Deloitte &
Touche

Little Creek Pond Emergency Spillway Vangorda Mine Yukon Territory

Report No. 1CD003.01

December, 1998

STEFFEN ROBERTSON & KIRSTEN
Consulting Engineers

1CD003.01

LITTLE CREEK POND EMERGENCY SPILLWAY VANGORDA MINE YUKON TERRITORY

Prepared for:

DELOITTE AND TOUCHE
1City Centre Drive
Suite 1100
Mississauga, Ontario
L5B 1M2

Prepared by:

STEFFEN ROBERTSON AND KIRSTEN (CANADA) INC.
Suite 800, 580 Hornby Street
Vancouver, B.C. V6C 3B6
Tel: (604) 681-4196 ● Fax: (604) 687-5532
E-mail: vancouver@srk.com Web site: www.srk.com

DECEMBER, 1998

1CD003.01

LITTLE CREEK POND
EMERGENCY SPILLWAY
VANGORDA MINE
YUKON TERRITORY

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1CD003.01

LITTLE CREEK POND
EMERGENCY SPILLWAY
VANGORDA MINE
YUKON TERRITORY

1. Introduction

In August 1998, Steffen Robertson and Kirsten (Canada) Inc (SRK) was retained by Deloitte and Touche to design and manage the construction of an emergency spillway for the Little Creek dam at the Vangorda/Faro Mine, Yukon Territory. The location of the mine is shown on Figure 1 and a site plan of the Little Creek dam is presented on Figure 2.

SRK was asked to review the hydrology of the site, develop a water balance for the Little Creek seepage collection pond, prepare design recommendations for the spillway and prepare construction drawings and technical specifications. A plan of the spillway is shown on Figure 3.

As construction of the spillway was fast tracked, SRK did not prepare a detailed design report prior to construction. An on site meeting was held on August 25, 1998 between SRK, Deloitte and Touche Inc. (DTI) and DIAND. The general specifications of the spillway were agreed to at that meeting. Following the meeting, SRK in association with Pat Bryan (Hydrologist) developed the hydrology, water balance and design flows for the pond and spillway. SRK then prepared construction drawings for the spillway and forwarded them to the site. Eric Denholm of (DTI) was responsible for on-site supervision and construction was completed by DTI personnel. The project was financed partly by DIAND and partly by DTI. Authorisation to proceed with the work was received on September 10, 1998. Work started on September 14, 1998 and was completed on October 15, 1998.

This report provides a summary of the hydrology and water balance analyse, design details of the spillway and outlet facility, construction drawings and a summary of the work completed.

2. Background

The Little Creek seepage collection pond was built in 1990 by Pelly Construction. The dam was designed for Curragh Resources Inc. by SRK (SRK, 1990). The dam is about 13.5 metres high and based on a recent survey, the low point of the crest is at El. 1113.8. The current maximum operating level of the pond is El.1112.6, which would provide an operating freeboard of 1.2m. The crest of the dam was originally designed with a crest elevation of EL. 1114.5m and a maximum operating freeboard of 1.9. The original design also provided for storage of a 200 year, 24 hour runoff event based on a catchment of 0.26 km^2. Under these conditions, there would have been a 1m freeboard maintained below the dam crest and construction of an emergency spillway was deferred until more accurate actual seepage and runoff data was collected.

The pond was designed to collect seepage from the Vangorda Pit and waste dumps. As the seepage was expected to be acidic and high in metal content, a system was put in place to pump the collected water to a treatment plant before discharge into the adjacent Vangorda Creek. The pond contains an intake and wet well with a pumping system capable of up to 900 USgpm. An HDPE pipeline conveys the water to the treatment facility. Current practice at the mine during the shutdown period, is to pump water collected in the pond to the Vangorda pit.

The design objectives for the spillway that were agreed to at the August 1998 meeting included the following:

- pass the peak flow during a 200 year runoff event while maintaining a reasonable freeboard;
- convey the flow to Vangorda Creek without impacting the toe of the dam and without significant erosion to the hillside;
- develop operating rules for the pond that would contain the runoff event within the pond and minimise the likelihood of discharge through the spillway;
- consider in the design, mitigating factors such as the ability to maximise the pump rate to the treatment plant and temporally interrupting drainage inflow from the Vangorda Pit.

3. Flood Hydrology

The key design objective for the emergency spillway in the Little Creek Dam is to allow safe passage of the 200-year flood event. In assessing how the spillway would perform during this event, it was necessary to develop an understanding of the volume characteristics of the flood. Determination of the instantaneous peak flow was of less importance because the Little Creek Pond possesses a large storage capacity that would significantly attenuate this peak. This section of the report describes the steps taken to estimate the water balance associated with the pond during a 200-year flood event. As it was unknown over what time frame the flood inflows could exceed the pumping capacity to the water treatment plant and result in a continuous rise of the reservoir level, the 200-year flood event was characterised for a range of durations from one day to one year.

The flood event was estimated using a technique known as Regional Analysis. This technique involves transposing the flood data from regional streamflow gauging stations to the dam site. Application of the technique entailed six broad steps.

Firstly, the networks of streamflow gauging stations in the central Yukon and the interior of Alaska were searched to find data representative of the dam site. In conducting the search, emphasis was placed on finding stations that gauge small catchments and that also have long periods of record. Table 1 provides details of the 14 stations that were identified in the search. These stations command catchments ranging from 13.7 to 7,250 km^2 and have records that span from 7 to 48 years. The flood data were obtained from the gauging networks of three government agencies, namely the Water Survey of Canada (WSC), Indian and Northern Affairs (IANA) and the U.S. Geological Survey (USGS). Perhaps the most important data were obtained from the streamflow gauging station located on Vangorda Creek. The Little Creek Pond is wholly contained within the catchment of this stream.

The second step in the analysis involved patching the daily streamflow records by making estimates for missing data. The records for twelve of the stations were complete and required no patching. The records for Vangorda Creek and Wheaton River required some infilling of missing data. Details of the patching exercise are presented in the footnotes to Table 1.

The third step involved extracting a total of ten annual series of flood values from each daily streamflow record. All of the annual series had one characteristic in common – they contained a list showing the highest discharge in each water year (The water year was defined as the period October 1 to September 30). The differences in the ten annual series related to the period over which the highest discharge was defined. The defined periods were 1, 2, 3, 7, 10, 30, 60, 90, 183 and 365 consecutive days.

The fourth step entailed fitting a theoretical frequency distribution (Log-Pearson Type III) to each annual series assembled in Step 3. This meant a total of 140 fittings were undertaken (i.e., 14 stations x 10 annual series per station). The fitted frequency distributions were then used to predict the magnitude of the 200-year flood discharges at each station for durations ranging from 1 day to 365 days. Steps 3 and 4 were performed using a suite of computer programs developed by the USGS for processing hydrological data (viz., IOWDM2.4, SWSTAT3.2 and ANNIE2.5). Table 1 summarises the results obtained from performing Step 4. To facilitate comparison of the floods generated on the differently sized catchments, the flood values in Table 1 have been expressed as unit discharges in units of $L/s/km^2$ (i.e., the absolute flood discharge has been divided by the contributing catchment area).

The fifth step involved transposing the 200-year flood values from the gauged sites to the Little Creek Pond catchment. Originally, it was thought that the unit flood discharges would exhibit an inverse trend with catchment area, particularly for the shorter durations of 1 to 7 days (i.e., it was assumed that the unit flood discharges would increase with decreasing catchment area). Plots of unit flood discharge versus catchment area revealed this was not the case. For the range of catchment sizes used in this analysis, the unit flood discharges were found to be independent of catchment area and, therefore, no adjustment was necessary to make them representative of the flood hydrology of the Little Creek Pond catchment. Based on the unit flood discharges in Table 1, two estimates of the inflow hydrograph to the Little Creek Pond were prepared, one being designated the "best estimate" and the other the "conservative estimate". The former estimate was determined by taking the average of the unit flood discharges of all 14 stations. An examination of Table 1 shows that the "best estimate" values are all greater than the predicted 200-year flood values for Vangorda Creek, which is the gauging station believed to be the most representative of the Little Creek Pond flood conditions. The "conservative estimate", on the other hand, was derived using an envelope approach. For durations from 1 to 7 days, the "conservative estimate" was set equal to the maximum of the flood values predicted for the 14 streamflow gauging stations. For durations greater than 7 days, the "conservative estimate" was set equal to a value between the highest and the second highest flood values. This latter procedure was adopted because the highest flood values in this table, for durations of 10 to 365 days, were judged unrepresentative of the conditions at the Little Creek Pond. The highest flood values are associated with a catchment that has a mean annual runoff (MAR) of 624 mm, which is over three times greater than the estimated MAR of the Little Creek Pond catchment.

The sixth and final step in the analysis entailed constructing the 200-year flood hydrograph for the Little Creek Pond catchment. Two estimates of this hydrograph were created, one based on the "best estimate" values of unit discharge and the other on the "conservative estimate" values. Figure 4 graphically portrays these two hydrographs and the following points should be noted:

- The hydrographs possess a daily time step and cover the period from January 1 to December 31;
- The peak daily discharge occurs on May 31 (based on the approximate average date on which the peak is observed to occur at streamflow stations in the region);
- The hydrographs represent the runoff from the total area that drains by gravity to Little Creek Pond, including the area controlled by the Vangorda Waste Dump collection ditch (a total of 0.72 km^2); and,
- The hydrographs were given a "symmetrical" shape.

To create the "symmetrical" shape, the flow rate was made to progressively increase towards the peak and then progressively decrease away from it. This was accomplished by placing the daily flows, from largest to smallest, in an alternating pattern about the peak. Accordingly, the largest daily flow was assigned to May 31, the second largest flow to May 30, the third largest flow to June 1, the fourth largest flow to May 29 etc. Beyond the tenth largest flow, this placement pattern was modified to create a skewed appearance to the hydrograph to approximate the shape of natural hydrographs in the region.

The 200 year "best estimate" hydrograph has a daily average peak of 148 L/s, which corresponds to a total volume of 12,800 m^3 during that day. The similar numbers for the 200 year "conservative estimate" hydrograph are 284 L/s and 24,600 m^3. The 200 year "best estimate" and "conservative estimate" hydrographs have annual average flows of 10.8 L/s and 14.4 L/s, respectively. As a comparison, the long-term average yield from the Little Creek Pond catchment is estimated to be about 4.4 L/s.

4. Water Balance Analysis

The seepage collection system for the Vangorda Mine comprises the following elements:

- A storage reservoir (Little Creek Pond) with an estimated capacity of 122,000 m^3 below the spillway invert elevation of 1112.8 m;
- A channel for collecting seepage from the southern portion of the Vangorda Waste Dump (known as the Vangorda Waste Dump Collector Ditch);
- pump from LCD to V.G. Pit
- The Vangorda Pit with a total capacity of about 4,600,000 m^3;
- A water treatment plant with a flow capacity of 2000 USgpm (10,900 m^3/d);
- A pumping system for delivering water from the Vangorda Pit to the Little Creek Pond; and,
- A pumping system for delivering water from the Little Creek Dam to the water treatment plant with a maximum capacity of 900 USgpm.

Ideally, these elements should act together to prevent the release of contaminated drainage to the receiving environment from Little Creek Pond. To demonstrate the pond's current handling capacity SRK has modelled the impact of the 200 year flood event.

The model is basically a spreadsheet set up to simulate the performance of the Pond during the occurrence of the 200-year wet year. The model was operated on a daily time step for the period January 1 to December 31. Inflows to the Pond were characterised using the estimates of flood hydrology made in Section 3, both for the "best estimate" and "conservative estimate" hydrographs. The model was run under the following conditions:

- No significant reclamation measures were assumed to be implemented at the Vangorda Waste Dump. These measures will result in an estimated 20% reduction of the catchment area draining to the pond by gravity. For the purpose of this study, the catchment area was assumed to remain unchanged from what it is today (i.e., 0.72 km^2).

- Water was assumed to be pumped from the pond to the water treatment plant at a rate of 600 USgpm. This is 67% of the installed pump capacity of 900 USgpm and 30% of the design capacity of the water treatment plant (2000 USgpm).

- The reservoir was assumed to be drawn down to a minimum operating level of 1109.0 m, which is 2 m higher than the value recommended in the pond's current operating manual.

- Water could be pumped from the Vangorda Pit to Little Creek Pond at a maximum rate of 900USgpm.

Further details on the model setup, particularly as they relate to the adopted operating rule for the reservoir, are presented in Table 2.

The spreadsheet model was run twice, once with the "best estimate" hydrograph and once with the "conservative estimate" hydrograph. Figures 4 and 5 present the results for the respective model runs. Each figure comprises five graphs, one for each of the five main components of the pond's water balance. The top two graphs represent the main inputs to the pond, namely:

- runoff from the total catchment that drains by gravity to the pond;
- and, dewatering flows pumped from the Vangorda Pit to the pond. The next two graphs represent the simulated outflows from the pond and comprise:
- abstraction of water from the pond to the water treatment plant; and,
- spillage through the pond's emergency spillway. The bottom graph depicts how the water level in the reservoir varied during the simulation. This last graph represents the storage component of the pond's water balance.

Figure 5 indicates how the pond would behave during the passage of the best estimate for the 200-year wet year. As indicated by the two bottom graphs, no spillage would occur during this event. It should be noted, however, that during the peak inflow months, there would be no dewatering of Vangorda Pit. The excess water in the pit would be stored in the Vangorda Pit for treatment in the following year.

The spreadsheet model was also run using the "conservative estimate" hydrograph. Figure 6 shows the simulated behaviour of the pond using the more extreme estimate of the 200-year wet year. As shown the lower two graphs, the water level in the reservoir would rise to the spillway invert elevation (1112.8 m), allowing a small amount of spillage to occur.

A third simulation was undertaken to ascertain whether or not this spillage could be prevented if a more stringent set of operating rules was adopted. Specifically, the pumping rate from the pond to the water treatment plant was increased from 600 to 900 USgpm and the minimum operating level was lowered from 1109.0 m to 1107.0 m. These revisions resulted in no spillage.

5. Spillway Design

5.1 Culvert Sizing and Design Discharge

The analysis undertaken in Section 4 indicates that the seepage collection system has a reasonable likelihood of preventing spillage of water during the 200-year wet event. However, this potential is predicated on two important conditions:

- Neither the pumping system nor the water treatment plant would experience a mechanical failure during periods of high inflow to the reservoir; and,

- Site personnel would monitor the conditions at the pond on a frequent basis, especially during periods of high potential for high inflows.

Because neither of these conditions can be guaranteed absolutely, there was a need to provide the pond with an emergency spillway. This section describes the analysis undertaken to estimate the design discharge for this structure.

The pond has a large storage capacity relative to the size of its catchment. Accordingly, the storage capacity can be used to reduce the instantaneous peak of the inflow hydrograph, resulting in a smaller outflow peak through the spillway. The amount of reduction that can be achieved is a function of the following factors:

- shape and volume of the inflow hydrograph;
- The storage characteristics of the reservoir; and,
- The hydraulic characteristics of the spillway's control section.

The first two items were quantified, however, the last item was determined by trial and error using different pipe diameters and discharges.

The following data and assumptions were used in performing the trial and error process:

- The spillway would have an invert level of 1112.8 m;
- The peak daily volume of the inflow hydrograph would be 24,600 m^3 based on the "conservative estimate" presented in Section 3;
- The water level in the reservoir would be just lapping at the spillway crest when the peak daily flood occurred; and,
- The storage characteristics of the reservoir are as indicated by the height-capacity curve presented in the design report for the Little Creek Dam (see Figure 4.3 of SRK Report 60627).

Using the above information, it was determined that a culvert with diameter of 900 mm would be adequate to pass the 200-year flood. With this size of culvert and the assumptions outlined above, the design discharge for the spillway was estimated to be 0.8 m^3/s. To pass this discharge, the reservoir level would have to rise to an elevation of about 1113.6 m, or 0.8 m above the spillway invert level. Considering that the low point on the dam's crest is at elevation 1113.8 m, the flood would be accommodated with a freeboard of about 0.2 m.

5.2 Plunge Pool

In order to dissipate the energy in the water discharging from the culvert and to minimise scouring of the outlet channel, a plunge pool was included in the spillway design. The plunge pool design was based on a method derived by Blaisdell and Anderson (1991). The original design was based on the following design parameters:

- Design Flow = 0.8 m^3/s
- Vertical distance between culvert invert and pond surface = 1.7m
- Riprap d_{50} = 0.25m
- Culvert exit velocity = 2.2 m/s
- Velocity of jet as it plunges into pool = 6.7 m/s
- Slope of culvert = 1 percent

The plunge pool was to have a base of 1m square with the deepest point of the pool located 2.4m downstream of the culvert outlet. The design also required the deepest point to be 4.4 metres vertically below the culvert invert and 2.7 m vertically below the pond surface. The pond surface was to be 9.1 m long by 8.5 m wide. Design drawings are included in Appendix A.

During construction of the culvert, pool and the exit ditch, unexpected soil conditions required the following modifications to the design:

- Vertical distance between culvert invert and pond surface = 2.3m
- Riprap d_{50} = 0.3 to 0.5m
- Culvert exit velocity = 3.1 m/s
- Velocity of jet as it plunges into pool = 7m/s
- Slope of culvert = 3 percent
- Dist. of deepest point in pool below culvert invert = 3.7m
- Dist. of deepest point in pool below water level during the 200 year event = 1.4m
- Hor. Dist from the culvert invert to deepest point in the pool = 6.5m

The key change to the design was the relocation of the pool several metres away from the culvert invert. This would cause the cascading discharge to impact the riprapped sideslope rather than the pool itself. As a consequence additional scouring of the sideslope could result. DTI have placed oversized riprap (D_{50} = 0.75m) on the slope as additional protection to prevent this scouring. However, as a contingency measure DTI is currently considering installing a half-round culvert chute from the culvert outlet to the pool tailwater level as a means of improving energy dissipation. Details of this flume would be finalised during the next inspection to the site by SRK.

As-constructed details of the plunge pool are shown on Figures 7 and 8.

5.3 Exit Chute

An outlet channel was also designed to take flow from the plunge pool away from the toe of the dam and direct the flow into an area that would minimise erosion without the need for a costly flume or riprapped channel down to Vangorda Creek. The as-built channel has an invert at the plunge pool outlet of El. 1109.32m. The ditch runs initially for a distance of about 26m at a grade of 5 percent. The ditch then steepens to a grade of 18 percent. The entire ditch has a base width of about 1 metre and is protected with riprap. Details of the ditch are shown in Figure 8.

6. Construction

6.1 General

Work on the Little Creek Dam emergency spillway commenced on September 14, 1998 and was completed on October 15, 1998.

The spillway facility comprises a 24.4 metre long x 900mm diameter corrugated metal pipe (CMP) with an inlet invert of El. 1112.8m located at west abutment of the Little Creek Dam as shown on Figure 2. A riprap lined plunge pool was constructed below the culvert to dissipate energy from the flow. An outlet ditch directs flow from the pool away from the toe of the dam and into an area of thick natural vegetative cover, where the risk of significant soil erosion is low.

Construction supervision was performed by Eric Denholm of DTI and the installation was performed by DTI personnel. An as-built survey was performed on October 28, 1998 by Yukon Engineering Services (YES).

The work was inspected on October 7, 1998 by Mr. B. McAlpine of DIAND, Water Resources, Whitehorse.

An inspection of the emergency overflow system by Peter Healey of SRK is tentatively scheduled for the summer of 1999 as part of the annual geotechnical inspection of the Vangorda Plateau minesite.

6.2 Work Activities

6.2.1 Source of Riprap Protection

The source of the riprap erosion protection, used to line the pond and the outflow ditch, was obtained from a quarry located at the west extent of the Grum rock dump. The quarry was previously established while the mine was operating. The rock in the riprap quarry is hard and angular and does not contain any visible sulphide mineralisation.

The quarry was inspected on August 25, 1998 by Messrs. Denholm (DTI), Healey (SRK) and McAlpine (DIAND). It was concluded, at that time, that sufficient blasted inventory was present to meet the needs of the project although the blasted inventory would need to be cleaned of fines prior to use as riprap.

In the absence of a conveniently located and sized screening facility, the blasted inventory was sorted or “cleaned” using a CAT 235 backhoe. Loose material was cascaded over a hard edge or a loose pile of between 2 to 4m in height to segregate the fine material from the coarse. The coarser material was then loaded from the toe of the slopes and hauled to Little Creek dam.

An estimated 125 m^3 of riprap was hauled to Little Creek dam with an average particle size diameter of 250 to 300 mm.

6.2.2 Culvert Excavation

The excavation for the CMP was performed with the CAT 235 backhoe with field control performed by Eric Denholm.

Excavation started at the upstream side of the dam to full depth and proceeded towards the downstream side of the dam. The maximum depth of excavation was about 2m.

The bottom width of the excavation varied from 2.7 metres to 3.1 metres (three times the pipe diameter). The sideslopes of the excavation were sub-vertical and flattened sufficiently to provide a safe work environment in the excavation.

The material excavated was a highly compacted clay till with a minor quantity of stones.

The initial excavation resulted in a grade of about 5 percent over a length of approximately 5 m. This section of the excavation was backfilled with compacted clay till in order to achieve design grade.

Following excavation with the backhoe and prior to assembly of the CMP, small depressions and irregularities in the bottom of the excavation were filled in by hand using clay till. The fill was then compacted to form a relatively smooth and even surface along the bottom of the excavation.

The overall completed grade of the excavation was surveyed at about 3 percent.

6.2.3 CMP Installation

The spillway culvert consists of a 900mm diameter CMP, with a wall thickness of 2mm. The culvert consists of four pipe sections each about 6m in length with three annular couplers. The in-place total assembled length was 24.4m.

The overhang of the culvert at the upstream end is about 0.3m (measured along the base). The resulting overhang at the downstream end is 3.5 metres (bottom of pipe).

6.2.4 Pipe Backfill

Following assembly of the CMP, clay till was placed under the haunches of the pipe and compacted by hand tampers.

Clay till, excavated from the dam was used as backfill around the pipe. Rocks greater than about 50 to 75mm in size were hand-picked from the till prior to compaction using a 56cm vibratory plate compactor in 150mm to 250mm lifts.

Compaction was achieved with 5 passes with the compactor.

6.2.5 Excavation of Plunge Pool

The initial grubbing of the area of the plunge pool resulted in a greater than anticipated depth of organic material. This meant that the actual ground elevation following grubbing was lower than expected, which required changes to the design.

These changes including moving the plunge pool further away from the culvert pipe and lowering the invert of the ditch outlet from 1110.63m to 1109.32 m. The revised outlet elevation allowed for the design 200 year flow event to pass within the natural ground rather than a constructed dyke. In the revised design, the constructed dyke around the east edge of the plunge pool and ditch provides 0.5 metres freeboard above the 200 year flow event.

The as-constructed configuration of the plunge pool and ditch is shown on Figures 7 and 8

6.2.6 Excavation of Exit Ditch

One small area of frozen ground was uncovered during the grubbing. The frozen ground covered an area of approximately 1.5m x 2.0m and was located above the west side of the outlet ditch approximately 20 metres from the ditch inlet. The area of frozen ground was located on the sideslope in natural ground approximately 1.0m above the top of the required ditch freeboard.

Survey results indicated that the grade of the ditch over the initial 26m was 5 percent. The bottom width of the ditch varied from 1.5m to 1.8m. The sideslope on the west side was in natural ground at a slope flatter than 2:1 (H to V). The original ground was grubbed clear of organic material to a height higher than the freeboard required in the design. The sideslope on the east side was established at 2:1 (H to V) in natural ground, which had already been cleared and grubbed.

An extension of the lower end of the ditch provides control over a steeper section of ground across an "old" skid trail. The purpose of the extension is to prevent significant soil erosion by allowing flow to discharge into an area of thick vegetation below the skid trail. The extension was estimated to be at a grade of approximately 18 percent.

6.2.7 Dyke Construction

A containment dyke was required along the lower (east) edge of the plunge pool and outlet ditch to provide the design freeboard (min. 0.5m) above the 1:200 year design event.

The dyke was constructed using clay till, which was excavated during construction of the plunge pool or otherwise locally borrowed. The clay till was fine grained, generally free of stones and similar in appearance to the material excavated from the dam.

The dyke around the plunge pool was constructed with a width at the base of between 2.5 and 3.0m and with sideslopes at 2:1. The dyke along the outlet ditch was constructed with a base width of between 1.5 to 2.0m and with sideslopes of 2:1. The construction method used for the dyke around the plunge pool and along the original design ditch (0 to 30m) involved spreading clay till with the backhoe, smoothing the till by hand, picking out stones greater than about 75mm in size, compacting with 3 to 5 passes of the 56cm vibratory plate compactor in lifts varying from 200 to 250mm in thickness.

The dyke was constructed to elevations estimated to provide the required freeboard as determined using field methods.

6.2.8 Placement of Riprap

Riprap, which had been previously hauled from the quarry, was placed at the inlet and outlet of the CMP. Sufficient riprap was placed to create an apron around the pipe and protect the surrounding soil from erosion.

Riprap was also placed as a lining for the plunge pool and outlet ditch. The rock was placed approximately 500 to 800 mm thick in the plunge pool and approximately 300mm thick in the ditch. All of the available riprap rock (est. 125m^3) was utilised.

The fines content of the riprap rock was generally low, although a minor quantity was present due to the incomplete cleaning at the quarry and due to the rehandling with the backhoe at Little Creek Dam.

A "pocket" of large boulders was constructed below the outlet of the CMP in order to provide additional erosion protection and energy dissipation. This pocket was in addition to the required 500mm thickness.

Additional riprap was placed under the downstream end of the CMP against the edge of the dam in order to provide extra physical support for the larger than designed CMP overhang. The effective overhang was reduced from 3.5 metres (from edge of dam) to 2.5 metres (from edge of rip rap).

Larger sized riprap was placed along the ditch extension for protection against the higher velocities that would be generated on this steeper section.

6.2.9 Final Dressing

The work areas around the plunge pool and outlet ditch were dressed at the completion of construction to remove unsightly and dangerous holes and piles. In particular, a large (2 metres high) windrow of organic debris which had been created as a result of clearing and grubbing, was removed.

6.2.10 Final As-Built Survey

An as-built survey of the work was complete by YES during a final survey relating to the work performed by the Ross River Development Corp. for DIAND.

The as-built survey was performed on October 28, 1998 following completion of construction.

7. Conclusions and Recommendations

As a result of the design changes to the plunge pool, any flow through the culvert would impact the riprapped sideslopes of the plunge pool before contacting the ponded water. This could cause erosion of the riprap and possible erosion of the toe of the dam. Although, DTI placed additional oversized riprap in this area, DTI should also consider installation of a half-round flume, which would be attached to the outlet culvert to convey flow directly into the plunge pool (see Figure 7). Modifications to the culvert may be required prior to the flume installation. Details of this flume would be finalised during the next inspection by SRK in 1999.

To lower the risk of spillage, the pumping system from the pond to the water treatment plant should maintain a pumping capacity of at least 900 USgpm. The mine should draw the water level in the LCD reservoir down to the 1109.0m level prior to the onset of winter. The current practice of pumping this water to the Vangorda Pit is acceptable during this period of suspended operations.

The mine should also fill in low points along dam crest, so that minimum elevation along crest is not less than 1114.0 m. This will provide a freeboard of 0.4 m during passage of the design flood (conservative estimate).

When funds become available, the mine should provide erosion protection for the lower steeper portion of outlet ditch that would convey the spillway releases from the plunge pool to Vangorda Creek.

This Report, **1CD003.01 - Little Creek Pond Emergency Spillway Vangorda Mine, Yukon Territories** has been prepared by:

STEFFEN ROBERTSON AND KIRSTEN (CANADA) INC.

P Healey

Peter Healey, P.Eng.
Senior Project Engineer, GeoEnvironmental

8. References

SRK Report 160636 (1990) Vangorda Plateau Development, As-built Construction Report for Little Creek Dam.

Blaisdell, F. W., and Anderson, C. L. (1991). "Pipe Plunge Pool Energy Dissipator." Journal of Hydraulic Engineering, ASCE, Vol. 117, No. 3, pp.303-323.

Tables

Calculated 200 yr event for each duration at each location

Table 1 Estimated 200-Year Floods at Regional Streamflow Gauging Stations

Streamflow Gauging Station		Length of Record	Catchment Area	Mean Annual Runoff	Authority[c]	Average discharge in L/s/km² for the following number of consecutive days[d]: (misleading)									
ID No.	Name	(years)	(km²)	(mm)		1	2	3	7	10	30	60	90	183	365
15439800	Boulder Creek near Central	18	81.0	131	USGS	265	243	216	164	139	65	47	33	16	8.2
15535000	Caribou Creek near Chatanika	15	23.8	200	USGS	183	149	120	73	71	63	47	38	24	15
10AB003	King Creek at km 20.9 Nahanni Range Road	12	13.7	290	WSC	159	134	116	97	89	77	69	57	34	17
15344000	King Creek near Dome Creek	7	15.2	100	USGS	132	125	123	105	83	44	21	13	8.7	4.8
15511000	Little Chena River near Fairbanks	30	963	199	USGS	395	373	342	214	162	69	43	35	24	13
09EA004	North Klondike River near the mouth	21	1100	379	WSC	188	168	151	113	101	81	65	52	32	18
09BA001	Ross River at Ross River	33	7250	293	WSC	122	121	119	105	94	77	53	40	23	13
15484000	Salcha River near Salchaket	48	5618	261	USGS	362	301	262	176	147	86	58	50	32	17
09AD002	Sidney Creek at km 46 South Canol Road	11	372	350	WSC	247	212	182	131	120	90	65	52	30	20
09AG003	South Big Salmon River below Livingstone Creek	13	515	246	WSC	225	196	177	122	108	79	57	46	26	17
09BB001	South MacMillan River at km 407 Canol Road	21	997	624	WSC	240	237	224	188	187	132	107	81	48	26
10AA002	Tom Creek at km 34.9 Robert Campbell Highway	18	435	218	WSC	112	109	109	105	97	85	63	58	32	18
29BC003	Vangorda Creek at Faro Townsite Road[a]	16	91.2	235	IANA	177	148	123	89	79	70	48	37	23	13
09AA012	Wheaton River near Carcross[b]	29	875	285	WSC	100	99	97	88	79	55	46	38	24	14
Little Creek Dam Inflow (Best Estimate)[e, f]		n/a	0.72	193	n/a	208	187	169	126	111	77	56	45	29	15
Little Creek Dam Inflow (Conservative Estimate)[g]		n/a	0.72	193	n/a	395	373	342	214	173	98	69	58	38	20

Notes:

a) The gauging station on Vangorda Creek is operated on a seasonal basis. Missing data within the daily record of this station were patched using a correlation with WSC Station 09BC001 (Pelly River at Pelly Crossing).

b) For Wheaton River, the largest flood of record occurred in June 1980. Because it was important to include this flood in the frequency analysis, missing data in the 1980 daily record were patched.

c) WSC = Water Survey of Canada; IANA = Indian and Northern Affairs; USGS = United States Geological Survey

d) For each station and each duration, the annual series of flood data were fitted to the Log-Pearson Type III distribution to estimate the magnitude of the 200-year flood discharge. A visual inspection revealed that the Log-Pearson Type III distribution provided a good fit to the data sets for all but a few of the stations. For the Salcha River and Little Chena River, the fit was only fair for durations from 1 to 30 days because of the existence of a high outlier.
To facilitate comparisons between the different catchment sizes, the flood values in this table have been expressed as unit discharges in units of L/s/km² (i.e., the absolute flood discharges have been divided by the contributing catchment areas).

e) The "best estimate" was derived by taking the average of the unit flood values of all 14 streamflow gauging stations.

f) The data assembled in this table indicate that unit flood discharges for durations of 1 day to 365 days are essentially independent of catchment area. Thus, the unit discharges for the larger catchments could be used, without adjustment, to represent the flood conditions on the small 0.72 km² catchment commanded by the the Little Creek Dam. One would expect a dependency on catchment area if larger catchments were included in the analysis or if durations less than a day were examined. For example, unit peak instantaneous floods should exhibit an increasing trend as catchment area decreases.

g) For durations from 1 to 7 days, the "conservative estimate" was set equal to the maximum flood value predicted for the 14 streamflow gauging stations. For durations greater than 7 days, the "conservative estimate" was set equal to a value between the highest and second highest flood values. This latter procedure was adopted because the highest flood values in this table, for durations of 10 to 365 days, were judged unrepresentative of the conditions at the Little Creek Dam. The highest flood values are associated with a catchment with a mean annual runoff (MAR) of 624 mm, which is over three times greater than the estimated MAR of the Little Creek Dam catchment.

Table 2 Summary of Assumptions and Data Used in Water Balance Spreadsheet

Item[a]	Value	Comment
Catchment area commanded by LCD[b]	0.72 km^2	Total area draining to LCD by gravity, including area commanded by VWD collection ditch.
Pumping rate from LCD to WTP	600 USgpm	This value represents a less-than-ideal level of pump discharge. At the time of its construction, the LCD was equipped with a pumping system capable of conveying 900 USgpm to the WTP. The WTP, in turn, was designed to treat a flow of 2000 USgpm.
Period that WTP is available to receive flows from LCD	May 1 to Nov 15	This was the assumed "activated" period for the WTP. During the remainder of the year, the WTP would be mothballed. The WTP would not, necessarily, operate continuously throughout the activated period.
LCD minimum operating level	42,000 m^3 (1109.0 m)	The LCD reservoir was assumed to be drawn down to this level before the WTP was mothballed for the winter.
Threshold reservoir storage for starting WTP[c]	55,000 m^3 (1109.8 m)	The WTP operates best if it is supplied a reasonably constant influent stream over a long time period. This condition can easily be met during spring freshet when runoff into the LCD is high but may be difficult to achieve during periods of low inflow. In such periods, the WTP is shutdown and water is allowed to accumulate in the LCD to a level that is sufficient to sustain the WTP for several days. The WTP is then reactivated and the water level is drawn down to the minimum operating level. The threshold criterion was built into the spreadsheet to simulate this periodic operation of the WTP during periods of low inflow to the LCD.
LCD full supply capacity	122,000 m^3	This is the total volume of the reservoir below the spillway crest elevation of 1112.8 m. The height-capacity curve for the LCD was obtained from the design report for this facility (see Figure 4.3 of SRK Report 160627, dated September 1990).
Period that LCD is available to receive dewatering flows from Vangorda Pit	Jun 15 to Nov 12	When a high snowpack portends the occurrence of a high inflow rate to the LCD, dewatering of the Vangorda Pit should be delayed until mid-June. By then, a large proportion of the spring runoff volume generated by the LCD catchment would have been treated by the WTP. During average climatic conditions, pit dewatering may commence earlier than June 15.
Maximum allowable reservoir storage while Vangorda Pit is being dewatered[d]	49,000 m^3 (1109.5 m)	This criterion was programmed into the spreadsheet so as to better reflect the actual operating conditions of the LCD. In essence, this criterion disallows pit dewatering while the water level in the LCD is high.
Average annual inflow to the Vangorda Pit	350,000 m^3	Estimated from volume of water accumulated in Vangorda Pit during the 1993 to 1995 mine shutdown. This volume comprises three main components, namely: leakage from the diversion ditches; groundwater discharge; and, runoff from the incremental catchment of the pit below the diversion ditches (approx. 0.8 km2). During each year, an attempt should be made to pump this volume of water from the Vangorda Pit to the LCD and, in turn, to the WTP. This attempt may not be entirely successful during an extreme wet year - a portion of the year's inflow may have to be stored in the Vangorda Pit for treatment in the following year.

Notes:

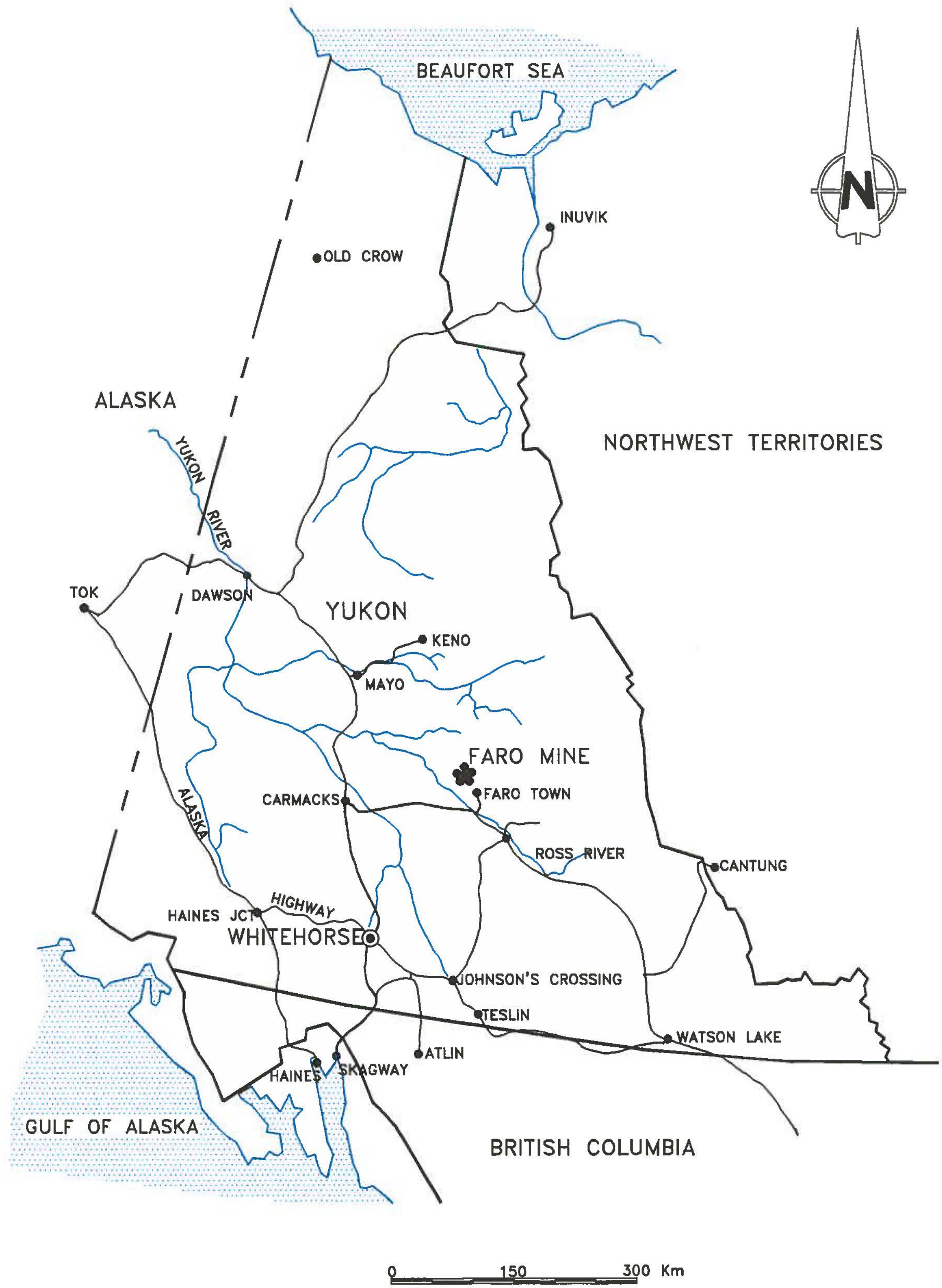
a) Abbreviations: LCD = Little Creek Dam; WTP = Water treatment plant; and, VWD = Vangorda waste dump.

b) The reclamation plan for the VWD calls for the construction of an impervious till cover over the entire waste dump. Drainage from the flatter portion of this cover will be clean and may be diverted away from the LCD. Such a diversion would reduce the LCD's catchment area to about 0.56 km^2. For the purpose of this study, the present-day catchment area of 0.72 km^2 was used in the water balance analysis.

c) The value adopted here for the threshold storage is somewhat arbitrary. In practice, the Receiver may use a different value to decide when to restart the WTP.

d) The selected value of 49,000 m^3 is somewhat arbitrary. In practice, the Receiver may use a different value to decide when pumping from the Vangorda Pit to the LCD should proceed.

Figures



STEFFEN ROBERTSON AND KIRSTEN
Consulting Engineers

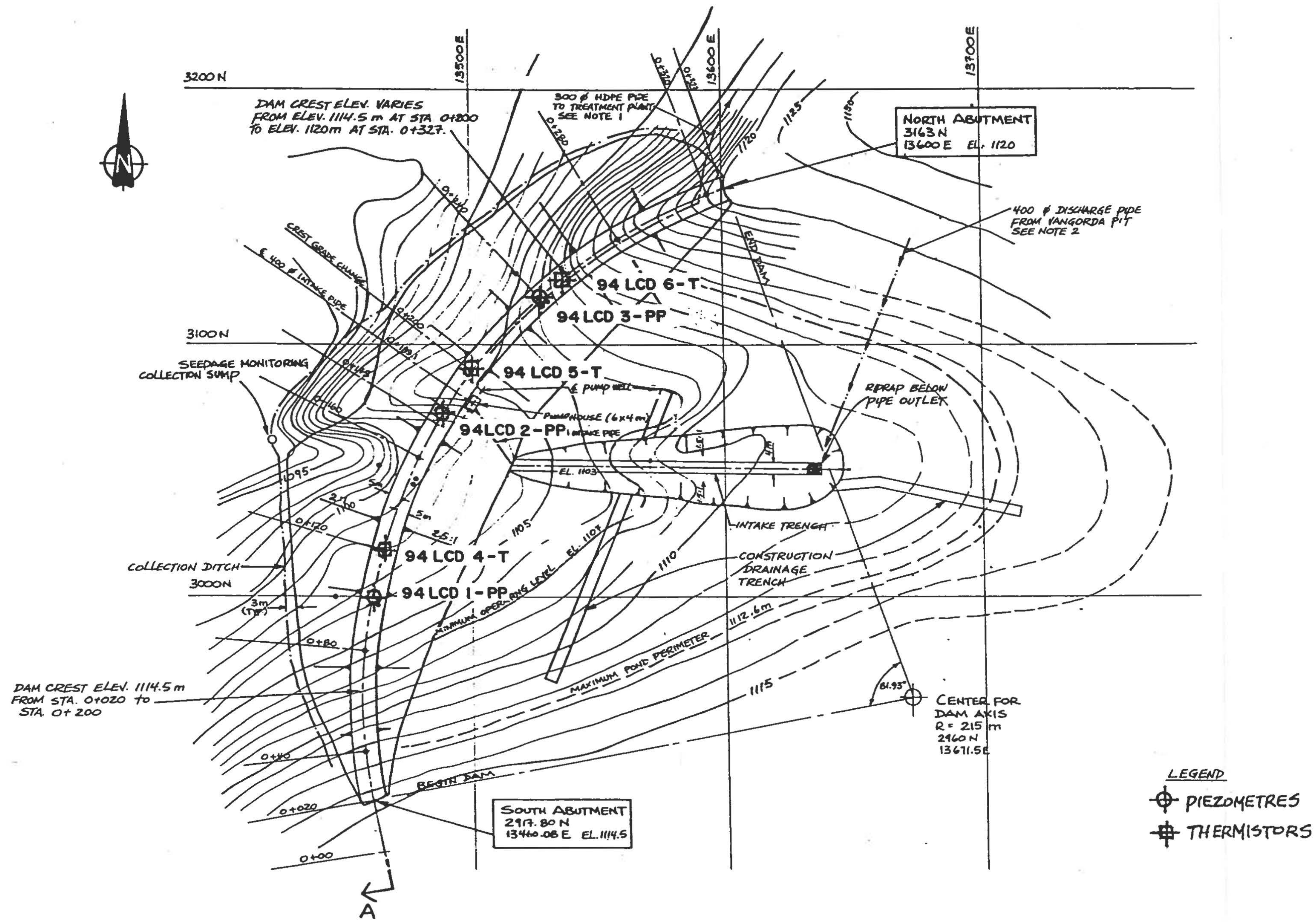
DELOITTE & TOUCHE LTD.

VANGORDA MINE

LOCATION MAP

PROJECT NO.	DATE	APPROVED	FIGURE
1CD003.01	DEC. 1998		1

FILE REF: YUKON



GENERAL ARRANGEMENT PLAN

SCALE - 1:2000

CONTOUR INTERVAL = 1 metre
GRID SHOWN IS MINE GRID

0 10 20 30 40 50 metres

STEFFEN ROBERTSON AND KIRSTEN
Consulting Engineers

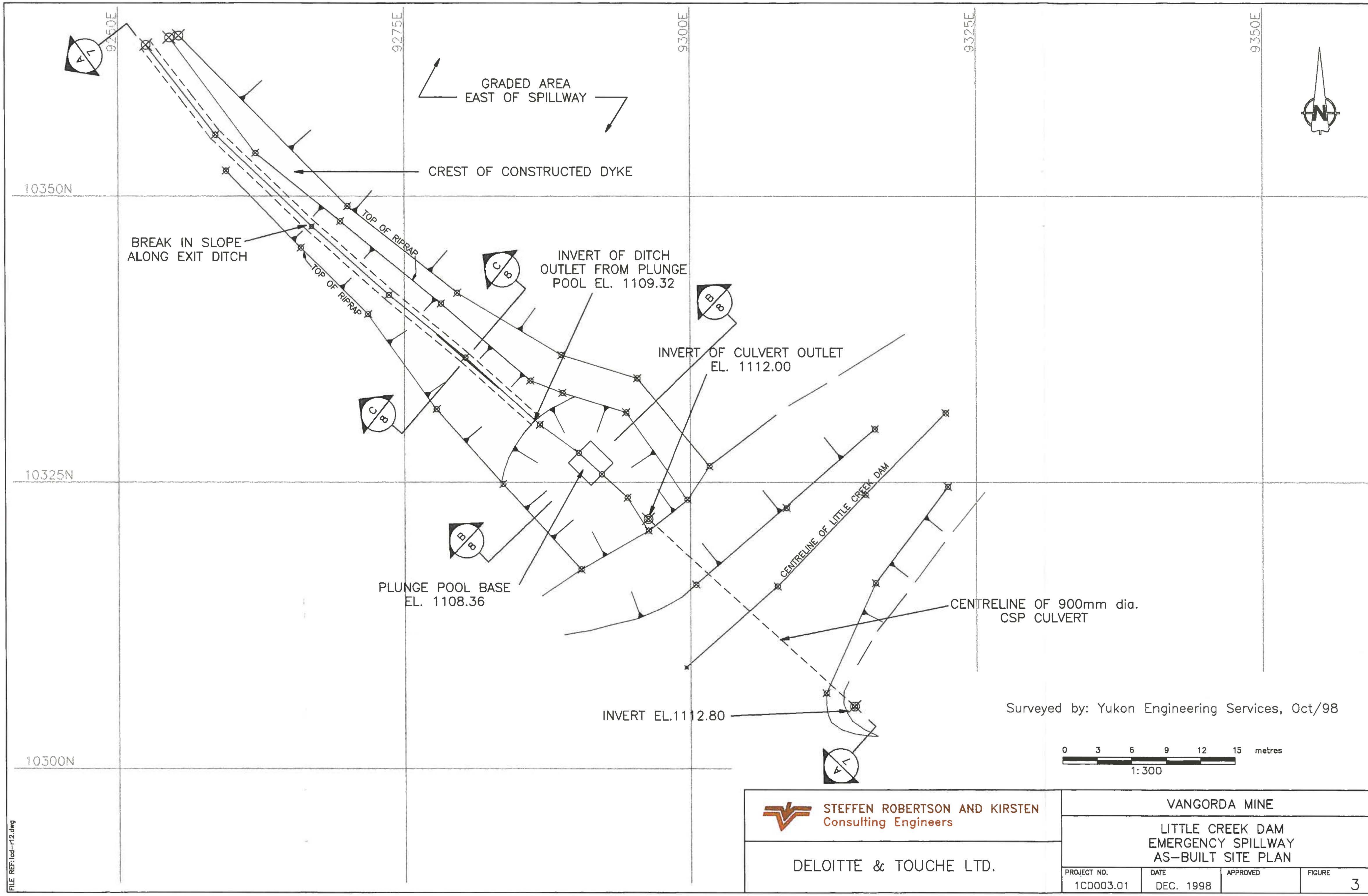
DELOITTE & TOUCHE LTD.

VANGORDA PLATEAU MINE

LITTLE CREEK DAM
GENERAL ARRANGEMENT PLAN

PROJECT NO.	DATE	APPROVED	FIGURE
1CD003.01	DEC. 1998		2

FILE REF: FIG-4


9250E
9275E
9300E
9325E
9350E
10350N
10325N
10300N
GRADED AREA
EAST OF SPILLWAY
CREST OF CONSTRUCTED DYKE
TOP OF RIPRAP
TOP OF RIPRAP
BREAK IN SLOPE
ALONG EXIT DITCH
INVERT OF DITCH
OUTLET FROM PLUNGE
POOL EL. 1109.32
INVERT OF CULVERT OUTLET
EL. 1112.00
CENTRELINE OF LITTLE CREEK DAM
PLUNGE POOL BASE
EL. 1108.36
CENTRELINE OF 900mm dia.
CSP CULVERT
INVERT EL.1112.80
A
7
B
8
C
8
N
Surveyed by: Yukon Engineering Services, Oct/98
0 3 6 9 12 15 metres
1:300
STEFFEN ROBERTSON AND KIRSTEN
Consulting Engineers
DELOITTE & TOUCHE LTD.
VANGORDA MINE
LITTLE CREEK DAM
EMERGENCY SPILLWAY
AS-BUILT SITE PLAN
PROJECT NO.
1CD003.01
DATE
DEC. 1998
APPROVED
FIGURE
3
FILE REF: lcd-r12.dwg

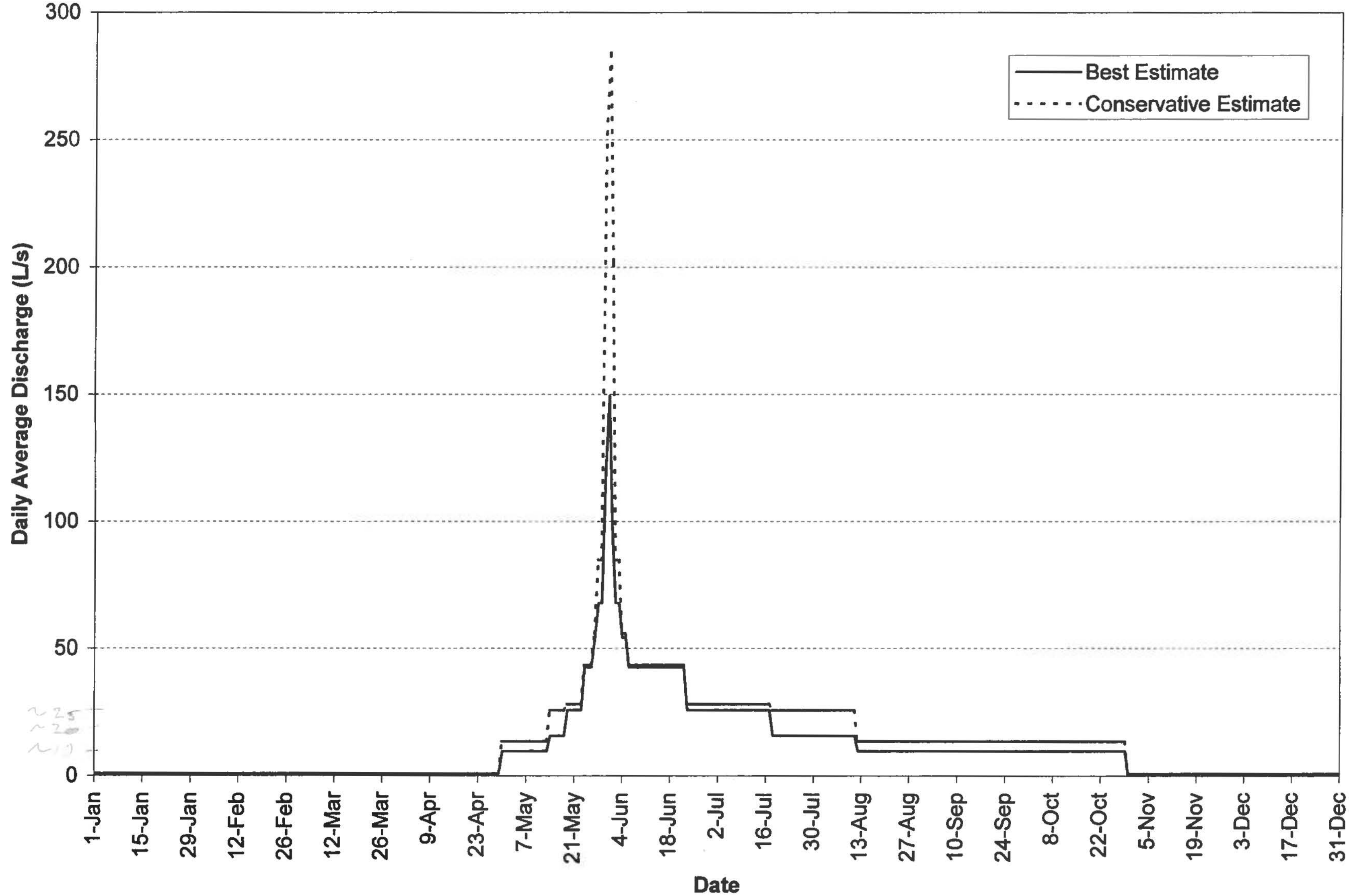


Figure 4 Synthesized 200-Year Inflow Hydrograph for Little Creek Pond

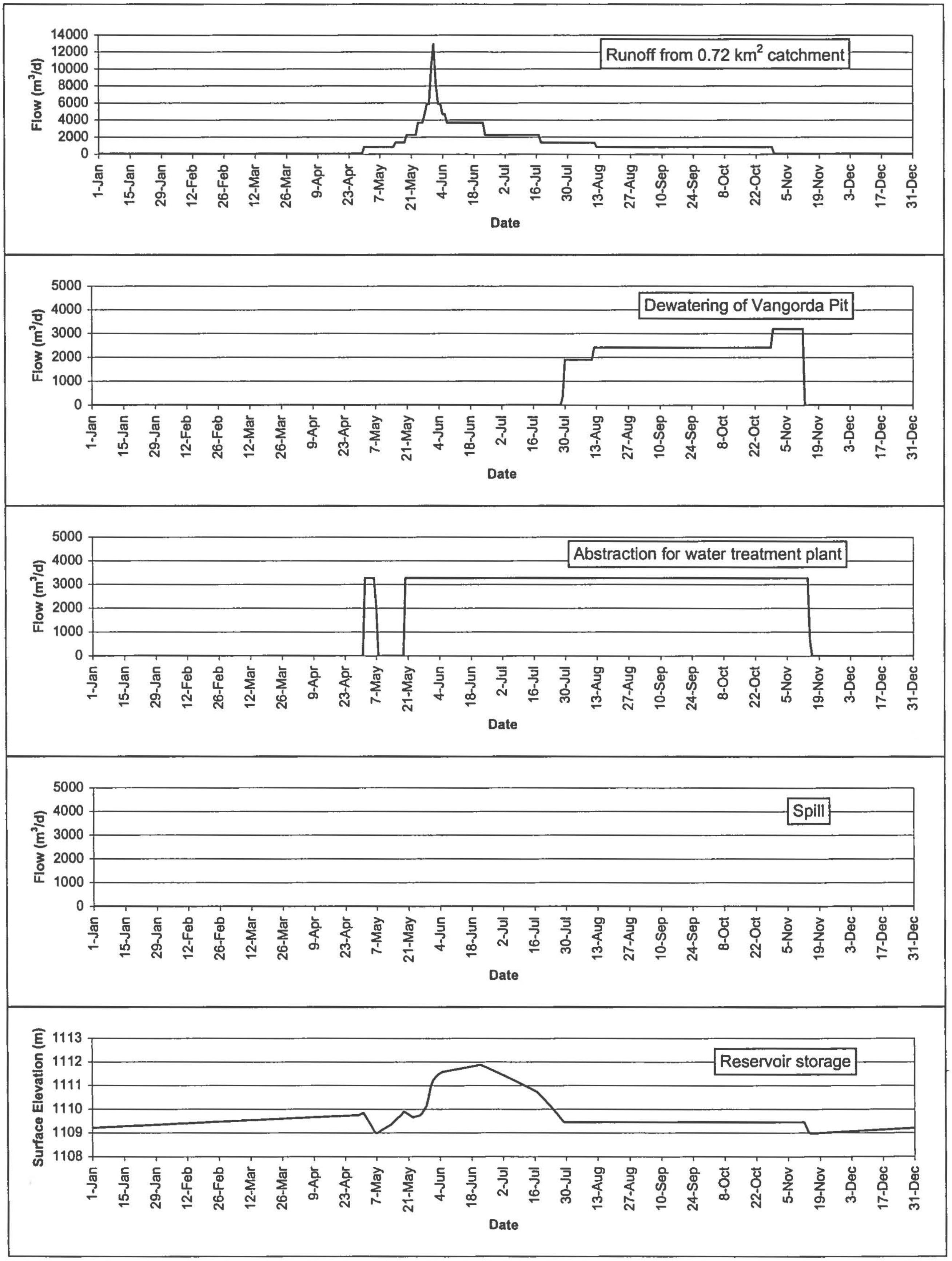
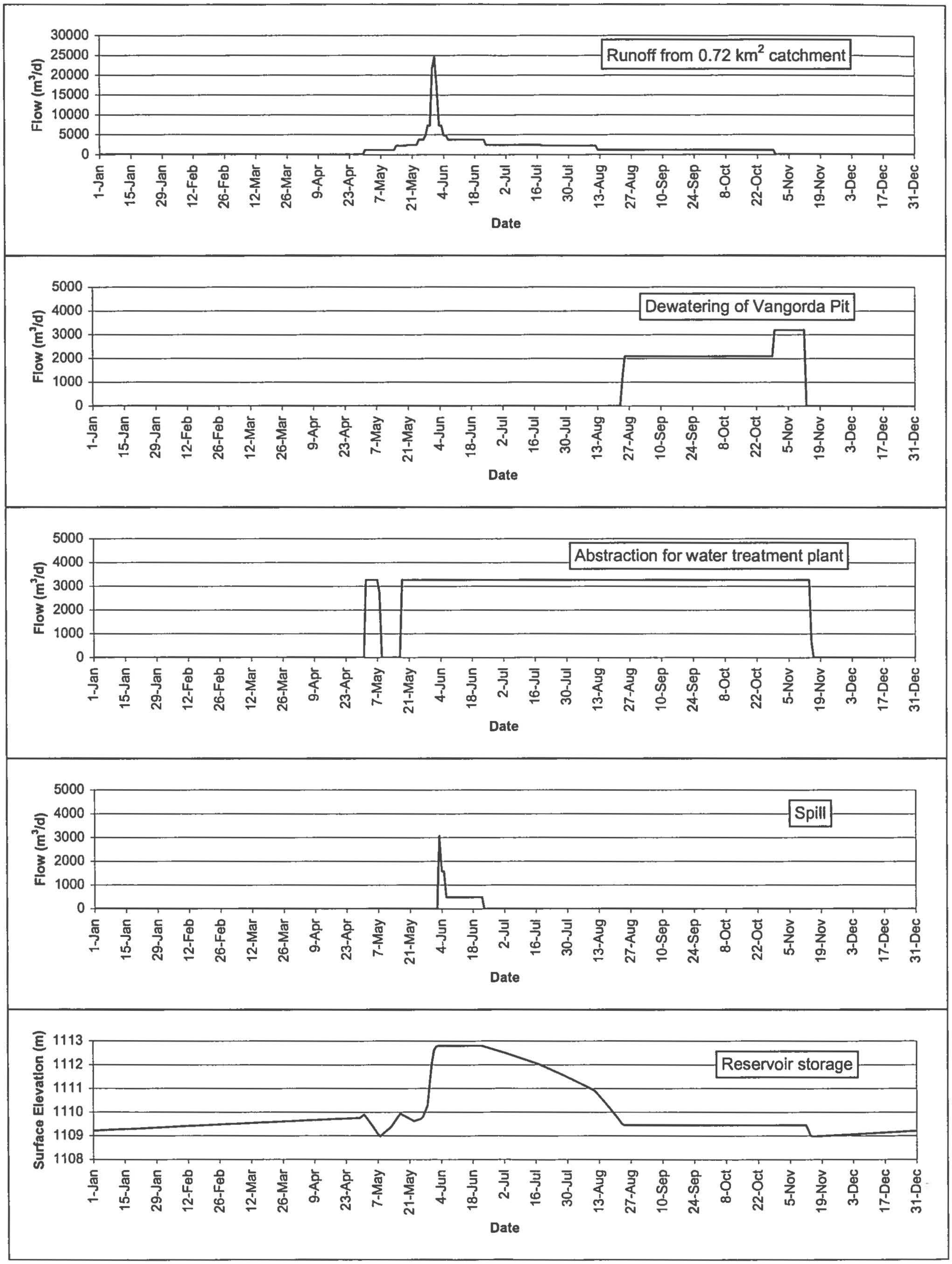


Figure 5 Simulated Behaviour of Little Creek Dam during an Extreme Wet Year (Best Estimate of Wet Year with a Return Period of 200 Years)

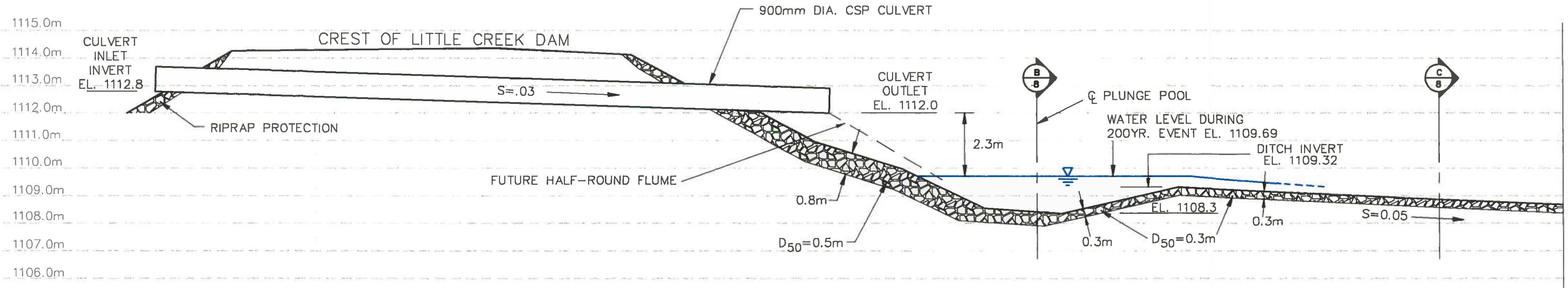
SRK Consulting
December, 1998

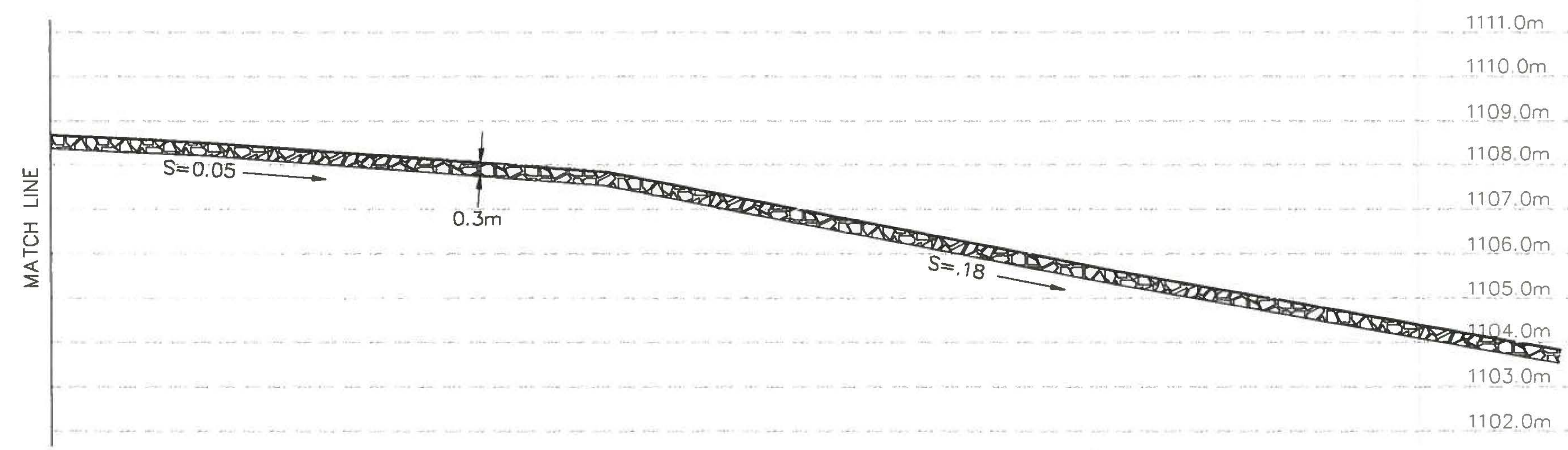


Regional Flood Analysis.xls

Figure 6 Simulated Behaviour of Little Creek Dam during an Extreme Wet Year (Conservative Estimate of Wet Year with a Return Period of 200 Years)

SRK Consulting
December, 1998





LEGEND

As-Built Survey by Y.E.S. Oct 28/98
(top of rip rap)

0 1.5 3.0 4.5 6.0 7.5 metres
1:150

STEFFEN ROBERTSON AND KIRSTEN
Consulting Engineers

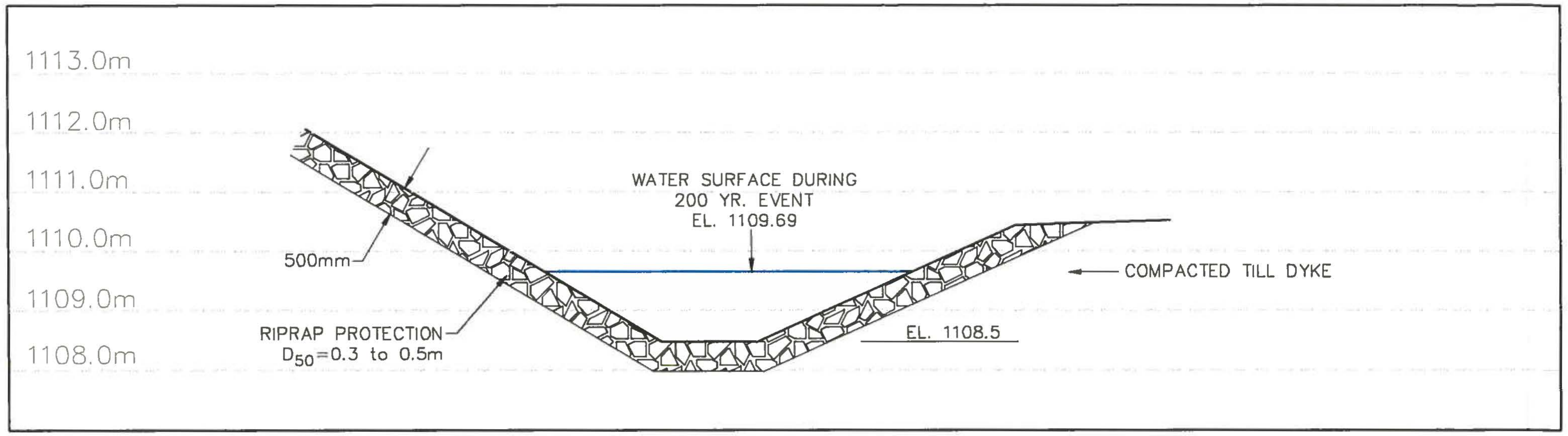
DELOITTE & TOUCHE LTD.

VANGORDA MINE

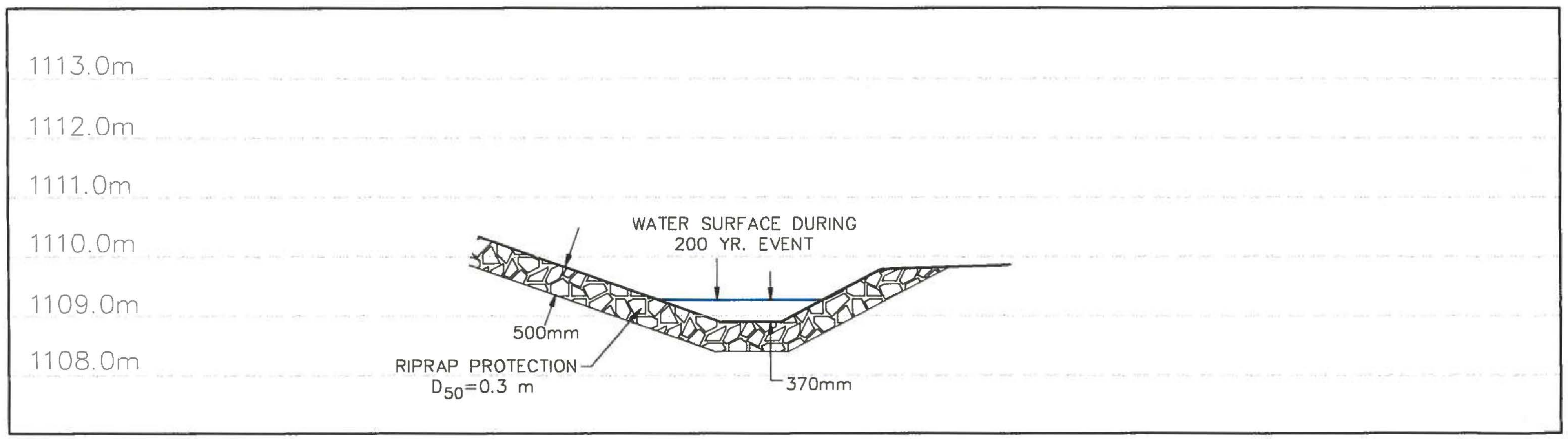
LITTLE CREEK DAM
SECTION A–A
SECTION ALONG SPILLWAY CENTRELINE

PROJECT NO.	DATE	APPROVED	FIGURE
1CD003.01	DEC. 1998		7

FILE REF:SECT-A-A.dwg



SECTION B–B – PLUNGE POOL



SECTION C–C – EXIT DITCH

LEGEND

As–Built Survey by Y.E.S. Oct 28/98 (top of rip rap)

0 1 2 3 4 5 metres
1:100

STEFFEN ROBERTSON AND KIRSTEN
Consulting Engineers

DELOITTE & TOUCHE LTD.

VANGORDA MINE

LITTLE CREEK DAM
EMERGENCY OVERFLOW SYSTEM
SECTIONS

PROJECT NO.	DATE	APPROVED	FIGURE
1CD003.01	DEC. 1998		8

FILE REF: SECT-BC.dwg

Photos

Photo 1 - Compaction of backfill around haunching of 900mm CNP culverts.

Photo 2 - Compaction of earth filled dyke.

Photo 3 - Placement of riprap in exit channel from plunge pool.

Photo 4 - Outlet of plunge pool.

Photo 5 - View from Little Creek Dam looking out over culvert outlet and the plunge pool.

Photo 6 - Elevation view of culvert outlet.

Photo 7 - View from dam over culvert outlet and plunge pool.

Photo 8 - Inlet of culvert spillway.

Photo 9 - Inlet to spillway

Photo 10 - View looking across at spillway with Little Creek pond to the left.

Photo 11 - View of pumphouse on Little Creek Dam

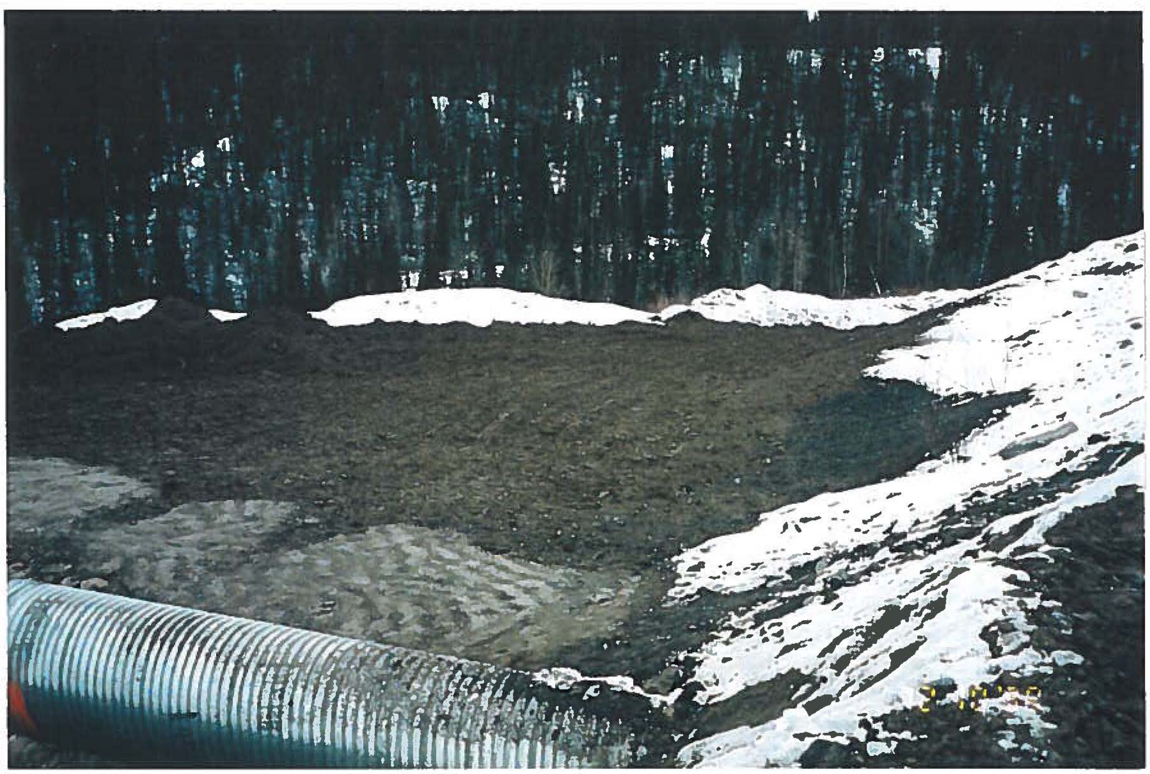
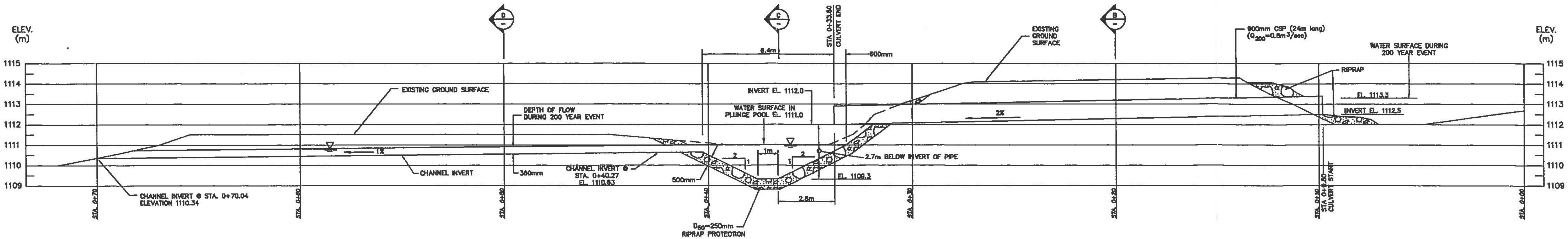


Photo 12 - Regraded area below culvert.

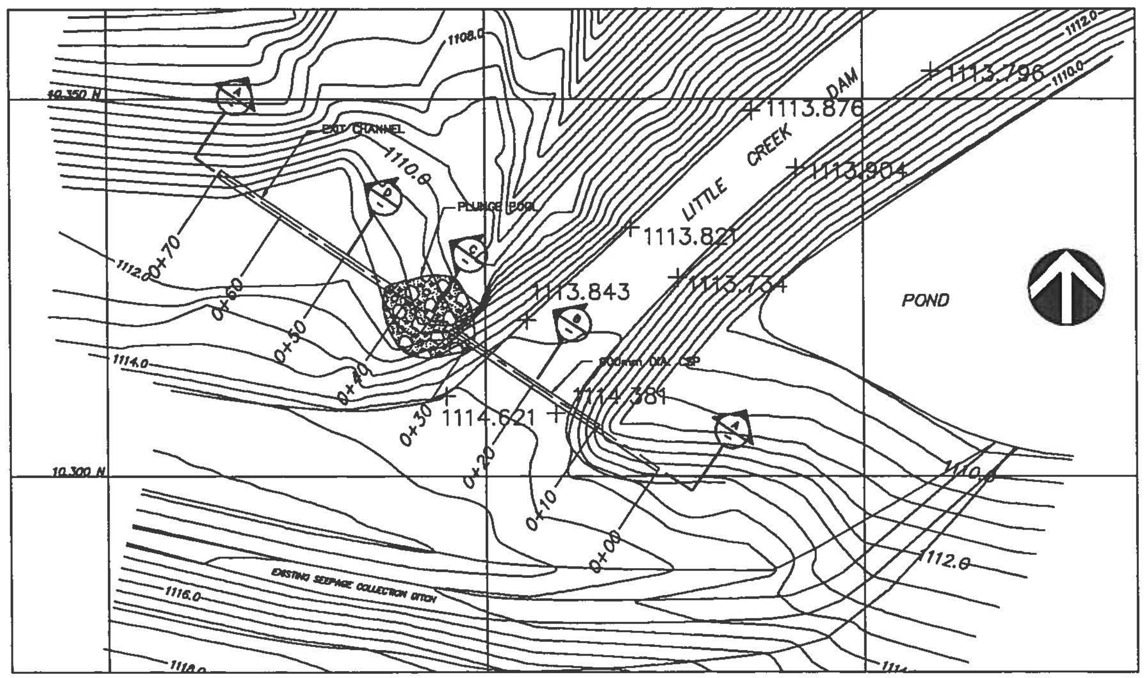
APPENDIX A

Design Drawings



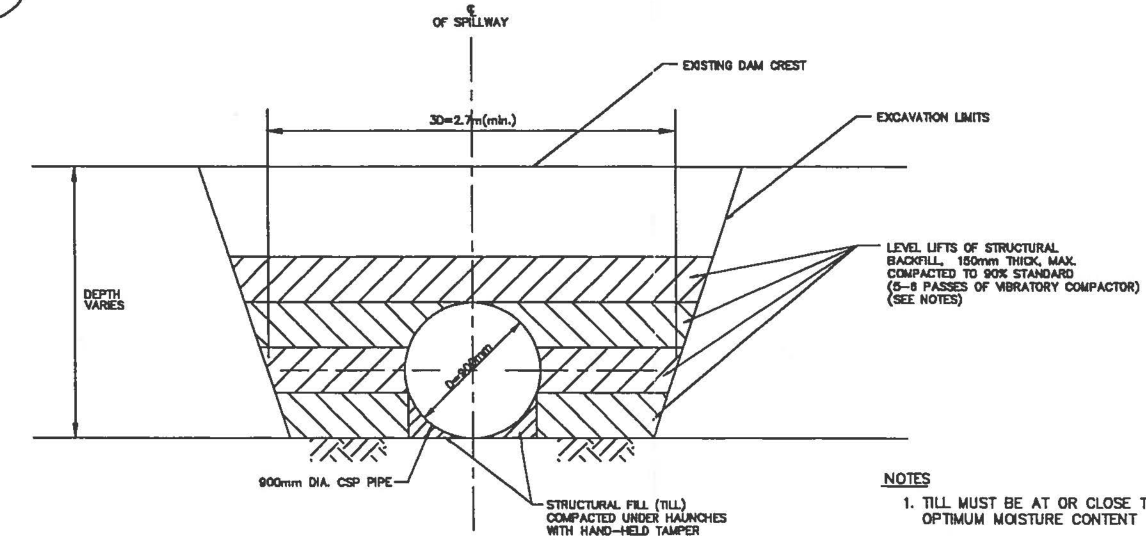
SECTION A

1:100



PLAN

1:500

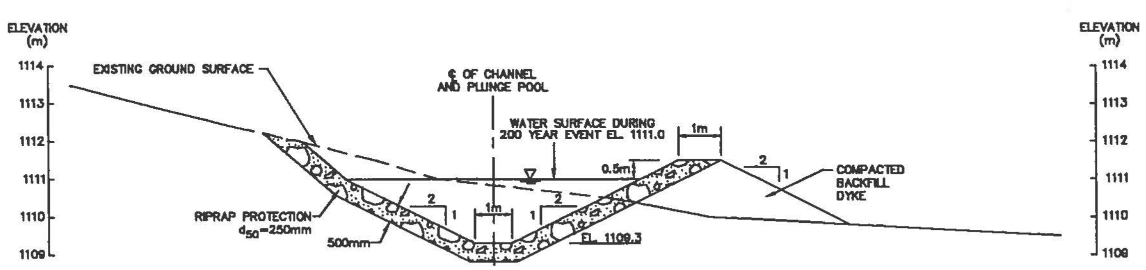


NOTES

1. TILL MUST BE AT OR CLOSE TO OPTIMUM MOISTURE CONTENT
2. BACKFILL MATERIAL MAY BE TILL REMOVED FROM EXCAVATION WITH ROCK LARGER THAN 75mm REMOVED

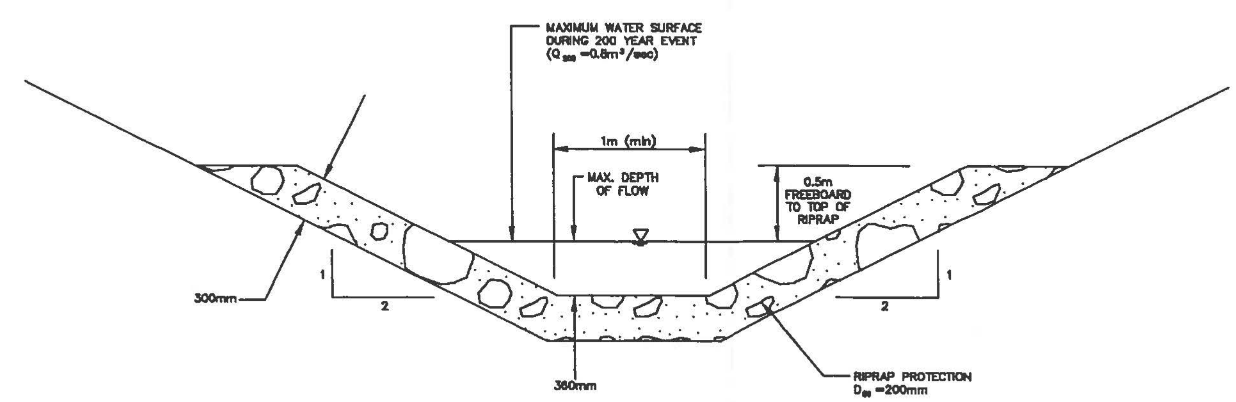
SECTION B

1:25



SECTION C

1:100



SECTION D

1:25

STEFFEN ROBERTSON AND KIRSTEN Consulting Engineers	VANGORDA PLATEAU MINE
DELOITTE & TOUCHE LTD.	LITTLE CREEK DAM PLAN, SECTION AND DETAILS OF SPILLWAY

FILE REFERENCE	PROJECT NO.	DRAWING NO.	REV.
PROFILE.DWG	1CD003.01		