PRELIMINARY SLUDGE HANDLING PLAN AND COST ESTIMATE DP-1341 CONDITION 86

Prepared for:

Phelps Dodge Tyrone, Inc.
Tyrone, New Mexico

Submitted by:

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October 22, 2004 013-1595.002

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October 22, 2004

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Mining Environmental Compliance Section
P. O. Box 26110
Santa Fe, New Mexico 87502

Mr. Holland Shepherd
Program Manager
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1220 South St. Francis Drive
Santa Fe, New Mexico 87505

Dear Ms. Menetrey and Mr. Shepherd:

Re: DP-1341, Condition 86, and Permit GR010RE, Condition 9.L.4
Phelps Dodge Tyrone, Inc. Sludge Handling Plan and Cost Estimate.

Pursuant to the New Mexico Environment Department (NMED) DP-1341, Condition 86, and the New Mexico Mining Division (MMD) Permit Revision 01-1 to Permit No. GR010RE, Condition 9.L.4. Phelps Dodge Tyrone, Inc. (Tyrone) hereby submits the Sludge Handling Plan and Cost Estimate.

Three copies of the document are being mailed to the NMED and two copies are being mailed to the MMD.

If you need further information, please contact Mr. Chuck Thompson at (505) 538-7181.

Very truly yours,

C C Thompson for

Thomas L. Shelley, Manager
Strategic Environmental Projects
New Mexico Operations

TLS:ct
Attachment(s)
20041022-102

xc: Keith Ehlert, NMED
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AMC	antecedent moisture condition
Ardaman	Ardaman & Associates, Inc.
cm/sec	centimeters per second
CN	Curve Number
DBS&A	Daniel B. Stephens & Associates, Inc.
DSM	dynamic system model
ETS	Evaporative Treatment System
FGD	flue gas desulfurization
ft/day	feet per day
gpm	gallons per minute
HDS	High-density Sludge
H:V	horizontal to vertical
in/yr	inches per year
kg/cm^2	kilograms per square centimeter
kPa	kiloPascals
lbs/ft^3	pounds per cubic foot
M3	M3 Engineering & Technology Corp.
mg/L	milligrams per liter
NMED	New Mexico Environment Department
NMWQCC	New Mexico Water Quality Control Commission
PDTI	Phelps Dodge Tyrone, Inc.
PLS	pregnant leach solution
the Plan	Tyrone Preliminary Sludge Handling Plan and Cost Estimate
RCRA	Resource Conservation and Recovery Act
SCS	Soil Conservation Service
SI	Saturation Index
SPLP	Synthetic Precipitation Leachate Procedure
TDS	total dissolved solids
TTEMI	Tetra Tech EM Inc.
USDA	U.S. Department of Agriculture

1.0 INTRODUCTION

This report presents the Tyrone Preliminary Sludge Handling Plan and Cost Estimate (the Plan), which is being submitted in satisfaction of the DP-1341 Condition 86 Work Plan, that was submitted to the New Mexico Environment Department (NMED) on February 27, 2004 (Van Riper Consulting, 2004).

This Plan contains nine sections, tables, figures, and appendices. The focus of this effort was to quantify the amount of sludge that will be generated by the Tyrone Water Treatment Plant, evaluate the quality of the sludge from a chemical and physical standpoint, and identify the most environmentally protective site for long-term sludge disposal. Section 8.0 presents a preliminary operational plan for the sludge management program when implemented following closure.

Section 2.0 presents a detailed review of site waters that will be collected and treated in the Tyrone Water Treatment System. The treatment system includes the Evaporative Treatment System (ETS) and the Nanofiltration/High-density Sludge (HDS) Plant. The amounts of sludge generated by year are projected, and the basis for these numbers is presented. The physical characteristics of the sludge will be essentially the same as gypsum produced from the neutralization of sulfuric acid. Analogous data from a plant that produces the same type of sludge are used to project physical properties of the sludge, which differ only slightly from those presented to the state in the past.

A detailed screening analysis was conducted to identify potential sites for disposal of the sludge. The screening procedure focused on identifying the most environmentally acceptable sites, followed by a comparison of the capital and operating costs for the preferred sites. This selection process is covered in Section 3.0. Two sites were identified as environmentally sound alternatives, the first being on a bench in the Main Pit and the second being on a stockpile in the Main Pit.

Specific design of the sludge management facilities is presented in Section 4.0, with corollary capital and operating costs presented in Section 6.0. Physical and chemical characterization of long-term sludge stability is presented in Section 5.0; Section 7.0 addresses how the proposed sludge management program is compliant with applicable regulations.

Capital and operating costs were estimated for both of the identified preferred alternatives. In today's dollars, capital costs range from $1.651MM for the in-pit stockpile site, to $2.149MM for the Main Pit bench. Operating costs range from $83,700 to $97,500 per year.

2.0 ESTIMATION OF SLUDGE MASS AND VOLUME GENERATED BY WATER TREATMENT SYSTEM

This section describes the technical basis for estimating the mass and volume of sludge that is expected to be produced by the proposed Water Treatment System at Tyrone. The technical basis includes the conceptual model of the Tyrone Mine system and subsystems, and the associated processes and physical conditions during and following mine reclamation and closure. The conceptual model was implemented mathematically as a dynamic system model (DSM) using the GoldSim simulation software platform. The DSM is a dynamic, probabilistic simulation model that projects the behavior of the mine system and the influence various closure activities have on its performance. The first iteration of the Tyrone DSM was used for estimating the mass and volume of sludge that will be produced by the proposed Water Treatment System.

The DSM contains two coupled subsystems that were used to estimate the mass and volume of sludge produced during a 100-year closure period:

- a *water balance–mass balance model* that tracks the volume and quality of water and process solutions that will be treated, and
- a *water treatment model* that projects the mass and volume of sludge produced based on the influent water quality and treatment method.

The sludge mass and volume projections will depend to a large extent on the closure activities that are implemented following cessation of operations at the Tyrone Mine. The closure activities assumed for the purpose of the sludge projections are described in Section 2.1. Section 2.2 describes the proposed Water Treatment System and the type and properties of sludge that is expected to be produced. The proposed Water Treatment System consists of three components: an ETS, a Nanofiltration Plant, and an HDS Plant. Section 2.3 describes the water balance-mass balance model that was used to project the quantity and quality of the water that will be handled by the Water Treatment System. The projected mass and volume of sludge produced over the 100-year simulation period are discussed in Section 2.4.

One of the primary purposes of simulation models is to gain a better understanding of a system and to evaluate ways to improve its performance from a regulatory compliance and cost standpoint. This process is iterative, and the conceptual model and the underlying assumptions and data may change as the simulation results are considered and factored into the closure strategy. Furthermore, the model consists of conceptual models of processes and closure activities that are based on field, laboratory, and modeling studies and layers of assumptions and input data. While a great deal of work has already been performed, Phelps Dodge Tyrone, Inc. (PDTI) is performing supplemental studies under Conditions 75 through 88 in DP-1341 that will provide additional data. The new information will be used to test the DSM component model and make changes to improve its accuracy. Nonetheless, we believe that this model is accurate enough to develop a design and cost projection consistent with guidelines for pre-feasibility work at ±30%.

2.1 Closure Alternative Description

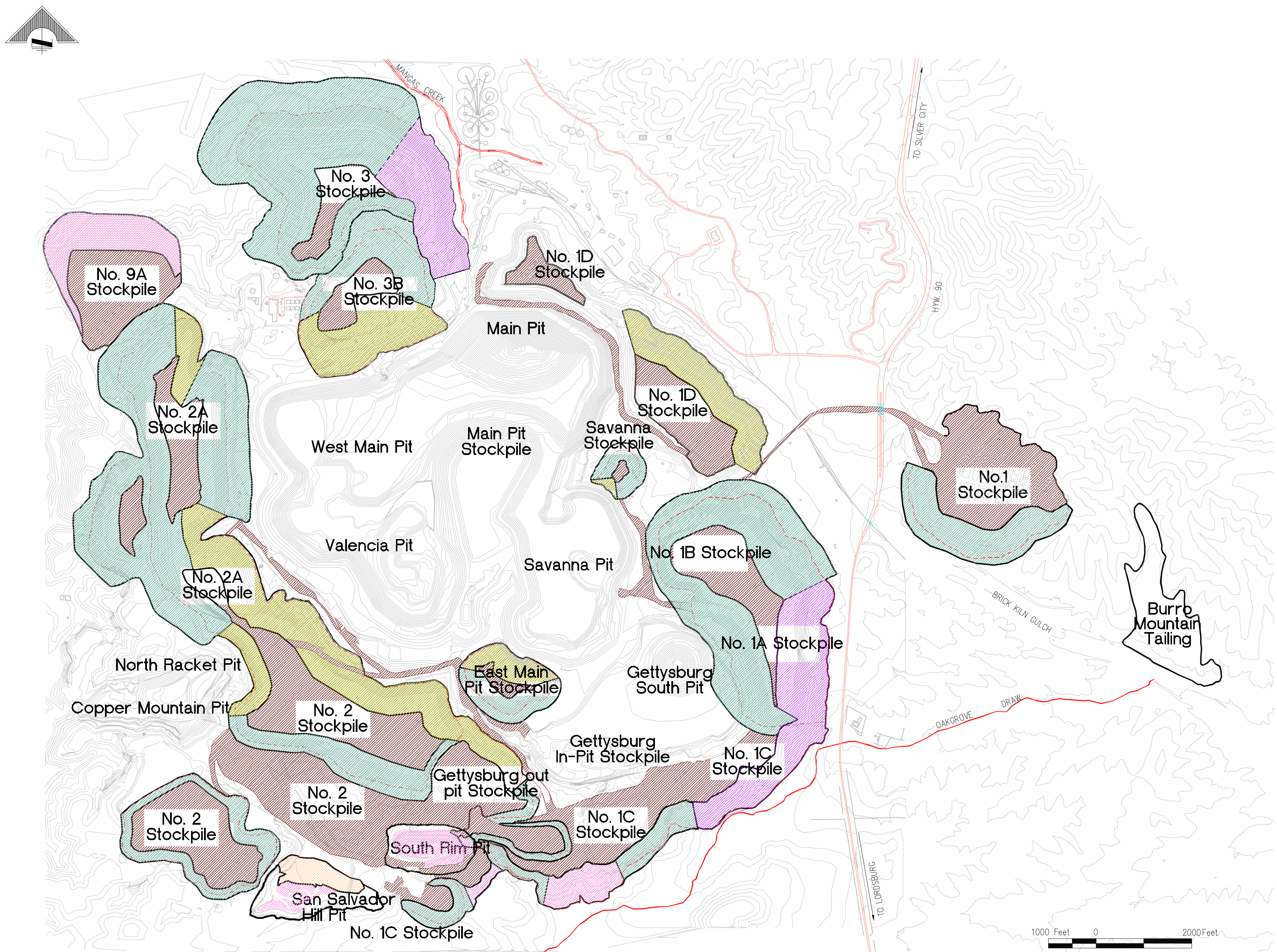
The sludge mass and volume estimates are based on waters collected under the closure conditions described in DP-1341. The closure conditions assumed in the DSM include the regrading of waste rock piles and leach ore stockpiles such that the interbench outslopes are no steeper than 3 horizontal to 1 vertical (H:V), with the exception of leach ore stockpiles located within the pit wall boundary of the Main and Gettysburg Pits. The top surface and slopes of all the leach ore stockpiles and waste rock piles are assumed to be covered with 36 inches of material and revegetated, with the exception of the stockpile outslopes within the boundary of the Main and Gettysburg Pits. The tailings impoundments are also assumed to have been regraded, covered with 24 inches of material, and revegetated.

The DSM includes a schedule for implementing the closure measures. The timing is important because runoff from uncovered leach ore stockpiles and waste rock piles is considered to be impacted and adds to the volume of water that must be treated. The schedule for closing the stockpiles and waste rock piles is shown in Table 2-1.

TABLE 2-1
SCHEDULE FOR COVERING WASTE ROCK PILES AND STOCKPILES IN DSM

Facility	Closure Year
1 Leach	4
1A Leach	6
1B Leach	6
1C Leach	6
1D Waste Rock	6
2 Waste Rock	11
2 Leach	11
Upper Main	11
3 Leach	6
3B Waste Rock	6
Tailings Ponds	0

Figure 2-1 identifies the potential disposal sites that were reviewed for this study.



Notes :

1. STOCKPILE 1D (SOUTH PORTION) USED AS COVER MATERIAL SOURCE.
2. STOCKPILE 9A IS DESIGNED @ 2H TO 1V OUTSLOPE.
3. AREAS COVERED, NOT REGRADED HAVE EXISTING SLOPES FLATTER THAN 3 TO 1.

Legend

- COVERED AREAS NOT REGRADED
- OUTSLOPE PULLBACK 2.5:1
- OUTSLOPE PUSHDOWN 2.5:1
- OUTSLOPE PULLBACK 3:1
- OUTSLOPE PUSHDOWN 3:1
- TOP SURFACE & ROADS
- AREAS NOT REGRADED OR COVERED
- EXISTING STOCKPILE TOE

REFERENCES		REFERENCES		REVISIONS						REVISIONS					
DWG. NO.	TITLE	DWG. NO.	TITLE	NO.	DESCRIPTION	BY	APP'D	DATE	CLIENT	NO.	DESCRIPTION	BY	APP'D	DATE	CLIENT

SCALE: AS NOTED		DATE
DESIGNED BY	A.G.	SEP '04
DRAWN BY	C.R.	SEP '04
CHECKED BY	A.G.	
PROJECT MGR	C.H.	
CLIENT APPR.		

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TYRONE CLOSURE / CLOSEOUT

MINE AREA
DP-1341
POTENTIAL SLUDGE
DISPOSAL SITES

JOB NO. M3-PN02060
DWG NO. FIGURE 2-1
REV NO.
DATE 09/16/04

The water and mass balance model for the Tyrone Mine contains sub-models representing surface runoff, infiltration into the covered or uncovered surface, seepage from the base with allocation between groundwater and near-surface flow, and draindown of leach stockpiles. The impacted runoff from the facilities prior to cover construction and any impacted groundwater are assumed to be intercepted and sent to the Water Treatment System (Section 2.2). The sub-models are discussed in Section 2.3.

2.2 Water Treatment System

Water quality has a defining role in which water treatment technology can effectively meet established limits. Water quality is also key to operating costs of all technologies, with high concentration waters being more expensive to treat. By separating the transient, process-related waters from the longer-term, better quality waters, specific technologies can be applied to each of the waters. Therefore, one of the objectives of the Water Treatment System for the Tyrone Mine is to separate the process-related impacts, which are transient and represent poorer quality water, from the longer-term, steady-state background conditions, and to treat them separately.

A water treatment strategy has been developed that relies on construction of three treatment systems, referred to as the ETS, a Nanofiltration Plant, and an HDS Plant, that when implemented, will treat all impacted waters so as to meet New Mexico Water Quality Control Commission (NMWQCC) water quality standards.

The overall water management strategy is to separate high sulfate, transient process-related waters from the longer-term waters, and to evaporate process-related waters over the first 5 years of operation. Therefore, the implementation of the Water Treatment System will be phased. The ETS is assumed to start at the beginning of closure activities and operate for 5 years.

The Nanofiltration Plant is assumed to become operational in Year 2. Feed water quality to the plant during the first few years is expected to have a relatively high sulfate concentration due to the process-related effects, but is expected to improve with time as the closure activities (e.g., stockpile cover construction and residual process water draindown) are completed. During the first 4 years of operation, high sulfate reject water from the Nanofiltration Plant will be routed to the ETS. In subsequent years, the reject from the plant will be sent to the HDS Plant, which will become operational in Year 6. Each of the water treatment subsystems are described below.

2.2.1 Evaporative Treatment System

The DSM assumes that an ETS will be used to treat (evaporate) as much of the process water as possible during the first 5 years of closure. The ETS is designed to handle approximately 1 billion gallons of pregnant leach solution (PLS) that is assumed to be present at the end of mining operations plus stockpile seepage, impacted runoff from stockpiles, impacted groundwater from interceptor wells, and reject from the Nanofiltration Plant. These process waters will have relatively high sulfate concentrations and would be technically difficult to treat using conventional water treatment methods.

The ETS consists of process reservoirs (ponds, tanks, etc.); pumps; pipelines; and a spray system. Draindown of process solution from the leach stockpiles and the various other sources identified above are assumed to be collected in the process reservoirs and pumped to the top of one or more stockpiles and sprayed through a network of pressure nozzles (atomizers) to maximize evaporation. The solution that is not evaporated is assumed to infiltrate through the stockpile and then re-circulated through the ETS. Detailed discussion of the ETS is presented under the Condition 86 Work Plan that the NMED has already received (Van Riper Consulting, 2004).

The ETS is assumed to be operated for 5 years. Any remaining process solution at the end of Year 5 will be allowed to drain from the ETS stockpiles into the surface reservoirs. Volumes in excess of the surface reservoirs capacity are assumed to be sent to the pit lake(s) for storage and subsequent processing. The surface reservoirs then become the holding ponds for feed to a Nanofiltration/HDS Plant.

The basic operation of the ETS in the DSM is based on M3 Engineering & Technology Corp. specifications (M3, 2001b). The average annual spray evaporation rate is assumed to be 13% of the spray rate with a maximum spray rate of 30,000 gallons per minute (gpm). The average spray evaporation rate is assumed to vary from year-to-year to reflect cooler and warmer climate years. The variability is based on the observed variability in pan evaporation data from the mine site and the surrounding area.

The DSM converts the annual spray loss rate to a monthly rate to account for seasonal variations, with adjustments based on monthly pan evaporation data for the area. A final adjustment is made to the evaporation rate to account for the influence of the high total dissolved solids (TDS) concentrations on vapor pressure), i.e., the evaporative rate is reduced by 10%.

2.2.2 Nanofiltration and High-density Sludge Plants

The Nanofiltration and HDS Plants represent the long-term treatment system for the Tyrone Mine. As mentioned above, the Nanofiltration Plant will become operational at the beginning of Year 2. The HDS Plant will become operational and integrated into the system in Year 6. The capacities of the Nanofiltration and HDS Plants are 2,300 and 600 gpm, respectively. Details of this treatment system can be found in Van Riper Consulting (2002).

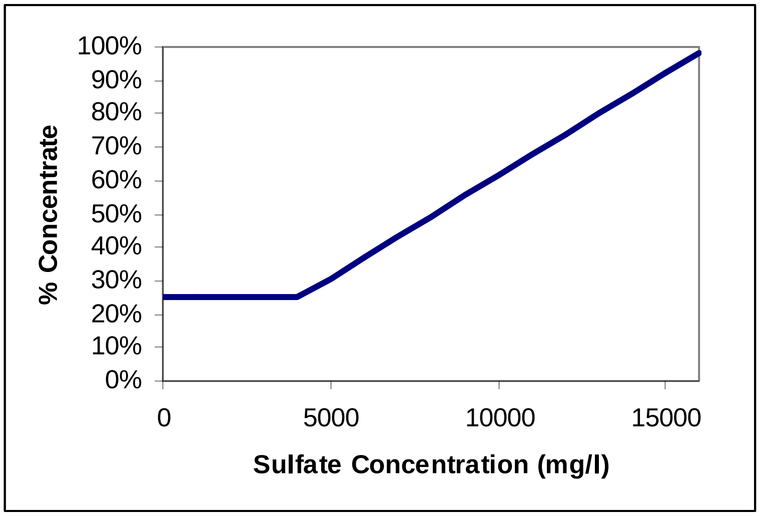
Source waters to be collected and treated in the Nanofiltration Plant during Years 2 through 5 are:

- Water present in the open pit sumps,
- Groundwater seepage inflows into the open pits,
- Stormwater inflows into the open pits, and
- Groundwater from interceptor wells.

During the initial 4-year period, concentrate from the Nanofiltration Plant will be pumped to the ETS for final disposition. When the HDS Plant is started at the beginning of Year 6 (and the ETS is shut down), the concentrate from the Nanofiltration Plant will be sent to the HDS Plant for treatment. At the same time, stockpile seepage, impacted runoff, and any residual PLS will be sent to the Nanofiltration Plant.

The discharge from the Nanofiltration Plant will consist of product water and a concentrate (reject) component. The relative percentages of the two outflows are a function of the sulfate concentration in the water being processed as shown on Figure 2-2. The DSM tracks the sulfate concentration of the influent based on the water quality of the various contributions. Influent to the Nanofiltration Plant with sulfate concentrations less than 4,000 milligrams per liter (mg/L) are expected to produce 75% product and 25% concentrate. The concentrate percentage increases with higher sulfate concentrations in the feed to the Nanofiltration Plant. The model assumes inflows with a sulfate concentration greater than 16,000 mg/L are pumped either to the ETS (while the system is operational) or the HDS Plant directly.

FIGURE 2-2
PERCENTAGE OF NANOFILTRATION PLANT INFLUENT REPORTING TO CONCENTRATE (REJECT) AS A FUNCTION OF THE SULFATE CONCENTRATION IN THE INFLUENT



The quality of the product water from the Nanofiltration Plant is expected to be suitable for discharge in compliance with water quality standards. The sulfate concentration is expected to be approximately 1.5% of the influent concentration. The product water is assumed to be commingled with product water from the HDS Plant and eventually discharged for beneficial use.

The sludge mass and volume estimates in the DSM are a function of the quantity and quality of water treated over the 100-year period. It is assumed that sludge recovered in the HDS plant will be dewatered in belt presses prior to landfilling. Final sludge density and water content are based upon an analog plant that produces a similar gypsum sludge, which is owned by a subsidiary of Phelps Dodge and is located in Ft. Madison, Iowa. Actual mass generation rates are based on testing of Tyrone water (Van Riper Consulting, 2002).

The mass generation rate is assumed to be primarily a function of the sulfate concentration in the feed to the HDS plant. The correlation is as follows:

$$S_M = R_{HDS} \times (-7.2795 + 0.00282 \times C_{SO4})$$

where:

S_M = dry weight mass (g) of sludge produced per liter of water treated in the HDS plant
R_{HDS} = treatment rate in the HDS (L)
C_{SO4} = sulfate concentration of the water being treated (mg/L)

The volume of sludge is calculated based on a pre-filter percent solids and specific gravity of the sludge of the Ft. Madison system, which is 30% solids by weight with an in-situ density of 84.35 pounds per cubic foot (lbs/ft^3). Following dewatering with a belt-press, the processed sludge ("cake") is expected to have 53% solids and an in-situ density of 96 lb/ft^3. Appendix A summarizes the Ft. Madison gypsum sludge characteristics.

The projected mass and volumes of sludge are presented in Section 2.4.

2.3 Water Balance and Water Quality Model

There are four sources of water that are likely to be sent to the proposed Water Treatment System:

1. residual PLS from the leach operations,
2. meteoric water that infiltrates through and is collected as seepage from the base of stockpiles,
3. impacted runoff, and
4. impacted groundwater.

The rates and quality of these sources are expected to vary as a function of time as the closure activities are completed and the associated processes reach pseudo-steady-state conditions. The assumptions and processes describing each of the four sources are discussed in the following sections.

2.3.1 Process Solution

The model assumes there is a total of 894 million gallons of process solution in inventory at the cessation of mining activities (M3, 2002). The solution is allowed to drain from the leach stockpiles, is collected, and then sent to the ETS (Section 2.2.1). Draindown from the ETS Stockpiles is re-circulated together with impacted runoff, stockpile seepage and water from groundwater extraction systems. Following cessation of ETS operations at the end of Year 5, any remaining process water will be allowed to drain from the ETS Stockpiles into the surface reservoirs. Volumes in excess of the surface reservoirs capacity are assumed to be sent to the pit sumps for storage and subsequent processing. The process solution and commingled sources remaining at the end of the ETS operation are assumed to be processed in the Nanofiltration Plant.

The DSM assumes that the rate solution drains from a stockpile is proportional to the drainable volume of solution in the stockpile. Therefore, as the volume of water in the stockpile decreases, the draindown rate also decreases. Stockpile draindown is simulated as a geometric progression in which a given fraction of the solution in a stockpile is released and recovered each month. The governing equation is:

$$Q_{sd} = k_{sd} * (V_t - V_r)$$

where:

Q_{sd} = stockpile drainage flow rate (gpm)
V_t = total storage volume (gallons)
V_r = residual (non-drainable) solution volume (gallons)
k_{sd} = stockpile decay constant (empirical calibration parameter) (min^{-1})

The initial estimate of the draindown rate decay constant was based on discussions with stockpile leach operations staff at PDTI who estimated that approximately 70% of the volume of solution drains from a stockpile in the first 30 days following cessation of applying raffinate to the surface. This is a equal to a rate decay constant of 0.04. The value of the decay constant determines the cycle time for solution to re-circulate within the ETS.

Assuming that only the initial volume of process solution is to be evaporated, and utilizing the local expected evaporation rates, the duration for eliminating the process solution is just over 2 years, significantly less than the 5 years of operation assumed in the closure plan for the Tyrone Mine. However, there are other sources of impacted water that will be added to the ETS following closure such as stockpile seepage, stormwater runoff, water from interceptor wells, and reject from the Nanofiltration Plant. These additional contributions will increase the time required for the ETS to achieve a given residual solution volume. The modeling results indicate that the ETS will reach a pseudo-steady-state condition after approximately 3 years when the evaporative loss from the system is approximately the same as the expected inflow rate from the miscellaneous sources. The projected volume of solution stored in the ETS Stockpile(s) at this time is approximately 400 million gallons.

The water quality of draindown water is based on PLS samples collected from the No. 1A, Gettysburg, and No. 2 Leach Stockpiles (M3, 2001a). The solution sulfate concentration (used to estimate the sludge volume produced by the HDS Plant) is assumed to be 25,356 mg/L.

2.3.2 Stockpile Seepage

Following the draindown of process solution, the major component in the seepage coming from the base of the stockpiles will transition to meteoric water that has infiltrated through the stockpile. The quantity and quality will be influenced by the infiltration rate of precipitation on the surface and through the stockpiles.

The percolation rate through the stockpiles is assumed to influence the quantity and quality of the seepage at the base of a stockpile. The annual infiltration rate used in the DSM was based on unsaturated flow modeling results from Tetra Tech EM Inc. (TTEMI, 2003) using the UNSAT-H program and the 100-year Ft. Bayard climate record. Covered and uncovered conditions were modeled to account for closure progression. The stockpile cover is assumed to be 36-inches thick with uniform composition and a saturated hydraulic conductivity of 10^{-3} centimeters per second (cm/sec). The average annual infiltration rate for an uncovered stockpile over the 100-year period is 3.0 inches per year (in/yr). The average annual infiltration rate for a stockpile with a 36 -inch cover is 0.61 in/yr.

The DSM includes the schedule for regrading and covering the stockpiles on a stockpile-by-stockpile basis (Section 2.1). The assumed closure schedule for the stockpiles is shown in Table 2-1. When the simulation time reaches the specified closure date for a stockpile, the annual infiltration rate into the stockpile is changed to the corresponding value from the UNSAT-H results.

After a stockpile is covered, the rate of seepage that emanates from the base of the stockpile is assumed to gradually transition to a lower, long-term rate, which is based on modeling conducted by Daniel B. Stephens & Associates, Inc. (DBS&A, 2003). Because the stockpile outslopes vary in thickness, it is assumed that some fluctuation in basal seepage rates over this portion of the stockpile may occur due to climate variability. Therefore, the basal seepage rate beneath the outslopes is based on the simulated annual infiltration rate for the current cover state, with delay and dispersion applied to represent the travel time through the stockpile. The assumed mean travel time and dispersion term in the DSM are both 10 years for both the covered and uncovered states.

Following draindown, the stockpile seepage quality is based on an abstraction of the hydrogeochemical model developed by DBS&A (2001), (Greystone Environmental Consultants, Inc. 2003). The model is used to estimate the seepage concentrations and mass fluxes for each stockpile complex. The projected quality is expressed as a function of the average basal seepage rate, stockpile thickness, outslope angle, stockpile mineralogy, and a kinetic rate scale factor.

The DSM apportions the seepage from the stockpiles into two flows: one that reports to the toe of the stockpile and another that is assumed to flow into fractures in the original ground surface and eventually the groundwater. The seepage rate into groundwater has an upper limit based on draindown modeling (DBS&A, 2003). This limit is equal to the fraction entering groundwater times the assumed long-term infiltration rate used in the DBS&A modeling. Apportionment of seepage applies to both uncovered and covered rates of infiltration.

2.3.3 Impacted Runoff

The surface runoff projections in the DSM were calculated using the Soil Conservation Service (SCS) Curve Number (CN) method (U.S. Department of Agriculture [USDA], 1986). This method for estimating runoff has been validated through field studies as a reliable method for use on semi-arid, reclaimed minelands (Schroeder, 1994). Precipitation excess (runoff) is assumed to be a function of cumulative precipitation, soil cover, land use, and antecedent moisture conditions (AMC). Until the accumulated rainfall exceeds some initial abstraction value, the precipitation excess, and hence the runoff, is assumed to be zero.

The selection of a CN defines the soil hydrological group, the percentage of impervious cover, the condition of vegetative cover, and the AMC. Guidance on selecting appropriate CNs for stockpile surfaces was provided in a technical memorandum from TTEMI (2003), in which recommended CNs range from the low 70s to the low 90s. Very high runoff is assumed within the open pits, ranging up to 100% of annual precipitation.

Runoff in the DSM is calculated by calculating the excess precipitation using the Ft. Bayard precipitation record and CN values for the various stockpiles, collection basins, etc., and multiplying the excess precipitation times the surface area involved. Runoff is calculated separately on each surface for each stockpile or stockpile complex.

Average water quality in runoff from stockpiles and pit surfaces was generally taken from the Tyrone Closure/Closeout Plan (M3, 2001a), with values based on leach samples collected by SARB (2000). The sulfate concentration is assumed to be 6,880 mg/L. Mass loading from runoff is assumed to be essentially constant on an annual basis, with concentrations increasing following dry periods and decreasing during wet periods.

The DSM segregates runoff into impacted (contaminated) and non-impacted (clean) flows. Runoff from covered and relegated stockpile surfaces is assumed to be non-impacted and eventually discharged to the environment (i.e., not sent to the Water Treatment System). The model tracks the impacted runoff on a stockpile-by-stockpile basis. The surface areas of many of the stockpiles change as a function of time following regrading of the outslopes.

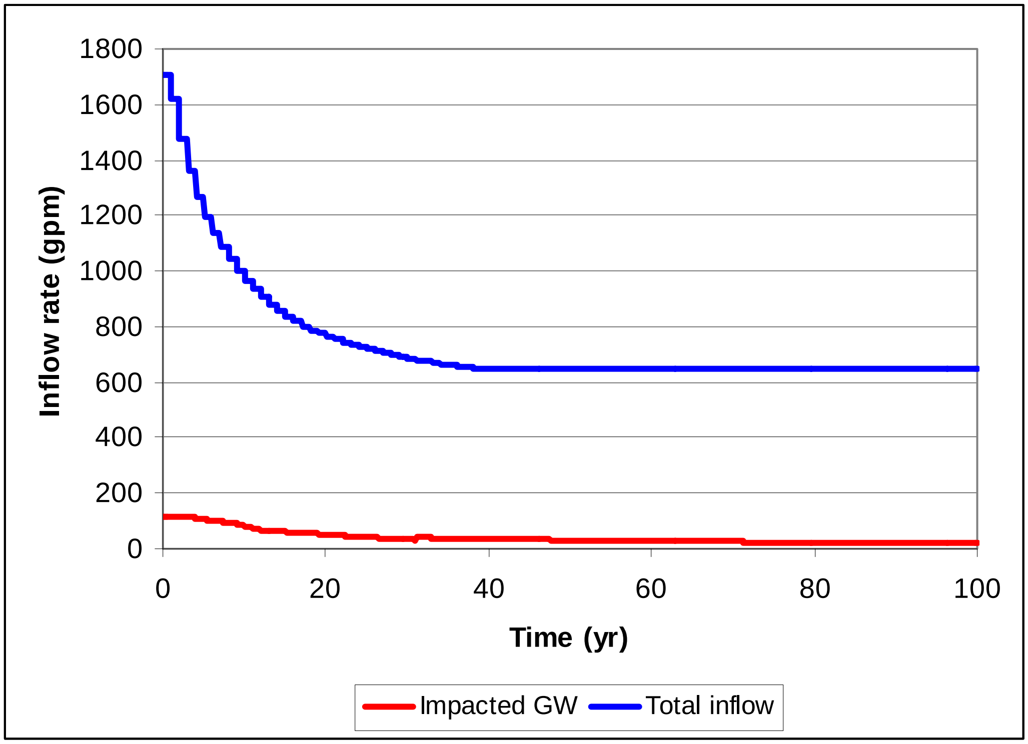
The runoff within the Main and Gettysburg Pits is also based on the SCS CN Method. The DSM assumes almost all of the precipitation falling within the pit rim is runoff. The sulfate concentration in pit wall runoff waters is assumed to be approximately 6,000 mg/L (SARB, 2003).

2.3.4 Impacted Groundwater

As discussed in Section 2.3.3, the DSM assumes that some portion of the seepage from the waste rock and leach stockpiles infiltrates through the original ground surface beneath these facilities and enters regional groundwater. The impacted groundwater is assumed to either report to one of the open pits or be captured by groundwater interceptor or abatement systems. The model apportions the impacted groundwater to the two zones based on the current delineation of the open-pit capture zone. All stockpile seepage entering groundwater within the open-pit capture zone is assumed to report to the Main Pit. Stockpile seepage entering groundwater outside the capture zone is assumed to be captured by interceptor and abatement systems.

The groundwater inflow into the pit consists of a combination of regional groundwater and groundwater impacted by the stockpile seepage. The overall groundwater inflow rate into the pit, as a function of time, is based on MODFLOW modeling conducted by DBS&A (1997b). This rate is divided between the regional and stockpile seepage components. The reduction in the pit inflow rate over the first 40 years is based on the assumption that a series of extraction wells is installed to capture the unimpacted groundwater before it reaches the pit. All stockpile seepage entering groundwater within the pit capture zone is assumed to report to the Main Pit. This rate is subtracted from the regional groundwater inflow rate to determine the rate of unimpacted groundwater inflow into the pit. A time history plot of the total and impacted inflow rates is shown on Figure 2-3.

FIGURE 2-3
TIME HISTORY OF THE TOTAL AND IMPACTED GROUNDWATER INFLOWS TO THE OPEN PIT ASSUMED IN THE DSM



The quality of the regional groundwater is based on groundwater samples from monitoring wells at Tyrone (4-6, 2-9, 2-4, P8-A, EM-1, 6-5, 6-3R, P-4A, P-6A, MB-10, TWS41, TWS8, MB-36, SXM01, TWS9, and GLD-7) reported in SARB (2000). The average sulfate concentration from these wells is 665 mg/L. The sulfate concentration in the impacted groundwater is based on the seepage concentrations coming from the different stockpiles, calculated in the stockpile mass loading model in the DSM (Section 2.3.2).

2.4 Sludge Mass and Volume Projections

The mass and volume of sludge were estimated based on the water treatment rate and the quality of the water being treated. As described in Section 2.3, there are four sources of water that will be sent to the Water Treatment System:

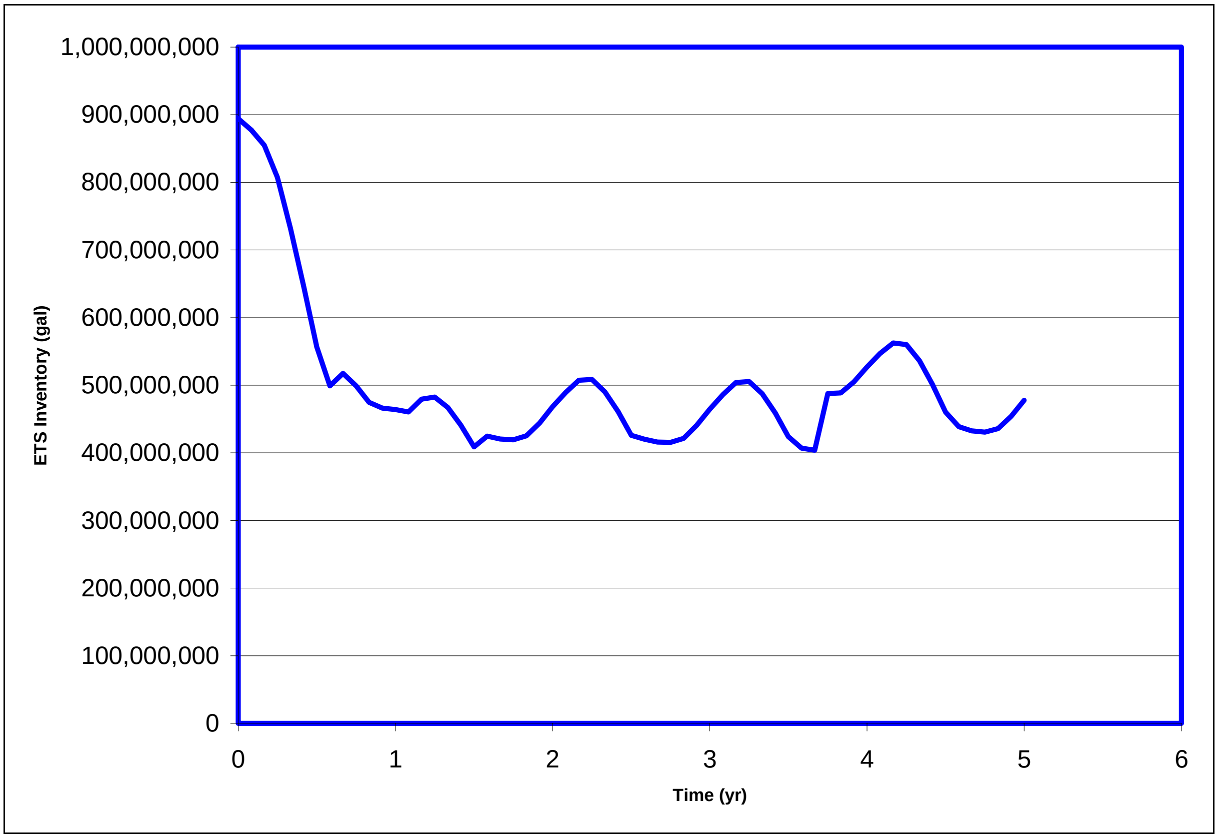
1. residual PLS,
2. meteoric water that infiltrates through and is collected as seepage from the base of stockpiles,
3. impacted runoff, and
4. impacted groundwater.

The HDS Plant is the only component of the Water Treatment System that will generate sludge. This component becomes operational in Year 6 following the cessation of the ETS. The unit will process reject from the Nanofiltration Plant that will in turn process residual solution from the ETS and all flows of impacted water within the Tyrone Mine. The mass and volume of sludge produced will depend on the rate and quality of the water treated. The final volume of the sludge will also depend on any post-processing steps to reduce the water content of the sludge, which will include belt press dewatering.

As noted in Section 2.2.1, the ETS eliminates a significant percentage of the initial volume of process solution present at the cessation of mining. In addition to the process solution, other sources of impacted water will be added to the ETS including stockpile seepage, stormwater runoff, water from interceptor wells, and reject from the Nanofiltration Plant. By the end of the 5-year period of operation assumed for the ETS, approximately 400 million gallons of solution will remain that have to be treated in the Nanofiltration and HDS Plants. The rate is determined by the draindown behavior of the ETS Stockpiles.

Figure 2-4 shows the projected volume of solution in the ETS during the first 5 years after cessation of mining. The volume of process solution is rapidly reduced during the first few years of operation of the spray evaporation system. The remaining volume of solution in the ETS reaches a pseudo-steady-state after approximately 3 to 4 years when the rate of evaporation is approximately equal to the rate of new impacted water being added (i.e., runoff, nanofiltration reject water, stockpile seepage, and interceptor wells). At the end of 5 years, the remaining solution is allowed to drain from the ETS Stockpile and is sent to the Nanofiltration/HDS Plants for treatment. As noted earlier, the volume of residual process solution at the end of the ETS period is a function of the draindown behavior of the ETS Stockpiles and the rate of miscellaneous inflows to the system (i.e., impacted water sources). The residual volume can likely be significantly reduced by modifying the ETS operation somewhat once pseudo-steady-state conditions are reached, i.e., when the rate of evaporation is approximately equal to the rate of new impacted water being added to the system. The evaporation rate could be increased by diverting some of the solution to one or more evaporation ponds where the solution is continuously re-circulated instead of allowing it to drain through the base of the spray evaporation area. The design and optimization of the ETS are being addressed in a separate study. Therefore, the projected sludge mass and volume from the residual process solution and ETS operation in the DSM are considered to be conservative; a reduction of residual contained solution in the stockpiles translates directly to a reduction in sludge generated in the HDS Plant.

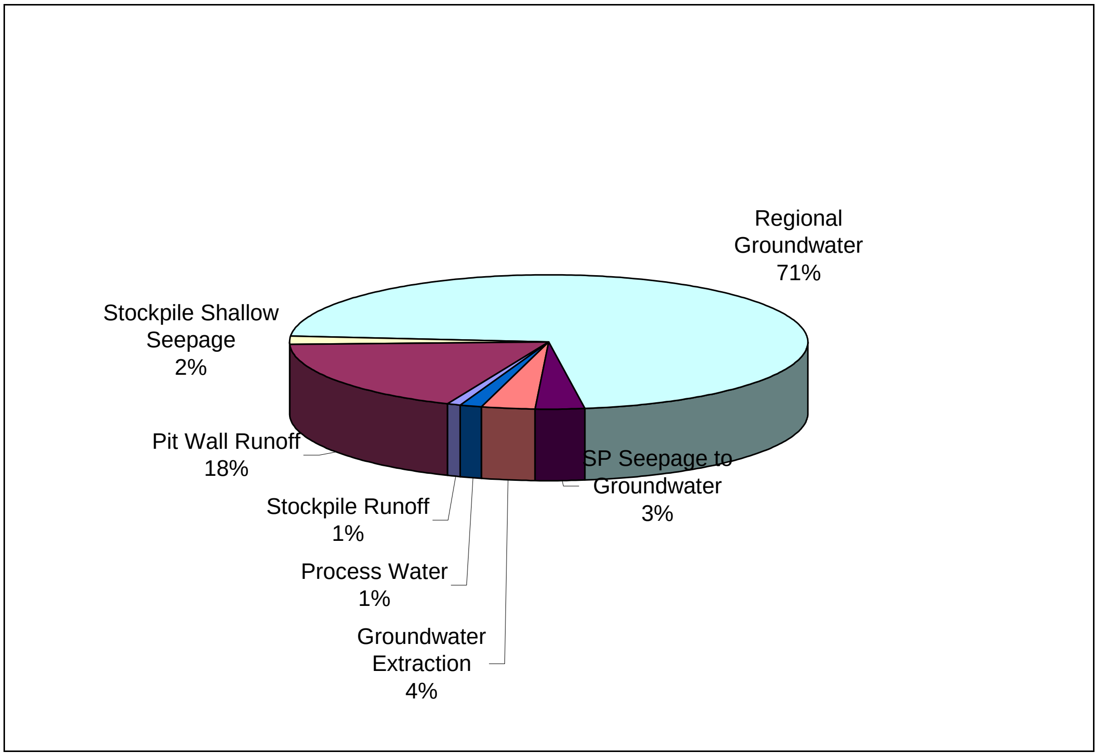
FIGURE 2-4
SOLUTION INVENTORY IN THE ETS DURING THE FIRST 5 YEARS OF OPERATION



Beginning in Year 6, the sources of new water that must be treated consist of precipitation that infiltrates through the tops and sides of the stockpiles that reports at the base as seepage, groundwater that is impacted by the seepage, and impacted runoff from the open pit and stockpiles that have yet to be covered and re-vegetated. As noted in Section 2.1, the DSM assumes that the last of the stockpiles will be covered 11 years after cessation of mining activities; therefore, the source of impacted runoff is expected to be significantly reduced by this time. The improvements in net water quality due to reclamation are significant.

The pie chart on Figure 2-5 shows the relative contributions of impacted water (by volume) handled by the water treatment system over the 100-year simulation period.

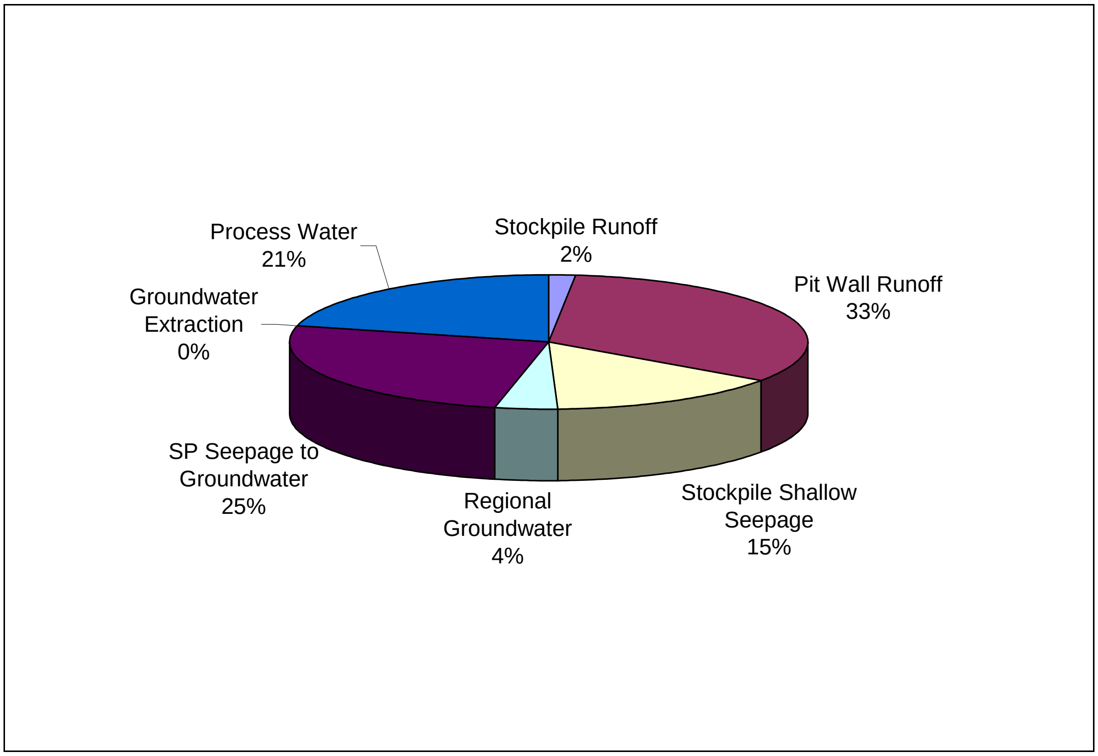
FIGURE 2-5
RELATIVE CONTRIBUTIONS OF IMPACTED WATER (BY VOLUME) SENT TO THE WATER TREATMENT SYSTEM OVER THE 100-YEAR SIMULATION PERIOD



The majority of the water (71%) is from groundwater inflow into the Main and Gettysburg pits. In general, the groundwater quality is expected to be good (i.e., sulfate concentrations less than 700 mg/L). The water is assumed to require treatment due to the difficulty in segregating it from impacted sources (e.g., runoff and stockpile seepage to groundwater). Runoff from the pit walls and bottom is the next largest volumetric contribution representing 18% of the total volume of water treated followed by water from the groundwater extraction wells (4%) and seepage from the stockpiles (3%).

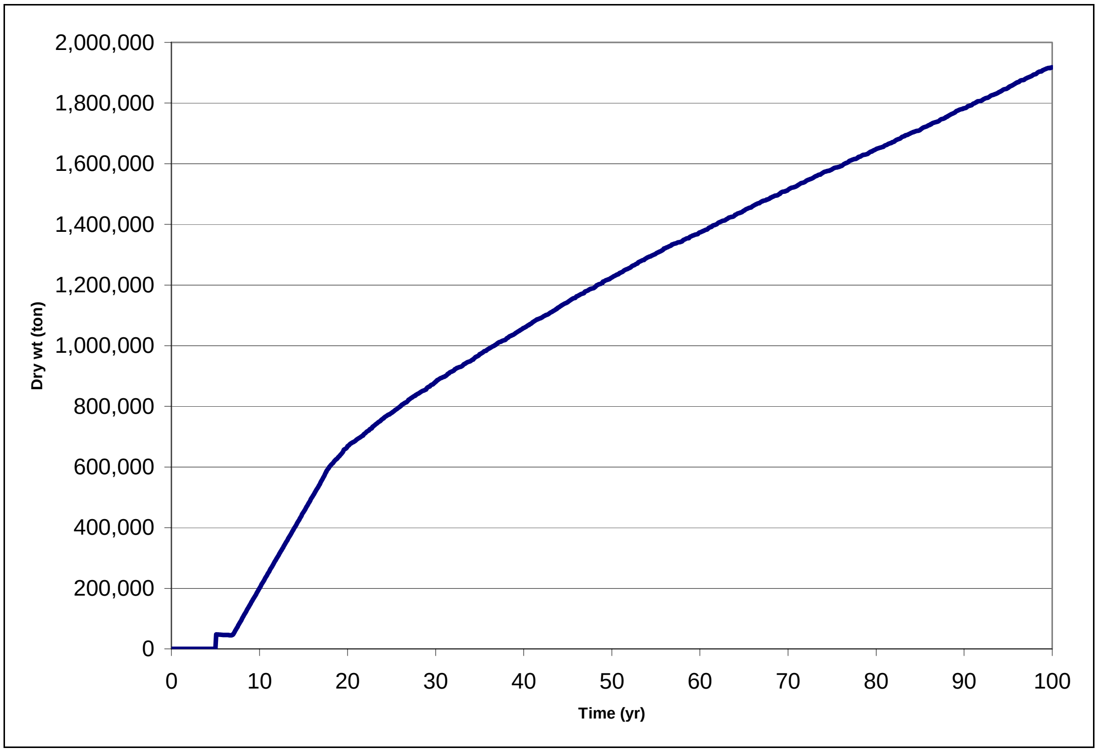
The pie chart on Figure 2-6 shows the relative contributions of impacted water on the basis of mass treated. The majority of the mass comes from the pit wall runoff (33%), seepage from the stockpiles (25%), and process water (21%). Groundwater inflow to the pit, the largest source of water treated by volume, contributes a relatively small percentage (4%) of the mass.

FIGURE 2-6
RELATIVE CONTRIBUTIONS OF IMPACTED WATER (BY MASS) SENT TO THE WATER TREATMENT SYSTEM OVER THE 100-YEAR SIMULATION PERIOD



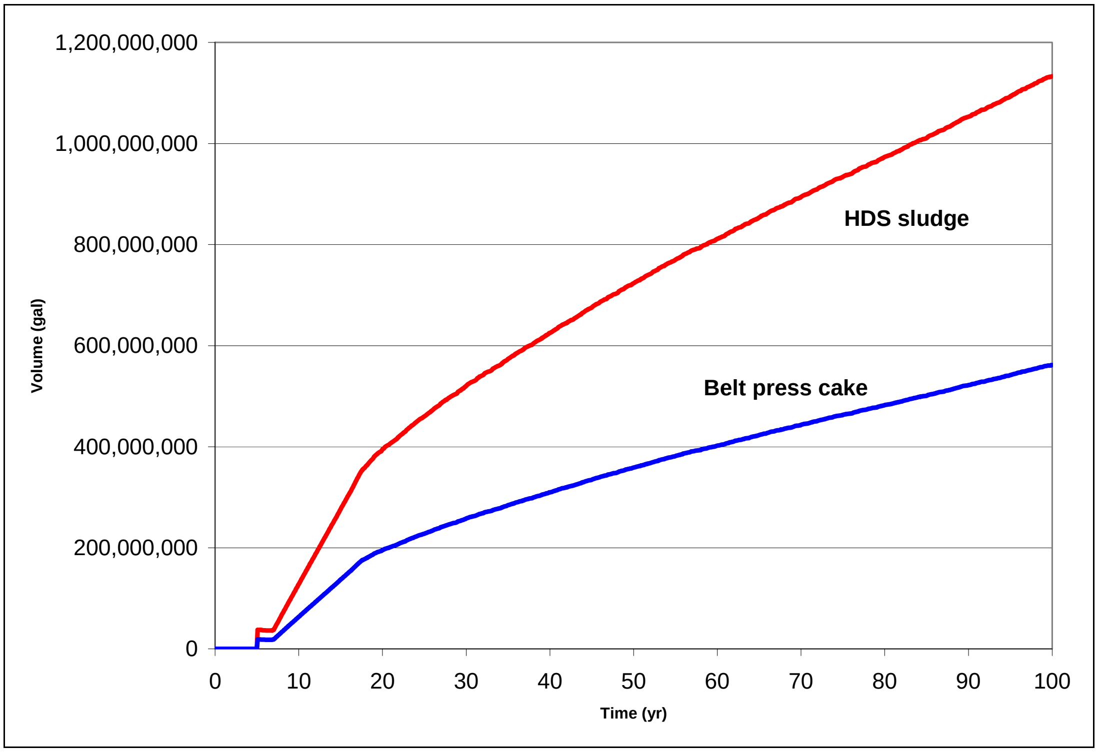
The net result of this analysis of waters collected is presented as a time-history plot of the mass of sludge produced (dry weight) by the Water Treatment System over the 100-year simulation period (Figure 2-7). The total mass of sludge produced over the 100 year simulation period is approximately 1.9 million tons. Sludge production will begin in Year 6 when the HDS Plant becomes operational. The rate of sludge production decreases around Year 20 when the residual process water is eliminated and all of the waste rock piles and leach stockpiles have been covered.

FIGURE 2-7
TIME HISTORY OF THE CUMULATIVE MASS (DRY WEIGHT) OF SLUDGE PRODUCED BY THE HDS PLANT



Dewatering of the sludge from the HDS Plant is expected to significantly reduce the volume that will eventually be placed in the Disposal Facility. A similar process at Ft. Madison has resulted in an over 50% volume reduction. The projected volume of sludge cake over the 100-year simulation period, based upon the analogous Ft. Madison data, is approximately 560 million gallons assuming 53% solids and an in-situ density of 96 lb/ft^3. This volume is significantly less than was noted in the Tyrone water treatment report (Van Riper Consulting, 2002). The time-history chart on Figure 2-8 shows the projected cumulative production of sludge from the HDS Plant and the associated sludge cake from the filter-press operation over the 100-year simulation period. Filter press cake is what will be sent to the sludge disposal sites.

FIGURE 2-8
CUMULATIVE VOLUME OF SLUDGE AND BELT PRESS CAKE FROM THE WATER TREATMENT SYSTEM



3.0 SELECTION OF SLUDGE MANAGEMENT AREAS

PDTI used a **multi-attribute** decision analysis method to evaluate alternative locations for a sludge disposal facility on site. Off-site disposal was considered, however, at this time, and given the size and capacity of local landfills, it does not appear practical to utilize off site disposal.

There are numerous potential sites within the Tyrone Mine site that could be used for disposal of the sludge from the planned Water Treatment System. A three-tiered approach was utilized that first screened sites as to environmental and physical criteria that would result in a decision to reject the site. The first step was to eliminate those locations that were either environmentally unacceptable or were physically too small. These *threshold* attributes were established to exclude alternatives from further consideration that obviously were not suitable disposal options. This screening step is described in Section 3.1. The second step was to compare the remaining alternative sites based on additional environmental and operational criteria. An *additive weighting method* was selected where different levels of importance were assigned to the criteria. Environmental criteria were given the highest weighting (compared with operational and cost criteria). The ranking process is described in Section 3.2. The results were then used to rank and choose the two alternatives with the best overall scores (Section 3.3). Ultimately, environmental protection criteria, as opposed to operational and cost criteria, drove the ranking process. Section 3.4 contains supporting hydrology and geology information, and a discussion that was used by the team to provide guidance on environmental considerations relative to the selection criteria. Section 3.5 considers the environmental impacts of disposing sludge in the two preferred areas, and in particular, whether there is a potential to leach metals from the sludge at the interface between the sludge and the underlying rock and what quantities might be leached. Also addressed under Section 3.5 is the potential for and the quantification of leaching of the sludge due to precipitation.

3.1 Screening of Alternatives

As noted above, there are a numerous potential sites within the Tyrone Mine site that could be used for sludge disposal. The list of potential sites included all waste rock piles, leach stockpiles, and open pits that are expected at the end of mine life. These disposal site alternatives are based on the current mine Closure/Closeout Plan (M3, 2001a) as well as mine planning and mining constraints. Potential accelerated reclamation plans under discussion with the NMED were also considered. The alternative sites included in the sludge disposal site evaluation are listed in Table 3-1. The locations of these sites are shown on the map on Figure 2-1.

Two screening attributes were used to eliminate those sites that were clearly not candidates. These attributes were:

1. an insufficient surface area to accommodate the disposal facility based on the projected sludge volume, leachate and surface water control structures, access, and facility design; and
2. the location was not within the hydraulic capture zone created by dewatering in the Main and Gettysburg Pits.

TABLE 3-1
INITIAL SET OF SLUDGE DISPOSAL SITE ALTERNATIVES

Type	Alternative
Stockpiles	No. 1
	No. 1A
	No. 1B
	No. 1C
	No. 1D
	No. 2
	No. 2A
	No. 3
	No. 3B
	Main Pit SP
	Gettysburg Out-Pit
	Gettysburg In-Pit
Pits	Main Pit
	East Main Pit
	Savanna Pit

The first criterion is an engineering constraint. The sludge disposal facility will require a sufficiently flat, relatively contiguous surface area of a size that allows for sludge-storage cells, surface water controls and conveyances, evaporation ponds, and access roads. The estimated surface area will depend on the final configuration of the cells and their ultimate height. The higher the stacks in the cells, the smaller the ultimate surface area required. Gypsum stockpiles have been constructed at other sites to over 100 feet in height (Section 4.0). A stack height of 100 feet was assumed for the screening step, which requires a surface area of approximately 20 acres based on the conservative volume estimates presented in Section 2.4. It is assumed that an additional 10 acres would be needed to accommodate the final sludge stack configuration for closure, ancillary facilities including stormwater collection, and access to the stacks for distribution and covering of sludge. In the screening step, sites with a suitable top surface area of less than approximately 50 acres were eliminated.

The second screening criterion is based on environmental risk management considerations, e.g., that any leachate that might result from the sludge is ultimately collected and treated. The sludge cake is expected to have a minimal volume of drainable water following the belt press operation. Evaporation is expected to further reduce the water content in the sludge, although this will be offset to some extent by precipitation that may infiltrate into the material. The disposal cells will be designed and constructed to collect and manage any draindown and runoff within the facility. Locating the disposal facility inside the pit capture zone further reduces the environmental risk by providing a redundant system for capturing solution that may seep from the sludge into the underlying bedrock on the pit bench or beneath the base of the stockpile and that is not collected in the toe collection system.

Table 3-2 presents the alternatives that were eliminated based on these two screening attributes. Surface area limitations eliminated four of the 15 sites. An additional four sites were eliminated based on their relative location to the hydraulic capture zone. The remaining seven sites were further evaluated as described in the next section.

TABLE 3-2
RESULTS OF SITE SCREENING PROCESS

Type	Alternative	Surface Area (acre)	Pit Capture Zone
Stockpiles	No. 1	128	Outside
	No. 1A	68	Outside
	No. 1B	50	Partial
	No. 1C	174	Partial
	No. 1D	51	Inside
	No. 2	388	Inside
	No. 2A	161	Inside
	No. 3	52	Partial
	No. 3B	34	Inside
	Main Pit SP	56	Inside
	Gettysburg Out-Pit	<10	Inside
	Gettysburg In-Pit	<10	Inside
Pits	Main Pit	<10 unless backfilled	Inside
	East Main Pit	<10 unless backfilled	Inside
	Savanna Pit	<10 unless backfilled	Inside

Eliminated from further consideration

3.2 Ranking Criteria

The remaining alternative sites were further evaluated based on additional environmental and operational criteria. Different levels of importance were assigned to the evaluation criteria, with environmental criteria given higher importance (weight) than engineering or cost criteria. The following criteria were used:

- Hydrogeological conditions/constraints,
- Level of engineered water management controls,
- Geochemical conditions, and
- Geotechnical stability.

Capital and operating cost criteria are considered, however, only for those sites that are believed to be fully protective of the environment. Costs are presented in Section 6.0.

Each evaluation criterion is discussed below.

3.2.1 Hydrogeological Conditions/Constraint

The depth to groundwater beneath a candidate disposal location and the original topography of the land surface beneath the leach and waste stockpiles were considered in the evaluation. For example, a site that is near the present or projected future groundwater elevation was considered to be less suitable. Additionally, stockpiles placed across or outside a topographic divide, which might allow seepage to migrate toward the perimeter of the stockpile, away from the pit capture areas, were also deemed less desirable, even though seepage toe collection facilities are in place in these perimeter areas. A detailed discussion of the site hydrological conditions relevant to this criterion is provided in Section 3.4.2. Table 3-3 lists all of the original sites and how they rank in terms of this criterion.

TABLE 3-3
RESULTS OF SITE RANKING PROCESS

Type	Alternative	Within Topographic Divide	Ranking
Stockpiles	No. 1	No	Unacceptable
	No. 1A	No	Unacceptable
	No. 1B	No	Unacceptable
	No. 1C	No	Unacceptable
	No. 1D	Straddles	Unacceptable
	No. 2	Straddles	Unacceptable
	No. 2A	Straddles	Unacceptable
	No. 3	No	Unacceptable
	No. 3B	No	Unacceptable
	Main Pit SP	Yes	Acceptable
	Gettysburg Out-Pit	Yes	Unacceptable
	Gettysburg In-Pit	Yes	Unacceptable
Pits	Main Pit	Yes	Acceptable
	East Main Pit	Yes	Acceptable
	Savanna Pit	Yes	Acceptable

Eliminated from further consideration (yellow)

Eliminated during screening process (cyan)

Pre-stockpile divide separates watersheds associated with Deadman Canyon, Mangas Wash and Oak Grove Wash from drainages created by mining

3.2.2 Level of Engineered Water Management Controls

The level of leachate collection, groundwater interception systems, and surface water controls at the individual sites were qualitatively evaluated and included as a criterion in the ranking matrix. Sites with existing collection systems designed for PLS collection and management (e.g., leach stockpiles) were ranked higher than those not having systems or having more limited systems (e.g., the waste rock piles), which are only designed to collect runoff and seepage from precipitation. Because of the heavy weight given to environmental criterion above, all but one of the stockpiles were eliminated from further consideration. Hence, this criterion was not practical for discriminating between the remaining alternatives.

3.2.3 Geochemical Conditions

If water were to escape from the sludge containment system, it would likely react quickly with porewater in the underlying materials. The porewater and underlying materials would generally be acidic. The excess alkalinity in the seepage would react with and neutralize available acidity until the alkalinity was consumed by this process. The result would be a general decrease in the pH of the seepage from the initial 10 to 11 range, and depending on the amount of seepage from the sludge, the pH and alkalinity would eventually approach that of the porewater in the underlying rock/waste rock. This seepage would have the effect of attenuating metals in solution through precipitation and sorption reactions. Sulfate concentrations would be controlled predominantly by the solubility of gypsum, which would also affect the TDS concentrations. Metals would precipitate as metal hydroxides and oxyhydroxides would come out of solution. A detailed discussion of the geochemical conditions is provided in Section 3.4.3. Because the geochemical conditions beneath the disposal site alternatives are very similar, this criterion did not discriminate between the remaining sites.

3.2.4 Geotechnical Stability

A qualitative assessment of geotechnical conditions at the individual sites was also conducted. This included the apparent structural stability of the facility and/or the risk of the facility being impacted by the failure of an adjacent structure. Of the sites that were identified as environmentally acceptable, none of the sites presented a problem with either the foundation material stability or stability issues with adjacent structures.

3.3 Preferred Alternatives

The level one screening criteria eliminated eight of the 15 site alternatives. The remaining sites included four stockpile areas and three in-pit areas. The environmental ranking criteria, hydrological considerations, resulted in eliminating three of the four remaining stockpiles from consideration. The remaining stockpile, Main Pit Stockpile, meets all of the environmental and engineering criteria and was selected as one of the preferred sites.

In terms of the remaining in-pit locations, within the Main Pit there is a bench that meets all of the selection criteria. The bench is above the 5,400-foot elevation in the Main Pit, above the elevation the pit is likely to be backfilled, and has sufficient surface area to accommodate the sludge disposal facilities. The bench is comprised of filled material over bedrock. Several of the existing pits (portions of the Main, East Main, and Savanna Pits) that might have provided adequate volume for sludge disposal and that are within the pit capture zone are scheduled to be either partially of fully backfilled. These pits would satisfy the environmental criteria, they were not ranked as most preferable as schedules for backfilling, and the extent of backfilling has not been defined. In the future, if the mine plan changes, or if there is a need to utilize one of these additional pit areas, then they will be considered further.

In summary, the Main Pit Stockpile and a bench within the Main Pit are the preferred sites for constructing, operating, and closing a sludge disposal system. Both locations have sufficient surface area for the facilities and the most favorable environmental and engineering conditions of the alternatives considered. The locations also fit into current mine operational plans as well as the closure/closeout and accelerated reclamation plans. The two locations are presented on Figure 4-1. An economics analysis of developing and operating a disposal facility at the two sites is presented in Section 6.0.

3.4 Supporting Hydrology and Geology Information

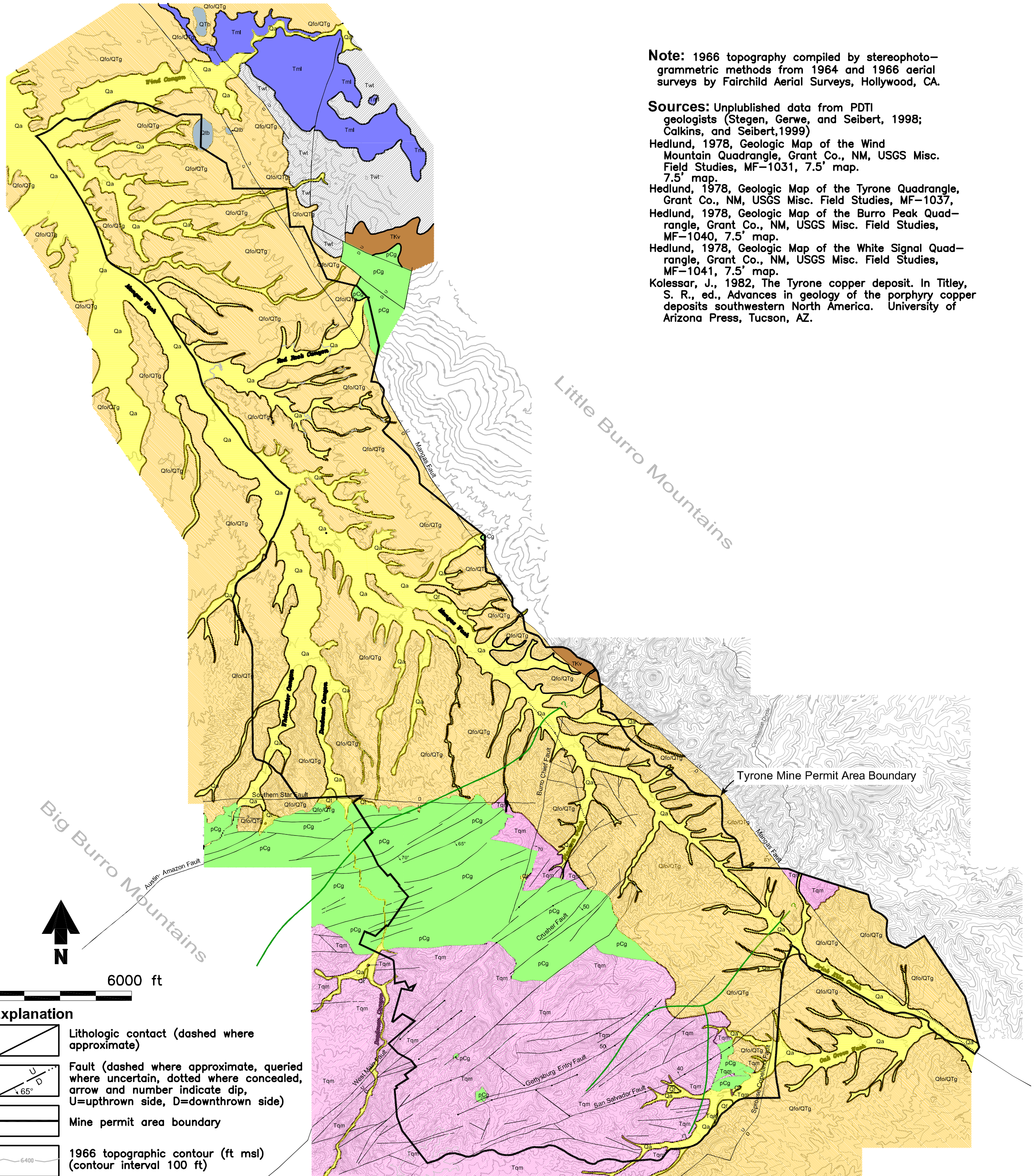
3.4.1 Site Geology

The Tyrone copper deposit generally occurs within a triangular area at the northeastern end of the Big Burro Mountains. It is bounded by the Burro Chief Fault on the west, the Sprouse-Copeland Fault on the east, and multiple smaller unnamed faults on the south. The geology of the deposit and surrounding area has been summarized by DuHamel et al. (1995), Kolessar (1982), and Paige (1922). A simplified geologic map of the pre-mining surface and mine permit area can be found on (Figure 3-1). The following discussion presents a general description of the geology in the vicinity of the Tyrone Mine, primarily as it relates to groundwater flow.

The rocks that crop out in the Big Burro Mountains, the Mangas Valley, and the Little Burro Mountains range in age from Precambrian to Quaternary. The Big Burro Mountains are primarily composed of Precambrian Burro Mountain granite, which is part of a batholith that was subsequently intruded by the Tyrone laccolith nearly 56 million years ago (Kolessar, 1982). The Tyrone laccolith is composed of four principal stages of porphyry intrusions (DuHamel et al., 1995), collectively referred to as the Tertiary Quartz Monzonite of Tyrone.

Exposures of the predominantly sedimentary Cretaceous rocks are limited to the Little Burro Mountains. The Cretaceous units include the thin-bedded to massive Beartooth quartzite and the Colorado Formation, which is a sandy shale (Kolessar, 1982). Cretaceous and Tertiary volcanic rocks (primarily andesites and rhyolites), overlie the Cretaceous sedimentary units (Figure 3-1). The youngest rocks in the area are of Late Tertiary and Quaternary age and consist mostly of sands, gravels, and conglomerates. The Gila Conglomerate, the oldest of the younger sedimentary rocks, was deposited as bolson fill and as fan deposits derived from Late Tertiary and older uplifts. The youngest sedimentary units were deposited unconformably on Gila Conglomerate and as valley fill along present-day drainages.

The predominant geologic structures at and near Tyrone are sets of northeast- and northwest-trending faults (Figure 3-1). The Sprouse-Copeland Fault near Oak Grove Wash strikes north-south and is nearly vertical, with displacement on the order of hundreds of feet. This fault has juxtaposed upthrown Precambrian Burro Mountain granite against the Gila Conglomerate, forming the east side of the Tyrone Horst. The other major northeast-striking faults in the area of the Tyrone Mine are the Austin-Amazon Fault along the west side of the Tyrone Horst and the Burro Chief Fault, which bisects the Tyrone Horst and forms the western limit of the Tyrone copper deposit (Kolessar, 1982). According to Hedlund (1978), these older faults are splayed and branched, and have been intruded by rhyolite and quartz monzodiorite porphyry dikes in some sections. The Tyrone ore deposits are associated with these faults and intrusions.



Note: 1966 topography compiled by stereophoto-grammetric methods from 1964 and 1966 aerial surveys by Fairchild Aerial Surveys, Hollywood, CA.

Sources: Unplublished data from PDTI geologists (Stegen, Gerwe, and Seibert, 1998; Calkins, and Seibert,1999)

Hedlund, 1978, Geologic Map of the Wind Mountain Quadrangle, Grant Co., NM, USGS Misc. Field Studies, MF–1031, 7.5' map. 7.5' map.

Hedlund, 1978, Geologic Map of the Tyrone Quadrangle, Grant Co., NM, USGS Misc. Field Studies, MF–1037,

Hedlund, 1978, Geologic Map of the Burro Peak Quad-rangle, Grant Co., NM, USGS Misc. Field Studies, MF–1040, 7.5' map.

Hedlund, 1978, Geologic Map of the White Signal Quad-rangle, Grant Co., NM, USGS Misc. Field Studies, MF–1041, 7.5' map.

Kolessar, J., 1982, The Tyrone copper deposit. In Titley, S. R., ed., Advances in geology of the porphyry copper deposits southwestern North America. University of Arizona Press, Tucson, AZ.

Explanation

- Lithologic contact (dashed where approximate)
- U D 65° — Fault (dashed where approximate, queried where uncertain, dotted where concealed, arrow and number indicate dip, U=upthrown side, D=downthrown side)
- Mine permit area boundary
- 6400 — 1966 topographic contour (ft msl) (contour interval 100 ft)
- Continental Divide
- Qa — Alluvium (Holocene): unconsolidated poorly sorted gravel, sand, and silt
- Qf — Fan deposits (Holocene and/or Pleisto-cene): sheet flood fan deposits
- Qt — Talus (Holocene and/or Pleistocene)
- Qtb — Basalt (Pleistocene and/or Pliocene?)
- Qfo/QTg — Undifferentiated older fan deposits, un-differentiated sheet flood deposits (Pleist-ocene) and Gila Conglomerate (Pleisto-cene, Pliocene, and Miocene): upper eroded surface locally cemented by caliche
- Tml — Andesite and basaltic andesite (Oligocene?) flows and pyroclastic rocks exposed in Wind Canyon
- Twt — Ash-flow tuff of Wind Mountain, undifferentiated (Oligocene?)
- TKv — Undifferentiated volcanic rocks (Cretaceous)
- Tqm — Quartz monzonite of Tyrone (Paleocene): undifferentiated quartz monzonite, quartz monzonite porphyry, and related intrusive rocks.
- pCg — Burro Mountain granite (Precambrian): contains dikes of quartz monzonite and other lithologies

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Geologic Map of the Tyrone Mine Area

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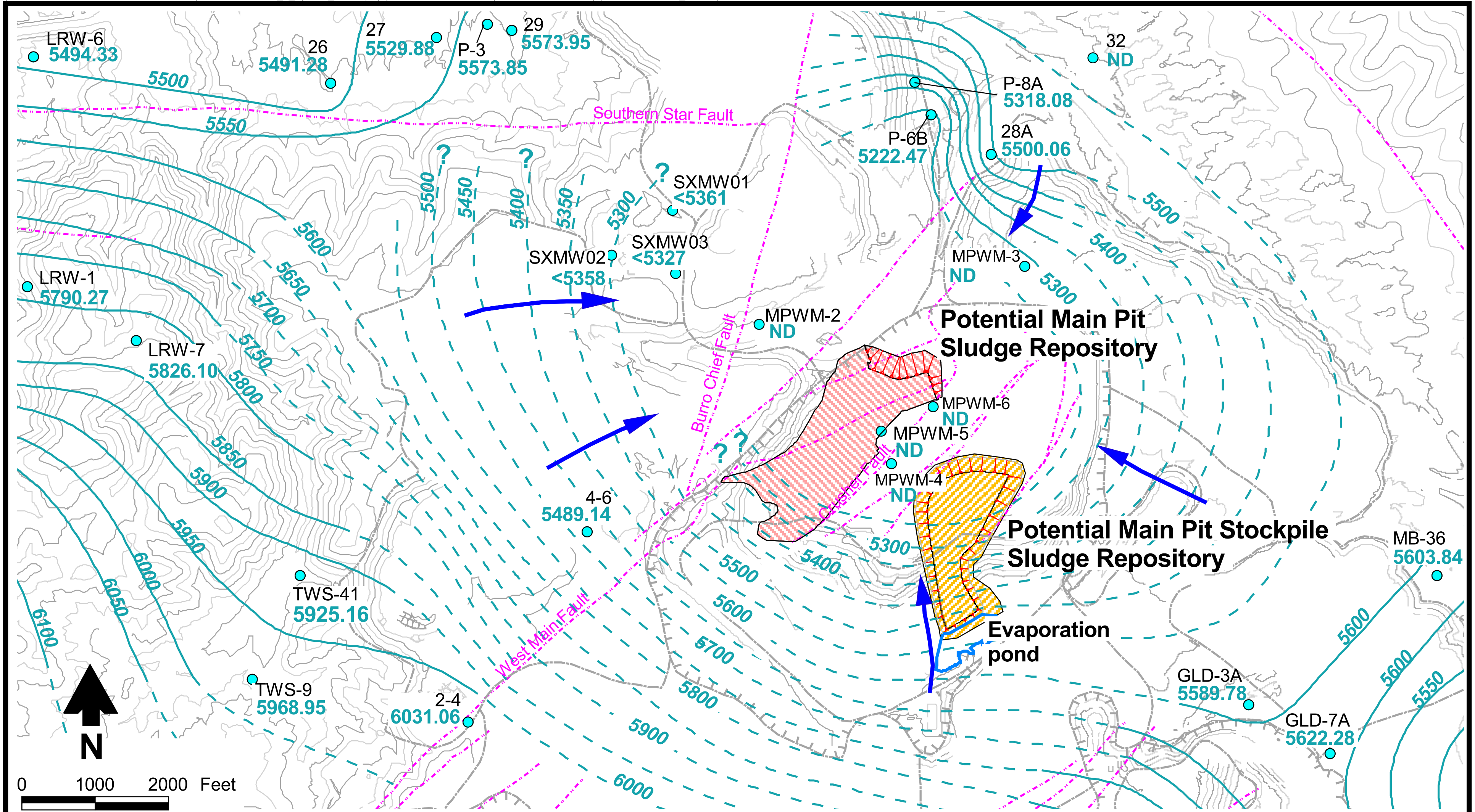
Figure 3-1

The younger, northwest-trending fault system controls the current topography in the area of the Tyrone Mine. The Mangas Fault strikes northwest-southeast with a dip of approximately 60 degrees southwest and forms a prominent scarp on the Little Burro Mountains. The Mangas Fault has juxtaposed Gila Conglomerate and bolson fill against the older rocks of the Little Burro Mountains (Kolessar, 1982). The generally east-west trending Southern Star Fault juxtaposes Precambrian rocks of the Big Burro Mountain against Gila Conglomerate and bolson fill in the Mangas Valley Tailings Unit and beneath the No. 3 Stockpile.

3.4.2 Site Hydrogeology

Three primary hydrostratigraphic units have been identified at Tyrone based on rock type, groundwater flow characteristics, and measured and estimated hydraulic parameters. The three hydrostratigraphic units are 1) intrusive igneous rocks (Precambrian granite and Tertiary quartz monzonite), 2) Tertiary/Quaternary Gila Conglomerate, and 3) Quaternary alluvium (DBS&A 1997b and d). The intrusive igneous rocks occur primarily in the Mine/Stockpile Unit. The Tertiary/Quaternary Gila Conglomerate is an unconsolidated to semi-consolidated sedimentary deposit present in the Mangas Valley Tailings Unit, the East Mine Unit-East Side Area, and along the northern and eastern boundaries of the Mine/Stockpile Unit. Quaternary alluvium is present within all three Tyrone Mine units and may contain perched water (e.g., Deadman Canyon and Oak Grove Wash) or regional groundwater (e.g., Mangas Valley). Both of the preferred sludge disposal units are within the Mine/Stockpile Unit within the confines Main Pit (Figure 3-2). Groundwater beneath each of the preferred sites occurs in the intrusive igneous rock hydrostratigraphic unit; consequently, the Gila Conglomerate and Quaternary alluvium hydrostratigraphic units will not be discussed further.



Explanation

MB-38 5991 — Regional aquifer monitor well with water level elevation (ft msl)

Water level elevation contour (ft msl), dashed where approximate (contour interval 50 ft)

Fault

Main Pit Stockpile top surface

Potential Main Pit sludge repository

Groundwater flow direction

Notes: Water level elevation data are from the econd half of 2003 unless otherwise noted.

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Potential Sludge Repository Areas with Regional Water 2003 Level Elevations

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Figure 3-2

Regional groundwater contour maps developed from observed data for the early 1980s through the present indicate that groundwater flow within the Mine/Stockpile Unit is primarily controlled by lithology, topography, the depth and location of the open pits that intersect groundwater, and geologic faults. Before surface mining, groundwater flow was either to the northwest into the Gila-San Francisco underground basin or toward the southeast into the Mimbres Valley underground basin. The divide separating these two underground basins was nearly coincident with the Continental Divide (Trauger, 1972). Since surface mining began, groundwater flow conditions have changed due to dewatering activities. Now, capture zones are associated with dewatering activities in the Main, Gettysburg, and Copper Mountain Pits. Groundwater not captured through dewatering either flows toward the Gila-San Francisco underground basin northwest of the mine or toward the Mimbres Valley underground basin southeast of the mine. Within the Mine/Stockpile Unit, most groundwater flow is toward the Main Pit.

Groundwater flow within the intrusive igneous rocks appears to be governed by secondary permeability such as joints, fractures, and faults. Hydraulic conductivity estimates from field testing range from 8.20 x 10^{-5} cm/sec (0.232 feet per day [ft/day]) to 5.06 x 10^{-3} cm/sec (14.3 ft/day), with a geometric mean of 8.86 x 10^{-4} cm/sec (2.51 ft/day). These values are most likely representative of the permeability of fracture zones near the individual wells tested. Sub-regional groundwater flow modeling of the Mine/Stockpile Unit at Tyrone yielded average, overall hydraulic conductivity estimates of 0.4 to 0.1 ft/day for the intrusive igneous rocks throughout much of the Main Pit area (DBS&A, 1999a, b, d, and 2002), although local values as high as 14 ft/day and as low as 0.002 ft/day were applied. Detailed seepage modeling for the No. 2 Stockpile area yielded vertical saturated hydraulic conductivity estimates of 7.9×10^{-7} to 7.9×10^{-8} cm/sec (0.002 to 0.0002 ft/day) for the igneous bedrock unit beneath the stockpile (DBS&A, 1999c). The mean values for storativity and specific yield are 9.50 x 10^{-3} and 1.54 x 10^{-2}, respectively.

In conclusion, any seepage that might escape containment in the sludge disposal area will flow toward the Main Pit capture area. Also, given the projected very low rates of potential seepage from the sludge area, it is highly unlikely that any detectable impact in mine water volume or quality in the Main Pit will be noted.

3.4.3 Site Environmental Geochemistry

The environmental geochemistry of the Tyrone copper deposit and the character of mined rock materials and the rock at the mine have been presented previously (DBS&A, 1997a and c), and are being assessed in more detail as part of supporting studies in Conditions 80 and 83 of Supplemental Discharge Plan DP-1341. The mineral assemblages at the Tyrone Mine have been characterized through standard geologic methods that have included exploration drilling, mapping, and ongoing mining. There is a large amount of detailed information concerning the geology of the mine site, and three-dimensional computerized geologic models have been developed by PDTI geologists. The volume percentage of each mineral assemblage in each stockpile and the geochemical characteristics of the piles have been assessed (DBS&A, 1997a and c). The principal mineral assemblages at the Tyrone Mine include:

- Mineral Assemblage 0 [Not mineralized], which includes Gila Conglomerate, younger alluvium, and soils.
- Mineral Assemblage 1 [Leached capping], which includes iron oxides as the dominant mineralogies and no sulfides are present.
- Mineral Assemblage 2 [Oxide copper], which includes rocks with copper oxide, copper carbonate, and copper silicate minerals, which are soluble in sulfuric acid and no sulfides are present.
- Mineral Assemblage 3 [Mixed oxide and chalcocite], which includes rocks with copper oxide, carbonate, and silicate minerals along with chalcocite and pyrite, is the transition zone from oxide to sulfide mineralogies. This is the primary leach-grade copper zone.
- Mineral Assemblage 4 [Chalcocite and pyrite], which includes rocks with chalcocite as the dominant copper mineral with some pyrite, is the primary leach-grade copper zone. This was also the main ore processed for copper in the concentrator circuit and deposited in the tailings ponds before the concentrator was shut down in February 1992.
- Mineral Assemblage 5 [Mixed chalcocite and chalcopyrite], which includes rocks with chalcocite and chalcopyrite as the dominant copper minerals along with pyrite and covellite, is a low-grade leach copper zone.
- Mineral Assemblage 6 [Chalcopyrite and pyrite], which includes rocks with chalcopyrite as the dominant copper mineral, abundant pyrite and very low leach recoveries, is not economically profitable to mine.

The bench at the 5,400-foot level in the Main Pit consists predominantly of Mineral Assemblage 4, which tends to be acid generating because of the pyrite content, especially in the rock with copper concentrations below the cutoff grades.

The Main Pit Stockpile is located between the Main Pit and East Main Pit Stockpile. Backfilling of the Main Pit as part of the development of the Upper Main Pit and Main Pit Stockpiles began in 1986 as the Main Pit was expanded. Mining in the Upper Main Pit was completed in 1989. The backfill material in the Upper Main Pit stockpile was derived from the Main Pit and was characterized by

DBS&A (1997a) as a mixture of all mineral assemblages. Depending on the location, the fill consists of 35 to nearly 80 percent Mineral Assemblages 0, 1, and 2, with the remainder being Mineral Assemblages 3 through 6. The detailed development of the Upper Main Pit Stockpile is presented in DBS&A (1997a). It is expected that the source of material for the continued development of the Main Pit Stockpile will come primarily from further expansion of portions of the Main Pit.

3.5 Qualitative Prediction of Environmental Impacts

The preferred sludge cell disposal design could result in exposure of the sludge to porewaters associated with acid-generating host rock or to precipitation for that portion of the cell that is active. In terms of the two preferred sites, for the in-pit bench area, there would be contact of sludge at the interface of the sludge and the underlying compacted rock of the pit bench. For the in-pit stockpile, there would be sludge in contact with the compacted waste rock. For the purpose of analyzing the chemistry and flow that might occur at the sludge-rock interface, each location is considered to have a similar acid-generating rock. There is a difference between the preferred sites in terms of physical characteristics of the underlying materials. The bench disposal area will be underlain with compacted material over unmined host rock, while the in-pit stockpile disposal area will consist of mined rock that has been compacted during placement and stockpile construction. Both covers will be ripped and compacted to ensure a low-permeability foundation.

3.6 Environmental Geochemistry Impacts on Sludge Disposal

Disposed sludge will not contain free-draining moisture. If seepage occurs due to precipitation or significant compression of the gypsum, the seepage from the sludge is likely to have chemistry very similar to the HDS, lime-treated discharge water quality reported in Van Riper Consulting (2002) and summarized in Table 3-4. As reflected in the table, the HDS discharge is highly alkaline, with a pH in the range of 10 to 11. The dominant ions in the solution are calcium and sulfate, and the TDS are expected to range from 2,500 to 3,130 mg/L, controlled largely by the solubility of gypsum. The captive water in the sludge, as represented, would not meet NMWQCC standards for pH, TDS, Al, F, SO_4, and at times, Mn.

Table 3-4 also contains a column of expected water quality that might be present in the base material under either of the sludge storage areas or within the host rock on the sludge cell side walls. As can be seen, the captive water quality of the sludge is of considerably better water quality than would be expected from the host rock material. The state has required that such other areas of mineralized host rock be capped with 3 feet of cover material and be graded to a 3H:1V slope at closure. The sludge areas will be closed under the same closure specifications.

TABLE 3-4
HDS, LIME-TREATED DISCHARGE WATER QUALITY FROM BENCH TESTING EVALUATION FOR THE WATER TREATMENT SYSTEM AT THE TYRONE MINE[a]

Analyte	Average Concentration (mg/L)	Range (mg/L)	Typical Waste Rock Seepage (mg/L)	NMWQCC Standards (mg/L)
Aluminum	**11.2**	**6.2 – 19.2**	187	**5.0**
Arsenic	0.014	0.012- 0.015	--	0.1
Boron	<0.05	<0.05	--	0.75
Calcium	649	562 – 760	--	-
Cadmium	<0.0026	<0.0006 - <0.0077	--	0.01
Cobalt	<0.05	<0.05	--	0.05
Chromium	<0.05	<0.05	--	0.05
Copper	<0.06	<0.05 – 0.08/570	--	1.0
Iron	0.06	<0.05 – 0.08	--	1.0
Potassium	32.8	27.7 – 37.5	--	-
Magnesium	2.1	0.9 – 3.0	--	-
Manganese	**0.09**	**<0.05 – 0.22**	0.76	**0.2**
Molybdenum	<0.05	<0.05 – 0.05	--	1.0
Sodium	104.5	91.4 – 114	--	-
Nickel	<0.05	<0.05	--	0.2
Lead	<0.002	<0.002	--	0.05
Zinc	<0.07	<0.05 - <0.07/147	--	10.0
Chloride	45	13 – 122	--	250.0
Fluoride	**4.8**	**2.8 – 7.1**	37	**1.6**
Sulfate	**1770**	**1620 – 2060**	4,564	**600.0**
TDS	**2718**	**2500 – 3130**	7,473	**1000.0**
pH	**10**	**Not reported**	--	**between 6 and 9**

[a] It should be noted that in the Tyrone flowsheet, this water quality will be combined with the nanofiltraion product and the combined flow will be discharged. Waste rock water quality is as projected by DBS&A (2001) and as used in the DSM.

If this alkaline, sludge-derived water were to reach the sludge-compacted base interface, it would likely react quickly with porewater in and with the underlying materials. The porewaters and underlying materials would generally be acidic. The excess alkalinity in the seepage would react with and neutralize available acidity until the alkalinity was consumed by this process. The result would be a general decrease in the pH of the seepage from the initial 10 to 11 range, and depending on the amount of seepage from the sludge, the pH and alkalinity would eventually approach that of the porewater in the underlying rock/waste rock, assuming there was no inhibition to flow path and volume. This alkaline seepage would have the effect of attenuating metals in solution through precipitation and sorption reactions. Sulfate concentrations would be controlled predominantly by the solubility of gypsum, which would also affect the TDS concentrations. Metals like iron, aluminum, and manganese would precipitate as metal hydroxides and oxyhydroxides at the sludge-compacted foundation interface. Other trace metals may co-precipitate with these metal hydroxides and oxyhydroxides or may be sorbed to their surfaces.

From a physical standpoint, precipitates that are formed by the mixing of alkaline solution from the sludge with acid solutions in the compacted base of the sludge cells will consist of metal hydroxides and gypsum. The physical characteristics of these precipitates are such that they will form a layer of extremely low-permeability material at the sludge-compacted foundation interface. Metal hydroxides exhibit permeabilities in the range of 10^{-7} to 10^{-8} cm/sec, which are similar to permeabilities exhibited by clay material. The end result of this precipitation is that there will be a lowering of the saturated hydraulic conductivity of the interface between the sludge layer and the underlying material. For this reason, it is not expected that appreciable transit of solution will occur between the sludge and the underlying materials, and that any solutions that might escape from the sludge pile will flow to the toe of the pile and be collected in the evaporation pond.

3.6.1 Neutralization Reaction Chemistry

Some geochemical speciation calculations were conducted to estimate the nature of the geochemical reactions that may result from contact of seepage from the sludge or evaporation ponds with underlying compacted foundation material. In addition, analysis of potential mixing scenarios between “reject” water from the treatment of Tyrone Main Pit (intended to represent seepage from water treatment sludge) and general porewater from stockpile and pit areas at the Tyrone Mine was conducted. Precipitating mineral phases, as well as those with the potential to control aqueous concentrations, were identified and changes in pH and alkalinity were noted.

Speciation of metals in various simulated mixes of “reject” water and porewater was accomplished using the algorithms available in PHREEQC (Version 2, Parkhurst and Appelo, 1999), a predictive equilibrium speciation and mass-transfer code developed by the U.S. Geological Survey. This model has the ability to simulate not only mixing of waters, but precipitation/dissolution of selected solids, redox reactions, atmospheric interaction, and adsorption of metals onto iron oxides as well. The MINTEQA2 thermodynamic database was selected for this project because it is considered by many in the geochemical and regulatory communities to be the most accurate geochemical database currently available.

For expected mixing ratios between porewater and alkaline water, precipitation of the following phases was consistently predicted:

- gypsum (CaCO4:2H2O),
- iron oxy-hydroxides,
- aluminum oxyhydroxides and hydroxyl-sulfates,
- alunite (KAl3(SO4)2(OH)6),
- jarosite (KFe3(SO4)2(OH)6), and
- copper hydroxyl-sulfates.

This preliminary geochemical analysis of these mixing ratios suggests that gypsum and metal oxides, and hydroxide are the equilibrium controlling phases for most mixing scenarios. The mixing appears to result in the precipitation of metal- (copper, iron, aluminum, and other metals) hydroxides and sulfates as well as fluorite. Hydroxide phases may control aqueous concentrations of any trace metals (if present), oxyhydroxide, and hydroxide phases of aluminum, manganese, and iron are predicted for most mixing scenarios. While these phases often provide sorption surfaces for metals in solution, their sorption efficiency is a function of pH.

The seepage from the Sludge Management Facility (due to compaction of the sludge) is expected to be extremely small (estimated to be approximately 2 gpm) and is expected to develop from the consolidation of the sludge. This seepage will be very alkaline, and as discussed above, when contacted with porewater from the underlying foundation materials, will precipitate metal hydroxides and sulfates, which will have the effect of lowering the permeability at the interface with the underlying materials. This will result in the blending of potential flow paths into the underlying compacted foundation material. For these reasons, lining under the Sludge Management Facility is not warranted. The low permeability of the bedrock in the Main Pit alternative will preferentially force any seepage from the sludge to be collected and diverted to evaporation ponds at the toe of the Sludge Management Facility. The seepage from the sludge will accumulate above the interface between sludge and the bedrock surface on the pit bench. In addition to the low-permeability hydroxides and sulfates that will form, the permeability of the bedrock is expected to be very low, estimated to be in the range of 10^{-7} to 10^{-8} cm/sec (DBS&A, 1999c).

Similarly, for the alternative where the Sludge Management Facility is located on a flat surface of the Main Pit Stockpile, the small amount of seepage will move along the compacted sub base/foundation material to the toe of the stockpile and be collected in the evaporation basin.

The runoff from precipitation on the uncovered portions of the Sludge Management Facility will also be collected in a similar manner and diverted to the evaporation ponds. As the sludge is covered with soil, runoff from these areas will be "clean" and will be segregated from any impacted runoff and seepage and will be diverted to a potential beneficial use.

3.6.2 Sludge Leachability

Current information suggests that due to the lower permeability of the gypsum, and design of the sludge disposal cells, little mixing of water with the sludge will occur from either lower pH water in the underlying rock or from precipitation. Nonetheless, a review was conducted of the sludge in terms of leaching under the assumption that solution contact with the sludge was possible.

Samples of the moist sludge "filter cakes" recovered from filtration during bench-scale testing by Hazen Research, Inc. (Hazen, 2002) were submitted for Synthetic Precipitation Leachate Procedure (SPLP) testing. The results are summarized in Table 3-5.

TABLE 3-5
RESULTS OF SPLP ANALYSES OF SELECTED SLUDGE SAMPLES FROM BENCH-SCALE TESTING OF WATER TREATMENT ALTERNATIVES AND COMPARISON TO REGULATORY LIMITS AND STANDARDS AT THE TYRONE MINE (Hazen, 2002)

Synthetic Precipitation Leaching Procedure Extraction of pH 10 Bulk Neutralization Solids								
Analyte or Analysis	**Assay Unit**	**pH 10 Bulk Neutralization Solids from Run No.**				**Limits, mg/L (except as noted)**		
		1	**2**	**3**	**4**	**Reporting Limit**	**EPA Limit**	**NMWQCC Standards**
Filter Cake % Moisture	wt. %	80.0	77.3	78.2	77.0	-	-	-
Silver	mg/L	<0.5	<0.5	<0.5	<0.5	0.5	5.0	0.05
Arsenic	mg/L	<0.5	<0.5	<0.5	<0.5	0.5	5.0	0.1
Barium	mg/L	<2	<2	<2	<2	2	100.0	1.0
Cadmium	mg/L	<0.1	<0.1	<0.1	<0.1	0.1	1.0	0.01
Chromium	mg/L	<0.5	<0.5	<0.5	<0.5	0.5	5.0	0.05
Lead	mg/L	<0.5	<0.5	<0.5	<0.5	0.5	5.0	0.05
Selenium	mg/L	<0.1	<0.1	<0.1	<0.1	0.1	1.0	0.05
Mercury	mg/L	<0.001	<0.001	<0.001	<0.001	0.001	0.2	0.002
Aluminum	mg/L	4.8	4.0	3.2	1.2	-	NA	5.0
Calcium	mg/L	549	520	541	508	-	NA	NA
Cobalt	mg/L	<0.02	<0.02	<0.02	<0.02	0.02	NA	0.05
Copper	mg/L	0.94	2.1	0.06	0.68	-	NA	1.0
Iron	mg/L	0.78	1.54	0.06	0.48	-	NA	1.0
Magnesium	mg/L	4	5	4	3	-	NA	NA
Manganese	mg/L	0.86	1.78	0.04	0.54	-	NA	0.2
Molybdenum	mg/L	<0.02	<0.02	<0.02	<0.02	0.02	NA	1.0
Nickel	mg/L	0.04	0.02	0.02	<0.02	0.02	NA	0.2
Potassium	mg/L	1	1	2	2	-	NA	NA
Sodium	mg/L	12	16	13	21	-	NA	NA
Zinc	mg/L	1.01	2.22	0.10	0.75	-	NA	10.0
Fluoride	mg/L	5	5	5	5	-	NA	1.6
Final Leachate pH	pH	9.08	9.44	9.18	8.87	-	NA	6 - 9

The SPLP data showed that the eight key metals of concern were less than detection in the leachate, and that the leach water quality and runoff from the sludge will have chemical properties similar to the lime-treated HDS water. These waters will be highly alkaline, with a pH in the 10 to 11 range. The dominant ions in these solutions will be calcium and sulfate, and the TDS will be largely controlled by the solubility of gypsum (TDS concentrations in seepage will likely be in the range of 2,500 to 3,130 mg/L). Some constituents of concern, i.e., Cu, Fe, Mn, and F will exceed NMWQCC standards, but these discharges will be collected and evaporated. Storm-related overflow from the evaporation basins will be routed to the Main Pit sump for collection and treatment. As mentioned in Section 3.6, the water quality associated with captive water in sludge is considerably better in quality when compared to the waste rock seepage quality in the sludge site disposal areas.

Runoff from the sludge will also be similar in nature to the leach water quality collected at the toe of the sludge cell, although it will be more dilute, with the degree of dilution a function of precipitation-runoff relationships. The concentrations of calcium sulfate and other soluble salts in the runoff will largely be influenced by the contract time between the precipitation and the sludge. Rapid runoff from more intense, short duration rainfall events will tend to be more dilute than runoff from less intense, longer-duration precipitation events. Ultimately, the upper limit to the concentration of dissolved salts in the seepage and runoff will be largely controlled by the solubility of gypsum.

4.0 DESIGN OF SLUDGE MANAGEMENT FACILITIES

Two sludge disposal areas have been identified that are considered environmentally protective: a bench in the Main Pit and on top of the in-pit leach stockpile within the Main Pit. A final decision has yet to be made on which site to use; therefore, this section discusses design of both facilities. Based on environmental and operational considerations, it was decided that, rather than pumping a sludge slurry to the disposal area and then dewatering, the sludge will be dewatered at the Water Treatment Plant and the belt press cake (dewatered sludge) hauled by truck to the disposal area. Figure 4-1 is a key plan that locates both areas and the haul roads from the storage bunker.

A storage bunker with a holding capacity of at least 3 days of sludge production will be constructed in the Water Treatment Plant area. The bunker will allow for sludge transport to the disposal area to be discontinued each weekend and accommodate disruptions in sludge transport during road maintenance and other short-term interruptions in the operation of the sludge handling facilities. Costs for the bunker storage facilities are provided in Section 6.0, along with costs for construction of the sludge disposal cells.

4.1 Main Pit Bench Sludge Management Facility

The Main Pit bench Sludge Management Facility would be located in the general area of the Main Pit. The facility would be constructed on a flat bench with a natural, gentle slope toward the Main Pit low point, so as to ensure that any seepage will be routed to the evaporation pond. The existing grade elevation at the high point of the bench is 5,525 feet. The Sludge Management Facility will have a footprint of approximately 80 acres. It will be functionally divided into four sludge disposal cells of approximately the same footprint acreage with an evaporation pond at the low point of the area that will collect, via gravity, surface runoff from precipitation events along with any potential drainage from the sludge disposal cells. The evaporation pond will have a surface area of approximately 5 acres, which is greater than required to hold the 25-year event runoff. The area that includes both of the sludge disposal area and the evaporation pond will be ripped and compacted to ensure low permeability of the foundation material.

Three sides of the facility will be constructed against existing highwalls in the pit. This will allow the facility to minimize perimeter outslopes that have to be constructed at 3H:1V slopes and maximize the space available for storage. The fourth side, near the evaporation pond, will be constructed with a 3H:1V outslope.

LEGEND:

SLUDGE MANAGEMENT FACILITY OUTLINE

HAUL ROAD

GRAPHIC SCALE

600 0 300 600 1200 2400

(IN FEET)

REFERENCES		REFERENCES		REVISIONS						REVISIONS					
DWG. NO.	TITLE	DWG. NO.	TITLE	NO.	DESCRIPTION	BY	APP'D	DATE	CLIENT	NO.	DESCRIPTION	BY	APP'D	DATE	CLIENT

SCALE:		DATE
DESIGNED BY	D.C.	OCT '04
DRAWN BY	C.R.	OCT '04
CHECKED BY	A.G.	
PROJECT MGR	C.H.	
CLIENT APPR.		

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TYRONE CLOSURE / CLOSEOUT

SLUDGE MANAGEMENT FACILITIES LOCATION PLAN

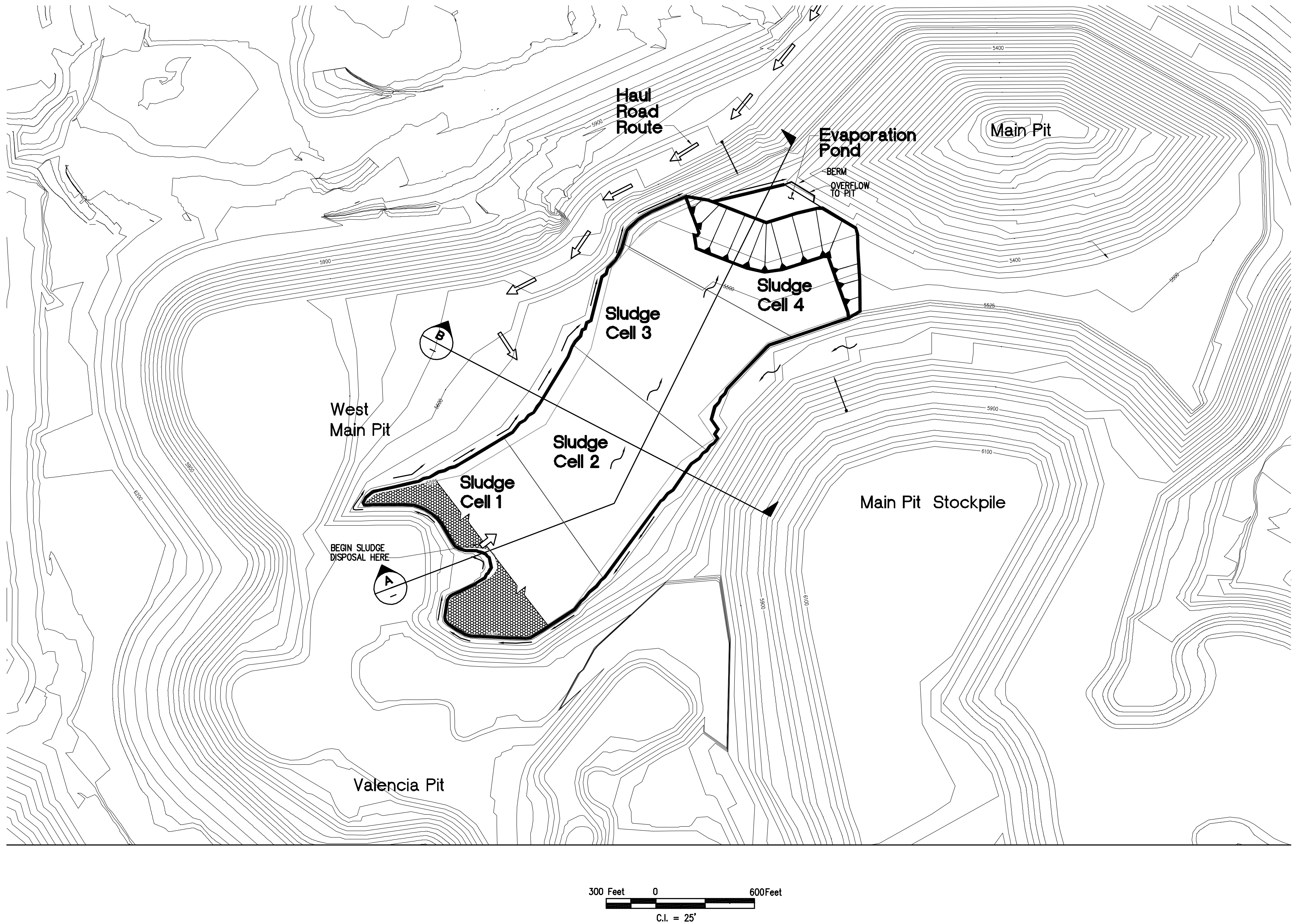
JOB NO. M3-PN02060

FIGURE 4-1

REV NO. DATE 10/13/04

NAME: P:\2002\02060\CIVIL\TYRONE-89 FIGURE 4-1.dwg LAST REV: LAST UPDATE: OCT 21, 2004 TIME: 9:37 AM BY: hp170 PLOT SCALE: 1:1

The sludge disposal cells will be operated in a sequential fashion. The first cell will be filled to a prescribed height before sludge is disposed in the second cell. Once a cell is filled to capacity, the surface will be leveled, and a store and release cover will be constructed to minimize exposure to precipitation (Section 4.1.3). The access road will be extended across the closed cells to transport sludge to the next disposal cell. This fill/close sequence will continue until the conclusion of the water treatment operations. It is expected that the sludge disposal cells will be filled to a nominal height of 25 feet at the conclusion of the water treatment sludge production based on the planned surface area of the disposal facility and the projected sludge volume (Section 2.4). Figures 4-2 and 4-3 are preliminary design drawings of the Main Pit bench Sludge Disposal Facility.



Total Sludge Volume Contained @ 25' Height	
GAL.	Cu. Yds.
719,354,529	3,561,619

Final Top Surface	
CELL	ACRES
No. 1	18.42
No. 2	19.06
No. 3	17.84
No. 4	17.58*

* Area includes outslopes

Legend

- EXISTING TOPOGRAPHY
- RUNON DIVERSION
- DRAINAGE
- SLUDGE

NOTE:

1. ALL EXTERIOR SLOPES CONSTRUCTED AT 3H TO 1V.
2. SEE FIGURE 4-3 FOR SECTIONS.

REFERENCES		REFERENCES		REVISIONS						REVISIONS					
DWG. NO.	TITLE	DWG. NO.	TITLE	NO.	DESCRIPTION	BY	APP'D	DATE	CLIENT	NO.	DESCRIPTION	BY	APP'D	DATE	CLIENT
TYRONE-86	MAIN PIT/SLUDGE REP./ SECTIONS														

SCALE: AS NOTED		DATE
DESIGNED BY	A.G.	OCT '04
DRAWN BY	C.R.	OCT '04
CHECKED BY	A.G.	
PROJECT MGR	A.G.	
CLIENT APPR.		

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TYRONE CLOSURE / CLOSEOUT

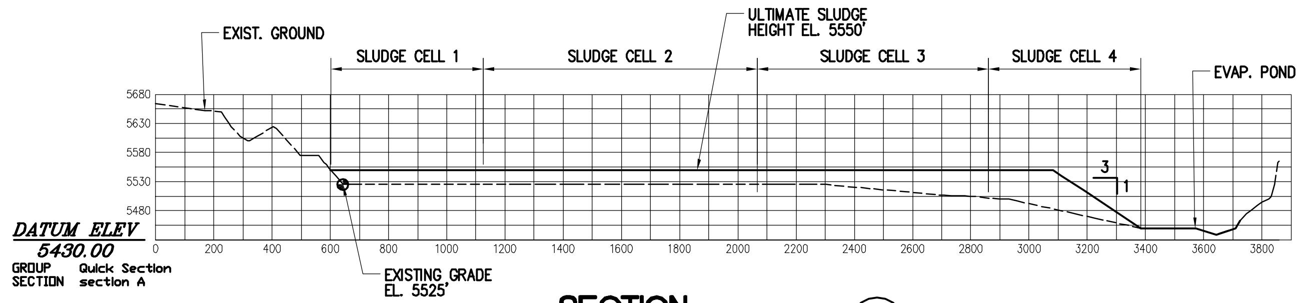
JOB NO. M3-PN02060

MAIN PIT SLUDGE MANAGEMENT FACILITY PLAN

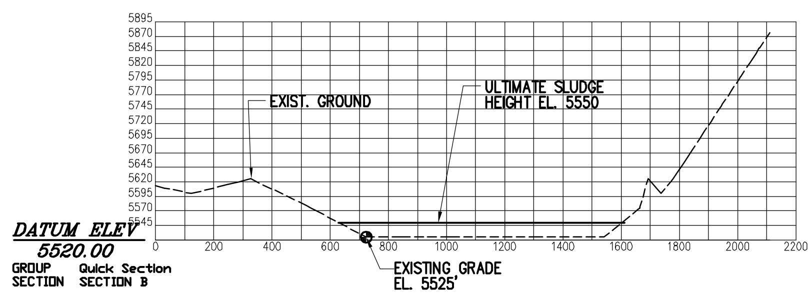
FIGURE 4-2

REV NO. | DATE 10/06/04

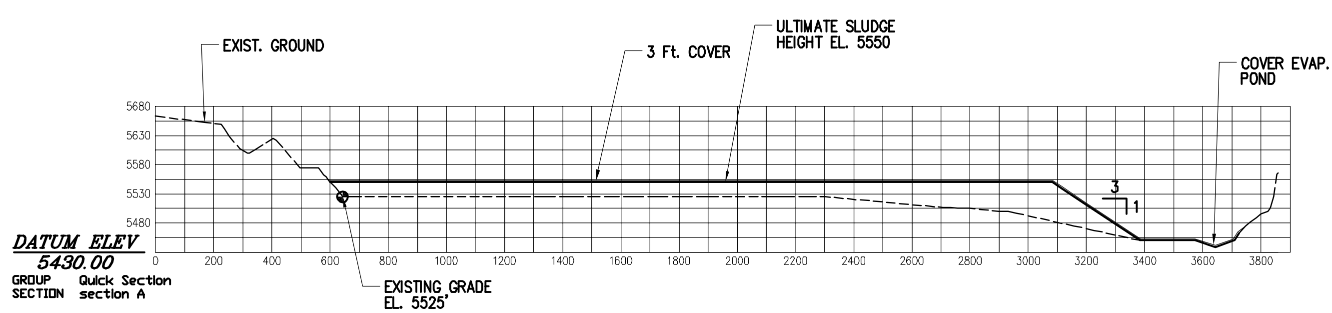
NAME: P:\2002\02060\CIVIL\TYRONE-85 (FIGURE 4-2).dwg LAST REV: PLOT LAST UPDATE: OCT 21, 2004 TIME: 9:08 AM BY: hp170 PLOT SCALE: 1:1



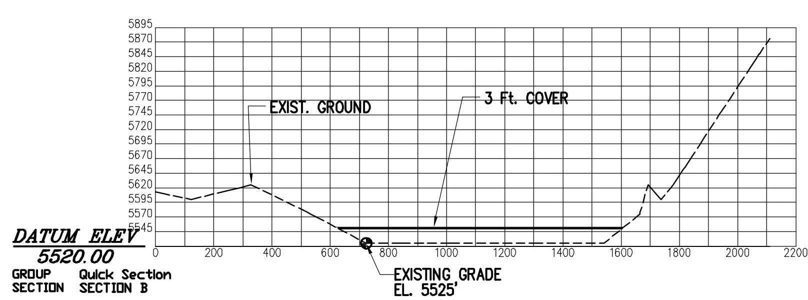
SECTION A
SCALE: VERTICAL EXAGGERATION = 2



SECTION B
SCALE: VERTICAL EXAGGERATION = 2



SECTION POST-CLOSURE A
SCALE: VERTICAL EXAGGERATION = 2



SECTION POST-CLOSURE B
SCALE: VERTICAL EXAGGERATION = 2

NOTE:

1. SEE FIGURE 4-2 FOR SECTION LOCATION.

REFERENCES		REFERENCES	
DWG. NO.	TITLE	DWG. NO.	TITLE
TYRONE-85	MAIN PIT/SLUDGE REP./PLAN		

REVISIONS: NO. | DESCRIPTION | BY | APP'D | DATE | CLIENT

SCALE: AS NOTED		DATE
DESIGNED BY	A.G.	OCT '04
DRAWN BY	C.R.	OCT '04
CHECKED BY	A.G.	
PROJECT MGR		
CLIENT APPR.		

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TYRONE CLOSURE / CLOSEOUT

MAIN PIT SLUDGE MANAGEMENT FACILITY SECTIONS

JOB NO. M3-PN02060

FIGURE 4-3

REV NO. | DATE 10/6/04

NAME: P:\2002\02060\CIVIL\TYRONE-86 (FIGURE 4-3).dwg LAST REV: PLOT LAST UPDATE: OCT 21, 2004 TIME: 9:16 AM BY: hp170 PLOT SCALE: 1:1

4.1.1 Decant Evaporation Pond

The evaporation pond will be sized to handle a 25-year storm event reporting to it from the surface of the Sludge Management Facility. The Tyrone DSM (Section 2.1) was used to estimate the requisite evaporation pond surface area based on a prescribed maximum pond depth of 5 feet. A pond area of approximately 3 acres resulted in a maximum pond depth of <4 feet. Any overflow from a storm event greater than the design event will report to the Main Pit through an evaporation pond overflow. Water reporting to the pit in such an overflow situation would be routed back to the Water Treatment Facility. The evaporation pond will be a compacted earthen structure. It will be periodically cleaned of accumulated sediments by the Sludge Management Facility operators. The sediment will be placed in the nearest active sludge disposal cell.

4.1.2 Stormwater Collection and Conveyance Features

The Sludge Management Facility will be constructed with runoff diversion channels at its perimeters to prevent storm run-on onto the sludge disposal cells from surrounding areas at higher elevations. The diversion channels will typically be V-shaped ditches cut into the existing terrain and will be sized to safely convey the collected runoff to the Main Pit. This water will be routed back to the water treatment facilities.

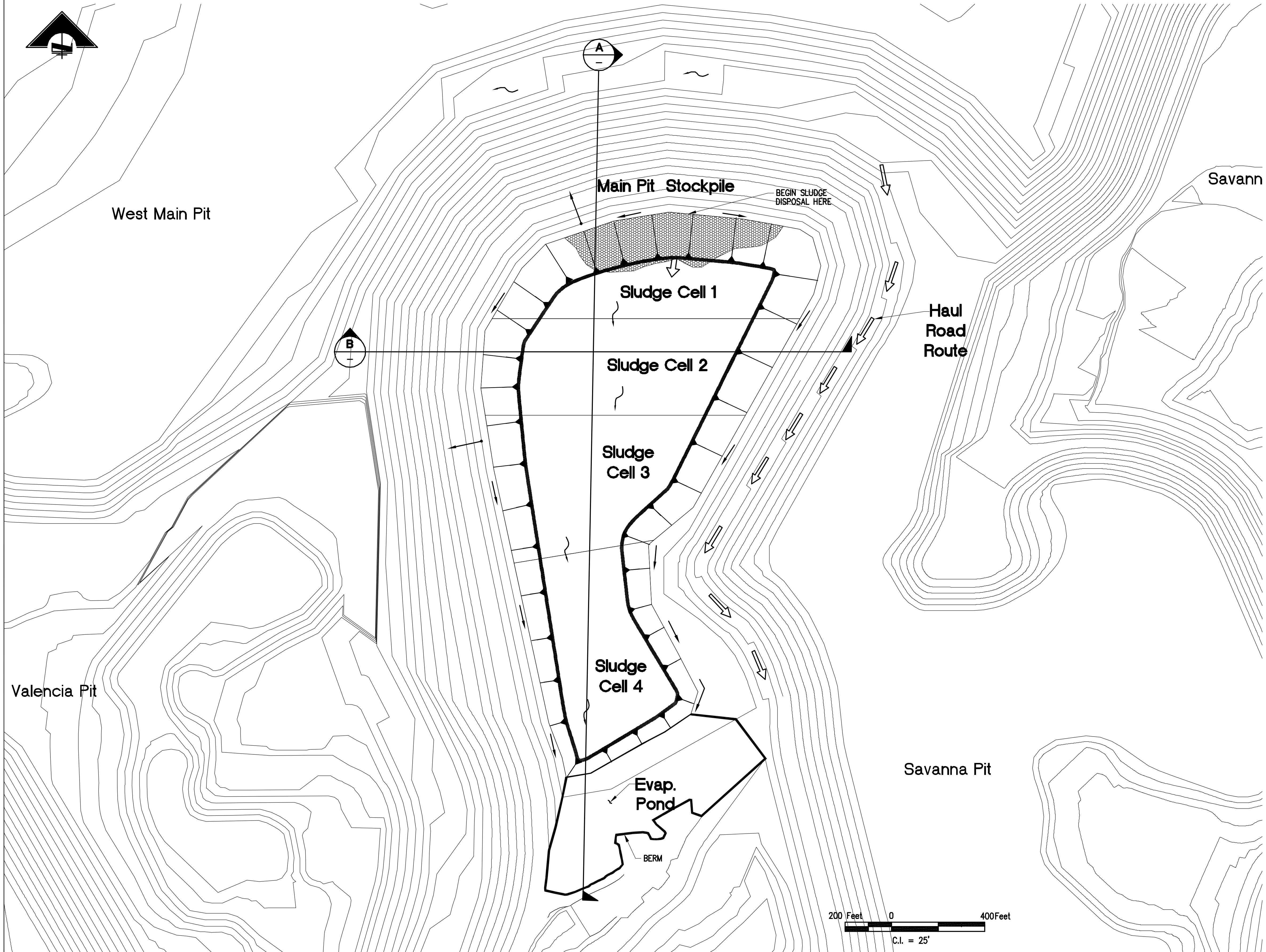
4.1.3 Covers for Sludge Cells

At the conclusion of the filling operation of each sludge disposal cell, the top surface of the sludge will be graded and leveled. Grading will provide a top surface slope of 0.5 to 5% to promote drainage from the finished surface. The top surface and the northern end outslope will be covered with 3 feet of cover material consistent with the closure/closeout measures throughout the rest of the Tyrone Mine. The covered surfaces will then be revegetated, again in accordance with reclamation measures in place for the remaining mine site.

4.2 Main Pit Stockpile Sludge Management Facility

The Sludge Management Facility proposed on a stockpile top surface is to be located on the Main Pit Stockpile. It is designed to have a final footprint of approximately 48 acres. The existing elevation of the sludge management area is at a grade elevation of 6,100 feet. It will be functionally divided into four sludge disposal cells of approximately the same footprint area. The southern end of the facility will be at the low point of the Sludge Disposal Facility where an evaporation pond will be located to collect, via gravity, sludge cell surface runoff from precipitation events, along with any potential drainage from the sludge disposal cells. Grade control will be maintained to ensure that all seepage flows to the low point, which will be toward the evaporation pond. All sides of the facility will be constructed with 3H:1V outslopes. The area that includes both of the sludge disposal area and the evaporation pond will be ripped and compacted to ensure low permeability of the foundation material.

The sludge disposal cells will be operated in a sequential fashion. The first cell will be filled to a prescribed height before sludge is disposed of in the second cell. Once a cell is filled to capacity, the surface will be leveled and a store and release cover will be constructed to minimize exposure to precipitation (Section 4.1.3). The access road will be extended across the closed cells to transport sludge to the next disposal cell. This fill/close sequence will continue until the conclusion of the water treatment operations. It is expected that the sludge disposal cells will be filled to a nominal height of 65 feet at the conclusion of the water treatment sludge production based on the planned surface area of the disposal facility and the projected sludge volume (Section 2.4). Figures 4-4 and 4-5 are preliminary design drawings of the Main Pit Stockpile Sludge Disposal Facility.



Total Sludge Volume Contained • 65' Height	
GAL.	Cu. Yds.
593,747,488	2,939,722

Final Top Surface	
CELL	ACRES
No. 1	11.82
No. 2	11.85
No. 3	11.86
No. 4	11.83

* Area includes outslopes

Legend

- EXISTING TOPOGRAPHY
- RUNON DIVERSION
- DRAINAGE
- SLUDGE

NOTE:

1. ALL EXTERIOR SLOPES CONSTRUCTED AT 3H TO 1V.
2. SEE FIGURE 4-5 FOR SECTIONS.

REFERENCES		REFERENCES		REVISIONS						REVISIONS					
DWG. NO.	TITLE	DWG. NO.	TITLE	NO.	DESCRIPTION	BY	APP'D	DATE	CLIENT	NO.	DESCRIPTION	BY	APP'D	DATE	CLIENT
TYRONE-88	MAIN PIT STOCKPILE/SLUDGE REP./SECT.														

SCALE: AS NOTED		DATE
DESIGNED BY	A.G.	OCT '04
DRAWN BY	C.R.	OCT '04
CHECKED BY	A.G.	
PROJECT MGR	A.G.	
CLIENT APPR.		

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TYRONE CLOSURE / CLOSEOUT

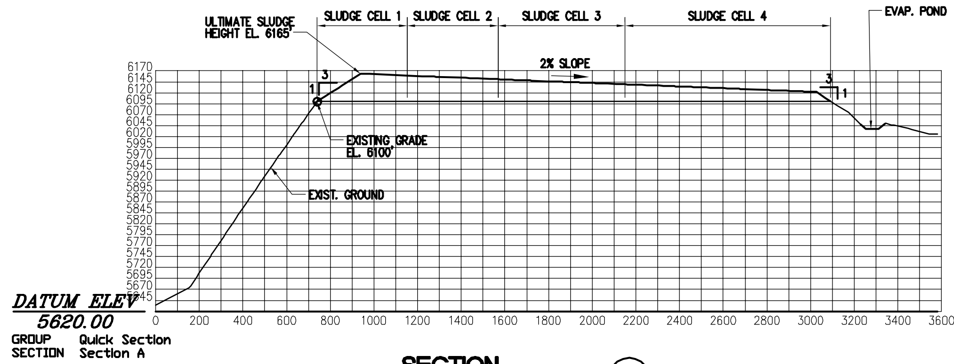
MAIN PIT STOCKPILE SLUDGE MANAGEMENT FACILITY PLAN

JOB NO. M3-PN02060

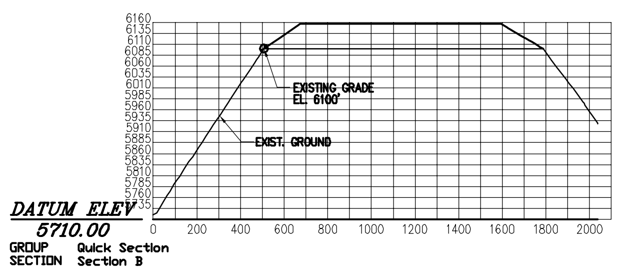
FIGURE 4-4

REV NO. DATE 10/8/04

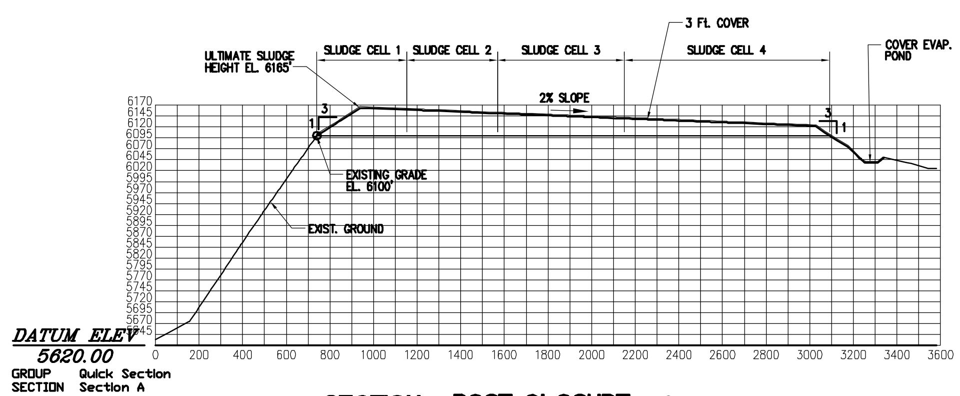
NAME: P:\2002\02060\CMI\TYRONE-87 (FIGURE 4-4).dwg LAST REV: LAST UPDATE: OCT 21, 2004 TIME: 9:18 AM BY: hp170 PLOT SCALE: 1:1



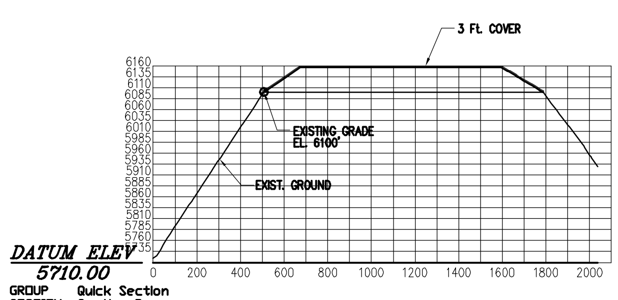
SECTION (A)
SCALE: VERTICAL EXAGGERATION = 2



SECTION (B)
SCALE: VERTICAL EXAGGERATION = 2



SECTION POST-CLOSURE (A)
SCALE: VERTICAL EXAGGERATION = 2



SECTION POST-CLOSURE (B)
SCALE: VERTICAL EXAGGERATION = 2

NOTE:
1. SEE FIGURE 4-4 FOR SECTION LOCATION.

REFERENCES		REFERENCES		REVISIONS						REVISIONS					
DWG. NO.	TITLE	DWG. NO.	TITLE	NO.	DESCRIPTION	BY	APP'D	DATE	CLIENT	NO.	DESCRIPTION	BY	APP'D	DATE	CLIENT
TYRONE-87	MAIN PIT STOCKPILE/SLUDGE REP./PLAN														

SCALE: AS NOTED	DATE
DESIGNED BY A.G.	OCT '04
DRAWN BY C.R.	OCT '04
CHECKED BY A.G.	
PROJECT MGR A.G.	
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TYRONE CLOSURE / CLOSEOUT

JOB NO. M3-PN02060

MAIN PIT STOCKPILE
SLUDGE MANAGEMENT
FACILITY
SECTIONS

FIGURE 4-5

REV NO. | DATE 10/8/04

NAME: P:\2002\02060\CIVIL\TYRONE-88 (FIGURE 4-5).dwg LAST REV: LAST UPDATE: OCT 21, 2004 TIME: 9:21 AM BY: hp170 PLOT SCALE: 1:1

4.2.1 Decant Evaporation Pond

The evaporation pond will be sized to handle a 25-year storm event reporting to it from the surface of the Sludge Management Facility. The Tyrone DSM (Section 2.1) was used to estimate the requisite evaporation pond surface area based on a prescribed maximum pond depth of 5 feet. A pond area of approximately 3 acres resulted in a maximum pond depth of <4 feet. The evaporation pond will be an unlined earthen structure. It will be periodically cleaned of accumulated sediments by the Sludge Management Facility operators. The sediment will be placed in the nearest active sludge disposal cell.

4.2.2 Stormwater Collection and Conveyance Features

The Sludge Management Facility will be constructed with runoff collection channels at its perimeters to carry storm runoff from the sludge cells surfaces to the evaporation pond located at the southern end of the Sludge Management Facility. The channels will typically be V-shaped ditches cut into the existing terrain and will be sized to safely convey the collected runoff to the evaporation pond.

4.2.3 Covers for Sludge Cells

At the conclusion of the filling operation of each sludge disposal cell, the top surface of the sludge will be graded and leveled. Grading will provide a top surface slope of approximately 2% to promote drainage from the finished surface. The top surface and the outslopes will be covered with 3 feet of cover material consistent with the closure/closeout measures throughout the rest of the Tyrone Mine. The covered surfaces will then be revegetated, again in accordance with reclamation measures in place for the remaining mine site.

5.0 CHARACTERIZATION OF LONG-TERM SLUDGE STABILITY

5.1 Use of Analogs to Evaluate Sludge and its Long-term Characteristics

An analog approach was used to evaluate the long-term sludge stabilization from both a chemical and physical standpoint. The analog approach was needed because there were no suitable materials at the mine to test, and the samples developed by Van Riper Consulting (2002), as part of their evaluation of a water treatment system for PDTI's Tyrone Mine, had been consumed in the earlier testing. In using analogs, PDTI reviewed data and other information from gypsum sludges that were expected to be similar to those produced at the Tyrone Mine. Gypsum sludges are produced by several processes, including flue gas desulfurization (FGD), neutralization of acid blowdown, and phosphate extraction.

Of the processes that generate gypsum sludge, the neutralization of acid blowdown and FGD appear most similar to the treatment process proposed for the Tyrone Mine, although considerable information is also available for the phosphate extraction industry, where the gypsum sludges are similar, but produced by significantly different processes. PDTI relied on several studies of gypsum sludges available in the public record (Ardaman & Associates, Inc. [Ardaman], 1980; Wissa A. E. Z., 1977; and Wissa A. E. Z., 1993), along with data and information regarding sludges produced at Phelps Dodge's Ft. Madison Plant in Iowa (personal communication, Christopher Deucher , Onyx Industrial Services, Inc. 2004).

Water treatment at Tyrone will produce a waste consisting largely of gypsum ($CaSO_4$-$2H_2O$) that will be disposed of in one of the proposed facilites. This material will be dewatered and transported by truck to the facility. Stacking methods of disposal are anticipated. These methods have been successfully implemented in other industries and applications for permanent disposal of gypsum sludge for more than 45 years (Ardaman, 1980).

5.1.1 Geotechnical Properties

The typical engineering characteristics of gypsum sludge produced in the phosphate extraction industry are controlled by properties such as density, strength, compressibility, and permeability (hydraulic conductivity). These properties are expected to be similar for the sludges produced at Tyrone, but may be influenced by the specific quality of the influent at any given point in time, the reaction process, the method of deposition, age, location, and depth within the facility in which it is placed. In general, the deeper the gypsum is within the facility and the older the stack, the higher the density and strength and the lower its compressibility and permeability, provided solution channels and cavities, which may form from infiltration of precipitation, are prevented from developing or are periodically repaired.

When produced at the treatment plant, the gypsum slurry will contain approximately 40% solids. PDTI anticipates that this slurry will be dewatered via belt press and stored in a bunker for up to 3 days. Trucks will be loaded from the concrete bunker for transport to one of the disposal cells. Data for materials from the Ft. Madison Plant in Iowa, which are expected to be very similar to the material produced at Tyrone, indicate that they have a solids content of approximately 53% and experience an overall waste volume reduction of approximately 50% at this point (Appendix A).

Based on analogous data from FGD gypsum sludge, the sludge tends to become relatively stiff and exhibits little consolidation for stresses below 1.0 kilograms per centimeter squared (kg/cm^2), comparable to those expected for a loosely packed sand. There will be little consolidation under additional imposed loads or with time due to secondary compression. This has also been the observation at the Ft. Madison Plant.

5.1.2 Mineralogical Character

According to Ardaman (1980), the mineralogy, crystal geometry, and particle size of waste gypsum typically provide settling, dewatering, and structural characteristics that allow disposal using stacks. In the phosphate industry, these gypsum stacks typically have large footprints, on the order of 50 to 100 acres. The stacks can reach heights greater than 100 feet. The drying curve characteristics of gypsum sludge from forced-oxidation FGD scrubbers have been studied by Ardaman (1980). Gypsum contains both chemically bonded and free water. The amount of bonded water expelled during drying increases with temperature. At temperatures above 50° Celsius (C), chemically bonded water can be released from the gypsum mineral structure resulting in mineral phase changes. Because temperatures in the sludge are expected to be less than 50° C, these types of mineralogical changes are not expected in the stacks.

5.1.3 Hydrologic Properties

The permeability of the gypsum is expected to vary within the stack. The in-situ permeability for sedimented gypsum in a 100-foot high stack decreases from approximately 10^{-3} cm/sec near the top surface to 6×10^{-4} cm/sec near the base of the stack.

The cohesive strength of the gypsum tends to increase with time as a result of cementation. The degree and rate of cementation varies based on the chemical constituents in the process water. The long-term moisture content within the gypsum stockpile is expected to range from 25 to 35%. While the water in the gypsum is expected to be chemically bonded to the gypsum, any leachate that might form will be collected in bermed diversions and directed to facilities and evaporated. Sludges from the evaporation ponds will be collected periodically and placed in the Sludge Disposal Facility.

5.2 Long-term Chemical Stability

The equilibrium solubility of the gypsum sludge is expected to range from 2,200 to 2,600 mg/L. The long-term chemical stability of the gypsum in the disposal facility will be largely controlled by the solubility of the gypsum and the flux of porewater that will infiltrate into the stack through the final cover. The proposed store and release cover for the disposal facility and the low permeability of the consolidated gypsum will minimize the infiltration through the cells. In this environment, the gypsum sludge is expected to remain stable.

5.3 Long-term Geotechnical Stability

Gypsum sludge is also expected to be stable from a geotechnical standpoint early on and become more stable with time. According to Ardaman (1980), FGD gypsum tends to be relatively stiff and exhibits little consolidation under stresses below 1.0 kg/cm^2. The compression ratio at this low stress level is approximately 0.01. Above a stress of 1.0 kg/cm^2, the compression ratio increases to approximately 0.05. These values are similar to those expected for loosely packed sand. The construction of 100-foot high stacks, with 3H:1V sideslopes and surface water controls, should produce gypsum piles that are stable when covered. With time, the cementation in the gypsum is expected to increase and the stack will continue to consolidate, increasing the material strength and long-term geotechnical stability of the disposal facility.

6.0 COST ESTIMATES FOR CAPITAL AND OPERATIONS

6.1 Capital Costs by Site

6.1.1 Main Pit Option

There are two components to the capital cost for the Main Pit Option: construction of a storage bunker and construction and closure of the disposal cells, along with their associated stormwater and evaporation systems.

The sludge storage and load out bunker is to be located adjacent to the proposed Water Treatment Plant. The bunker is a concrete structure open to the environment, with no utilities. It is designed as a three-wall bunker with a concrete floor and concrete apron for truck load out, and will hold 3 days of belt press cake production.

The capital costs associated with the disposal cell include construction of stormwater diversion channels around the cells and an earth berm around the evaporation pond. Because the cells will be constructed on fill material, there is an additional cost for ripping and compacting of the existing surface to provide a stable, impermeable foundation for the future cell deposition. Closure activities included in the capital estimate are haul and placement of a 3-foot thick store and release cover on the completed sludge cells, along with revegetation of those covered areas. The Sludge Management Facility evaporation pond will be decommissioned and cleaned of any residual sediment by the Sludge Management Facility operator at the end of the project. No cover of the evaporation pond surface area is required. The pond area will be ripped and revegetated. An annual revegetation maintenance cost is included in the capital estimate for all areas. The annual maintenance cost is estimated as 5% of the initial revegetation cost and is assumed to be required during the first 12 years after closure.

The estimated direct cost for the Main Pit Option is $1,404,259. Indirect cost for the Main Pit Option is estimated at $745,197, which yields a total project cost of $2,149,456.

6.1.2 Stockpile Option

There are two components under the Stockpile Option: construction of a storage bunker and construction and closure of the disposal cells, along with their associated stormwater and evaporation systems.

The sludge storage and load out bunker is the same for both the Main Pit and Stockpile Options, and is discussed in Section 6.1.1

Capital costs associated with disposal cell construction in this option are similar to those for the Main Pit Option. These include construction of stormwater diversion channels around the cells, construction of the earth berm around the evaporation pond, and ripping/compacting the existing surface. Closure activities included in the capital estimate for the Stockpile Option are similar to those as discussed for the Main Pit Option in Section 6.1.1. An additional cost is included in the Stockpile Option for haul and placement of cover material for the evaporation pond area. An annual revegetation maintenance cost is included in the capital estimate for all areas. The annual maintenance cost is estimated as 5% of the initial revegetation cost and is assumed to be required during the first 12 years after closure.

Estimated direct cost for the Stockpile Option is $1,078,661. Indirect cost for the Stockpile Option is estimated at $572,412, which yields a total project cost of $1,651,073.

Scheduling of these expenditures would occur as follows:

- construction of sludge storage bunker – Year 5 following closure,
- preparation of entire foundation for sludge disposal site – Year 5,
- construction of evaporation pond and stormwater overflow – Year 5, and
- closure of cells as follows:
- Cell 1 – Year 15,
- Cell 2 – Year 35,
- Cell 3 – Year 65,
- Cell 4 – Year 100.

A full breakdown of direct and indirect costs for the Main Pit bench disposal site and the Main Pit Stockpile site are presented in Appendix B.

Table 6-1 presents a summary of the capital and operating costs for the preferred alternatives.

TABLE 6-1
SUMMARY OF CAPITAL AND OPERATING COSTS
FOR PREFERRED ALTERNATIVES

	Main Pit Bench	**Main Pit Stockpile**
Direct Capital Costs	$1,404,259	$1,078,661
Indirect Costs	$745,197	$572,412
Total Capital Costs	$2,149,456	$1,651,073
Annual Operating Costs	$83,700	$97,500

A net present value for the operating costs and capital expenditures is not included in this report but is being prepared by PDTI. It should be pointed out that approximately 50% of the capital cost is associated with capping, grading, and seeding of the sludge cells following closure. Therefore, a major portion of capital costs will be after Year 15 and subsequently into the future when cells are closed.

6.1.3 Operating Cost Summary for Both Sites

Table 6-2 provides a summary of operating costs for both alternative disposal areas.

TABLE 6-2
SUMMARY OF OPERATING COSTS FOR THE SLUDGE MANAGEMENT FACILITY

Tyrone Closure/Closeout Plan
Operating Cost
SLUDGE MANAGEMENT FACILITY
Annual Cost Summary

Cost Item	Annual Cost	
	Pit Location	Stockpile
Sludge Management Facilities		
Labor	$ 51,400	$ 51,400
Sub-Total labor	$ 51,400	$ 51,400
Sludge Management Facilities		
Sludge Transport	32,300	46,100
Sub-Total Sludge Transport	$ 32,300	$ 46,100
Total Sludge Management	$ 83,700	$ 97,500

7.0 COMPLIANCE WITH APPLICABLE WASTE MANAGEMENT REGULATIONS AND OTHER PERMITTING ISSUES

The sludge created from the treatment of mine waters at the Tyrone Mine should be excluded from regulation as “hazardous waste” under 20.4.1.200 NMAC (incorporating by reference, 40 CFR Part 261) and 40 CFR 261.4(b)(7). Specifically, acid mine waters are generally considered to be a solid waste uniquely associated with and generated from the extraction and beneficiation of ores at the mining site. Because the sludge will result from the treatment of acid mine waters at an active mine, and isn’t mixed in any way with any hazardous wastes, it should remain exempt. The New Mexico Solid Waste Regulations contain a similar exclusion, 20.9.1.105.BV.3 NMAC.

The sludge will be dominantly calcium sulfate or the mineral gypsum. Leach testing of the sludge produced as part of preliminary treatment testing of the mine water from the Tyrone Mine (Hazen, 2002) is summarized in Table 3-5. In reviewing the results, Ag, As, Ba, Cd, Cr, Pb, Se, Hg, Co, and Mo were below analytical reporting limits and therefore, below the federal regulatory limits. Because the reporting limits were higher than the NMWQCC standards, they could not be compared. The metals Al, Cu, Fe, and Mn, as well as pH and F exceeded NMWQCC standards in one or more of the SPLP analyses. These data suggest that leachate derived from seepage through or runoff from precipitation that contacts the sludge could potentially exceed NMWQCC standards. In the Operation Plan, this water will be contained and evaporated.

The sludge is not expected to exhibit any corrosive or toxicity characteristics as defined under RCRA regulations. Even if the sludge where to exhibit corrosive or toxicity characteristics in the future, which isn’t expected, it would, as a pollution-control waste, continue to remain exempt because it was generated from the treatment of an excluded waste.

The sludge is also excluded from state Subtitle D (solid waste) requirements. That is, the state solid waste laws and regulations do not apply to the sludge because mining waste is excluded from the regulations by 20.9.1.7 NMAC, because it “…is exclusively and uniquely regulated by the New Mexico Energy, Minerals, and Natural Resources Department” and will also be regulated by an applicable discharge plan (personal communication with Ed Hansen, NMED with Bob Newcomer, Golder, September 28, 2004). This Plan was developed in accordance with Condition 86 of the Supplemental Discharge Permit for Closure, DP-1341 (April 8, 2003). The permit is pursuant to the New Mexico Water Quality Act, NMSA 1978 && 74-6-1 through 74-6-17 (1993), and the

NMWQCC Regulations, 20.6.2 NMAC. The Sludge Disposal Facility will be designed, at a minimum, to meet the following regulatory requirements:

- NMWQCC Regulation 3107.A.11, which states that a discharge plan shall provide for "[a] closure plan to prevent the exceedance of standards of Section 3103 or the presence of a toxic pollutant in groundwater after the cessation of operations, which includes: a description of closure measures, maintenance and monitoring plans, post-closure maintenance and monitoring plans, financial assurance, and other measures necessary to prevent and/or abate such contamination."
- NMWQCC Regulation 3103, which provides standards for allowable concentrations in groundwater of individual regulated pollutants.

In addition, the plan also is designed to meet the New Mexico Mining Act requirements for existing mines as addressed under Sections 6936-11B(3) and (4) of the Mining Act and Subparts 506.A and B of the New Mexico Mining Act Rules.

8.0 OPERATION PLAN

8.1 Introduction

The purpose of this Operation Plan is to develop a framework within which the preliminary sludge management plan can be cast. The information contained in this plan is of sufficient detail to allow for review of adequacy from an operational standpoint as well as an environmental standpoint.

This Operation Plan is divided in to sections dealing with Facility Description, Operational Procedures, Health and Safety Program, Emergency Response Procedures, and Monitoring and Compliance Program.

This Operation Plan is based upon information that has been presented in prior sections of this submittal and relies upon truck haul and placement in dedicated cells in the Main Pit. The sludge material is expected to be dewatered to the extent that normal loader/truck equipment and procedures will be adequate to handle the primarily gypsum sludge. It is anticipated that this plan will be refined and expanded in detail as the final plan is developed in the future; however, the main elements and discussion in this plan are not expected to substantially change in future, more expanded versions of this plan.

8.2 Facility Description

Battery limits for the Sludge Management Facility will start at the discharge from the water treatment belt presses. These presses are dewatering devices that will generate a sludge with slightly over 50% solids and that will not be free draining. Sludge from the presses will drop into a sludge storage bunker that is designed for holding up to 3 days of sludge production. An operator during the day shift will be dedicated to management of the Sludge Facility and will report to the manager of the Water Treatment Plant. This operator will work on a 10-hour, 7-day a week basis. The operator will be responsible for loading the stored sludge into a standard tandem truck (approximately 14 cubic yard capacity) and to transport and dump the sludge into the disposal cell. Based upon the projected volume of sludge to be generated, it is estimated that the operator will make six round trips a day to the disposal cell.

Construction of the storage cell and stormwater collection and handling will be on a contract basis, and will be the responsibility of the Water Treatment Plant operator. Specifics as to cell design and construction are covered in previous sections of this submittal, as well as costs involved in cell construction.

Other than mobile equipment used in loading and hauling sludge, there is not other major operating equipment that is required for sludge handling. There will be the normal sampling equipment and a laboratory support area required to support sludge handling; however, this area and supplies required will fall within the Water Treatment Plant operations.

8.3 Operational Procedures

The sludge management operator will be responsible for the following operational procedures:

- daily record keeping of sludge amounts transported;
- loading and hauling required for daily sludge production to the disposal cell;
- daily visual inspection of the:
- ▪ load-out facilities,
- ▪ safety check of operating equipment,
- ▪ inspection of the haul road for any spillage or required repairs,
- ▪ inspection of the sludge off loading area,
- ▪ inspection of the stormwater handling facility (once a month or after storm events), and
- ▪ identify dusting issues if any.
- annual sampling of the as-generated sludge for SPLP testing confirmation (composite for the day the sample is taken);
- recording of inspections and sampling dates and details;
- reporting of all non-conforming findings to the manager of the Water Treatment Plant with recommendations as to required actions; and
- confirm moisture content on a weekly basis.

The manager of the water treatment plant will be responsible for the following operational procedures:

- manning schedule of sludge management operators,
- scheduling of routine maintenance for sludge management mobile equipment,
- scheduling of sludge cover activities as specified in previous sections of this submittal,
- scheduling and coordination of cell construction requirements and cell closure requirements,
- coordination and scheduling for addressing non-conforming findings as presented by the sludge operator,

- reporting to state and local authorities as required under approval conditions under DP-1341,
- reporting of and response to any violations under approval conditions as required under DP-1341 or other applicable regulations,
- routine safety reviews of ongoing sludge handling operations,
- maintaining necessary safety equipment and supplies for the sludge handling area, and
- routine budget projections and control.

There are no special provisions required in handling and disposal of the water treatment sludge. The sludge easily passes the SPLP and is slightly alkaline in nature, ranging in pH from 9 to 10. Normal safety equipment is required, including goggles. Because the material is not free draining, special truck liners are not required, nor is special handling equipment. If there is a malfunction in the filter presses, and generated sludge has a higher moisture content, the sludge operator has the option of routing the sludge back to the press feed tank or temporarily lining the truck for transport to the disposal cell.

8.4 Emergency Response Procedures

There are three areas or activities where an emergency could occur. First, a worker might be involved in an accident related to the equipment being used to load and haul sludge. Second, there could be a spill of sludge while the sludge is being transported to the disposal cell. Third, a major storm event could occur that might impact one or more of the disposal cells.

From the worker safety standpoint, the Water Treatment Plant Operations Manual will have detailed response measures as to the required and appropriate response in given situations. Necessary first aid supplies and equipment will be located on site in the Water Treatment Plant and all employees will be trained in how and when to use these supplies and equipment. The manger of the Water Treatment Plant will have assigned a designated safety officer for the site, and this officer will be responsible for ensuring that all employees and contractors are trained as required under MSHA. Arrangements will be made with local emergency response authorities that can be pulled in as required. These authorities will be toured through and familiarized with the Tyrone Mine and operating procedures.

In the event that there is a sludge spill during transport, routine clean up will be conducted and the recovered material will be disposed in one of the active cells. Because the sludge will not be free draining, a spill response would involve solids pickup and visual confirmation that the spill has been effectively dealt with. Due to the benign nature of the sludge, exotic cleanup and sampling procedures are not anticipated to be required. Any reporting requirements as to the event will be coordinated by the Water Treatment Plant Manager or his designee.

The sludge disposal cells and stormwater collection system are designed to handle a 25-year event, so as to contain and evaporate all collected water. If an event occurs over the 25-year event, the collection system is designed to route the excess flow to the Main Pit lake for recycle to treatment. The overflow system to the Main Pit is designed to handle flow resulting from a 100-year event. As each cell is reclaimed, runoff waters will be routed away from the active cell evaporation area, thus reducing the impact of storm events on the active cell operation.

8.5 Monitoring and Compliance Program

Monitoring and compliance is yet to be defined under the final permit; nonetheless, as the sludge management will be under the water treatment operation, monitoring and reporting will be integrated into the program as defined for the Water Treatment Plant. Section 8.4 lists activities for both the Sludge Operator and the Water Treatment Manager. Monitoring will include those activities. All records will be kept at the plant for a period of 3 years, unless otherwise required. It is expected that either a semi-annual or an annual report covering operations for the preceding period will be required by the state.

The level of detail required by the state covering normal operations and non-conforming events reporting has yet to be defined. It is expected that non-conforming events that exceed a certain yet to be defined threshold, will require reporting within a certain period of the events occurrence.

In the event that sludge SPLP testing exceeds any of the eight metals limits, the state will be immediately notified by phone, and an action plan will be drafted that addresses the believed cause of the exceedance and a corrective action to be taken. The corrective action plan will be mailed to the state within 30 days of notification to the state.

All other monitoring related to generation of the sludge will be under an Operation Plan developed for the Water Treatment Plant.

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APPENDIX A

FT. MADISON GYPSUM SLUDGE CHARACTERISTICS

PROCESS SUMMARY & PRODUCTION ESTIMATES

See the table provided below for a detailed summary of the sludge properties, the sludge dewatering characteristics, and the anticipated belt press production rates. The table and the data contained therein illustrate the significant parameters and variables that impact the dewatering process and its ultimate production rate (i.e., amount of dry tons produced per day).

"In-situ" Sludge Properties

In-situ Percent Dry Solids (% by weight)	29.86	pH of Sludge	6-8
In-situ Density (lbs/ft3)	84.35	Temp. of Sludge (degrees F; A = ambient)	A
In-situ Volume (cubic yards)	11,002	***In-situ Dry Solids (total Dry Tons)***	***3,741***

"Feed" Sludge Data

Dredge Dilution Factor (X:1) by Volume	None	"Feed" Density (lbs/gallon)	11.27
"Feed" Volume (gallons)	2,223,382	"Feed" Percent Dry Solids (by weight)	29.86

Process Data – Belt Press Technology

Belt Press Feed Rate (gallons/minute)	62.3	Working Hours per Day	24
Avg. Size of Belt Press (meters)	2.3	"On-line" Operating Factor	85%
Cake Density (lbs/cubic foot)	95.93	Operating hours per Day	20.4
Cake Percent Dry Solids (by weight)	53.20	Number of Belt Presses	2
Dry Tons of Cake per hour per press (tons)	6.3	***Dry Tons of Solids per Day***	***257***

Chemical Data (Sludge Conditioning)

Polymer Dosage (ppm)	500	Volume of Polymer needed (gallons)	2,668

Project Schedule Data

Number of Operating Days Required	15	Number of Calendar Weeks Required	2.5
Number of Operating Days per Week	6	Number of Calendar Months Required	< 1

Cake T&D Data

Total Dry Solids to Haul (dry tons)	3,741	Weight of Cake per Load (tons)	22
Percent Dry Solids in Cake (by weight)	53.20	**Cake Produced per Day (tons)**	**483**
Total Weight of Cake Produced (tons)	7,032	Number of Containers Hauled per Day	18
Total Volume of Cake Produced (cu. yds)	5,453	***Overall Waste Volume Reduction***	***50%***

The process summary data shows that two (2) belt presses will produce an average of 483 tons of cake per day (or 257 dry tons/day) operating 24-hours/day.

APPENDIX B

SUPPORTING COST DATA

Sludge Loadout Bunker, Main Pit Option

	DESCRIPTION	Quantity		Labor MH/ Unit	MH	Labor Rate	Unit Matl	Unit Sub	Labor Cost	Material Cost	Permanent Equipment Cost	Sub Contract Cost	Const Equip Cost	Total Cost
1000	Sitework													
	Structural Excavation	185.18519	cy	0.15	28	36.3			$1,008	$0		$0	$301	$1,310
	Structural Backfill	147.68519	cy	0.175	26	36.3	15		$938	$2,215		$0	$337	$3,490
	Diversion Ditch	7,400	lf		0	36.3		23.71	$0	$0		$175,454	$0	$175,454
	Evap Berm	4,200	cy	0.175	735	36.3	15		$26,681	$63,000		$0	$9,585	$99,265
	Cover Pit Sludge Cell #1	89,153	cy	0.013	1172	28.84		1.66	$33,802	$0		$147,967		$181,769
	Revegetate Sludge Cell #1	18	acre		0	36.3		746.8	$0	$0		$13,756		$13,756
	Maintain Sludge Cell #1 Vegetation	60.00	%		0	36.3			$0	$0		$8,253		$8,253
	Cover Pit Sludge Cell #2	92,250	cy	0.013	1213	173.5		1.66	$210,477	$0		$153,108		$363,585
	Revegetate Sludge Cell #2	19	acre		0	36.3		746.8	$0	$0		$14,234		$14,234
	Maintain Sludge Cell #2 Vegetation	60.00	%		0	36.3			$0	$0		$8,540		$8,540
	Cover Pit Sludge Cell #3	86,346	cy	0.013	1135	0		1.66	$0	$0		$143,307		$143,307
	Revegetate Sludge Cell #3	18	acre		0	36.3		746.8	$0	$0		$13,323		$13,323
	Maintain Sludge Cell #3 Vegetation	60.00	%		0	36.3			$0	$0		$7,994		$7,994
	Cover Pit Sludge Cell #4	85,087	cy	0.013	1119	0		1.66	$0	$0		$141,219		$141,219
	Revegetate Sludge Cell #4	18	acre		0	36.3		746.8	$0	$0		$13,128		$13,128
	Maintain Sludge Cell #4 Vegetation	60.00	%		0	36.3			$0	$0		$7,877		$7,877
	Rip Pit Bottom Surface	73	acre		0	36.3		63.66	$0	$0		$4,641		$4,641
	Compact Pit Bottom Surface	73	acre		0	36.3		2104	$0	$0		$153,410		$153,410
	Rip Pond Surface	3	acre		0	36.3		63.66	$0	$0		$191		$191
	Revegetate Pond	3	acre		0	36.3		746.8	$0	$0		$2,240		$2,240
	Maintain Pond Vegetation	60.00	%		0	36.3			$0	$0		$1,344		$1,344
					0	36.3			$0	$0		$0		$0
	Total				5428				$272,907	$65,215	$0	$1,009,985	$10,223	$1,204,921
2000	Concrete													
	Concrete Slab	38	cy	1.5	56	36.3	85		$2,042	$3,188		$0		$5,229
	Forms	90	sf	0.25	23	36.3	2.5		$817	$225		$0		$1,042
	Reinforcing Steel	2	ton	24	38	36.3	850		$1,388	$1,355		$0		$2,743
	Concrete Walls	20	cy	2.5	50	36.3	85		$1,815	$1,700		$0		$3,515
	Forms	2,160	sf	0.25	540	36.3	2.5		$19,602	$5,400		$0		$25,002
	Reinforcing Steel	2	ton	24	36	36.3	850		$1,307	$1,275		$0		$2,582
	Misc Concrete	1	lot	37.15	37	36.3	657.1		$1,349	$657		$0		$2,006
	Construction Equipment	12.2	day										$3,810	$3,810
	Total				780				$28,319	$13,799	$0	$0	$3,810	$45,929
3000	Structural Steel													
					0	36.3			$0	$0		$0		$0
	Construction Equipment	0.0	day						$0	$0		$0		$0
	Total				0				$0	$0	$0	$0	$0	$0
5000	Process Equipment													
					0	36.3			$0	$0		$0		$0
	Construction Equipment	0.0	day						$0	$0		$0		$0
	Total				0				$0	$0	$0	$0	$0	$0
6000	Piping													
					0	36.3			$0	$0		$0		$0
					0	36.3			$0	$0		$0		$0
	Misc Ftgs & Spts	1	lot	0	0	36.3			$0	$0		$0		$0
	Construction Equipment	0.0	day						$0	$0		$0		$0
	Total				0				$0	$0	$0	$0	$0	$0
7000	Electrical													
					0	41.25			$0	$0		$0		$0
	Total				0				$0	$0	$0	$0	$0	$0
8000	Instrumentation													
					0	41.25			$0	$0		$0		$0
	Total				0				$0	$0	$0	$0	$0	$0
	Total Direct Cost				6,208				$301,226	$79,015	$0	$1,009,985	$14,034	$1,404,259

M3 PN02060
PHELPS DODGE - TYRONE
O R D E R   O F   M A G N I T U D E   E S T I M A T E
TOTAL PROJECT COST SUMMARY SHEET
Sludge Management Facility

Previous Estimate
Current Update 20-Oct-04

Plant Area	Description	Manhours	Plant Equipment	Material	Labor	Subcontract	Construction Equipment	Total
	DIRECT COST							
	Sludge Loadout Bunker, Main Pit Option	6,208	$0	$79,015	$301,226	$1,009,985	$14,034	$1,404,259
	Subtotal DIRECT COST	6,208	$0	$79,015	$301,226	$1,009,985	$14,034	$1,404,259
	Indirect Cost							
	Engineering Redesign @4.5%							$63,192
	Construction Management/Project Controls @5%							$70,213
	Mobilization and Demobilization @1%							$14,043
	Contingency @7%							$98,298
	Profit @4%							$56,170
	Overhead @21%							$294,894
	Storm Water Prevention Plan @0.1%							$1,404
	Reclamation Monitoring Fee @2%							$28,085
	Gross Receipts Tax @ 5.9375							$118,897
	Total Project Cost							$2,149,456

Sludge Loadout Bunker, Stockpile Option

	DESCRIPTION	Quantity		Labor MH/ Unit	MH	Labor Rate	Unit Matl	Unit Sub	Labor Cost	Material Cost	Permanent Equipment Cost	Sub Contract Cost	Const Equip Cost	Total Cost
1000	Sitework													
	Structural Excavation	185.18519	cy	0.15	28	36.3			$1,008	$0		$0	$301	$1,310
	Structural Backfill	147.68519	cy	0.175	26	36.3	15		$938	$2,215		$0	$337	$3,490
	Diversion Ditch	6,700	lf		0	36.3		23.71	$0	$0		$158,857	$0	$158,857
	Evap Berm	6,067	cy	0.175	1062	36.3	15		$38,539	$91,000		$0	$13,845	$143,383
	Cover Pit Sludge Cell #1	57,209	cy	0.013	752	28.84		1.66	$21,691	$0		$94,949		$116,640
	Revegetate Sludge Cell #1	12	acre		0	36.3		746.8	$0	$0		$8,827		$8,827
	Maintain Sludge Cell #1 Vegetation	60.00	%		0	36.3			$0	$0		$5,296		$5,296
	Cover Pit Sludge Cell #2	57,354	cy	0.013	754	173.5		1.66	$130,858	$0		$95,190		$226,048
	Revegetate Sludge Cell #2	12	acre		0	36.3		746.8	$0	$0		$8,849		$8,849
	Maintain Sludge Cell #2 Vegetation	60.00	%		0	36.3			$0	$0		$5,310		$5,310
	Cover Pit Sludge Cell #3	57,402	cy	0.013	755	0		1.66	$0	$0		$95,271		$95,271
	Revegetate Sludge Cell #3	12	acre		0	36.3		746.8	$0	$0		$8,857		$8,857
	Maintain Sludge Cell #3 Vegetation	60.00	%		0	36.3			$0	$0		$5,314		$5,314
	Cover Pit Sludge Cell #4	57,257	cy	0.013	753	0		1.66	$0	$0		$95,030		$95,030
	Revegetate Sludge Cell #4	12	acre		0	36.3		746.8	$0	$0		$8,834		$8,834
	Maintain Sludge Cell #4 Vegetation	60.00	%		0	36.3			$0	$0		$5,301		$5,301
	Rip Stockpile Surface	47	acre		0	36.3		63.66	$0	$0		$3,015		$3,015
	Compact Stockpile Surface	47	acre		0	36.3		2104	$0	$0		$99,664		$99,664
	Cover Evap Pond	14,520	cy	0.013	191	30.14		1.66	$5,753	$0		$24,099		$29,852
	Revegetate Sludge Evap Pond	3	acre		0	36.3		746.8	$0	$0		$2,240		$2,240
	Maintain Sludge Cell #1 Vegetation	60.00	%		0	36.3			$0	$0		$1,344		$1,344
					0	36.3			$0	$0		$0		$0
	Total				4320				$198,787	$93,215	$0	$726,246	$14,483	$933,068
2000	Concrete													
	Concrete Slab	38	cy	1.5	56	36.3	85		$2,042	$3,188		$0		$5,229
	Forms	90	sf	0.25	23	36.3	2.5		$817	$225		$0		$1,042
	Reinforcing Steel	2	ton	24	38	36.3	850		$1,388	$1,355		$0		$2,743
	Concrete Walls	20	cy	2.5	50	36.3	85		$1,815	$1,700		$0		$3,515
	Forms	2,160	sf	0.25	540	36.3	2.5		$19,602	$5,400		$0		$25,002
	Reinforcing Steel	2	ton	24	36	36.3	850		$1,307	$1,275		$0		$2,582
	Misc Concrete	1	lot	37.15	37	36.3	657.1		$1,349	$657		$0		$2,006
	Construction Equipment	12.2	day										$3,810	$3,810
	Total				780				$28,319	$13,799	$0	$0	$3,810	$45,929
3000	Structural Steel													
					0	36.3			$0	$0		$0		$0
	Construction Equipment	0.0	day						$0	$0		$0		$0
	Total				0				$0	$0	$0	$0	$0	$0
5000	Process Equipment													
					0	36.3			$0	$0		$0		$0
	Construction Equipment	0.0	day						$0	$0		$0		$0
	Total				0				$0	$0	$0	$0	$0	$0
6000	Piping													
					0	36.3			$0	$0		$0		$0
					0	36.3			$0	$0		$0		$0
	Misc Ftgs & Spts	1	lot	0	0	36.3			$0	$0		$0		$0
	Construction Equipment	0.0	day						$0	$0		$0		$0
	Total				0				$0	$0	$0	$0	$0	$0
7000	Electrical													
					0	41.25			$0	$0		$0		$0
	Total				0				$0	$0	$0	$0	$0	$0
8000	Instrumentation													
					0	41.25			$0	$0		$0		$0
	Total				0				$0	$0	$0	$0	$0	$0
	Total Direct Cost				5,100				$227,107	$107,015	$0	$726,246	$18,294	$1,078,661

M3 PN02060
PHELPS DODGE - TYRONE
ORDER OF MAGNITUDE ESTIMATE
TOTAL PROJECT COST SUMMARY SHEET
Sludge Management Facility

Previous Estimate
Current Update 20-Oct-04

Plant Area	Description	Manhours	Plant Equipment	Material	Labor	Subcontract	Construction Equipment	Total
	DIRECT COST							
	Sludge Loadout Bunker, Stockpile Option	5,100	$0	$107,015	$227,107	$726,246	$18,294	$1,078,661
	Subtotal DIRECT COST	5,100	$0	$107,015	$227,107	$726,246	$18,294	$1,078,661
	Indirect Cost							
	Engineering Redesign @4.5%							$48,540
	Construction Management/Project Controls @5%							$53,933
	Mobilization and Demobilization @1%							$10,787
	Contingency @7%							$75,506
	Profit @4%							$43,146
	Overhead @21%							$226,519
	Storm Water Prevention Plan @0.1%							$1,079
	Reclamation Monitoring Fee @2%							$21,573
	Gross Receipts Tax @ 5.9375							$91,329
	Total Project Cost							$1,651,073