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REPORT ON

001514

**1995 ANNUAL GEOTECHNICAL
PERFORMANCE EVALUATION
and
INSTRUMENTATION DATA REPORT
FARO MINE
YUKON
VOLUME I**

Submitted to:

**Anvil Range Mining Corporation
Faro, Yukon
Y0B 1K0**

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March 14, 1996

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Anvil Range Mining Corporation
Postal Bag 1000
Faro, Yukon Y0B 1K0

Attention: Mr. R. E. Arndt, P.Eng., Chief Engineer

RE: 1995 ANNUAL GEOTECHNICAL PERFORMANCE EVALUATION- FARO MINE

Dear Sir:

Bound herewith is Golder Associates Ltd.'s annual geotechnical inspection report covering the Down Valley Project, the Fresh Water Supply Reservoir Dam, the North Fork Rose Creek Causeway flow-through drain, as well as selected of the mine's waste rock dumps.

The conclusion of our visual inspection for the facilities noted above is that they are in generally good condition, but that continued observation of their performance is necessary. A schedule is provided for 1996 concerning instrument observations.

Some items of maintenance are recommended, most of which were first noted on September 22, 1995. Attention to the maintenance items recommended in this report would remove concern related to project performance during a design runoff event.

It is recommended that Anvil Range not operate the Fresh Water Supply Reservoir above the spillway sill level until the crest is rehabilitated to remove deterioration due to ongoing frost-induced cracking. Recommendations concerning the nature of the work are provided. In conjunction with this work it is recommended also that a rational approach be taken to establish its maximum operating level and that the spillway stop-log works be modified to avoid any future surcharging of the reservoir.

Finally, this report includes detailed instrumentation data files and plots together with instructions and manuals which will enable Anvil Range to collect, process, and plot all future data using in-house staff.

Yours very truly,

GOLDER ASSOCIATES LTD.

H.C. Gilchrist

H.C. Gilchrist, P.Eng.
Principal

cc: Mr. Gregg Jilson, Access Mining Consultants Ltd
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1.0 INTRODUCTION

1.1 Scope of Services and Reporting

Following submission and review of proposals concerning annual geotechnical inspection for several components of Faro Mine's works, and for reading of geotechnical instruments and training of an Anvil range employee in these procedures, Anvil Range Mining Corp. retained Golder Associates Ltd. for an agreed scope of work. The work product is presented herein and comprises:

- a) Field geotechnical inspection results and related recommendations concerning:
 - Down Valley Project components comprising:
 - ◇ Cross valley Dam and Emergency Spillway
 - ◇ Intermediate Dam and Emergency Spillway
 - ◇ Rose Creek Diversion Channel dyke top, top of backslope, and toe of slope
 - ◇ North Valley Wall Interceptor
 - North Fork Rose Creek flow-through rock drain;
 - waste rock dumps overlooking North Fork Rose Creek, particularly upstream of the rock drain; and
 - the fresh water supply dam and spillway.
- b) A record of repairs and maintenance done in 1994 on the instrumentation, including instruments installed in Little Creek Dam on the VanGorda property.
- c) Reading of the geotechnical instrumentation previously installed on the Down Valley Project (piezometers, thermistors, slope indicators) and of instrumentation installed in the Little Creek dam.
- d) Presentation of instructions set for obtaining instrumentation readings and for data reduction and presentation.
- e) Preparation of recommendations concerning readings schedule for geotechnical instrumentation.

In addition, this report discusses the results of monitoring surveys done by Underhill Engineering in 1994 (for KPMG Environmental Services Inc.) to determine movement of critically positioned stations on the Down Valley Project. This recent data complements the data set initiated in 1981 right after the works were constructed.

For those familiar with previous annual inspection reports issued for Faro Mine by Golder Associates, it is noted that one of Anvil Range Mining's objectives is to take a more active role in instrumentation observation and data reduction than had been practised by previous operators of the property, hence the somewhat altered scope of this report.

1.2 General Background Relating to Inspection and Instrumentation

The Down Valley Tailings Project and Fresh Water Supply Dam - The Faro Mine Down Valley Tailings Project comprises of three major components, viz. the Diversion Canal, the Intermediate Dam and the Cross Valley Dam. An extensive geotechnical monitoring program was initiated in December, 1981, and is continuing on an ongoing basis. This report presents an assessment of the results of this program to December, 1995 and documents Golder Associates Ltd.'s inspection of the Fresh Water Supply Dam which is located on Rose Creek approximately 2.5 km upstream of the Down Valley Tailings Project. Monitoring data has been obtained traditionally by the mine's operators and supplied to Golder Associates for interpretation and inclusion in annual issues of this report. However, as a consequence of interruption in operation of the mine, and a change of ownership, no data is available for 1993, 1994 readings were taken by Golder Associates in conjunction with other work performed for KPMG. Readings for 1995 were taken by Golder Associates during the course of training an Anvil Range Mining employee concerning procedures involved.

North Fork Rose Creek Causeway - The causeway was built of calcium silicate waste during 1987. The causeway was advanced by dumping waste from causeway grade to provide a zone of preferentially larger particles in the lower portion of the fill. This zone conveys creek flows through the structure, the driving head being provided by some ponding of water on the upstream side of the causeway. Inspections have concentrated on hydraulic performance of the causeway. Pond level and creek flow data accumulated by the operator

were analyzed for the 1992 report and an expression was developed therefrom for prediction of head pond level for flows which may occur in future. No pond level data has been obtained since 1992.

Faro Mine Waste Rock Dumps - Selected of the waste rock dumps have been inspected for face stability on several previous occasions for the previous operator. Emphasis has been placed on those for which failure might compromise environmental performance of the facility, particularly with reference to those for which failure might possibly block the natural channel of the North Fork Rose Creek.

2.0 1994 INSTRUMENT REPAIRS AND MONITORING PROGRAM

Under a 1994 instruction from KPMG Environmental Services Inc., Golder Associates performed maintenance and repairs to the Down Valley Project and Fresh Water Supply dam instrumentation. In cases where repairs were not possible but ongoing acquisition of data was important, replacement instrumentation was installed. In the process of performing this assignment, Golder Associates also read all of the instrumentation.

In addition, some test pits were excavated in the crest of the Fresh Water Supply dam for the purpose of investigating the nature of longitudinal cracking found generally upstream of centreline.

Further detail concerning the repairs work is presented in Appendix I; test pit information concerning the crest of the Fresh Water Supply Dam is presented in Appendix II.

3.0 1995 MONITORING PROGRAM

3.1 Introduction

Historically, the monitoring program has comprised a specific schedule for reading the instrumentation, depending on the type of instrument, its location, the performance trend indicated by the accumulated data, and the like. As performance of the works was more firmly demonstrated, frequency of readings was reduced for reasons of economy or irrelevance of additional data, or because the installations became dysfunctional. Conversely, there have been some instances where instrumentation and visual observation justified more frequent readings, and installation of additional instrumentation.

In September, 1995, readings were obtained for all of the accessible instruments excluding the settlement observation casings. These casings were not read because it had been found shortly after their 1981 installation that the interpreted data was not dependable. All of the instruments were read because it represents a new 'start' for the project, and because, since 1992, the data has been sparse.

As a complement to the instrumentation data obtained, various components of the Faro Mine were visually inspected during the period September 20 to 22, 1995. Details of the inspection are discussed in Section 7, Field Inspection and Identified Remedial Works Requirements.

3.2 Down Valley Project Monitoring

A plan of the Down Valley Project layout and the monitoring locations is presented on Figures 1 and 2 of this report. Monitoring data was obtained during the period September 20 to 22, 1995. Monitoring was performed by Golder Associates' Lawrence Low, and Anvil Range Mining's environmental affairs technician, Yolande Vandermeer assisted full time with the data acquisition. As such, Yolande was fully trained in the techniques and operation of the thermistor, pneumatic piezometer, slope inclinometer, and water level monitoring

apparatus. She also became fully familiar with the filed locations of the instruments, and the numbering system used for their identification.

4.0 HISTORICAL RECORD AND 1995 MONITORING RESULTS

4.1 Down Valley Project Diversion Canal

4.1.1 Canal Dyke

Thermal Regime - Thermal performance of the canal dyke for the period September, 1983 to September, 1992 is presented in Table 1 together with related data for the backslope and spoil piles. Thermistors were not read during 1993. Readings for 1994 were obtained by Golder Associates during May-June and again in September; for 1995 they were obtained in September. Tabulated data appearing in Appendix IV bridges from the initial reading to the June, 1994 reading, and provides subsequent data, as well as related plots.

The dyke foundation ground temperature trend for thermistors installed along the canal dyke has been one of general warming since it was instrumented; some trend interruptions have been observed and these probably reflect variation in the readings schedule, annual climatic effects, and the like. The warming has consumed virtually all of the permafrost that was initially present. Locations for which warming above 0° C has been delayed the longest are believed to reflect greater content of excess ice in the soil. As such, it would be typical that these locations would have undergone relatively more settlement during the course of melting of this ice than for locations which warmed more quickly because relatively less excess ice was present.

As can be seen from the body of data presented in Appendix IV of this report, there are only 4 locations for which data indicates an ongoing permafrost condition in the foundation. These locations are:

- Thermistor location 81-125 at Sta. 2+100 where permafrost persists below about 8 m but ongoing warming is indicated;
- Thermistor location CD-21 at Sta. 2+100 where permafrost persists below about 11 m but ongoing warming is indicated;

- Thermistor location 88-7 at Sta. 2+115 where permafrost persists below about 6 m but very little warming has occurred; and
- Thermistor location 88-11 at Sta. 2+160 where permafrost persists below about 6 m but very little warming has occurred.

All of these locations are on a short reach of dyke upstream of the Intermediate Dam. This area has been typified by a history of settlement. The data would suggest that some additional settlement should be expected, particularly in the locale of 88-7 and 88-11.

Elsewhere along the canal dyke, temperature fluctuations now being observed are due to seasonal temperature variations, coupled with some influences related to seepage of water from the canal to the tailings pond downslope.

Locations where ground temperatures suggest the possibility of seepage from the canal are CD-4 at Sta. 0+400 where temperature is about 6° C and at CD-24 at Sta. 2+365 where temperature is similar. The latter installation is downstream of the Intermediate Dam where seepage gradient has the possibility of being steeper because the polishing pond water level is about 16.5 m lower in elevation than is the pond upstream of the dam.

Finally, it is interesting to note that annual freezing of the body of the dyke and foundation occurs to a depth of between 6 and 8 metres.

Piezometers - Plotted data for piezometers installed along the crest of the canal dyke is provided in Volume 2. No data was obtained during 1993 for reasons noted previously. Readings for 1994 were obtained by Golder Associates during May-June and again in September; for 1995 they were obtained in September. Tabulated data and plotted records cover the entire period of observation from November, 1981 to September, 1995.

Over the period of records the water level in the tailings pond retained by the Intermediate Dam has been raised several times; its current FSL is 1080.0 metres. Dyke crest elevation opposite the south abutment of the Intermediate Dam is approximately 1085.2 m and the invert of the 0.6 m deep pilot channel is at approximately 1081.2 metres. Fall flows

typically just inundate the bench adjacent to the pilot channel, suggesting a diversion channel water surface elevation of about 1081.9 to 1082.0 m, i.e. a level barely two metres above the level of the tailings pond. Gradient on the channel is 0.19% and the tails beach limit is about 1100 m upstream of the Intermediate Dam.

In balance, the above-noted relative water levels mean that the difference in elevation between the channel water surface and base level (water or tailings) upstream of the Intermediate Dam ranges from about 2 m at the Intermediate Dam to approximately 4.0 m at the beach limit, whereafter it would be maintained at about 4.0 m from there upstream. For these conditions and a uniform head loss between the diversion channel water level and the tailings pond, piezometers should be indicating levels of about 1081.5 m just upstream of the Intermediate Dam, to about 1083.5 m at the limit of the beach. In fact, the observed levels are generally lower and the double piezometers indicate a downward flow direction except for recent data in CD-13 and CD-15. Aside from this reversal in gradient with depth, it is concluded from the data that the seepage performance of the dyke foundation has not been markedly affected by the rising tailings pond.

Whereas the single piezometers and some of the deep piezometers are indicating water levels which are easily understood as noted above, the deep piezometers at locations CD-19, CD-21 and 88-11 indicate piezometric pressures which are 2 to 5 m lower than the elevation of the adjacent tailings pond in spite of their locations being between 300 and 600 m upstream of the Intermediate Dam. Only speculative explanations are possible and they would presume either a pneumatic leak in the pressure leads for each of the piezometers registering the low heads, or a relatively more pervious material at depth which communicates with an outlet downstream of the Intermediate Dam.

Downstream of the Intermediate Dam, CD-26 at Sta. 2+600 indicates essentially free drainage to depth. The lower piezometer, although some 70 m west of the pond shoreline, indicates a water level only about 11 m above the elevation of the pond.

Ground Movements - Plotted data for slope indicator installations situated along the crest of the canal dyke is provided in Appendix IV. No data was obtained during 1993 for reasons

noted previously. Readings for 1994 were obtained by Golder Associates during May-June and again in September; for 1995 they were obtained in September. Tabulated data appearing in Appendix IV bridges from the initial reading to the June, 1994 reading, and provides subsequent data, as well as related plots.

Of the 10 installations positioned between Sta. 0+990 and 2+300, 4 are original installations, 5 were installed in response to observed ground movement, and one (94CD-1) was installed to replace an original, but destroyed, location for which an ongoing data record was deemed important.

Reviewing the data from upstream to downstream, there has been movement in both the upslope and downslope directions. Upslope movement is considered a reflection of differential melting of dyke foundation materials which contained some excess ice. Downslope movement would be viewed as more conventional in nature.

A small amount of downslope movement has been recorded by SI's at stations 0+990 and 1+530 but the latter has shown about 25 mm of upslope movement over the last year. Neither the upslope nor downslope movement has been concentrated at one depth and it is inferred to be the result of permafrost melting at depth.

The BH91-CD-1 SI located at Sta. 1+767 has shown about 120 mm of upslope movement since it was initialized in 1991. Movement in the period 1994-1995 has been about 25 mm, and it is distributed over the range of 6 to 10 m depth. At CD-19 at Sta. 1+900 there has been about 25 mm of upslope movement between 9.5 and 10.0 m depth over the interval September 1994 to September 1995. Ongoing loss of permafrost is the likely cause although the thermistors at that depth are suspect for reading very warm temperatures (14.0 to 15.8° C). The direction of movement is not of concern and the survey monument data (see Underhill Engineering Report presented in Appendix IV) is in agreement.

In contrast, the SI at BH91-CD-2 at Sta. 1+998 has shown virtually no movement since September, 1991; it's 'zero' reading was taken in July, 1991. Ground temperatures at 10 m depth are well above freezing and likely this is the reason for the observed absence of

movement. In contrast, the SI associated with CD-21 at the same location, but on the upstream edge of the dyke registered upslope movement but, since June, 1992, the movement has been downhill. The observed 100 mm downhill movement is concentrated between the 6 and 10 m depths; thermistors at this location suggest that some permafrost is still present.

The SI at BH 88-6 (Sta. 2+115) is registering some deflection and most of it is occurring between the 6 and 8 m depths. During the first 31 months to April 1992 it was 165 mm (approx.) compared with an additional 145 mm over the 29 month period to September 1994. The average monthly rate is 5.32 and 5.00 mm respectively. The 1995 readings have been examined and are considered spurious (the data suggests plane strain movement from the bottom of the casing). Such movement is highly unlikely because the adjacent thermistor 88-7 suggests that the ground is frozen below a depth of 6 metres. Interestingly, the pneumatic piezometer tip at 14.9 m depth is indicating a piezometric level below the level of the tailings pond water level. This low head reading may be indicative of a leaking lead and, in conclusion, it is believed that the slope indicator deflection data is unreliable. Were the deflections real, some surface evidence should have been apparent during the site inspection.

The SI at BH88-10 (Sta. 2+160) has registered about 75 mm of downslope movement over a short increment of depth centred at about 6 m; it occurred between September 1988 and September 1994. The 1995 data indicates no further movement. The adjacent thermistor (88-11) indicates frozen ground below a depth of 6 metres but, here too, the nearby piezometer is indicating virtually no head at a depth of about 14 metres.

Further downstream at Sta. 2+313, SI location BH94CD-1 has registered about 20 mm of downslope movement between 8 and 14 m depths since it was installed in June, 1994.

The conclusion that is reached from study of the above data is that the canal dyke reach from about Sta. 1+900 to 2+100 continues to exhibit downslope movement, but the movement which was being experienced at Sta. 2+160 has apparently ceased. The movement tends to be concentrated at a depth which is about coincident with the tailings pond water level. As

such, degradation of permafrost below pond level and behind the reservoir wall may be responsible for the movements being observed.

Installations CD-28 and CD-29, located just upstream and downstream of the Cross Valley Dam's south abutment were destroyed several years ago and the installations have not been replaced. However, the surface movement hubs which were surveyed by Underhill (see Appendix V) indicates only about 0.2 m of upslope movement, about half of which occurred between the 1990 and 1994 observations. The survey monuments associated with CD-28 and CD-29 sites were also destroyed.

4.1.2 Canal Backslope

Thermal Regime - Thermal performance of the canal backslope for the period September, 1983 to September, 1992 is presented in Table 1 together with related data for the backslope and spoil piles. Thermistors were not read during 1993. Readings for 1994 were obtained by Golder Associates during May-June and again in September; for 1995 they were obtained in September. Tabulated data appearing in Appendix IV bridges from the initial reading to the June, 1994 reading, and provides subsequent data, as well as related plots.

The 1994-1995 data indicates that, aside from 4 locations where permafrost remains, all other instrumented locations are thawed to the 10 m depth of the instrumentation. Originally, of the 10 installations, 6 recorded permafrost and 4 recorded thawed profiles. Three of the four still-frozen locations which were in permafrost and one originally-thawed location now appears to be showing permafrost. For these cases the frozen zones appear to be cooling, suggesting that the canal backslope is serving as a heat loss surface.

The last two September data sets indicate, in general, that the temperature gradient is about $\frac{1}{4}$ to 1° C per meter depth and that temperatures at 2 m depth are approaching 5° C in September.

The conclusion reached through study of the thermistor data is that the canal backslope has essentially reached a new equilibrium and that a substantial thickness of natural soils behind

the gravel-mantled backslope (thermal liner) are now thawed. As such, the possibility of excess pore pressures and possible instabilities related to insufficient drainage during thaw of ice-rich permafrost is diminished.

Piezometers - Plotted data for piezometers installed along the top edge of the backslope is provided in Appendix IV. No data was obtained during 1993 for reasons noted previously. Readings for 1994 were obtained by Golder Associates during May-June and again in September; for 1995 they were obtained in September. Tabulated data and plotted records cover the entire period of observation from November, 1981 to September, 1995.

Review of the data indicates that, except for location BS-5 at Sta. 0+960, the downward trend in backslope water levels noted in Golder Associates' 1992 report has continued.

The BS-5 location indicated a May, 1994 reading of only 2.5 m below surface which was a spike of 2.95 m above the September, 1992 reading. This spike was also 0.9 m higher than the spring spike recorded in May, 1982. With these spikes excluded, the general trend of the BS-5 data has been an increasing water level at a rate of about 0.05 m/year.

At the time of the September, 1995 reading for the piezometer, the water level in the canal at Sta. 0+960 would have been about 1084.9 m, or a about 3 m below the piezometric level. The spring reading spikes (1982 and 1994) result in transient levels some 2½ to 3 m higher and these would be primarily the result of spring freshet water levels in the canal.

On the basis of the whole of the piezometric data it is apparent that the backslope is quite well drained at depth, and that the trend toward lower levels is continuing. This is of benefit to general stability. Although not evident from the piezometric data, it is noted that there is a spring and summer period perched water table near surface due to the slow melting of the winter's frozen zone. This water is either channelled over the thermal blanket on the backslope, or it seeps along the contact between the thermal blanket and the natural soils beneath it.

Ground Movement - Five slope movement monitors are located along the top of the backslope. Plotted data for these installations is provided in Appendix IV. No data was obtained during 1993 for reasons noted previously. Readings for 1994 were obtained by Golder Associates during May-June and again in September; for 1995 they were obtained in September. Tabulated data appearing in Appendix IV bridges from the initial reading to the recent readings, and provides related data and plots.

The data indicates very little movement over the period of observation (1981 to 1995) other than 25 to 100 mm of movement in the upper 2 m; in some cases it is upslope and in some cases downslope. The only exception to these observations is for location BS-10 at Sta. 1+900 where a uniformly distributed downslope movement of about 25 mm occurred over the 4 to 8 m depth range during the 5 year period to September, 1995. It appears to be associated with melting of the permafrost during the interval between the readings. There was no 1994 reading due to presence of ice in the casing. Finally, the 1995 upslope-downslope reading of BS-6 is considered to be spurious.

4.1.3 Spoil Piles

Performance of the construction waste (spoil) piles downslope of the canal dyke has been of interest because they were loosely placed frozen materials for which downslope failure into the tailings pond might be abrupt. During the course of deposition the possibility of failure has diminished because of the ever-higher level of the tailings, to the point that, except for the area extending a short distance upstream from the Intermediate Dam. Thermal performance has been monitored at two locations upstream of the Intermediate Dam, surface movement has been tracked by survey at two locations, and deformation to depth has been measured at one location using a slope indicator.

In addition to the instrumentation locations noted above, the spoil pile overlooking the south abutment of the Cross Valley Dam is also instrumented for surface and subsurface movement, and temperature.

Instrumentation data is discussed below:

Thermal Regime - Thermal performance of the spoil piles over the period March, 1982 to September, 1992 is presented in Table 1 together with related data for the backslope and spoil piles. Thermistors were not read during 1993. Readings for 1994 were obtained by Golder Associates during May-June and again in September; for 1995 they were obtained in September. Tabulated data appearing in Appendix IV bridges from the initial reading to the spring, 1994 reading (except for SP-2), and provides subsequent data, as well as related plots.

The data indicates that the spoil piles remain frozen below a depth of 7 to 8 m, and that no warming trend within the still-frozen zone is evident even though the installations upstream of the Intermediate Dam extend 8 m below tailings pond water level. In the case of the SP-5 installation situated above the Cross Valley Dam abutment, the zone below about 7 m remains frozen. Furthermore, the data suggests that the permafrost remaining is getting marginally colder. Referring to original data, the depth of spoil over natural ground at SP-2, SP-3, and SP-5 is 7.5, 3.5, and 5.5 m, respectively.

Ground Movements - At SP-2 (Sta. 1+530) the data indicates some deformation of the spoil mass and about 125 mm of downslope deformation between depths of 4 and 7 metres. At SP-5 situated above the south abutment of the Cross Valley Dam, deformation between depths of 3 and 7 m has been about 50 mm. The data trend for both installations indicates that movement is continuing; the rate is sufficiently slow that instrument accuracy is insufficient for yearly readings to be meaningful.

Surveys of the ground surface movement hubs indicate eastward movement (about 45° to the bank face) at SP-2; 0.25 m from inception to 1990, and 0.06 m between 1990 and 1994. At SP-5 surface movement is interpreted to be southwest, i.e. upslope at about 45° to the face of the bank. Since 1990 the direction has shifted to a more westerly direction. This data does not agree with the inclinometer data. However, it does not indicate movement toward the valley bottom.

4.2 Down Valley Project Cross Valley Dam

The Cross Valley Dam site was instrumented before construction, additional instrumentation was installed after construction was complete, and, in 1988 some thermistors were installed in the crest of the dam. In addition, several survey monuments were installed in the crest of the dam to monitor surface deflection.

Instrumentation readings have been taken with variable frequency, depending on circumstances, and piezometric data has been obtained most frequently. Data for these installations is presented in Appendix IV and is discussed below. While, traditionally, readings have been obtained by the Faro Mine personnel, no data was obtained during 1993 for reasons noted previously, and the readings taken in 1994 and 1995 were obtained by Golder Associates.

Thermal Regime - A summary through to the end of 1992 data is provided in Table 3, taken from a previous annual report. The 1994 and 1995 data is presented in Appendix IV together with the initial set of thermistor readings taken when the instruments were installed. This data is also presented in graphical form.

Installation CVDT-4 is situated at Sta. 0+630 near the backslope toe at the south abutment. While the first reading (see Table 3) indicated thawed conditions, the December, 1982 readings indicated a frozen profile to the full 15.5 m depth of the installation. During the period to 1995, available data indicates that the permafrost has melted to about 14 m depth, or to about 4 - 6 m below the base elevation of the dam at that section.

Installation CVDC-11 is situated at Sta. 0+645 on the crest of the dam. The upper 3 m of the installation is in embankment material and the lower 12 m is in abutment foundation material. Initially, all of the natural material was permafrost but by about 1986, the entire profile had thawed. The most recent readings indicate that temperatures at depth are well above freezing and the abutment may still be warming. The loss of permafrost and the subsequent warming was expected, primarily because of the heating influence of the reservoir.

Thermistor string CVDC-6 was installed from the dam crest at Sta. 0+340 to observe the lower section of the embankment and the local permafrost beneath it. In spite of the presence of the permafrost, it had already melted by December, 1982, probably due to seepage-related heating. Since that time the temperature of the foundation has been in the range of 1 to 3° C and the recent data suggests a mean temperature of between 1 and 3° C for the lower section of the embankment.

The zone immediately below the crest was instrumented in 1988 to research reasons for longitudinal cracking of the crest. The installations are BH-88-4 and BH88-5 positioned at approximately the one-third points of the 500 m crest section south of the edge of the spillway. The data for these installations is in agreement on an annual basis and the temperature excursions at 4 m depth are in the range of 5 to 7 ° Celsius. In contrast, ground temperatures beneath the embankment and in the abutments vary only slowly over time in response to the seepage regime in the foundation, seepage from the spillway section, and by seepage from the diversion canal.

Thermistors 88-4 and 88-5 indicated depth of freezing to about 3½ m in the winter of 1988-89, and to about 3 m for the winters of 89/90 and 90/91. Accumulation of the winter's freezing index in combination with the winter's snow cover, as well as polishing pond level, are factors which should exert some influence over the depth to which the crest is frozen each year (as revealed by the thermistors). While the only data for 1994 is a late May observation, it indicated that the 3½ m depth was still frozen at that time, implying that it may have been frozen to even greater depth during the winter of 1993/94, probably reflecting the reduced polishing pond water level.

Piezometer Readings - Instruments comprise both pneumatic and hydraulic piezometers. Two foundation sections are instrumented from as much as 20 m upstream of centreline to 7 m downstream of centreline. As well, 5 locations on centreline are instrumented; tips range in position from about 11 m below crest to about 13 m below the bottom of the cutoff trench. Finally, it is noted that the embankment core is attached to an upstream blanket of core-type glacial till material which extends 30 m upstream of centreline. This blanket is connected with a secondary blanket of 'second-rate' glacial till material which is 60 m wide.

The function of these blankets is to reduce the hydraulic gradient in the mixed alluvial strata present beneath the dam.

On the basis of the data available the following general observations can be made:

- Piezometric level at centreline below the embankment is about 1050 m and the upstream to downstream gradient is acceptably low;
- Pressure head at depth below the foundation is approximately equal to that at the base of the core;
- At CVDC-9 (situated at Sta. 0+565 near the south abutment) piezometer tips situated 6 and 13 m below cutoff base indicate a $\pm 30\%$ upward pressure gradient. While the piezometric levels fluctuate by 1 to 2 m, the difference remains quite constant. The data does not suggest a trend to ever-higher levels;
- At CVDC-11 (situated at Sta. 0+645, 14.9 m below the end of the crest at the south abutment) the piezometric level has been about 5 m above those for 1984 and before. The step in head is coincident with loss of permafrost at that location; and
- At Sta. 0+215 a hydraulic piezometer on centreline indicates that the gradient through the core is about 220 percent. The data trend for this location indicates an average annual rise of about 0.25 m of head, indicating that the flow net in the core may not yet be stabilized.

It is believed that the embankment is performing in an acceptable manner.

Seepage - Seepage emerging at the toe of the Cross Valley Dam is collected by a granular toe drain which was constructed in 1991. Seepage rate is normally measured by observing three tributary V-Notch weirs and a combined flow weir (see Figure 1). Each of the tributaries collects seepage from a discrete portion of the toe drain. The seepage rate also includes some which derives from spillway / decant area recharge downstream of the core section of the dam, hence the north weir is measuring a combination of foundation seepage and that reporting when gravity overflow is occurring, as has been the case in 1995.

For reasons noted previously, seepage rate data has been sparse since 1992. However, as a matter of record, the 1992 data and the annual data are presented in Tables 4 and 5. Figure 3 presents both historical and available 1995 flow rate data for Weir X-13 together with the year-by-year trend in flow rate.

On the basis of the available data it appears that the average annual seepage rate is substantially lower for 1995 than has been measured previously (reduction in mean annual seepage rate of about 40 percent compared with 1992 data). This reduction has occurred in spite of the fact that weirs X-11 and X-12 do not consistently support this trend toward lower flows. While it may be possible that the central weir, W3 (see Figure 1 for location), has had a dramatically reduced flow during 1995, it is more likely that Weir X-13 has been damaged and that some of the flow is bypassing the weir, hence reduced flows are reported. According to annual September photographs of the W3 site, there is no support for the flow reduction needed to satisfy the X-13 measurements. It is suspected that Weir X-13 is leaking and that the data should be disregarded pending inspection (and repair) of the weir.

Finally, it is noted that the measured seepage rate for Weir X-12 may, on occasion, have included some overland drainage which crossed the road from the west; it then flowed across the surface of the toe berm and exited via the weir X-12.

Surveyed Movement - Survey of the reference monuments indicates that the crest has settled about 0.1 m since installation. Displacement has been registered to 1990 but it is known that the protective casings may have been disturbed by crest traffic so the data is suspect.

4.3 Down Valley Project Intermediate Dam

The Intermediate Dam now has a crest elevation of 1081.7 m; initial construction in 1980 was to only 1068.8 metres. The dam was raised as follows in response to tailings storage requirements using the downstream method:

- To elevation 1073.0 in the summer of 1988 (spillway crest at 1071.5);

-
- To elevation 1078.0 in the summer of 1989 (spillway crest at 1076.5); and
 - To elevation 1081.7 in the summer of 1991 (spillway crest at 1080.0).

Tailings discharge was always from the upstream end of the basin, hence a water pond was always present immediately upstream of the dam. Tail water level downstream of the dam is at elevation 1063.5 m, as controlled by the spillway crest of the Cross Valley Dam. Foundation elevation is approximately 1050.0 m in the original bed of Rose Creek near the south side of the valley, meaning that the maximum height of constructed dam is now 31.7 metres.

The original construction phase and first raising (1988) had the emergency spillway at the south abutment; it was moved to the opposite end of the dam during 1989 construction, and rebuilt in 1991 when the dam was raised to its present elevation. As a consequence of this general construction activity, all of the pre-construction and post-construction geotechnical performance instruments have been destroyed, some replacements have been made, and new instruments have been installed as appropriate.

Original instrumentation included piezometers (hydraulic and pneumatic types), and one string of thermistors. The piezometers observed conditions in the embankment, and in the foundation. The thermistor was installed in the permafrost of the south abutment.

Current instrumentation consists of eleven piezometers, as detailed in Appendix IV. Two sets of instruments are located in the south abutment, and the remainder are positioned at depth downstream of the core.¹ These instruments were installed in 1988 and 1991.

Thermal Regime - Thermistor readings in the south abutment area of interest were last taken in 1991. None were taken during 1992 for the south abutment installation because, as reported in Golder Associates' 1992 report, the thermistor had been destroyed. In that prior

¹ Note that the north 2/3 of the first stage dam has a sloping core terminated at about elev. 1053 m; below about 1064.5 m the core was placed on an excavated slope cut into a broad terrace of mixed alluvial material.

years' readings had indicated that the ground was thawed to the full depth of the instrumentation, the absence of this data is not viewed as critical.

Piezometers - Plotted data for piezometers installed at the Intermediate Dam is provided in Appendix IV. No data was obtained during 1993 for reasons noted previously. Readings for 1994 were obtained by Golder Associates during May-June and again in September; for 1995 they were obtained in September. Tabulated data and plotted records cover the entire period of observation from November, 1981 to September, 1995.

As of the 1992 data, the piezometers generally showed an increase in water level of between 0.22 and 1.34 metres compared with levels observed in 1991. However, these increases were disregarded because the 1991 levels were taken well after the pond was lowered by 1 to 1.5 m to facilitate the 1991 dam raising. It was also inferred from the 1991 data that piezometers 91-ID5 may be leaking since water levels had declined by 5.14 and 14.35 metres at the shallow and deep tips, respectively.

The 1994 and 1995 data for the south abutment (locations BH88-3 and BH91-ID-3) is presented in Appendix IV. Location BH88-3 is positioned about 10 m upstream of present centreline and BH91-ID-3 is further downstream. All of the piezometer tips are located in the natural embankment materials.

The recent data for BH88-3 indicates little change in piezometric level since 1991 but the deep tip reading for May, 1994 showed a spike of about 1.5 m, about equalling the 1069.45 level of spikes recorded in the spring and summer of 1990. The September, 1994, and September, 1995 readings differ by 0.28 m; and these readings are below the average of readings taken since 1990. Noting the location of the piezometer and the 1080.0 m water level in the tailings pond upstream of the dam, these recorded water levels are quite low. And, although the pond water level was raised 3.5 m due to the 1991 dam raising, the lower tip has shown a rise of about 1.0 m and the shallow tip was not affected.

Recent data for BH91-ID-3 indicates a trend toward lower levels since September 1992 but these levels are higher than those recorded for BH88-3 situated farther upstream along

the abutment. It is believed that both of these piezometers reflect abutment conditions dominated by drainage from upslope, not the level of the tailings pond upstream of the dam. That observation would be supported by the fact of the June, 1992 spike of about 2 m, which would be coincident with the spring freshet in the adjacent diversion channel. Should this be the case, the decline in piezometric pressure level may be related to better drainage associated with ongoing loss of permafrost in the abutment downstream of the dam. Piezometric level declines have also been experienced since September, 1992 at canal dyke location CD-26 situated a short distance downstream from BH91-ID-3.

Piezometers BH91-ID-4, ID-5, ID-6 and ID-7 were installed from the berm along the backslope toe a short time before the dam was raised in the summer of 1991. ID-5 and ID-6 are at Sta. 0+625 and 0+630 respectively, but ID-6 is about 20 m upstream of ID-5. The data for ID-5 indicates that both pneumatic leads are leaking because, since September, 1992, interpreted water levels have been very consistent at 5 to 13 m below the polishing pond level. ID-6, with tips at approximately the same elevations as those for ID-5, is registering 1.0 m of artesian pressure between the lower and upper tips, thus demonstrating the influence of the tailings pond upstream of the Intermediate Dam. The shallow tip appears to be reflecting the polishing pond although detailed pond water level data is not available.

Location ID-7 is south of the above-discussed installations and it has only one tip; it is situated at about the same elevation as the shallow tips for the other installations (about 7 m depth). The data trend for ID-7 tracks with that for ID-6 but the ID-7 levels are about 2.0 m higher. Disregarding the low reading when the polishing pond was drawn down in the fall of 1992, recorded piezometric levels are quite consistent at about 1.0 m above downstream pond full supply level.

On the basis of the above discussion of the data, it is concluded that no disturbing piezometric trends are occurring, and that the structure is functioning as intended.

4.4 Fresh Water Supply Dam

Thermal Regime - One crest area thermistor (BH88-5) with sensors to 8.1 m depth has been used to observe core zone temperature since 1985. The interest in temperature derived from the need to research cracking that was occurring along the crest of the dam, as much was also observed for the Cross Valley Dam crest.

As for other instrumentation on the project, the thermistor string was not read during 1993 but it has been read in May and September, 1994, and in September, 1995. These readings were obtained by Golder Associates. The May, 1994 reading indicates that the core was frozen to at least 3.7 m below crest during the winter of 1993-94. This recent data supports the previous observation that frost penetration depth ranged somewhat either side of 3 metre depth, probably in response to the severity of the winter and as influenced by pond water level. Unfortunately, no reservoir water level data is available for the 1993/94 winter period.

Piezometers - The embankment and its downstream toe area contain a number of piezometers installed for the purpose of monitoring groundwater pressures. They are located as shown on Figure 4. Plotted data is provided in Appendix IV. No data was obtained during 1993 for reasons noted previously. Readings for 1994 were obtained by Golder Associates during May-June and again in September; for 1995 they were obtained in September. Tabulated data and plotted records cover the entire period of observation from date of installation (1985 or 1988) to September, 1995.

As of the 1992 readings, piezometric levels in the dam were generally higher than for 1991 (in the range of 0.68 to 2.11 metres with piezometer 85-3 indicating a slight drop in water level by 0.02 metres). The data and other details of the installations can be found in Golder Associates' 1992 performance monitoring report, Appendix I. The difference in levels is attributed to reservoir operation influences.

Piezometers installed from the crest of the dam are numbered BH85-4, BH85-5, and BH88-15.

Referring to the data plots presented in Appendix IV, BH85-5 continues to fluctuate within its traditional range of 9 to 10½ m below crest level and the tip is 11.4 m below crest level. Location BH85-4 is a similar installation and it fluctuates from about 5.7 to 6.7 m below crest level. This piezometer tip is 1.9 m above the position of the BH85-5 tip.

Installation BH88-15 has tips at three levels; 4.5, 12.9, and 19.6 m below crest level. The shallow tip has recorded some fluctuation in piezometric level but there is no general trend toward higher levels. The intermediate and deep piezometers also exhibit similar fluctuations, but the heads are lower by 5 and 7 m respectively. This is consistent with what would be expected because of influences related to the greater thickness of the core at depth.

Piezometers installed from the downstream toe berm are numbered BH85-2, BH85-3, and BH88-16. Location 85-2 has shown a drop of about a meter since 1989 and the recent data indicates no trend toward higher levels. Similarly, the BH88-16 and BH85-3 installations also indicate steady conditions and no trend toward increased levels.

Installation BH85-1 is near the valve house; data is sparse but the 1994 readings are about 2½ m below readings taken in 1990. The reduction may be a reflection of the drainage changes which occurred when the toe berm was both raised and widened in 1989. A like-positioned BH85-6 piezometer has registered a 2½ m drop from traditional levels before September, 1988.

Seepage Monitoring - A counterweight toe berm was installed along the downstream toe of the dam in 1989. It was provided with a preferentially pervious lower section to afford easy exit of artesian seepage and weirs were installed along a collector ditch to measure flow rates but no data is available for 1993, 1994, or 1995.

5.0 FIELD INSPECTION AND RECOMMENDED MAINTENANCE

The Down Valley Project, the Fresh Water Supply Dam, The North Fork Rose Creek causeway some rock dump faces were inspected by Mr. H. Glen Gilchrist of Golder Associates Ltd. during the period 20 to 23 September, 1995. While the Down Valley Project has been inspected annually beginning in 1983, annual inspection of the Fresh Water Supply Dam began in 1988, and that for the causeway and rock dumps even more recently.

The purpose of the 1995 site inspection was to examine the facilities in detail for evidence of deficient performance, to provide a basis for possible adjustment to the frequency of monitoring, to observe maintenance undertaken subsequent to the 1994 inspection, and then to review points of immediate concern with site representatives.

During the course of the time on site, discussions were held with Messrs. Dick Arndt and Bill Horne, a post-inspection site tour was made with Joe Vandebroek to review the results of the inspection, and brief contact was made with Derek Condie. At the conclusion of the inspection an interim hand-written field memo was prepared for Dick Arndt and Bill Horne (see Appendix III). The purpose of the field memo was to highlight items of concern and items requiring immediate attention, such having been observed during the subject inspection.

5.1 Down Valley Tailings Project

The Diversion Canal, the North Valley Wall Interceptor Ditch, the Cross Valley Dam and the Intermediate Dam were all inspected on foot. As for previous inspections, a camera and dictaphone were used to record conditions and observations. It is understood that, aside from possible short term exceptions, tailings has not been consigned to the Down Valley Project since Anvil Range Mining assumed control of Faro Mine.

5.1.1 Diversion Canal

The order of the inspection comprised the top of the constructed (right side) dyke, the shoreline downslope of the diversion canal, and examination of the weir cascades and the channel sections. Points of particular note are discussed below.

Canal Dyke - The dyke crest and immediate backslope were inspected by walking. The principal reason for this inspection historically has been to examine the dyke for surface cracking, such being in response to deterioration of foundation permafrost. However, each time the dyke crest is graded to remove ruts and ridges for better traffic conditions, the cracks are also obliterated. Fortunately, the crest has not been graded since before the 1994 inspection; it may also be that the crest has not been graded since the summer of 1992. This is of advantage because the cracking 'snapshot' is at least one year, and possibly 3 years long.

As opposed to the findings of previous years, no 'active' cracking was seen anywhere along the length of the canal dyke crest. However, depression-like remnants of prior cracking remain evident and the most apparent of these is illustrated by the photographs of Figure 5. It is also noted that the trend toward decreased incidence of cracking was noted in the 1993 last formal inspection report. This year's observations corroborate the trend.

While making the inspection the presence of a water-filled sump was noted. It is located somewhat to the right of the dyke crest and somewhat downstream of the Intermediate Dam. Its detail is illustrated by the photograph presented in Figure 6. This sump was built and lined with plastic in order to contain fuel, oil, and greasy spillages associated with operation of a large diesel generating set located there in 1994. The sump has since filled with water, the liner has ruptured, and seepage from it is detrimental to bank stability in the area. It must be drained and breached to prevent ongoing recharge to the area.

It remains important to continue with the program of visual and instrument observations until it is clearly apparent that thaw-related adjustments are complete. At that time the requirements for ongoing observation can be reassessed.

Toe-of-Slope Area - This area was inspected by walking the shoreline from the Cross Valley Dam to the Diversion Dam. The objectives of the inspection were to identify seepage occurrences and areas of possible slope instability insofar as they may provide an indication of concern for the integrity of the canal.

At the time of the inspection pond levels either side of the Intermediate Dam were at full supply level. The syphons at the south end of the Intermediate Dam were inoperative and the north end spillway was conveying the local runoff from upstream. The main interest in inspection is to view any areas of seepage, and to make comparisons with past observations.

For the reach of shoreline between the two dams, no seepage was observed until about 120 m downstream of the Intermediate Dam. From there to the Intermediate Dam some areas of seepage emergence were noted; some were marked by iron staining while others were free of such precipitate. Compared with the 1993 inspection, evidence of seepage is now present nearly 100 m further toward the Cross Valley Dam. The 1994 inspection, conducted when the water level was drawn down about 1.7 m below FSL, recorded seepage from this point upstream as well, so the 1995 observation is not a new condition. The sum of estimated flows emerging from the toe of the slope is little changed from that estimated in 1993. Currently, the seepage rate is between 13 and 16 litres per minute, of which an estimated 4 to 5 litres/min is emerging at the junction of the intermediate Dam and its abutment. The area is iron stained, suggesting a tailings pond source whereas the seepage along the shoreline downstream does not produce staining, suggesting local discharge and possibly seepage from the canal upslope.

Upstream of the Intermediate Dam, and excluding seepage from the upper tailings area into the abandoned diversion outfall, the only significant seepage occurrence was found issuing from berm level on the dyke backslope at approximately Sta. 1+400. The flow was estimated to be about 15 litres per minute which is markedly less than the rate in 1988, for instance.

The slope faces between the two dams showed no evidence of instability and examination of the upper area shows no noticeable change.

Upstream of the Intermediate Dam the pond water level is now quite close to the constructed toe of the canal dyke. Generally speaking, the lower slopes are quite gentle by comparison with earlier tailings level stages.

No evidence of seepage emerging at water's edge (for the pond line upstream of the dam), or of seepage emerging onto the tailings shoreline was observed except from the tails-filled Borrow Pit I situated at about Sta. 1+400. Seepage has always emerged into the area, the emergence points have always been in the same locations, and the rate of seepage has been relatively steady. The 1995 inspection indicates that west end seepage has diminished from a 1993 rate of 15 to 20 litres/min to less than one litre/min, while the east end seepage rate has remained at about 15 to 20 litres/minute.

No other areas of seepage emergence were seen between the Borrow Pit I site and the Diversion Canal Dam although some seepage is emerging from right side natural alluvium into the abandoned channel downstream of this dam.

The conclusion of the inspection was that the slopes and the area between the canal dyke toe and the tailings / water's edge are in good condition, thus posing no field-evident danger to the integrity of the diversion canal or dyke.

Canal Backslope and Thermal Liner - While no new erosion gullies have formed in the face of the thermal liner recently and most not already armoured have become pseudo-stable, erosion is still occurring at the 7+50 and 1+920 (approx.) locations. They appear to be the result of redirected runoff from upslope. Both of these gullies are easily identified from the canal dyke vantage.

Whereas it would be beneficial to protect the above-described gullies with blast rock, and to similarly protect others that have not been treated, redirection of flow over the backslope edge has proven to be an unfortunate consequence of such repairs being done from the top of the backslope. In consequence it is recommended that consideration be given to armouring the gullies before spring break-up, but by gaining access from the ice level in the canal. The feasibility of the work should be determined by a trial at one gulley location.

It is suggested that well-graded blast rock having a 300 to 500 mm maximum particle size be used for the test. Several front end loader scoops of the material could be dumped from the canal dyke crest as far toward the canal ice surface as possible. Taking care not to damage the riprapped slope, a tracked loader could then transfer the material to the gulley and distribute it up the feature, leaving a concave shape to the finished section. If the approach proves workable, the program could either be continued immediately or plans could be made to tackle the rest of the gullies in early 1997. No material should be left on ice surface because it will disrupt the normal flow in the diversion canal.

Inspection of the top of the thermal liner in the vicinity of Sta. 1+900 indicates little or no additional movement since 1994. Details of the area are provided by the photographs of Figures 7 and 8. Some surface drainage was flowing across the surface at one location at the time of the inspection. While the site had been deteriorating until about 1983, the fact of relatively little change since that time is encouraging with respect to diminished possibility of a new and major displacement. And, knowing from instrumentation data that the natural strata behind the thermal liner now appear to be in a new thermal equilibrium, it is recommended that the area be observed for another year before implementing repair work recommended by previous reports. Contention that a new thermal equilibrium has been attained is supported by the fact of little or no movement having occurred during the past two years, such movement likely having been at least partially due to melting of ice-rich ground behind the thermal liner.

Aside from the conditions noted above, the backslope is considered to be in good repair.

Weir Cascades - The weir cascades were considered to be in good condition although, on occasion, an occasional crest-section boulder still gets displaced. This is most likely location for these displacements involves the first few weirs at the upstream end of the cascade because the materials of construction for these were of slightly smaller size than for the rest of the weirs. The consequence is that some of these weir crests are becoming relatively ill-defined compared with those downstream. Using photo comparisons, the remainder of the weirs have shown relatively little change from year to year. Finally, and as has been

recommended by previous reports, the west end of the last weir of the downstream cascade would benefit from repair.

5.1.2 North Valley Wall Interceptor Ditch

The inspection indicates that interceptor system is capable of conveying routine small flows without difficulty. However, as has been noted by previous inspections, some work needs to be done to restore the facility to its design capacity. Briefly, the required work is as follows:

1. At the upstream end (just north of the mill area guard house) the diversion dyke still appears to be low although it was strengthened in about 1991. It should be widened to a top width of at least four m using material than can be obtained from the spoil dykes downstream; the elevation of the crest should be between 1.5 and 2 m above channel invert.
2. As illustrated in Figure 9, the dyke top width is inadequate where the natural channel is diverted to the channel dyked across the borrow area upslope of the Intermediate Dam. It is recommended that the dyke be widened to a minimum top width of 4 m by filling on the inside; the dyke crest should be not less than 2 m above the invert of the channel. Locally available glacial till can be used for the construction.
3. As illustrated by Figure 10, the culverts carrying the flow through the roadways leading to the Cross Valley Dam spillway area and to the downstream borrow areas are of inadequate capacity. The capacity of these culverts is well below design requirements and, either properly sized culverts should be installed, or the adjacent road sections should be shaped to ensure a safe failure of the culvert when a large flood occurs. Alternatively, a well armoured, ford-type of crossing would permit vehicle travel for most of the year.

4. The channel leading from the lower of the two culverts discussed above is illustrated in Figure 11. While there have been previous recommendations to restore its capacity to that for which it was designed ($17.7 \text{ m}^3/\text{s}$ for 50 yr. return period), no work has been done. In the absence of adequate capacity, the intercepted (clean water) flow will enter the polishing pond to the detriment of its operation and the quality of the resulting increased discharge. The design section required for the 1:50 return period flow is of 2H:1V sideslopes, 6.1 m bottom width and bank height of 2.6 m when allowing for 0.5 m of freeboard. It would appear that the right side roadway material should be excavated by backhoe for transfer to the left bank where it would be spread and compacted in lifts. Dyke top width should be a minimum of 4 m.

5.1.3 Cross Valley Dam

At the time of the inspection the retained reservoir was at full supply level, or slightly higher. A general view of the crest of the dam, and another of the spillway entrance are provided in Figure 12.

Dam Crest - As has been described by previous reports, the crest of the dam has undergone some episodes of centreline-parallel cracking for which width appears to be sensitive to time of inspection and the severity of the previous winter. They have been interpreted to be the consequence of frost heave ice lensing within the upper part of the core. For this reason two thermistor strings were installed to several metres below crest in 1988 and some crack mapping was begun by mine personnel. This data has tended to confirm the belief that they are the result of ice lense formation.

The condition of the crest at the time of the 1995 inspection is typified by the photographs presented in Figures 13 and 14. On the basis of the condition of the cracking traces, activity during the winter of 1994/95 appears to have been less extensive than for the winter of 1993/94. As well, new cracking locations appear not to have developed. Aside from the variation in winter conditions between last winter and the previous winter, the fact of the

lowered pond level for the winter of 1993/94 may have been a factor in promoting frost heave of the core materials, this being the suspected cause of the observed cracking.

The conclusion of this aspect of the inspection is that the past winter appears to have had little effect on the condition of the upper portion of the core. However, this portion of the core has lost some of its as-compacted density. It is recommended that the pond level be maintained at FSL in the interests of its seemingly beneficial effect in reducing core section cracking.

Upstream and Downstream Slopes - Both the upstream riprap and the downstream slopes are considered to be in good condition.

Downstream Toe Area Seepage - The surface of the berm placed during 1991 remains dry. While the berm-edge collector ditches are working adequately, it is again recommended that the north end ditch be deepened to avoid winter time icing of the roadway. Visually, the rate of flow in the seepage collector ditches seemed typical of previous years.

It is also apparent that the roadway culvert draining the south end of the berm drainage system is choked with sand and gravel at its inlet end, and to some extent at its outlet end. This accumulation of material must be removed, the erosion scarring repaired, the causes corrected. The cause appears to be one of drainage which crosses to the berm side of the road some distance west of the culvert. The road needs to be regraded to prevent general drainage from crossing the road, flowing across the surface of the berm, and then draining away via the culvert, while eroding the local area.

Spillway - Visually, the spillway was in good condition but the crest of the weir-like fill across the mouth of the spillway should be checked for elevation (see Figure 12). If it is higher than 1063.5 m, it must be trimmed to prevent surcharging of pond level.

5.1.4 Intermediate Dam

The dam was inspected by walking the crest, the downstream toe at berm level, and the emergency spillway. At the time of the inspection the retained reservoir was at full supply level. A general view of the dam, and another of the spillway entrance are provided in Figure 14.

Crest - The crest of the dam is in good condition, as typified by the upper photograph in Figure 15. As for previous inspections, there was no evidence of cracking similar to that usually seen on the Cross Valley Dam. However, the crack associated with the over-steepened turning area fill perched over the 2H:1V design backslope noted during the 1993 inspection is still evident. riprap condition was seen to be acceptable, and no cracks were visible in the crest at any location except for the immediate south end (near the left abutment) where some excess gravelly material had been dumped over the backslope. This uncompacted material contained a crack coincident with the downstream edge of the crest of the dam and a shallow slough on the steep downstream-facing slope. Neither of these are of concern to the performance of the dam.

Upstream and Downstream Slopes - Upstream water level was at FSL and the riprap is in good condition. The downstream slope showed no evidence of unacceptable performance or seepage; what appears to be a displaced frost slab was seen on the backslope (see Figure 15). The condition is not of concern to the dam's function.

Seepage - The toe berm area is about 0.5 m above polishing water level (see Figure 16 for related photographs). Some seepage was observed along the berm, as indicated by the darker areas shown in the upper photograph of Figure 16. Contrary to last year's observation, no seepage was seen at the junction of the embankment with the spillway bank at the north end of the dam. This change has occurred even though standing water is still present in the spillway, as was also the case last year.

Emergency Spillway - The left bank of the spillway is illustrated by the photographs in Figure 17. Although some work was done in late 1993 to make the spillway retaining dyke section

more robust just downstream from the dam crest, insufficient work was done. Referring to the lower picture presented in Figure 17, the dyke is of deficient height in the foreground. Additional material should be placed to make it match with the crest of the dam. Trucks should be used. The material should be spread and lifts and compacted. When complete, the gradient of the dyke crest from dam crest to the road crossing should be consistent.

The inspection also revealed the fact of damage to the spillway invert due to dozer travel, as illustrated by the upper photo in Figure 17. The spillway invert and boulder array has been substantially disturbed and needs to be carefully reinstated to prevent unnecessary and possibly severe damage to the spillway, should it be required to carry its design flow. Removal of the crossing ramps is also recommended for the same reason. Neither the spillway retaining dyke nor the crest of the Intermediate dam should be used to gain access to the south end of the dam for servicing of water treatment facilities, or to work on the siphons.

5.2 Fresh Water Supply Dam

5.2.1 Spillway and Channel

The spillway structure and outfall channel appeared to be in good condition. The culverts used for the site access crossing at the downstream end of the spillway channel are of large size, but they are probably not capable of carrying the design capacity of the spillway. Should this culvert crossing be damaged or washed out during such flows, it would eliminate convenient access to the spillway for stop-log removal, to the embankment and valve house, and the like. A plan for emergency access should be formulated, particularly for the machine that would be needed to enable proper management of the spillway stoplogs.

At the time of the inspection the reservoir was at its highest-ever water level. In contrast, in 1993 the spillway was stop-logged to 7 logs high with one bay at 5 stoplogs and in 1994 none of the stop-logs were in place. This year it was stopped to 10 logs high, except for one bay at 9 stop-logs (see Figure 18). The 1994 un-stopped condition was the consequence of a recommendation made as of Golder Associates' 1993 inspection that it be lowered

immediately because of the relatively more severe state of cracking of the crest seen at that time, and its possible affect on the integrity of the uppermost section of the embankment core.

As a consequence of the 1995 inspection, it was recommended that the stop-logged level be lowered immediately by at least a metre, and that the stop-log guides be cut off to prevent future surcharging of the reservoir. It is now further recommended that spillway discharge capacity be reviewed to determine the theoretically allowable maximum stop-log level in light of allowable reservoir operation parameters, flood routing capability of a full reservoir, and an appropriate design storm and runoff event.

It is also recommended that the crest of the dam be rehabilitated in accordance with the recommendations provided by the document presented in Appendix II **if** a reservoir level above spillway sill invert is required to provide adequate storage, and if a maximum reservoir level above sill elevation is admissible.

5.2.2 Embankment Crest, Riprap and Slopes

The crest has a history of cracking along its upstream side and its state was judged to have been relatively more severe at the time of the 1993 inspection than previously. As a consequence it was recommended that the reservoir be lowered to spillway sill level pending crest reconstruction. Following discussion with KPMG Environmental Services Inc., test pit investigation of the crest was undertaken in June, 1994 and a report was prepared for KPMG dated June 28, 1994. It presented the results of the investigation together with recommendations for repair of the crest. A copy of this report is attached as Appendix II for reference.

Should it be decided that the crest will be rehabilitated, it is vital that all of the instrumentation be protected and preserved from damage because of its ongoing importance in monitoring the performance of the structure. If it is not protected, virtually all of it will have to be replaced; costs would far outweigh the cost of the inconvenience of working around the installations.

The 1995 inspection has revealed 1994/95 cracking of only minor width, as observed where 1994 test pit backfilling provided a fresh observation site. Some examples of the weathered cracking traces and of the 1994/95 cracking are provided by the photos in Figures 19, 20 and 21.

As a consequence of the very high water level some erosion of the face of the dam was occurring, judged by the presence of turbid water along the waters edge. Riprap condition below water level could not be evaluated because of this murky water.

Finally, readjustment of the spillway stop-log channels will have to be done before the reservoir refills in the spring. Then, should crest rehabilitation be intended, the crest must be thawed and the borrow area must be thawed before the work can begin. The activity must be carefully planned and the work pattern should be designed to enable completion of the work without having more than about 20 m of the crest below top elevation at any one time. This should be possible if a backhoe is used to load a truck which takes the waste to the south abutment and down to berm level, while new fill is supplied simultaneously by truck from the spillway end. As explained by the document presented in Appendix II, crest rebuilding has to extend to 0.7 m depth. Again, it is of utmost importance that the instrumentation situated on the crest of the dam be protected and kept functional for future monitoring of the structure's performance.

5.2.3 Seepage

At the time of the inspection the left abutment slope downstream of the embankment had seepage at surface and the amount of seepage emerging around the valve house was judged to be greater than has been seen during previous inspections.

Seepage is emerging on the natural slope downstream of the left abutment opposite the point where the embankment is only about 3 m in height. Rate of flow is estimated to be in the range of 6 to 10 litres/min and, although it is substantial, it enters the ground again somewhat further downslope.

Seepage emerging around the valve house is judged to be at a rate of 30 to 40 litres/min (reservoir level retained by 9 stop-logs), compared with the 1994 estimate of 15 to 20 litres/min when the reservoir was at spillway sill level, and 30 to perhaps 50 litres/min in 1993 when the reservoir was retained above sill by 5 stop-logs. Indeed, pictures on file from the 1993 inspection confirm a higher water level at the side of the valve house in 1993, than in 1995.

The surface of the berm placed in 1989 was dry and the collector ditch situated along its downstream edge was working effectively to collect seepage from the drainage layer beneath the berm. While this flow is being measured by two weirs, both require maintenance to more effectively seal them against bypassing flow.

As has been discussed in previous inspection reports, the seepage flow emerging from around the valve house is substantial, and appears to reflect reservoir water level to some extent. As has also been noted previously, there is still concern for the integrity of the pipe upstream of the valve. Again, it is recommended that it be inspected with suitable TV equipment and other apparatus to obtain an indication of its condition. The seepage reporting at the valve house may or may not be an indication of holes in the pipe but, if they are discovered, appropriate action could be taken on a timely basis, including maintenance attention to the valves.

5.3 North Fork Rose Creek Causeway

The causeway was inspected on September 21, 1995.

The discharge area was observed to be flowing clear water and there was no evidence of distress in the slope above, nor ravelling of the toe of the slope. On this basis it appeared that the downstream portion of the causeway section was functioning as intended, and that it was not deteriorating.

As it has been observed by previous inspections, the upstream toe area of the causeway is littered with debris; the upper limit seen in 1993 remained through 1994, and the 1995 freshet appears to have made no changes. Head pond level observed in 1993 was marginally higher than for 1994, and the 1995 level is marginally higher again. However, this is consistent with the observed higher level of the creek where it enters the culvert beneath the main road downstream of the causeway, compared with the 1993 creek level at the same location. On the basis of the observations described above it is concluded that hydraulic performance continues to be good.

The haul road crest of the causeway could not be inspected for cracks because it is regularly maintained and heavily used by ore carriers, hence any evidence of cracks would be obliterated on a regular basis.

5.4 Waste Rock Dumps

The dumps reach along the North Fork Rose Creek between the VanGorda causeway and the Faro Creek diversion outfall were inspected from the toe, as well as from the crest, except where the crest was inaccessible. In addition, the dump west of the VanGorda haulroad and north of the causeway was checked at crest level. The inspection was made on September 21 and 22, 1995.

5.4.1 Upstream of the VanGorda Causeway

From examination along the toe and along the crest (mostly free-dumped area) of the 600 m reach (approx.) from the causeway to the valley-bottom access ramp, it is concluded that conditions relative to previous inspections are unchanged. The area immediately upstream of the causeway was examined in particular detail for evidence of new cracking and none was found.

Upstream (east) of the access ramp toe and lower slope conditions remain as seen previously but there has been a bit of additional sloughing of the lower portion of a local glacial till face, probably due to frost action and local drainage.

The crest edges of the reach of dumps upstream of the causeway were inspected for evidence of fresh cracking but no such evidence was seen. On the basis of this crest area inspection and no observed changes being seen along the toe areas, the waste rock dumps are believed to be stable.

The low elevation dump bulb west of the VanGorda causeway was also inspected. As for the other dumps inspected, conditions are unchanged and there is no cracking across the dozer-cut ramp. Accordingly, it is concluded that there has been no movement in that immediate area.

The general conclusion concerning the dumps inspected is that they are believed not to be in danger of failure at any location. However, it would be prudent to maintain a vigil over them; concentrating on crest area cracking is expected to be an earlier identifier of possible movement compared with toe area examination because none of the dumps are active.

6.0 ANNUAL REVIEWS AND ROUTINE INSPECTIONS

6.1 Annual Reviews

As has been noted in previous annual reports covering the same works, the performance monitoring and annual inspections have served as a basis for:

- a) judging current performance of the facilities;
- b) providing some forewarning of any trends towards potentially troublesome performance;
- c) adjusting the frequency of observation of instrumentation;
- d) installing additional instrumentation;
- e) undertaking maintenance work.

In keeping with the key importance and the nature of these facilities, and the ongoing value of a comprehensive performance history, it remains prudent to sustain the data acquisition where current data is of both immediate and ongoing value, to review such data in relation to the existing data base, and to visually inspect the works on an annual basis for evidence of deteriorating or deficient performance.

The annual inspection should be done during the early part of September, in keeping with the schedules held for previous inspections, and for the advantage of consistency of condition.

6.2 Routine Inspections by On-Site Personnel

6.2.1 Down Valley Project

In addition to the basic monitoring schedule outlined in Figure 22, it is important that a responsible and routinely available person (preferably an engineer) visit the key structures for inspection purposes as described below, and that a log of the visits and observations be maintained:

1. To inspect, on a monthly basis, the 400 m reach of the Diversion Canal dyke immediately upstream of the Intermediate Dam for evidence of cracking;
2. To view, on a monthly basis, the opposite side of the Diversion Canal from the driving dyke particularly the 50 m long segment about 500 m upstream of the Intermediate Dam, looking for change to the top profile of the gravelly backslope, possible narrowing of the flow channel, and other changes which might be attributed to sloughing of the backslope;
3. To inspect in June, just after spring runoff is completed, the top of the thermal liner on the backslope of the Diversion Canal at the location of the somewhat-sloughed area situated about 500 m upstream of the Intermediate Dam, such inspection to determine if new (sharp-edged) cracking has developed. While there the inspector should redirect surface drainage to keep it from ponding along the back side of the thermal liner crest, and to keep it from unnecessarily entering crest area cracks. This inspection requires some walking, the inspector should carry a hand shovel to direct surface flow. Pictures should be taken for comparison with those in Figures 7 and 8 of this report. Golder Associates should be advised of any evidence that movement has occurred in the area.
4. To inspect, weekly, the Cross Valley Dam's downstream toe berm culverts for consistency of flow rate.
5. To inspect, monthly, the abutments of the Cross Valley Dam and the Intermediate Dam for evidence of changing conditions (sloughing of the embankment fill and/or the adjacent slopes), and for evidence of changing seepage rates and locations.

Any change in condition that is noted as a consequence of this program of routine inspection must be brought immediately to the attention of the inspector's superiors. Golder Associates must also be notified so that the condition can be evaluated in light of the data base and prior performance history of the structures, and to provide any necessary geotechnical advice

related to the concerns at hand. Pictures of the changed condition should be taken and also forwarded to Golder Associates.

6.2.2 Fresh Water Supply Dam

In addition to the basic monitoring schedule outlined in Figure 22, it is important that a responsible and routinely available person (preferably an engineer) make twice-monthly visits to the dam for inspection purposes described below and that a log of the visits and observations be maintained:

1. To inspect the abutments of the Fresh Water Supply Dam for evidence of changing conditions (sloughing of the embankment fill and/or the adjacent slopes), and for evidence of changing seepage rates and locations.
2. To inspect the valve house area at the Fresh Water Supply Dam for evidence of seepage flow rate change.

Any change in condition that is noted as a consequence of this program of routine inspection must be brought immediately to the attention of the inspector's superiors. Golder Associates must also be notified so that the condition can be evaluated in light of the data base and prior performance history of the structures, and to provide any necessary geotechnical advice related to the concerns at hand. Pictures of the changed condition should be taken and also forwarded to Golder Associates.

6.2.3 North Fork Rose Creek Flow-through Rock Drain

It is important that, monthly, a responsible and routinely available person (preferably an engineer) check the level of the headpond at the North Fork Rose Creek causeway (VanGorda Causeway) to be assured that its relative level generally reflects the relative quantity of flow in the creek at the Faro Mine road crossing downstream.

Any change in condition that is noted as a consequence of this program of routine inspection must be brought immediately to the attention of the inspector's superiors. Golder Associates must also be notified so that the condition can be evaluated in light of the data base and prior performance history of the structures, and to provide any necessary geotechnical advice related to the concerns at hand.

6.4 Waste Rock Dumps

It is important that a responsible and routinely available person (preferably an engineer) make once-monthly inspections of the waste dump area immediately east of the north end of the VanGorda Causeway for crest and/or dozer ramp cracking, such being indicative of revived movement of the local area.

Any change in condition that is noted as a consequence of this program of routine inspection must be brought immediately to the attention of the inspector's superiors. Golder Associates must also be notified so that the condition can be evaluated in light of the data base and prior performance history of the dumps, and to offer assistance concerning the need for immediate mitigative action or otherwise.

7.0 ONGOING DATA ACQUISITION

7.1 Introduction

The frequency of readings of the instrumentation has been greatly reduced from the initial practice of quarterly observations because confidence in the performance of the project has been substantiated by accumulated data. As well, some interruptions in data gathering have occurred while Faro Mine has been inoperative, or otherwise manned with a skeleton staff.

7.2 Down Valley Project

7.2.1 General

In light of the data base, and particularly the 1994 and 1995 readings, as well as the results of the 1995 and previous inspections, it is recommended that the observation schedule be as detailed by Figure 22. For purposes of general planning, it is anticipated that the requirements for 1997 will be the same. Instruments which have been excluded from the 1996 requirement fall in areas for which acceptable conditions have been solidly demonstrated, for total thawing has occurred in the case of thermistors, and the like. This has also been the basis from which the frequency of observation has gradually been reduced over the period since the Down Valley Project was constructed in 1980/81.

7.2.2 Cross Valley Dam

It is recommended that the monitoring program be as detailed by Figure 22. It is particularly noted that the weirs are to be measured for flow rate on a regular basis, and that, should Weir X-13 be found in need of repair, that such repairs be made immediately.

7.3 Fresh Water Supply Dam

It is recommended that the monitoring program be as detailed by Figure 22. It is particularly noted that the weirs are to be measured for flow rate on a regular basis, and that they are in need of leakage repairs to insure that all of the flow goes through the weirs, not around them.

7.4 North Fork Rose Creek Causeway

Headpond water level observations for both the causeway and the road culvert downstream should be observed on a monthly basis. Data during periods of high flow is particularly important and, as a minimum, the headpond should be viewed weekly in the late afternoon for the period from about April 15th until June 30th. In addition, it is recommended that a electronic continuous automatic recording and data storage device be used to obtain water level data for the head pond and upstream of the road culvert. Data accumulated by such apparatus can be conveniently down-loaded to a lap top computer. The advantage of such a system is that virtually continuous data is obtained, that the data can be graphed and compared readily, and that a comparative data base is then available for evaluation of year-by-year performance.

7.5 Waste Rock Dumps Flanking North Fork Rose Creek

The trimmed-off portion of the dump face immediately upstream of the causeway (VanGorda haul road) should be viewed from the causeway on a monthly basis for evidence of cracking or movement. Any such evidence or other unexplainable changes noted should be communicated to supervisory personnel, with advice to Golder Associates of condition changes noted. No other surveillance is considered necessary.

7.6 Rose Creek Water Levels

While not specifically noted herein, it is assumed that water level recorder situated at the Diversion Dam on the Rose Creek Diversion Canal will be reactivated, or preferably, that an electronic recorder will be installed (see Section 9.4 above).

8. ROUTINE PHYSICAL AND INSTRUMENTATION MAINTENANCE

It is important that the crest of the Diversion Canal dyke be dressed each September after the annual inspection to close areas where cracks have developed. The purpose of this treatment is to prevent ingress of dyke surface run-off that may be concentrated in the settled areas, perhaps to enter local cracks to the disadvantage of stability. Blading should be used to accomplish this work. Care must be taken not to disturb the existing instrumentation which has been installed to monitoring performance of the dyke. No other blading should be done through the year.

Although all of the instrumentation which is still required, or may be required, was rehabilitated in 1994, minor repairs may still be needed from time to time. These should be accomplished immediately a need is noted.

9. PHYSICAL WORKS MAINTENANCE REQUIREMENTS SUMMARY

As a point-form summary of the maintenance and repair recommendations presented in Section 7.0, Field Inspection, as well as those presented in the Field Memo of Appendix III follows.

9.1 Down Valley Project

9.1.1 Diversion Canal

- Grade the dyke crest in September after the annual inspection is completed;
- Remove the water-filled sump downstream of the intermediate dam;
- Undertake a trial armouring of a thermal liner gully using an 'off-the-ice' approach before spring breakup; and
- Repair the last weir in the second cascade where flow is returned to the natural creek channel.

9.1.2 North Valley Wall Interceptor Ditch

- Dyke strengthening at the diversion point north of the mill complex guardhouse;
- Dyke strengthening where the flow is diverted from the natural channel to the dyked section which crosses the borrow area east of the north abutment of the Cross Valley Dam;
- Replace the road culverts upstream of the Cross valley Dam or otherwise modify the local roadways to maintain control of water even though the culverts might be washed out; and
- Restore the channel downstream from the last culvert to design standard.

9.1.3 Cross Valley Dam

- Deepen the north end seepage collection ditch upstream of the culvert to reduce the potential that the road will be overflowed in winter;

- Remove accumulated material from the upstream and downstream ends of the Weir X-12 culvert and replace material locally eroded from the berm;
- Regrade the road from the south to prevent local drainage from crossing the road, hence to wash across the berm, and to exit the area via Weir X-12;
- Remove / lower the spillway inlet dyke to be assured of an elev. 1063.5 max. polishing pond level; and
- Check Weir X-13 for leakage and repair as necessary.

9.1.4 Intermediate Dam

- Place additional material on the right bank of the spillway;
- Smooth the spillway channel riprap and restore the boulders in the channel to their correct positions; and
- Remove the road ramps from the spillway.

9.2 Fresh Water Supply Dam

- Determine allowable spillway stop-log crest and cut away all higher portions of the stop log guide channels;
- Rehabilitate the crest of the dam if future water levels above spillway invert are contemplated;
- Arrange for an inspection of the riparian outlet pipe for condition; and
- Repair the berm edge weirs to eliminate leakage.

In that some of these maintenance items were first brought to the attention of Anvil range personnel on September 22, 1995 (see Appendix III), they may already have been accomplished. Other wise they should be scheduled for the 1996 as appropriate.

DIVERSION CANAL THERMAL REGIMES

LOCATION No. Stn	THERMAL REGIME (Depth in metres)									
	Sept. 27, 1983	Sept. 28, 1984	Oct. 05, 1985	Oct. 1986	Sept. 30, 1987	Oct. 01, 1988	Sept. 02, 1989	Oct. 03, 1990	Sept. 06, 1991	Sept. 22, 1992
CANAL DYKE										
CD4 0+400	Thawed	Thawed	Thawed	Thawed, warmer than 84 & 85	Thawed, colder than 86	Thawed, warmer than 87 & 88	Thawed	Thawed	-	Thawed
CD5 0+510	Frozen 4.8-5.2	-	Thawed	Thawed, warmer than 84 & 85	Thawed, colder than 86	Thawed, warmer than 87 & 88	Thawed	Thawed	-	Thawed
CD10 0+990	Thawed	Frozen 4.8-5.4	Thawed	Thawed, warmer than 84 & 85 except at 7.8 m	Thawed, colder than 86	Thawed, warmer than 87 & 88	Thawed	Thawed	-	Thawed
CD15 1+530	Thawed	Thawed	Thawed	Thawed and warmer	Thawed, colder than 86	Thawed, warmer than 87	Thawed	Thawed	-	Thawed
CD17 1+705	Thawed	Frozen 7.8-8.2	Frozen 1.5-2.4	Thawed to 4.4 m	Thawed, colder than 86	Thawed, warmer than 87 & 88	Thawed	Thawed to approx. 9.5 m	-	Thawed to approx. 9.5 m
CD18 1+900	Thawed to 4.5	Thawed to 3.8	Thawed to 4.2	Frozen 6.2-6.7	Thawed to 4.3 m; warmer than 86	Thawed to 4.7 m; warmer than 87 & 88; frozen at same temp.	Thawed to 4.8 m	-	Thawed except at 6 to 7 m	Thawed
CD20 2+000	Thawed to 6.0	Thawed to 5.3	Frozen 5.3-6.9	Thawed to 4.4 m	Partially frozen 6.0-9.0	Frozen 6.4-6.5; warmer than 87 & 88	Thawed	Thawed	Thawed to approx. 6.0 m	Thawed
CD21 2+100	Thawed to 4.3	Thawed to 6.0	Thawed to 4.8		Colder than 86	Thawed to approx. 4.9 m	Thawed to approx. 6.0 m	Thawed to approx. 4.0 m	Thawed to approx. 6.0 m	Thawed to approx. 6.0 m
88-7 2+115					Thawed to approx. 4.7 m similar to 86	Thawed to approx. 4.9 m colder than 87	Thawed to approx. 5.0 m	Thawed to approx. 6.0 m	Thawed to approx. 4.0 m	-
88-9 2+120							Thawed to approx. 3.0 m	Thawed to approx. 4.0 m	Thawed to approx. 6.0 m	-
88-11 2+160							Thawed to 5.0 m	Thawed to approx. 6.0 m	Thawed to approx. 4.0 m	-
88-13 2+160							Thawed to approx. 3.0 m	Thawed to approx. 4.0 m	Thawed to approx. 6.0 m	Thawed
CD24 2+365	Thawed	Thawed	Thawed	Thawed and slightly warmer	Thawed, warmer than 86	Thawed, warmer than 87 & 88	Thawed	Thawed	Thawed	Thawed
CD25 2+460	Thawed	Thawed	Thawed	Thawed and warmer	Thawed, similar to 86	Thawed, warmer than 87 & 88	Thawed	Thawed	Thawed	Thawed
CD26 2+600	Frozen 5.5-7.8	Frozen 4.5-7.7	Frozen 4.5-7.0	Thawed	Thawed, colder than 86	Thawed, warmer than 87 & 88	Thawed	Thawed	Thawed	Thawed to approx. 8.5 m
CD27 2+765	Thawed	Thawed	Thawed	Thawed and warmer	Thawed, colder than 86	Thawed, warmer than 87 & 88	Thawed	Thawed except at 2.3 m	Thawed	Thawed
CD28+900	Frozen 3.0-6.2	Frozen 3.3-5.4	Frozen 4.0-5.2	Thawed to 7.7 m	Thawed to approx. 7.7 m warmer than 86	CD28 destroyed, adjacent 81-96 indicates thawed, warmer than 87	Thawed except at 7.5 m (81-96)	Thawed (81-96)	Thawed (81-96)	81-96 destroyed
CD29 3+000	Thawed to 2.9	Thawed to 3.4	Thawed to 3.2	Frozen 4.2-6.2	Thawed, warmer than 86	Thawed, warmer than 87	Thawed	Thawed	Thawed	destroyed
CD30 3+130	Thawed	Thawed	Thawed	Thawed	Thawed, warmer than 86	Thawed, slightly warmer than 87	Thawed	Thawed	Thawed	destroyed
CANAL BACKSLOPE										
BS2 0+400	Frozen 2.0-7.8	Frozen 1.5-8.5	Frozen to 7.8 m	Frozen full depth	No readings taken in 87	Frozen approx. from 5.3-6.7; warmer than 86	No readings taken in 1989	Thawed to approx. 5.0 m; warmer than 88	No readings taken in 1991	Thawed
BS4 0+710						Thawed, warmer than 86		No readings taken in 1991		No reading taken in 1992
BS5 0+960	Frozen 2.3-2.8	Thawed	Thawed to 5.5 m	Thawed full depth		Thawed, warmer than 86		Thawed to approx. 6.0 m; colder than 88		Thawed
BS9 1+530	Thawed	Thawed	Thawed	Thawed and slightly warmer		Thawed, warmer than 86		Thawed		Thawed
BS10 1+900	Thawed to 2.2 m	Thawed to 2.0 m	Thawed to 2.0 m	Thawed to 2.8 m		Thawed to 3.9 m; warmer than 86		Thawed to approx. 5.0 m warmer than 88		Thawed to approx. 6.0 m
BS11 2+100	Thawed to 0.5 m	Frozen	Frozen	Thawed to 1.0 m		Thawed to 1.6 m; warmer than 86		Thawed to 3.5 m; warmer than 88		No reading taken in 1992
BS12 2+260	Thawed	Thawed	Thawed	Thawed		Thawed, warmer than 86		Thawed, warmer than 88		Thawed
BS15 2+780		Thawed	Thawed	Thawed		Thawed, warmer than 86		Thawed, warmer than 88		Thawed
BS16 2+900	Thawed to 2.0 m	Thawed to 2.3 m	Thawed	Thawed to 3.2 m		Thawed to 4.6 m; warmer than 86		Thawed except at 6.5 m; warmer than 88		No reading taken in 1992
BS17 2+900	Thawed to 2.5 m	Thawed to 2.5 m	Frozen	Thawed to 3.3 m		Thawed to 4.1 m; warmer than 86		Thawed to 4.3 m; warmer than 88		Thawed to 6.0 m
BS18 3+100	Thawed to 3.4 m	Thawed to 2.8 m	Thawed to 3.1 m	Thawed to 4.1 m		Thawed to 5.9 m; warmer than 86		Thawed, warmer than 88		Thawed
SPOIL PILE										
SP2 1+530	Thawed to 3.8 m	Thawed to 3.0 m	N/D	Thawed to 3.3 m	Thawed to approx. 4.9 m warmer than 86	Only 2 out of 10 thermistor tips giving readings	Only 3 out of 10 thermistor tips giving readings	Only 7 out of 10 thermistor tips giving readings; thawed to approx. 8 m	No readings taken in 1991	Only 1 out of 10 thermistor tips giving readings.
SP3 1+900	Thawed to 2.6 m	Thawed to 2.6 m	N/D	Thawed to 4.3 m	Thawed to approx. 4.6 m warmer than 86	Thawed to 5.0 m; warmer than 87	Thawed to 6.5 m	Thawed to 6.0 m		Thawed to 6.0 m
SP5 2+950	Thawed to 3.1 m	Thawed to 4.7 m	Thawed to 3.4 m	Thawed to 4.4 m	Thawed to approx. 3.7 m colder than 86	Thawed to 4.9 m; warmer than 87	N/D	Thawed to 6.0 m		Thawed to 6.5 m

TABLE 2- TOTAL PRECIPITATION - FARO AIRPORT

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
April	2.2	2.5	13.9	12.9	10.0	8.2	2.0	7.0	2.8	15.8	6.0	4.8	5.2
May	20.6	36.8	17.2	35.1	40.0	38.0	17.9	23.4	22.4	14.4	76.7	39.8	10.9
June	55.6	49.1	28.2	12.8	50.8	37.3	41.0	45.4	30.2	11.4	48.6	24.2	33.9
July	49.1	16.7	62.6	76.3	92.4	97.2	51.7	30.0	115.4	68.1	50.2	22.0	73.4
August	65.8	65.0	80.8	28.7	63.5	25.6	16.9	64.4	33.4	34.4	56.0	25.2	63.4
Sept.	21.2	5.5	46.3	44.4	30.2	43.3	30.8	66.2	47.4	47.8	43.2	48.4	23.8
Oct.	16.3	11.0	20.0	22.7	26.8	29.4	45.9	22.2	49.6	11.4	35.7	39.2	**
TOTAL	230.8	186.6	269.0	282.9	313.8	279.0	206.2	58.6	301.2	203.3	316.4	203.6	210.6

NOTE: All precipitation readings in mm.

** No data for October, 1995.

TABLE 3

CROSS VALLEY DAM THERMAL REGIME

LOCATION		THERMAL REGIMES (Depth in metres)										
No.	Stn.	Sept./82	Sept./83	Sept./84	Oct./85	Oct./86	Sept./87	Oct./88	Sept./89	Oct./90	Sept./91	Sept./92
CVDT4	0+630	Thawed 4.5-14.2	Thawed 2.5-8.5	-	Thawed to 8.4	Thawed to >11.4	Thawed to approx. 14m warmer than 1986.	Thawed, slightly warmer than 1987.	Thawed to approx. 12 m	Thawed to approx. 14 m	No Reading	No Reading
CVDC1	0+050	Frozen 4.8-5.8	Thawed	Thawed >15	Thawed >15	Thawed and warmer	Thawed, slightly cooler than 1986.	Thawed, warmer than 1987.	N/D	N/D	No Reading	Damaged
CVDC110	+645	Thawed to 4.6	Thawed to 5.4	Thawed to 4.4 and 9.2-12.8	Thawed	Thawed and very warm	Thawed, slightly warmer in 1986.	Thawed, slightly colder than 1987.	Thawed	N/D	No Reading	Thawed
79-20	(north abut.)			Frozen 4.5-6.5	-	No change from 1984	Thawed from 2 to 12 m; slightly warmer than 1986	Thawed from 2 to 12 m; similar to 1987.	N/D	N/D	No Reading	No Reading
CVDC6	0+340	Thawed	Thawed	Thawed	-	Thawed	Thawed, colder than 1986.	Thawed, except at 21 m; warmer than 1987.	Thawed except at 21 m.	Thawed except at 21 m.	No Reading	Thawed except at 21 m

Note: For locations of instrumentation see Figure 1

TABLE 4- CROSS VALLEY DAM SEEPAGE FLOWS (1995)

DATE	WEIR X11 (N. ABUT.)	WEIR X12 (S. ABUT.)	WEIR X13
January, 1995	277	79	580
February, 1995	257	78	578
March, 1995	131	13	673
April, 1995	224	90	N/A
May, 1995	106	18	831
June, 1995	414	101	837
July, 1995	382	105	699
August, 1995	N/A	N/A	736
September, 1995	N/A	N/A	725
October, 1995	N/A	N/A	656
November, 1995	N/A	N/A	506
December, 1995	N/A	N/A	462

Notes:

1. For location of weirs see Figure 1.
2. Weir X13 measures the combined flows of X11, X12, and the centre weir (old W3).
3. Weir X12 is suspect; it is believed to have measured local drainage from west of the road on occasion.

TABLE 5- CROSS VALLEY DAM SEEPAGE WEIR FLOWS (1982 - 1995)

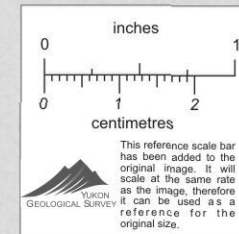
YEAR	MEAN POND ELEVATION (m)	MINIMUM FLOW (month) (igpm)	MAXIMUM FLOW (month) (lgpm)	AVERAGE YEARLY FLOW (ipgm)
1982	1058.55	1203 (Sept)	4400 (June)	1828
1984	1059.85	1075 (Oct)	1345 (Dec)	1209
1985	1061.99	1330 (Sept - Dec)	1800 (Jul)	1477
1986	1063.2	1265 (May)	1795 (Sept)	1487
1987	≈ 1063.2	1220 (May)	1682 (Aug - Sept)	1497
1988	≈ 1063.5	1250 (June)	1750 (Aug)	1514
1989	≈ 1063.5	1146 (Mar)	1551 (Aug)	1358
1990	≈ 1063.5	1028 (Mar)	1631 (Sept)	1312
1991	≈ 1063.5	1056 (Oct)	1443 (Jun)	1293
1992	N/A	852(Nov)	1439	1084
1993	N/A	N/A	N/A	N/A
1994	N/A	N/A	N/A	N/A
1995	1063.5	409 (Nov)	837 (June)	663

NOTES:

1. For locations of weirs see Figure 1.
2. Flows for 1983, 1984 and 1985 based on records for period June to December and flow for 1991 based on records for period January to November.
3. High flow through Weir 3 in June, 1982 due to siphon discharge above weir.
4. Weir 3 was replaced by X13 as a consequence of the seepage filter construction conducted in the summer of 1991.
5. Drainage from west of south abutment road crossed to berm drainage collector during 1995; some readings may therefore be too high.

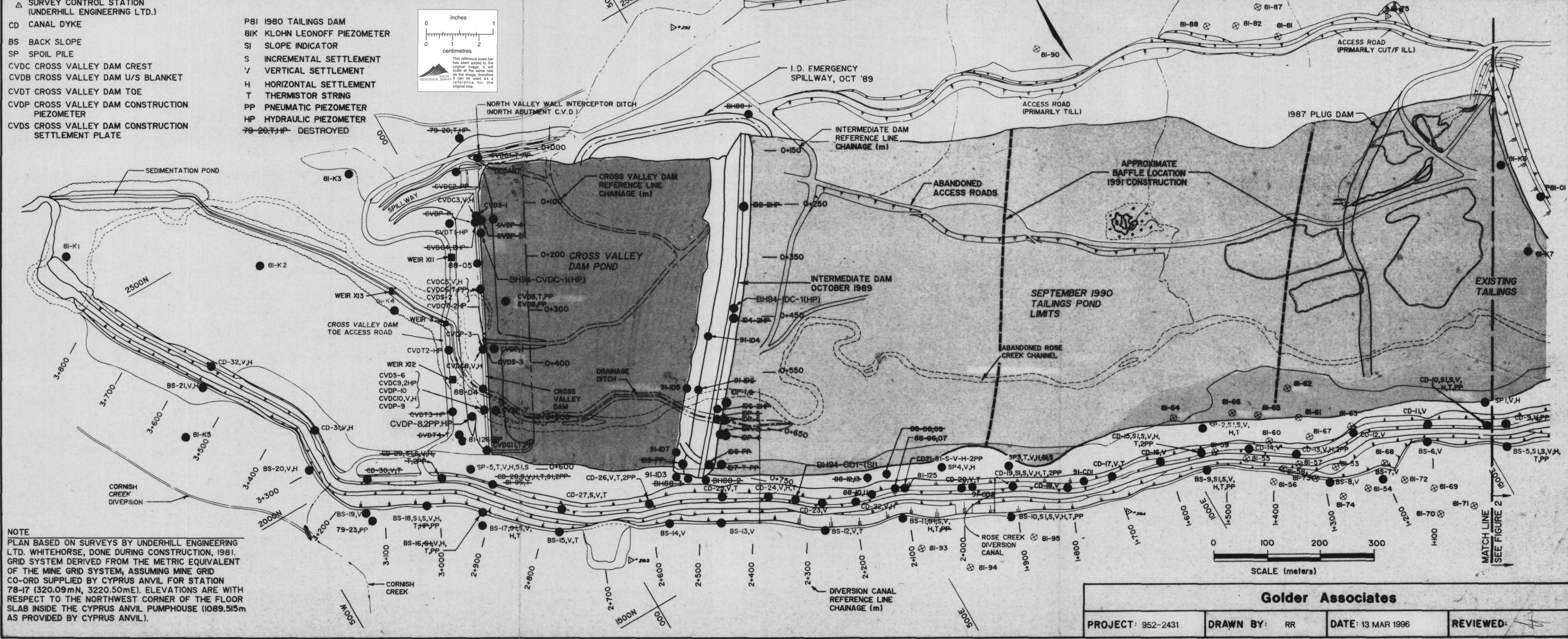
LEGEND

- ⊕ SITE INVESTIGATION BOREHOLES
- INSTRUMENTATION BOREHOLES
- △ SURVEY CONTROL STATION (UNDERHILL ENGINEERING LTD.)
- CD CANAL DYKE
- BS BACK SLOPE
- SP SPOIL PILE
- CVDC CROSS VALLEY DAM CREST
- CVDB CROSS VALLEY DAM U/S BLANKET
- CVDT CROSS VALLEY DAM TOE
- CVDP CROSS VALLEY DAM CONSTRUCTION PIEZOMETER
- CVDS CROSS VALLEY DAM CONSTRUCTION SETTLEMENT PLATE
- ID INTERMEDIATE DAM
- IDP INTERMEDIATE DAM CONSTRUCTION PIEZOMETER
- P81 1980 TAILINGS DAM
- B1K KLOHN LEONOFF PIEZOMETER
- SI SLOPE INDICATOR
- S INCREMENTAL SETTLEMENT
- V VERTICAL SETTLEMENT
- H HORIZONTAL SETTLEMENT
- T THERMISTOR STRING
- PP PNEUMATIC PIEZOMETER
- HP HYDRAULIC PIEZOMETER
- 79-20.T.H.P. DESTROYED

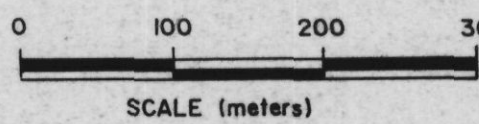


DOWN VALLEY TAILINGS CONTAINMENT INSTRUMENT LOCATIONS
1 of 2

Figure 1



NOTE
 PLAN BASED ON SURVEYS BY UNDERHILL ENGINEERING LTD. WHITEHORSE, DONE DURING CONSTRUCTION, 1981. GRID SYSTEM DERIVED FROM THE METRIC EQUIVALENT OF THE MINE GRID SYSTEM, ASSUMING MINE GRID CO-ORD SUPPLIED BY CYPRUS ANVIL FOR STATION 78-17 (320.09mN, 3220.50mE). ELEVATIONS ARE WITH RESPECT TO THE NORTHWEST CORNER OF THE FLOOR SLAB INSIDE THE CYPRUS ANVIL PUMPHOUSE (1089.515m AS PROVIDED BY CYPRUS ANVIL).



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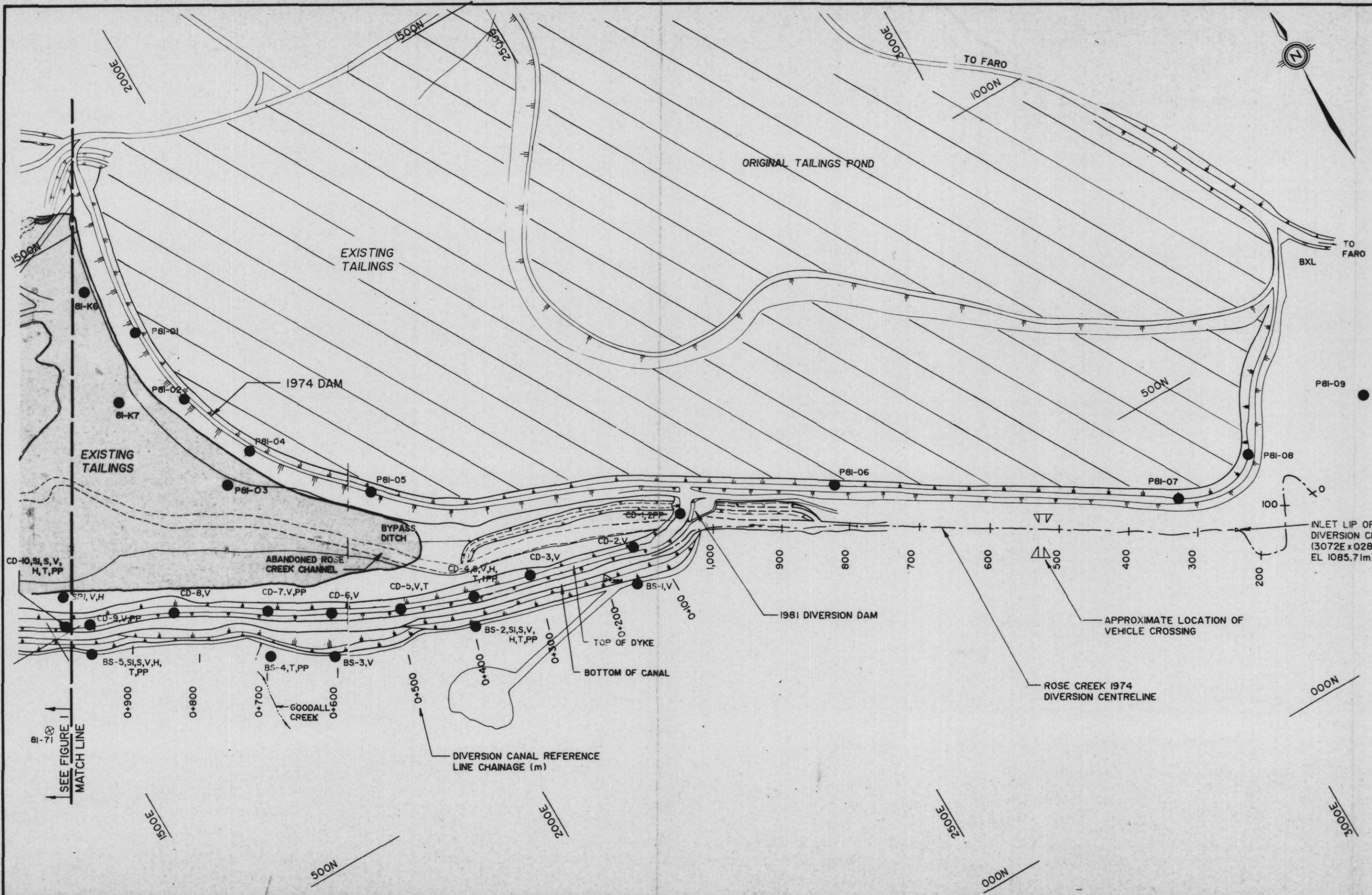
**DOWN VALLEY TAILINGS CONTAINMENT
INSTRUMENT LOCATIONS**

Figure 2

2 of 2

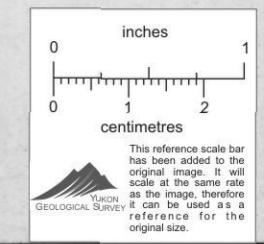
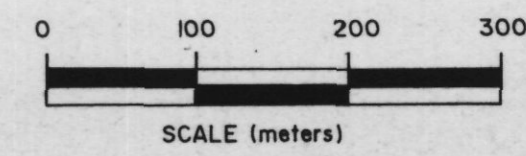
LEGEND

- | | |
|--|--|
| ⊕ SITE INVESTIGATION BOREHOLES | ID INTERMEDIATE DAM |
| ● INSTRUMENTATION BOREHOLES | IDP INTERMEDIATE DAM CONSTRUCTION PIEZOMETER |
| △ SURVEY CONTROL STATION
(UNDERHILL ENGINEERING LTD.) | |
| CD CANAL DYKE | PBI 1980 TAILINGS DAM |
| BS BACK SLOPE | BK KLOHN LEONOFF PIEZOMETER |
| SP SPOIL PILE | SI SLOPE INDICATOR |
| CVDC CROSS VALLEY DAM CREST | S INCREMENTAL SETTLEMENT |
| CVDB CROSS VALLEY DAM U/S BLANKET | V VERTICAL SETTLEMENT |
| CVDT CROSS VALLEY DAM TOE | H HORIZONTAL SETTLEMENT |
| CVDP CROSS VALLEY DAM CONSTRUCTION
PIEZOMETER | T THERMISTOR STRING |
| CVDS CROSS VALLEY DAM CONSTRUCTION
SETTLEMENT PLATE | PP PNEUMATIC PIEZOMETER |
| | HP HYDRAULIC PIEZOMETER |
| | 79-20.T.H.P. DESTROYED |



NOTE

PLAN BASED ON SURVEYS BY UNDERHILL ENGINEERING LTD. WHITEHORSE, DONE DURING CONSTRUCTION, 1981. GRID SYSTEM DERIVED FROM THE METRIC EQUIVALENT OF THE MINE GRID SYSTEM, ASSUMING MINE GRID CO-ORD SUPPLIED BY CYPRUS ANVIL FOR STATION 78-17 (320.09mN, 3220.50mE). ELEVATIONS ARE WITH RESPECT TO THE NORTHWEST CORNER OF THE FLOOR SLAB INSIDE THE CYPRUS ANVIL PUMPHOUSE (1089.515m AS PROVIDED BY CYPRUS ANVIL).

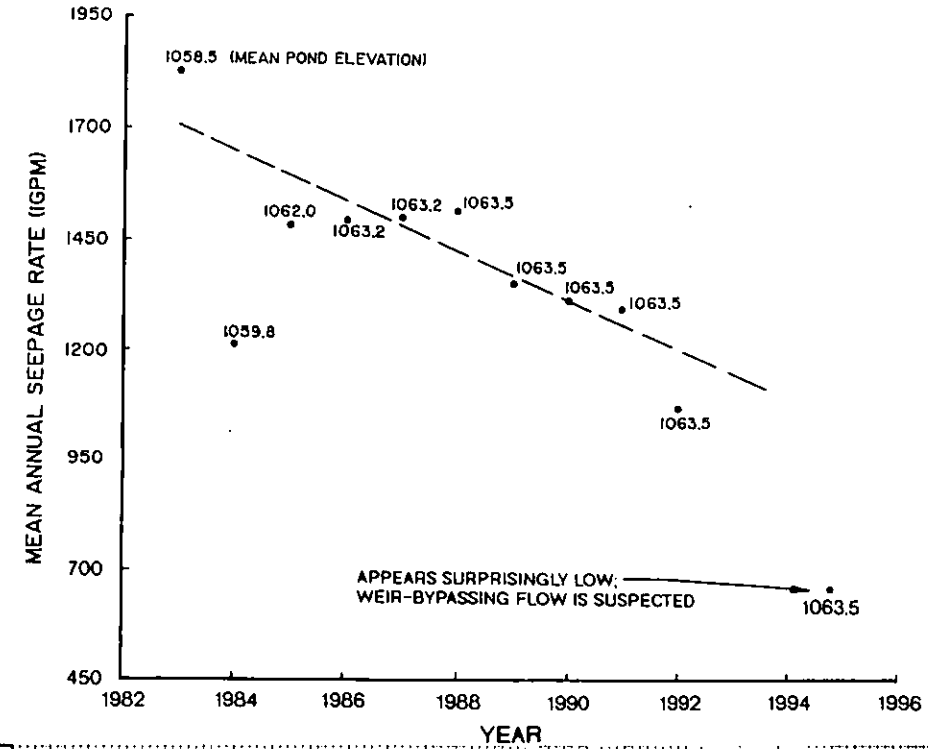
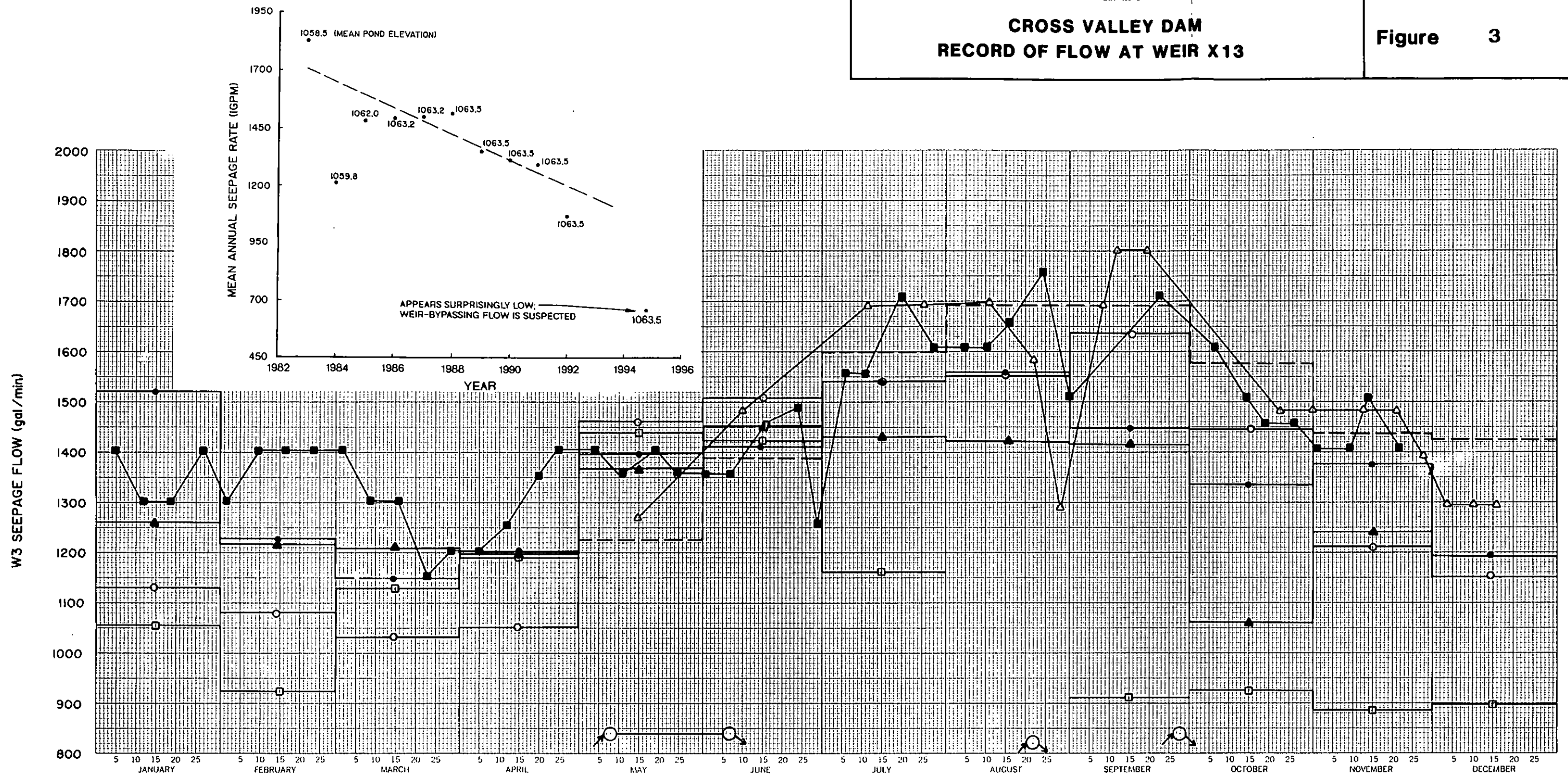


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CROSS VALLEY DAM RECORD OF FLOW AT WEIR X13

Figure 3



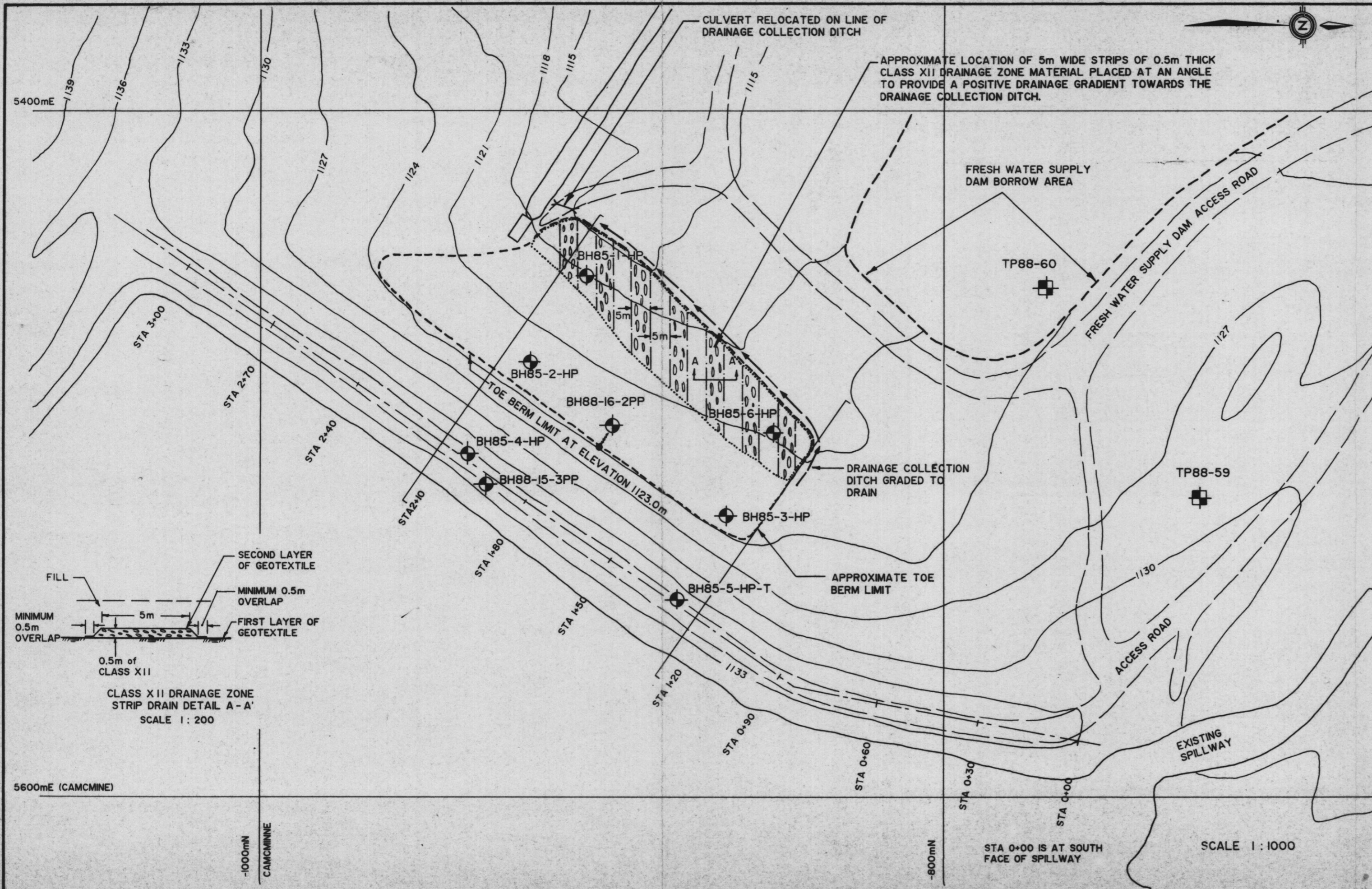
- LEGEND**
- △—△ 1986
 - 1987 MONTHLY AVERAGE FLOW
 - 1988
 - 1989 MONTHLY AVERAGE FLOW
 - 1990 MONTHLY AVERAGE FLOW
 - ▲—▲ 1991 MONTHLY AVERAGE FLOW
 - 1992 MONTHLY AVERAGE FLOW
 - 1995 INSTANTANEOUS FLOW DATA:
MONTHLY MEANS BELOW 800 IGPM
FOR ALL MONTHS IN 1995

- NOTE**
1. 1983, 1984 and 1985 FLOWS NOT PLOTTED (SEE PREVIOUS GOLDER REPORT No. 882-2412 FOR 1983-1985 FLOWS).
 2. A TOE-OF-SLOPE SEEPAGE FILTER WAS INSTALLED ON THE CROSS VALLEY DAM IN 1991.
 3. ONLY THOSE 1995 FLOWS EXCEEDING 800 IGPM HAVE BEEN PLOTTED (ALL DATA IS SUSPECT).

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**FRESH WATER SUPPLY DAM
INSTRUMENTATION PLAN**

Figure 4

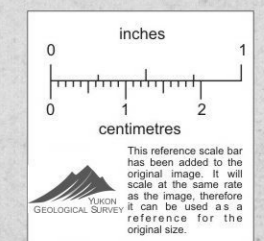
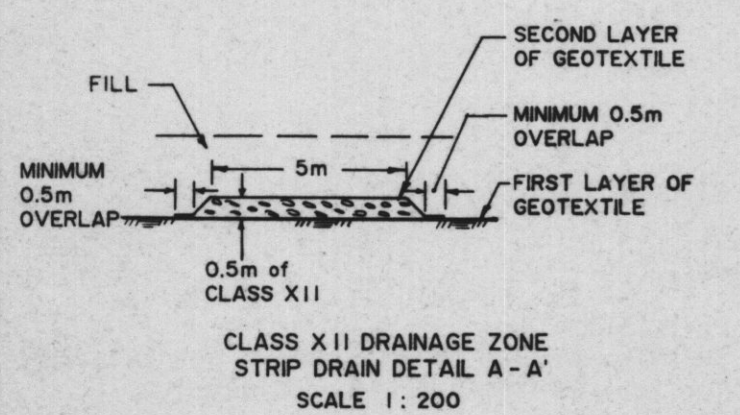


LEGEND

- BH88-15,16 INSTRUMENTATION BOREHOLES DRILLED IN 1988 BY GOLDER ASSOCIATES LTD.
- BH85-1 to 6 INSTRUMENTATION BOREHOLES DRILLED IN 1985 BY DOME PETROLEUM LTD.
- TP88-59,60 TEST PIT LOCATIONS DUE IN 1988 BY GOLDER ASSOCIATES LTD.
- PP PNEUMATIC PIEZOMETER TIPS LOCATION
- INSTRUMENT TIP LOCATION
- INSTRUMENT READING LOCATION
- HP HYDRAULIC PIEZOMETER (STANDPIPE) LOCATION
- T THERMISTOR STRING LOCATION

NOTES

- 1) ELEVATIONS (m) CONVERTED FROM NORTH WEST GEOGRAPHIC SERVICES LTD. MAPPING COMPILED FROM AERIAL PHOTOGRAPHY TAKEN IN SEPTEMBER 1985, USING FORMULAE, MINE SITE ELEVATION (m) = (UTM ELEVATION (ft) + 109.57 x 0.3048).
- 2) CONVERSION TO CAMCMINE GRID (m) FROM CYPRUS ANVIL MINING CORPORATION, PROGRAM L200, CONVERSION OF DATA POINTS BETWEEN GRID SYSTEMS.
- 3) AS BUILT TOE BERM TOPOGRAPHY TAKEN FROM SURVEY BY YUKON ENGINEERING SERVICES (NO SURVEY INFORMATION AVAILABLE FOR THE BORROW AREA).
- 4) FOR TYPICAL DAM CROSS-SECTIONS SEE FIGURES III-2.1 and III-2.2 IN APPENDIX III-2.



Golder Associates

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SCALE 1:1000

STA 0+00 IS AT SOUTH FACE OF SPILLWAY

DIVERSION CANAL DYKE INSPECTION PHOTOS
STA. 2+100 AREA

Figure 5



Looking downstream from about Sta. 2+100, the above photo illustrates the condition of the dyke top. The lower photo is of the area between the two right side barrels; it illustrates a case of a partially-collapsed crack in the crest of the dyke.



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DIVERSION CANAL DYKE INSPECTION PHOTOS
STA. 2+100 AREA

Figure 6



Situated just off the edge of the canal dyke and somewhat downstream of the Intermediate Dam, this unused sump is providing groundwater recharge to the area and it must be drained in the interests of local stability.

DATE 12 MAR 1995

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DIVERSION CANAL BACKSLOPE PHOTOS
STA. 1+950 AREA

Figure 7

Looking downstream, the area in the central foreground has suffered displacement, beginning in 1991. It appears that there has been no movement during the past year. Note that a portion of the top of the thermal liner (to the left) is not involved in the movement. See next figure for further details.

DIVERSION CANAL BACKSLOPE PHOTOS
STA. 1+950 AREA

Figure 8



Referring to the previous figure, the upper photo is viewing upstream. Note the scarp in the centre of the photo. It appears not to have moved in the past year. Likewise, comparison of the lower photo with a similar 1994 photo indicates little or no movement in the lower left area.



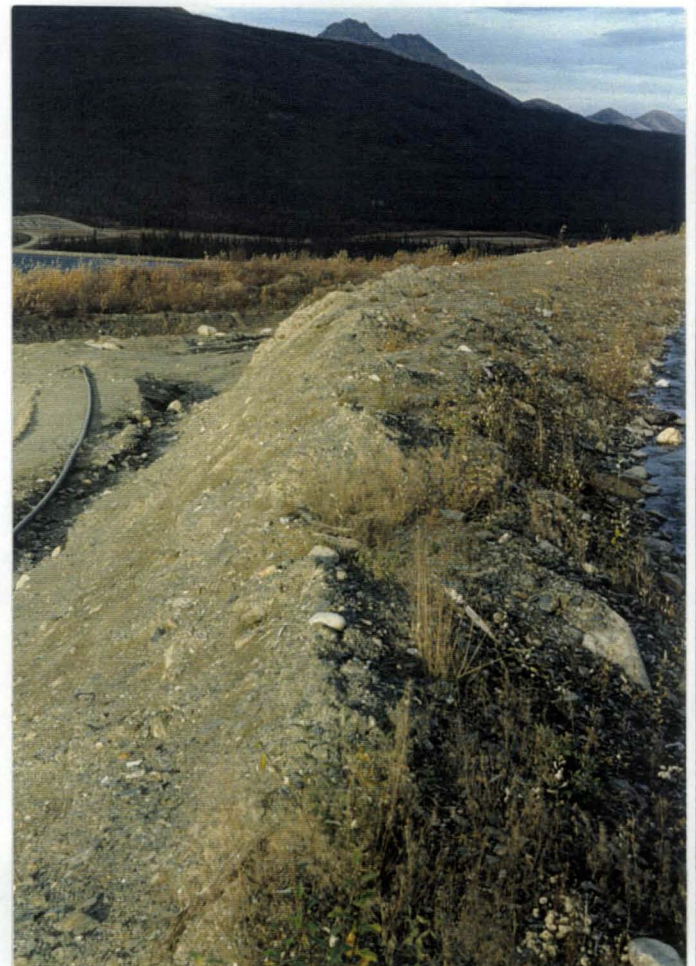
PROJECT 942-2431 DRAWN MOH REVIEWED DATE 12 MAR 1995

NORTH VALLEY WALL INTERCEPTOR PHOTOS
BORROW PIT TRAVERSE INLET

Figure 9



The subject area is upstream and above the north abutment of the Intermediate Dam. The north main access road is in the left centre of the upper photo. The adjacent dyke must contain the interceptor flow. As indicated by the lower photo, it needs to be raised and widened.

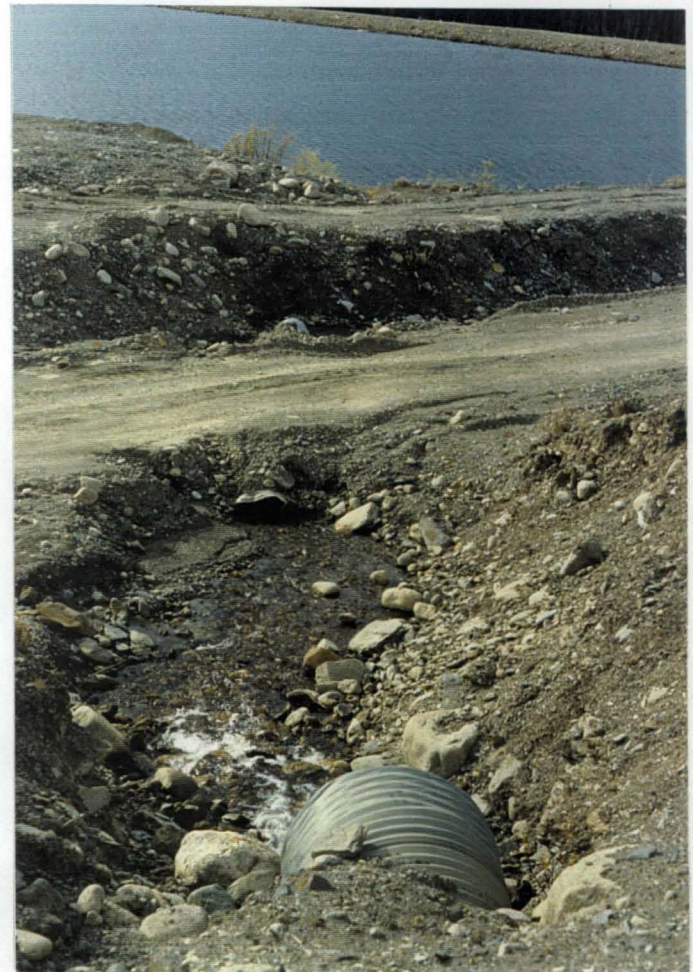


NORTH VALLEY WALL INTERCEPTOR PHOTOS
ROAD CROSSING AREA

Figure 10



The upper photo is looking westerly across the main north wall access road; the lower photo across the trail that parallels the channel which conveys all flow past the Cross Valley Dam's north abutment. These culverts are of insufficient size to convey the $17.7 \text{ m}^3/\text{s}$ design flow (50 yr. return period).



PROJECT 942-2431 DRAWN MOH REVIEWED DATE 12 MAR 1995

NORTH VALLEY WALL INTERCEPTOR PHOTOS
CHANNEL OUTFALL REACH

Figure 11



The outfall channel that conveys the flow past the Cross Valley Dam is insufficiently sized for the 50 yr. design flow of $17.7 \text{ m}^3/\text{s}$; 2H:1V sideslopes, 6.1 m bottom width and bank height of 2.6 m is the required design section, including 0.5 m of freeboard.

CROSS VALLEY DAM PHOTOS

Figure 12



The upper photo illustrates the crest of the dam, looking northward. The lower photo is of the inlet to the spillway; the dyke may be retaining a pond level slightly above design FSL.



PROJECT 942-2431 DRAWN MOH REVIEWED DATE 12 MAR 1995



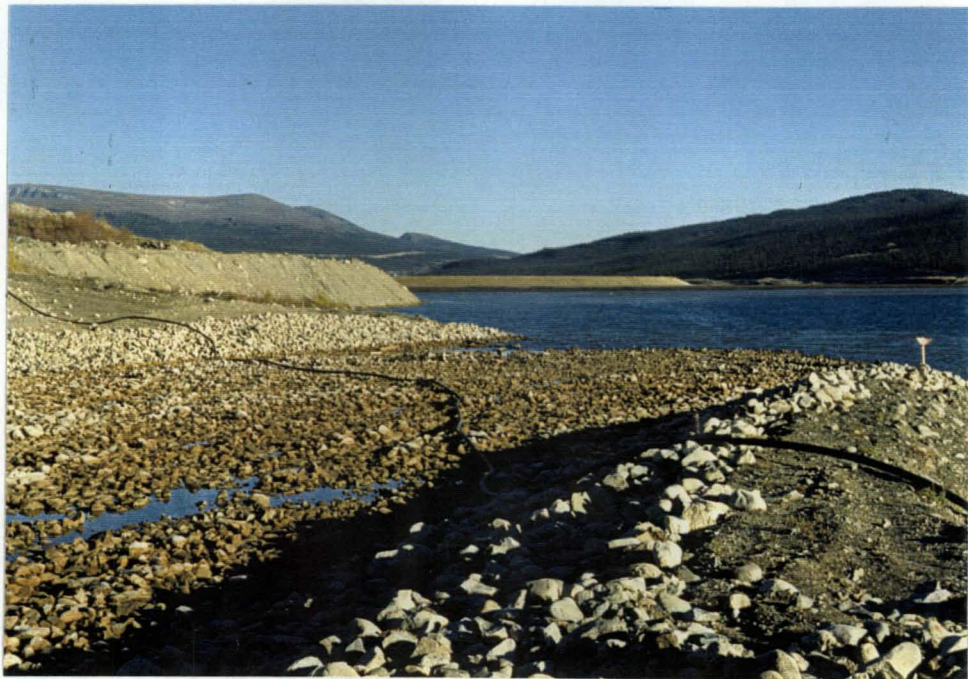
Looking southward along the crest, these photos illustrate the weathered status of old cracking. No sharp-edged cracks were observed.



PROJECT 942-2431 DRAWN MOH REVIEWED DATE 12 MAR 1995



The upper photo illustrates the crest of the dam, looking northward. The lower photo is of the inlet to the spillway. Pond level is at FSL.



PROJECT 942-2431 DRAWN MOH REVIEWED DATE 12 MAR 1995



The upper photo illustrates the condition of the crest, viewing south. The lower photo is of the backslope, illustrating what appears to be a frost slab, perhaps dislodged by rill drainage, and propped up by sand carried along with the flow. The feature is about 3 m in length.



PROJECT 942-2431 DRAWN MOH REVIEWED *JS* DATE 12 MAR 1995



The upper photo is a general view of the backslope, looking northward. The wet area on the toe berm in the left foreground is illustrated in detail by the lower photograph. Seepage rate was an estimated 10 l/minute. Seepage is issuing from the drainage layer which daylights at berm level.





The upper photo is a general view of the gently graded spillway section with the retaining dyke to the left. The lower photo, taken from the dam crest, illustrates the crest of the spillway dyke. The dyke needs to be raised further, in spite of work done in late 1994.



PROJECT 942-2431 DRAWN MOH REVIEWED DATE 12 MAR 1995



The upper photo illustrates the degree to which the spillway was stop-logged on September 20, 1995. The lower photo indicates that, as a consequence of this excessively high water level, waves have driven debris onto the crest. **This high water level is an unacceptable condition.**

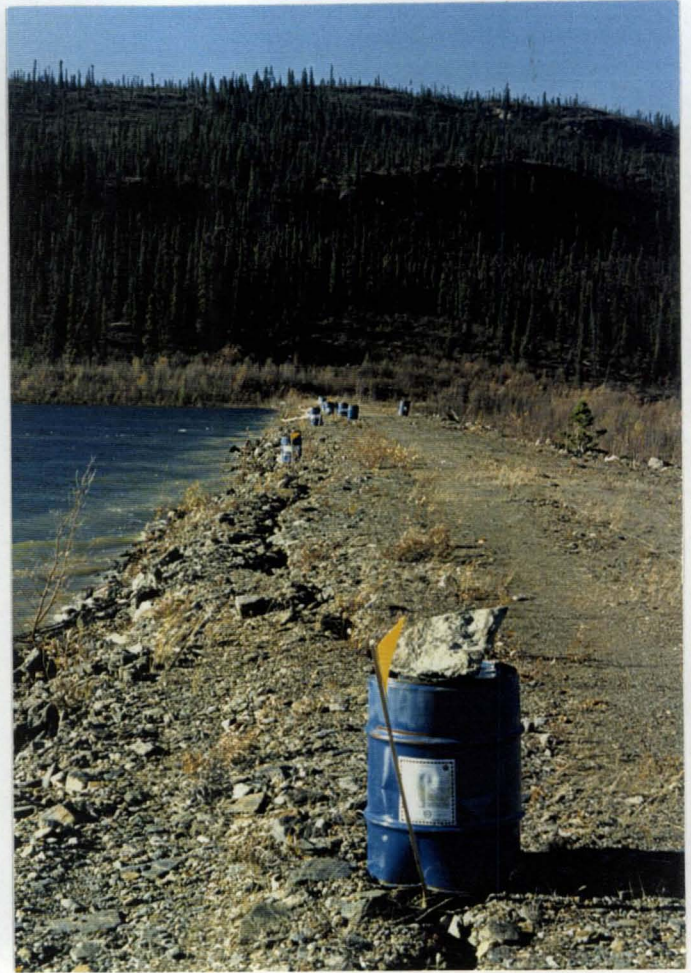


PROJECT 942-2431 DRAWN MOH DATE 12 MAR 1995 REVIEWED *[Signature]*



The upper photo illustrates the crest, looking south along the crest from near the spillway. The near-foreground blue barrel in this photo is captured by the lower photo, and the nature of the crest cracking can be noted.





The left photo is of a test pit area, excavated and backfilled in June, 1994. Not much cracking has occurred since it was backfilled. The barrel in the foreground of the right photo can be seen in the left photo. Cracks in this area have not been disturbed by test pit activity.

DATE 12 MAR 1995

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PROJECT



The upper photo shows a well-worn major crack at the edge of the crest, as well as 2 minor cracks farther to the right. The lower photo is a close-up of the test pit area immediately behind the barrel shadow. The lath can be used for scale to appreciate the width of the 1994/95 crack.



SCHEDULED 1996 INSTRUMENTATION READINGS

Figure 22

BASE


1996 INSTRUMENTATION READINGS	JAN 96	FEB 96	MAR 96	APR 96	MAY 96	JUN 96	JUL 96	AUG 96	SEP 96	OCT 96	NOV 96	DEC 96
1. Diversion Canal												
THERMISTORS												
- Canal Dyke 81-125, CD-21, 88-7, 88-11									***			
- Spoil Pile SP-2, SP-3, SP-5									***			
- Backslope BS-10, BS-11, BS-17									***			
SLOPE INDICATORS												
- Canal Dyke CD-21, BH94CD-1, BH88-6				***					***			
BH88-10				***					***			
CD-15, CD-19, BH91-CD-2, CD-28, CD-29									***			
- Spoil Pile SP-2, SP-5									***			
- Backslope BS-9, BS-10, BS-11									***			
BS-17, BS-18												
PIEZOMETERS												
- Canal Dyke CD-13 & all others downstream				***					***			
- Backslope				No piezometer readings needed until further notice.								
SURVEY MONUMENTS				No further triangulation-based measurements of the movement hub network until further notice.								
2. Cross Valley Dam												
THERMISTORS - BH88-4,5			***	***	***				***			
CVDT-4, CVDC-11									***			
PIEZOMETERS (all installations)				***					***			
WEIR FLOWS: X-11, X-12, W3	***	***	***	***	***	***	***	***	***	***	***	***
WEIR FLOWS: X-13	weekly	weekly	weekly	weekly	weekly	weekly	weekly	weekly	weekly	weekly	weekly	weekly
POLISHING POND WATER LEVEL	***	***	***	***	***	***	***	***	***	***	***	***
3. Intermediate Dam												
THERMISTORS				No functioning thermistors; no cold ground, no further interest.								
PIEZOMETERS (all)				***					***			
4. Fresh Water Supply Dam												
THERMISTORS (all)			***	***	***				***			
PIEZOMETERS (All)				***					***			
TOE BERM SEEPAGE WEIR FLOWS	***	***	***	***	***	***	***	***	***	***	***	***
RESERVOIR WATER LEVEL	***	***	***	***	***	***	***	***	***	***	***	***
5. Miscellaneous												
ROSE CREEK FLOW, Recording Station				Rehabilitate for continuous recording of stream level data								
NOTES:												
1. It is anticipated that the 1997 and ongoing data requirements will be essentially as for 1996, as detailed above.												
2. Functioning instruments not specifically called up or otherwise inferred for scheduled 1996 observation will not be read in 1996, or in future, unless specifically requested.												

Golder Associates

PROJECT: 952-2431

DRAWN BY: MVZ

DATE: 13 MAR 96

REVIEWED: 

APPENDIX I
INSTRUMENTATION REPAIRS
AND
REHABILITATION REPORT

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2.0 DAMAGED OR NON-FUNCTIONING INSTRUMENTS	iv
2.1 Down Valley Tailings Storage Facility	iv
2.2 Fresh Water Supply Dam.....	viii
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3.1 Down Valley Tailings Storage Facility	ix
3.2 Fresh Water Supply Dam.....	ix
4.0 LITTLE CREEK DAM.....	x

LIST OF FIGURES

FIGURE I-1 LITTLE CREEK DAM - INSTRUMENTATION LOCATIONS

LIST OF ATTACHMENTS

ATTACHMENT I RECORD OR BOREHOLES

1.0 BACKGROUND

The Down Valley project at Faro Mine has a number of important earthen structures, and the geotechnical performance of these structures are important to the mine for both operational and environmental purposes. For this reason, performance instrumentation (slope indicators, piezometers, settlement gauges, and thermistors) was installed in the fall of 1981. Additional instrumentation has since been installed for a variety of reasons.

In addition to instrumentation installed in the Down Valley Project works, piezometers and thermistors have been installed in the Fresh Water Supply Dam, either by Golder Associates, or by others. Golder Associates has been working with this instrumentation since 1988.

Damage to some of the instrumentation has occurred over the years since it was installed, some weathering of nylon and plastic parts has occurred, some installations have been choked with ice, etc., to the point that there was concern about an absence of potentially troubling data. Accordingly, and at the request of KPMG Environmental Services Inc., Golder Associates undertook to repair these installations during 1994, addressing only those instruments which were believed to be of importance in the future. Where instruments had been irreparably damaged, and for which future data was important, new instruments were installed. The instruments of both the Down Valley Project and the Fresh Water Supply Dam were involved in the rehabilitation program.

Finally, at the request of KPMG Environmental Services Inc., Golder Associates also installed instrumentation in Little Creek Dam situated on the Vangorda Plateau. Gilbert Gagnon, a senior technician with Golder Associates, was on site from May 27, 1994 to June 20, 1994 to perform the instrument rehabilitation work, and to supervise installation of new instruments, as well as for the purpose of obtaining readings from all functioning or repaired instruments.

2.0 DAMAGED OR NON-FUNCTIONING INSTRUMENTS

2.1 Down Valley Tailings Storage Facility

As a consequence of the rehabilitation work, found instruments were brought back to adequate function, or left in as-found condition, as detailed by Table I-1. Repairs typically comprised cleaning of electrical leads and leads reconnection (thermistors), splicing in new leads at surface and replacing pneumatic piezometer lead adapters, and removing ice from slope indicator casings. In addition, all installations were left with a stamped metal tag to permanently identify the installation.

TABLE I-1: INSTRUMENT CONDITION INVENTORY- DOWN VALLEY PROJECT

(sheet 1)

KEY: SI = slope indicator, PP = pneumatic piezometer, HP = hydraulic piezometer, T = thermistor string

Reference Number	Instrument Abbreviation	Post-Rehabilitation Program Condition	Location	Chainage
BH94 CVDC-1	T,PP	Under Road	Cross Valley Dam	0+215
CVDC-1	T, PP	N.V.W.I.D. Dyke	Cross Valley Dam	0+050
CVDC-2	PP	Destroyed	Cross Valley Dam	0+150
79-20	T,HP	Slope Caved in - Destroyed	Cross Valley Dam	North Abutment CVD
CVDT3	HP	Destroyed	Cross Valley Dam	0+490 approx
CVDC-4	2HP	1 Plugged	Cross Valley Dam	0+215
CVDC-6	T, PP	PP Plugged, unable to repair	Cross Valley Dam	0+340
CVDC-7	2 PP	1 Plugged, unable to repair	Cross Valley Dam	0+450
CVDC-9	2 PP	Working Order	Cross Valley Dam	0+565
CVDC-11	T, PP	Working Order	Cross Valley Dam	0+645
CVDT-4	T	Fluctuating readings	Cross Valley Dam	0+630
CVDP-1	PP	Working Order	Cross Valley Dam	0+450, 20m u/s of CL
CVDP-2	PP	Working Order	Cross Valley Dam	0+450, 5m u/s of CL
CVDP-3	PP	Under Water	Cross Valley Dam	0+450, 7m d/s of CL
CVDP-4		Destroyed	Cross Valley Dam	0+210
CVDP-5	PP	Working Order	Cross Valley Dam	0+210, 9m u/s of CL
CVDP-6	PP	Destroyed	Cross Valley Dam	0+210, 5m d/s of CL
CVDP-7	PP	Working Order	Cross Valley Dam	0+570
CVDP-8	2 PP, HP	2 leak, 1 plugged - unable to repair	Cross Valley Dam	0+570
CVDP-9	PP	Working Order	Cross Valley Dam	0+570
CVDP-10	PP	Working Order	Cross Valley Dam	0+570
BH88-4	T	Working Order	Cross Valley Dam	0+450
BH88-5	T	Working Order	Cross Valley Dam	0+295
81-96	T	Destroyed	Cross Valley Dam	above south abutment
88-2		Destroyed	Intermediate Dam	0+770 approx
88-3	2 PP, T	T Destroyed	Intermediate Dam	South Abutment
ID3	2HP	Working Order	Intermediate Dam	South Abutment
ID4	2HP	Working Order	Intermediate Dam	0+500
ID9	PP	Destroyed	Intermediate Dam	0+740 approx
ID6	2HP	Under water	Intermediate Dam	0+600
ID5	2HP	Working Order	Intermediate Dam	0+600
IDP-5		Under water	Intermediate Dam	0+650 approx
IDP-2	PP	Destroyed	Intermediate Dam	0+605 approx
IDP-6		Under water	Intermediate Dam	0+635 approx
IDP-3		Under water	Intermediate Dam	0+670 approx
IDP-4		Under water	Intermediate Dam	0+670 approx
ID8	PP	Under water	Intermediate Dam	0+740 approx

TABLE I-1: INSTRUMENT CONDITION INVENTORY- DOWN VALLEY PROJECT

(sheet 2)

KEY: SI = slope indicator, PP = pneumatic piezometer, HP = hydraulic piezometer, T = thermistor string

Reference Number	Instrument Abbreviation	Post-Rehabilitation Program Condition	Location	Chainage
ID7	T,PP	Under water	Intermediate Dam	0+720
ID2	2HP	Destroyed	Intermediate Dam	0+250 approx.
ID4	2HP	Destroyed	Intermediate Dam	0+455 approx.
88-1		Destroyed	Intermediate Dam	North Abutment
88-6	SI	Plugged, unable to thaw	Canal Dyke	2+115
91-CD 1	SI	Working Order	Crest of Canal Dyke	1+767
91-CD 2	SI	Working Order	Crest of Canal Dyke	1+998
CD-4	PP, T	PP Destroyed	Canal Dyke	0+400
CD-5	T	Working Order	Canal Dyke	0+510
CD-7	PP	Working Order	Canal Dyke	0+710
CD-9	PP	Working Order	Canal Dyke	0+960
CD-10	SI, PP ==	Working Order	Canal Dyke	0+990
CD-13	PP	Working Order	Canal Dyke	1+350
CD-15	SI, PP	Working Order	Canal Dyke	1+530
CD-17	T	Working Order	Canal Dyke	1+705
CD-19	SI, T, 2PP	Working Order	Canal Dyke	1+900
CD-20	T	Working Order	Canal Dyke	2+000
CD-21	SI, T, 2PP	Working Order	Canal Dyke	2+100
CD-24	T	Working Order	Canal Dyke	2+365
CD-25	T	Working Order	Canal Dyke	2+460
CD-26	PP	Working Order	Canal Dyke	2+600
CD-27	T	Working Order	Canal Dyke	2+765
SP-2	SI, T	Working Order	Canal Dyke	1+530
SP-3	SI,T	SI - Plugged, unable to thaw	Canal Dyke	1+900
SP-5	SI, T	Working Order	Canal Dyke	2+950
CD-28	S,V,H,T,SI,2P P	Destroyed	Canal Dyke	2+900
CD-29	SI,S,V,H,T,2P P	Destroyed	Canal Dyke	3+000
CD-30	V,T	Destroyed	Canal Dyke	3+150 approx.
BS2	SI, PP, T	Working Order	Backslope CD	0+400
BS4	T, PP	Working Order	Backslope CD	0+710
BS5	SI, PP, T	Working Order	Backslope CD	0+960
BS9	SI, PP, T	Working Order	Backslope CD	1+530
BS10	SI,T, PP	Working Order	Backslope CD	1+900
BS11	T, SI,PP	SI & PP Unable to thaw	Backslope CD	2+100
BS12	T	Working Order	Backslope CD	2+260
BS15	T	Working Order	Backslope CD	2+760
BS16	T, SI	SI Pipe broken, unable to read	Backslope CD	2+900

TABLE I-1: INSTRUMENT CONDITION INVENTORY- DOWN VALLEY PROJECT

(sheet 3)

KEY: SI = slope indicator, PP = pneumatic piezometer, HP = hydraulic piezometer, T = thermistor string.

Reference Number	Instrument Abbreviation	Post-Rehabilitation Program Condition	Location	Chainage
BS17	T, SI	SI Pipe broken, unable to read	Backslope CD	2+900
BS18	SI, T, PP, HP	HP Plugged	Backslope CD	3+000
88-07	PP	Working Order	Canal Dyke	2+120 (approx)
88-08		Under Water	D/S of Canal Dyke	2+140 approx
88-09		Under Water	D/S of Canal Dyke	2+140 approx
88-10	SI	Working Order	Canal Dyke	2+160
88-11	PP	Working Order	Canal Dyke	2+160 (approx)
88-12		Under Water	D/S of Canal Dyke	2+160 approx
88-13		Under Water	D/S of Canal Dyke	2+160 approx
BH91-CD-1	SI, 2PP	2PP Destroyed	Canal Dyke	1+767
BH91-CD-2	SI	Working Order	Canal Dyke	1+998
BH81-125	T	Working Order	Canal Dyke	2+100

2.2 Fresh Water Supply Dam

As a consequence of the rehabilitation work, found instruments were brought back to adequate function, as detailed by Table 1-2. Repairs typically comprised cleaning of electrical leads and leads reconnection (thermistors), splicing in new leads at surface and replacing pneumatic piezometer lead adapters as necessary. In addition, all installations were left with a stamped metal tag to permanently identify the installation.

**TABLE I-2: INSTRUMENT CONDITION INVENTORY- FRESH WATER SUPPLY
DAM**

KEY: SI = slope indicator, PP = pneumatic piezometer, HP = hydraulic piezometer,
T = thermistor string

Reference Number	Instrument Abbreviation	Post-Rehabilitation Program Condition	Location	Chainage
BH85-4	HP	Working Order	Fr. Water Supply Dam	2+03
BH88-15	3PP	Working Order	Fr. Water Supply Dam	1+92
BH85-2	HP	Working Order	Fr. Water Supply Dam	2+04
BH88-16	2PP	Working Order	Fr. Water Supply Dam	1+71
BH85-3	HP	Working Order	Fr. Water Supply Dam	1+30
BH85-1	HP	Working Order	Fr. Water Supply Dam	2+04
BH85-5	HP, T	Working Order	Fr. Water Supply Dam	1+27
BH85-6	HP	Working Order	Fr. Water Supply Dam	1+32

4.0 LITTLE CREEK DAM

The general configuration of the dam is presented on Figure I-1. This dam was constructed by the mine operator in 1991, and against the recommendations of the designer (SRK), instrumentation was not installed during its construction. Because of an absence of data affirming its performance, it was decided by others that the structure should be instrumented. The program was initiated by KPMG Environmental Services Inc.

A total of nine instruments were installed in the Little Creek Dam during the 1994 rehabilitation program. These included 6 pneumatic piezometers, and 3 thermistors. The following table summarises this new instrumentation.

KEY: SI = slope indicator, PP = pneumatic piezometer, HP = hydraulic piezometer,
T = thermistor string.

Reference Number	Approximate Reference Chainage	Type of Instrument	Location	Date Installed
LCD-1	0+100	2 PP	Little Creek Dam	June 8, 1994
LCD-2	0+180	2 PP	Little Creek Dam	June 10, 1994
LCD-3	0+240	2 PP	Little Creek Dam	June 9, 1994
LCD-4	0+120	T	Little Creek Dam	June 8, 1994
LCD-5	0+200	T	Little Creek Dam	June 8, 1994
LCD-6	0+250	T	Little Creek Dam	June 9-10, 1994

Details of each of the installations are presented on the logs of boreholes at the end of this Appendix.

3.0 REPLACEMENT INSTRUMENT INSTALLATIONS

3.1 Down Valley Tailings Storage Facility

Three replacement instruments were installed in the Down Valley Tailings Storage Facility area during the 1994 rehabilitation program. The following table lists information regarding these installations. Borehole logs describing installation details are presented at the end of this appendix.

KEY: SI = slope indicator, PP = pneumatic piezometer, HP = hydraulic piezometer,
T = thermistor string.

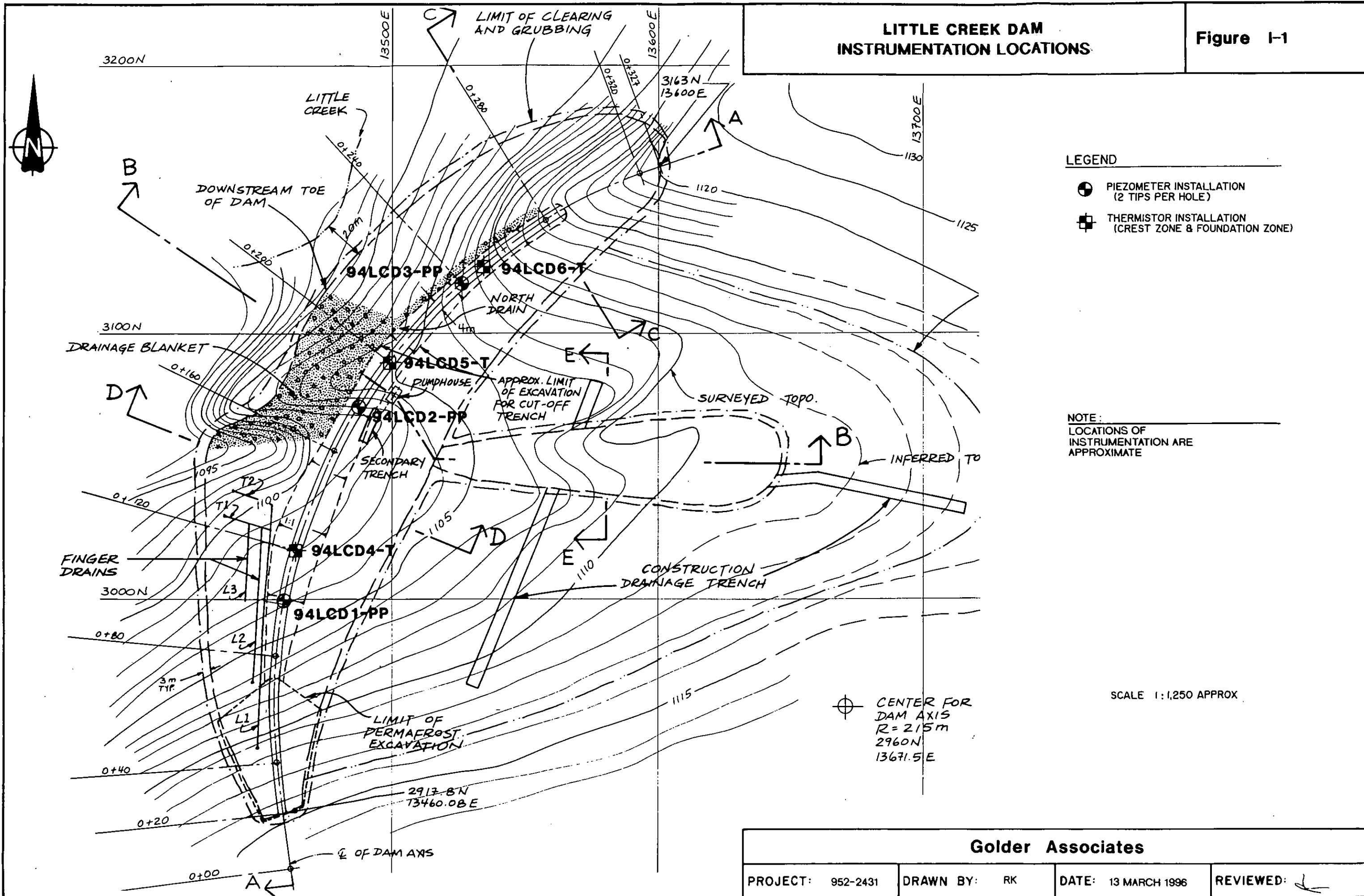
Reference Number	Approximate Reference Chainage	Type of Instrument	Location	Date Installed
BH94-IDC-1	0+460	HP	Intermediate Dam	June 11, 1994
BH94-CVDC-1	0+225	HP	Cross Valley Dam	June 12, 1994
BH94-CD-1	2+313	SI	Canal Dyke	June 8, 1994

3.2 Fresh Water Supply Dam

No replacement instrumentation was installed in the Fresh Water Supply Dam area during the 1994 rehabilitation program.

LITTLE CREEK DAM INSTRUMENTATION LOCATIONS

Figure I-1



- LEGEND**
- PIEZOMETER INSTALLATION (2 TIPS PER HOLE)
 - ⊠ THERMISTOR INSTALLATION (CREST ZONE & FOUNDATION ZONE)

NOTE:
LOCATIONS OF INSTRUMENTATION ARE APPROXIMATE

SCALE 1:1,250 APPROX

⊕ CENTER FOR DAM AXIS
R = 215m
2960N
13671.5E

Golder Associates			
PROJECT: 952-2431	DRAWN BY: RK	DATE: 13 MARCH 1996	REVIEWED: [signature]

PROJECT: 952-2431

RECORD OF BOREHOLE BH94 IDC-1

SHEET: 1 OF 1



LOCATION: See Location Plan

BORING DATE: 11 June 1994

DATUM:

SAMPLER HAMMER: 63.5kg; DROP: 760mm

PENETRATION TEST HAMMER: 63.5kg; DROP: 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	20	40	60	80	20	40		
0		GROUND SURFACE		0.00											
1		Compact, homogeneous, moist, medium brown GRAVELLY SAND to SAND and GRAVEL, fine to coarse gravel, fine to trace coarse subrounded to subangular (FILL)													
2															
3															
4															
5															
6															
7	CME 750 Solid Stem Auger														
8															
9															
10		—Increased clay and silt content below 10.0m to silty gravel, some clay, some sand													
11															
12															
13															
14		End of Borehole		14.00											
15															

DATA INPUT: C. Gibson

Cement Grout

Bentonite Chips

Granular Filter

Casing protector installed
Piezo Stickup = 0.37m

DEPTH SCALE

1 to 75

Golder Associates

LOGGED: G. Gagnon

CHECKED: **CSG**

PROJECT: 952-2431

RECORD OF BOREHOLE BH94 CVDC-1

SHEET 1 OF 1



LOCATION: See Location Plan

BORING DATE: 12 June 1994

DATUM:

SAMPLER: HAMMER, 63.5kg; DROP: 760mm

PENETRATION TEST: HAMMER, 63.5kg; DROP: 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s		ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION		
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH				WATER CONTENT, PERCENT				
								20	40	60	80	nat. V - +			U - O	rem. V - @
0	CME 750 Hollow Stem Auger	GROUND SURFACE		0.00												
1		Loose, intermixed, dry to moist, medium brown SAND and GRAVEL, cobbles/boulders throughout, gravel fine to coarse, sand fine to coarse (FILL)														
2		Compact, intermixed, moist to wet, medium orange brown SANDY SILT, some gravel, trace to some clay, sand, fine to coarse, gravel, coarse, schist fragments (FILL)		1.00	1	DO	25/100									
3					2	DO	35/150									
4																
5		Hard, homogeneous, moist, medium orange brown to medium grey CLAYEY SILT to SANDY SILT, some gravel, sand, coarse, gravel, coarse, schist fragments (FILL)	4.00	3	DO	54										
6																
7																
8																
9																
10																
11																
12																
13																
13		End of Borehole		12.60												
14																
15																

DATA INPUT: C. Gibson

Cement Grout

Bentonite Chips

Granular Filter

Slough

Casing protector installed
Piezo Stickup = 0.70m

DEPTH SCALE
1 to 75

Golder Associates

LOGGED: G. Gagnon
CHECKED: CSG

PROJECT: 952-2431

RECORD OF BOREHOLE BH94 CD-1

SHEET: 1 OF 1



LOCATION: See Location Plan

BORING DATE: 08 June 1994

DATUM:

SAMPLER/HAMMER: 63.5kg; DROP: 760mm

PENETRATION TEST HAMMER, 63.5kg; DROP: 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION	
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH				WATER CONTENT, PERCENT				
							20	40	60	80						
							nat.V - + Q - ●				Wp ----- Wl					
							rem.V - ⊗ U - ○				20 40 60 80					
0		GROUND SURFACE		0.00												
1		Stiff, intermixed, moist, medium to dark grey to medium greyish brown GRAVEL-SAND-SILT, some clay, gravel, fine to coarse, sand, fine to coarse (FILL)														Bentonite Chips
2																
3																
4																
5		Compact, homogeneous, moist to wet, medium brown to greyish brown GRAVELLY SILT, some sand, trace clay to SANDY SILT, some gravel, trace clay, occasional cobble (TILL)		5.00												
6																
7	CME 750 Hollow Stem Auger															
8		---Becoming saturated below 7.6m														
9																
10		---Inferred permafrost at 9.5m														
11																
12		---Gravelly layer 12.3-13.4m														
13																
14		End of Borehole		13.40												SI installed Casing protector installed
15																

DATA INPUT: C. Gibson

DEPTH SCALE

1 to 75

Golder Associates

LOGGED: G. Gagnon

CHECKED: CSG

PROJECT: 952-2431

RECORD OF BOREHOLE BH94 LCD-1

SHEET 1 OF 2

LOCATION: See Location Plan

BORING DATE: 08 June 1994

DATUM:

SAMPLER HAMMER: 63.5kg; DROP: 760mm

PENETRATION TEST HAMMER, 63.5kg; DROP: 760mm



DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	SHEAR STRENGTH				WATER CONTENT, PERCENT					
							Cu, kPa		rem. V. U - O		Wp		W			
0		GROUND SURFACE		0.00												
1		Stiff to very stiff, homogenous, moist, dark grey CLAYEY SILT to SILT, some clay, low to medium plastic, trace to some gravel, trace sand, schist fragments throughout (FILL)													Cement Grout	
2																
3					1	DO	59									
4																
5																
6																
7																
8	CME 750 Solid Stem Auger															
9																
10																
11															Bentonite Chips	
12															Granular Filter	
13															Bentonite Chips	
14																
15		CONTINUED ON NEXT PAGE		15.00												

DATA INPUT: C. Gibson

DEPTH SCALE

1 to 75

Golder Associates

LOGGED: G. Gagnon

CHECKED: *CSG*

PROJECT: 952-2431

RECORD OF BOREHOLE BH94 LCD-1

SHEET: 2 OF 2



LOCATION: See Location Plan

BORING DATE: 08 June 1994

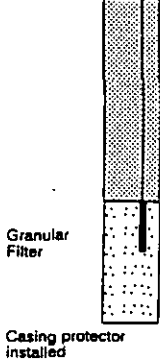
DATUM:

SAMPLER: HAMMER, 63.5kg; DROP: 760mm

PENETRATION TEST: HAMMER, 63.5kg; DROP: 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k_f cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION	
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH				WATER CONTENT, PERCENT					
								Cu, kPa		rem. V. U. O.		Wp		W			
15	CME 750 Solid Stem Auger	CONTINUED FROM PREVIOUS PAGE		15.00	5	DC	18										
16		Very stiff, massive, wet, dark grey CLAYEY SILT, low to medium plastic, some gravel, trace sand, seepage at 15.3m (TILL)															
17																	
18		End of Borehole		18.20													
19																	
20																	
21																	
22																	
23																	
24																	
25																	
26																	
27																	
28																	
29																	
30																	

DATA INPUT: C. Gibson



DEPTH SCALE
1 to 75

Golder Associates

LOGGED: G. Gagnon
CHECKED: *CSG*

PROJECT: 952-2431

RECORD OF BOREHOLE BH94 LCD-2

SHEET: 1 OF 2



LOCATION: See Location Plan

BORING DATE: 10 June 1994

DATUM:

SAMPLER HAMMER, 63.5kg; DROP: 760mm

PENETRATION TEST HAMMER, 63.5kg; DROP: 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	20	40	60	80	20	40		
0		GROUND SURFACE		0.00											
1		Stiff to very stiff, homogeneous, moist, dark grey CLAYEY SILT, low to medium plastic, some gravel, trace sand (FILL)													Cement Grout
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14		—Becoming wet at 13.5m Stiff, homogeneous, wet, medium orange brown CLAYEY SILT to SILT, some clay, low to medium plastic, some gravel, trace to some sand (FILL)		13.70											Bentonite Chips Granular Filter Bentonite Chips
15		CONTINUED ON NEXT PAGE													

DATA INPUT: C. Gibson

DEPTH SCALE
1 to 75

Golder Associates

LOGGED: G. Gagnon
CHECKED: CSG

PROJECT: 952-2431

RECORD OF BOREHOLE BH94 LCD-2

SHEET 2 OF 2



LOCATION: See Location Plan

BORING DATE: 10 June 1994

DATUM:

SAMPLER HAMMER: 63.5kg; DROP: 760mm

PENETRATION TEST HAMMER: 63.5kg; DROP: 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION	
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH				WATER CONTENT, PERCENT					
								Cu, kPa		rem. V - U - O		Wp		W			
15	CME 750 Solid Stem Auger	CONTINUED FROM PREVIOUS PAGE															
16		CLAYEY SILT to SILT (FILL) As Above			1	DO	10										
18		Very stiff, wet, medium grey CLAYEY SILT to GRAVELLY SILT, low plastic, some sand, gravel lenses and pockets (TILL)		18.10	2	DO	10/ 25										
19														Slough			
21		End of Borehole		21.40											Casing protector installed		
22																	
23																	
24																	
25																	
26																	
27																	
28																	
29																	
30																	

DATA INPUT: C. Gibson

DEPTH SCALE
1 to 75

Golder Associates

LOGGED: G. Gagnon
CHECKED: *CSG*

PROJECT: 952-2431

RECORD OF BOREHOLE BH94 LCD-3

SHEET 1 OF 1



LOCATION: See Location Plan

BORING DATE: 09 June 1994

DATUM:

SAMPLER HAMMER: 63.5kg; DROP: 760mm

PENETRATION TEST HAMMER: 63.5kg; DROP: 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION	
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH				WATER CONTENT, PERCENT					
								Cu, kPa		rem. V - U - O		Wp		W			
0		GROUND SURFACE		0.00													
1	CMET750 Solid Stem Auger	Stiff to very stiff, homogeneous, moist, dark grey CLAYEY SILT to SILT, some clay, low to medium plastic, some gravel, trace sand, schist fragments (FILL)														Bentonite Chips Cement Grout Bentonite Chips Granular Filter Bentonite Chips Granular Filter Casing protector installed	
5				1	DO	16											
6				2	DO	23											
9				3	DO	22											
12					Very stiff, massive, moist, dark grey CLAYEY SILT, low to medium plastic, some gravel, trace sand (TILL)		12.00	4	DO	15							
13					End of Borehole		13.30										

DATA INPUT: C. Gagnon

DEPTH SCALE

1 to 75

Golder Associates

LOGGED: G. Gagnon

CHECKED: CSG

PROJECT: 952-2431

RECORD OF BOREHOLE BH94 LCD-4

SHEET 1 OF 2



LOCATION: See Location Plan

BORING DATE: 08 June 1994

DATUM:

SAMPLER HAMMER: 63.5kg; DROP: 760mm

PENETRATION TEST HAMMER: 63.5kg; DROP: 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION		
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH				WATER CONTENT, PERCENT					
								Cu, kPa		rem. V.		Wp				W	
0		GROUND SURFACE		0.00													
1		Borehole stratigraphy not logged Thermistor installed													Bentonite Chips		
2																	
3																	
4																	
5																	
6																	
7																	
8	CME 750 Solid Stem Auger																
9																	
10																	
11																	
12																	
13																	
14																	
15																	

DATA INPUT: C. Gibson

CONTINUED ON NEXT PAGE

DEPTH SCALE
1 to 75

Golder Associates

LOGGED: G. Gagnon
CHECKED: CSG

PROJECT: 952-2431

RECORD OF BOREHOLE BH94 LCD-4

SHEET 2 OF 2



LOCATION: See Location Plan

BORING DATE: 08 June 1994

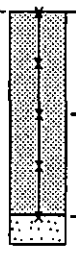
DATUM:

SAMPLER: HAMMER, 63.5kg; DROP: 760mm

PENETRATION TEST: HAMMER, 63.5kg; DROP: 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RESISTANCE				CONDUCTIVITY					
								20	40	60	80	WATER CONTENT, PERCENT		CONDUCTIVITY			
15	CME 750 Solid Stem Auger	CONTINUED FROM PREVIOUS PAGE															
16																	
17																	
17.30		End of Borehole															
18																	
19																	
20																	
21																	
22																	
23																	
24																	
25																	
26																	
27																	
28																	
29																	
30																	

DATA INPUT: C. Gibson



Granular Filter

DEPTH SCALE
1 to 75

Golder Associates

LOGGED: G. Gagnon
CHECKED: CSG

PROJECT: 952-2431

RECORD OF BOREHOLE BH94 LCD-5

SHEET 1 OF 2

LOCATION: See Location Plan

BORING DATE: 08 June 1994

DATUM:

SAMPLER HAMMER: 63.5kg DROP: 760mm

PENETRATION TEST HAMMER: 63.5kg DROP: 760mm



DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k_v cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH		WATER CONTENT, PERCENT					
								20	40	60	80	nat. V. +	rem. V. -		
0		GROUND SURFACE		0.00											
1		Borehole stratigraphy not logged Thermistor installed													Bentonite Chips
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14															
15															

CME 750 Solid Stem Auger

DATA INPUT: C. Gibson

CONTINUED ON NEXT PAGE

DEPTH SCALE
1 to 75

Golder Associates

LOGGED: G. Gagnon
CHECKED: CSG

PROJECT: 952-2431

RECORD OF BOREHOLE BH94 LCD-5

SHEET 2 OF 2



LOCATION: See Location Plan

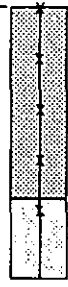
BORING DATE: 08 June 1994

DATUM:

SAMPLER: HAMMER: 63.5kg; DROP: 760mm

PENETRATION TEST: HAMMER: 63.5kg; DROP: 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION	
		DESCRIPTION	STRATA PLOT	ELEV.	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH				WATER CONTENT, PERCENT					
				DEPTH (m)				Cu, kPa	nat.V. +	rem.V. ⊕	U - ●	U - ○	Wp	W			Wt
15	CME 750 Solid Stem Auger	CONTINUED FROM PREVIOUS PAGE															
16																	
17																	
18		End of Borehole		17.70													
19																	
20																	
21																	
22																	
23																	
24																	
25																	
26																	
27																	
28																	
29																	
30																	



Bentonite Grout
Casing protector installed

DATA INPUT: C. Gibson

DEPTH SCALE
1 to 75

Golder Associates

LOGGED: G. Gagnon
CHECKED: CSG

PROJECT: 952-2431

RECORD OF BOREHOLE BH94 LCD-6

SHEET 1 OF 1



LOCATION: See Location Plan

BORING DATE: 09-10 June 1994

DATUM:

SAMPLER HAMMER: 63.5kg; DROP: 760mm

PENETRATION TEST HAMMER: 63.5kg; DROP: 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RESISTANCE				CONDUCTIVITY					
								SHEAR STRENGTH		WATER CONTENT, PERCENT		Wp		W			
0		GROUND SURFACE		0.00													
1		Borehole stratigraphy not logged Thermistor installed														Bentonite Chips	
2																	
3																	
4																	
5																	
6																	
7	CME 750 Hollow Stem Auger																
8																	
9																	
10																	
11																	
12																	
13		End of Borehole		12.90											Casing protector installed		
14																	
15																	

DATA INPUT: C. Gibson

DEPTH SCALE

1 to 75

Golder Associates

LOGGED: G. Gagnon

CHECKED: *CSG*

APPENDIX II

**FRESH WATER SUPPLY DAM CREST
CRACKING INVESTIGATION
AND
CREST REPAIRS RECOMMENDATIONS**

Golder Associates Ltd.

1011 6th Avenue S.W.
Calgary, Alberta, Canada T2P 0W1
Telephone (403) 299-5600
Fax (403) 299-5606



28 June 1994

942-2416

KPMG Environmental Services Inc.
P.O. Box 31, Commerce Court West, 33rd Floor
King & Bay Street
Toronto, Ontario
M5L 1B2

FILE COPY

Attention: Mr. Bob Coleman, P.Eng.

RE: PRELIMINARY INVESTIGATION OF CRACKS ALONG THE CREST OF THE
FRESH WATER DAM

Dear Sir:

Further to your conversation with our Gilbert Gagnon at Faro Mine on the evening of 14 June, 1994, Golder Associates is pleased to submit this letter report summarizing observations made during a shallow subsurface investigation conducted on 14 June, 1994.

Verbal confirmation to conduct the investigation was received from KPMG Environmental on or about the 13th of June.

1.0 GENERAL

A total of three shallow probe holes, in the form of slot trenches, were excavated perpendicular to the orientation of the crack(s) along the north-south trending crest of the Fresh Water Dam. PH94-1 was excavated at an approximate station of 0+90, PH94-2 at 1+80 and PH94-3 at 2+65¹. The depth to the base of the excavated trenches ranged from 1.2 metres to 1.5 metres. The slot trenches were excavated with a small excavator attachment mounted on a Bobcat type 843 skid loader rented from a local source in Faro. The investigation was conducted under the supervision of a representative of Golder Associates on the afternoon of 14 June, 1994.

2.0 OBSERVATIONS

2.1 General - Surface

The cracking observed by the investigation typically follows a path parallel to the dam centreline and is generally confined to an area between 1.0 and 3.0 metres from the upstream shoulder of the crest. The cracking is first observable approximately 47 metres south of the south wingwall of the spillway and extends to near the south abutment of the dam. The principal crack varied from 50 to 250 millimetres in width and was open to a maximum depth of about 200 to 300 millimetres, but typically it was open to only about 100 millimetres depth.

¹Station 0+00 is at the south wall of the spillway.

The backslope (downstream slope) of the dam was observed to be generally smooth and uniform and appeared to be at about a 2.0 horizontal to 1.0 vertical slope. The portion of the upstream slope of the dam above water level had two distinct slopes. Firstly, a riprap section extending to within approximately 1.5 metres of the dam crest that was estimated to be at 2.0 horizontal to 1.0 vertical slope. Above the riprap section of slope, very coarse and silty fill material was observed which extended to the crest at a noticeably steeper angle. The slope of this portion of the upstream face was estimated to be between 0.8 and 1.2 horizontal to 1.0 vertical. Some minor sloughing and small, localized erosion gulleys were observed along this upper portion of the slope.

2.2 Subsurface - Probeholes

PH94-1 (90 m along the crest from the spillway wall).

The slot trench was excavated perpendicular to the crack and to a depth of 1.2 metres. The material encountered was observed to be generally loose, slightly moist and was visually classified as a gravelly silt with trace to some clay containing approximately 20 to 25% cobbles and boulders (>75 mm diameter).

The crack was observed to be partially infilled near the surface and extended to a depth of approximately 0.80 metres below the crest. There was no evidence of frozen soil or ice structures within the soil. The fill material below the crack appeared to be undisturbed. Soil material in the area of the crack could be easily removed by hand. Other areas of the face of the trench could also be easily excavated or caved with minimal effort.

PH94-2 (180 m along the crest from the spillway wall).

This slot trench was excavated perpendicular to the crack and to a depth of 1.4 metres. An upper layer of material of about 1.2 metre thickness was fully penetrated and 0.2 metres of a lower layer was exposed. The upper layer comprised a loose, slightly moist, gravelly silt with trace to some clay, containing approximately 5% cobbles and the occasional boulder. The underlying material, penetrated for only 0.2 metres, comprised a stiff to very stiff, moist, dark grey, low to medium plastic clayey silt with trace to some gravel and trace sand. This lower layer might represent the upper surface of the impervious core zone of the dam.

Within this slot trench the crack was observed to extend to a depth of about 0.7 metres below the crest and was confined to the upper gravelly silt layer. There was no evidence of frozen material or ice structures within either of the layers. Fill material in the vicinity of the crack was relatively easily excavated by hand.

PH94-3 (265 m along the crest from the spillway wall).

This slot trench was excavated perpendicular to the crack to a depth of 1.5 metres. The material encountered was observed and visually classified as a loose, slightly

moist, mixture of gravel and silt with some sand and trace clay. The material was estimated to contain approximately 25 to 35% cobbles and boulders including some cubic metre sized rock fragments.

The crack was observed to extend to a depth of about 1.0 metre and followed a path downwards through the fill that interconnected a series of small voids around the end of a large boulder. There was no evidence of frozen material or ice structures within the fill.

3.0 SUMMARY OF OBSERVATIONS

- 1) The top portion of the dam crest, about 1.5 metres in thickness, appears to have been constructed using a coarse, random fill material that contains a relatively large amount of oversize material. It was observed to be gap-graded, i.e. it comprises very coarse material and relatively fine material but there is a relative absence of the intermediate sized material necessary to provide proper infilling of voids and to effect soil interlock.
- 2) The material was observed to be loose in all three slot trenches which may indicate that the fill material had not been properly compacted during construction.
- 3) Several fist-sized voids were observed within the fill and generally occurred in areas adjacent to or within zones having a high cobble or boulder content. Typically, a fist-sized void would be observed in the space surrounding the contact surfaces of two or more large cobbles or boulders.
- 4) The crack trace, although partial infilled, appeared to follow a path of least resistance around the ends of cobbles and boulders and progressed downward as a series of interconnected voids or partially filled void spaces.

4.0 PROPOSED METHOD OF REPAIR

On the basis that the investigation revealed little or no evidence of open cracks extending below the depth of investigation it appears that the crest repair need only deal with a relatively shallow depth of material, all of which is within the freeboard zone of the dam. The repair procedures envisaged comprise the following steps:

- a) Excavate the upper 0.7 metres of material for a width of 5 metres along the upstream side of the crest. The base of the excavation would daylight to the upstream face of the dam. This bench-like excavation should extend longitudinally along the crest for a distance of 10.0 metres beyond the ends of the crack network and will thus involve most of the crest length of the dam.

-
- b) The base of the 5.0 metre wide bench-like surface along the crest should be thoroughly compacted to produce a solid, uniform and level prepared subgrade. The removal of large boulders along this surface during preparation of the subgrade should be performed in conjunction with the compactive effort.
 - c) Import suitable and select native soil from a local borrow source that is well graded and possesses sufficient fines content to act as a soil binder.
 - d) Place and compact the imported fill material in 200 millimetre thick layers along the full length of the excavation with equipment suited to the type of fill material (ie: pad or sheepsfoot compactors for fine grained clays and silts or smooth drum compactors for sands and gravels).
 - e) The completed backfill along the crest should be capped with a minimum thickness of 200 millimetres of traffic gravel or other suitable wear surfacing material.
 - f) The slope of the completed earthwork should be trimmed to a uniform surface at a slope of 2.0 horizontal to 1.0 vertical.

The excavated material arising from step (a) can be locally wasted adjacent to the north edge of the backslope toe berm where it can be trimmed to complement the berm.

As an alternative to disposing of the excavated material and providing new material from elsewhere, excavated materials removed from along the crest of the dam could be locally stockpiled and processed through a rock screen or grizzly to remove rock particles and boulders greater than 150 millimetres in diameter. The resulting material could then be reused as backfill along the dam crest. The realized quantity would be insufficient to complete the work and some supplementary material would be needed.

The alternative of merely recompacting the crest at surface with a heavy vibratory compactor is now viewed as probably being somewhat ineffective at depth because of the gap-graded nature of the material and its boulder content.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The results of the investigation described above do not provide clear evidence concerning the cause of the cracking which is observed, and which has been a feature of the condition of the crest for many years.

The sub-crest traces of the cracking, as revealed by the test trenches, do not provide a basis for registering serious concern for embankment performance related to use of the reservoir to full supply level (± 2.0 m of freeboard with top-of-core ± 1.5 m below crest) However, were the reservoir level to encroach substantially on the freeboard for a period of time

(unusual flood, etc.) the nature of the crest materials may permit some leakage and it would be exacerbated by the cracking.


The indicated repairs would serve to return the offending portion of the crest width to a good state of repair but, unless the gap-graded material is fully removed (± 1.5 m depth), a performance question will remain. In addition, there is no assurance that similar cracks will not develop in future unless the over-steepened face of the present section (see Section 2.1 above) is the primary cause of the problem. As such, it is important to appreciate that there may be need to repeat the repair process at some future time, whether or not the repair removes material sufficient to expose the upper surface of the core.


Golder Associates considers that it is not critical to effect the repairs detailed above immediately but, because they are easier to perform when the reservoir is at its current level (spillway sill), repairs should be done before the pond is refilled to FSL. Even after repair, refilling should not be done until a mine operator assumes responsibility for the Fresh Water Supply Dam, and can observe its performance on a routine basis.

We believe it is necessary to reach some agreement concerning repair of the cracks (steps "a" through "f" outlined above) vs. undertaking more extensive crest improvements because the costs will be substantially different and because the more extensive work would serve to improve the dam, rather than to just maintain it.

Finally, the outlined repair program will be quite expensive (could exceed \$20,000 before contingency allowance) and there appears to be no basis from which to consider the work as urgent provided the reservoir is maintained at its spillway sill level.

Yours truly
GOLDER ASSOCIATES LTD.


for H.G. Gilchrist, P.Eng.


G. Gagnon, C.E.T.

HGG:GG/cgs

APPENDIX III

**FIELD INSPECTION MEMO
SEPTEMBER 22, 1995**

MEMORANDUM
Golder Associates Ltd.

TO: Anvil Range Mining Corporation
Attention: Mr. Dick Arndt
Mr. Ian Horne

September 22, 1995
952-2431

FROM: Golder Associates Ltd.
H. Glen Gilchrist

RE: GEOTECHNICAL INSPECTION

Geotechnical Inspection:

- a) Fresh Water Supply Dam
- b) Down Valley Tails Project
- c) North Fork Rose Creek Causeway (Flow-Through component)
- d) Certain Waste Rock Dumps (Overlooking North Fork Rose Creek)

1. INTRODUCTION

The purpose of this field memo is to highlight any items requiring immediate attention, such having been discovered during inspection of the referenced works/structures during the period Sept. 20 to Sept. 23, 1995.

2. FRESH WATER SUPPLY DAM

- a) Crest cracking parallel centre line has not occurred during winter 94/95 to any significant degree, compared with 93/94 for instance.
- b) Cracked condition of crest still causes concern respecting operation at levels above spillway invert (see last year's memo to KPMG).
- c) Given existing condition of crest and the belief that core top is some two feet below crest of dam, current water level (about 0.9 m [min.] below crest level) is too high. It is recommended that water level be lowered by at least 1.0 m by removal of spillway stoplogs. Release should be controlled.
- d) To prevent over-filling of reservoir in future stoplog guides should be modified to be assured of correct operation.

3. DOWN VALLEY PROJECT

3.1 Diversion Canal

- No maintenance is needed.

3.2 Intermediate Dam

- The spillway at the north abutment has a left side earth bank which needs to be raised near its upstream end. The grade from dam crest to the road crossing is to be

consistent. Dump trucks, spreading dozer and packer should be used with locally available material.

- No other maintenance is required.

3.3 Cross Valley Dam

- The south abutment road is directing drainage into the toe berm. This has caused erosion of the berm and partial blockage of the west toe drainage culvert. Redirect drainage to the left (downstream) side of the road and dig out both ends of the culvert. Backfill erosion gulley with coarse sand and gravel.
- The Polishing Pond is at or somewhat above full design level. It should be kept at spillway invert level, not above.

3.4 North Valley Wall Interceptor Ditch

- At the absolute upstream end (upslope from a point between Truck Shop and Gatehouse). The dyke needs to be raised and the crest widened. On a preliminary basis, use dyke top 2 m above channel. Invert and top width of 5 m. Dumped and spread material from the nearby glacial till borrow area would be the approach recommended.
- Similarly, the channel dyke just beside the road where it descends to the Intermediate Dam also needs to be strengthened. Material is being taken from its backslope by road ditch maintenance procedures. Install a dyke section with ≥ 5 m top and crest level 1.5 m above invert. Construction lifts and compact, using glacial till (See Attachment 1).

4. NORTH FORK ROSE CREEK CAUSEWAY

Flow through section of causeway is passing creek flow with out apparent difficulty. No attention needed. Upstream pond level monitoring should be reinstated (it is understood that there used to be an automatic data logger there). The purpose of the data is to be assured / forewarned that the capacity to carry flow is not diminishing with time.

5. WASTE ROCK DUMPS

Dumps overlooking the North Fork Rose Creek upstream of the Causeway have been inspected (base area & crest edge) and there is no apparent evidence that movement is occurring.

6. CONCLUSIONS

Aside from the requirements for pre-winter maintenance and Freshwater reservoir lowering as noted above, no other immediate maintenance is required. The project components are considered to be in a condition suitable to their function (see Attachment 1).

ATTACHMENT 1

Reference: North Valley Wall Diversion Channel

The diversion channel is delivering water to a culvert beneath the main road going to the borrow area downstream beyond the Down Valley Project. That culvert is too small and the channel which goes from there to the Cross Valley Dam is gradually being filled in as the low level road is gradually improved. Capacity to pass a large flood is inadequate.

Plans should be made to remove the lower road and to install much larger culvert (a bridge would be better for winter icing avoidance).