1CD003.04

INTERIM REPORT ON THE FEASIBILITY OF RECLAIMING VANGORDA PIT AS A CLEAN WATER SYSTEM

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INTERIM REPORT ON THE FEASIBILITY OF RECLAIMING VANGORDA PIT AS A CLEAN WATER SYSTEM

1. INTRODUCTION

Since cessation of mining in January, 1998, precipitation and runoff has been allowed to accumulate in Vangorda Pit. Concentrations of some metals (eg. zinc and cadmium) in the pit lake are currently above permitted levels, and will need to be treated prior to discharge. Based on current filling rates, it is likely that active management of the pit water may be required by 2001 or 2002.

One of the closure options for Vangorda Pit is to return the flow of Vangorda Creek into the pit. The most significant issue associated with this option is whether metal concentration at the outlet of the pit lake would be acceptable for discharge.

At the request of Deloitte & Touche Inc., SRK has completed a detailed evaluation of the pit geochemistry, including:

- field and laboratory investigations of seepage quality, and waste and talus geochemistry (Sections 2 and 3);
- estimates of the current mass load to the pit (Section 4); and,
- dilution modelling to estimate the impact on downstream water quality (Section 5).

The results of this evaluation are presented herein.

2. METHODS

2.1 Field Investigation

Field investigations were conducted on June 6, 2000 and June 29, 2000. The first field investigation included a detailed seep survey, collection of pit lake samples, and collection of waste rock and talus samples. The second investigation involved field testing of the seeps, identification of any new seeps and evaluation of minerology.

On June 6, a total of 12 seeps were sampled in the Vangorda Pit. Samples for dissolved metals were filtered and preserved immediately following sample collection. Samples for "immediates" (pH, conductivity, anions etc) were placed in a cooler following collection, and then refrigerated prior to shipping.

A second set of seep and lake samples was collected by September 9, 2000, following a heavy rainstorm. Samples were placed in a cooler prior to shipping but were not filtered or preserved in the field.

Lake samples were collected from the center of the pit at 2 metres and 12.5 metres depth. The lake samples were collected using a weighted bailer, therefore, some mixing of the water could have occurred, particularly in the deeper sample. Lake profile of temperatures pH conductivity and dissolved oxygen were also measured at three locations.

Waste rock and talus[1] samples were sieved through a 10 mesh screen. A portion of the fines were retained for field rinse pH and electrical conductivity tests. The remainder of the fines were placed in sample bags and shipped to the testing laboratory. The paste pH and conductivity tests were completed at the end of the field sampling program, i.e. within 3 days of sample collection. Approximately 60 mL of fines were mixed with 100 mL of distilled water and allowed to sit for 15 minutes. The pH and conductivity of the resulting solution was then recorded.

[1] Talus is used in this report to describe loose rock occurring on pit walls and pit benches. The source of this rock is assumed to be rock falling from overlying benches, rather than that dumped during mining

Secondary minerals observed at various locations in the pit were collected in plastic jars and retained for mineralogical characterization.

2.2 Laboratory Testing

Seep and lake samples were submitted to ASL Laboratories in Vancouver for analysis of pH, electrical conductivity, acidity, alkalinity, sulphate, and a 30 element ICP scan.

The waste rock and talus samples were submitted to Canadian Environmental and Metallurgical Inc. in Vancouver for solids element analysis, acid base accounting and leach extraction tests. The acid base accounting tests were completed using the modified Sobek method with sulphur speciation. Leach extraction tests were completed on the as-received material at a 20:1 water to solids ratio. The mixture was contacted for a total of 96 hours, then filtered through a 0.45 μm filter. The leachate was submitted for analysis of pH, electrical conductivity, acidity/alkalinity, sulphate, and a 30 element ICP scan.

Secondary mineral samples were submitted to Cominco's Exploration Research Laboratory for XRD analysis.

2.3 Equilibrium Modelling

Equilibrium modelling was used to determine whether the seep and lake samples were at chemical saturation with respect to any secondary minerals. The model simulations were completed in MINTEQA2 Version 3.11 (Allison *et al.*, 1991). The standard MINTEQA2 database was modified to incorporate revised thermodynamic constants presented in Nordstrom *et al.*, (1990).

Simulations were based on the laboratory results, with the modelled pH values fixed at the laboratory pH. Redox couples were specified for iron, manganese and copper. However, since reliable redox data were not available, redox in the model runs was set such that ferrihydrite was below saturation in seeps that were not iron stained, and slightly above saturation in seeps that were iron stained. This approach provided some insight into the speciation of the other redox sensitive metals. However, the results need to be interpreted with some caution, as the stains may not have reflected conditions in the seeps at the time of sample collection. The model output was only used to identify saturated minerals. Therefore, minerals were not allowed to form or dissolve in the model runs.

3. RESULTS

3.1 Water Sampling Results

3.1.1 Seep Samples

The locations of the seep samples are shown in Figure 3.1 and photos 1 to 10, with brief descriptions and field observations provided in Table 3.1.

TABLE 3.1
Descriptions of Seep Sample Locations

		June 6		June 29	
Sample	Description	Field pH	Photograph #	Field pH	Field EC
VP-SEEP-1	Rusty seep emerging on upper part of the ramp, below the low grade stockpile area. Flow ~0.5 L/s	4.9	1	5.1	5200
VP-SEEP-2	South wall of main pit, above the In-pit dump. Flow ~0.5 L/s	6.9	2	7.9	480
VP-SEEP-3	Drip face, 2/3 distance down the ramp, east side. Flow ~<0.1L/s	6.8	3	6.5	1700
VP-SEEP-4	Groundwater spring emerging from a drill hole in the center of ramp, about half way between the hairpin turn and the main pit. Water is clear at point of emergence, but becomes iron stained about 5 metres downstream. Flow ~0.2 L/s	5.7	4	5.6	4400
VP-SEEP-5	Drip face on east wall just above Seep 4. Flow is very slow <0.01 L/s.	5.7	5	DRY	
VP-SEEP-6	Groundwater spring emerging in the ditch along the west wall of the slot, below phyllite dump.	5.7	6	5.9	4000
VP-SEEP-7	15 m d/s of Seep 6, upwelling indicates new inflow at this location, but water is mixture of new inflow and Seep 6 water.	5.6	7	5.6	3800
VP-SEEP-8	Small stream flowing from phyllites and carbonaceous phyllites on north wall of pit. Flow ~0.1 L/s	6.2	8	-*	-*
VP-SEEP-9	Fast flowing stream entering pit at location of old Vangorda creek channel. Flow difficult to estimate due to multiple channels, but probably >5L/s.	7.9	na	-*	-*
VP-SEEP-12	Located in Northwest part of pit, accessible by boat. This seep is a side channel of Seep 13, stained with greenish blue ppts. Flow ~0.2 L/s	5.9	9	-*	-*
VP-SEEP-13	Located in Northwest part of pit, accessible by boat only. Main part of channel, rusty stained seepage, with a flow of ~ 2L/s.	3.1	9	-*	-*
VP-SEEP-14	Seep flowing over upper bench of south pit area. Flow ~0.5L/s. Sides of channel covered in precipitates, but main channel is clean massive sulphides.	7.6	10	~3	-

Note: *Seeps 8 to 13 were not accessible on June 29.

Results of the June 6, 2000 seep survey are provided in Appendix A and summarized in Table 3.2. Results of the September 9, 2000 seep survey are provided in Appendix F. The following discussion pertains to the June 6, 2000 samples. However, a comparison of the June and September results indicating the results are reasonably consistent.

Seepage pH's ranged from 3.24 to 7.96, with several of the seeps in the range of 5 to 6. Acidity levels were extremely high in several of the seep samples, and were correlated with high iron, manganese and zinc concentrations. Despite the high acidity, many of the seeps had moderate alkalinity levels, indicating some carbonate buffering is still occurring in this system. Concentrations of cadmium, cobalt, iron, manganese, nickel and zinc were elevated in most of the seeps. Seeps with lower pH also had high aluminum, copper, lead and nickel concentrations.

Seeps can be divided into 5 groups on the basis of their location in the pit, flow characteristics and chemistry.

Seeps on Northwest Wall (Seeps 8, 12 and 13)

All of these seeps are from the northwest part of the pit, and are in contact with phyllites and carbonaceous phyllites. These seeps flow over the pit walls and contact wall rock and talus. Common features of these seeps are that the iron and manganese concentration are relatively low compared to seeps in other parts of the pit. Zinc concentrations ranged from 174 to 196 mg/L, and cadmium concentrations from 0.38 to 0.98 mg/L. MINTEQA2 modelling indicates that seeps 8 and 13 are below saturation with respect to most secondary minerals, suggesting that concentrations are limited by the amount of oxidation products they encounter along their flow paths. Seep 12 is a side channel of Seep 13, and is buffered to a higher pH. Antlerite, jarosite, and malachite were at saturation, and gypsum and celestite were close to saturation. The MINTEQA2 results are summarized in Appendix B.

TABLE 3.2

Summary of June 6, 2000 Seep Survey Results

Parameters	Units	NW Wall			GW Springs			East Wall of Slot			Waste Rock	Fast Flowing	
		SEEP-8	SEEP-12	SEEP-13	SEEP-4	SEEP-6	SEEP-7	SEEP-2	SEEP-3	SEEP-5	SEEP-1	SEEP-9	SEEP-14
Conductivity	umhos/cm	1500	2550	2120	5630	5280	5260	705	3080	9290	7570	246	231
pH	s.u.	6.68	6.01	3.24	5.59	5.04	4.99	6.92	6.99	5.38	3.88	7.96	7.76
Acidity (to pH 8.3)	mg CaCO3 eq/L	293	358	599	2480	2420	2380	59	445	4520	4970	4	13
Alkalinity-Total	mg CaCO3 eq/L	20	11	<1	36	13	13	59	19	20	5	66	101
Sulphate	mg/L	940	1680	1260	5160	4690	4610	324	2370	9910	7690	57	21
Aluminum	mg/L	<0.2	<0.2	24.4	0.4	3.8	3.3	<0.2	<0.2	<1	9	<0.2	<0.2
Cadmium	mg/L	0.38	0.63	0.59	1.06	1.33	1.29	0.04	0.11	2.36	3.55	<0.01	<0.01
Calcium	mg/L	145	388	233	374	407	395	85.1	256	441	392	42.2	37.8
Cobalt	mg/L	0.38	0.98	0.76	4.56	5.48	5.33	0.08	1.47	8.85	8.63	<0.01	<0.01
Copper	mg/L	0.07	18.7	57.2	<0.01	0.08	0.07	<0.01	<0.01	<0.05	24.1	<0.01	0.01
Iron	mg/L	0.05	22.9	35.2	405	539	517	14.4	0.62	337	1090	<0.03	<0.03
Lead	mg/L	0.05	<0.05	0.45	1.4	1.14	1.08	<0.05	<0.05	0.8	1.4	<0.05	<0.05
Magnesium	mg/L	71.1	99.7	67.3	296	313	302	25.5	213	882	497	5.9	9.8
Manganese	mg/L	16.3	8.94	7.88	184	173	166	9.08	128	600	426	0.073	0.007
Nickel	mg/L	0.63	1.79	1.23	2.89	3.51	3.43	0.06	0.86	6.8	6.2	<0.05	<0.05
Potassium	mg/L	2	4	3	9	8	8	2	10	26	<10	<2	<2
Sodium	mg/L	2	4	3	7	8	8	4	6	<10	<10	2	2
Strontium	mg/L	0.828	4.43	1.39	1.16	1.25	1.2	0.402	0.847	1.34	0.83	0.165	0.17
Zinc	mg/L	174	177	196	814	826	804	32.6	258	2300	1670	0.524	0.032

Groundwater Springs on Ramp (Seeps 4, 6, 7)

All of these seeps were located half way down the ramp, and emerged as groundwater springs . This location is known to have seepage for much of the year, including the winter months, as evidenced by the formation of a large ice lens. The presence of winter flows suggests that the water is at least in part from a deeper source of groundwater. This group of seeps had extremely high acidities (>2000 mg $CaCO_3$ eq/L), iron concentrations of >405 mg/L, manganese concentrations of >166 mg/L, cadmium concentrations of >1 mg/L and zinc concentrations in the range of 804 to 826 mg/L. Given the similarity in chemistry, it is likely that these seeps have a common source. However, it is not evident whether that source is exposed materials within the pit, contact with undisturbed sulphides at depth, or some combination of the two. MINTEQA2 modelling suggests that these seeps are strongly reducing, with most of the iron present in its ferrous form. Sulphate is close to equilibrium with gypsum, and concentrations of trace metals are generally below saturation with respect to secondary minerals.

Seeps on East Wall of Slot (Seeps 2, 3, and 5)

These seeps are from various locations along the east wall of the slot. All are slow flowing seeps in intimate contact with the wall rock, which consists of interbedded phyllites and massive sulphides. The seeps appear to originate between the contact of the massive sulphides and the underlying phyllites. However, none can be clearly isolated from the waste rock piled on benches above them. Two of the seeps (3 and 5) were essentially from drip faces, the third (Seep 2) cascaded over the pit wall. The chemical composition of these seeps was variable, with sulphate concentrations ranging from 324 to 9910 mg/L, zinc concentrations from 33 mg/L to 2300 mg/L and iron from 12 from 337 mg/L. This variability reflects the amount and type of rock the seeps are in contact with. MINTEQA2 modelling of the seeps indicates that Seep 5 is in equilibrium with gypsum, Seep 3 is in equilibrium with gypsum and saturated with respect to zinc carbonate and Seep 2 is saturated with respect to zinc carbonate, rhodocrosite, siderite, and jarosite.

Seeps from Waste Rock (Seep 1)

This was the only seep to clearly emerge from waste rock piles. The source of the water was probably the small stream entering the pit above the stockpile area (at Seep-14), which flows into the stockpile pad. Seep 1 had an acidic pH (3.88), and very high iron (1090 mg/L), manganese (426 mg/L), cadmium (3.55 mg/L), cobalt (8.63 mg/L) and zinc (1670 mg/L) concentrations. MINTEQA2 modelling of this seep indicates that it is in equilibrium with gypsum, slightly below saturation with respect to anglesite ($PbSO_4$), and below saturation with respect to all other secondary minerals. This suggests that metal concentrations are limited by the amount of stored oxidation products present along the flow path.

Fast Flowing Seeps (Seeps 9 and 14)

Both of these seeps flowed over competent, unstained massive sulphides. Flow rates in these seeps were relatively fast, and it is likely that the water was flushing away any oxidation products faster than they were being produced. Therefore, the water quality in these seeps reflects the characteristics of the seeps prior to entering the pit, plus some unknown additional contribution from the wall rocks. Both seeps had slightly alkaline pH's, high alkalinities, and low sulphate and metal concentrations. Zinc concentrations were 0.52 and 0.032 respectively. There is some evidence that the chemistry of these seeps may change dramatically when flows decrease. A pH of about 3 was recorded two weeks after these samples were collected. The change may either reflect a lower water to solids ratio caused by lower flows, or flushing of stored oxidation products along the margins of the seeps, which would tend to be flushed when flows in the seep first increase. MINTEQA2 modelling indicates that both seeps are slightly undersaturated with respect to calcite, and well below saturation with respect to most other secondary minerals.

3.1.2 Lake Samples

Profiles of pH, conductivity, dissolved oxygen and temperature were completed in the pit on June 6th and June 29. During both occasions, the pit lake was murky, with a rusty brown appearance. According to site personnel, the pit lake is usually clear and that the murky appearance is a seasonal phenomena (*pers. comm.* Eric Denholm, June 2000). The results of the pit profiles are presented in Figure 3.2. The results indicate that the pit water chemistry changes with depth, with lower pH and higher conductivity at depth. Dissolved oxygen concentrations and temperature are also lower in the bottom of the pit. The implication is that samples collected in the regular monitoring program only reflect the chemistry of the pit lake surface, and do not necessarily provide an accurate indication of the overall pit chemistry, nor of changes in pit chemistry over time.

Water samples were collected at 12.5 metres (Lake-10) and 2 metres (Lake-11) depth. The results are provided in Appendix A and summarized in Table 3. As expected, the deeper sample had higher sulphate and metal concentrations than the shallow sample. Zinc concentrations in the deeper sample were approximately 10x higher than in the surface sample.

Equilibrium modelling of the pit lake water indicates that the deeper samples are at chemical saturation with respect to smithsonite, $ZnCO_3{\cdot}H_2O$ and rhodocrosite. The shallower sample is saturated with respect to $ZnCO_3{\cdot}H_2O$, and close to saturation with $Zn(OH)_2$ and rhodocrosite. Precipitation of these minerals is a likely control on zinc and manganese concentrations in the pit lake.

TABLE 3.3
Summary of Pit Lake Sample Results

Parameters	Units	SEEP-10 (12.5 m)	SEEP-11 (2 m)
Conductivity	umhos/cm	1440	444
pH	s.u.	7.28	7.89
Acidity (to pH 8.3)	mg CaCO3 eq/L	118	12
Alkalinity-Total	mg CaCO3 eq/L	82	66
Sulphate	mg/L	830	166
Aluminum	mg/L	<0.2	<0.2
Cadmium	mg/L	0.08	0.01
Calcium	mg/L	181	54
Cobalt	mg/L	0.41	0.03
Copper	mg/L	0.02	0.02
Iron	mg/L	0.11	0.06
Lead	mg/L	<0.05	<0.05
Magnesium	mg/L	69.7	16.5
Manganese	mg/L	19.7	1.5
Nickel	mg/L	0.41	0.07
Potassium	mg/L	4	<2
Sodium	mg/L	6	2
Strontium	mg/L	1.4	0.51
Zinc	mg/L	70.1	6.27

3.2 Waste rock and Talus Results

3.2.1 Paste Parameters

Descriptions of the waste rock and talus samples are provided along with the field rinse pH and conductivity results in Table 3.4. Sample locations are shown on Figure 3.1.

Rinse pH's ranged from 2.2 to 7.1, and paste conductivities ranged from 450 to >2000 uS/cm, indicating that most of the samples contained a considerable amount of stored oxidation products. There were no apparent differences in the range of rinse pH or conductivity values observed in different types of samples (waste rock versus talus) or different rock types (phyllites versus sulphides).

TABLE 3.4
Sample Descriptions and Field Results

Sample Number	Location	Type	Description	Rinse pH	Paste Conductivity
VP-WR-01	Low grade stockpile area (pad)	Waste rock	Phyllite and massive sulphides	5.7	1900
VP-WR-02	Low grade stockpile area (pad)	Waste rock	Phyllite and massive sulphides	7.1	> 2000
VP-WR-03	Low grade stockpile area (pad)	Waste rock	Phyllite and massive sulphides	6.7	1360
VP-WR-04	North wall of pit	Talus*	Phyllite and carbonaceous phyllite	6	970
VP-WR-05	North wall of pit	Talus	Black phyllite	5.6	450
VP-WR-06	North wall of pit	Talus	Lighter colored phyllites	6.1	690
VP-WR-07	East wall of main pit	Talus	Mixture of phyllites and massive sulphides	5.6	690
VP-WR-08	East wall of main pit	Talus	Weathered sulphides	4.6	1280
VP-WR-09	Northwest wall of main pit	Talus	Carbonaceous phyllites	5.9	1080
VP-WR-10	Northwest wall of main pit	Talus	Till	7.1	> 2000
VP-WR-11	Berm above west wall of pit	Waste rock	Phyllite with white ppts.	4.8	> 2000
VP-WR-12	Dump above southwest side of slot	Waste rock	Phyllites	5.8	1220
VP-WR-13	Dump above southwest side of slot	Waste rock	Massive sulphides (weathered)	5.8	1900
VP-WR-14	Dump inside hairpin	Waste rock	Mixture of dark grey to black phyllite with white ppts.	5.8	> 2000
VP-WR-15	South wall, adjacent to hairpin	Talus	Strongly weathered rusty stained phyllite with some sulphides	2.2	> 2000
VP-WR-16	South wall, adjacent to hairpin	Talus	Weathered carbonaceous phyllites, white ppts.	4.2	> 2000
VP-WR-17	South wall of south pit area	Talus	Phyllite in shear area	3.2	> 2000
VP-WR-18	East wall of south pit area	Talus	Massive sulphides (weathered)	2.3	> 2000
VP-WR-19	Dumped material along west wall of slot	Waste rock	Phyllite	6.4	1640

Notes: Talus is used in this report to describe loose rock occurring on pit walls and pit benches. The source of this rock is assumed to be rock falling from overlying benches, rather than that dumped during mining

3.2.2 Bulk Chemistry

The bulk chemistry results are summarized in Table 3.5, and provided in Appendix C. The results indicate that all of the samples are contain elevated levels of arsenic, copper, iron, manganese, lead, and zinc. Approximately half of the samples had zinc concentrations of greater than 1%.

TABLE 3.5
Summary of Bulk Chemistry Results

Sample	As ppm	Ba ppm	Cd ppm	Co ppm	Cu ppm	Fe %	Mn ppm	Pb ppm	Sb ppm	Zn ppm	S(T) %
VP-WR-1	1870	10	<1	141	2311	14.86	2175	6578	70	14100	14.0
VP-WR-4	635	20	27	78	559	11.09	3995	16200	45	30800	9.32
VP-WR-7	740	20	<1	59	906	12.47	3955	8766	25	12200	7.54
VP-WR-8	515	10	<1	217	4771	26.5	3485	8818	30	13200	19.9
VP-WR-9	140	390	5	15	720	3.57	360	1408	5	2548	0.48
VP-WR-11	345	170	24	32	671	3.99	435	4214	20	3522	1.37
VP-WR-12	635	60	<1	30	336	8.03	1380	2144	15	6260	2.79
VP-WR-14	540	40	4	51	644	8.70	1610	5474	15	10100	4.19
VP-WR-15	1755	70	<1	27	951	11.18	315	6088	25	1858	2.81
VP-WR-16	245	50	<1	56	449	10.15	1660	1678	5	5918	3.18
VP-WR-17	1575	10	1	65	4158	18.7	1090	31900	75	24000	18.5
VP-WR-18	1655	10	<1	289	6696	23.4	255	10300	45	1955	21.2
VP-WR-19	450	50	<1	43	444	8.29	1570	5082	20	10000	3.46

3.2.3 Acid Base Accounting

ABA results are summarized in Table 3.6. All but two of the fourteen samples tested had greater than 1 percent sulphides, and six had greater than 5 percent sulphide. Several of the samples were strongly oxidized, as indicated by the relatively high amounts of sulphate. Neutralization potentials were in the range of -25 to 42 kg $CaCO_3$ eq/tonne. All but one of the samples had negative net neutralization potentials, indicating a potential for acid generation. The single sample (VP-WR-10) with a positive net neutralization potential was a till sample. Carbonate NP's were in the range of 0 to 82 kg $CaCO_3$ eq/tonne, and were correlated with the modified Sobek NP's. However, the actual values were typically 25 kg $CaCO_3$ eq/tonne higher than the modified Sobek NP's. The difference between modified Sobek NP and carbonate NP is likely due to the presence of iron carbonates, which are a source of inorganic carbon, but not a source of buffering in the modified Sobek tests. Iron carbonates (for example, ankerite) were observed in association with massive sulphide.

The acid base accounting results indicate that there is still sufficient NP to provide buffering in most areas of the pit. However, there is a strong potential for acid generation once the NP has been consumed. It is therefore anticipated that the pH of most, if not all of the seeps will tend to decrease over time. This change in pH is expected to have a significant impact on the solubility of metals, and will likely result in increased metal loading to the pit.

TABLE 3.6
Acid Base Accounting Results

SAMPLE	Paste pH	S(T) %	S(SO4) %	AP	NP	NET NP	NP/AP	TIC %	CNP
VP-WR- 1	6.3	14.0	0.30	428.1	16.8	-411.4	<0.1	0.76	63.3
VP-WR- 4	7.5	9.32	0.02	290.6	42.0	-248.6	0.1	0.72	60.0
VP-WR- 7	6.9	7.54	0.07	233.4	19.1	-214.3	0.1	0.52	43.3
VP-WR- 8	4.7	19.9	0.42	608.8	6.0	-602.8	<0.1	0.36	30.0
VP-WR- 9	7.0	0.48	0.10	11.9	9.0	-2.9	0.8	0.23	19.2
VP-WR- 10	7.4	0.35	0.24	3.4	9.8	6.3	2.8	0.13	10.8
VP-WR- 11	5.7	1.37	0.54	25.9	4.9	-21.0	0.2	0.12	10.0
VP-WR- 12	7.3	2.79	0.13	83.1	20.1	-63.0	0.2	0.71	59.2
VP-WR- 14	6.6	4.19	0.48	115.9	23.9	-92.1	0.2	0.66	55.0
VP-WR- 15	2.7	2.81	1.35	45.6	-16.5	-62.2	<0.1	0.01	0.8
VP-WR- 16	5.0	3.18	0.42	86.3	4.4	-81.9	0.1	0.59	49.2
VP-WR- 17	4.0	18.5	1.40	534.4	-21.6	-556.0	<0.1	0.09	7.5
VP-WR- 18	2.9	21.2	1.45	617.2	-25.5	-642.7	<0.1	0.01	0.8
VP-WR- 19	7.0	3.46	0.14	103.8	31.8	-72.0	0.3	0.98	81.7

3.2.4 XRD Results for Secondary Minerals

Secondary mineral precipitates were found in several locations in the Vangorda pit, notably along seepage faces, in cracks and overhanging areas on the pit walls, and as surface coatings on loose rock samples. Five of these secondary mineral samples were submitted for x-ray diffraction (XRD) tests. The results are presented in Appendix D and summarized in Table 3.7.

The results indicate most of the secondary minerals are sulphate salts. The white mineral found throughout the pit was identified as bianchite, a hydrated zinc sulphate mineral.

TABLE 3.7
XRD Results for Secondary Minerals

Sample	Description	Mineral
VP-SALT-1	Green precipitate found in moist crack in massive sulphides	Melanterite ($FeSO_4$)
VP-SALT-2	Ferricrete forming in ditch below Seeps 6 and 7.	Limonite, quartz and mica
VP-SALT-3	White to peach coloured precipitate found on massive sulphides near Seep 14 (and several other location in the pit)	Initially identified as Moorhousite (a hydrated $CoSO_4$). Later ICP scan of solids indicated the dominant cation was zinc. The mineral also matched the pattern for Bianchite ($ZnSO_4.6H_2O$).
VP-SEEP-5	Dark rusty red precipitates at the drip face of Seep 5.	Predominantly Gypsum, with minor quartz.
VP-WR-16	White precipitates associated with the carbonaceous phyllites near the hairpin turn.	As for VP-Salt-3, likely Bianchite ($ZnSO_4.6H_2O$).

3.2.4 Leach Extraction Test Results

The leach extraction test results are presented in Appendix C and summarized in Table 3.8. The results indicate that most of the samples contained a significant amount of stored oxidation products, including sulphate, aluminum, cadmium, calcium, cobalt, copper, iron, lead, magnesium, manganese, nickel and zinc.

Zinc concentrations ranged from 0.679 mg/L to 279 mg/L in the test leachate, which is equivalent to 13.6 to 5580 mg soluble zinc per kg of rock. The highest soluble zinc amounts tended to occur in weathered sulphide and phyllite samples, and were highest in talus samples in the south pit area. However, samples with high soluble zinc loads were distributed throughout the pit, and were found in all types of rock. A breakdown of soluble zinc amounts by area is provided in Table 3.9.

TABLE 3.8

Summary of Leach Extraction Results

Sample	pH	Cond (uS/cm)	Redox (mV)	Alkalinity (mg CaCO3/L)	Acidity (to pH 8.3)	SO_4 (mg/L)	Al mg/L	Cd mg/L	Ca mg/L	Co mg/L	Cu mg/L	Fe mg/L	Pb mg/L	Mg mg/L	Mn mg/L	Ni mg/L	K mg/L	Sr mg/L	Zn mg/L
VP-WR- 1	5.9	693	298	5.3	36.0	395	<0.2	0.09	112	0.09	<0.01	<0.03	0.26	21.1	6.6	0.12	5	0.372	19.7
VP-WR- 4	6.4	279	282	15.3	7.5	128	<0.2	0.02	43.6	<0.01	<0.01	<0.03	0.14	6.3	0.092	<0.05	<2	0.387	4.76
VP-WR- 7	6.3	149	292	8.3	8.0	59	<0.2	0.01	20	0.01	<0.01	<0.03	<0.05	3.2	1.2	<0.05	<2	0.13	4.31
VP-WR- 8	4.3	477	276	0.0	81.0	262	<0.2	0.03	30.8	0.12	0.01	16.7	3.71	12	42.2	0.11	<2	0.107	28.1
VP-WR- 9	6.6	207	250	8.8	3.0	96	<0.2	0.01	26.1	<0.01	<0.01	<0.03	<0.05	8.4	0.109	<0.05	<2	0.214	0.812
VP-WR- 11	6.1	924	322	2.5	87.0	591	<0.2	1.0	151	0.66	0.1	<0.03	0.28	27.4	5.48	0.83	<2	0.262	48.4
VP-WR- 12	6.8	397	262	15.3	2.5	188	<0.2	<0.01	58.3	0.01	<0.01	<0.03	<0.05	11.9	1.25	<0.05	<2	0.315	0.679
VP-WR- 14	6.5	858	300	9.0	22.0	524	<0.2	0.1	156	0.11	<0.01	<0.03	0.11	30.5	4.24	<0.05	4	0.397	14.5
VP-WR- 15	2.7	1549	511	0.0	450.0	591	31.7	0.29	31.6	0.76	4.54	37.4	<0.05	7.5	3.34	0.29	<2	0.037	49.9
VP-WR- 16	5.0	695	395	1.3	39.0	414	<0.2	0.05	103	0.23	<0.01	0.4	0.24	26.8	20	0.33	<2	0.307	19
VP-WR- 17	3.8	1339	441	0.0	450.0	962	3.8	0.98	110	0.41	3.99	6.85	1.74	37.8	36.1	0.29	<2	0.211	279
VP-WR- 18	2.8	1305	484	0.0	405.0	450	10.1	0.06	4.73	0.26	14.1	112	<0.05	6.5	9.46	0.08	<2	0.014	32.2
VP-WR- 19	6.8	414	343	13.8	3.5	210	<0.2	0.01	55.7	0.02	<0.01	<0.03	<0.05	27	0.842	<0.05	<2	0.25	2.17

Cadmium concentrations were high (>0.1 mg/L) in only three of the samples, indicating cadmium may not be present in all areas of the pit. However samples with high levels of soluble cadmium did not correlate with those that had elevated concentrations of cadmium in the solids.

Concentrations of the other metals tended to be highest in the low pH samples, particularly WR-15 and 17 and 18, which were all from wall rocks in the south pit area. It is possible that these rocks are in a more advanced stage of oxidation than rocks in other parts of the pit as a result of natural weathering and leaching of the carbonates prior to mining.

TABLE 3.9
Soluble Zinc and Cadmium by Area

Area	Samples	Water Soluble Zn (mg/kg)	Water Soluble Cd (mg/kg)
Overall Average	All	775	4.1
NW Wall	4, 9, 11, 19	281	5.2
E Wall	7, 8	324	0.4
S Pit Dumps	1, 12, 14	233	1.3
S Pit Walls	15, 16, 17, 18	1901	6.9

Notes: Loads are arithmetic mean of all samples within the area. The overall average is an arithmetic mean of all of the samples, and is not weighted by area.

4. MASS LOAD ESTIMATES

This section of the report presents several different estimates of the annual zinc and cadmium loading entering the pit under current conditions. The intention of the calculations is to show the magnitude of metal load that is entering the pit lake under current conditions. Zinc and cadmium were selected because ratios of the current pit water metal concentrations to receiving water quality criteria were highest for these metals, indicating they are the parameters most likely to impact receiving water quality. In addition, these metals are relatively soluble under circum-neutral pH conditions, and are therefore more mobile in the environment

4.1 Seep Sample Estimates

Seep samples are considered one of the most representative source of data for estimating metal concentrations in runoff entering the pit lake. Loads are estimated as follows:

$$L_M = C_M \, x \, MAR \, x \, A$$

Where:

L_M = metal load (kg)
C_M = metal concentration in seeps (mg/L)
MAR = mean annual runoff (206 mm/yr, see Section 5.1.2)
A = catchment area (m^2).

The simplest form of this calculation is to use average concentrations measured in the seep survey (604 mg/L Zn and 0.95 mg/L Cd) and apply these to runoff from the entire pit catchment area of 80 ha. The resulting loads are shown in Table 4.1.

TABLE 4.1
Estimated Annual Metal Load from Vangorda Pit
Based on Average Seep Survey Data and Runoff from Entire Catchment

Parameter (M)	C_M (mg/L)	L_M (kg/yr)
Zn	604	99,600
Cd	0.95	160

It is possible that some of the runoff entering the pit from undisturbed areas in the old Vangorda creek catchment and from above the south pit area is channelized by the time it enters the pit, and is therefore only in contact with a small portion of the pit rock. The undisturbed area represents approximately 42 hectares, or 52% of the pit catchment. In addition, water falling directly on the pit lake does not contact the pit walls, and therefore does not contribute to the loading. As of June, 2000, the pit lake represented approximately 4.1 hectares, or 5% of the total pit catchment. The metal loading that would result assuming that only water contacting the disturbed area within the pit (34 ha or 43% of the catchment area) is contributing to the load is shown in Table 4.2.

TABLE 4.2
Estimated Annual Metal Load from Vangorda Pit
Based on Average Seep Survey Data and Runoff from
the Disturbed Catchment Only

Parameter	C_M (mg/L)	L_M (kg/yr)
Zn	604	42,300
Cd	0.95	66

The average seepage concentrations used in the above calculations are strongly influenced by the high concentration seeps entering the pit from the south pit area. As a further refinement, area weighted calculations were also completed. The pit was divided into three areas, as shown in Figure 4.1. Area 3 includes two distinct groups of seeps: true seeps from the pit walls and waste rock, and groundwater springs. Since the source of these groups cannot be distinguished, Area 3 was arbitrarily divided in half, with seeps representing half the area and springs representing the remaining half of the area. Similar to the previous calculation, this calculation excludes any loading picked up by runoff entering the pit from undisturbed areas. The resulting load distribution is shown in Table 4.3. The calculations show that approximately 92% of the zinc load and 85% of the cadmium load is from the south pit area. Total loading to the pit from all areas is approximately 47,600 kg Zn/yr and 74 kg Cd/yr by this calculation method.

TABLE 4.3
Estimated Annual Metal Load from Vangorda Pit
Based on Area Weighted Seep Survey Data

Area	Seeps	Size (ha)	Zn (mg/L)	Cd (mg/L)	Zn (kg/yr)	Cd (kg/yr)
1. North/West pit walls	12, 13, 8	9.2	182	0.53	3,500	10
2. East pit wall	2	5.7	33	0.040	400	0.47
3a. South Pit (Seeps)	1, 3, 5	9.5	1,409	2.01	27,700	39
3b. South Pit (Springs)	4, 6, 7	9.5	815	1.23	16,000	24
TOTAL		34.1			47,600	74

4.2 Pit Lake Monitoring Data Estimates

A second method of calculating metal loading to the pit is to calculate accumulation of metal load within the pit lake.

Calculations of the annual accumulation are based on the net accumulation over a one year period are completed as follows:

$$\textit{Load Accumulation in 1999} = (C_{1998} \times V_{1999}) - (C_{1998} \times V_{1999})$$

Where:

C is the concentration

V is the volume of the pit lake (m^3).

The calculated loads in 1998 and 1999 are shown in Table 4.4.

TABLE 4.4
Estimated Accumulation of Metal Load in Vangorda Pit

Year	Volume of Pit Lake (m^3)	Zn (mg/L)*	Cd (mg/L)*	Zn Load (kg)	Cd Load
1998	238,000	23.8	0.0505	5,664	12.0
1999	550,000	23.7	0.0453	13,035	24.9
1998 to 1999 accumulation**	312,000			7,371	12.9

Notes: * Average total metal concentration at pit lake station (V22).

** Calculated as difference between 1998 and 1999 amounts

Total accumulation since cessation of mining in January 1998 is calculated as:

$$Total\ Accumulation = V_{June\ 2000} \times C_{June\ 2000}$$

Where:

$V_{June\ 2000}$ = 650,000 m^3 (based on a water level of about 1173 m and the height capacity curve generated by SRK July, 1999),

$C_{June\ 2000}$ = Average dissolved metal concentrations in the pit lake samples collected during the June seep survey.

Total and annual accumulations since January 1998 are summarized in Table 4.5.

TABLE 4.5

Estimated Accumulation of Metal Load in Vangorda Pit

Year	Volume of Pit Lake (m^3)	Zn (mg/L)*	Cd (mg/L)*	Zn Load (kg)	Cd Load
January 1998 to June 2000	650,000	38.2	0.045	24,830	29
Annual Accumulation	-	-	-	9,900	12

Notes: * Average total metal concentration at pit lake station (V22).

A key assumption of this method is that the metals of interest behave conservatively, (i.e., there are no sinks such as chemical precipitation or attenuation within the pit lake). As discussed in Section 3.1.2, the pit is at chemical saturation with respect to zinc carbonates and possibly zinc hydroxides. Therefore, at least part of the zinc load entering the pit is precipitating as secondary minerals. In addition, iron hydroxides were forming in the pit lake. Freshly precipitated iron hydroxides are excellent scavengers for metals, and could be removing zinc, cadmium and other metals from the water column. The implication of non-conservative behavior is that, at best, load calculations based on the pit lake samples provide a lower bound on the amount of metals entering the pit lake.

Another important assumption is that the pit lake samples represent conditions throughout the pit lake. As discussed in Section 3.1.2, concentrations were significantly higher in the bottom of the pit lake. Therefore average concentrations in the pit may also be significantly higher than indicated by the regular monitoring program, and the load calculations would tend to underestimate the amount of zinc accumulation within the pit.

4.3 Extraction Test Estimates

Extraction tests provide a direct measure of the amount of soluble oxidation products contained within a given mass of rock. However, they do not provide a direct measure of the rate of release. Factors controlling the rate of release are the amount of water contacting the rock, the contact time, the kinetics of dissolution, and chemical constraints such as solubility limits. The main purpose of the extraction tests was therefore to provide an indication of the distribution of soluble metals on pit walls and waste rock. As discussed in Section 3.2.5, samples with high zinc loads are distributed throughout the pit, and occur in both waste rock and talus samples.

Although release rates cannot be directly quantified, a calculation of the relative magnitude of stored load on the pit walls was completed. The results of the calculation are presented in Table 4.7. The calculation assumes that a 10 cm thick layer of rock fines is distributed uniformly over the pit area. In reality, the pit benches are covered by very thick accumulations (a few metres) of rock talus, and in pit waste dumps have even greater accumulations. Field observations suggest most of this surface area is in the phyllites and in areas where waste rock has been dumped. Therefore, these results represent a lower bound on the stored soluble metal loads. It is possible that the average thickness could be up to 1 metre thick, which would result in a stored load 10x that presented in Table 4.7.

TABLE 4.7
Estimated Annual Metal Load from Vangorda Pit
Based on Average Extraction Test Data and 10 cm Thick Layer of Fines

	Extraction Test Results (mg/kg)	Total Load to Pit* (kg/yr)
Zn	775	52,800
Cd	4.1	280

Notes: Pit area = 34 ha = 260,000 m^2
Mass of fines/unit area = 0.1 m x 2000 kg/m^3 = 200 kg/m^2
Total mass of fines in pit = 6.8 x 10^7 kg
Load = Extraction Test Results (mg/kg) x Mass of Fines (kg)

Similar to the seep based calculations, an area-based calculation was completed to show the relative distribution of loads. As in the previous calculation, it was assumed that there was a 10 cm thick layer of fines. The results are presented in Table 4.8. As indicated in the table, the majority of the zinc load, and half of the cadmium load can be accounted for by samples from the south pit walls. A significant portion of the cadmium loading can also be accounted for by samples from the northwest pit walls.

TABLE 4.8
Estimated Annual Metal Load from Vangorda Pit
Based on Area Weighted Extraction Test Data and a 10 cm Thick Layer of Fines

Area	Waste Rock Samples	Size (ha)	Zn (mg/kg)	Cd (mg/kg)	Zn (kg/yr)	Cd (kg/yr)
1. North/West pit walls	4, 9, 11, 19	9.2	281	5.2	5,200	96
2. East pit wall	7,8	5.7	324	0.4	3,700	5
3a. South Pit (Dumps)	1, 12, 14	9.5	233	1.3	4,400	25
3b. South Pit (Walls)	15, 16, 17, 18	9.5	1901	6.9	36,300	130
TOTAL		34.1			49,600	260

4.4 Comparison of Estimates

A comparison of the mass load estimates is presented in Table 4.9.

As indicated previously, the estimates that were based on seep data are considered to be the most accurate. Of these, the two estimates that are based on the disturbed area of the pit only are probably the most reasonable.

For reasons discussed in Section 4.2, estimates based on accumulation in the pit lake are considered to be a lower bound on the total load entering the pit. These are approximately $1/6^{th}$ the load estimated from the seepage data.

Estimates based on extraction test data show that the stored load present in a 10 cm thick layer of fines is greater than the estimates of load entering or residing in the pit lake. This is considered to be a lower bound on the total stored load because the actual accumulation of fines is considerably higher.

TABLE 4.9
Comparison of Mass Load Estimates

Calculation Method	Source	Zn Load (kg/yr)	Cd Load (kg/yr)
Seep Samples (Total Catchment)	Table 4.1	99,600	160
Seep Samples (Disturbed Areas Only)	Table 4.2	42,300	66
Seep Samples by Area (Disturbed Areas Only)	Table 4.3	47,600	74
Pit Lake Accumulation (1999)	Table 4.4	7,400	13
Pit Lake Accumulation (1998-2000)	Table 4.5	9,900	12
Extraction Tests*	Table 4.6	52,800	280
Extraction Tests by Area*	Table 4.7	49,600	260

Notes: * Stored load present in each 10 cm layer of fines. Actual accumulations and therefore loads could be much greater.

5. IMPACT ON RECEIVING WATER QUALITY

A dilution model was used to estimate the water quality at the pit outlet and various points downstream of the Vangorda pit, assuming Vangorda Creek is redirected through Vangorda pit. Specific objectives of the model were to:

1) Estimate the maximum possible load that could be generated by the Vangorda Pit while still meeting discharge water quality standards at the outlet of the pit (0.5 mg/L Zn and 0.02 mg/L Cd).

2) Show the impact of the above concentrations at various locations downstream of the mine.

3) Estimate the maximum possible load that could be generated by the Vangorda Pit while still meeting receiving water quality standards at the outlet of the pit (0.03 mg/L Zn and 0.00003 mg/L Cd)

The intent of Objective 1 was to show whether the metal loads estimated in Section 4 of this report would result in metal concentrations at the outlet of the pit that would exceed discharge water quality standards. Discharge water quality standards were selected as the maximum possible discharge concentration that could be tolerated in a flow-through pit option. The intent of Objective 2 was to show the impact of these concentrations on receiving water quality at various points downstream of Vangorda Pit. Because Vangorda Creek is a fish bearing creek, receiving water standards may be a more appropriate criteria for the pit outlet. Objective 3 provides an estimate of the maximum load that would be required to meet these standards.

Details of the dilution model are provided in Appendix E.

The dilution model was set-up to simulate the following scenario:

- the Vangorda Creek Diversion Channel is abandoned and Vangorda Creek is redirected to pass through Vangorda Pit;
- metal loads from the pit are completely mixed with Vangorda Creek waters within the pit lake.

- there is no attenuation of metals within the pit lake. (Although metals are currently being precipitated in the lake, Vangorda Creek is expected to provide sufficient dilution to ensure that metal concentrations will be below chemical saturation.)

- the Northeast Interceptor Ditch is breached so that the complete yield from Subcatchment 2 enters Vangorda Pit;

- all drainage from Vangorda Waste Dump is captured, treated and discharged outside of the Vangorda Creek catchment;

- there is no groundwater bypass from the Vangorda Waste Dump (Subcatchment 4) to Vangorda Creek;

- all drainage from the Grum Pit and most of it from the Grum Waste Dumps (Subcatchment 5) is captured, treated and discharged outside of Vangorda Creek catchment; and,

- there is no groundwater bypass from Grum Pit and the Grum Waste Dumps (Subcatchment 5) to Vangorda Creek.

The results of dilution model are presented in a series of flowsheets.

Figure 5.1 presents the flowsheet representing the average annual water balance for the entire Vangorda Creek catchment. Boxes on the figure symbolize subcatchments. The number in the upper left-hand corner of each box corresponds to the subcatchment number shown on the map of the Vangorda Creek catchment (see Figure E.1). The numbers in the bottom portion of the boxes represent the average annual runoff volume generated by each subcatchment, or group of subcatchments, in units of 1000 m^3. Lines and arrows on the flowsheet depict the movement of water between the subcatchments. Numbers on the lines represent the average annual flow, also in units of 1000 m^3.

With the introduction of Vangorda Creek to the pit, the long-term average flow rate at the outlet of the pit (Box 3) would be about 7886 m^3/year, or 0.25 m^3/s. Flow in Vangorda Creek above Shrimp Creek (Station V27) (Box "6a to 6c") would only be marginally greater at 9111 m^3/yr or 0.29 m^3/s. Flow in Vangorda Creek near its mouth (Station V8) (Box "7a to 7d") is roughly 2.5 times that at the pit outlet, or 0.65 m^3/s.

Figures 5.2 and 5.3 provide the average annual load balances for, respectively, zinc and cadmium. The format of the presentation is similar to that used in the load balance flowsheets, except that the numbers in the lower portions of the boxes and on the left sides of the flow lines represent the average annual metal load generated by the subcatchment in units of kilograms, and bracketed numbers on the right sides of the lines represent the flow-weighted average annual metal concentration in units of mg/L. For all the boxes except Nos. 3 to 5, the quoted values of annual loading represent present-day conditions (see Table E.3). For Boxes 4 and 5, no loading has been estimated as discussed in Appendix E. The loading in Box 3 is a computed value. It represents the maximum possible load that could be generated by the Vangorda Pit and still achieve discharge water quality criteria at the outlet of the pit (0.50 mg/L for zinc and 0.02 mg/L for cadmium).

The results in Figures 5.2 and 5.3 indicate:

- the annual zinc loading generated by the Vangorda Pit would have to be limited to about 3700 kg in order to achieve discharge water quality criteria at the pit outlet;

- the annual cadmium loading generated by the pit would have to be less than 160 kg to meet discharge water quality criteria; and,

- If metal loads from the pit were as high as 3700 kg Zn and 160 kg Cd, (i.e. equal to discharge concentrations), concentrations at Stations V27 (above Shrimp Creek) and V8 (near its outlet at the Faro townsite) would greatly exceed receiving water quality criteria for the protection of aquatic life (0.03 mg/L Zn and 0.00003 to 0.00006 mg/L Cd), and would slightly exceed drinking water quality criteria (0.005 mg/L Cd). As discussed in Appendix E, this analysis ignores any contribution from the Vangorda Waste Dump (Catchment 4) and the Grum Pit and Waste Dump (Catchment 5).

As discussed in Section 4, zinc and cadmium loads were estimated to be in the order of 45,000 and 70 kg/yr respectively, based on seepage data, and 10,000 and 12 kg/yr respectively, based on accumulation within the pit. A substantial reduction in the amount zinc load entering the pit would therefore be required to meet the discharge water quality standards. Even if the loads could be reduced to achieve discharge water quality standards, it is clear that concentrations in Vangorda Creek would still exceed receiving water standards.

A second set of calculations was completed to estimate the zinc loads that could be tolerated while still meeting receiving water quality at the pit outlet. The results indicated that loads would have to be as low as 37 kg Zn to meet receiving standards. These represent load reductions of approximately of 1/1000th of the estimated zinc load to the pit.

A similar calculation for cadmium showed that the present day concentrations are approximately 10x higher than the receiving water criteria. Therefore, even if the cadmium loads from the pit were close to zero, it would not be possible to meet receiving water quality criteria. This is in part an artifact of the detection limits, which also exceed the criteria. However, it is likely that this system is already stressed with respect to cadmium loading, and a small amount of additional load from the Vangorda Pit could be tolerated without impacts to the receiving environment.

6. SUMMARY AND CONCLUSIONS

Results of the field and laboratory investigations indicate:

- Elevated zinc and cadmium concentrations were found in seeps from all areas of the pit, in both the June and September seep surveys.

- Average zinc concentrations in the June seeps within Vangorda Pit were 600 mg/L.

- The pit lake is stratified, with zinc concentrations of 70 mg/L at depth and 6.3 near the surface.

- MINTEQA2 modelling indicates that zinc concentrations in the pit lake are limited by precipitation of zinc carbonate, smithsonite and zinc hydroxide. Freshly precipitated iron oxides may also scavenge metals such as zinc and cadmium from the water column.

- Acid base accounting results indicate that all of the talus and waste rock samples were potentially acid generating, with negative NNP's, suggesting that seepage pH's are likely to decrease in the future. Lower pH's in the seeps could overwhelm the alkalinity in the pit lake, which would likely result in increased acidity and metal concentrations in the pit lake. Such changes could have a marked effect on the effectiveness of any water treatment options.

- Leach extraction tests indicate that soluble zinc is present in both waste rock and talus samples, and is distributed throughout the pit. Samples from the south end of the pit tended to have higher soluble concentrations than samples from the rest of the pit. However, these were found both in the waste rock and pit wall samples.

Mass load estimates presented in Section 4 indicate:

- Mass load estimates based on seep data were on the order of 45,000 kg/yr zinc and 70 kg/yr cadmium

- Mass load estimates based on accumulation in the pit lake were approximately 9,900 kg zinc and 12 kg cadmium. This estimate represents a lower bound on metal loads to the pit because it reflects precipitation and attenuation within the pit. It should be noted that under a flow through scenario, the pit will be sufficiently diluted that these controls will not significantly limit metal loads leaving the pit. In fact, during the first several exchanges of water, the stored load already present in the pit may dissolve and contribute to the load at the pit outlet.

- Mass load estimates based on extraction test data were of sufficient magnitude to support the loads estimated by the seep survey and pit lake accumulation

The dilution model indicates:

- Metal loads would have to be less than 3700 kg/yr zinc to meet discharge water quality standards at the pit outlet. This is approximately 10 times lower than the estimated load entering the pit. Therefore, a reduction of 90% of the zinc load would be required to meet the discharge water quality standards.

- Even if discharge water quality standards could be met at the pit outlet, concentrations at the downstream stations within Vangorda creek would exceed CCME guidelines for receiving water quality.

- Receiving water quality standards could only be met at the pit outlet if the zinc loads were reduced to 37 kg/yr, which represents a reduction of approximatley 1/1000th that of the current estimates. Such a reduction does not appear to be a practical option for the closure of Vangorda Pit.

7. RECOMMENDATIONS

Regular monitoring of the pit lake should be continued on a quarterly basis to ensure any changes in water quality can be picked up. The regular monitoring samples are currently taken from the shore of the pit lake. Samples collected at depth in the pit lake indicate that concentrations in the pit are not uniform. Therefore, it would be preferable to collect a composite sample that represents average conditions within the pit lake. A station should be established in the center of the lake, and a sample composite should be prepared from samples taken from the bottom, middle and top of the profile. A Van Doorn type sampler to isolate these samples would be preferable to the bailer that was used for this study. Samples should be collected for both total and dissolved metals.

Future investigations in the Vangorda Pit should focus on developing alternative management strategies, including treatment of the pit water. Alternative management strategies should consider the possibility of increased acidity and metal loading as the neutralization potential in the pit walls is exhausted.

It is not clear what the current source of alkalinity entering the pit lake is, or whether the alkalinity entering the pit will continue to offset acidity contributed from the seeps. Further investigation is needed, including continued monitoring of the pit lake alkalinity and acidity levels as well as periodic monitoring of seeps and larger streams entering the pit.

Sediment samples from the bottom of the pit, and/or characterization of the suspended sediments in the pit lake could help to confirm whether secondary minerals are forming in the pit.

This report, **1CD003.04, Feasibility of Reclaiming Vangorda Pit as a Clean Water System**, has been prepared by:

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FIGURES

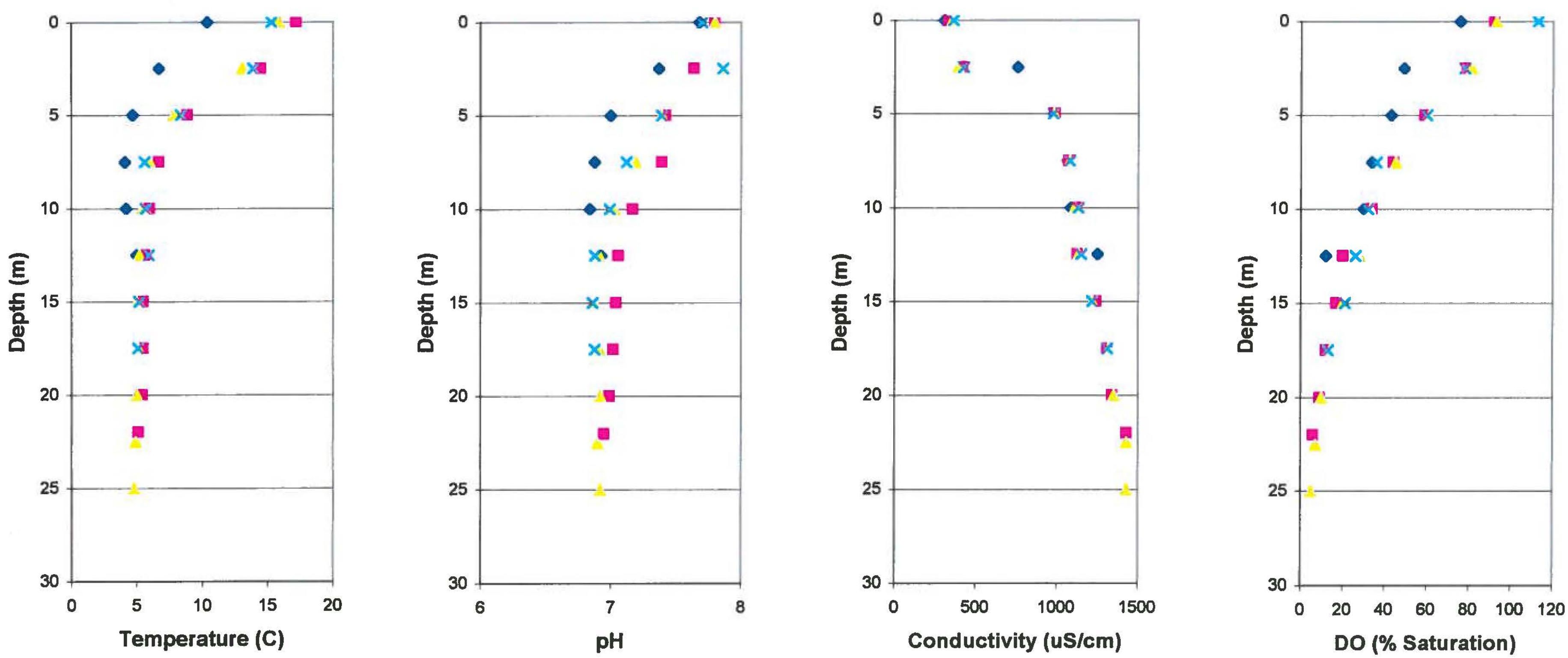
SRK Consulting
Engineers and Scientists

DELOITTE & TOUCHE

VANGORDA PIT GEOCHEMISTRY

VANGORDA PIT
SEEP & WASTE ROCK
SAMPLE LOCATIONS

FILE REFERENCE	PROJECT NO.	DRAWING NO.	REV.
SAMPLE-BASE	1CD003.04	3.1	



Legend

- June 6 - Center of Pit
- June 29 - Center of Pit
- June 29 - South End of Pit
- June 29 - South End of Pit, Near Waste Rock

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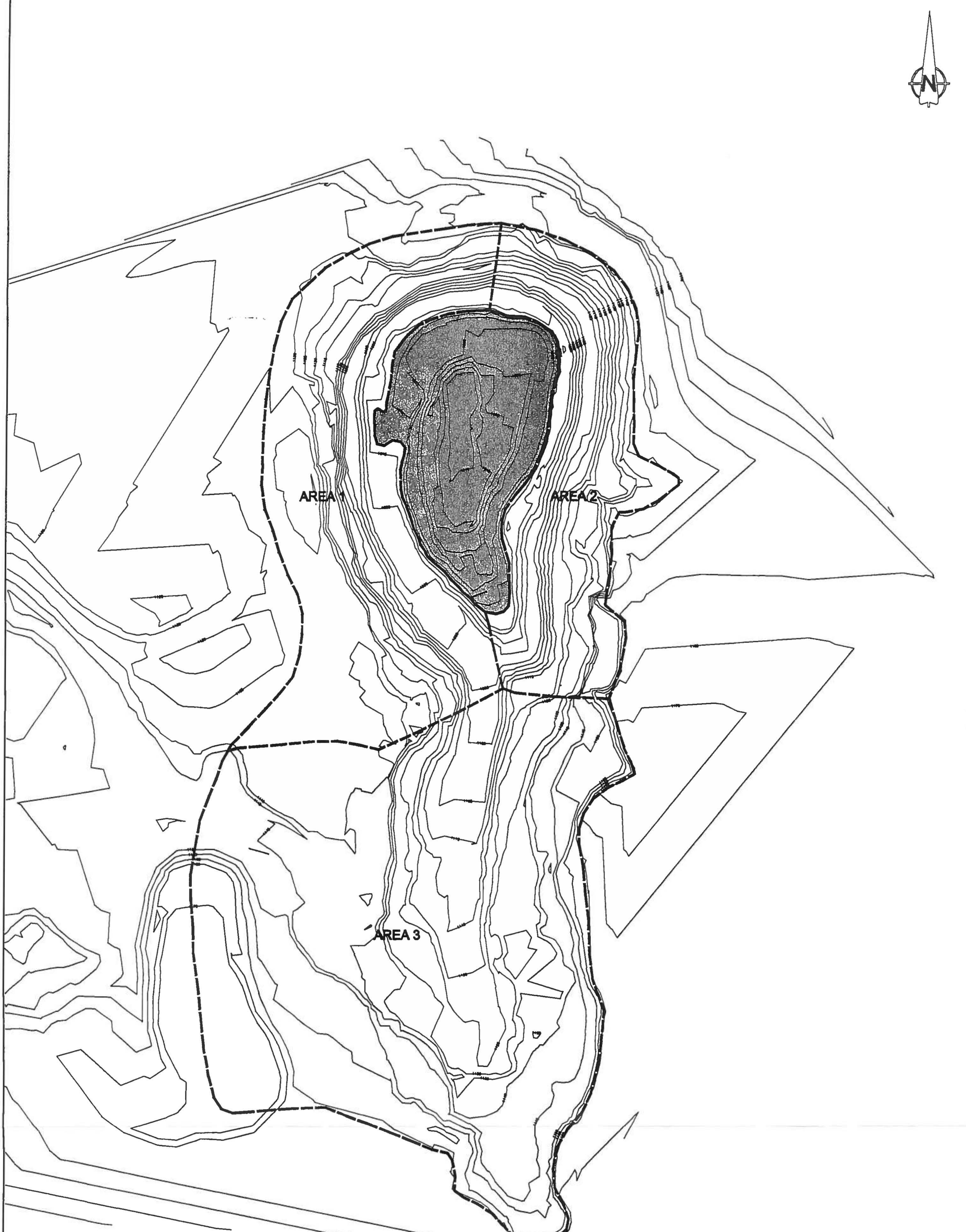
Deloitte & Touche

Vangorda Pit Geochemistry

Pit Lake Profiles

Project	Date	Approved	Figure
1CD003.04	Sept, 2000		3.2



SRK Consulting Engineers and Scientists	VANGORDA PIT GEOCHEMISTRY
	PIT SUB-AREAS
DELOITTE & TOUCHE	FILE REFERENCE: PIT-SUB-AREAS.DWG; PROJECT NO.: 1CD003.04; DRAWING NO.: 4.1; REV.:

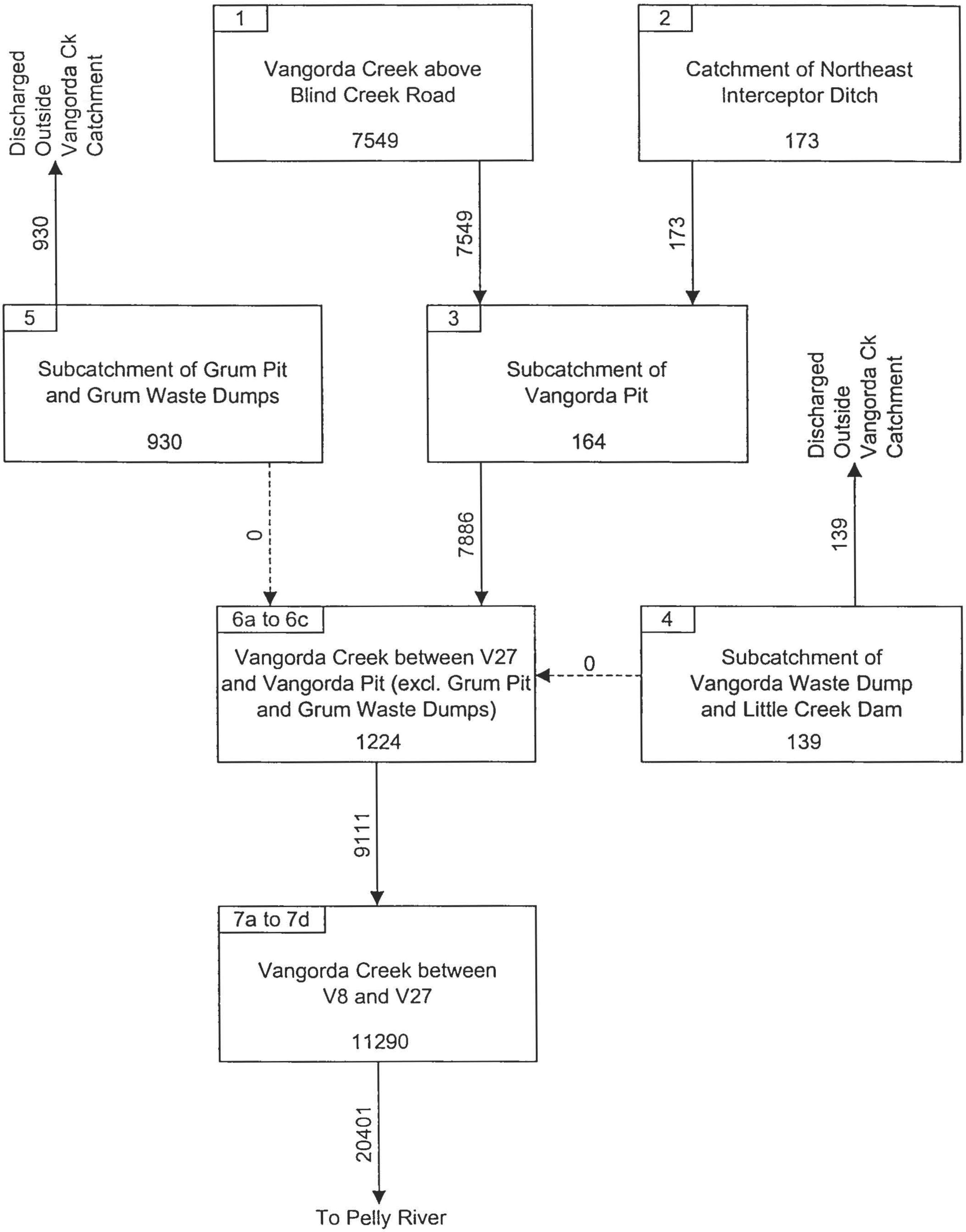


Figure 5.1 Average Annual Water Balance for Vangorda Creek Catchment (1000 m^3)

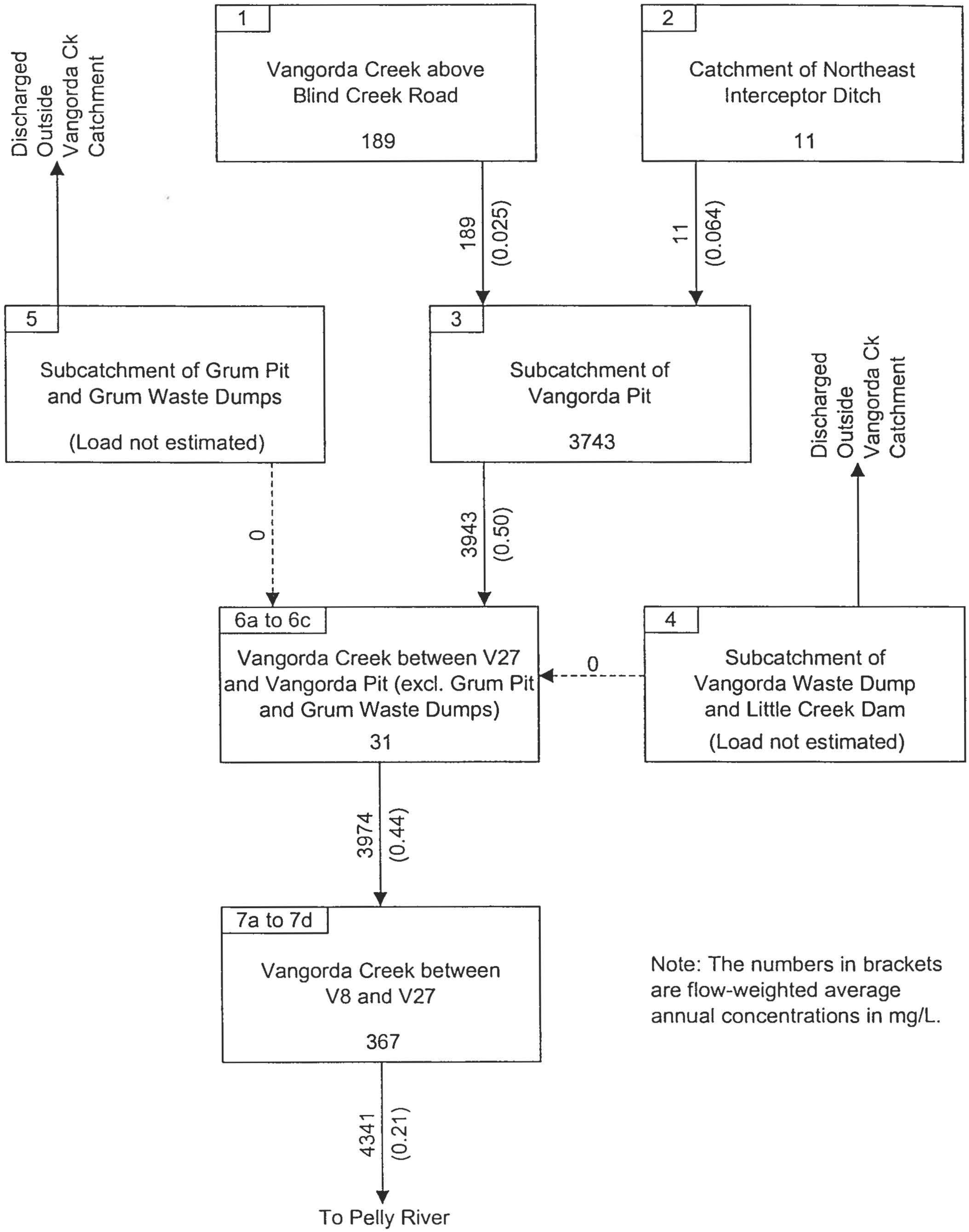
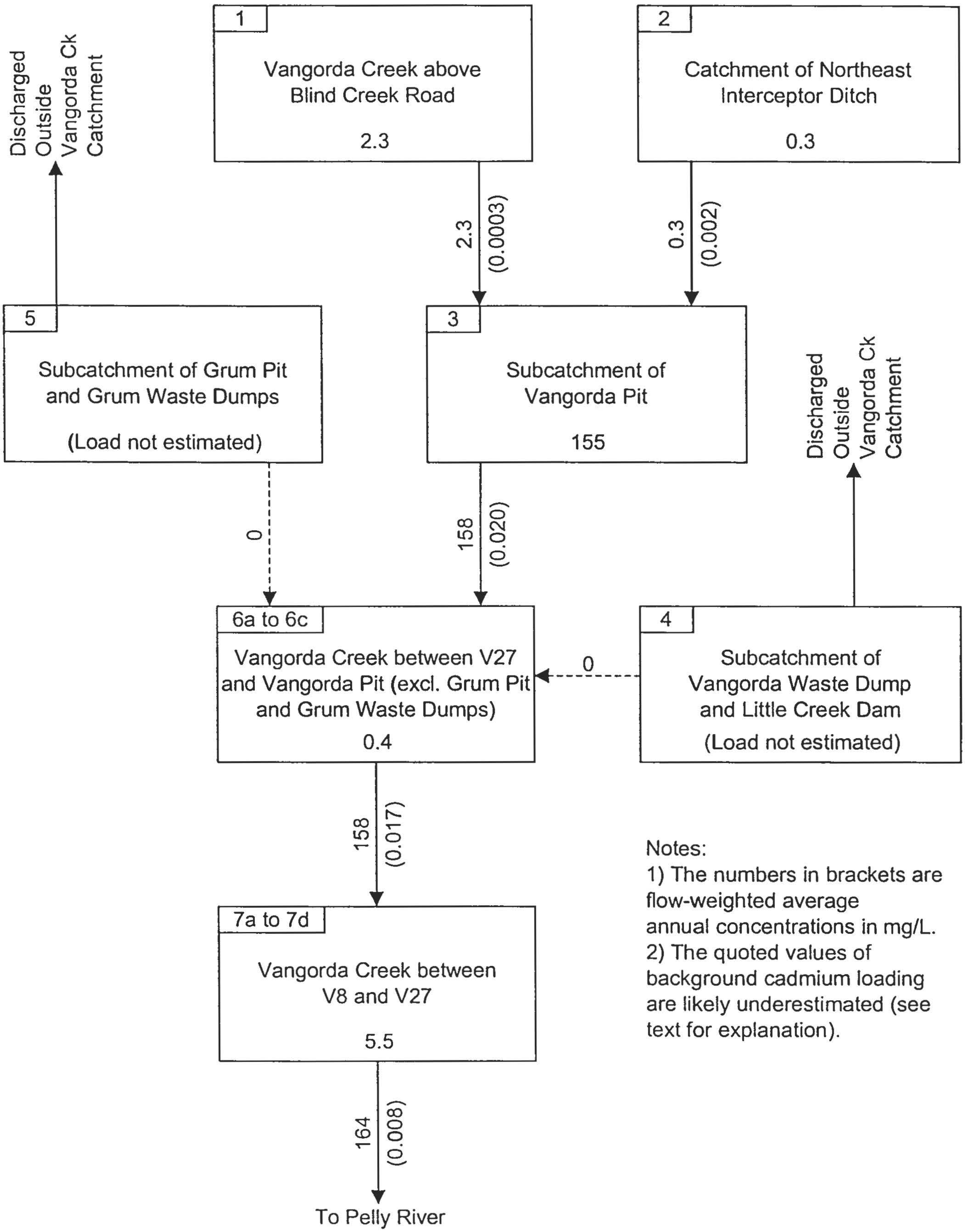


Figure 5.2 Average Annual Zinc (Total) Balance for Vangorda Creek Catchment (kg), with Zinc Concentrations at the Pit Outlet at Discharge Water Quality Concentrations



Notes:
1) The numbers in brackets are flow-weighted average annual concentrations in mg/L.
2) The quoted values of background cadmium loading are likely underestimated (see text for explanation).

Figure 5.3 Average Annual Cadmium (Total) Balance for Vangorda Creek Catchment (kg), with Cadmium concentrations at Pit Outlet at Discharge Water Quality Concentrations

PHOTOS

Photo 1 - VP-Seep 1 - Near top of ramp (below hairpin)

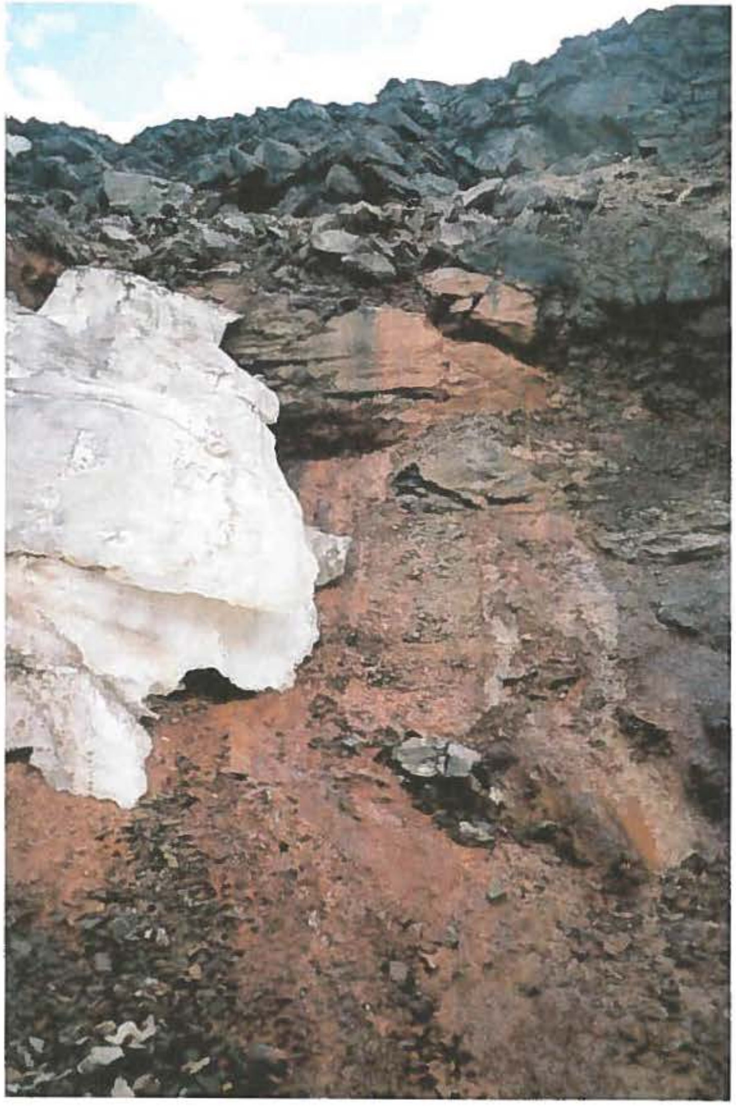


Photo 2 - Salts along moist seepage face

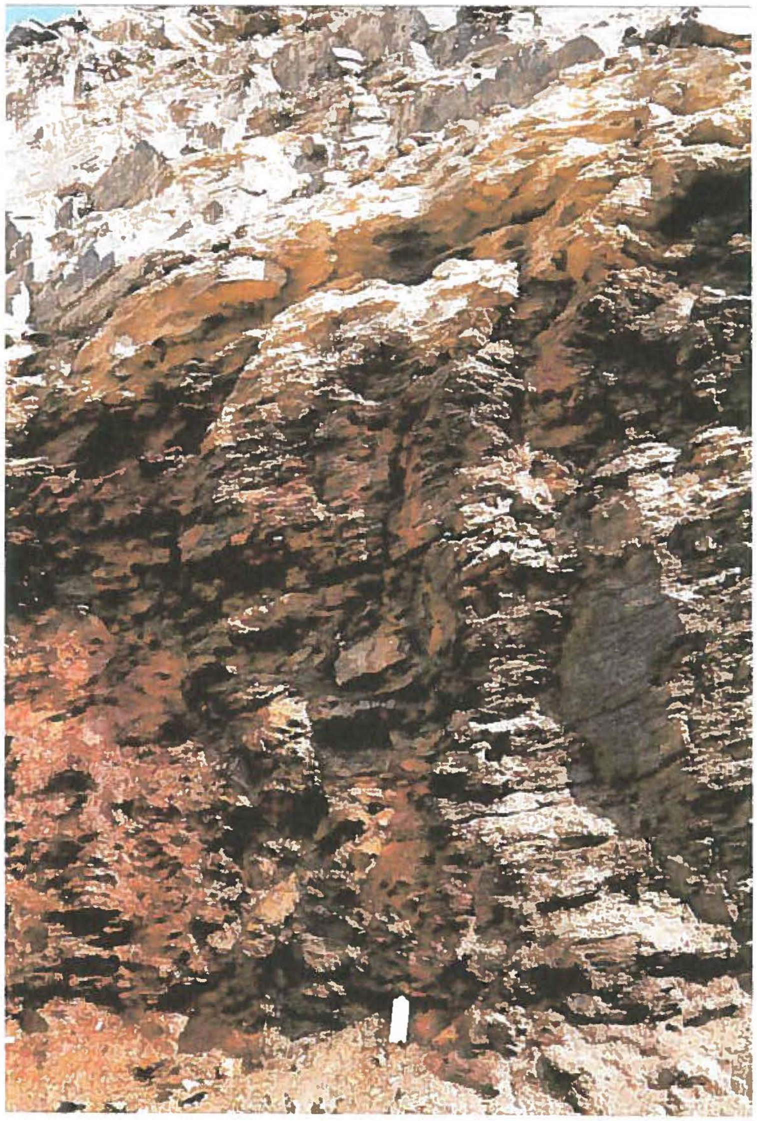


Photo 3 - Seep 3 - Drip face

Photo 4 - VP - Seep 4 Upwelling Water

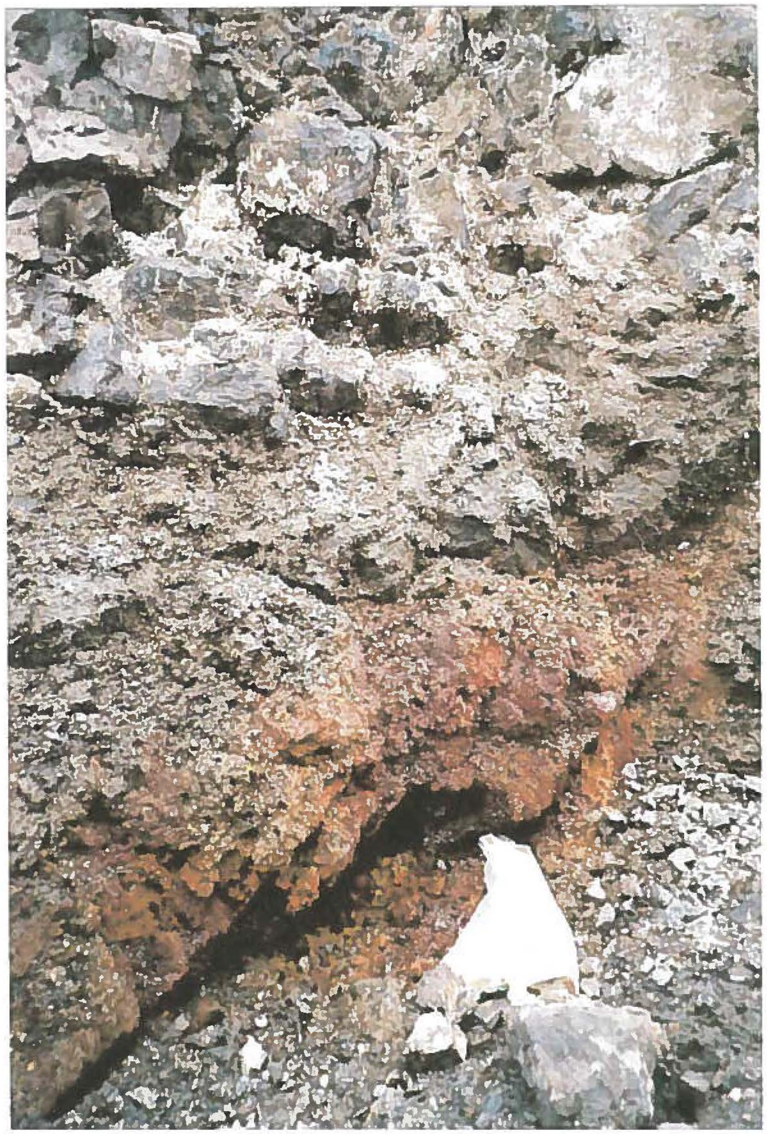


Photo 5 - Seep 5 - Drip face - mineral ppts taken for XRD were predominately gypsum

Photo 6 - Seep 6 Upwelling Water

Photo 7 - Seep 7 more water under larger rock

Photo 8 - Seep 8 North wall of pit

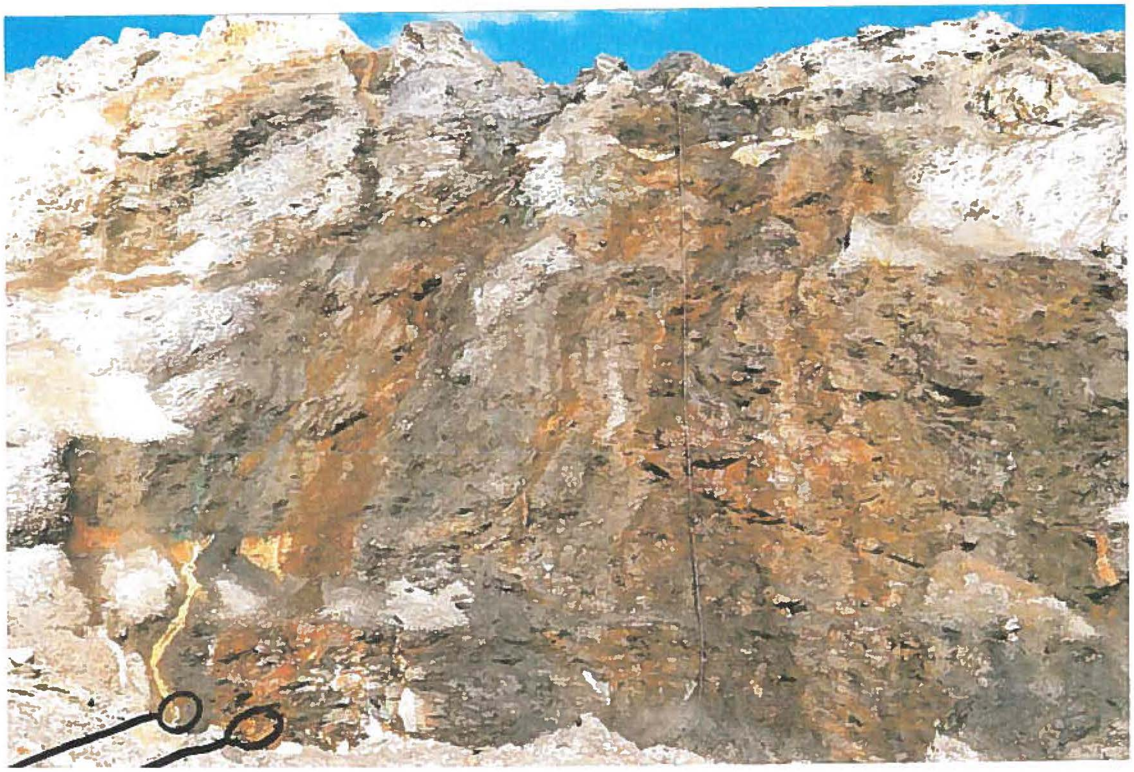


Photo 9 - Surface face neer seeps 12 and 13

Photo 10 - Upper bench - Seep 14

APPENDIX A

June 6, 2000 Seep Survey Results

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CHEMICAL ANALYSIS REPORT

Date:	August 28, 2000
ASL File No.	L7778rr
Report On:	IC1001.07 Water Analysis Vangorda
Report To:	**Steffen Robertson and Kirsten** (Canada) Inc. Suite 800, 580 Hornby Street Vancouver, BC V6C 3B6
Attention:	**Ms. Kelly Sexsmith**
Received:	June 9, 2000

ASL ANALYTICAL SERVICE LABORATORIES LTD.
per:

Joanne Patrick, B.Sc. - Project Chemist
Can Dang, B.Sc. - Project Chemist

REMARKS File No. L7778rr

Please note that this report, ASL File L7778rr, supersedes the reports L7778 and L7778r.

The detection limits were increased for the dissolved metals for the samples "VP-SEEP-1" and "VP-SEEP-5" due to the elevated zinc in these samples.

RESULTS OF ANALYSIS - Water File No. L7778rr

Sample ID		VP-SEEP-1	VP-SEEP-2	VP-SEEP-3	VP-SEEP-4	VP-SEEP-5
Sample Date		00 06 06	00 06 06	00 06 06	00 06 06	00 06 06
Physical Tests						
Conductivity	(umhos/cm)	7570	705	3080	5630	9290
pH		3.88	6.92	6.99	5.59	5.38
Dissolved Anions						
Acidity (to pH 8.3)	CaCO3	4970	59	445	2480	4520
Alkalinity-Total	CaCO3	5	59	19	36	20
Sulphate	SO4	7690	324	2370	5160	9910

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Water

File No. L7778rr

Sample ID		VP-SEEP-1	VP-SEEP-2	VP-SEEP-3	VP-SEEP-4	VP-SEEP-5
Sample Date		00 06 06	00 06 06	00 06 06	00 06 06	00 06 06
Dissolved Metals						
Aluminum	D-Al	9	<0.2	<0.2	0.4	<1
Antimony	D-Sb	<1	<0.2	<0.2	<0.2	<1
Arsenic	D-As	<1	<0.2	<0.2	<0.2	<1
Barium	D-Ba	<0.05	0.02	<0.01	<0.01	<0.05
Beryllium	D-Be	<0.03	<0.005	<0.005	<0.005	<0.03
Bismuth	D-Bi	<0.5	<0.1	<0.1	<0.1	<0.5
Boron	D-B	<0.5	<0.1	<0.1	<0.1	<0.5
Cadmium	D-Cd	3.55	0.04	0.11	1.06	2.36
Calcium	D-Ca	392	85.1	256	374	441
Chromium	D-Cr	<0.05	<0.01	<0.01	<0.01	<0.05
Cobalt	D-Co	8.63	0.08	1.47	4.56	8.85
Copper	D-Cu	24.1	<0.01	<0.01	<0.01	<0.05
Iron	D-Fe	1090	14.4	0.62	405	337
Lead	D-Pb	1.4	<0.05	<0.05	1.40	0.8
Lithium	D-Li	0.27	0.02	0.08	0.09	0.23
Magnesium	D-Mg	497	25.5	213	296	882
Manganese	D-Mn	426	9.08	128	184	600
Molybdenum	D-Mo	<0.2	<0.03	<0.03	<0.03	<0.2
Nickel	D-Ni	6.2	0.06	0.86	2.89	6.8
Phosphorus	D-P	<2	<0.3	<0.3	<0.3	<2
Potassium	D-K	<10	2	10	9	26
Selenium	D-Se	<1	<0.2	<0.2	<0.2	<1
Silicon	D-Si	14.3	3.91	4.22	7.61	9.5
Silver	D-Ag	<0.05	<0.01	<0.01	<0.01	<0.05
Sodium	D-Na	<10	4	6	7	<10
Strontium	D-Sr	0.83	0.402	0.847	1.16	1.34
Thallium	D-Tl	<1	<0.2	<0.2	<0.2	<1
Tin	D-Sn	<0.2	<0.03	<0.03	<0.03	<0.2
Titanium	D-Ti	<0.05	<0.01	0.02	0.02	0.06
Vanadium	D-V	<0.2	<0.03	0.11	0.11	<0.2
Zinc	D-Zn	1670	32.6	258	814	2300

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Water

File No. L7778rr

Sample ID			VP-SEEP-6	VP-SEEP-7	Field Blank	VP-SEEP-8	VP-SEEP-9
Sample Date			00 06 06	00 06 06	00 06 07	00 06 07	00 06 07
Physical Tests							
Conductivity	(umhos/cm)		5280	5260	<2	1500	246
pH			5.04	4.99	5.63	6.68	7.96
Dissolved Anions							
Acidity (to pH 8.3)		CaCO3	2420	2380	2	293	4
Alkalinity-Total		CaCO3	13	13	<1	20	66
Sulphate	SO4		4690	4610	<1	940	57

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Water File No. L7778rr

Sample ID		VP-SEEP-6	VP-SEEP-7	Field Blank	VP-SEEP-8	VP-SEEP-9
Sample Date		00 06 06	00 06 06	00 06 07	00 06 07	00 06 07
Dissolved Metals						
Aluminum	D-Al	3.8	3.3	<0.2	<0.2	<0.2
Antimony	D-Sb	<0.2	<0.2	<0.2	<0.2	<0.2
Arsenic	D-As	<0.2	<0.2	<0.2	<0.2	<0.2
Barium	D-Ba	<0.01	<0.01	<0.01	0.02	0.04
Beryllium	D-Be	<0.005	<0.005	<0.005	<0.005	<0.005
Bismuth	D-Bi	<0.1	<0.1	<0.1	<0.1	<0.1
Boron	D-B	<0.1	<0.1	<0.1	<0.1	<0.1
Cadmium	D-Cd	1.33	1.29	<0.01	0.38	<0.01
Calcium	D-Ca	407	395	0.12	145	42.2
Chromium	D-Cr	<0.01	<0.01	<0.01	<0.01	<0.01
Cobalt	D-Co	5.48	5.33	<0.01	0.38	<0.01
Copper	D-Cu	0.08	0.07	<0.01	0.07	<0.01
Iron	D-Fe	539	517	0.09	0.05	<0.03
Lead	D-Pb	1.14	1.08	<0.05	0.05	<0.05
Lithium	D-Li	0.11	0.10	<0.01	0.04	<0.01
Magnesium	D-Mg	313	302	<0.1	71.1	5.9
Manganese	D-Mn	173	166	0.027	16.3	0.073
Molybdenum	D-Mo	<0.03	<0.03	<0.03	<0.03	<0.03
Nickel	D-Ni	3.51	3.43	<0.05	0.63	<0.05
Phosphorus	D-P	<0.3	<0.3	<0.3	<0.3	<0.3
Potassium	D-K	8	8	<2	2	<2
Selenium	D-Se	<0.2	<0.2	<0.2	<0.2	<0.2
Silicon	D-Si	9.03	8.70	<0.05	5.80	4.16
Silver	D-Ag	<0.01	0.01	<0.01	<0.01	<0.01
Sodium	D-Na	8	8	<2	2	2
Strontium	D-Sr	1.25	1.20	<0.005	0.828	0.165
Thallium	D-Tl	<0.2	<0.2	<0.2	<0.2	<0.2
Tin	D-Sn	<0.03	<0.03	<0.03	<0.03	<0.03
Titanium	D-Ti	0.02	0.01	<0.01	<0.01	<0.01
Vanadium	D-V	<0.05	<0.03	<0.03	<0.03	<0.03
Zinc	D-Zn	826	804	<0.005	174	0.524

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Water

File No. L7778rr

Sample ID		VP-SEEP-10	VP-SEEP-11	VP-SEEP-12	VP-SEEP-13	VP-SEEP-14
Sample Date		00 06 07	00 06 07	00 06 07	00 06 07	00 06 08
Physical Tests						
Conductivity	(umhos/cm)	1440	444	2550	2120	231
pH		7.28	7.89	6.01	3.24	7.76
Total Suspended Solids		4	15	-	-	-
Dissolved Anions						
Acidity (to pH 8.3)	$CaCO_3$	118	12	358	599	13
Alkalinity-Total	$CaCO_3$	82	66	11	<1	101
Sulphate	SO_4	830	166	1680	1260	21

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Water File No. L7778rr

Sample ID		VP-SEEP-10	VP-SEEP-11	VP-SEEP-12	VP-SEEP-13	VP-SEEP-14
Sample Date		00 06 07	00 06 07	00 06 07	00 06 07	00 06 08
Dissolved Metals						
Aluminum	D-Al	<0.2	<0.2	<0.2	24.4	<0.2
Antimony	D-Sb	<0.2	<0.2	<0.2	<0.2	<0.2
Arsenic	D-As	<0.2	<0.2	<0.2	<0.2	<0.2
Barium	D-Ba	0.02	0.04	0.03	0.03	0.06
Beryllium	D-Be	<0.005	<0.005	<0.005	0.006	<0.005
Bismuth	D-Bi	<0.1	<0.1	<0.1	<0.1	<0.1
Boron	D-B	<0.1	<0.1	<0.1	<0.1	<0.1
Cadmium	D-Cd	0.08	0.01	0.63	0.59	<0.01
Calcium	D-Ca	181	54.0	388	233	37.8
Chromium	D-Cr	<0.01	<0.01	<0.01	0.02	<0.01
Cobalt	D-Co	0.41	0.03	0.98	0.76	<0.01
Copper	D-Cu	0.02	0.02	18.7	57.2	0.01
Iron	D-Fe	0.11	0.06	22.9	35.2	<0.03
Lead	D-Pb	<0.05	<0.05	<0.05	0.45	<0.05
Lithium	D-Li	0.03	0.02	0.06	0.08	<0.01
Magnesium	D-Mg	69.7	16.5	99.7	67.3	9.8
Manganese	D-Mn	19.7	1.50	8.94	7.88	0.007
Molybdenum	D-Mo	<0.03	<0.03	<0.03	<0.03	<0.03
Nickel	D-Ni	0.41	0.07	1.79	1.23	<0.05
Phosphorus	D-P	<0.3	<0.3	<0.3	<0.3	<0.3
Potassium	D-K	4	<2	4	3	<2
Selenium	D-Se	<0.2	<0.2	<0.2	<0.2	<0.2
Silicon	D-Si	2.63	2.79	8.77	12.8	6.21
Silver	D-Ag	<0.01	<0.01	<0.01	<0.01	<0.01
Sodium	D-Na	6	2	4	3	2
Strontium	D-Sr	1.40	0.510	4.43	1.39	0.170
Thallium	D-Tl	<0.2	<0.2	<0.2	<0.2	<0.2
Tin	D-Sn	<0.03	<0.03	<0.03	<0.03	<0.03
Titanium	D-Ti	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	D-V	<0.03	<0.03	<0.03	<0.03	<0.03
Zinc	D-Zn	70.1	6.27	177	196	0.032

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

Appendix 1 - QUALITY CONTROL - Replicates

File No. L7778rr

Water			VP-SEEP-5 00 06 06	VP-SEEP-5 QC # 200058
Physical Tests				
Conductivity	(umhos/cm)		9290	9230
pH			5.38	5.29
Dissolved Anions				
Acidity (to pH 8.3)		$CaCO_3$	4520	4510
Alkalinity-Total		$CaCO_3$	20	20
Sulphate	SO_4		9910	10400

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

Water		VP-SEEP-5	VP-SEEP-5
		00 06 06	QC # 200058
Dissolved Metals			
Aluminum	D-Al	<1	<1
Antimony	D-Sb	<1	<1
Arsenic	D-As	<1	<1
Barium	D-Ba	<0.05	<0.05
Beryllium	D-Be	<0.03	<0.03
Bismuth	D-Bi	<0.5	<0.5
Boron	D-B	<0.5	<0.5
Cadmium	D-Cd	2.36	2.39
Calcium	D-Ca	441	448
Chromium	D-Cr	<0.05	<0.05
Cobalt	D-Co	8.85	8.87
Copper	D-Cu	<0.05	<0.05
Iron	D-Fe	337	351
Lead	D-Pb	0.8	0.8
Lithium	D-Li	0.23	0.25
Magnesium	D-Mg	882	888
Manganese	D-Mn	600	617
Molybdenum	D-Mo	<0.2	<0.2
Nickel	D-Ni	6.8	6.9
Phosphorus	D-P	<2	<2
Potassium	D-K	26	25
Selenium	D-Se	<1	<1
Silicon	D-Si	9.5	9.5
Silver	D-Ag	<0.05	0.07
Sodium	D-Na	<10	<10
Strontium	D-Sr	1.34	1.38
Thallium	D-Tl	<1	<1
Tin	D-Sn	<0.2	<0.2
Titanium	D-Ti	0.06	0.06
Vanadium	D-V	<0.2	<0.2
Zinc	D-Zn	2300	2380

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

Outlines of the methodologies utilized for the analysis of the samples submitted are as follows:

Conductivity in Water

This analysis is carried out using procedures adapted from APHA Method 2510 "Conductivity". Conductivity is determined using a conductivity electrode.

Recommended Holding Time:
Sample: 28 days
Reference: APHA
For more detail see ASL "Collection & Sampling Guide"

pH in Water

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode.

Recommended Holding Time:
Sample: 2 hours
Reference: APHA
For more detail see ASL "Collection & Sampling Guide"

Acidity in Water

This analysis is carried out using procedures adapted from APHA Method 2310 "Acidity". Acidity is determined by potentiometric titration to a specified endpoint.

Recommended Holding Time:
Sample: 14 days
Reference: APHA
For more detail see ASL "Collection & Sampling Guide"

Alkalinity in Water by Colourimetry

This analysis is carried out using procedures adapted from EPA Method 310.2 "Alkalinity". Total Alkalinity is determined using the methyl orange colourimetric method.

Recommended Holding Time:

Sample: 14 days
Reference: APHA
For more detail see ASL "Collection & Sampling Guide"

Sulphate in Water

This analysis is carried out using procedures adapted from APHA Method 4500-SO4 "Sulphate". Sulphate is determined using the turbidimetric method.

Recommended Holding Time:
Sample: 28 days
Reference: APHA
For more detail see ASL "Collection & Sampling Guide"

Metals in Water

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" 20th Edition 1998 published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures may involve preliminary sample treatment by acid digestion, using either hotplate or microwave oven, or filtration (EPA Method 3005A). Instrumental analysis is by atomic absorption/emission spectrophotometry (EPA Method 7000 series), inductively coupled plasma - optical emission spectrophotometry (EPA Method 6010B), and/or inductively coupled plasma - mass spectrometry (EPA Method 6020).

Recommended Holding Time:

Sample:	6 months
Reference:	EPA
For more detail see:	ASL "Collection & Sampling Guide"

Solids in Water

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total dissolved solids (TDS) and total suspended solids (TSS) are determined by filtering a sample through a glass fibre filter, TDS is determined by evaporating the filtrate to dryness at 180 degrees celsius, TSS is determined by drying the filter at 104 degrees celsius. Total solids are determined by evaporating a sample to dryness at 104 degrees celsius. Fixed and volatile solids are determined by igniting a dried sample residue at 550 degrees celsius.

Recommended Holding Time:
Sample: 7 days
Reference: APHA
For more detail see ASL "Collection & Sampling Guide"

End of Report

APPENDIX B

MINTEQA2 Modelling

Summary of Saturation Indices of Seep Samples

Solid Phase	NW Wall			GW Spring		East Wall of Slots			Waste Rock	Fast Flowing	
	Seep 8	Seep 12	Seep 13	Seep 4	Seep 6	Seep 2	Seep 3	Seep 5	Seep 1	Seep 9	Seep 14
$Al_4(OH)_{10}SO_4$	10.195	8.58	-8.987	3.51	4.262	9.127	9.323	4.521	-6.262	5.685	6.436
Alunite	6.658	6.917	-2.348	4.794	5.147	5.048	5.858	5.415	-0.505	-0.657	-0.334
Goethite	6.367	6.997	-1.076	0.319	5.301	8.883	7.493	4.017	0.063	6.51	6.445
Lepidocrocite	4.558	5.188	-2.884	-1.49	3.493	7.075	5.684	2.208	-1.746	4.944	4.878
Gibbsite (C)	3.173	2.397	-3.354	0.73	0.762	3.119	3.04	0.954	-2.474	2.548	2.744
Boehmite	2.498	1.722	-4.029	0.055	0.088	2.445	2.365	0.281	-3.147	1.784	1.98
Gibbsite (MC)	1.867	1.091	-4.66	-0.576	-0.544	1.813	1.734	-0.352	-3.78	1.214	1.41
Ferrihydrite	1.038	1.668	-6.405	-5.01	-0.028	3.554	2.164	-1.313	-5.267	1.423	1.358
$AlOH_3$(A)	0.339	-0.437	-6.188	-2.104	-2.072	0.286	0.206	-1.88	-5.307	-0.348	-0.151
$ZnCO_3$, $1H_2O$	-0.104	-1.155	-	-2.074	-1.456	0.019	0.334	-2.898	-5.976	-0.718	-1.914
Rhodocrosite (C)	-0.182	-0.489	-	-1.693	-1.124	1.394	1.015	-2.418	-5.531	-0.578	-1.605
$AlOHSO_4$	-0.378	0.334	0.019	0.265	0.921	-1.287	-0.851	0.603	0.103	-4.157	-3.995
Smithsonite	-0.533	-1.584	-	-2.503	-1.884	-0.41	-0.095	-3.326	-6.404	-1.22	-2.416
Gypsum	-0.687	-0.2	-0.476	-0.069	-0.067	-1.171	-0.31	0.03	-0.055	-1.939	-2.406
Rhodocrosite (SY)	-0.867	-1.173	-	-2.377	-1.808	0.709	0.331	-3.102	-6.216	-1.238	-2.266
Anhydrite	-0.969	-0.482	-0.758	-0.35	-0.347	-1.453	-0.591	-0.249	-0.335	-2.247	-2.715
$Zn(OH)_2$ (E)	-1.157	-2.584	-8.02	-3.422	-4.062	-1.286	-0.541	-3.09	-6.167	-1.027	-2.612
Otavite	-1.193	-2.042	-	-3.429	-2.71	-1.284	-1.48	-4.369	-7.121	-0.644	-0.637
Celestite	-1.25	-0.46	-1.018	-0.891	0.106	-1.819	-1.106	-0.799	-1.042	-2.686	-3.093
Tenorite	-1.349	-0.241	-5.228	-7.107	-4.712	-1.882	-1.851	-4.342	-4.62	-1.634	-1.692
Cerrusite	-1.359	-2.356	-	-3.522	-1.994	-0.786	-1.175	-4.041	-6.728	-0.494	-0.49
$Zn(OH)_2$ (G)	-1.367	-2.794	-8.23	-3.632	-4.272	-1.496	-0.751	-3.3	-6.377	-1.237	-2.822
$Zn(OH)_2$ (B)	-1.407	-2.834	-8.27	-3.672	-4.312	-1.536	-0.791	-3.34	-6.417	-1.277	-2.862
$Fe_3(OH)_8$	-1.498	1.061	-20.387	-12.482	-3.057	6.59	2.348	-5.251	-15.614	1.319	1.323
$Ni(OH)_2$	-1.689	-2.613	-8.259	-3.848	-4.424	-2.348	-1.127	-3.561	-6.563	-0.628	-1.018
Calcite	-1.787	-2.412	-	-3.959	-3.322	-1.163	-1.247	-5.128	-8.141	-0.257	-0.302
$Zn(OH)_2$ (C)	-1.857	-3.284	-8.72	-4.122	-4.762	-1.986	-1.241	-3.79	-6.867	-1.727	-3.312
Anglesite	-1.873	-1.758	-0.817	-1.245	-0.352	-2.409	-1.851	-0.495	-0.255	-3.845	-4.263
Aragonite	-1.983	-2.608	-	-4.155	-3.517	-1.359	-1.443	-5.323	-8.336	-0.485	-0.53
$Zn(OH)_2$ (A)	-2.107	-3.534	-8.97	-4.372	-5.012	-2.236	-1.491	-4.04	-7.117	-1.977	-3.562
$Cu(OH)_2$	-2.37	-1.262	-6.248	-8.129	-5.733	-2.902	-2.872	-5.364	-5.642	-2.655	-2.712
Magnesite	-2.487	-3.39	-	-4.444	-3.82	-2.081	-1.713	-5.209	-8.421	-1.601	-1.381
Malachite	-2.569	0.024	-	-13.792	-7.743	-3.382	-3.752	-9.418	-9.974	-3.704	-3.43
$Zn_2(OH)_2SO_4$	-2.59	-3.956	-9.391	-4.033	-4.69	-3.704	-1.698	-3.255	-6.483	-5.865	-9.069
$Pb(OH)_2$ (C)	-2.664	-4.037	-8.532	-5.122	-4.852	-2.344	-2.302	-4.485	-7.173	-1.37	-1.755
$Zn_4(OH)_6SO_4$	-2.803	-7.025	-23.33	-8.776	-10.714	-4.176	-0.68	-7.335	-16.717	-5.818	-12.193
Siderite (C)	-3.048	-1.372	-	-1.64	-0.92	0.261	-1.63	-2.958	-5.413	-1.787	-1.263
Epsomite	-3.097	-2.889	-3.114	-2.267	-2.278	-3.799	-2.487	-1.769	-2.051	-4.851	-5.054
Goslarite	-3.346	-3.286	-3.285	-2.528	-2.545	-4.33	-3.071	-2.088	-2.236	-6.695	-8.314
Jarosite K	-3.458	1.019	-15.212	-16.138	-0.935	2.641	-0.482	-5.099	-12.599	-8.569	-9.031
Antlerite	-3.478	1.334	-8.191	-17.669	-9.86	-5.932	-5.326	-9.261	-7.168	-7.105	-7.31
Strontianite	-3.536	-3.858	-	-5.969	-4.336	-2.997	-3.23	-7.146	-10.316	-2.17	-2.155
Siderite (P)	-3.599	-1.922	-	-2.19	-1.471	-0.29	-2.181	-3.509	-5.964	-2.385	-1.862
Brochantite	-3.666	2.255	-12.257	-23.615	-13.411	-6.652	-6.016	-12.443	-10.627	-7.323	-7.586
Bianchite	-3.675	-3.615	-3.614	-2.857	-2.874	-4.659	-3.4	-2.416	-2.564	-7.082	-8.701
Larnakite	-3.687	-4.946	-8.499	-5.517	-4.354	-3.902	-3.303	-4.129	-6.576	-4.275	-5.078
Dolomite (O)	-3.747	-5.274	-	-7.875	-6.614	-2.717	-2.432	-9.809	-16.034	-1.373	-1.198
$CuCO_3$	-4.215	-2.73	-	-9.678	-6.024	-4.495	-4.895	-8.069	-8.347	-4.989	-4.657
Dolomite (D)	-4.361	-5.888	-	-8.489	-7.228	-3.331	-3.047	-10.423	-16.648	-2.015	-1.84
Azurite	-4.829	-0.752	-	-21.516	-11.813	-5.922	-6.692	-15.532	-16.366	-6.806	-6.2
$ZnSO_4$, $1H_2O$	-5.276	-5.215	-5.215	-4.455	-4.472	-6.261	-5	-4.01	-4.16	-8.859	-10.478
Otavite	-6.235	-7.461	-12.964	-8.766	-9.306	-6.579	-6.345	-8.552	-11.303	-4.942	-5.324
Melanterite	-6.512	-3.725	-3.591	-2.317	-2.232	-4.311	-5.258	-2.372	-1.897	-7.918	-7.817

Summary of Saturation Indices of Water Samples Collected from the Vangorda Pit

Solid Phase	V-Lake10 (at depth)	V-Lake11 (2 m)
$Al_4(OH)_{10}SO_4$	10.382	6.483
Alunite	5.324	0.558
Goethite	5.125	7.065
Lepidocrocite	3.558	5.498
Gibbsite (C)	3.146	2.608
Boehmite	2.382	1.844
Al_2O_3	2.064	0.989
Gibbsite (MC)	1.811	1.274
Rhodocrosite (C)	1.019	0.605
Cuprite	0.911	-0.373
$ZnCO_3$, $1H_2O$	0.63	0.25
Rhodocrosite (SY)	0.358	-0.056
$AlOH_3$(A)	0.25	-0.287
Smithsonite	0.128	-0.252
Ferrihydrite	0.038	1.978
$Zn(OH)_2$ (E)	-0.362	-0.103
Calcite	-0.545	-0.308
$Ni(OH)_2$	-0.556	-0.537
$Zn(OH)_2$ (G)	-0.572	-0.313
Gypsum	-0.605	-1.477
$Zn(OH)_2$ (B)	-0.612	-0.353
Cerrusite	-0.621	-0.503
Otavite	-0.712	-0.816
Aragonite	-0.774	-0.536
$Zn_4(OH)_6SO_4$	-0.853	-1.567
Anhydrite	-0.914	-1.786
Celestite	-1.05	-1.839
$Zn(OH)_2$ (C)	-1.062	-0.803
$AlOHSO_4$	-1.254	-3.54
$Zn(OH)_2$ (A)	-1.312	-1.053
Magnesite	-1.433	-1.307
Dolomite (O)	-1.494	-1.131
Siderite (C)	-1.537	-1.118
Tenorite	-1.58	-1.34
$Fe_3(OH)_8$	-1.885	3.053
Siderite (P)	-2.135	-1.716
Dolomite (D)	-2.136	-1.773
Strontianite	-2.157	-1.836
$Pb(OH)_2$ (C)	-2.179	-1.423
$Zn_2(OH)_2SO_4$	-2.23	-3.461
Anglesite	-2.349	-3.341
$Cu(OH)_2$	-2.6	-2.36
Malachite	-2.913	-3.07
Epsomite	-3.062	-4.045
Goslarite	-3.726	-5.214
Hydcerrusite	-3.834	-2.842
Bianchite	-4.113	-5.602
$CuCO_3$	-4.252	-4.65
Antlerite	-4.637	-5.664
Brochantite	-4.8	-5.587
Azurite	-5.277	-5.833
Otavite	-5.693	-5.158
$ZnSO_4$, $1H_2O$	-5.889	-7.378
$NiCO_3$	-5.928	-6.547
Melanterite	-6.047	-6.736

APPENDIX C

Geochemical Results from Waste Rock Tests

Table C-1
Sample Descriptions

Sample Number	Location	Type	Description		Paste pH	Paste Conductivity
VP-WR-01	Low grade stockpile area (pad)	Waste rock	Phyllite and massive sulphides	ps	5.7	1900
VP-WR-02	Low grade stockpile area (pad)	Waste rock	Phyllite and massive sulphides	ps	7.1	> 2000
VP-WR-03	Low grade stockpile area (pad)	Waste rock	Phyllite and massive sulphides	ps	6.7	1360
VP-WR-04	North wall of pit	Talus	Phyllite and carbonaceous phyllite	p	6	970
VP-WR-05	North wall of pit	Talus	Black phyllite	p	5.6	450
VP-WR-06	North wall of pit	Talus	Lighter colored phyllites	p	6.1	690
VP-WR-07	East wall of main pit	Talus	Mixture of phyllites and massive sulphides	ps	5.6	690
VP-WR-08	East wall of main pit	Talus	Weathered sulphides	s	4.6	1280
VP-WR-09	Northwest wall of main pit	Talus	Carbonaceous phyllites	p	5.9	1080
VP-WR-10	Northwest wall of main pit	Talus	Till	t	7.1	> 2000
VP-WR-11	Berm above west wall of pit	Waste rock	Phyllite with white ppts.	p	4.8	> 2000
VP-WR-12	Dump above southwest side of slot	Waste rock	Phyllites	p	5.8	1220
VP-WR-13	Dump above southwest side of slot	Waste rock	Massive sulphides (weathered)	s	5.8	1900
VP-WR-14	Dump inside hairpin	Waste rock	Mixture of dark grey to black phyllite with white	p	5.8	> 2000
VP-WR-15	South wall, adjacent to hairpin	Talus	Strongly weathered rusty stained phyllite with s	p	2.2	> 2000
VP-WR-16	South wall, adjacent to hairpin	Talus	Weathered carbonaceous phyllites, white ppts.	p	4.2	> 2000
VP-WR-17	South wall of south pit area	Talus	Phyllite in shear area	p	3.2	> 2000
VP-WR-18	East wall of south pit area	Talus	Massive sulphides (weathered)	s	2.3	> 2000
VP-WR-19	Dumped material along west wall of slot	Waste rock	Phyllite	p	6.4	1640

Table C-2
Waste Rock Solids Analysis

Parameter	Units	VP-WR-1	VP-WR-4	VP-WR-7	VP-WR-8	VP-WR-9	VP-WR-11	VP-WR-12	VP-WR-14	VP-WR-15	VP-WR-16	VP-WR-17	VP-WR-18	VP-WR-19
Ag	ppm	13.0	22.0	11.2	11.6	0.8	1.8	3.6	7.0	7.8	2.8	38.8	19.4	6.8
Al	%	0.73	1.10	1.25	0.36	0.76	1.07	1.53	1.18	0.85	0.80	0.79	0.32	1.10
As	ppm	1870	635	740	515	140	345	635	540	1755	245	1575	1655	450
Ba	ppm	10	20	20	10	390	170	60	40	70	50	10	10	50
Be	ppm	0.5	0.5	0.5	<0.5	0.5	0.5	<0.5	0.5	<0.5	0.5	<0.5	<0.5	0.5
Bi	ppm	15	5	5	20	<5	<5	<5	<5	10	5	10	45	<5
Ca	%	0.63	1.02	0.48	0.22	0.48	0.57	0.64	0.95	0.12	0.55	0.26	0.03	0.69
Cd	ppm	<1	27	<1	<1	5	24	<1	4	<1	<1	1	<1	<1
Co	ppm	141	78	59	217	15	32	30	51	27	56	65	289	43
Cr	ppm	94	69	106	57	111	104	110	123	65	70	99	109	146
Cu	ppm	2311	559	906	4771	720	671	336	644	951	449	4158	6696	444
Fe	%	14.86	11.09	12.47	26.5	3.57	3.99	8.03	8.70	11.18	10.15	18.7	23.4	8.29
K	%	0.10	0.10	0.17	0.04	0.10	0.16	0.16	0.17	0.30	0.09	0.09	0.06	0.12
Mg	%	0.56	0.71	0.82	0.34	0.46	0.71	1.41	1.06	0.35	0.65	0.31	0.08	1.36
Mn	ppm	2175	3995	3955	3485	360	435	1380	1610	315	1660	1090	255	1570
Mo	ppm	<2	4	<2	<2	20	4	2	4	2	14	4	2	2
Na	%	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01
Ni	ppm	45	74	41	33	40	74	61	71	19	68	36	24	108
P	ppm	520	460	490	480	1550	490	650	690	1200	1390	630	470	610
Pb	ppm	6578	>10000	8766	8818	1408	4214	2144	5474	6088	1678	>10000	>10000	5082
Pb	%	-	1.62	-	-	-	-	-	-	-	-	3.19	1.03	-
Sb	ppm	70	45	25	30	5	20	15	15	25	5	75	45	20
Sc	ppm	1	2	2	<1	3	2	4	3	1	2	2	<1	3
Sn	ppm	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Sr	ppm	15	19	20	10	58	36	44	43	36	34	5	4	37
Ti	%	<0.01	0.01	0.01	<0.01	0.01	0.01	0.01	0.01	0.02	<0.01	0.01	<0.01	0.01
V	ppm	34	23	27	29	48	22	43	35	47	49	39	32	32
W	ppm	30	60	20	30	<10	10	10	20	<10	10	50	<10	20
Y	ppm	5	6	6	1	9	4	7	6	2	12	2	<1	5
Zn	ppm	>10000	>10000	>10000	>10000	2548	3522	6260	>10000	1858	5918	>10000	1955	>10000
Zn	%	1.41	3.08	1.22	1.32	-	-	-	1.01	-	-	2.40	-	1.00
Zr	ppm	16	12	20	17	15	15	14	14	24	26	17	20	12

Table C-3
ABA Results for Waste Rock Samples

SAMPLE		PASTE pH	S(T) %	S(SO4) %	AP	NP	NET NP	NP/AP	TIC %	CO_3-NP
VP-WR-	1	6.3	14.0	0.30	428.1	16.8	-411.4	<0.1	0.76	63.3
VP-WR-	4	7.5	9.32	0.02	290.6	42.0	-248.6	0.1	0.72	60.0
VP-WR-	7	6.9	7.54	0.07	233.4	19.1	-214.3	0.1	0.52	43.3
VP-WR-	8	4.7	19.9	0.42	608.8	6.0	-602.8	<0.1	0.36	30.0
VP-WR-	9	7.0	0.48	0.10	11.9	9.0	-2.9	0.8	0.23	19.2
VP-WR-	10	7.4	0.35	0.24	3.4	9.8	6.3	2.8	0.13	10.8
VP-WR-	11	5.7	1.37	0.54	25.9	4.9	-21.0	0.2	0.12	10.0
VP-WR-	12	7.3	2.79	0.13	83.1	20.1	-63.0	0.2	0.71	59.2
VP-WR-	14	6.6	4.19	0.48	115.9	23.9	-92.1	0.2	0.66	55.0
VP-WR-	15	2.7	2.81	1.35	45.6	-16.5	-62.2	<0.1	0.01	0.8
VP-WR-	16	5.0	3.18	0.42	86.3	4.4	-81.9	0.1	0.59	49.2
VP-WR-	17	4.0	18.5	1.40	534.4	-21.6	-556.0	<0.1	0.09	7.5
VP-WR-	18	2.9	21.2	1.45	617.2	-25.5	-642.7	<0.1	0.01	0.8
VP-WR-	19	7.0	3.46	0.14	103.8	31.8	-72.0	0.3	0.98	81.7

AP = ACID POTENTIAL IN TONNES CaCO3 EQUIVALENT PER 1000 TONNES OF MATERIAL.
NP = NEUTRALIZATION POTENTIAL IN TONNES CaCO3 EQUIVALENT PER 1000 TONNES OF MATERIAL.
NET NP = NET NEUTRALIZATION POTENTIAL = TONNES CaCO3 EQUIVALENT PER 1000 TONNES OF MATERIAL.
NOTE: WHEN S(T) AND/OR S(SO4) IS REPORTED AS <0.01, IT IS ASSUMED TO BE ZERO FOR THE AP CALCULATION.
TIC = TOTAL INORGANIC CARBON.

Table C-4
Leach Extraction Results (Physical Parameters)

SAMPLE	DISTILLED WATER VOLUME (mL)	SAMPLE WEIGHT (g)	Unfiltered Leachate				96 Hr. Filtered Leachate			
			TIME	pH	CONDUCTIVITY (uS/cm)	REDOX (mV)	ALKALINITY (mg $CaCO_3$/L)	ACIDITY (pH 4.5) (mg $CaCO_3$/L)	ACIDITY (pH 8.3) (mg $CaCO_3$/L)	SULPHATE (mg/L)
VP-WR- 1	1500	75	10 min.	6.0	252					
			1 Hr.	6.1	303					
			4 Hr.	6.5	373					
			24 Hr.	6.4	544					
			48 Hr.	6.1	607					
			96 Hr.	5.9	693	298	5.3	0.0	36.0	395
VP-WR- 4	1500	75	10 min.	6.2	85					
			1 Hr.	6.2	96					
			4 Hr.	6.7	122					
			24 Hr.	6.7	203					
			48 Hr.	6.4	241					
			96 Hr.	6.4	279	282	15.3	0.0	7.5	128
VP-WR- 7	1500	75	10 min.	6.3	34					
			1 Hr.	6.3	46					
			4 Hr.	6.8	67					
			24 Hr.	6.7	109					
			48 Hr.	6.4	125					
			96 Hr.	6.3	149	292	8.3	0.0	8.0	59
VP-WR- 8	1500	75	10 min.	4.3	139					
			1 Hr.	4.2	180					
			4 Hr.	4.2	253					
			24 Hr.	4.4	372					
			48 Hr.	4.4	415					
			96 Hr.	4.3	477	276	0.0	0.5	81.0	262
VP-WR- 9	1500	75	10 min.	6.0	98					
			1 Hr.	6.5	117					
			4 Hr.	7.0	137					
			24 Hr.	6.8	178					
			48 Hr.	6.3	192					
			96 Hr.	6.6	207	250	8.8	0.0	3.0	96

Table C-4
Leach Extraction Results (Physical Parameters)

SAMPLE	DISTILLED WATER VOLUME (mL)	SAMPLE WEIGHT (g)	Unfiltered Leachate TIME	pH	CONDUCTIVITY (uS/cm)	REDOX (mV)	96 Hr. Filtered Leachate ALKALINITY (mg $CaCO_3$/L)	ACIDITY (pH 4.5) (mg $CaCO_3$/L)	ACIDITY (pH 8.3) (mg $CaCO_3$/L)	SULPHATE (mg/L)
VP-WR- 11	1500	75	10 min.	5.3	475					
			1 Hr.	5.5	496					
			4 Hr.	6.0	530					
			24 Hr.	5.8	702					
			48 Hr.	5.7	803					
			96 Hr.	6.1	924	322	2.5	0.0	87.0	591
VP-WR- 12	1500	75	10 min.	6.1	116					
			1 Hr.	6.5	137					
			4 Hr.	7.0	184					
			24 Hr.	6.4	298					
			48 Hr.	6.5	339					
			96 Hr.	6.8	397	262	15.3	0.0	2.5	188
VP-WR- 14	1500	75	10 min.	6.0	283					
			1 Hr.	6.2	313					
			4 Hr.	6.7	375					
			24 Hr.	6.2	600					
			48 Hr.	6.2	740					
			96 Hr.	6.5	858	300	9.0	0.0	22.0	524
VP-WR- 15	1500	75	10 min.	3.2	503					
			1 Hr.	3.0	617					
			4 Hr.	3.0	821					
			24 Hr.	2.9	1326					
			48 Hr.	2.8	1435					
			96 Hr.	2.7	1549	511	0.0	285.0	450.0	591
VP-WR- 16	1500	75	10 min.	4.7	216					
			1 Hr.	4.7	257					
			4 Hr.	4.8	334					
			24 Hr.	4.9	524					
			48 Hr.	5.1	608					
			96 Hr.	5.0	695	395	1.3	0.0	39.0	414

Table C-4
Leach Extraction Results (Physical Parameters)

SAMPLE	DISTILLED WATER VOLUME (mL)	SAMPLE WEIGHT (g)	Unfiltered Leachate TIME	pH	CONDUCTIVITY (uS/cm)	REDOX (mV)	96 Hr. Filtered Leachate ALKALINITY (mg $CaCO_3$/L)	ACIDITY (pH 4.5) (mg $CaCO_3$/L)	ACIDITY (pH 8.3) (mg $CaCO_3$/L)	SULPHATE (mg/L)
VP-WR- 17	1500	75	10 min.	3.9	930					
			1 Hr.	3.8	982					
			4 Hr.	3.8	1040					
			24 Hr.	3.8	1278					
			48 Hr.	3.8	1300					
			96 Hr.	3.8	1339	441	0.0	10.0	450.0	962
VP-WR- 18	1500	75	10 min.	3.3	327					
			1 Hr.	3.2	391					
			4 Hr.	3.1	575					
			24 Hr.	3.0	1064					
			48 Hr.	2.9	1175					
			96 Hr.	2.8	1305	484	0.0	170.0	405.0	450
VP-WR- 19	1500	75	10 min.	6.0	151					
			1 Hr.	6.4	163					
			4 Hr.	6.9	190					
			24 Hr.	6.1	318					
			48 Hr.	6.4	364					
			96 Hr.	6.8	414	343	13.8	0.0	3.5	210

Table C-5
Leach Extraction Results (Metal Analyses)

Parameter	Units	VP-WR-1	VP-WR-4	VP-WR-7	VP-WR-8	VP-WR-9	VP-WR-11	VP-WR-12	VP-WR-14	VP-WR-15	VP-WR-16	VP-WR-17	VP-WR-18	VP-WR-19
Al	mg/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	31.7	<0.2	3.8	10.1	<0.2
Sb	mg/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
As	mg/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Ba	mg/L	0.03	0.03	0.06	0.02	0.05	0.02	0.03	0.02	0.02	0.02	0.01	0.02	0.03
Be	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
	mg/L													
Bi	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Bi	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cd	mg/L	0.09	0.02	0.01	0.03	0.01	1	<0.01	0.1	0.29	0.05	0.98	0.06	0.01
Ca	mg/L	112	43.6	20	30.8	26.1	151	58.3	156	31.6	103	110	4.73	55.7
Cr	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01
	mg/L													
Co	mg/L	0.09	<0.01	0.01	0.12	<0.01	0.66	0.01	0.11	0.76	0.23	0.41	0.26	0.02
Cu	mg/L	<0.01	<0.01	<0.01	0.01	<0.01	0.1	<0.01	<0.01	4.54	<0.01	3.99	14.1	<0.01
Fe	mg/L	<0.03	<0.03	<0.03	16.7	<0.03	<0.03	<0.03	<0.03	37.4	0.4	6.85	112	<0.03
Pb	mg/L	0.26	0.14	<0.05	3.71	<0.05	0.28	<0.05	0.11	<0.05	0.24	1.74	<0.05	<0.05
Li	mg/L	0.02	<0.01	0.01	0.02	<0.01	0.04	0.02	0.02	0.04	0.01	0.02	0.01	<0.01
	mg/L													
Mg	mg/L	21.1	6.3	3.2	12	8.4	27.4	11.9	30.5	7.5	26.8	37.8	6.5	27
Mn	mg/L	6.6	0.092	1.2	42.2	0.109	5.48	1.25	4.24	3.34	20	36.1	9.46	0.842
Mo	mg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Ni	mg/L	0.12	<0.05	<0.05	0.11	<0.05	0.83	<0.05	<0.05	0.29	0.33	0.29	0.08	<0.05
P	mg/L	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
	mg/L													
K	mg/L	5	<2	<2	<2	<2	<2	<2	4	<2	<2	<2	<2	<2
Se	mg/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Si	mg/L	0.54	0.61	0.63	1.49	0.61	1.1	0.28	0.77	6.31	0.93	4.04	3.14	0.46
Ag	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Na	mg/L	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
	mg/L													
Sr	mg/L	0.372	0.387	0.13	0.107	0.214	0.262	0.315	0.397	0.037	0.307	0.211	0.014	0.25
Tl	mg/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Sn	mg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Ti	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
V	mg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
	mg/L													
Zn	mg/L	19.7	4.76	4.31	28.1	0.812	48.4	0.679	14.5	49.9	19	279	32.2	2.17

APPENDIX D

XRD Results

Cominco Ltd. / Exploration Research Laboratory / 1486 East Pender Street / Vancouver, B.C. / Canada V5L 1V8
Phone: (604) 685-3032 / Fax: (604) 844-2686

Cominco

Kelly Sexsmith
SRK Consulting
#800 - 580 Hornby Street
Vancouver, B.C.
V6C 3B6

14 July, 2000

Dear Kelly: ***RE: Vangorda Open Pit Samples / E.R.L. Job V00-0400R***

Six samples were submitted for x-ray diffraction analysis. The results are as follows:

SAMPLE R00:6124 (VP-SALT-1).

This green salt material proved to be melanterite ($FeSO_4 \cdot 7H_2O$).

SAMPLE R00:6125 (VP-SALT-2).

This ferricrete material consists of limonite (high noisy background) quartz and mica.

SAMPLE R00:6126 (VP-SALT-3).

This material gives a good match for the mineral moorhouseite ($CoSO_4 \cdot 6H_2O$).

SAMPLE R00:6127 (VP-SEEP-5).

This seep material consists mostly of gypsum with very minor quartz.

SAMPLE R00:6128 (VP-WR-16).

The dominant mineral phase is moorhouseite ($CoSO_4 \cdot 6H_2O$).

Attached are the x-ray diffractograms.

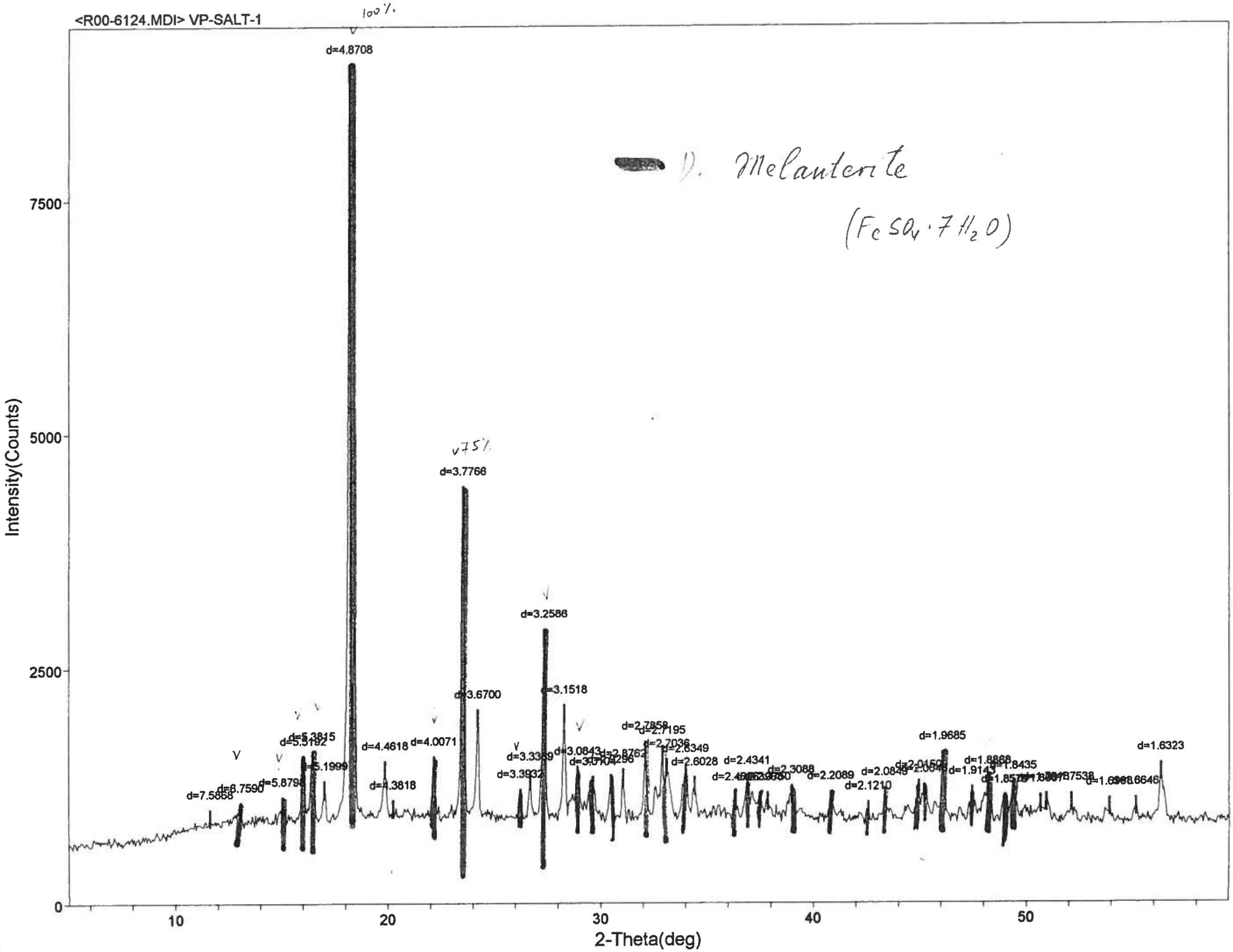
Yours truly,

J.A. McLeod, M.A.Sc., P.Eng.
Manager, Exploration Technical Services

JAM/skw

App. (diffractograms)

v = 16-487 bieberite $CoSO_4 \cdot 7H_2O$



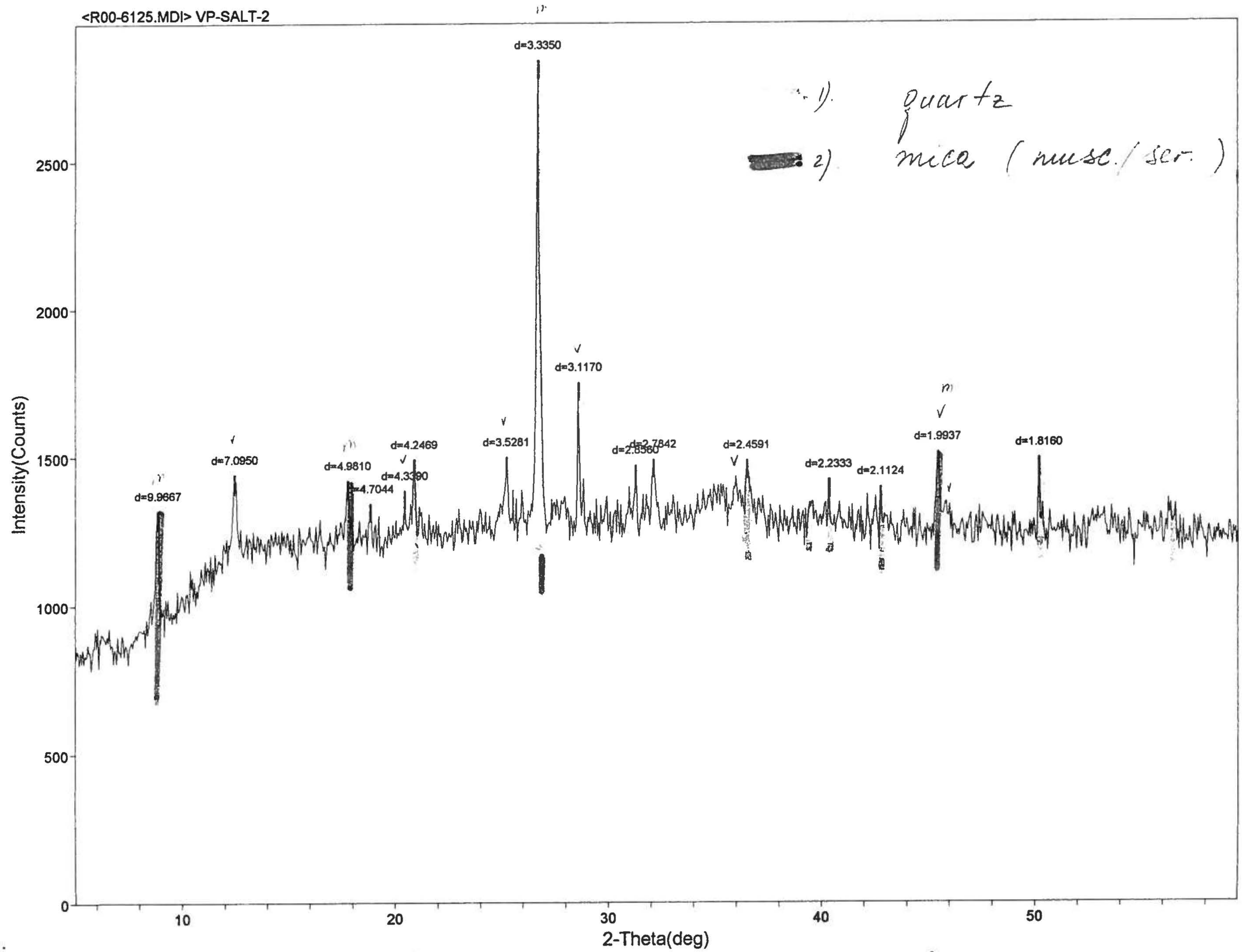
<R00-6124.MDI> VP-SALT-1 [JADE - Peak List Report]

Scan Parameters: Range = 5.0-59.5/0.05, Dwell = 1(sec), Max-I = 8893, Anode = CU Date: 07-12-00@09:45

Search Parameters: Filter = 11(pts), Threshold = 3.0(esd), Peak-Cutoff = 0.5%, 2-Theta Zero Offset = 0.0(deg)

Note: Intensity data from raw counts, Summit peak location, Wavelength for computing d-spacing = 1.540562<CU, K-alpha1>

#	2-Theta	d(A)	h	k	l	BG	Peak	P%	Area	A%	FWHM	Size(A)	#
1	11.654	7.5868				823	107	1.3	10	0.7	0.071	>1000	1
2	13.088	6.7590				867	133	1.7	16	1.1	0.091	>1000	2
3	15.055	5.8798				906	154	1.9	19	1.3	0.095	>1000	3
4	16.045	5.5192				951	543	6.8	78	5.6	0.114	>1000	4
5	16.459	5.3815				955	591	7.4	115	8.3	0.154	>1000	5
6	17.037	5.1999				965	263	3.3	33	2.4	0.099	>1000	6
7	18.198	4.8708				941	7952	100.0	1375	100.0	0.138	>1000	7
8	19.883	4.4618				925	517	6.5	91	6.6	0.141	>1000	8
9	20.249	4.3818				924	99	1.2	9	0.6	0.065	>1000	9
10	22.166	4.0071				923	566	7.1	91	6.6	0.127	>1000	10
11	23.538	3.7766				1023	3348	42.1	511	37.1	0.122	>1000	11
12	24.231	3.6700				1003	984	12.4	134	9.7	0.109	>1000	12
13	26.242	3.3932				939	197	2.5	21	1.5	0.083	>1000	13
14	26.693	3.3369				979	345	4.3	44	3.2	0.101	>1000	14
15	27.347	3.2586				981	1861	23.4	309	22.4	0.133	>1000	15
16	28.292	3.1518				1170	863	10.9	98	7.1	0.091	>1000	16
17	28.925	3.0843				1186	194	2.4	20	1.4	0.082	>1000	17
18	29.651	3.0104				987	283	3.6	64	4.6	0.180	>1000	18
19	30.488	2.9296				935	355	4.5	53	3.8	0.118	>1000	19
20	31.068	2.8762				975	375	4.7	46	3.3	0.096	>1000	20
21	32.103	2.7858				992	652	8.2	88	6.4	0.108	>1000	21
22	32.908	2.7195				973	624	7.8	122	8.8	0.156	>1000	22
23	33.107	2.7036				965	492	6.2	162	11.8	0.263	390	23
24	33.996	2.6349				952	450	5.7	114	8.3	0.202	633	24
25	34.428	2.6028				1030	232	2.9	32	2.3	0.110	>1000	25
26	36.348	2.4696				939	156	2.0	17	1.2	0.087	>1000	26
27	36.897	2.4341				973	301	3.8	61	4.4	0.160	>1000	27
28	37.493	2.3968				944	150	1.9	30	2.2	0.158	>1000	28
29	37.851	2.3750				993	104	1.3	12	0.8	0.089	>1000	29
30	38.978	2.3088				912	258	3.2	45	3.2	0.138	>1000	30
31	40.819	2.2089				873	233	2.9	42	3.0	0.142	>1000	31
32	42.590	2.1210				889	106	1.3	9	0.6	0.067	>1000	32
33	43.364	2.0849				884	258	3.2	37	2.7	0.113	>1000	33
34	44.949	2.0150				933	285	3.6	52	3.7	0.144	>1000	34
35	45.203	2.0043				953	222	2.8	64	4.6	0.230	460	35
36	46.071	1.9685				948	576	7.2	86	6.2	0.118	>1000	36
37	47.455	1.9143				913	241	3.0	53	3.8	0.174	758	37
38	48.188	1.8868				902	361	4.5	86	6.2	0.190	634	38
39	48.987	1.8579				918	141	1.8	31	2.2	0.172	768	39
40	49.396	1.8435				936	270	3.4	50	3.6	0.147	>1000	40
41	50.651	1.8007				899	166	2.1	28	2.0	0.133	>1000	41
42	50.923	1.7918				896	186	2.3	35	2.5	0.150	>1000	42
43	52.107	1.7538				860	220	2.8	32	2.3	0.113	>1000	43
44	53.895	1.6998				853	178	2.2	27	2.0	0.121	>1000	44
45	55.130	1.6646				875	159	2.0	25	1.8	0.124	>1000	45
46	56.314	1.6323				867	535	6.7	111	8.0	0.165	811	46
@	End-of-List												



<R00-6125.MDI> VP-SALT-2
d=3.3350
d=3.1170
d=9.9667
d=7.0950
d=4.9810
d=4.7044
d=4.3390
d=4.2469
d=3.5281
d=2.8560
d=2.7842
d=2.4591
d=2.2333
d=2.1124
d=1.9937
d=1.8160
1). quartz
2) mica (musc./ser.)
Intensity(Counts)
2-Theta(deg)

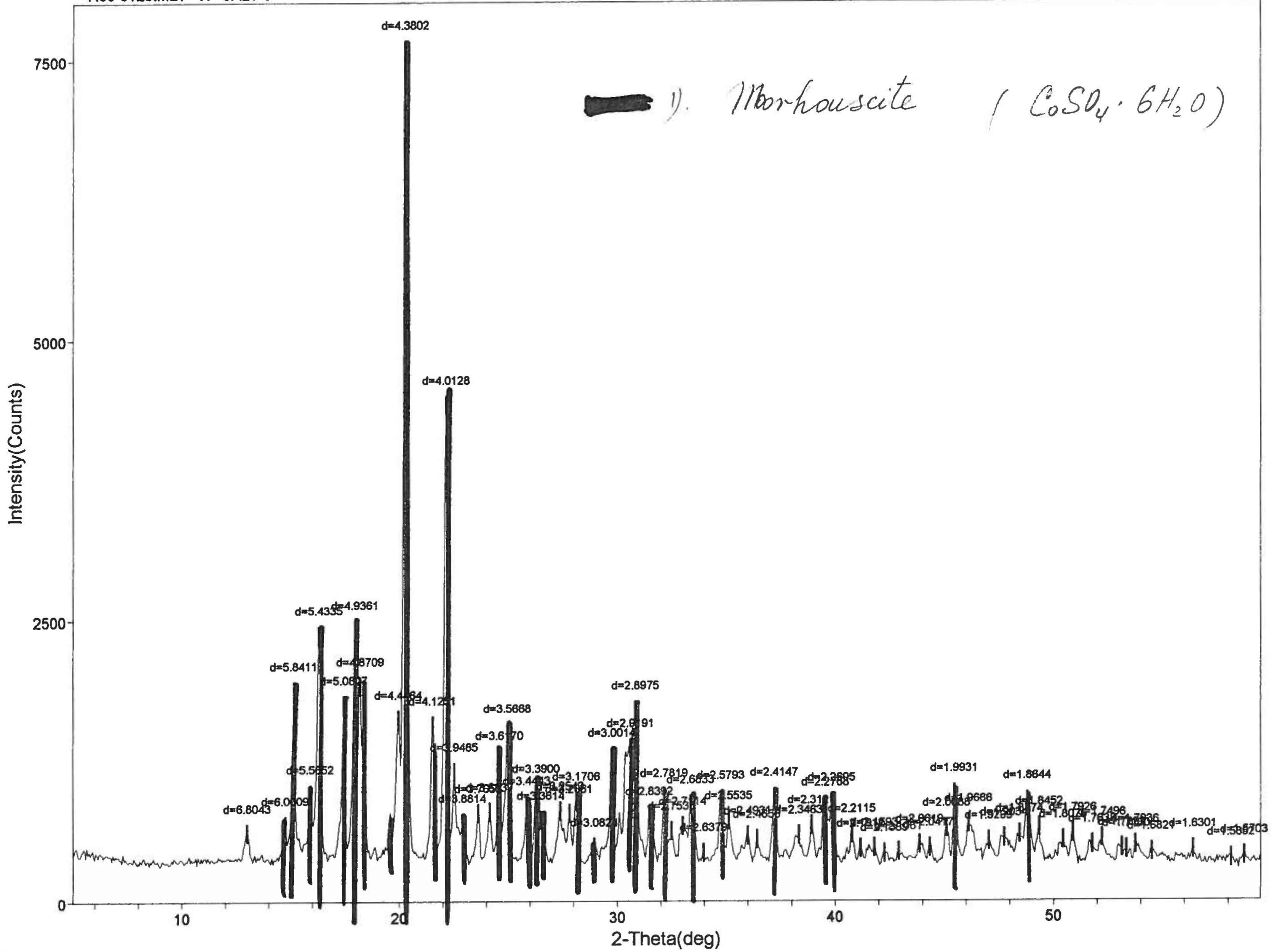
Scan Parameters: Range = 5.0-59.5/0.05, Dwell = 1(sec), Max-I = 2822, Anode = CU Date: 07-12-00@08:45

Search Parameters: Filter = 11(pts), Threshold = 3.0(esd), Peak-Cutoff = 0.5%, 2-Theta Zero Offset = 0.0(deg)

Note: Intensity data from raw counts, Summit peak location, Wavelength for computing d-spacing = 1.540562<CU, K-alpha1>

#	2-Theta	d(A)	h	k	l	BG	Peak	P%	Area	A%	FWHM	Size(A)	#
1	8.865	9.9667				951	347	22.6	56	17.9	0.128	>1000	1
2	12.465	7.0950				1166	253	16.5	48	15.2	0.149	>1000	2
3	17.792	4.9810				1214	185	12.0	32	10.2	0.136	>1000	3
4	18.848	4.7044				1208	112	7.3	15	4.5	0.100	>1000	4
5	20.451	4.3390				1221	143	9.3	16	4.9	0.085	>1000	5
6	20.899	4.2469				1240	229	14.9	35	11.1	0.120	>1000	6
7	25.236	3.5261				1272	204	13.3	33	10.4	0.126	>1000	7
8	26.708	3.3350				1286	1536	100.0	311	100.0	0.162	>1000	8
9	28.615	3.1170				1332	397	25.8	44	14.2	0.089	>1000	9
10	31.293	2.8560				1299	149	9.7	16	5.0	0.083	>1000	10
11	32.122	2.7842				1289	178	11.6	32	10.1	0.141	>1000	11
12	36.509	2.4591				1302	162	10.5	21	6.7	0.102	>1000	12
13	40.352	2.2333				1279	119	7.7	11	3.2	0.067	>1000	13
14	42.772	2.1124				1254	120	7.8	11	3.4	0.071	>1000	14
15	45.456	1.9937				1250	240	15.6	53	16.9	0.174	775	15
16	50.195	1.8160				1239	231	15.0	24	7.5	0.081	>1000	16
@	End-of-List												

<R00-6126.MDI> VP-SALT-3



<R00-6126.MDI> VP-SALT-3 [JADE - Peak List Report]

Scan Parameters: Range = 5.0-59.5/0.05, Dwell = 1(sec), Max-I = 7628, Anode = CU Date: 07-12-00@10:12

Search Parameters: Filter = 11(pts), Threshold = 3.0(esd), Peak-Cutoff = 0.5%, 2-Theta Zero Offset = 0.0(deg)

Note: Intensity data from raw counts, Summit peak location, Wavelength for computing d-spacing = 1.540562<CU, K-alpha1>

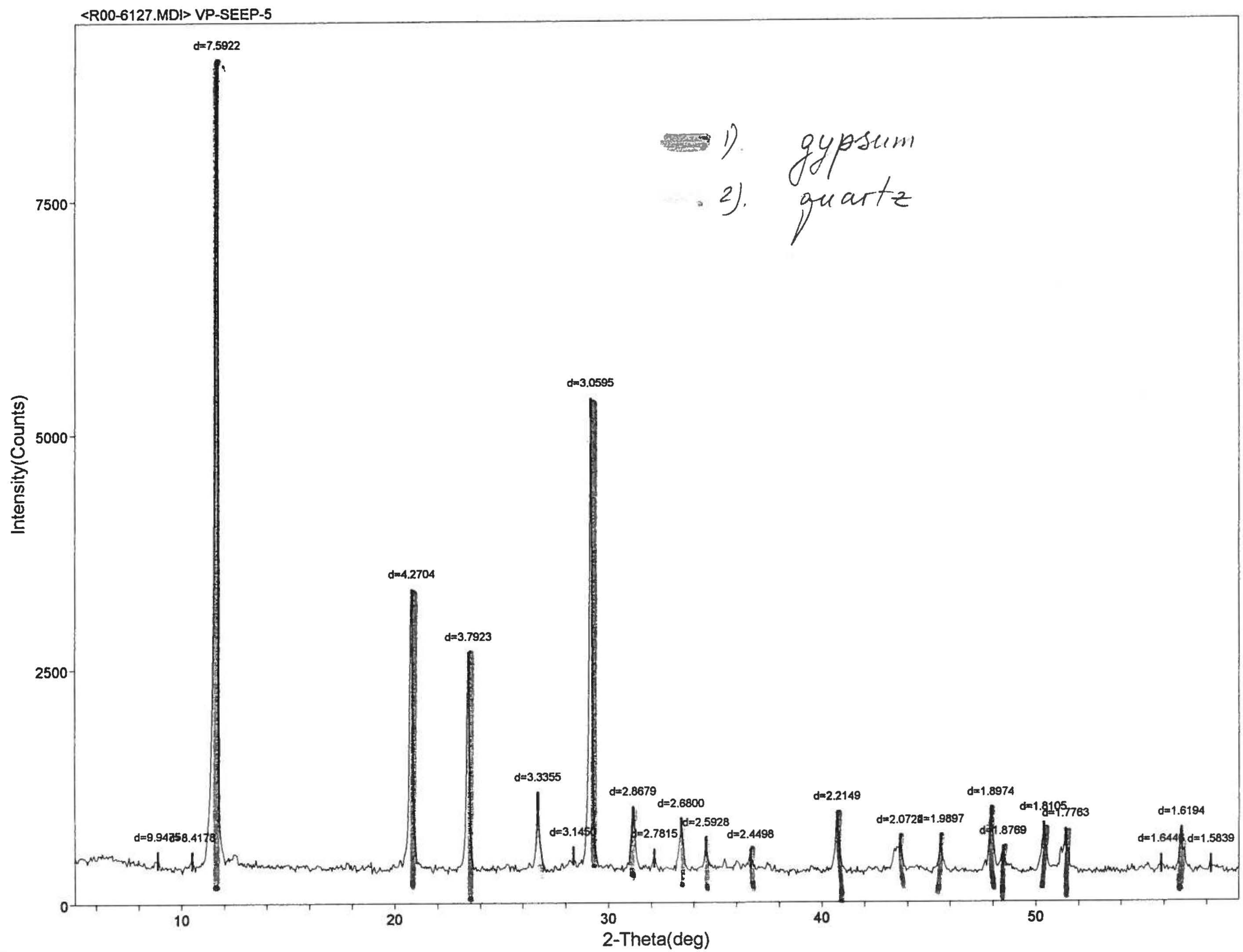
#	2-Theta	d(A)	h	k	l	BG	Peak	P%	Area	A%	FWHM	Size(A)	#
1	13.000	6.8043				358	265	3.7	61	4.5	0.183	>1000	1
2	14.750	6.0009				416	273	3.8	50	3.7	0.144	>1000	2
3	15.156	5.8411				456	1436	19.9	252	18.7	0.140	>1000	3
4	15.912	5.5652				463	505	7.0	95	7.0	0.149	>1000	4
5	16.300	5.4335				431	1953	27.1	404	30.1	0.165	>1000	5
6	17.440	5.0807				400	1366	19.0	224	16.6	0.131	>1000	6
7	17.955	4.9361				681	1751	24.3	266	19.8	0.121	>1000	7
8	18.198	4.8709				635	1298	18.0	385	28.6	0.237	572	8
9	19.952	4.4464				396	1238	17.2	329	24.5	0.213	781	9
10	20.257	4.3802				422	7206	100.0	1343	100.0	0.149	>1000	10
11	21.524	4.1251				632	949	13.2	132	9.8	0.111	>1000	11
12	22.134	4.0128				619	3824	53.1	583	43.4	0.122	>1000	12
13	22.510	3.9465				370	795	11.0	241	17.9	0.242	500	13
14	22.893	3.8814				370	340	4.7	66	4.9	0.154	>1000	14
15	23.609	3.7653				434	362	5.0	56	4.2	0.123	>1000	15
16	24.140	3.6837				526	282	3.9	35	2.6	0.098	>1000	16
17	24.592	3.6170				425	845	11.7	154	11.4	0.145	>1000	17
18	24.943	3.5668				462	1049	14.6	181	13.5	0.138	>1000	18
19	25.846	3.4443				483	381	5.3	54	4.0	0.112	>1000	19
20	26.267	3.3900				370	602	8.4	117	8.7	0.155	>1000	20
21	26.494	3.3614				451	282	3.9	56	4.1	0.158	>1000	21
22	27.383	3.2543				499	319	4.4	65	4.8	0.161	>1000	22
23	27.803	3.2061				347	447	6.2	96	7.1	0.171	>1000	23
24	28.121	3.1706				579	321	4.5	43	3.1	0.105	>1000	24
25	28.942	3.0824				396	96	1.3	17	1.2	0.138	>1000	25
26	29.741	3.0014				603	689	9.6	106	7.8	0.122	>1000	26
27	30.600	2.9191				583	795	11.0	403	29.9	0.405	221	27
28	30.834	2.8975				552	1162	16.1	324	24.1	0.223	531	28
29	31.483	2.8392				475	296	4.1	42	3.1	0.113	>1000	29
30	32.150	2.7819				429	498	6.9	76	5.6	0.122	>1000	30
31	32.490	2.7535				443	193	2.7	27	2.0	0.111	>1000	31
32	33.008	2.7114				436	245	3.4	72	5.3	0.234	473	32
33	33.365	2.6833				411	461	6.4	151	11.2	0.261	395	33
34	33.956	2.6379				372	72	1.0	7	0.5	0.074	>1000	34
35	34.752	2.5793				388	518	7.2	98	7.3	0.151	>1000	35
36	35.114	2.5535				383	347	4.8	80	5.9	0.183	810	36
37	35.993	2.4931				388	205	2.8	39	2.9	0.150	>1000	37
38	36.409	2.4656				407	156	2.2	17	1.2	0.083	>1000	38
39	37.205	2.4147				413	522	7.2	97	7.2	0.147	>1000	39
40	38.330	2.3463				412	188	2.6	32	2.3	0.134	>1000	40
41	38.921	2.3121				425	264	3.7	41	3.0	0.123	>1000	41
42	39.549	2.2768				415	432	6.0	121	8.9	0.222	497	42
43	39.845	2.2605				390	499	6.9	116	8.6	0.186	714	43
44	40.767	2.2115				392	217	3.0	30	2.2	0.109	>1000	44
45	41.162	2.1912				354	127	1.8	19	1.4	0.119	>1000	45
46	41.799	2.1593				368	117	1.6	20	1.4	0.131	>1000	46
47	42.257	2.1369				353	84	1.2	10	0.7	0.090	>1000	47
48	42.905	2.1061				363	90	1.2	9	0.6	0.077	>1000	48
49	43.873	2.0619				354	162	2.2	29	2.1	0.141	>1000	49
50	44.330	2.0417				344	141	2.0	25	1.8	0.138	>1000	50
51	45.096	2.0088				491	169	2.3	20	1.5	0.093	>1000	51

Scan Parameters: Range = 5.0-59.5/0.05, Dwell = 1(sec), Max-I = 7628, Anode = CU Date: 07-12-00@10:12

Search Parameters: Filter = 11(pts), Threshold = 3.0(esd), Peak-Cutoff = 0.5%, 2-Theta Zero Offset = 0.0(deg)

Note: Intensity data from raw counts, Summit peak location, Wavelength for computing d-spacing = 1.540562<CU, K-alpha1>

#	2-Theta	d(A)	h	k	l	BG	Peak	P%	Area	A%	FWHM	Size(A)	#
52	45.470	1.9931				392	574	8.0	97	7.2	0.134	>1000	52
53	46.117	1.9666				418	281	3.9	64	4.7	0.180	719	53
54	47.048	1.9299				416	132	1.8	21	1.6	0.127	>1000	54
55	47.744	1.9034				434	140	1.9	38	2.8	0.216	506	55
56	48.447	1.8774				461	147	2.0	32	2.4	0.173	771	56
57	48.807	1.8644				481	421	5.8	97	7.2	0.183	680	57
58	49.349	1.8452				444	226	3.1	29	2.1	0.100	>1000	58
59	50.449	1.8075				355	198	2.7	60	4.4	0.239	436	59
60	50.898	1.7926				347	265	3.7	56	4.1	0.166	821	60
61	51.790	1.7638				345	168	2.3	56	4.2	0.266	377	61
62	52.241	1.7496				360	214	3.0	44	3.3	0.164	848	62
63	53.138	1.7222				391	92	1.3	10	0.7	0.085	>1000	63
64	53.344	1.7160				372	99	1.4	11	0.8	0.088	>1000	64
65	53.763	1.7036				371	137	1.9	16	1.2	0.091	>1000	65
66	54.506	1.6821				363	83	1.2	11	0.8	0.104	>1000	66
67	56.397	1.6301				335	130	1.8	21	1.5	0.124	>1000	67
68	58.147	1.5852				321	68	0.9	9	0.6	0.097	>1000	68
69	58.749	1.5703				323	87	1.2	15	1.1	0.135	>1000	69
@	End-of-List												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d=7.5922
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2). quartz
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d=3.1450
d=2.8679
d=2.7815
d=2.6800
d=2.5928
d=2.4498
d=2.2149
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d=1.7763
d=1.6194
d=1.6446
d=1.5839
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d=8.4178
Intensity(Counts)
7500
5000
2500
0
10
20
30
40
50
2-Theta(deg)

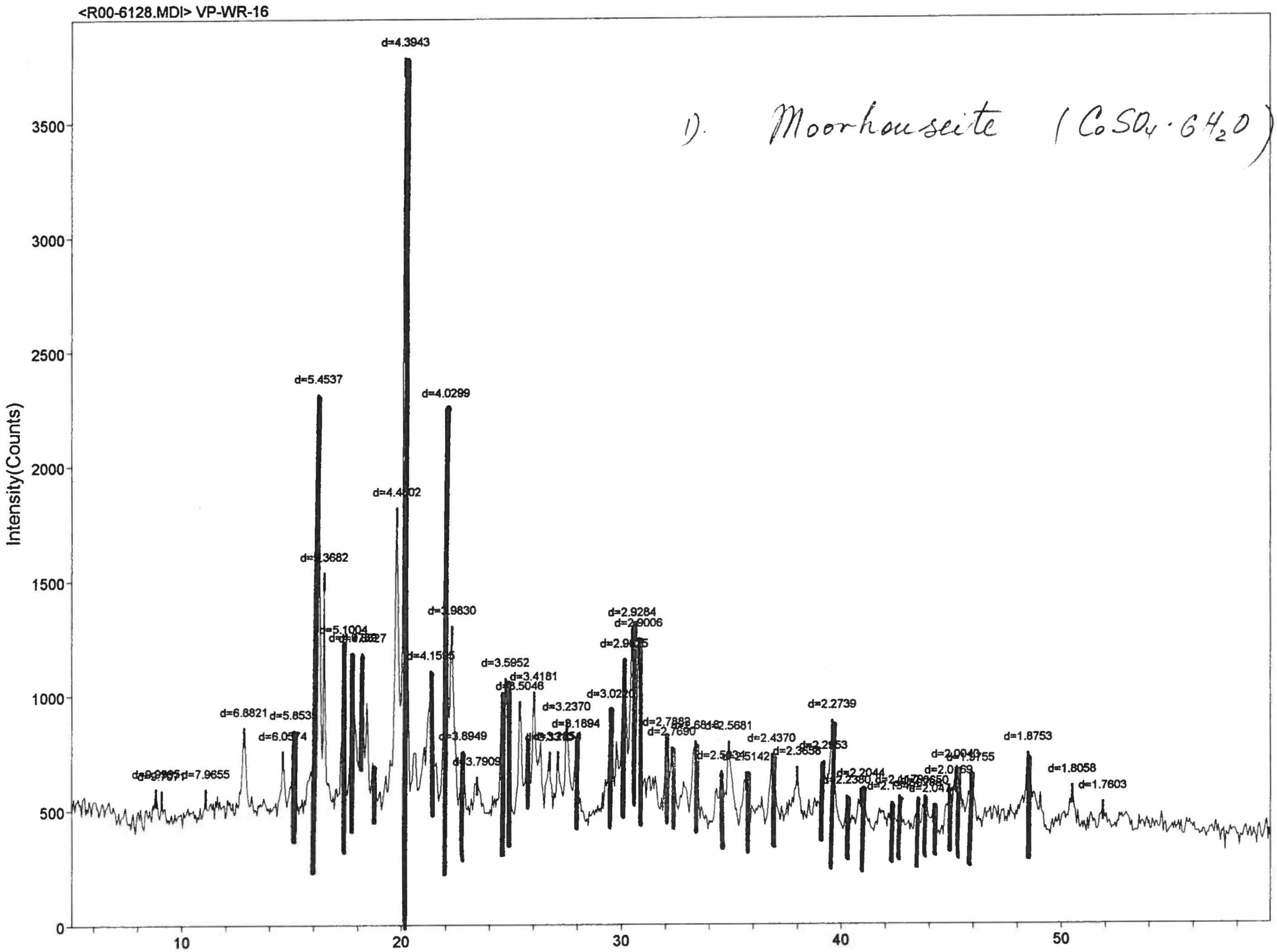
<R00-6127.MDI> VP-SEEP-5 [JADE - Peak List Report]

Scan Parameters: Range = 5.0-59.5/0.05, Dwell = 1(sec), Max-I = 8957, Anode = CU Date: 07-12-00@11:10

Search Parameters: Filter = 11(pts), Threshold = 3.0(esd), Peak-Cutoff = 0.5%, 2-Theta Zero Offset = 0.0(deg)

Note: Intensity data from raw counts, Summit peak location, Wavelength for computing d-spacing = 1.540562<CU, K-alpha1>

#	2-Theta	d(A)	h	k	l	BG	Peak	P%	Area	A%	FWHM	Size(A)	#
1	8.882	9.9475				374	110	1.3	18	0.9	0.126	>1000	1
2	10.501	8.4178				391	85	1.0	10	0.5	0.094	>1000	2
3	11.646	7.5922				430	8527	100.0	1954	100.0	0.183	>1000	3
4	20.784	4.2704				357	2918	34.2	590	30.2	0.162	>1000	4
5	23.439	3.7923				345	2260	26.5	379	19.4	0.134	>1000	5
6	26.704	3.3355				332	769	9.0	156	7.9	0.161	>1000	6
7	28.355	3.1450				393	124	1.5	13	0.6	0.082	>1000	7
8	29.164	3.0595				386	4923	57.7	921	47.1	0.150	>1000	8
9	31.160	2.8679				358	587	6.9	129	6.6	0.174	>1000	9
10	32.154	2.7815				368	122	1.4	19	1.0	0.122	>1000	10
11	33.407	2.6800				342	473	5.5	109	5.5	0.183	844	11
12	34.566	2.5928				359	252	3.0	37	1.9	0.117	>1000	12
13	36.653	2.4498				359	121	1.4	21	1.0	0.135	>1000	13
14	40.702	2.2149				313	574	6.7	135	6.9	0.188	687	14
15	43.643	2.0722				334	295	3.5	85	4.3	0.230	464	15
16	45.553	1.9897				311	324	3.8	68	3.4	0.166	882	16
17	47.903	1.8974				323	600	7.0	154	7.9	0.205	552	17
18	48.459	1.8769				399	108	1.3	18	0.9	0.126	>1000	18
19	50.359	1.8105				344	420	4.9	99	5.0	0.187	641	19
20	51.398	1.7763				349	342	4.0	84	4.3	0.194	598	20
21	55.858	1.6446				317	94	1.1	16	0.8	0.132	>1000	21
22	56.805	1.6194				320	383	4.5	75	3.8	0.156	920	22
23	58.200	1.5839				302	102	1.2	17	0.8	0.128	>1000	23
@	End-of-List												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d=3.4181
d=3.5046
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d=3.1894
d=6.8821
d=7.9655
d=2.2739
d=2.4370
d=2.5681
d=2.7690
d=1.8753
d=1.8058
d=1.7603
d=3.8949
d=3.7909
d=5.1004
d=2.2044
d=2.0040
d=1.9755

<R00-6128.MDI> VP-WR-16 [JADE - Peak List Report]

Scan Parameters: Range = 5.0-59.5/0.05, Dwell = 1(sec), Max-I = 3761, Anode = CU Date: 07-12-00@11:44

Search Parameters: Filter = 11(pts), Threshold = 3.0(esd), Peak-Cutoff = 0.5%, 2-Theta Zero Offset = 0.0(deg)

Note: Intensity data from raw counts, Summit peak location, Wavelength for computing d-spacing = 1.540562<CU, K-alpha1>

#	2-Theta	d(A)	h	k	l	BG	Peak	P%	Area	A%	FWHM	Size(A)	#
1	8.836	9.9995				457	107	3.4	19	3.5	0.140	>1000	1
2	9.103	9.7071				460	94	3.0	10	1.7	0.079	>1000	2
3	11.099	7.9655				482	79	2.5	8	1.4	0.075	>1000	3
4	12.853	6.8821				507	324	10.3	73	13.5	0.180	>1000	4
5	14.611	6.0574				565	162	5.1	19	3.5	0.093	>1000	5
6	15.123	5.8535				568	250	7.9	36	6.5	0.113	>1000	6
7	16.239	5.4537				536	1750	55.6	372	68.5	0.170	>1000	7
8	16.500	5.3682				547	961	30.5	116	21.3	0.096	>1000	8
9	17.373	5.1004				701	490	15.6	60	11.1	0.098	>1000	9
10	17.800	4.9789				630	523	16.6	105	19.3	0.160	>1000	10
11	18.229	4.8627				665	487	15.5	84	15.4	0.137	>1000	11
12	19.800	4.4802				593	1197	38.0	274	50.4	0.183	>1000	12
13	20.191	4.3943				611	3150	100.0	542	100.0	0.138	>1000	13
14	21.344	4.1595				642	433	13.7	94	17.3	0.173	>1000	14
15	22.039	4.0299				615	1607	51.0	278	51.1	0.138	>1000	15
16	22.301	3.9830				587	684	21.7	156	28.6	0.181	>1000	16
17	22.813	3.8949				570	153	4.9	18	3.2	0.091	>1000	17
18	23.448	3.7909				497	114	3.6	31	5.7	0.216	653	18
19	24.743	3.5952				506	535	17.0	130	23.9	0.194	947	19
20	25.394	3.5046				649	291	9.2	35	6.3	0.094	>1000	20
21	26.047	3.4181				659	322	10.2	46	8.4	0.113	>1000	21
22	26.741	3.3310				599	117	3.7	14	2.5	0.091	>1000	22
23	27.119	3.2854				602	118	3.7	11	2.0	0.072	>1000	23
24	27.532	3.2370				538	311	9.9	51	9.3	0.130	>1000	24
25	27.951	3.1894				498	277	8.8	54	10.0	0.156	>1000	25
26	29.534	3.0220				697	206	6.5	26	4.7	0.098	>1000	26
27	30.141	2.9625				874	249	7.9	30	5.4	0.093	>1000	27
28	30.501	2.9284				677	582	18.5	101	18.5	0.138	>1000	28
29	30.800	2.9006				786	427	13.6	55	10.0	0.102	>1000	29
30	32.075	2.7882				532	247	7.8	42	7.7	0.136	>1000	30
31	32.304	2.7690				544	193	6.1	39	7.2	0.161	>1000	31
32	33.383	2.6818				521	244	7.7	56	10.2	0.181	891	32
33	34.557	2.5934				452	180	5.7	60	11.0	0.266	382	33
34	34.908	2.5681				461	300	9.5	83	15.3	0.221	518	34
35	35.681	2.5142				477	149	4.7	29	5.3	0.153	>1000	35
36	36.852	2.4370				487	220	7.0	42	7.7	0.152	>1000	36
37	38.003	2.3658				477	172	5.5	36	6.5	0.164	>1000	37
38	39.217	2.2953				456	218	6.9	51	9.4	0.187	711	38
39	39.600	2.2739				456	398	12.6	103	18.8	0.205	575	39
40	40.263	2.2380				444	78	2.5	9	1.6	0.086	>1000	40
41	40.904	2.2044				424	127	4.0	34	6.2	0.211	540	41
42	42.300	2.1349				419	75	2.4	10	1.8	0.105	>1000	42
43	42.654	2.1179				441	81	2.6	7	1.3	0.068	>1000	43
44	43.498	2.0788				419	88	2.8	10	1.8	0.087	>1000	44
45	43.803	2.0650				413	105	3.3	28	5.0	0.208	548	45
46	44.200	2.0474				405	77	2.4	10	1.8	0.102	>1000	46
47	44.905	2.0169				441	123	3.9	31	5.6	0.199	588	47
48	45.209	2.0040				429	203	6.4	114	20.9	0.446	202	48
49	45.900	1.9755				488	130	4.1	21	3.7	0.123	>1000	49
50	48.504	1.8753				431	278	8.8	119	21.9	0.342	275	50
51	50.500	1.8058				423	144	4.6	33	6.0	0.181	683	51

Scan Parameters: Range = 5.0-59.5/0.05, Dwell = 1(sec), Max-I = 3761, Anode = CU Date: 07-12-00@11:44

Search Parameters: Filter = 11(pts), Threshold = 3.0(esd), Peak-Cutoff = 0.5%, 2-Theta Zero Offset = 0.0(deg)

Note: Intensity data from raw counts, Summit peak location, Wavelength for computing d-spacing = 1.540562<CU, K-alpha1>

#	2-Theta	d(A)	h	k	l	BG	Peak	P%	Area	A%	FWHM	Size(A)	#
52	51.899	1.7603				424	70	2.2	10	1.7	0.105	>1000	52
@	End-of-List												

SRK CONSULTING

Job V 00-400R

Vangordo/ICD003.04 KSS

Report date: 25 AUG 2000

LAB NO	FIELD NUMBER	Cu ppm	Pb ppm	Zn ppm	Ag ppm	As ppm	Ba ppm	Cd ppm	Co ppm	Ni ppm	Fe %	Mo ppm	Cr ppm	Bi ppm	Sb ppm	V ppm	Sn ppm	W ppm	Sr ppm	Y ppm	La ppm	Mn ppm	Mg %	Ti %	Al %	Ca %	Na %	K %	P ppm
R0006126	VP-SALT-3	13630	441	175400	<.4	125	6	288	170	58	.62	24	<4	<5	5	<2	<2	30	<2	4	<2	6723	0.40	<.01	0.50	0.06	0.01	<.01	<10

I=insufficient sample   X=small sample   E=exceeds calibration   C=being checked   R=revised
If requested analyses are not shown, results are to follow

ANALYTICAL METHODS
ICP PACKAGE : 0.5 gram sample digested in hot reverse aqua regia (soil,silt) or hot Aqua Regia(rocks).

APPENDIX E

Dilution Model

APPENDIX E
DILUTION MODEL

E.1 Introduction

The steps in creating the dilution model were:

1) Subdivide the Vangorda Creek catchment was into a number of subcatchments, as dictated by the locations of water quality monitoring stations, diversion ditches, tributary confluences, open pits, seepage collection ponds and waste dumps;

2) Estimate flows generated by each subcatchment;

3) Estimate metal loadings (net) generated within the boundaries of each subcatchment; and,

4) Combine the flows and loadings from the individual subcatchments in a spreadsheet model to simulate the movement of water and associated metal loadings through the Vangorda Creek drainage system.

Details of these step are provided in the following sections.

E.2 Define Subcatchments

The dilution model used for this project employs catchment areas as the basic "building block". Subcatchments were selected based on the following criteria:

- allow estimates of metal concentration to be made at three key locations downstream of the Vangorda Pit;
- account for modifications to the drainage system caused by development of the Vangorda and Grum mines (i.e., allow for effects of stream diversions, seepage collection ditches, seepage collection ponds and open pits);
- select areas where the background metal loadings could be readily estimated (e.g., a total catchment area located above a single water quality monitoring station or an intervening area located between two such stations); and,

- allow for the assessment of the **net** impact of the Vangorda Pit on the receiving water quality of Vangorda Creek (i.e., allow for the scenario in which metal loadings from other mine-related sources of contamination are set to zero for the purpose of the dilution calculations).

Based on the above criteria, a total of 12 subcatchments were selected. The subcatchments are shown in Figure E.1. Figure E.1 also shows the local drainage pattern and the locations of the main mine elements, such as open pits and waste rock dumps. Each subcatchment is labelled with an identification number, which is used to explain the structure of the dilution model. Table E.1 provides details of the subcatchments, including the identification number, a descriptive name, and the measured drainage area. The outlet of the flow-through pit will command a total drainage area of 21.8 km^2. At Station V8, or the most downstream point of interest on Vangorda Creek, the total drainage area is 90.5 km^2.

It is important to note that two of the subcatchments (Nos. 4 and 5) were not considered in the dilution calculations. These subcatchments are highlighted in Figure E.1. Subcatchment 4 encompasses the area occupied by the Vangorda Waste Dump and the associated seepage collection pond (Little Creek Pond). Subcatchment 5 comprises two areas: i) the area draining to the Grum pit; and, ii) most of the area occupied by the Grum waste dumps (Main and Southwest). The flow and chemical loadings from these two subcatchments were excluded in the calculations so as to focus the report exclusively on the examination of potential closure measures for the Vangorda Pit. It should be noted that the flows from these two subcatchments are negligible relative to the total runoff generated by the Vangorda Creek catchment. However, the metal loadings from the two subcatchments have the potential to be large. The exclusion of the flow and loading contributions from the two subcatchments means that the results of the dilution model represent the net impact of the proposed flow-through pit on the water quality of the Vangorda Creek. In effect, they represent a potential closure scenario in which: i) Vangorda Creek is routed through the Vangorda pit; and ii) the runoffs from Subcatchments 4 and 5 are completely intercepted and then treated and discharged outside the boundaries of the Vangorda Creek catchment. This could be achieved if, for example, the runoffs from Subcatchments 4 and 5 are pumped to the Faro pit for subsequent treatment by a water treatment plant in the Rose Creek catchment.

Insert Figure E.1 here

TABLE E.1
Details of Vangorda Creek Subcatchments

Subcatchment ID No.	Subcatchment Description	Drainage Area (km^2)	Median Elevation (m)	Mean Annual Unit Runoff (mm)	Mean Annual Runoff ($1000\ m^3$)
1	Vangorda Creek above Blind Creek Road	20.2	1570	374	7549
2	Total catchment of Vangorda Northeast Interceptor Ditch	0.78	1200	222	173
3	Incremental catchment of Vangorda Pit	0.80	1160	206	164
4	Area occupied by Vangorda Waste Dump and the Little Creek Pond	0.72	1130	193	139
5	Area occupied by Grum Waste Dumps and the Grum Pit	3.81	1254	244	930
6a	Catchment of upper segment of Grum Northeast Interceptor Ditch	1.8	1350	284	510
6b	Incremental catchment of Sheep Pad Ponds and Vangorda Northwest Interceptor Ditch	1.4	1240	238	334
6c	Vangorda Creek between Station V27 and the plunge pool (excluding Subcatchment 5)	2.1	1100	181	380
7a	Shrimp Creek above Station V4 (excluding Subcatchment 2)	12.1	1150	202	2438
7b	AEX Creek above Station V6A	4.4	1360	288	1265
7c	West Fork Vangorda Creek above Station V5 (excluding Subcatchment 7b)	26.9	1190	218	5862
7d	Vangorda Creek above V8 and below V27, V4 and V5	15.5	930	111	1725
1 to 7d	Vangorda Creek above Station V8	90.5	-	237	21470

E.3 Average Annual Flows

The investigation of the flow-through pit option is at the feasibility stage. With this in mind, the use of the dilution model was limited to examining long-term average metal concentrations within Vangorda Creek.

To assess average metal concentrations, the dilution model had to be supplied with estimates of mean annual runoff (MAR). These estimates were based on an empirical runoff relationship derived during preparation of the ICAP document, or the latest closure plan for the Anvil Range Mine Complex (RGC, 1996). This empirical relationship used the well-known observation that runoff tends to increase with increasing elevation in a mountainous region. In the ICAP document, the empirical relationship was presented as a graph (see Figure 3-16 of the ICAP main report). Here, the relationship has been converted to an equivalent equation, as follows:

$$Q = A\,(0.41\,E - 270)$$

where:

> Q = mean annual runoff generated by a given subcatchment in units of 1000 m^3;
>
> A = drainage area of the subcatchment in km^2; and,
>
> E = median elevation of the subcatchment in m (or, in other words, the contour that divides the subcatchment exactly into halves).

Table E.1 presents the results of applying the above equation to the 12 subcatchments adopted for preparing the dilution model. The values of MAR are expressed in this table in two units, namely as a volume and as an equivalent depth of water. Examination of this table reveals that the estimated values of MAR range from 111 mm in the most downstream subcatchment (7d) to 374 mm in the headwater subcatchment (1). The Vangorda Pit catchment has an estimated MAR of 206 mm.

E.4 Present-day Annual Metal Loads

Estimated annual metal loads in the Vangorda Creek catchment were estimated by:

- computing the average metal concentrations at various water quality monitoring stations within the Vangorda Creek catchment; and

- using these computed concentrations, together with the flow estimates from Section 1.2, to estimate the metal loadings washed off each of the dilution model subcatchments.

The mine has operated an extensive network of water quality monitoring stations in the Vangorda Creek catchment. From this network, a total of ten stations were selected to assist in establishing the present-day metal loadings washed from the subcatchments. Table E.2 lists these stations and provides statistics on two metal species, zinc and cadmium. As described later, a screening analysis of the open pit chemistry identified these two metals as having the potential to exceed minimum discharge criteria if Vangorda Creek was introduced to the pit.

The following points should be noted about Table E.2:

- Two statistics are provided for each metal, namely the flow-weighted average annual concentration and the arithmetic average. The former statistic was computed because it provides a more accurate estimate of annual loading, particularly if the metal concentrations exhibit a marked seasonal pattern. The technique used to compute the flow-weighted average is defined in the footnotes to the table. In Table E.2 the flow-weighted and arithmetic averages do not differ by much. This indicates that total zinc and total cadmium do not experience wide variations in their concentrations on a seasonal basis.

- The statistics determined on total metal determinations (i.e., the combined dissolved and particulate metal in the water column).

- Many of the water quality samples used in computing the averages had metal concentrations below the laboratory detection limit. These particular samples were handled differently for the two metals. For zinc, the concentrations of these samples were set to half the detection limit. This was a suitable procedure for zinc because the proportion of "below-detection" samples was small. Furthermore, for the majority of samples, the measured zinc concentration was well above detection. In such a case, the computed averages are reasonably insensitive to the method selected for dealing with samples at below detection. For example, little change would have resulted if these values were set to the full detection limit, rather than half the value.

TABLE E.2

Present-day Zinc and Cadmium Concentrations at Key Locations in the Vangorda Creek Catchment

Water Quality Monitoring Station			Zinc (Total) [c]				Cadmium (Total) [c]			
ID	Name	Period of Record Used in Computing Statistics	Flow-weighted Average Annual Conc. [a]	Arithmetic Average Conc. [b]	Total No. of Samples	No. of Samples Below Detection Limit	Flow-weighted Average Annual Conc. [a]	Arithmetic Average Conc. [b]	Total No. of Samples	No. of Samples Below Detection Limit
			(mg/L)	(mg/L)			(mg/L)	(mg/L)		
V1	Vangorda Creek above Blind Creek Road [d]	1988 - 1999	0.025	0.021	44	8	0.00031	0.00025	32	29
V4	Shrimp Creek	1988 - mid 2000	0.033	0.028	28	7	0.00078	0.00065	20	16
V5	West Fork of Vangorda Creek [e]	1988 - mid 2000	0.035	0.037	70	10	0.00046	0.00086	53	44
V6A	AEX Creek	1989 - mid 2000	0.035	0.036	74	12	0.00017	0.00054	52	45
VGMAIN	Vangorda Creek above West Fork	1998 - mid 2000	0.055	0.064	17	0	0.00060	0.00053	17	13
V8	Vangorda Creek near the mouth	1998 - mid 2000	0.045	0.046	26	2	0.00042	0.00064	26	18
V18	Grum NE Interceptor Ditch	1991 - 1998	0.035	0.043	39	3	0.00042	0.00051	19	16
V20	NE Interceptor Ditch above Vangorda Pit	1991 - 1998	0.066	0.073	14	2	0.0019	0.0028	6	5
V22	Vangorda Pit	1998 - mid 2000	n/a	27.1	6	0	n/a	0.047	6	1
V27	Vangorda Creek above Shrimp Creek	1998 - mid 2000	0.055	0.054	9	0	0.00012	0.00012	9	7

Notes: a) The flow-weighted average concentrations were computed using the following equation:

$$C_{Annual} = 0.12\, C_{Nov\text{-}Apr} + 0.565\, C_{May\text{-}Jul} + 0.315\, C_{Aug\text{-}Oct}$$

where: C_{Annual} = flow-weighted average annual concentration;

$C_{Nov\text{-}Apr}$ = average concentration of samples taken during 6-month period from November to April;

$C_{May\text{-}Jul}$ = average concentration of samples taken during 3-month period from May to July; and,

$C_{Aug\text{-}Oct}$ = average concentration of samples taken during 3-month period from August to October.

The constants in the equation add to one and represent the relative amounts of runoff generated in each of the 3 periods. For example, during an average year, the period from May to July accounts for approximately 56.5% of the total annual runoff generated by the Vangorda Creek catchment.

b) The arithmetic averages were computed by summing all sample concentrations and dividing by the number of samples.

c) Different procedures were used for zinc and cadmiu to handle samples with concentrations below the detection limit. For zinc, the concentration of the sample was set equal to half the detection limit. For cadmium, the concentration was set to zero.

d) The computed average zinc concentrations for Station V1 exclude a sample with an anomalously-high concentration of 17.5 mg/L.

e) The computed average zinc concentrations for Station V5 exclude a sample with an anomalousl -high concentration of 1.31 mg/L.

- A different approach was required to deal with the "below-detection" values for cadmium, for three reasons. Firstly, and in contrast to zinc, a large percentage of the cadmium samples had concentrations below the laboratory detection limit. Secondly, a wide range of detection limits has been used ove r the years for cadmium (from 0.0001 to 0.006 mg/L). Finally, when a cadmium concentration was measurable, it was often just above the detection limit. Therefore, the computed average concentration was very sensitive to the method adopted for dealing with samples at below the detection limit. This is of potential concern for cadmium because its receiving water quality guideline is very close to the limits of detection that can be achieved by a testing laboratory. Accordingly, the method of dealing with the "below-detection" samples could have a bearing on whether or not the flow-through option is accepted or not. For example, if the adopted method ends up overestimating the true background cadmium concentration in Vangorda Creek, then the (potentially erroneous) judgement might be made that this stream is too near its maximum desirable concentration and it can not accept the additional loading from the flow-through option. To avoid this problem, the concentrations of the "below-detection" samples were set to zero for the purpose of computing averages. In this way, it was at least known that the computed averages underestimated the true background concentrations and, therefore, the flow-through pit option could not be rejected simply because the true assimilative capacity of the Vangorda Creek was erroneously underestimated. The assimilative capacity is defined here as the receiving water quality limit minus the background concentration.

- Different periods of record were used in computing the statistics appearing in Table E.2. For stations with chemistries that may have been significantl influenced by the mining operation, the averages were computed using the data collected from 1998 to present, corresponding to the period of the latest temporar shutdown. This was done to provide averages representative of reasonabl homogeneous conditions in which upstream mining activity was not changing much (e.g., the waste dumps were not being added to). For all other stations, the complete period of record was employed in calculating the averages. The implicit assumption for these stations was that the water quality records do not contain trends.

Once the flow-weighted concentrations were computed, the next task was to establish the annual metal loadings from each of the minesite subcatchments. Table E.3 summarizes the techniques used to estimate the annual loadings. These techniques can be categorized into two groups, namely headwater catchments and incremental catchments. For the first case, the computation of annual metal loading was a relatively straightforward exercise. The headwater catchments were purposely defined so that their outlets were located at a water quality monitoring station. Accordingly, the average annual loading for each metal and each headwater catchment could be obtained by taking the product of the observed flow-weighted concentration (see Table E.2) and the estimated average annual runoff volume (see Table E.1) at the outlet station.

For incremental catchments, the assessment of annual loading was more involved. Either of two courses of action was possible. In the case where the metal loading from the incremental catchment was large relative to upstream sources, computations were made of the metal loadings at water quality stations located at both the upstream and downstream ends of the incremental catchment. The difference in computed loadings at the two stations was then assumed to represent the chemical loading generated by the intervening catchment between the two stations. In cases where the incremental catchment generated a small relative load, the somewhat arbitrary assumption was made that the runoff from the incremental catchment attained the same concentration as measured at Station V1 (Vangorda Creek above Blind Creek Road).

Table E.3 presents the estimated zinc and cadmium average annual loads for all the subcatchments except Nos. 3, 4 and 5. Estimated loads from catchment 3 are discussed in Section 4 of this report. As indicated above, the chemical loadings from subcatchments 4 and 5 were not included in the dilution model calculations and, therefore, it was unnecessary to establish their magnitudes.

TABLE E.3

Estimated Present-day Loadings Washed Off Subcatchments of the Vangorda Creek Catchment

Sub-catchment ID No.	Subcatchment Description	Average Annual Load		Method of Estimation	Comments
		Zn (T) (kg)	Cd (T) (kg)		
1	Vangorda Creek above Blind Creek Road	189	2.3	(estimated average flow generated by Subcatchment 1) x (average observed concentration at Station V1)	Inflows from part of Subcatchment 1 enter Vangorda Creek downstream of Station V1.
2	Total catchment of Vangorda Northeast Interceptor Ditch (VNEID)	11	0.3	(estimated average flow generated by Subcatchment 2) x (average observed concentration at Station V20)	Some portion of the load washed off Subcatchment 2 bypasses the VNEID and reports to the Vangorda Pit.
3	Incremental catchment of Vangorda Pit			See Section 4	
4	Area occupied by Vangorda Waste Dump and the Little Creek Pond	-	-	Not computed	Loading from this subcatchment was assumed to be completely intercepted and diverted out of the Vangorda Ck catchment.
5	Area occupied by Grum Waste Dumps and the Grum Pit	-	-	Not computed	Loading from this subcatchment was assumed to be completely intercepted and diverted out of the Vangorda Ck catchment.
6a to 6c	Vangorda Creek between Station V27 and the plunge pool (excluding Subcatchments 4 and 5)	31	0.4	(estimated runoff generated by Subcatchments 6a to 6c) x (average observed concentration at Station V1)	Difficult to separate effects of various mine elements in reach between plunge pool and Station V27. Combined runoff from Subcatchments 6a to 6c was assumed to have same concentration as Station V1.
7a	Shrimp Creek above Station V4 (excluding Subcatchment 2)	75	1.7	(estimated load at Station V4) - (estimated load at Station V20)	No allowance made for leakages from VNEID and VWDCD in performing load calculations. These ditch leakages would form only a negligible net contribution to flows at V4.
7b + 7c	West Fork Vangorda Creek above Station V5	249	3.3	(estimated runoff generated by Subcatchments 7b and 7c) x (average observed concentration at Station V5)	This catchment has only been minimally influenced by the mining operation.
7d	Vangorda Creek above V8 and below V27, V4 and V5	43	0.5	(estimated runoff generated by Subcatchment 7d) x (average observed concentration at Station V1)	Runoff from this subcat. was assumed to have same conc. as V1. A 2nd estimation technique was employed as a rough check on the 1st technique. In equation form, this second technique may be written: (load at V8)-(load at V5)-(load at V27)-(load at V4).

E.5 Spreadsheet Model

After assembling the information on subcatchments, flows and present-day metal loadings, the next task was to organize the data into a spreadsheet model. The whole purpose of the spreadsheet was to accumulate the subcatchment flows and metal loads in the correct upstream to downstream order so that chemical concentrations could be predicted at various points along the main stem of Vangorda Creek.

The dilution model was set-up to simulate the following scenario:

- the Vangorda Creek Diversion Channel is abandoned and Vangorda Creek is directed to pass through the Vangorda Pit;
- the Northeast Interceptor Ditch is breached so that the complete yield from Subcatchment 2 enters the Vangorda Pit;
- all drainage from Vangorda Waste Dump is captured, treated and discharged outside of the Vangorda Creek catchment;
- no groundwater bypass from the Vangorda Waste Dump (Subcatchment 4) to Vangorda Creek;
- all drainage from the Grum Pit and most of it from the Grum Waste Dumps (Subcatchment 5) is captured, treated and discharged outside of Vangorda Creek catchment; and,
- no groundwater bypass from Grum Pit and the Grum Waste Dumps (Subcatchment 5) to Vangorda Creek.

APPENDIX F
September 9, 2000 Seep Survey

APPENDIX F
SEPTEMBER 9, 2000 SEEP SURVEY

A second seep survey was completed in September, 2000 by Gartner Lee Ltd, following a period of heavy rain. Due to time constraints, field measurements were not taken, and the samples were not filtered or preserved in the field. Sample locations are shown in Figure F.1, and descriptions are provided in Table F.1. It should be noted that the seep numbers to not correspond to seep numbers from the June seep survey. However some of the locations are the same.

Samples were submitted to Cavendish Laboratory Ltd. in Vancouver for analysis of pH, electrical conductivity, sulphate, and a full suite of dissolved metals by ICP.

The results are presented in Table F.2. A comparison of the results to the June seep survey results is presented in Table F.3. In general, the results follow the same patterns as observed in the June seep survey. Metal concentration were in the same order of magnitude, but tended to be slightly lower than in the June samples. Arsenic, antimony and molybdenum concentrations seem to be an exception. They appear to be much higher in the recent samples. This may reflect differences in the laboratory used for the testing.

Comparisons of the June and September samples are discussed as follows:

- The pit lake sample was taken from the ramp, similar to the regular monitoring samples. The pH of this sample was slightly lower than the earlier pit samples. Sulphate and metal concentrations were in the range of the surface and deep samples taken in the June seep survey.

- Seep 2 had a lower pH and higher sulphate and metal concentrations than the corresponding sample taken in June.

- Seeps 4, 5 and 6, corresponding to June seeps 4, 6 and 7 had similar sulphate and slightly lower metal concentrations compared to the June samples. Lower iron and zinc concentrations observed in Seeps 4 and 5 could be because these seeps were sampled several meters downstream of the point of emergence, or because they were not filtered in the field. Both these sampling differences could have lead to precipitation of iron and co-precipitation or sorption of the associated zinc.

- Seep-7 corresponds to the June seep 1. This sample had slightly lower sulphate and metal concentrations compared to the June sample.

- Seep 9 corresponds to June seep 14. However it was taken from a higher bench and therefore had a shorter flow path. Despite this, the pH was lower and metal concentrations were higher than the sample taken in June. This reflects the lower rate of flow.

- Seeps 1 and 3 were taken from the ditch near the bottom of the pit. These seeps were not sampled previously. The results indicate this water has a low pH and very high metal concentrations.

- Seeps 8 and 10 are from above the hairpin turn in the south area of the pit. Flow paths are relatively short, and are isolated to the pit walls. These seeps were not flowing during the June site visit. Despite the short flow paths, these seeps were both acidic, with high sulphate and metal concentrations.

TABLE F.1

Descriptions of Samples Collected September 9, 2000 by E. Denholm

Seep	Description
PIT	-Vangorda pit water at surface on pond side of inside road berm; minor film(?) floating on surface at edges
SEEP1	- seepage flow at bottom of ramp near pond water ~0.5Lps; lt orange staining
SEEP2	- seepage over wall in ~SE corner above in pit dump bench; split in two over wall combined ~0.3Lps; lt orange staining
SEEP3	- east side ramp ditch at in pit dump bench that reports directly into pond; lt orange staining; ~0.7Lps
SEEP4	- west side of ramp centreline near top of ramp emerges from floor; dk orange staining; ~0.05Lps
SEEP5	- centre of ramp near top emerges from floor; dk orange staining; ~0.1 Lps
SEEP6	- west side ramp ditch ~2/3 to top at toe; emerges from toe of in-pit rock dump; ~0.5Lps
SEEP7	- emerges from toe of fill above east outside corner at top of ramp and flows into east side ramp ditch; lt orange staining; ~0.7 Lps
SEEP8	- emerges from toe of fill above south side of ramp at snow fence and runs down ramp centre (not side ditches to near in-pit dump bench; med orange staining; ~0.3 Lps
SEEP9	- east side of south end upper stockpile area on upper bench where flow emerges from original ground; ~0.7 Lps; clear/no staining
SEEP10	- surface flow in centre of ramp above snow fence originating from stockpile area to west of pit at toe of till stockpile; clear/no staining; ~0.05 Lps

Notes: Rainfall, ground condition and creek/seepage flows much greater/wetter than normal for the preceding summer.

Vangorda pit water elevation at approximately stake 11.8

TABLE F.2
Sept 9, 2000 Seep Survey Results

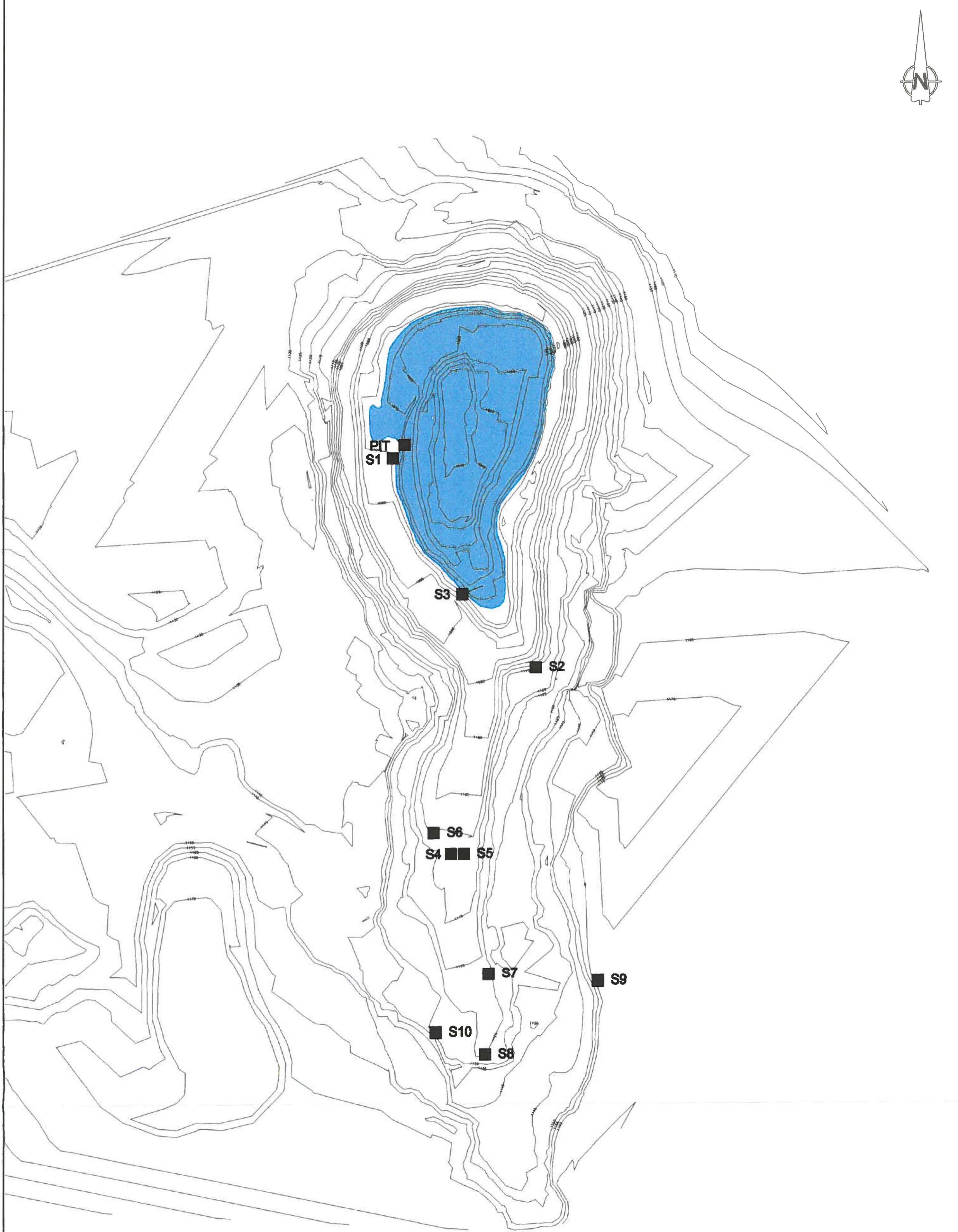
Parameter	Units	Pit Lake	SEEP-1	SEEP-2	SEEP-3	SEEP-4	SEEP-5	SEEP-6	SEEP-7	SEEP-8	SEEP-9	SEEP-10
Conductivity	uS	700	4650	1530	5000	5550	5500	6450	5550	5500	275	1860
pH	s.u.	6.74	3.31	4.64	3.20	4.61	4.32	4.42	3.57	3.66	6.74	3.47
SO4	mg/L	361	4130	1103	4986	5540	5492	6213	5190	5209	20	1422
Ag	mg/L	<.003	.009	<.003	.010	<.003	<.003	<.003	.025	.023	<.003	.006
Al	mg/L	.14	5.78	.32	4.55	1.11	1.04	2.73	5.65	6.95	.11	10.25
As	mg/L	<.005	.484	.073	.425	.477	.417	.520	.542	.503	<.005	.155
B	mg/L	.10	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	.10	.05
Ba	mg/L	.064	.043	.044	.036	.045	.040	.042	.038	.040	.220	.050
Be	mg/L	<.001	.004	<.001	.004	.004	.004	.005	.005	.005	<.001	.003
Bi	mg/L	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Ca	mg/L	68.6	238.8	141.6	234.7	396.6	336.7	328.6	249.2	260.5	34.8	131.1
Cd	mg/L	.043	1.686	.102	1.709	1.147	1.399	1.455	2.684	1.748	.007	.894
Co	mg/L	.099	3.579	.283	3.884	4.530	4.393	5.468	4.553	4.697	<.005	.470
Cr	mg/L	<.005	.071	<.005	.074	.100	.090	.117	.086	.088	<.005	.014
Cu	mg/L	.030	8.465	.056	8.718	.075	.135	.136	16.226	21.596	.157	4.891
Fe	mg/L	<.01	326.26	56.73	366.63	188.10	209.33	465.63	574.38	538.66	2.52	19.24
K	mg/L	<1	5	<1	5	13	8	9	7	6	<1	<1
La	mg/L	<.005	.205	.019	.167	.264	.197	.199	.178	.229	<.005	<.005
Mg	mg/L	28.2	248.3	69.5	258.7	414.2	346.6	375.6	277.4	283.8	10.9	86.9
Mn	mg/L	5.46	139.21	31.03	148.16	176.29	172.55	174.00	194.29	150.00	.22	21.76
Mo	mg/L	.026	1.052	.177	1.098	1.337	1.185	1.338	1.308	1.220	<.002	.479
Na	mg/L	5	9	9	9	12	10	12	10	10	5	5
Ni	mg/L	.169	2.603	.151	2.717	3.640	3.284	4.258	3.127	3.205	.016	.572
P	mg/L	5	163	31	155	199	178	197	198	199	<1	85
Pb	mg/L	<.01	3.56	.52	3.61	3.26	3.11	4.02	4.56	4.42	.41	2.58
S	mg/L	115	1372	363	1657	1842	1826	2066	1725	1731	12	469
Sb	mg/L	.09	2.33	.43	2.46	2.94	2.67	3.07	2.79	2.65	<.03	1.12
Se	mg/L	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005
Si	mg/L	1.7	9.3	3.6	9.1	5.8	5.9	9.4	12.2	13.0	5.0	6.8
Sn	mg/L	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Sr	mg/L	.624	.764	.922	.748	2.382	1.284	1.595	.689	.818	.158	.376
Ti	mg/L	<.005	.033	.009	.032	.058	.046	.048	.038	.040	<.005	<.005
V	mg/L	.040	.061	.016	<.005	.009	<.005	.019	.019	.024	<.005	.020
W	mg/L	<.03	.07	<.03	.08	.10	.09	.11	.10	.09	<.03	<.03
Zn	mg/L	18.79	474.55	75.15	482.70	550.30	513.24	587.98	557.81	530.64	.54	205.36

TABLE F.3
Comparison of June and September Seep Survey Results

Parameter	Units	VP-SEEP-10 6-Jun	VP-SEEP-11 6-Jun	Pit Lake (Surface) 9-Sep	VP-SEEP-2 6-Jun	SEEP-2 9-Sep	VP-SEEP-4 6-Jun	VP-SEEP-6 6-Jun	VP-SEEP-7 6-Jun	SEEP-4 9-Sep	SEEP-5 9-Sep	SEEP-6 9-Sep
Conductivity	uS	1440	444	700	705	1530	5630	5280	5260	5550	5500	6450
pH	s.u.	7.28	7.89	6.74	6.92	4.64	5.59	5.04	4.99	4.61	4.32	4.42
Acidity (to pH 8.3)	mg CaCO3eq/L	118	12		59		2480	2420	2380			
Alkalinity-Total	mg CaCO3eq/L	82	66		59		36	13	13			
Sulphate	mg/L	830	166	361	324	1103	5160	4690	4610	5540	5492	6213
Aluminum	mg/L	<0.2	<0.2	.14	<0.2	.32	0.4	3.8	3.3	1.11	1.04	2.73
Arsenic	mg/L	<0.2	<0.2	<.005	<0.2	.073	<0.2	<0.2	<0.2	.477	.417	.520
Cadmium	mg/L	0.08	0.01	.043	0.04	.102	1.06	1.33	1.29	1.147	1.399	1.455
Calcium	mg/L	181	54	68.6	85.1	141.6	374	407	395	396.6	336.7	328.6
Cobalt	mg/L	0.41	0.03	.099	0.08	.283	4.56	5.48	5.33	4.530	4.393	5.468
Copper	mg/L	0.02	0.02	.030	<0.01	.056	<0.01	0.08	0.07	.075	.135	.136
Iron	mg/L	0.11	0.06	<.01	14.4	56.73	405	539	517	188.10	209.33	465.63
Lead	mg/L	<0.05	<0.05	<.01	<0.05	.52	1.4	1.14	1.08	3.26	3.11	4.02
Magnesium	mg/L	69.7	16.5	28.2	25.5	69.5	296	313	302	414.2	346.6	375.6
Manganese	mg/L	19.7	1.5	5.46	9.08	31.03	184	173	166	176.29	172.55	174.00
Molybdenum	mg/L	0.41	0.07	.026	0.06	.177	2.89	3.51	3.43	1.337	1.185	1.338
Nickel	mg/L	<0.03	<0.03	.169	<0.03	.151	<0.03	<0.03	<0.03	3.640	3.284	4.258
Potassium	mg/L	4	<2	<1	2	<1	9	8	8	13	8	9
Sodium	mg/L	6	2	5	4	9	7	8	8	12	10	12
Antimony	mg/L	<0.2	<0.2	.09	<0.2	.43	<0.2	<0.2	<0.2	2.94	2.67	3.07
Strontium	mg/L	1.4	0.51	.624	0.402	.922	1.16	1.25	1.2	2.382	1.284	1.595
Zinc	mg/L	70.1	6.27	18.79	32.6	75.15	814	826	804	550.30	513.24	587.98

TABLE F.3 (Cont.)
Comparison of June and September Seep Survey Results

Parameter	Units	VP-SEEP-1	SEEP-7	VP-SEEP-14	SEEP-9	SEEP-1	SEEP-3	SEEP-8	SEEP-10
		6-Jun	9-Sep	6-Jun	9-Sep	9-Sep	9-Sep	9-Sep	9-Sep
Conductivity	uS	7570	5550	231	275	4650	5000	5500	1860
pH	s.u.	3.88	3.57	7.76	6.74	3.31	3.20	3.66	3.47
Acidity (to pH 8.3)	mg CaCO3eq/L	4970		13					
Alkalinity-Total	mg CaCO3eq/L	5		101					
Sulphate	mg/L	7690	5190	21	20	4130	4986	5209	1422
Aluminum	mg/L	9	5.65	<0.2	.11	5.78	4.55	6.95	10.25
Arsenic	mg/L	<1	.542	<0.2	<.005	.484	.425	.503	.155
Cadmium	mg/L	3.55	2.684	<0.01	.007	1.686	1.709	1.748	.894
Calcium	mg/L	392	249.2	37.8	34.8	238.8	234.7	260.5	131.1
Cobalt	mg/L	8.63	4.553	<0.01	<.005	3.579	3.884	4.697	.470
Copper	mg/L	24.1	16.226	0.01	.157	8.465	8.718	21.596	4.891
Iron	mg/L	1090	574.38	<0.03	2.52	326.26	366.63	538.66	19.24
Lead	mg/L	1.4	4.56	<0.05	.41	3.56	3.61	4.42	2.58
Magnesium	mg/L	497	277.4	9.8	10.9	248.3	258.7	283.8	86.9
Manganese	mg/L	426	194.29	0.007	.22	139.21	148.16	150.00	21.76
Molybdenum	mg/L	6.2	1.308	<0.05	<.002	1.052	1.098	1.220	.479
Nickel	mg/L	<0.2	3.127	<0.03	.016	2.603	2.717	3.205	.572
Potassium	mg/L	<10	7	<2	<1	5	5	6	<1
Sodium	mg/L	<10	10	2	5	9	9	10	5
Antimony	mg/L	<1	2.79	<0.2	<.03	2.33	2.46	2.65	1.12
Strontium	mg/L	0.83	.689	0.17	.158	.764	.748	.818	.376
Zinc	mg/L	1670	557.81	0.032	.54	474.55	482.70	530.64	205.36



■ **S9** SEPT. 9, 2000 SEEP LOCATIONS

0 20 40 60 80 100 metres
1:4,000

SRK Consulting Engineers and Scientists	VANGORDA PIT GEOCHEMISTRY			
DELOITTE & TOUCHE	VANGORDA PIT SEPT. 9, 2000 SEEP LOCATIONS			
	FILE REFERENCE SEEP-BASE	PROJECT NO. 1CD003.04	DRAWING NO. F1	REV.