Appendix 6

Cresson Project
East Cresson Overburden Storage Area
Design

Prepared for:

Cripple Creek & Victor Gold Mining Company
Victor, Colorado 80860

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1. INTRODUCTION

The Cripple Creek Mining District ("District") is located in a seven square mile volcanic diatreme structure and contiguous rocks that have been altered by the diatremal volcanic activity in the central Colorado Rocky Mountains near the cities of Cripple Creek and Victor. Gold has been produced from this District for more than a century, primarily from underground mines operated between 1890 and 1940. To facilitate underground mining, the entire Mining District was dewatered by a series of tunnels constructed between the late 1800s and 1942. In 1993 large-scale mining was restarted in the District using surface mining methods, with overburden storage near the mines, and ore processing in a valley leach facility ("VLF") at the south end of the district (the "Cresson Project").

Cripple Creek & Victor Gold Mining Company (CC&V) is proposing a mine life expansion ("MLE"), by mining an additional 360 million tons of rock in the district, of which approximately 110 million tons would be processed as ore in a phased expansion of the VLF, and approximately 250 million tons of overburden would be used for mine backfill or placed in constructed overburden storage facilities.

The expansion proposes creation of the East Cresson Overburden Storage Area (ECOSA). This facility will store up to 66 million tons of overburden, and is located within Grassy Valley, at the northern edge of the diatreme. This report presents the design of that facility to be protective of the environment in Grassy Valley.

2. DESIGN OBJECTIVES

The objective of the ECOSA is to provide a location to store up to 66 million tons of project overburden.

The physical constraints of the design are:

- Honor property boundaries
- Remain clear of existing or future surface mines

The environmental objectives of the design are:

- Minimize infiltration through the facility
- Minimize air entry to overburden
- Minimize flow of infiltrated water from the facility to Grassy Valley
- Minimize water quality impact to Grassy Valley

3. EAST CRESSON OVERBURDEN STORAGE AREA

3.1 Location

The ECOSA is proposed to be located on the northern edge of the Cripple Creek Mining District, to the north of the backfilled East Cresson Mine (Plate 1). This location is on the southern flank of Grassy Valley, and terminates at the northern edge of the backfill of the East Cresson Mine (Figure 1).

3.2 Geology

The geology of the ECOSA is as follows:

0.5-1 foot	Growth medium/Soil
30-60 feet	Colluvium (silt and clay with gravel and boulders)
>1000 feet	Bedrock (Tertiary volcanic breccia and phonolite of Cripple Creek diatreme to southeast, and Precambrian granite and gneiss to the north)

The geology in the vicinity of the ECOSA is shown on Figure 2. The ECOSA falls almost entirely within the Cripple Creek diatreme.

3.3 Hydrology

3.3.1 Climate

The ECOSA area receives an average of 19.58 inches per year of total precipitation (Table 1), one quarter falls in the winter and spring (mostly as snow), and three quarters falls in spring and summer.

The potential evaporation for the area is 44.29 inches per year (Table 2).

3.3.2 Runoff

Surface water flow in the vicinity of the ECOSA is limited. Surface water flow in Grassy Valley has been monitored in the period 1997-present. The flow is highly variable. The annual average flow is 40 gpm (ABC, 2008) at GV-3 (Figure 1). This comprises a yield of approximately 0.6 inches per year on the 2 square mile catchment of Grassy Valley above GV-3.

3.3.3 Infiltration

Infiltration to the natural ground surface in the area has been determined to be 5 ± 1 inches per year (ABC, 2008).

3.3.4 Fate of Infiltration

The ECOSA is substantially within the Cripple Creek diatreme, and is entirely within the ground water catchment area of the diatreme (ABC, 2008). Plate 1 shows the location of the ECOSA, the diatremal boundary, and the ground water catchment limit of the diatreme.

Infiltration in the vicinity of the ECOSA passes through the soil and colluvium into the underlying diatremal bedrock. The water likely then passes into the main diatreme and becomes part of the regional ground water eventually flowing into Four Mile Creek through the Carlton Tunnel. It is possible that some component of the infiltrating flow emerges into the alluvium of Grassy Valley, but flow data from Grassy Creek suggests that little, if any, ground water baseflow enters the creek.

4. DESIGN

Design of the ECOSA to meet the design objectives set forth in Section 2 above is presented in detail in Attachment 1. This section sets out the general design, and summarizes the performance anticipated for the facility.

4.1 Design

The design of the ECOSA is as follows:

- Lift height 50 ft (end dumped, with upper surface sloped 1% to south)
- Inter-bench slope 2.5:1 (to allow material placement, proof-rolling, and compaction)
- Bench width 10 ft (benches sloped to remove surface runoff from slope)
- Clay base course 24" (15% plasticity index ["PI"], -24", clayey gravel, proof rolled)
- Compacted clay 12" (15% PI, -2", clayey gravel, compacted to 95% of optimum)
- Growth Medium 6" (native soil, recovered from pile footprint)

4.2 Quantities

Quantities of materials in the ECOSA are as follows (Table 4):

- Overburden stored 66 million tons
- Base course clay cover 906,000 tons
- Compacted clay cover 453,000 tons
- Growth medium 226,000 tons

4.3 Infiltration

During construction of the ECOSA, the infiltration that will occur is evaluated as follows:

1. <u>End-dumped slopes.</u> Infiltration to exposed end-dumped slopes during construction will be high (estimated at 10" year, twice the revegetated infiltration). The exposed end-dumped area will be maintained at a minimum, and will average approximately 9.1 acres at any time. The infiltration to this face will comprise an average of approximately 4.7 gallons per minute ("gpm") infiltration for the construction period of the ECOSA. This infiltrating water will be retained in the overburden material, and will provide approximately 2% of the water required for the overburden to reach field capacity (7.5% by volume).
2. <u>Wheel-compacted surface.</u> The upper surface of each lift will be wheel compacted, and will retain, shed, and evaporate precipitation in a manner similar to reclaimed surfaces. Infiltration is therefore expected to be approximately 5" per year, the same as the reclaimed infiltration. The average exposed upper surface during the construction of the ECOSA is computed to be approximately 63 acres. The infiltration to this surface will comprise an average of approximately 16 gpm for the construction period of the ECOSA. This infiltrating water will also be retained in the overburden, and will contribute approximately 7% of the water required for the overburden to reach field capacity.

3. Reclaimed surface. All surfaces are to be progressively reclaimed after placement of overburden and completion of the cover. The material that is replaced on the surface is the more plastic of the material that was borrowed from beneath the footprint of the ECOSA, and compacted to approximately 95% of optimum density. Accordingly it is expected to exhibit no more infiltration than occurred through the surface material before it was borrowed, processed, and compacted to form the cover for the overburden. Soil testing (Attachment 2) indicates that the material with a PI of >15% exhibits a hydraulic conductivity when compacted of approximately $<5x10^{-7}$ cm/sec (<0.5 ft/yr). Infiltration through this material would be limited as follows (assuming that the surface were saturated for the entire year):

   Infiltration = K I < 0.5 ft/yr * 1 ~ 5"/yr

   where: K = hydraulic conductivity of the material (0.5 ft/yr)
   I = hydraulic gradient (assumed to be unity, representing vertical gravitational flow)

   As the ground surface is frozen for a significant portion of the year, and is not saturated for a significant portion of the rest of the year, the infiltration through this material cannot be greater than approximately 2.5" per year, half the average infiltration of 5" for the Cripple Creek Mining District in general (ABC, 2008), and half the maximum infiltration rate restricted by the low permeability of the reclaimed cover.

   During the 6 years of construction of the ECOSA (currently estimated to be approximately 2011-2016), the average reclaimed area is approximately 71 acres, and the average infiltration through the reclaimed area is approximately 9 gpm. This infiltration during construction contributes approximately 4% of the water required for the overburden to reach field capacity.

After reclamation of the ECOSA (estimated to be complete in approximately 2016) the moisture content of the overburden will be approximately 14% of field capacity. The infiltration that will enter the reclaimed facility after reclamation is computed to be approximately 22.6 gpm. This infiltration will take approximately 50 years to satisfy the remaining 80 million cubic feet of field capacity. After this time, flow from the base of the ECOSA is anticipated begin at a rate of up to 22.6 gpm.

4.4 Sulfide Oxidation

Sulfide within the ECOSA will react with available oxygen and other oxidants, locally producing acid and mobilized metals. The amount of sulfide oxidation that could occur in the ECOSA is controlled by the limited access of oxygen to the overburden due to the low permeability clay cover.

Oxygen can enter the overburden pile by up to four routes (Table 5):

1. Emplacement. Oxygen is contained in the atmosphere of the ECOSA at emplacement. The total oxygen mass that is emplaced is approximately 3,624 tons, which can oxidize a like mass of pyrite.
2. Airflow through Dry Cover. In the event that the ECOSA cover was to desiccate, airflow through the permeable cover materials would be the principal method of oxygen passage from the atmosphere to the overburden. Based on "breathing" of the pile under varying barometric

conditions and consumption of oxygen within the pile by sulfide oxidation, it is conservatively estimated that an equivalent airflow through the reclaimed ECOSA cover would occur at a rate of approximately 130 tons per year, and would oxidize a like mass of pyrite.

3. Diffusion through Wet Cover. In the event that the ECOSA cover were to remain at or close to saturation (which is expected), the principal method of oxygen passage from the atmosphere to the overburden would be by gaseous diffusion. The mass flux of oxygen through the cover by diffusion, assuming no airflow through the cover, is approximately 175 tons per year. This oxygen would oxidize a like mass of pyrite.

4. Oxygen Transport by Infiltrating Water. After reclamation it is anticipated that approximately 22.6 gpm of water will infiltrate through the ECOSA cover materials. This water has the potential to have up to approximately 10 mg/L of oxygen dissolved in it. The maximum oxygen flux that can be transported to the overburden by this means is approximately 0.5 tons/year, which is a negligible component of the total.

The total average oxygen flux through the cover is computed to be approximately 295 tons/year.

4.5 Pyrite Availability

The reactive pyrite content of the ECOSA overburden is expected to be approximately 1.33% (ABC, 2008). In the approximate 66 million tons of overburden this computes to a total of approximately 878,000 tons of pyrite. At the rate of consumption of pyrite of approximately 177 tons per year (Table 5), it will take approximately 5,000 years for all the reactive pyrite in the ECOSA to be consumed.

4.6 Carbonate Neutralization

The acid and metals liberated by sulfide oxidation in the ECOSA overburden are bought into immediate contact with carbonates in the overburden, which are present at a concentration of approximately 1.43% $CaCO_3$. In the 66 million tons of overburden, this computes to a total of approximately 943,800 tons of calcium carbonate. At the rate of consumption of calcium carbonate of approximately 295 tons per year (Table 5), this carbonate will provide neutralization for approximately 3,200 years.

In the event that this entire inventory within the ECOSA were to be consumed, the ECOSA is located over approximately 1,000 ft of diatremal material, with a minimum of approximately 1.43% $CaCO_3$. This inventory of neutralization provides additional neutralization protection for approximately 20,000 years at the sulfide generation rate of the ECOSA. This is more than enough to neutralize the remaining approximate 1,800 years of sulfide oxidation products that may not be internally neutralized within the ECOSA.

In the unlikely event that despite this large excess of neutralization, acidic water was to emerge from the base of the ECOSA, it would be at a very low flux rate (equivalent to approximately 2.5 inches per year). Accordingly, this acidic water would be expected to move vertically downward and then south to the main Cripple Creek Diatreme, from wich it would ultimately flow through the Carlton Tunnel to Four Mile Creek. The water from the ECOSA would be bought into contact with an overwhelmingly large quantity of neutralizing rock over that approximately 9 mile journey (ABC, 2008). Neutralization of any acidic products from the ECOSA is therefore assured by the geochemistry of the rock that comprises the potential flowpath.

4.7 Neutralization Products

Contact and neutralization of water containing the products of pyrite oxidation with natural calcite has been tested (ABC, 2008), and causes the following (Table 9):

- Increases the pH of the water from ~3 units to ~8 units
- Increases alkalinity from essentially zero to >100 mg/L
- Eliminates acidity
- Increases total dissolved solids concentration to ~3,000 mg/L
- Decreases Al, As, Cd, Cr, Fe, Mn, Ni, and Zn, most to close to detection
- Leaves Cu, Pb, Hg, and Se essentially unchanged, but generally at low levels
- Increases Mo, Sb, Sr and U due to the presence of these constituents in the natural calcite

The water quality resulting from neutralization of the products of oxidation of overburden material is substantially the same as the quality of water emerging from the Carlton Tunnel (Table 6). Accordingly, no impact is anticipated as a result of neutralized pyrite oxidation water generated within the ECOSA.

5. CONSTRUCTION

5.1 Base Construction

The base of the ECOSA will be prepared as follows (Figure 3):

1. Remove approximately 0.5 to 1 ft of soil from entire footprint to stockpile for reclamation (estimated quantity 290,000 cubic yards - Table 4).
2. Excavate clayey gravel material from identified borrow area for use as underliner for the VLF Phase 5 Extension (approximately 1.5 million tons) and for use in construction of the cover for the ECOSA facility (approximately 1.9 million tons). Place material in a clay stockpile off the ECOSA footprint.

The material that will form the base of the ECOSA will be left in an ungraded and roughened state, to maximize the holding capacity of the surface for meteoric water that will infiltrate through the overburden. This will maximize the extent to which this water will enter the diatremal rock beneath the ECOSA, and will prevent direct flow from the toe of the overburden.

5.2 Overburden Placement

5.2.1 <u>Lift Construction</u>

Following preparation of the base of the pile, overburden will be placed as follows (Figure 4):

1. Placement by end dumping in 50 foot lifts.

2. Upper surface of each lift grading to the south at a minimum of 1%.
3. Upper surface of pile wheel compacted by traffic during placement.

5.2.2 Face Construction

At the completion of each overburden lift, the face will be constructed as follows (Figure 5):

1. Face inter-bench slope flattened to 2.5:1 to allow cover placement and erosion control.
2. Construct 10' drainage benches located on contour at the toe of each 50' lift.
3. Slope drainage benches to each side of facility at 1% ± 0.5% grade, to facilitate drainage of water off face of overburden storage area.
4. Provide rip-rap lined end-drain, to conduct water from slope drains to Grassy Valley (Figure 4).

5.3 Cover Construction

Following completion of the placement and shaping of the overburden, a cover will be constructed on the upper surface of the overburden storage area, as follows:

1. Place 24" thick layer of clayey sand and gravel in a single lift. Material is to be borrowed from clay borrow area, and selected to have PI not less than 15%. Remove boulders >24" diameter, and proof roll surface to provide a base for placement of compacted clay layer.
2. Place 12" thick layer of clayey sand and gravel in a single lift. Material to be borrowed from clay borrow area, selected to have PI not less than 15%, and screened to remove all material >2" nominal diameter. Compaction shall be to 95% of optimum.
3. Place 6" layer to act as growth medium.

5.4 Revegetation

Following placement of the growth medium, the overburden storage area will be progressively revegetated as follows:

1. Seed cover material with CC&V standard reclamation seed mix.
2. Plant tree seedlings per CC&V standard tree planting protocol.
3. Fertilize and if necessary water seeded areas to initiate growth.

6. REFERENCE

ABC, 2008. *Cresson Project Hydrogeochemical Evaluation.* Report prepared for Cripple Creek & Victor Gold Mining Company by Adrian Brown Consultants, Inc., in support of Amendment No. 9, Office of Mined Land Reclamation Permit M-80-244. Dated April 4, 2008.

TABLES

Table 1 - Cresson Mine Precipitation

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOT
1992	0.04	0.12	1.67	0.31	3.28	3.84	2.10	3.13	0.17	0.31	0.80	0.41	**16.18**
1993	0.24	0.47	0.97	0.48	2.11	1.07	1.38	2.21	2.78	2.11	1.23	0.14	**15.19**
1994	0.71	0.00	1.20	2.49	5.17	1.63	1.88	6.32	2.18	2.15	0.78	3.06	**27.57**
1995	1.36	0.85	2.69	2.62	4.03	3.72	2.92	4.36	2.72	0.23	0.30	0.16	**25.96**
1996	1.98	0.15	0.60	1.30	1.99	1.85	3.23	2.97	1.43	0.70	0.30	0.28	**16.78**
1997	0.17	0.80	0.50	1.03	2.01	3.78	2.45	3.60	1.59	0.21	0.71	0.31	**17.16**
1998	0.31	0.79	0.85	0.16	0.09	0.06	10.47	5.40	0.88	0.12	0.00	0.00	**19.13**
1999	0.00	0.86	0.15	5.44	2.81	1.97	5.95	4.10	0.91	1.39	0.28	0.12	**23.98**
2000	0.74	0.53	2.25	1.02	1.83	2.04	2.92	5.26	0.50	0.91	0.40	0.47	**18.87**
2001	0.41	0.64	1.50	1.21	2.53	1.68	4.06	6.68	0.52	0.07	0.98	0.20	**20.48**
2002	0.45	0.80	0.74	0.23	1.50	0.73	3.76	1.20	1.48	1.65	0.28	0.05	**12.87**
2003	0.20	1.49	2.43	1.01	1.83	3.18	2.71	3.60	1.25	0.64	0.36	0.26	**18.96**
2004	0.78	0.62	0.75	3.03	0.49	4.02	4.08	3.40	0.91	0.70	0.43	0.17	**19.34**
2005	0.80	0.73	1.19	1.52	0.71	1.53	2.29	4.50	1.48	0.41	0.58	0.52	**16.26**
2006	0.46	0.33	1.57	1.19	1.16	1.17	5.40	5.11	1.35	2.21	0.38	0.67	**21.00**
2007	1.94	0.90	2.33	2.08	4.06	1.58	4.01	3.91	1.54	0.46	0.23	*0.45*	**23.49**
Avg	**0.66**	**0.63**	**1.34**	**1.57**	**2.22**	**2.12**	**3.73**	**4.11**	**1.36**	**0.89**	**0.50**	**0.45**	**19.58**
% Tot	**3%**	**3%**	**7%**	**8%**	**11%**	**11%**	**19%**	**21%**	**7%**	**5%**	**3%**	**2%**	**100%**

Notes:
1. Data taken from Bateman Station at the mine office unless noted below.
2. DMR data from Guffey, CO station used for 1/92 through 6/94; Florissant Fossil Beds used for 2/92.
3. Hunter's Data used for 5/98 and during power outage at Bateman in 4/99 and 5/99.
4. 11/00 data from Carlton Security, 12/00 through 5/01 data from Security Office ("Rigi")
5. Guffey station data used for 10/95, 11/95, 12/95, 2/96, 3/96, 4/96, 5/96
6. NOAA data used for 3/97
7. Belfort rain gauge at Bateman Stations used for 6/98.
8. Storm water sampler (Sigma 900 Max) gauge used for 7/98 and 8/98.
9. 2000 data are average of Rigi and Bateman, except Nov and Dec 2000 are only Rigi
10. 2001 data are average of Rigi and Bateman (Pad), except June-September based on Bateman
11. 2002 and 2003 data are from Bateman
12. 2004 data are average of Bateman and Rigi
13. 2005 and later data are from Rigi
14. Data in italics are fill for the year based on monthly average.

Table 2 – Cresson Mine Area Evaporation

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1994	2.23	2.30	3.01	3.35	4.43	6.54	6.00	4.58	4.27	3.01	2.29	2.13	44.14
1995	1.96	2.58	2.78	2.90	3.30	5.12	6.32	5.68	3.63	4.37	3.09	2.11	43.84
1996	2.29	2.72	2.97	4.12	6.12	5.32	5.57	5.09	3.33	3.61	3.07	2.08	46.29
1997	2.23	1.57	3.01	2.71	3.90	5.20	5.48	4.14	3.96	3.57	2.20	1.71	39.68
1998	2.29	1.54	2.66	3.56	3.85	10.45	6.85	4.40	2.58	2.24	0.55	2.37	43.34
1999	2.38	3.09	3.62	3.47	5.00	6.59	5.79	4.78(1)	4.58	3.90	3.18	2.08	48.46
Avg	**2.23**	**2.30**	**3.01**	**3.35**	**4.43**	**6.54**	**6.00**	**4.78**	**3.73**	**3.45**	**2.40**	**2.08**	**44.29**

Notes:

(1) The reported evaporation in August 1999 was 18.88"; this value is omitted, and the average August value used for tabulation

(2) Source: Amendment No. 8, Office of Mined Land Reclamation Permit M-80-244. CC&V, March 2000.

Table 3 - Surface Water Flow in Grassy Valley

Month	GV-1 (gpm)	GV-2 (gpm)	GV-3 (gpm)
Jan	0.0	0.0	0.0
Feb	*0.0*	*0.0*	*0.0*
Mar	13.4	13.8	17.0
Apr	53.7	20.3	1.0
May	17.8	61.9	78.9
Jun	49.1	54.2	143.4
Jul	0.3	11.5	8.2
Aug	20.8	37.9	92.9
Sep	1.6	15.8	11.2
Oct	0.0	3.9	11.1
Nov	0.0	1.6	0.0
Dec	*0.0*	*0.0*	*0.0*
Average	**13.1**	**18.4**	**30.3**

Notes:
1. Values in italics are table fillers; no data are available in these months
2. A single reading at GV-2 of 10 gpm in December is considered unreliable; flow has been set to zero
3. The averages are on a monthly, rather than a reading, basis.

Table 4 - ECOSA Quantities

BASIC INFORMATION FROM PLAN

Area	Square Feet	Acres
Planar Area	7,658,402	176
Upper Surface Area	8,148,673	187
Lower Surface Area	7,820,621	180
Volume	**Cubic Feet**	**Cubic Yards**
Volume Contained	1,192,875,943	44,180,590

GROWTH MEDIUM RECOVERY

Material	Volume (cu.yd.)	Weight (ton)
Growth Medium recovered (6")	151,000	226,500

QUANTITIES PLACED

Material	Volume (cu.yd.)	Weight (ton)
Overburden stored	44,000,000	66,000,000
Base Cover (2', proof rolled)	604,000	906,000
Compacted Cover (12")	302,000	453,000
Growth Medium (6", revegetated)	151,000	226,500

CLAY COVER QUANTITIES REQUIRED

Material	Volume (cu.yd.)	Weight (ton)
Base cover	604,000	906,000
Material >2' to waste (10%)	67,000	101,000
Compacted cover	302,000	453,000
Material >2" to waste (50%)	302,000	453,000
Total requirement	1,275,000	1,913,000

Table 5 - Oxygen Availability in ECOSA

Mechanism	Oxygen Flux (ton/yr)	Pyrite Oxidized (ton/yr)	$CaCO_3$ to Neutralize (ton/yr)
Emplacement (1)	1	1	2
Airflow through dry cover (2)(4)	130	130	218
Diffusion through wet cover (3)(4)	175	175	293
Oxygen with Infiltration through cover	0.5	0.5	1
Total System (5)	**177**	**177**	**295**

Notes:

(1) Oxygen assumed to be consumed in approximately 3,600 years (aggregate burn-out time)
(2) Airflow is dominant mechanism for cover that desiccates.
(3) Diffusion is dominant mechanism for cover that retains moisture.
(4) Diffusion and airflow are alternatives; if airflow occurs, diffusion is prevented by concentration equalization
(5) Conservatively assumes that diffusion dominates, which can only occur if airflow through the cover is minimal.

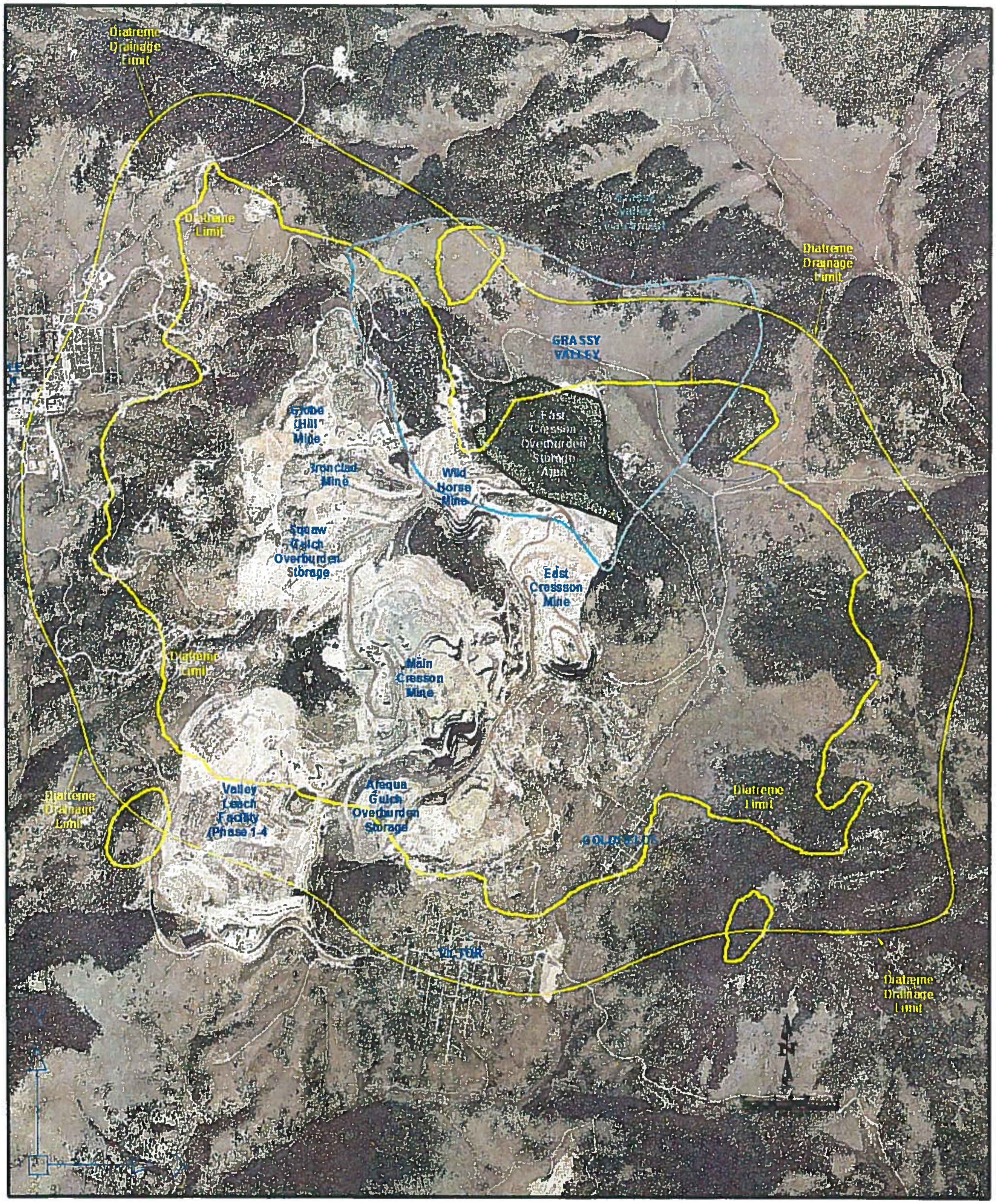
Table 6 - Neutralization Test Results

Species	Unit	HCT Test Water (1)	Calcite-Neutralized HCT Water(2)	Carlton Tunnel Water(3)
pH		3.10	8.04	7.83
SO4	mg/L	435	1685	1250
Acidity	mg $CaCO_3$/L	507	5.4	<25
Alkalinity	mg $CaCO_3$/L	1.0	136	260
TDS	mg/L	608	2805	2220
Al	mg/L	9.8	0.011	<0.1
Sb	mg/L	0.001	0.014	n/a
As	mg/L	0.172	0.001	<0.005
Cd	mg/L	0.029	0.000	<0.001
Cr	mg/L	0.002	0.001	<0.001
Cu	mg/L	0.123	0.172	<0.005
Fe	mg/L	117	0.050	<0.05
Pb	mg/L	0.002	0.002	<0.001
Mn	mg/L	4.544	1.025	0.51
Hg	mg/L	0.00002	0.00007	<0.0001
Mo	mg/L	0.001	0.156	<0.02
Ni	mg/L	0.073	0.016	<0.01
Se	mg/L	0.001	0.005	<0.005
Sr	mg/L	0.1	14.9	12
U	mg/L	0.054	0.211	n/a
Zn	mg/L	0.854	0.024	0.052

Notes: (1) Average of leachate samples from four different HCT tests
(2) Calcite from samples taken from depth in Main Cresson and Globe Hill areas
(3) Data represents median value of approximately 200 water samples taken 1988-2007
(4) n/a indicates "not analyzed"

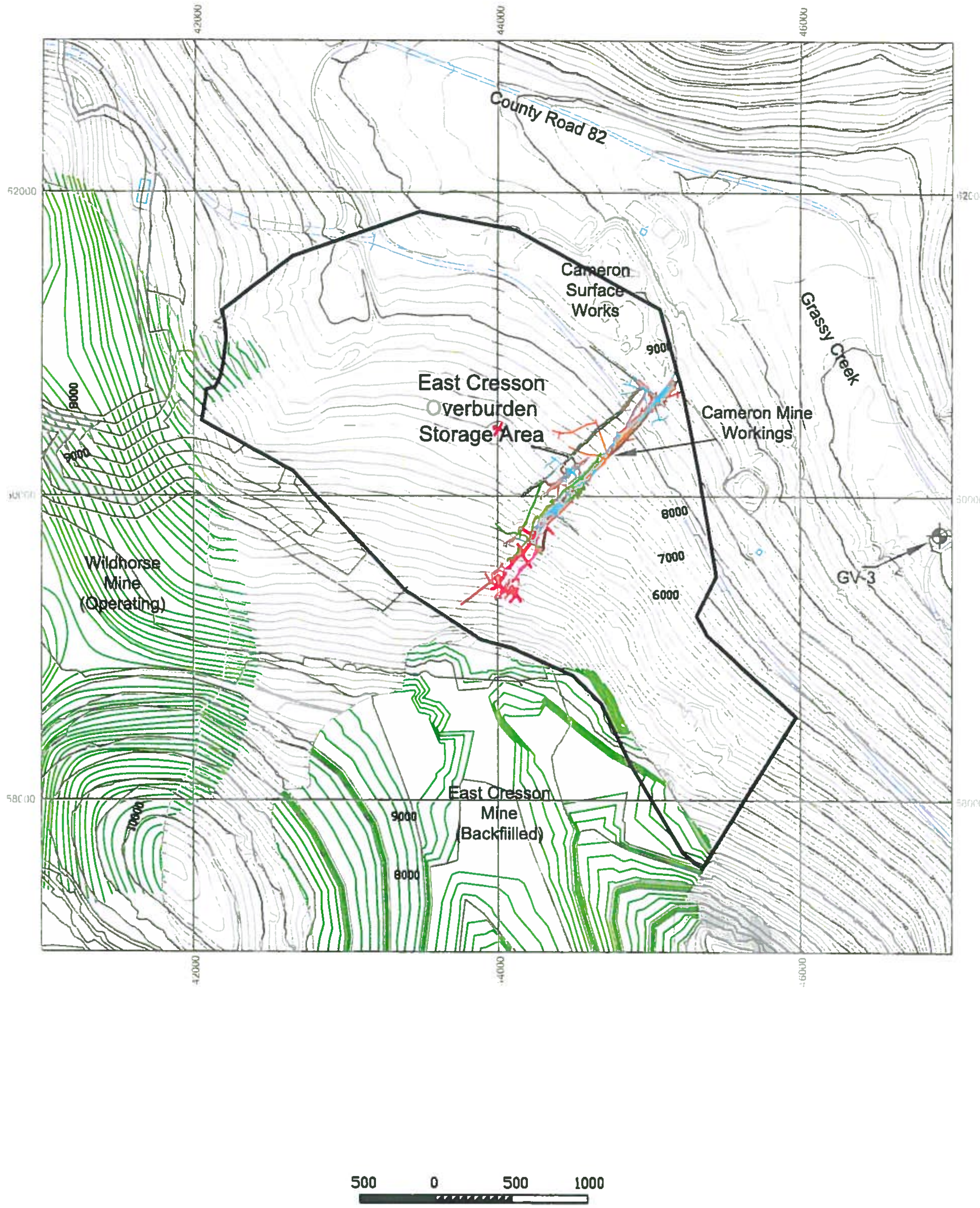
PLATE

Plate 1 – ECOSA Location in Cripple Creek Mining District

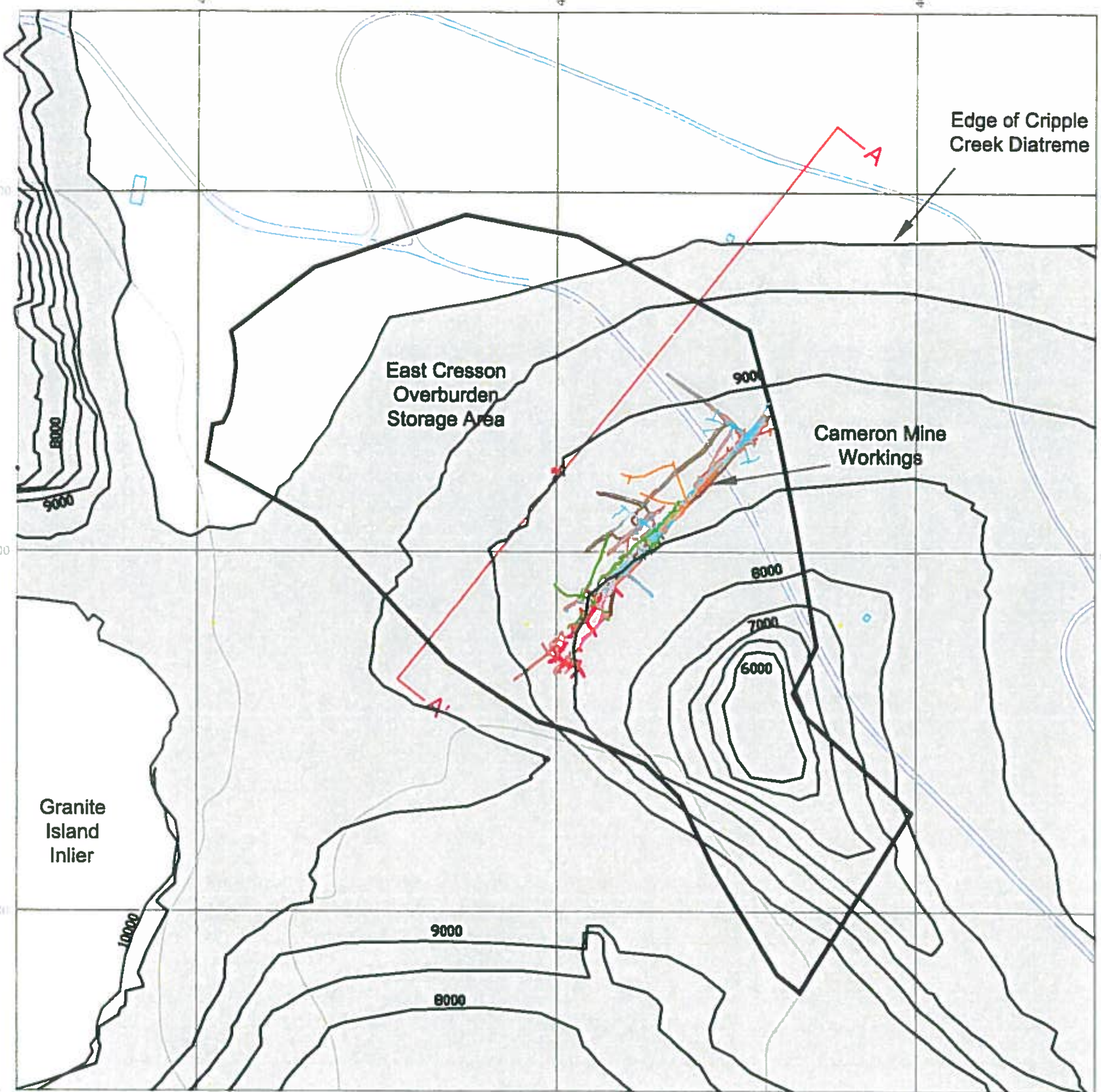


FIGURES

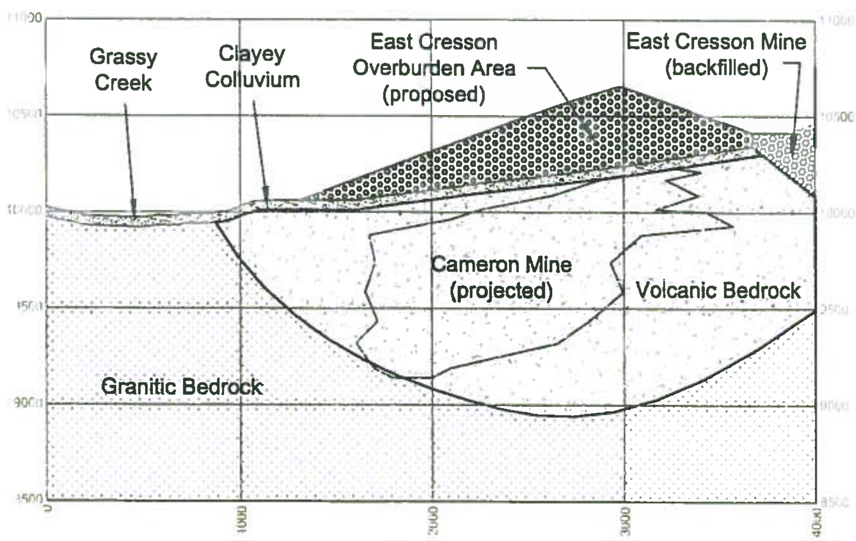
Sample (SWTP-)	Depth (ft)	Description	Cobbles (%)	Gravel (%)	Sand (%)	Silt/Clay (%)	D_{10} (mm)	K (Hazen) (cm/s)	Plastic Limit (%)	Liquid Limit (%)	Plasticity Index (%)	UCS	Optimum MC (%)	Hydraulic Conductivity (5 psi) (cm/s)	Hydraulic Conductivity (20 psi) (cm/s)	Hydraulic Conductivity (40 psi) (cm/s)
2	2	Brown clayey SAND with gravel	0	34.2	43.2	22.6	0.003	9.0E-06	20	33	13	SC				
3	3	Brown silty SAND with gravel	0	36.9	39.1	24	0.017	2.9E-04	30	39	9	SM				
3	9	Brown silty SAND with gravel	0	35.6	50.2	14.2	0.04	1.6E-03	29	48	19	SM				
4	3	Brown poorly graded SAND with silt and gravel	0	31.8	56.6	11.6	0.05	2.5E-03	NP	NP	NP	SP-SM				
4	8	Brown silty GRAVEL with sand	0	53.8	32.4	13.8	0.02	4.0E-04	30	38	8	GM				
5	5.5	Brown clayey SAND with gravel	0	17.6	39.4	43	0.009	8.1E-05	20	30	10	SC				
6	8	Brown clayey GRAVEL with sand	3.1	49.2	22.7	25	0.003	9.0E-06	20	30	10	GC				
7	10	Brown clayey SAND with gravel	0	24.8	54.2	21	0.009	8.1E-05	21	30	9	SC				
8	3.5	Dark brown lean CLAY with gravel	0	14.4	9.3	76.3	0.0001	1.0E-08	16	39	23	CL				
8	3.5	Brown silty GRAVEL with sand	0	46.9	25.8	27.3	0.006	3.6E-05	NP	NP	NP	GM				
8	12	Brown silty clayey GRAVEL with sand	0	46.4	28.3	25.3	0.006	3.6E-05	18	24	6	GC-GM				
10	10	Brown clayey GRAVEL with sand	0	37.3	34	28.7	0.0025	6.3E-06	16	28	12	GC				
12	8	Brown clayey SAND with gravel	0	30.8	32.5	36.7	0.00025	6.3E-08	21	41	20	SC				
15	4.5	Brown clayey GRAVEL with sand	0	44.9	37.4	17.7	0.015	2.3E-04	19	30	11	GC				
17	9	Brown clayey GRAVEL with sand	0	53	33.7	13.3	0.025	6.3E-04	15	24	9	GC				
18	4	Brown clayey GRAVEL with sand	0	53.2	30.2	16.6	0.013	1.7E-04	18	26	8	GC				
23	3	Brown clayey GRAVEL with sand	0	53.5	30.3	16.2	0.02	4.0E-04	18	26	8	GC				
25	6	Brown silty clayey SAND with gravel	0	36.9	40	23.1	0.007	4.9E-05	18	25	7	SC-SM				
27	4	Brown clayey GRAVEL with sand	0	54.3	24	21.7	0.002	4.0E-06	18	29	11	GC				
27	11	Brown clayey SAND with gravel	0	32.6	35.7	31.7	0.003	9.0E-06	16	27	11	SC				
28	6.5	Brown clayey GRAVEL with sand	0	37.6	36.3	26.1	0.0045	2.0E-05	20	31	11	GC				
29	4	Brown silty clayey SAND with gravel	0	41.3	42.4	16.3	0.03	9.0E-04	18	22	4	SC-SM				
30	6	Brown silty SAND with gravel	0	30.5	51.8	17.7	0.035	1.2E-03	NP	NP	NP	SM				
35	3.5	Brown clayey GRAVEL with sand	0	40.8	34.2	25	0.009	8.1E-05	20	31	11	GC				
36	4	Brown clayey GRAVEL with sand	0	38.3	33	28.7	0.005	2.5E-05	14	36	22	GC				
47	3	Brown clayey GRAVEL with sand	3.4	41.6	24.5	30.5	0.0027	7.3E-06	16	39	23	GC				
48	5	Brown clayey GRAVEL with sand	0	50.8	25.5	23.7	0.014	2.0E-04	13	37	24	GC				
53	6	Brown clayey SAND with gravel	0	22	46.5	31.5	0.007	4.9E-05	15	23	8	SC				
56	6	Brown clayey GRAVEL with sand	0	44.3	28.6	27.1	0.0065	4.2E-05	19	29	10	GC				
65	4.5	Brown clayey SAND with gravel	0	28.6	38.7	32.7	0.0075	5.6E-05	17	25	8	SC				
68	8	Brown clayey SAND with gravel	0	28.5	31.8	39.7	0.002	4.0E-06	18	35	17	SC				
70	5	Brown clayey SAND with gravel	0	24.6	35.9	39.5	0.00007	4.9E-09	23	36	13	SC	17.9	1.9E-06	4.0E-07	
71	2	Brown silty clayey SAND with gravel	0	18.8	43.9	37.3	0.003	9.0E-06	18	24	6	SC-SM		2.2E-07		
75	4	Brown clayey SAND with gravel	0	21.9	37	41.1	0.0014	2.0E-06	18	26	8	SC		1.5E-07		
78	4	Brown sandy fat CLAY	0	13.6	18.8	67.6	0.0001	1.0E-08	15	56	41	CH				
79	8	Brown clayey GRAVEL with sand	0	32.5	24.2	43.3	0.0002	4.0E-08	17	40	23	GC				
85	2	Brown clayey GRAVEL with sand	0	34.2	28.8	37	0.001	1.0E-06	18	32	14	GC				
85	7	Brown clayey GRAVEL with sand	0	40	21.6	38.4	0.001	1.0E-06	21	29	8	GC	13.7	7.2E-07		
86	7	Brown clayey SAND with gravel	0	33.5	36.3	30.2	0.0085	7.2E-05	19	27	8	SC				
87	10	Brown silty SAND	0	11.9	61	27.1	0.009	8.1E-05	27	40	13	SM		1.6E-06	6.4E-07	
88	4	Brown sandy SILT	0	1.7	38.8	59.5	0.01	1.0E-04	NP	NP	NP	ML	13.9			
88	10	Brown clayey GRAVEL with sand	0	40.1	27.5	32.4	0.0028	7.8E-06	16	25	9	GM				
89	4	Brown lean CLAY	0	0	2.1	97.9	0.0001	1.0E-08	23	35	12	CL				
91	5	Brown silty SAND with gravel	0	40.8	41.1	18.1	0.025	6.3E-04	26	32	6	SM				
94	8	Brown clayey SAND with gravel	0	23.9	45.1	4.4/26.6	0.0001	1.0E-08	18	45	27	SC		2.4E-07		
96	10	Brown clayey SAND with gravel	0	23	36.5	40.5	0.003	9.0E-06	14	36	22	SC				
98	3	Brown clayey SAND with gravel	0	32.7	40.1	15.0/12.2	0.002	4.0E-06	21	29	8	SC	11	1.0E-05	3.3E-06	
99	12	Brown sandy lean CLAY with gravel	7.3	21.9	23.8	17.1/29.9	0.0002	4.0E-08	21	45	24	CL	15.6	1.2E-05	2.4E-07	
103	14	Brown clayey SAND	0	12.3	64.5	6.8/16.4	0.0006	3.6E-07	25	40	15	SC	16.9	3.7E-06	2.3E-06	
107	9	Brown clayey SAND with gravel	0	25.7	52	22.3	0.014	2.0E-04	18	26	8	SC				
107	15	Brown poorly graded GRAVEL	25.4	68.3	5	1.3	17.4	3.0E+02	14	23	9	GP				
113	8	Brown clayey SAND with gravel	0	25.6	39	11.7/23.7	0.0005	2.5E-07	17	36	19	SC	13.6	2.1E-08	1.1E-08	
118	0-10	Brown clayey GRAVEL with sand	0	41.5	40	18.5	0.017	2.9E-04	18	29	11	GC				
119	0-10	Brown clayey GRAVEL with sand	0	54.8	32.9	12.3	0.04	1.6E-03	19	35	16	GC				
120	0-10	Brown clayey GRAVEL with sand	0	55.3	30.1	14.6	0.025	6.3E-04	18	34	16	GC				
121	0-6	Brown poorly graded GRAVEL with clay and sand	0	64.5	25.2	10.3	0.07	4.9E-03	19	35	16	GP-GC				
122	0-10	Brown silty GRAVEL with sand	0	55.4	30.4	14.2	0.025	6.3E-04	20	53	33	GM				
123	0-10	Brown poorly graded GRAVEL with clay and sand	0	63.7	26.8	9.5	0.0902	8.1E-03	20	40	20	GP-GC				
BH-1	10	Brown clayey SAND with gravel	0	27.7	54.9	17.4	0.014	2.0E-04	22	34	12	SC				
BH-1	10.5	Brown silty SAND with gravel	0	17.8	65.5	16.7	0.027	7.3E-04	26	34	8	SM				
BH-2	5	Brown silty SAND	0	13.4	42.9	43.7	0.004	1.6E-05	25	33	8	SM				
BH-2	5.5	Brown well-graded sand with silt and gravel	0	40.5	50	9.5	0.0881	7.8E-03	NP	NP	NP	SW-SM				
N.Mine Stpl		Brown clayey GRAVEL with sand	0	36.1	35.9	28	0.0008	6.4E-07	15	34	19	GC	8.9	2.7E-06	1.9E-07	
S.Mine.Stpl		Brown clayey GRAVEL with sand	0	33.3	33.1	33.6	0.0007	4.9E-07	17	30	13	GC	10.5	6.9E-05	3.9E-05	2.8E-05
AVERAGE			**0.6**	**35.1**	**35.7**	**28.7**	**0.3**	**4.7**	**19.3**	**33.0**	**13.7**		**13.6**	**8.5E-06**	**5.8E-06**	**2.8E-05**



Adrian Brown	Scale	1" = 1,000'	East Cresson Overburden Storage Area
	Drawn:	A. Brown 5-Apr-2008	FIGURE 1
Adrian Brown Consultants, Inc. 130 West 4th Ave, Denver CO 303-698-9080	Drawing:	138521-ECOB-50	ECOSA LOCATION PLAN
	File:	\1385_cri\5\4\8	



SECTION A-A'



AdrianBrown Adrian Brown Consultants, Inc. 130 West 4th Ave, Denver CO 303-698-9080	Scale	1" = 1,000'	**East Cresson Overburden Storage Area**
	Drawn:	A. Brown 5-Apr-2008	**FIGURE 2**
	Drawing:	138521-ECOB-50	**ECOSA GEOLOGY**
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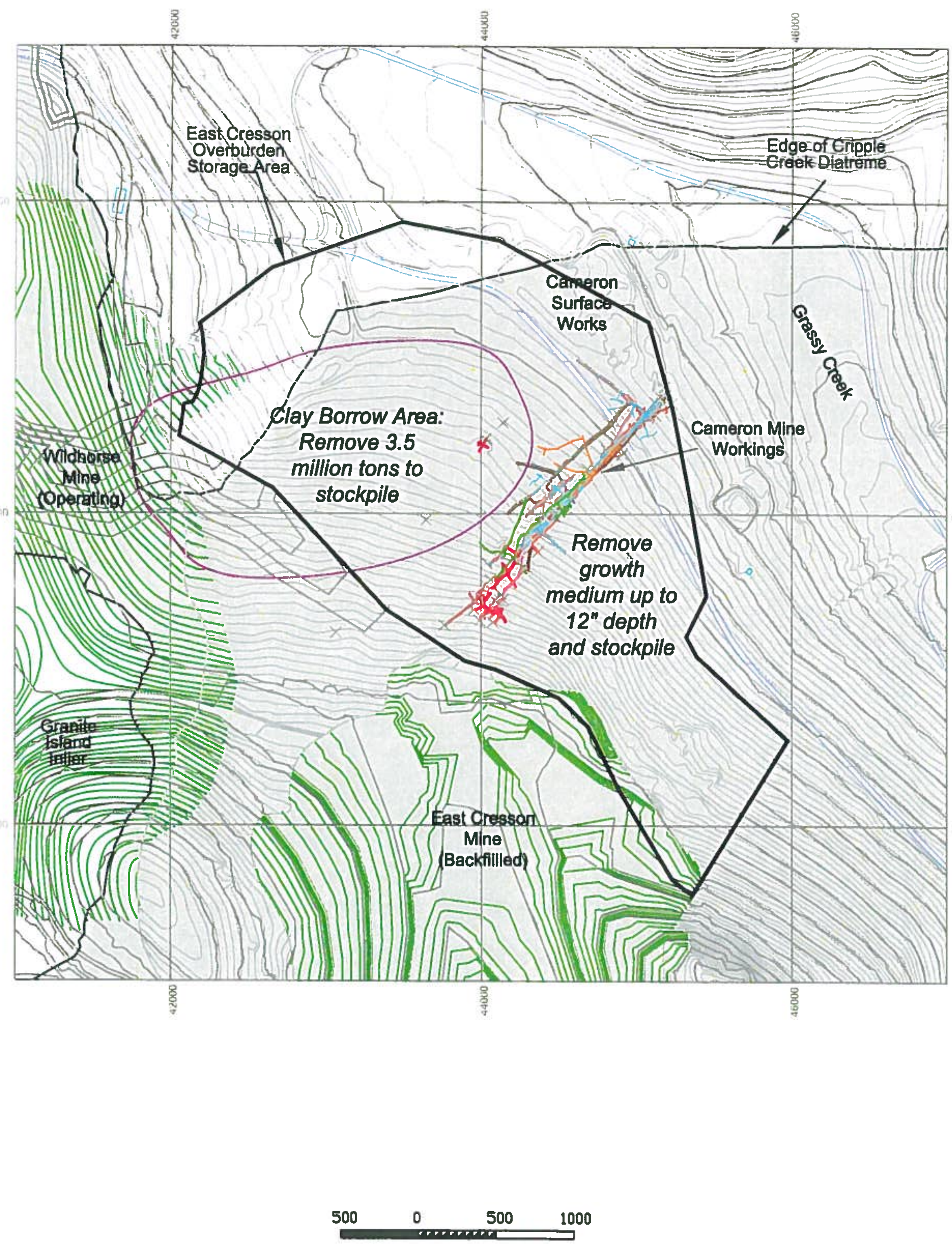

AdrianBrown Adrian Brown Consultants, Inc. 130 West 4th Ave, Denver CO 303-698-9080	Scale	1" = 1,000'	**East Cresson Overburden Storage Area**
	Drawn:	A. Brown 5-Apr-2008	**FIGURE 3**
	Drawing:	138521-ECOB-50	**BASE PREPARATION PLAN**
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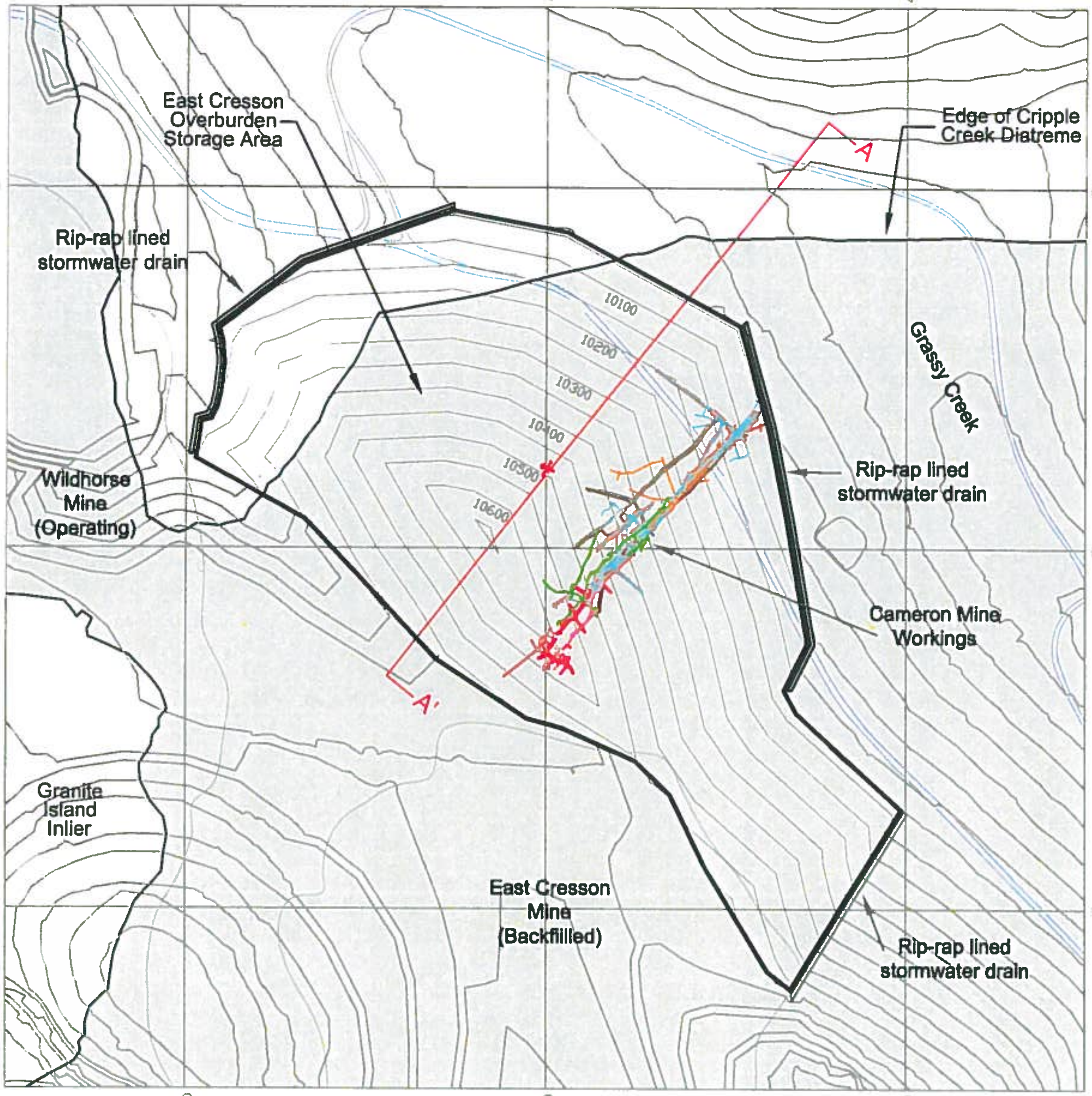
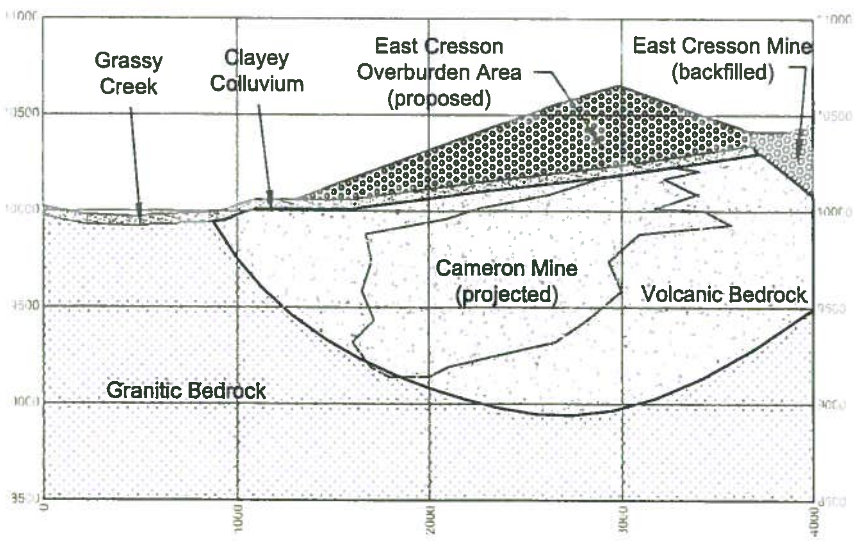


SECTION A-A'



Adrian Brown Adrian Brown Consultants, Inc. 130 West 4th Ave, Denver CO 303-698-9080	Scale	1" = 1,000'	**East Cresson Overburden Storage Area**
	Drawn:	A. Brown 5-Apr-2008	**FIGURE 4**
	Drawing:	138521-ECOB-50	**OVERBURDEN STORAGE PLAN**
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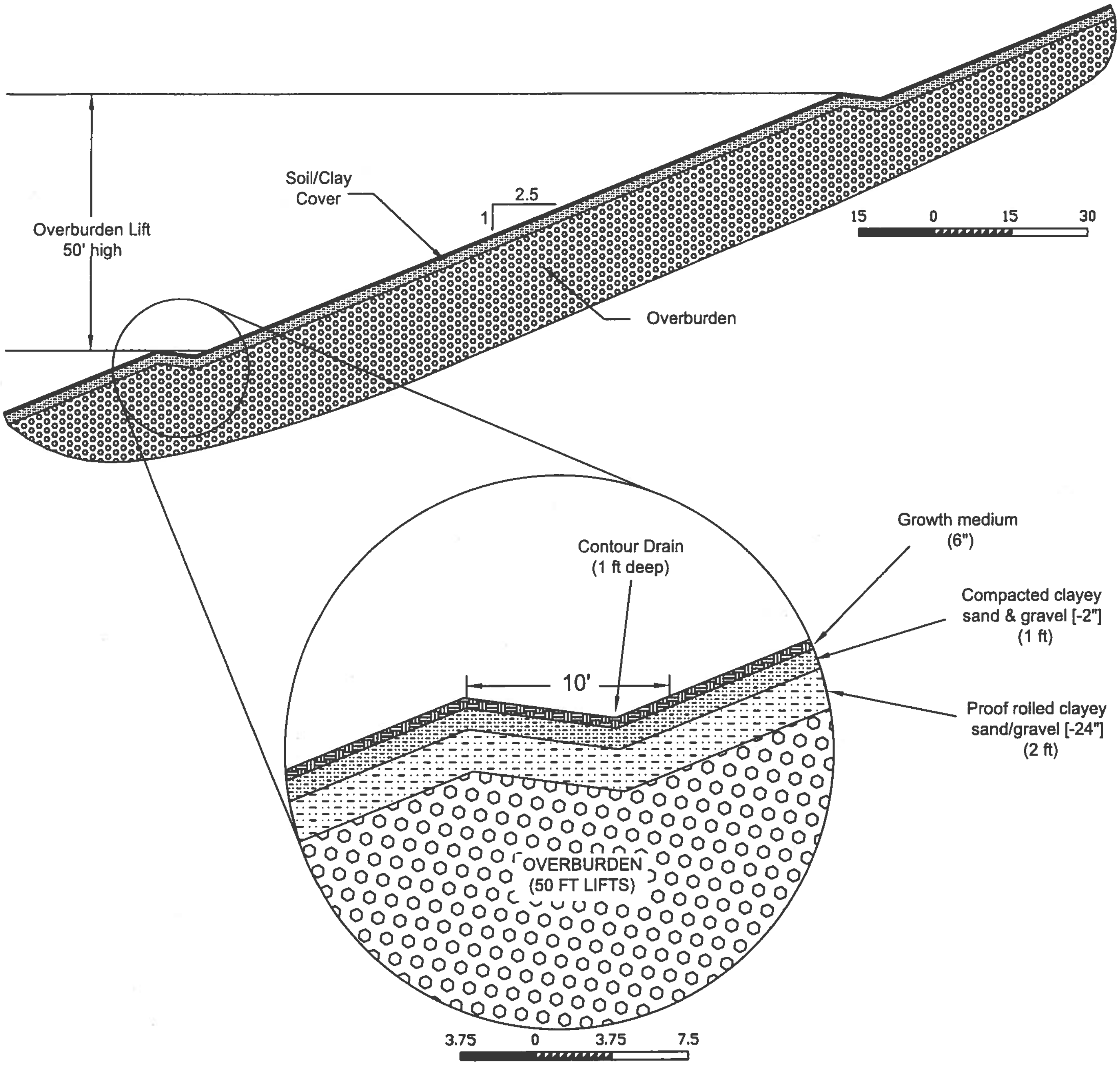

AdrianBrown Adrian Brown Consultants, Inc. 130 West 4th Ave, Denver CO 303-698-9080	Scale	Varies	**East Cresson Overburden Storage Area**
	Drawn:	A. Brown 5-Apr-2008	**FIGURE 5**
	Drawing:	138521-ECOB-50	**SLOPE AND BENCH DETAIL**
	File:	\1385_cri\5\4\8	

ATTACHMENT ONE

DESIGN COMPUTATIONS

1.0 OBJECT

Design the East Cresson Overburden Storage Area.

2.0 QUANTITIES FOR CONSTRUCTION OF ECOSA

BASIC INFORMATION FROM PLAN		
Area	Square Feet	Acres
Planar Area	7,658,402	176
Upper Surface Area	8,148,673	187
Lower Surface Area	7,820,621	180
Volume	Cubic Feet	Cubic Yards
Volume Contained	1.193E+09	44,180,590

GROWTH MEDIUM RECOVERY		
Material	Volume (cuyd)	Weight (ton)
Growth Medium (6")	145,000	217,500

QUANTITIES PLACED		
Material	Volume (cuyd)	Weight (ton)
Overburden stored	44,000,000	66,000,000
Base Cover (2', proof rolled)	604,000	906,000
Compacted Cover (12")	302,000	453,000
Growth Medium (6")	151,000	226,500

QUANTITIES REQUIRED		
Material	Volume (cuyd)	Weight (ton)
Base cover	604,000	906,000
Material >2' to waste (10%)	67,000	101,000
Compacted cover	302,000	453,000
Material >2" to waste (50%)	302,000	453,000
Total requirement	1,275,000	1,913,000

3.0 EVALUATION OF INFILTRATION TO ECOSA

3.1 INFILTRATION DURING CONSTRUCTION

Infiltration to the ECOSA in construction occurs through three different surface types:

1. Infiltration through the reclaimed face of each lift
2. Infiltration through the upper bench surface of each lift.
3. Infiltration through the end-dumped front face of each lift.

Each is considered separately, and the construction infiltration computed as a combination.

3.1.1 Infiltration Through Reclaimed Area

ECOSA has a three-component cover with the following components:

1. Growth medium (6" thick)
2. Compacted clay layer (12" thick, -2", PI>15%, compacted to 95% optimum)
3. Proof-rolled clay base layer (24" thick, -24", proof rolled)

Infiltration rate through the cover is controlled by the hydraulic conductivity of the compacted clay layer.
The hydraulic conductivity of the clay material (<2") has been laboratory tested, as follows:

Hydraulic Conductivity: Clay Borrow Area

Sample SWTP-	Moisture Content (%)	Plasticity Index (%)	Confining Pressure (psi)	Hydraulic Conduct-ivity (cm/sec)
71-2'	14.5	6	5	2.2E-07
75-4'	14.6	8	5	1.5E-07
85-7'	14.7	8	5	7.2E-07
98-3'	11.0	8	5	1.0E-05
70-5'	18.3	13	5	1.9E-06
87-10'	16.0	13	5	1.6E-06
103-14'	16.9	15	5	3.7E-06
113-8'	13.6	19	5	2.1E-08
99-12'	15.6	24	5	1.2E-05
94-8'	13.9	27	5	2.4E-07
98-3'	11.0	8	20	3.3E-06
70-5'	18.3	13	20	4.0E-07
87-10'	16.0	13	20	6.4E-07
103-14'	16.9	15	20	2.3E-06
113-8'	13.6	19	20	1.1E-08
99-12'	15.6	24	20	2.4E-07
GeoMeans	14.9	13.2		6.4E-07
PI>15%	15.1	20.0		3.9E-07

For materials with PI>15%, the geometric mean hydraulic conductivity is 3.9×10^{-7} cm/sec.

The infiltration through the compacted cover is computd from Darcy's Law:

Hydraulic conductivity =	4.0E-07	cm/sec		
Head gradient =	1.0E+00			
Specific discharge when saturated=	4.1E-01	cuft/sqft/yr=	5.0	in/yr
Area =	7.7E+06	sqft		
Maximum infiltration flow rate =	3.2E+06	cuft/yr =	45.1	gpm

The compacted cover is frozen or dry for approximately 5 months of the year.
Based on this flow limitation, the infiltration through the cover is estimated as follows:

Hydraulic conductivity =	4.0E-07	cm/sec		
Head gradient =	1.00			
Specific discharge when saturated=	0.41	cuft/sqft/yr=	5.0	in/yr
Time frozen/unsaturated =	1/2			
Average specific discharge =	0.21	cuft/sqft/yr=	2.5	in/yr
Area =	7.7E+06	sqft		
Maximum infiltration flow rate =	1.6E+06	cuft/yr =	22.6	gpm

3.1.2 Infiltration Through Upper Bench Surface

The upper bench surface is wheel-compacted by truck and equipment traffic.
The surface has significant holding capacity, and significant permeability.
It is expected that this surface will have similar behavior to revegetated areas.
Accordingly, the infiltration rate has been set at 5"/yr, equal to the regional average (Brown, 2008)

3.1.3 Infiltration Through End Dumped Face

The end-dumped face is highly permeable, and accepts any precipitation that falls on it.
It is subject to evaporation of water and wicking, drawing water back to the surface in hot periods.
It is estimated that the infiltration to this surface will be twice the regional average, or 10"/yr.

3.1.4 Summary Of Infiltration Rates

Infiltration:	End dumped face	10	inches/year
	Upper bench surface	5	inches/year
	Revegetated cover	2.5	inches/year

3.1.5 Infiltration To Ecosa

Infiltration to the ECOSA as it is being constructed is computed in the table below.
Three states are considered:

1. Infiltration to the advancing end-dumped face of each lift.
2. Infiltration to the expanding upper surface of each lift.
3. Infiltration to the reclaimed face of each lift.

Total infiltration is computed by summing the three factors.

Overburden Construction by Lift

Elevation	Lift Area (sf)	Face Length (ft)	Lift Volume (cf)	Placed Mass (ton)	Cumul. Mass (ton)	Lift Filled by (year)	Lift Fill Time (year)
10050	1.316E+05	1496	6.581E+06	3.656E+05	3.656E+05	0.032	0.032
10100	1.274E+06	3651	6.372E+07	3.540E+06	3.905E+06	0.345	0.312
10150	2.171E+06	4330	1.085E+08	6.030E+06	9.935E+06	0.877	0.532
10200	2.939E+06	5787	1.469E+08	8.163E+06	1.810E+07	1.597	0.720
10250	3.337E+06	5996	1.669E+08	9.270E+06	2.737E+07	2.415	0.818
10300	3.371E+06	5685	1.685E+08	9.363E+06	3.673E+07	3.241	0.826
10350	3.268E+06	5758	1.634E+08	9.076E+06	4.581E+07	4.042	0.801
10400	3.232E+06	6070	1.616E+08	8.977E+06	5.478E+07	4.834	0.792
10450	2.517E+06	6599	1.258E+08	6.991E+06	6.178E+07	5.450	0.617
10500	1.338E+06	6311	6.688E+07	3.715E+06	6.549E+07	5.778	0.328
10550	6.719E+05	4212	3.359E+07	1.866E+06	6.736E+07	5.943	0.165
10600	2.285E+05	2518	1.142E+07	6.347E+05	6.799E+07	5.999	0.056
10650	4.687E+03	480	2.344E+05	1.302E+04	6.800E+07	6.000	0.001
TOTALS	**2.448E+07**	**58893**	**1.224E+09**	**6.800E+07**			**6.000**

Infiltration During Construction Of ECOSA

Elevation	Face area (sf)	Face Infiltration (cf)	Surface Area (sf)	Surface Infiltration (cf)	Reclaimed Area (sf)	Reclaimed Infiltration (cf)	Total Infiltration (cf)
10050	106828	2872	131630	1769	201965	251099	255741
10100	260737	67861	1274347	165835	492939	580787	814483
10150	309205	137081	2170695	481169	584572	623960	1242209
10200	413201	247995	2938681	881870	781182	716605	1846470
10250	428123	291792	3337141	1137231	809393	604571	2033594
10300	405915	279435	3370671	1160199	767408	441138	1880773
10350	411167	274389	3267521	1090276	777335	317158	1681823
10400	433450	286084	3231653	1066472	819464	199132	1551688
10450	471230	242209	2516678	646778	890888	102011	990997
10500	450678	123114	1337556	182694	852034	39373	345181
10550	300794	41276	671890	46100	568669	6770	94145
10600	179810	8390	228476	5331	339942	81	13802
10650	34269	33	4687	2	64788	0	35
TOTALS	**4205407**	**2002531**	**24481626**	**6865724**	**7950577**	**3882687**	**12750942**

Summary Of Infiltration During Construction Of Ecosa

Infiltration Location	End-Dumped Face	Upper Bench Surface	Reclaimed Surface	Total ECOSA
Average Area (acre)	9.2	63.0	0.0	0.0
Flow rate (gpm)	4.7	16	9	30
Volume (% of total)	1.636E-03	5.609E-03	3.172E-03	1.042E-02
% of field capacity	2.18%	7.48%	4.23%	13.89%

3.3 INFILTRATION AFTER CONSTRUCTION

Infiltration after construction will occur to the entire revegetated pile.

The rate of infiltration and the total infiltration flow will be as computed above for the compacted layer:

Long Term Infiltration

Total surface area of ECOSA	7,658,402	sq.ft.
Infiltration rate after Remediation	2.5	in/yr
Total infiltration flow after remediation	22.7	gpm

3.3 SATISFACTION OF FIELD CAPACITY IN ECOSA

The infiltration that occurs during construction serves to satisfy some of the field capacity of the pile.

Satisfaction of Field Capacity

Total surface area of ECOSA	7,658,402	sq.ft.
Infiltration rate after Remediation	2.5	in/yr
Total infiltration flow after remediation	22.7	gpm
Volume represented by field capacity	91,806,098	cuft
Volume satisfied up to reclamation	12,750,942	cuft
Volume remaining	79,055,156	cuft
Reclaimed infiltration rate	1,595,500	cuft/yr
Additional time to satisfy remaining field capacity	50	yr

4 SULFIDE OXIDATION

Materials placed in the ECOSA contain low concentrations of sulfide, mainly in the form of pyrite.
These materials react with any available oxygen or other oxidizer in the presence of water.
Acid and metals may be released by this process.
The ECOSA materials also contain low concentrations of carbonate, which neutralize these acidic products.

4.1 PYRITE OXIDATION AND NEUTRALIZATION

Pyrite oxidation involves the following overall reaction (if pH <4.5) (Brown and Logsdon, 1990):

$$FeS_2 + 7/2\ O_2 + H_20 = Fe^{2+} + 2\ SO_4^{2-} + 2\ H^+$$

$$CaCO_3 + 2H^+ = Ca^{2+} + H_20 + CO_2$$

Neutralized overall equation:

$$FeS_2 + 7/2\ O_2 + CaCO_3 = Fe^{2+} + Ca^{2+} + 2\ SO_4^{2-} + CO_2$$

Moles of pyrite oxidized by one mole of oxygen =	0.286
Grams of pyrite oxidized by 1 gram of oxygen =	1.071

For oxidized conditions (which we expect overall, by the time the water exits to the stream or diatreme)

$$FeS_2 + 15/4\ O_2 + 7/2\ H_20 = Fe(OH)_3 + 2\ SO_4^{2-} + 4\ H^+$$

Neutralized overall equation:

$$FeS_2 + 15/4\ O_2 + 3/2\ H_20 + 2CaCO3 = 2Ca^{2+} + CO2 + Fe(OH)_3 + 2\ SO_4^{2-}$$

The stoichiometry of the pyrite oxidation and neutralization reactions is as follows:

Moles of pyrite oxidized by one mole of oxygen =	0.267
Grams of pyrite oxidized by 1 gram of oxygen =	1.000
Moles of calcite to neutralize acid from 1 mole of pyrite =	2
Grams of calcite to neutralize acid from 1 gram pyrite =	1.668
Grams of water consumed per gram of pyrite =	0.225

4.2 OXYGEN SUPPLY TO PYRITE OXIDATION

Oxygen is required to support pyrite oxidation.
With the cover in position, the ECOSA overburden is protected from oxygen ingress.
This section evaluates the oxygen supply to the overburden, by a number of mechanisms.

Moles of pyrite oxidized by one mole of oxygen =	0.267
Grams of pyrite oxidized by 1 gram of oxygen =	1.000
Moles of calcite to neutralize acid from 1 mole of pyrite =	2
Grams of calcite to neutralize acid from 1 gram pyrite =	1.668
Grams of water consumed per gram of pyrite =	0.225

4.2.1 Oxidation By Emplaced Air

At emplacement, the overburden has air contained within it.
The oxygen is available to react with the pyrite in the overburden.
The quantity of acid generated, and of carbonate consumed neutralizing it, is computed below:

Emplaced Air Pyrite Oxidation

Emplaced porosity	40%	
Volume of overburden	1.193E+09	cuft
Volume of emplaced air	477,150,377	cuft
Density of air	0.0653	lb/cuft
Mass of air	15589	ton
Oxygen content of air	20.95%	v/v
Oxygen content of air	23.25%	w/w
Mass of oxygen	3,624	ton
Mass of pyrite oxidized	3,624	ton
Mass of $CaCO_3$ to neutralize	6,046	ton
OB carbonate concentration	1.43%	(ABC, 2008)
Carbonate in OB	947,674	tons
Percent of neutralization used	0.64%	
Mass of water taken up	815	tons
Infiltration during construction	397,829	tons
Percentage of infiltration used	0.2%	

Based on this computation, the emplaced air contains sufficient oxygen to oxidize 3,624 tons of pyrite.
The overburden contains a great excess of carbonate to neutralize expected oxidation products.
The reaction takes up a minnimal amount of infiltrating water.
No significant impact is expected as a result of the emplacment oxygen.

4.2.2 Air Entry To Cap

The cover material constitutes a saturated, low permeabilty material overlying the highly porous overburden material.
The cover would be expected to limit "breathing" of the pile due to atmospheric pressure changes.
The limiting mechanism would be capillary tension in the pores of the material preventing air entry to the cap.
This section evaluates the air entry limitation of the clay material.

The permeability of the soil material is controlled by the diameter that 10% of the sample is finer than.
A total of 63 samples of clay borrow were tested for grainsize, with the following result:

Average D_{10}	0.285	mm =	0.000936	ft

The capillary equation is:

p = 2 phi / r

where:
- p = capillary pressure (lb/ft^2)
- phi = surface tension of water in contact with air (0.00498 lb/ft)
- r = radius (0.00047 ft)

Applying the equation:

p =	2 * 0.00498 / 0.00047 =	21.2	lb/ft^2
p =	0.15	psi	

The atmospheric pressure in Cripple Creek is computed from the standard pressure-altitude equation:

Pressure (in. Hg) = 29.921* (1-6.8753*0.000001 * altitude, ft.)^5.2559

http://www.hi-tm.com/Documents/Calib-boil.html

For an elevation of 10,000 feet:

Pressure =	20.58	inches Hg

The maximum sustained pressure change

Max. pressure change =		2.50%	of standard =	0.51	in Hg
	Conversion:	29.921	in Hg =	14.7	psi
Max. pressure change =		0.25	psi =	36.4	psf

This is approximately 1.7 times the air entry value, so on peak days, air will betin to enter the soil.
Thus it appears that capilary tension will not of itself prevent all air entry into the cap due to breathing.
However, for the majority of the time, the pressure differential across the cap is insufficient to cause air entry.
And the air-entry process requires movement of water away from the point of entry, so this is a slow process.
The "breathing" process is cyclic, typically diurnal, but also with longer period variations due to storms.
Accordingly, elevated air pressure conditions exist an insufficient period of time to cause breakthrough.

4.2.3 Air Permeability of Cap

The clay material in the cover is of low permeability.
This section evaluates whether the permeability is low enough to prevent air movement through the cover.

Intrinsic Permeability of the Clay Cover

The intrinsic permeability of the clay cover is computed from the hydraulic conductivity of the clay material.

	K_{cap} =	5.0E-07	cm/s =	5.0E-09	m/s

The equation for computation of the intrinsic permeability is:

	k = (K μ) / (ρ g)		
where:	k = intrinsic permeability		
	K = hydraulic conductivity =	5.0E-09	m/s
	μ = viscosity of water	1.00E-03	N.s/m2
	ρ = density	1.0E+03	kg m-3
	γ = specific weight =	9.8E+03	N m-3
	g = gravitational acceleration	9.80665	m s-2
Thus:			
	k_{cap} =	5.1E-16	m2

Air Density in Cripple Creek

Parameter	Imperial Units		SI Units	
Temperature	F	77	C	25
Elevation	ft	10000	m	3048
Air Density	lb/ft3	0.0506	kg/m3	0.8105

Head Driving Air Flow through Cap

	P = ρ g h			
	h = p / (ρ g)			
where:	P = pressure =		0.147	psi
	Note:	1 psi =	6895	N m-2
	P = pressure =		1014	N m-2
	ρ = density =		0.8105	kg m-3
	g = gravitational accel.=		9.8067	m s-2
Thus:				
	h = p / (ρ g) =	127.5	meters of air	

Airflow Through Cap							
Darcy's Law:							
	v = (k ρ g / μ) dh/dl						
where:	v = specific volume of airflow (flow per unit area) (m3 s-1)						
	μ = viscosity =		1.85E-05	N.s/m2			
	k = permeability =		5.11E-16	m2			
	ρ = density =		0.81053	kg m-3			
	g = gravitational accel.=		9.8067	m s-2			
	dh = head change =		127.5	meters of air			
	dl = airflow distance =		1.0	meter			
Thus:							
	v =	2.798E-08	cubic meters/square meter/second				
Mass Flux through Cap							
The computed mass flux of oxygen through the cap is computed as follows:							
	M = mass flux = A * v * ρ						
where:	M = mass flux of oxygen through cap (tonne/yr)						
	A = cap area =		711,489	sq.m.			
	v = air flux rate =		2.798E-08	m3 m-2 s-1			
	ρ = density =		0.81053	kg m-3			
	Oxygen content =		23.25%	w/w			
Thus:							
	M =	118	tonne/yr =	130	ton/yr		
Conclusion							
Air entry is for dry soil, with air as the only fluid in the porespace.							
In this case the soil is saturated with essentially immovable water.							
Result does not directly apply to saturated, low permeability cover on ECOSA.							
However it does set a limit for the amount of air that could flow through the cover in the event that it dried out.							
This limit is that the maximum airflow through the cover is 118 tonne/yr (130 ton/yr)							
4.2.4 Diffusion Of Air							
Equation							
Fick's first law is used in steady-state diffusion of a gas through a solid.							
In one (spatial) dimension, this is							
	J = -D dϕ/dx						
where							
	J is the diffusion flux in dimensions of [(amount of substance) length-2 time-1]							
	D is the diffusion coefficient or diffusivity in dimensions of [length2 time-1]							
	phi (for ideal mixtures) is the concentration in dimensions of [(amount of substance) length-3]							
Diffusion Coefficient							
The diffusion coefficient in a saturated soil is a function of moisture content:							
	log[Diffusion Coefficient (m2/s)] = 0.32*log[MC (%v/v)]^2 + 1.42*log[MC (% v/v)] - 10.22						
	http://www.ufaventures.com/ufa_ventures/calculator.html#diffusion_coefficient						
For a moisture content of 30%, typical for a clay (not measured in this clay)							
	D =	3.765E-08	m2 s-1				

Oxygen Content

Air Density in Cripple Creek

Parameter	Imperial Units		SI Units	
Temperature	F	77	C	25
Elevation	ft	10000	m	3048
Air Density	lb/ft3	0.0506	kg/m3	0.8105

Concentration of oxygen =		21.0%	by volume		
Concentration of oxygen =		23.2%	by mass		
Thus, for oxygen:					
	ϕ =	0.1884	kg m-3		

If all the oxygen is consumed in the pile, then $d\phi = \phi$

Diffusion

Diffusion of oxygen through the overlying cap is given by Fick's Law:

$J = -D\, d\phi/dx$

where

- J is the diffusion flux in dimensions of [(amount of substance) length-2 time-1]
- D is the diffusion coefficient or diffusivity (3.76E-08 m2 s-1)
- phi (for ideal mixtures) is the concentration (0.188 kg m-3)
- dx = thickness of the cap = 1.0 m

Thus:					
	J =	7.09E-09	kg m-2 s-1		
For the entire cover:					
	Area =	711,489	m2		
	Flux =	5.05E-03	kg/sec		
		159,159	kg/yr		
		159	tons/yr =	175	ton/yr

Diffusion of oxygen through pile

In one (spatial) dimension, this is

$J = -D\, d\phi/dx$

where

- J is the diffusion flux in dimensions of [(amount of substance) length-2 time-1]
- D is the diffusion coefficient or diffusivity in dimensions of [length2 time-1]
- phi (for ideal mixtures) is the concentration in dimensions of [(amount of substance) length-3]

For oxygen diffusing through a nitrogen atmosphere:					
	D =	0.219	cm2 s-1 =	2.19E-05	m2 s-1
	$d\phi$ =	0.1884	kg m-3		
	dx =	23.7	m	(void volume/area)	
Thus:					
	J =	1.74E-03	kg m-2 s-1		
For the entire cover:					
	Area =	711,489	m2		
	Flux =	1.24E+03	kg/sec		
		3.90E+10	kg/yr		
		39,004,702	tonne/yr		

This is so much greater diffusion that the only significant resistance occurs in the cover.

Conclusion

Thus the cover provides significant protection against diffusion of oxygen from the atmosphere to the overburden.
The maximum diffusion that can occur transports 175 tons/year of oxygen to the overburden.

4.2.5 Evaluation of Infiltration Transport of Oxygen to ECOSA

Infiltration to the ECOSA occurs due to precipitation.
This infiltration can transport oxygen to the overburden dissolved in the water.
Law of Mass Action:

$M = C * \rho * Q$

where: M = mass of material transported
C = oxygen concentration in water = 10 mg/L
Q = volumetric flow rate of water = 22.6 gpm
ρ = density of water = 1000 kg m-3

Thus:
M = 0.45 tonne/yr = 0.49 ton/yr

Based on this evaluation, the infiltration of water transports approximately 0.5 tons/year of oxygen to ECOSA.
This is negligible as an oxygen input to ECOSA.

4.2.6 Oxygen Availability

Oxygen availability for the ECOSA is as follows:

Mechanism	Oxygen Flux (ton/yr)	Pyrite Oxidized (ton/yr)	$CaCO_3$ to Neutralize (ton/yr)
Emplacement (1)	1	1	2
Airflow through dry cover (2)(4)	130	130	218
Diffusion through wet cover (3)(4)	175	175	293
Oxygen with Infiltration through cover	0.5	0.5	1
Total System (5)	**177**	**177**	**295**

Notes:
(1) Oxygen assumed to be consumed in 3200 years (aggregate burn-out time)
(2) Airflow is dominant mechanism for cover that dessicates.
(3) Diffusion is dominant mechanism for cover that retains moisture.
(4) Diffusion and airflow are alternatives; if airflow occurs, diffusion is prevented due to equalization of concentration
(5) Assumes that diffusion dominates (conservative).

4.2.7 Pyrite Availability

Pyrite availability for oxidation in the ECOSA is as follows:

Mass of overburden in ECOSA	66,000,000	tons
Reactive pyrite content of overburden	1.33%	(ABC, 2008)
Pyrite in ECOSA	877,800	tons
Rate of consumption of pyrite	177	ton/yr
Time to consume ECOSA carbonate	4,957	years

Based on this assessment, the reactive pyrite in the ECOSA will be consumed in approximately 5,000 years.

4.2.8 Neutralization Availability

Neutralization is available in the overburden located in the ECOSA.

Mass of overburden in ECOSA	66,000,000	tons
Carbonate content of overburden	1.43%	
Carbonate in ECOSA	943,800	tons
Rate of consumption of carbonate	295	ton/yr
Time to consume ECOSA carbonate	3195	years

Based on this assessment, the ECOSA has sufficient neutralization capacity to provide neutralization for sulfide oxidation products for approximately 3,600 years.

In the event that this entire inventory were to be consumed, the ECOSA is located over approximately 1000 ft of diatremal material, with an average of 1.43% carbonate content. This inventory of neutralization provides the following additional neutralization protection:

Area of ECOSA	7,658,402	sq.ft.
Depth of diatreme beneath ECOSA	1000	ft
Volume of diatremal rock beneath ECOSA	7.66.E+09	cu.ft.
Mass of diatremal rock beneath ECOSA	425,466,789	tons
Carbonate content of overburden	1.43%	
Carbonate in ECOSA	6,084,175	tons
Rate of consumption of carbonate	295	ton/yr
Time to consume ECOSA carbonate	20,596	years

This additional neutralizing potential far exceeds that needed to neutralize the entire inventory of products resulting from the oxidation of all reactive pyrite in the ECOSA.

In the event that this acidic water were to emerge from the ECOSA and its environs, it is likely that the very low water flux from the ECOSA that results from the low conductivity, high evapotranspiration cover, will move vertically downward and then south to the main Cripple Creek Diatreme, and thence via Carlton Tunnel to Four Mile Creek. During this approximately 9 mile journey, the water from the ECOSA would be bought into contact with an overwhelmingly large quantity of neutralizing rock (ABC, 2008). Neutralization of any acidic products from the ECOSA is guaranteed.