	100	Yes- Winter Ops	No	400/650	Yes- winter ops	Low	Very Good (along central and northeast wells)	Yes (central wells and north wells)	Good	Good to Excellent	Yes - Winter Ops very costly, look at reducing treated winter water to 0	Yes- central wells decreasing in importance, but still critical during winter operations.
4	Large Wells	1	Northeast	150	150																
		3	Central	100	-																
	Intermediate Wells	1	East	60	60																
	Small Wells	5	Southwest	30	30																
		5	North	30	30																
		4	Northeast	30	30																
	Cutoff Wall		Southwest			930	630	Yes	450	0	No	No	350/570	No	Low	Very Good (along central and northeast wells)	Yes (central wells and north wells)	Good	Good to Excellent	Treatment during winter eliminated through the addition of many wells. Appears to be a cost-effective solution	System can effectively dewater during baseflow conditions without treating water. Central wells vital during summer operations.

Criteria:

1. What is the quantity of groundwater pumped during winter and summer operations?
2. Does groundwater need to be treated during winter operations?
3. How much groundwater needs to be treated during summer operations?
4. Does the design violate any of the considerations for effective groundwater dewatering design (Section 7 2 3 4)?
5. What is the possibility of a portion of the tailings not being effectively dewatered?
6. How much reserve capacity is available for groundwater treatment and sediment settling?
7. Does the design contain expectations for conditions that have not been confirmed by site investigations?
8. What is the potential for the system freezing during winter operations and what are the consequences?
9. How easily can the system be adapted to the growing size of the tailings excavation and the shrinking size of the groundwater dewatering system?
10. Can portions of the system be shut down without shutting down the entire dewatering system?
11. Does the system account for localized dewatering deeper pockets of saturated tailings?
12. How well does the system account for heterogeneous conditions, including localized seeps and upwelling groundwater?
13. Can a cost-effective substitution be made for any of the physical components?
14. Does the system rely to heavily on any one component that if it fails, will shut down the entire dewatering system?

APPENDIX F

TECHNICAL SPECIFICATIONS