

**Preliminary Engineering for
Tailings Relocation Using
Hydraulic Monitoring Methods**

**Anvil Range Mining Complex
Yukon**

Report Prepared for
Deloitte & Touche Inc.

Report Prepared by



January 2005

Preliminary Engineering for Tailings Relocation Using Hydraulic Monitoring Methods

Anvil Range Mining Complex Yukon

Deloitte & Touche Inc.

**Interim Receiver of Anvil Range Mining Corporation
Suite 1900, 79 Wellington Street West
Toronto, ON M5K 1B9**

**SRK Consulting (Canada) Inc.
Suite 800, 1066 West Hastings Street
Vancouver, B.C. V6E 3X2**

Tel: 604.681.4196 Fax: 604.687.5532
E-mail: vancouver@srk.com Web site: www.srk.com

SRK Project Number 1CD003.057

January 2005

**Authors
Cam Scott, P.Eng
John Chapman, P.Eng
Pat Bryan, P.Eng
Dave Jansson**

**Reviewed by
Daryl Hockley, P.Eng.**

Table of Contents

1	Introduction	1
1.1	General	1
1.2	Scope of Work.....	1
1.3	Previous Studies on Tailings Relocation.....	2
1.4	Site Inspection.....	2
1.5	Revised ECMP Report	3
2	Description of Rose Creek Tailings Impoundment	4
2.1	Overview	4
2.1.1	Location and Physical Dimensions	4
2.1.2	Stored Tailings Volumes	4
2.1.3	Tailings Thicknesses	5
2.2	Description of Containment Dams	6
2.3	Tailings Properties.....	6
2.3.1	Physical Properties.....	6
2.3.2	Geochemical Properties	7
2.4	Phreatic Levels in the Tailings	7
3	Project Overview	8
3.1	Methodologies	8
3.2	Relocation Options	8
3.2.1	Main Options	8
3.2.2	Other Options	9
4	Proposed Hydraulic Monitoring Operations	10
4.1	Equipment	10
4.1.1	Monitors	10
4.1.2	Water Supply Pumps and Pipelines.....	10
4.1.3	Sump Pumps.....	10
4.1.4	Main Pumps.....	11
4.1.5	Earthmoving Equipment	11
4.2	Mine Plan	11
4.2.1	General.....	11
4.2.2	Schedule.....	12
4.3	Operational Issues.....	12
4.3.1	Factors Affecting the Positioning of the Monitors.....	12
4.3.2	Impact of Slope Stability on the Mining Method	13
4.3.3	Maximum Depth of a Single Cut.....	13
4.3.4	Maximum Distance between the Monitor Nozzle and the Slope.....	13
4.3.5	Removal of Trash from the Intake to the Transfer Pump	13
4.3.6	Ditch Slope	13
4.3.7	Equipment Maintenance.....	14
4.3.8	Movement of Monitors and Pipes.....	14
4.3.9	Implications of Concurrent Operation of Multiple Transfer Pumps	14
5	Pumping Slurry to Faro Pit.....	15
5.1	Base Case.....	15
5.2	Thickening Option	15

6	Lime Addition	16
6.1	Introduction	16
6.2	Sampling and Testing.....	16
6.2.1	Field Sampling.....	16
6.2.2	Laboratory Testing	16
6.3	Results	17
6.3.1	Lime Demand.....	17
6.3.2	Settling Tests.....	18
6.3.3	Water Quality.....	19
7	Disposal at the Pit.....	20
7.1	New Information	20
7.1.1	Topographic Data from 2003.....	20
7.1.2	Bathymetric Data from 2004.....	20
7.2	Pit Storage Capacity.....	20
7.3	Tailings Storage Requirements	21
7.3.1	Laboratory Test Data on Tailings without Lime Addition.....	21
7.3.2	Density Analyses.....	22
7.4	Expected Tailings Levels.....	22
7.5	Impact of Lime Addition	23
8	Water Management	25
8.1	Water Management Plan.....	25
8.2	Water Balance.....	26
9	Dam Breaches and Basin Remediation.....	30
9.1	General	30
9.2	Revegetation	30
10	Costs.....	32
10.1	Summary.....	32
10.2	Lime Costs	33
10.3	Water Treatment Costs	35
10.4	Basin Cleanup.....	35
10.5	Dam Breaches.....	35
11	Conclusions	36
11.1	Key Conclusions.....	36
11.2	Risks	36
12	References.....	38

List of Tables

Table 2.1: Summary of Tailings Quantities at the Rose Creek Tailings Impoundment	5
Table 6.1: Tailings Composite Sample Properties	17
Table 6.2: Lime Demand Test Results.....	18
Table 6.3: Summary of Settling Test Results.....	18
Table 6.4: Summary of Supernatant and Porewater Quality	19
Table 7.1: Storage Capacity Based on ICAP and Data Collected in 2003 and 2004.....	21
Table 8.1: Average Annual Water Balance for the Sump Catchment.....	27
Table 10.1: Estimated Costs for Total Tailings Relocation.....	33

List of Figures

Figure 1.1 Photographs of the Field Monitoring Test
Figure 2.1 Site Layout
Figure 2.2 Aerial View of the Faro Site
Figure 2.3 Tailings Thickness Isopachs
Figure 3.1 Typical Photographs of Tailings Relocation in Chile
Figure 3.2 Typical Photographs of Tailings Relocation in Southern Africa
Figure 3.3 Plan Views Illustrating the Total and Partial Relocation Options
Figure 3.4 Sections Illustrating the Total and Partial Relocation Options
Figure 4.1 Schematic View of the Initial Mine Plan
Figure 5.1 Pumping and Piping System Layout
Figure 5.2 Pipeline Profile Between Main Pumphouse and Faro Pit
Figure 6.1 Relationship between pH, Lime Demand and Settled Density
Figure 7.1 Pit Bathymetry and Section Locations
Figure 7.2 Sections Through Current Faro Pit
Figure 7.3 Storage Capacity Curve for the Faro Pit
Figure 7.4 Schematic Section Illustrating Key Elevations in the Faro Pit
Figure 8.1 Simulated Monthly Outflows from the Sump Catchment
Figure 8.2 Simulated Filling of Faro Pit
Figure 9.1 Remedial Requirements Following Total and Partial Tailings Relocation

List of Appendices

- Appendix A As-built Information for the Tailings Dams
- Appendix B ECMP Report on Hydraulic Monitoring
- Appendix C Incremental Information from Pump Suppliers
- Appendix D Geochemical Investigation and Test Results for Tailings
- Appendix E Bathymetry Survey of Faro Pit Lake
- Appendix F Geotechnical Test Results for Tailings
- Appendix G Consolidation Modeling for Tailings in Faro Pit
- Appendix H Water Quantity and Cost Calculations

1 Introduction

1.1 General

The development of a Final Closure and Reclamation Plan for the Anvil Range Mining Complex near Faro, Yukon commenced in early 2002 with the identification of potential decommissioning methods to address site-specific elements or problems. One of the potential decommissioning methods identified for the Rose Creek tailings impoundment was the relocation of all or part of the tailings to the Faro Pit. A scoping-level assessment of potential relocation methodologies and the corresponding relocation costs was completed in 2002-2003 by SRK Consulting (SRK).

In 2003-2004, SRK completed a study that evaluated and compared the utilization of three tailings relocation methodologies, namely dredging, hydraulic monitoring and mechanical excavation, to relocate all or part of the tailings to the Faro Pit. Specialist contractors provided input to the engineering concepts and related costs associated with each of these methodologies. The principal conclusion of the 2003-2004 study was that the hydraulic monitoring method is the most advantageous method in terms of technical feasibility, risk minimization and cost. Dredging is feasible, but compared with hydraulic monitoring, has significant environmental risks and slightly higher costs. The mechanical excavation option has severe challenges due primarily to trafficability issues and, as a result, faces significant risk and uncertainty with respect to technical feasibility and cost.

Based on the foregoing conclusions, the participants of a Technical Workshop in Vancouver in February 2004 agreed that the next phase of assessment should be based on hydraulic monitoring as a means of tailings relocation and should provide an estimate of all relocation and remediation costs. SRK, in conjunction with ECMP, a South African engineering firm with extensive experience in the practical application of hydraulic monitoring, were subsequently commissioned to complete a preliminary engineering assessment of tailings relocation based on hydraulic monitoring. The results of the engineering assessment are the subject of this report.

1.2 Scope of Work

The preliminary engineering assessment of the hydraulic monitoring option commenced with a visit to the Anvil Range Mining Complex by representatives of SRK and ECMP in June 2004. ECMP subsequently developed a plan to undertake the relocation of the tailings to the Faro open pit based on total and partial removal of the tailings. In addition, field and laboratory studies were performed, including a bathymetric study to confirm the capacity of the Faro pit, geotechnical testing to determine the tailings storage volume requirement and tailings neutralization testing to determine the lime addition required to treat the soluble acidity contained in the tailings. This information was compiled and used in the development of the conceptual tailings relocation plan and estimate of costs.

1.3 Previous Studies on Tailings Relocation

Several studies related to the mining or relocation of the tailings in the Rose Creek valley have been completed over the past 14 years. The reports describing the results of these studies were appended to the SRK tailings relocation report completed in 2003-2004 (SRK, 2004). A brief description of each of these studies is provided below.

The earliest was a study completed by Kilborn Engineering in 1991 on behalf of Curragh Resources, the mine operator at the time. The Kilborn study addressed the use of hydraulic monitoring methods to transport the tailings to the plant site for re-processing.

SRK Consulting (SRK) completed a review of tailings relocation practices and costs as part of a scoping study for the closure of the Anvil Range Mining Complex (SRK, 2003). The results of the review were summarized in a technical memorandum. Three methods are commonly considered for tailings relocation and/or rehandling: dredging, hydraulic mining (monitoring) and mechanical excavation. The review compared the advantages and disadvantages of each of these methods, as well as the typical cost(s) associated with each method.

In 2003, Department of Indian Affairs and Northern Development (DIAND) Type II Mines commissioned Brodie Consulting Ltd. to complete a review of tailings relocation projects and methodologies.

Various other studies or technical papers related to tailings relocation are referenced in SRK (2003) and Brodie (2003).

1.4 Site Inspection

David Jansson of ECMP visited the site in the evening of June 8th, all day on June 9th and the morning of June 10th, 2004. The primary purpose of the visit was to for Mr. Jansson to observe the site-specific conditions as they relate to the development of a plan and costs associated with a relocation of tailings from the Rose Creek tailings impoundment to the Faro Pit.

In addition to the site visit, Mr. Jansson met with the Mine Manager, Dana Haggar, to discuss the implication of the existing infrastructure and care and maintenance operations to tailings relocation activities and costs estimations. The results of these discussions contributed to the finalization of the cost estimates for tailings relocation based on the hydraulic monitoring method.

Lastly, Mr. Jansson undertook a rudimentary field test to evaluate the feasibility of monitoring the Rose Creek tailings. A portable pressure washer was moved to the tailings impoundment and a high pressure water jet from the pressure washer was applied to the tailings. The water jet cut through the tailings quite easily. Bud McAlpine of DIAND Type II Mines and Milos Stepanek, a geotechnical consultant to DIAND, observed the field test. Mr. Stepanek took a group of six digital photos during the course of the field test, two of which are shown on Figure 1.1.

1.5 Revised ECMP Report

Following the site visit and the acquisition of the information from Dana Haggar, ECMP revised the estimate of the hydraulic monitoring costs that was contained in the ECMP report of January 2004. This estimate has been used to finalize the comparative assessment of tailings relocation methods (SRK, 2004).

Following the site visit, pump suppliers were contacted for information on pumps, thickened tailings and related costs. The information provided by pump suppliers and thickened tailings is discussed in Sections 4 and 5, respectively.

2 Description of Rose Creek Tailings Impoundment

2.1 Overview

2.1.1 Location and Physical Dimensions

The Rose Creek tailings impoundment is situated in the Rose Creek valley, immediately southeast of the Faro Pit, waste dumps and processing plant, as shown on the accompanying layout plan (Figure 2.1) and aerial photomosaic (Figure 2.2). The impoundment contains the vast majority of the tailings produced as a result of ore processing at the Anvil Range Mining Complex between 1969 and 1992. The approximate quantity of tailings in the Rose Creek tailings impoundment is 57.0 million tonnes (Robertson GeoConsultants Inc., 1996).

The tailings impoundment is approximately 3,100 m long and 430 to 700 m wide and occupies approximately 196 hectares (ha) of the Rose Creek valley. Rose Creek, which flows from east to west, is diverted around the impoundment in a channel on the south side of the valley. A polishing pond situated immediately downstream of the tailings impoundment, occupies an area of approximately 22 ha.

The Rose Creek tailings impoundment was developed in stages. This has resulted in three general areas, each of which is identified on Figure 2.1. From east to west, they are the 1969, or Original tailings area (approximately 41 ha), the 1974 or Second tailings area (approximately 61 ha) and the Intermediate Dam tailings area (approximately 94 ha). Between the Intermediate Dam and the Cross Valley Dam is the polishing pond mentioned above. As a group, these are also referred to as the Down Valley facilities.

2.1.2 Stored Tailings Volumes

Table 2.1 provides a summary of the three areas described above including, for each, the respective surface area in hectares and the tailings volume in cubic metres. The top half of the table summarizes the information from the Interim Closure and Abandonment Plan (ICAP) completed in 1996 (Robertson GeoConsultants Inc., 1996). The bottom half of Table 2.1 provides the same information based on the predevelopment topography and the 2003 topographic maps.

The two sets of data in Table 2.1 vary slightly when evaluated on the basis of individual impoundments. However, when taken as a whole, the two sets of data for the entire Rose Creek tailings impoundment are quite similar.

Table 2.1: Summary of Tailings Quantities at the Rose Creek Tailings Impoundment

Impoundment	Period of Tailings Deposition	Surface Area (ha)	Tailings Volume (m ³)
From the ICAP (Robertson GeoConsultants Inc., 1996)			
Original	Sept. '69 to June '82	41.7	6,300,000
Second	Mid '75 to June '82; June '86 to Oct. '86	54.5	10,400,000
Intermediate Dam	Oct. '86 to July '92	99.5	11,900,000 ¹
Totals		195.7	28,600,000
From Comparison of Pre-development Topography with the 2003 Topographic Data			
Original		41.0	6,082,000 ²
Second		60.6	9,274,000 ²
Intermediate Dam		94.2	13,593,000 ³
Totals		195.8	28,949,000

Note 1: This volume is based on the assumption that 4,300,000 m³ of tailings were deposited in the Intermediate Dam impoundment from Sept. 17, 1990 to July 31, 1992 (350,000 tonnes per day at a settled density of 1.75 tonnes per m³).

Note 2: This volume is based on topographic surfaces from mapping undertaken at the site of the Rose Creek tailings impoundment prior to its construction and in 2003. For calculation purposes, it assumes the dam is vertical and equivalent in width to the dam crest.

Note 3: This volume is based on topographic surfaces from mapping undertaken at the site of the Rose Creek tailings impoundment prior to its construction and in 2003. For calculation purposes, this volume assumes that the tailings are up to the level of the pond immediately upstream of the Intermediate Dam pond and that the tailings extend all the way to the centreline of the Intermediate Dam, i.e. it includes part of the volume of the Intermediate Dam as tailings.

2.1.3 Tailings Thicknesses

The thickness of the tailings is summarized on Figure 2.3, which was extracted from the ICAP and shows the thickness contours (isopachs) in 5 m increments over the entire impoundment as of 1990. The ICAP assumed that 4.3 million m³ of tailings were deposited on the Intermediate Dam impoundment between 1990 and 1992. As a consequence, a new set of isopachs were prepared based on the predevelopment topography and the 2003 topographic data. A comparison of the new isopachs with those shown on Figure 2.3 indicates that they are essentially the same. As a consequence, Figure 2.3 is believed to provide a reasonable representation of the variability of tailings thickness at the Rose Creek tailings impoundment.

This conclusion is supported by field evidence. Figure 2.3 was used by as a basis for predicting tailings thickness at specific locations during a program of cone penetration test (CPTs) completed in the tailings by Golder Associates in 2003 (Golder, 2004). The tailings thicknesses encountered at the CPT locations compared favourably with the isopach data on Figure 2.3 (J. Cunning, pers comm.).

The tailings thickness over most of the Original and Second tailings impoundments is between 10 and 25 m, with a mean of about 15 to 20 m. The maximum thickness, slightly over 25 m, coincides with a point immediately upstream of the west limb of the Second tailings dam.

The tailings thickness over most of the Intermediate Dam tailings impoundment is between 5 and 20 m, with a mean of about 10 to 15 m.

2.2 Description of Containment Dams

The containment dams at the Rose Creek tailings impoundment include the Original Dam, Second Dam, Intermediate Dam and, at the polishing pond, the Cross Valley Dam. Information on each of these dams is provided in the ICAP (Robertson GeoConsultants Inc., 1996). Cross-sections through each of these dams are provided in Appendix A.

2.3 Tailings Properties

The tailings were deposited hydraulically from various locations around each of the impoundments. In general, coarse tailings, comprised mainly of fine sand, settled out close to the discharge points and the finer tailings, comprised of silt and clay-sized particles, settled out at areas distant from the discharge points. A description of the depositional history of the facility is provided in Golder Associates (2004). The report, which includes the results of cone penetration tests (CPT) completed at various locations within the tailings facility, also provides information on how the particle size distribution of the tailings changes with location and depth.

A brief description of the physical and geochemical properties of the tailings is provided below.

2.3.1 Physical Properties

Physical characteristics of the tailings of relevance to tailings relocation include particle size distribution and specific gravity. Geotechnical information specific to these and other properties is summarized in existing reports, such as those by SRK (1991), Robertson GeoConsultants Inc. (1996) and Golder Associates (2004). Comments on the specific properties used in this study are provided below.

Particle Size Distribution

As noted above, the particle size distribution of the tailings varies with location and depth. Coarse tailings consist of medium to fine sand with a trace of fines (silt and clay) whereas the fine tailings consist of silt or clayey silt with some fine sand. In both cases, the gradation is relatively uniform, which is typical of tailings.

Specific Gravity

The ICAP (Robertson GeoConsultants Inc., 1996) indicated that the mean specific gravity (Gs) of the tailings in the Original impoundment (Gs = 4.5) was significantly higher than that of the Secondary Dam impoundment (Gs = 3.8) and Intermediate Dam impoundment (Gs = 3.9). On the basis of a weighted average using this data, the specific gravity of the tailings is typically about 4.0.

Data from cover studies undertaken at the tailings facility in 2003 indicates that the specific gravity of the oxidized tailings that occupy the top metre or so of the tailings impoundment, particularly the Original and Secondary Dam impoundments, is significantly less than 4.0 (SRK, 2004). The mean

value from the tests on oxidized tailings was 2.8. However, gradation testing by Golder Associates in 2004 and by SRK in 2004 (Appendix F) support a specific gravity of about 4.0 in the unoxidized tailings.

Calculations undertaken in support of this report use a specific gravity of 4.0.

2.3.2 Geochemical Properties

The tailings are acid generating (SRK 1991) and contain soluble secondary mineral phases. The porewater within the tailings has stored acidity, comprising free acid (low pH) and elevated concentrations soluble metals, in particular zinc. The amount of stored acidity varies with location and depth, and depends on the degree of oxidation and the hydrogeologic regimes within the tailings. Additional information on the geochemical properties of the tailings is not relevant to tailings relocation, although the need for lime addition to neutralize the stored acidity is discussed in Section 6.0.

2.4 Phreatic Levels in the Tailings

The hydrogeology of the tailings impoundment is discussed in two reports by Gartner Lee Limited (2002 and 2004). The phreatic levels vary seasonally but, based on these reports, the phreatic levels away from the pond that overlies the western portion of the Intermediate Dam tailings impoundment are typically as much as about 4 m on the Intermediate Dam impoundment, and between about 5 and 13 m. However, based on shallow auger holes completed at the tailings impoundment in support of cover studies in 2003, observations indicated that the partially saturated tailings above the phreatic levels but below a depth of about 2 to 3 m generally have a high moisture content despite being partially saturated (M. Rykaart, 2004).

3 Project Overview

3.1 Methodologies

Tailings relocation as it applies to this engineering assessment is based on the relocation of all or part of the tailings from the Rose Creek tailings impoundment to the Faro Pit. The relocation would be achieved using primarily the hydraulic monitoring method.

Hydraulic monitoring, which is also known by terms such as hydraulic mining, hydro-sluicing or the cutting and slurry method, involves the use of hydraulic water guns to direct a high pressure water jet onto the deposit surfaces to produce slurry. The slurry gravitates to a pumping station where it is diluted with water and pumped to its destination or to a booster pump, depending on topography and pumping distances. Photos illustrating the hydraulic monitoring method are provided on Figures 3.1 and 3.2.

In order to neutralize the tailings before they get to the Faro Pit, lime would be added to the tailings at one of the pump stations. Deposition at the Faro Pit would be based on the development of a relatively horizontal, uniform tailings surface.

It is expected that hydraulic monitoring would have to be complemented by mechanical excavation. Specifically this would include truck and shovel operations to breach the dams, as appropriate, and to remove a layer of residual tailings and/or surficial soil of unknown thickness at the base of the tailings deposit.

3.2 Relocation Options

3.2.1 Main Options

The following two relocation options were given primary consideration in this study:

- Total Relocation Option: Relocation of the entire quantity of tailings from the Rose Creek tailings impoundment, approximately 57.0 million tonnes, to the Faro Pit.
- Partial Relocation Option: Relocation of a portion of these tailings, approximately 43.0 million tonnes, to the Faro Pit with the remainder to be left in the tailings impoundment under a water cover.

These two relocation options are illustrated by the schematic plan views and cross-sections provided on Figures 3.3 and 3.4, respectively.

The rationale for the total relocation option is that, once the tailings have been relocated to a secure location (the Faro Pit), there is no risk of a dam failure that can lead to the movement of tailings to the downstream environment. The logical consequence of this option is the breaching or removal of

the various containment dams and the reclamation of the area currently occupied by the Rose Creek tailings impoundment.

The rationale for the partial relocation option is based on cessation of acid generation by the use of a water cover. Rather than raising the Intermediate Dam, tailings above elevation 1042 m would be relocated to the Faro open pit and covered by water. The tailings that are left in the impoundment, i.e. those below elevation 1042 m, would be covered by 3 m of water. The existing Intermediate Dam is adequate to provide up to about 5.7 m of water cover before water starts to flow through the spillway. The spillway could be left as is or, allowing for a freeboard of approximately 1 m, the invert of the spillway could be lowered by 1.7 m, from elevation 1047.7 m to elevation 1046 m.

3.2.2 Other Options

One other relocation option is under consideration, namely the relocation of the tailings solely within the Intermediate Dam tailings impoundment. The tailings behind the Second and Original Dams would be left in place. An additional cost item required with this option is a buttress at the downstream toe of the Second Dam. A recent seismic stability study by Klohn Crippen (2004) indicates that an earthquake-induced failure of this dam would be possible unless the buttress is installed. The Intermediate and Cross Valley Dams would likely be breached or at least lowered. Modifications to the Rose Creek diversion channel would likely be less costly than otherwise envisioned.

Depending on the results of the assessment of the main options, this option can be evaluated relatively easily as part of subsequent meetings with other stakeholders.

The following two options warrant mention but have been excluded from the tailings relocation assessment:

- i. Partial relocation, as described in the second of the two main tailings relocation options, need not include a water cover. Other cover options, such as a dry or wet soil covers, could be utilized. However, since tailings covers are addressed by studies that specifically address cover options, the assessment of cover alternatives has been excluded from the tailings relocation assessment.
- ii. Lastly, if none of the tailings were relocated, a water cover could theoretically be developed. However, in order to submerge the tailings at the Original Dam and Second Dam impoundments, the Intermediate Dam and spillway would have to be raised significantly as would part of the Second Dam. In addition, there would be complications related to the Rose Creek diversion channel, particularly at the middle section of the Rose Creek tailings impoundment. The measures associated with these issues are far from trivial and, as a consequence, this option has been excluded from the tailings relocation assessment.

4 Proposed Hydraulic Monitoring Operations

This section has been prepared primarily on the basis of the site visit by ECMP and Mr. Jansson's subsequent report, a copy of which is contained in Appendix B. Information related to pumps has been provided by select pump manufacturers (Appendix C).

4.1 Equipment

4.1.1 Monitors

The hydraulic monitoring operation would be based on nine monitors. Each monitor will be mounted on skids that, if necessary, can be filled with water to provide additional weight for stability. The monitors will be hydraulically operated and electrically controlled from a wheel-mounted, weatherproof cabin. The cabin will have the capacity to be elevated to allow the operator enhanced visibility for the operation.

The monitors will be moved around using a 12-tonne excavator on low ground pressure tracks.

4.1.2 Water Supply Pumps and Pipelines

For the monitor feed pumps and the water from the pit, two barge-mounted, vertical turbine pumps, each rated at 227 l/s at a discharge pressure of 26 bar, are recommended (with the elevation differential relative between the water supply and the operating site, this pressure should give the 32 bar pressure required at each of the monitors). Available data suggests that a 7-stage unit would be required and each stage would be complete with a 1,000 hp motor. The motor would be mounted above the water level and one or more stages would be submerged.

The pipeline used to supply water to the monitors would consist, in part, of the existing steel line presently running between the barge and the plant. This line would be extended to the tailings impoundment and will be the "mother" or main supply line. From the "mother" line, 200m/m light weight piping take offs will be installed to each monitor.

4.1.3 Sump Pumps

Vertical spindle transfer pumps (also known as cantilever pumps) would be used to pump the slurry from the sumps to the main pumps on the north side of the tailings impoundment. The density of the slurry pumped by the vertical spindle transfer pumps is expected to be about 46% solids by weight.

It is anticipated that three 200 mm vertical spindle transfer pumps would be required. Each pump will be accompanied by a 200 hp motor and rated at 165 l/s at 30 m.

4.1.4 Main Pumps

The main pumps that will be used to pump the tailings to the Faro Pit will be housed on a flat area on the north side of the tailings impoundment. The pumping arrangement required to pump the slurry, at a density of about 46% solids by weight, to the Faro Pit will consist of a single line of five pumps made up of a mixture of high pressure and standard pumps (type AHP and AH), all with the same basic drive consisting of 850 hp motors, gears and three element bases. Four pumps will be direct drive with the pump at the end of the drive fitted with a variable speed motor.

Other equipment that may be required in this area includes a system for adding lime to the slurry prior to pumping. Further comments on the lime addition are provided in Section 6.

4.1.5 Earthmoving Equipment

Earthmoving equipment, consisting of an excavator or loader, trucks and dozers, would be required periodically for the development of small internal dykes to control runoff at select stages in the relocation process. The same type of earthmoving equipment will also be required to breach the tailings dams and to remediate the grade and condition of the valley floor where tailings or dams previously existed. Further comments on the breaches and remediation requirements are provided in Section 9.

4.2 Mine Plan

4.2.1 General

A detailed mine plan has not been developed but a general description of the monitoring operation as it would likely proceed is provided below. Figure 4.1 provides a schematic representation of the mine plan.

- ECMP envisages re-mining the Second Dam impoundment first and then going into and through the Original Dam impoundment, initially leaving the toe dyke in place.
- The first cut would be a gully, mined from west to east which would have laterals going off to the north and south, creating a herring bone system of collection trenches. These laterals would then be mined in an east west direction, with the slurry reporting to the gully.
- The mining would be undertaken in benches of approximately 8 m. It is expected, however, that the bench height would be increased or decreased depending on the in situ moisture content and gradation of the tailings.
- The slurry will gravitate to a sump, which would be constructed on the upstream side of the Second dam, approximately 200 m south of its west end. The sump would be constructed from wood, as it would be dismantled and lowered periodically.
- When the second cut is created, ECMP recommends breaching through the Second Dam into the Intermediate Dam impoundment so that this impoundment can be mined at a slower rate, thereby allowing a drying out period, as this impoundment appears to be the wettest.

- Starter dykes will be left intact and any removal thereof will be a truck and shovel operation.

4.2.2 Schedule

The schedule for tailings relocation is based on a multi-year sequence during which operations continue for approximately six months per year. Based on this sequence, the estimated time to complete the total and partial relocation options is 12 and 9 years, respectively.

The annual operational sequence is expected to consist of the following main actions:

- Hydraulic monitoring operations will operate annually between ± 1 April and ± 30 September (summer months), though this could shift to 1 May and 31 October or something in between.
- On or about the end of the operational cycle, the equipment will be dismantled and placed in storage for the winter period. The operating crew will be laid off for the winter period.
- Approximately 2 weeks prior to the commencement of operations, the operating crew will be re-hired. The crew will remove the equipment from storage and re-assemble it in anticipation of recommencing operations.

4.3 Operational Issues

This section provides information on issues related to the day-to-day operation of the proposed hydraulic monitoring system.

4.3.1 Factors Affecting the Positioning of the Monitors

The area of the tailings to be removed dictates the method of monitoring, i.e. monitoring from the top of the slope versus monitoring from the bottom.

When working from the top, the cut slope angle can be controlled, but would never be less than 60 degrees. However, compared with monitoring from the bottom, monitoring from the top requires more frequent monitor moves and produces lower slurry densities.

Conversely, the principal advantages of working from the bottom of the slope are that the monitor moves are less frequent and higher slurry densities can be obtained. However, when working from the bottom, it is not possible to work in areas with a high water table and it is difficult to control the cut slope angle.

In the case of the Rose Creek tailings impoundment, the area is not large enough to allow sufficient drying time prior to coming back for the second cut. Monitoring would, therefore, be undertaken from the top of the slope.

4.3.2 Impact of Slope Stability on the Mining Method

The slope stability of the tailings affects the mining method primarily in relation to the bench height. As noted above, the current plan would be to establish a bench height of approximately 8 m. However, the height of the bench cuts will depend on the stability of the cut slopes which, in turn, will depend on the in situ moisture content and gradation of the tailings. It is expected, however, that the bench height would be increased or decreased depending on the bench performance, i.e. the occurrence of sloughing.

4.3.3 Maximum Depth of a Single Cut

The maximum depth of a single cut in tailings varies and is dependent on the following:

- Moisture content of the product, dependent primarily on the position of the water table
- Grading of the tailings
- Water pressure
- Nozzle size

ECMP envisages that a 20 m cut would be possible at Faro. However, as shown in Figure 2.3, the total thickness of tailings over much of the impoundment is in the range of only 10 to 15 m.

4.3.4 Maximum Distance between the Monitor Nozzle and the Slope

The maximum distance over which the water jet would be effective is dependent entirely on the water pressure, the nozzle size and the grading of the material. At Faro, it is envisaged that the system would be set up to effectively mine a face at a maximum 20 metres from the nozzle.

4.3.5 Removal of Trash from the Intake to the Transfer Pump

At the invert to the vertical spindle pump sump, there will be a static screen, which will be manned, the debris will be raked off and put to one side for collection by mechanical means.

4.3.6 Ditch Slope

Typically the gradient at which slurry will flow is dependent on the make up of the tailings within the slurry. If the slurry contains mainly a coarse fraction, then the gradient of the slurry flow at the sump will be steep, approximately 3% to 7%. However, if the slurry contains mainly a fine fraction (about 85% minus 200 microns), the gradient of the slurry flow will be flat, approximately 0.5% to 1%.

Although the CPT investigation (Golder, 2004) confirmed the gradation of the tailings changes broadly as a function of the depositional history, the slimes facility does not have a steep beach from the point where the slurry was deposited to the overflow. Similarly, the inspections and field test conducted the high-pressure washer during the June site visit did not indicate the presence of a

coarse fraction. These factors suggest that, in general, the tailings slimes were deposited as a relatively homogeneous product and will therefore flow at a gradient of between 1% and 1.5%. However, if the operation requires a significant number of starts and stops, then the trenches may silt up. If this occurs, the product will not flow and the methodology appropriate for coarse slurries would have to be adopted. In particular, satellite pumps would need to be installed, one for each monitor. These pumps then need to be moved on a daily basis to ensure that the slurry gets to the main pump sump, which in turn would be fitted with an agitator.

4.3.7 Equipment Maintenance

The system, by necessity, would have redundancy. For example, for every operating monitor, there would be a monitor either being moved or on standby. Maintenance would not be done when the equipment is situated in an area with a high water table. Under these conditions, assuming it was the monitor that required maintenance, the monitor would be moved to an area of more favourable conditions, thereby avoiding any potential difficulties.

Similarly, there would be a standby pump for the vertical spindle transfer pump at the end of the main trench.

A maintenance schedule would be developed for the main pumps that will pump slurry from the north side of the tailings impoundment to the Faro Pit. It is anticipated that the system would be stopped for a morning once per week and a day once per month.

On a normal production operation there would be two trains of pumps.

4.3.8 Movement of Monitors and Pipes

The general rule of thumb is that if a person can walk on the slimes, then there is no difficulty in relocating the monitor or the pipes.

Experience has shown that if there is a wet area, the water hammer in this area brings the water to the surface, and when the monitor returns to this area the area will have dried out sufficiently to be traversable.

4.3.9 Implications of Concurrent Operation of Multiple Transfer Pumps

The current plan for pumping to the pit calls for a single train of pumps. Although there could be more than one pump on the tailings dam, all tailings slurry would have to report to the main pump sump.

5 Pumping Slurry to Faro Pit

5.1 Base Case

The main pumps used to pump tailings to the Faro Pit would be housed on a flat area on the north side of the Rose Creek tailings impoundment. One feasible location for these pumps is shown on Figure 5.1, which also shows the approximate alignment of the pipeline route from the pump house to the southeast ramp at the Faro Pit. The ground profile along this pipeline route is shown on Figure 5.2.

These two figures indicate that the pipeline for this alignment would be about 3.7 km long. Up to an additional 1 km of pipe, plus floats, could be needed to distribute the tailings over the Faro Pit so that a flat tailings surface is developed below the water line.

The vertical rise to get from the pump house to the high point in the pipeline route would be about 120 m. The maximum gradient, as shown on Figure 5.2, would be about 9%, but falls to -4.5% as it continues down the ramp, on the southeast corner of the pit, to the pit lake.

The pumping arrangement will consist of a single line of five pumps that would be a mixture of high pressure and standard pumps(type AHP and AH), all with the same basic drive comprising of 850 hp motors, gears and three element bases.

5.2 Thickening Option

In order to reduce the volume and, potentially, the cost of pumping tailings slurry to the Faro Pit, consideration was given to thickening the tailings to about 75% solids by weight at the pump house on the north side of the Rose Creek tailings impoundment. ECMP contacted a pump supplier, IST Delkor, in South Africa. Following a review of the pipeline route and tailings characteristics, IST Delkor indicated that, given the relatively long uphill gradient and the associated rheological issues, there would be significant challenges in pumping thickened tailings from the pump house to the pit. They indicated it would be preferable to pump the slurry to a paste thickener at the pit, and thicken to 75% and to then deposit the paste on the pit floor (Appendix C).

The main benefit of the IST Delkor recommendation would be that the thickened tailings deposited into the Faro Pit using a tremie line would have a higher density, and therefore a smaller volume, than tailings which are deposited subaqueously and allowed to segregate as they settle through the column of pit lake water. The thickened tailings option would involve incremental costs but, depending on other closure issues, it may be warrant further consideration. For purposes of this report, it is assumed that the tailings will not be thickened.

6 Lime Addition

6.1 Introduction

A field and laboratory program was completed to assess the amount of lime that would need to be added to neutralize the tailings, and to estimate the likely pore and supernatant water quality that would result from lime amendment. It is uncertain whether lime addition would be required.

However, SRK has recent experience with projects where waste rock was relocated to open pits and, in these cases, there were requirements to add sufficient lime to neutralize the soluble acidity. We believe, therefore, that a similar requirement is likely to be put on tailings relocated to the Faro Pit.

6.2 Sampling and Testing

6.2.1 Field Sampling

A series of test pits, two in each of the Original, Second and Intermediate Dam impoundments, were excavated in September 2004. The test pits were located in close proximity to the following drill hole locations:

- P03-08 - Intermediate Dam Impoundment
- P01-05 - Intermediate Dam Impoundment
- P01-07 - Second Dam Impoundment
- P03-06 - Second Dam Impoundment
- P03-07 - Original Dam Impoundment
- P01-10 - Original Dam Impoundment

Each test pit was excavated to a depth of 1 m and a composite sample was obtained to represent the entire depth of the test pit. Paste pH and conductivity of the composite samples were measured in the field. Approximately 5 kg of each composite sample was shipped to CEMI in Vancouver for testing. The field observations and test pit logs are provided in Part I of Appendix D.

6.2.2 Laboratory Testing

The tailings samples were used on an ‘as received’ basis for testing. The paste pH, conductivity and moisture content were determined for representative sub-samples from each composite sample. The tailings subsamples were also submitted for sulphate analysis.

The testing was carried in two stages. In the first stage, carried out in 5 L beakers equipped with stirrers, 1.5 kg of tailings were mixed with 3 litres of water, well mixed and neutralized with a milk of lime solution to an endpoint pH of 9.5. Because there was a significant drift in the pH within the first twenty minutes, the pH was re-adjusted after 4, 24, 30, 48 and 96 hours.

Once a stable pH had been obtained, the tailings slurry was well mixed and decanted into clear Plexiglas columns, each with an internal diameter of 4 inches and an overall height of 24 inches. The base of the column was sealed and equipped with an outlet. A fine mesh filtration ‘plate’ (3 to 4 nylon mesh disks) was placed at base of the column to prevent tailings loss during porewater sampling.

Once the tailings slurry was deposited in the column, the settling rate and settled volume were measured. After seven days, the supernatant and porewater (from the base of the column) were sampled and analysed. Sampling was repeated after an additional 14 days had elapsed.

6.3 Results

6.3.1 Lime Demand

The tailings solids moisture content, paste pH and sulphate analyses are summarised in Table 6.1. As indicated by the paste pH results, the state of oxidation of the tailings in the Original and Second Dam impoundments is well advanced from that contained in the Intermediate Dam impoundment.

Table 6.1: Tailings Composite Sample Properties

Sample	Location	Moisture (Wt%)	S-SO ₄ (%)	Paste pH
TP-P01-05	Intermediate	7.1	0.68	3.5
TP-P03-08	Intermediate	13.2	0.30	4.6
TP-P01-07	Second	13.3	2.11	2.8
TP-P03-06	Second	12.4	1.19	2.8
TP-P01-10	Original	10.6	1.67	2.5
TP-P03-07	Original	9.4	1.62	2.6

Detailed results from the lime demand tests are provided in Part II of Appendix D, and are summarised in Table 6.2. As shown in the table, the lime demand ranged from as low as 1.1 kg Ca(OH)₂ per tonne in the Intermediate Dam impoundment to as high as 59 kg Ca(OH)₂ per tonne of tailings in the Original Dam impoundment. The lime demand was found to correlate well with the paste pH, as shown in Figure 6.1a. This correlation is used later to estimate the overall lime demand for the tailings based on the field measurements completed in 2001 and 2003 (GLL, 2002, 2004)

Table 6.2: Lime Demand Test Results

Test	Parameter	Units	Time (h)						Total
			0.33	4	24	30	48	96	
TP-P01-05 Intermediate	pH		4.1	7.0	7.5	8.1	8.6	9.2	98
	Lime Addition	mL at 200 g Ca(OH) ₂ /L	82	6	4	4	1	1	
	Consumed	kg (Ca(OH) ₂)/tonne	12	0.8	0.6	0.6	0.1	0.1	
	End pt. pH		9.5	9.4	9.6	9.5	9.6	9.7	
TP-P03-08 Intermediate	pH		7.4	7.6	7.9	8.1	8.2	8.6	28
	Lime Addition	mL at 50 g Ca(OH) ₂ /L	9	4	3	2	6	4	
	Consumed	kg (Ca(OH) ₂)/tonne	0.3	0.2	0.1	0.1	0.2	0.2	
	End pt. pH		9.4	9.5	9.9	9.6	9.5	9.6	
TP-P01-07 Second	pH		2.4	5.7	8.0	7.9	8.2	7.9	377
	Lime Addition	mL at 200 g Ca(OH) ₂ /L	280	80	7	5	1	4	
	Consumed	kg (Ca(OH) ₂)/tonne	43	12	1.1	0.8	0.2	0.6	
	End pt. pH		9.7	9.8	9.5	9.7	9.7	9.5	
TP-P03-06 Second	pH		3.9	5.7	6.1	7.6	8.4	7.1	465
	Lime Addition	mL at 50 g Ca(OH) ₂ /L	325	92	28	10	4	6	
	Consumed	kg (Ca(OH) ₂)/tonne	12	3.5	1.1	0.4	0.2	0.2	
	End pt. pH		9.8	9.6	9.6	9.5	9.8	9.7	
TP-P01-10 Original	pH		1.8	6.6	7.7	8.0	8.3	8.2	396
	Lime Addition	mL at 200 g Ca(OH) ₂ /L	345	41	3	2	2	3	
	Consumed	kg (Ca(OH) ₂)/tonne	51	6.1	0.4	0.3	0.3	0.4	
	End pt. pH		9.4	9.9	9.6	9.8	9.8	9.5	
TP-P03-07 Original	pH		2.6	6.8	7.9	8.1	8.0	8.4	241
	Lime Addition	mL at 200 g Ca(OH) ₂ /L	220	7	6	2	2	4	
	Consumed	kg (Ca(OH) ₂)/tonne	32	1.0	0.9	0.3	0.3	0.6	
	End pt. pH		9.8	9.5	9.7	9.5	9.5	9.6	

6.3.2 Settling Tests

Detailed results from the settling tests are provided in Appendix D, Part III, and are summarised in Table 6.3. The results are also illustrated in Figure 6.1b. As shown, increased lime addition affects the rate of settling and the final settled density of the tailings.

Table 6.3: Summary of Settling Test Results

Test	Location	Lime Demand (kgCa(OH) ₂ /tonne)	Initial Density (% solids by weight)	Settled Density after 24 hrs. (% solids by weight)	Estimated ¹ Void Ratio	
					Initial	After 24 hrs.
P01-05	Intermediate	14	32.5	63.2	8.10	2.27
P03-08	Intermediate	1.1	30.9	72.1	8.72	1.51
P01-07	Second	58	28.3	53.3	9.63	3.33
P03-06	Second	18	27.7	56.0	9.92	2.99
P01-10	Original	59	28.4	47.7	11.35	4.93
P03-07	Original	35	30.1	57.1	10.45	3.38

Note 1: The void ratio has been estimated based on an assumed specific gravity of 4.5 for tailings from the Original Dam impoundment, 3.8 for tailings from the Second Dam impoundment and 3.9 for tailings from the Intermediate Dam impoundment.

6.3.3 Water Quality

Analytical results for the supernatant and water after 7 and 21 days are provided in Appendix D, Part IV and are summarised in Table 6.4. As shown, even though lime addition was completed under controlled conditions for a period of 96 hours, the pH in some of the tests continued to decrease with time. The magnitude of the change in pH does not appear to be closely related to the lime demand. For example, the results for the samples from the Original Dam impoundment (P01-10 and P03-07) remained slightly alkaline and low zinc concentrations were achieved. The results for Sample P03-06 from the Second Dam impoundment, which had significantly lower lime demand, showed a far greater change in pH and zinc concentrations remained elevated. It further appears that oxidation of iron on the supernatant water led to its acidification. It is also evident that reducing conditions in the porewater are causing the release of iron, as shown by a comparison of iron concentrations in consecutive porewater samples.

Nonetheless, the results show that low zinc concentrations can be achieved at appropriate lime addition rates.

Table 6.4: Summary of Supernatant and Porewater Quality

Sample	Time	pH	Redox mV	Acidity	Alkalinity	SO ₄ (mg/L)	Copper (mg/L)	Iron (mg/L)	Lead (mg/L)	Zinc (mg/L)	
P01-05	S	7	7.7	225	7	58	2215	<0.010	<0.030	0.067	2.73
	S	21	7.8	261	6	47	1790	<0.020	0.655	0.171	1.64
	P	7	8.0	176	5	147	1895	0.016	<0.030	0.244	8.53
	P	21	6.7	139	17	168	2005	<0.010	1.23	0.32	5.74
P01-07	S	7	8.1	205	2	179	1715	0.011	<0.030	<0.050	0.052
	S	21	7.9	289	5	74	1120	<0.010	1.72	0.122	0.124
	P	7	8.2	154	1	452	1640	<0.010	0.073	<0.050	0.243
	P	21	7.5	193	24	443	1605	<0.010	14.8	<0.050	0.304
P01-10	S	7	8.2	196	1	230	1515	<0.010	<0.030	<0.050	<0.005
	S	21	8.0	272	6	128	1500	<0.010	0.624	0.11	0.009
	P	7	7.8	153	301	744	1320	<0.010	0.036	<0.050	0.12
	P	21	7.1	285	350	576	1350	0.027	5.67	0.578	0.109
P03-06	S	7	3.7	280	1060	0	2615	<0.010	551	2.46	22.4
	S	21	4.2	222	827	0	1980	<0.010	376	1.84	23.0
	P	7	5.0	70	1377	2	2865	<0.010	782	<0.050	43.1
	P	21	5.8	-104	1180	4	2670	<0.010	563	0.093	26.6
P03-07	S	7	8.2	190	1	158	1800	0.05	<0.030	<0.050	0.019
	S	21	8.0	201	4	90	1470	0.028	0.503	<0.050	0.061
	P	7	8.0	126	15	365	1540	<0.010	7.53	<0.050	0.396
	P	21	6.8	230	12	265	1550	0.026	11	<0.050	0.099
P03-08	S	7	7.8	190	9	52	1915	<0.010	<0.030	<0.050	1.50
	S	21	7.5	277	5	28	1450	<0.010	0.304	0.096	1.66
	P	7	7.4	39	21	129	2080	<0.010	22.4	<0.050	2.44
	P	21	7.0	-35	61	60	1900	<0.010	54.4	<0.050	0.126

Note : S = Supernatant; P = Porewater
 Alkalinity and Acidity in mgCaCO₃/L

7 Disposal at the Pit

7.1 New Information

During the preparation of the ICAP (Robertson GeoConsultants Inc., 1996), a storage capacity curve for the Faro Pit was prepared. New data obtained in 2003 and 2004 allowed the calculation of a revised storage capacity curve. Further details regarding the development of the revised storage capacity curve are provided below.

7.1.1 Topographic Data from 2003

Geographic Air Survey in Edmonton was contracted in 2003 to obtain aerial photographs of the Anvil Range Mining Complex. On July 25th, 2003, the site was flown and black and white aerial photographs were taken at a scale of 1:10,000 and 1:20,000. The photographs were sent to The Orthoshop in Calgary and the 1:20,000 photographs were used to develop site-wide topographic maps at a contour interval of 2 m. The topographic maps were completed in September 2003.

7.1.2 Bathymetric Data from 2004

Laberge Environmental Services (LES) of Whitehorse conducted a bathymetric survey of the Faro Pit Lake on July 15 and 16, 2004. The equipment used comprised a Raytheon Survey Fathometer and a Garmin eTrex Summit GPS. The sounder was a Precision Survey Depth Recorder mounted on a 4.6 m long Grumman flat bottom boat. Sixteen sounding lines were completed and for each sounding line, a chart recording was generated. Further details regarding the bathymetric survey are provided in the LES report, a copy of which is contained in Appendix E.

The chart recordings, which indicate the depth to the bottom of the pit lake, were provided to SRK on August 19th, 2004. SRK converted the data to a bathymetric contour map, Figure 7.1, which shows the bathymetry of the Faro Pit in plan view. Each colour on Figure 7.1 refers to an elevation range in metres, as indicated in the legend. Two sections through the pit are shown in Figure 7.2. The tailings layer in Figure 7.2 has been interpreted as the difference between the pit floor and walls (bedrock surface) as surveyed when the mine was operating and the current pit floor (top of tailings or, in areas where tailings are not present, top of bedrock) as estimated by the bathymetric survey.

7.2 Pit Storage Capacity

The storage capacity curve developed during preparation of the ICAP was updated using the recently acquired topographic and bathymetric information. As shown in Figure 7.3, the two storage curves are very similar. Table 7.1 provides a comparison of the storage available at five select elevations between 1061 m and 1159 m, inclusive. For the elevations selected, the revised curve indicates there is up to an additional 90,000 m³ of storage compared to the ICAP data. However, above elevation 1160 m, the revised curve indicates there is less available storage than indicated by the ICAP data.

Table 7.1: Storage Capacity Based on ICAP and Data Collected in 2003 and 2004

Elevation (m)	Storage Capacity in m ³ (from ICAP)	Storage Capacity in m ³ (from 2003 & 2004 Data)
1061	0	8.35 x 10 ⁵
1085	5.27 x 10 ⁶	5.78 x 10 ⁶
1110	1.37 x 10 ⁷	1.41 x 10 ⁷
1134	2.44 x 10 ⁷	2.48 x 10 ⁷
1159	3.79 x 10 ⁷	3.88 x 10 ⁷

Another comparison, which is not evident in Figure 7.3, is the estimated volume of tailings present in the Faro Pit as a result of plant operation associated with the Vangorda and Grum ore bodies in the 1990's. The ICAP estimate was 6.30 million m³ of tailings. The latest estimate, based on the final pit topography and the 2004 bathymetric data, is very similar at 6.18 million m³ of tailings.

7.3 Tailings Storage Requirements

7.3.1 Laboratory Test Data on Tailings without Lime Addition

Sixteen tailing samples, of which 10 were fine grained and 6 were coarse grained, were obtained from an inventory of samples collected by Gartner Lee Limited of Whitehorse as part of their tailings investigation completed in 2003 (GLL, 2004). In mid-2004, the samples were sent to EBA Engineering Consultants Ltd. in Edmonton for additional geotechnical testing, including gradation analyses, specific gravity determinations, column sedimentation tests and consolidation tests. The samples were combined in order to provide two samples of fine tailings (FT-1 and FT-2) and two of coarse tailings (CT-1 and CT-2). Tables 7.2 and 7.3 summarize the results of tests on these four composite samples. Further details of the testing and test results are provided in Appendix F.

Table 7.2: Summary of the Specific Gravity and Column Sedimentation Tests Results

Sample	Specific Gravity	Column Sedimentation Test	
		Dry Density (tonnes/m ³)	Average Void Ratio ⁺
FT-1	4.300	1.638	1.63
FT-2	4.008	1.612	1.49
CT-1	3.720	Not tested	
CT-2	4.168	Not tested	
<i>Average</i>	<i>4.049</i>	<i>1.625</i>	<i>1.56</i>

Table 7.3: Summary of the Consolidation Test Results

Sample	Initial Dry Density (tonnes/m ³)	Final Dry Density (tonnes/m ³)*	Initial Void Ratio	Final Void Ratio*	Average Coefficient of Consolidation C _v (m ² /yr)*	Average Hydraulic Conductivity K (cm/s)*
FT-1	1.852	2.309	1.3219	0.7888	39.10	3.012 x 10 ⁻⁰⁶
FT-2	1.594	2.015	1.5150	0.9097	35.48	4.949 x 10 ⁻⁰⁶
<i>Average</i>	<i>1.723</i>	<i>2.162</i>	<i>1.4185</i>	<i>0.8493</i>	<i>37.29</i>	<i>3.980 x 10⁻⁰⁶</i>

* Results averaged from 4 kPa to 1,025 kPa load range

7.3.2 Density Analyses

Data from the laboratory program described above was used to determine relationships between void ratio, permeability and effective stress. These relationships were entered into a finite element computer program, FSCONSOL developed by GWP Software Inc. (GWP Software Inc., 1999) in order to predict the behaviour of the tailings under large-strain, self-weight consolidation. The program was run in a single-drainage mode wherein all drainage is upwards, to the surface of the tailings.

The model results, which are summarized in Appendix G, include predictions of the excess pore water pressures and the resulting tailings density as a function of time. The average tailings density at the end of the relocation process is estimated to be approximately 2.0 t/m³. In the long term, when all of the excess pore pressure has dissipated, the model predicts that the average tailings density will be about 2.1 t/m³. The time required for 90% of the excess pore pressure to dissipate will take about 70 years, by which time approximately 3 m of settlement will have occurred on the surface of the tailings.

7.4 Expected Tailings Levels

Based on an estimated tailings density of 2.0 t/m³ and the revised storage capacity curve for the Faro Pit (Figure 7.3), the surface elevation of the in-pit tailings at the end of the relocation process will be as shown in Table 7.4.

Figure 7.4 illustrates schematically how the tailings levels for total and partial relocation compare against other key elevations in the Faro Pit, including:

- The base of the Faro Creek channel on the south side of the pit, elev. 1158 m (pit water above this elevation may seep into the Faro Creek sediments);
- The base of a highly fractured bedrock zone in the vicinity of the site of a possible plug dam on the southeast end of the pit, elev. 1139 m (pit water above this elevation may seep into the Zone 2 Pit);
- The base of the possible plug dam on the southeast end of the pit, elev. 1151 m;
- The maximum allowable water level assuming that the plug dam is constructed, 1168 m; and
- The maximum practical elevation of the plug dam, if it is constructed, elev. 1170 m.

Table 7.4: In-pit Tailings Levels for Total and Partial Relocation Options

Parameter	Total Relocation	Partial Relocation
Quantity of Tailings (tonnes)	57.0	43.0
Average Density of Tailings (t/m ³)	2.0	2.0
Volume of Settled Tailings (m ³)	28.5 million	21.5 million
Elevation at Top of Tailings (m)*	1142	1128

* Assumes that the surface of the tailings deposited in the pit is flat and horizontal.

7.5 Impact of Lime Addition

The laboratory test results on tailings which were obtained within 1 m of the tailings surface and then mixed with lime are discussed in Section 6. The settled density results from Table 6.3 have been converted to a dry density (in tonnes per cubic metre) and compared with the settled density results for tailings without lime (Table 7.5).

Table 7.5: Comparison of Settled Density Results from Tailings With and Without Lime Addition

Test	Location	Lime Demand (kg Ca(OH) ₂ /tonne)	Estimated ¹ Void Ratio		Estimated Dry Density (t/m ³)	
			Initial	After 24 hrs.	Initial	After 24 hrs.
P01-05	Intermediate	14	8.10	2.27	0.43	1.19
P03-08	Intermediate	1.1	8.72	1.51	0.40	1.55
P01-07	Second	58	9.63	3.33	0.36	0.88
P03-06	Second	18	9.92	2.99	0.35	0.95
P01-10	Original	59	11.35	4.93	0.36	0.76
P03-07	Original	35	10.45	3.38	0.39	1.03
FT-1		No lime added		1.63		1.64
FT-2		No lime added		1.49		1.61

Table 7.5 indicates that when a relatively large amount of lime is added to the tailings, which was the case for most of the samples due to their shallow depth and the fact that tailings in the upper few metre or so at the Original Dam and Second Dam tailings impoundments are quite oxidized, the density of the “with lime” samples will be significantly lower than the “without lime” samples. It is noteworthy, however, that the likely lime demand for most of the tailings at the Intermediate Dam impoundment and substantial portions of the Original Dam and Second Dam tailings impoundments is more fairly represented by Test P03-8. Only a small amount of lime was needed for the sample from Test P03-8, which resulted in a density which is similar to density of samples FT-1 and FT-2, which received no lime.

An approximation of the impact of lime has been made on the basis of the settled density results in Table 7.5 and the lime consumption results in Section 10.2. The analysis indicates that the average lime demand for the total and partial tailings relocation options is about 4.6 kg/tonne and 6.2 kg/tonne, respectively. Using 5 kg/tonne as an overall mean value and the results in Table 7.5, the impact of lime addition on the “after 24 hour” settled density results would be to reduce the dry density of the tailings and lime by about 5% to 11% (due to scatter, the result depends on the trend line selected to define the relationship). If one applies the same 5% and 11% reduction factors to the average tailings density at the end of the relocation process, the average tailings density would drop to between approximately 1.8 and 1.9 t/m³. Based on these estimated tailings densities and the revised storage capacity curve for the Faro Pit (Figure 7.3), the surface elevation of the in-pit tailings at the end of the relocation process will be as shown in Table 7.6.

Table 7.6: In-pit Tailings Levels with Lime Addition

Parameter	Total Relocation	Partial Relocation
Quantity of Tailings & Lime (tonnes)	57.29	43.22
Average Density of Tailings/Lime (t/m ³)	1.8 to 1.9**	1.8 to 1.9**
Volume of Settled Tailings & Lime (m ³)	30.2 – 31.8 million	22.7 – 24.0 million
Elevation at Top of Tailings/Lime (m)*	1144 – 1147**	1130 – 1133**

* Assumes that the surface of the tailings deposited in the pit is flat and horizontal.

** Depends on the trend line used to define the relationship between the dry density of the tailings and the required lime consumption.

In comparison with Table 7.4, the analysis described above indicates that the addition of lime will increase the final level of the tailings in the Faro Pit by about 2 to 5 m.

8 Water Management

8.1 Water Management Plan

The water management plan would have the following primary objectives:

- provide the hydraulic monitors with a reliable source of water;
- remove water from Faro Pit to free up space for deposition of the relocated tailings; and,
- treat and release excess water that accumulates in the system.

The preliminary engineering assessment by ECMP, presented in Appendix B, suggests the tailings in the Rose Creek tailings impoundment would be mined over about 9 to 12 seasons, depending on whether the relocation is partial or total. Each season would extend over a 6-month period from April to September.

The water management plan for the hydraulic monitoring option would have to be closely coordinated with the mining plan for the relocation of the tailings. An adequate characterization of the water management plan and water balance could be made with just a coarse outline of the mine plan.

ECMP is proposing a preliminary mining plan comprised of two stages, as follows:

Stage 1. The first stage would last about 2 seasons and would involve cutting the tailings surfaces in the Original Dam and Second Dam impoundments down to about the 1057 m elevation. The sump used to collect slurried tailings would be located on the upstream side of the Second Dam. To reduce extraneous inflows to the sump, and thereby reduce the cost of pumping water from the tailings impoundment to the Faro Pit, the flow in the old Faro Creek channel would be diverted to the Intermediate Dam impoundment.

Stage 2. Mining of the Intermediate Dam impoundment would commence in this stage. For the complete removal of all tailings in the three impoundments, this stage would take about 10 seasons. For the partial removal option, this stage would last 7 seasons. The inflow of water to the collection sump is expected to increase significantly over what would be experienced during the first stage. The total drainage area controlled by the collection sump would be larger for this stage than the last one. Also, leakage from the Rose Creek Diversion and the North Wall Interceptor Ditch would become a significant inflow component to the sump. The sump would have to be relocated at least once during this stage to facilitate transport of the slurried tailings by gravity from the areas being mined to the sump.

During both stages, the water supply for the hydraulic monitors would be obtained exclusively from the Faro Pit.

The final two objectives of the water management plan would be implemented by running a water treatment plant (WTP). The amount of water to be treated would increase substantially over levels currently experienced during care and maintenance of the property.

8.2 Water Balance

A spreadsheet was set up to simulate the water balance for the tailings relocation operation. The model is based on an operation that lasts 12 years (i.e., implementation of the total relocation option). The spreadsheet was operated on a monthly time step and was organized around two elements: i) the catchment area controlled by the collection sump; and ii) the Faro Pit.

The following assumptions were made about conditions during the operation:

- The annual volume of water treated by the WTP would remain more or less constant from year to year, even though the amount of water delivered to the Faro Pit would be expected to increase substantially during the second stage of the operation. This strategy would take advantage of the large storage available in the pit to minimize the required size of the WTP.
- The water level in the Faro Pit would be at 1142 m at the beginning of the operation.
- The slurried tailings would experience minimal transmission losses as they flow by gravity from the areas being mined to the collection sump. Based on this assumption, the hydraulic monitoring was assumed to not increase seepage from the tailings impoundment to the underlying valley aquifer above levels already experienced.
- The slurried tailings flowing to the sump is assumed to have a solids concentration of about 46% by weight. Most of the water used to create this slurry would originate from the hydraulic monitors, but a portion would also result from the release of the water trapped in the voids of the deposited tailings. The sump would also collect local runoff from the tailings impoundment and intercepted leakage from the two diversions located on either side of the impoundment.

The original intention was to construct the water balance for the entire tailings impoundment. However, it was recognized that the analysis could be simplified by concentrating only on the area of the tailings impoundment where excavation activities were actually taking place. The smallest element that could be usefully considered in the water balance was the combination of the sump and the catchment area draining to the sump. In selecting this element, flows of water not directly related to the operation could be excluded from consideration. For example, runoff in the Intermediate Impoundment did not have to be kept track of during the simulation of Stage 1 activities.

Table 8.1 provides the average annual water balance for the sump catchment over the anticipated 12 year life of the operation. Average climatic and hydrologic conditions were assumed to prevail throughout the simulation period.

The inflow components are, in descending order: i) water discharged from the hydraulic monitors; ii) seepage from Rose Creek Diversion; iii) water released from voids of tailings; and iv) local runoff from the tailings surface and the undiverted catchment areas draining onto the tailings surface.

The outflow components are, again in descending order: i) water content of tailings slurry pumped to Faro Pit; ii) enhanced evaporation due to wetting of tailings surface by the hydraulic monitors; and iii) spray evaporation losses from jets of water issuing from the hydraulic monitors. Seepage from the sump catchment to the underlying alluvial aquifer was assumed to be negligible.

Table 8.1: Average Annual Water Balance for the Sump Catchment

Water Balance Component	Average Annual Volume (1000 m ³)
INFLOWS	
Local runoff from catchment of sump ¹	415
Seepage from Rose Creek Diversion Channel and North Wall Interceptor Ditch ²	1,537
Water released from voids of tailings ³	1,085
Water demand from Faro Pit for running hydraulic monitors ⁴	4,491
Total	7,528
OUTFLOWS	
Enhanced evaporation due to wetting of catchment by hydraulic monitoring ⁵	276
Water content of tailings slurry pumped to Faro Pit (plus excess water) ⁶	7,162
Spray evaporation losses from hydraulic monitors ⁷	90
Seepage from sump catchment to underlying alluvial aquifer ⁸	0
Total	7,528

- Notes: 1) Flows in old Faro Creek channel will be diverted around hydraulic monitoring operation.
 2) This source will likely be negligible while the hydraulic monitoring operation is confined to the Original and Second Impoundments. However, once the operation moves to the Intermediate Impoundment, this source will likely become large. Based on previous water balance analyses of the Down Valley Tailings Impoundment, the magnitude of this source was estimated to be approximately 4% of flow conveyed by the Rose Creek Diversion Channel. Some portion of this ditch leakage may recharge the underlying alluvial aquifer and hence bypass the sump.
 3) The water stored in the voids of the deposited tailings will become a source of inflow to the sump as the tailings are mined. The deposited tailings were assumed to have an average water content of 45% by volume (i.e., nearly saturated).
 4) The combined water from the hydraulic guns and the water contained in the tailings voids will create a slurry with a solids concentration of about 46% by weight.
 5) Assumed to raise annual evaporation from tailings surface to level similar to a shallow lake.
 6) Equal to all water reporting to sump catchment minus evaporation losses.
 7) Assumed to be 2% of flows discharged by hydraulic monitors.
 8) Assumed to be negligible. If there turns out to be a significant loss, then the seepage to the aquifer will have to be intercepted below the Cross Valley Dam and returned to the Faro Pit.

Figure 8.1 shows the estimated monthly outflows from the sump catchment over the 12 years of excavation. Examination of this figure reveals the amount of water pumped to the Faro Pit is expected to increase significantly once the operation shifts from the first to the second stage. This additional water would primarily be due to an increased interception of leakage from the Rose Creek Diversion. An increase in the catchment area controlled by the sump would also result in more inflows to the system.

Table 8.2 presents the estimated average annual mass balance for the Faro Pit with implementation of the hydraulic monitoring method. A mass balance had to be used in this case, rather than a water balance, to account for the displacement of water caused by the subaqueous deposition of tailings solids. The mass balance comprises six inflow streams, four outflow streams and three different types of storage. The three largest inflows to the open pit are expected to be, in descending order: i) water content of tailings slurry pumped from the tailings impoundment; ii) leakage from the two diversions located around the Faro Pit; and iii) solids content of the tailings slurry. The three largest outflows are anticipated to be, also in descending order: i) flows to the water treatment plant; ii) water supply for the hydraulic monitors; and iii) evaporation from the pit lake.

The open pit would fill at an average rate of 0.5 million m³ per year during the operational period. Given the estimated specific gravity of the tailings solids (4.0) and the estimated dry density of the deposited tailings (2.0 tonnes/m³), the annual increase in the storage of tailings solids will be almost exactly matched by the increase in the volume of water trapped in the voids of the deposited tailings. The volume of the lake overlying the tailings surface would steadily decrease during the 12-year operation. Figure 8.2 provides a prediction of how the surfaces of the pit lake and the submerged tailings would change over time. Under the assumptions made, the water level would always remain below the low point on the perimeter of the Faro Pit. At the end of the operation, a 10 m deep lake would overlie the surface of the in-pit tailings (assuming an average dry density of 2.0 tonnes/m³).

The main conclusions of the water balance analysis are:

- The Faro Pit has adequate storage to contain all tailings from the Rose Creek tailings impoundment and to act as a reservoir to regulate flows to the water treatment plant and supply water to the hydraulic monitors.
- The water treatment plant would have to treat approximately 5.2 million m³ of water each year to prevent the water level in the open pit from rising above the low point on the pit perimeter. Of this annual total, approximately 3.4 million m³ are directly attributable to the tailings relocation and 1.8 million m³ are related to annual treat and discharge amounts that are required to maintain the water in Faro Pit at normal operating levels.

Table 8.2: Average Annual Mass Balance for Faro Pit

Mass Balance Component	Average Annual Volume (1000 m ³)
INFLOWS	
Direct precipitation on pit lake ¹	234
Local runoff ²	393
Seepage from Faro Creek Diversion Channel and Faro Valley Interceptor Ditch ³	1,349
Dewatering of Zone II Pit ⁴	69
Solids content of tailings slurry ⁵	1,188
Water content of tailings slurry (plus excess water that accumulates in sump) ⁶	7,162
Total	10,395
OUTFLOWS	
Evaporation from pit lake ⁷	269
Water supply for hydraulic monitors ⁶	4,491
Seepage from pit (via alluvium in old Faro Creek channel) ⁸	0
Flows to water treatment plant ⁹	5,165
Total	9,925
CHANGE IN STORAGE	
Tailings solids ¹⁰	1,188
Water in voids of deposited tailings ¹¹	1,188
Water in lake overlying surface of deposited tailings ¹²	-1,906
Total	470

- Notes: 1) Allowance made for variations in surface area of pit lake as pit fills and empties.
 2) This is runoff from area above pit lake and below the Faro Creek Diversion Channel and the Faro Valley Interceptor Ditch.
 3) This component represents flow that originated as runoff in catchments of the two diversion channels. The flow discharges to the Faro Pit as either leakage from the channels or groundwater bypass under the channels. Based on previous water balance analyses, the magnitude of the seepage was estimated to equal approximately 24% of the total yield generated by the catchments controlled by the two diversion channels. In other words, the diversions have an efficiency of about 76%.
 4) This represents the net contribution from the Zone II Pit. It is the runoff generated by the small catchment controlled by this open pit. The Zone II Pit will also receive seepage from the Faro Pit. This seepage did not have to be explicitly accounted for in the water balance because it is an internal flow between the two pits (i.e., the seepage out of the Faro Pit nearly cancels the amount of seepage intercepted by the Zone II Pit and returned to the Faro Pit).
 5) Estimated using a specific gravity for the tailings solids of 4.0.
 6) Obtained from the average annual water balance for the sump catchment.
 7) Will generally increase with time as pit fills and surface area of pit lake grows.
 8) Calculations done for ICAP indicate this component would be small.
 9) The water treatment plant was assumed to treat the same amount of water each year over the 12 year operating period.
 10) Approximately 1.2 million m³ of tailings solids will be deposited in the open pit each year.
 11) Based on an assumed dry density of 2.0 tonnes/m³. With a specific gravity of 4.0, the tailings solids occupy virtually the same volume as the interstitial water.
 12) The volume of water overlying the deposited tailings will shrink from the beginning to the end of the tailings relocation operation. The average rate of shrinkage will be about 1.9 million m³/y.

9 Dam Breaches and Basin Remediation

9.1 General

Each of the two tailings relocation options will require incremental site remediation beyond what can be achieved solely by the hydraulic monitoring of the tailings. As an example, the Fresh Water Supply Dam (FWSD), which was situated upstream of the Rose Creek tailings impoundment, was breached in late 2003. The process and requirements associated with the breach of this structure provide a reasonable indication of what is likely to be required for final remediation of the Rose Creek tailings impoundment (SRK, BGC and GLL, 2003). The comments provided below reflect the experience obtained from the breach of the FWSD.

For the total relocation option, each of the four dams (Original, Second, Intermediate and Cross Valley) would have to be breached and fish-friendly habitat would have to be established within the footprint of each dam breach that coincides with Rose Creek. Based on the experience at the FWSD, riprap-lined, meandering channels would likely have to be constructed within the footprint of the breach zones. In addition, the footprints of both the tailings impoundment and the area between the Intermediate and Cross Valley Dams would likely have to be revegetated, to the extent possible (Figure 9.1). However, it is assumed that, due to the geochemical characteristics of the tailings, a thin layer of remnant tailings and highly contaminated soil would have to be stripped from the impoundments in order to expose material that is suitable for revegetation. Comments on revegetation are provided in Section 9.2. Lastly, the Rose Creek Diversion Canal would have to be decommissioned since it would no longer be required.

For the partial relocation option, a slot would likely have to be excavated through the Original and Second Dams. The slot would be similar to a breach, but would not extend all the way down to the base of each dam, although it would be relatively close to the base in both cases. The areas that will be exposed as a result of the partial relocation option are shown in Figure 9.1. The portion of the basin above elevation 1042 m (the proposed level of the water cover) would be stripped and revegetated on the basis of Figure 9.1. Based on the presence of the remaining tailings, no fish friendly habitat would be required as part of this option. The Rose Creek Diversion Canal would still be required, but potential modifications that would be required in order to meet closure criteria are beyond the scope of this report.

9.2 Revegetation

The details of the revegetation program, including the need for fertilizer and the spacing of seedlings, would be advanced as part of further studies and as the impoundment basin starts to become exposed. For the current assessment, it is assumed that the revegetation requirements would be similar in concept to what was implemented within the reservoir upstream of the FWSD. On that

basis, the basin would be seeded with a seed mixture that would likely consist of a wide variety of native grasses including some, such as rye, that would germinate rapidly and provide immediate erosion control. It is expected that the seed mixture would be manually broadcast unless the soil is dry enough to permit the use of a four-wheel all terrain vehicle, or “quad.” The exposed riparian zone would be revegetated with grass, willow and spruce or alpine fir seedlings planted in a 10 m wide zone (extending 10 m from the edge of the bank of Rose Creek) and a 5 m wide zone adjacent to tributaries.

There is considerable uncertainty about the condition of the basin soils following the removal of the remnant tailings and a thin layer of contaminated soil. While the broad revegetation concepts are assumed to be similar to those of the FWSD, the conditions within the footprint of the Rose Creek tailings impoundment are likely to be significantly more severe due to the unfavourable geochemical conditions that are likely to remain despite the removal of the tailings and a layer of soil. Ultimately, it is reasonable to assume that the success of the revegetation program will be significantly less than what was achieved at the FWSD.

10 Costs

10.1 Summary

The cost of tailings relocation for the total and partial relocation options have been estimated and are provided, in summary form, in Tables 10.1 and 10.2. The general items included in Tables 10.1 and 10.2 include the following:

- The cost to relocate the tailings from the Rose Creek tailings impoundment to the Faro Pit using hydraulic monitoring equipment and methods and an incremental (booster) pump system;
- The cost to add lime, if necessary, to neutralize the stored acidity in the porewater of the tailings;
- The cost to treat water that is displaced by the tailings as they are deposited to the Faro Pit;
- The cost to strip any remnant tailings and a layer of soil from the floor of the valley after the tailings have been removed by hydraulic monitoring methods;
- The cost to breach the tailings dams, as necessary, in order to facilitate a return to the natural hydrologic surface flow regimes;
- The cost to revegetate areas within the current footprint of the tailings facility which become exposed as a result of either total or partial tailings relocation;
- In the case of the total tailings relocation option, the cost to provide fish habitat enhancement in the area of the dam breaches;
- In the case of the partial tailings relocation option, the cost to lower the spillway at the Intermediate Dam to develop a lower operating level in the adjacent pond;
- An allowance of 5% for design, construction supervision and project management.
- A 20% contingency.

Not included in these estimates are the costs of:

- Upgrading the Second Dam, Intermediate Dam or the Cross Valley Dam in order to meet closure criteria for long term stability. The recent study by Klohn Crippen (2004) indicates that, depending on the final closure plan, some level of remediation is likely to be required to fulfill the long term stability requirements of these dams.
- Implementing modifications to the Rose Creek Diversion Canal that could potentially be required. In the case of total relocation, the entire diversion canal would likely have to be remediated, which could consist of canal deconstruction, the re-establishment of drainage channels that link to the existing natural drainage channels and revegetation efforts. In the case of partial relocation, the capacity of the residual section of the diversion canal would have to be increased in order to pass the closure design flood.

Select information regarding the design assumptions and the basis of the unit costs used in the development of Tables 10.1 and 10.1 is provided below, in Sections 10.2 through 10.6. Spreadsheets containing the quantities, unit costs and detailed cost calculations are provided in Appendix H.

Table 10.1: Estimated Costs for Total Tailings Relocation

Task	Total
Tailings monitoring & initial pumping	\$ 86,300,000
Tailings relocation (operating booster pump station)	\$ 27,600,000
Lime Addition	\$ 82,300,000
Water Treatment	\$ 5,900,000
Basin cleanup, truck & shovel	\$ 5,790,000
Dam breaches*	\$ 6,450,000
Revegetation	\$ 460,000
Fish habitat enhancements	\$ 184,000
Subtotal	\$ 214,984,000
Project management, design & construction supervision @ 5% of Subtotal	\$ 10,749,200
Contingency @ 20% of Subtotal	\$ 42,996,800
Total	\$ 268,914,000

* The alternative option of complete removal of each of the Original, Secondary, Intermediate and the Cross Valley Dams would cost a total of \$26.6 million.

Table 10.2: Estimated Costs for Partial Tailings Relocation

Task	Total
Tailings monitoring & initial pumping	\$ 57,310,000
Tailings relocation (operating booster pump station)	\$ 20,700,000
Lime Addition	\$ 81,720,000
Water Treatment	\$ 4,410,000
Basin cleanup, truck & shovel	\$ 1,810,000
Dam breaches	\$ 1,190,000
Revegetation	\$ 140,000
Spillway lowering	\$ 27,000
Subtotal	\$ 167,307,000
Project management, design & construction supervision @ 5% of Subtotal	\$ 8,365,350
Contingency @ 20% of Subtotal	\$ 33,461,400
Total	\$ 209,133,750

10.2 Lime Costs

The correlation between paste pH and lime demand, as shown in Figure 7.1, and the depth profiles of paste pH that were obtained in 2001 and 2003 by GLL, were used to estimate the lime requirements for the tailings contained in each of the impoundments. At a lime supply cost of \$320 per ton FOB the site, the estimated lime costs to neutralize the tailings are shown in Table 10.3. The estimated

total cost to meet the lime demand, in the event the soluble acidity within the tailings requires neutralization during relocation, is about \$82.3 million.

The estimated cost of the lime, \$320 per ton, is based on current operations. It is possible that, based on the significantly higher level of lime consumption that would be required for tailings relocation, the lime cost, FOB the site, may be reduced to a unit cost in the range of \$240 per ton to \$250 per ton. If this were the case, the estimated total cost to meet the lime demand for tailings neutralization during relocation would drop as much as about \$20 million, to about \$62 million.

Table 10.3: Estimated Lime Demand within the Rose Creek Tailings Impoundment

Depth (m)	Lime Demand (kg Ca(OH) ₂ /m ³)			Lime Costs (\$/m ³)			Total Lime Costs (\$ x 1000)			
	Original	Second	Interm.	Original	Second	Interm.	Original	Second	Interm.	
1	99	79	16.0	\$ 34.85	\$27.81	\$5.63	\$13,463	\$15,854	\$4,326	
2	64	36	0.5	\$ 22.39	\$12.60	\$0.16	\$8,650	\$7,180	\$ 123	
3	36	25	0.1	\$ 12.69	\$8.82	\$0.02	\$4,901	\$5,028	\$14	
4	44	5.1	0.1	\$ 15.40	\$1.78	\$0.05	\$5,939	\$1,016	\$32	
5	42	2.8	0.4	\$ 14.85	\$1.00	\$0.16	\$5,663	\$ 565	\$109	
6	1.0	19	0.0	\$0.36	\$6.58	\$0.00	\$ 135	\$3,663	\$ 2	
7	6.2	6.8	0.9	\$2.19	\$2.39	\$0.32	\$ 810	\$1,311	\$193	
8	2.2	2.0	0.5	\$0.79	\$0.71	\$0.19	\$ 282	\$ 379	\$99	
9	1.1	0.5	0.5	\$0.40	\$0.19	\$0.19	\$ 138	\$98	\$85	
10	3.5	0.8	0.1	\$1.24	\$0.26	\$0.03	\$ 407	\$136	\$12	
11	0.5	1.3	1.4	\$0.17	\$0.47	\$0.48	\$55	\$ 236	\$180	
12	0.3	1.0	0.4	\$0.11	\$0.33	\$0.13	\$32	\$ 156	\$ 41	
13	0.6	1.1	0.4	\$0.22	\$0.37	\$0.13	\$64	\$ 150	\$ 35	
14	0.1	0.8	0.4	\$0.05	\$0.30	\$0.15	\$15	\$ 104	\$ 30	
15	0.3	0.1	1.1	\$0.12	\$0.03	\$0.38	\$31	\$ 9	\$ 59	
16	0.4	1.3	0.2	\$0.13	\$0.45	\$0.07	\$32	\$ 126	\$ 9	
17	0.1	0.2	0.2	\$0.02	\$0.07	\$0.07	\$ 4	\$18	\$ 7	
18	0.1	0.1		\$0.02	\$0.02		\$ 3	\$ 5	\$-	
19	0.1	2.7		\$0.02	\$0.94		\$ 3	\$ 154	\$-	
20		0.9			\$0.31		\$-	\$36	\$-	
21		0.4			\$0.15		\$-	\$10	\$-	
22		0.4			\$0.15		\$-	\$ 7	\$-	
23		1.3			\$0.44		\$-	\$16	\$-	
24		0.4			\$0.15		\$-	\$ 3	\$-	
25		0.4			\$0.15		\$-	\$ 2	\$-	
	Subtotal							\$40,637	\$36,273	\$5,364
	Total							\$82,275		

Note: Original, Second and Interm. refer to the tailings impoundments behind the Original, Second and Intermediate Dam Impoundments

10.3 Water Treatment Costs

A report that looked at the cost of water treatment based on the existing system and a new high density sludge (HDS) system was completed by SRK in early 2004. That report concluded that the cost of water treatment for an HDS system installed at the Faro Mill would be about \$0.144/m³. This unit cost assumes that the water quality is the same in future as it is presently.

The water treatment costs are currently under review. In the event that there are any changes to the estimated water treatment costs as a result of this review, these changes will be accounted for in the final version of this report.

10.4 Basin Cleanup

For estimating purposes, it has been assumed that the average thickness of material (tailings and/or intensely contaminated soil) that would be excavated from the impoundment floor after the hydraulic monitoring has been completed would be 0.5 m. In reality, the thickness would depend on actual field conditions, and it is likely that the excavated thickness would be significantly less than 0.5 m in some areas and significantly more in others. A truck and shovel operation, complemented by a dozer, would be used for this work. The excavated material would be hauled to the southeast corner of the Faro Pit and dumped into the pit lake.

The revegetation program would likely be at least as expensive as the cost of revegetation at the FWSD reservoir. This is because organic soils that were present at the fresh water supply dam reservoir would likely be absent at the tailings impoundment following the expected stripping by a truck and shovel operation. There is also the risk of remnant acidity within the soils and/or acidic groundwater flowing back into the impoundment for some period of time, likely many months or even years, following the relocation of the tailings. These issues are addressed as part of the contingency factor.

10.5 Dam Breaches

The scenarios under which the various dams at the tailings facility would be breached are discussed in Section 9.1. For estimating purposes, since it is consistent with the approach taken for the FWSD, it is assumed that each breach will be designed and implemented on the basis of meeting the design criteria at the minimum construction cost. It is expected, therefore, that each breach would only be wide enough to pass the design flood event while preventing erosion at the sides of the breach.

The entire removal of any of the dams, as could be considered in the case of the total relocation option, is considered unnecessary. However, the estimated cost of completely removing each of the dams is provided in Appendix H.

11 Conclusions

11.1 Key Conclusions

A preliminary engineering assessment of tailings relocation based on has been completed. Two options were considered: total and partial relocation.

The relocation of the tailings using hydraulic monitoring methods is considered feasible. The relocation work for total and partial relocation would take 12 and 9 years, respectively. There is sufficient room in the Faro Pit to store all of the tailings but this should be re-evaluated in conjunction with the potential relocation of waste rock to the open pit.

A cost estimate has been prepared. It accounts for the relocation of tailings to the Faro Pit, the potential addition of lime to neutralize the soluble acidity within the tailings, treatment and discharge of excess water, breaching of redundant dams, development of fish-friendly habitat, where necessary, cleanup and revegetation of the impoundment basin, an allowance for design and engineering supervision and a contingency to account for unknowns.

Based on the foregoing factors, the estimated costs of the two options are as follows:

	Total Relocation	Partial Relocation
Cost exclusive of engineering, proj. man. and contingency	\$ 214,984,000	\$ 167,307,000
Engineering, project management and 20% contingency	\$ 53,746,000	\$ 41,826,750
Total Estimated Cost	\$ 268,914,000	\$ 209,133,750

11.2 Risks

As with most engineering projects, there are risks that the execution of the project does not unfold as expected. In the case of tailings relocation, the following risks have been identified:

- Hydraulic monitoring may face unforeseen challenges that make it more difficult and, therefore, more costly, to relocate tailings to the Faro Pit.
- The cleanup of the basin using mechanical methods may be more difficult to achieve than expected due to, for example, trafficability issues.
- The development of a vegetative cover may take much longer, or achieve limited success relative, than currently expected.

To the extent that reasonable contingency plans are developed and expectations are appropriately managed, these risks can be mitigated.

This report, **Preliminary Engineering for Tailings Relocation Using Hydraulic Mining Methods, Yukon - 1CD003.057**, was prepared by SRK Consulting

Prepared by

Cam Scott, P.Eng.
Principal Engineer

John Chapman, P.Eng.
Senior Engineer

Pat Bryan, P.Eng.
Associate Consultant

Dave Jansson.
ECMP Consultant

Reviewed by

Daryl Hockley, P.Eng.
Principal Engineer

12 References

Robertson, ICAP, 1996

SRK, 2004a on relocation options using 3 different methods

SRK, 2004b on cover studies

SRK 2004c on water treatment costs

Golder Associates, CPT, 2004

Cunning John, personal communication, 2003

SRK 1991 decommissioning plan

Klohn Crippen draft report, 2004

SRK, BGC, GLL 2003 design report on the FWSD


GWP Software Inc., FSConsol, Canada, 1999.

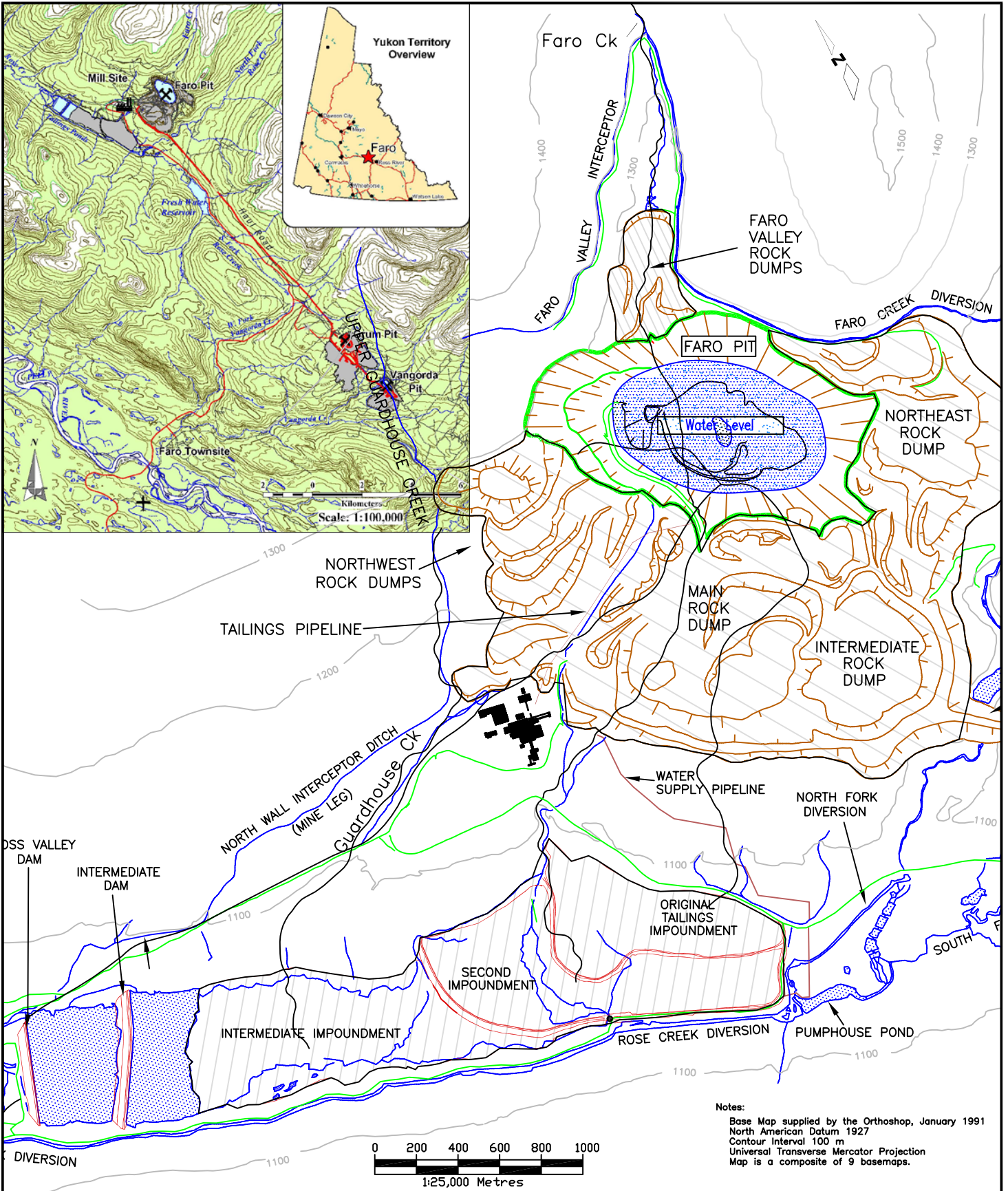


Photo 1.1A: David Jansson of ECMP commences field test to evaluate the feasibility of monitoring the Rose Creek tailings.



Photo 1.1B: Pressure washer was able to cut into the tailings surface adjacent to the Intermediate Dam with relative ease.

 SRK Consulting <i>Engineers and Scientists</i>	Anvil Range Mining Complex Tailings Relocation Assessment		
	Photographs of the Field Monitoring Test		
Deloitte & Touche	PROJECT: 1CD003.57	DATE: Nov. 2004	APPROVED: CCS
			FIGURE: 1.1

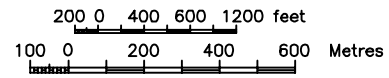


TAILINGS RELOCATION ASSESSMENT

SITE LAYOUT

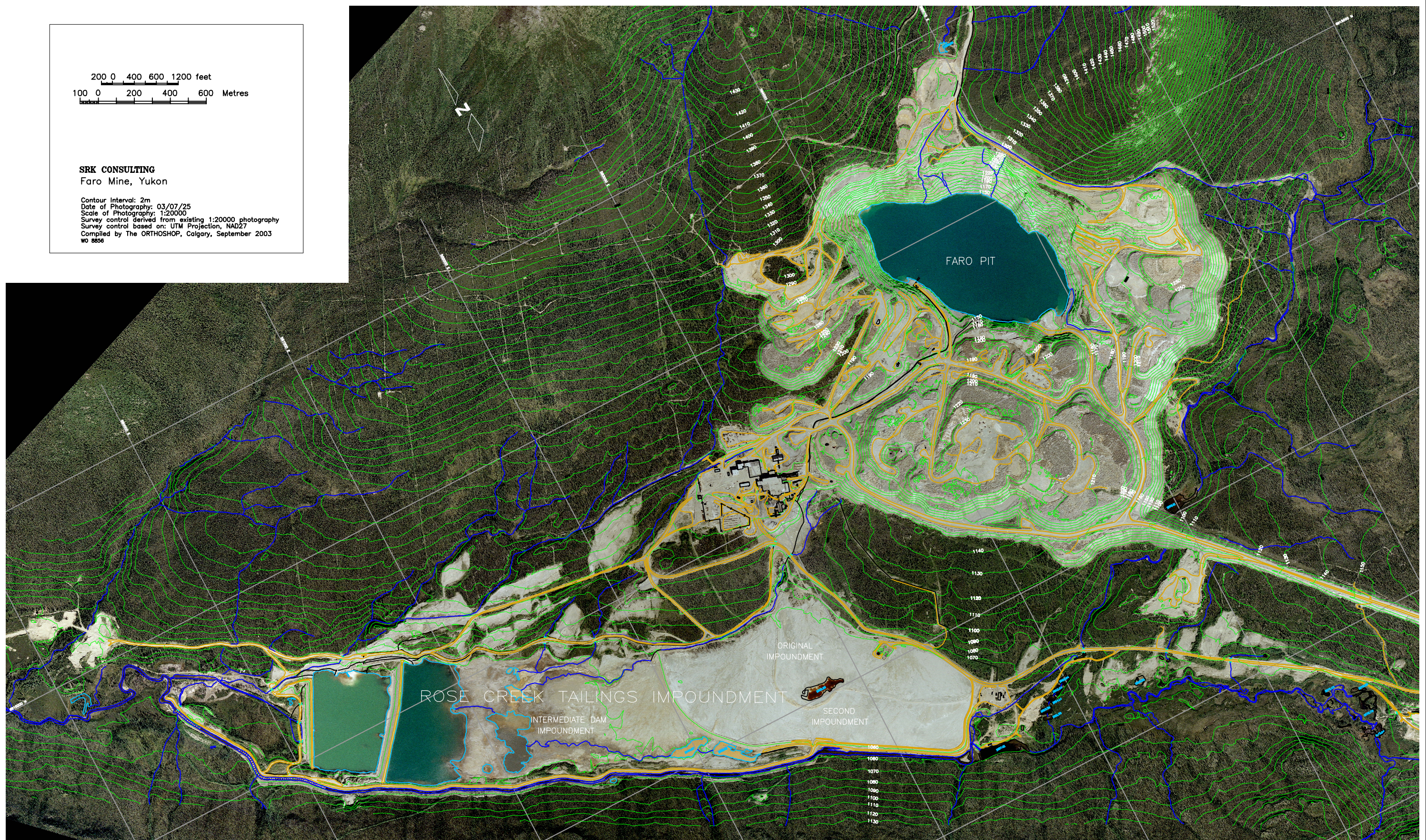
PROJECT NO.	DATE	APPROVED	FIGURE
1CD003.057	Nov.2004	C.C.S.	2.1

Dwg Ref: wchwg



SRK CONSULTING
Faro Mine, Yukon

Contour Interval: 2m
Date of Photography: 03/07/25
Scale of Photography: 1:20000
Survey control derived from existing 1:20000 photography
Survey control based on: UTM Projection, NAD27
Compiled by The ORTHOSHOP, Calgary, September 2003
WO 8856



File Ref: 2003_SITE_PLAN-photodwg

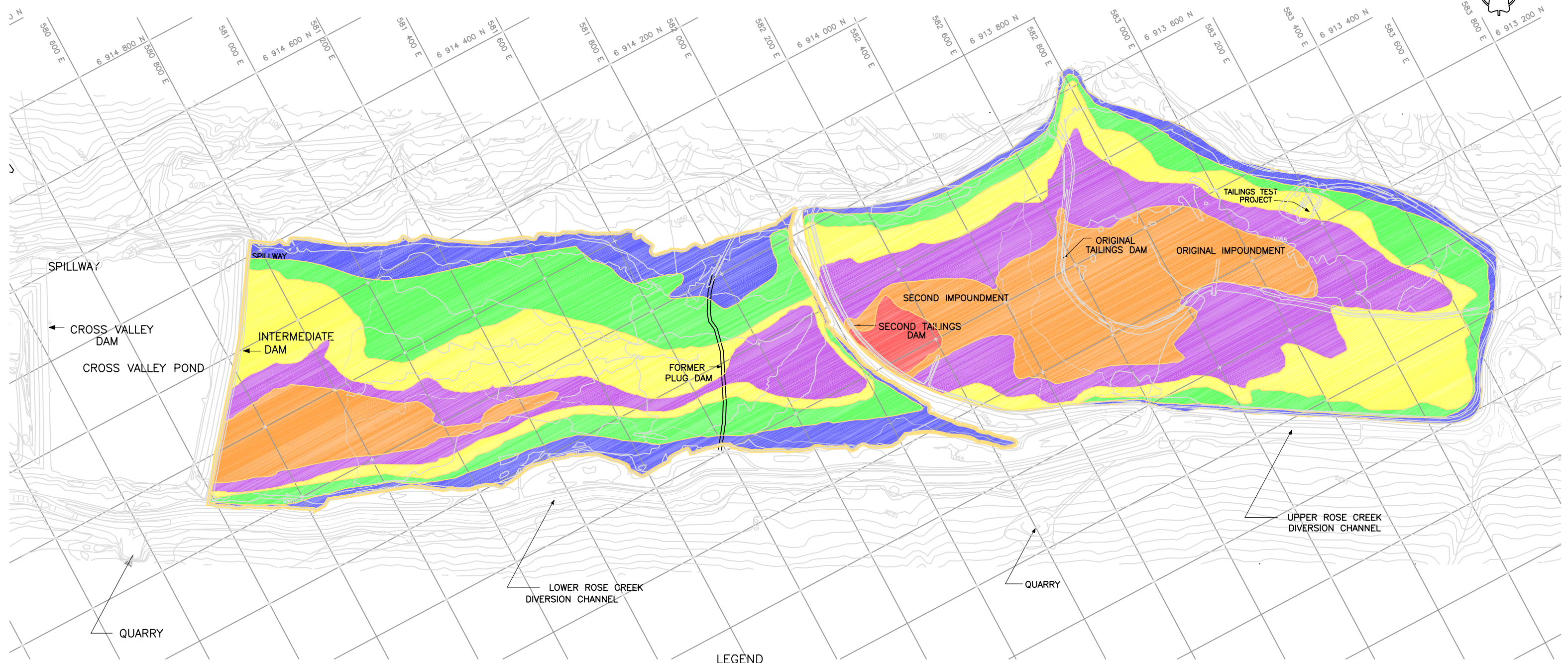
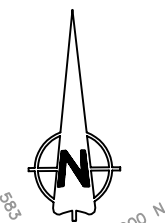


Deloitte & Touche

TAILINGS RELOCATION ASSESSMENT

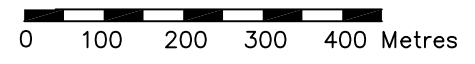
AERIAL VIEW OF THE FARO SITE

PROJECT NO.	DATE	APPROVED	FIGURE
1CD003.28	Nov. 2004		2.2



LEGEND

- > 25m
- 20-25m
- 15-20m
- 10-15m
- 5-10m
- 0-5m



SCALE 1 : 10,000

MAPPING COMPILED BY THE ORTHOSHOP, CALGARY, ALBERTA, JANUARY, 1991. BASED ON AERIAL PHOTOGRAPHY, SEPTEMBER 17, 1990, AT A SCALE OF 1 : 10 000. SURVEY CONTROL WAS SUPPLIED BY CURRAGH RESOURCES INC.

CONTOUR INTERVAL = 5 METRES.
 COORDINATES ARE UTM IN METRES.
 ELEVATIONS ARE RELATIVE TO MEAN SEA LEVEL (NAD27)
 TAILINGS THICKNESSES SHOWN ARE AS OF SEPT. 17, 1990.



FARO TAILINGS RELOCATION ASSESSMENT

TAILINGS THICKNESS ISOPACHS

PROJECT NO. 1CD003.053	DATE Nov. 2004	APPROVED CCS	FIGURE 2.3
---------------------------	-------------------	-----------------	---------------

File Ref: Sample_plan-NAD27.dwg



Photo 3.1a: A hydraulic monitoring gun in the Chilean Andes.



Photo 3.1b: Hydraulic monitoring from the top down.



**Deloitte
& Touche**

Anvil Range Mining Complex
Tailings Relocation Assessment

**Typical Photographs of Tailings
Relocation in Chile**

PROJECT:
1CD003.57

DATE:
Dec. 2004

APPROVED:
CCS

FIGURE:
3.1



Photo 3.2a: Hydraulic monitoring from the bottom up.



Photo 3.2b: Slurried tailings flowing through a grizzly prior to reporting to settling tanks and pumping station for subsequent deposition.



Anvil Range Mining Complex
Tailings Relocation Assessment

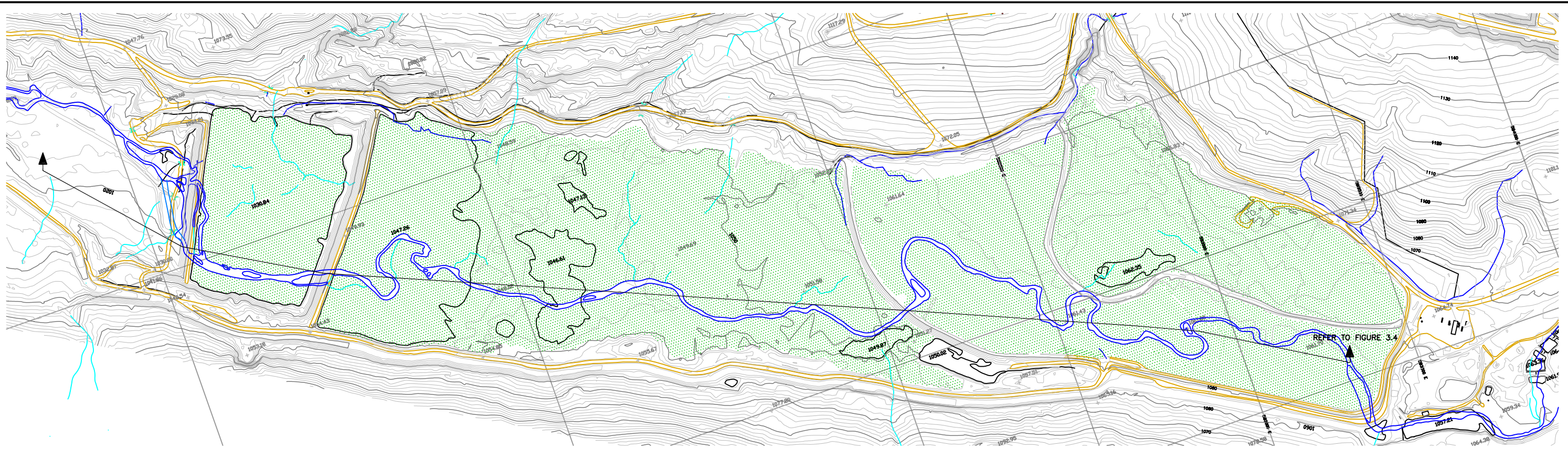
**Typical Photographs of Tailings
Relocation in Southern Africa**

PROJECT:
1CD003.57

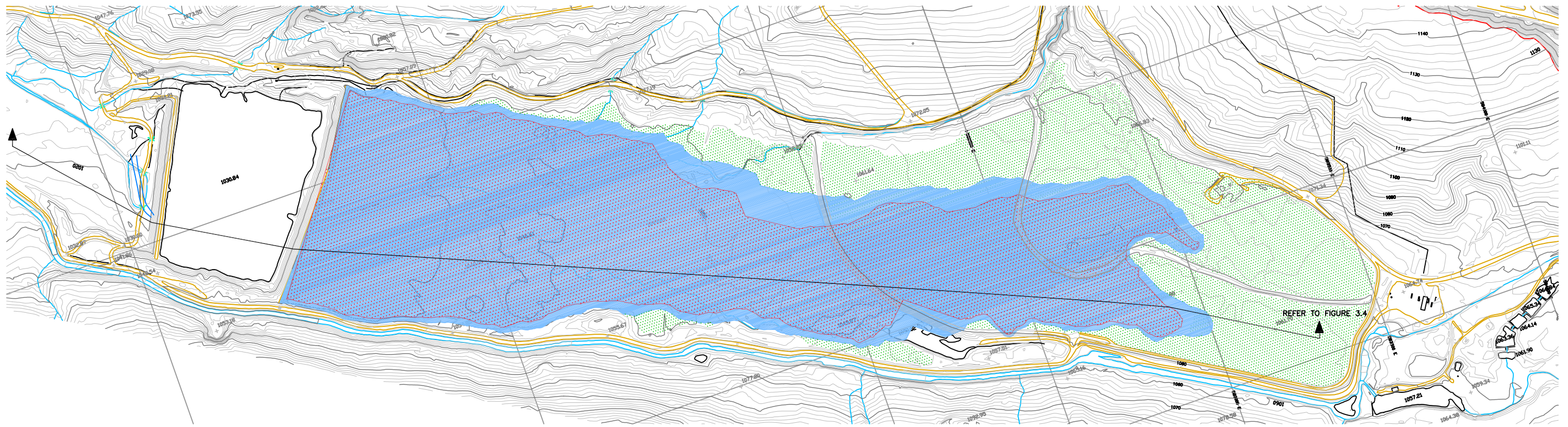
DATE:
Dec. 2004

APPROVED:
CCS




FIGURE:
3.2



TOTAL RELOCATION OF TAILINGS



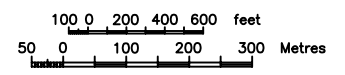
PARTIAL RELOCATION OF TAILINGS



- LEGEND**
-  OUTLINE OF TAILINGS AT ELEVATION 1042m
 -  WATER COVER AT ELEVATION 1045m
 -  AREAS OF REVEGETATION

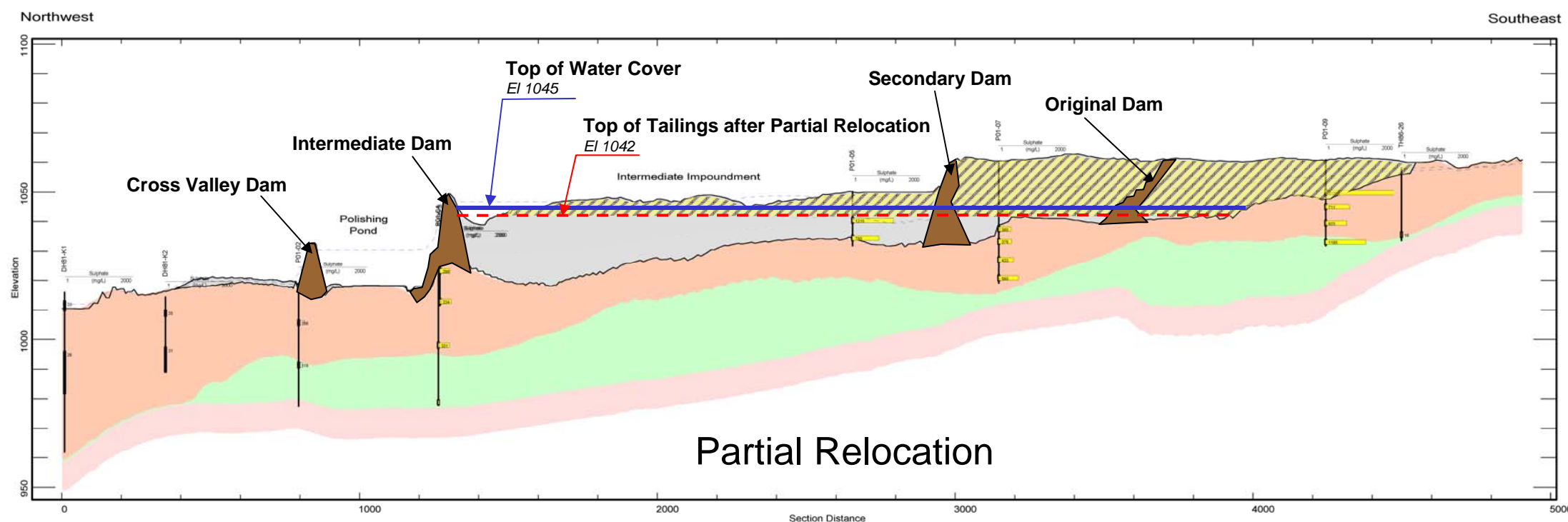
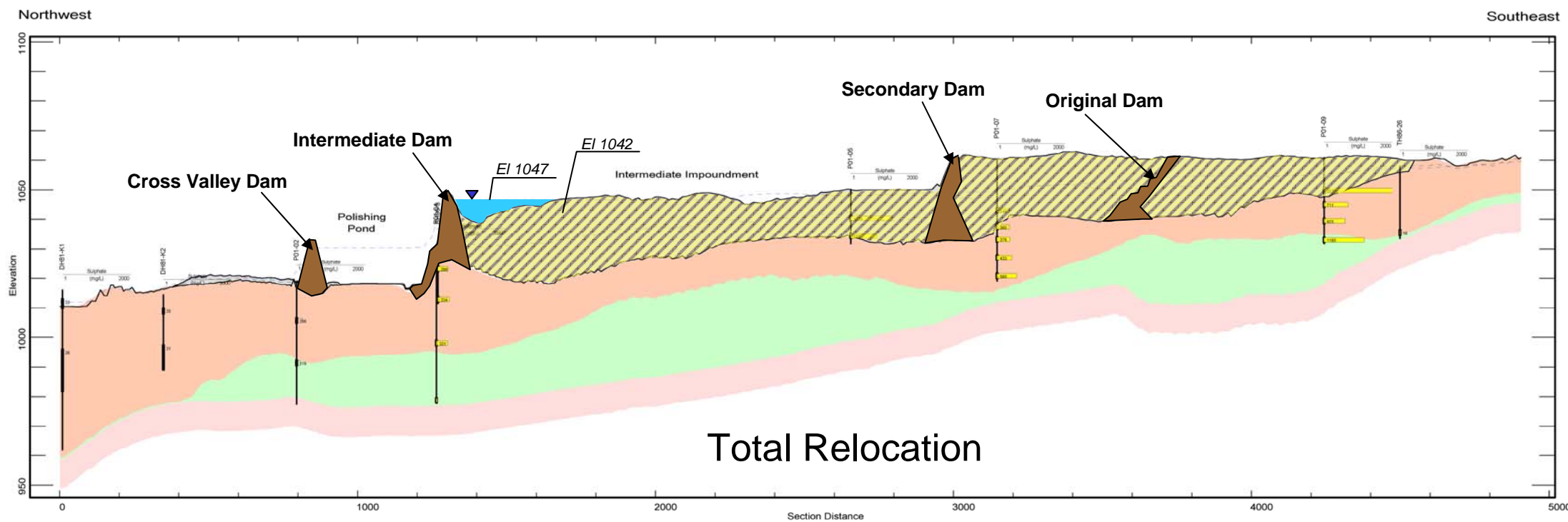
File Ref: 2003 SITE PLAN_rose creek.dwg



SRK CONSULTING
 Faro Mine, Yukon
 Map Scale : 1:4000
 Contour Interval: 2m
 Date of Photography: 03/07/25
 Scale of Photography: 1:20000
 Survey control derived from existing 1:20000 photography
 Survey control based on: UTM Projection, NAD27
 Compiled by The ORTHOSHOP, Calgary, September 2003
 wo 8856



 SRK Consulting Engineers and Scientists		FARO TAILINGS RELOCATION ASSESSMENT	
		Plan Views Illustrating Total and Partial Tailings Relocation	
PROJECT NO. 1CD003.57	DATE Nov. 2004	APPROVED CCS	FIGURE 3.3
 Deloitte & Touche			



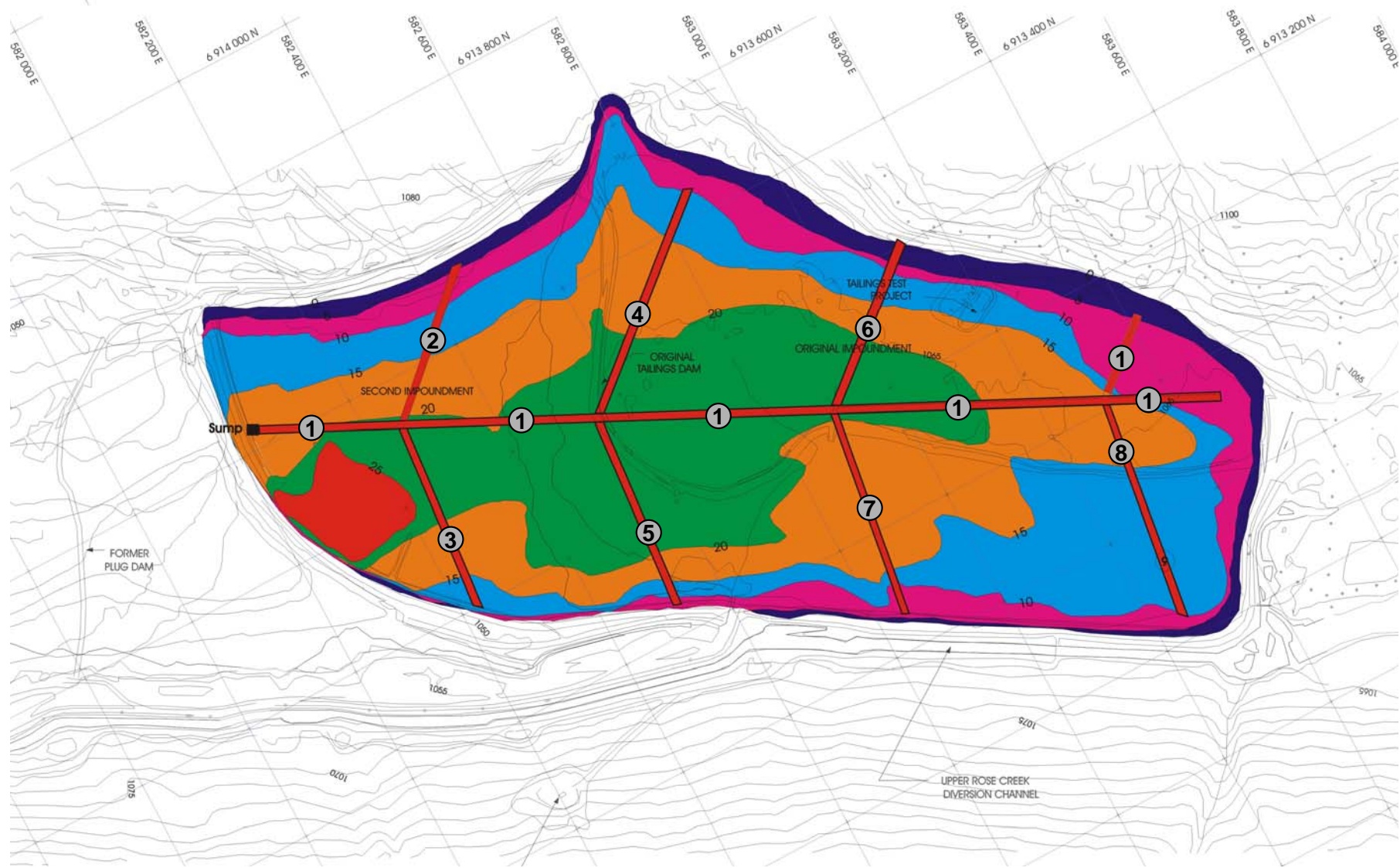
Source: from Gartner Lee Limited, Rose Creek Tailings Facility, Figure 6.3, 2002



Anvil Range Mining Complex
Tailings Relocation Assessment

**Sections Illustrating Total and
Partial Relocation Options**

PROJECT: 1CD003.57	DATE: Nov. 2004	APPROVED: CCS	FIGURE: 3.4
-----------------------	--------------------	------------------	-----------------------



Note: ① through ⑧ refers to mining sequence in Section 4.2 of this report

Source: ECMP Report, Aug. 2004

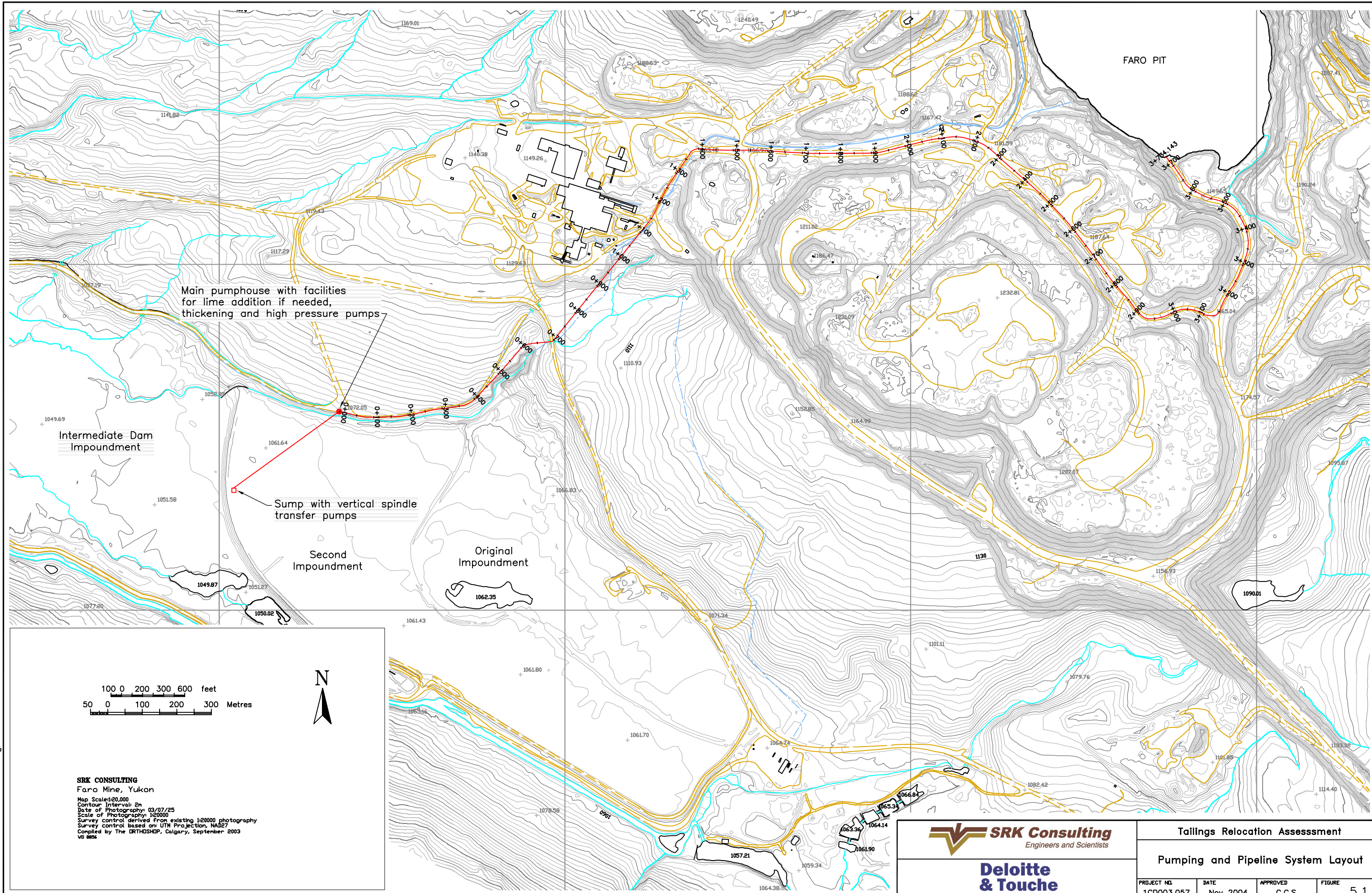


Deloitte & Touche

Anvil Range Mining Complex
Tailings Relocation Assessment

Schematic View of the Initial Mine Plan

PROJECT: 1CD003.57	DATE: Nov. 2004	APPROVED: CCS	FIGURE: 4.1
-----------------------	--------------------	------------------	-----------------------



Main pumphouse with facilities for lime addition if needed, thickening and high pressure pumps

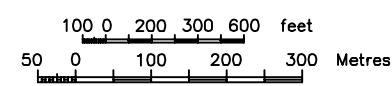
Intermediate Dam Impoundment

Sump with vertical spindle transfer pumps

Second Impoundment

Original Impoundment

FARO PIT



SRK CONSULTING
 Faro Mine, Yukon
 Map Scale: 1:20,000
 Contour Interval: 2m
 Date of Photography: 03/07/25
 Scale of Photography: 1:20,000
 Survey control derived from existing 1:20,000 photography
 Survey control based on UTM Projection, NAD27
 Compiled by The GRTHDSHP, Calgary, September 2003
 v0 88%



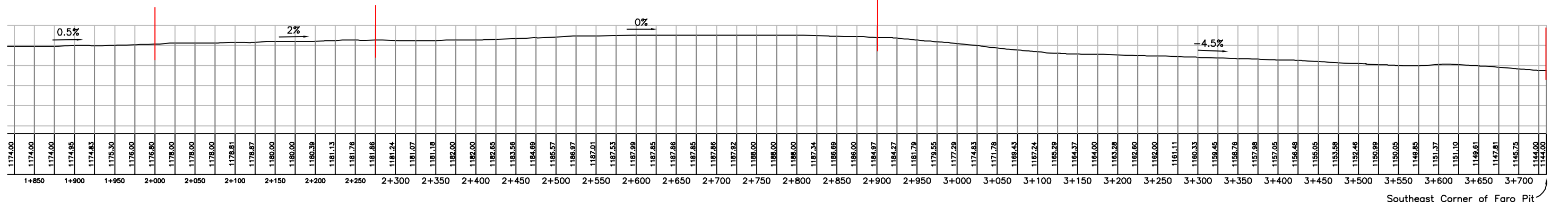
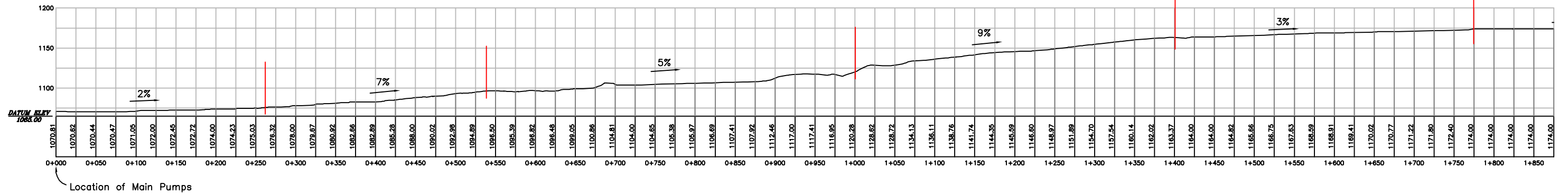
Deloitte & Touche

Tailings Relocation Assessment

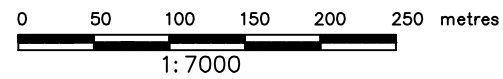
Pumping and Pipeline System Layout

PROJECT NO.	DATE	APPROVED	FIGURE
1CD003.057	Nov 2004	C.C.S.	5.1

File Ref: 2003 FARO SITE PLAN-LDD.dwg



Note: The slope on each segment is the average value taken between two adjacent points. Each of these points is defined by the intersection of the red vertical line with the ground profile.



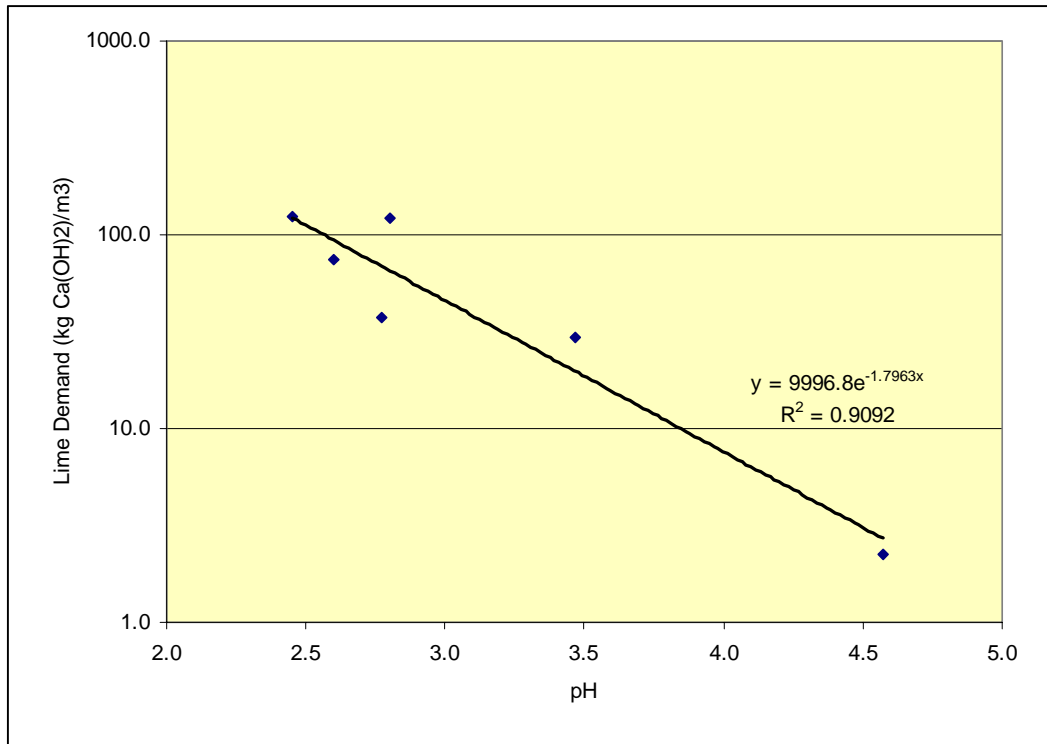


Figure 7.1a Correlation between Lime Demand and Paste pH

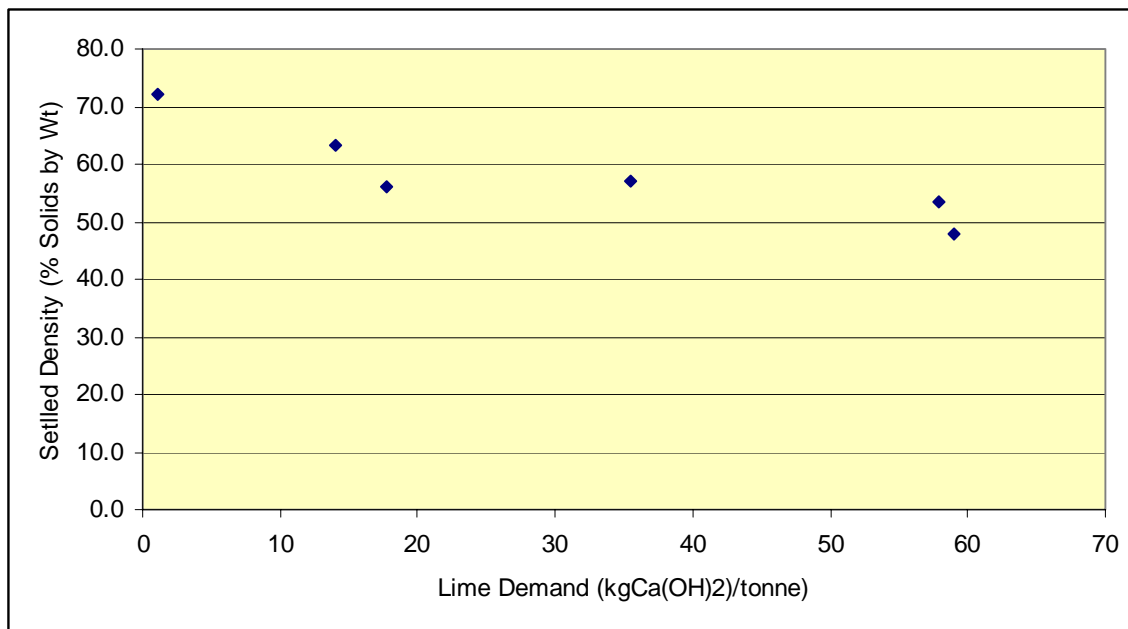


Figure 7.1b Effect of Lime Addition on Settled Density after 24 Hours



Anvil Range Mining Complex
Tailings Relocation Assessment

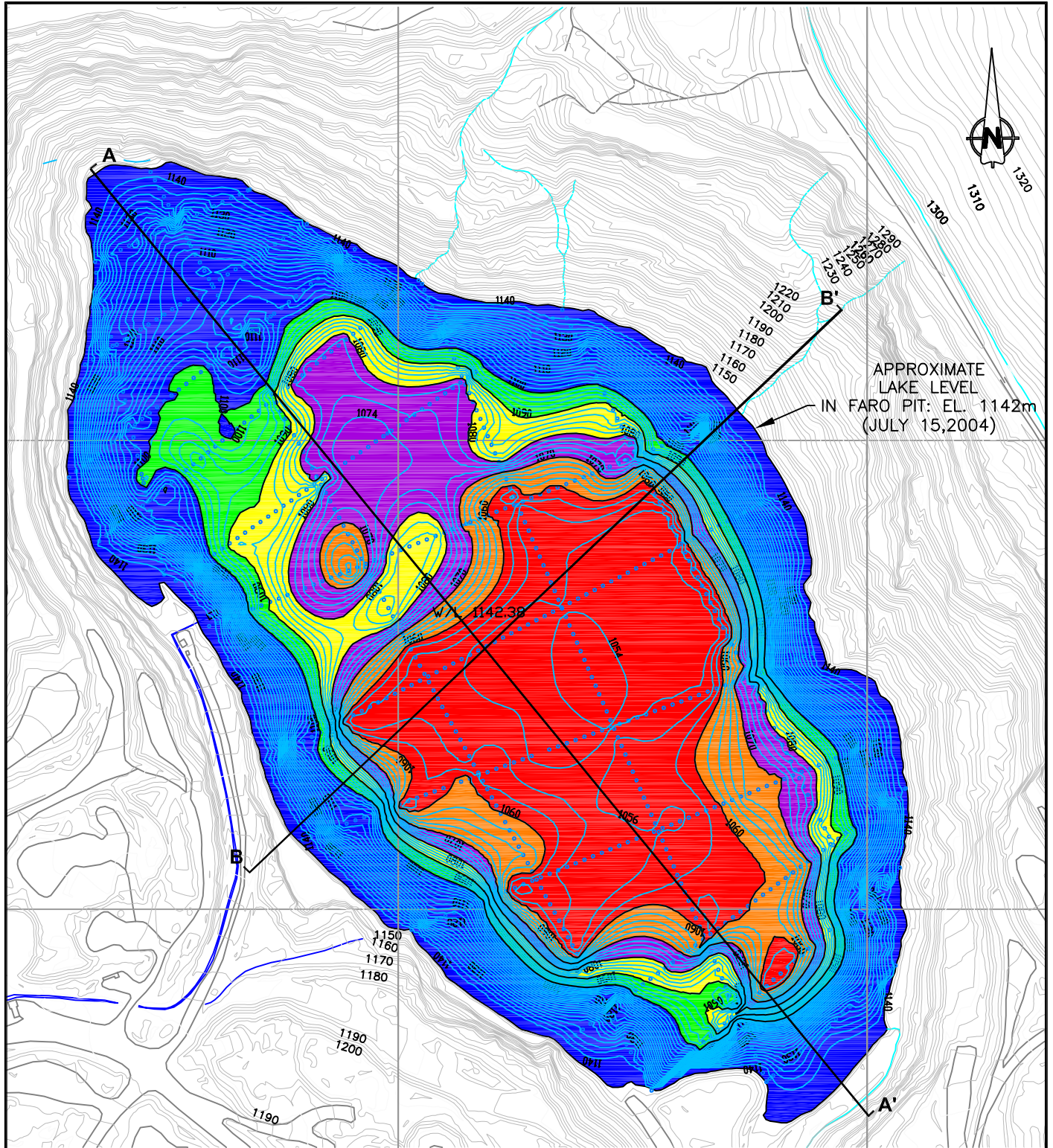
**Relationship between Paste pH,
Lime Demand and Settled Density**

PROJECT:
1CD003.57

DATE:
Nov. 2004

APPROVED:
CCS

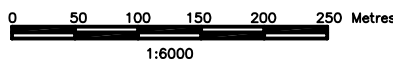
FIGURE:
6.1



APPROXIMATE
LAKE LEVEL
IN FARO PIT: EL. 1142m
(JULY 15, 2004)

Faro Mine, Yukon

Contour Interval: 2m
Date of Photography: 03/07/25
Scale of Photography: 1:20000
Survey control derived from existing 1:20000 photography
Survey control based on: UTM Projection, NAD27
Compiled by The ORTHOSHOP, Calgary, September 2003
wo 8856



ELEVATION	
Blue	1100–1142m
Green	1090–1100m
Yellow	1080–1090m
Purple	1070–1080m
Orange	1060–1070m
Red	>1060m

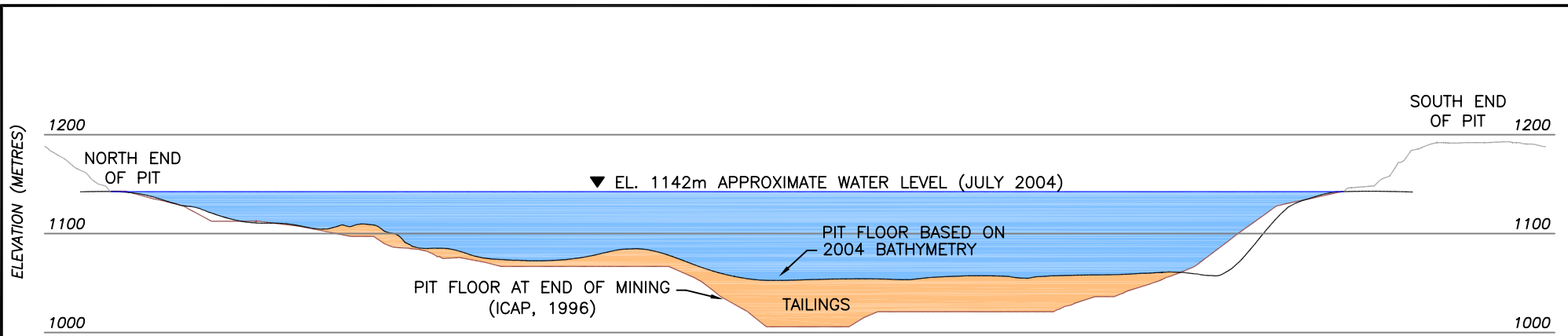


TAILINGS RELOCATION ASSESSMENT

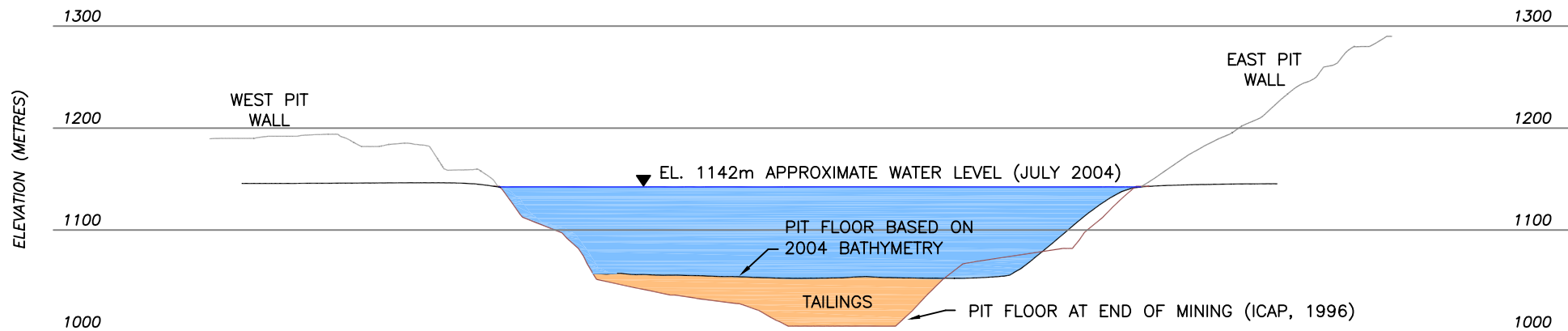
PIT BATHYMETRY AND
SECTION LOCATIONS

PROJECT NO.	DATE	APPROVED	FIGURE
1CD003.057	Nov. 2004	CCS	7.1

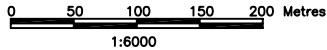
Dwg. Ref: HEIGHT-CAP.DWG



SECTION A-A'



SECTION B-B'



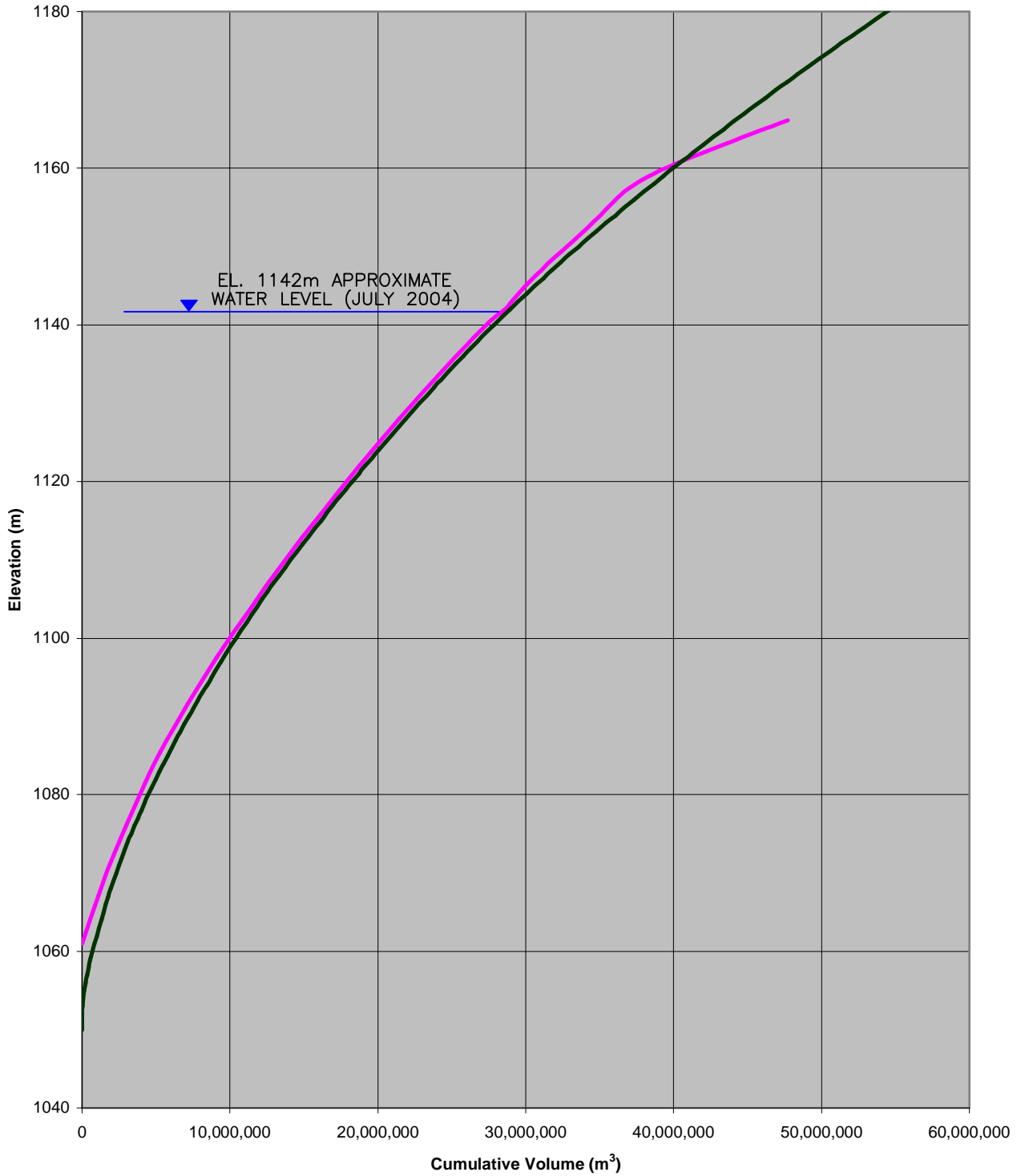
TAILINGS RELOCATION ASSESSMENT

SECTIONS THROUGH
CURRENT FARO PIT

PROJECT NO. 1CD003.057	DATE Nov.2004	APPROVED CCS	FIGURE 7.2
---------------------------	------------------	-----------------	---------------

Faro Pit

Old Data (from ICAP) New Data (from 2003 topo & 2004 bathymetry)

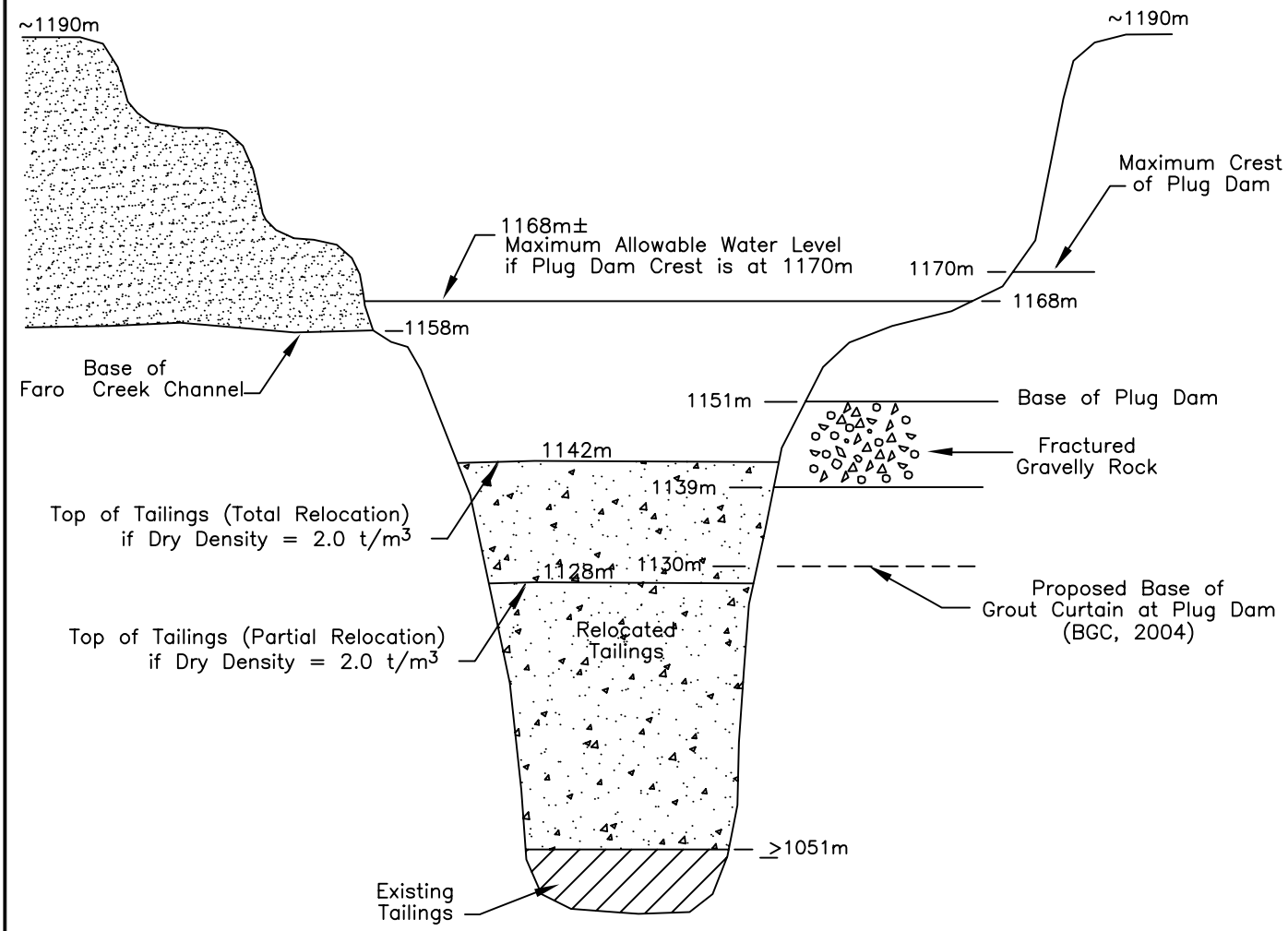


TAILINGS RELOCATION ASSESSMENT

STORAGE CAPACITY CURVE

PROJECT NO. 1CD003.057	DATE Nov.2004	APPROVED CCS	FIGURE 7.3
---------------------------	------------------	-----------------	---------------

Dwg Ref: #.dwg

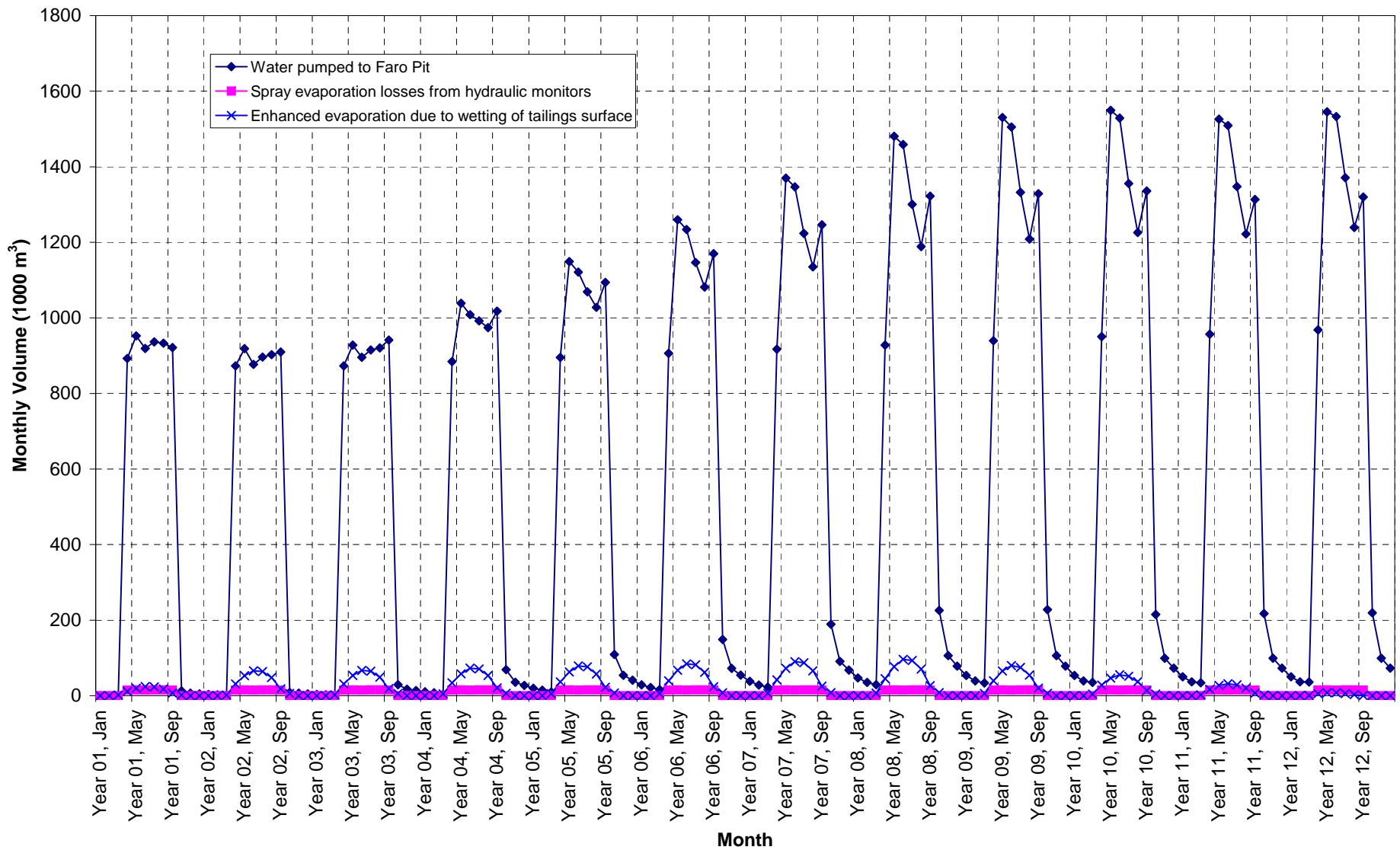


TAILINGS RELOCATION ASSESSMENT

SCHMATIC SECTION ILLUSTRATING KEY ELEVATIONS IN THE FARO PIT

PROJECT NO.	DATE	APPROVED	FIGURE
1CD003.057	Nov.2004	CCS	7.4

Dwg Ref: #.dwg



Deloitte & Touche

Anvil Range Mining Complex
Tailings Relocation Assessment

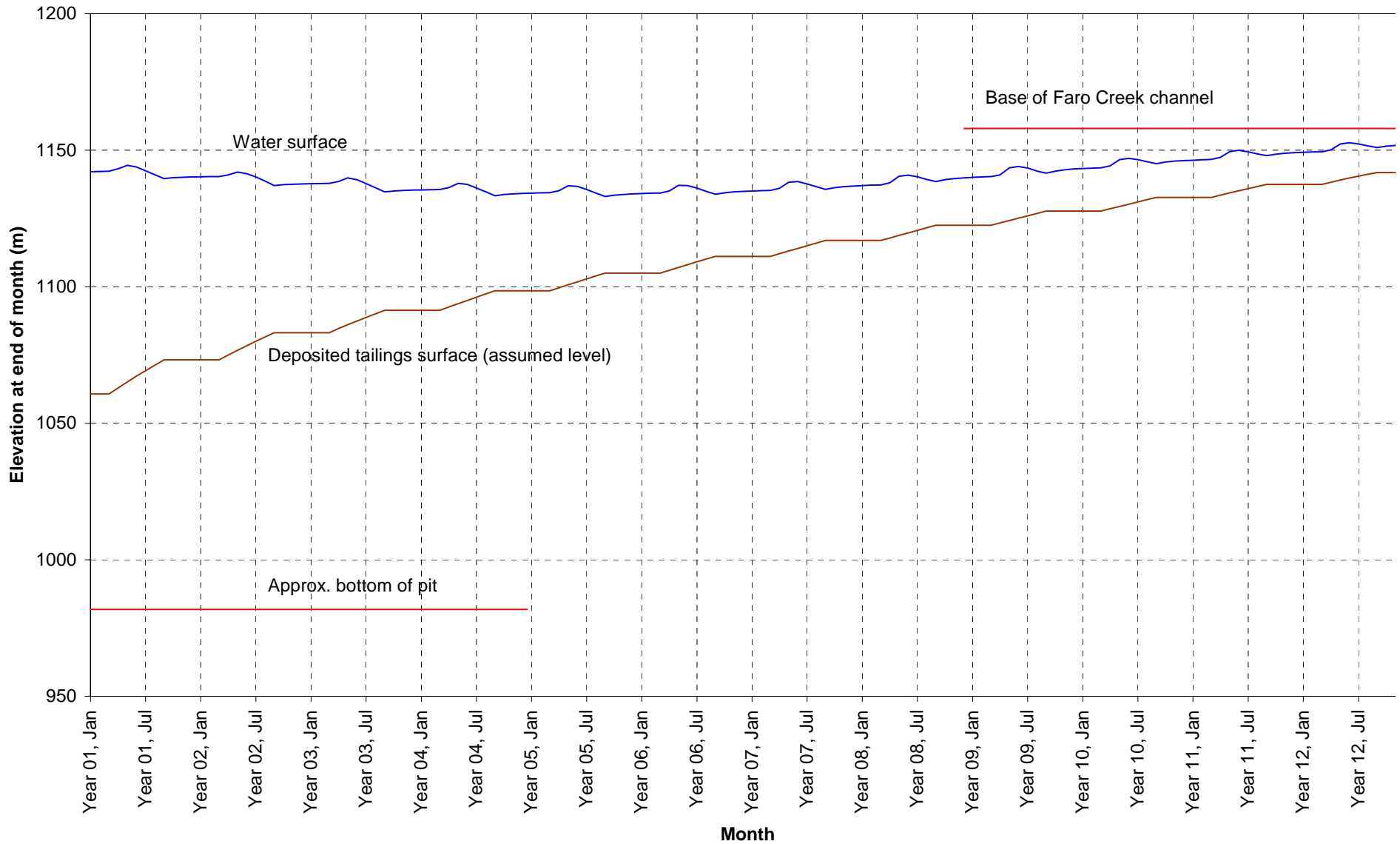
Simulated Monthly Outflows from Sump Catchment

PROJECT:
1CD003.57

DATE:
Nov. 2004

APPROVED:
CCS

FIGURE:
8.1



Anvil Range Mining Complex
Tailings Relocation Assessment

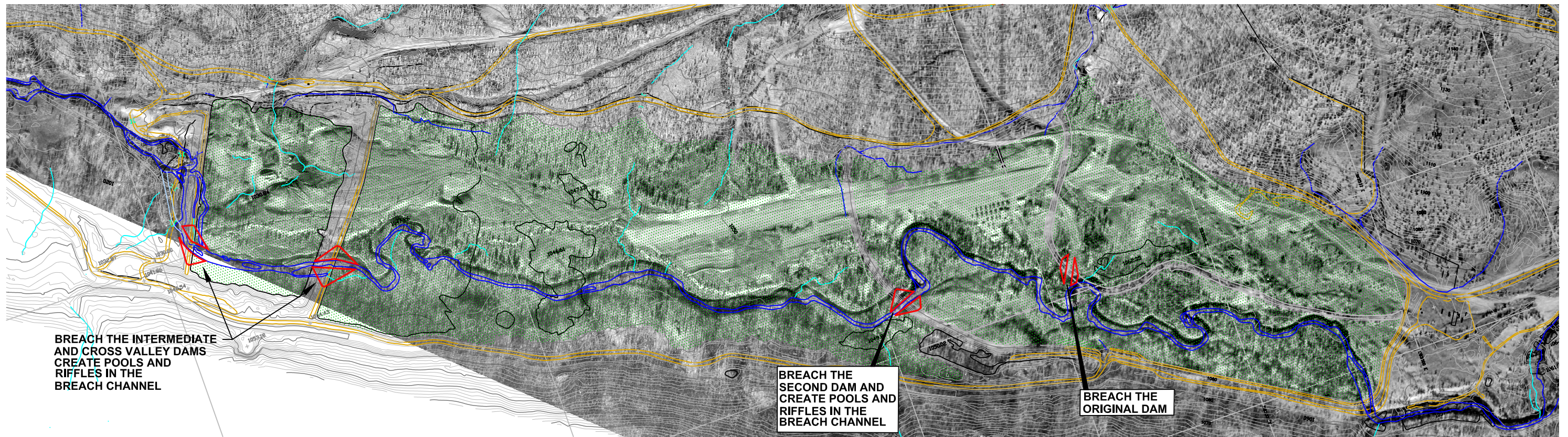
Simulated Filling of Faro Pit

PROJECT:
1CD003.57

DATE:
Nov. 2004

APPROVED:
CCS

FIGURE:
8.2

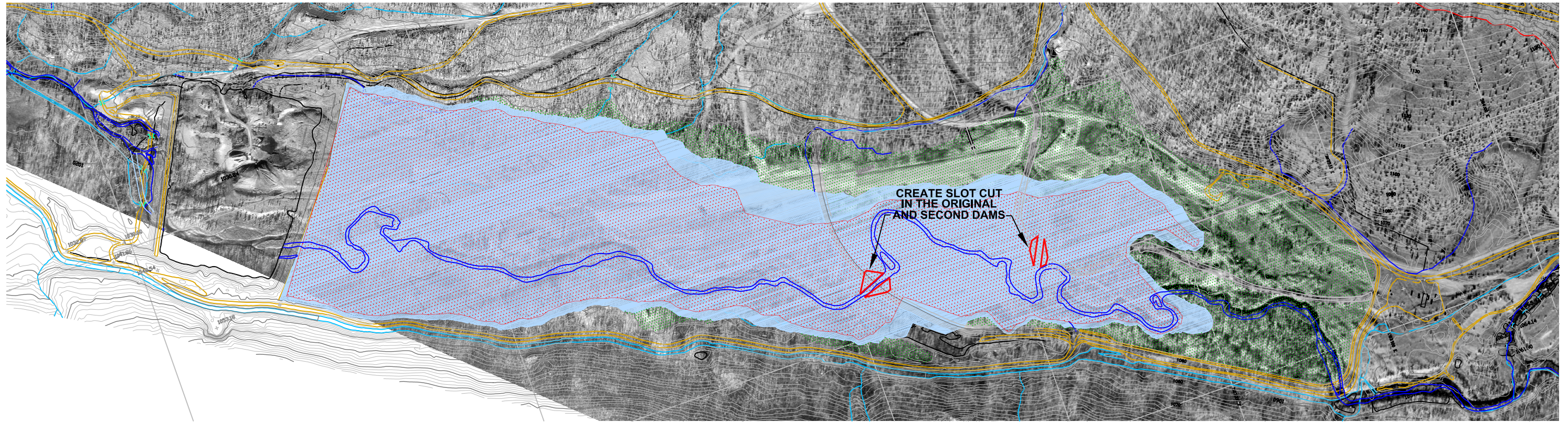


BREACH THE INTERMEDIATE AND CROSS VALLEY DAMS
AND CREATE POOLS AND RIFFLES IN THE
BREACH CHANNEL

BREACH THE
SECOND DAM AND
CREATE POOLS AND
RIFFLES IN THE
BREACH CHANNEL




BREACH THE
ORIGINAL DAM

TOTAL RELOCATION OF TAILINGS



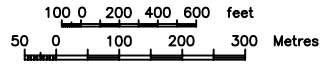
CREATE SLOT CUT
IN THE ORIGINAL
AND SECOND DAMS

PARTIAL RELOCATION OF TAILINGS

- LEGEND**
-  OUTLINE OF TAILINGS AT ELEVATION 1042m
 -  WATER COVER AT ELEVATION 1045m
 -  AREAS OF REVEGETATION



SRK CONSULTING
Faro Mine, Yukon
Map Scale : 1:4000
Contour Interval: 2m
Date of Photography: 03/07/25
Scale of Photography: 1:20000
Survey control derived from existing 1:20000 photography
Survey control based on: UTM Projection, NAD27
Compiled by The ORTHOSHOP, Calgary, September 2003
wo 8856



FARO TAILINGS RELOCATION ASSESSMENT

Remedial Works After
Tailings Relocation

PROJECT NO. 1CD003.57	DATE Nov. 2004	APPROVED CCS	FIGURE 9.1
--------------------------	-------------------	-----------------	---------------

Appendix A

As-built Information for the Tailings Dams

Appendix B

ECMP Report on Hydraulic Monitoring

Appendix C

Incremental Information from Pump Suppliers

Appendix D

Geochemical Investigation and Test Results for Tailings

Appendix E

Bathymetry Survey of Faro Pit Lake

Appendix F

Geotechnical Test Results for Tailings

Appendix G

Consolidation Modeling for Tailings in Faro Pit

Appendix H

Detailed Quantity and Cost Calculations