

Arctic Environment Strategy Action on Waste Program

VENUS MINE Tailings Characterization

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SUMMARY OF RESULTS

In May 1994, the Arctic Environment Strategy - Action on Waste Program commissioned Poushinsky Consulting and B&L Rock Group to investigate the acid generation and metal leaching potential of the abandoned Venus mine tailings. The scope of the investigation included a field investigation, a laboratory testing program and data interpretation to answer specific, practical questions regarding the potential for, and control of, metal release from the site.

Analysis of metals in the tailings solids shows that the tailings are typical of polymetallic sulphide deposits. The iron and sulphur analyses shown that the sulphide mineral content ranges from about 3 to 20 %. Arsenic concentrations in the solids range from 2.5 to 7 %. Other metals that are of interest with respect to water quality include cadmium, lead, and zinc, and to a lesser degree copper, cobalt and nickel. The concentration of these elements is variable over the impoundment, with no clear zones of enrichment. An exception is test pit TP94-V-5 with somewhat elevated cadmium and other metal concentrations.

The concentration of these elements in the tailings solids themselves is not necessarily a problem in a tailings impoundment. If the metals occur as sulphides, they are chemically stable under natural reducing conditions. However, while these elements may be chemically stable under non-oxidising conditions, oxidation and acid generation can render them mobile in solution. If metals are present in a sulphate, oxide or hydroxide form, the metal may be chemically mobile under a range of conditions. In this case, while arsenic was thought to have originally occurred primarily as arsenopyrite, geochemical processes such as oxidation and reduction in the solids can produce less chemically stable arsenic minerals.

It is clear from the acid base account testing that the tailings mass is not acid generating. Ratios of neutralisation potential (NP) to acid potential (AP) are less than 1:1 in all samples, with the exception of one sample which has been extensively oxidized. There is however some neutralisation potential (i.e. alkaline, carbonate minerals) remaining in most of the tailings solids. These alkaline minerals neutralise the acidity produced by the oxidation of the sulphides. This NP explains why the drainage from the impoundment is generally neutral to alkaline.

and has resulted in a lag time until net acidic conditions are seen, or will be seen, in the impoundment.

The development of acid rock drainage (ARD) is a time dependent process. In the early stages of oxidation, the acidity produced by sulphide oxidation is neutralised by the available alkalinity. Over time, as the alkalinity is consumed, or made unavailable by coatings or precipitates, the drainage water becomes more acidic (pH values decrease to about 4.5). At this point, the rate of oxidation tends to increase as bacteria begin to catalyse the oxidation process. The drainage water becomes acidic (pH 2), most heavy metals become more soluble, and the "classic" ARD is formed.

The samples show that the Venus tailings are, for the most part, still in the early stages of oxidation. Isolated layers have oxidized more quickly and are acidic with elevated metals in the pore water, and in the extraction tests. There is the potential for net acidic conditions to develop however the available alkalinity will continue to provide neutralisation in the tailings mass for some time.

The evidence that there has been oxidation in many of the samples is seen in the elevated sulphate (SO_4^{2-}), calcium and magnesium concentrations of the extraction tests, and in the pore water samples. However, at this stage, the bulk of the tailings has not oxidized extensively.

Even in the early stages of ARD development, the leaching of metals can be a concern. Leaching and migration of metals through the tailings mass is occurring, with elevated concentrations of arsenic and zinc in the pore water samples. Extraction tests show similar results. Surface layers, and zones with visible oxidation and vertical cracking tend to have higher soluble metal concentrations. This is quite typical of the development of ARD in a tailings mass.

Thus, the results show that the tailings mass has the potential to be net acid generating. At this time, acidic conditions are only found within isolated zones in the impoundment. Oxidation is occurring in zones throughout the impoundment, however, there is alkalinity present in the solids which is maintaining generally alkaline conditions. While this condition may continue for several years, the

balance between acid producing and acid consuming minerals suggests that net acidic conditions would develop with time.

With respect to water quality from the tailings, both arsenic and zinc are soluble throughout most of the tailings mass at levels that would represent a water quality concern. Oxidation and acid generation enhance the dissolution of these, and other metals (e.g. cadmium, copper, iron). The distribution of dissolved metals throughout the tailings mass may be a combination of oxidation and dissolution in zones, and of migration of "contaminated" water. In other words, not all layers are oxidising and producing soluble metals at this time. The bulk of the tailings has the potential to become acidic and leach metals in future.

VENUS MINE TAILINGS CHARACTERIZATION

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1. BACKGROUND

1.1 Terms of Reference

In May 1994, the Arctic Environment Strategy - Action on Waste Program commissioned Poushinsky Consulting and B&L Rock Group to investigate the acid generation and metal leaching potential of the abandoned Venus mine tailings. The scope of the investigation included a field investigation, a laboratory testing program and data interpretation to answer specific, practical questions regarding the potential for, and control of, metal release from the site.

In 1994, Klohn Crippen Ltd. conducted an evaluation of alternative remediation options for the abandoned Venus mine tailings. One of the recommendations of the report was to complete bulk characterization testing of the tailings which is the objective of the investigation reported herein. This characterization was necessary to select the most technically and economically feasible option to ensure long-term environmental stability in the area of the tailings. Prior to the first phase of this investigation, the extent of potential acid generation and metal leaching had not been suspected. The concerns were primarily associated with surface oxidation and leaching, and with wind and water erosion of the tailings. As a result of the initial observations and acid base account tests, the scope of testing and analyses was expanded during the investigation to determine the spatial variability and distribution of potentially acid generating and leachable materials in the impoundment.

This report details the field investigation, test procedures and results, and discusses the implications of these for water quality and site remediation. The detailed field and laboratory data are included, to facilitate further evaluations of the data by the reader.

1.2 Objectives

There is concern that the abandoned Venus mine tailings, located south of Carcross, YT, are releasing arsenic and other heavy metals including cadmium, lead, and zinc to the surrounding environment. The tailings were milled in the early 1970's, and are currently stored in an uncontrolled impoundment area. The term *uncontrolled* highlights the potential for contamination of water and soil via several routes, including; wind (particulate), surface water (particulate and dissolved), and groundwater (dissolved).

Water quality data has been collected since 1975. In 1981 a baseline study was carried out prior to the operation of the new Venus Mill located in British Columbia. Evaluations of arsenic mobility and water quality at the site were done in 1981 and 1986 by Environment Canada. In 1994 Klohn Crippen Ltd. completed an evaluation of alternative remediation options, out of which the need for this investigation became apparent.

There were five specific objectives to the field investigation and testing program discussed in this report:

1. To identify the source(s) of the metals in the surface drainage from the tailings area.
2. To determine the mechanisms controlling release to the extent that (i) it can be determined if the metal release will increase or decrease over time, and (ii) suitable remediation measures can be defined.
3. To determine the heterogeneity of the tailings insofar as identifying the extent of the acid generating and leachable materials, and for evaluation of reprocessing of the tailings.
4. To identify any chemical or physical conditions that would constrain remediation measures.
5. To identify measures that should be taken during remediation to prevent increased metal loadings in the short term.

The emphasis of the field investigation and laboratory testing was on detailed characterization of the tailings mass. The emphasis of the data analysis was on a practical evaluation of the need for, and practical constraints to, water quality control measures.

2. FIELD INVESTIGATION

2.1 Site Description

The Venus mine tailings are located approximately 22 km south of Carcross, on the east side of the highway and adjacent to the edge of Windy Arm (Tagish Lake). It has been estimated that approximately 54,000 tonnes of tailings are contained in the abandoned impoundment (Klohn Crippen, 1994).

The tailings area is confined by natural ground and bedrock exposures to the north and west, and at the northern end of the east side. A constructed perimeter dike confines the tailings solids at the south end but is not a water retaining structure. During the 1980's a portion of the dike at the southeast corner was removed for access to the tailings, with subsequent removal of approximately 400 ton for reprocessing. This excavation has allowed erosion of the tailings during high surface runoff periods, from the impoundment area to the lake. A more detailed description of the physical characteristics of the site, including the estimated isopach thickness plot, is provided in the Klohn Crippen report.

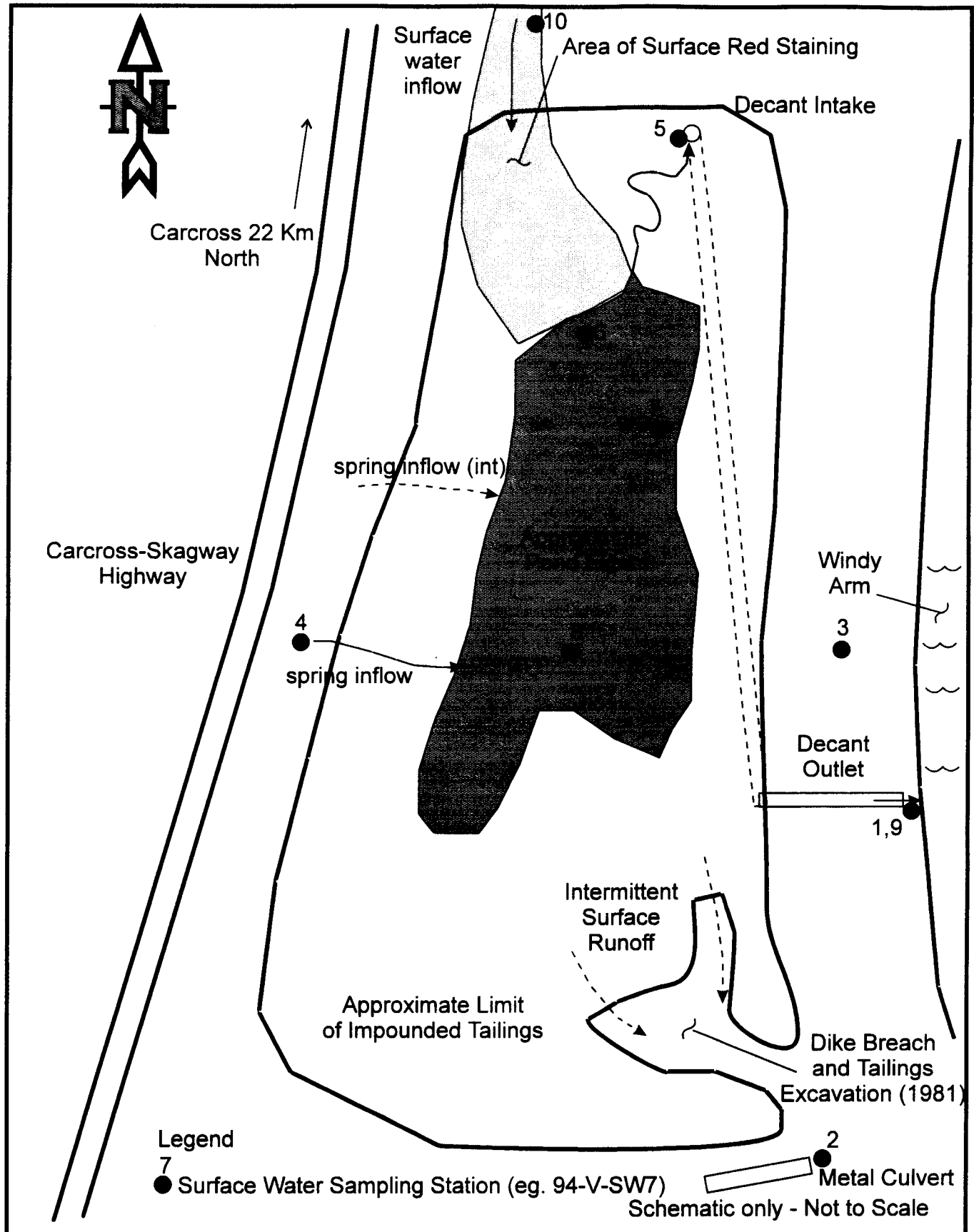
2.2 Field Program

The following tasks were completed during the site visit of May/June 1994:

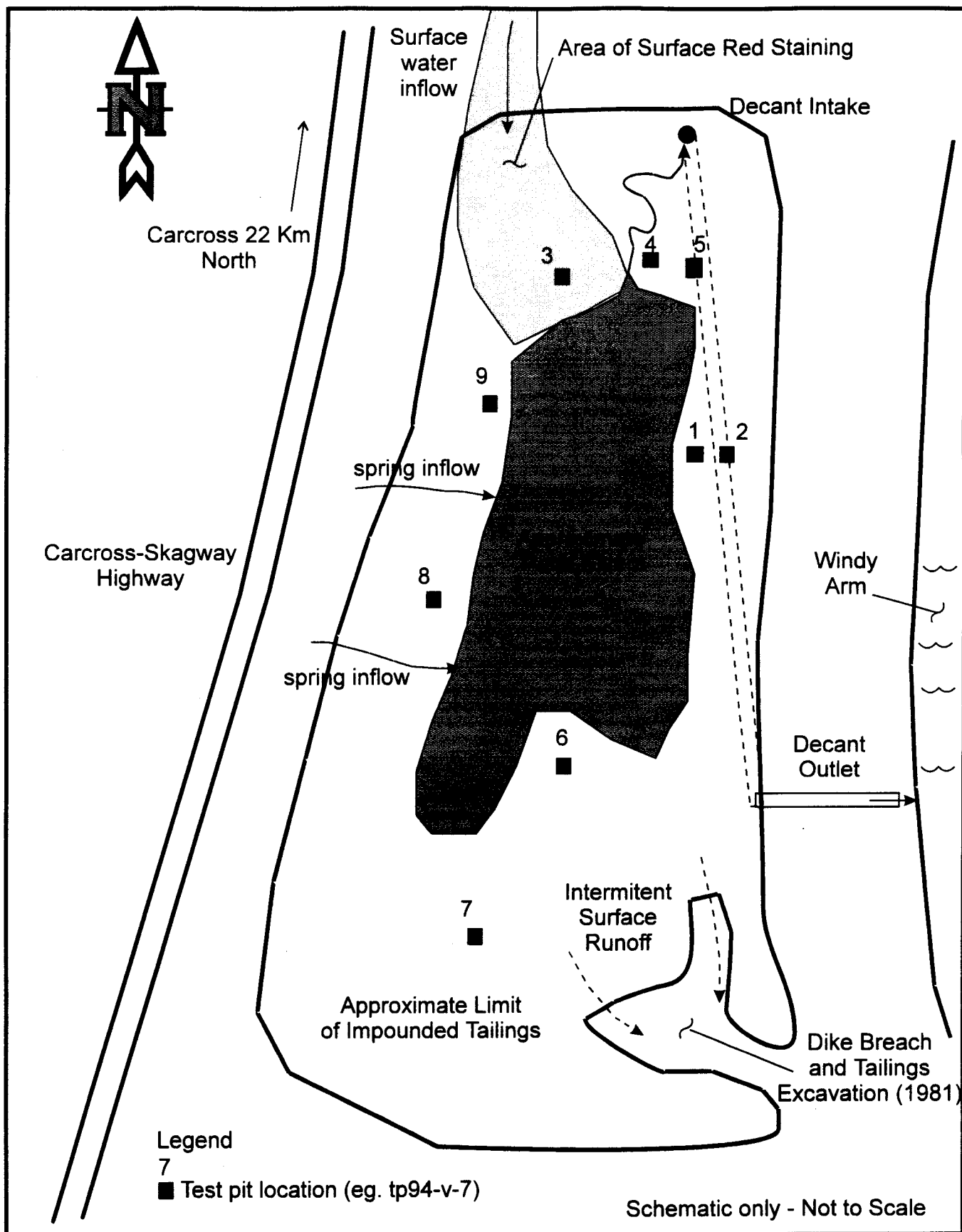
- visual observation and photographs of the area, including sampling sites;
- collection of surface water samples from 9 locations upstream, downstream and at the suspected sources of arsenic;
- excavation of nine test pits within the tailings with sampling of solids and water as discussed below; and,
- local pH and conductivity testing at upstream sites including highway rockfill and soil sites.

Water quality monitoring stations and the test pit locations are shown on site schematic plans, Figures 1 and 2 respectively.

**Figure 1. Abandoned Venus Tailings Pond
1994 Water Sampling Stations (approximate)**



**Figure 2. Abandoned Venus Tailings Pond
1994 Test Pit Locations (approximate)**



The impoundment has several observed surface water inflow sources, including;

- artesian spring(s) located at approximately the lowest point in the highway rock fill;
- surface water runoff from the observed resloped area immediately north of the impoundment (indicated by red staining on beach surface downstream of the area); and,
- other intermittent surface and spring flows that likely occur during spring melt period.

The pond elevation is primarily controlled by the fixed decant elevation located at the northern end of the pond. The decant discharges via an asbestos culvert buried in the tailings/dike material to the lake shore line as indicated on Figure 1. The decant was observed to be littered with wood and other waste debris. While the decant was draining freely at the time of the site visit, it is surprising that the system has provided adequate control of the pond level. The combination of debris, tailings solids, and freezing temperatures could contribute to reduce the efficiency of the system, perhaps even causing it's failure.

The pond level was observed to be relatively constant as evident by level marks on the beach. During the site visit, total inflows from the upstream spring identified at station 94-V-SW4 were roughly equivalent to observed flow in the decant at station 94-V-SW1.

Much of the southern end of the impoundment is comprised of beach above the existing pond. This area was observed to cause significant dusting during windy periods. Many small aeolian (wind) erosional features were observed on the surface of the tailings in this area. An order of magnitude estimate of the depth of erosion based on these observations is 2 cm. Observations of surface water channelling were also recorded in the southern beach area, draining from the impoundment through the breached dike at the south-east corner.

The south east corner was excavated in 1981 to obtain a 400 ton feed to the mill. The limits of the excavation are still visible and further investigation shows indications of red staining and the development of hard-pan layering in the exposed cuts.

Several areas exhibited signs of presumed frost-heave. These are characterized by mounded surfaces up to 25 m in diameter above the adjacent beach. In addition, the observed mounds have deep vertical cracking, and polygonal surface features. Similar features are observed in muskeg in areas of discontinuous permafrost.

2.3 Testing Program

The samples were shipped to the CESL Analytical Laboratory in Vancouver, B.C. for laboratory testing and co-ordination of analyses. All water analyses were completed at Analytical Services Laboratories in Vancouver. Solid ICP analyses were done by Minen Laboratories of North Vancouver.

Analysis of the test pits samples included:

- paste pH and conductivity measurements with depth in the field;
- solid sampling with depth;
- laboratory analysis of pH, metals by ICP and AA, and ABA on selected samples;
- laboratory short-term extraction tests; and,
- extraction of pore water (under nitrogen atmosphere for samples at, or near, the water table).

Metal analyses were done by ICP for most samples. Arsenic concentrations in the solids were higher than the ICP detection limit, and were subsequently analysed by AA. Acid base account tests were done using the modified Sobek procedure. Short-term extraction tests were done using a 250 g sample in 500 mL of distilled water, which was gently agitated for 24 hours followed by filtration and solution analyses. Pore water samples were extracted by filtering under pressure with nitrogen.

Detailed analyses were done on six of the test pits, selected to represent the range of materials types and spatial distribution around the impoundment. The intention of the sampling was to represent the range of *all* material types seen in the test pits.

The geochemical model "MINTEQA2" (Felmy et al., 1984) was used to evaluate the chemical speciation in the surface water and extraction leachates. This analysis was done to identify the minerals which are dissolving or precipitating and therefore determining the concentrations of different species in solution. The intent of this evaluation was to identify the controls on water chemistry, particularly for arsenic, which can affect the selected remediation option. Experience in the mining industry has shown that arsenic chemistry in tailings (and treatment plant residues) can be somewhat complicated to interpret and it is important to identify the minerals or processes which are controlling arsenic mobility.

3. RESULTS AND DISCUSSION

3.1 Test Pits

The test pit logs are provided in Appendix A. These logs also include tabular summaries of the test results and graphical presentations of the key data. The following observations were made during the test pit investigations.

Within the test pits, the majority of the tailings at depth appeared to be "fresh" (i.e. no visible oxidation or staining). In the areas of frost action, vertical cracking from surface has resulted in oxidation of sulphides and precipitation of iron oxide and hydroxide products in the cracks, within otherwise alkaline nearly saturated tailings. In test pits 5 and 9 there were distinct layers of oxidation up to 0.5 m thick, as indicated by iron staining, lower paste pH values and high paste conductivity values in field measurements.

Observations of the water table in each of the test pits suggests that these "hard pan" layers have affected the migration of water through the tailings, by establishing very low permeability layers. As shown in the test pit logs, the depth to the water table varied from 0.3 m to 1.5 m in test pits located within 2 m of the pond.

As shown in the test pit logs, the tailings solids can be described in four general groups:

- Type 1: oxidized, sandy or buff ranging from sand to silt, generally occurring near surface;
- Type 2: red/brown sandy silt or silt with cracking and iron staining;
- Type 3: grey/brown mottled, silty to sandy moist tailings; and,
- Type 4: dark grey, saturated, fine tailings at depth throughout the impoundment.

3.2 Surface Water Samples

Surface water samples were collected from various upstream, in-pond, and downstream locations. Three bottles of each were retained after field measurement of pH and conductivity. These samples include an *immediate* (not filtered, not preserved), a *total metals* (not filtered, preserved), and a *dissolved metals* (filtered, preserved) sample for each sampling station.

The sampling station locations were selected to include:

- flows into, and out of, the tailings impoundment;
- sites for which historical data are available for comparison;
- local seeps or groundwater discharge; and,
- along a solution flowpath.

The locations of the surface water sampling stations are shown on Figure 1 and described in Appendix B. The detailed results are also provided in Appendix B and are summarized for key water quality parameters in Table 1.

In summary, the results show that the surface discharge from the tailings impoundment and downstream seeps contains elevated arsenic and zinc. However, one upstream sample (94-V-SW10) at the north end of the pond also showed elevated arsenic concentrations. The source is probably mineralised waste rock or ore deposited in the area. The solutions are uniformly neutral to alkaline.

TABLE 1
SURFACE WATER QUALITY SUMMARY - JUNE 1994

Station	pH	SO ₄ ²⁻ (mg/L)	D. As (mg/L)	D. Ca (mg/L)	D. Zn (mg/L)
94-V-SW1	8.26	125	0.557	46.0	0.021
94-V-SW2	7.98	124	0.0017	51.5	0.046
94-V-SW3	7.64	199	3.19	87.5	0.129
94-V-SW4	7.89	118	0.0049	44.9	<0.005
94-V-SW5	8.37	126	0.558	46.3	0.022
94-V-SW6	8.33	125	0.541	45.9	0.019
94-V-SW7	8.34	123	0.522	45.2	0.019
94-V-SW8	8.35	126	0.560	45.6	0.016
94-V-SW9	8.33	124	0.546	46.3	0.021
94-V-SW10	8.21	135	1.73	90.4	0.006

Dissolved arsenic concentrations range from 0.005 mg/L in the upstream "background" sample, to a high of 3.2 mg/L in a downstream seep. The pond water and surface water decant showed approximately 0.5 mg/L As. Cadmium and lead concentrations were consistently below detection. To provide an indication of what these data mean in terms water quality, Table 2 shows some of the guidelines that have been established for the quality of both drinking water, and water for the protection of freshwater aquatic life.

TABLE 2
CANADIAN RECEIVING WATER GUIDELINES (CCREM, 1987)

Parameter	Drinking Water	Aquatic Life
pH	6.5 to 8.5	6.5 to 9.0
SO ₄ ²⁻ (mg/L)	500	no value
As (mg/L)	0.05	0.05
Cd (mg/L)	0.005	0.2 to 1.8 (varies with hardness)
Fe (mg/L)	0.3	0.3
Pb (mg/L)	0.05	0.001 to 0.007 (varies with hardness)
Zn (mg/L)	5	0.03

Solutions were analysed for both dissolved and total concentrations, to evaluate the extent of physical erosion in the transport of arsenic. For the most part, dissolved values represented at least 80 % of the total metal concentration. Thus, at the time of the sampling, the majority of the metals in the drainage water were present as dissolved values. Surface water arsenic concentrations at stations for which previous data are available were similar to previous sampling periods.

3.3 Solids Metal Analysis

The tailings solids samples were analysed by ICP and AA (for As) with the detailed results provided in Appendix C. The tailings samples are reasonably typical of a polymetallic deposit with sulphide contents ranging from 3 to 20 %, iron from 4 to 9 %, with associated arsenic (2.5 to 7 %), zinc (0.05 to 1 %) and to a lesser degree cadmium, cobalt, copper, lead and nickel values.

The concentrations of metals varied both across the impoundment and over depth. Test pit 5 at the north end of the impoundment was somewhat different from the other test pits, with generally higher metal concentrations in the solids, particularly for cadmium. This test pit also had two oxidized layers, which were depleted in sulphide and metals compared to the other tailings solids. Comparison of the molar ratios between arsenic, iron and sulphide indicate that up to 5 % of the arsenic may be present in a non-sulphide form (e.g. as a metal arsenate or sulphate).

The metals analyses in the solids do not show any strong trends in spatial distribution. Figure 3 shows that there is an apparent correlation between metal content and material type (as described in Section 3.1). Generally, the "fresh" saturated tailings at depth have higher metal content as compared to the near surface, oxidized tailings from which metals may have been leached. The results do show that sulphides and metals are distributed throughout the impoundment. The comparatively elevated concentrations of cadmium and other metals at test pit 5 are not seen elsewhere in the impoundment.

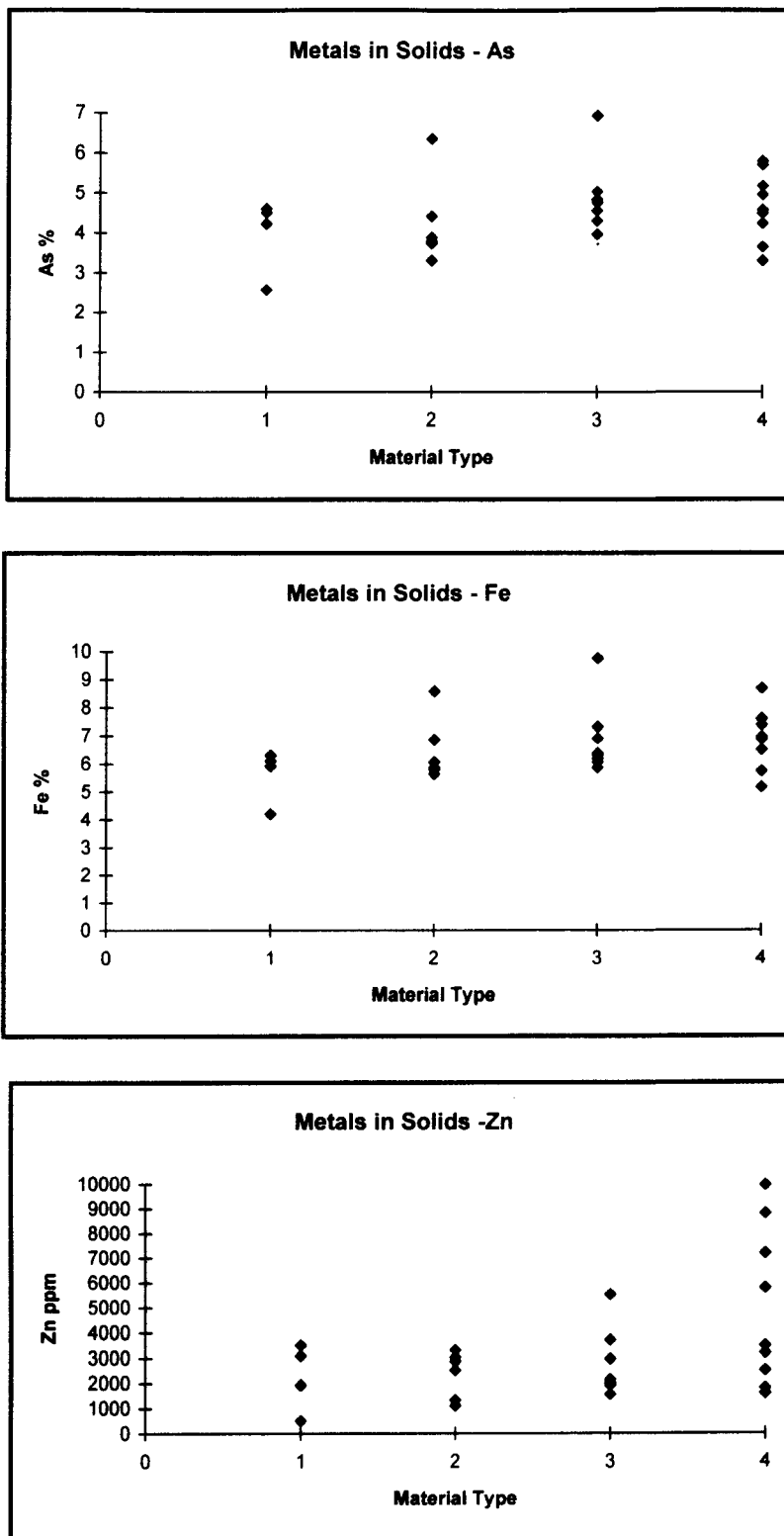


Figure 3 Relationship of Metal Concentrations to Tailings Material Description

3.4 Acid Base Accounting

Acid base account (ABA) tests were done on samples from the test pits. These tests are used to define the potential for acid generation in a solid sample. The tests are done in two parts; to measure the potentially acid producing content (sulphide content) and the potentially acid consuming content (generally carbonate minerals). Theoretically, a sample is net acid generating if the acid potential (AP) is greater than the neutralising potential (NP). This can be expressed in two ways; by difference and by ratio. In practice, it has been found that the ratio between the acid generating and acid consuming potentials provides a clearer indication of the field net acid generation potential than does the net neutralisation potential.

The detailed results are provided in Appendix C. In the test pit logs of Appendix A, the ABA data are also shown graphically for each test pit. The results can be summarized as follows:

- the tailings mass is net acid generating with generally negative NNP's and NP/AP ratios less than 1;
- there are alkaline minerals (neutralisation potential) remaining in the tailings which is maintaining near neutral conditions in most of the samples;
- the sulphide sulphur (i.e. oxidisable form) content may be slightly overestimated in some samples due to the occurrence of barium. Barium can occur as the relatively insoluble mineral barite, which reports as a sulphide in most sulphur analyses, but which does not oxidize and produce acidity. Thus the AP may be slightly overestimated;
- in some samples the rate of oxidation and acid generation has exceeded the rate at which alkalinity was released, resulting in net acidic paste pH values (e.g. TP-V4, TP-V5); and,
- samples within visibly oxidized zones show up to two thirds of the total sulphur present at sulphate, that is, in the oxidized form.

Thus, the tailings mass has the potential to become acidic over time as neutralisation potential is depleted throughout the impoundment. Kinetic tests

would typically be required to estimate the lag time until this neutralisation potential was consumed, however it is probably in the order of several years.

3.5 Pore Water Samples

Pore water samples were extracted from the tailings solids at the base of each test pit in which water (saturation) was encountered. Pore water analyses indicate the extent of oxidation within a zone of tailings, and the quality of water migrating through and from the tailings mass. Since the pore water does move through the tailings, the results would not directly correspond with the analyses of the solids from which the pore water was extracted. Rather, the pore water results indicate the geochemical conditions at the source and along the flow path. For simplicity, this flow path is assumed to be a vertical column of tailings, as represented by each test pit.

The results of the analyses of the pore water are summarized in Table 3 with detailed results provided in Appendix A.

TABLE 3
PORE WATER QUALITY SUMMARY - JUNE 1994

Station	pH	SO ₄ ²⁻ (mg/L)	D. As (mg/L)	D. Ba (mg/L)	D. Ca (mg/L)	D. Zn (mg/L)
94-V-PW1	7.09	290	0.72	0.03	105	1.02
94-V-PW5	7.15	1478	0.33	0.03	429	4.22
94-V-PW9	7.40	1534	0.61	0.04	523	1.86

The results show that:

- oxygen is depleted at depth in the tailings;
- solutions are alkaline with pH values ranging from 7 to 8;
- pore water samples from test pits 94-V-2, -5, and -9 show elevated sulphate concentrations, indicating oxidation of sulphides or dissolution of sulphate minerals. Generally, oxidation is limited by saturated (wet) conditions, and the elevated sulphates in the saturated layers may have migrated with the tailings pore water from a zone of oxidation;

- Ca and Mg values are elevated correspondingly to sulphate concentrations, further indicating that oxidation and neutralisation are occurring. The ratio of sulphate production to alkalinity release (Ca + Mg) increases at the higher sulphate concentrations indicating that acidic conditions may be anticipated;
- dissolved concentrations of key metals of concern (As, Zn) are elevated in each of the samples for which results are available;
- MINTEQA2 analyses show that the pore water samples solutions are not at chemical equilibrium. Solutions are near saturation for gypsum (which will limit sulphate concentrations) and barite (which will control limit barium concentrations) and are supersaturated with respect to both ferric and barium arsenate (which will limit iron and arsenic concentrations).

Concentrations are similar to those found in the extraction tests supporting the indication from these data that pH/solubility constraints are limiting the release of metals into solution, and therefore the total potential soluble load may be higher than shown.

The practical consideration with respect to arsenic solubility is for remediation measures; to determine if placement of the tailings underwater will control arsenic release into solution. From these limited data it appears that, even under reducing conditions, arsenic is slowly soluble. However, it is considered likely that dissolved arsenic has been transported into the porewater samples from a zone of oxidation and is precipitating out of solution under the more reducing, oxygen depleted conditions at depth. Experience at other sites has indicated that a rigorous scientific interpretation of arsenic/iron chemistry is complex and is not warranted for this project.

3.6 Short-term Extraction Tests

Extraction tests were done to estimate the total soluble load from the tailings mass. Results of the extraction tests are summarized in Appendix A, and shown in detail in Appendix D. These tests are useful to determine the extent of oxidation and metal migration in the tailings to date, and to determine the effect

of remediation activities on local water quality. The results of the extraction tests are directly related to the material descriptions in the test pits logs.

Considerable information about solution chemistry and metal migration can be extracted from these test results and the complete data set is appended. The key points relative to the assessment of the extent of oxidation and implications for future water quality and remediation include:

- layers with depressed paste pH values, and the underlying layers, generally have higher dissolved sulphate concentrations than near neutral layers;
- Ca and Mg concentrations are also elevated in these layers, further confirming that oxidation and neutralisation reactions are occurring;
- near neutral layers with low extractable loads are generally found at depth, and at or near saturation with water. Water limits the amount of oxygen available for the oxidation reactions, and therefore the amount of oxidation that occurs;
- extractions of metals such as arsenic, zinc, cadmium, and to a lesser extent aluminum, copper, and nickel are higher in oxidized (high sulphate) layers than the deeper near neutral layers; and,
- MINTEQ analyses of solutions show that chemical saturation is limiting the dissolved concentrations of arsenic at alkaline pH values as would be expected. Several iron minerals are supersaturated suggesting that there may have been co-precipitation of arsenic with the iron (although ferric arsenate is undersaturated). At pH values below 6, saturation constraints are not limiting metal concentrations significantly, and the total soluble load is extracted into the leaching solutions.

The interpretation of metal release from layered materials is somewhat complicated by the transport of metals from the oxidation zones by water flow through the tailings mass, and by the pH/solubility controls for each metal. Generally, zinc and sulphate are relatively soluble over a wide pH range, as compared to elements such as copper. Within the pH range of these solutions, copper solubility increases with decreasing pH. Elements such as arsenic tend to have a higher solubility at the extremes of the pH scale, depending on the other species present in solution.

The extraction tests do provide a good indication of the soluble load under the sample pH conditions, and show that the metals of concern at this site are increasingly soluble at low pH. Thus control of sulphide oxidation to prevent acidic conditions will limit dissolved metal concentrations in drainage water. The results also show that disturbing the tailings will release some or all of this soluble load, particularly if a hydraulic method (i.e. slurring the tailings) is used.

The extraction test results were used to estimate a total potential loading and concentrations for key metals from the tailings mass, in the event of disturbance of the tailings. It is emphasised that this is a rough estimate, that can be used for evaluation of possible water control or water treatment requirements during remediation. It is not an estimate of instantaneous loadings from the tailings mass in-situ.

There are two parameters to consider in water chemistry; the concentration in solution (usually expressed in mg/L), and the total amount or "loading" (usually expressed in kg per unit time or unit mass) that could be released into solution from the unit mass. Loading is calculated from flow multiplied by concentration.

The loading was estimated from a weighted average loading per unit mass from each test pit. Assuming that the test pits for which these analyses were done represent the range of materials found in the impoundments, the individual test pit loadings were averaged and multiplied by the estimated total mass of tailings. The depth of each test pit and the total mass of the tailings was estimated from Figure 2 of the March 1994 Kohn Crippen report entitled "Venus Mine Tailings - Study of Remedial Options".

These calculations show that, at present, the total possible *soluble load* that could be released from the tailings mass if it were disturbed is relatively low at 110 kg arsenic, 90 kg iron, 160 kg manganese and 140 kg zinc. However, the possible *solution concentrations*, as indicated by the results of the pore water and extraction tests, may be at a level of concern for receiving waters, necessitating control during remediation.

4. CONCLUSIONS

The conclusions of this investigation are discussed in terms of the original objectives of the program, as outlined in Section 1 of this report.

The surface water data indicate that the tailings are the major source of dissolved metals to the surface drainage. However, surface water sampling to the north of the impoundment shows that there are pockets of waste rock or ore which are also oxidising and releasing arsenic and zinc to surface water.

There are zones of oxidation throughout the impoundment but the presence of alkali minerals and saturated conditions at depth is maintaining near neutral conditions overall. Most of the arsenic and zinc would be present as the sulphide minerals, with the exception of oxidized layers. Oxidation of the sulphide minerals results in arsenic, zinc and other metal release from the solids. Mineralogical analyses would be required to determine if there are also oxidized arsenic minerals (such as scorodite) which are dissolving. However, these analyses would not change the conclusions of this report regarding remediation measures.

Wind blown and surface water erosion of the tailings has distributed the tailings solids beyond the original boundaries of the impoundment. The impact of this erosion on the nearby vegetation is reportedly significant (Environment Canada, 1985). Raspberry bushes consistently show elevated arsenic concentrations which can be somewhat reduced by washing of the berries. This indicates a physical, rather than a chemical/biochemical, process is the primary cause of elevated arsenic concentrations in the vegetation.

However, arsenic dissolution and migration is also evident in water samples. Metal concentrations in the pore water and extraction test samples show that there is a soluble metal load in most of the tailings mass. Therefore, any remediation measures must address both further oxidation and acid generation, and the release of dissolved and soluble metals.

While there are differences in the solids metal concentrations and sulphide content over the area of the impoundment, there are over-riding characteristics in terms of water quality. Samples throughout the breadth and depth of the impoundment are potentially acid generating. Metal concentrations in all of the solids are sufficiently high that, if acidic conditions develop, metals would be released into solution. Thus, any remediation should include the whole of the tailings mass.

For the remediation measures that are currently being considered, the following comments are offered:

1. Revegetation would not be sufficient to control future oxidation, acid generation and metal leaching.
2. Further oxidation and acidic conditions can be expected in the unsaturated zones of the tailings in future with increased metal loadings to the pore water and drainage from the impoundment.
3. Covering of the tailings in-situ to limit infiltration and surface runoff would reduce the metal concentrations in the surface decant. Sampling has shown however that soluble metals are present at depth; therefore in addition to any upgrading of the existing impoundment to ensure physical stability, measures, such as an upstream cutoff wall, would be required to control groundwater infiltration into the tailings.
4. It is currently considered in the industry that the most effective control of oxidation is a water cover. If these tailings were flooded some alkali addition may also be required to remove the soluble products from solution. The soluble product load is relatively low (i.e. for the most part the metals of concern are present in sulphides which are chemically stable in a reducing environment) in which case only short-term (possibly batch) treatment would be required. If arsenic species other than sulphides are present and testing shows that they are soluble under reducing conditions, the tailings could be placed under water and covered with a layer of silt or till to attenuate any short-term arsenic release.

5. A permanent water cover could not be established on the current impoundment without considerable upgrading of the physical stability of the embankments and the decant system.
6. It is expected that re-processing of the tailings by flotation and/or leaching would remove most of the soluble contaminant load. Flotation of sulphides could be used to produce net acid consuming tailings.
7. If the tailings are to be moved, it would be prudent to consider a shovel and truck operation of dewatered tailings, rather than any hydraulic techniques to minimize the release of soluble products from the tailings.

Removal of this relatively small volume of tailings to another deposition facility appears to be the most feasible alternative. There are several options that have been used at other sites including deposition under water in a constructed or natural water body, deposition within a net acid consuming tailings mass, or placement underground as (cemented) backfill. Cementing adds lime and therefore alkalinity to the tailings, reducing acid generation potential.

The final option which must be considered for any site is that of "do-nothing". It is clear that at the very least, revegetation must be encouraged to reduce the erosion of surface solids. If no further actions are taken it is anticipated that the following risks are incurred:

- that the frost action on the tailings will increase the extent of disturbance and access of oxygen to the tailings at depth, thereby accelerating the oxidation and acidification;
- that the physical disturbance by frost heave will adversely affect revegetation efforts and continually expose tailings solids to erosion by wind and water;
- that the decant system could be blocked, changing the hydrology of the tailings area, and resulting in flow from other areas of the impoundment and breaching of the embankment. It is not anticipated that this would result in a major failure (physical) but it could lower the water table within the tailings mass, and expose more tailings to oxygen and oxidation.

- that the extent of oxidation and acidification of the tailings will increase over time. As the remaining alkalinity is consumed, the pH will drop, and result in higher concentrations of metals in solution and "worse" water quality in the drainage;

In conclusion, the results indicate that the tailings mass does contain soluble metals, and that the release of these metals into solution is accelerated by oxidation and acidic conditions. At this time, only a small portion of the tailings is acidic. However, the static test results also show that the tailings solids through the impoundment have the potential to become acidic over time as a result of sulphide oxidation and acid generation. This would tend to increase the release of dissolved metals. Physical erosion is also contributing to the arsenic mobility in the area of the tailings impoundment.


The physical structure of the tailings impoundment does not permit a simple and successful remediation to prevent further acid generation and metal migration. Removal of the tailings to another location in which oxidation can be controlled is advisable. During removal or other disturbance of the tailings some form of water control and treatment would be required, although the total soluble load is relatively low and probably confined to the tailings at and above the water table.

The tests conducted herein show no indication of extensive oxidation or alteration of the tailings that would preclude reprocessing. Reprocessing may have an added benefit of reducing the contaminant load from the tailings, making underwater disposal a relatively straightforward solution. Alternatively, it is likely that the tailings could be reprocessed to remove the bulk of the sulphides (and the associated arsenic) and produce non acid generating tailings.

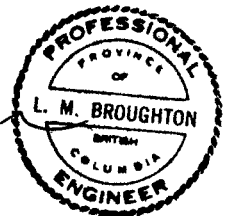
B&L Rock Group Ltd.



Scott E. Broughton, P.Eng.
Project Manager



Linda M. Broughton, P.Eng.
Geo-Environmental Consultant



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APPENDIX A

Test Pit Logs

VENUS TAILINGS TEST PIT DATA SHEETS

TEST PIT: TP94-V-1

Excavated 31-May-94

LOCATION: East side of pond, midway.
2 m from edge of pond.

DESCRIPTION: The east pond beach slopes at approximately 10-15 degrees to the pond.
The beach is generally undisturbed, however, vertical cracking to a depth of approximately 0.3 m was observed

Depth to water table: 30 cm

TEST PIT LOG

DEPTH from	(cm) to	LAYER	DESCRIPTION	FIELD PASTE		SAMPLES	
				pH	COND.	SOLIDS	WATER
0	10	A	Brown-grey mottled, moist, s. silt, red st. bands.	7.4	520	SA	
10	30	B	Brown-grey mottled, wet, s. silt, flowing at 30cm.	7.4	220	SB	
30	38	C	Grey mottled, saturated, silt.	7.3	260	SC	PWC

STATIC CHARACTERISTICS

SAMPLE #	PASTE pH	S(T) %	S(SO4) %	AP	NP	NET NP	NP/AP
TP94-V1-SA	8.31	2.97	0.04	91.6	44.6	-47.0	0.5
TP94-V1-SB	8.37	5.50	0.03	170.9	40.1	-130.9	0.2
TP94-V1-SC	8.21	6.21	0.04	192.8	42.8	-150.0	0.2

POREWATER CHEMISTRY

SAMPLE #	D. O2 mg/L	pH	Cond. uS/cm	Redox mV	Alkalinity mg/L CaCO3	Acidity mg/L CaCO3	SO4 mg/L
TP94-V1							
PWC	1.35	7.09	832	117	162.5	6.3	290

ICP ANALYSIS OF POREWATER

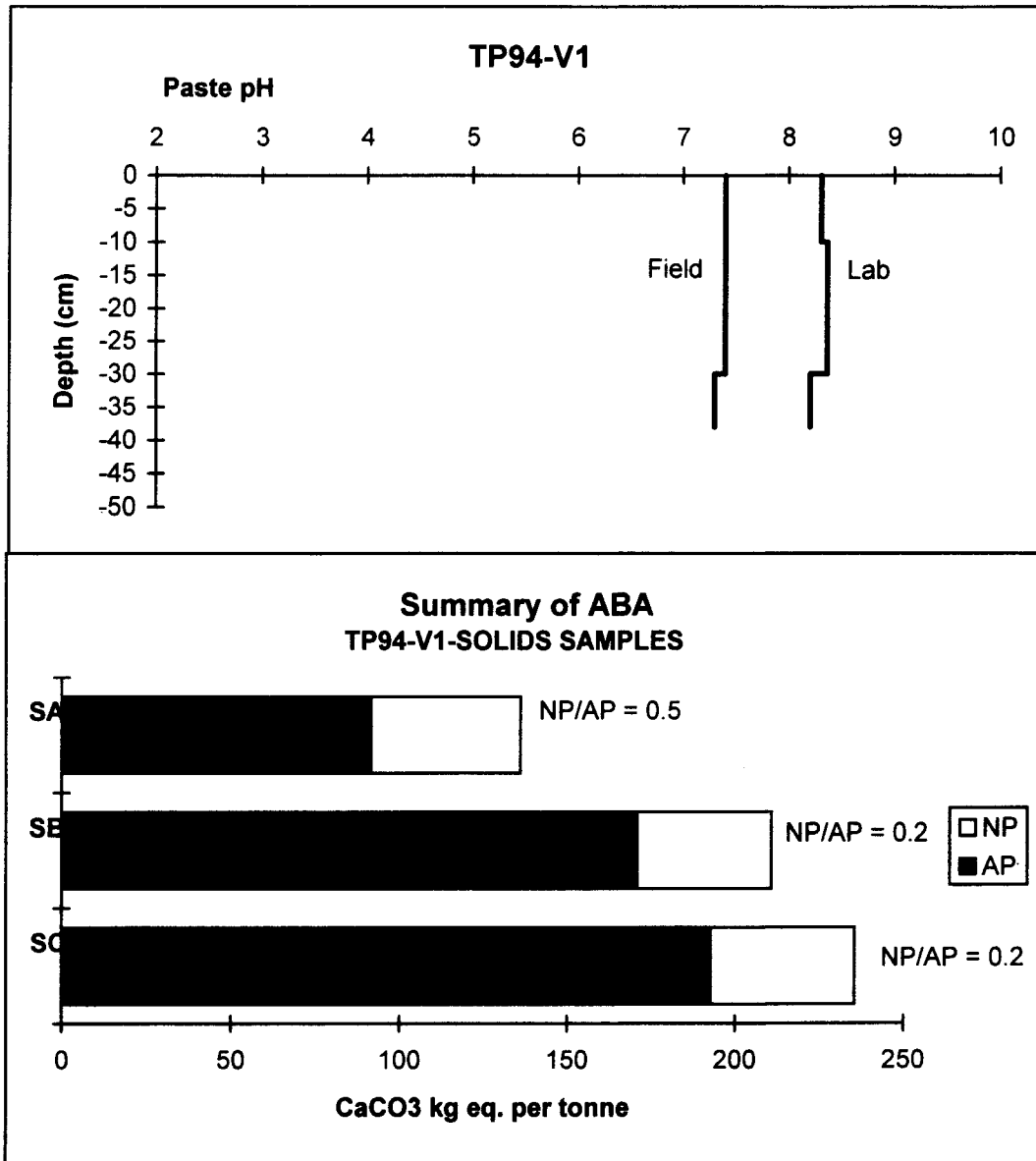
TP94-V1

PWC

Element	units	Conc.
As	mg/L	0.72
Cd	mg/L	0.056
Ca	mg/L	105.0
Fe	mg/L	< 0.03
Mg	mg/L	50.2
Zn	mg/L	1.02

**VENUS TAILINGS
TEST PIT DATA SHEETS**

GRAPHS



VENUS TAILINGS TEST PIT DATA SHEETS

TEST PIT: TP94-V-2

LOCATION: East side of impoundment.
4 m East of TP94-V-1.

Excavated 31-May-94

DESCRIPTION: The east pond beach slopes at approximately 10-15 degrees to the pond.
The beach is generally undisturbed, however, vertical cracking to a depth of approximately 0.3 m was observed

Depth to water table: 110 cm

TEST PIT LOG

DEPTH (cm)		LAYER	DESCRIPTION	FIELD PASTE		SAMPLES	
from	to			pH	COND.	SOLIDS	WATER
0	60	A	Brown-grey mottled, moist, sandy silt.			SA	
60	75	B	Stratified grey/red stained, moist, fine silt.	6.7	220	SB	
75	91	C	Dark brown mottled grey, moist to wet.	6.8	200	SC	
91	110	D	Dark grey/brown, wet, sat. at 1.1m.	7.2	140	SD	
110	115	E	Dark grey, visible sulphides.	6.7	470	SE	PWE

STATIC CHARACTERISTICS

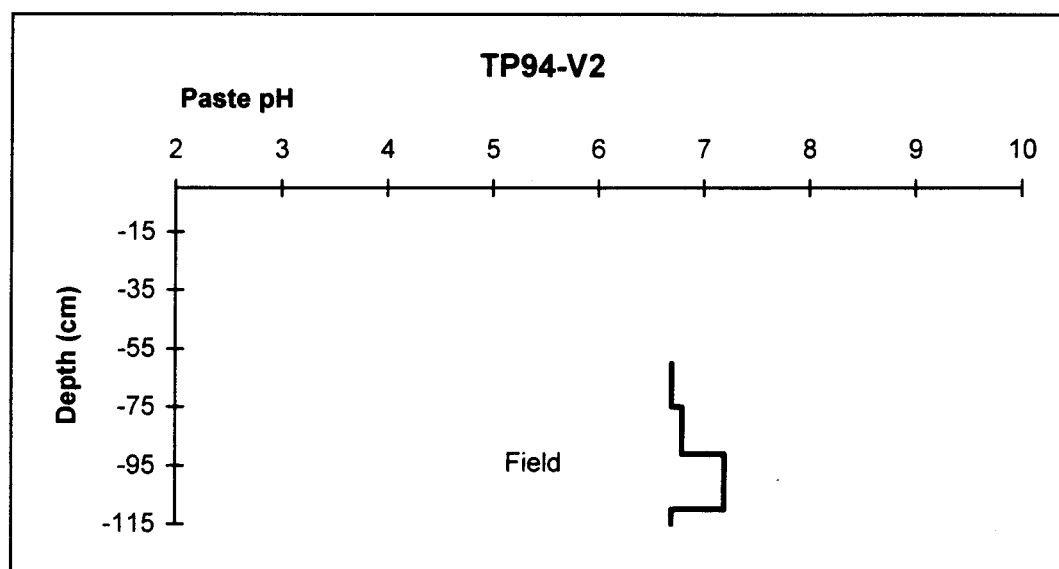
SAMPLE #	
TP94-V2-SA	Stored
TP94-V2-SB	Stored
TP94-V2-SC	Stored
TP94-V2-SD	Stored
TP94-V2-SE	Stored

POREWATER CHEMISTRY

SAMPLE #	D. O2 mg/L	pH	Cond. uS/cm	Redox mV	Alkalinity mg/L CaCO3	Acidity mg/L CaCO3	SO4 mg/L
TP94-V2							
PWE	0.80	7.43	1083	132	157.5	6.3	485

**VENUS TAILINGS
TEST PIT DATA SHEETS**

GRAPHS



VENUS TAILINGS **TEST PIT DATA SHEETS**

TEST PIT: **TP94-V-3**

LOCATION: North-west end of impoundment.
 5 m from N end of pond

Excavated 31-May-94

DESCRIPTION: The north-west pond beach slopes at approximately 5-10 degrees to the pond.
 The beach is generally undisturbed, however, water level is very near surface
 and it is characterized by red staining due to intermittent surface water
 flow from the north, and mossy plant growth on surface

Depth to water table: 6 cm

TEST PIT LOG

DEPTH from	(cm) to	LAYER	DESCRIPTION	FIELD PASTE		SAMPLES	
				pH	COND.	SOLIDS	WATER
0	5	A	Red/brown staining, moist, sandy silt.	7.1	350	SA	
5	10	B	Grey/brown , moist to flowing, sandy silt	6.9	250	SB	
10	20	C	Dark grey/brown fine silt. Water inflowing.	6.7	320	SC	PWC

STATIC CHARACTERISTICS

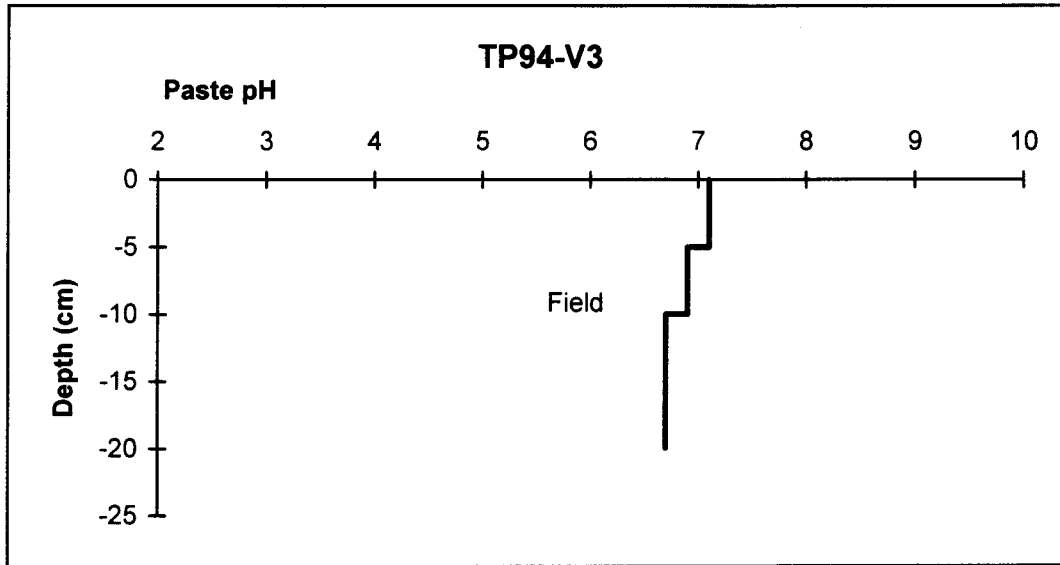
SAMPLE #	
TP94-V3-SA	Stored
TP94-V3-SB	Stored
TP94-V3-SC	Stored

POREWATER CHEMISTRY

SAMPLE #	D. O2 mg/L	pH	Cond. uS/cm	Redox mV	Alkalinity mg/L CaCO3	Acidity mg/L CaCO3	SO4 mg/L
TP94-V3							
PWC	0.05	7.28	748	120	352.0	6.3	55

**VENUS TAILINGS
TEST PIT DATA SHEETS**

GRAPHS



VENUS TAILINGS **TEST PIT DATA SHEETS**

TEST PIT: **TP94-V-4**

LOCATION: North-east end of impoundment.
 3 m east of decant stream, 5 m north of pond

Excavated 31-May-94

DESCRIPTION: The north-east pond beach slopes at approximately 10-15 degrees to the pond.
 The beach is generally disturbed by frost heave action causing deep vertical cracks to a depth of + 1m. Surface colour is dark grey, with 'eruptions' of light buff coloured oxidized material at major crack locations. Frost heave action has caused an undulating surface profile.

Depth to water table: Water table was not observed

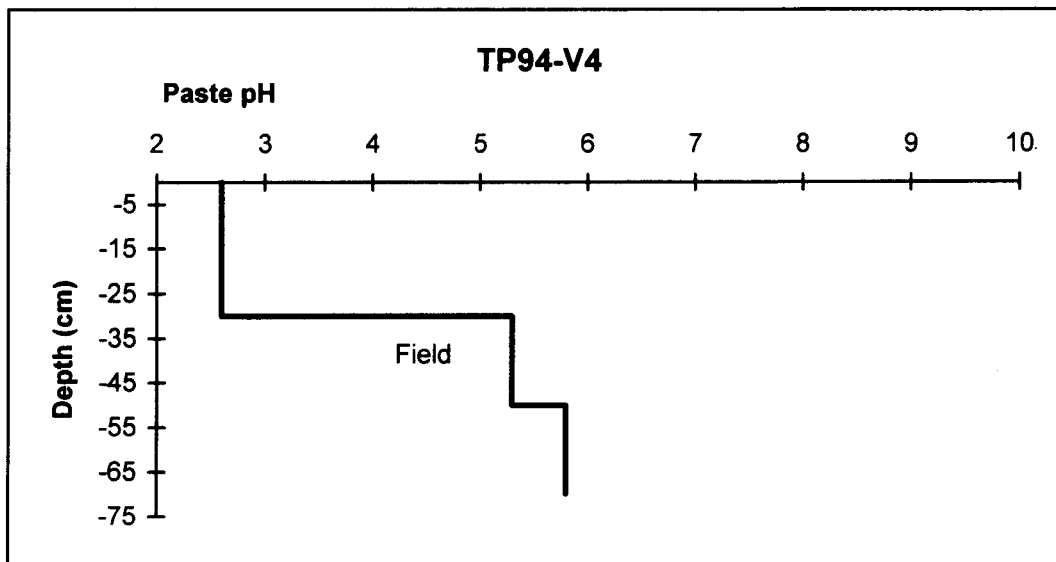
TEST PIT LOG

DEPTH from	(cm) to	LAYER	DESCRIPTION	FIELD PASTE		SAMPLES	
				pH	COND.	SOLIDS	WATER
0	30	A	Light buff/red, oxidized zone with moist sandy silt and hardpan at base.	2.6	2000	SA	
30	50	B	Dark grey, dense, firm silt.	5.3	1360	SB	
50	70	C	Grey/brown mottled soft, dense sandy silt.	5.8	680	SC	

STATIC CHARACTERISTICS

SAMPLE #	
TP94-V4-SA	Stored
TP94-V4-SB	Stored
TP94-V4-SC	Stored

GRAPHS



VENUS TAILINGS **TEST PIT DATA SHEETS**

TEST PIT: **TP94-V-5**

Excavated 31-May-94

LOCATION: North-east end of impoundment.
5 m east of decant stream, 3 m north of pond

DESCRIPTION: The north-east pond beach slopes at approximately 10-15 degrees to the pond.
The beach is generally disturbed by frost heave action causing deep vertical cracks to a depth of + 1m. Surface colour is dark grey, with 'eruptions' of light buff coloured oxidized material at major crack locations. Frost heave action has caused an undulating surface profile.

Depth to water table: +1.2 m

TEST PIT LOG

DEPTH (cm)		LAYER	DESCRIPTION	FIELD PASTE		SAMPLES	
from	to			pH	COND.	SOLIDS	WATER
0	25	A	Dark, brown moist sandy silt. Dry near surface.	6.4	1530	SA	
25	40	B	Light brown/buff, moist, oxidized, very fine with hard clasts.	2.8	1540	SB	
40	50	C	Dark grey, very fine, dense, soft.	5.9	630	SC	
50	53	D	Coarser sand, dense, firm, moist, red stained.	3.2	920	SD	
53	63	E	As "D", less staining, moist sandy silt.	6.0	530	SE	
63	75	F	Dark grey, very fine, soft, moist.	6.3	530	SF	
75	77	G1	Very hard, red stained, 2 cm layer.	6.0	350	SG1	
77	80	G2	Sandy silt, red stained.	5.8	390	SG2	
80	120	H	Dark grey, fine, wet, soft.	5.9	960	SH	PWH

STATIC CHARACTERISTICS

SAMPLE #	PASTE pH	S(T) %	S(SO4) %	AP	NP	NET NP	NP/AP
TP94-V5-SA	7.22	4.57	0.75	119.4	29.6	-89.8	0.2
TP94-V5-SB	2.51	0.96	0.61	10.9	24.2	13.2	2.2
TP94-V5-SC	7.46	4.81	0.14	145.9	49.4	-96.5	0.3
TP94-V5-SD	5.08	4.27	0.18	127.8	3.9	-123.9	0.0
TP94-V5-SE	7.53	5.93	0.05	183.8	31.1	-152.7	0.2
TP94-V5-SF	7.73	8.45	0.04	262.8	55.8	-207.0	0.2
TP94-V5-SG1	7.23	7.39	0.13	226.9	21.8	-205.1	0.1
TP94-V5-SG2	7.54	5.10	1.48	113.1	26.3	-86.8	0.2
TP94-V5-SH	7.65	2.45	0.08	74.1	40.8	-33.3	0.6

POREWATER CHEMISTRY

SAMPLE #	D. O2 mg/L	pH	Cond. uS/cm	Redox mV	Alkalinity mg/L CaCO3	Acidity mg/L CaCO3	SO4 mg/L
TP94-V5							
PWH	0.90	7.15	2760	142	192.5	17.5	1478

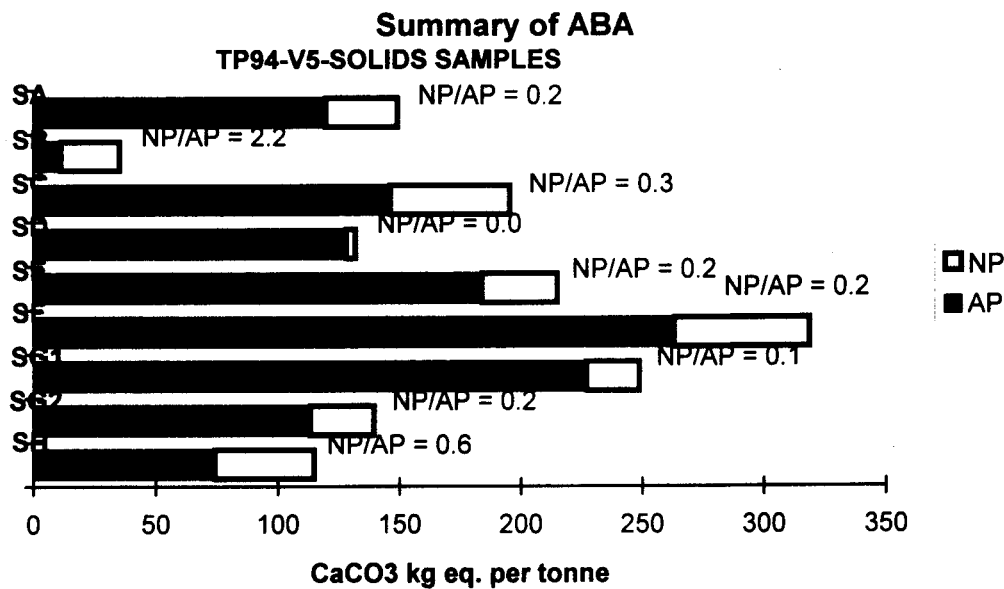
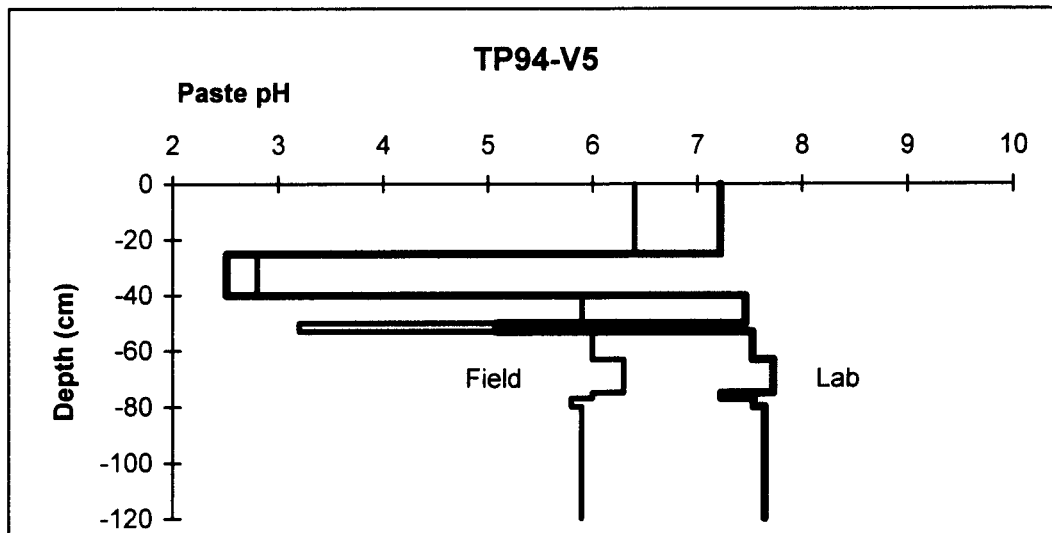
VENUS TAILINGS **TEST PIT DATA SHEETS**

ICP ANALYSIS OF POREWATER

TP94-V5
PWH

Element	units	Conc.
As	mg/L	0.33
Cd	mg/L	0.019
Ca	mg/L	429.0
Fe	mg/L	0.257
Mg	mg/L	203.0
Zn	mg/L	4.22

GRAPHS



VENUS TAILINGS **TEST PIT DATA SHEETS**

TEST PIT: **TP94-V-6**

Excavated 31-May-94

LOCATION: South end of impoundment.
3 m south of pond

DESCRIPTION: The south pond beach slopes at approximately 10-15 degrees to the pond.
The area appears to be frost heaved but no deep vertical cracks were observed. Surface colour is sand/brown, particle size is primarily sand size.
Frost heave action has caused a slightly undulating surface profile.

Depth to water table: 97 cm

TEST PIT LOG

DEPTH from	(cm) to	LAYER	DESCRIPTION	FIELD PASTE		SAMPLES	
				pH	COND.	SOLIDS	WATER
0	35	A	Brown/dark grey stratified (1 cm) moist, silty sand.	6.8	550	SA	
35	60	B	Red/brown oxidized silty sand, moist to wet at depth.	6.9	360	SB	
60	67	C	Dark grey soft, very fine, moist, flowing at base.	7.3	150	SC	
67	97	D	Red/brown oxidized zone, silty sand, flowing.	6.9	750	SD	
97	100	E	Below water level	7.2	-	SE	PWE

STATIC CHARACTERISTICS

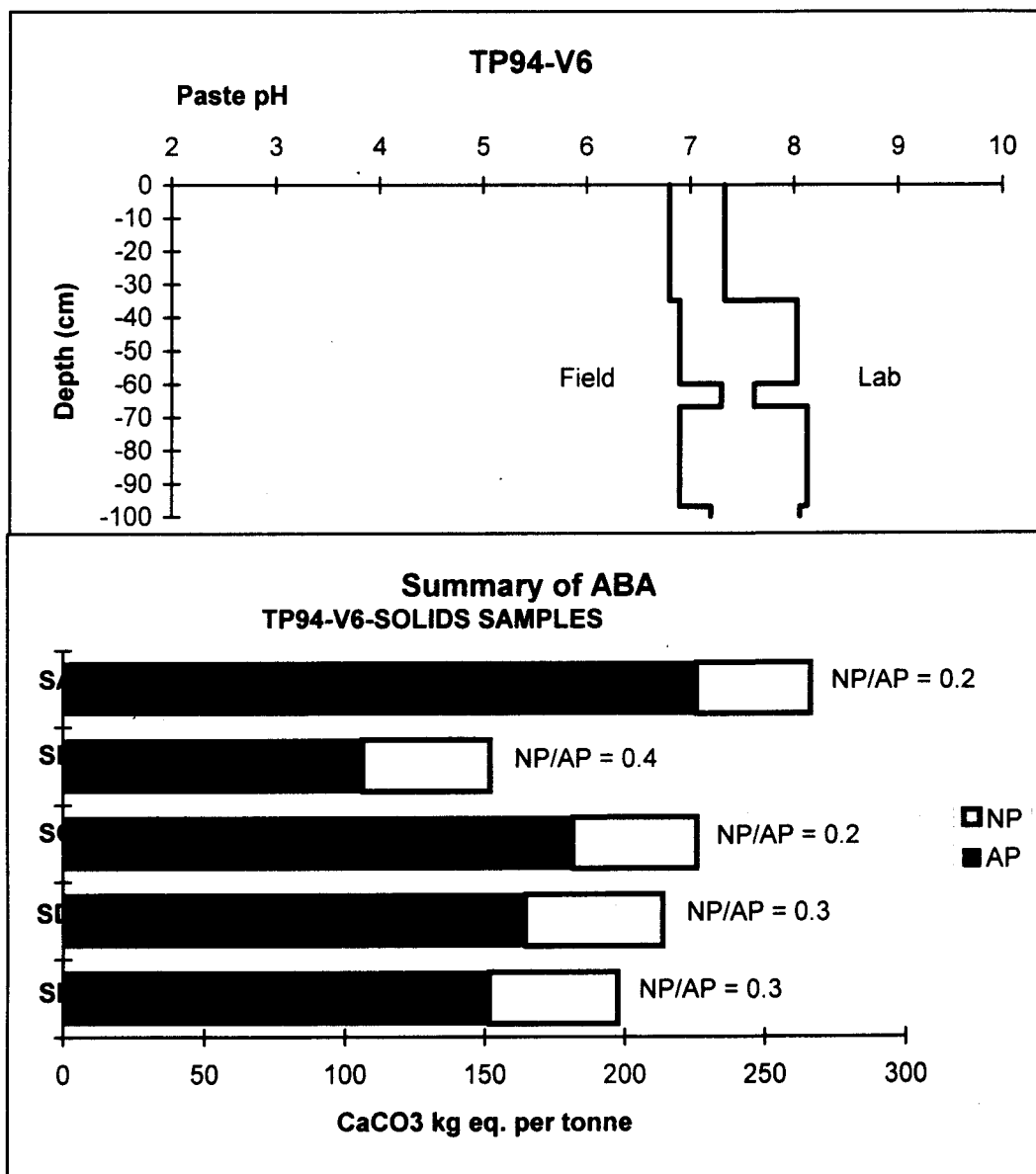
SAMPLE #	PASTE pH	S(T) %	S(SO4) %	AP	NP	NET NP	NP/AP
TP94-V6-SA	7.33	7.25	0.04	225.3	40.8	-184.5	0.2
TP94-V6-SB	8.03	3.43	0.03	106.3	45.6	-60.7	0.4
TP94-V6-SC	7.62	5.90	0.10	181.3	44.4	-136.9	0.2
TP94-V6-SD	8.13	5.30	0.04	164.4	49.3	-115.1	0.3
TP94-V6-SE	8.06	4.88	0.03	151.6	46.1	-105.5	0.3

POREWATER CHEMISTRY

SAMPLE #	D. O2 mg/L	pH	Cond. uS/cm	Redox mV	Alkalinity mg/L CaCO3	Acidity mg/L CaCO3	SO4 mg/L
TP94-V6							
PWE	0.65	7.57	880	130	158.8	5.0	296

VENUS TAILINGS TEST PIT DATA SHEETS

GRAPHS



VENUS TAILINGS **TEST PIT DATA SHEETS**

TEST PIT: **TP94-V-7**

Excavated 31-May-94

LOCATION: South end of impoundment
6 m south of pond

DESCRIPTION: The south pond beach slopes at approximately 10-15 degrees to the pond.
The area appears to be frost heaved but no deep vertical cracks
were observed. Surface colour is sand/brown, particle size is primarily sand size.
Frost heave action has caused a slightly undulating surface profile.

Depth to water table: not observed

TEST PIT LOG

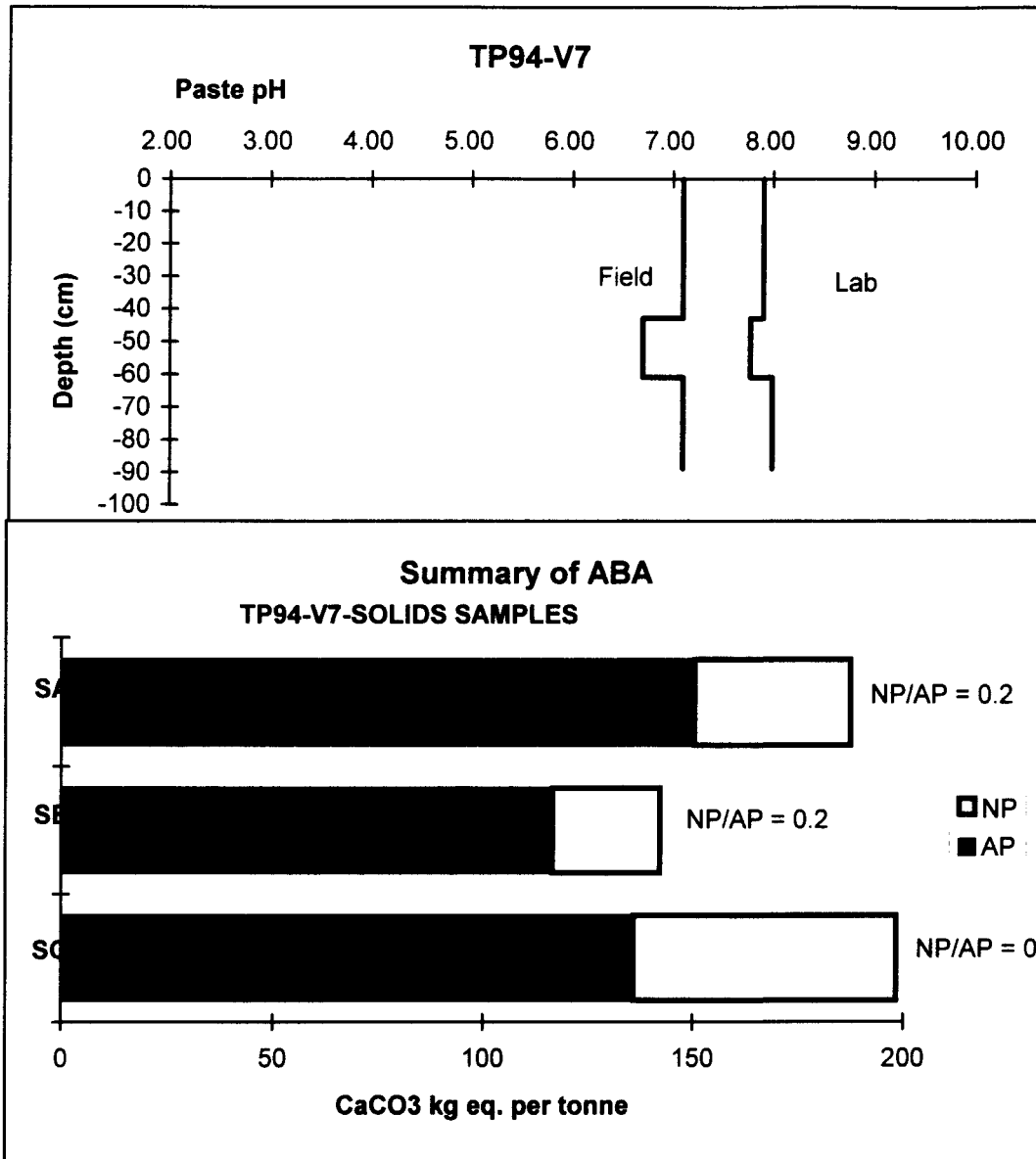
DEPTH from	(cm) to	LAYER	DESCRIPTION	FIELD PASTE		SAMPLES	
				pH	COND.	SOLIDS	WATER
0	43	A	Brown/grey mottled sandy silt, dry to moist.	7.1	330	SA	
43	61	B	Red stained, oxidized sandy silt.	6.7	280	SB	
61	89	C	Dark grey silt, very fine, soft, moist.	7.1	300	SC	-

STATIC CHARACTERISTICS

SAMPLE #	PASTE pH	S(T) %	S(SO4) %	AP	NP	NET NP	NP/AP
TP94-V7-SA	7.90	4.84	0.03	150.3	37.1	-113.3	0.2
TP94-V7-SB	7.77	3.76	0.03	116.6	25.7	-90.9	0.2
TP94-V7-SC	7.99	4.37	0.02	135.9	62.5	-73.5	0.5

VENUS TAILINGS TEST PIT DATA SHEETS

GRAPHS



VENUS TAILINGS **TEST PIT DATA SHEETS**

TEST PIT: **TP94-V-9**

Excavated 31-May-94

LOCATION: West side of impoundment, 2/3 N. distance along length
4 m from edge of pond.

DESCRIPTION: The east pond beach slopes at approximately 10-15 degrees to the pond.
The beach is generally disturbed by frost heave action causing deep vertical cracks
to a depth of +0.5m. Surface colour is dark grey, with minor 'eruptions' of light
buff coloured oxidized material at major crack locations. Frost heave action has
caused an undulating surface profile.

Depth to water table: 60 cm

TEST PIT LOG

DEPTH from	(cm) to	LAYER	DESCRIPTION	FIELD PASTE		SAMPLES	
				pH	COND.	SOLIDS	WATER
0	10	A	Brown/grey mottled sandy silt, dry to moist.	6.3	850	SA	
10	35	B	Red/brown, oxidized sandy silt, firm, moist	5.9	610	SB	
35	60	C	Dark grey silt, very fine, soft, moist. pockets of hard/dry, light red-buff	5.9	240	SC	pwc
				6	820	SD	

STATIC CHARACTERISTICS

SAMPLE #	PASTE pH	S(T) %	S(SO4) %	AP	NP	NET NP	NP/AP
TP94-V9-SA	7.26	3.64	0.09	110.9	25.6	-85.4	0.2
TP94-V9-SB	7.30	2.98	0.12	89.4	27.3	-62.1	0.3
TP94-V9-SC	8.20	6.19	0.15	188.8	67.0	-121.8	0.4
TP94-V9-SC	7.40	5.05	0.04	156.6	34.3	-122.3	0.2

POREWATER CHEMISTRY

SAMPLE #	D. O2 mg/L	pH	Cond. uS/cm	Redox mV	Alkalinity mg/L CaCO3	Acidity mg/L CaCO3	SO4 mg/L
TP94-V9							
PWC	1.00	7.90	637	120	125.0	5.0	161

ICP ANALYSIS OF POREWATER

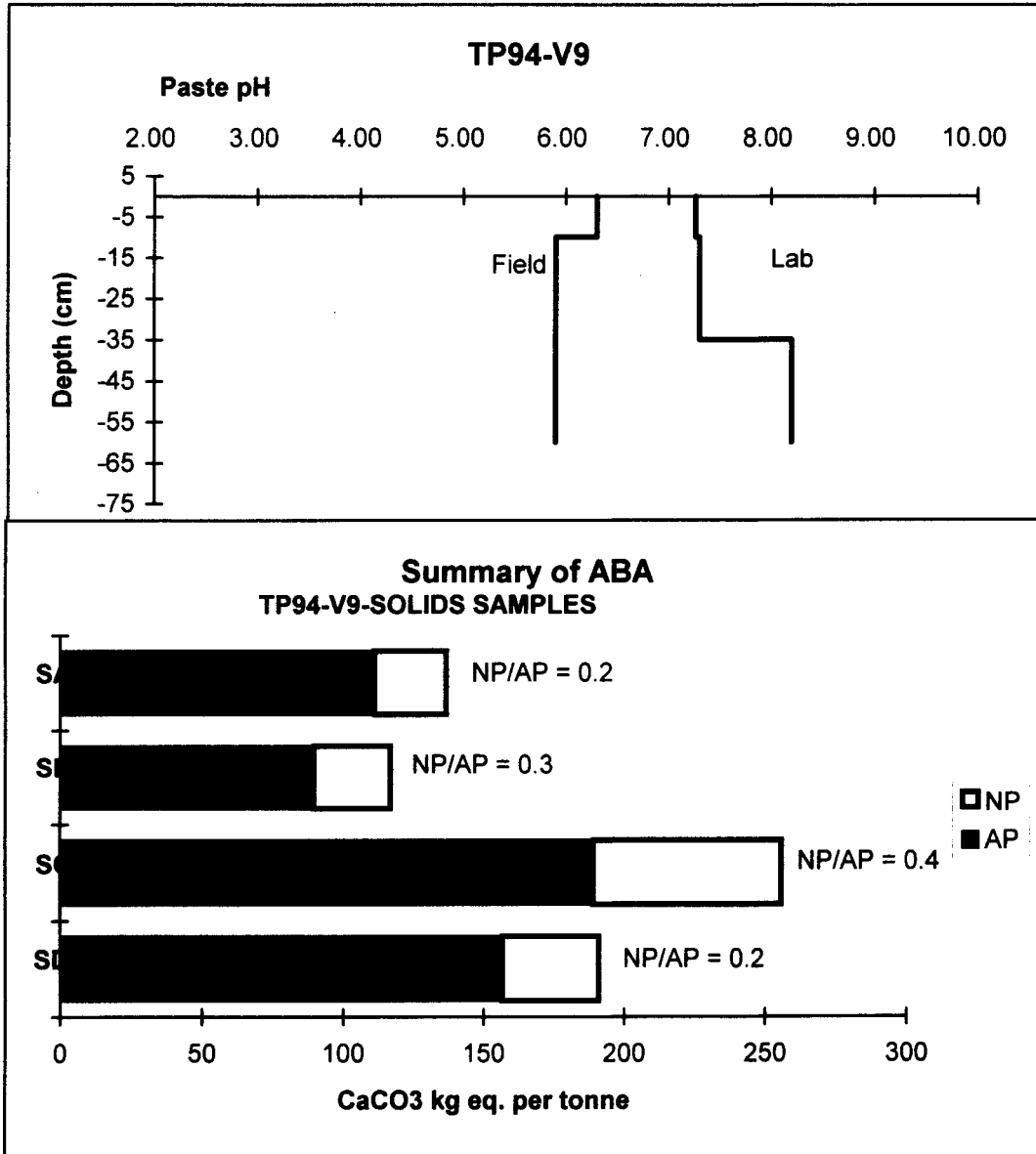
TP94-V9

PWC

Element	units	Conc.
As	mg/L	0.61
Cd	mg/L	0.06
Ca	mg/L	523.0
Fe	mg/L	0.053
Mg	mg/L	140.0
Zn	mg/L	1.86

**VENUS TAILINGS
TEST PIT DATA SHEETS**

GRAPHS



VENUS TAILINGS **TEST PIT DATA SHEETS**

TEST PIT: **TP94-V-8**

Excavated 31-May-94

LOCATION: West side of impoundment, mid distance along length
2 m from edge of pond.

DESCRIPTION: The east pond beach slopes at approximately 10-15 degrees to the pond.
The beach is generally disturbed by frost heave action causing deep vertical cracks to a depth of +0.5m. Surface colour is dark grey, with minor 'eruptions' of light buff coloured oxidized material at major crack locations. Frost heave action has caused an undulating surface profile.

Depth to water table: 85 cm

TEST PIT LOG

DEPTH from	(cm) to	LAYER	DESCRIPTION	FIELD PASTE		SAMPLES	
				pH	COND.	SOLIDS	WATER
0	15	A	Brown/grey mottled sandy silt, dry to moist.	6.1	140	SA	
15	30	B	Red/brown, oxidized sandy silt, firm, moist	6.1	120	SB	
30	85	C	Dark grey silt, very fine, soft, moist.	7.5	130	SC	PWC

STATIC CHARACTERISTICS

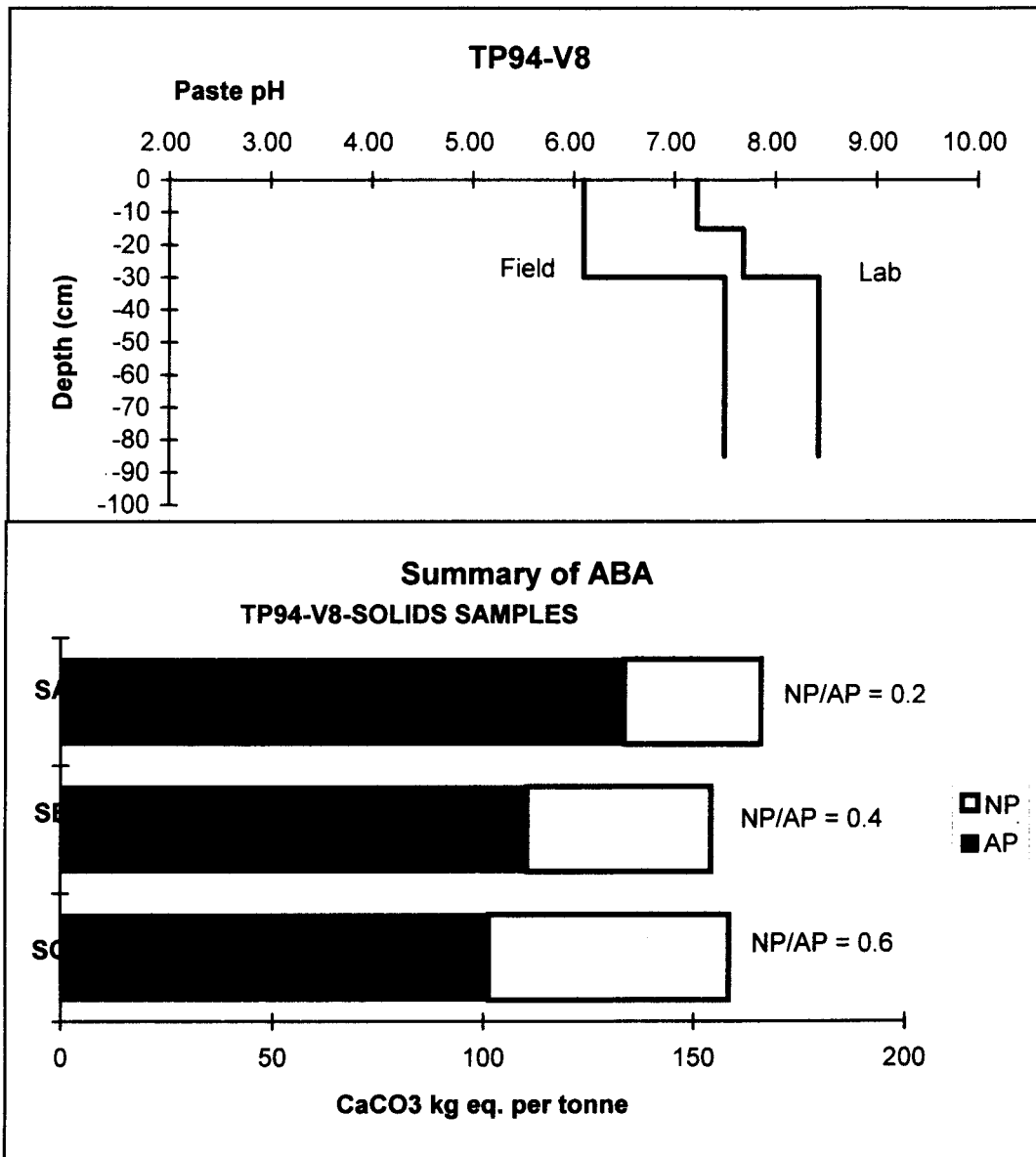
SAMPLE #	PASTE pH	S(T) %	S(SO4) %	AP	NP	NET NP	NP/AP
TP94-V8-SA	7.22	4.40	0.13	133.4	32.4	-101.0	0.2
TP94-V8-SB	7.68	3.58	0.05	110.3	43.8	-66.5	0.4
TP94-V8-SC	8.43	3.29	0.05	101.3	57.1	-44.2	0.6

POREWATER CHEMISTRY

SAMPLE #	D. O2 mg/L	pH	Cond. uS/cm	Redox mV	Alkalinity mg/L CaCO3	Acidity mg/L CaCO3	SO4 mg/L
TP94-V8							
PWC	1.00	7.90	637	120	125.0	5.0	161

VENUS TAILINGS TEST PIT DATA SHEETS

GRAPHS



APPENDIX B

Surface Water Quality Data

FIELD DATA SHEET - SURFACE WATER QUALITY Date: MAY 30/94BY: SEPPage: 1

Sampling Station (no., description, photo no.)	Flow	pH Distilled = 6.9	Conductivity	Bottles		
				imm.	tot.	diss.
94-V-SW <u>4</u> : Upstream SPRING ADJACENT TO POWER POLE - 2 PHOTOS MID DIST. OF RRM	1-2 l/s	7.3	420	✓	✓	✓
94-V-SW <u> </u> : Upstream						
94-V-SW <u> </u> : Upstream						
94-V-SW <u>1</u> : Decant (19) PHOTO #1 ASBESTOS DECANT CULVERT DISCHARGE 5m FROM LAKE	2-3 l/s	7.8	420	✓	✓	✓
94-V-SW <u>2</u> : Other culvert (18) PHOTO 2 LS CULVERT DISCHARGE + 30m FROM LAKE	1 l/s	7.4	480	✓	✓	✓
94-V-SW <u>3</u> : Seep (20) VERY SMALL FLOW COLLECTED FROM SHALL POND BELOW PHOTO 3.	< 0.01 l/s	7.0	680	✓	✓	✓

V.
COLN.


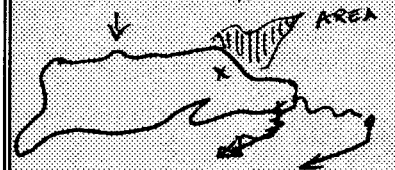
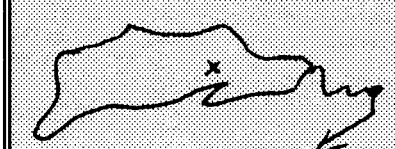
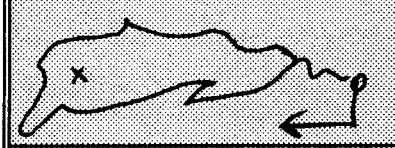
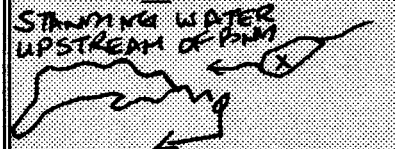
4

FIELD DATA SHEET - SURFACE WATER QUALITY

Date: MAY 30/94

SEB

Page: 2

Sampling Station (no., description, photo no.)	Flow	pH	Conductivity	Bottles		
				imm.	tot.	diss.
94-V-SW5: NEAR DECAHT POINT. DECAHT INTAKE 	SAMPLE TAKEN FROM 6" BELOW WATER LEVEL + SURFACE WATER	7.8	490	✓	✓	✓
94-V-SW6: RED STAIN AREA 	SAMPLE TAKEN FROM SURFACE BELOW WATER LEVEL.	7.7	480	✓	✓	✓
94-V-SW7: 	SAMPLE TAKEN 6-8" BELOW WATER LEVEL.	7.6	470	✓	✓	✓
94-V-SW8: 	SAMPLE TAKEN 6-8" BELOW WATER LEVEL	7.8	390	✓	✓	✓
94-V-SW9: MAY 31/94 DECAHT DISCHARGE (DAY 2 SAMPLE).	1-2 Q/S NOTICABLY LESS THAN YESTERDAY	7.8	440	✓	✓	✓
94-V-SW10: MAY 31/94 STANDING WATER UPSTREAM OF DAM 	SAMPLE 6-8" BELOW SURFACE.	7.8	760 800	✓	✓	✓

WARM

WARM



RESULTS OF ANALYSIS

File No. D9898

		94-V-SW1	94-V-SW2	94-V-SW3	94-V-SW3 ¹ Recheck	94-V-SW4
		94 05 30	94 05 30	94 05 30	94 05 30	94 05 30
Physical Tests						
Conductivity	umhos/cm	492	537	740	-	485
pH		8.26	7.98	7.64	-	7.89
Total Suspended Solids		<1	<1	1	3	2
Dissolved Anions						
Alkalinity - Total	CaCO ₃	138	152	201	-	140
Sulphate	SO ₄	125	124	199	-	118
Total Metals						
Aluminum	T-Al	<0.20	-	<0.20	-	-
Antimony	T-Sb	<0.20	-	<0.20	-	-
Arsenic	T-As	0.60	-	3.21	-	-
Barium	T-Ba	<0.010	-	0.021	-	-
Beryllium	T-Be	<0.005	-	<0.005	-	-
Bismuth	T-Bi	<0.10	-	<0.10	-	-
Boron	T-B	<0.10	-	<0.10	-	-
Cadmium	T-Cd	<0.010	-	<0.010	-	-
Calcium	T-Ca	46.0	-	88.8	-	-
Chromium	T-Cr	<0.015	-	<0.015	-	-
Cobalt	T-Co	<0.015	-	<0.015	-	-
Copper	T-Cu	<0.010	-	<0.010	-	-
Iron	T-Fe	0.077	-	0.042	-	-
Lead	T-Pb	<0.050	-	<0.050	-	-
Lithium	T-Li	<0.015	-	<0.015	-	-
Magnesium	T-Mg	37.6	-	46.9	-	-
Manganese	T-Mn	0.006	-	0.005	-	-
Molybdenum	T-Mo	<0.030	-	<0.030	-	-
Nickel	T-Ni	<0.020	-	<0.020	-	-
Phosphorus	T-P	<0.30	-	<0.30	-	-
Potassium	T-K	<2.0	-	2.5	-	-
Selenium	T-Se	<0.20	-	<0.20	-	-
Silicon	T-Si	2.66	-	4.83	-	-
Silver	T-Ag	<0.015	-	<0.015	-	-
Sodium	T-Na	3.4	-	5.2	-	-
Strontium	T-Sr	0.242	-	0.820	-	-
Thallium	T-Tl	<0.10	-	<0.10	-	-
Tin	T-Sn	<0.30	-	<0.30	-	-
Titanium	T-Ti	<0.010	-	<0.010	-	-
Tungsten	T-W	<0.10	-	<0.10	-	-

< = Less than the detection limit indicated.

Results are expressed as milligrams per litre except for pH and Conductivity (umhos/cm).

¹This sample was reanalyzed for confirmation of Total Suspended Solids.

**RESULTS OF ANALYSIS**

File No. D9898

		94-V-SW1	94-V-SW2	94-V-SW3	94-V-SW3 ¹ Recheck	94-V-SW4
		94 05 30	94 05 30	94 05 30	94 05 30	94 05 30
<u>Total Metals</u>						
Vanadium	T-V	<0.030	-	<0.030	-	-
Zinc	T-Zn	0.030	-	0.132	-	-

< = Less than the detection limit indicated.

Results are expressed as milligrams per litre except for pH and Conductivity (umhos/cm).

¹This sample was reanalyzed for confirmation of Total Suspended Solids.

**RESULTS OF ANALYSIS**

File No. D9898

	94-V-SW5	94-V-SW6	94-V-SW7	94-V-SW8	94-V-SW9
	94 05 30	94 05 30	94 05 30	94 05 30	94 05 30
<hr/>					
<u>Physical Tests</u>					
Conductivity umhos/cm	498	498	498	498	500
pH	8.37	8.33	8.34	8.35	8.33
Total Suspended Solids	2	2	<1	3	1
<u>Dissolved Anions</u>					
Alkalinity - Total	CaCO3 141	139	137	137	140
Sulphate SO4	126	125	123	126	124

< = Less than the detection limit indicated.
Results are expressed as milligrams per litre except for pH and
Conductivity (umhos/cm).



RESULTS OF ANALYSIS

File No. D9898

94-V-SW
10
94 05 30

94-V-SW
10
LRep
94 05 30

Physical Tests

Conductivity umhos/cm
pH
Total Suspended Solids

876
8.21
6

-
-
5

Dissolved Anions

Alkalinity - Total CaCO₃
Sulphate SO₄

355
135

-
-

Total Metals

Aluminum T-Al
Antimony T-Sb
Arsenic T-As
Barium T-Ba
Beryllium T-Be

<0.20
<0.20
1.78
0.058
<0.005

-
-
-
-
-

Bismuth T-Bi
Boron T-B
Cadmium T-Cd
Calcium T-Ca
Chromium T-Cr

<0.10
<0.10
<0.010
91.8
<0.015

-
-
-
-
-

Cobalt T-Co
Copper T-Cu
Iron T-Fe
Lead T-Pb
Lithium T-Li

<0.015
<0.010
0.203
<0.050
<0.015

-
-
-
-
-

Magnesium T-Mg
Manganese T-Mn
Molybdenum T-Mo
Nickel T-Ni
Phosphorus T-P

60.6
0.036
<0.030
<0.020
<0.30

-
-
-
-
-

Potassium T-K
Selenium T-Se
Silicon T-Si
Silver T-Ag
Sodium T-Na

6.1
<0.20
5.57
<0.015
27.6

-
-
-
-
-

Strontium T-Sr
Thallium T-Tl
Tin T-Sn
Titanium T-Ti
Tungsten T-W

0.603
<0.10
<0.30
<0.010
<0.10

-
-
-
-
-

< = Less than the detection limit indicated.

Results are expressed as milligrams per litre except for pH and Conductivity (umhos/cm).



RESULTS OF ANALYSIS

File No. D9898

94-V-SW
10
94 05 30

94-V-SW
10
LRep
94 05 30

Total Metals

Vanadium T-V
Zinc T-Zn

<0.030
0.006

-
-

< = Less than the detection limit indicated.
Results are expressed as milligrams per litre except for pH and
Conductivity (umhos/cm).



RESULTS OF ANALYSIS

File No. D9898

		94-V-SW1	94-V-SW2	94-V-SW3	94-V-SW4	94-V-SW5
		94 05 30	94 05 30	94 05 30	94 05 30	94 05 30
<u>Dissolved Metals</u>						
Aluminum	D-Al	<0.20	<0.20	<0.20	<0.20	<0.20
Antimony	D-Sb	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic	D-As	0.557	0.0017	3.19	0.0049	0.558
Barium	D-Ba	<0.010	<0.010	0.021	<0.010	<0.010
Beryllium	D-Be	<0.005	<0.005	<0.005	<0.005	<0.005
Bismuth	D-Bi	<0.10	0.14	<0.10	0.12	0.13
Boron	D-B	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium	D-Cd	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium	D-Ca	46.0	51.5	87.5	44.9	46.3
Chromium	D-Cr	<0.015	<0.015	<0.015	<0.015	<0.015
Cobalt	D-Co	<0.015	<0.015	<0.015	<0.015	<0.015
Copper	D-Cu	<0.010	<0.010	<0.010	<0.010	<0.010
Iron	D-Fe	<0.030	<0.030	<0.030	<0.030	<0.030
Lead	D-Pb	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium	D-Li	<0.015	<0.015	<0.015	<0.015	<0.015
Magnesium	D-Mg	37.2	37.8	45.5	36.0	37.5
Manganese	D-Mn	0.005	<0.005	<0.005	<0.005	<0.005
Mercury	D-Hg	<0.00005	-	-	<0.00005	-
Molybdenum	D-Mo	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel	D-Ni	<0.020	<0.020	<0.020	<0.020	<0.020
Phosphorus	D-P	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium	D-K	<2.0	<2.0	2.5	<2.0	<2.0
Selenium	D-Se	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon	D-Si	2.44	3.09	4.40	3.02	2.43
Silver	D-Ag	<0.015	<0.015	<0.015	<0.015	<0.015
Sodium	D-Na	3.3	6.1	5.2	3.6	3.7
Strontium	D-Sr	0.242	0.247	0.799	0.222	0.242
Thallium	D-Tl	<0.10	<0.10	<0.10	<0.10	<0.10
Tin	D-Sn	<0.30	<0.30	<0.30	<0.30	<0.30
Titanium	D-Ti	<0.010	<0.010	<0.010	<0.010	<0.010
Tungsten	D-W	<0.10	<0.10	<0.10	<0.10	<0.10
Vanadium	D-V	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc	D-Zn	0.021	0.046	0.129	<0.005	0.022

< = Less than the detection limit indicated.

Results are expressed as milligrams per litre except for pH and Conductivity (umhos/cm).



RESULTS OF ANALYSIS

File No. D9898

		94-V-SW6	94-V-SW7	94-V-SW8	94-V-SW9	94-V-SW10
		94 05 30	94 05 30	94 05 30	94 05 30	94 05 30
<u>Dissolved Metals</u>						
Aluminum	D-Al	<0.20	<0.20	<0.20	<0.20	<0.20
Antimony	D-Sb	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic	D-As	0.541	0.522	0.560	0.546	1.73
Barium	D-Ba	<0.010	<0.010	<0.010	<0.010	0.057
Beryllium	D-Be	<0.005	<0.005	<0.005	<0.005	<0.005
Bismuth	D-Bi	0.12	0.13	0.12	0.11	<0.10
Boron	D-B	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium	D-Cd	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium	D-Ca	45.9	45.2	45.6	46.3	90.4
Chromium	D-Cr	<0.015	<0.015	<0.015	<0.015	<0.015
Cobalt	D-Co	<0.015	<0.015	<0.015	<0.015	<0.015
Copper	D-Cu	<0.010	<0.010	<0.010	<0.010	<0.010
Iron	D-Fe	<0.030	<0.030	<0.030	<0.030	0.099
Lead	D-Pb	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium	D-Li	<0.015	<0.015	<0.015	<0.015	<0.015
Magnesium	D-Mg	37.3	36.7	37.0	37.5	58.2
Manganese	D-Mn	0.005	0.005	<0.005	<0.005	0.012
Mercury	D-Hg	-	-	-	<0.00005	-
Molybdenum	D-Mo	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel	D-Ni	<0.020	<0.020	<0.020	<0.020	<0.020
Phosphorus	D-P	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium	D-K	<2.0	<2.0	<2.0	<2.0	6.1
Selenium	D-Se	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon	D-Si	2.44	2.40	2.40	2.39	5.03
Silver	D-Ag	<0.015	<0.015	<0.015	<0.015	<0.015
Sodium	D-Na	3.7	3.6	3.7	3.7	27.4
Strontium	D-Sr	0.240	0.231	0.239	0.240	0.585
Thallium	D-Tl	<0.10	<0.10	<0.10	<0.10	<0.10
Tin	D-Sn	<0.30	<0.30	<0.30	<0.30	<0.30
Titanium	D-Ti	<0.010	<0.010	<0.010	<0.010	<0.010
Tungsten	D-W	<0.10	<0.10	<0.10	<0.10	<0.10
Vanadium	D-V	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc	D-Zn	0.019	0.019	0.016	0.021	0.006

< = Less than the detection limit indicated.

Results are expressed as milligrams per litre except for pH and Conductivity (umhos/cm).



METHODOLOGY

File No. D9898

Samples were analyzed by methods acceptable to the appropriate regulatory agency. Outlines of the methodologies utilized are as follows:

Conventional Parameters in Water

These analyses are carried out in accordance with procedures described in "Standard Methods for the Examination of Water and Wastewater" 18th Ed. published by the American Public Health Association, 1992. Further details are available on request.

Metals in Water

These analyses are carried out in accordance with procedures described in "Standard Methods for the Examination of Water and Wastewater" 18th Edition published by the American Public Health Association, 1992. The procedures involve a variety of instrumental analyses including atomic emission spectrophotometry (ICP) and atomic absorption spectrophotometry (AA) to obtain the required detection limit for each element. Specific details are available on request.

End of Report

APPENDIX C

Results of Solids Analyses

VENUE TAILINGS
ICP OF SOLIDS

Element	TP94-V1 SA	TP94-V1 SB	TP94-V1 SC	TP94-V5 SA	TP94-V5 SB	TP94-V5 SC	TP94-V5 SD	TP94-V5 SE	TP94-V5 SF	TP94-V5 SG1
Ag ppm	23.5	27	37.1	55.4	67.6	55.2	33.9	38.6	66.8	28.7
Al %	0.39	0.31	0.33	0.61	0.64	0.73	0.32	0.27	0.64	0.19
As* %	2.57	5.03	5.19	4.55	4.50	4.58	3.97	4.55	4.96	4.6
B ppm	17	20	22	25	27	30	19	17	35	23
Ba ppm	55	48	51	102	128	120	49	47	105	38
Be ppm	0.6	0.6	0.7	0.7	0.8	1.1	0.6	0.7	1	0.7
Bi ppm	8	10	12	20	25	19	11	12	32	15
Ca %	0.83	0.69	0.75	1.06	0.25	0.87	0.37	0.63	1	0.61
Cd ppm	0.1	0.1	0.1	0.1	0.1	1.5	0.1	0.1	99.2	0.1
Co ppm	8	10	11	11	6	12	8	9	12	9
Cu ppm	35	27	43	109	18	96	42	36	171	42
Fe %	4.21	6.19	6.96	6.3	5.92	6.49	5.86	6.06	7.38	6.3
K %	0.2	0.16	0.16	0.3	0.36	0.37	0.16	0.16	0.34	0.13
Li ppm	3	2	2	4	2	3	2	2	3	1
Mg %	0.5	0.42	0.46	0.47	0.11	0.59	0.18	0.36	0.63	0.27
Mn ppm	681	556	630	899	61	997	261	569	1039	637
Mo ppm	2	1	1	2	2	3	1	1	3	1
Na %	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Ni ppm	29	33	40	39	23	42	30	31	45	28
P ppm	680	560	620	770	810	870	600	520	800	440
Pb ppm	1660	2012	2583	4331	5663	5070	2531	2835	6411	2443
Sb ppm	39	55	66	80	97	90	54	57	96	54
Sr ppm	67	61	70	114	80	107	38	59	104	61
Th ppm	8	9	9	9	7	10	8	9	11	8
Ti %	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
V ppm	9.6	7.9	8.5	13.1	12.6	15.1	7.3	6.6	12.3	4.9
Zn ppm	1940	2022	2510	3715	502	5805	1558	1930	8802	3097
Ga ppm	5	1	1	1	1	4	1	1	2	1
Sn ppm	1	1	1	1	1	1	1	1	1	1
W ppm	6	5	5	7	3	8	5	5	11	5
Cr ppm	63	48	28	47	34	31	46	38	33	28

VENUE TAILINGS
ICP OF SOLIDS

Element	TP94-V5 SG2	TP94-V5 SH	TP94-V6 SA	TP94-V6 SB	TP94-V6 SC	TP94-V6 SD	TP94-V6 SE	TP94-V7 SA	TP94-V7 SB	TP94-V7 SC
Ag ppm	37	83	54.8	29.6	67.9	39.5	39.7	29.6	25.4	85.8
Al %	0.18	0.49	0.68	0.64	1.22	0.56	0.84	0.76	0.81	0.91
As* %	6.36	5.81	6.92	3.31	5.72	4.41	4.24	4.76	3.89	4.49
B ppm	27	36	6	1	15	1	4	3	1	1
Ba ppm	33	80	103	94	172	83	111	103	108	141
Be ppm	0.6	1.1	0.2	0.4	0.7	0.5	0.5	0.4	0.6	0.7
Bi ppm	18	36	17	10	29	17	15	12	11	31
Ca %	0.55	0.81	1.07	1.26	1.25	1.25	1.24	1.02	0.83	1.73
Cd ppm	>100	>100	>100	0.1	>100	0.1	0.1	0.1	0.1	23.2
Co ppm	12	12	15	9	14	11	12	11	10	13
Cu ppm	64	191	73	45	177	71	66	39	33	220
Fe %	8.58	7.58	9.75	5.63	8.68	6.85	6.88	6.9	5.86	7.6
K %	0.12	0.29	0.37	0.37	0.66	0.32	0.46	0.41	0.46	0.4
Li ppm	1	2	4	4	5	3	3	4	3	7
Mg %	0.27	0.44	0.52	0.59	0.61	0.57	0.6	0.51	0.39	0.88
Mn ppm	467	780	756	895	1034	903	914	829	619	1144
Mo ppm	1	5	5	2	5	5	12	1	9	2
Na %	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Ni ppm	35	42	46	29	50	40	46	37	35	45
P ppm	440	630	750	820	860	770	790	750	680	1040
Pb ppm	3040	6065	3877	1909	6215	2671	2898	2305	1692	6754
Sb ppm	75	101	88	46	106	58	61	60	54	104
Sr ppm	50	82	92	89	117	93	91	82	79	146
Th ppm	8	11	10	9	10	9	9	9	9	11
Ti %	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
V ppm	4.3	9.7	14.3	12.8	21.2	12.7	18.3	15.5	16.3	18.4
Zn ppm	3328	9956	2160	1116	7192	2882	3199	2028	2524	3494
Ga ppm	1	1	1	5	2	3	3	5	4	6
Sn ppm	1	1	1	1	1	1	1	1	1	1
W ppm	5	12	17	10	18	12	22	13	23	6
Cr ppm	27	41	292	155	201	165	373	197	413	34

VENUE TAILINGS
ICP OF SOLIDS

Element	TP94-V8 SA	TP94-V8 SB	TP94-V8 SC	TP94-V9 SA	TP94-V9 SB	TP94-V9 SC	TP94-V9 SD	TP94-V9 SOIL
Ag ppm	39.9	23.1	30.6	60.4	49.3	45.7	50.5	2.8
Al %	0.76	0.89	0.38	0.67	0.88	0.67	0.72	3.58
As* %	4.83	3.73	3.31	4.3	3.79	3.65	4.22	0.2
B ppm	9	8	1	35	29	23	24	1
Ba ppm	109	123	58	109	139	119	121	467
Be ppm	0.5	0.6	0.4	0.9	1.1	1	0.9	0.9
Bi ppm	16	11	12	23	21	18	20	14
Ca %	1.01	1.19	1.39	1.93	0.82	1.25	0.82	1.39
Cd ppm	0.1	0.1	0.1	56.1	0.1	0.1	0.1	0.1
Co ppm	12	10	9	11	9	10	10	18
Cu ppm	59	42	60	131	155	107	129	76
Fe %	7.31	5.79	5.17	6.37	6.06	5.74	6.11	5.12
K %	0.42	0.48	0.17	0.36	0.43	0.34	0.38	0.61
Li ppm	3	4	3	3	4	4	4	29
Mg %	0.46	0.57	0.65	0.39	0.45	0.71	0.47	2.32
Mn ppm	780	804	943	1086	852	1099	1009	940
Mo ppm	3	49	2	6	5	3	4	2
Na %	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.08
Ni ppm	43	37	38	40	36	38	38	86
P ppm	760	820	880	810	940	900	880	860
Pb ppm	3662	1788	2328	6729	4639	3545	5270	214
Sb ppm	81	55	52	101	80	65	84	19
Sr ppm	91	100	104	137	133	108	105	81
Th ppm	9	9	9	8	10	10	10	17
Ti %	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.19
V ppm	15.6	18.8	10.4	13.3	16.7	14.5	14.2	117.6
Zn ppm	2974	1339	1603	5529	3049	1821	3518	307
Ga ppm	1	7	7	3	3	6	2	14
Sn ppm	1	1	1	1	1	1	1	4
W ppm	12	23	4	8	6	5	6	11
Cr ppm	171	430	22	37	34	37	38	136

**VENUS MINE TAILINGS
ACID-BASE ACCOUNTING**

SAMPLE #	PASTE pH	S(T) %	S(SO4) %	AP	NP	NET NP	NP/AP
TP94-V1-SA	8.31	2.97	0.04	91.6	44.6	-47.0	0.5
TP94-V1-SB	8.37	5.50	0.03	170.9	40.1	-130.9	0.2
TP94-V1-SC	8.21	6.21	0.04	192.8	42.8	-150.0	0.2
TP94-V5-SA	7.22	4.57	0.75	119.4	29.6	-89.8	0.2
TP94-V5-SB	2.51	0.96	0.61	10.9	24.2	13.2	2.2
TP94-V5-SC	7.46	4.81	0.14	145.9	49.4	-96.5	0.3
TP94-V5-SD	5.08	4.27	0.18	127.8	3.9	-123.9	0.0
TP94-V5-SE	7.53	5.93	0.05	183.8	31.1	-152.7	0.2
TP94-V5-SF	7.73	8.45	0.04	262.8	55.8	-207.0	0.2
TP94-V5-SG1	7.23	7.39	0.13	226.9	21.8	-205.1	0.1
TP94-V5-SG2	7.54	5.10	1.48	113.1	26.3	-86.8	0.2
TP94-V5-SH	7.65	2.45	0.08	74.1	40.8	-33.3	0.6
TP94-V9-SA	7.26	3.64	0.09	110.9	25.6	-85.4	0.2
TP94-V9-SB	7.30	2.98	0.12	89.4	27.3	-62.1	0.3
TP94-V9-SC	8.20	6.19	0.15	188.8	67.0	-121.8	0.4
TP94-V9-SD	7.40	5.05	0.04	156.6	34.3	-122.3	0.2
TP94-V6-SA	7.33	7.25	0.04	225.3	40.8	-184.5	0.2
TP94-V6-SB	8.03	3.43	0.03	106.3	45.6	-60.7	0.4
TP94-V6-SC	7.62	5.90	0.10	181.3	44.4	-136.9	0.2
TP94-V6-SD	8.13	5.30	0.04	164.4	49.3	-115.1	0.3
TP94-V6-SE	8.06	4.88	0.03	151.6	46.1	-105.5	0.3
TP94-V7-SA	7.90	4.84	0.03	150.3	37.1	-113.3	0.2
TP94-V7-SB	7.77	3.76	0.03	116.6	25.7	-90.9	0.2
TP94-V7-SC	7.99	4.37	0.02	135.9	62.5	-73.5	0.5
TP94-V8-SA	7.22	4.40	0.13	133.4	32.4	-101.0	0.2
TP94-V8-SB	7.68	3.58	0.05	110.3	43.8	-66.5	0.4
TP94-V8-SC	8.43	3.29	0.05	101.3	57.1	-44.2	0.6
N.END SOIL	8.25	0.27	0.03	7.5	19.3	11.8	2.6

APPENDIX D

Results of Extraction Tests

ICP ANALYSIS OF FINAL LEACHATES FROM SMALL SCALE SHAKE FLASK TESTS

Element	TP94-V1 SA	TP94-V1 SB	TP94-V1 SC	TP94-V5 SA	TP94-V5 SB	TP94-V5 SC	TP94-V5 SD	TP94-V5 SE	TP94-V5 SF	TP94-V5 SG1
Al mg/L	<0.20	<0.20	<0.20	<0.20	15	<0.20	<0.20	<0.20	<0.20	<0.20
Sb mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
As mg/L	1.1	0.36	0.49	0.52	13.2	1.06	<0.20	<0.20	0.63	<0.20
Ba mg/L	<0.010	<0.010	<0.010	0.012	0.016	0.017	0.017	<0.010	0.017	<0.010
Be mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Bi mg/L	<0.10	<0.10	<0.10	0.12	0.17	0.11	0.21	<0.10	<0.10	0.11
B mg/L	<0.10	1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cd mg/L	<0.010	<0.010	<0.010	0.086	1.9	0.029	0.782	0.025	0.022	0.018
Ca mg/L	55.6	18.9	22.2	462	359	228	314	41.8	170	110
Cr mg/L	<0.015	<0.015	<0.015	<0.015	0.052	<0.015	<0.015	<0.015	<0.015	<0.015
Co mg/L	<0.015	<0.015	<0.015	<0.015	0.085	<0.015	0.065	<0.015	<0.015	<0.015
Cu mg/L	<0.010	<0.010	<0.010	<0.010	1.17	<0.010	0.089	<0.010	<0.010	<0.010
Fe mg/L	<0.030	<0.030	<0.030	<0.030	105	0.05	0.189	<0.030	<0.030	<0.030
Pb mg/L	<0.050	<0.050	<0.050	<0.050	2.16	<0.050	<0.050	<0.050	<0.050	<0.050
Li mg/L	<0.015	<0.015	<0.015	<0.015	0.03	<0.015	0.023	<0.015	<0.015	<0.015
Mg mg/L	20.4	8.79	9.7	73.8	99.5	69.4	213	22.2	53.1	50.8
Mn mg/L	<0.005	0.033	0.108	3.6	9.13	5.75	24.1	0.606	2.2	1.5
Mo mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Ni mg/L	<0.020	<0.020	<0.020	0.069	0.266	0.079	0.172	<0.020	0.056	<0.020
P mg/L	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
K mg/L	<2.0	<2.0	<2.0	5.7	8.6	4.4	2.1	<2.0	3.2	2.2
Se mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Si mg/L	2.15	0.654	0.917	2.75	23.1	3.87	5.3	0.667	2.86	0.954
Ag mg/L	<0.015	<0.015	<0.015	<0.015	0.055	<0.015	<0.015	<0.015	<0.015	<0.015
Na mg/L	<2.0	<2.0	<2.0	2.1	2.9	<2.0	<2.0	<2.0	<2.0	<2.0
Sr mg/L	0.304	0.078	0.101	1.93	1.42	1.02	1.71	0.218	0.621	0.512
Ti mg/L	<0.10	<0.10	<0.10	<0.10	0.13	<0.10	<0.10	<0.10	<0.10	<0.10
Sn mg/L	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Ti mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
W mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
V mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Zn mg/L	0.05	0.091	0.054	6.12	46.9	1.99	30.8	0.416	0.536	0.929

INUS TAILIN
ICP ANALYSIS

Element	TP94-V6 SA	TP94-V6 SB	TP94-V6 SC	TP94-V6 SD	TP94-V6 SE	TP94-V7 SA	TP94-V7 SB	TP94-V7 SC
Al mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Sb mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
As mg/L	1.19	0.27	0.62	0.67	0.39	0.24	0.71	1.05
Ba mg/L	<0.010	<0.010	0.021	0.011	0.011	<0.010	<0.010	0.021
Be mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Bi mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
B mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cd mg/L	<0.010	<0.010	0.014	<0.010	0.01	<0.010	<0.010	<0.010
Ca mg/L	53.6	37	133	31.3	35	33.2	28.6	184
Cr mg/L	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015
Co mg/L	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015
Cu mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Fe mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Pb mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Li mg/L	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015
Mg mg/L	20.8	20.2	37.2	8.23	9.55	21.1	18.7	68.4
Mn mg/L	0.196	0.205	1.3	0.32	0.327	0.125	0.215	0.768
Mo mg/L	<0.030	<0.030	<0.030	0.032	<0.030	<0.030	<0.030	<0.030
Ni mg/L	<0.020	<0.020	0.027	<0.020	<0.020	<0.020	<0.020	<0.020
P mg/L	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
K mg/L	4.7	<2.0	4	<2.0	2	3.3	3	9.4
Se mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Si mg/L	0.949	0.677	2.9	0.977	0.571	0.761	0.547	2.55
Ag mg/L	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015
Na mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	5.7
Sr mg/L	0.321	0.195	0.541	0.2	0.31	0.18	0.14	0.961
Tl mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Sn mg/L	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Ti mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
W mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
V mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Zn mg/L	0.401	0.031	0.206	0.022	0.037	0.354	0.244	0.043

ANUS TAILIN
ICP ANALYSIS

3 of 3

Element	TP94-V8 SA	TP94-V8 SB	TP94-V8 SC	TP94-V9 SA	TP94-V9 SB	TP94-V9 SC	TP94-V9 SD	NORTH END SOIL
Al mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	0.22
Sb mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
As mg/L	0.83	0.38	0.89	0.71	<0.20	0.79	0.36	<0.20
Ba mg/L	<0.010	0.011	0.026	0.013	0.011	0.033	0.011	0.026
Be mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Bi mg/L	<0.10	<0.10	<0.10	<0.10	0.1	<0.10	0.14	<0.10
B mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cd mg/L	0.038	<0.010	<0.010	0.132	<0.010	<0.010	0.019	<0.010
Ca mg/L	93.9	43.7	37.7	531	167	92.8	250	18.3
Cr mg/L	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015
Co mg/L	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015
Cu mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Fe mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	0.144
Pb mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Li mg/L	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015
Mg mg/L	11.8	10.5	3.9	35.7	59.5	16.6	90.4	4.03
Mn mg/L	1.17	0.406	0.123	3.19	0.931	0.152	2.29	0.005
Mo mg/L	<0.030	0.04	0.049	<0.030	<0.030	0.052	<0.030	<0.030
Ni mg/L	0.056	<0.020	<0.020	0.045	0.02	<0.020	<0.020	<0.020
P mg/L	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
K mg/L	11.2	13.3	15.6	8.2	10.7	7.7	9.9	2.4
Se mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Si mg/L	1.04	0.639	0.915	3.85	1.52	1.9	2.11	3.61
Ag mg/L	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015
Na mg/L	<2.0	<2.0	<2.0	2.8	2.7	<2.0	4.5	5.1
Sr mg/L	0.466	0.387	0.451	2	0.713	0.546	0.848	0.074
Tl mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Sn mg/L	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Ti mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.012
W mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
V mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Zn mg/L	1.67	0.073	0.014	5.7	0.314	0.018	0.751	0.008

POREWATER	DISSOLVED O: mg/L	pH	CONDUCTIVITY uS/cm	REDOX mV	ALKALINITY mg/L CaCO3	ACIDITY mg/L CaCO3	SO4 mg/L		
TP94-V-1	POREWATER	1.35	7.09	832	117	162.5	0.0	6.3	290
TP94-V-3	POREWATER	0.05	7.28	748	120	352.0	0.0	6.3	55
TP94-V-8	POREWATER	1.00	7.90	637	120	125.0	0.0	5.0	161
TP94-V-9	POREWATER	2.30	7.40	2780	140	270.0	0.0	15.0	1534
TP94-V-2	POREWATER	0.80	7.43	1083	132	157.5	0.0	6.3	485
TP94-V-6	POREWATER	0.65	7.57	880	130	158.8	0.0	5.0	296
TP94-V-5	POREWATER	0.90	7.15	2760	142	192.5	0.0	17.5	1478