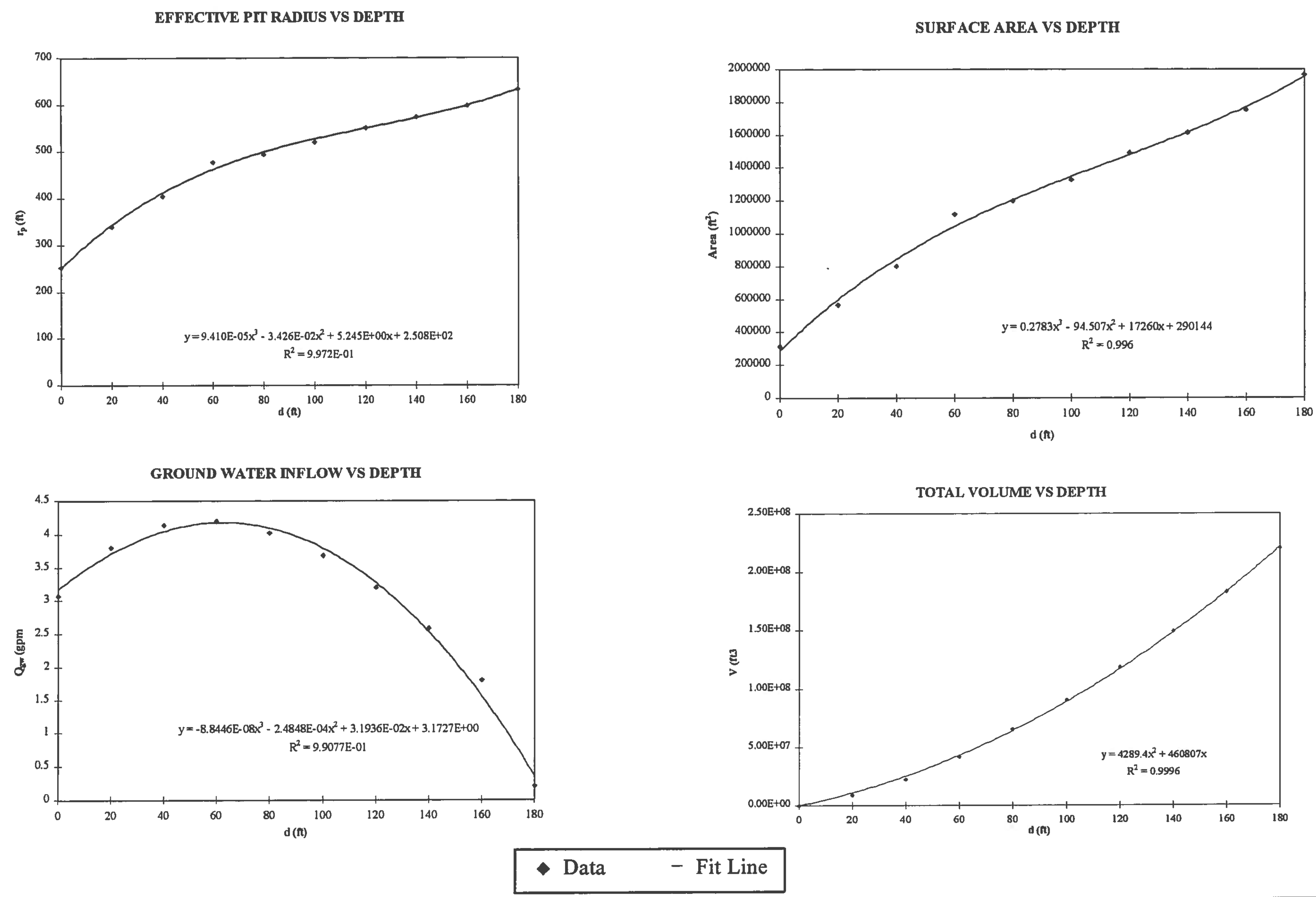

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FIGURE E4-1
POLYNOMIAL RELATIONSHIPS OF PIT RADIUS, AREA, VOLUME, AND GROUND WATER INFLOWS AS A FUNCTION OF DEPTH FOR THE NON-EXPANDED CONTINENTAL PIT

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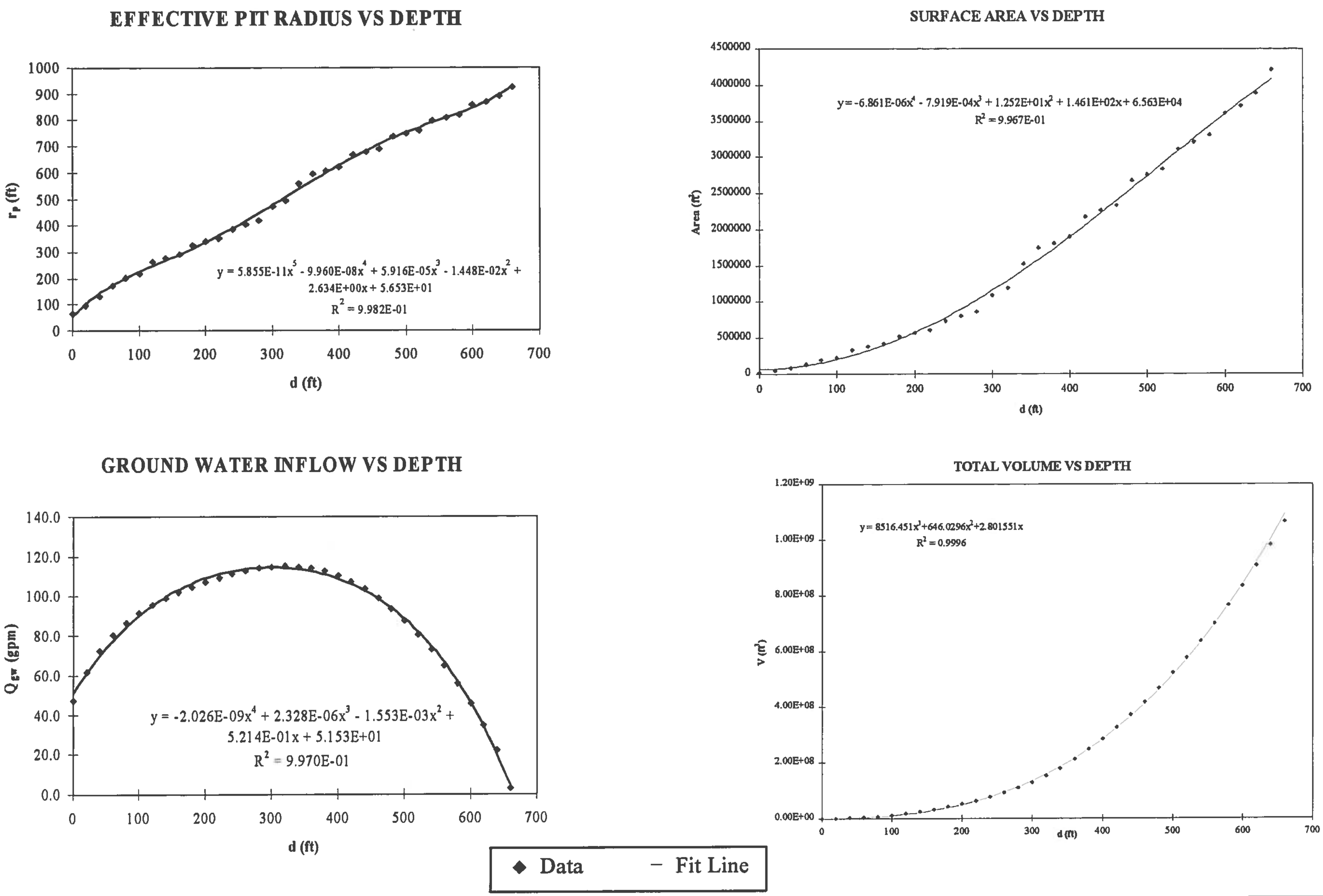

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FIGURE E4-2
POLYNOMIAL RELATIONSHIPS OF PIT RADIUS, AREA, VOLUME, AND GROUND WATER INFLOWS AS A FUNCTION OF DEPTH FOR THE EXPANDED CONTINENTAL PIT

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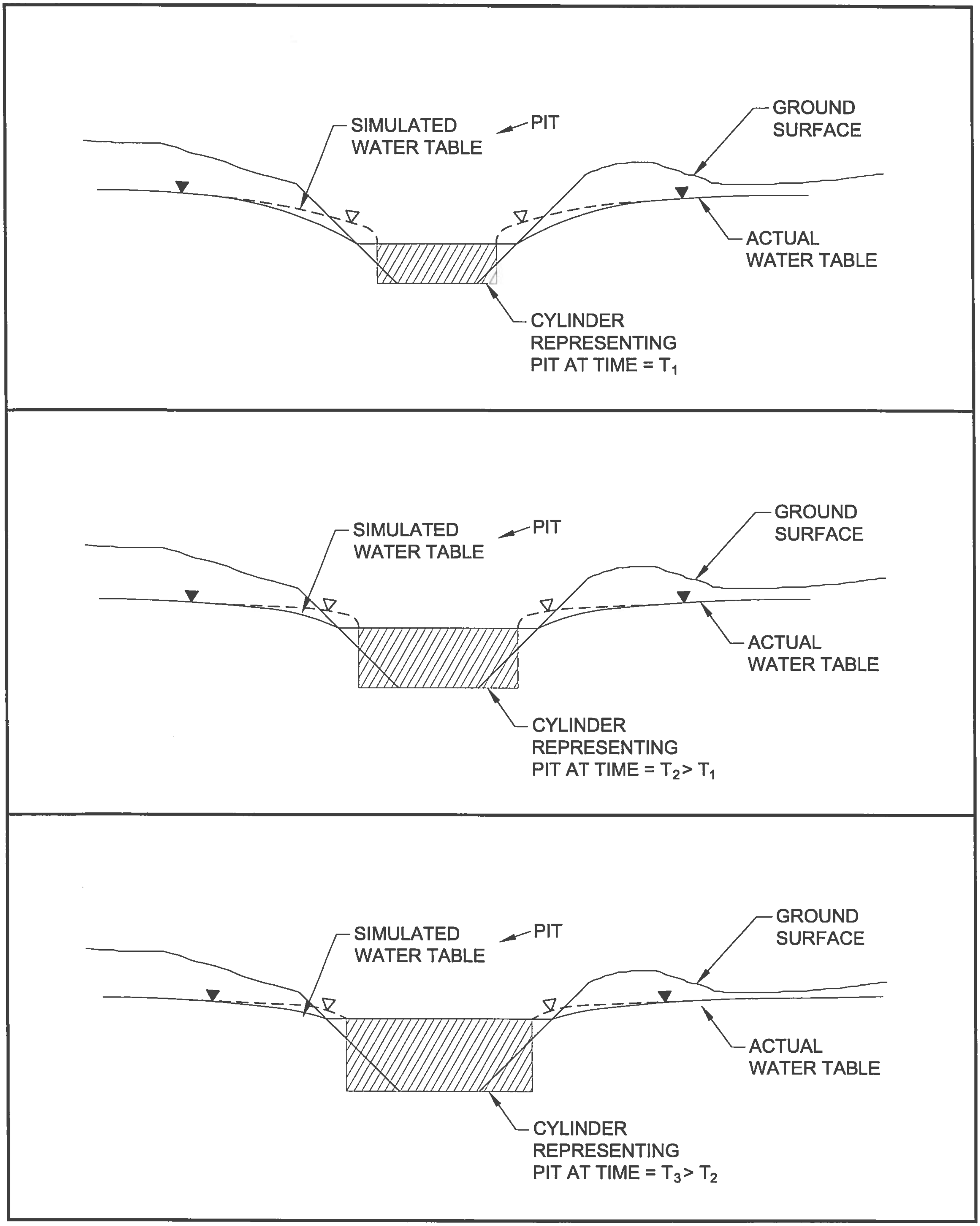

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FIGURE E4-3
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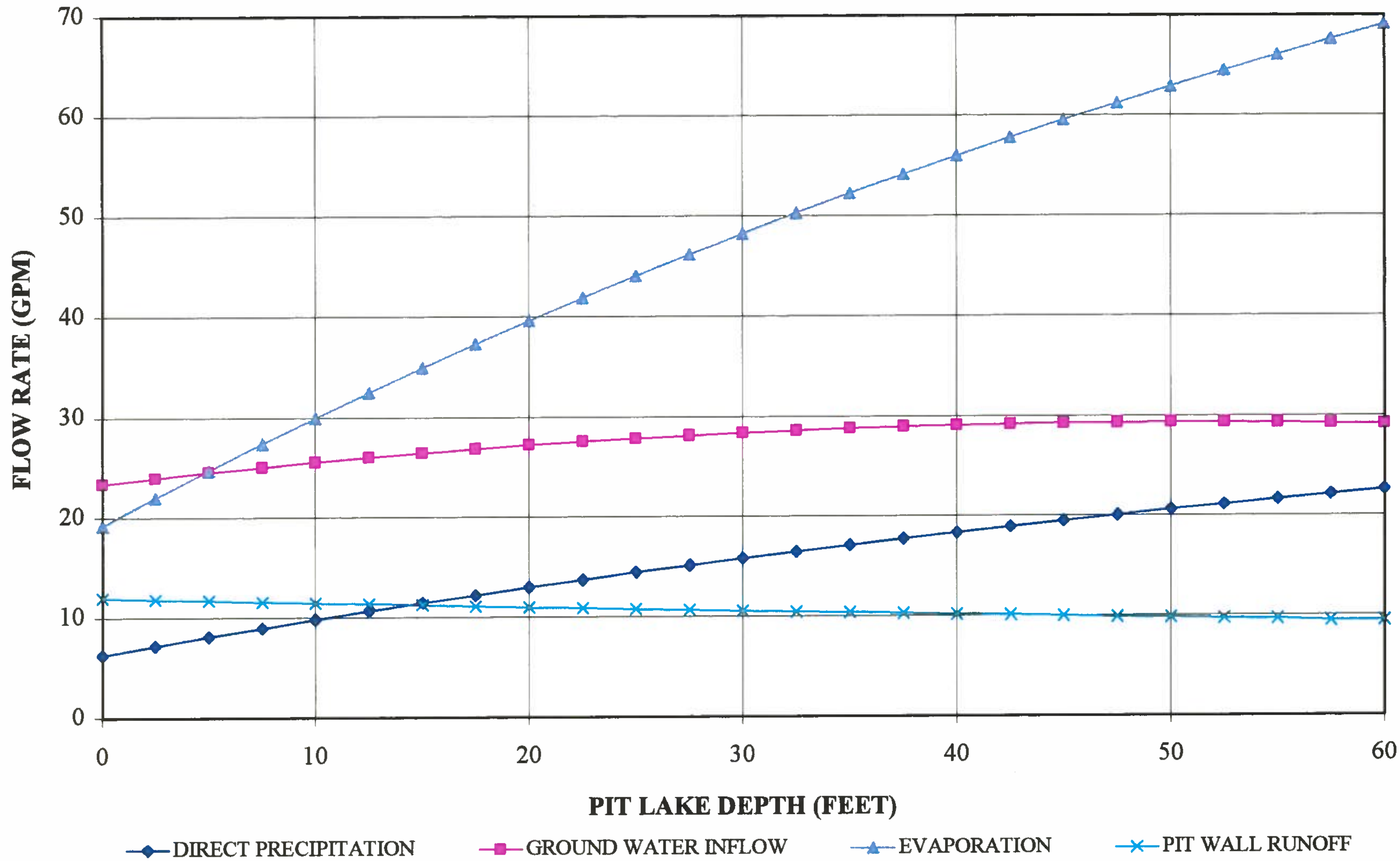

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FIGURE E4-4
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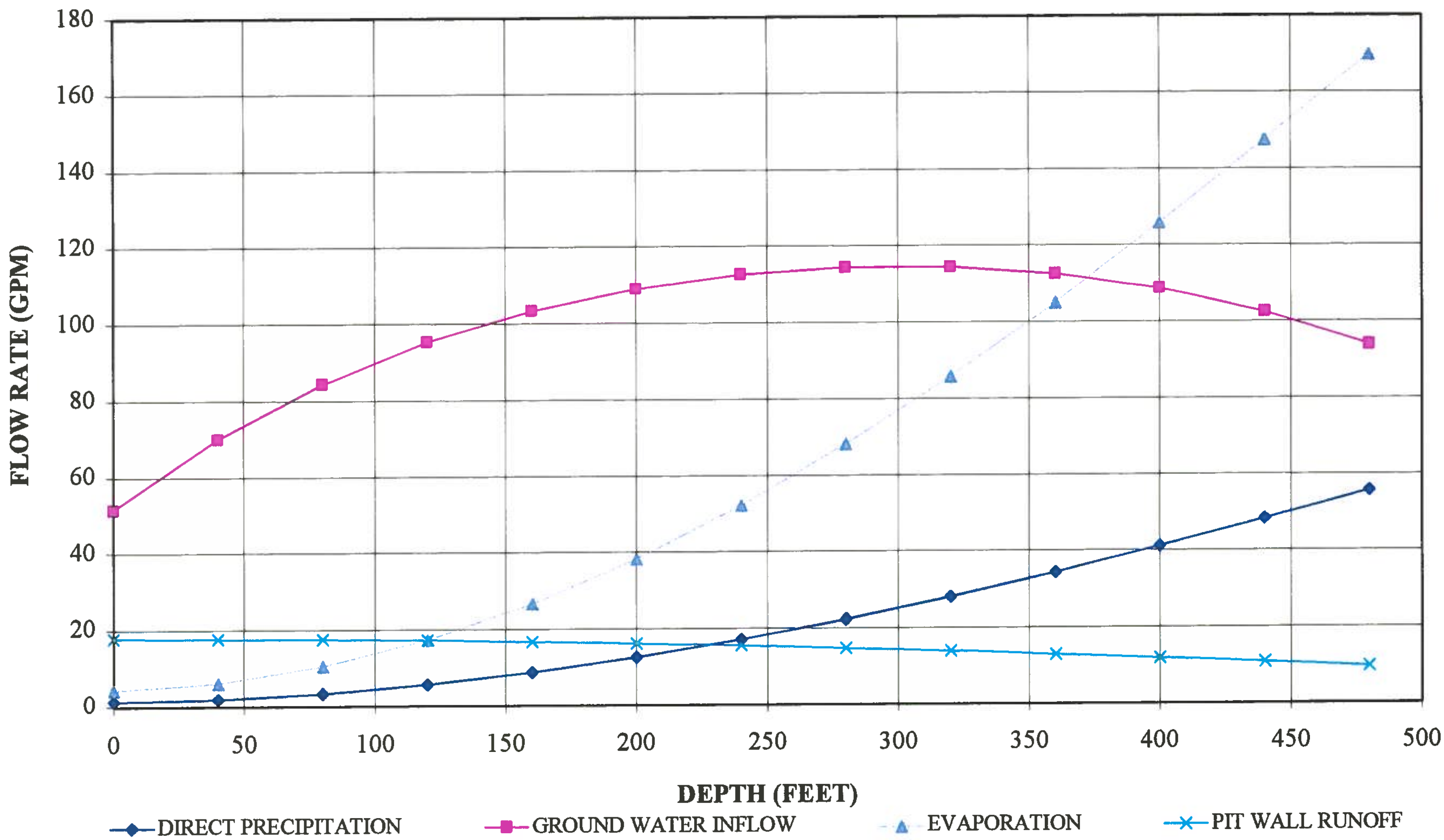

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FIGURE E4-5
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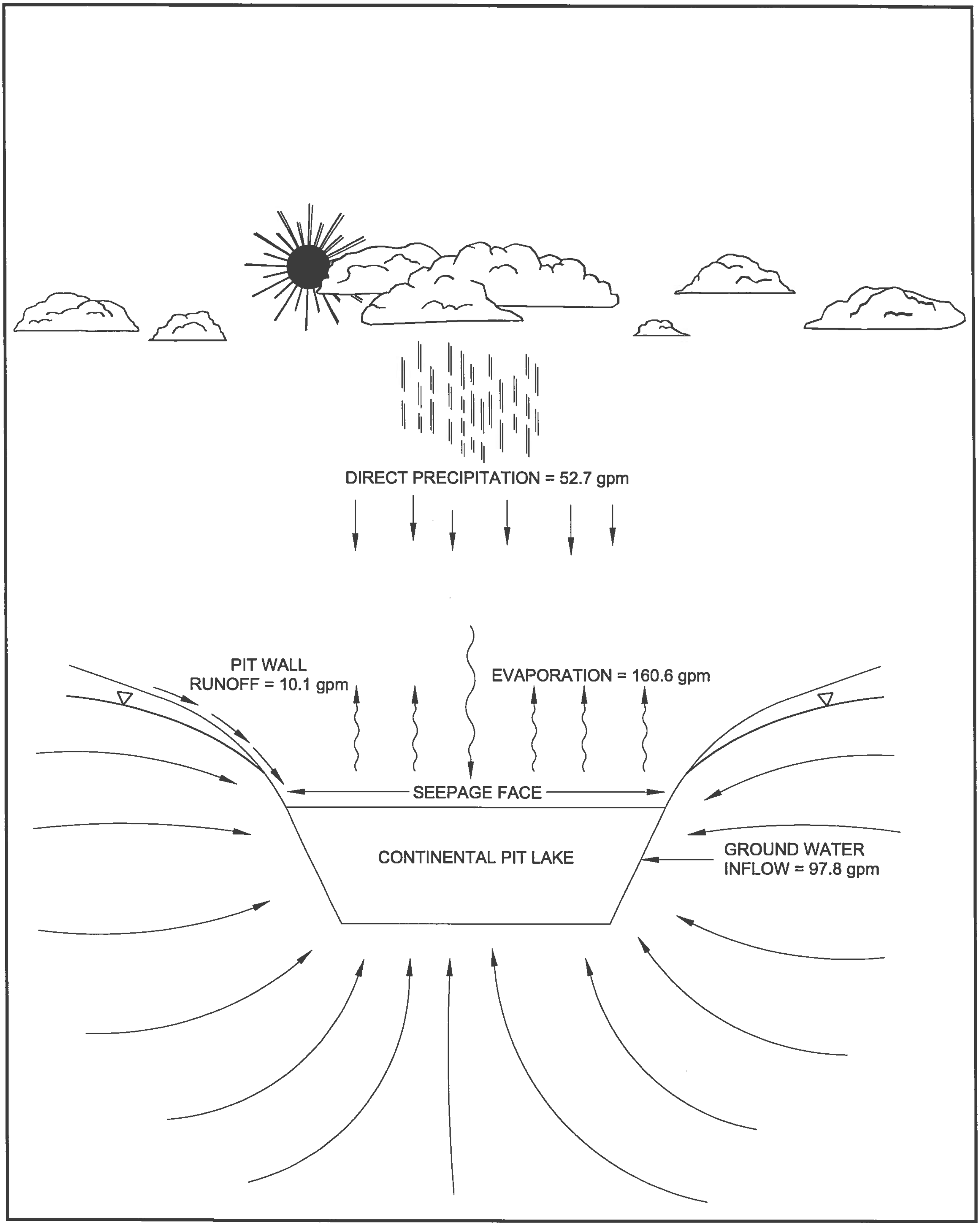

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FIGURE E4-6
CONTINENTAL PIT LAKE
WATER BALANCE AT STEADY STATE

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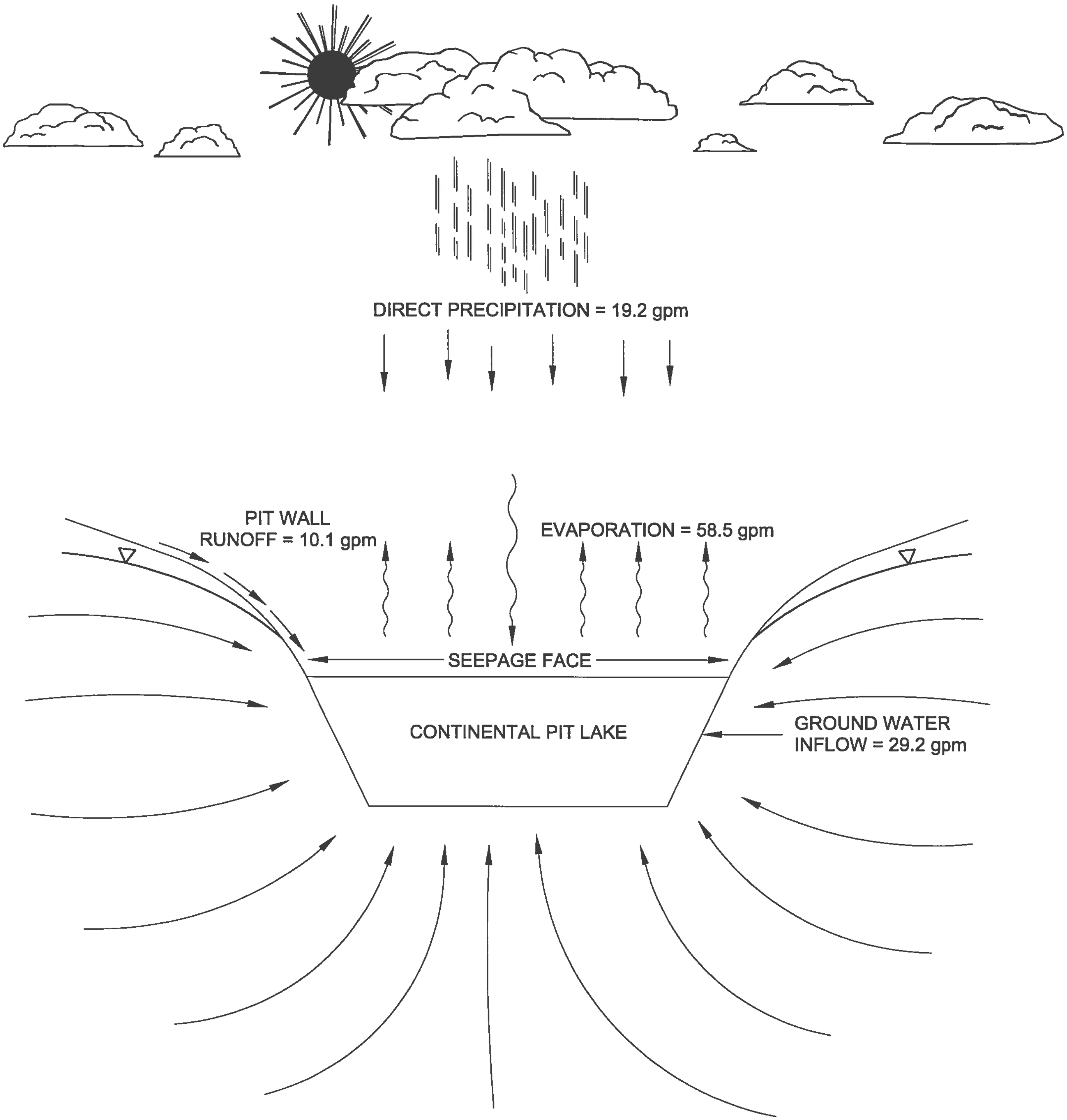

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FIGURE E4-7
EXPANDED CONTINENTAL PIT LAKE
WATER BALANCE AT STEADY STATE

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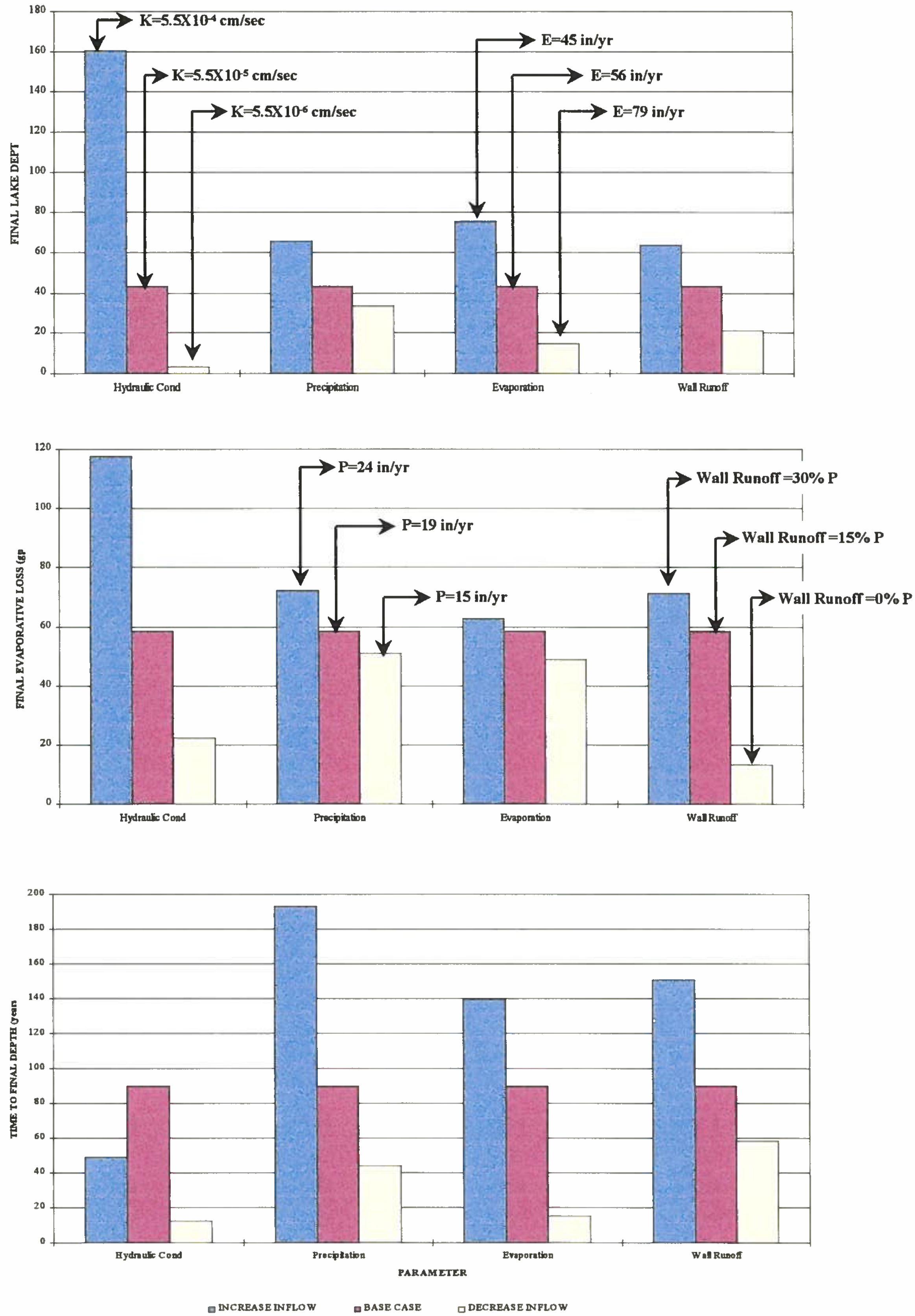

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ATTACHMENTS TO APPENDIX E

WATER BALANCE MODELS FOR THE PROPOSED CONTINENTAL MINE EXPANSION PROJECT, GRANT COUNTY, NEW MEXICO

Prepared for:
Cobre Mining Company, Inc.
c/o Chino Mines Company
No.14 Chino Boulevard
Hurley, New Mexico 88043

Prepared by:
Shepherd Miller, Inc.
3801 Automation Way, Suite 100
Fort Collins, Colorado 80525

December 1999

SHEPHERD MILLER
INCORPORATED

ATTACHMENTS TO APPENDIX E

WATER BALANCE MODELS FOR THE PROPOSED CONTINENTAL MINE EXPANSION PROJECT, GRANT COUNTY, NEW MEXICO

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INTRODUCTION

The following attachments describe the rationale and analytical models used to develop impact predictions presented in Appendix E. Available data are presented along with assumptions and descriptions of the computational methods used to estimate hydrologic conditions at various stages of mining.

PROBLEM STATEMENT AND OBJECTIVES

New mining and expansion of existing operations proposed by Cobre Mining Company will change the existing hydrology of the site area. Water-level data from monitoring wells and piezometers, installed near the proposed Hanover open-pit mine, indicate that the pit will intersect the local ground water table and may intersect the regional ground water table, creating the potential for a pit lake to develop after cessation of mining. In 1997, the Continental Pit did not require dewatering because pumping of the Underground Workings lowered the water table to below the pit bottom. However, if pumping of the Underground Workings is discontinued, the water table will rise above the current pit bottom and a pit lake will likely form. The proposed Continental Pit expansion also creates the potential for a pit lake to form after mining ends. The expanded South WRDF, 1997 proposed Tailings Pond expansion, 1997 planned expansion of the Underground Workings, and the Fierro Leach Pad all have the potential to affect the hydrologic regime. This attachment describes the hydrologic analyses performed by SMI to predict the following:

- Likelihood of pit lake development in the Continental and Hanover Pits
- Final water-surface elevation in the ultimate (stable) pit lakes after cessation of mining
- Time for the water levels in the pit lakes and Underground Workings to reach a stable equilibrium
- Steady-state pit lake water balance components for both pits
- Magnitudes of water balance components for the 1997 Tailings Pond

- Magnitudes of water balance components at the end of mining (but before dewatering ceases) for the expanded Tailings Pond, the Underground Workings, and both open pits
- Magnitudes of water balance components, after mining ceases and reclamation is complete, for the expanded Tailings Pond, the Underground Workings, and both open pits.

WATER BALANCE MODELING APPROACH

The water balance conceptual models presented in the following sections are semi-quantitative representations of the expected hydrologic regimes. The conceptual models are different for each phase of mining (current, end-of-mine, or post-closure) and for each location (open pits, Tailings Pond, or Underground Workings). Key components of each conceptual model are described in the following sections.

To meet the objectives of the water balance calculations, SMI performed the following:

- Developed conceptual models and estimated each component of the water balance for current conditions, near the end of mining, and at post-closure for the:
  - Pits
  - Tailings Pond
  - Underground Workings
- Evaluated flow components in these areas by solving the following discrete equation:

$$\frac{\Delta S}{\Delta t} = \left[(\Sigma \text{ (Inflow) } - \Sigma \text{ (Outflow)}\right]$$

where:

ΔS = change in the storage volume

Δt = change in time

Σ (Inflow) = total water inflow rate to the specified system

Σ (Outflow) = total water outflow rate from the specified system.

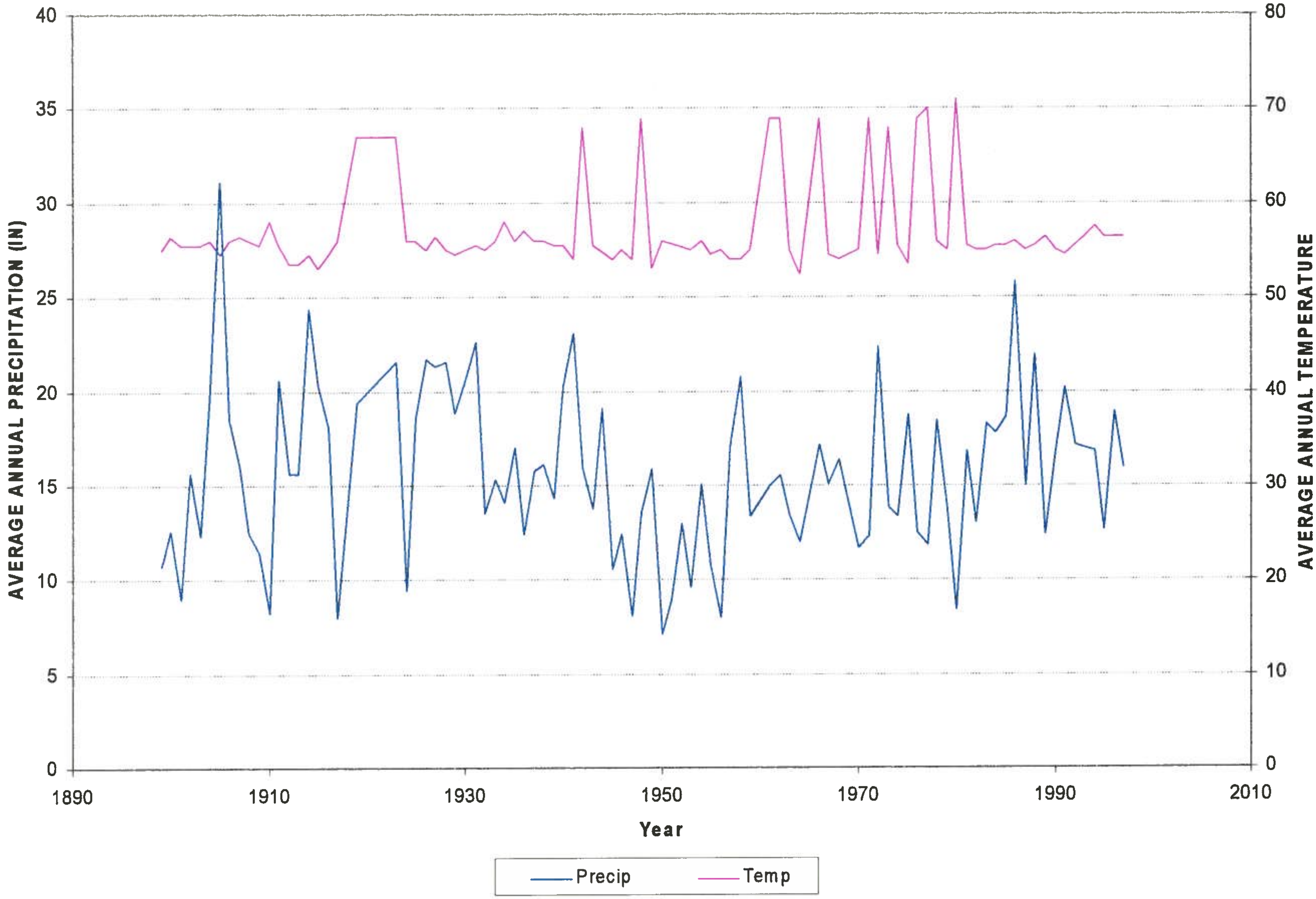

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FIGURE E1-1
YEARLY PRECIPITATION AND AVERAGE TEMPERATURE
FORT BAYARD, NEW MEXICO

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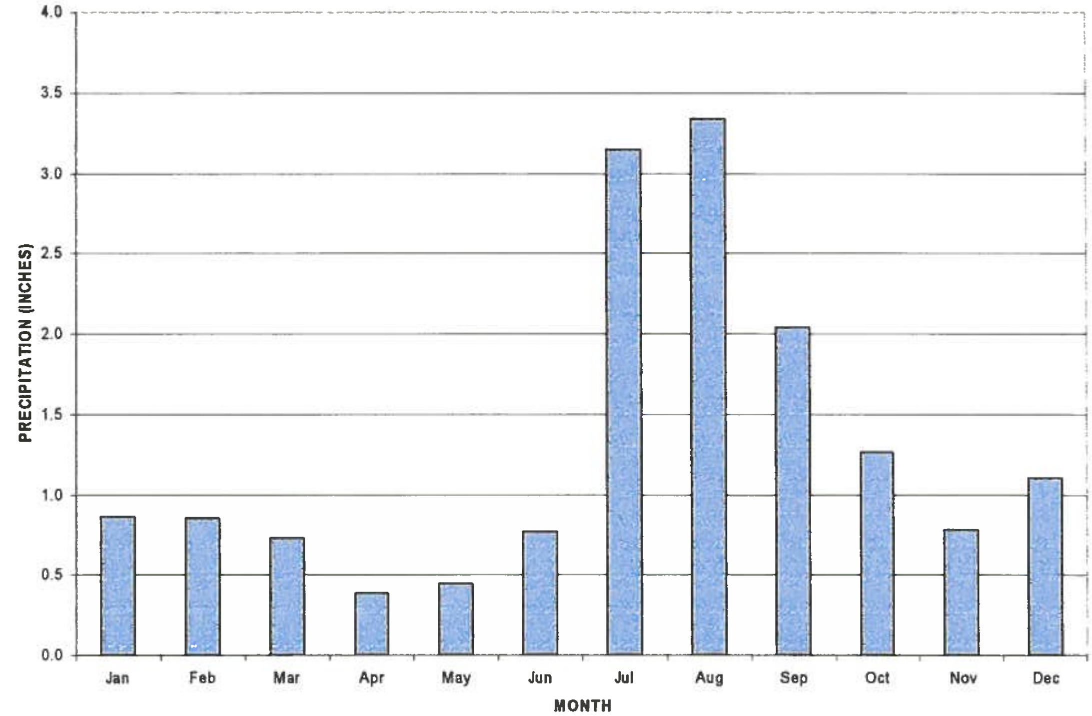

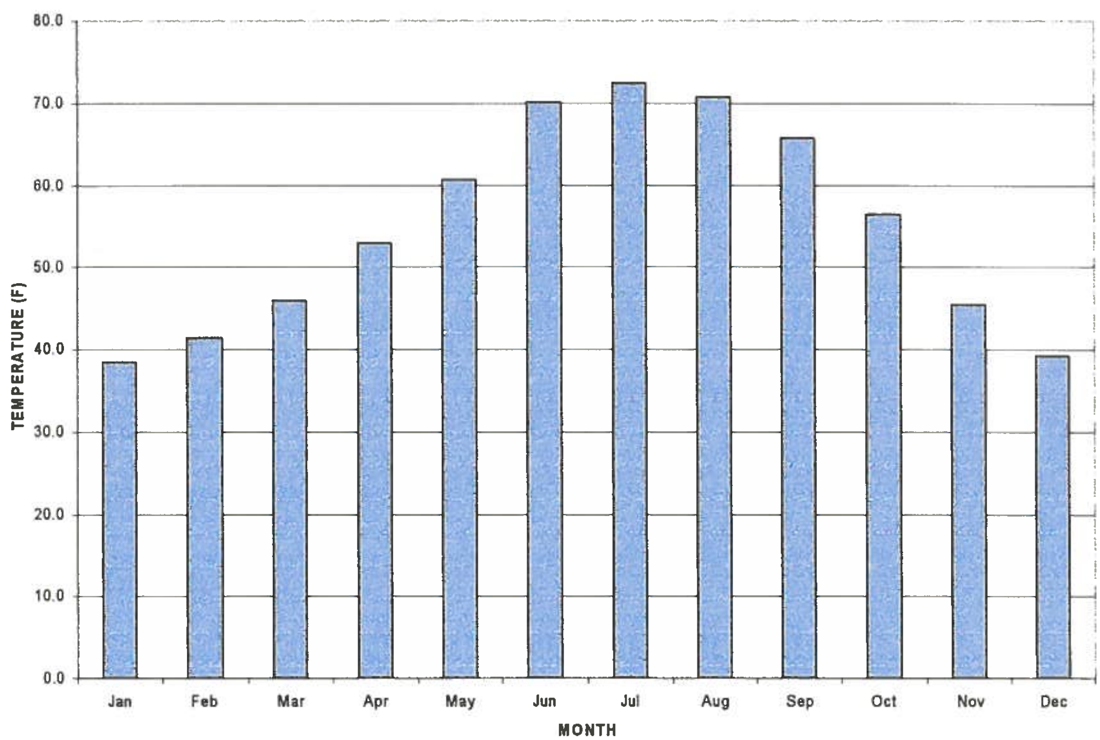

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FIGURE E1-2
MONTHLY PRECIPITATION AND DAILY AVERAGE TEMPERATURE DISTRIBUTION
FORT BAYARD, NEW MEXICO

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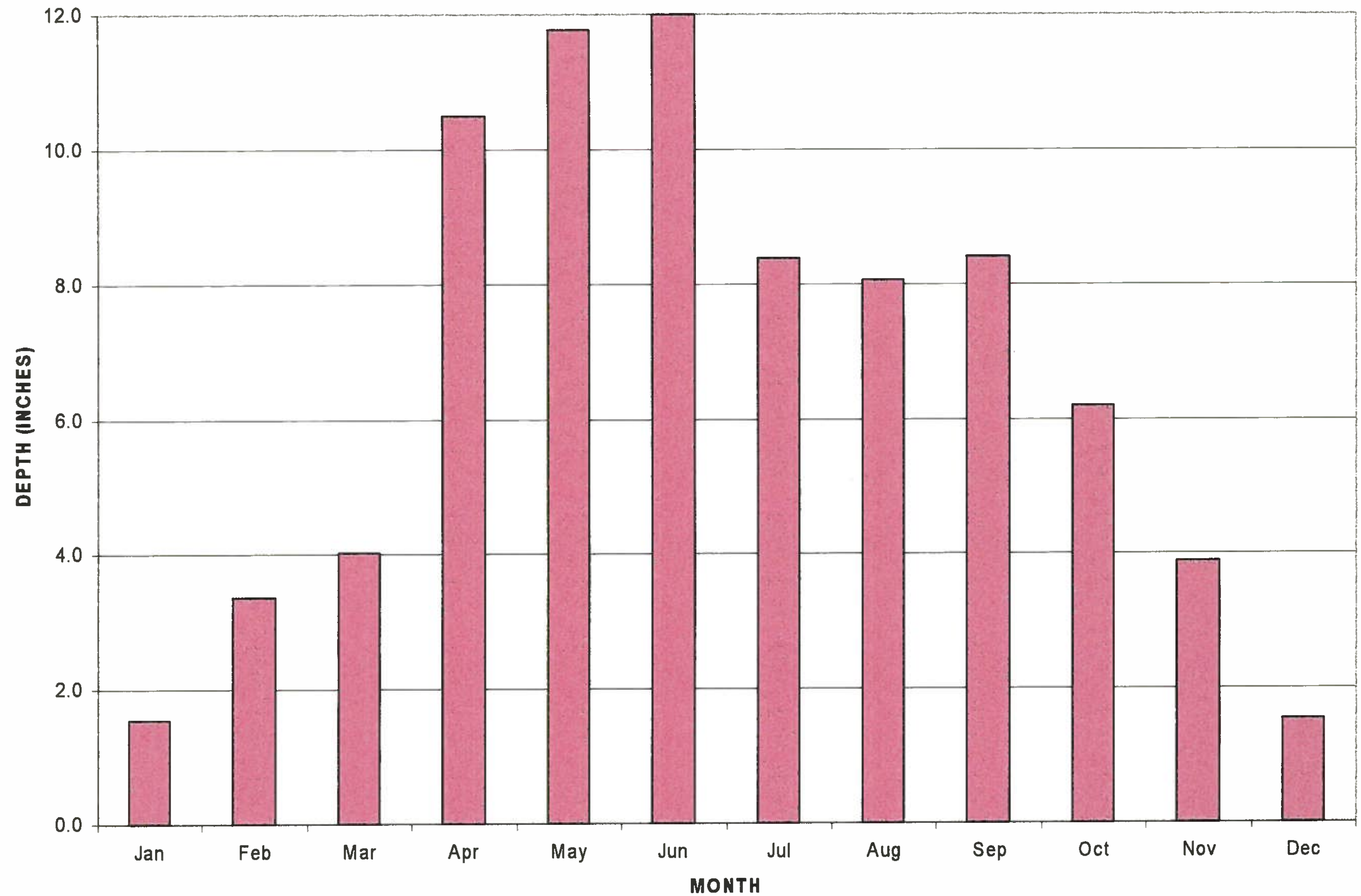

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FIGURE E1-3
MONTHLY EVAPORATION
CHINO MINE, NEW MEXICO

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ATTACHMENT E1

CLIMATIC INPUTS TO THE WATER BALANCES ASSOCIATED WITH THE PROPOSED CONTINENTAL MINE EXPANSION PROJECT, GRANT COUNTY, NEW MEXICO

E1-1.0 CLIMATE

E1-1.1 Available Data

EarthInfo (1996) indicates that the Fort Bayard weather station has recorded temperature and precipitation data from 1897 through 1994. Figure E1-1 shows annual precipitation and mean daily temperature for this time period. Annual precipitation has a mean of 15.7 inches/year and a standard deviation from the mean of 4.5 inches/year. The graph suggests that mean annual precipitation has been gradually increasing since about 1950. Figure E1-2 shows distinct seasonal variations in the monthly distributions of precipitation and temperature at Fort Bayard. Daily average temperatures range from 38°F in January to 72°F in July. The average minimum temperature is 25°F in January and the average maximum temperature is 87° in July.

Evaporation data are available from the Chino Mine. WESTEC (1997) reports that the average annual pan evaporation at the Chino Mine is approximately 79.7 inches/year. The monthly distribution of pan evaporation at Chino Mine are shown on Figure E1-3.

E1-1.2 Climate at the Continental Mine

No long-term, site-specific climatic data are available for the Continental Mine. Therefore, interpretations from available climatic data must be made in order to develop input parameters for the water balance calculations for the Continental Mine Expansion. The following sections discuss these interpretations.

E1-1.2.1 Precipitation and Temperature

Previously, Cobre has used a mean annual precipitation of 18.3 inches/year (WESTEC, 1997) in its water balance calculations. This value agrees with contours on the Average Annual Precipitation Map of New Mexico (Daly et al., 1994) for the site area. A portion of this map is reproduced on Figure E-3 of the main text. This annual precipitation value is used in the various water balance calculations. Assuming that the monthly rainfall distribution at the Continental Mine is similar to that measured at the Fort Bayard weather station, the precipitation at the mine has been estimated as shown in Table E1-1.

Table E1-1 Monthly Precipitation Distributions

Month	Fort Bayard Average Monthly Precipitation (inches)	Continental Mine Site Estimated Average Monthly Precipitation (inches)
January	0.87	1.02
February	0.85	0.99
March	0.73	0.85
April	0.39	0.45
May	0.45	0.52
June	0.77	0.89
July	3.15	3.67
August	3.34	3.88
September	2.04	2.37
October	1.26	1.46
November	0.78	0.91
December	1.10	1.28
Annual Total	15.73	18.29

Because of the proximity of the Continental Mine to Fort Bayard, mean monthly temperatures at the site were assumed equal to those measured at Fort Bayard. Table E1-2 shows the Fort Bayard weather station measured data and estimated monthly temperatures for the Continental Mine site.

Table E1-2 Estimated Average Monthly Temperature for the Continental Mine Site

Month	Continental Mine Estimated Average Monthly Temperature (°F)
January	38.4
February	41.4
March	45.8
April	52.9
May	60.6
June	70.2
July	72.2
August	70.6
September	65.9
October	56.5
November	45.6
December	39.2
Annual Average	54.9

E1-1.2.2 Evaporation

Pan evaporation at the Continental Mine is expected to be similar to that observed at the Chino Mine. Pan evaporation rates are typically larger than evaporation rates from small lakes or ponds. Thus, it is standard practice to apply a correction factor to pan evaporation rates in order to estimate lake evaporation rates. Schwabb et al. (1981) reports this correction factor to be 0.7 for a Class A evaporation pan. Estimated monthly evaporation rates for open bodies of water at the Continental Mine are computed by multiplying monthly pan evaporation rates by the above factor. Table E1-3 summarizes average pan evaporation data from the Chino Mine and the computed (corrected) lake evaporation rates at the Continental Mine.

Table E1-3 Monthly Evaporation from the Chino Mine

Month	Mean Monthly Pan Evaporation at the Chino Mine (inches)	Mean Monthly Lake Evaporation at the Continental Mine (inches)[1]
January	1.55	1.09
February	3.36	2.35
March	4.03	2.82
April	10.50	7.35
May	11.78	8.25
June	12.00	8.40
July	8.37	5.86
August	8.06	5.64
September	8.40	5.88
October	6.20	4.34
November	3.90	2.73
December	1.55	1.09
Annual Total	79.70	55.79

[1] The Continental Mine mean monthly lake evaporation is equal to 0.7 times the Chino Mine mean monthly pan evaporation rate.

E1-1.2.3 Runoff and Infiltration

Runoff and infiltration associated with the various areas of the Continental Mine were analyzed by others (e.g., Daniel B. Stephens and Associates, Schafer and Associates, Inc, and Brown and Root, WESTEC, and Cobre) as part of the Close-out/Closure Plan and during ongoing mine expansion design. Several of the analyses were completed with different average annual rainfall than that reported in Section E1-1.2.1. Where appropriate, SMI scaled these estimates to ensure consistency throughout this document.

Upland runoff will be diverted around the facilities discussed in these analyses. Therefore, upland runoff not affected by mine changes was not incorporated into water balances. Runoff changes due to additional capture were analyzed using the SCS curve number method and 100 years of daily rainfall data.

The SCS curve number method is an empirical method originally developed to assist rural land planners and agriculturists in predicting runoff from agricultural fields. Since its inception, it has become a standard method used to predict runoff volumes for a variety of areas. The SCS curve number formulas and the assumptions used to estimate runoff from undisturbed mine areas are as follows:

$$\text{Runoff}_{\text{depth}} = \frac{(P - I_a)^2}{(P - I_a - S)}$$

where:

$\text{Runoff}_{\text{depth}}$ is the depth of runoff

P is the precipitation depth (from a measured a single storm event). Using the HELP model (Schroeder et al. 1994) synthetic weather generator, daily P values were generated using the monthly average precipitation values presented in Attachment E-1 and weather coefficients from El Paso, Texas. I_a is the initial rainfall abstraction due to small surface depressions or capture by vegetation (typically assumed to be 0.2 times S)

S is the empirically derived formula relating the curve number (CN) to runoff:

$$S = \frac{1000}{CN - 10}$$

CN is an empirically derived value used to represent land use and soil hydrologic conditions. For undisturbed mining areas at the Continental Mine, DBS&A (1998) assumed a CN of 58.

SMI used a spreadsheet to perform this analysis. The method estimated that over a 100-year period, rainfall runoff could range from zero to 1.61 inches/yr with an average of 0.21 inches/yr. The area to be disturbed by the development of the Hanover Pit is approximately 160 acres. Because this excess precipitation will no longer overland flow to Hanover Creek, on average, approximately 2.8 acre-feet of runoff will be lost annually. This is equivalent to 1.7 gpm of continuous flow. Fierro Leach Pad disturbance will be approximately 130 acres and will result in a direct runoff loss of approximately 2.3 acre-feet annually. The additional area to be disturbed by the expanded footprint of the South WRDF (beyond December of 1999) is very small and not included in this analysis.

E1-2.0 REFERENCES

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EarthInfo. 1996. "NCDC Summary of the Day." EarthInfo, Inc., Boulder, Colorado.

Schroeder, P.R., C.M. Loyd, and P.A. Zappi, 1994. *The Hydrologic Evaluation of Landfill Performance (HELP) Model. User's Guide for Version 3.* EPA/600/9-94/168a. U.S. Environmental Protection Agency Risk Reduction Engineering Laboratory, Cincinnati, OH.

Schwabb, G.O., R.K. Frevert, T.W. Edminster, and K.K. Barnes. 1981. *Soil and Water Conservation Engineering*, third edition. John Wiley and Sons: New York.

ATTACHMENT E2

TAILINGS POND WATER BALANCES FOR THE PROPOSED CONTINENTAL MINE EXPANSION PROJECT, GRANT COUNTY, NEW MEXICO

E2-1.0 INTRODUCTION: TAILINGS POND

The evaluation presented below is based on the 1997 proposed expansion of the Tailings Pond and the associated analysis performed in 1997. Cobre had planned to expand the 1997 Tailings Pond and increase its height to an ultimate elevation of 7,140 feet. The Tailings Pond includes the Tailings Pond, the Reclaim Pond, and the Toe Collection Pond. At the time, there were no plans to increase milling production rates. Although the water from the Tailings Pond met primary state drinking water standards, it exceeds secondary standards for sulfate and TDS. Thus, it was important to evaluate the significance of leakage and the potential chemical changes to ground water quality.

E2-1.1 Objectives

The objectives of this Tailings Pond water balance are to:

- Evaluate the overall water balance for 1997
- Evaluate the 1997 and future leakage rates for the facility
- Estimate the downward leakage rates from the facility to the lower bedrock units and the Fierro Area.

E2-1.2 Approach

The general water balance equation was used to quantitatively describe the water balance for the 1997 facility and the previously proposed expansion. Inflows and outflows of the water balance include both measured and estimated components. Because it is a lined pond and due to its small size, evaporation and leakage from the toe collection pond were assumed to be negligible and were therefore excluded from the analysis.

Measured flow components and their corresponding magnitudes are summarized in Table E2-1. The values in this table are a result of measurements taken between January and October 1997. Also included in this table are the 1997 changes in storage in the interstitial pore spaces of the Tailings Pond (i.e., the average water content of the settled tailings) and in the Reclaim Pond (i.e., changes in the surface elevation of the Reclaim Pond).

Estimated flow components of the water balance are based on several different calculations. Inflow from precipitation is a result of multiplying the planar area of the Tailings and Reclaim Ponds by the average precipitation. Outflow due to evaporation is calculated in a similar manner. Outflows due to leakage from the Tailings and Reclaim Ponds are based on hydraulic potentials, cross-sectional area of flow, and measured hydraulic conductivities. Section E2-2.0 describes these calculations in detail.

Assumptions incorporated in the water balance of the Tailings Pond facility include:

- All overland flow from areas upgradient of the Tailings Pond would be diverted around the facility.
- The tailings are saturated and vertical flow through the tailings is a result of a unit hydraulic gradient.
- The tailings have a saturated conductivity of $1x10^{-7}$ cm/sec.
- The weathered bedrock and alluvium beneath the Tailings Pond has an average thickness of 10 feet and a saturated hydraulic conductivity of approximately $1.5x10^{-3}$ to $1.0x10^{-2}$ cm/sec.

Table E2-1 Measured Components for the 1997 Tailings Pond Facility Water Balance

	January	February	March	April	May	June	July	August	September	October
Inflows (Gallons)										
Water in Mill Tailings	134,943,525	123,274,697	137,260,791	143,480,717	158,625,385	151,209,592	149,818,107	151,868,423	145,530,582	143,516,345
Concentrate Decant/Filtrate	5,758,060	5,636,557	5,615,774	5,626,965	5,945,090	5,556,610	5,087,218	6,097,267	6,466,993	7,106,245
Collection Pond Returns	1,375,000	2,401,000	4,638,000	4,173,000	4,701,000	1,191,000	4,804,000	462,000	4,554,000	4,576,000
Outflows (Gallons)										
Reclaim	89,930,000	86,660,000	96,940,000	98,210,000	90,700,000	87,930,000	97,790,000	106,300,000	101,160,000	91,440,000
Decant Sump	17,000,000	15,004,500	15,824,200	15,774,300	16,174,700	15,773,800	15,500,000	15,500,000	15,500,000	15,500,000
Changes in Storage (Gallons)										
Settled Tailings Interstitial Moisture[1]	21,842,806	20,782,254	22,245,024	22,300,360	20,688,249	20,642,146	20,135,492	21,615,947	21,575,480	21,195,324
Change in Reclaim Storage[2]	9,110,640	1,691,976	(1,041,216)	(1,301,520)	16,269,000	10,672,464	4,945,776	(1,561,824)	4,815,624	12,364,440

Notes:
1. This value is based on measurements of the water content of the tailings after settlement
2. This value is based on elevation (stage) measurements of the Reclaim Pond

E2-2.0 CALCULATIONS

E2-2.1 1997 Tailings Pond Facility Water Balance

Table E2-2 summarizes the yearly based, average daily flow rates of measured input water balance components. Three of the water balance components (i.e., inflow due to precipitation and outflows due to evaporation and leakage) shown in Table E2-2 were not directly measured. Estimates for the precipitation and evaporation components were based on the daily average precipitation and evaporation data presented in Attachment E1. The leakage rate estimate of 112 gpm was determined using the general water balance equation:

$$\frac{\Delta S}{\Delta t} = \left[(\Sigma\ (\text{Inflow})\ -\ \Sigma\ (\text{Outflow})\right]$$

where:

$$\frac{\Delta S}{\Delta t} = 615 \text{ gpm}$$

$$\Sigma(\text{Inflow}) = 3{,}619 \text{ gpm}$$

$$\Sigma(\text{Outflow}) = 2{,}892 \text{ gpm} + \text{Leakage}$$

Solving for the "Leakage" term yields:

$$\text{Leakage} = 615 \text{ gpm} + 2{,}892 \text{ gpm} - 3{,}619 \text{ gpm} = 112 \text{ gpm}$$

Table E2-2 Yearly Average Flow Rates for the 1997 Tailings Pond Facility

	Average Daily Flow Rate (gpm)
INFLOWS	
Water in Mill Tailings	3,288
Concentrate Decant/Filtrate	135
Collection Pond Returns	75
Toe Collection Return	502
Precipitation	121
TOTAL INFLOWS	**4,121**
OUTPUTS	
Reclaim	2,163
Decant Sump	360
Evaporation	369
Toe Collection	502
Leakage	112
TOTAL OUTFLOWS	**3,506**
CHANGE IN STORAGE	
Settled Tailings Interstitial Moisture	487
Change in Reclaim Storage	128
TOTAL STORAGE CHANGE	**615**

E2-2.2 1997 Flows to the Fierro Area and Lower Bedrock Units

Figure E-13 (main text) shows the hydrologic conceptual model of the current Tailings Pond facility and surrounding area. The total leakage from the Tailings Pond facility in 1997 (i.e., 112 gpm) derives from two areas:

1. Leakage from the Tailings Pond
2. Leakage from the Reclaim Pond.

Leakage from the Tailings Pond is controlled by the vertical hydraulic conductivity of the tailings materials and the hydraulic head distribution within the tailings material. Assuming that the tailings are completely saturated from top to bottom, the following form of Darcy's Law is applicable:

$$Q = AK\frac{dh}{dl} \tag{E2-1}$$

where:

Q = Flow rate

A = The cross sectional area of flow (4,810,771 feet^2 - the saturated, planar area of the Tailings Pond)

K = The average (bulk) hydraulic conductivity

$\frac{dh}{dl}$ = Hydraulic gradient through the impoundment

The hydraulic gradient ($\frac{dh}{dl}$) through the Tailings Pond is approximately equal to one. From the above form of Darcy's law, the flux through the tailings was estimated to be 7.1 gpm, assuming an average saturated hydraulic conductivity of the tailings of 1×10^{-7} cm/sec. The leakage from the Reclaim Pond is then 105 gpm (112 gpm - 7 gpm).

Knowing the cross-sectional area of flow and hydraulic gradient associated with the shallow aquifer beneath the facility, the bulk hydraulic conductivity of this aquifer was estimated from the simplified form of Darcy's Law:

$$K = \frac{Q}{A\frac{dh}{dl}} \tag{E2-2}$$

Where:

Q = 105 gpm

A = 10,500 feet^2 (10-foot thickness times 1,050-foot width of flow)

$\frac{dh}{dl}$ = 0.068 (change in head from the Reclaim Pond to the toe of the Tailings Pond [285.7 feet] divided by the flow length [approximately 4,175 feet])

This results in an estimated hydraulic conductivity of 9.9×10^{-3} cm/sec, which agrees well with the geometric mean of the measured hydraulic conductivity in monitoring well MW-24 (7.2×10^{-3} cm/sec), which is screened in the same shallow alluvial aquifer.

The leakage from the shallow aquifer into the lower bedrock units is considered to be small because of the probable unsaturated zone created by the underground dewatering; however, a high-end estimate of potential flow to the lower bedrock units was made assuming saturated, unit gradient conditions. The vertical hydraulic conductivity of the lower bedrock units was assumed to be 1×10^{-7} cm/sec, and the cross-sectional area of flow was assumed equal to the total area covered by the Tailings Pond. Because these are the same parameters used in estimating the leakage from the tailings materials, the high end estimated flow to the lower bedrock units is approximately 7 gpm.

E2-2.3 End-of-Mining Tailings Pond Water Balance Including Flows to the Fierro Area and Lower Bedrock Units

At the end of mining, the final elevation of the Tailings Pond will be approximately 7,140 feet. The map area of the expanded Tailings Pond will be about 264 acres, and the Reclaim Pond will probably occupy an area similar to the current condition. These areas result in an estimated evaporation loss and precipitation inflow rates of approximately 760 and 256 gpm, respectively.

Using the same approach as that used for estimating the 1997 tailings-leakage rate (see Equation E2-1), the estimated end-of-mining leakage rate is approximately 17 gpm. With a cross-sectional area of flow of 38,140 feet^2, a gradient of 0.062, and a hydraulic conductivity of 9.9×10^{-3} cm/sec, the estimated leakage rate from the end-of-mining Reclaim Pond is estimated to be approximately 345 gpm. If the Lower Bedrock Units are saturated, the estimated high-end flow rate from the shallow aquifer is approximately 17 gpm.

E2-2.4 End-of-Mining Water Balance

The previously proposed expansion at the Continental Mine does not call for a significant increase in the milling and tailings production rates. Incorporating the water balance approach described in the introduction of this attachment yields the following water balance:

$$\sum \text{inflows} = \sum \text{outflows} + \frac{\Delta S}{\Delta t}$$

$$Q_{\text{Precipitation}} + Q_{\text{Process Inflows}} = Q_{\text{Evaporation}} + Q_{\text{Leakage}} + Q_{\text{ProcessOutflows}} + \frac{\Delta S}{\Delta t}$$

Substituting the estimated end-of-mining magnitudes into the above equation and rearranging yields:

$$Q_{\text{Process Inflow}} - Q_{\text{Process Outflow}} - \frac{\Delta S}{\Delta t} = 784\text{gpm} + 362\text{gpm} - 257\text{gpm} = 889\text{gpm}$$

The current net process water flows and storage change ($Q_{\text{Process Inflow}} - Q_{\text{Process Outflow}} - \frac{\Delta S}{\Delta t}$) are 362 gpm. This suggests that the process inflows would have to increase substantially for the predicted leakage rates to be possible. Since there are no plans to drastically increase the production of the mill, the leakage predictions presented in the previous section can be considered conservative (i.e., over estimated).

E2-2.5 Post-Closure Tailings Pond Water Balance Including Flows to the Fierro Area and Lower Bedrock Units

Post-closure inflows and outflows associated with the Tailings Pond will consist of steady-state infiltration of direct precipitation, run-on from upgradient areas, runoff from the reclaimed tailings, evapotranspiration from the reclaimed tailings, and long-term downward seepage from the bottom of the facility. DBS&A (1999) estimated the magnitudes of the various post-closure, Tailings Pond water balance components based on a precipitation rate of 15.5 inches/yr and the chosen reclamation scenario. These rates were scaled up to be consistent with previous Tailings Pond analysis based on 18.3 inches/yr precipitation (See Table E2-3). Using this approach, it was predicted that the covered 264-acre Tailings Pond would receive approximately 249.6 gpm of precipitation (18.3 in/yr) and approximately 0.6 gpm of run-on. Of this 250.2 gpm, approximately 1.9 gpm would run off, approximately 224.6 gpm would evaporate, and approximately 24.7 gpm would infiltrate. Assuming steady-state conditions, the seepage from the bottom of the impoundment is equal to the infiltration. Partitioning the seepage between flow to lower bedrock units and the Fierro Area, based on the ratio of flows presented for the current and end-of-mine scenarios results in flow of 1.3 gpm and 23.4 gpm, respectively (See Table E2-4).

Table E2-3 Determination of Post-Closure Water Balance Components

Water Balance Component	DBS&A Predicted Rates (acre-ft/yr)[1]	DBS&A Predicted Rates (in/yr)[2]	Scaled DBS&A Predicted Rates (in/yr)[3]	Post-Closure Predicted Rates (gpm)[4]
Average Precipitation	177.0	15.54	18.30	249.6
Average Run on	0.4	0.04	0.04	0.6
Average Runoff	0.6	0.02	0.02	1.9
Average Actual ET	159.3	13.99	16.47	224.6
Average Infiltration	17.5	1.54	1.81	24.7

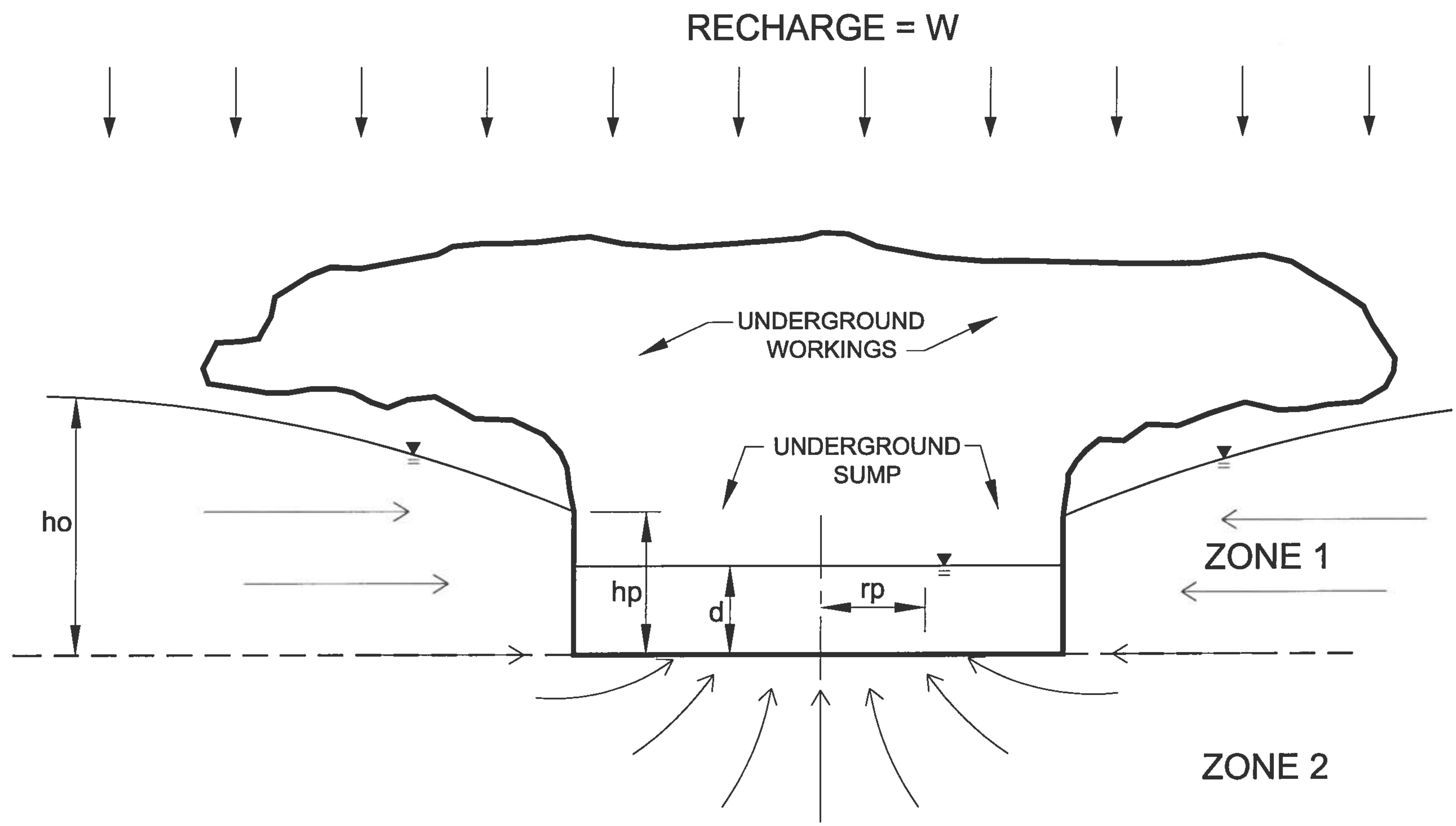
[1] Based on an average annual precipitation rate of 15.5 in/yr.
[2] DBS&A Tailings Pond area = 137 acres.
[3] DBS&A Unit rates multiplied by the ratio of 18.3/15.5.
[4] Post-closure Tailings Pond area = 264 acres.

Table E2-4 Partitioning of Tailings Pond Seepage Between Flow to the Fierro Area and Flow to the Lower Bedrock Units.

	Current Flow Rate (gpm)	End-of-Mine (gpm)	Post-Closure (gpm)
Tailings Seepage	7 (6%)	16.4 (5%)	24.7 (100%)
Reclaim Pond Seepage	105 (94%)	345 (95%)	-
Total Seepage	112 (100%)	361.4 (100%)	24.7 (100%)
Flow to Fierro Area	105 (94%)	345 (95%)	23.4 (95%)
Flow to Bedrock Units	7 (6%)	16.4 (5%)	1.3 (5%)

E2-3.0 SUMMARY

The objectives set forth in Section E2-1.1 were satisfied by the calculations presented above. The leakage rate from the current Tailings Pond were estimated to be approximately 112 gpm based on measured components of the water balance. It is possible that approximately 7 gpm of this total leakage may flow to the lower bedrock units, while the remainder flows laterally downgradient to the Fierro Area. At the end of mining, the potential leakage rate may increase to 362 gpm, of which about 17 gpm may flow to the lower bedrock units and the remainder (about 345 gpm) to the Fierro Area. The post-closure seepage rate will decrease to approximately 24.7 gpm with approximately 1.3 gpm flowing to the lower bedrock units and approximately 23.4 gpm flowing to the Fierro Area. The most important conclusion to recognize from this work is that a majority of the leakage from the Tailings Pond flows to the Fierro Area and relatively little leaks downward into the lower bedrock units.



SHEPHERD MILLER
INCORPORATED

FIGURE E3-1
SCHEMATIC REPRESENTATION
OF FLOW TO THE UNDERGROUND SUMP

Date:	DECEMBER 1999
Project:	100029\T5
File:	DIAG-REP

ATTACHMENT E3

UNDERGROUND WORKINGS WATER BALANCES FOR THE PROPOSED CONTINENTAL MINE EXPANSION PROJECT, GRANT COUNTY, NEW MEXICO

E3-1.0 INTRODUCTION: UNDERGROUND WORKINGS

This attachment has been prepared to provide a preliminary assessment of ground water inflows into current and future Underground Workings at the Continental Mine. This preliminary assessment includes an estimate of the ground water inflow rate into the final mine (as previously planned) in addition to a prediction of the re-flooding time after mine operations are terminated. Calculations are performed using analytical solutions for mine inflow, empirical information on the current inflow rates, and available site characterization data. This evaluation provides information that can be used for assessment of ground water impacts.

Specific evaluations in this attachment include:

- Comparison of current inflow rates with predictions of an analytical model to calibrate the bulk hydraulic conductivity value used in subsequent calculations
- Estimation of inflow rates into Underground Workings at the end of mining
- Evaluation of mine re-flooding time.

E3-2.0 CALCULATIONS

E3-2.1 Evaluation of the Current Ground Water Inflow Rate

The evaluation presented below is based on the 1997 proposed mine expansion plan and the associated analysis performed in 1997. During a site visit on May 30, 1997, SMI observed that nearly all inflow into the current mine excavation occurred in a large sump (the "upper" sump) located at the base of the workings. A second sump (the "lower" sump), located in the vicinity of the upper sump, but at a slightly lower elevation, is also used to remove water from the Underground Workings. The total ground water inflow rate to the sumps average approximately 132 gpm. Approximately 92% of this water is pumped from the upper sump and the remaining 8% is pumped from the lower sump. The upper sump elevation (5,550 feet) is about 1,120 feet below what is believed to be the static water elevation (6,670 feet) prior to dewatering of the Underground Workings (i.e., water levels in distant observation wells). For the purposes of this analysis, all water was assumed to be extracted from the location of the upper sump. The analysis presented in this attachment and Appendix E does not take into consideration water carried in the ventilation air exiting the mine. This is because ventilation air humidity and temperature variations are unknown and excluding this component results in only small changes the modeling results. Air exits the mine via the #3 Borehole Vent (air flow rate of 102,703 cubic-feet per minute [cfm]) and the #4 Shaft (air flow rate of 32,800 cfm). Assuming 100 percent relative humidity (maximum allowed) at an average temperature of 26.6 degrees C, calculations indicate that air venting could remove approximately 23 gpm of water. Thus, if the air were exiting at 100 percent relative humidity (i.e., the extreme case), the results would only be changed by approximately 17 percent.

A schematic representation of flow to the sump is shown on Figure E3-1. The sump inflow rate can be computed using the approach and equations described in Attachment E6, which were originally developed for flow to an open excavation. The assumption of flow to an "open" excavation is reasonable for the Underground Workings, due to the following reasons:

- Nearly all inflow occurs in the floor and sides of the sump
- Continuous pumping keeps the sump essentially dewatered.

Parameters used in the sump calculations are summarized in Table E3-1.

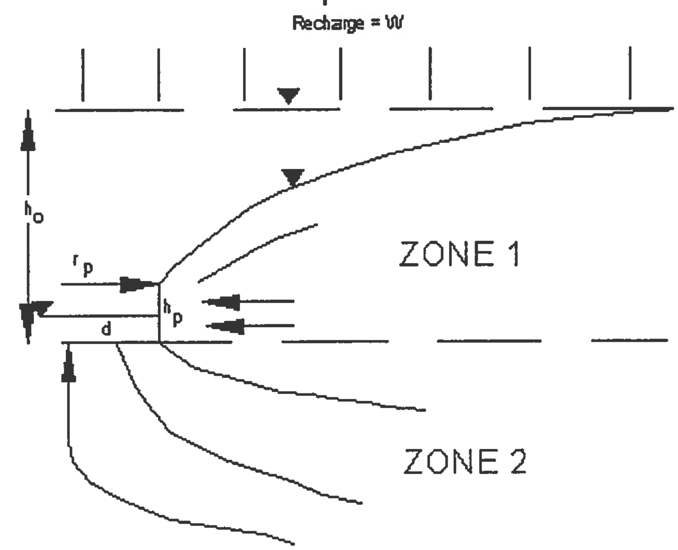
Table E3-1 Input Parameters Used in the Calculation of Bulk Hydraulic Conductivity

Parameter	Description	Value and Units	Notes
h_o	Depth of sump below static water table	1,120 feet	Based on the assumed, pre-mining average static water level of 6,670 feet and the current sump elevation of 5,550 feet
d	Depth of Pond in Sump	10 feet	Assumed
h_p	Height of seepage face plus the depth of the lake	20 feet	Assumed
r_p	Average effective sump radius	100 feet	Visually estimated
W	Regional ground water recharge rate	1.24 inch/year	Based on the average, assumed saturated vertical conductivity ($1x10^{-7}$ cm/s)
K	Bulk hydraulic conductivity of rock	-	Calibration Parameter

Using equations described in Attachment E6 and the parameters values from Table E3-1, hydraulic conductivity was varied until the computed sump inflow rate equaled the observed rate of 132 gpm. The hydraulic conductivity value of 5.5×10^{-6} cm/sec provides a calculated inflow rate of 132 gpm. This hydraulic conductivity value is similar to those obtained from pumping tests conducted in monitoring wells MW-5 and MW-20 (screened in the Lake Valley Formation) and in production well PW-1 (screened over the Oswaldo and Lake Valley Formations). A summary of the calculations used to calibrate the hydraulic conductivity value is provided on the MathCad© worksheet shown in Table E3-2.

Table E3-2 Calculation Summary of Hydraulic Conductivity Calibration

Conceptual Model



K_1

K_2

Input Parameters

$$h_o := 6670\,ft - 5550\,ft$$

$$d := 10\cdot ft$$

$$h_p := 20\cdot ft$$

$$r_p := 100\,ft$$

$$W := 10^{-7}\cdot\frac{cm}{sec}$$

$$H_o := 6670\,ft$$

$$h_o = 1.12\cdot 10^{3}\cdot ft$$

$$W = 1.242\cdot\frac{in}{yr}$$

$$K_1 := 5.5\cdot 10^{-6}\cdot\frac{cm}{sec}$$

$$K_2 := 5.5\cdot 10^{-6}\cdot\frac{cm}{sec}$$

Determine Radius of Influence (r_o) by Iterations

Input trial value of r_o

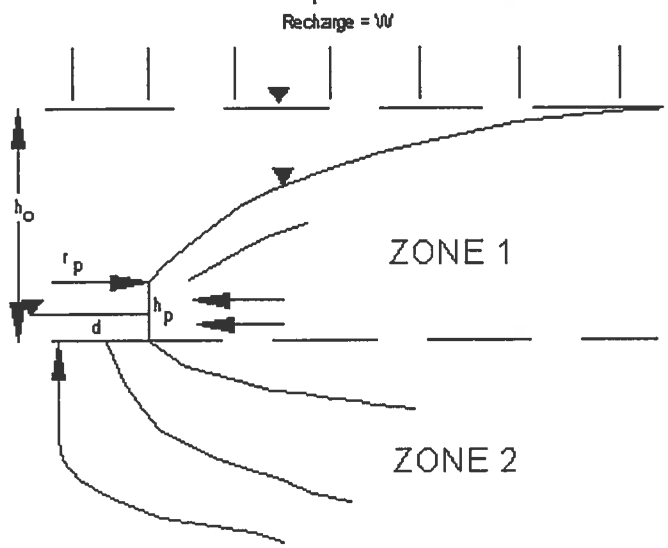
$$r_o := 4558.25\,ft$$

$$h_i := \sqrt{\frac{W}{K_1}\cdot\left(r_o^2\cdot\ln\left(\frac{r_o}{r_p}\right) - \frac{r_o^2 - r_p^2}{2}\right) + h_p}$$

$$h_o = 1120\cdot ft$$

Table E3-2 Calculation Summary of Hydraulic Conductivity Calibration

Conceptual Model



K_1

K_2

Input Parameters

$$h_o := 6670\,ft - 5550\,ft$$

$$d := 10 \cdot ft$$

$$h_p := 20 \cdot ft$$

$$r_p := 100 \cdot ft$$

$$W := 10^{-7} \cdot \frac{cm}{sec}$$

$$H_o := 6670\,ft$$

$$h_o = 1.12 \cdot 10^3 \cdot ft$$

$$W = 1.242 \cdot \frac{in}{yr}$$

$$K_1 := 5.5 \cdot 10^{-6} \cdot \frac{cm}{sec}$$

$$K_2 := 5.5 \cdot 10^{-6} \cdot \frac{cm}{sec}$$

Determine Radius of Influence (r_o) by Iterations

Input trial value of r_o

$$r_o := 4558.25\,ft$$

$$h_i := \sqrt{\frac{W}{K_1} \cdot \left(r_o^2 \cdot \ln\left(\frac{r_o}{r_p}\right) - \frac{r_o^2 - r_p^2}{2} \right)} + h_p$$

$$h_o = 1120 \cdot ft$$

Table E3-2 Calculation Summary of Hydraulic Conductivity Calibration (cont.)

Compare ho and h_i

$$h_i = 1120 \cdot ft$$

Compute Flow in Zone 1

$$Q_1 := \pi \cdot W \cdot \left(r_o^{\,2} - r_p^{\,2}\right)$$

$$Q_1 = 96.074 \cdot \frac{gal}{mi}$$

Compute Flow in Zone 2

$$Q_2 := 4 \cdot K_2 \cdot \left(h_o - d\right) \cdot r_p$$

$$Q_2 = 35.96 \cdot \frac{gal}{mi}$$

Total Inflow Rate

$$Q_a := Q_1 + Q$$

$$Q_a = 132.033 \cdot \frac{gal}{mi}$$

E3-2.2 Prediction of the Future Ground Water Inflow Rate

Underground mining will progress from the current excavations to the south and then east in a broad arc. The depth of the eastern-most mining will be about 200 feet lower than the bottom of the current excavations. Due to the complex geometry of the final mine workings, ground water inflows were predicted assuming two pumping centers in the final mine. One pumping center is taken as the current sump that has a measured inflow rate of 132 gpm. The second pumping center is assumed located at the furthest western extent of mining. This second pumping center is conceptually similar to the current sump, except that is assumed to be somewhat larger and about 200 feet deeper. The flow rate into the second (future) sump was computed using equations in Attachment E6 and the parameter values in Table E3-3.

Table E3-3 Parameters Used in the Calculation of Ground Water Inflows at the End of Mining

Parameter	Description	Value and Units	Notes
h_o	Depth of sump below static water table	1,320 feet	Based on the assumed, pre-mining average static water level of 6,670 feet and the current sump elevation of 5,350 feet
d	Depth of Pond in Sump	10 feet	Assumed
h_p	Height of seepage face plus the depth of the lake	20 feet	Assumed
r_p	Average effective sump radius	100 feet	Visually estimated
W	Regional ground water recharge rate	1.24 inch/year	Based on the average, assumed saturated vertical conductivity ($1x10^{-7}$ cm/s)
K	Bulk hydraulic conductivity of rock	-	Calibration Parameter

A summary of this calculation is provided on the MathCad© worksheet shown in Table E3-4. The predicted inflow rate to the second pumping center (Q_b) is 170 gpm.

The combined inflow rate from the two pumping centers is about 302 gpm. This is the best estimate mine inflow rate at the end of operations; however, based on professional judgment, the estimated probable-minimum inflow rate is approximately 170 gpm and the probable-maximum rate is 500 gpm.

Table E3-4 Calculation Summary of Ground Water Inflow Rate at End of Mining

$$h_o := 6670\,ft - 5350\,ft$$

$$K_1 := 5.5 \cdot 10^{-6} \cdot \frac{cm}{sec}$$

$$K_2 := 5.5 \cdot 10^{-6} \cdot \frac{cm}{sec}$$

$$h_o = 1.32 \cdot 10^3 \cdot ft$$

Determine Radius of Influence (r_o) by Iterations

Input trial value of r_o

$$r_o := 5260.22\,ft$$

$$h_i := \sqrt{\frac{W}{K_1} \cdot \left(r_o^2 \cdot \ln\left(\frac{r_o}{r_p}\right) - \frac{r_o^2 - r_p^2}{2} \right) + h_p}$$

$$h_o = 1320 \cdot ft$$

Compare ho and h_i

$$h_i = 1320 \cdot ft$$

Compute Flow in Zone 1

$$Q_1 := \pi \cdot W \cdot \left(r_o^2 - r_p^2 \right)$$

$$Q_1 = 127.958 \cdot \frac{gal}{mi}$$

Compute Flow in Zone 2

$$Q_2 := 4 \cdot K_2 \cdot \left(h_o - d \right) \cdot r_p$$

$$Q_2 = 42.439 \cdot \frac{gal}{mi}$$

Total Inflow Rate

$$Q_b := Q_1 + Q$$

$$Q_b = 170.397 \cdot \frac{gal}{mi}$$

Estimate total flow rate at the end of mining

Assume that the first pumping center at elevation 5550 will still intercept the water table and convey water to the lower sump via adits.

$$Q_{total} := Q_a + Q_b$$

$$Q_{total} = 302.43 \cdot \frac{gal}{mi}$$

This is the best estimate total sump rate at the ultimate depth in the Underground Workings. Based on professional judgment, these rates may be as low as 170 gpm and range as high as 500 gpm.

E3-2.3 Evaluation of Mine Re-flooding

At the end of mining, pumping from the sump will be terminated and ground water will flood the mine workings. The time required for the water level in the mine to reach a certain elevation is given by the following general equation:

$$t(z) = \int_{z_b}^{z} \frac{A(z)}{Q(z)} dz \tag{E3-1}$$

where:

t (z) = The time since the end of mining as a function of water-level elevation

z = The water-level elevation in the mine

z_b = The elevation at the bottom of the mine workings

Q(z) = The estimated ground water inflow rate as a function of water-level elevation.

As a first approximation, it was assumed that the flow rate will decrease linearly from the end-of-mining value (Q_b), when $z = z_b$, to zero when the water level reaches the static water level ($z = z_o$). The equation for Q(z) is therefore:

$$Q(z) = \begin{cases} 0 & \text{for} \quad z > z_o \\ Q_b \dfrac{(z_o - z)}{(z_o - z_b)} & \text{for} \quad z \leq z_o \end{cases} \tag{E3-2}$$

A(z) is defined as the volume of voids in the mine per unit change in water level, which depends on elevation. It is equal to the cross-sectional area of mine voids that would be observed in horizontal plane at elevation z. The following equation for A(z) is based on:

1. Past (11,000,000 ton) and future (22,558,100 ton) tonnage to be excavated from the mine (Cobre, 1997)
2. The depth of mining at different points in time
3. An assumed density of limestone of 168.9 lb/feet^3 for in-place rock.

$$A(z) = \begin{cases} 1.05 \times 10^6 \text{ feet}^2 & \text{for } 5350 \le z < 5550 \text{ feet} \\ 1.69 \times 10^5 \text{ feet}^2 & \text{for } 5550 \le z < 6670 \text{ feet} \\ 0 \text{ feet}^2 & \text{for } 6670 \text{ feet} \le z \end{cases} \qquad \text{(E3-3)}$$

Evaluation of the integral in Equation (E3-1), subject to the functions in Equations (E3-2) and (E3-3), was performed using a MathCad© worksheet. Input parameters in the calculations are summarized in Table E3-5.

Table E3-5 Parameters Used in the Calculation of Time to Fill the Underground Workings

Parameter	Description	Value and Units
Q_b	Total inflow rate at the end of mining	302 gpm
z_b	Elevation at bottom of mine workings	5,350 feet
z_o	Elevation of static water table	6,670 feet

Results of the calculations are shown on the MathCad© worksheets in Table E3-6. The estimated time required for the water table in the Underground Workings to reach elevation of 6,500 feet is approximately 53 years for an assumed end-of-mining inflow rate of 302 gpm. If the previously proposed expansion were to occur, it would likely take over 120 years for the Underground Workings to fill to pre-dewatering elevation of 6,670 feet. If no expansion beyond the 1997 configuration occurs, it will take approximately 38 years to re-flood the workings to 6,500 feet elevation.

Table E3-6 Calculation Summary of Time to Fill Underground Workings

Estimate volume of Underground Workings

Data from Cobre:

$$M_{previous} := 11 \cdot 10^{6} \cdot ton$$

$$M_{planned} := 22558100 ton$$

$$SpecVol_{cobre} := 9.4 \cdot \frac{ft^3}{ton}$$

Check the reasonableness of the given density

$$\rho_{cobre} := SpecVol_{cobre}^{-}$$

$$\rho_{cobre} = 3.408 \cdot \frac{gm}{cm^3}$$

This seems too high because ρ_{quartz} = 2.65 gm/cm^3

Assume $\rho = \rho_{limestone}$.

$$\rho := 2.69 \frac{gm}{m}$$

$$V_{previous} := \frac{M_{previous}}{\rho}$$

$$V_{planned} := \frac{M_{planned}}{\rho}$$

$$V_{previous} = 1.31 \cdot 10^{8} \cdot ft^3$$

$$V_{planned} = 2.687 \cdot 10^{8} \cdot ft^3$$

$$V_{ug} := V_{previous} + V_{planned}$$

$$V_{ug} = 3.997 \cdot 10^{8} \cdot ft^3$$

Calculate the time for the Underground Workings to refill

$$z_o := 6670 ft$$

$$z_b := 5350 ft$$

$$A(z = \begin{cases} 1.05 \, 10^{6} \, ft^2 & \text{if } 5350ft \;\; z \;\; 5550ft \\ 1.69 \, 10^{5} \, ft^2 & \text{if } 5550ft \;\; z \;\; 6670ft \\ 0 \, ft^2 & \text{if } 6670ft \;\; z \end{cases}$$

$$Q(z) := \begin{cases} 0 & \text{if } z > z_o \\ \left(\frac{z_o - z}{z_o - 5550 ft}\right) \cdot Q_a & \text{if } 5550 ft \le z < 6670 ft \\ Q_a + Q_b \cdot \left(\frac{5550 ft - z}{5550 ft - z_b}\right) & \text{if } 5350 ft \le z < 5550 ft \end{cases}$$

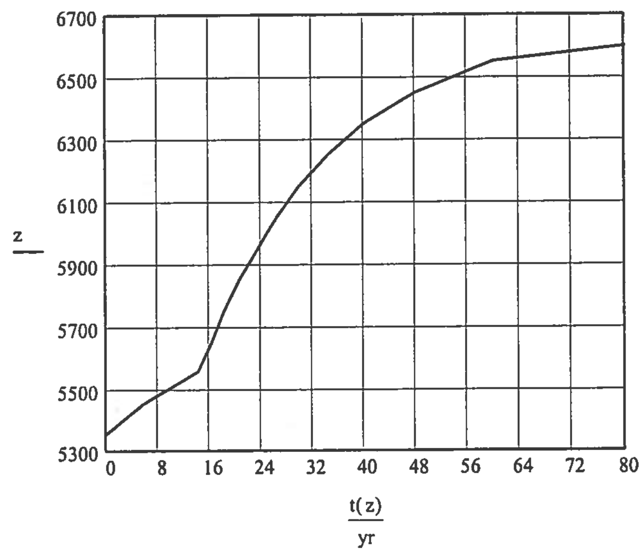
Check the Volume

$$V_{total} := \int_{z_b}^{z_o} A(z)\, d \qquad V_{total} = 3.99 \cdot 10^8 \cdot ft^3$$

Water Level vs Time Calculation

$$t(z) := \int_{z_b}^{z} \frac{A(z)}{Q(z)}\, d$$

$$z := 5350ft\ 5450ft\ \ 6670ft$$



Water-Level Elevation (ft.MSL)

Time Since End-of-Mining (yr)

$$t(6500\,ft) = 53 \cdot yr$$

$$t(6665\,ft) = 124.9 \cdot yr$$

If no expansion occurs and the workings are allowed to fill up.

$$t_{noexpand} := t(6500\,ft) - t(5550\,ft)$$

$$t_{noexpand} = 38.445 \cdot yr$$

E3-3.0 SUMMARY AND CONCLUSIONS

The purposes of this attachment are to document the following:

- Estimation of a value for the bulk hydraulic conductivity associated with current dewatering of the Underground Workings
- Prediction, based on the estimated bulk hydraulic conductivity value, of the end-of-mining inflow rates into the Underground Workings
- Estimation of the flooding time required for the Underground Workings after dewatering ceases.

Based on calculations of quasi-steady state flow into the Underground Workings, SMI estimated that the bulk hydraulic conductivity of the formations supplying water to the Underground Workings is 5.5×10^{-6} cm/s. This value agrees with the results of the short-term aquifer testing of monitoring wells MW-5 and MW-21. For the previously proposed mine expansion, the best estimated inflow rate at the end of mining is 302 gpm. After dewatering operations are terminated, it is estimated that complete flooding of the Underground Workings will take over 120 years.

The objectives described in Section E3-1.0 have been satisfied. The results of this preliminary analysis are not intended to provide a precise answer; rather, the results give a general indication of the flow rates and refilling times that can be expected. These results are adequate for impact assessment, but should not be used for engineering design purposes.

E3-4.0 REFERENCES

Cobre Mining Company, Inc. 1997. Personal Communications from Roger Dancause, Cobre Mining Company. *Estimate of Past and Planned Underground Mining Production.*

Cobre Mining Company, Inc. 1998. Personal Communications from Roger Dancause, Cobre Mining Company. *Table of Cobre Water Rights and Usage for the Past 5 Years.*

ATTACHMENT E4

CONTINENTAL PIT WATER BALANCES
FOR THE PROPOSED CONTINENTAL MINE EXPANSION PROJECT,
GRANT COUNTY, NEW MEXICO

E4-1.0 INTRODUCTION: CONTINENTAL PIT

E4-1.1 Problem Statement and Objectives

The evaluation presented below is based on a 1997 proposed expansion and the associated analysis performed in 1997. In 1997, the Continental Pit was dry (except during precipitation events) and required no dewatering. This condition is believed to result from dewatering of the Underground Workings, which has depressed the water table in the lower bedrock unit. However, observations made during blast-hole drilling and from the water-level data in nearby wells indicate that the water table is very near the current pit bottom (elevation 6,480 feet). After dewatering of the Underground Workings ceases and water levels rise to their pre-mining condition, it is probable that the Continental Pit will collect water and form a pit lake.

The objectives of this attachment are to document the following:

- Verification that a pit lake will form after the cessation of mining
- Estimation of the ultimate (stable) water level in the pit lake after closure
- Prediction of the time required for the pit lake to reach the ultimate elevation
- The input parameters provided for the predictive water quality model of the future pit lake.

E4-1.2 Approach

The water balance components associated with the Continental Pit, both before and after expansion, include the following:

- Direct precipitation to the pit lake surface
- Runoff and infiltration from precipitation falling on the pit walls
- Evaporation from the lake surface
- Ground water inflows from the pit walls and pit bottom.

The overall water balance and estimated filling times were accomplished using a succession of steady-state solutions that were calculated based on average flow rates for various pit lake water levels. The following list describes this process:

1. The geometry of the storage volume and lake area were calculated for various pit lake depths (e.g., for the expanded Continental Pit 0-20 feet depth interval, the average lake area = 10.1 acres, and the average end-area volume = 326,000 cubic yards).

2. The magnitude of each individual water balance component was estimated for various pit lake depth intervals (e.g., the precipitation to the lake for this interval is the average area times the average yearly rainfall).

3. The water balance approach described in the introduction to the attachments was used to estimate the time to fill the chosen depth interval.

4. This process was repeated for successive depth intervals until total inflows balanced the outflows, indicating no change in the pit lake volume (i.e., steady-state conditions). The pit lake elevation where total inflows equal total outflows corresponds to the predicted ultimate pit lake elevation.

E4-2.0 CALCULATIONS

E4-2.1 Data and Assumptions

The magnitudes of precipitation (18.3 inches/year) and evaporation (55.8 inches/year) are presented in Attachment E1. Runoff and infiltration from the pit walls can be estimated from several types of runoff analyses, but for this preliminary estimate, 15% of the precipitation (2.7 inches/year) falling on the pit walls was assumed to enter the pit lake.

Polynomial relationships were developed relating depth to pit lake surface area and volume. Figures E4-1 and E4-2 display these relationships (developed from contour maps) for the current and proposed Continental Pits, respectively.

Ground water inflow rates into the Continental Pit, assuming no expansion, were computed using equations in Attachment E6 and the parameter values shown in Table E4-1. The curve of ground water inflow rate versus pit depth is shown on Figure E4-1.

Table E4-1 Parameters for the Non-expanded Continental Pit Ground Water Inflow Calculations

Parameter	Description	Value and Units	Notes
h_o	Depth of pit bottom below static water table	190 feet	Based on the assumed, pre-mining average static water level of 6,670 feet and the current pit bottom elevation of 6,480 feet
d	Depth of lake	0 to 60 feet	Varies in 20 foot intervals
h_p	Height of seepage face plus the depth of the lake	d + 10 feet	
r_p	Average pit lake radius	Function of Depth	0.8 times the effective radius of the pit lake surface
W	Regional ground water recharge rate	1.24 inch/year	Assumed
K	Bulk hydraulic conductivity of rock	5.5×10^{-6} cm/s	Determined from the analysis of the Underground Workings (See Section E3-2.1)

Ground water inflow rates into the Continental Pit, assuming the proposed action expansion occurs, were computed using equations in Attachment E6 and the parameter values shown in Table E4-2. The curve of ground water inflow rate versus pit depth is shown on Figure E4-2. The calculations indicate an increase in ground water flows to the pit lake with increasing pit lake depth. This behavior may seem counter-intuitive because, in well hydraulics, the inflow to a well decreases as the water level in the well rises. The difference between the pit lake calculations and what is observed in a well is that the radius of the pit lake changes dramatically with depth. If the radius of the pit were more uniform, this increasing trend in ground water inflow rates would not occur.

Table E4-2 Parameters for the Expanded Continental Pit Ground Water Inflow Calculations

Parameter	Description	Value and Units	Notes
h_o	Depth of pit bottom below static water table	670 feet	Based on the assumed, pre-mining average static water level of 6,670 feet and the current pit bottom elevation of 6,480 feet
d	Depth of lake	0 to 470 feet	Varies in 20 foot intervals
h_p	Height of seepage face plus the depth of the lake	D + 10 feet	
r_p	Average pit lake radius	Function of Depth	0.8 times the effective radius of the pit lake surface
W	Regional ground water recharge rate	1.24 inch/year	Assumed
K	Bulk hydraulic conductivity of rock	5.5×10^{-6} cm/s	Determined from the analysis of the Underground Workings (See Section E3-2.1)

Additional assumptions used in the ground water inflow calculations are:

- Steady-state flow. While the steady-state flow assumption is not valid for short time periods (e.g., initial pit dewatering), it is a valid assumption for the long time frames considered in this evaluation (i.e., several decades).

- Isotropic and homogeneous aquifer. Based on the scale of the problem and the objectives of the calculation set, this assumption is reasonable.

- Radial flow to a terminal pit lake. For preliminary estimates, this assumption is valid. It is based on the estimated pre-mining hydraulic gradients in the area, and the large expected drawdown in the pit (i.e., the drawdown is sufficient to cause inflow into the pit from all directions).

- As the pit lake rises, the pit is modeled as a series of cylinders with increasing radii (see Figure E4-3). This assumption is inherent to the analytical equation used to predict ground water inflows. It is appropriate for the objectives of the calculation set.

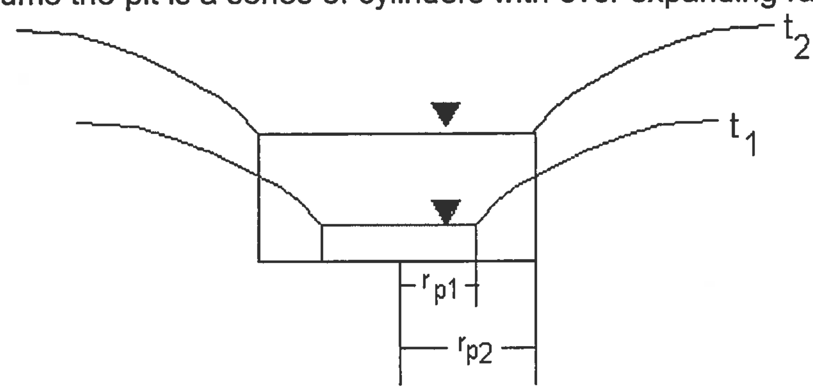
E4-2.2 Water Balance

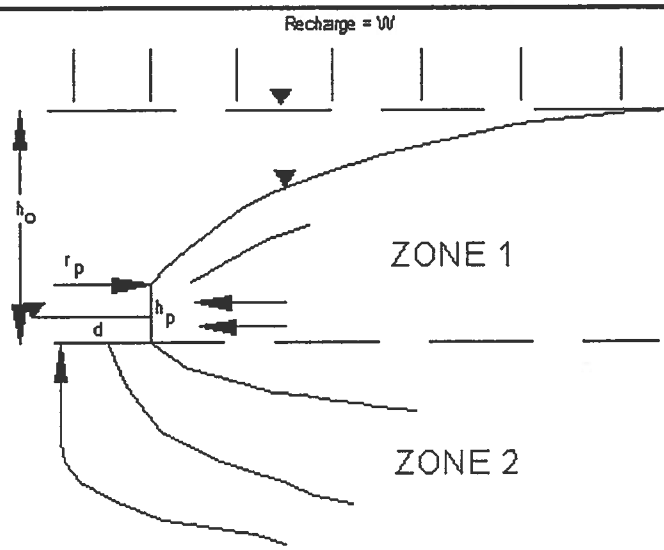
Figures E4-4 and E4-5 show the magnitudes of the various water balance components as a function of depth for the non-expansion and expansion case, respectively. Figure E4-6 and E4-7 show the predictions concerning the final steady-state pit lakes. For the non-expanded Continental Pit, the final pit lake is estimated to be 43 feet deep and have a net evaporative loss of approximately 58 gpm. For the expanded Continental Pit, the final pit lake is estimated to be 464 feet deep and have a net evaporative loss of 161 gpm. Table E4-3 shows the MathCad© worksheet used to develop Figures E4-4 through E4-7.

Table E4-3 Worksheet Showing Development of Figures E4-4 through E4-7

Calculations. Non-Expanded Continental Pit

Ground water inflows
Assume the pit is a series of cylinders with ever expanding radius.





Using the 2 zone approach illustrated above, the following empirical relationship between depth and total ground water inflows was developed.

$$Q_{gw}(d) := 3.7811\cdot 10^{-6}\cdot\frac{gal}{min\cdot ft^3}\cdot d^3 - 2.669\cdot 10^{-3}\cdot\frac{gal}{min\cdot ft^2}\cdot d^2 + 0.24266\frac{gal}{min\cdot ft}\cdot d + 23.431\cdot\frac{gal}{mi}$$

An empirical relationship was also developed for lake surface area (A_{lake}) and Volume (S) versus depth.

$$A_{lake}(d = 0.2783\frac{1}{ft}\cdot d^3 - 94.507d^2 + 17260ft\ d \quad 290144ft$$

$$S(d) = 4289.4\ ft^2\ d + 460807\ ft^2\ d$$

The effective radius, r_{eff}, is defined as the radius of a circle that would reproduce the correct area.

$$r_{eff}(d) := \sqrt{\frac{A_{lake}(d)}{\pi}} \qquad r_p := 0.8\cdot r_{eff}(d)$$

Other definitions:

$$Q_{precip}(d) := A_{lake}(d)\cdot$$

$$Q_{wallprecip}(d) := 0.15\cdot P\cdot\left(A_{total} - A_{lake}(d)\right)$$

$$Q_{evap}(d) := E_{lake}\cdot A_{lake}(d)$$

$$Q_{out}(d) := Q_{evap}(d)$$

$$Q_{in}(d) := Q_{precip}(d) + Q_{wallprecip}(d) + Q_{gw}(d)$$

Where:

Q_{precip} = the flow from direct precipitation on the lake

$Q_{wallprecip}$ = the flow from precipitation falling on the pit walls

Q_{evap} = the evaporative loss from the lake surface

Q_{in} = sum of the inflows to the pit lake

Q_{out} = sum of the outflows from the pit lake

Water balance at steady state Q_{in} = Q_{out}:

Iterate on d until the relative percent difference (rpd) is small

$$d := 43.44644\,ft$$

$$Elev_{Lake} := Elev_{pit\_bot} + d$$

$$rpd := \frac{(Q_{in}(d) - Q_{out}(d))\cdot 2}{Q_{in}(d) + Q_{out}(d)}$$

$$Q_{in}(d) - Q_{out}(d) = -6.92\cdot 10^{-6}\cdot\frac{gal}{mi}$$

$$rpd = -1.183\cdot 10^{-5}\cdot\%$$

Results:

$$A_{lake}(d) = 20.304\cdot acre \qquad Elev_{Lake} = 6.523\cdot 10^{3}\cdot ft$$

$$Q_{precip}(d) = 19.173\cdot\frac{gal}{mi} \qquad Q_{gw}(d) = 29.246\cdot\frac{gal}{mi}$$

$$Q_{evap}(d) = 58.485\cdot\frac{gal}{mi} \qquad Q_{wallprecip}(d) = 10.065\cdot\frac{gal}{mi}$$

Calculations. Expanded Continental Pit

Using the 2 zone approach illustrated above, the following empirical relationship between depth and total ground water inflows was developed.

$$Q_{gw}(d) := -2.026\cdot 10^{-9}\cdot\frac{gal}{min\cdot ft^4}\cdot d^4 + 2.328\cdot 10^{-6}\cdot\frac{gal}{min\cdot ft^3}\cdot d^3 - 1.553\cdot 10^{-3}\cdot\frac{gal}{min\cdot ft^2}\cdot d^2 + 0.5214\cdot\frac{gal}{min\cdot ft}\cdot d + 51.53\cdot\frac{g}{m}$$

An empirical relationship was also developed for lake surface area (A_{lake}) and Volume (S) versus depth.

$$A_{lake}(d) := -6.861\cdot 10^{-6}\cdot d^4\cdot ft^{-2} - 7.919\cdot 10^{-4}\cdot d^3\cdot ft^{-1} + 12.52\cdot d^2 + 146.1\cdot d\cdot ft + 65630\,ft$$

$$S(d) := 8516.451\cdot d^3 + 646.0296\cdot d^2\cdot ft - 2.801551\cdot d\cdot ft$$

The effective radius, r_{eff}, is defined as the radius of a circle that would reproduce the correct area.

$$r_{eff}(d) := \sqrt{\frac{A_{lake}(d)}{\pi}} \qquad r_p := 0.8\cdot r_{eff}(d)$$

Other definitions:

$$Q_{precip}(d) := A_{lake}(d)\cdot$$

$$Q_{wallprecip}(d) := 0.15\cdot P\cdot(A_{total} - A_{lake}(d))$$

$$Q_{evap}(d) := E_{lake}\cdot A_{lake}(d)$$

$$Q_{out}(d) := Q_{evap}(d)$$

$$Q_{in}(d) := Q_{precip}(d) + Q_{wallprecip}(d) + Q_{gw}(d)$$

Where:

Q_{precip} = the flow from direct precipitation on the lake

$Q_{wallprecip}$ = the flow from precipitation falling on the pit walls

Q_{evap} = the evaporative loss from the lake surface

Q_{in} = sum of the inflows to the pit lake

Q_{out} = sum of the outflows from the pit lake

Water balance at steady state $Q_{in} = Q_{out}$:

Iterate on d until the relative percent difference (rpd) is small

$$d := 463.675 ft$$

$$Elev_{Lake} := Elev_{pit\_bot} + d$$

$$rpd := \frac{(Q_{in}(d) - Q_{out}(d)) \cdot 2}{Q_{in}(d) + Q_{out}(d)}$$

$$Q_{in}(d) - Q_{out}(d) = 3.24 \cdot 10^{-4} \cdot \frac{gal}{mi}$$

$$rpd = 2.016 \cdot 10^{-4} \cdot \%$$

Results:

$$A_{lake}(d) = 55.763 \cdot acre \qquad Elev_{Lake} = 6.464 \cdot 10^{3} \cdot ft$$

$$Q_{precip}(d) = 52.657 \cdot \frac{gal}{mi} \qquad Q_{gw}(d) = 97.829 \cdot \frac{gal}{mi}$$

$$Q_{evap}(d) = 160.619 \cdot \frac{gal}{mi} \qquad Q_{wallprecip}(d) = 10.133 \cdot \frac{gal}{mi}$$

The estimated time for the pit lake to fill to the ultimate depth was calculated using the following steps:

1. An incremental volume was calculated based on the depth-volume relationships presented in Table E4-3 (e.g., for the non-expansion case, the volume between depth of 0 and 20 feet is approximately 1.09×10^{7} feet^{3}).

2. The average, total inflow into the pit (inflows minus outflows) for the incremental depth was calculated (e.g., for the non-expansion case, the average inflow rate is approximately 17 gpm for the 0 to 20 foot incremental depth).

3. The time to fill the incremental volume of interest was calculated as the volume of the increment divided by the average inflow rate (e.g., for the 0 to 20 foot increment of the non-expansion case, the estimated time to fill is approximately 7.3 years).

4. This process was repeated until the ultimate depth was reached.

For the non-expansion case, this calculation method predicted that the ultimate depth (43 feet) would be reached in approximately 300 years but that the lake would fill to a depth of 40 feet within approximately 35 years. For the expansion case, the calculations predict that it will take approximately 680 years to reach the ultimate depth of 464 feet, and that the pit lake would fill to a depth of 400 feet within approximately 60 years.

E4-2.3 Water Balance Sensitivity

Because the values of the input parameters are not precisely known, the results from the calculations of the most likely cases (discussed above) have some uncertainty. Therefore, a sensitivity analysis was used to evaluate the range of probable values. For the non-expanded Continental Pit, Figure E4-8 displays the sensitivity of the prediction of the final pit lake depth, time to fill, and evaporative loss as they relate to changes in hydraulic conductivity, precipitation, evaporation, and inflows from pit wall runoff and infiltration.

A one order-of-magnitude increase in hydraulic conductivity:

- Increases the predicted depth of the lake to approximately 160 feet
- Increases the evaporative loss about two times
- Reduces the filling time to approximately 50 years

A one order-of-magnitude decrease in hydraulic conductivity:

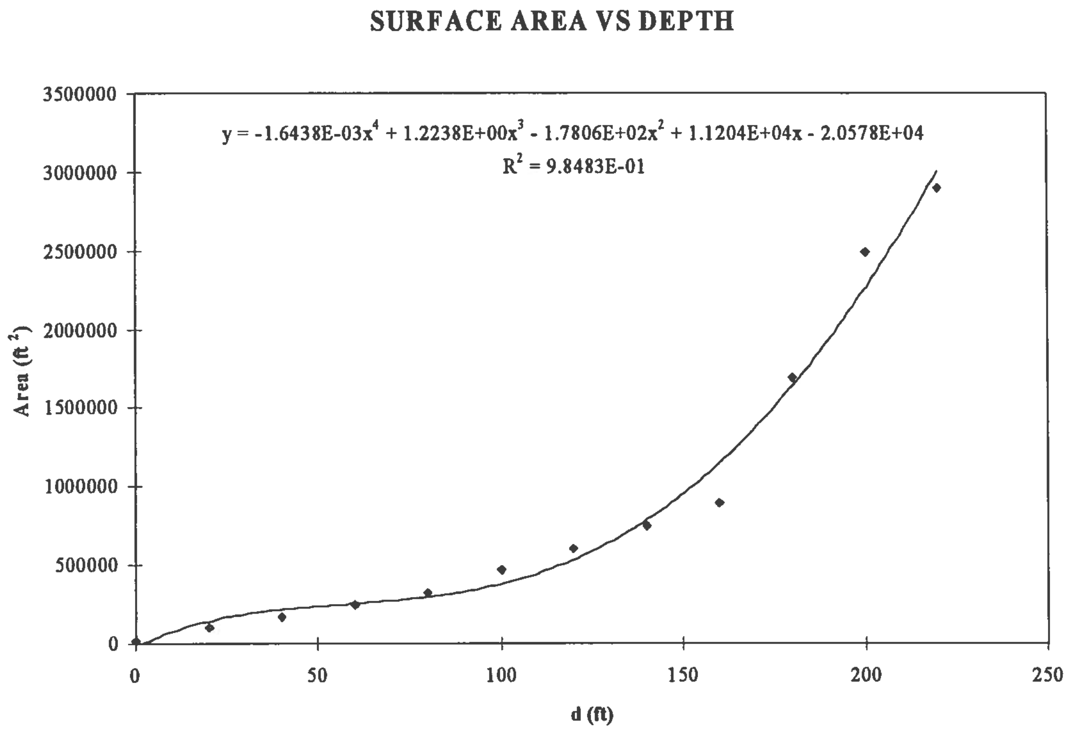
- Results in a much shallower lake (3 feet deep)
- Decreases the evaporative loss by a factor of three
- Reduces the filling time to approximately 12 years (compared to approximately 90 years for the base case).

Increasing the precipitation to 24 inches/year increases the predicted lake depth to approximately 65 feet. It also results in a larger evaporative loss and a much longer time to fill (approximately 190 years). Decreasing the precipitation to 15 inches/year decreases the predicted pit lake depth to approximately 35 feet. This results in a smaller evaporative loss and a shorter time to fill.

As can be expected, increasing the evaporation rate has the reciprocal effect from the precipitation. Increasing the percentage of precipitation falling on the pit walls that contributes flow to the pit lake has the same effect as increasing the precipitation rate.

E4-3.0 SUMMARY AND CONCLUSIONS

Water balance calculations indicate a strong probability that a pit lake will form in the Continental Pit after mining ceases and ground water levels recover from previous dewatering of the Underground Workings. If the Continental Pit is not expanded, the ultimate water-level elevation in the lake will be approximately 6,523 feet with a net loss due to evaporation of approximately 58 gpm. For this condition, the pit lake depth will be about 43 feet. If the Continental Pit is expanded, the ultimate water-level elevation in the lake will be approximately 6,464 feet and will result in a net loss due to evaporation of about 161 gpm. This pit lake will have a depth of about 464 feet. For the non-expanded and expanded Continental Pits, it will take approximately 35 and 80 years, respectively, for the lake to reach approximately 90% of its predicted ultimate depth.



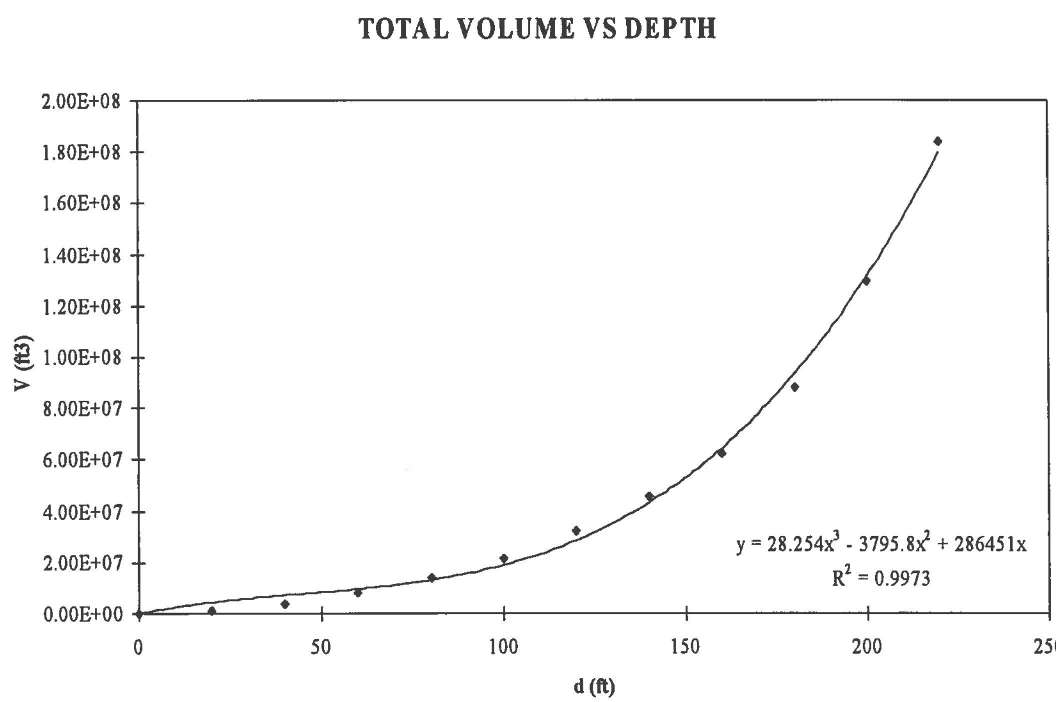


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FIGURE E5-1
PIT LAKE STORAGE AND SURFACE AREA vs. PIT LAKE DEPTH

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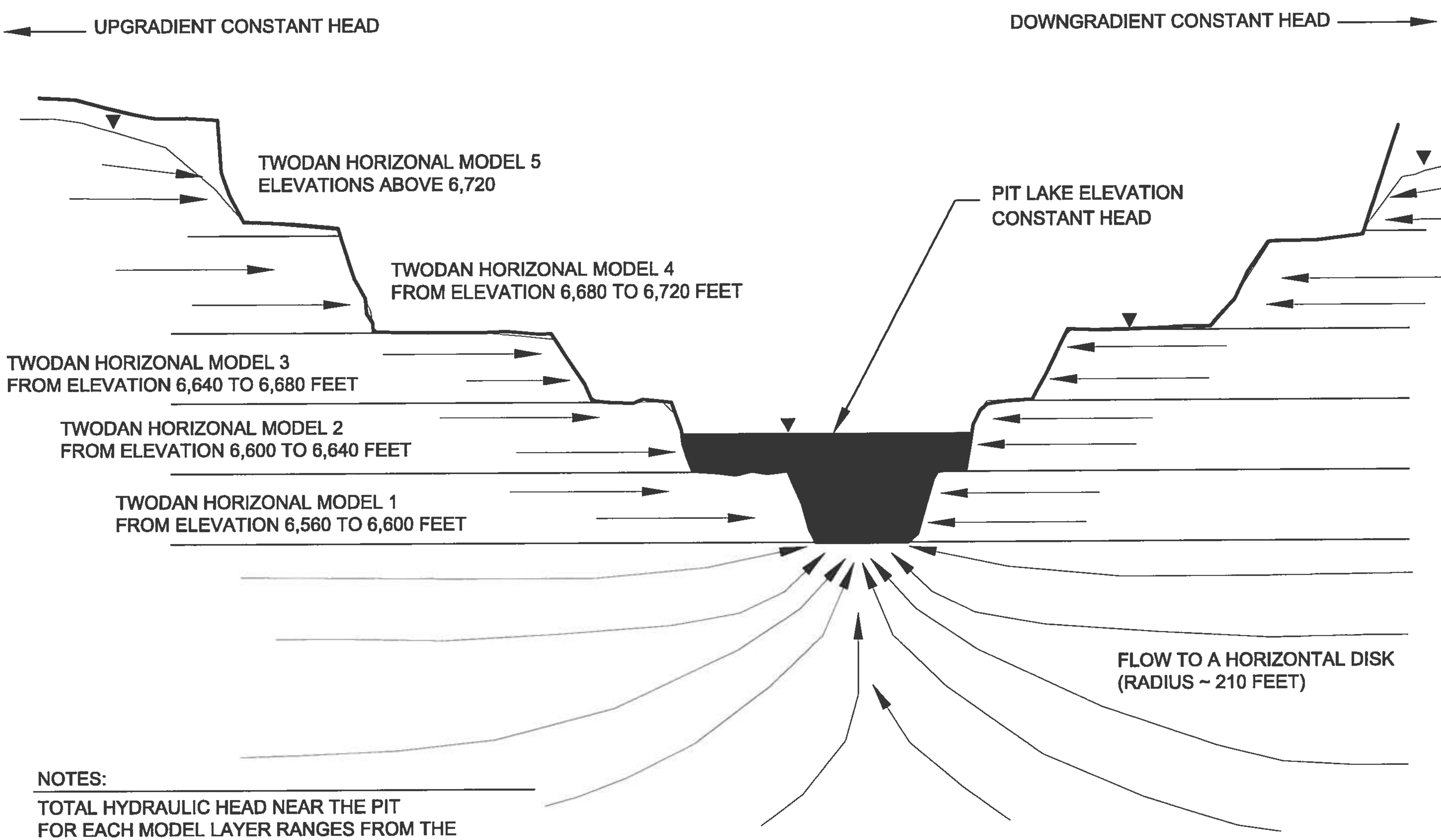

NOTES:

TOTAL HYDRAULIC HEAD NEAR THE PIT FOR EACH MODEL LAYER RANGES FROM THE LAYER BOTTOM ELEVATION (MINIMUM) TO THE PIT LAKE ELEVATION (MAXIMUM). UPGRADIENT AND DOWNGRADIENT BOUNDARIES ARE SHARED BY EACH INDIVIDUAL MODEL.

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FIGURE E5-2
HANOVER PIT LAKE CONCEPTUAL GROUND WATER MODEL
CROSS-SECTIONAL VIEW

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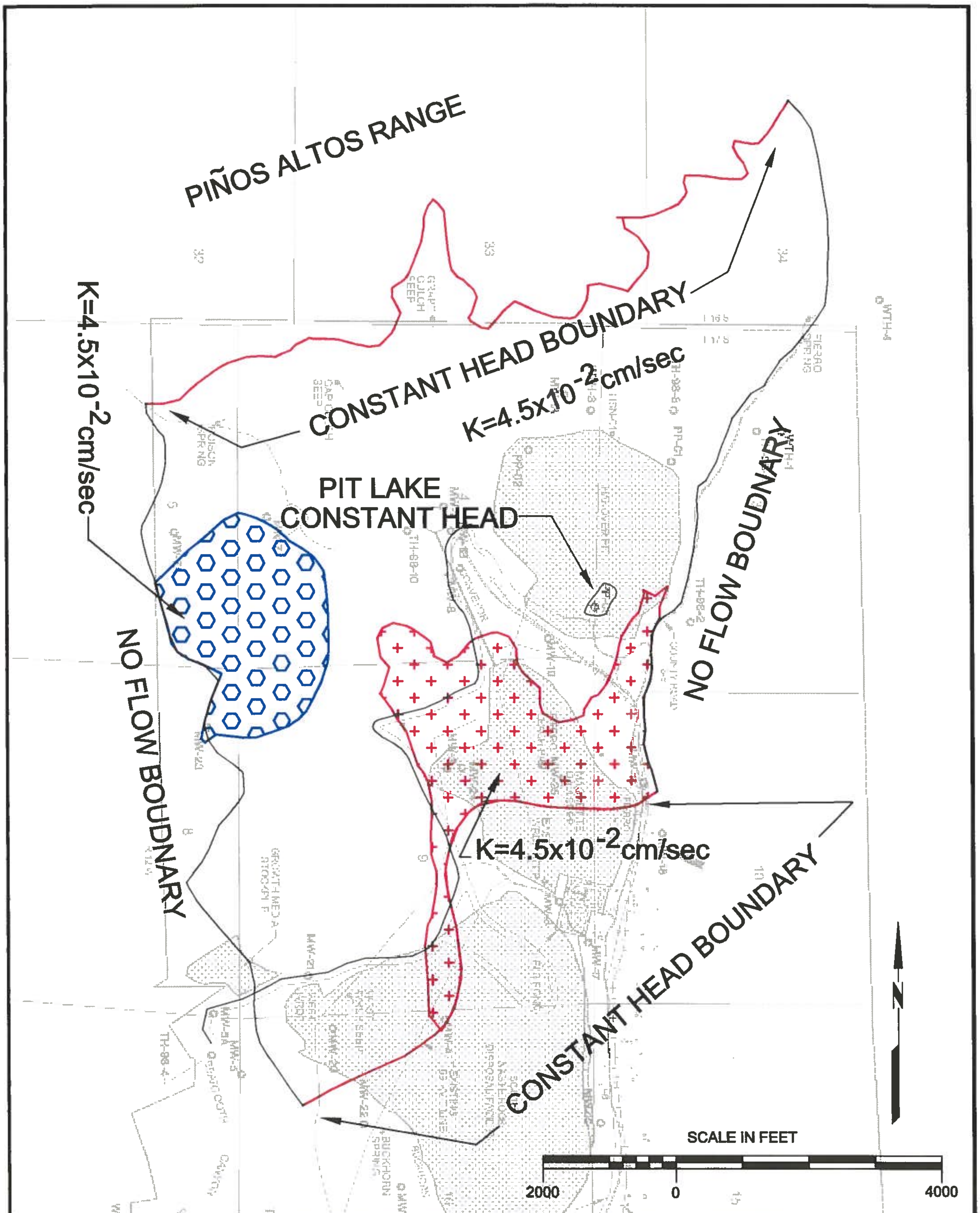

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FIGURE E5-3
ANALYTICAL MODEL FRAMEWORK
ELEVATIONS 6,560 TO 6,600 FEET

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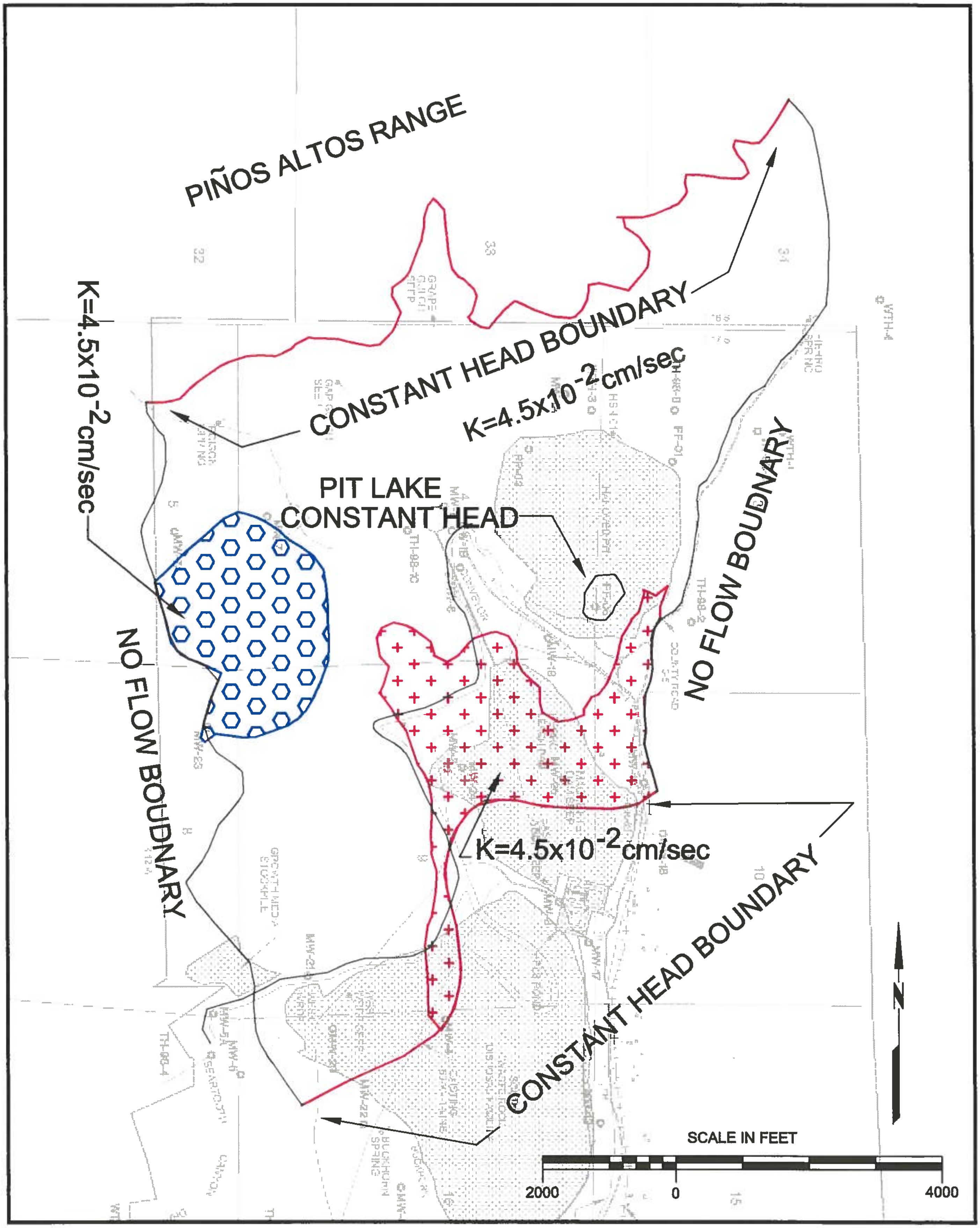

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FIGURE E5-4
ANALYTICAL MODEL FRAMEWORK
ELEVATIONS 6,600 TO 6,640 FEET

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Project:	100029
File:	TWO-DAN-MODEL

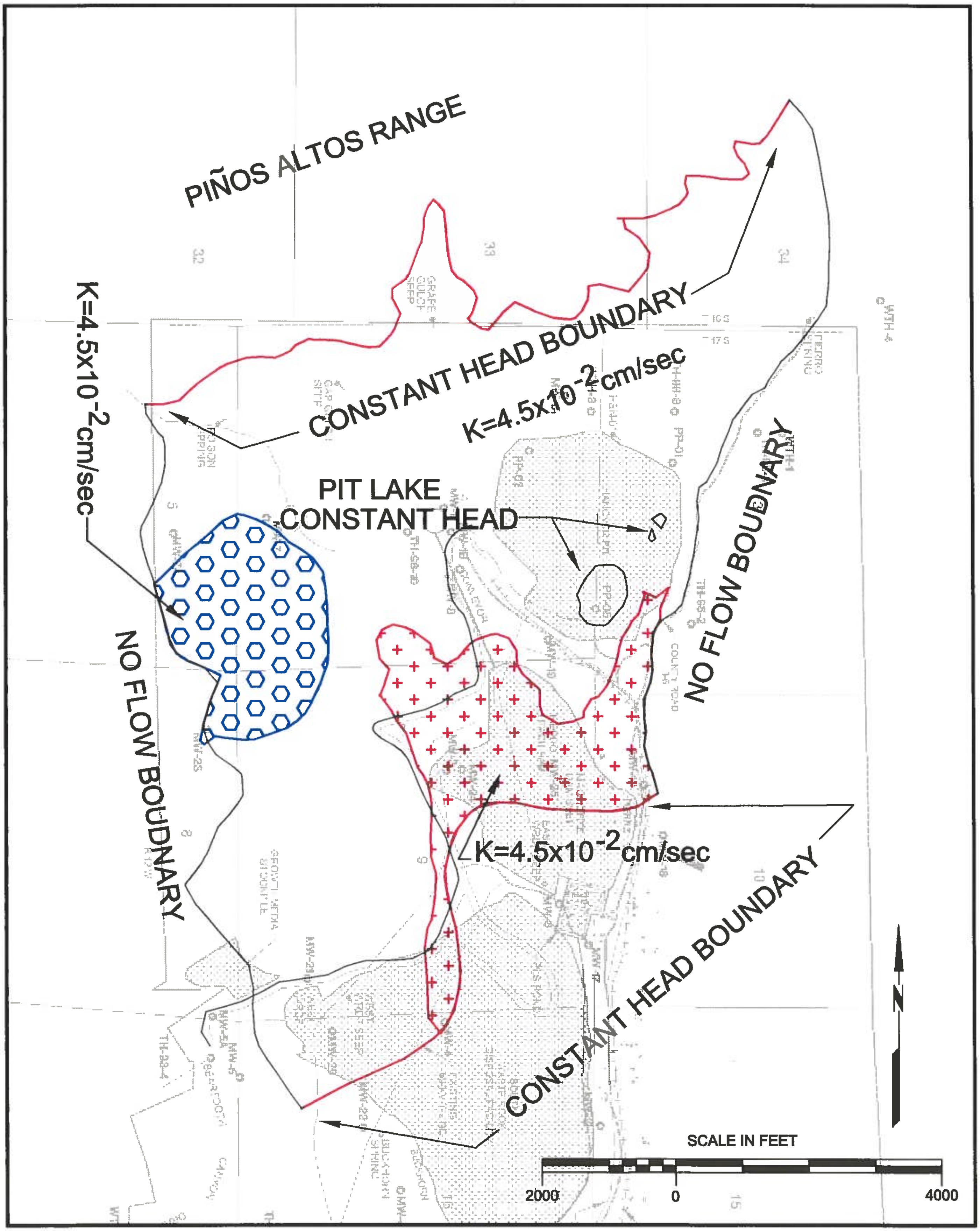

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FIGURE E5-5
ANALYTICAL MODEL FRAMEWORK
ELEVATIONS 6,680 TO 6,720 FEET

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Project:	100029
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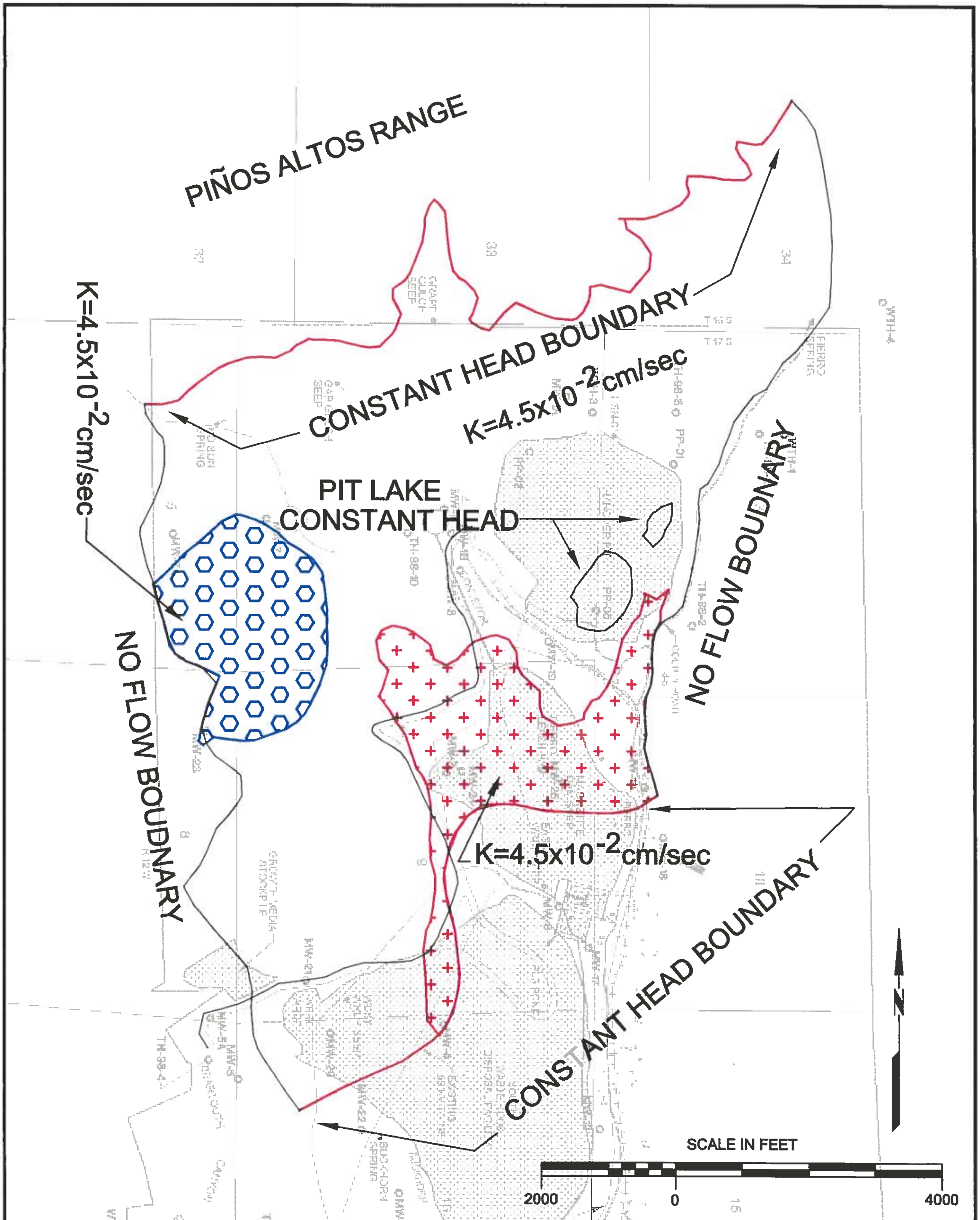

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FIGURE E5-6
ANALYTICAL MODEL FRAMEWORK
ELEVATIONS 6,720 TO 6,760 FEET

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Project:	100029
File:	TWO-DAN-MODEL

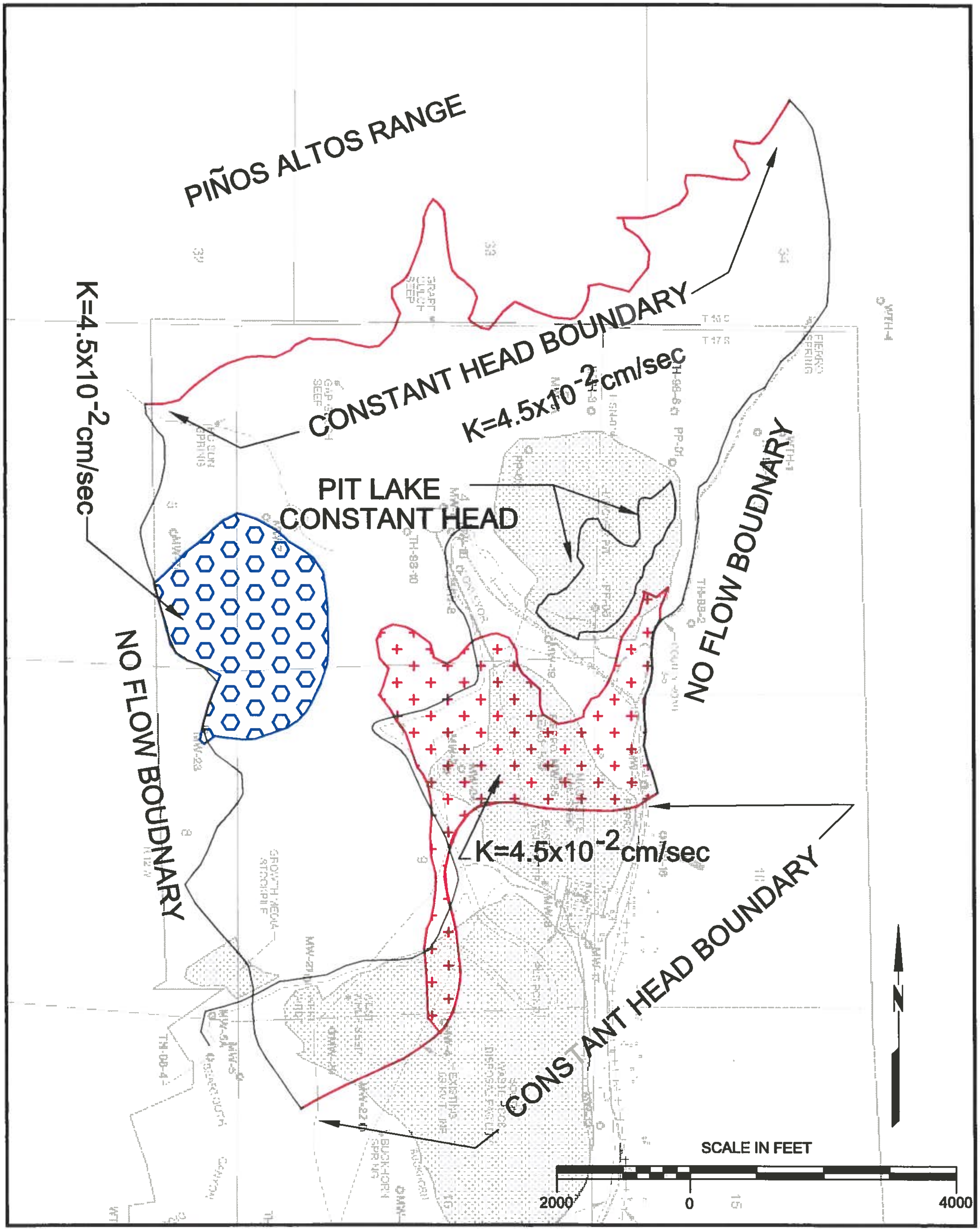

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FIGURE E5-7
ANALYTICAL MODEL FRAMEWORK
ELEVATIONS ABOVE 6,760 FEET

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Project:	100029
File:	TWO-DAN-MODEL

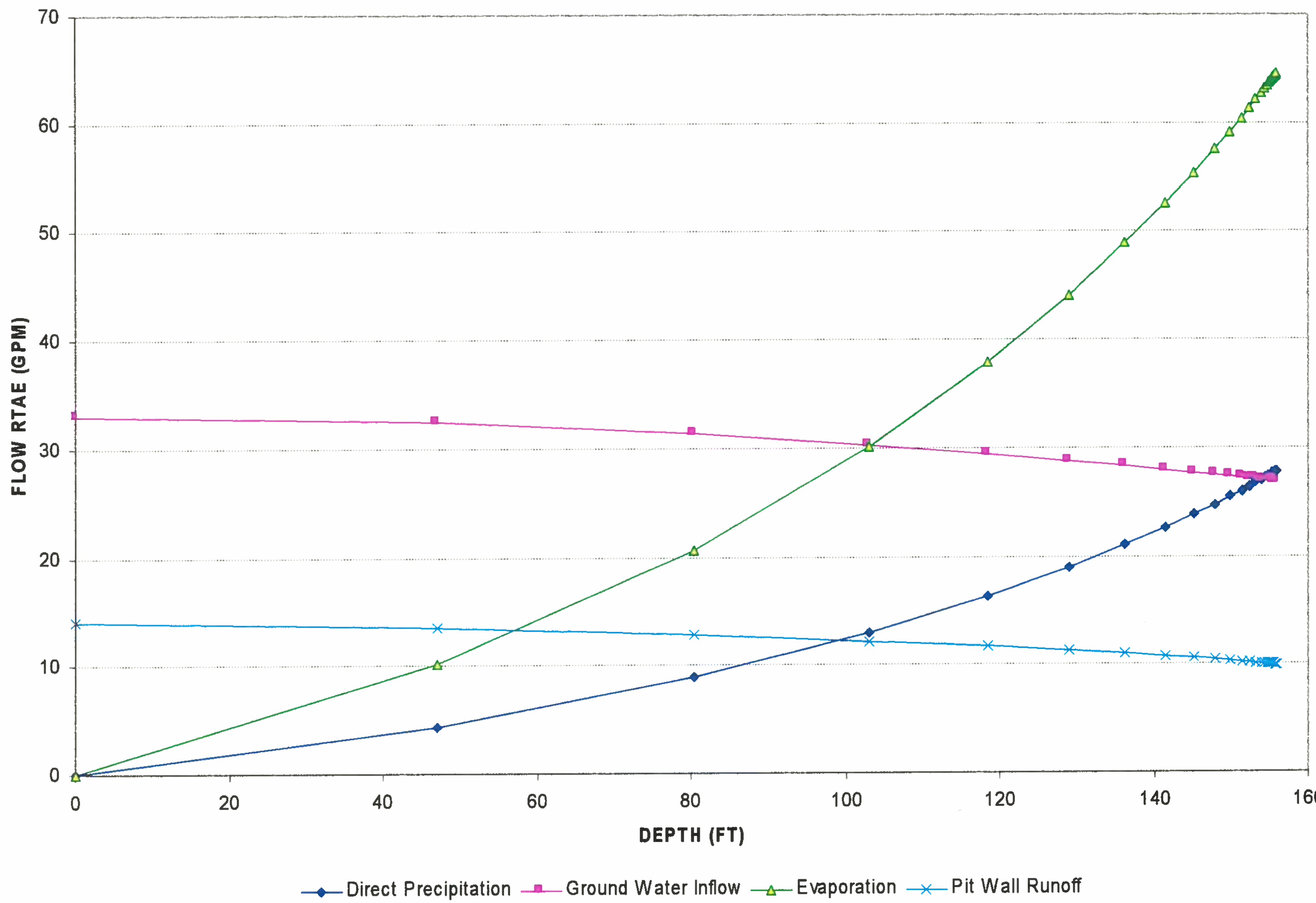

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FIGURE E5-8
MAGNITUDES OF THE WATER BALANCE COMPONENTS AS A FUNCTION OF DEPTH FOR THE HANOVER PIT

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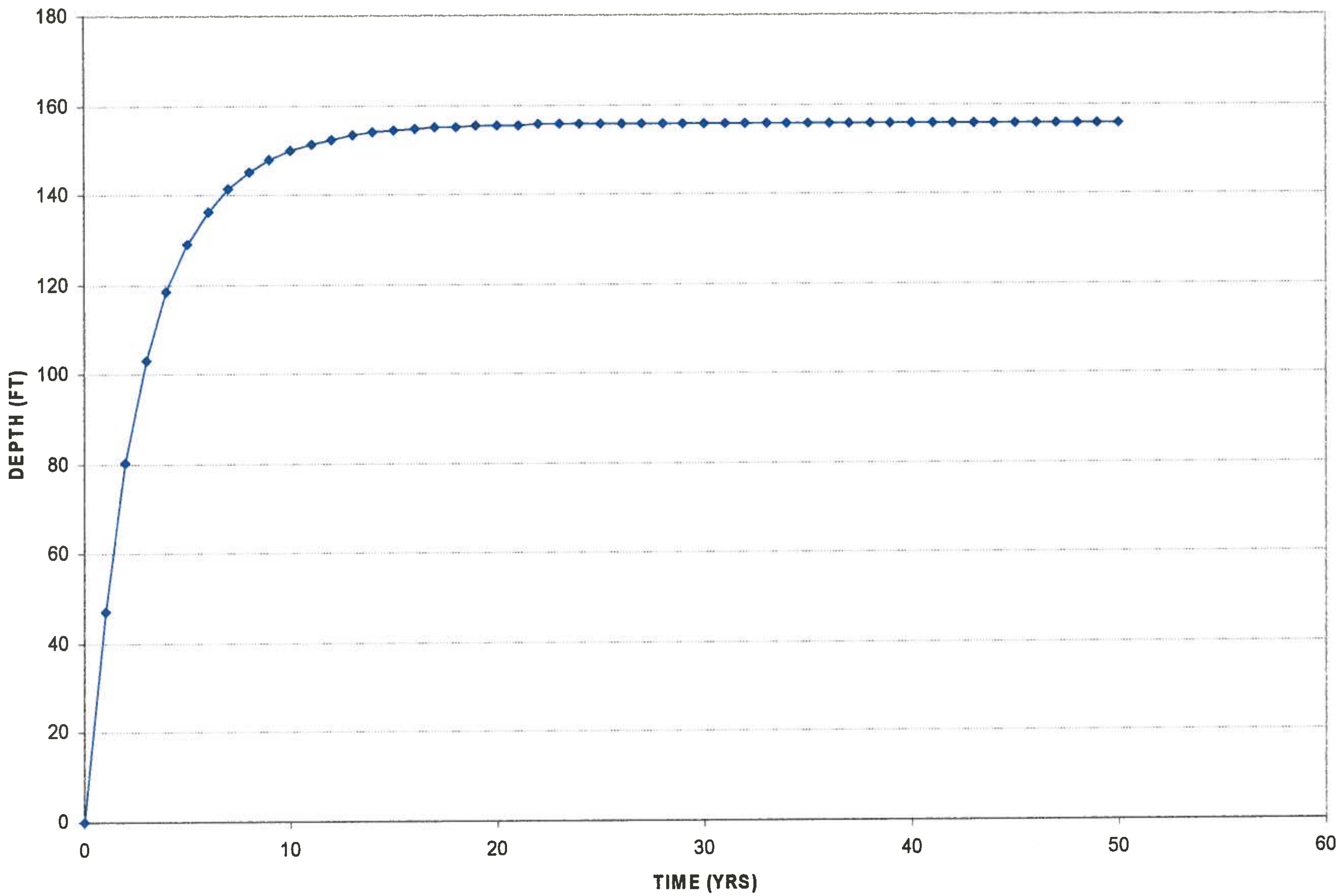

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FIGURE E5-9
FILLING TIME OF THE HANOVER PIT LAKE

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ATTACHMENT E5

HANOVER MOUNTAIN WATER BALANCES FOR THE PROPOSED CONTINENTAL MINE EXPANSION PROJECT, GRANT COUNTY, NEW MEXICO

E5-1.0 INTRODUCTION: HANOVER MOUNTAIN

E5-1.1 Problem Statement and Objectives

Exploration drilling and water level data from wells near Hanover Mountain indicate that the water table is higher than the proposed bottom of the Hanover Pit. Thus, the potential exists for a pit lake to form in the future excavation.

The objectives of this attachment are to:

- Verify that a pit lake may form after the cessation of mining
- Estimate the water level elevation of the ultimate (stable) pit lake after closure
- Estimate the time required for the pit lake to reach the stable water-level elevation
- Provide input parameters to be used in the predictive water quality model of the future pit lake.

E5-1.2 Approach

The chosen approach to meeting the above listed objectives is to estimate the individual components of the water balance associated with the final Hanover Pit. The individual components are then tied together using a dynamics system modeling approach.

The water balance components associated with the Hanover Pit after expansion include the following:

- Direct precipitation to the pit lake surface
- Runoff and infiltration from precipitation falling on the pit walls
- Evaporation from the lake surface
- Ground water inflows and outflows from the pit walls and the pit bottom.

The overall water balance and estimated filling times were evaluated using a succession of steady-state solutions, each based on average flow rates over an increment of time (quasi-steady-state approach). The following list describes this process:

- The storage volume and lake area were characterized as a function of pit-lake depth (see Figure E5-1).

- The average, yearly flow rate of each individual water-balance component was estimated as a function of pit-lake depth.

- The water balance approach described in the introduction to the attachments was used to estimate the time to fill the chosen depth interval.

- This process was integrated over the entire pit-lake depth to estimate the time required to reach steady state (i.e., a dynamics system modeling approach).

E5-2.0 CALCULATIONS

E5-2.1 Climatic Components to the Water Balance

The magnitudes of precipitation (18.3 inches/year) and evaporation (55.8 inches/year) are presented in Attachment E1. Runoff and infiltration from the pit walls can be estimated using several types of runoff analyses; however for this estimate, 15% of the precipitation (2.7 inches/year) falling on the pit walls was assumed to enter the pit lake.

E5-2.2 Ground Water Components to the Water Balance

E5 –2.2.1 Horizontal Ground Water Flow Component

Horizontal ground water inflow rates into the proposed Hanover Pit were computed using a two-dimensional, analytical-element ground water model (TWODAN) developed by Charles R. Fitts (1995). TWODAN is a computer code based on the principle of superposition of linear differential equations and the Analytic Element Method described by Strack (1989). The code is well documented and publicly available through such sources as the International Ground Water Modeling Center in Golden, Colorado.

The parameter values used in the horizontal, steady state ground water model are shown in Table E5-1a along with the justification and assumptions used to derive these values.

Additional assumptions used in the horizontal ground water inflow calculations include:

- Quasi-steady-state flow through seepage faces and the saturated zone. Given the relatively short dewatering time in the pit (i.e., excavation below the water table is expected to take place for only a couple of years), this assumption allows an estimate of transient flow conditions with a steady-state model.

- Isotropic and horizontally homogeneous aquifer properties (within specific formations). Based on the scale of the problem, this assumption is appropriate. Heterogeneities between significant formations were considered in all calculations.

To calculate the horizontal flow to the pit lake, a series of 40-foot thick, 2-dimensional models (TWODAN) were set up. Each individual model had a different sized constant head boundary representing the changing pit area as a function of depth. Figure E5-2 shows this conceptualization. For calculation purposes, it was assumed that a "seepage" face would exist along the entire pit face because of the short time frame associated with mining below the water table. This is not expected to actually happen. Rather, this is a steady-state method to simulate the nature of the transient flow expected to occur from mine dewatering. Calculated flows from each individual model were summed to estimate the horizontal flow to the pit.

Figures E5-3 through E5-7 displays the analytical framework for each horizontal model. Each horizontal model consists of three distinct hydraulic conductivity "zones," which are based on the formations encountered at the various model depths. The various zones are based on geologic block modeling performed by Cobre. The geologic block modeling shows that the lateral extent of the geologic formations do not change significantly through the depths associated with the proposed Hanover Pit. Therefore, all TWODAN models have the same hydraulic conductivity zone configuration.

Each horizontal model consists of a constant head boundary at the up and downgradient ends of the model (north and south sides, respectively). These boundaries are based on the interpretation of water level measurements presented in Appendix A. As described in Table E5-1, the east and west sides of each horizontal model are modeled as no flow boundaries. The four lowest models (covering elevations 6,560 feet through 6,720 feet) are confined, each representing a single 40-foot aquifer thickness. The top horizontal model (elevations above 6,720 feet) is unconfined.

Using the Colorado Formation geometric mean hydraulic conductivity value for data available as of July, 1999 (approximately 1.56×10^{-5} cm/sec), horizontal flow to the pit at the end of mining is estimated to be approximately 33 gpm. If the maximum hydraulic conductivity (approximately 3.0×10^{-4} cm/sec) for the Colorado Formation is used, the horizontal flow component could be as high as 640 gpm. Using the minimum hydraulic conductivity of the Colorado Formation (approximately 4.5×10^{-7} cm/sec) yields a horizontal flow estimate of 0.72 gpm.

Table E5-1a Parameters for the Proposed Hanover Pit Ground Water Inflow Calculations - Horizontal Flow

Description	Value and Units	Notes
Aerial Recharge	0.0	Aerial recharge is expected to be a minor component of the flow system, given the small scale of the model. Constant head boundaries provide the majority of the modeled flow
Pumping Wells	none	The Hanover Mountain aquifer system is hydraulically disconnected from the system containing the underground workings and the sump.
North Boundary: (Upgradient)	7,000 ft.	Modeled as a line sink. The boundary is sufficiently removed from the area of interest as to not influence conclusions based on the model results.
South Boundary (Downgradient)	6,560 ft.	Modeled as a line sink. The boundary is sufficiently removed from the area of interest as to not influence conclusions based on the model results.
East Boundary	No Flow (i.e., flow line boundary)	Assumed to coincide with Hanover Creek. In the area of Hanover Pit, the Barringer Fault and Hanover Creek roughly coincide. In these areas the no flow boundary was assumed to coincide with Hanover Fault.
West Boundary	No Flow	Assumed to coincide with the surface water divide located west of the site.
Hydraulic Conductivity: Colorado Formation	0.045 ft/day ($1.56*10^{-5}$ cm/s)	Equal to the geometric mean of all Colorado Formation pumping test analysis results.
Hydraulic Conductivity: Breccia Pipe	0.135 ft/day ($4.76*10^{-5}$ cm/s)	Assumed to be three times more permeable than the Colorado Formation. This assumption is based on the brecciated nature of this formation.
Hydraulic Conductivity: Un-weathered Hanover-Fierro Stock	0.0225 ft/day ($7.94*10^{-6}$ cm/s)	The geometric mean of all pumping test analysis for the Hanover-Fierro Stock is 0.053 ft/day (1.88E-05 cm/s). This value is thought to be more indicative of the weathered portion of the stock. Therefore, the hydraulic conductivity of the un-weathered stock was assumed to be one-half as permeable as the value used for the Colorado Formation.
Reference Head	6,900 ft	This is an internal value used in TWODAN to initiate calculations. It is located outside model specified boundaries, therefore, the value and location of the reference head have no effect within the modeled domain.
Lake Elevation	6,560 to 6,800 feet	Varies in 20 foot intervals
Model Bottom Elevation	6,560 feet	This is the expected pit bottom elevation.

E5-2.2.2 Vertical Ground Water Flow Component

Vertical ground water inflow rates into the proposed Hanover Pit bottom were computed using the Zone 2 equation presented in Attachment E6 (Section E6-2.3) and the parameter values shown in Table E5-1b. At the end-of-mining, ground water flow through the bottom of the pit is predicted to be approximately 4.6 gpm. Reducing the horizontal to vertical hydraulic conductivity ratio to one increases this predicted flow to 45.5 gpm.

Table E5-1b Parameters for the Proposed Hanover Pit Ground Water Inflow Calculations - Vertical Flow

Parameter	Description	Value and Units	Notes
h_o	Depth of pit bottom below static water table	238 feet	Based on the assumed, pre-mining average static water level of 6,798[1] feet and the current pit bottom elevation of 6,560 feet
d	Depth of lake	0 to 220 feet	Varies in 20 foot intervals
h_p	Height of seepage face plus the depth of the lake	d + 10 feet	
r_p	Average radius of the pit lake bottom	209 feet	This is the radius required for a circle to have an equivalent area to that of the proposed pit bottom.
K	Bulk hydraulic conductivity of rock	$1.56*10^{-6}$ cm/s	Assumed to be 1/10 of the geometric mean of hydraulic conductivity data near Hanover Mountain (i.e., assume a horizontal to vertical ratio of hydraulic conductivity equal to 10 to 1)

[1] Average of PP-01-1, PP-01-2, PP-01-3, PP-01-4, PP-02-1, PP-02-2, PP-02-3, PP-02-4, PP-05-1 and PP-05-2 data for 11/23/96 and 12/16/96.

E5-2.2.3 Ground Water Balance

The flows from the horizontal models were summed with the flows calculated for the pit bottom to develop a relationship between ground water flow and as a function of pit lake depth. A second-order polynomial equation was fit to this relationship for use in the overall water balance (See Figure E5-8).

E5-2.3 Water Balance

Figure E5-8 shows the magnitudes of the various water balance components as a function of depth. Figure E5-9 shows the water balance predictions for the ultimate pit lake. For the proposed Hanover Pit, the final pit lake is expected to have a depth of 156 feet and a net evaporative loss of approximately 80 gpm. Table E5-2 shows the dynamics system model results used to develop Figure E-9.

Predictions of the time to fill the Hanover Pit Lake were performed in the same manner as those described for the Continental Pit Lake. Calculations predict that it will take approximately 21 years to reach the ultimate depth of 156 feet, and that the pit lake would fill to a depth of 140 feet within approximately 7 years.

Table E5-2 Worksheet Showing Development of Figures E4-3 through E4-4

Time (years)	Pit Lake Depth (feet)	GW Inflow (gpm)	Pit Wall Runoff (gpm)	Direct Precipitation (gpm)	Evaporation (gpm)
0	0.0	22.5	14.1	0.0	0.0
1	47.2	20.9	13.6	3.3	7.6
2	80.3	22.7	13.1	6.5	15.1
3	102.9	25.3	12.7	9.7	22.6
4	118.2	27.9	12.2	12.9	30.0
5	128.7	30.2	11.7	15.9	37.0
6	136.0	32.1	11.3	18.8	43.6
7	141.2	33.4	10.9	21.3	49.6
8	144.9	34.3	10.6	23.6	54.8
9	147.7	35.0	10.3	25.5	59.2
10	149.7	35.5	10.1	27.1	63.0
11	151.2	35.8	9.8	28.4	66.1
12	152.3	36.1	9.7	29.5	68.7
13	153.1	36.2	9.5	30.5	70.8
14	153.8	36.4	9.4	31.2	72.6
15	154.3	36.5	9.3	31.8	74.0
16	154.6	36.6	9.3	32.3	75.2
17	154.9	36.6	9.2	32.7	76.1
18	155.1	36.7	9.2	33.1	76.9
19	155.3	36.8	9.1	33.4	77.6
20	155.4	36.8	9.1	33.6	78.1
21	155.5	36.8	9.0	33.8	78.5
22	155.6	36.8	9.0	33.9	78.9

Table E5-2 Worksheet Showing Development of Figures E4-3 through E4-4 (continued)

Time (years)	Pit Lake Depth (feet)	GW Inflow (gpm)	Pit Wall Runoff (gpm)	Direct Precipitation (gpm)	Evaporation (gpm)
23	155.7	36.9	9.0	34.1	79.2
24	155.7	36.9	9.0	34.2	79.4
25	155.7	36.9	9.0	34.2	79.6
26	155.8	36.9	9.0	34.3	79.8
27	155.8	36.9	9.0	34.4	79.9
28	155.8	36.9	9.0	34.4	80.0
29	155.8	36.9	8.9	34.5	80.1
30	155.8	36.9	8.9	34.5	80.2
31	155.8	36.9	8.9	34.5	80.2
32	155.8	36.9	8.9	34.5	80.3
33	155.8	37.0	8.9	34.6	80.3
34	155.8	37.0	8.9	34.6	80.4
35	155.8	37.0	8.9	34.6	80.4
36	155.8	37.0	8.9	34.6	80.4
37	155.8	37.0	8.9	34.6	80.4
38	155.9	37.0	8.9	34.6	80.4
39	155.9	37.0	8.9	34.6	80.5
40	155.9	37.0	8.9	34.6	80.5
41	155.9	37.0	8.9	34.6	80.5
42	155.9	37.0	8.9	34.6	80.5
43	155.9	37.0	8.9	34.6	80.5
44	155.9	37.0	8.9	34.6	80.5
45	155.9	37.0	8.9	34.6	80.5
46	155.9	37.0	8.9	34.6	80.5
47	155.9	37.0	8.9	34.6	80.5
48	155.9	37.0	8.9	34.6	80.5
49	155.9	37.0	8.9	34.6	80.5
50	155.9	37.0	8.9	34.6	80.5
51	155.9	37.0	8.9	34.6	80.5
52	155.9	37.0	8.9	34.6	80.5
53	155.9	37.0	8.9	34.6	80.5
54	155.9	37.0	8.9	34.6	80.5
55	155.9	37.0	8.9	34.6	80.5
56	155.9	37.0	8.9	34.6	80.5
57	155.9	37.0	8.9	34.6	80.5
58	155.9	37.0	8.9	34.6	80.5
59	155.9	37.0	8.9	34.6	80.5
60	155.9	37.0	8.9	34.6	80.5

E5-3.0 SUMMARY AND CONCLUSIONS

Water balance calculations indicate a strong probability that a pit lake will form in the Hanover Pit after mining ceases. The steady-state water elevation in the lake will be approximately 6,716 feet with a net loss due to evaporation of approximately 80 gpm. The estimated depth of the pit lake is 156 feet. It will take approximately 7 years for the lake to reach 90% of its predicted ultimate depth.

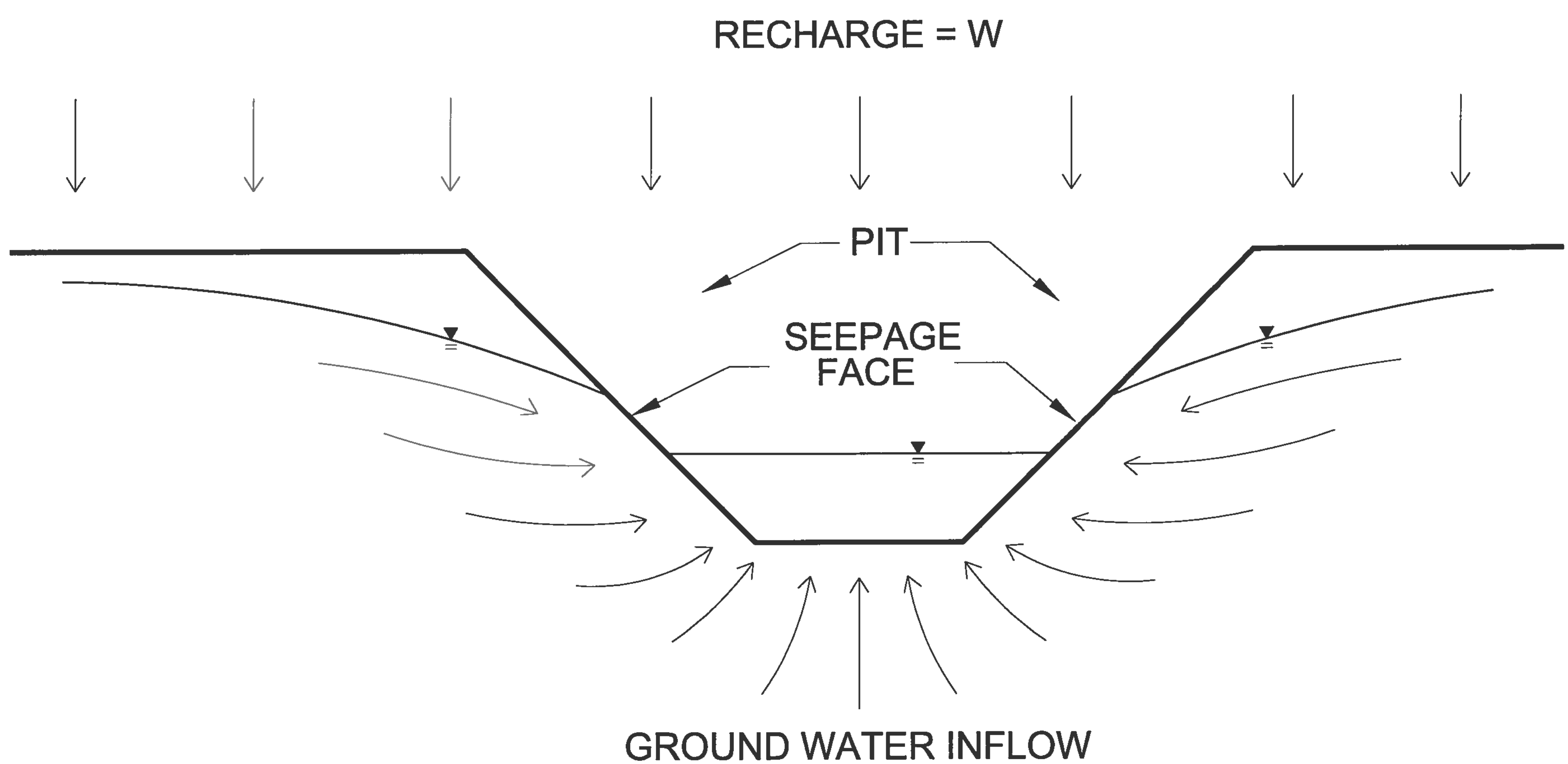

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FIGURE E6-1
CONCEPTUAL MODEL
OF GROUND WATER FLOW TO AN OPEN PIT

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Project:	100029\T5
File:	CON-FLOW

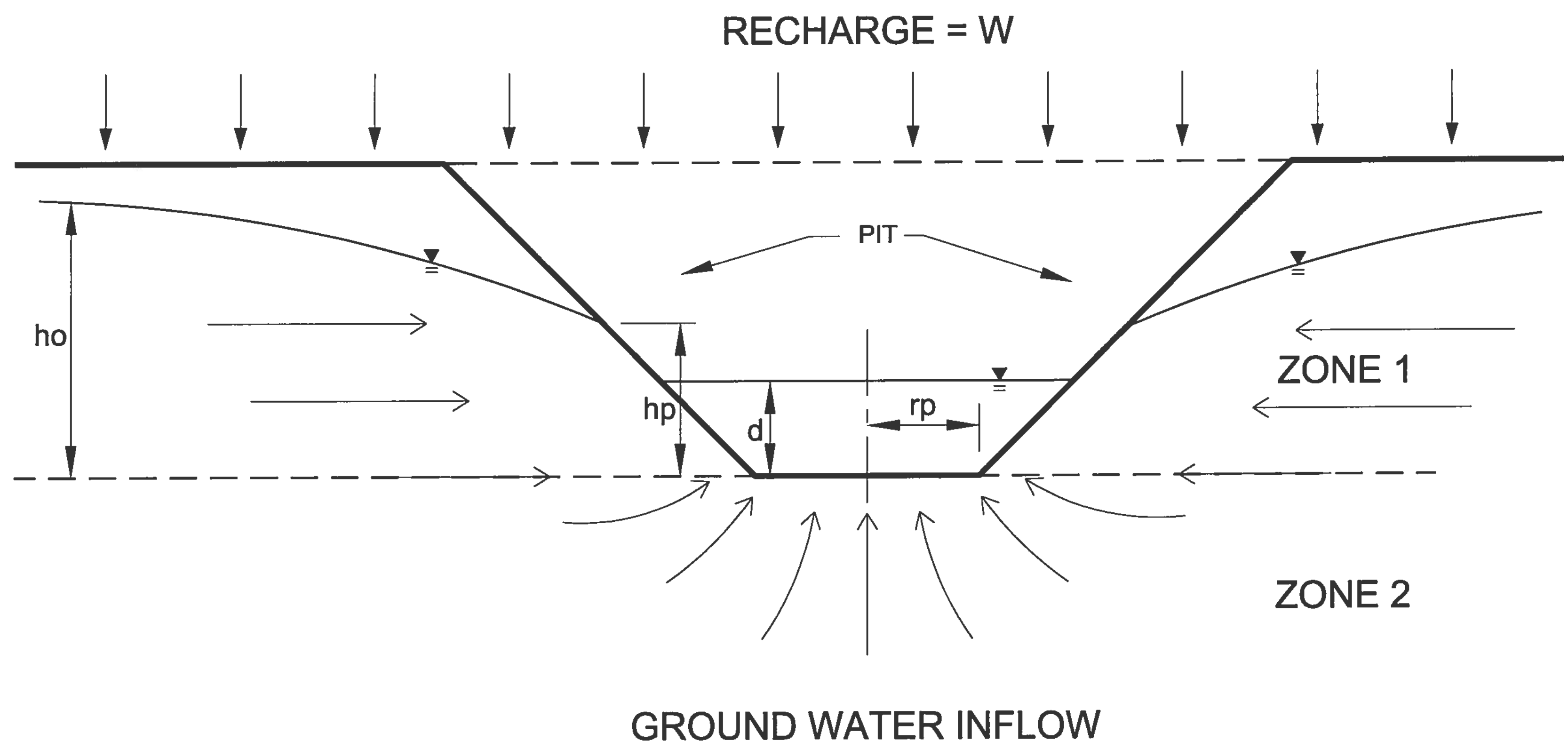

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FIGURE E6-2
CONCEPTUAL MODEL BASED ON TWO-PART
ANALYTICAL SOLUTION OF GROUND WATER FLOW TO A PIT

Date:	DECEMBER 1999
Project:	100029\T5
File:	CONM-2PT

ATTACHMENT E6

ANALYTICAL GROUND WATER MODEL FOR FLOW TO THE CONTINENTAL PIT AND UNDERGROUND WORKINGS FOR THE PROPOSED CONTINENTAL MINE EXPANSION PROJECT, GRANT COUNTY, NEW MEXICO

E6-1.0 INTRODUCTION: ANALYTICAL MODEL

Mine feasibility and environmental evaluations can benefit from the use of analytical tools for predicting ground water inflow to open mine pits. While numerical modeling may be required in some cases, analytical equations can be used in many instances to predict inflow rates. Equations for predicting ground water inflows to open pits and underground excavations are presented in Goodman et al. (1965), Verma and Brutsaert (1970, 1971), Singh and Atkins (1984), and Atkinson et al. (1989). The solutions presented in these technical papers apply to inflow problems with particular sets of boundary conditions and simplifying assumptions. The *applicability* of a solution depends on the extent to which the real problem under consideration is consistent with assumptions used to derive the mathematical equations. If a solution is judged to be applicable, its *accuracy* is generally dictated by the appropriateness of the bulk hydraulic conductivity value used to perform the calculations.

This section presents two analytical solutions that can be useful for predicting the inflow to an open mine pit which is excavated below the water table. A lake of finite depth may or may not exist within the pit. While the equations apply to a fairly specific physical problem, they are relevant to hydrogeologic conditions encountered at many mine sites. The solutions, however, are not appropriate for all mining situations. They should therefore be used only after carefully comparing the associated mathematical assumptions to the known or inferred site conditions.

E6-2.0 THEORETICAL DEVELOPMENT

- The solutions in this section address the conceptual model for pit inflow shown on Figure E6-1. Important assumptions of the conceptual model are summarized below.
- The materials near the pit are assumed to be isotropic with regard to hydraulic conductivity.
- Lowering of the water table within the pit decreases the saturated thickness of rock materials providing inflow through the pit walls.
- Relative to inflow from the pit walls, significant inflow occurs through the pit bottom.
- The rock formation is semi-infinite below the pit and there exists no impermeable boundary at depth.
- Steady-state flow conditions exist near the mine pit. This assumption is reasonable for moderate to high permeability materials and mine pits which are excavated over a period of years.

For the purpose of calculations, the conceptual flow model on Figure E6-1 is approximated by the analytical models shown on Figure E6-2. The flow region is divided into two zones. Zone 1 exists above the base of the pit and represents flow to the pit walls. Zone 2 extends from the bottom of the pit downward and considers flow to the pit bottom. The analytical models both assume that there is no ground water flow between Zones 1 and 2.

E6-2.1 Zone 1 Analytical Solution

The analytical solution for Zone 1 considers steady-state, unconfined, horizontal radial flow with uniform distributed recharge. Additional assumptions of this solution are as follows:

- The pit walls are approximated as a right circular cylinder.
- Ground water flow is horizontal. The Dupuit-Forchheimer approximation (McWhorter and Sunada, 1977; p. 96) is used to account for changes in saturated thickness due to depression of the water table.

- The static (pre-mining) water table is horizontal.
- Uniform distributed recharge occurs across the site as a result of surface infiltration. All recharge within the radius of influence (cone of depression) of the pit is assumed to be captured by the pit.
- Ground water flow towards the pit is axially symmetric.

The following equation applies for these assumed conditions:

$$h_o = \sqrt{h_p^2 + \frac{W}{K_1}\left[r_o^2 \ln\left(\frac{r_o}{r_p}\right) - \frac{r_o^2 - r_p^2}{2}\right]} \qquad \text{(E6-1)}$$

where W is the distributed recharge flux, K_1 is the hydraulic conductivity of materials within Zone 1, r_p is the effective pit radius, h_p is the saturated thickness above base of Zone 1 at r_p, r_o is the radius of influence (maximum extent of the cone of depression), and h_o is the initial (pre-mining) saturated thickness above the base of Zone 1. Given the values of W, K_1, r_p, h_p, and h_o, the radius of influence (r_o) is determined from Equation (E6-1) by iteration. Once r_o is determined, the pit inflow rate from Zone 1 is computed by:

$$Q_1 = W\pi\left(r_o^2 - r_p^2\right) \qquad \text{(E6-2)}$$

where Q_1 represents the inflow from the pit walls. Note that the pit inflow rate is maximized when h_p is set to zero.

The Dupuit-Forchheimer approximation assumes horizontal flow within Zone 1. In cross-section, hydraulic head contours are approximated as vertical lines that are described by the following equation:

$$H_1(r) = H_o - h_o + \sqrt{h_p^2 + \frac{W}{K_1}\left[r_o^2 \ln\left(\frac{r}{r_p}\right) - \frac{r^2 - r_p^2}{2}\right]} \qquad \text{(E6-3)}$$

where H_o is the initial (pre-mining) elevation of the water table, H_1 is the steady-state hydraulic head elevation, and r is radial distance from center of pit.

E6-2.2 Derivation of the Zone 1 Analytical Solution

The equation for steady-state, axially-symmetric, horizontal, unconfined flow is given by (McWhorter and Sunada, 1977; p. 151; eq. 4-79):

$$Q(r) = 2\pi\, K r h \frac{dh}{dr} \qquad \text{(E6-4)}$$

where r is horizontal radial distance, Q is the flow across the cylindrical surface of radius r, h is the saturated thickness above the base of the aquifer, and K is the hydraulic conductivity of the aquifer materials. If it is assumed that all flow is derived from recharge within the radius of influence (r_o), then the flow rate at radius r is given by:

$$Q(r) = W\pi \left(r_o^{\,2} - r^2\right) \qquad \text{(E6-5)}$$

where W is the distributed recharge flux. Substituting (E6-5) into (E6-4) and integrating leads to:

$$\frac{W}{2K} \int_{r_p}^{r} \left(\frac{r_o^{\,2}}{r} - r \right) dr = \int_{h_p}^{h} h \, dh \qquad \text{(E6-6)}$$

where r_p is the radial distance from the center of the pit to the pit wall and h_p is the saturated thickness at the pit wall. Carrying out the integration gives:

$$h(r) = \sqrt{h_p^{\,2} + \frac{W}{K_1}\left[r_o^{\,2} \ln\!\left(\frac{r}{r_p}\right) - \frac{r^2 - r_p^{\,2}}{2} \right]} \qquad \text{(E6-7)}$$

Hydraulic head is equal to:

$$H(r) = H_o - h_o + h(r) \tag{E6-8}$$

where H is the elevation (hydraulic head) of the current water table and H_o is the elevation of the initial static water table. Substitution of (E6-7) into (E6-8) leads to Equation (E6-3). Evaluating (E6-7) at $r = r_o$ and requiring that the initial saturated thickness (h_o) occurs at the radius of influence (r_o) gives:

$$h_o = \sqrt{h_p^{\,2} + \frac{W}{K_1}\left[r_o^{\,2}\ln\left(\frac{r_o}{r_p}\right) - \frac{r_o^{\,2} - r_p^{\,2}}{2}\right]} \tag{E6-9}$$

which is Equation (E6-1). Evaluating (E6-7) at $r = r_p$ gives the flow rate through the pit walls:

$$Q(r_p) = W\pi\left(r_o^{\,2} - r_p^{\,2}\right) \tag{E6-10}$$

which is Equation (E6-2).

E6-2.3 Zone 2 Analytical Solution

The analytical solution for Zone 2 is based on steady-state, confined flow to one side of a circular disk sink of constant drawdown. The sink represents the bottom of the pit. This solution is based on the following assumptions:

- Hydraulic head is initially uniform (hydrostatic) throughout Zone 2. Initial head is equal to the elevation of the initial water table in Zone 1.
- The disk sink has a constant hydraulic head that is equal to the elevation of the pit lake water surface. If the pit is completely dewatered, the disk sink head is equal to elevation of the pit bottom.
- Flow to the disk sink is three-dimensional and axially symmetric.

The steady-state inflow rate to one side of the disk sink is given by (adapted from Carslaw and Jaeger, 1959, p. 215, eq. 10):

$$Q_2 = 4\,K_2\,r_p\left(h_o - d\right) \tag{E6-11}$$

where Q_2 is the pit inflow rate from Zone 2 (through the pit bottom), K_2 is the hydraulic conductivity of materials within Zone 2, and d is the depth of the pit lake. Note that in the above equation, $(h_o - d)$ is the hydraulic drawdown at the bottom of the pit.

Hydraulic head contour lines within the Zone 2 region are computed by (from Carslaw and Jaeger, 1959, p. 215, eq. 9):

$$H_2(r,z) = H_o - \frac{2\left(h_o - d\right)}{\pi}\sin^{-1}\left\{\frac{2\,r_p}{\sqrt{\left(r - r_p\right)^2 + z^2} + \sqrt{\left(r + r_p\right)^2 + z^2}}\right\} \tag{E6-12}$$

where H_2 is the hydraulic head elevation within Zone 2 and z is the vertical depth below the base of the pit (positive downward).

E6-3.0 REFERENCES

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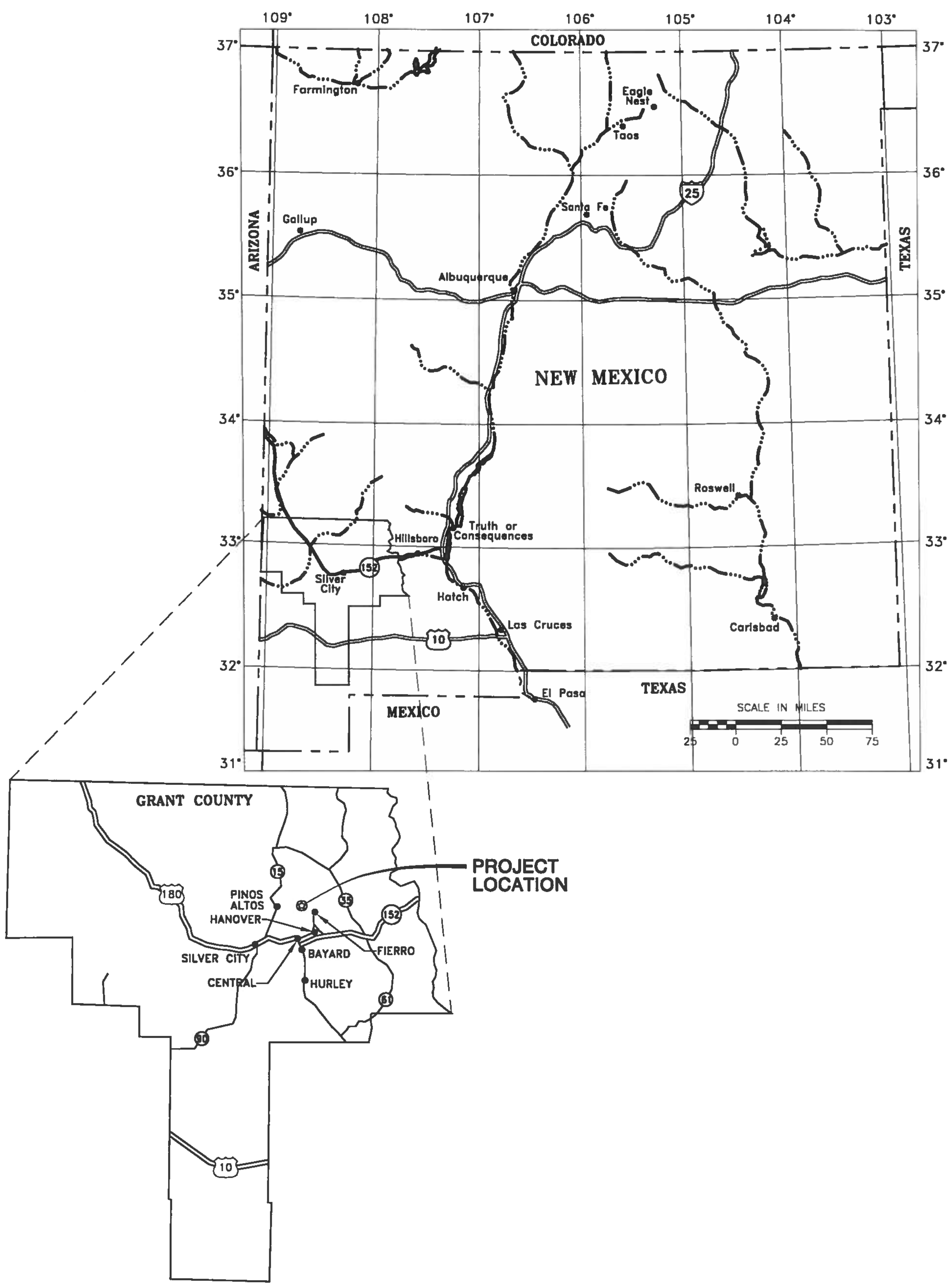

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FIGURE E-1
PROJECT LOCATION

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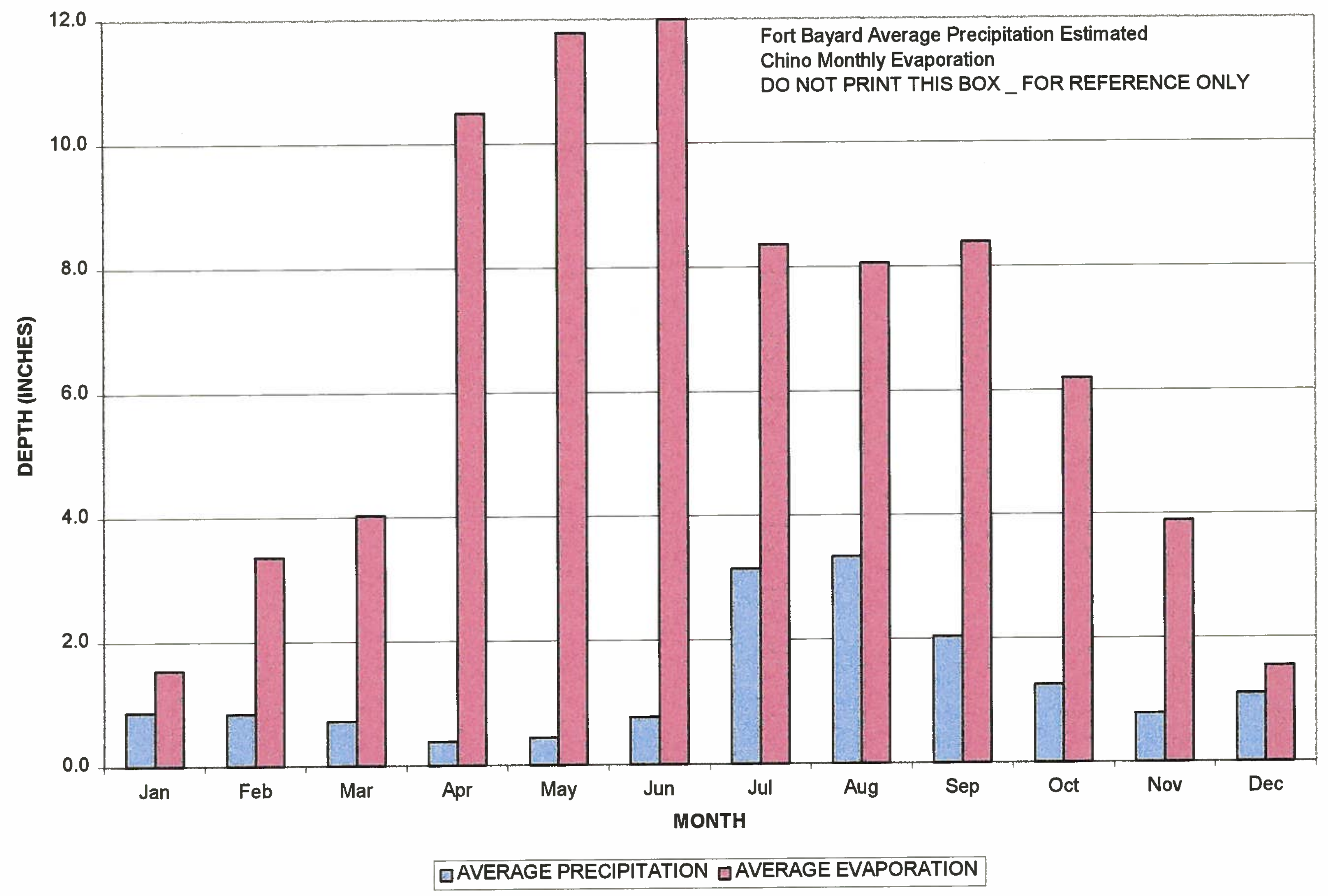

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FIGURE E-2
MONTHLY PRECIPITATION AND EVAPORATION
FORT BAYARD AND CHINO MINE, NEW MEXICO

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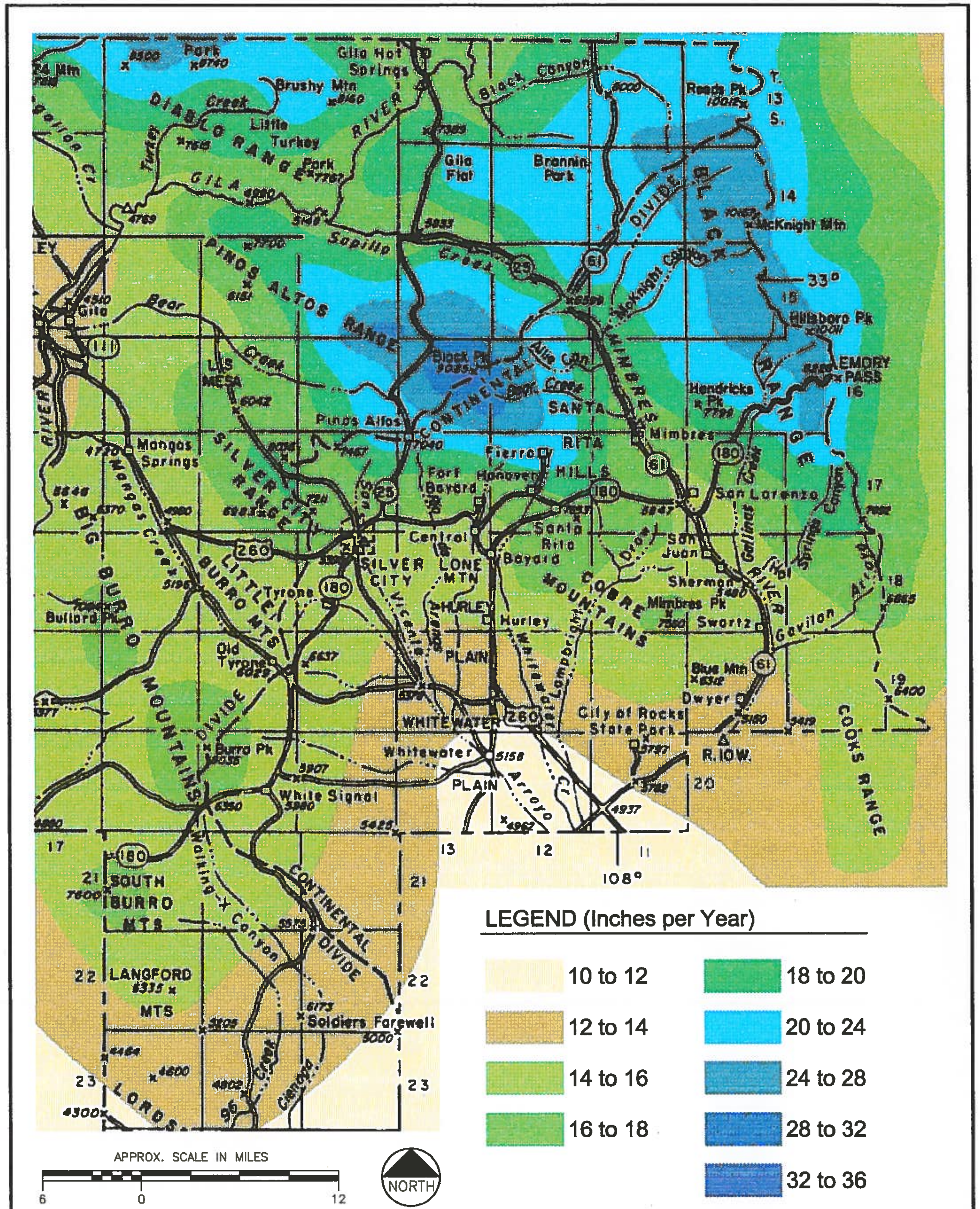

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FIGURE E-3
PRISM ESTIMATED PRECIPITATION
WITHIN GRANT COUNTY

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Project:	100029\T5
File:	PRECIP-01.DWG

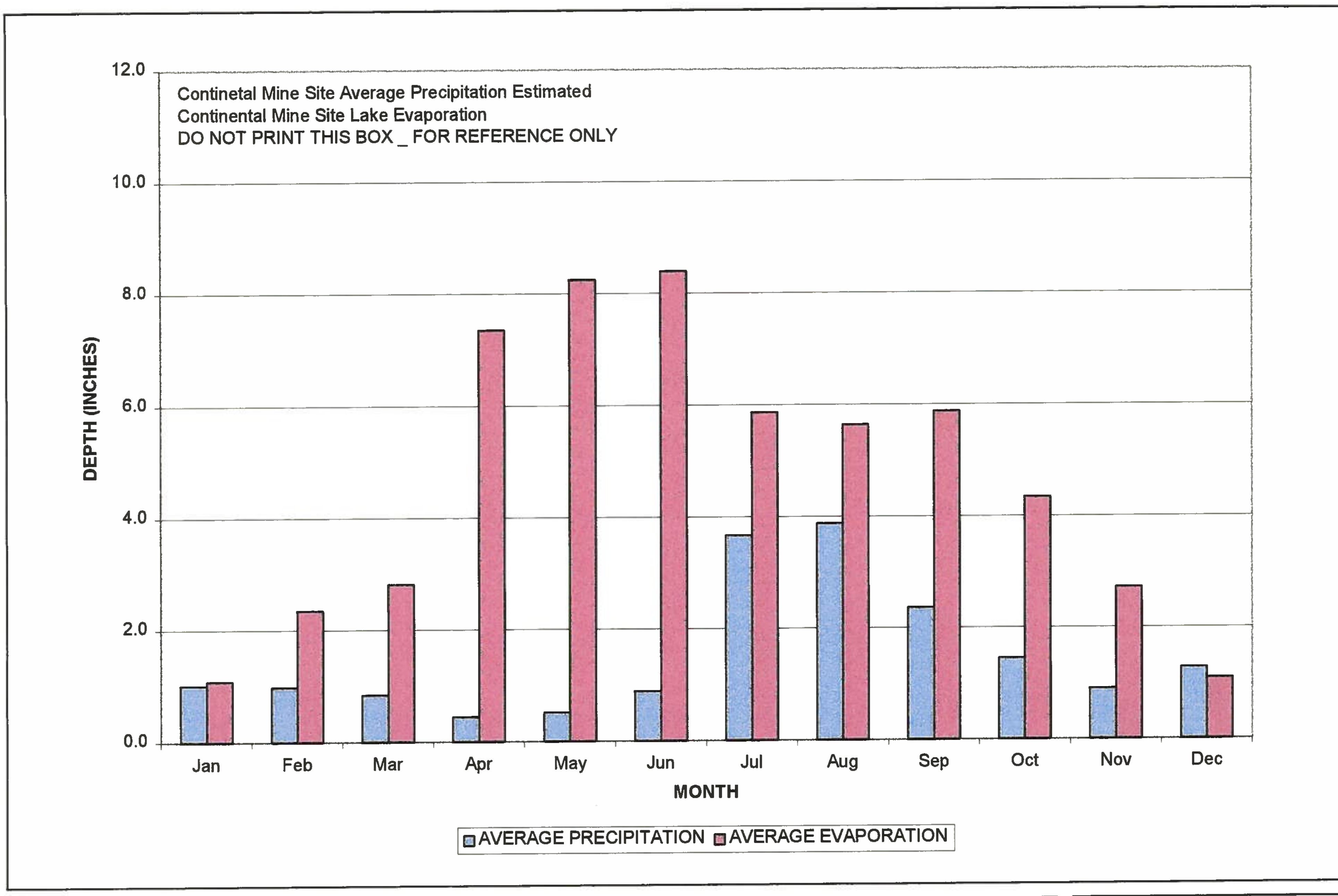

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FIGURE E-4
MONTHLY PRECIPITATION AND LAKE EVAPORATION
CONTINENTAL MINE, NEW MEXICO

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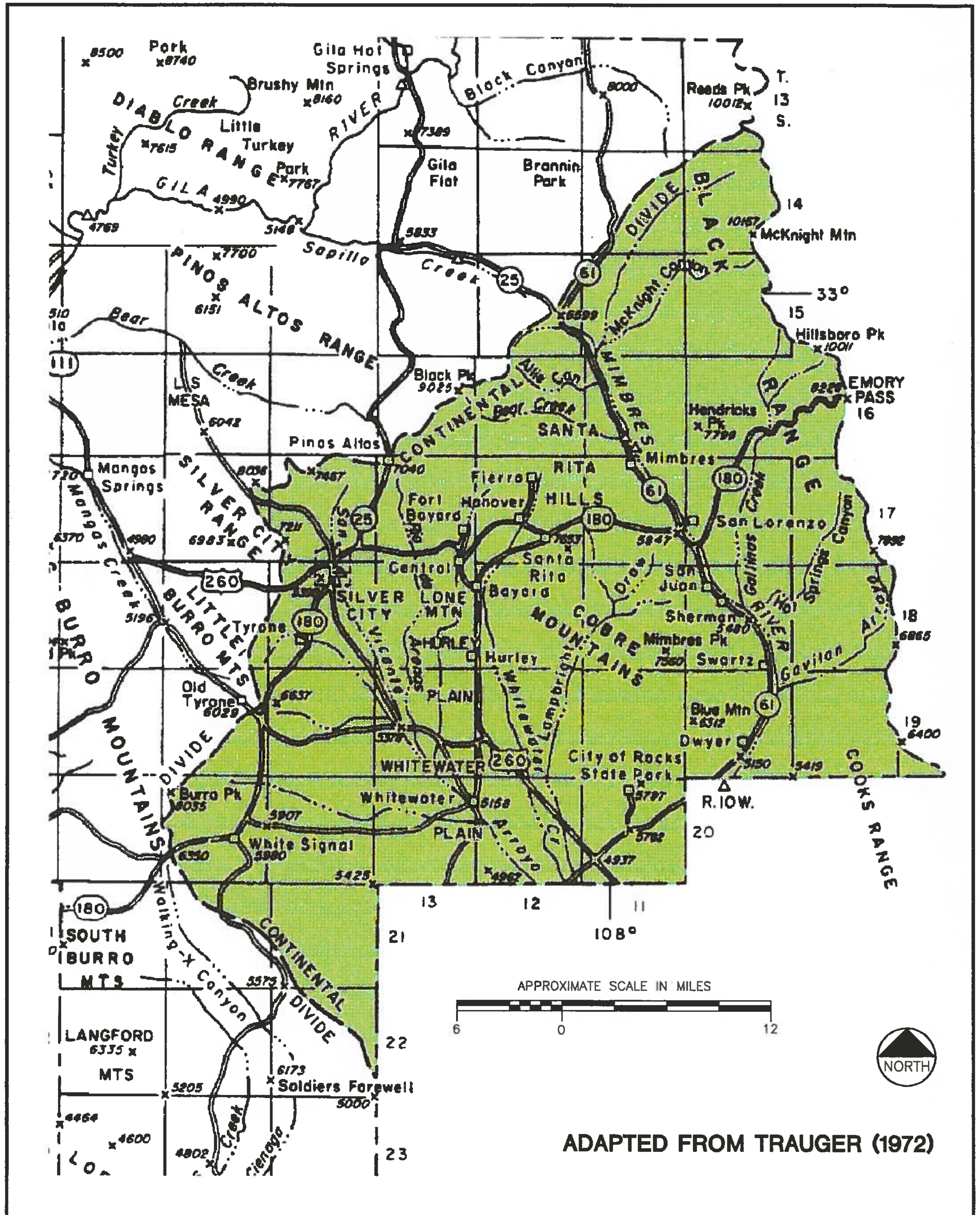

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FIGURE E-5
MIBRES RIVER BASIN
WITHIN GRANT COUNTY

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Project:	100029\T5
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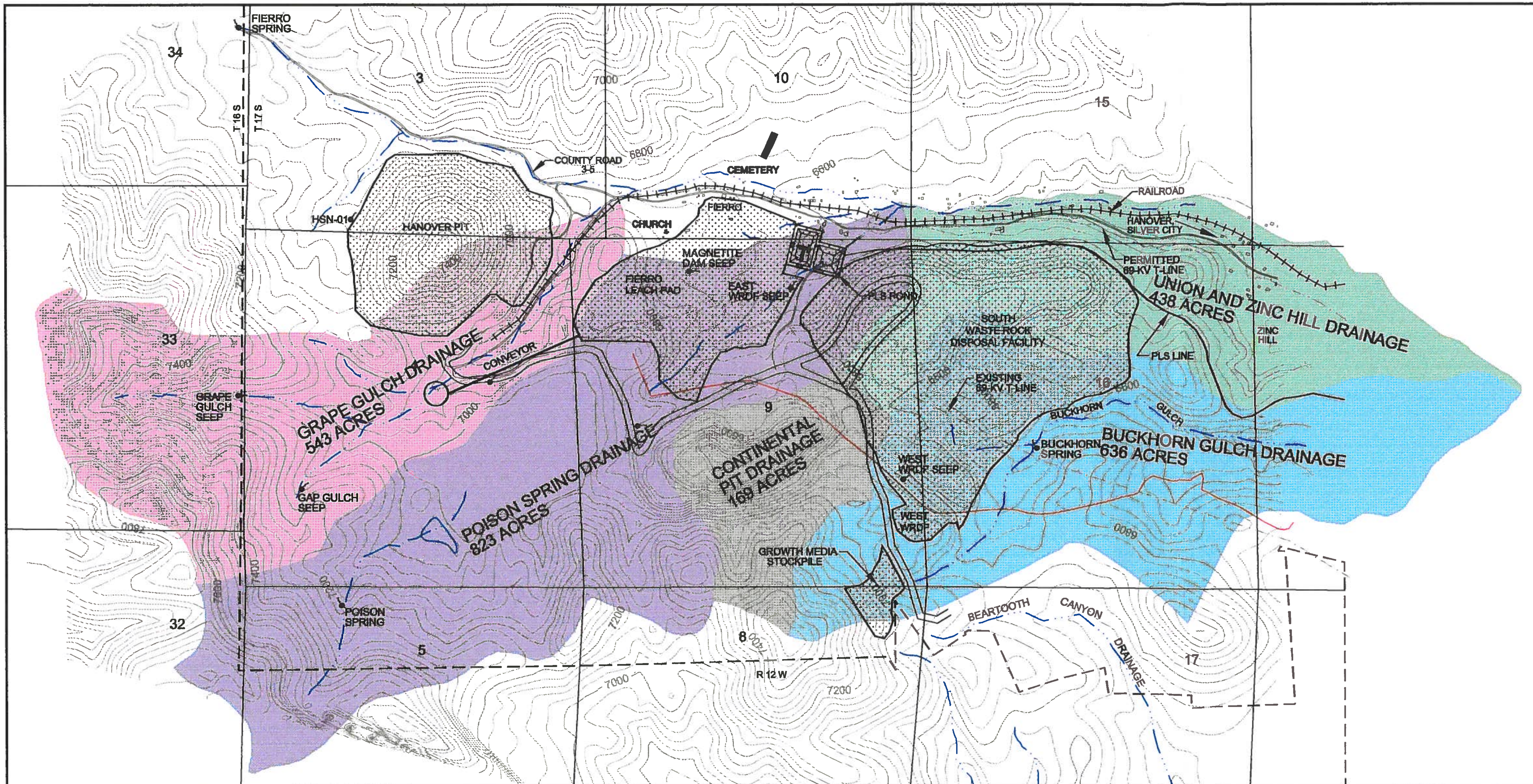

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FIGURE E-6
SURFACE WATER DRAINAGES
WITHIN THE HANOVER CREEK BASIN

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Date:	DECEMBER 1999
Project:	100029\T5
File:	SURF-WAT

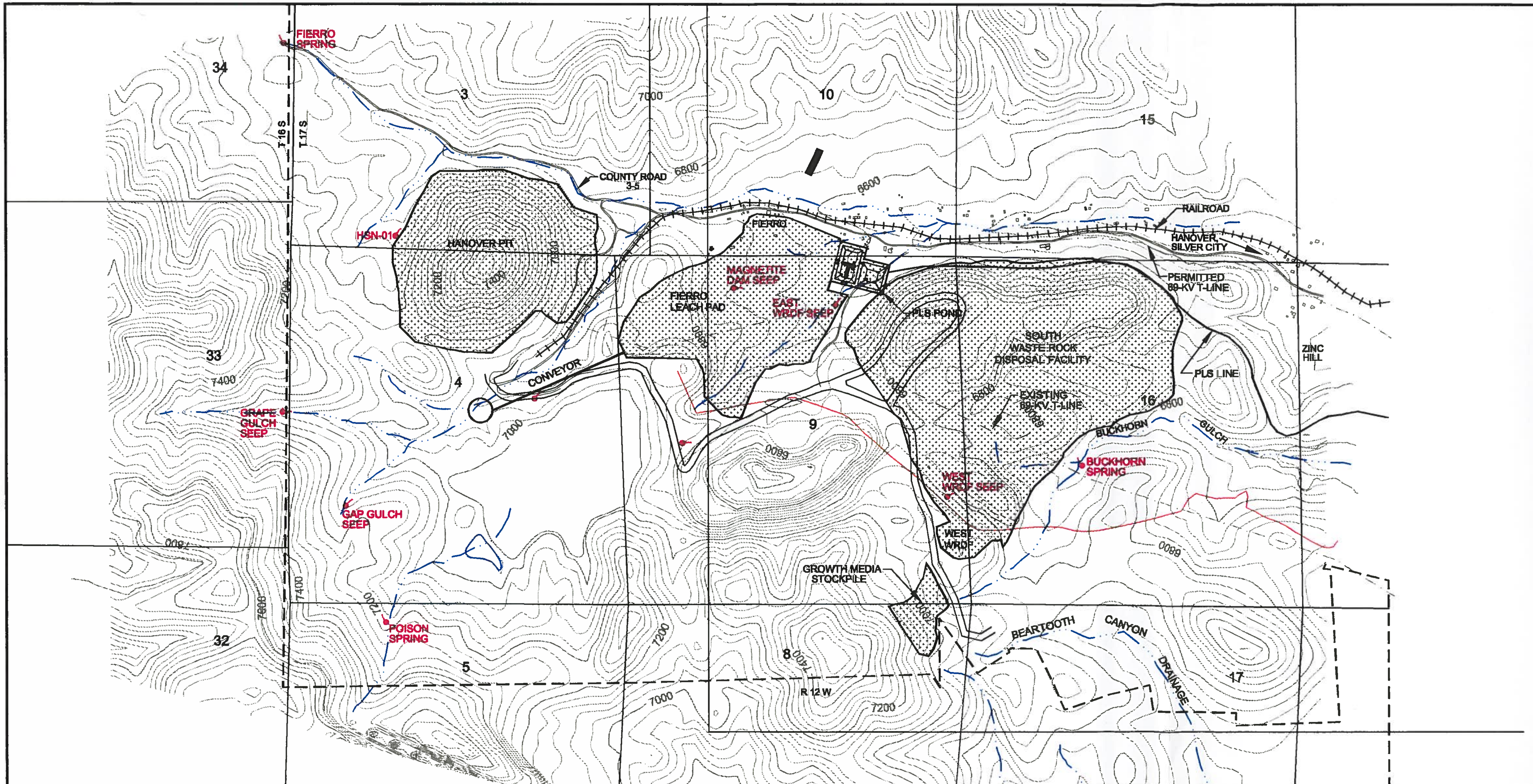

FIGURE E-7
LOCATIONS OF SEEPS AND SPRINGS AT THE CONTINENTAL MINE

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Date:	DECEMBER 1999
Project:	100029\T5
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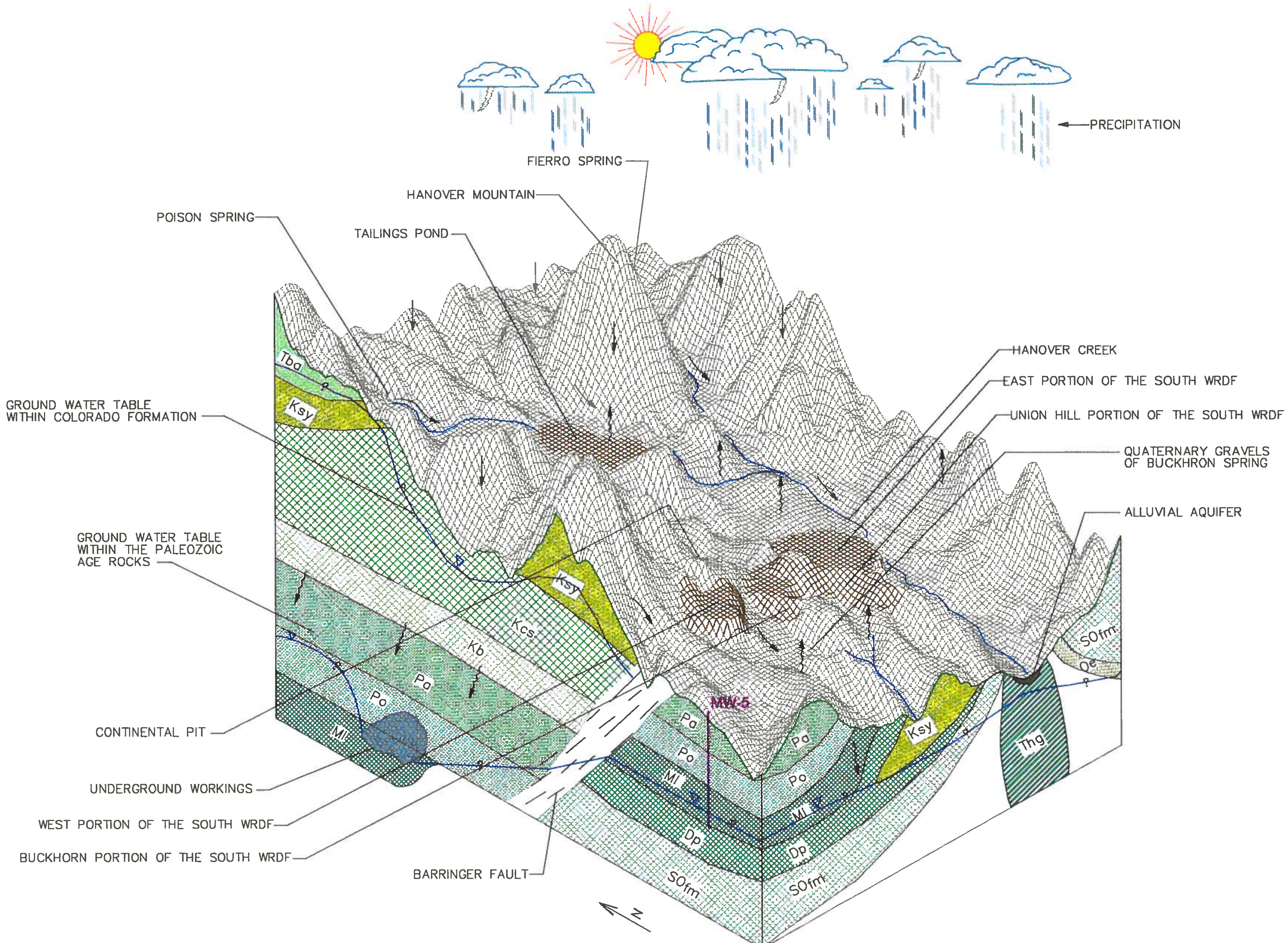
Date: 02/03/2000



NOT TO SCALE

EXPLANATION

Tba = VOLCANIC FLOWS AND TUFFS
Thg = HANOVER FIERRO STOCK
Ksy = SYENODIORITE PORPHYRY
Kcs = COLORADO FORMATION
Kb = BEARTOOTH QUARTZITE
Pa = ABO FORMATION
Po = OSWALDO FORMATION
Ml = LAKE VALLEY LIMESTONE
Dp = PERCHA SHALE
SOfm = FUSSELMAN AND MONTOYA DOLOMITES
QAL = QUATERNARY ALLUVIUM

PIEZIOMETRIC SURFACE
RECHARGE TO DEEP AND SHALLOW GROUND WATER
EVAPOTRANSPIRATION
OVERLAND FLOW

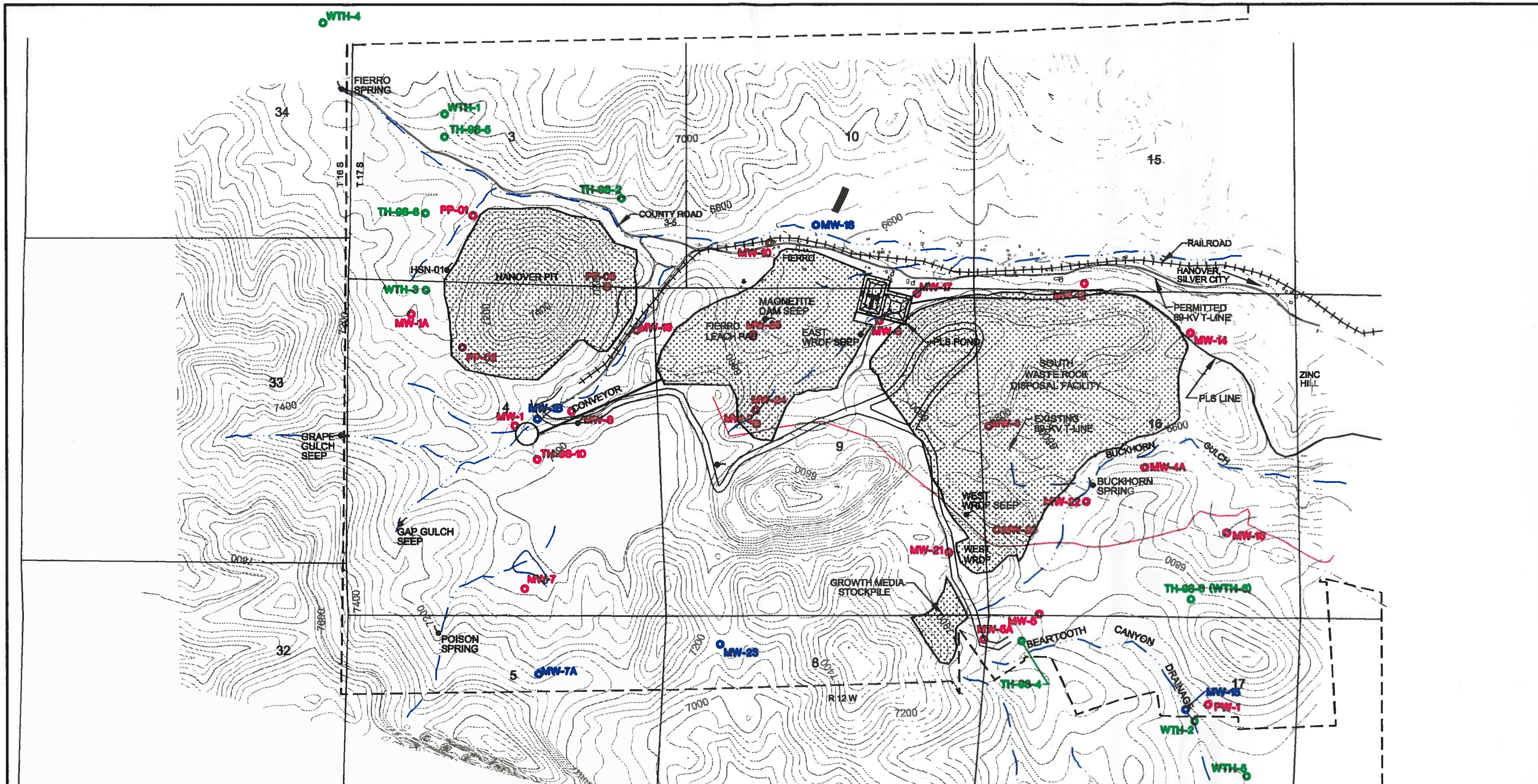
FIGURE E-8
CONCEPTUAL HYDROLOGIC MODEL OF THE CONTINENTAL MINE

SHEPHERD MILLER INCORPORATED

Date:	DECEMBER 1999
Project:	100029\T5
File:	CONMODEL

Filename: E:\100029\Task5\CONMODEL.dwg
Date: 02/03/2000

Filename: E:\100029\Task5\LOCWELLS.dwg
Date: 02/03/2000



LEGEND

MW-1A	LOCATION OF EXISTING MONITORING WELL, PIEZOMETER, OR GROUNDWATER EXPLORATION WELL
MW-15	PROPOSED LOCATION OF MONITORING WELL OR PIEZOMETER
TH-98-2	APPROXIMATE LOCATION OF EXISTING GROUNDWATER EXPLORATION WELL

NORTH

SCALE IN FEET

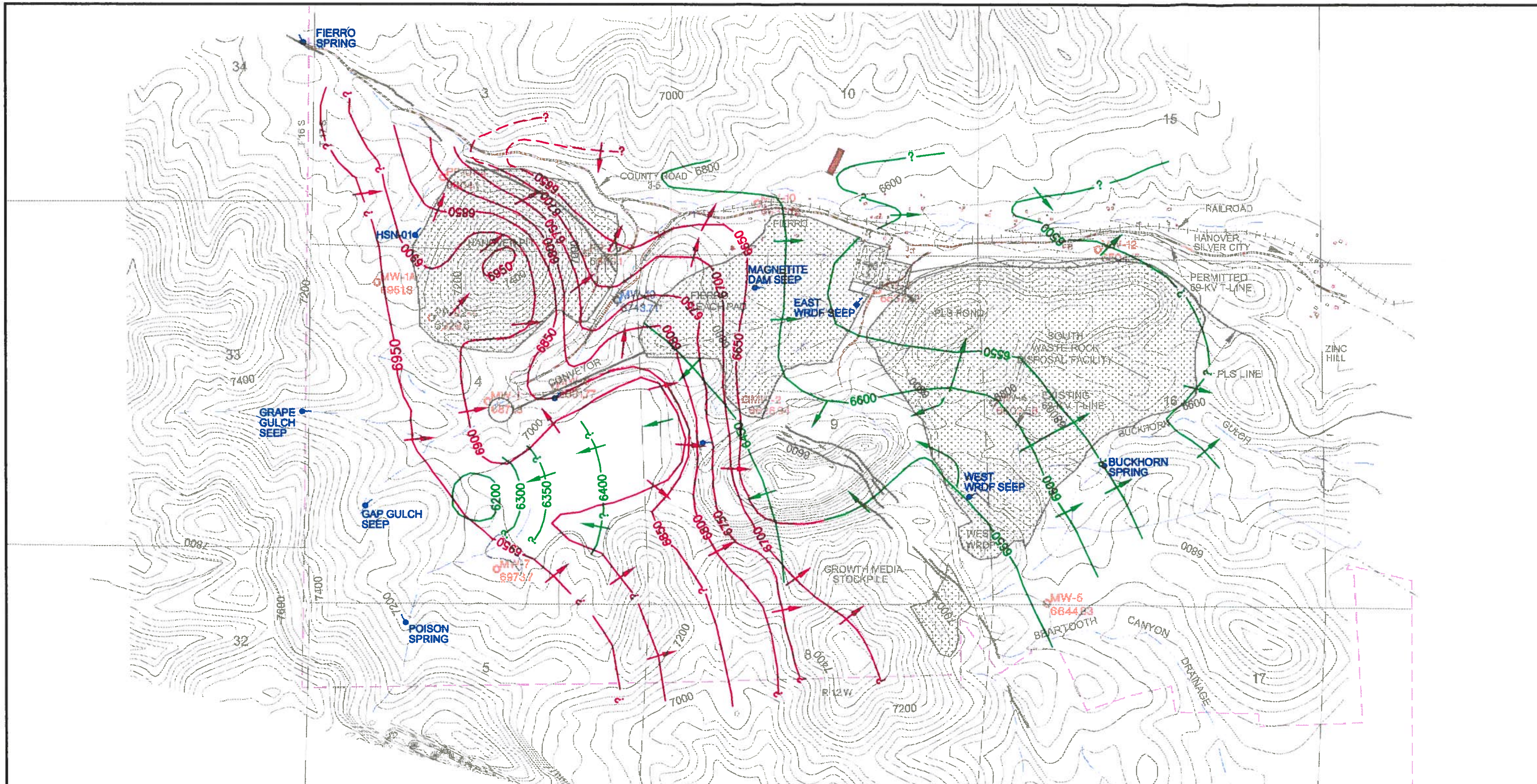
1600 0 3200

CONTOUR INTERVAL = 100 FT.

FIGURE E-9
LOCATION OF EXISTING AND PROPOSED MONITORING WELLS

SHEPHERD MILLER INCORPORATED

Date:	DECEMBER 1999
Project:	100029\T5
File:	LOCWELLS.DWG



—6400— LINE OF EQUI-HYDRAULIC HEAD IN UPPER FORMATIONS

—6400— LINE OF EQUI-HYDRAULIC HEAD IN LOWER FORMATIONS

NORTH

SCALE IN FEET

1500 0 3000

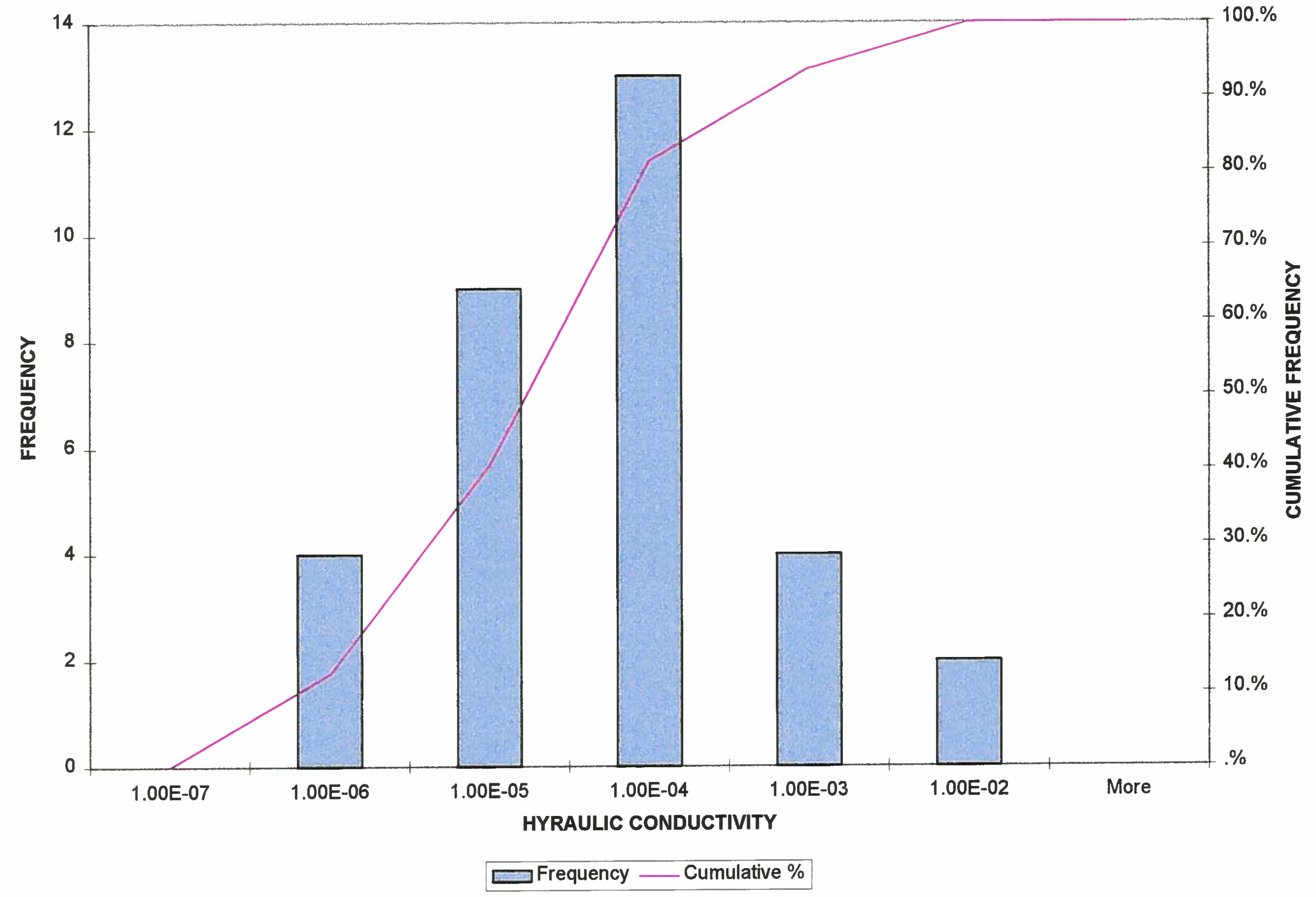
CONTOUR INTERVAL = 100 FT.

FIGURE E-10
GROUND WATER FLOW DIRECTIONS AND HYDRAULIC HEADS

SHEPHERD MILLER INCORPORATED

Date:	DECEMBER 1999
Project:	100029\T5
File:	GRND-WAT

Filename: E:\100...\Task5\GRND-WAT.dwg
Date: 02/03/2000



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INCORPORATED

FIGURE E-11
DISTRIBUTION OF MEASURED HYDRAULIC CONDUCTIVITY
IN BASEMENT ROCKS

Date:	DECEMBER 1999
Project:	P:\100029\..
File:	FIG-MAINH.PPT

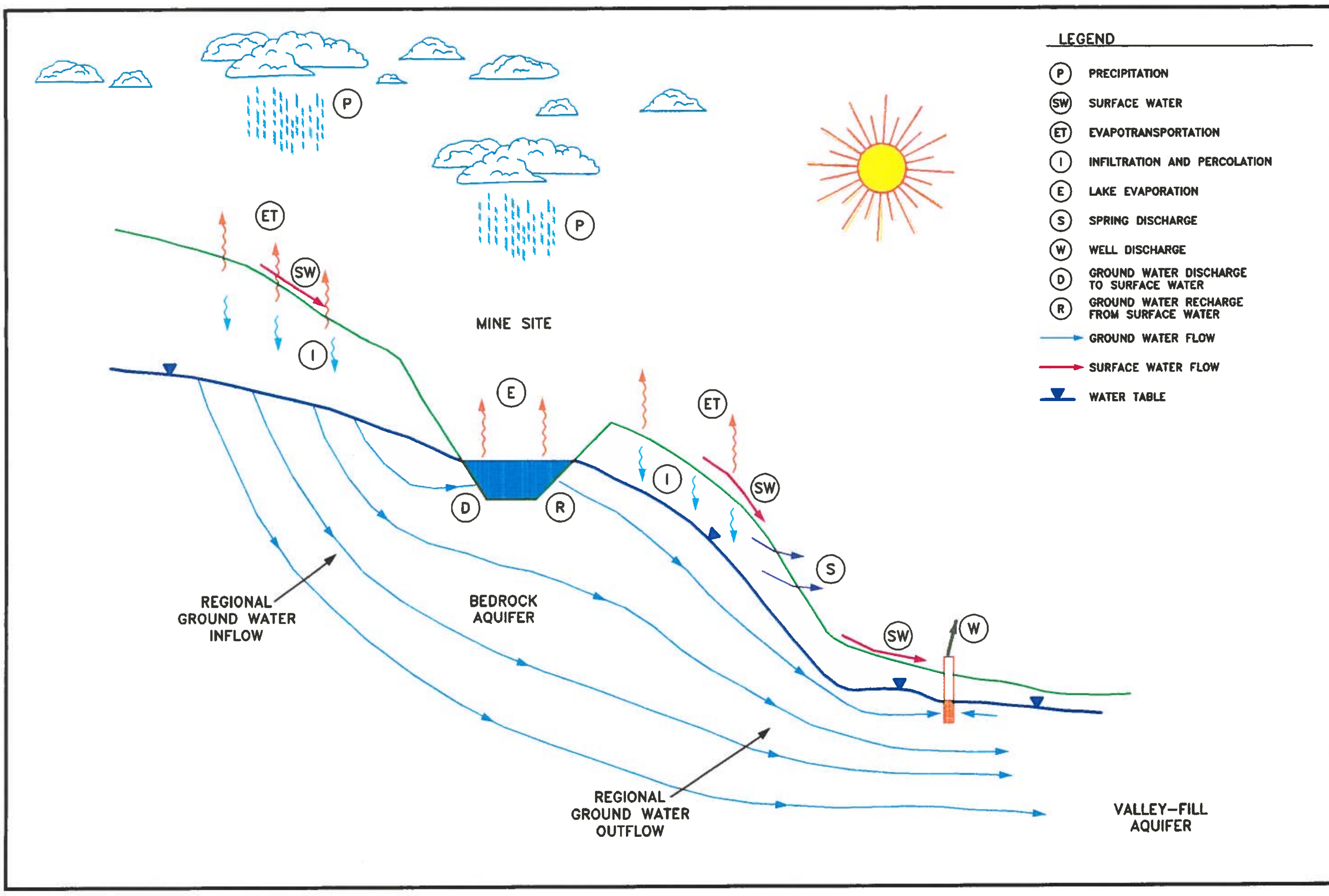

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FIGURE E-12
COMPONENTS OF THE CONCEPTUAL WATER BUDGET

Date:	DECEMBER 1999
Project:	100029\T5
File:	CONCEPT

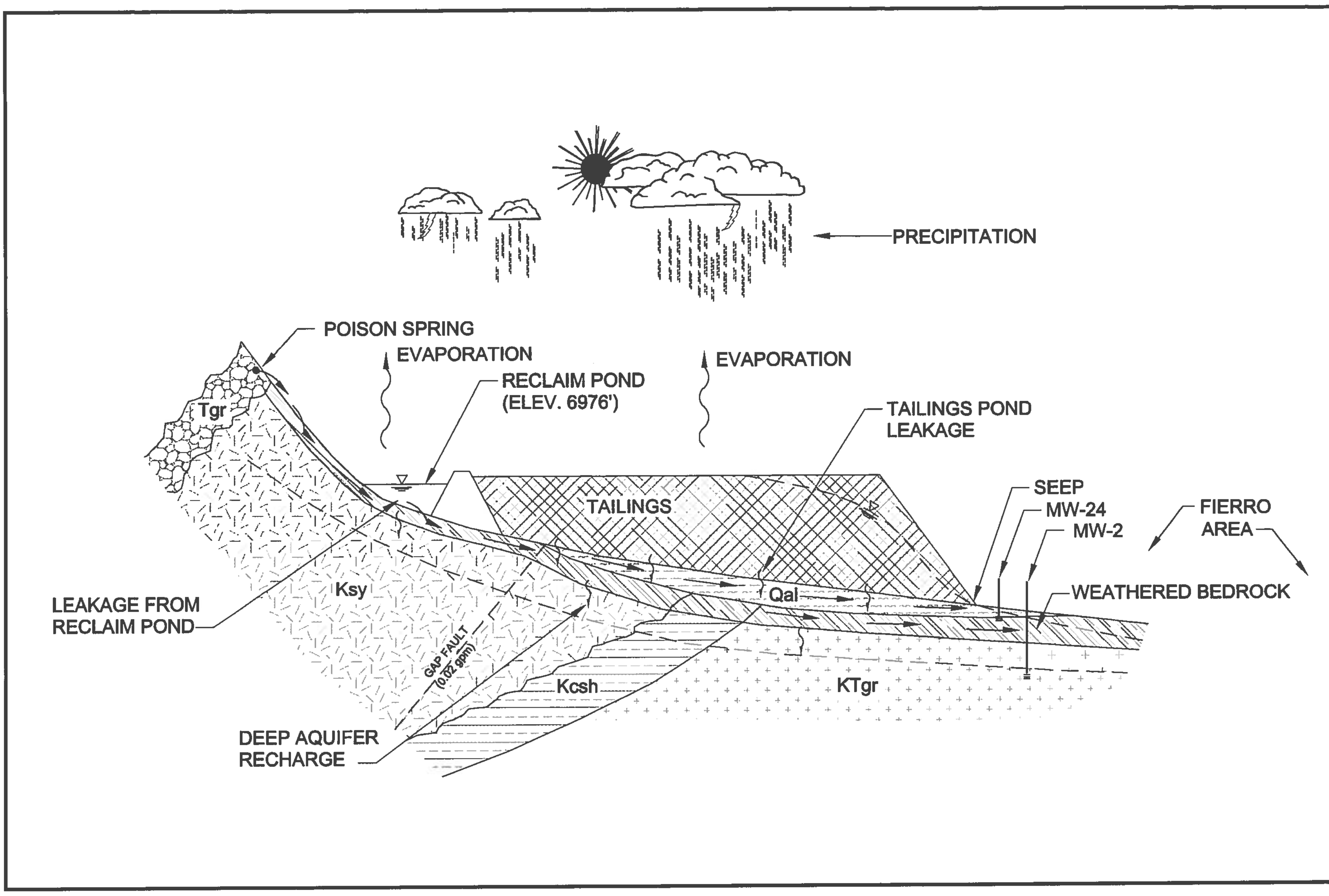

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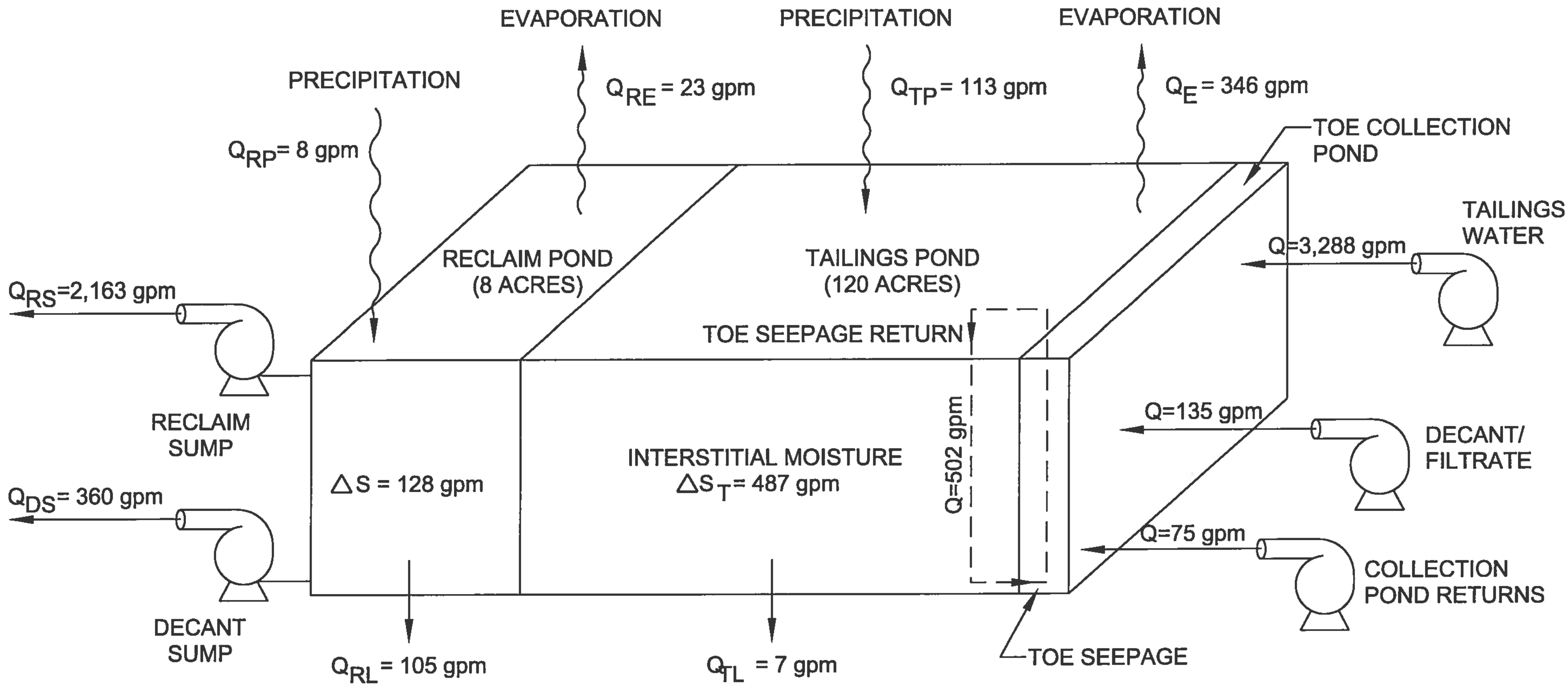
FIGURE E-13
CURRENT TAILINGS POND
HYDROLOGIC CONCEPTUAL MODEL

Date:	DECEMBER 1999
Project:	100029\T5
File:	XSEC-01



DAILY AVERAGE WATER BALANCE

$Q_{IN} - Q_{OUT} = \Delta S$
Q_{IN} = 3,619 gpm
Q_{OUT} = 2,892 gpm + Q_{RL} + Q_{TL}
ΔS = 615 gpm
$Q_{RL} + Q_{TL}$ = 112 gpm
Q_{RL} = 105 gpm
Q_{TL} = 7 gpm

PAN EVAPORATION = 79.7 in/yr
LAKE EVAPORATION = 55.8 in/yr
PRECIPITATION = 18.29 in/yr (WESTEC, 1996)

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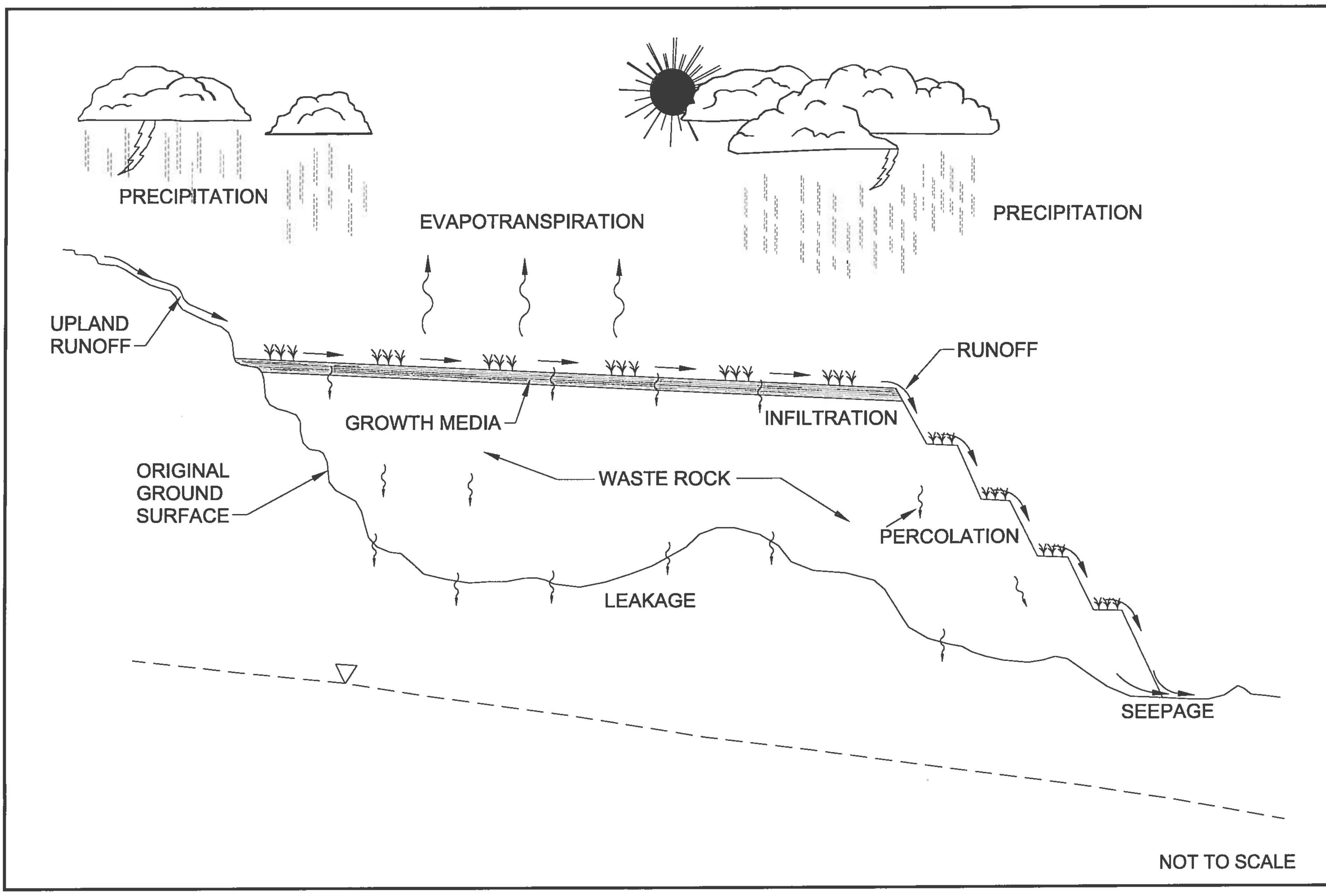
INCORPORATED

FIGURE E-14
CURRENT (1997) TAILINGS POND
WATER BALANCE

Date:	DECEMBER 1999
Project:	100029\T5
File:	WAT-BAL



SHEPHERD MILLER INCORPORATED

FIGURE E-15
WATER BALANCE COMPONENTS
ASSOCIATED WITH A TYPICAL WRDF

Date:	DECEMBER 1999
Project:	100029\T5
File:	WBALWRDF

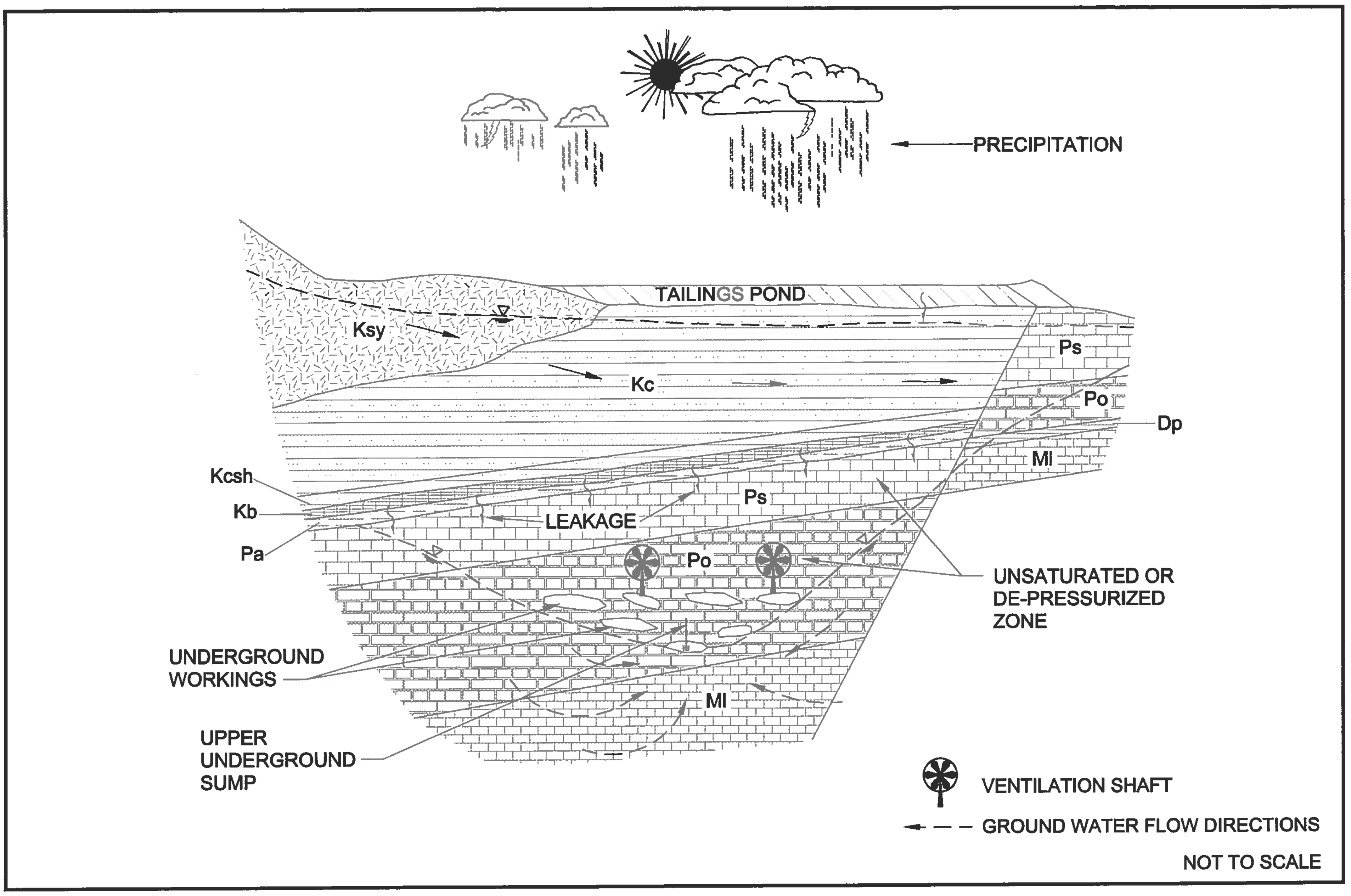


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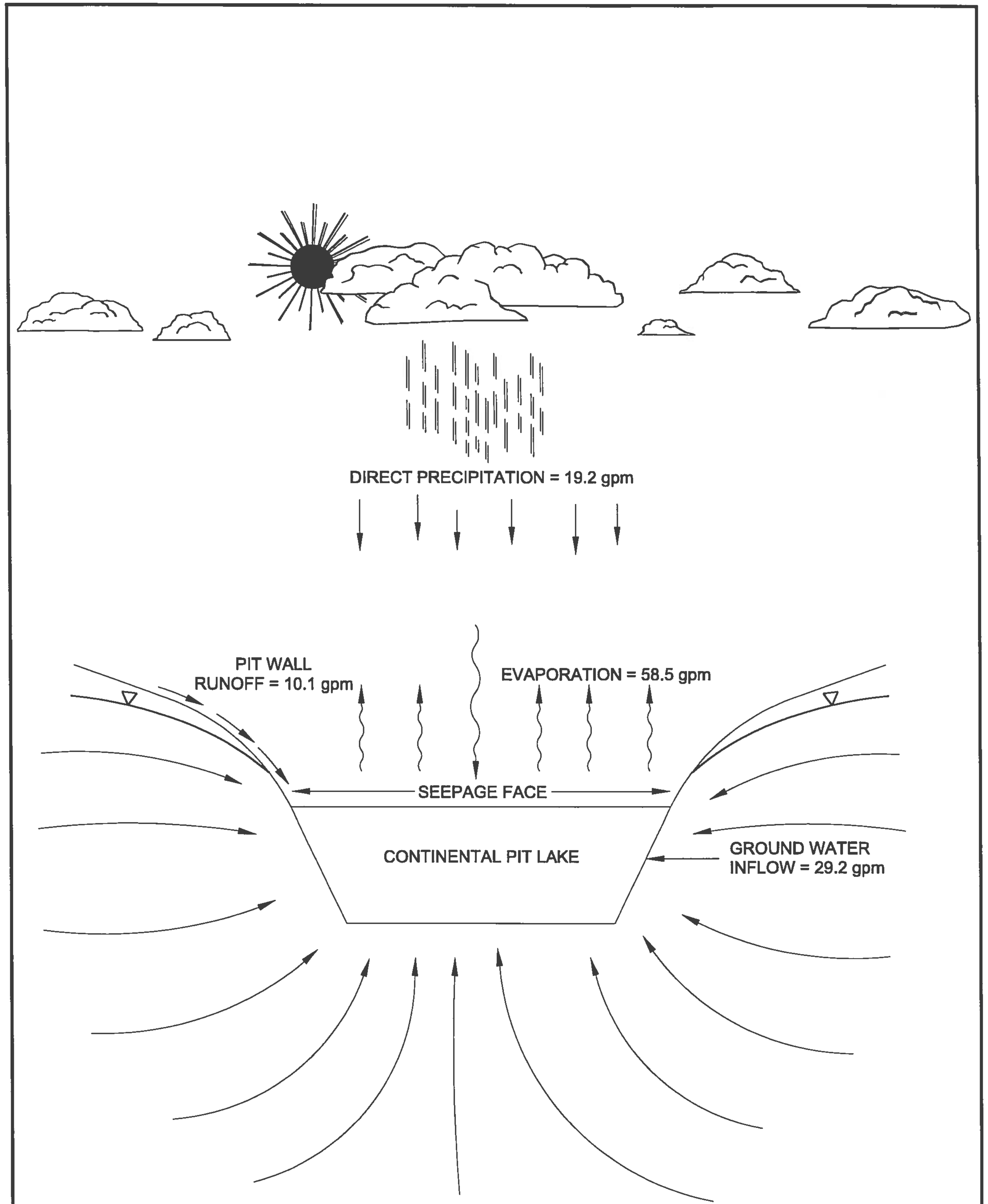
FIGURE E-16
CURRENT UNDERGROUND WORKINGS
HYDROLOGIC CONCEPTUAL MODEL

Date:	DECEMBER 1999
Project:	100029\T5
File:	XSEC-CUR



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INCORPORATED

FIGURE E-17
1997 CONTINENTAL PIT LAKE
WATER BALANCE AT STEADY STATE

Date:	DECEMBER 1999
Project:	100029\TASK5
File:	WBAL-CEX

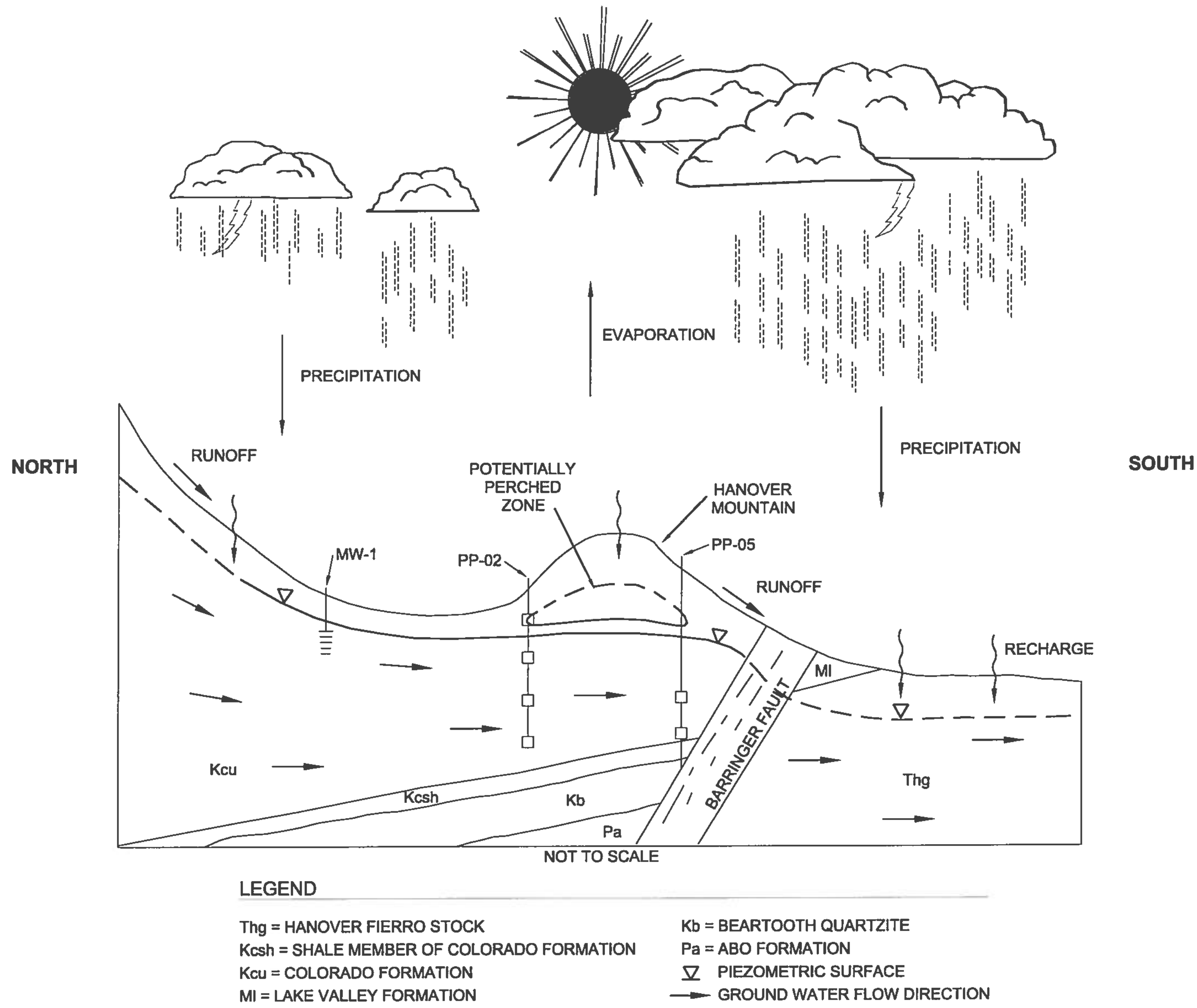

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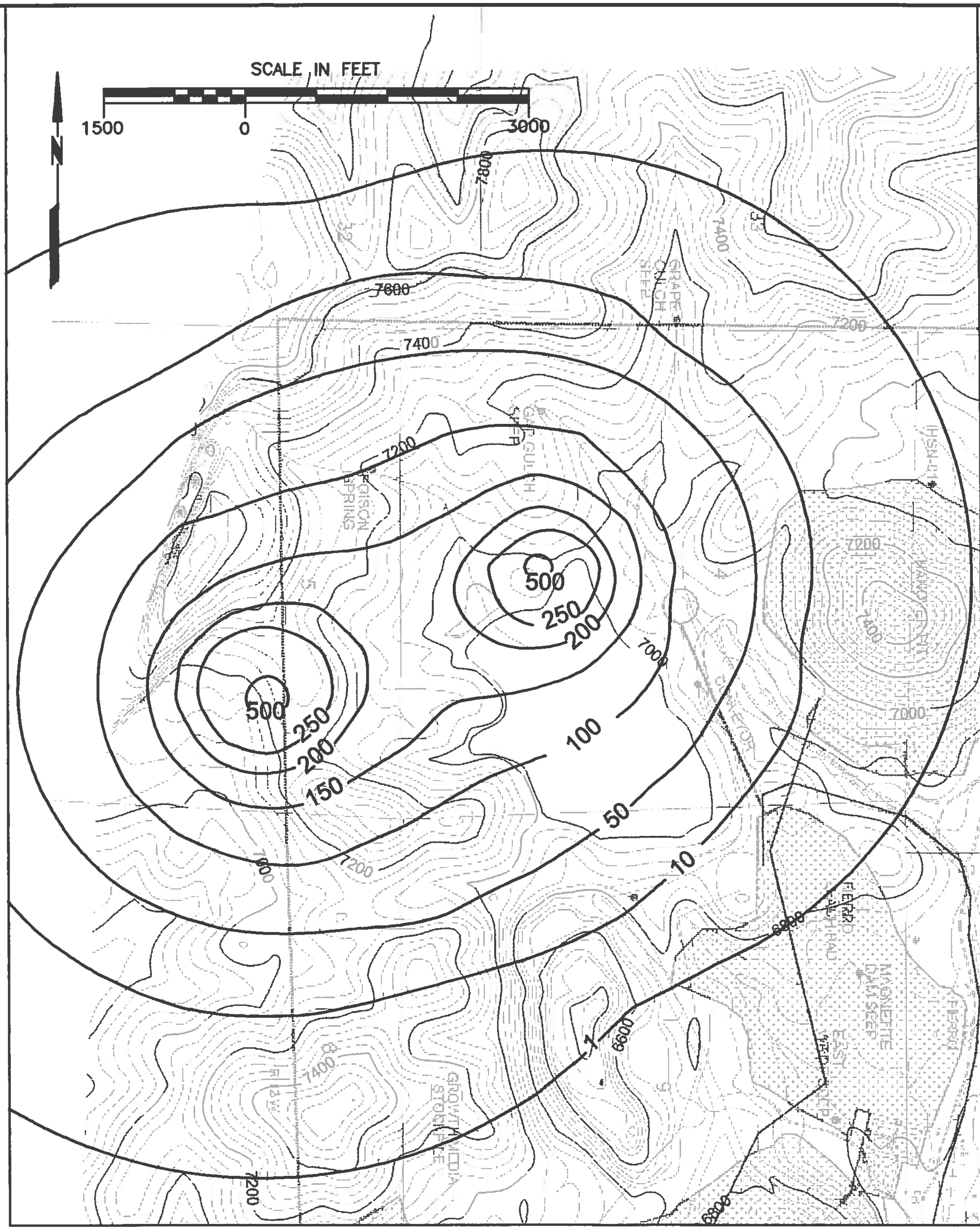
FIGURE E-18
HANOVER MOUNTAIN
CONCEPTUAL HYDROLOGIC MODEL

Date:	DECEMBER 1999
Project:	100029\T5
File:	CONC-HAN

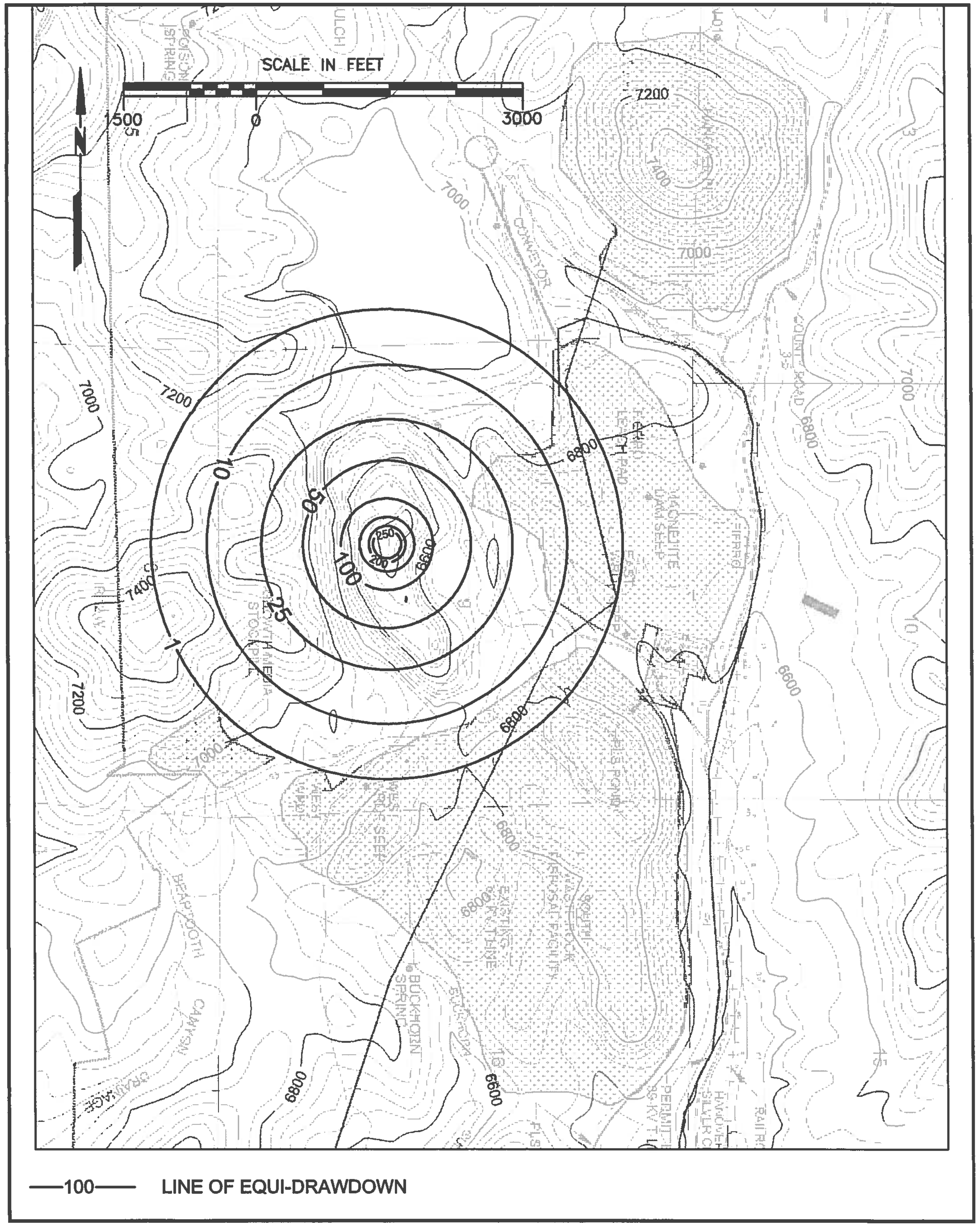


—50— LINE OF EQUI-DRAWDOWN

SHEPHERD MILLER INCORPORATED

FIGURE E-19
PREDICTED DRAWDOWN FROM UNDERGROUND DEWATERING AT END OF MINING

Date:	DECEMBER 1999
Project:	100029\T5
File:	DRAW-UND



SHEPHERD MILLER INCORPORATED

FIGURE E-20
PREDICTED DRAWDOWN FROM CONTINENTAL PIT DEWATERING AT END OF MINING

Date:	DECEMBER 1999
Project:	100029\T5
File:	DRAW-CON

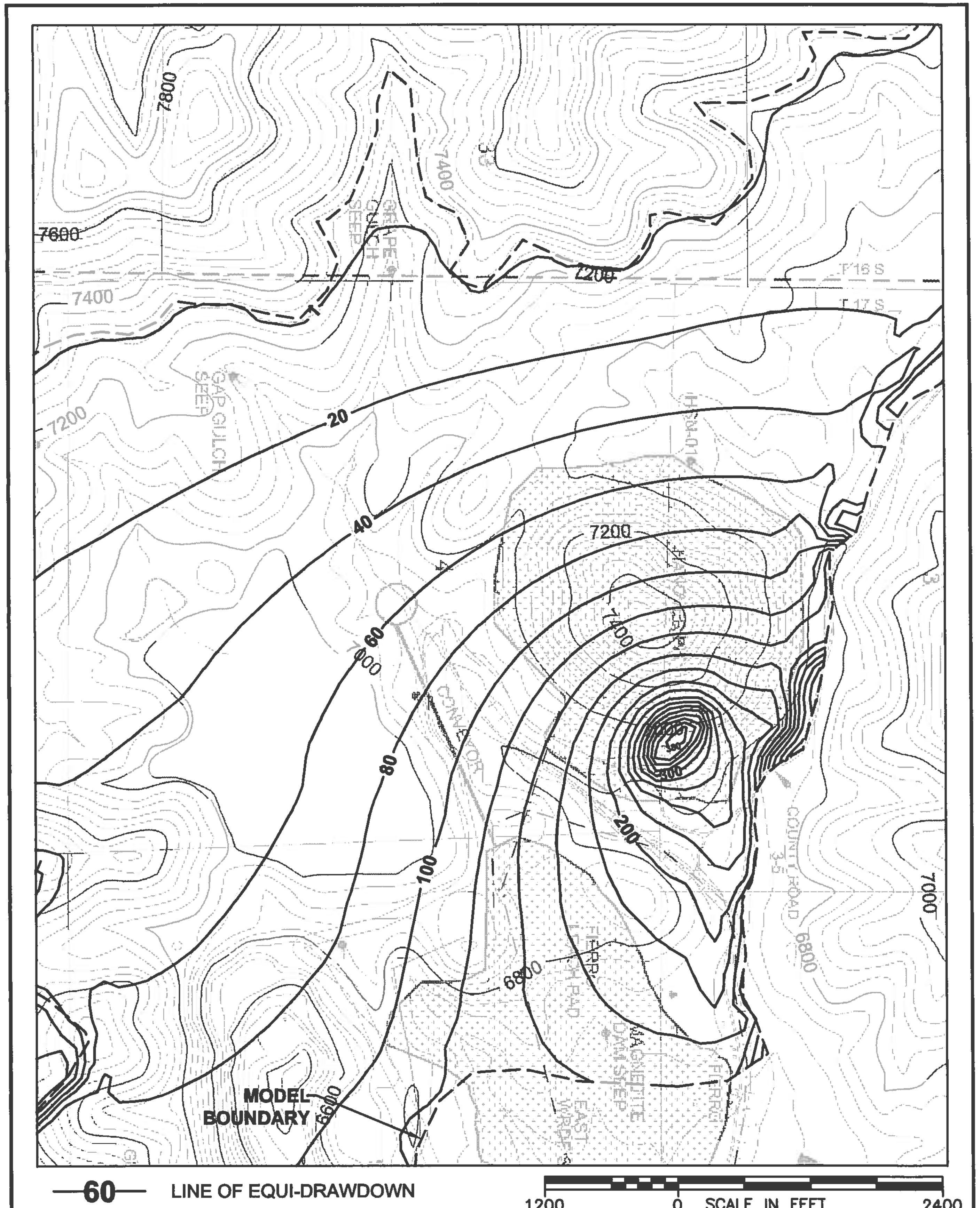


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FIGURE E-21
PREDICTED MAXIMUM DRAWDOWN FROM HANOVER PIT DEWATERING AT END OF MINING

Date:	DECEMBER 1999
Project:	100029\T5
File:	DRAW-HAN

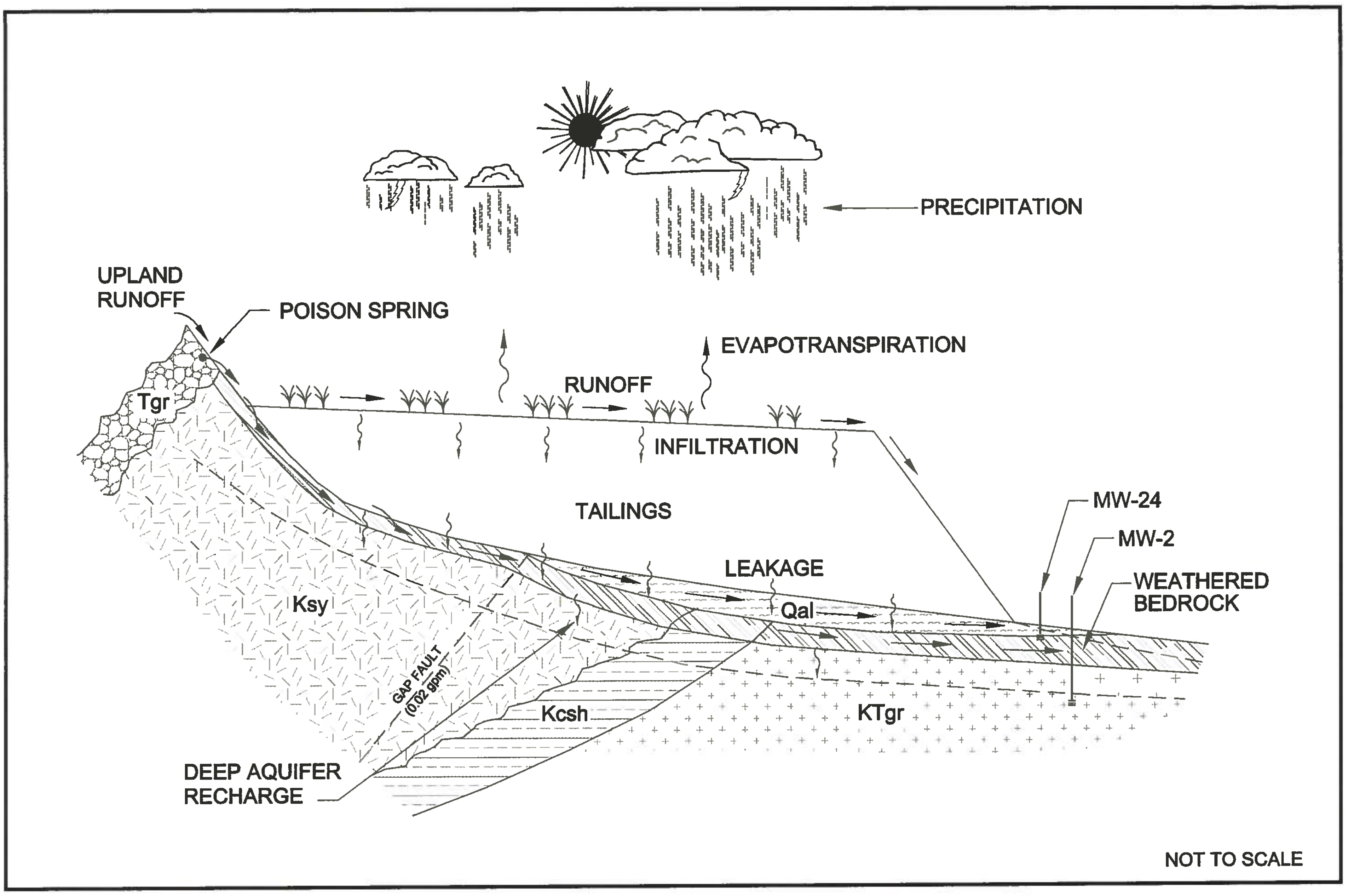

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FIGURE E-22
POST CLOSURE TAILINGS POND
HYDROLOGIC CONCEPTUAL MODEL

Date:	DECEMBER 1999
Project:	100029\T5
File:	XSEC-PC

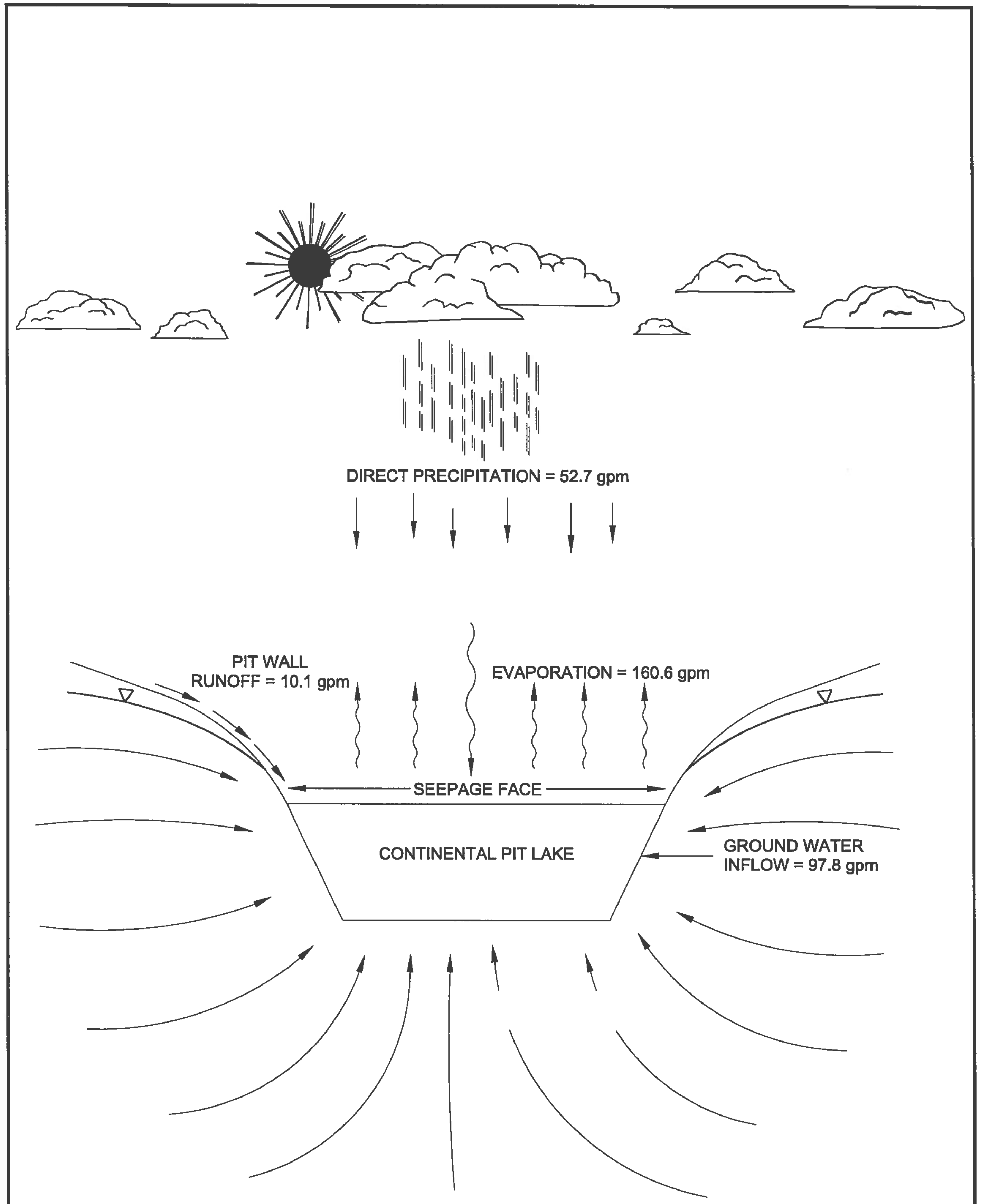

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FIGURE E-23
EXPANDED CONTINENTAL PIT LAKE
WATER BALANCE AT STEADY STATE

Date:	DECEMBER 1999
Project:	100029\TASK5
File:	WBAL-CON

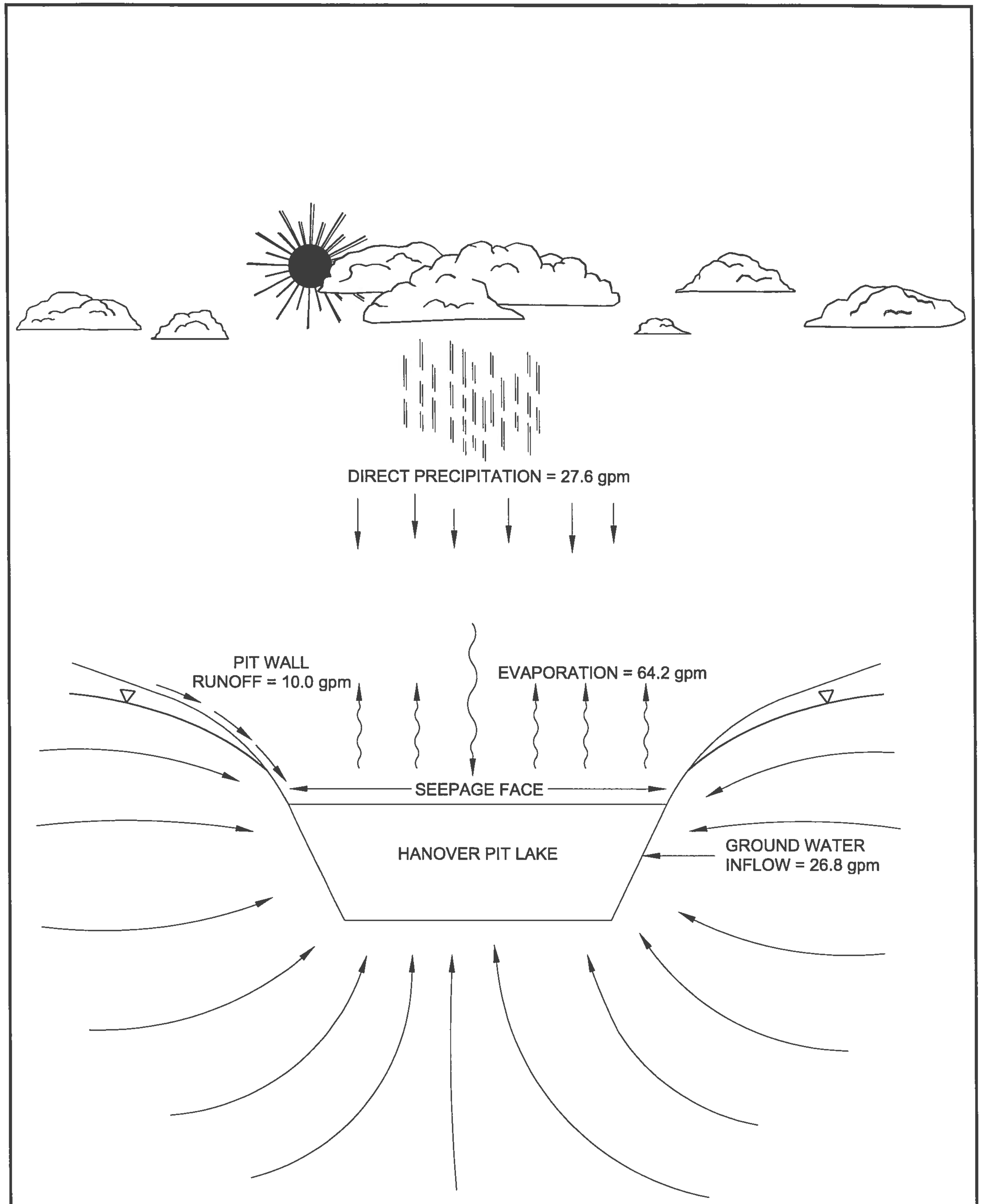

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FIGURE E-24
HANOVER PIT LAKE
WATER BALANCE AT STEADY STATE

Date:	DECEMBER 1999
Project:	100029\TASK5
File:	WBAL-HAN

BASELINE CHARACTERIZATION OF THE HYDROLOGY, GEOLOGY, AND GEOCHEMISTRY OF THE PROPOSED CONTINENTAL MINE EXPANSION PROJECT

APPENDICES E-H

Prepared for:

Cobre Mining Company, Inc.
c/o Chino Mines
NO. 14 Chino Boulevard
Hurley, NM 88043

Prepared by:

Shepherd Miller, Inc.
3801 Automation Way, Suite 100
Fort Collins, CO 80525

December 1999

SHEPHERD MILLER
INCORPORATED

APPENDIX E

GENERAL HYDROLOGY AND WATER BALANCE MODELS FOR THE PROPOSED CONTINENTAL MINE EXPANSION PROJECT, GRANT COUNTY, NEW MEXICO

Prepared for:
Cobre Mining Company, Inc.
c/o Chino Mines
No.14 Chino Boulevard
Hurley, New Mexico 88043

Prepared by:
Shepherd Miller, Inc.
3801 Automation Way, Suite 100
Fort Collins, Colorado 80525

December 1999

SHEPHERD MILLER
INCORPORATED

APPENDIX E

GENERAL HYDROLOGY AND WATER BALANCE MODELS FOR THE PROPOSED CONTINENTAL MINE EXPANSION PROJECT, GRANT COUNTY, NEW MEXICO

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1.0 LOCAL AND REGIONAL CLIMATE AND HYDROLOGY

The Continental Mine is located approximately 3 miles north of Hanover, in Grant County, New Mexico (see Figure E-1). The climate is semi-arid and only a few isolated stretches of perennial surface waters exist at or near the site. Elevations at the site range from a high of approximately 7,500 feet on Hanover Mountain to low of approximately 6,600 feet near the South Waste Rock Disposal Facility (WRDF). Ground water exists at depths of tens of feet in shallow alluvial aquifers and hundreds of feet below the ground surface in deeper regional bedrock aquifers. The following sections describe in more detail the climate, hydrology, and water balance of the Cobre Continental Mine site.

1.1 Climate

1.1.1 Regional

The Continental Mine is located in a semi-arid region of New Mexico. The climate of the area can be approximately described by meteoric data collected at Fort Bayard (EarthInfo, 1996) and the Chino Mine (WESTEC, 1996). For the Fort Bayard weather station, the following statistics are based on the years 1897 through 1994 for which complete data exist (i.e., years with partial data were omitted from the analysis):

- Mean annual rainfall of 15.74 inches per year (in/yr), with a median of 15.66 in/yr
- Mean annual temperature (average of maximum and minimum daily temperatures) of 54.8 degrees Fahrenheit (°F)
- Temperatures ranging from a mean daily minimum of 25.0°F (January) to a mean daily maximum of 86.7°F (June and July).

An average pan evaporation rate of 79.7 in/yr was measured at the Chino Mine.

Figure E-2 shows that precipitation measured at the Fort Bayard weather station displays a distinct wet season during the months of July, August, and September. Figure E-2 also shows that the average mean monthly pan evaporation at the Chino Mine is greater than precipitation, even during cooler winter months.

1.1.2 Local

The limited site-specific climatic information collected at the site is inadequate to estimate long-term climatic trends. However, climatic trends can be extrapolated from regional climatic data and from ecological observations, such as the extent of observable erosion and vegetative cover. Daly et al. (1994) have developed the expert system PRISM (Parameter-Elevation Regressions on Independent Slopes Model), which extrapolates climatic data from point measurements, including precipitation and temperature. Cooperating with the New Mexico State Climatologist, Dr. Daly's team at Oregon State University generated a precipitation map of the State of New Mexico. Figure E-3 is a copy of a portion of this map, showing that the estimated annual precipitation at the Continental Mine Site ranges from approximately 14 in/yr at the Cron Ranch to 18 in/yr near the town of Hanover to over 24 in/yr north of the site.

The temporal rainfall distribution at the site is probably similar to the measured precipitation distribution at the Fort Bayard weather station (Figure E-2). Average pan evaporation rates at the site are assumed to equal those at Chino Mine and were used to estimate lake evaporation rates at the Continental Mine (see Attachment E1). Figure E-4 shows the SMI interpretation (see Attachment E1) of the monthly precipitation and lake evaporation data for the Continental Mine as used in the water balance predictions of the Continental and Hanover Pits. The sum of these monthly values total 18.3 in/yr. During an average year, the monthly lake evaporation is predicted to be greater than monthly precipitation for all but the months of December and January.

1.2 Surface Water Hydrology

1.2.1 Regional Surface Water Hydrology

The project area is located within the Mimbres River Basin (Figure E-5), a closed basin that recharges an extensive, alluvial-fill aquifer in Luna County, New Mexico. The Mimbres River drains the west slope of the Black Range and the east slopes of the Piños Altos and Cobre Mountain Ranges (a total area within Grant County of approximately 460 square miles [mi^2]). Typically, perennial surface water exists in the Mimbres River from a location near the mouth of McKnight Canyon, upgradient of the town of San Lorenzo (Trauger, 1972). Irrigation diversions cause much of the river to remain dry downstream of San Lorenzo.

A major tributary to the Mimbres River is the San Vicente Arroyo-Whitewater Creek Drainage system. This system drains the large lowland area known as the San Vicente Basin which is bounded by the Big Burro Mountains to the west, the Cobre Mountains and Santa Rita Hills to the east, and the Piños Altos Range to the north (an area of approximately 390 mi^2 within Grant County). No perennial flows exist in this drainage system, except possibly at the headwaters of tributaries. Prior to 1885, perennial flows may have existed where the San Vicente Arroyo cuts through the Silver City area. Rio de Arenas, Cameron Creek, and Whitewater Creek (approximately 5 miles south of the Continental Mine) also used to contain perennial flow prior to long-term drought conditions, which began in 1885 (Trauger, 1972).

1.2.2 Local Surface Water Hydrology

Locally, the project area is situated within the Hanover Creek Drainage system (Figure E-6). The Piños Altos Range bounds this system on the north. Humbolt and Hermosa Mountains, part of a northerly-trending ridge, define the western hydrologic boundary of the system. A ridge that includes Fierro and Topknot Hills defines the eastern hydrologic system boundary. The highest point within the Hanover Creek Drainage system is located north of Hanover Mountain, in the Piños Altos Range, at an approximate elevation of 7,820 feet. The lowest elevation (approximately 6,000 feet) occurs at the mouth of Hanover Creek at its confluence with Whitewater Creek near the Chino Mine.

Over its length, Hanover Creek is generally an ephemeral stream. However, local perennial reaches exist near Fierro Spring and also adjacent to the towns of Hanover and Fierro, where it is suspected that local septic systems recharge the stream.

The contributing drainage area of Hanover Creek is approximately 10.9 mi^2 (6,990 acres), of which about 70 percent is downstream of previous mining activity (e.g., prospecting, open pit mining, and underground workings). Several ephemeral tributaries discharge underflow (i.e., ground water) and storm runoff to Hanover Creek. Tributaries adjacent to or traversing the currently disturbed areas of the project area include the following:

- Grape Gulch. This gulch has a drainage basin area of approximately 0.85 mi^2 (543 acres), which is approximately 0.2 percent of the San Vicente-Arroyo-Whitewater Creek Drainage system. It originates in the Piños Altos Range and continues for 11,280 feet through the Continental Mine (between the office area and the tailings pond area) to the discharge point at Hanover Creek near the guard shack. Perennial flow exists in this drainage only near its headwaters, where several small seeps exist.

- Poison Spring Drainage. This drainage has an area of approximately 1.29 mi^2 (823 acres), which is approximately 0.3 percent of the San Vicente Arroyo-Whitewater Creek Drainage system. It begins approximately 3,400 feet upgradient from Poison Spring. A perennial flow of 0.6 gpm (measured in February 1996 [SMI, 1998a]) begins at the spring and exists for approximately 1,200 feet downstream, where it appears to percolate into the thickening alluvium. Approximately 2,200 feet downgradient from the spring, the drainage is intercepted by the existing Tailings Pond. Downgradient from the Tailings Pond and approximately 2,200 feet upgradient from its confluence with Hanover Creek, the drainage contains a small perennial flow (0.7 gpm measured in February 1996). This flow probably occurs because of the following reasons:

  - The alluvium becomes thinner in this area

  - The main Tailings Pond and magnetite dam may provide enhanced recharge in this area

  - A seep, located on the north side of the South WRDF, may provide some surface water flow.

- Buckhorn Gulch. This gulch has a drainage area of 0.99 mi^2 (636 acres), which is approximately 0.25 percent of the San Vicente-Whitewater Creek Drainage system. It originates to the south of the existing mine area. Perennial flow is sustained at the confluence of the east and west forks of this drainage by the Buckhorn Spring. Upgradient of the spring, flow is intermittent. Downgradient of the spring, perennial flow continues for approximately 1,000 feet until it percolates into the thickening alluvium of Buckhorn Gulch.

- Ansones and Beartooth Creeks. These creeks have a combined drainage area of 6.2 mi^2. The headwaters of these two creeks are located on the south side of Hermosa Mountain. Beartooth Creek, an ephemeral stream, drains approximately 1,040 acres above its confluence with Ansones Creek. Ansones Creek drains approximately 2,900 acres of the North Star Basin, west of the Continental Mine. Ansones Creek is an ephemeral stream and a tributary to Cameron Creek, which flows through the Fort Bayard Military Reservation.

Other surface water of interest are springs and seeps. Several seeps and springs exist in the area of the Continental Mine site (Figure E-7).

Perennial seeps and springs upgradient of the mine site originate at the base of a Tertiary-age gravel unit that overlies the Colorado Formation. Precipitation falling in the Piños Altos Range infiltrates and percolates through overlying volcanic flows and is collected by this relatively permeable gravel unit. The contrast in permeability between the gravel and the underlying, lower permeability Colorado Formation causes the percolating water to "pond" in the gravel unit. The ponded water in the gravel unit flows to outcrop areas, where it discharges as springs and seeps. Seeps and springs associated with this gravel unit include the following:

- Fierro Spring. This spring is located near the headwaters of Hanover Creek and has been used by the local communities as a source of drinking water. The spring itself has been encased in a concrete housing. As the populations of Fierro and Hanover have decreased and a municipal supply has been provided to the town of Hanover, the importance of the spring as a drinking water source has diminished.

- Several seeps that exist in Grape Gulch and Gap Canyon. Stream flow estimates made in February 1996 indicate that flows from these seeps are less than 1 gallon per minute (gpm).

- Poison Spring. This spring is located northwest of the Tailings Pond, near the United States Forest Service and Bureau of Land Management boundary. Flow from this spring is channeled through a small-diameter pipe to a stock-watering tank.

Seeps and springs downgradient of the mine site include the following:

- Buckhorn Gulch Spring. This spring is supplied by ground water discharging from Tertiary- and Quaternary-age gravels extending west of the spring location (BLM, 1997). In February 1996, a flow rate of 0.4 gpm was measured with a cut-throat flume. Observations by Cobre personnel indicate that this flow rate is typical of the base flow in Buckhorn Gulch Spring.

- Several small seeps that exist along Hanover Creek. Their occurrence may correlate with septic systems associated with housing areas. The algae growth near these seeps indicate high nutrient levels that may result from septic leachfields.

The following seeps appear to be associated with past and current mining facilities:

- Several seeps that exist at the downgradient perimeter of the Tailings Pond. Flows from these seeps are captured in surface containment facilities and the water is recirculated into the milling process stream or pumped directly back to the Tailings Pond. The average flow rate of recirculated seep water is 2 gpm.

- The West WRDF. Seeps from this area are intermittent and occur on the east side of this disposal facility. The facility was started in the 1950s as a waste disposal facility for the Pearson-Barnes workings. The facility was later expanded in the early 1970s when a previous operator executed a "push-back" to start the Continental Pit. The seeps are intermittent and only flow during and immediately after precipitation events. Water from the seeps is collected in lined impoundments and pumped into tanker trucks. The water is then trucked to a discharge point where it is introduced into the milling process water system or gravity-fed to the make-up water tanks.

- The Buckhorn Portion of the South WRDF. This seep is located at the toe of the South WRDF in a small branch of Buckhorn Gulch, due east and directly downgradient of the West WRDF seep. Similar to the West WRDF seeps, flow from this seep is intermittent and appears only during and immediately following precipitation events. Because the chemistry of the rocks contained in the Buckhorn Portion of the South WRDF do not match that measured in the seep, it is suspected that this seep is a manifestation of upgradient ground water originating in the Pearson-Barnes and West WRDF areas. Further characterization work is underway to better understand the hydrology associated with this seep.

- The East Portion of the South WRDF. The seep is perennial and located on the north side of the South WRDF, near monitoring well MW-3. A concrete containment facility collects water from the seep and allows it to evaporate. The containment facility is monitored and pumped as a water source for dust suppression. The average flow rate from this seep is estimated at less than 1 gpm.

- The Magnetite Dam Seep. This seep is located downstream of the toe of the magnetite tailings area. Flow measurements in February 1996 indicated that the flow rate from this seep was less than 1 gpm.

1.3 Ground Water Hydrology

1.3.1 Regional Ground Water Regime

Trauger (1972) describes the regional ground water regime in Grant County. Ground water is the main source of municipal, domestic, livestock, agricultural, and industrial water supplies throughout Grant County. The availability, volume, and quality of ground water are dependent mainly on rock type. The following five main rock types are found in Grant County:

- Metamorphic and plutonic igneous rocks. These rocks typically have low permeabilities, especially in non-weathered zones. Wells completed in these rocks produce water at flow rates ranging form less than 1 gpm to slightly over 15 gpm. Weathered granitic rocks generally provide sufficient amounts of water for domestic or livestock use. Non-weathered rocks generally make poor aquifers and are not utilized for ground water supply.

- Volcanic rocks. Generally, these rocks make poor aquifers and are most likely to behave as aquitards, especially in massive volcanic flows. The exception can be pyroclastic rocks, which make relatively good aquifers if the particles are large and unconsolidated. Several stock wells in Grant County have been completed in well-sorted, water-deposited pyroclastic rocks.

- Marine sedimentary rocks (carbonates and clastics). Generally, carbonate rocks do not make good aquifers; however, they are likely to yield an adequate supply of water if they have been fractured or solution channeled. In Grant County, water supplies from carbonate rocks are usually the result of fracturing near fault zones and not from solution channels. Solution channels are not conspicuous in outcrops around the county, but some channels have been observed in brecciated zones. Clastic rocks are not good aquifers. Generally, wells up to 300 feet deep yield small amounts of water for domestic or stock use.

- The Gila Conglomerate. This conglomerate is an extensive continental sedimentary deposit and spans most of the north and central areas of the county. The lower part of the Gila furnishes very little water to wells and the upper part of the formation may provide moderate amounts of water.

- Alluvial deposits. These formations are generally the most important sources of ground water in Grant County. Some important alluvial deposits include the following:

- The Bolson Deposit (alluvial sediments that fill extensive intermontane areas), which is several thousands of feet thick in the lowland areas in the southern portion of the county. This deposit produces relatively high-yielding wells.
- Isolated terrace gravels that cap low ridges and generally overlie less permeable rocks. These are generally thin and well drained when they are above the water table. Small amounts of ground water are found locally in these gravels where extensive deposits overlie low permeability rocks.
- Channel alluvium in major tributaries of the Gila and Mimbres Rivers. These deposits are typically not more than 5 to 20 feet thick and become thinner at the headwaters of streams. They have relatively high permeabilities and may yield small amounts of water during wet seasons.

Geologic structures play a significant role in determining the ability of an aquifer to provide an adequate supply of ground water. For example, in the Colorado Formation, wells that are relatively close together may exhibit artesian or non-artesian flow conditions and have highly variable well yields. These differences are attributed to geologic structures, such as intrusive dikes, sills, and faults, that may have enhanced or reduced permeabilities.

In the northern portion of the county, ground water from the Piños Altos and Black Ranges discharges to the Gila River system. Deep ground water flows through, and is stored in, the Gila Conglomerate and Bolson Formations in the southern portion of the county.

1.3.2 Local Ground Water Regime

Figure E-8 shows the current conceptual hydrologic model of the Continental Mine. Within this conceptual model, two local ground water flow regimes exist:

- <u>Ground water in the basement (deep) rocks.</u> This ground water is part of the regional system and is essentially contained in the basement and intrusive rocks underlying the Continental Mine. Locally, this ground water regime is divided into two hydrogeologic units:
  - Upper Basement Unit (Colorado and Beartooth Formations)

- Lower Basement Unit (Paleozoic sedimentary rocks including the Oswaldo, Lake Valley, and Montoya Fusselman formations and the Hanover Fierro Stock)

- Ground water in shallow alluvial and perched systems. Ground water in this system is generally the result of surface waters percolating downward into local, high permeability zones (i.e., alluvium, weathered bedrock), that overlie less permeable stratum.

Figure E-9 shows the locations of existing/proposed monitoring wells and pneumatic piezometers in the Continental Mine area. Appendix A discusses specific information regarding the existing wells. Monitoring wells MW-1, MW-1A, MW-7, MW-8, and MW-19 and piezometers PP-01, PP-02, and PP-05 are located north of the Barringer Fault. The remaining wells are located either in the fault zone (MW-5A) or south of the fault.

1.3.2.1 Ground Water in Basement Rock

Water level data were obtained from monitoring wells, exploration drilling on Hanover Mountain, measurements by Trauger (1972), and measurements in the sump located at the base of the underground workings. These data were used to develop Figure E-10, which shows hydraulic head contours and inferred flow directions in the basement units at the Continental Mine. Because the wells are completed in different stratigraphic units, the following assumptions were used to generate the contour lines and flow paths shown on the Figure E-10:

- The hydrologic regime at the Continental Mine has been undergoing similar stresses for over 30 years (e.g., dewatering of the underground workings and deposition of tailings). Thus, the ground water flow regime in basement rocks is considered to be in a quasi-steady-state.

- The Barringer Fault behaves as a low permeability feature. This is due to the large offset of the fault and because it displaces several different geologic units. This assumption is supported by:

  - The results from a 24-hour pumping test conducted at water test hole TH-98-5 (August, 1999) that showed the well was surrounded by low permeability features.

- Short-term aquifer testing results on monitoring well MW-5A
- The observation that no ground water enters the underground working where they intersect the Barringer Fault.

Figure E-10 shows that ground water in the Lower Bedrock Units at the Continental Mine generally flows to the south and is strongly influenced by the dewatering of the underground workings. It also shows that the ground water in the Upper Bedrock Units flows to the south. A large portion of this water discharges to the underground workings. The rest discharges to the Fierro area, combining with flow from the Tailings Pond.

Permeability of rocks comprising the basement rock aquifers are summarized from aquifer testing results in Appendix A along with a detailed description of the determination of hydraulic conductivity. Figure E-11 shows the distribution of measured hydraulic conductivity data from the formations comprising the basement rocks at the Continental Mine. The estimated values of hydraulic conductivity reported in Appendix A (Table A-9) for monitoring wells range from 1.60×10^{-7} centimeters per second (cm/sec) to 7.3×10^{-3} cm/sec. The geometric mean of the hydraulic conductivity estimates is 2.4×10^{-5} cm/sec. The estimated values of hydraulic conductivity reported in Appendix A (Table A-10) for specific capacity analysis on exploration borehole data range from 9.5×10^{-7} centimeters per second (cm/sec) to 2.8×10^{-4} cm/sec. The geometric mean of the hydraulic conductivity estimates is 2.1×10^{-5} cm/sec.

1.3.2.2 Ground Water in Shallow Alluvial Systems

Several shallow alluvial and perched aquifers exist in the Continental Mine area. The three main alluvial systems are the Upper Buckhorn Gulch, Poison Spring Drainage, and Grape Gulch.

BLM (1997) provides a detailed description of the shallow aquifers in Upper Buckhorn Gulch and the Poison Springs drainage. The Buckhorn Gulch Springs are fed by the Quaternary/Tertiary age colluvium that overlies less permeable intrusive and sedimentary rocks. These gravels receive recharge from infiltration of precipitation and upgradient ground water flow from beneath the West WRDF. The shallow aquifer in the Poison

Springs Drainage upgradient of the Tailings Pond is composed of very shallow alluvium and weathered bedrock. The main recharge to this system in the upper reaches of the drainage is flow from Poison Springs and infiltration of precipitation and surface water runoff.

Grape Gulch is very similar to the Poison Springs system. The aquifer in the upper portions of the gulch is limited to shallow alluvial fill and weathered bedrock. The alluvium thickens downslope to several tens of feet as indicated in Monitoring Well MW-19, near the Number One Mill. Flow in the upper portions of this aquifer originates from springs in Grape Gulch and Gap Canyon. Ground water flow in the lower portions of the system is supplied from infiltration of precipitation and surface runoff.

The hydraulic conductivity of these shallow aquifers is highly dependent on the formations in which they are contained. The colluvial material in which MW-24 is screened has a hydraulic conductivity of approximately $7x10^{-3}$ cm/sec while the Percha Shale, represented by an aquifer test in MW-20, has a permeability of approximately $1.6x10^{-7}$ cm/sec.

2.0 SITE WATER BALANCE COMPONENTS

Components of the water balance were evaluated to provide an understanding of processes that add or subtract site water and cause changes in water storage. Figure E-12 depicts important components to be considered in a water balance, which are as follows:

- Precipitation
- Surface runoff
- Evapotranspiration
- Infiltration and percolation
- Surface water/lake evaporation
- Spring discharge
- Well discharge
- Ground water discharge and recharge.

The pre-expansion magnitudes of some of these components are discussed in previous sections of this report. This section focuses on the current, expansion, and post-mining components of the water balance. Effects from previously planned expansion of the Tailings Pond, Underground Workings, and Continental Pit are included in these discussions to assist in the preparation of the cumulative impacts portions of the EA and EIS. However, Cobre has no immediate plans to follow the previous planned expansion of these facilities and may decide on an entirely different operational approach.

2.1 Current Water Balance Components

2.1.1 Tailings Pond

Figure E-13 shows the conceptual hydrologic model of the current (circa 1997) Tailings Pond. The Tailings Pond has been in operation since the late 1960s, when the Number One Mill was brought on-line. It was originally constructed in the Poison Springs Drainage over an alluvial deposit. The underlying alluvium and weathered bedrock are high permeability units that collect seepage from the Tailings Pond and Reclaim Pond. These seepage rates have likely decreased due to the progression of the Reclaim Pond westward, away from this natural drainage material. The evaluation presented below is based on an analysis performed in 1997. The Continental Mine went into standby status in the summer of 1999. At the time of publication, no tailings or process water was being discharged to the Tailings Pond nor was process water being extracted from the Reclaim Pond. Also at the time of publication, updated information was not available regarding the water balance components associated with the Tailings and Reclaim Ponds.

In 1996, Cobre initiated tracking methods to measure components of the water balance associated with the Tailings and Reclaim Ponds. The results of this water balance are shown on Figure E-14. Average inflows to the Tailings and Reclaim Ponds for 1997 were measured or estimated as follows:

- Direct precipitation on the Tailings Pond and Reclaim Pond —121 gpm, based on 18.3 in/yr of precipitation
- Water in the tailings slurry— 3,288 gpm
- Returns from the collection pond located in Grape Gulch, near Mill Number One — 75 gpm
- Water removed from the ore concentration process, also known as concentrate decant — 135 gpm
- Seepage from the Toe of the dam – 500 gpm (this rate has declined significantly since the summer of 1999).

Measured and estimated outflows from the Reclaim Pond were as follows:

- Reclaimed water from the Reclaim Pond — 2,163 gpm
- Decant from the Tailings Pond — 360 gpm
- Change in storage of the reclaim and Tailings Pond — 615 gpm
- Evaporation from the Tailings Pond and Reclaim Pond — 369 gpm, based on 55.8 in/yr.
- Leakage from the bottom of the Tailings and Reclaim Pond — 112 gpm

- Toe seepage collection return – 500 gpm.

It is estimated that, at the present time, approximately 105 gpm of the seepage from the Tailings Pond and the Reclaim Pond flows downvalley toward the Fierro area and approximately 7 gpm seeps downward into the deep bedrock aquifer. Attachment E2 presents the calculations used to estimate these components of the Tailings Pond water balance.

2.1.2 Waste Rock Disposal Facilities

The conceptual model of the current water balance for the waste rock disposal facilities after reclamation is shown on Figure E-15. While the magnitudes of the inflows and outflows are different for each facility, the conceptual model holds true for each facility. The following sections describe the magnitudes of the inflows and outflows for each of the waste rock disposal facilities.

2.1.2.1 South Waste Rock Disposal Facility

Inflows to the current South WRDF consist of infiltration of direct precipitation. All other surface water is diverted around this facility. Current water outflows from the South WRDF include evaporation, seepage from the East WRDF Seep, runoff, and deep percolation through the facility. Using a 30-year data set from Ft. Bayard to represent average conditions, DBS&A (1999) predicted that the uncovered South WRDF (comprised of the Buckhorn, East and Union Hill areas) receives 138.7 gpm (223.8 acre-ft/yr) of precipitation (15.5 in/yr). Of this 138.7 gpm, 88.0 gpm (142 acre-ft/yr) evaporates and 50.7 gpm (81.8 acre-ft/yr) infiltrates. For conservatism, it was assumed that none of the precipitation becomes runoff.

The average annual rainfall value used in DBS&A's analysis (15.5 in/yr) is less than average annual rainfall used in analyses presented elsewhere in this report (18.3 in/yr). Therefore, prior to comparing the results of this analysis to analyses presented elsewhere in this report, the results should be scaled up based on the ratio of 18.3/15.5. Scaling the results based on this ratio results in the prediction that the uncovered South WRDF receives 163.8 gpm (264.2 acre-ft/yr) of precipitation. Of this 163.8 gpm, 103.9 gpm (167.7 acre-ft/yr) evaporates and 59.9 gpm (96.6 acre-ft/yr) infiltrates.

2.1.2.2 West Waste Rock Disposal Facility

Inflow to the current West WRDF consists of infiltration of direct precipitation. All other surface water is diverted around this facility. Current water outflows from the West WRDF include evaporation, runoff, and deep percolation through the facility. Using a 30-year data set from Ft. Bayard to represent average conditions, DBS&A (1999) predicted that the uncovered West WRDF would receive 45.4 gpm (73.3 acre-ft/yr) of precipitation (15.5 in/yr). Of this 45.4 gpm (73.3 acre-ft/yr), 28.8 gpm (46.5 acre-ft/yr) evaporates and 16.6 gpm (26.8 acre-ft/yr) infiltrates. For conservatism, it was assumed that none of the precipitation becomes runoff.

Again, the average annual-rainfall value used in this analysis (15.5 in/yr) is less than average annual rainfall used in analyses presented elsewhere in this report (18.3 in/yr). Scaling the results based on the ratio of 18.3/15.5 results in the prediction that the uncovered West WRDF receives 53.6 gpm (86.5 acre-ft/yr) of precipitation. Of this 53.6 gpm, 34 gpm (54.9 acre-ft/yr) evaporates and 19.6 gpm (31.6 acre-ft/yr) infiltrates.

2.1.3 Underground Workings

Prior to 1964, historic dewatering occurred in several shafts in the area of the Continental Mine. During 1964, the Number 3 Shaft of the current underground workings was excavated and this became the main dewatering shaft at the site (SMI, 1997). Figure E-16 shows the hydrologic conceptualization of the current underground workings.

Currently, the underground workings are dewatered at an average rate of 132 gpm. Approximately 92% of the water is pumped from the "upper" sump while approximately 8% is pumped from the "lower" sump. For the purposes of the analysis presented in this report, all water was assumed to be extracted from the location of the upper sump. It should be noted that the analysis presented in this report does not take into consideration water exiting the mine via the #3 Borehole Vent (air flow rate of 102,703 cfm) and the #4

Shaft (air flow rate of 32,800 cfm). Assuming 100 percent relative humidity at an average temperature of 26.6 degrees C, calculations indicate that air venting could remove approximately 23 gpm of water.

It is believed that most of the collected water comes from the Lake Valley and Oswaldo Formations in the deepest portions of the mine, at the location of the sump. There are no significant seeps at the higher elevations in the underground workings or any indications that water enters the mine from the Barringer Fault. Small amounts of water enter the underground workings from drill holes that penetrate the overlying Beartooth Quartzite (SMI, 1997) and also approximately 0.02 gpm flows from the intersection between the Gap Fault and the underground workings.

Because dewatering operations in the underground workings have occurred for a significant period of time, they can be viewed as a long-term pumping test from which a bulk hydraulic conductivity can be estimated. Based on an evaluation of the long-term inflow rate (132 gpm) and the estimated value of the pre-mining static head (6,670 feet), the estimated bulk hydraulic conductivity of the Lake Valley and the Oswaldo Formations is approximately 5.5×10^{-6} cm/sec. This value is in good agreement with the geometric mean of hydraulic conductivities measured by single borehole tests performed in the Lake Valley Formation.

If no new mining or expansion occurs and dewatering ceases, it is estimated that it would take approximately 38 years to flood the underground workings to an approximate elevation of 6,500 feet. The calculations used in this estimate are presented in Attachment E3.

2.1.4 Continental Pit[1]

Currently (circa 1997), no springs or seeps exist in the Continental Pit except during precipitation events. The task of mapping seeps during precipitation events is on-going but is highly dependent on the weather. Precipitation and runoff collected in the pit bottom flows through historical adits to the underground workings, where it eventually is collected in the underground sumps. The evaluation presented below is based on an analysis performed in 1997.

If no new mining or expansions occur at the Continental Pit, modeling results indicate that a pit lake will form in the Continental Pit after water levels have recovered from previous dewatering of the underground workings. The pit lake would develop over a time frame of approximately 35 years after water level recovery from underground dewatering. The lake would probably be terminal (i.e., ground water will not flow away from the lake), have a final stage elevation of approximately 6,523 feet, a depth of approximately 43 feet, and a surface area of approximately 20 acres. After the pit lake has reached steady state, the maximum drawdown around the pit lake is predicted to be approximately 147 feet and the radius of the 1-foot drawdown contour is expected to be approximately 1,500 feet from the center of the pit.

Figure E-17 shows the conceptual steady-state water balance model for the Continental Pit lake. Table E-1 presents the pit inflows and outflows predicted by the pit lake modeling. Attachment E4 provides a complete description of the inputs and calculations used to estimate the final pit lake parameters.

[1] At the time of publication, expansion of the Continental Pit has been put on hold until a new development plan is created. Mining is not expected to resume in the Continental Pit in the near future. Therefore, no updates to the 1997 hydrologic analyses have been conducted for this report.

Table E-1 Predicted Steady-State Water Balance Components of the Continental Pit Lake

COMPONENT	PREDICTED FLOW RATE gpm (acre-feet/yr) (A positive value indicates flow into the pit lake)
Ground Water Inflow	29.2 (47.2)
Surface Water Runoff into Pit Lake from Precipitation Falling on Pit Walls	8.7 (14.0)
Direct Precipitation into Pit Lake	28.5 (46.0)
Evaporation from Pit Lake Surface	-86.9 (-140.3)

2.1.5 Hanover Mountain

Figure E-18 shows the current conceptual hydrologic model of Hanover Mountain. Flow directions and hydraulic head contours are based on site-specific information from monitoring wells (MW-1A and MW-1), multi-level pneumatic piezometers (PP-01, PP-02, and PP-03), exploration borehole drilling, and Trauger (1972). Basically, recharge upgradient in the Piños Altos Range (leakage through Tertiary gravels) flows through the Colorado Formation and discharges to the upper, weathered portion of the Hanover Fierro Stock. The lower Colorado Formation (shale unit) and the Beartooth Quartzite act as aquitards to vertical flow. This conceptualization is based on the low permeability of the shale unit (short-term aquifer test for MW-1 presented in Appendix A), the confined conditions encountered in the Beartooth Quartzite during the installation of PP-05, and observations in the underground workings (see Section 2.1.3). Enhanced infiltration through weathered bedrock and fractures on Hanover Mountain creates a slight ground water mound beneath the mountain. The Barringer Fault, located south and southeast of Hanover Mountain, restricts deep ground water flow and causes ground water to flow towards the higher permeability zones of the weathered Hanover Fierro

Stock and shallow alluvial aquifers. Current lateral ground water flow through the proposed Hanover Pit area has been estimated by Darcy's Law to be approximately 22 gpm[2]. The following assumptions were used to estimate this flow:

- A 500-foot-thick aquifer
- A width of 3,200 feet
- Hydraulic conductivity of 1.6×10^{-5} cm/sec (0.045 ft/day), based on hydraulic conductivity values measured near Hanover Mountain
- Hydraulic gradient equal to 0.06, based on gradients observed near Hanover Mountain.

2.1.6 Proposed Leach Pad Area

2.1.6.1 Fierro Leach Pad

In the current conceptual model of ground water flow in the Fierro Area, Quaternary alluvium in the valleys of Poison Springs and magnetite dam drainages and weathered granodiorite overlie competent granodiorite of the Hanover-Fierro Stock. The overlying material exhibit permeabilities ranging from 1×10^{-5} (at MW-25) to 7×10^{-3} (at MW-24) cm/sec (Appendix A), while the lower portions of the stock exhibit hydraulic conductivities on the order of 1×10^{-6} to 1×10^{-5} cm/sec. Based on the water balance of the Tailings Pond and the conceptual model of the Tailings Pond and Fierro Area (Figure E-13), SMI estimates that the current ground water flow through the proposed Fierro Leach Pad area is slightly over 100 gpm.

It is currently planned that the proposed Fierro Leach Pad will be built over the existing Magnetite Tailings Dam. The Magnetite Tailings Dam has not been in use since the late 1970s, and piezometers completed in the magnetite dam went dry in 1996.

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[2] This is not the expected ground water inflow to Hanover Pit. Excavation and dewatering of the pit will result in a much wider area of influence. This value is presented only to indicate the magnitude of ground water flow in the pre-mining area.

Present day inflows to the Magnetite Tailings Dam occur only from the infiltration of direct precipitation, and, prior to standby, emergency discharges from processing facilities. All other surface water is diverted around this facility. Current outflows include evaporation and downward seepage from the bottom of the facility. Using a 30-year data set from Ft. Bayard to represent average conditions, DBS&A (1999) predicted that the uncovered Magnetite Tailings Pond receives 15.5 gpm (25.0 acre-ft/yr) of precipitation (15.5 in/yr). Of this 15.5 gpm, 0.2 gpm (0.4 acre-ft/yr) becomes runoff, 9.8 gpm (15.8 acre-ft/yr) evaporates and 5.5 gpm (8.8 acre-ft/yr) infiltrates.

The average annual-rainfall value used in this analysis (15.5 in/yr) is less than average annual rainfall used in analysis presented elsewhere in this report (18.3 in/yr). Scaling the results based on the ratio of 18.3/15.5 results in the prediction that the uncovered Magnetite Tailings Pond receives 18.3 gpm (29.5 acre-ft/yr) of precipitation. Of this 18.3 gpm, 0.3 gpm (0.5 acre-ft/yr) becomes runoff, 11.6 gpm (18.7 acre-ft/yr) evaporates and 6.4 gpm (10.4 acre-ft/yr) infiltrates.

2.2 Water Balance Components and Impacts at the End of Mining

Changes to the local surface water regime will take place after new mining and expansion commences. Changes to the surface water regime (from current conditions) will consist of diverting surface water runoff around the proposed Hanover Pit, the previously proposed enlargement of the Continental Pit, the expanded South WRDF, and the Fierro Leach Pad. The only additional changes in surface flow will be the loss of surface water runoff captured by the proposed Hanover Open Pit and the Fierro Leach Pad. Prior to new mining and expansion, a portion of this flow lost to surface water runoff would have recharged the shallow alluvial aquifers, which could have ultimately recharged deeper bedrock aquifers. During mining, this surface water runoff would be captured by mining facilities (i.e., heap leach pad and pit dewatering systems) and used for mine process water.

The runoff currently contributing to the Hanover Creek watershed from the proposed expansion areas (Hanover Pit, South WRDF, and the Fierro Leach Pad) was estimated using the SCS method of rainfall abstractions (SCS curve number method presented in Attachment E1). Combined, the areas from the Hanover Pit and Fierro Leach Pad currently contribute approximately 3.2 gpm to the Hanover Creek watershed. (The post 1999 expansion of the South WRDF is small and not included in the analysis). With the exception the South WRDF, runoff that would have occurred from these areas will no longer contribute to the watershed following mine closure.

During new mining and previously planned expansion, changes to the ground water flow regime would include dewatering at the Hanover Pit, possible dewatering in the Continental Pit, increased dewatering in the Underground Workings, and increased process water pumped from the Cron Ranch water supply wells (see Appendix B). On average, Cobre plans to use approximately 900 gpm (1,452 acre-feet/yr) for its mining activities over an estimated mine life of 10 years. As mining progresses, ground water flows into the open pits and Underground Workings would increase and the water removed during dewatering could be used as process water, reducing the amount pumped from the other sources.

2.2.1 Tailings Pond

Components of the current (circa 1997) water balance for the Tailings Pond are discussed in Section 2.1.1. Estimates of future process flow rates (e.g., tailings production rates and decant sump pumping rates) are not available. However, predictions of the end-of-mining (i.e., immediately following mining) inflows and outflows associated with the Tailings and Reclaim Ponds can be based on ratios of the proposed increases in area and elevation of the Tailings Pond. Natural inflows and outflows at the end of mining are estimated to be as follows:

- Direct precipitation (256 gpm)
- Evaporation (760 gpm)
- Leakage (362 gpm).

Of the estimated 362 gpm leakage, approximately 345 gpm would flow downvalley toward the Fierro area and approximately 17 gpm would seep downward into the bedrock aquifer. In order to sustain these flow rates, Cobre would have to increase their milling production approximately 300 percent over 1997 rates, and the previously planned mining production rates are not expected to increase by this much. Therefore, this estimate is probably overly conservative. Attachment E2 presents the calculations used to estimate inflows and outflows.

2.2.2 Waste Rock Disposal Facilities

2.2.2.1 South Waste Rock Disposal Facility

Inflow to the end-of-mining (i.e., immediately after mining and before reclamation) South WRDF will consist of infiltration of direct precipitation. All other surface water will be diverted around this facility. End-of-mining water outflows from the South WRDF will include evaporation, seepage from the East WRDF Seep, runoff, and deep percolation through the facility. In order to determine the various end-of-mine water balance components, the unit rates for the current uncovered South WRDF were applied to the uncovered end-of-mining South WRDF. Using this approach, it was predicted that on the end-of-mining South WRDF would receive 264.9 gpm of precipitation (15.5 in/yr). Of this 264.9 gpm, 169.2 gpm would evaporate and 97.4 gpm would infiltrate. For conservatism, it was assumed that none of the precipitation would become runoff.

The average annual rainfall value used in this analysis (15.5 in/yr) is less than average annual rainfall used in analyses presented elsewhere in this report (18.3 in/yr). Scaling the results by the ratio of 18.3/15.5 results in the prediction that the end-of-mining South WRDF would receive 312.8 gpm (504.8 acre-ft/yr) of precipitation. Of this 312.8 gpm, 199.8 gpm (322.4 acre-ft/yr) would evaporate and 115.0 gpm (185.6 acre-ft/yr) would infiltrate.

2.2.2.2 West Waste Rock Disposal Facility

Inflow to the end-of-mining (i.e., immediately after mining and before reclamation) West WRDF will consist of infiltration of direct precipitation. All other surface water will be diverted around this facility. End-of-mining water outflows from the West WRDF will include evaporation, runoff, and deep percolation through the facility. Since no changes are planned for the West WRDF the water balance for the current uncovered West WRDF is the same as the water balance for the end-of-mine West WRDF (See Section 2.1.2.2).

2.2.3 Underground Workings

The evaluation presented below is based on the 1997 planned expansion and the resulting analysis performed in 1997 and does not include water exiting the underground workings via ventilation shafts. The expanded underground workings would progress approximately 200 feet deeper and 7,500 feet laterally over the current configuration. The workings were not expected to intersect new formations; therefore, the previously estimated bulk hydraulic conductivity (5.5×10^{-6} cm/sec) associated with the current dewatering of the workings is considered appropriate for predicting future inflows to the underground sumps. The estimated end-of-mining dewatering rate from the underground workings is between 170 and 500 gpm. Figure E-19 shows the predicted drawdown cone due to dewatering at the end of mining. Below the mine, the water level will be depressed to about 1,450 feet below ground surface (corresponding to the final sump elevation of 5,350 feet). At the end of mining, the radial distance to the 1-foot drawdown contour is estimated to be approximately 5,500 feet. The calculations used to estimate this radial distance are presented in Attachment E3.

2.2.4 Continental Pit

The evaluation presented below is based on the 1997 proposed expansion and associated analysis performed in 1997. At the end of mining, assuming that ground water levels have recovered from dewatering of the underground workings, the ground water level below the Continental Pit would be about 760 feet below ground surface (corresponding to a pit-bottom elevation of 6,000 feet). Evaporative losses would be approximately 161 gpm. The radial distance to the 1-foot drawdown contour would be approximately 3,000 feet from the center of the pit. Figure E-20 shows the predicted drawdown cone at the end of mining for the expanded Continental Pit. The best estimated steady-state dewatering rate from the Continental Pit at the end of mining was expected to range between 60 and 120 gpm. The calculations used to estimate drawdown, radius of influence, and dewatering rate are presented in Attachment E4.

2.2.5 Hanover Mountain

At the end of mining, the ground water level below Hanover Mountain will be approximately 240 feet below the current average water table elevation of 6,798 feet. At maximum drawdown, the maximum distance from the pit to the 1-foot drawdown contour, will be approximately 8,100 feet from the center of the pit (see Figure E-21). The expected end-of-mining dewatering rate from the Hanover Pit will be approximately 38 gpm (Attachment E5).

2.2.6 Fierro Leach Pad Area

End-of-mining inflows to the Fierro Area will consist of barren leach solution and direct precipitation; all other runoff will be diverted around this facility. End-of-mining outflows from the Fierro Area include evaporation and pregnant leach solution. After the end of mining, this area will operate as zero discharge facility.

Water balance modeling conducted by Schafer & Associates (1996) for the formerly proposed Humbolt Leach Pad predicted average seepage rates from the unreclaimed leach pad to be approximately 65 gpm (8.1 in/yr) for an average precipitation year (18.3 in/yr). The analysis for the formerly proposed pad also predicted an average runoff rate of 5 gpm (0.6 in/yr), an average evaporation rate of 76 gpm (9.5 in/yr), and an average percolation of 65 gpm (8.1 in/yr). Assuming that the 149 acre Fierro Area and the formerly proposed 150 acre Humbolt Area have similar configurations, the various water balance components for the Fierro Leach Pad will be the same as those predicted for the Humbolt Leach Pad.

2.3 Post-Closure Water Balance Components

Evaluation of post-closure water balance components is presented in the following sections. The water balance component calculations are based on the following assumptions:

- Dewatering of the underground workings, Continental Pit, and Hanover Pit has ceased and inflows and outflows are at equilibrium.
- Reclamation of the waste rock disposal facilities has been completed and inflows and outflows are at equilibrium.
- Inflows and outflows to and from the Tailings and Reclaim Ponds are at equilibrium.

2.3.1 Tailings Pond

The conceptual model of the post-closure water balance is shown on Figure E-22. Post-closure inflows and outflows associated with the Tailings Pond after closure will consist of steady-state infiltration of direct precipitation, run-on from upgradient areas, runoff from the reclaimed tailings, evapotranspiration from the reclaimed tailings, and long-term downward seepage from the bottom of the facility. In order to determine the various post-closure water balance components, the unit rates for the current covered Tailings Pond (DBS&A, 1999) were scaled up to be consistent with previous Tailings Pond analysis and applied to the covered post-closure Tailings Pond. Using this approach, it was predicted that the covered 264-acre Tailings Pond would receive approximately 249.6 gpm of precipitation (18.3 in/yr) and approximately 0.6 gpm of run-on. Of this 250.2 gpm, approximately 1.9 gpm would run off, approximately 224.6 gpm would evaporate, and approximately 24.7 gpm would infiltrate. Assuming steady-state conditions, the seepage from the bottom of the impoundment is equal to the infiltration. Partitioning the seepage between flow to lower bedrock units and the Fierro Area, based on the ratio of flows presented for the current and end-of-mine scenarios results in flow of 1.3 gpm and 23.4 gpm, respectively.

2.3.2 Waste Rock Disposal Facilities

2.3.2.1 South Waste Rock Disposal Facility

Inflow to the post-closure South WRDF will consist of steady-state infiltration of direct precipitation. All other surface water will be diverted around this facility. Post-closure water outflows from the South WRDF will include evaporation, seepage from the East WRDF Seep, runoff, and deep percolation through the facility. In order to determine the various post-closure water balance components, the unit rates for the current covered South WRDF were applied to the covered post-closure South WRDF. Using this approach, it was predicted that the covered South WRDF would receive 264.9 gpm (427.6 acre-ft/yr) of precipitation (15.5 in/yr). Of this 264.9 gpm, 0.5 gpm (0.8 acre-ft/yr) would run off, 237.6 gpm (383.5 acre-ft/yr) would evaporate and 29.1 gpm (47.0 acre-ft/yr) would infiltrate.

The average annual rainfall value used in this analysis (15.5 in/yr) is less than average annual rainfall used in analyses presented elsewhere in this report (18.3 in/yr). Scaling the results by the ratio of 18.3/15.5 results in the prediction that the post-closure South WRDF would receive 312.8 gpm (504.8 acre-ft/yr) of precipitation. Of this 312.8 gpm, 0.6 gpm (1.0 acre-ft/yr) would run off, 280.5 gpm (452.8 acre-ft/yr) would evaporate and 34.4 gpm (55.5 acre-ft/yr) would infiltrate.

2.3.2.2 West Waste Rock Disposal Facility

Inflow to the post-closure West WRDF will consist of steady-state infiltration of direct precipitation. All other surface water will be diverted around this facility. Post-closure water outflows from the West WRDF will include evaporation, runoff, and deep percolation through the facility. Using a 30-year data set from Ft. Bayard to represent average conditions, DBS&A predicted that the covered West WRDF would receive 45.4 gpm (73.3 acre-ft/yr) of precipitation (15.5 in/yr). Of this 45.4 gpm, 0.1 gpm (0.2 acre-ft/yr) would run-off, 40.5 gpm (65.4 acre-ft/yr) would evaporate and 4.8 gpm (7.7 acre-ft/yr) would infiltrate. Scaling these values up as before results in 53.6 gpm of direct precipitation to the reclaimed West WRDF of which: 0.12 gpm (0.24 acre-ft/yr) would run-off, 47.8 gpm (77.2 acre-ft/yr) would evaporate, and 5.7 gpm (9.1 acre-ft/yr) would infiltrate.

2.3.3 Underground Workings

The evaluation presented below is based on the 1997 expansion plans and the associated analysis performed in 1997. After mining and dewatering cease, it is estimated that the expanded underground workings would flood to an elevation of 6,500 feet in approximately 53 years. It could have taken 125 years to flood the underground workings to the estimated pre-mining water table elevation of 6,665 feet. These times would be much less if no further expansion takes place. The calculations used to determine the flooding level and time to flood for the underground workings are presented in Attachment E3.

2.3.4 Continental Pit

The evaluation presented below is based on the proposed 1997 expansion and associated analysis performed in 1997. During the post-mining period, modeling results indicate that a pit lake will form in the bottom of the Continental Pit. The pit lake is predicted to reach a depth of 200 feet 8 years after the recovery of drawdown from the underground workings. It could take approximately 60 years to reach a depth of 400 feet. The lake will be terminal (i.e., ground water will not flow away from the lake), have a final stage elevation of approximately 6,464 feet, a depth of approximately 464 feet, and a surface area of approximately 56 acres. After the pit lake has reached steady state, the lake water level will be about 206 feet lower than the estimated pre-mining water level. The drawdown cone associated with the ultimate pit lake may extend up to 3,300 feet from the center of the pit. Figure E-23 shows the conceptual water balance model for the expanded Continental Pit at the end of mining. Table E-2 presents the pit inflows and outflows used for the pit lake modeling. Attachment E4 provides a complete description of the inputs and calculations used to determine the final pit lake parameters.

Table E-2 Predicted Steady-State Water Balance Components of the Lake for the Expanded Continental Pit

COMPONENT	PREDICTED FLOW RATE gpm (acre-feet/yr) Positive value indicates flow into the pit lake
Ground Water Inflow	97.8 (157.9)
Ground Water Flow into Pit Lake from Above Pit Lake Bottom (i.e., Seepage Face and Horizontal Ground Water Flow)	64.0 (103.3)
Direct Precipitation into Pit Lake	64.1 (103.5)
Evaporation from Pit Lake Surface	-195.5 (-315.5)

2.3.5 Hanover Mountain

After mining and dewatering cease, modeling results indicate that a pit lake will form in the bottom of the Hanover Pit. Predictions indicate that the pit lake will be terminal (i.e., ground water will not flow away from the lake) and that it will take approximately 21 years to reach a steady-state elevation of 6716 feet. At this water level, the lake will have a depth of approximately 156 feet and a surface area of approximately 22.3 acres. Evaporative losses will be approximately 64.2 gpm. The maximum steady-state drawdown at the pit lake is predicted to be approximately 157 feet. At the pit lake final elevation, the distance to the 1-foot drawdown contour will be approximately 8,000 feet from the center of the pit.

Figure E-24 shows the post-closure conceptual water balance model for the Hanover Pit. Table E-3 presents the predicted pit inflows and outflows for the steady-state Hanover Pit Lake. Attachment E5 provides a complete description of the inputs and calculations used to determine the final pit lake flow rates.

Table E-3 Predicted Steady-State Water Balance Components of the Hanover Pit Lake

COMPONENT	PREDICTED FLOW RATE gpm (acre-feet/yr) Positive value indicates flow into the pit lake
Ground Water Flow into Pit Lake	26.8 (43.3)
Surface Water Runoff into Pit Lake from Precipitation Falling on Pit Walls	10.0 (16.1)
Direct Precipitation into Pit Lake	27.6 (44.6)
Evaporation from Pit Lake Surface	64.2 (103.6)

2.3.6 Fierro Leach Pad

Post-closure inflows to the Fierro Leach Pad will consist only of infiltration from direct precipitation through the reclaimed heap leach pad. All other surface water will be diverted around this facility. Outflows will consist of long-term seepage from the facility. This seepage will be treated passively if it does not meet water quality criteria.

For an average precipitation year (18.3 in/yr), water balance modeling conducted by Schafer & Associates (1996) predicted average seepage rates from the formerly proposed Humbolt Leach Pad to be less than 4 gpm (0.5 in/yr) under revegetated conditions. The analysis for the formerly proposed pad also predicted an average runoff rate of 2.4 gpm (0.3 in/yr), an average evapotranspiration rate of 141.6 gpm (17.7 in/yr), and an average percolation of 1.6 gpm (0.2 in/yr). Assuming that the 149-acre Fierro Leach Pad and the formerly proposed 150-acre Humbolt Leach Pad have similar configurations, the various water balance components for the Fierro Leach Pad will be the same as those predicted for the Humbolt Area.

3.0 SUMMARY

During expansion mining, approximately 5.2 gpm of surface water runoff will no longer contribute to recharge of the alluvial and bedrock aquifers. After Hanover Pit intersects the water table and if the previously proposed Continental Pit and Underground Workings expansions take place, ground water withdrawal in the area will increase from 132 gpm to approximately 380 gpm at the end of mining. This ground water can be used to decrease the amount of process water pumped from the other water supplies.

After cessation of mining, terminal pit lakes are expected to form in the Continental and Hanover Pits. The lake associated with the previously proposed expanded Continental Pit will be approximately 464 feet deep, have a surface area of approximately 56 acres, and take over 60 years to form. The Hanover Pit lake will be approximately 156 feet deep, have a surface area of 22.3 acres, and take approximately 21 years to reach a steady state elevation of 6716 feet. Evaporative losses will be approximately 161 gpm (260 acre-feet/yr) from the expanded Continental Pit lake and approximately 64.2 gpm (103.6 acre-feet/yr) from the Hanover Pit lake.

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