Klohn Crippen Berger

# Yukon Government

## Faro Mine Complex, Yukon Territory

***Operations, Maintenance and Surveillance Manual for:***

***Intermediate Dam, Cross Valley Dam and Little Creek Dam***

March 2014
M09770A03.730

March 31, 2014

Yukon Government
Faro Mine Remediation Project
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**Karen Furlong, EIT**
**Project Manager**

Dear Ms. Furlong:

**Faro Mine Complex, Yukon Territory**
**Operations, Maintenance and Surveillance Manual for:**
**Intermediate Dam, Cross Valley Dam and Little Creek Dam**

We are pleased to submit this report entitled, Operations, Maintenance and Surveillance Manual (OMS) for: Intermediate Dam, Cross Valley Dam and Little Creek Dam. This updated report is based on the earlier version prepared by BGC Engineering (BGC 2008c). It represents the result of a joint effort by the Yukon Government (YG), Tlicho Engineering and Environmental Services (TEES) and Klohn Crippen Berger (KCB).

Key project information was obtained from past reports submitted by various consultants, and changes to site management and operations are described in this updated manual. This OMS manual follows the information requirements and approach outlined in the Canadian Dam Association (CDA) Dam Safety Guidelines (CDA 2007) and the Mining Association of Canada (MAC 2002) guidelines for Developing an Operation, Maintenance and Surveillance Manual for Tailings and Water Management Facilities.

It is the responsibility of the site management to ensure that this manual is up to date. The CDA recommends updating when major changes occur or new studies are available. One main item to be updated annually is the list of contacts.

The purpose of this manual is to document the current operating procedures for the three dams at the site for the benefit of site personnel. Although there are numerous dams and dykes in the Faro Mine Complex, the manual focuses on the following three specific dams:

- Intermediate Dam within the Down Valley;
- Cross Valley Dam downstream of the Intermediate Dam within the Down Valley; and



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- Little Creek Dam below the Vangorda Waste Rock Dump.

The present update was largely based on the 2008 version of the OMS manual (BGC 2008c). Additional information contained in various reports prepared for the mine site since that time was also used as source material for this update. The OMS manual is a "living document" that will require future updating as site reclamation work proceeds, and as directed by the Yukon Government.

Yours truly,
**KLOHN CRIPPEN BERGER LTD.**

Robert C. Lo

Robert C. Lo, P.Eng.
Project Manager

RL:dl

# Yukon Government

## Faro Mine Complex, Yukon Territory

***Operations, Maintenance and Surveillance Manual for:***

***Intermediate Dam, Cross Valley Dam and Little Creek Dam***

## CLARIFICATIONS REGARDING THIS REPORT

This report is prepared by a joint effort of Yukon Government, Tlicho Engineering and Environmental Services (TEES) and Klohn Crippen Berger Ltd. (KCB). The material in it reflects the judgment of all parties involved in light of the information available at the time of report preparation. Any use which a third party (i.e. other than YG, TEES and KCB) makes of this report, or any reliance on decisions to be based on it are the responsibility of such third parties. The contributing parties of this report accept no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

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### List of Appendices

# 1 INTRODUCTION

The Faro lead-zinc mining complex is located approximately 200 km north-northeast of Whitehorse, Yukon, as shown on the site location plan in Figure A-001. It consists of the Faro Mine which was in production from 1969 to 1992 (with production rates of 5,000 to 9,300 tonnes per day), and the Vangorda Plateau Mine which was in production from 1986 to 1998. From 1998 to 2008, the mine site was under the management of Deloitte & Touche (2002), who were the court-appointed interim receiver. From 2009 to date, the Yukon Government has actively managed the mine complex. Ongoing care, maintenance, and environmental protection activities were carried out by Denison Environmental Services from 2009 to 2012, focusing on a seasonal pumping and water treatment program for the Faro and Vangorda open pits, and inspection and maintenance of water retention and diversion structures. Since 2012, on site care and maintenance activities have been carried out by Tlicho Engineering and Environmental Services (TEES).

## 1.1 Purpose

This manual describes the site facilities, operating systems and procedures at the closed Faro Mine Complex in Yukon Territory, focusing on Intermediate Dam, Cross Valley Dam and Little Creek Dam. The manual covers only the earth dams and civil water management aspects of operation, maintenance and surveillance of the facilities. It does not cover other aspects such as electrical, pumping and mechanical facilities, etc. The objectives of this manual are to define and describe:

- key components of the Faro Mine Complex facilities;
- roles and responsibilities of personnel assigned to the site care and maintenance activities; and
- procedures required to operate, monitor and maintain the site facilities to ensure that these facilities function properly according to design, meeting regulatory requirements and guiding emergency planning and response procedures.

This document provides an easy and quick reference for operations personnel or other interested persons who may be unfamiliar with established procedures on site. Additional information is available in separate key project documents; a list of which is given at the end of this manual. The information presented in this manual should be reviewed annually and, if required, revised and updated. This version updates and replaces the current version dated 2008.

## 1.2 Administration and Responsibilities

The care and maintenance activities at Faro Mine Complex are administered by the Government of Yukon (YG) under the Faro Mine Remediation Project. Tlicho Engineering and Environmental Services (TEES) has been the site manager of the existing facilities under contract with Yukon Government since 2012.

Yukon Government has contracted with CH2MHILL as its consultant for the ongoing mine closure work since 2012. Currently, Klohn Crippen Berger carries out annual reviews of the geotechnical and hydrotechnical aspects of the site facilities, while Golder conducts periodical reviews of pitwall stability for the three pit lakes at Faro, Grum and Vangorda open pits, and in 2013 CH2MHILL reviewed the Grum pitwall deformation survey program.

## 1.3 Key Dam Structures

Figure B-002 shows the mine site topography and access roads of the Faro Mine Complex, including the locations of the three dams under consideration: Intermediate Dam, Cross Valley Dam and Little Creek Dam. The Intermediate and Cross Valley dams are located in the Rose Creek Valley (see Figures B-003 and B-004) and were constructed between 1981 and 1991 to form the Down Valley tailings area. The Little Creek Dam, constructed in 1991, is located adjacent to Vangorda Creek to capture water discharging from the Vangorda Waste Rock Dump (see Figures B-005 and B-006).

All of the dams are earth and rockfill embankment structures, which have performed satisfactorily over their lifetimes under the mine operational conditions. From 1998-2008 the mine site was under the management of Deloitte and Touche, the court-appointed Interim Receiver. Yukon Government has taken over the administration of the Faro Mine Complex since 2009. From 2009-2012 Denison Environmental Services, and from 2012-present Tlicho Engineering and Environmental Services (TEES) has been the site manager under contract with Yukon Government. Site staff are responsible for ongoing care, maintenance and environmental protection activities, which involves seasonal pumping and water treatment for the Faro and Vangorda pit and since 2013 the Grum pit, and inspection and maintenance of water retention and water diversion structures.

The 2007 Dam Safety Review (KCB 2008) classified the Intermediate and Cross Valley Dams as High Consequence failure structures. The Little Creek Dam was considered then to be in the Low Consequence failure category. In a recent dam breach and inundation study (KCB 2014a), the consequence classification of the Intermediate and Cross Valley Dams was confirmed as High, while the classification of the Little Creek Dam was raised from Low to Significant or High. KCB (2014a) indicated that a more detailed dam breach and inundation study using better topography would be required to confirm the classification of the Little Creek Dam. The next Dam Safety Review is scheduled by Yukon Government to take place in 2014.

The subsequent sections of this OMS Manual provide operating information and procedures for these three dams, which take into account the dam safety requirements and the site water licence.

## 1.4 Water License Conditions

In 2009, the Faro Mine Remediation Project (FMRP) obtained a Minister’s Determination entitled “Faro Mine Complex Reclamation and Closure Activities”, as per Section 37(1) of the Waters Act (YG 2009)*,* for works to be undertaken at the Faro Mine Complex (FMC). This document is included in Appendix I. Section C of the Minister’s Determination, “Measures to be Taken,” and provides authorization for a list of activities that the Assessment and Abandoned Mines Branch (AAM) may undertake to “prevent, counteract, mitigate, or remedy any resulting adverse effects on persons, property, or the environment, and in particular the Surrounding Waters.” This Determination is an authorization provided by the YG’s Department of Environment directly to AAM, Department of Energy, Mines and Resources. Section 37 of the Waters Act states:

37(1) Where the Minister believes, on reasonable grounds, that

(a) a person has closed or abandoned, temporarily or permanently, a work related to the use of waters or the deposit of waste, and

(b) either

(i) the person has contravened or failed to comply with any condition of a licence or any provision of this Act or the regulations, whether or not the condition or provision relates to closing or abandonment, or

(ii) a danger to persons, property, or the environment may result from the past operation of the work or from its closing or abandonment, the Minister may take any reasonable measures to prevent, counteract, mitigate, or remedy any resulting adverse effect on persons, property, or the environment, and for that purpose may enter any area, place, or premises, except one that is designed to be used and is being used as a permanent or temporary private dwelling-place.

The following sections should be used as reference for the provisions that are relevant to the operation, maintenance and surveillance of dams and water diversion structures at the mine site.

## 1.5 Survey Datum

The figures contained in this report were compiled from a variety of sources, and no attempt was made to reconcile the various survey grids and vertical datum used. The reader is cautioned to be aware of the survey datum differences across the site. Each drawing is annotated showing the source of the drawing and the particular survey datum used.

In general, National Topographic System (NTS) base maps are based on the 1927 North American Datum (NAD27) - Universal Transverse Mercator (UTM) grid system. All recent as-built surveys of the dams done by Yukon Engineering Services (YES) were done using this datum. The vertical datum for NAD 27 is mean sea level (msl).

The elevations shown on many of the dam drawings typically refer to either "Mine Datum" (MD) or Down Valley Datum" (DVD). The following conversion rules were applied to convert these elevations to metres above mean sea level (m amsl) (Robertson Geoconsultants 1996):

- To convert from Mine Datum to m amsl, subtract 33.3 m (109.2 ft).
- To convert from Down Valley Datum to m amsl, subtract 32.3 m (106 ft).

Unless noted otherwise, for reference, the survey datum used for each of the dam drawings included in this OMS manual are:

- Cross-Valley Dam- originally DVD but now NAD 27 (m amsl).
- Intermediate Dam- originally DVD but now NAD 27 (m amsl).
- Little Creek Dam - elevations are referenced to NAD 27 datum (m amsl). However, both UTM and mine grids are used for the coordinate systems.

Both the dam crests and the spillways of the Intermediate and Cross Valley Dams were surveyed by YES in 2003.

To clarify dam-related terminology, Figure A-007 is used to illustrate some of these terms, such as freeboard, maximum water level (MWL), full supply level (FSL), etc. By familiarizing oneself with these terms, the reader will be able to follow descriptions given in various tables included herein.

## 1.6 Key Technical Contacts

Personnel from KCB, CH2MHILL, Golder and Gomm have been providing geotechnical, hydrotechnical, dam safety and environmental consulting services to Yukon Government. For the information of site staff, the following summarize their respective roles:

- KCB - geotechnical and hydrotechnical aspects of the Faro and Vangorda Plateau water and tailings storage dams, diversion channels, pit lakes and waste rock and overburden dumps.
- CH2MHILL - mine closure aspects of Faro and Vangorda Plateau facilities and 2013 Grum pitwall deformation survey program.
- Golder – pitwall stability aspects of Faro, Grum and Vangorda open pits.
- Gomm – environmental aspect.

Contact numbers for the various consultants involved with the Intermediate, Cross Valley and Little Creek Dams are provided in Table 1.1, and also presented in Appendix II.

**Table 1.1 Summary of Consultant Contacts**

| | | | |
|---|---|---|---|
| Geotechnical | Robert Lo | Klohn Crippen Berger | (604) 251-8455 (w)<br>(604) 278-7126 (h) |
| Geotechnical – Alternate | Jaco Esterhuizen | CH2MHILL | (541) 602-0309 |
| Hydrotechnical | Arvind Dalpatram | Klohn Crippen Berger | (604) 251-8511 (w)<br>(604) 434-3907 (h) |
| Environmental (YG) | Adrienne Turcotte | Assessment and Abandoned Mines | (867) 667-3153 (w)<br>(867) 334-9799 (c) |
| Environmental - Alternate | Steve Momeyer | CH2MHILL | (867) 668-2201 ext 2012 |
| Environmental Engineering | Leslie Gomm | Gomm Environmental | (867) 334-7237 |

## 1.7 Status of Manual

### 1.7.1 Changes since Last Revision

Because considerable changes have occurred in the administration of the Faro Mine Remediation Project since the last revision of this manual in 2008, the current update contains substantial revisions. However, the structure of the 2008 manual has been kept wherever practical. This section highlights the main changes for each update and can be used for capturing future updates.

### 1.7.2 Site Staff Training

Site staff training on the use of the OMS manual has taken place in the past. Yukon Government plans to conduct similar training for site staff on the use of this updated manual. Records of these periodical training activities will be kept on site. Records should include, among other things: date, participants, training content, etc.

### 1.7.3 Dam Inspection Form and Site Personnel Pull-out Sheets

Appendix III provides a visual inspection form to be used by site staff performing dam inspection.

Appendix IV presents the following four pull-out sheets which serve as quick references to guide site personnel in conducting their operation activities:

- Dam Monitoring Schedule;
- Intermediate Dam Quick Reference Guide;
- Cross Valley Dam Quick Reference Guide; and
- Little Creek Dam Quick Reference Guide.

# 2 TAILINGS AND WATER STORAGE FACILITIES

## 2.1 Facility Overview

Figures B-003 and B-005, respectively, show the general layout of the Faro and Vangorda Plateau sites which are the two main development areas for the Faro Mine Complex. A single water licence applies to the entire mine complex.

The Faro mine site is located within the Rose Creek drainage basin, which drains via Anvil Creek into the Pelly River. There are no infrastructure facilities or permanent human habitation downstream of the mine along this drainage system. The Vangorda Plateau is drained by Vangorda Creek, which flows directly into Pelly River. The Town of Faro is located on Vangorda Creek, downstream of the mine site.

### 2.1.1 Facility Components

The following primary structures are located in the Faro Mine site (see Figures B-003 and B-004):

- Faro Main Pit;
- Faro Zone 2 Pit;
- Faro Waste Rock Dumps (main, intermediate, northwest, Faro valley, and northeast);
- Rose Creek Tailings Facility: including Original, Secondary and Intermediate impoundments;
- Cross Valley Dam and Pond;
- Mill and other Buildings;
- Water Treatment Facilities;
- Faro Creek Diversions;
- Breached Fresh Water Supply Dam;
- Pumphouse Pond and Dam;
- North Fork Rose Creek Rock Drain and Diversion;
- K8 Creek Rock Drain;
- North Wall Interceptor Ditch; and
- Rose Creek Diversion Channel (RCDC), Canal Dyke and fuse-plug diversion dam.

A general arrangement of these facilities is presented in Figures B-003 and B-004. It should be noted that the Intermediate and Cross Valley Dams, in combination with the North Wall Interceptor Ditch and the Rose Creek Diversion Channel, are also referred to in the past as the Down Valley Project. These structures, along with the Original and Secondary Tailings Dams, form the Down Valley tailings facility.

The following primary structures are located in the Vangorda Mine site (see Figures B-005 and B-006):

- Vangorda Pit;
- Vangorda Waste Rock Dump, including seepage collection system;
- Grum Pit;
- Grum Waste Rock Dump and Overburden Dump;
- Little Creek Dam;
- Vangorda Creek Diversion Flume;
- Vangorda Northeast Interceptor Ditch;
- Water Treatment Plant and Sludge Pond Embankments;
- Office, Heavy Equipment Shop and Other Buildings;
- Grum Interceptor Ditch;
- Sheep Pad Sediment Ponds;
- Electrical Substation and Control Gear; and
- Grum Sulphide Cell.

The subsequent sections of this manual will focus on the Intermediate, Cross Valley and Little Creek Dams in more detail. The manual may refer to other components of the mine facilities listed above, as required. Reports detailing specific aspects of mine facilities are referenced as appropriate to supplement the data included in this manual. Summary descriptions of these structures are included in the 2003-2008 Water Licence renewal application (Gartner Lee 2003 to 2008).

### 2.1.2 Site Mining History

Mining has been carried out at the Faro mine site since the late 1960s, originally under the direction of the Anvil Mining Corporation. During initial mine development, the original tailings facility was created, concurrent with the Fresh Water Supply Dam, then known as the Rose Creek Water Reservoir. Mining was mainly focused on the large Faro No. 1 zone ore body (Main Pit). Increased production in 1975 gave rise to an expansion of the tailings facility, creating the second impoundment. Also, in 1975, the mining operations were taken over by the Cyprus Anvil Mining Corporation. In 1979, further mineral resources were acquired, including the Faro No. 2 zone, Grum, Vangorda and Swim deposits. In response to the anticipated increasing mine production, the Intermediate Dam and Cross Valley Dam were built downstream of the Original and Secondary tailings impoundments forming the Down Valley Tailings Facilities (Golder 1980). Initial construction of the Intermediate and Cross Valley Dams was completed in 1981 (Golder 1982), prior to a two-year mine shut-down due to low metal prices. Curragh Resources took over the mining operations in 1985, taking the Vangorda and Grum pits into production on the Vangorda Plateau and continuing production of the No. 3 zone Faro Pit. This led to the continuation of underground ore extraction until 1992. Another mine shut down occurred in 1992 until 1994 when the Anvil Range Mining Corporation took control. The Anvil Range Mining Corporation focused on the Vangorda and Grum ore bodies until the most recent mine shut-down in 1998, in which the resources of the Vangorda and Grum Pits were, respectively, fully or partially depleted.

## 2.2 Site Conditions

### 2.2.1 Climate

Climate data from the Faro Mine site weather station (at elevation 1158 m) for the period 1967 to 2007 indicates that the mean annual temperature was -2.1°C. The mean monthly maximum daily temperature was 14.9°C in July, while the mean monthly minimum temperature was -20.5°C in January. Months with above zero mean temperatures were May, June, July and August (BGC 2008c).

The 19841 – 2010 climate normals at the Faro Airport station (Station No. 2100517, elevation 716 m) indicate a mean annual precipitation of 320 mm, comprising roughly 65% as rainfall and 35% as snowfall. The monthly mean rainfall ranges from a minimum of 3 mm in April to a maximum of 56 mm in July.

Snow accumulation at the Faro tailings impoundment typically begins in October and the snow cover is generally melted by the end of April.

Prevailing wind direction in the region is from the southeast.

### 2.2.2 Geology

The Faro mining complex is located within the Yukon Plateau, on the north side of the Tintina Trench. This trench forms a broad, northwest trending valley occupied by the Pelly River, with a floodplain at about 600 m above sea level. The Vangorda Plateau is a subdivision of the Yukon Plateau, rising from 1000 m to 1400 m above mean sea level (amsl), and is drained by the Vangorda Creek and Rose Creek watersheds. To the northeast, the peaks of the Anvil Range Mountains rise above 2000 m in elevation.

Bedrock consists of regionally metamorphosed sedimentary rock ranging in age from late Precambrian to Permian (approximately 900 million to 250 million years ago). Metamorphic grade ranges from moderate (schist) to low (phyllite). Phyllites are common in the area and are classified as carbonaceous, calcareous or non-calcareous. The calcareous phyllite becomes calc-silicate rock at higher metamorphic grade.

Five stratiform, massive sulphide lead-zinc-silver ore bodies were discovered in the area: Faro, Grum, Vangorda, Grizzly and Swim. Mining has completely depleted the known economic reserves at the Faro and Vangorda deposits and was partially complete at Grum when the mine closed.

The bedrock surface was shaped during the last ice age and covered with surficial deposits between 35,000 and 10,000 years ago. The surficial deposits consist of colluvial, glaciofluvial and morainal (till) as a discontinuous cover over bedrock in the upland areas. These increase in thickness towards valleys such as Rose Creek. Glacial deposits are relatively absent above 1500 m elevation. The area surrounding the Vangorda Mine is characterized by a thick till blanket overlying bedrock. The till comprises a poorly sorted deposit of clay, silt, sand, gravel and angular boulders, commonly underlying glaciofluvial deposits in areas of former melt water drainage.

The Rose Creek Valley is infilled with a complex assemblage of fan and outwash sand and gravel deposits, dissected by stream channel and lacustrine materials. On the north side of the valley, prominent terraces and fans partly underlie the existing Down Valley tailings area. A large colluvial apron covers the south slope of Rose Creek valley, extending upslope of the Cross Valley Dam to downstream of the Down Valley tailings area. Another colluvial apron extends along the base of the south slope of the Rose Creek valley between the site of breached Fresh Water Storage Dam and the original tailings impoundment. A large colluvial fan is located east of the upper Rose Creek near the Faro Pit.

Most of the surficial deposits in the Faro mine area are granular glacial or fluvial deposits. Glaciolacustrine deposits were noted near the Cross Valley and Intermediate Dams, comprising fine sand to sandy silt up to 20 m thick. This unit is commonly buried by a sequence of sand and gravel.

The region is located within the discontinuous permafrost zone. In the Rose Creek Valley, most of the south valley wall consisted of frozen coarse till, whereas the same material in the north valley wall was unfrozen. Solifluction is common on slopes above the tree line. Frost shattered bedrock (Felsenmeer) is frequently found in the alpine areas of the Anvil Range.

### 2.2.3 Hydrology

Rose Creek and Vangorda Creek are the main watercourses on the property. As part of the 1996 closure plan, a comprehensive hydrological assessment was carried out for the Faro and Vangorda Plateau mine site areas (Robertson Geoconsultants 1996). A hydrotechnical assessment of the Faro Mine site was undertaken in 2001 (NHC 2001) for the now breached Fresh Water Supply Dam and Down Valley tailings facility at the Faro mine site. Table 2.1 presents a summary of the flood flows for the Faro Mine site (NHC, 2004).

**Table 2.1 Estimated Floods for the Faro Mine Site (after NHC 2004)**

| Mine Site Sub- Basins | Drainage Area ($km^2$) | 2 Year ($m^3/s$) | 50 Year ($m^3/s$) | 100 Year ($m^3/s$) | 200 Year ($m^3/s$) | 500 Year ($m^3/s$) |
|---|---|---|---|---|---|---|
| North Fork Rose Creek at flow-through rock drain | 118 | 9.3 | 48 | 59 | 72 | 92 |
| Fresh Water Supply Dam Catchment | 67 | 5.6 | 31 | 39 | 49 | 63 |
| Rose Creek above Tailings Diversion Channel | 203 | 15 | 71 | 88 | 105 | 135 |
| Rose Creek downstream of Tailings Diversion Channel | 230 | 17 | 78 | 96 | 115 | 145 |

Rock outcrops are extensive in the upper portion of the basin, while the lower portions of the basin are overlain by low-permeability tills, frequently containing permafrost. These factors, in addition to the general lack of tree cover and topsoil or forest litter, result in an increased runoff potential.

The Vangorda Creek watershed covers a total area of about 92 $km^2$, of which 17.7 $km^2$, lies above the headworks for the Vangorda Creek Diversion (Curragh, 1988). The stream drops about 760 m in elevation from the highest point on Mt. Mye to the Pelly River over a distance of about 18 km. The major tributary is Aex Creek, which joins Vangorda Creek, just above the Town of Faro.

Flow in Vangorda Creek has been monitored intermittently since 1975 using a hydrometric station located upstream of the Faro town site road crossing (Station no. 29bc003). Since 1977, this station has been operated by Department of Indian Affairs and Northern Development (DlAND), with flow measurements being taken only during ice-free periods. The catchment area above this gauging station is 91.2 $km^2$ (Robertson Geoconsultants 1996). Hydrology studies utilized regional Water Survey of Canada (WSC) stations that have recorded over long periods and have year-round observations to "patch" the missing stream flow data, using a series of analytical steps. The patched daily record was then converted into a monthly record to calculate mean monthly and mean annual flows. Mean annual runoff for the period 1977-1995 (Robertson Geoconsultants 1996) for Vangorda Creek at Faro town site road was 0.68 $m^3/s$, equivalent to 235 mm of runoff over the catchment area.

With respect to the Little Creek Dam, its catchment has been significantly modified by the mining development on the Vangorda Plateau (Golder 1994), as summarized below:

- Some of the natural catchment has been intercepted for redirection around Little Creek Dam due to construction of a major NW-SE trending haul road.
- Some of the natural catchment has been intercepted through construction of a diversion ditch east of the eastern limit of the Vangorda Waste Rock Dump (see Figure B-005).
- A collection ditch paralleling the south and west sides of the noted waste rock dump has added the catchment (see Figure B-005).
- Pit drainage from both the Grum and Vangorda pits can be directed (by pumping) to the Little Creek facility where needed for water management during mining operation.

Little Creek Dam was originally designed to store the 24-hour runoff from the 200-year snowmelt event, with 1.0 m of encroachment on the 1.9 m freeboard allowance, based on a catchment of 0.26 $km^2$ (SRK, 1990). Subsequently, SRK (1998) recommended that an emergency spillway be installed to discharge the peak flow corresponding to the 1:200 year runoff event.

To design the emergency spillway, SRK estimated the water balance for the pond for a 200-year wet year. An updated regional analysis was carried out to create a "conservative" estimate hydrograph with a flow of 284 L/s or 24 600 $m^3$/day. The 200-year, 365-day hydrograph has an average annual flow of 14.4 L/s, compared with the long-term average yield from Little Creek pond of 4.4 L/s. The peak daily discharge occurs around May 31, based on the approximate average date on which the peak is observed to occur at stream flow stations in the region. The hydrographs represent runoff from the total area of 0.72 $km^2$ that drains by gravity to Little Creek pond, including the area controlled by the Vangorda waste dump collection ditch.

# 3 STORAGE DAMS

## 3.1 General

Sections 3.2 to 3.4 provide an overview of the general characteristics of each of the following three storage dams, respectively:

- Intermediate Dam;
- Cross Valley Dam; and
- Little Creek Dam.

These sections cover the original design criteria and/or description of subsequent analyses, design cross sections, identification of the nature of the materials making up the dams, pond elevations, storage volumes and water conveyance to and from each of the ponds upstream of the respective dams.

The updated Emergency Response Plan (ERP) (KCB 2014b), based on the earlier version (BGC 2008b), specifies the following three incident levels in the increasing degree of severity that may threaten the safety of the above three dams:

- Alert level;
- Emergency level; and
- Failure levels.

The alert level is the first or lowest level of action for a given incident. This level of action, assigned to typical operations and maintenance conditions, is covered in the OMS manual. No external (off mine-site) notification is required. Typical incidents at this level may include the following:

- seasonal frost cracking at the crest of a dam;
- minor seepage;
- piezometric response to changing adjacent pond level(s);
- minor erosion gullies due to runoff;
- spillway flowing at design capacity with no erosion; and
- diversion channel flowing at design capacity with no erosion.

The OMS manual provides operating procedures, guidelines and protocols for prompt actions at site in dealing with these "routine" incidents and system failures that can be easily and quickly corrected or repaired. However, some of these incidents, if ignored, may progress into an emergency level that must be dealt with outside of the normal scope of the OMS activities. As the incident at the emergency level further deteriorates, it could lead to eventual failure level. This progression of the incident level is demarcated by "trigger levels", or thresholds at which the ERP is put into action.

Section 3.5 describes maintenance and surveillance requirements, and Section 3.6 outlines training requirements to ensure that all site personnel are familiar with the OMS manual.

## 3.2 Intermediate Dam

The Intermediate Dam is located along the Rose Creek valley, immediately downhill from the mine and milling operations. It was built in conjunction with the Cross Valley Dam beginning in 1981, with three subsequent dam raises in 1988, 1989 and 1991, to a final crest elevation of 1049.4 m amsl (converted from DVD). The Intermediate Dam was built downstream of the Original and Secondary Tailings Impoundments, as additional tailings storage was required.

Figure A-008 shows the location plan of the Intermediate and Cross Valley Dams surveyed in 2003. The crest and the emergency spillway surveyed profiles are shown on Figure A-009. Figure A-010 shows the location plan of test holes used for the subsoil investigation of the Intermediate and Cross Valley Dams, while Figure A-011 presents the foundation stratigraphy along a longitudinal section of the Intermediate Dam.

### 3.2.1 General

The general characteristics of the Intermediate Dam are summarized in Table 3.1.

**Table 3.1 General Characteristics of the Intermediate Dam**

| | |
|---|---|
| Type of Dam | Zoned Earthfill Dam (see Figure B-012) |
| Fill Details | - Gravel shells with a silty till core.<br>- Starter Dam with a vertical core, which was modified to an upstream sloping core During subsequent dam raises. |
| Foundation Cut-off | Partially silty-till cut-off. |
| Purpose | Retain tailings solids, supernatant water and run-off water. |
| Year Constructed | Staged construction during 1981, 1988, 1989 and 1991. |
| Location | See Figures B-003 and B-004. |
| Access | - Access to north end via access road to Down Valley area from the main mine access road and across the emergency spillway. Access to south end of dam via Canal-Dyke crest of Rose Creek Diversion Channel. |
| Failure Consequence | High (CDA 2007 classification, KCB 2014a). |
| Reason for Consequence Classification | - Potential for release of non-compliant water and tailings.<br>- Qualitative risk assessment damages include repair cost, regulatory fines and clean-up cost, with total cost estimated between US $10-100 million (KCB 2008). |
| Emergency Spillway (Yes/No) | (Yes)<br>- Riprap-lined, excavated channel in overburden. Un-gated free overflow into channel. |
| Operation Spillway | Removable 12-inch diameter carbon steel siphon |

Notes: No other appurtenances.

### 3.2.2 Design Criteria

Design criteria and elevations, based on mean sea level (NAD27) datum, for the Intermediate Dam are provided in Table 3.2.

**Table 3.2 Intermediate Dam Design Criteria and Elevations**

| | | | |
|---|---|---|---|
| Crest of Dam | | | 1049.4 m amsl design crest<br>1048.83 m amsl low point 2003 survey (NHC 2006) |
| Top of Core | | | 1048.5 m amsl (2003/2004 survey) |
| Inflow Design Flood (IDF) Level | | | 1048.2 m amsl, 500-year flood (NHC 2006) |
| Full Supply Level, FSL | | | 1047.7 m amsl (2005 survey) |
| Spillway Inlet | | | 1047.7 m amsl (2005 survey) |
| Downstream berm | | | ~1031.7 m amsl |
| Design Freeboard | | | 0.5 m (Golder 1980) |
| Actual Freeboard | | | 0.63 m, 500-year flood (NHC 2006) |
| Design Seepage | | | 0.22 $m^3/s$ (Golder 1980) |
| Pond Area | | | 1,957,000 $m^2$ (Gartner Lee 2002) |
| Total Storage Capacity | | | 28,600,000 $m^3$ (Gartner Lee 2002) |
| Design Requirements | Slope Stability | Upstream/Downstream, static state | FS = 1.5 |
| Design Requirements | Slope Stability | Upstream, rapid drawdown | FS = 1.2 |
| Design Requirements | Earthquake Peak Ground Acceleration (PGA) | Closure Requirement - 1:10,000 year | 0.3 g (Atkinson 2004)<br>0.24 g (Atkinson 2013) |
| Design Requirements | Earthquake Peak Ground Acceleration (PGA) | CDA Requirement- 1:2,500 year | 0.21 g (Atkinson 2004)<br>0.12 g (Atkinson 2013) |
| Design Requirements | Earthquake Peak Ground Acceleration (PGA) | Water Licence Requirement- 1:475 year | 0.08 g (Atkinson 2004)<br>0.04 g (Atkinson 2013) |
| Design Requirements | Inflow Design Flood | Closure Requirement- PMF | 692 $m^3/s$ (WMC 2006) |
| Design Requirements | Inflow Design Flood | CDA Requirement- 1/3 between 1:1,000 year and PMF | 342 $m^3/s$ (NHC 2004)<br>(WMC 2006) |
| Design Requirements | Inflow Design Flood | Water Licence Requirement- 1:500 year | 11.2 $m^3/s$ (NHC 2006) |
| Spillway | | Type | Earthen Spillway |
| Spillway | | Rating Curve | see Figure A-016 |
| Spillway | | Capacity | 32 $m^3/s$, water level at dam core (NHC 2006) |
| Spillway | | Comments | - Meets the requirements of the water license but not the higher requirements required by normal practice of a high hazard dam (CDA 2007). |
| Static Slope Stability | | Downstream | FS = 1.6 (see Figure A-013, BGC 2008a) |
| Static Slope Stability | | Upstream | FS = 1.6 (BGC 2008a) |
| Static Slope Stability | | Upstream, rapid drawdown | FS = 1.0 to 1.1 (see Figure A014, BGC 2008a) |
| Seismic Slope Stability | | Comments | - Recent work indicates that this dam can withstand the 1:10,000 year earthquake (PGA= 0.3 g, which is reduced to 0.24 g in 2013). Thus the dam is stable for both the 500 and 2,500 year return periods (KC 2006a and 2006b and Atkinson 2004 and 2013). |

### 3.2.3 Design Section and Dam Materials

A brief discussion of the construction history and nature of the dam materials making up the Intermediate Dam (see Figure B-012) are given below in Table 3.3.

**Table 3.3 Intermediate Dam - Design Section and Dam Materials**

| | |
|---|---|
| Crest Width | 6 m to 7 m |
| Crest Length | 650 m |
| Max. Dam Height | 32 m |
| U/S Slope | 2H:1V |
| D/S Slope | 2H:1V (2.1H:1V overall, including a 20 m wide berm) |
| Type/Source Of Construction Materials | - 3 main damfill materials: gravel/drain rock, filter, and silty glacial till.<br>- Gravel sources – upper-level terrace (north of Rose Creek and upstream of Cross Valley Dam), terrace deposits downstream (D/S of the Cross Valley Dam (outfall area of Rose Creek Diversion Channel and further D/S), extension of the upper-level terraces in the north abutment area of the Cross Valley Dam.<br>- Glacial till sources - north valley wall and excavated material from the Rose Creek diversion channel.<br>- Filter material sources – screened materials from gravel and glacial till sources. |
| Description of Construction | - First stage (1981) - built to Elev. 1035.7 m amsl* (fill height -20 m), foundation area raised to 1031.7 m amsl* in preparation for future raises.<br>- Second stage (1988) – raise to 1040.7 m amsl*, emergency spillway moved from south to north abutment.<br>- Third stage(1989) – raise to 1045.7 m amsl*.<br>- Final stage (1991) – raise to 1049.4 m amsl*, final emergency spillway at north abutment.<br>- Intermediate Dam and raise - designed by Golder Associates (1988, 1989, 1991), and constructed by Pelly Construction.<br>- Dam seepage is controlled by a 5-m wide inclined upstream glacial till blanket against the excavated terrace north of 0 + 550 m, a vertical low permeability till core with a foundation cut-off trench. The till core is inclined at 2H:1V above 1031.7 m amsl*.<br>- At end of construction, a 20 m downstream berm at 1031.7 m amsl* was kept in place to form an overall downstream slope of 2.1H:1V. |
| Method of Construction | Downstream construction method |

*Converted from Down Valley Datum (DVD) survey data.

### 3.2.4 Pond Elevations, Storage Volumes and Water Conveyance

The storage capacity versus elevation curve is given in Figure A-015. Pond elevations, based on mean sea level (NAD27) datum, storage volumes and water conveyance information are summarized in Table 3.4.

**Table 3.4 Intermediate Dam Pond Elevations, Storage Volumes and Water Conveyance**

| | |
|---|---|
| Remaining Storage Capacity | 800,000 $m^3$ |
| Full Supply Pond Elevation | Same as spillway inlet elevation at 1047.7 m amsl* |
| Historical Pond Elevations | - Prior to 2002, the minimum pond level was about 1047.3 m and the maximum was 1047.8 m. Since 2002 the pond level has fluctuated in a greater range with typical minimum and maximum of 1043.1 m and 1047.6 m, respectively. |
| Water Conveyance | - The Intermediate Dam retains water and tailings. Water was siphoned from the Intermediate Pond into the Polishing Pond in the past. Previously lime treatment of the water was carried out in line during the process. The Intermediate Dam has an emergency spillway located at the north abutment.<br>- Normally, the level of Intermediate Pond is controlled by pumping water from the pond to Faro water treatment plant, but pumping to the water treatment plant was suspended in 2013 due to safety concerns at the plant. A temporary filtration plant was set up at the Cross Valley Pond, which treated and discharged the water to the North wall Interceptor Ditch. |
| Storage Capacity Curve | See Figure A-015 |

*Converted from Down Valley Datum (DVD) survey data.

- Based on recorded pond levels between 1999 and 2012, it was shown that the pond was generally operated within the range of 1043.5 m amsl and 1047.6 m amsl. Water coming from the Faro Pit is now being treated at the Faro Mine water treatment plant and is discharged indirectly through the Cross Valley Pond (Polishing Pond) into Rose Creek. The recent water management strategy has reduced the minimum pond level to about 1043.5 m, and will most likely continue to do so.
- In 2013, Faro Pit Lake water treatment operation was suspended due to a safety issue at the water treatment plant at Faro site. To cope with this temporary situation, a filtration plant was set up at the north abutment of the Cross Valley Dam to treat water from the Polishing Pond and release to the North Valley Interceptor Ditch when water quality is in compliance with discharge criteria. In addition, excess water in the Intermediate Pond was pumped out and returned to the Faro Pit.
- The current temporary situation is expected to end, once the new interim water treatment plant at Faro site is commissioned by the summer of 2014, and the water conveyance operation at the Intermediate Pond is returned to normal.

The Intermediate Dam spillway rating curve developed by NHC (2006) is presented on Figure A-016.

### 3.2.5 Operating Procedures for Pond Levels

The operating procedures for pond levels are shown in Table 3.5. It is noted that the "Trigger Level for ERP" refers to the pond level that should trigger the site response as described in the Emergency Response Plan (KCB 2014b).

**Table 3.5 Intermediate Dam Operating Pond Levels**

| | |
|---|---|
| Maximum Flood Level | 1048.2 m amsl (500-year flood) |
| Full Supply Level | 1047.7 m amsl |
| Maximum Operating Pond Level | 1047.7 (historical high and spillway level) |
| Minimum Operating Pond Level | 1043.5 m amsl (approximate tailings surface level) |
| Elevation Ranges of two Riprap Zones with a gap (See Figure B-012) | upper riprap zone 1046.7 to 1048.7 m amsl<br>lower riprap zone 1043.2 m to 1045.2 m amsl |
| Alert Level | 1047.7 m amsl for dam overtopping |
| Trigger Levels for ERP | 1048.2 m amsl for dam overtopping; and<br>lower levels for other failure modes, see Table 3.7 |

NOTE: Maximum and minimum operating pond levels shown are normal operating limits based on the assumption that the Faro Water Treatment Plant is operating.

### 3.2.6 Instrument Monitoring

Instrumentation at the Intermediate Dam (see Figure B-017) consists of a pond level measurement of the intermediate pond; 14 standpipe piezometers at 9 locations; one single pneumatic piezometer and three paired pneumatic piezometers with tips at shallow and deep depths. The piezometers are installed in the embankment zones downstream of the core above, in and below the horizontal drain at the downstream berm elevation as well as in the dam foundation. They are distributed from the northeast dam segment to the southwest dam abutment.

A summary of current maximum and minimum pond and piezometric levels as well as corresponding historical maximum and minimum levels are shown in Table 3.6.

### Table 3.6 Historical and Current Intermediate Pond and Water Level at Piezometers Located at Intermediate Dam

| Location | Name | Historical[1] (m) | | Current (2013 (m) | | Comments |
|---|---|---|---|---|---|---|
| | | Max | Min | Max | Min | |
| Water Level Readings | | | | | | |
| Int. Pond | IP | 1047.58 | 1043.47 | 1046.92 | 1044.31 | Target El. 1043 m |
| Standpipe Piezometers (Nested piezometers at P01-4, BH96-3 and BH96-4) | | | | | | |
| Dam Crest | BH96-1 | 1031.65 | 1027.37 | 1029.25 | 1028.49 | -Tip El. At 1027.35 m |
| | BH96-2 | 1031.94 | 1028.87 | 1029.66 | 1028.97 | -Tip El. At 1028.87 m |
| | BH94-IDC-1 | Dry | Dry | Blocked | Blocked | - |
| | BKS04-06 | Dry | Dry | Dry | Dry | - |
| | BKS04-07 | Dry | Dry | Dry | Dry | - |
| Dam Toe | P01-3 | 1030.63 | 1027.48 | 1029.33 | 1028.60 | - |
| | P01-4A | 1032.24 | 1029.27 | 1031.13 | 1030.81 | Shallow |
| | P01-4B | 1032.17 | 1029.06 | 1030.28 | 1030.17 | Deep |
| | BH96-3A | 1031.38 | 1026.62 | 1029.19 | 1028.35 | Shallow |
| | BH96-3B | 1031.45 | 1027.48 | 1029.22 | 1028.42 | Deep |
| | BH96-4A[3] | 1032.04 | 1027.61 | - | - | No readings for 2012 |
| | BH96-4B[3] | 1032.28 | 1028.39 | - | - | No readings for 2012 |
| | BH96-4C[3] | 1031.64 | 1027.74 | - | - | No readings for 2012 |
| | BH96-4D[3] | 1031.75 | 1027.62 | 1029.39 | 1028.76 | - |
| Pneumatic Piezometers (BH91-ID3 to ID6 are nested piezometers with one tip deep and one shallow) | | | | | | |
| South Abutment | BH91-ID3 | 1039.23 | 1036.82 | 1036.96 | 1036.89 | Shallow |
| | | 1038.04 | 1029.95 | 1033.66 | 1032.12 | Deep |
| Dam Toe | BH91-ID4 | 1035.91 | 1028.28 | 1030.45 | 1029.47 | Shallow |
| | | 1031.85 | 1026.74 | 1028.91 | 1028.14 | Deep |
| | BH91-ID6[2] | 1040.9 | 1026.62 | 1028.58 | 1024.80 | Shallow |
| | | 1034.96 | 1020.82 | 1029.57 | 1016.9 | Deep |
| | BH91-ID7 | 1035.2 | 1028.82 | 1029.94- | 1028.82- | -Destroyed in winter 2011/2012 |

Notes:
1. Historical data taken from 2011 Annual Geotechnical Review (KCB,2012).
2. BH91-ID6 Shallow and Deep: Three sets of readings taken in June, September and October show no piezometric head above tip.
3. BH96-4: 4 nested piezometers with -4A being the shallowest, and -4D being the deepest.

The current monitoring frequency for this instrumentation is discussed in the Annual Geotechnical Report (KCB 2014c). The frequency may change each year as required.

### 3.2.7 Alert Level

Table 3.7 outlines conditions at the alert level for the Intermediate Dam. The following piezometric monitoring observations should trigger an alert-level incident:

- An increasing trend in the measured piezometric elevation that appears to exceed the historical maximum reading shown in Table 3.6.
- A piezometer at the toe of the dam that reads a water level above the downstream pond level in the Polishing Pond.

**Table 3.7 Intermediate Dam Conditions at Alert Level**

| Incident | Alert Level |
|---|---|
| Dam Overtopping | Pond level is at normal operating level and starts to rise to maximum operating level. |
| Dam Embankment Instability | Appearance of new cracks or the opening of existing cracks on crest or faces of dam. Increasing pore pressures in piezometers or high one-time reading of a single piezometer. |
| Piping – Internal Erosion of Dam | Small quantities of clear seepage flowing from the toe, abutment or downstream face of a dam that may be considered normal, but should be recorded as part of the regular visual inspections. The location and seepage rate, preferably measured by a weir or by the time required to fill a container of known volume, should be monitored. Changes in the location, and/or rate of seepage may be related to pond levels, precipitation, snowmelt, thawing of ground ice, or surface runoff.<br>Turbidity of the seepage and its change with time is as important as the monitored rate of seepage. |
| Seismic Instability and Large Earthquake Events | Site staff should inspect all dams after a seismic event has been felt at the site, regardless of the size of the event. Pore pressure readings should be taken on all piezometers. Information about the earthquake may be obtained from the PGC website given in the ERP regarding recent seismic events in western and northern Canada and Alaska. |

### 3.2.8 Dam Slope Stability

<u>Downstream Static Dam Stability</u>

BGC (2008a) has performed static downstream slope stability analysis for the Intermediate Dam as illustrated in Figure A-013. The static safety factor for long term downstream slope stability is 1.6.

<u>Upstream Static Dam Stability</u>

BGC (2008a) also performed static stability analysis for the upstream slope under rapid drawdown condition as illustrated in Figure A-014. The safety factor for the upstream slope under rapid drawdown condition is greater than unity, and under the long term seepage condition is 1.6.

Seismic Dam Stability

KC (2006a and 2006b) carried out a seismic response analysis for the Intermediate Dam for a design earthquake corresponding to a return period of 10,000 years with the peak ground acceleration (PGA) of 0.3 g. The analysis confirms that the granular foundation soils underneath the Intermediate Dam are capable of withstanding this level of earthquake without liquefaction. Since Atkinson (2013) reduced the PGA of this level of earthquake to 0.24 g in her seismic hazard analysis update, it is confirmed that calculations indicate that the Intermediate Dam is able to withstand the earthquake of a return period of 10,000 years.

Normally, the water level in the Intermediate Pond is normally controlled by pumping water from the pond to Faro water treatment plant. Treated water is then discharged to the Polishing Pond from where water is released through the siphon outlet to the downstream channel. The annual operation of the Faro treatment plant is governed by the allowable drawdown rate of the Intermediate Pond. At the end of water treatment season, the pond level is drawn down to the lowest level to maximize the pond storage for the following year. As indicated in Section 3.2.4, the operation of the Faro water treatment plant was suspended in 2013 due to a safety issue, and a temporary treatment plant was set up at the Cross Valley Pond. Normal operations will resume when the faro treatment plant is back in operation.

The current target seasonal drawdown level of the Intermediate Pond is El. 1043.0 m. Therefore, it is advantageous to operate the pond level in the range of El. 1043 m to El. 1046.5 m, as far as practical. According to stability analysis under rapid drawdown condition, if drawdown starts from pond level at El. 1046.5 m, the incident level could be kept within the range of “normal” to “emergency” level without encroaching on the “failure” level.

Historically, the maximum drawdown rate at the Intermediate Pond has been restricted to 25 mm/day. Starting from 2012, this maximum drawdown is increased initially to 40 mm/day on an experimental basis with close monitoring of the dam performance. The allowable drawdown rate will be reviewed and confirmed based on good dam performance involving the increased rate over an adequate period of operation.

During rapid drawdown period, all piezometers at the Intermediate Dam should be monitored on a monthly basis, with Piezometers P96-1 and P96-2 monitored weekly. In addition, site monitoring and observation of dam performance should be communicated to the geotechnical consultant on a weekly basis by e-mail, including photos (as needed).

Because the technical background of the site personnel is not geotechnical, it is important for them to be vigilant in looking for unusual dam behaviour, such as: cracks, slope slumps, differential movements along the crest and dam slopes, etc. If anything appears to be different from what they have observed before, they should take photos both in close up and at distance to show the full picture of the observed condition. In the event that an unfavourable performance of the dam is observed, the geotechnical consultant should be immediately notified, and further drawdown of pond level should be stopped.

## 3.3 Cross Valley Dam

The Cross Valley Dam is located immediately downstream of the Intermediate Dam, forming the polishing pond for the tailings containment system, as shown on Figure A-008. The dam was constructed to its final elevation of 1033.5 m masl (converted from Down Valley Datum) in 1981. The crest and the lower portion of the spillway were surveyed in 2003, and the surveyed longitudinal dam crest profile and the emergency spillway profile are shown in Figure A-018.

### 3.3.1 General

The general characteristics of the Cross Valley Dam is summarized in Table 3.8.

**Table 3.8 Cross Valley Dam General Characteristics**

| | |
|---|---|
| Type | Zoned Earthfill Dam (see Figure A-020) |
| Fill Details | Gravel shells with a central silty till core |
| Foundation Cut-off | Partially silty-till cut-off |
| Purpose | Serve as a polishing pond, and retain treatment residue (some of the residue was excavated out in 2001). It has a design capacity to retain 60-days of treatment discharge water and seepage from the Intermediate Dam. |
| Year Constructed | Constructed in 1980-1981, with downstream toe drain added in 1991 (see Figure B-023). |
| Location | See Figures B-003 and B-004 |
| Access | Access to north end via access road to Down Valley area from the main mine access road to dam toe area and cross the spillway channel from downstream reach and follow access road adjacent to the spillway up to dam crest. Access to south end of dam toe area via Canal-Dyke crest of Rose Creek Diversion Channel. Consideration is given by YG to provide access to the dam crest at south abutment from the Canal-Dyke crest. |
| Failure Consequence | High (CDA 2007 classification, KCB 2014a). |
| Reason for Consequence Classification | Potential for release of non-compliant water and treatment residue. Qualitative Risk Assessment damages include repair, regulatory fines and clean-up, with total cost estimated between US $10-100 million (KCB 2008). |
| Operation Spillway | Removable 10 inch diameter and 16 inch diameter HDPE siphons |
| Emergency Spillway (Yes/No) | (Yes)<br>Riprap-lined earthen channel with un-gated free overflow into channel |

Note: No other appurtenances.

### 3.3.2 Design Criteria

Design criteria and elevations, based on mean sea level (NAD27) Datum, for the Cross Valley Dam are summarized in Table 3.9. The typical dam cross section is shown on Figure B-022. The plan view and longitudinal profile of the 1991 toe drain are shown on Figure B-023.

**Table 3.9 Cross Valley Dam Design Criteria**

| | | | |
|---|---|---|---|
| Crest of Dam | | | 1033.5 m amsl design (NHC 2006)<br>1032.7 m amsl low point, 2003 survey (NHC 2006) |
| Top of Core | | | 1032.5 m amsl (Converted from Down Valley Datum survey data) |
| Inflow Design Flood (IDF) Level | | | 1031.07 m amsl, 500-year flood (NHC 2006) |
| Full Supply Level, FSL | | | 1030.78 m amsl (NHC 2006) |
| Spillway Inlet | | | 1030.7 m amsl (2003 survey) |
| Design Freeboard | | | 0.5 m design (NHC 2006) |
| Actual Freeboard | | | 1.6 m (NHC 2006) |
| Design Seepage | | | 0.03 $m^3/s$ (Golder 1980) |
| Pond Area | | | 320,000 $m^2$ (Gartner Lee 2002) |
| Total Storage Capacity | | | 1,400,000 $m^3$ (Gartner Lee 2002) |
| Design Requirements | Slope Stability | Downstream static state | FS = 1.5 |
| | | Upstream, static state | FS = 1.5 |
| | Earthquake Peak Ground Acceleration (PGA) | Closure Requirement- 1:10,000 year | 0.3 g (Atkinson 2004)<br>0.24 g (Atkinson 2013) |
| | | CDA Requirement- 1:2,500 year | - |
| | | Water Licence Requirement- 1:475 year | 0.11 g for 1:500 year (KCB 2007) |
| | Inflow Design Flood | Closure Requirement- PMF | 692 $m^3/s$ (WMC 2006) |
| | | CDA Requirement -1/3 between 1:1,000 year and PMF | 342 $m^3/s$<br>(NHC 2004) (WMC 006) |
| | | Water Licence Requirement- 1:475 year | 15.5 $m^3/s$ for 500 year (NHC 2006) |
| Spillway | | Type | Earthen Spillway |
| | | Rating Curve | see Figure A-025 |
| | | Capacity | 300 $m^3/s$, water level at dam core (NHC 2006) |
| | | Comments | The spillway has the appropriate capacity to handle the water licence requirement but not enough for the normal practice dam safety requirements for a high hazard dam (CDA 2007) |
| Static Slope Stability | | Downstream | FS = 1.6, See Figure A-021 for stability design chart (Golder 1980) |
| | | Upstream | FS = 1.6, See Figure A-022 for stability design chart (Golder 1980) |
| Seismic Slope Stability | | Comments | Recent work indicates that this dam can withstand the 1:500 year earthquake (PGA= 0.11 g) as required by the regulators. It should be noted that the dam will not withstand the seismic loading corresponding to closure conditions (KCB 2007). |

### 3.3.3 Design Section and Dam Materials

A brief discussion of the construction history and nature of the dam materials making up the Cross Valley Dam (see Figure A-020) are given below in Table 3.10.

**Table 3.10 Cross Valley Dam - Design Section and Dam Materials**

| | |
|---|---|
| Crest Width | 6-7 m |
| Crest Length | 500 m |
| Max. Dam Height | 17 m |
| U/S Slope | 2H:1V |
| D/S Slope | 2H:1V |
| Type/Source of Construction Materials | 3 main damfill materials: gravel/ drain rock, filter, and glacial till.<br>Gravel sources – upper-level terrace (north of Rose Creek and upstream of Cross Valley Dam), terrace deposits downstream (D/S of the Cross Valley Dam (outfall area of Rose Creek Diversion Channel and further D/S), extension of the upper-level terraces in the north abutment area of the Cross Valley Dam.<br>Glacial till sources - north valley wall and excavated material from the Rose Creek diversion channel.<br>Filter material sources - screened materials from gravel and glacial till sources. |
| Description of Construction | Built in 1980-1981 as a water retaining structure.<br>Cross Valley Dam and toe drain – designed by Golder Associates, and constructed by Pelly Construction Ltd.<br>Seepage control measures include: an upstream seepage control blanket, a central till core and a partial foundation cut-off trench. A downstream toe drain was later added in 1991 to improve seepage control. |
| Method of Construction | Single phase with later addition of toe drain in 1991 (see Figure B-023). |

### 3.3.4 Pond Elevations, Storage Volumes and Water Conveyance

The storage capacity versus elevation curve is shown on Figure A-024. Pond elevations based on mean sea level (NAD27) datum, storage volumes and water conveyance information are summarized in Table 3.11.

**Table 3.11 Cross Valley Dam Pond Elevations, Storage Volumes and Water Conveyance**

| | |
|---|---|
| Total Storage Capacity | 2,100,000 $m^3$ |
| Pond Elevations | Due to improved water treatment techniques, Polishing pond levels are currently kept in a lower range than that in early years of operation. Normal pond levels are maintained between 1029.4 m amsl and 1031.7 m amsl (based on records from 1996 to 2013). |
| Historical Pond Elevations | Based on annual monitoring records, the minimum and maximum pond levels recorded were 1026.25 m amsl in 1982 and 1031.7 m amsl in May 1999. |
| Water Conveyance | Water from the Intermediate Dam was discharged into the Polishing Pond through a siphon. Water from the Polishing Pond is siphoned in summer months directly into Rose Creek. Currently, water from the Faro Pit is being treated through the mill water treatment system and discharged indirectly to Rose Creek through the Polishing Pond. |
| Storage Capacity Curve | See Figure A-024. |

### 3.3.5 Operating Procedures for Pond Levels

The operating procedures for pond levels are shown in Table 3.12. It is noted that the "Trigger Level for ERP" refers to the pond level that should trigger the site response as described in the Emergency Response Plan (KCB 2014b).

**Table 3.12 Cross Valley Dam Operating Pond Levels**

| | |
|---|---|
| Maximum Flood Level | 1031.07 m amsl (500-year flood) |
| Full Supply Level | 1030.78 m amsl |
| Maximum Operating Pond Level | 1030.3 (historical high (CH2MHILL 2013)) |
| Minimum Operating Pond Level | 1027.5 (exposure of sludge beds (CH2MHILL 2013)) |
| Base of Riprap | 1030.2 m amsl |
| Alert Level | 1030.78 m amsl for dam overtopping |
| Trigger Levels for ERP | 1031.07 m amsl for dam overtopping; and<br>lower levels for other failure modes, see Table 3.15. |

Notes:

1. Elevations are converted from Don Valley Datum survey data.
2. Maximum and minimum operating pond levels shown are normal operating limits based on the assumption that the Faro Water Treatment Plant is operating.

The Cross Valley Dam emergency spillway rating curve developed by NHC (2006) is presented in Figure A-025.

### 3.3.6 Instrument Monitoring

Instrumentation at the Cross Valley Dam (see Figure B-026) consists of a pond level measurement, 12 standpipe piezometers, four pneumatic piezometers and two thermistors. Except one piezometer installed in the embankment zone downstream of the core, all other piezometers are installed in the dam foundation at and beyond the downstream toe and beneath the dam crest. One functional shallow thermistor string (BH88-4) is installed in the dam fill zone upstream of the dam core, and one deep thermistor string is installed in the dam foundation underneath the upstream dam crest shoulder (CVDC-6). In addition, four weirs are installed downstream of the dam, Weir X11, X12, X13, and Weir 3.

A summary of current maximum and minimum pond and piezometric levels as well as corresponding historical maximum and minimum levels are shown in Table 3.13. A similar summary for seepage rates at the downstream toe weirs is given in Table 3.14.

**Table 3.13 Historical and Current Polishing Pond and Cross Valley Dam Water Level and Piezometer Readings**

| Structure | Name | Historical[1] (m) | | Current (2013 (m) | | Comments |
|---|---|---|---|---|---|---|
| | | Max | Min | Max | Min | |
| Water Level Readings | | | | | | |
| Polish Pond | PP | 1030.33 | 1026.31 | 1029.37 | 1027.54 | Target El. 1027 m |
| Standpipe Piezometers | | | | | | |
| Dam Toe | CVDT-1 | 1018.57 | 1017.13 | 1017.91 | 1017.80 | - |
| | CVDT-2 | 1019.5 | 1015.43[2] | 1015.63 | 1015.40[2] | - |
| | P01-02 | 1018.3 | 1017.42 | - | - | Shallow |
| | | 1019.73 | 1017.86 | - | - | Deep |
| | P01-11 | 1017.83 | 1016.57 | 1016.74 | 1016.58 | - |
| Dam Crest | CVDC-4 | 1019.05 | 1016.72 | 1018.77 | 1018.55 | Deep |
| | CVDC-7 | 1017.74 | 1015.14 | 1015.34 | 1015.15 | Shallow |
| | | 1019.21 | 1015.27 | 1017.66 | 1017.39 | Deep |
| | 94CVDC-1 | 1024.58 | 1022.71 | 1023.34 | 1023.21 | - |
| | CVDC-9 | 1024.74 | 1019.91 | 1020.85 | 1020.47 | Shallow |
| | | 1025.61 | 1021.18 | 1023.66 | 1023.22 | Deep |
| Pneumatic Piezometers | | | | | | |
| Dam Toe | CVDP-1 | 1019.83 | 1017.38 | 1018.22 | 1018.08 | - |
| | CVDP-3[3] | 1017.65 | 1016.11 | - | - | - |
| | CVDP-5 | 1022.05 | 1018.13 | 1020.86 | 1020.44 | - |
| | CVDP-6 | 1019.55 | 1016.99 | 1017.94 | 1017.8 | - |

Notes:
1. Historical data taken from Geotechnical 2011 Data Review (Golder 2011).
2. CVDT-2: Historical minimum has been reduced by 0.03 m from 1015.43 m to 1015.40 m on May 22, 2013.
3. CVDP-3 broken in winter 2011/2012.

**Table 3.14 Historical and Current Maximum and Minimum Weir Flow Downstream of Cross Valley Dam**

| Weir Number | Historical[1] (L/s) | | 2013 (L/s) | |
|---|---|---|---|---|
| | Maximum | Minimum | Maximum | Minimum |
| X11 (North) | 20.9 | 2.56 | 14.62 | 3.79 |
| W3 (Central) | 7.1 | 0.13 | 5.59 | 1.9 |
| X12 (South) | 2.03 | 0.03[2] | 0.8 | 0.02[2] |
| X13 (Combined) | 43.9[3] | 8.08[4] | 46.12[3] | 7.45[4] |

Notes:
1. Historical data taken from 2013 Annual Geotechnical Review (KCB 2014c).
2. X12: Minimum flow decreased by 0.01 L/s from 0.03 to 0.02 L/s on January 24, 2013.
3. X13: Maximum flow increased by 2.22 L/s from 43.9 to 46.12 L/s on July 11, 2013.
4. X13: Minimum flow decreased by 0.63 L/s from 8.08 to 7.45 L/s on November 21, 2013.

The current monitoring frequency for this instrumentation is discussed in the Annual Geotechnical Report (KCB 2014c). The frequency may change each year as required.

### 3.3.7 Alert Level

Table 3.15 outlines conditions at the alert level for the Cross Valley Dam. In addition to the trigger levels covered in Table 3.15, the following instrument monitoring observations should trigger an alert-level incident:

- An increasing trend in the measured piezometric elevation that appears to exceed the historical maximum readings shown in Table 3.13.
- A piezometer at the toe of the dam that reads a water level above the surface of the toe seepage drain.
- An increasing trend in the measured seepage rate at the toe seepage weirs that appears to exceed the historical maximum readings shown Table 3.14.

**Table 3.15 Cross Valley Dam Conditions at Alert Level**

| Incident | Alert Level |
|---|---|
| Dam Overtopping | Reservoir level is at normal operating level and starts to rise to maximum operating level. |
| Dam Embankment Instability | Appearance of new cracks or the opening of existing cracks in crest or faces of dam. Significant warming trend in thermistors, increasing pore pressures in piezometers or high one-time reading from a single piezometer. |
| Piping – Internal Erosion of Dam | Small quantities of clear seepage water flowing from the toe or abutment of a dam may be considered normal, but should be recorded as part of the regular visual inspections being carried out. The location and seepage quantities, preferably measured by a weir or by the time required to fill a container of known volume should be monitored. Changes in the location, rate of flow may be related to reservoir levels, precipitation, snowmelt or thawing of ground ice. May be associated with warming trend in thermistors. |
| Seismic Instability and Large Earthquake Events | Site staff should inspect all dams after a seismic event has been felt at the site, regardless of the size of the event. Pore pressure readings should be taken on all piezometers. Information may be obtained from the PGC website given in the ERP regarding recent seismic events in western and northern Canada and Alaska. |

### 3.3.8 Dam Slope Stability

Stability design charts prepared by Golder (1980) for the Cross Valley Dam are reproduced on Figures A-021 and A-022, for the downstream and upstream slope respectively. For the long term seepage condition, a safety factor of 1.6 is indicated in BGC (2008c) for both the downstream and upstream slope.

KCB (2007) carried out a seismic response analysis for the Cross Valley Dam for a design earthquake corresponding to a return period of 500 years with the peak ground acceleration of 0.11 g. The analysis indicates that the granular foundation soils underneath the Cross Valley Dam are capable of withstanding this level of earthquake without liquefaction. Based on the updated seismic hazard analysis by Atkinson (2013), the peak ground acceleration corresponding to the return periods of 2,500 years and 475 years are 0.12 g and 0.04 g, respectively. Thus calculations indicate that the existing Cross Valley Dam could, in fact, withstand a design earthquake with a return period close to 2,500 years.

## 3.4 Little Creek Dam

The Little Creek Dam was constructed in 1990, immediately northwest of the Vangorda waste rock dump (see Figures B-005 and B-006). The dam is located in the side valley of Little Creek, a small tributary of Vangorda Creek (approximately 90 m upstream of Vangorda Creek). The collection pond upstream of the dam was created to hold water pumped from the Vangorda Pit, and seepage and runoff from the nearby Vangorda waste rock dump. Currently, the pond collects seepage and runoff from the nearby Vangorda waste rock dump and returns the pond water to the Vangorda Pit by pumping for treatment. In this update, previously available survey information is used.

### 3.4.1 General

The general characteristics of the Little Creek Dam are given in Table 3.16.

**Table 3.16 Little Creek Dam General Characteristics**

| Type of Dam | Zoned Earthfill Dam (see Figure A-028) |
|---|---|
| Fill Details | Homogeneous glacial till earthfill embankment with a downstream drainage blanket and finger drains. |
| Foundation Cut-off | Partial till cut-off. |
| Purpose | Originally collect water from Vangorda Pit, runoff and seepage coming from Vangorda waste rock dump for treatment. Currently, water collected in the pond is pumped to Vangorda Pit, from where it is then pumped to the treatment plant. |
| Year Constructed | 1990, and Emergency Spillway added in 1998. |
| Location | See Figures B-005 and B-006. |
| Access | Access to north end of dam via the Vangorda Main Haul Road. Alternative access around east and south side of Vangorda waste rock dump. |
| Failure Consequence | Significant to High (CDA 2007 classification, KCB 2014a). A detailed dam breach and inundation analysis is required to confirm the classification. |
| Reason for Consequence Classification | Downstream consequences in the vicinity of the Town of Faro. |
| References for Consequence Information | KCB 2008 and KCB 2014a. |
| Emergency Spillway (Yes/No) | (No, from 1991 to 1998, and Yes, since 1998)<br>Un-gated 900-mm CSP culvert to a riprap-lined earthen channel installed in 1998. |
| Appurtenances | Power sub-station, pumphouse for power supply, pump barge with a 30-hp Flygt pump , intake pipe, discharge pipe, power pole line, overflow spillway culvert and plunge pool. Note that the collection sump at the toe was never constructed. |

### 3.4.2 Design Criteria

Design criteria and elevations based on mean sea level (NAD 27) datum for the Little Creek Dam are provided in Table 3.17. A general arrangement plan and typical dam cross section of the dam are presented in Figures B-027 and B-028, respectively. A longitudinal dam section with drill holes and test pits is shown on Figure A-029, and a transverse dam section with similar information is shown on Figure A-030. The dam foundation stratigraphy is shown on a longitudinal section on Figure A-031. The dam design cross sections and details are shown on Figure B-032, while the layouts for the as-built foundation cut-off trench excavation and drainage blanket are presented on Figures A-033.

SRK (1990) specified the dam fill to be placed in horizontal lifts not exceeding one foot (300 mm) in thickness, and compacted to 95% of Standard Proctor maximum dry density. SRK (1991) as-built construction report includes results of laboratory and field test results conducted by EBA Engineering.

SRK (1998) designed an emergency spillway to allow safe passage of the 200-year wet year (i.e., 365 day) inflows. The 200 year "best estimate" and "conservative estimate" hydrographs have annual average flows of 10.8 L/s and 14.4 L/s, respectively, as compared to 4.4 L/s which is the long-term average yield from the Little Creek Pond catchment area of 0.72 $km^2$.

**Table 3.17 Little Creek Dam Design Criteria and Elevation**

<table>
<tr><td colspan="3">Crest of Dam</td><td colspan="2">1114.5 to 1120 m amsl. Information from SRK (1998) indicates that the low point on the crest and core was surveyed at 1113.8 m amsl. In 2001 a 0.45 m layer of compacted gravel was placed on the crest and core of the dam raising the current crest to El. 1114.3 m. A survey is required to verify the final crest elevations.</td></tr>
<tr><td colspan="3">Top of Core</td><td colspan="2">Low point of dam core is 1113.8 m amsl</td></tr>
<tr><td colspan="3">Inflow Design Flood (IDF) Level</td><td colspan="2">1113.6 m amsl, 200-year flood (SRK 1998)</td></tr>
<tr><td colspan="3">Full Supply Level, FSL</td><td colspan="2">1112.8 m amsl</td></tr>
<tr><td colspan="3">Spillway Inlet</td><td colspan="2">1112.8 m amsl. (Should be confirmed by survey)</td></tr>
<tr><td colspan="3">Design Freeboard</td><td colspan="2">1.9 m</td></tr>
<tr><td colspan="3">Actual Freeboard</td><td colspan="2">0.7 m (to be confirmed by survey of spillway inlet and dam crest levels)</td></tr>
<tr><td colspan="3">Design Seepage</td><td colspan="2">Undefined</td></tr>
<tr><td colspan="3">Reservoir Area</td><td colspan="2">28,600 $m^2$</td></tr>
<tr><td colspan="3">Total Storage Capacity</td><td colspan="2">122,000 $m^3$</td></tr>
<tr><td rowspan="8">Design Requirements</td><td rowspan="2">Slope Stability</td><td colspan="2">Downstream, steady state</td><td>FS = 1.5</td></tr>
<tr><td colspan="2">Upstream, steady state</td><td>FS = 1.5</td></tr>
<tr><td rowspan="3">Earthquake</td><td colspan="2">Closure Requirement - 1:500 year*<br>*Needs to be confirmed by Faro Mine Closure Planning Office</td><td>0.08 g (Atkinson 2004)</td></tr>
<tr><td colspan="2">CDA Requirement - 1:500 year</td><td>0.08 g (Atkinson 2004)</td></tr>
<tr><td colspan="2">Water Licence Requirement - 1:475 year</td><td>0.08 g (Atkinson 2004)</td></tr>
<tr><td rowspan="3">Flood</td><td colspan="2">Closure Requirement – PMF</td><td>Not defined</td></tr>
<tr><td colspan="2">CDA Requirement – to be determined after confirmation of dam classification</td><td>Not defined</td></tr>
<tr><td colspan="2">Water Licence Requirement – 1:200 year.</td><td>14.4 L/sec (SRK 1998)</td></tr>
<tr><td rowspan="4">Spillway</td><td colspan="2">Type</td><td colspan="2">900 mm CMP culvert leading to an earthen spillway outflow channel</td></tr>
<tr><td colspan="2">Rating Curve</td><td colspan="2">None Found</td></tr>
<tr><td colspan="2">Capacity</td><td colspan="2">0.8 $m^3/s$ (KCB 2002) (SRK 1998)</td></tr>
<tr><td colspan="2">Comments</td><td colspan="2">Need to update the hydrology and check against design criteria. Need to confirm closure requirement. The 200 year flood is successfully routed through the spillway. (SRK 2008)</td></tr>
<tr><td rowspan="2">Slope Stability</td><td colspan="2">Downstream</td><td colspan="2">None Found, likely acceptable given the design and construction of the dam following the general practice for water retention dam.</td></tr>
<tr><td colspan="2">Upstream</td><td colspan="2">None Found, likely acceptable given the design and construction of the dam following the general practice for water retention dam.</td></tr>
<tr><td>Earthquake</td><td colspan="2">Comments</td><td colspan="2">None Found, likely acceptable given the design and construction of the dam following the general practice for water retention dam.</td></tr>
</table>

### 3.4.3 Design Section and Dam Materials

A brief discussion of the construction history and nature of the dam materials making up the Little Creek Dam are given below in Table 3.18.

**Table 3.18 Little Creek Dam - Design Section and Dam Materials**

| | |
|---|---|
| Crest Width | 10 m |
| Crest Length | 310 m |
| Max. Dam Height | 10 m |
| U/S Slope | 2.5H:1V |
| D/S Slope | 2H:1V |
| Type/Source of Construction Materials | Main damfill materials: glacial till and gravely sand drain.<br>Till source - overburden stripping from the Vangorda open pit.<br>Gravelly sand source - excavated from within the collection pond. |
| Description of Construction | Embankment dam constructed as a homogeneous till dam with a foundation seepage cut-off trench and downstream blanket and finger drains. Historically, a wet well, intake and discharge pipes were installed to transmit water from the collection pond to the water treatment facility. Construction completed between 1990 and 1991. A culvert spillway was added in 1998 at the south abutment. Currently water is pumped from a submersible pump to the Vangorda Pit for treatment during ice-free period. |
| Method of Construction | Conventional dam construction. |

### 3.4.4 Pond Elevations, Storage Volumes and Water Conveyance

The storage capacity versus elevation curve is included as Figure A-034 from the SRK (1990) design report. Pond elevations based on mean sea level (NAD27) datum, storage volumes and water conveyance information are included in Table 3.19.

**Table 3.19 Little Creek Dam Pond Elevations, Storage Volumes and Water Conveyance**

| | |
|---|---|
| Design Storage Capacity | 122,000 $m^3$ |
| Existing Storage Capacity | 122,000 $m^3$ |
| Pond Elevations | Normal pond levels were initially maintained between 1112.6 m and 1109 m amsl. Generally the pond was drawn down to 1109 m amsl before the winter shut-down period. Currently, the pond level is maintained below the design FSL, as the pond is no longer required to take water from the Vangorda Pit. |
| Historical Pond Elevations | Based on annual monitoring records, the maximum and minimum pond levels recorded were 1111.7 m amsl in May 2008 and 1105 m amsl in Sept 1999. |
| Water Conveyance | Originally, the wet well and pumphouse were used to pump water from the pond to the water treatment plant. Currently the pumphouse and associated pumping infrastructure are non-operational except the power supply. Water accumulating in the pond is pumped to the Vangorda Pit using a float with an electric 30-hp pump and 6-inch HDPE pipeline. Water from the pit is then transferred to the Vangorda water treatment plant. |
| Storage Capacity Curve | See Figure A-034. |

### 3.4.5 Operating Procedures for Pond Levels

The operating procedures for pond levels are shown in Table 3.20. It is noted that the "Trigger Level for ERP" refers to the pond level that should trigger the site response as described in the Emergency Response Plan (KCB, 2014b).

**Table 3.20 Little Creek Dam Operating Pond Levels**

| | |
|---|---|
| Maximum Flood Level | 1113.6 m amsl (200-year flood) |
| Full Supply Level | 1112.8 m amsl |
| Maximum Operating Pond Level | 1111.8 m amsl licence limit |
| Minimum Operating Pond Level | 1107.0 m amsl |
| Base of Riprap | No riprap placed |
| Alert Level | 1112.8 m amsl for dam overtopping |
| Trigger Levels for ERP | 1113.6 m amsl for dam overtopping and<br>lower levels for other failure modes, see Table 3.22 |

The design and construction of the 1998 Emergency Spillway is described in SRK (1998). The spillway design is shown in plan, section and details on Figure A-035, and the as-built spillway details are shown in Figures B-036 and B-037.

### 3.4.6 Instrument Monitoring

Instrumentation at the Little Creek Dam (see Figure A-038) consists of a pond level measuring point; three pared pneumatic piezometers (P94-LCD-1 to P94-LCD-3) with tips at both shallow and deep depths; three thermistor strings installed in 1994 on the dam crest (94LCD-4T to 94LCD-6T) to a depth ranging from 13 m to 17 m; and seven piezometers (P09-LCD-1 to P09-LCD-7) installed in 2010 along the downstream toe (SRK 2011). The ground temperature profiles beneath the dam crest monitored in 2012 indicate that the dam fill and foundation is essentially thawed with the exception of the surficial zone down to a depth of 4 m to 5 m undergoing seasonal freezing. Thus, ground temperature measurement is no longer critical for ongoing monitoring of the Little Creek Dam. The pond level and maximum piezometric level and corresponding date in 2012 for these piezometers are summarized in Table 3.21.

**Table 3.21 Historical and Current Little Creek Pond and Water Level at Piezometers at Little Creek Dam**

| Location | Name | Historical (masl) | | 2013 (masl) | | Comments |
|---|---|---|---|---|---|---|
| | | Max | Min | Max | Min | |
| Water Level Readings | | | | | | |
| Pond Level | LCD | 1111.70 | 1106.48 | 1110.68 | 1107.92 | Licence Limit = 1111.80 |
| Standpipe Piezometers | | | | | | |
| Downstream Toe | P09-LCD-1[1] | 1093.74 | 1093.45 | - | - | - |
| | P09-LCD-2[1] | 1093.46 | 1093.26 | - | - | - |
| | P09-LCD-3[1] | 1092.10[2] | 1091.83 | - | - | - |
| | P09-LCD-4[1] | 1091.62 | 1082.00 | - | - | - |
| | P09-LCD-6[1] | 1090.91[3] | 1089.46 | - | - | - |
| | P09-LCD-7[1] | 1097.41 | 1096.93 | - | - | - |
| Pneumatic Piezometers (BH94-LCD1 to LCD3 are nested piezometers with one tip deep and one shallow) | | | | | | |
| Dam Crest | BH94-LCD1 | 1105.77 | 1104.16 | 1104.93 | 1104.86 | Shallow |
| | | 1105.82 | 1103.79 | 1105.26 | 1104.98 | Deep |
| | BH94-LCD2 | 1101.76 | 1100.50 | - | 1100.71 | Shallow |
| | | 1102.39 | 1098.54 | - | 1099.31 | Deep |
| | BH94-LCD3 | 1106.76 | 1105.50 | 1105.78 | Dry[4] | Shallow |
| | | 1108.69 | 1102.89 | 1104.28 | 1103.65 | Deep |

Notes:
1. No reading is available for these instruments in 2013.
2. P09-LCD-3: Maximum level increased by 0.06 m from 1092.04 m to 1092.10 m on May 9, 2012.
3. P09-LCD-6: Maximum level increased by 0.34 m from 1090.57 m to 1090.91 m on May 9, 2012.
4. Tip elevation for BH94-LCD3 (shallow) is at 1105.50 m. Therefore, it is assumed that this piezometer is dry.

The current monitoring frequency for this instrumentation is discussed in the Annual Geotechnical Report (KCB 2014c). The frequency may change each year as required.

### 3.4.7 Alert Level

Table 3.22 outlines conditions at the alert level for the Little Creek Dam.

**Table 3.22 Little Creek Dam Conditions at Alert Level**

| Incident | Alert Level |
|---|---|
| Dam Overtopping | Reservoir level is at normal operating level and starts to rise above maximum operating level. |
| Dam Embankment Instability | Appearance of new cracks or the opening of existing cracks in crest or faces of dam. Significant warming trend in thermistors, increasing pore pressures in piezometers or high one-time reading from a single piezometer. |
| Piping – Internal Erosion of Dam | Small quantities of clear seepage water flowing from the toe or abutment of a dam may be considered normal, but should be recorded as part of the regular visual inspections being carried out. The location and seepage quantities, preferably measured by a weir or by the time required to fill a container of known volume should be monitored. Changes in the location, rate of flow may be related to reservoir levels, precipitation, snowmelt or thawing of ground ice. May be associated with warming trend in thermistors. |
| Seismic Instability and Large Earthquake Events | Site staff should inspect all dams after a seismic event has been felt at the site, regardless of the size of the event. Pore pressure readings should be taken on all piezometers. Information may be obtained from the PGC website given in the EPP regarding recent seismic events in western and northern Canada and Alaska. |

Piezometric and seepage trends such as increasing trend of piezometric levels and/or downstream rate of seepage and appearance of murky downstream seepage should trigger an alert level response.

### 3.4.8 Dam Slope Stability

No dam slope stability analyses information were found in available project reports. However, the dam slope stability is likely acceptable given the design and construction of the dam follow the general practice for water retention dam and no incident of dam slope instability has been reported.

## 3.5 Maintenance and Surveillance

### 3.5.1 Maintenance Requirements

Typical maintenance procedures for all dams, including the spillway channels, are outlined below (Gartner Lee 2003):

1. Investigate the potential causes of surficial cracks and review implications with Geotechnical Consultant. Do not cover any cracks prior to the site observation of these cracks by the Geotechnical Consultant, unless instructed otherwise by the Geotechnical Consultant. Generally, minor cracks can be graded over with either a grader or possibly a loader. Material used to backfill cracks should be compatible with the parent material proximal to the crack. After grading the crest of the dam, it is usual to grade the entire crest towards the upstream slope where riprap is located. Generally, the crest of a dam is never graded towards the downstream slope, unless erosion protection measures are placed.

2. Riprap on the upstream dam slope and within spillway channels needs to be kept in good condition. Small erosional scarps can develop in response to ice and/or wave action on the upstream slope. Construction activity and vehicle access within and across the spillway may disturb riprap. Flood events and frost action may also disturb riprap placed around culvert

inlets. Riprap placed for repair should be of similar size to the riprap that was eroded. A filter between the underlying material and the riprap may be required. Generally, angular riprap is preferable than rounded riprap. Larger stone sizes will be required if rounded riprap is used. Review the required stone size with the Geotechnical Consultant if rounded riprap is to be used. Any riprap placed should be compatible with adjacent ground so that no edges or corners would be formed to attract erosive energy.

3. Erosion gullies and their associated debris cones should be backfilled and graded over to prevent enlargement of existing erosion. In some cases, erosion gullies could be formed as the result of settlement and/or cracks of nearby features such as crest and roads. The original causes of settlement and cracks should be assessed, before the gullies are backfilled. In general, material with angular particle shape is more resistant than that with rounded particle shape.
4. Maintenance of the crest, spillway or other features of the dam to their initial design configurations is important for their proper functions.
5. Siphon pipes and the associated infrastructure needs to be kept in good operating condition so that it can be used for both routine and emergency water discharges. To that end, the siphon pipes should be kept in good condition with the pipe welds checked periodically and the pipes kept clear of blockages due to ice, snow and soil debris. It may be necessary to properly drain the pipes in the fall so that ice blockages do not occur when the pipes are required in the following spring. Valves and air suction inlet pipes must also be kept in good repair and inspected periodically to confirm their readiness for proper operation.
6. Excessive growth of trees and shrubs on the dams and in the spillway channels must be removed. Growth of short grass, which does not hinder visual inspection of these structures or reduce the discharge capacity of the channels, is acceptable and would be beneficial in terms of providing erosion protection.
7. Accumulated debris must be removed from the spillway on a regular basis.

Maintenance may also be required on the various monitoring instruments including staff gauges, weirs, piezometers, inclinometers and thermistors. The staff gauge in the head pond should be checked to ensure that it is stable and has not been pushed over by ice action or water flows. If any settlement and/or standing water is noted around piezometer casing, the surface should be sealed with bentonite pellets ("Peltonite") to prevent the ingress of surface water down the piezometer casing. Surface casing caps should be provided and maintained on all instrumentation to prevent their damage by weather and the public at large.

All maintenance activities should be documented. Site staff should record these activities on checklists or report forms to record pertinent information in a consistent manner.

Maintenance records may become important sources of information to identify and deal with changed or changing conditions at the facility. Records that document maintenance activities may include (MAC 2002):

- equipment logs;
- work history;
- quality control records;
- daily diary entries;
- communication and activity records;
- photographic and/or video records;
- inventory of spares, materials, tools and equipment;
- schedules;
- change orders;
- memos; and
- reports.

These records will document the frequency and cause of problems that may be important in assessing site conditions and reliability of various components.

### 3.5.2 Surveillance Requirements

As required in the Water Licence, site staff should undertake weekly inspections of the visual condition of the dam. These inspectors should look for, and document, any changes to the structure including, but not limited to, the following items:

- new or opening cracks on the dam crest or slopes;
- settled or depressed areas, where standing water may be present;
- significant erosion gullies and related debris fans formed by running water;
- displacements or erosion of the riprap on the upstream slope or within spillway; and
- new or increasing amounts of seepage at the toe or downstream face (important to check seepage at the toe of the south abutment); whenever checking for seepage, ensure to note whether the water is clear of any sediment or turbidity; report immediately the increase of turbidity of seepage water that is not related to the influence of surface runoff.

These observations should be recorded in a log book, field form (Appendix III) or file so that changes may be documented. Selected photos and/or hand-drawn sketches can also be provided to illustrate details of description.

In combination with the weekly inspection, the pond water level should be recorded and documented.

Inspection visits by a professional geotechnical engineer are also a requirement of the Water Licence. Over the recent years, these inspections have been undertaken in May/June (following spring freshet and thawing) and August/September (following an entire summer season of runoff) to assess the conditions of the dams. Site visit memos and/or annual geotechnical inspection reports contain comments by the Geotechnical Consultant on required maintenance and monitoring issues to complement the typical monitoring protocols provided herein.

## 3.6 Training

### 3.6.1 Site Personnel Training on OMS Manual

In the past, the OMS manual was reviewed, updated, and improved in response to:

- life-cycle changes and closure requirements;
- changes in the site management organization, roles, responsibilities and operating and reporting procedures; and
- regulatory change.

There was also a regular training program that consists of two major phases:

- Phase 1: Introduce the components of the OMS Manual to new site staff. This will ensure that each individual is aware of their roles and responsibilities, particularly with regard to reporting and acting on observations.
- Phase 2: Regular (annual) updating of the above details to reflect ongoing changes in physical conditions, operating procedures, reporting procedures and management changes.

Phase 1 training was conducted in 2004 and repeated to any new permanent site staff hired during this time, and Phase 2 training was conducted on a yearly basis from 2004 to 2008. With the update of the OMS manual, TEES is planning to roll out and revitalize the related training program.

### 3.6.2 OMS Improvement

The current update is the first after Yukon Government took over the management of ongoing care and maintenance activities on site in 2009. As the long-term closure measures being developed by CH2M HILL consultant under the guidance of Yukon Government, site activities and procedures are expected to undergo future changes. The ongoing improvement and update of the OMS manual as well as its training program is the responsibility of the site care and maintenance contractor, Tlicho Engineering and Environmental Services. The following outlines some of the improvements need to be implemented:

- Section 2.2.1 provided a summary of site temperature based on data from 1967 to 2007. We recommend that this summary to be updated, and recent changes, if any, to be identified. The detection of any long-term climate trend is important for both ongoing care and maintenance activities and development of appropriate closure measures for the site facilities.

# 4 CLOSING

This report, "Operations, Maintenance and Surveillance Manual: Intermediate Dam, Cross Valley Dam and Little Creek Dam", provides a compilation of data from numerous reports and drawings gleaned from various sources. KCB has not carried out any independent verification of such data and information. Therefore all such data has been assumed to be accurate.

The failure consequence classification of the three dams covered in this OMS Manual is based on a recent dam breach and inundation study (KCB 2014a) following the Canadian Dam Association (CDA 2007) guidelines. These guidelines provide engineering guidance on required standards for dam safety, such as design flood, design earthquake and periodical dam safety review.

**KLOHN CRIPPEN BERGER LTD.**

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March 31, 2014

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Project Manager

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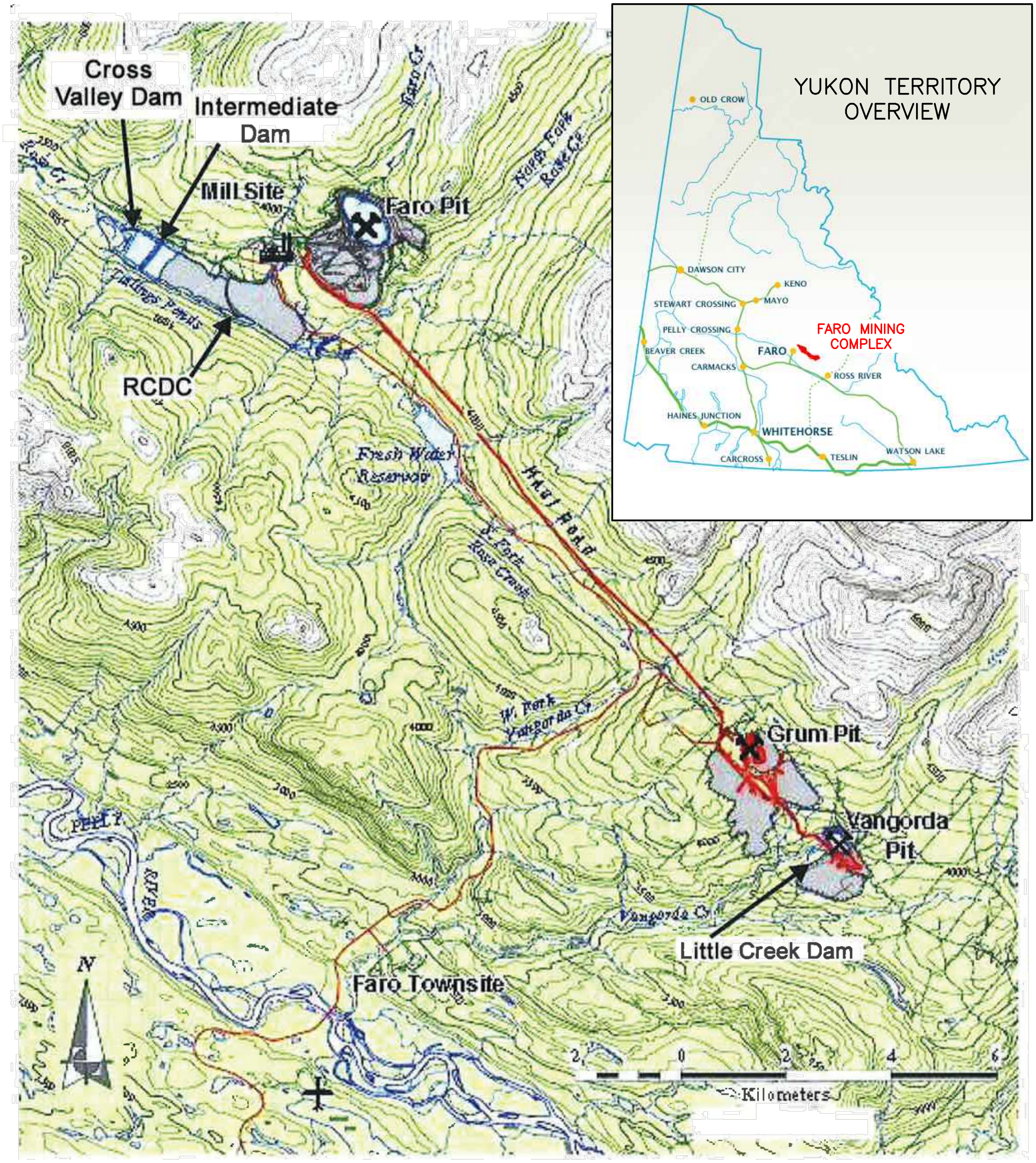
# FIGURES






NOTE

1. BASE MAP FIGURE PROVIDED BY GARTNER LEE LIMITED.

| CLIENT | PROJECT |
|---|---|
| Yukon Government | FARO MINE COMPLEX<br>OMS MANUAL FOR DAMS |
| Klohn Crippen Berger | TITLE<br>SITE LOCATION PLAN |
| | PROJECT No. M09770A03 02 01 — FIG. No. A-001 |

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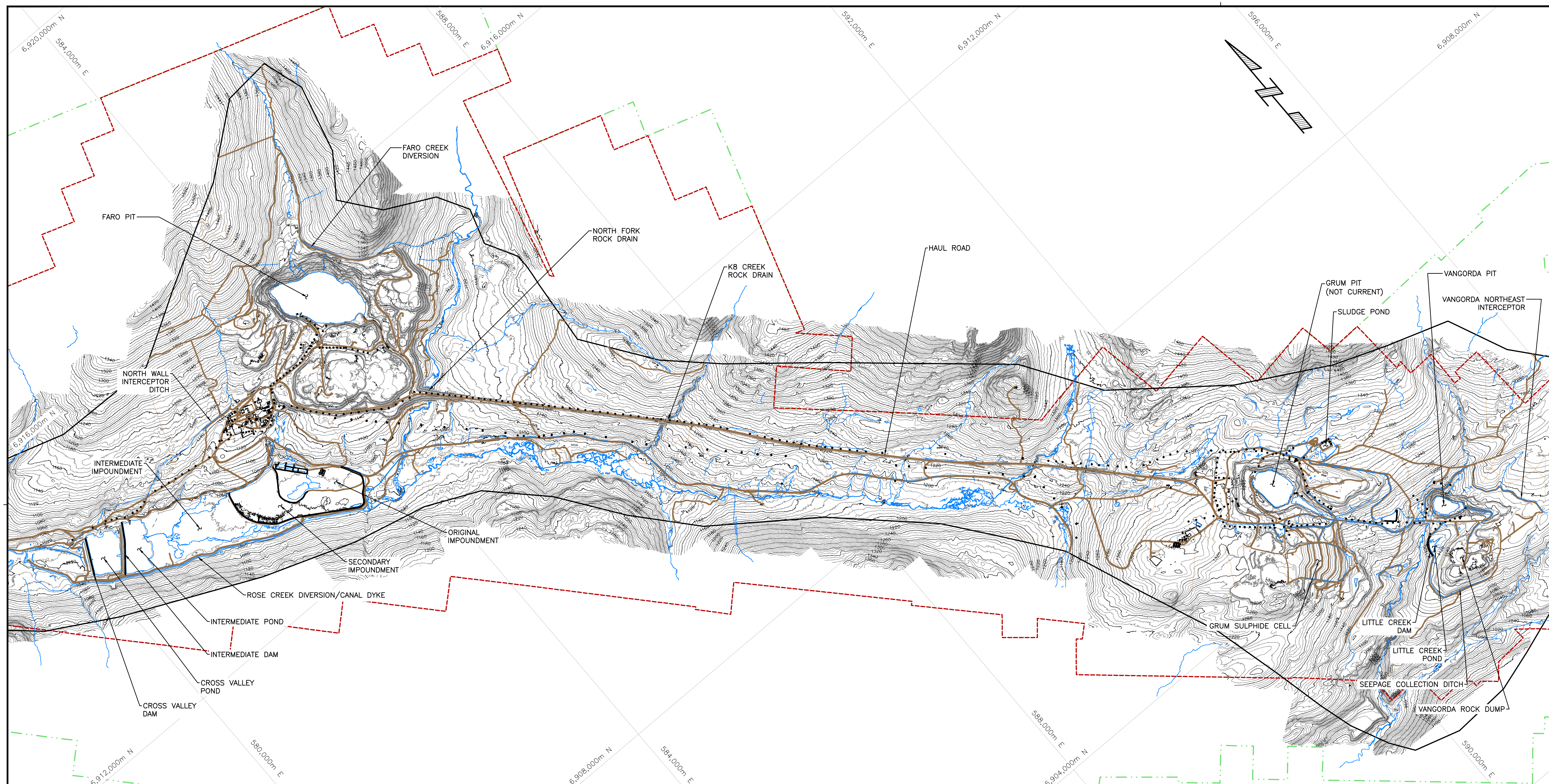
Drawing File: \\int.klohn.com\ProjData\M\VCR\M09770A03-GovtYukon-2013 Faro\400 Drawings\OMS_Manual\FIG_A-001_Site_Location.dwg (afischer)

KCB-R-MPA




**LEGEND**

- PROTECTED AREA WITHDRAWN FROM STAKING MINERAL CLAIMS OIC #2007/168
- IMPACTED AREA BOUNDARY
- ACCESS ROADS
- STREAMS
- ● ● ● POWER POLE

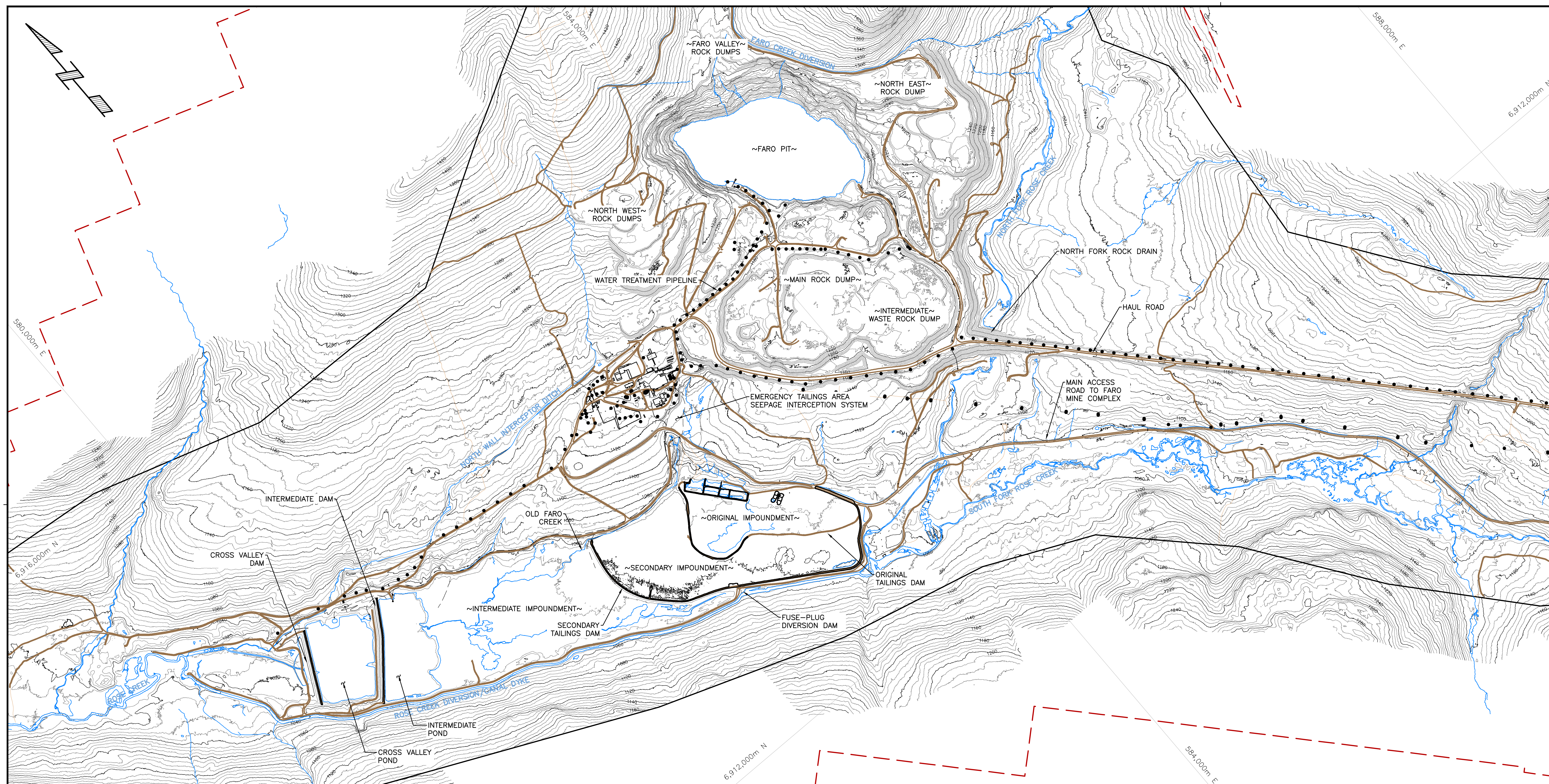
SCALE 0 — 2000m



| | |
|---|---|
| CLIENT | Yukon Government |
| | Klohn Crippen Berger |
| PROJECT | FARO MINE COMPLEX<br>OMS MANUAL FOR DAMS |
| TITLE | MINE SITE TOPOGRAPHY AND ACCESS ROADS |
| PROJECT No. | M09770A03 02 01 |
| FIG. No. | B-002 |

KCB-R-MLD

Date:1/29/2013 Time:13:25:10 Scale:1:2,585
Filename: \\INT.KLOHN.COM\PROJDATA\M\VCR\M09770A03-GOVTYUKON-2013 FARO\400 DRAWINGS\OMS_MANUAL\FIG_B-002_SITE_TOPOGRAPHY.DWG




LEGEND

- IMPACTED AREA BOUNDARY
- ACCESS ROADS
- STREAMS
- POWER POLE

SCALE 0 — 1000m

AS A MUTUAL PROTECTION TO OUR CLIENT, THE PUBLIC AND OURSELVES, ALL REPORTS AND DRAWINGS ARE SUBMITTED FOR THE CONFIDENTIAL INFORMATION OF OUR CLIENT FOR A SPECIFIC PROJECT AND AUTHORIZATION FOR USE AND/OR PUBLICATION OF DATA,STATEMENTS,CONCLUSIONS OR ABSTRACTS FROM OR REGARDING OUR REPORTS AND DRAWINGS IS RESERVED PENDING OUR WRITTEN APPROVAL.

CLIENT: Yukon Government

Klohn Crippen Berger

PROJECT: FARO MINE COMPLEX OMS MANUAL FOR DAMS

TITLE: FARO SITE GENERAL LAYOUT

PROJECT No. M09770A03 02 01

FIG. No. B-003

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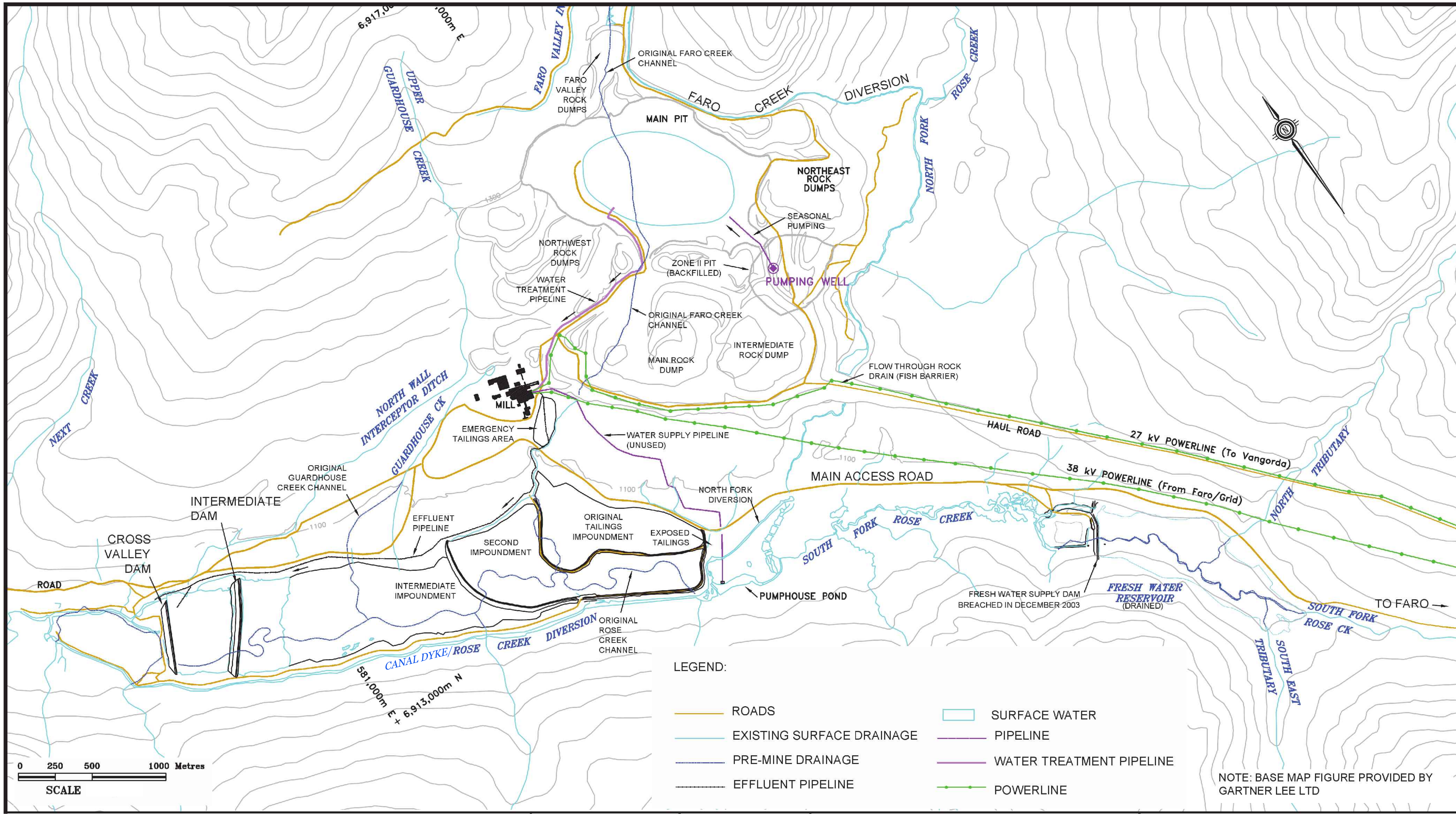
Filename: \\INT.KLOHN.COM\PROJDATA\M\VCR\M09770A03-GOVTYUKON-2013 FARO\400 DRAWINGS\OMS_MANUAL\FIG_B-003&B-005.DWG

KCB-R-MLD




NOTE

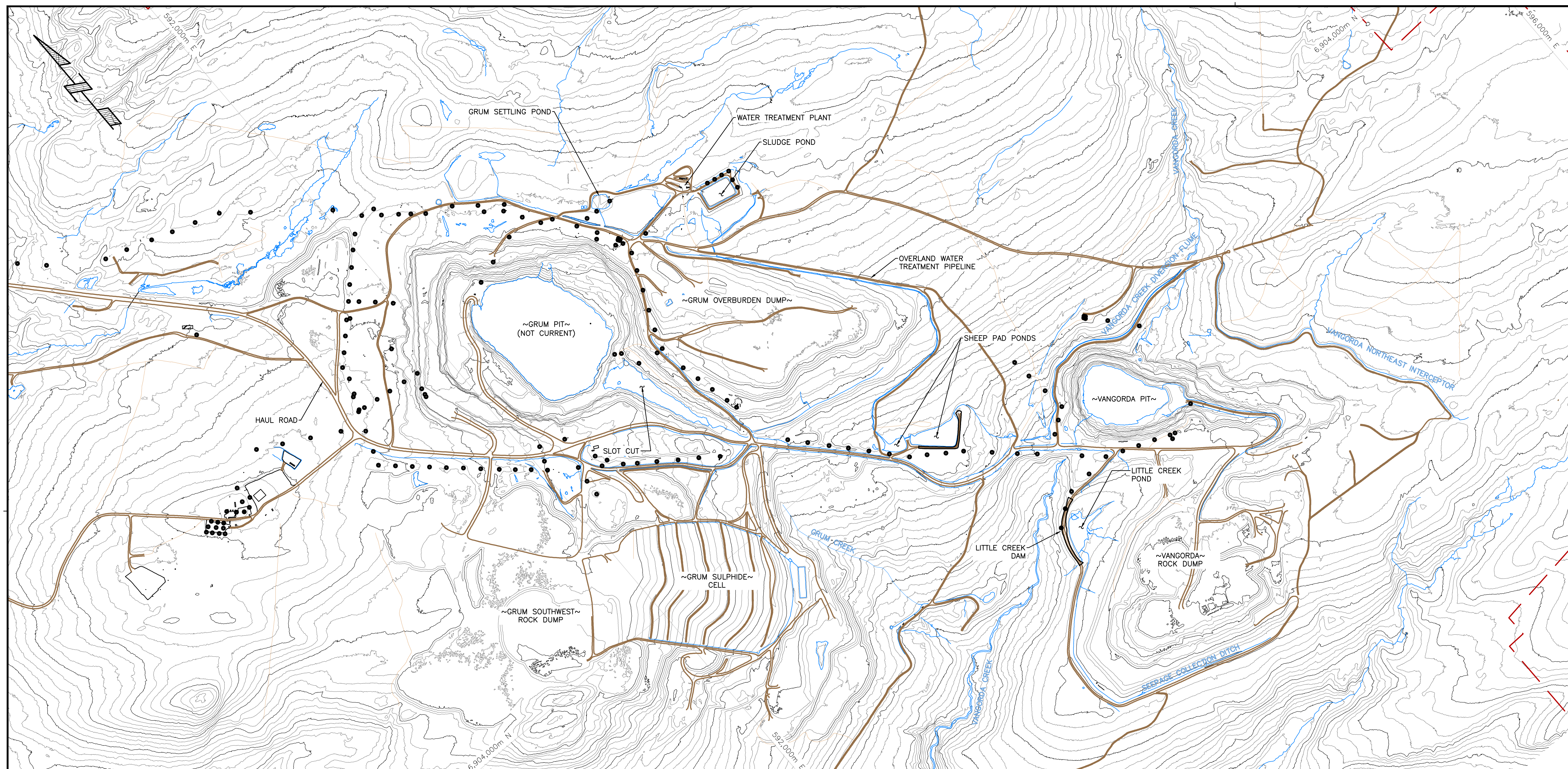
1. ORIGINAL FIGURE PROVIDED BY BGC ENGINEERING.



| | |
|---|---|
| CLIENT | Yukon Government |
| | Klohn Crippen Berger |
| PROJECT | FARO MINE COMPLEX OMS MANUAL FOR DAMS |
| TITLE | FARO SITE DETAIL LAYOUT |
| PROJECT No. | M09770A03 02 01 |
| FIG. No. | B-004 |

Date:1/29/2013 Time:13:25:10 Scale:1:2,585
Filename: \\INT.KLOHN.COM\PROJDATA\M\VCR\M09770A03-GOVYUKON-2013 FARO\400 DRAWINGS\OMS_MANUAL\FIG_B-004_DETAIL_LAYOUT.DWG

KCB-R-MLD




LEGEND

- IMPACTED AREA BOUNDARY
- ACCESS ROADS
- STREAMS
- POWER POLE

SCALE 0 750m



CLIENT: Yukon Government

Klohn Crippen Berger

PROJECT: FARO MINE COMPLEX
OMS MANUAL FOR DAMS

TITLE: VANGORDA PLATEAU SITE
GENERAL LAYOUT

PROJECT No. M09770A03 02 01

FIG. No. B-005

KCB-R-MLD

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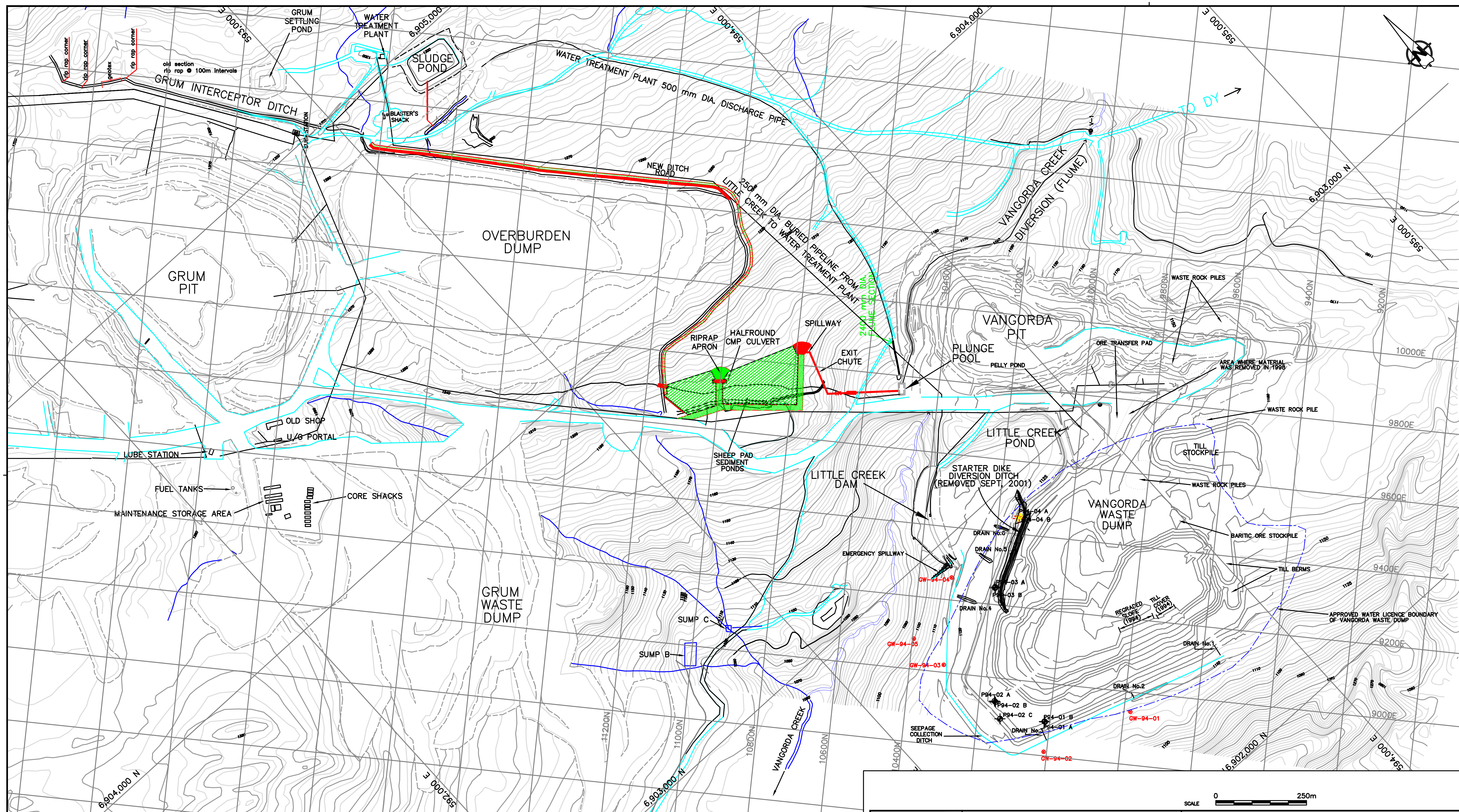


NOTES

1. ORIGINAL SOURCE BY DELOITTE & TOUCHE.
2. TOPOGRAPHIC MAP PROVIDED BY ANVIL RANGE MINING CORPORATION.



CLIENT: Yukon Government

Klohn Crippen Berger

PROJECT: FARO MINE COMPLEX OMS MANUAL FOR DAMS

TITLE: VANGORDA PLATEAU SITE DETAIL LAYOUT

PROJECT No. M09770A03 02 01

FIG. No. B-006

KCB-R-MLD

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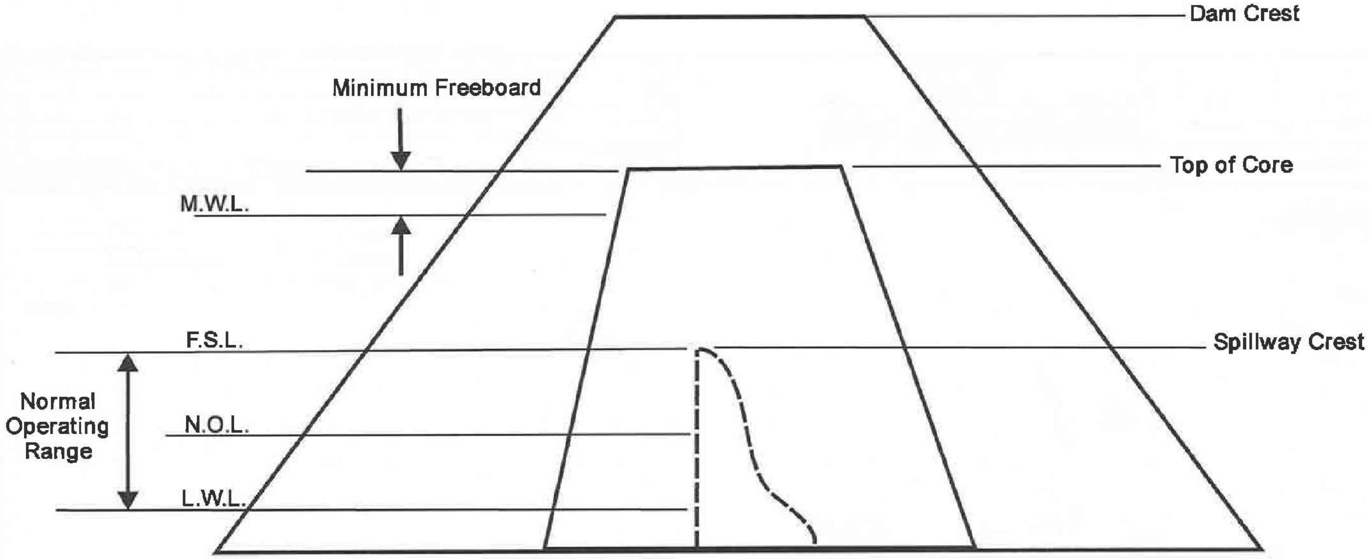
Filename: \\INT.KLOHN.COM\PROJDATA\M\VCR\M09770A03-GOVYUKON-2013 FARO\400 DRAWINGS\OMS_MANUAL\FIG_B-006_VANGORDA_PLATEAU_DETAIL.DWG




**Notes:**

**M.W.L. Maximum Water Level** - This occurs when the spillway is passing the design flood. Surcharge to reservoir above F.S.L. is temporary until end of flood.

**F.S.L. Full Supply Level** - Headpond level is same as sill level of spillway.

**N.O.L. Normal Operating Level** - Headpond level used for normal operations. May be the same as F.S.L.

**L.W.L. Lowest Water Level** - May be constrained by riprap on dam. This is the lowest level the headpond may be operated at. Headpond may be drawn down to this level to increase flood storage capacity.

**Normal Operating Range**: Headpond may vary in elevation between this range during normal operations.

**Freeboard**: The vertical distance between the top of the water retaining element of the dam (top of core) and the water level in the reservoir.

NOTE

1. ORIGINAL SOURCE BY BGC ENGINEERING INC. (2008).



| | |
|---|---|
| CLIENT | Yukon Government / Klohn Crippen Berger |
| PROJECT | FARO MINE COMPLEX<br>OMS MANUAL FOR DAMS |
| TITLE | TERMINOLOGY FOR DAM OPERATIONS |
| PROJECT No. | M09770A03 02 01 |
| FIG. No. | A–007 |

KCB–R–MLA

Time: 16:54:16
Date: 3/31/2014
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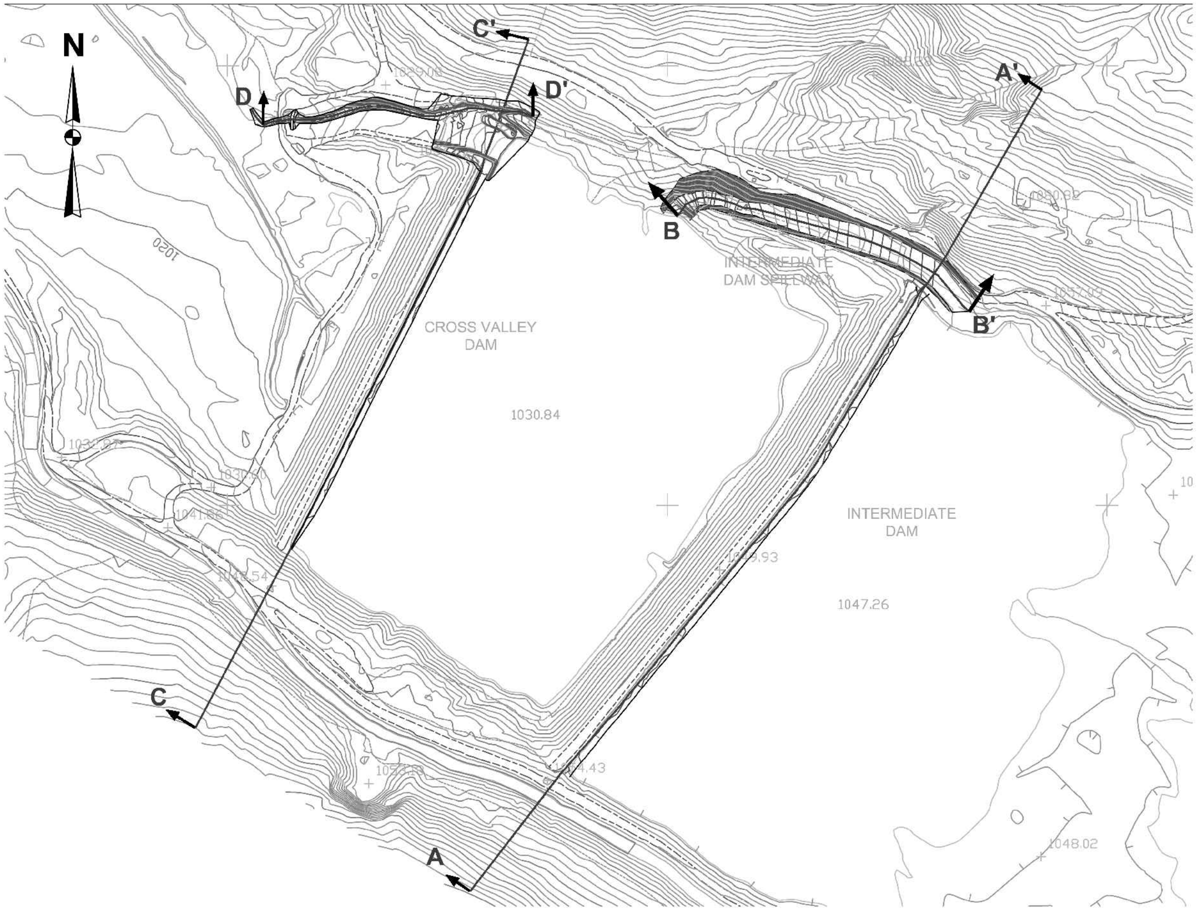
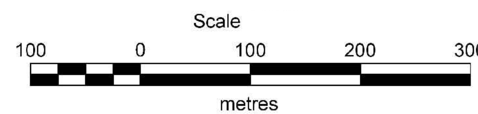



NOTE:
1. DAM AND SPILLWAY TOPOGRAPHY FROM YES DATED SEPT, 2003.
2. SITE WIDE TOPOGRAPHY FROM DIGITAL MAP BY THE ORTHOSHOP, PHOTO TAKEN JULY 25, 2003.
3. ALL ELEVATIONS AND COORDINATES ARE REFERENCED TO NAD27 DATUM AND GRID.




**NOTE**

1. ORIGINAL SOURCE BY BGC ENGINEERING INC. (2008).



CLIENT: Yukon Government

Klohn Crippen Berger

PROJECT: FARO MINE COMPLEX OMS MANUAL FOR DAMS

TITLE: INTERMEDIATE AND CROSS VALLEY DAMS 2003 SURVEY PROFILES LOCATION PLAN

PROJECT No.: M09770A03 02 01

FIG. No.: A–008

KCB–R–MLA

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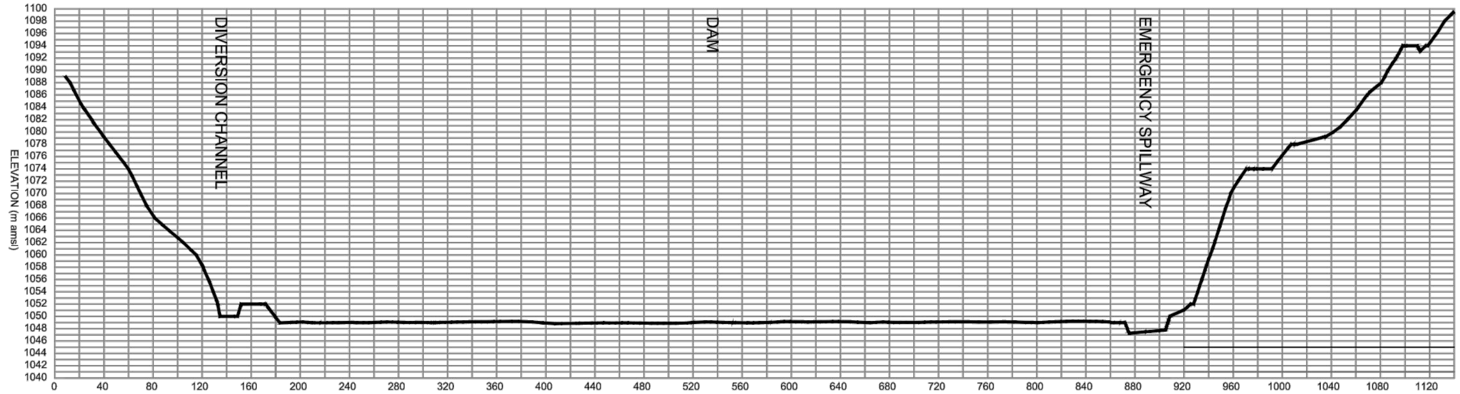
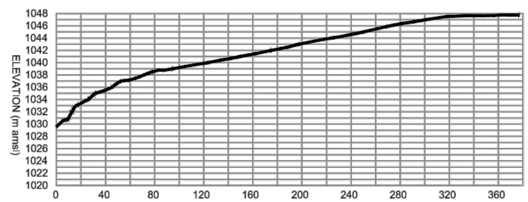



SECTION A - A'
DAM PROFILE




SECTION B - B'
EMERGENCY SPILLWAY PROFILE

NOTE:
1. DAM AND SPILLWAY TOPOGRAPHY FROM YES DATED SEPT, 2003.
2. SITE WIDE TOPOGRAPHY FROM DIGITAL MAP BY THE ORTHOSHOP, PHOTO TAKEN JULY 25, 2003.
3. ALL ELEVATIONS AND COORDINATES ARE REFERENCED TO NAD27 DATUM AND GRID.
4. LOCATION OF SECTIONS ON FIGURE 5

**NOTE**

1. ORIGINAL SOURCE BY BGC ENGINEERING INC. (2008).



CLIENT
Yukon Government

Klohn Crippen Berger

PROJECT
FARO MINE COMPLEX
OMS MANUAL FOR DAMS

TITLE
INTERMEDIATE DAM
2003 SURVEY PROFILES

PROJECT No. M09770A03 02 01

FIG. No. A–009

KCB–R–MLA

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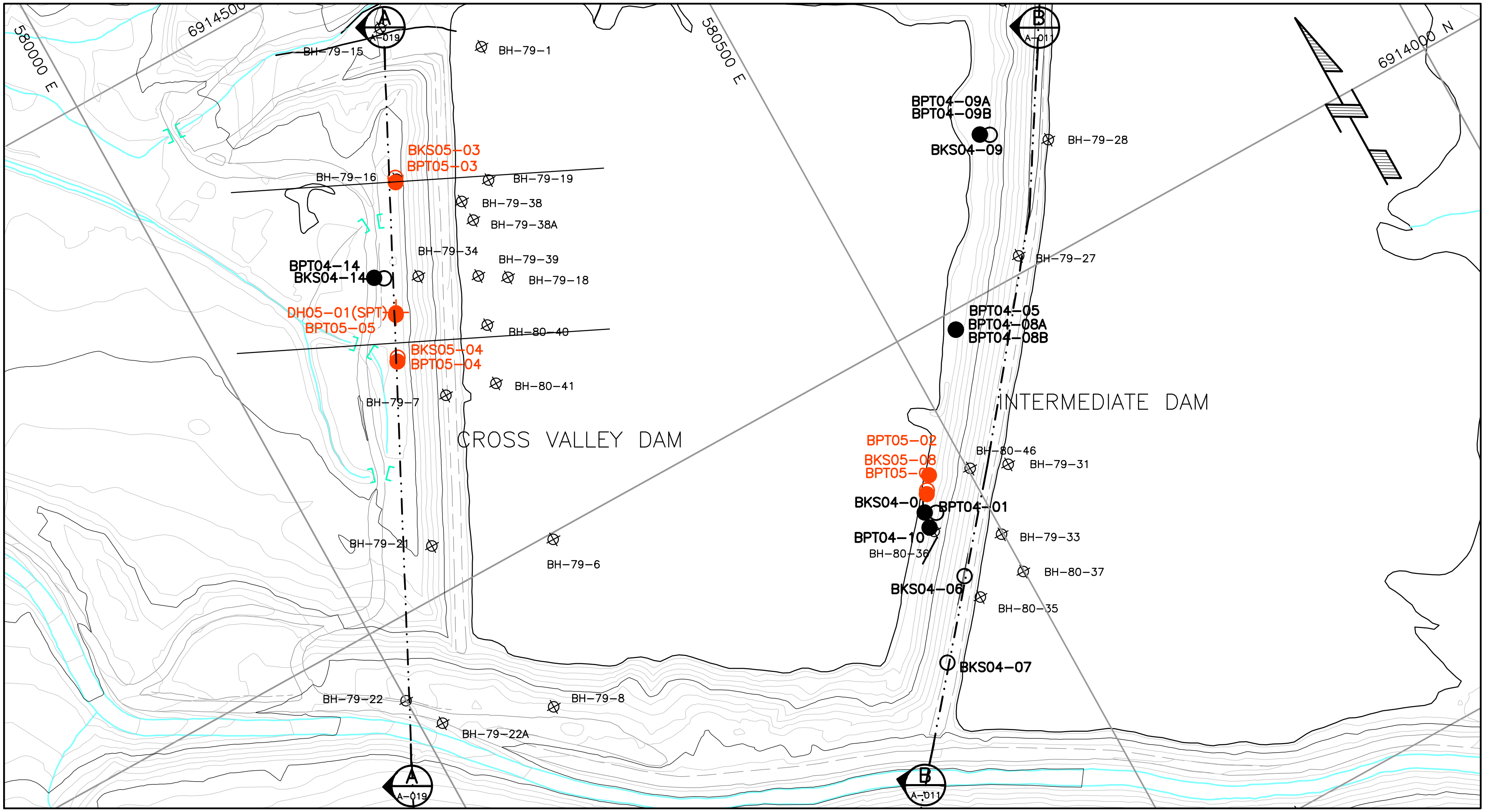



LEGEND

BH–80–36 GOLDER TEST HOLE

BKS05–03 KLOHN CRIPPEN OPEN BECKER TEST

BPT05–04 KLOHN CRIPPEN CLOSED BECKER TEST

DH05–01 KLOHN CRIPPEN TEST HOLE

SCALE 0 125 m

## NOTES

1. BASE PLAN TAKEN FROM 2003 FARO SITE PLAN1_Ver2000.DWG PROVIDED BY SRK.
2. CONTOUR INTERVAL IS 2m RELATIVE TO MEAN SEA LEVEL.
3. BH3 TO BH6 AND BH–D–2 LOCATIONS ARE APPROXIMATE.



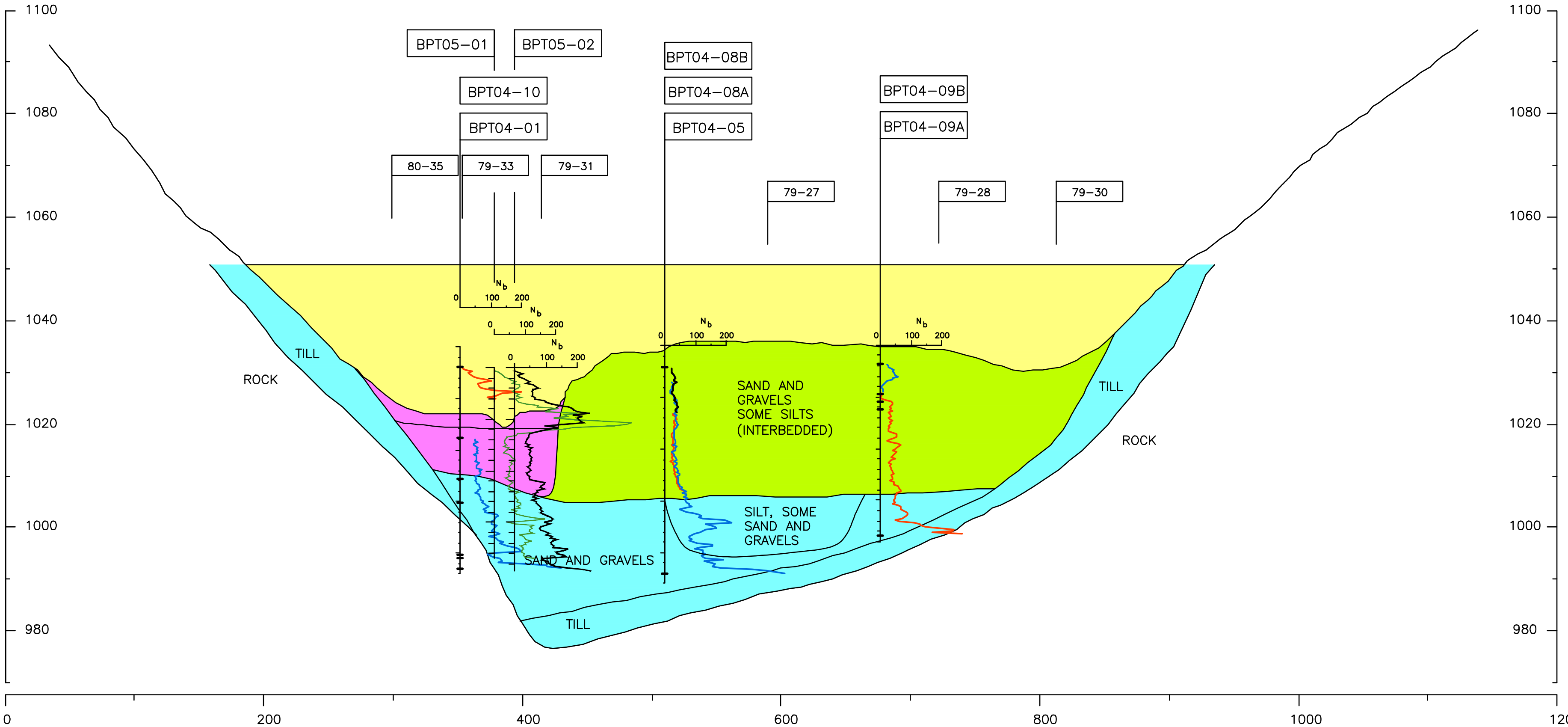
CLIENT
Yukon Government
Klohn Crippen Berger

PROJECT
FARO MINE COMPLEX
OMS MANUAL FOR DAMS

TITLE
INTERMEDIATE AND CROSS VALLEY DAMS
LOCATION PLAN OF TEST HOLES

PROJECT No. M09770A03 02 01
FIG. No. A–010

KCB–R–MLA




SECTION B (A–010)

LEGEND

- FILL
- ROSE CREEK SEDIMENTS
- GLACIO–FLUVIAL SEDIMENTS–TERRACE
- PLEISTOCENE SEDIMENTS

HORIZONTAL SCALE 0 — 125 m

NOTE

1. SECTION IS TAKEN FROM KLOHN LEONOFF (1981) DRAWING FOR GROUND CONDITIONS BENEATH CENTERLINE OF INTERMEDIATE DAM. KC BECKER HOLE INFORMATION IS SUPERIMPOSED AND WAS OBTAINED ON DOWNSTREAM BERM.



CLIENT: Yukon Government

Klohn Crippen Berger

PROJECT: FARO MINE COMPLEX OMS MANUAL FOR DAMS

TITLE: INTERMEDIATE DAM FOUNDATION STRATIGRAPHY

PROJECT No.: M09770A03 02 01

FIG. No.: A–011

KCB–R–MLA

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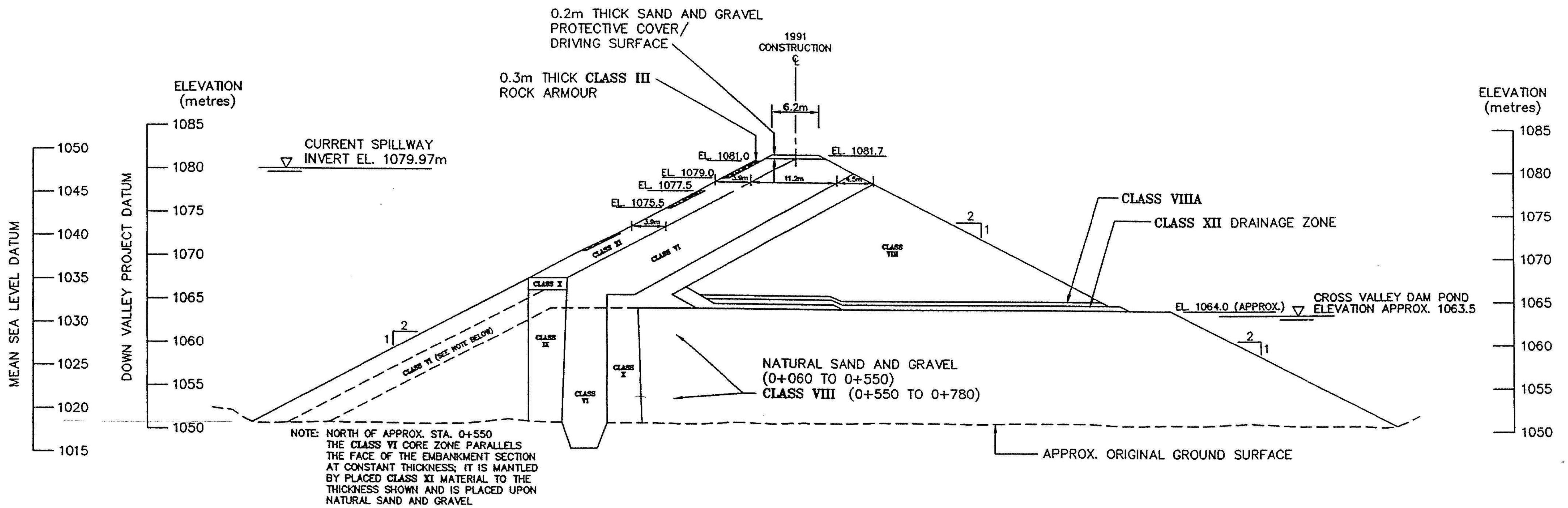


NOTES :

1. Embankment geometry and internal zoning as shown in Golder Associates Drawing 912–2402–3, Int. Dam Raising & C.V. Dam Toe Drain, Cross Section and Detailed Plan, Rev. 1, Aug. 8, 1991.

2. All elevations are referenced to Down Valley Project Datum. Subtract 32.3m from elevations shown to convert to mean sea level (NAD27) datum.

3. Refer to Golder Associates as built reports for detailed descriptions of material classes. General descriptions as follows :

| | |
|---|---|
| CLASS VI | Dam Core (glacial till) |
| CLASS VII | Upstream Shell (silty sand and gravel) |
| CLASS VIII | Downstream Shell (sand and gravel) |
| CLASS VIIIA | Drainage Filter (sand and gravel) |
| CLASS IX | Upstream Filter (silty sand) |
| CLASS X | Downstream Filter (sand and gravel) |
| CLASS XI | Tailings Sand (fine to medium sand) |
| CLASS XII | Drainage Zone (gravel) |

0 5 10 15 20 25 metres



CLIENT: Yukon Government

Klohn Crippen Berger

PROJECT: FARO MINE COMPLEX
OMS MANUAL FOR DAMS

TITLE: INTERMEDIATE DAM
TYPICAL DAM SECTION

PROJECT No. M09237A03 02 01

FIG. No. B–012

Scale: 1:2.5849(PS)
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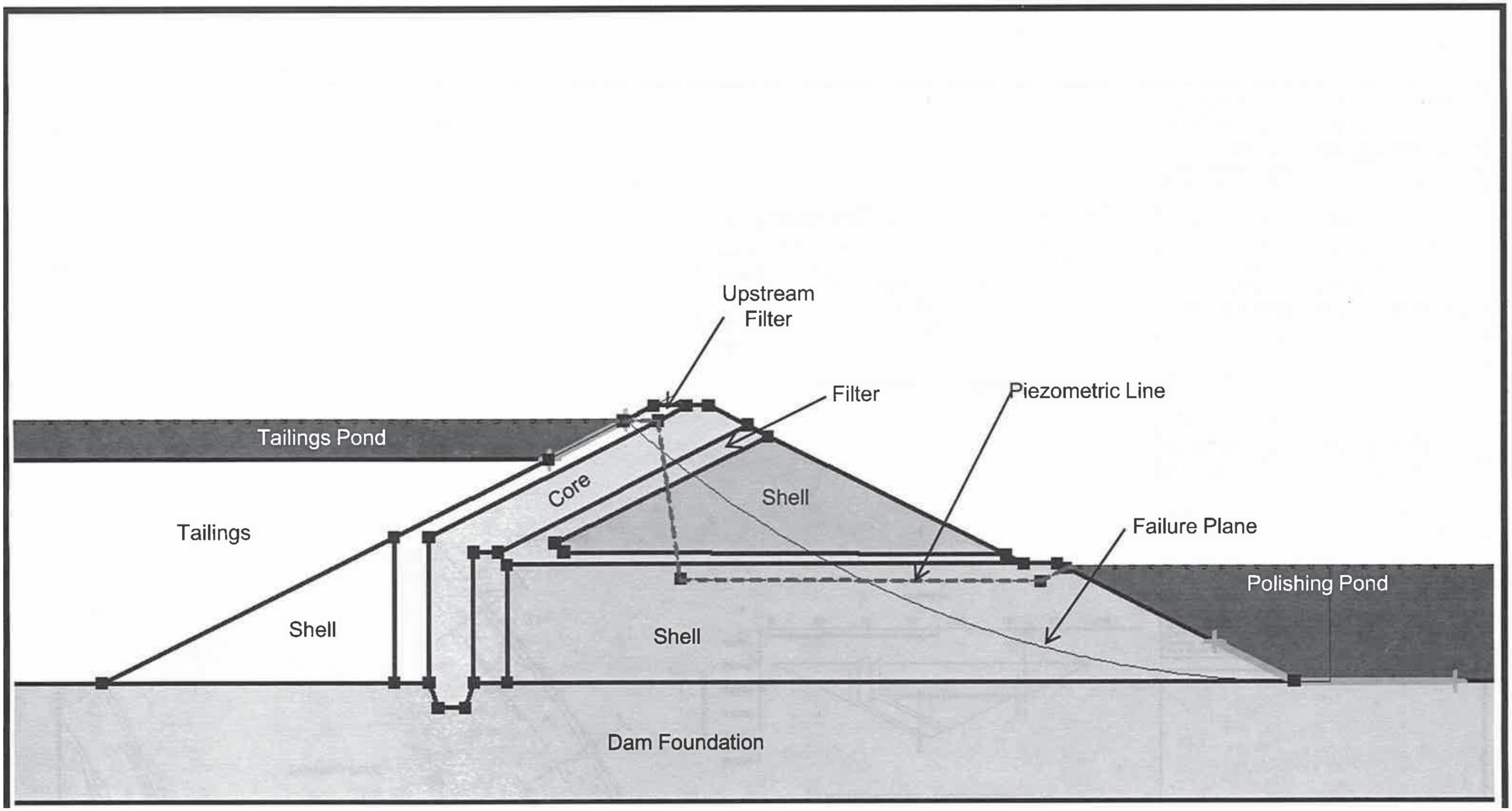


**NOTE**

1. ORIGINAL SOURCE BY BGC ENGINEERING INC. (2008).



CLIENT

Yukon Government

Klohn Crippen Berger

PROJECT

FARO MINE COMPLEX
OMS MANUAL FOR DAMS

TITLE

INTERMEDIATE DAM
STABILITY ANALYSIS CROSS SECTION
(TYPICAL CONDITIONS)

PROJECT No. M09770A03 02 01

FIG. No. A-013

KCB-R-MLA

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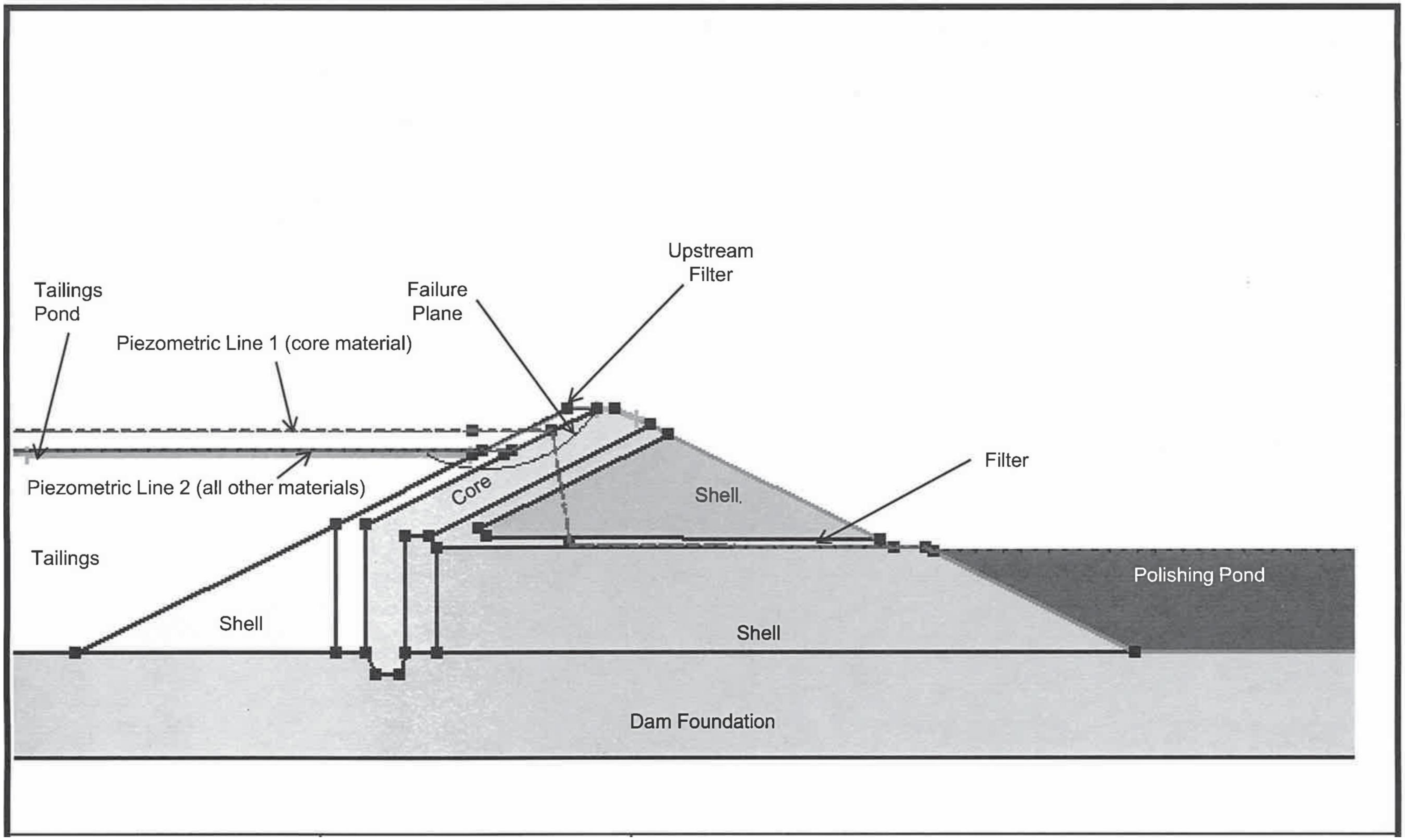


NOTE

1. ORIGINAL SOURCE BY BGC ENGINEERING INC. (2008).



CLIENT: Yukon Government / Klohn Crippen Berger

PROJECT: FARO MINE COMPLEX
OMS MANUAL FOR DAMS

TITLE: INTERMEDIATE DAM
STABILITY ANALYSIS CROSS SECTION
(RAPID DRAW DOWN)

PROJECT No. M09770A03 02 01

FIG. No. A–014

KCB–R–MLA

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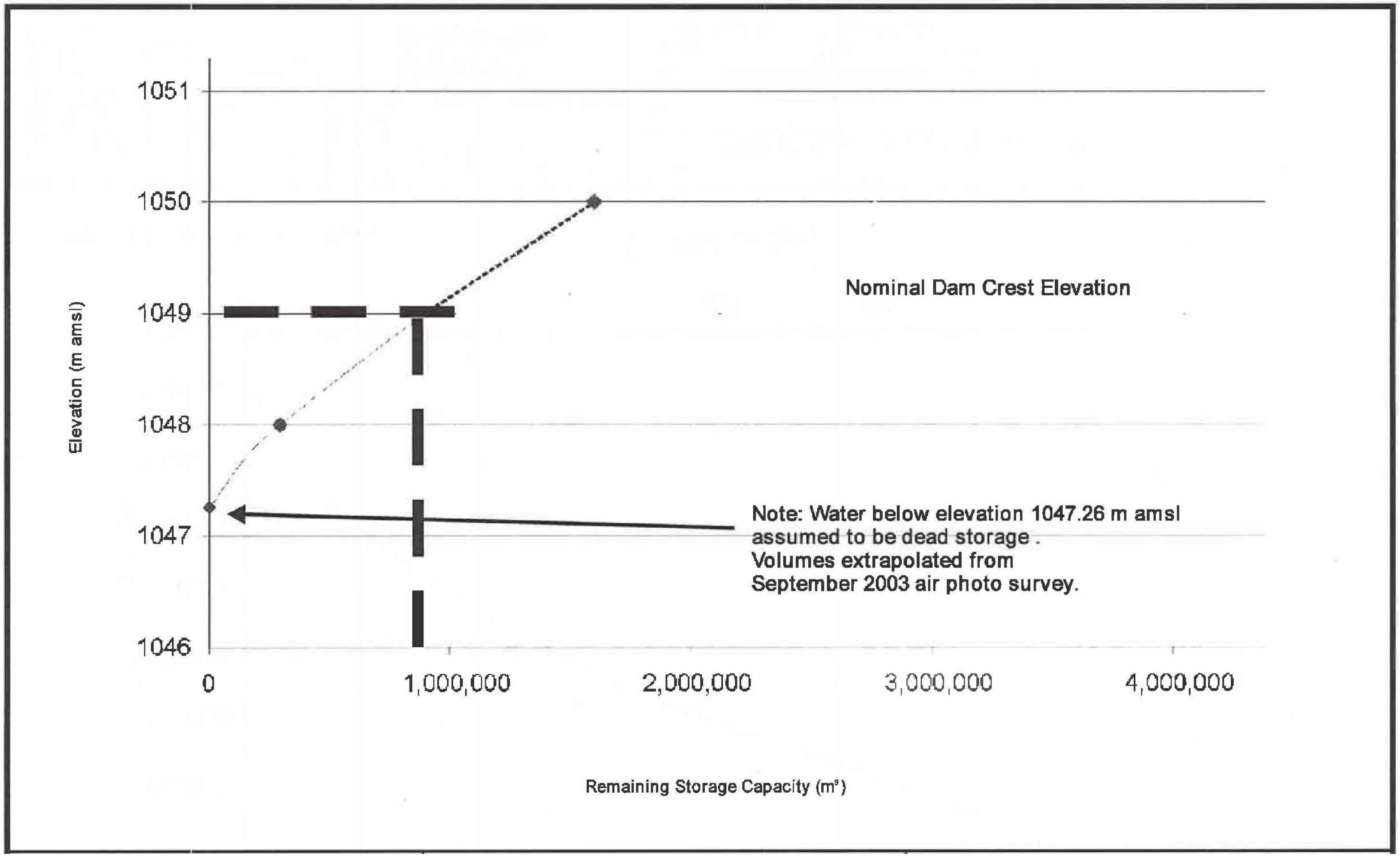


**NOTE**

1. ORIGINAL SOURCE BGC ENGINEERING INC. (2008).



CLIENT: Yukon Government

Klohn Crippen Berger

PROJECT: FARO MINE COMPLEX
OMS MANUAL FOR DAMS

TITLE: INTERMEDIATE DAM
STORAGE CAPACITY CURVE

PROJECT No. M09770A03 02 01

FIG. No. A–015

KCB–R–MLA

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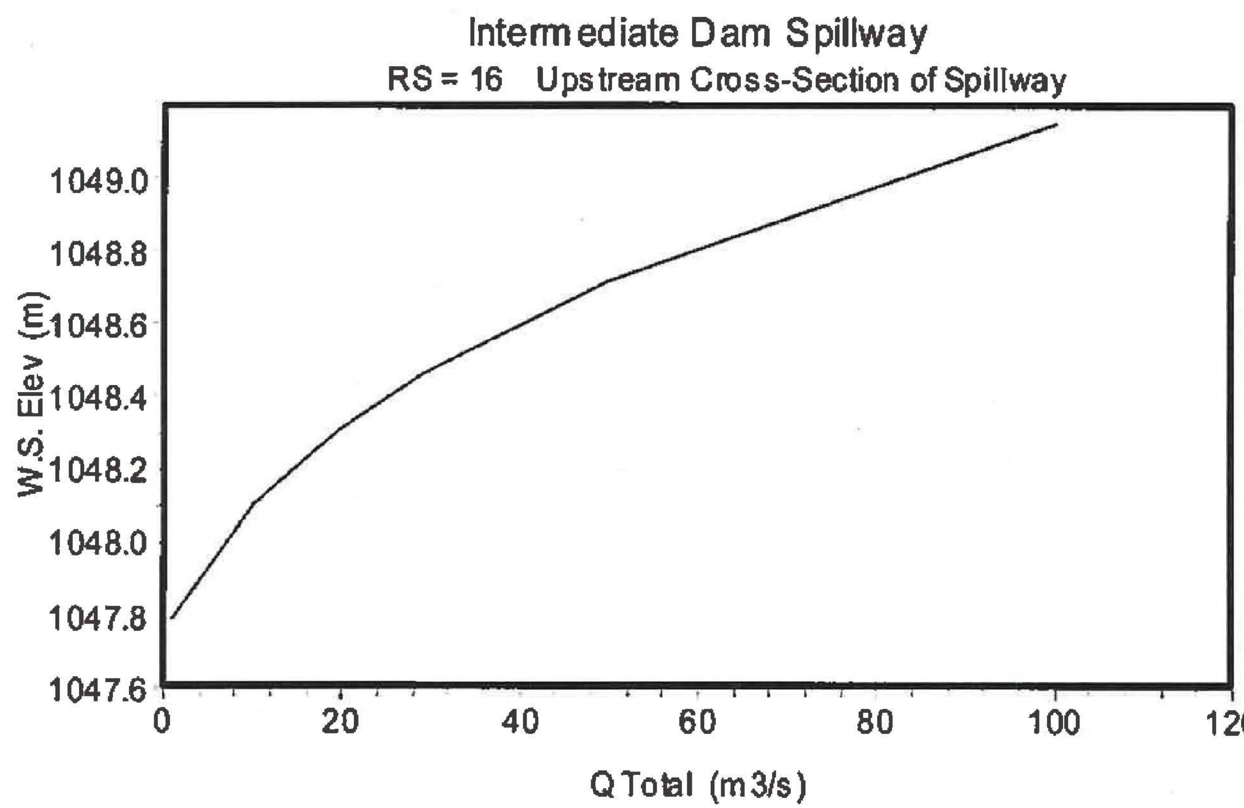


NOTES

1. ORIGINAL SOURCE BGC ENGINEERING INC. (2008).
2. DATUM: NAD27.



CLIENT: Yukon Government

Klohn Crippen Berger

PROJECT: FARO MINE COMPLEX
OMS MANUAL FOR DAMS

TITLE: INTERMEDIATE DAM
SPILLWAY RATING CURVE

PROJECT No.: M09770A03 02 01

FIG. No.: A-016

KCB-R-MLA

Time: 09:58:47
Date: 3/21/2014
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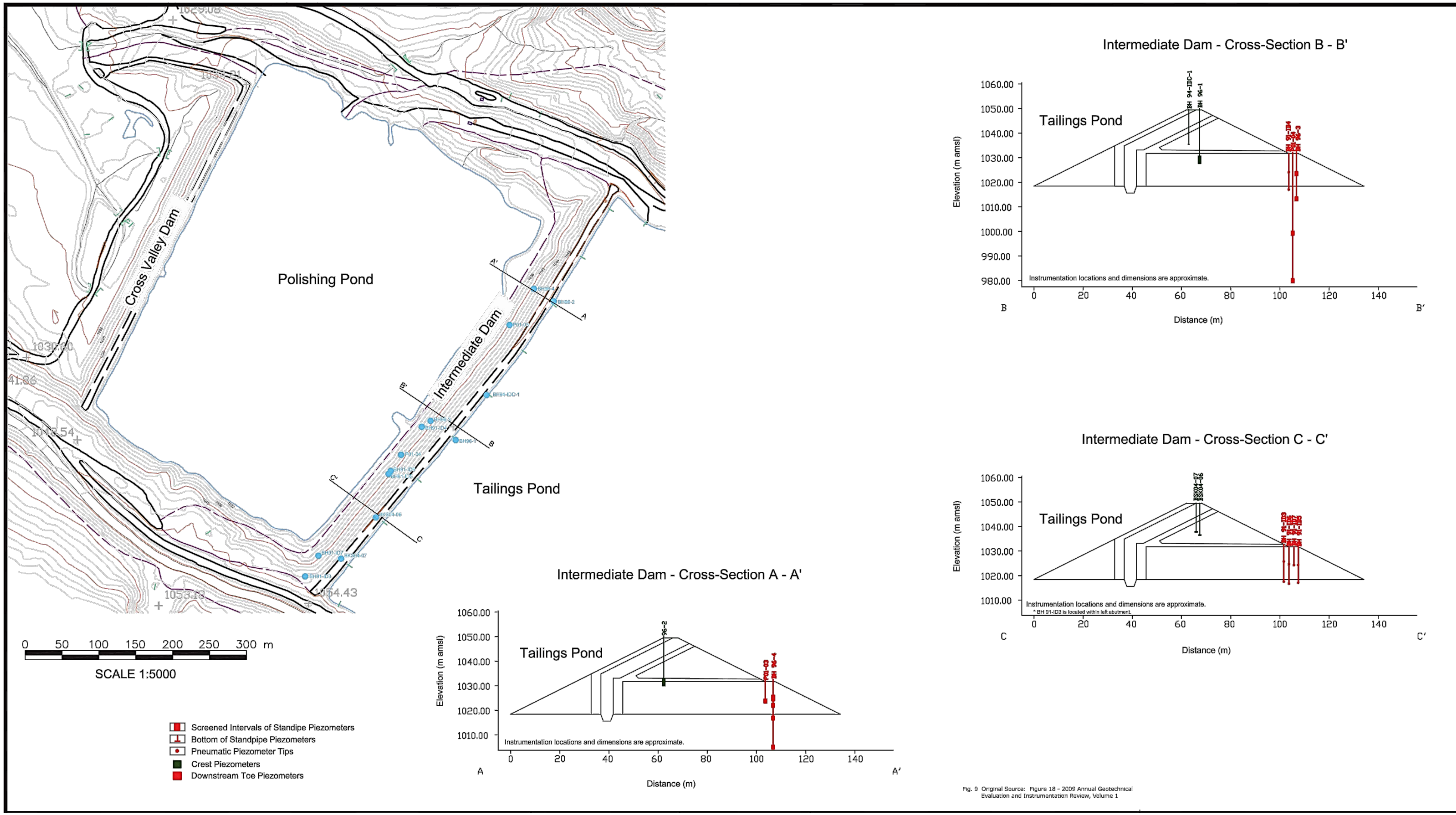



Fig. 9 Original Source: Figure 18 - 2009 Annual Geotechnical Evaluation and Instrumentation Review, Volume 1

**NOTE:**

1. ORIGINAL FIGURE PROVIDED BY BGC ENGINEERING (2010).



CLIENT: Yukon Government

Klohn Crippen Berger

PROJECT: FARO MINE COMPLEX OMS MANUAL FOR DAMS

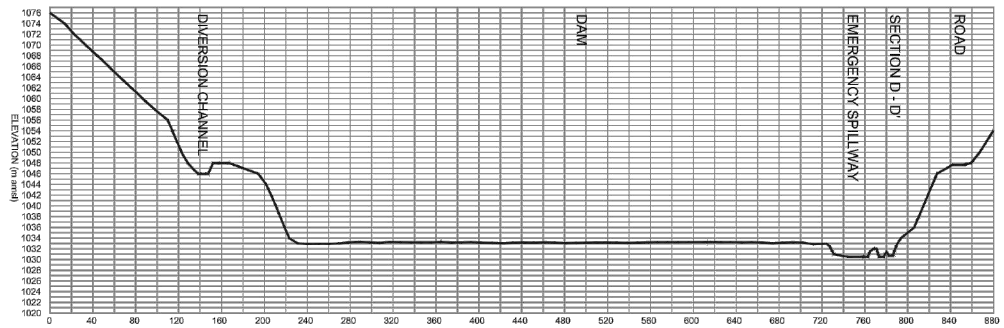
TITLE: INTERMEDIATE DAM INSTRUMENTATION PLAN AND SECTIONS

PROJECT No. M09770A03 02 01

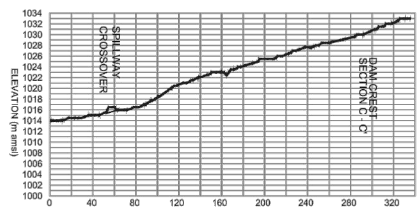
FIG. No. B-017

KCB-R-MLD

Date: 1/29/2013 Time: 13:25:10 Scale: 1:2,585
Filename: \\INT.KLOHN.COM\PROJDATA\M\VCR\M09770A03-GOVTYUKON-2013 FARO\400 DRAWINGS\OMS_MANUAL\FIG_B-017_INTERMEDIATE_DAM_INSTRUMENTATION_PLAN&SECTION.DWG




SECTION C - C'
DAM PROFILE




SECTION D - D'
EMERGENCY SPILLWAY PROFILE

NOTE:
1. DAM AND SPILLWAY TOPOGRAPHY FROM YES DATED SEPT, 2003.
2. SITE WIDE TOPOGRAPHY FROM DIGITAL MAP BY THE ORTHOSHOP, PHOTO TAKEN JULY 25, 2003.
3. ALL ELEVATIONS AND COORDINATES ARE REFERENCED TO NAD27 DATUM AND GRID.
4. LOCATION OF SECTIONS ON FIGURE 5

**NOTE**

1. ORIGINAL SOURCE BY BGC ENGINEERING INC. (2008).



CLIENT
Yukon Government

Klohn Crippen Berger

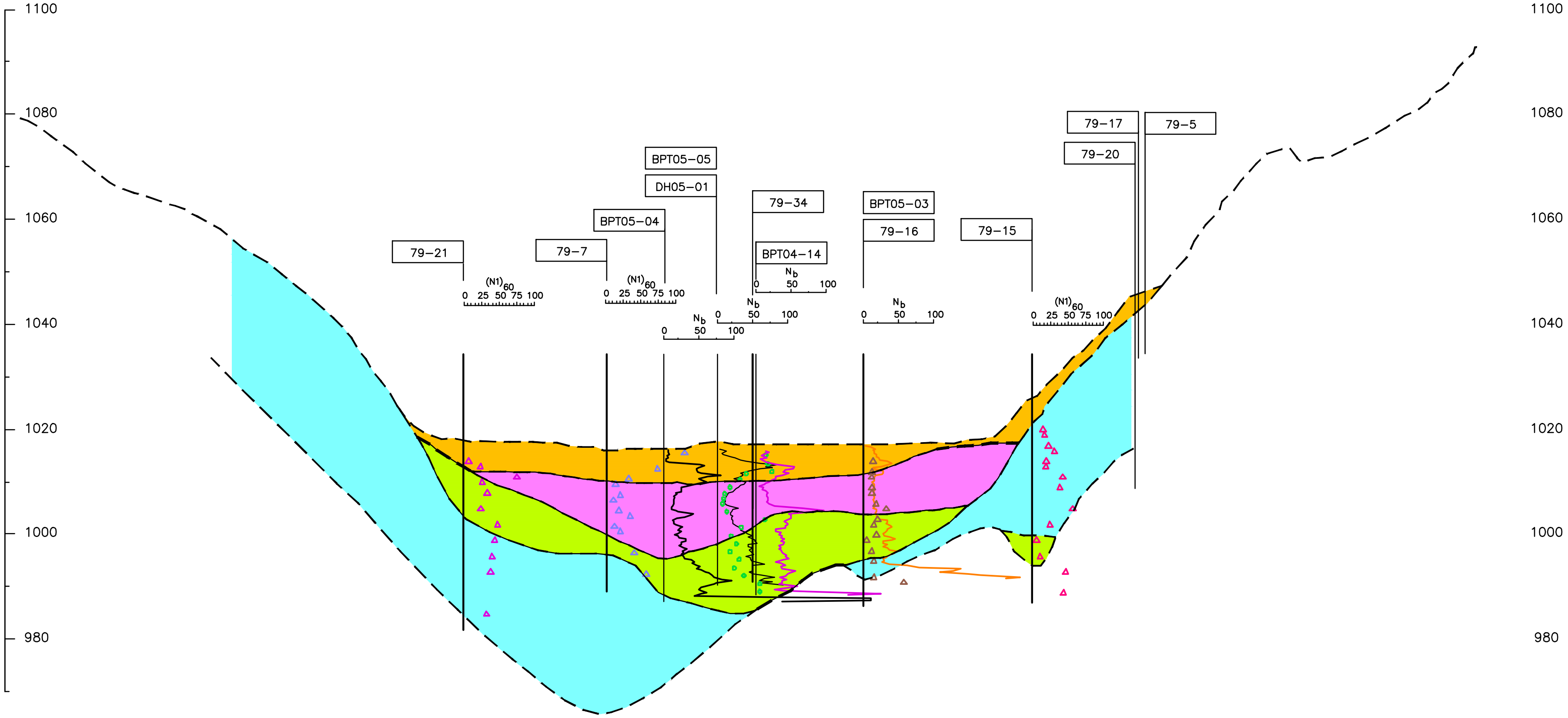
PROJECT
FARO MINE COMPLEX
OMS MANUAL FOR DAMS

TITLE
CROSS VALLEY DAM
2003 SURVEY PROFILES

PROJECT No. M09770A03 02 01
FIG. No. A-018

KCB-R-MLA

Time: 17:26:04
Date: 3/31/2014
Scale: 1:2.5849(PS)
Drawing File: \\int.klohn.com\projdata\M\VCR\M09770A03-GovtYukon-2013 Faro\400 Drawings\OMS_Manual\FIG_A-018_CrossValley_Dam_2003_survey_profiles.dwg (afischer)




SECTION A
A-010

LEGEND

- ROSE CREEK ALLUVIUM – DENSE
- ROSE CREEK ALLUVIUM – LOOSE
- PLEISTOCENE SANDS AND GRAVELS – DENSE
- PLEISTOCENE GLACIAL TILL

## NOTES

1. SECTION IS TAKEN FROM KLOHN LEONOFF (1981) DRAWING AND UPDATED WITH KC BECKER AND DRILL HOLE INFORMATION.
2. FOUNDATION CONDITIONS ARE KNOWN ONLY AT THE TEST HOLE LOCATIONS. THE SOIL STRATIGRAPHY SHOWN BETWEEN THE TEST HOLES IS AN INTERPRETATION ONLY.
3. THE ACCURACY OF THE 79/80 TEST HOLE LOCATIONS IS NOT KNOWN.
4. N – MEASURED BECKER BLOW COUNTS AND (N ) – CORRECTED SPT/LPT BLOW COUNTS.

HORIZONTAL SCALE 0 100 m



CLIENT: Yukon Government

Klohn Crippen Berger

PROJECT: FARO MINE COMPLEX OMS MANUAL FOR DAMS

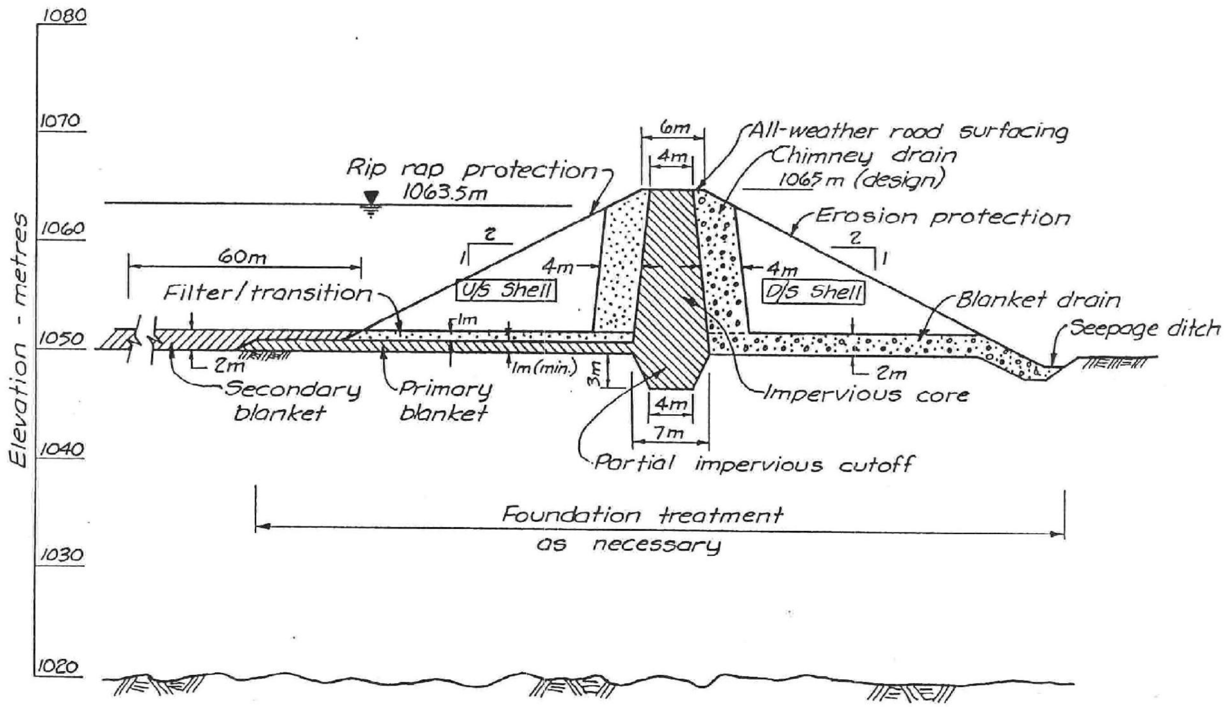
TITLE: CROSS VALLEY DAM FOUNDATION STRATIGRAPHY

PROJECT No. M09770A03 02 01

FIG. No. A-019

KCB-R-MLA

Time: 17:27:44
Date: 3/31/2014
Scale: 1:2.5849(PS)
Drawing File: \\int.klohn.com\projdata\M\VCR\M09770A03-GovtYukon-2013 Faro\400 Drawings\OMS_Manual\FIG_A-019_CrossValley_Dam_FOUNDATION_STRATIGRAPHY.dwg (afischer)




NOTES:
FIGURE SHOWING THE TYPICAL DESIGN SECTION OF THE CROSS VALLEY DAM TAKEN FROM GOLDER ASSOCIATES REPORT TO CYPRUS ANVIL MINING DATED JUNE 1980.

**NOTE**

1. ORIGINAL SOURCE BY BGC ENGINEERING INC. (2008).



CLIENT: Yukon Government

Klohn Crippen Berger

PROJECT: FARO MINE COMPLEX
OMS MANUAL FOR DAMS

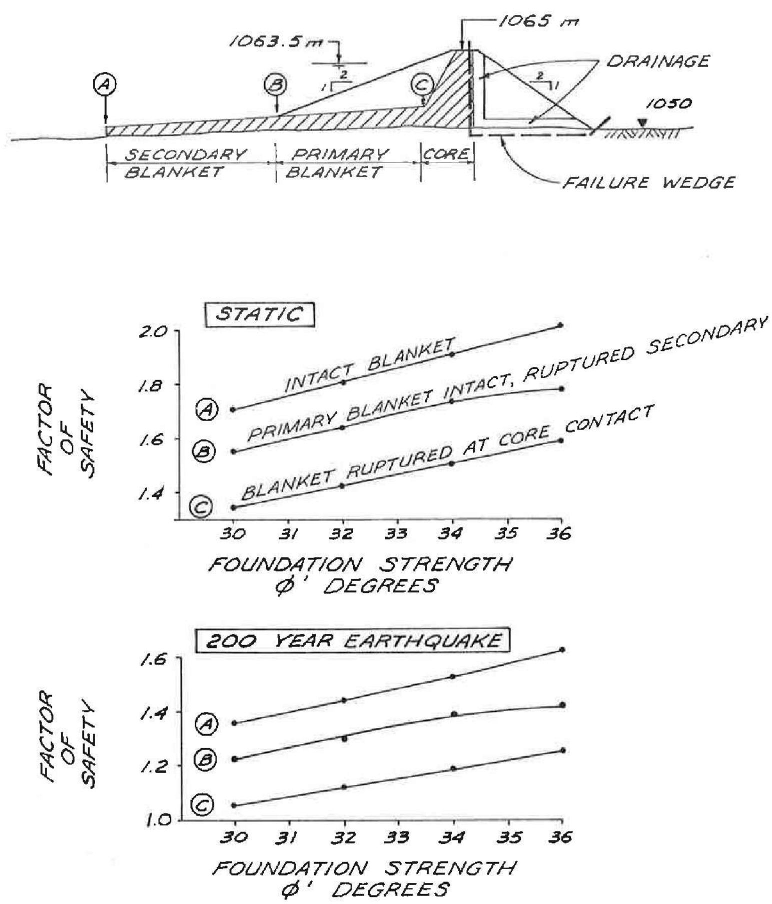
TITLE: CROSS VALLEY DAM
TYPICAL DAM SECTION

PROJECT No.: M09770A03 02 01

FIG. No.: A-020

KCB-R-MLA

# STABILITY ANALYSES - DOWNSTREAM SLOPE Figure VI- 5




Notes:
(1) Janbu analyses used to assess stability.
(2) Earthquake loading simulated by simple pseudodynamic method.
(3) Core strength chosen as C' = 0 Ø = 35°
(4) Core considered to be leaking.
(5) Impervious blanket considered effective downstream of points A, B, or C, eg. B assumes secondary blanket ruptured.

Project No. 792-2025 Drawn BAD Reviewed ______ Date May '80

Golder Associates



**NOTE**

1. ORIGINAL SOURCE BY GOLDER ASSOCIATES (1980).

CLIENT: Yukon Government

Klohn Crippen Berger

PROJECT: FARO MINE COMPLEX
OMS MANUAL FOR DAMS

TITLE: CROSS VALLEY DAM
STABILITY ANALYSIS
(DOWNSTREAM SLOPE)

PROJECT No. M09770A03 02 01

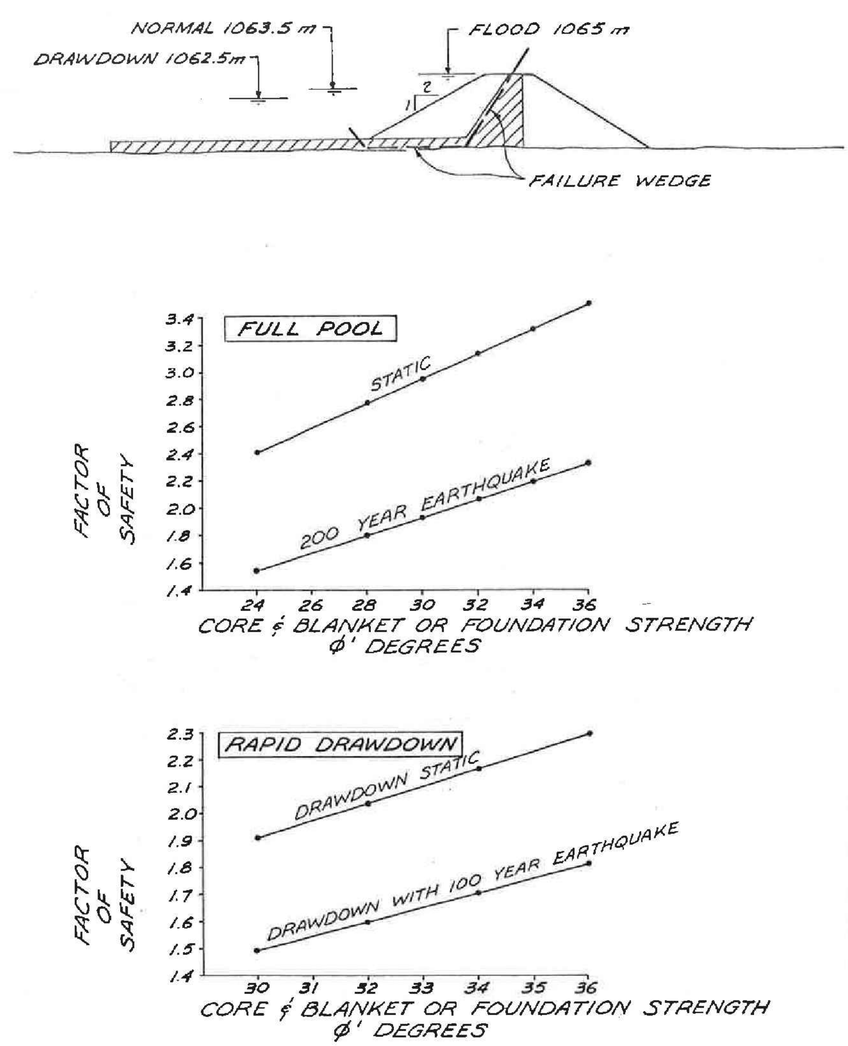
FIG. No. A-021

KCB-R-MPA

Time: 17:32:35
Date: 3/31/2014
Scale: 1:2.5849(PS)
Drawing File: \\int.klohn.com\projdata\M\VCR\M09770A03-GovtYukon-2013 Faro\400 Drawings\OMS_Manual\FIG_A-021_CrossValley_Dam_StabilityAnalysis_downstream.dwg (afischer)

## STABILITY ANALYSES - UPSTREAM SLOPE

**Figure VI-4**




Notes:
(1) Janbu analyses used to assess stability.
(2) Earthquake loading simulated by simple pseudostatic method.
(3) Maximum drawdown of 2.5 m assuming no pore pressure dissipation from core or blanket.

Project No. 792-2035 Drawn BAD Reviewed ______ Date May '80

**Golder Associates**



NOTE

1. ORIGINAL SOURCE BY GOLDER ASSOCIATES (1980).

CLIENT

Yukon Government

Klohn Crippen Berger

PROJECT

FARO MINE COMPLEX
OMS MANUAL FOR DAMS

TITLE

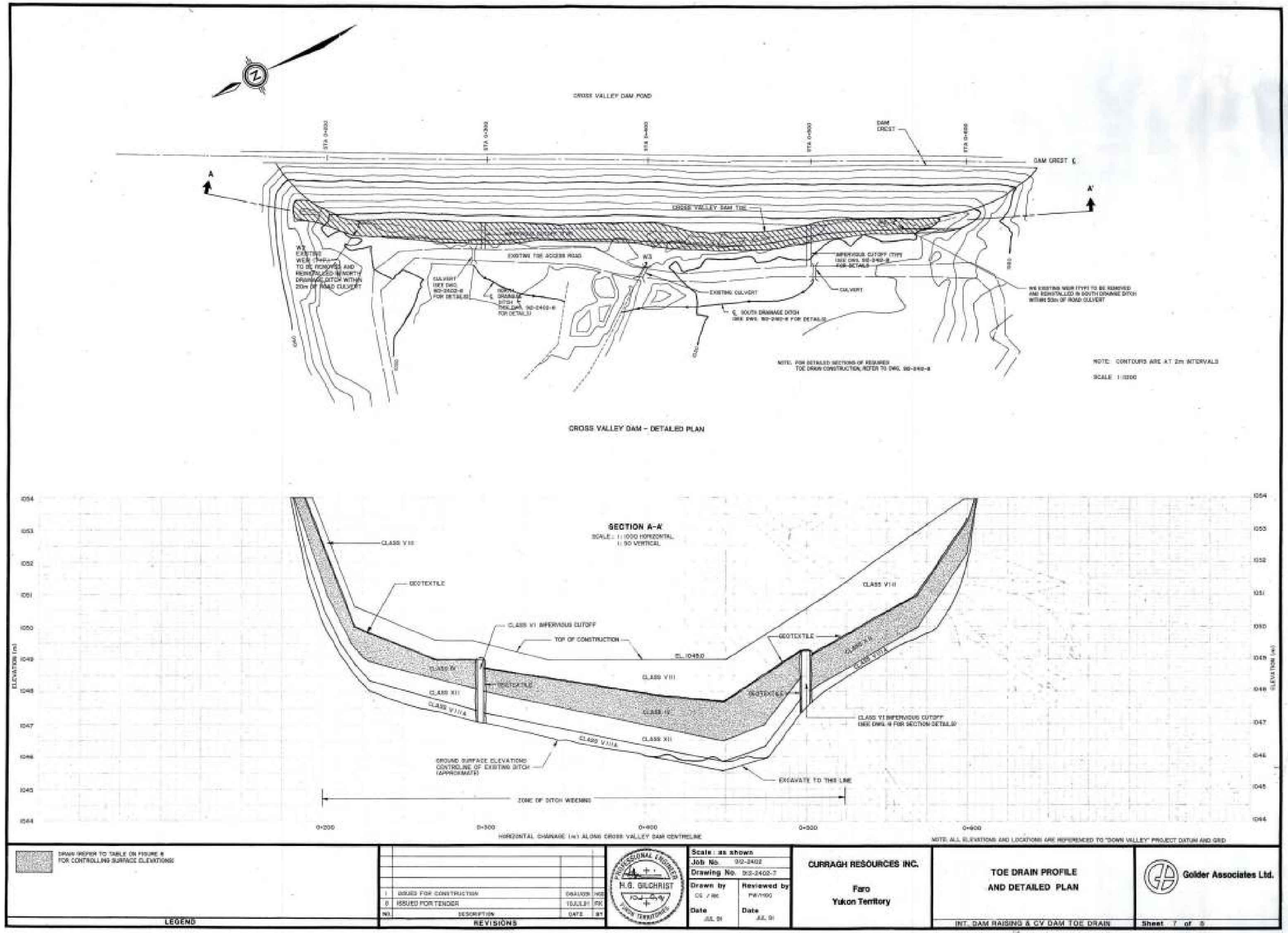
CROSS VALLEY DAM
STABILITY ANALYSIS
(UPSTREAM SLOPE)

PROJECT No. M09770A03 02 01

FIG. No. A-022

KCB-R-MPA

Time: 15:43:29
Date: 3/19/2014
Scale: 1:2.5849(PS)
Drawing File: \\int.klohn.com\projdata\M\VCR\M09770A03-GovtYukon-2013 Faro\400 Drawings\OMS_Manual\FIG_A-022_CrossValley_Dam_StabilityAnalysis_upstream.dwg (afischer)




Source: Golder Associates Ltd (1991)
Intermediate Dam Raising and
Cross Valley Toe Drain Construction Drawings.

Note: All elevations and coordinates
are referenced to DVD.

NOTE

1. ORIGINAL FIGURE PROVIDED BY BGC ENGINEERING INC. (2008).
2. DVD IS DOWN VALLEY DATUM.



CLIENT
Yukon Government
Klohn Crippen Berger

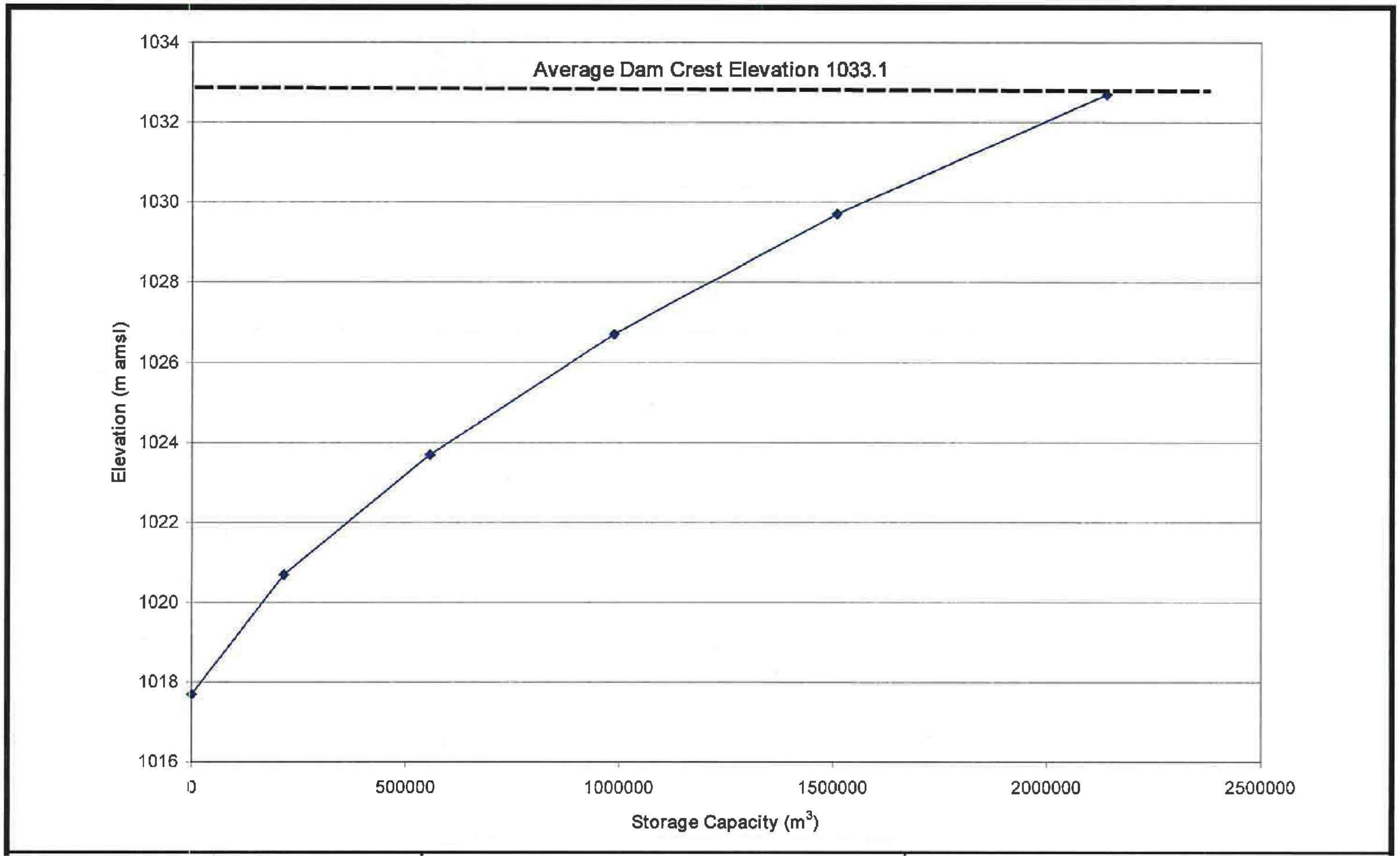
PROJECT
FARO MINE COMPLEX
OMS MANUAL FOR DAMS

TITLE
CROSS VALLEY DAM
TOE DRAIN
PROFILE AND DETAILED PLAN

PROJECT No. M09770A03 02 01
FIG. No. B-023

Date: 1/29/2013 Time: 13:25:10 Scale: 1:2,585
Filename: \\INT.KLOHN.COM\PROJDATA\M\VCR\M09770A03-GOVTYUKON-2013 FARO\400 DRAWINGS\OMS_MANUAL\FIG_B-023_CROSSVALLEYDAM_TOEDRAIN_PROFILE&DETAILEDPLAN.DWG

KCB-R-MLD




## NOTES

1. ORIGINAL SOURCE BGC ENGINEERING INC. (2008).
2. DATUM: NAD27.



CLIENT: Yukon Government

Klohn Crippen Berger

PROJECT: FARO MINE COMPLEX
OMS MANUAL FOR DAMS

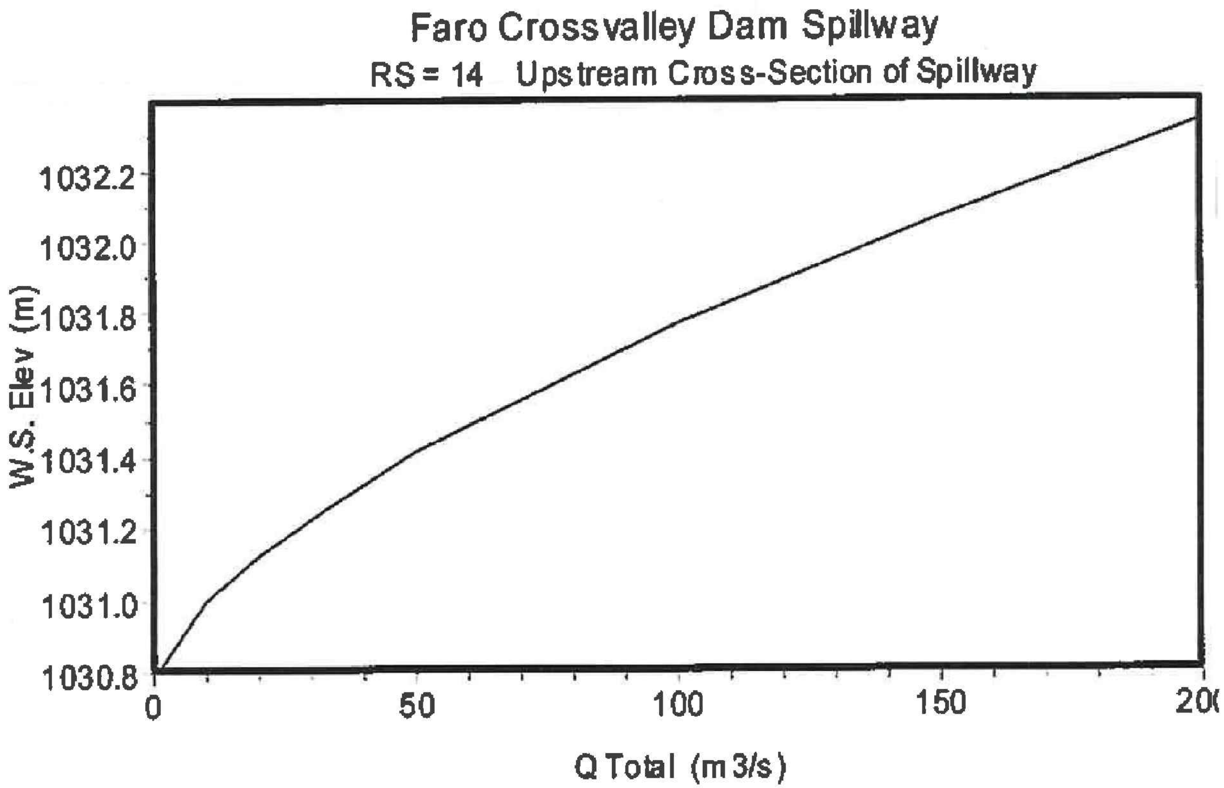
TITLE: CROSS VALLEY DAM
STORAGE CAPACITY CURVE

PROJECT No. M09770A03 02 01

FIG. No. A–024

KCB–R–MLA

Time: 17:35:54
Date: 3/31/2014
Scale: 1:2.5849(PS)
Drawing File: \\int.klohn.com\projdata\M\VCR\M09770A03–GovtYukon–2013 Faro\400 Drawings\OMS_Manual\FIG_A–024_CrossValleyDam_StorageCapacityCurve.dwg (afischer)




**NOTES**

1. ORIGINAL SOURCE BGC ENGINEERING INC. (2008).
2. DATUM: NAD27.



CLIENT: Yukon Government

Klohn Crippen Berger

PROJECT: FARO MINE COMPLEX
OMS MANUAL FOR DAMS

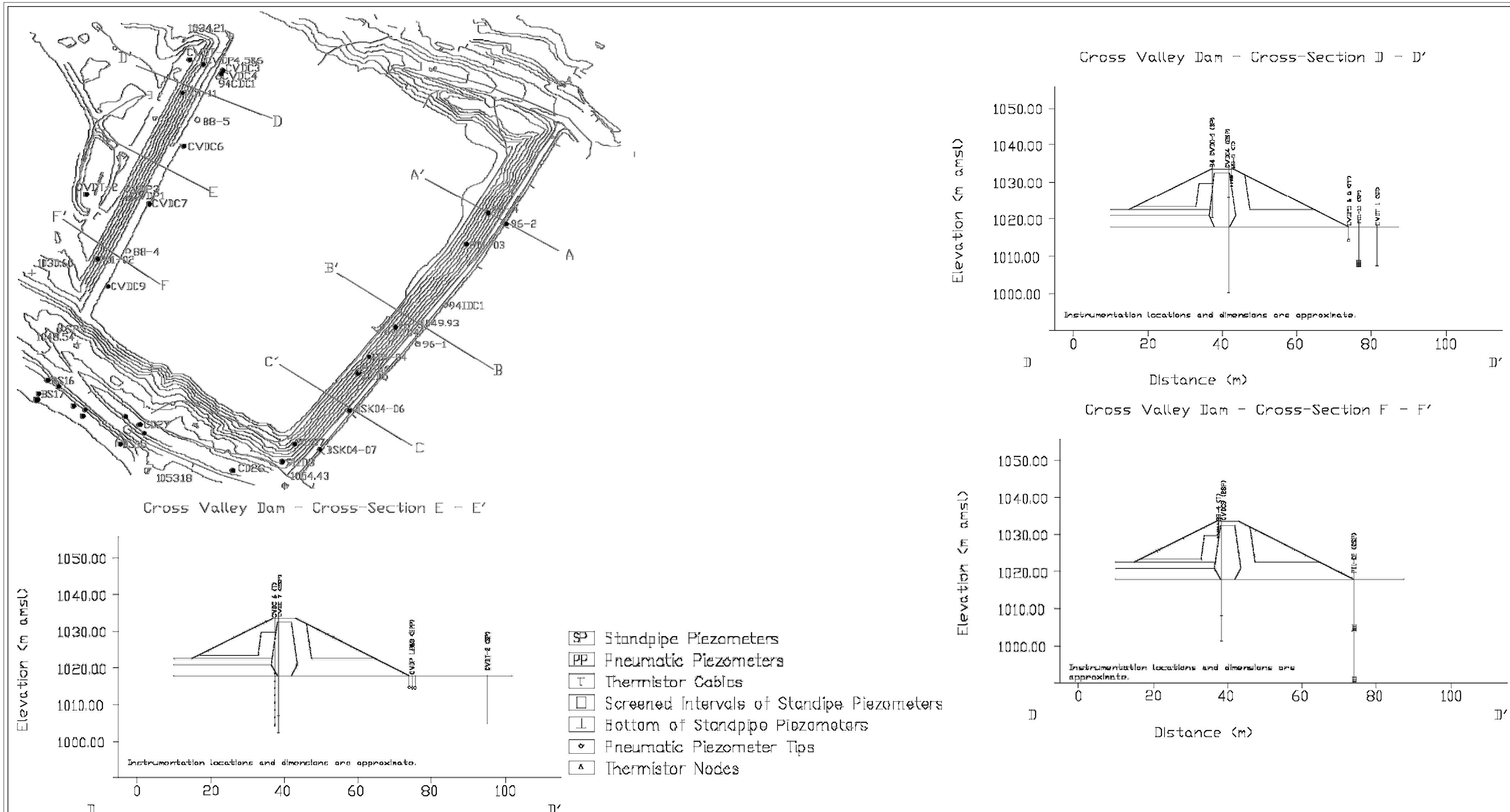
TITLE: CROSS VALLEY DAM
SPILLWAY RATING CURVE

PROJECT No.: M09770A03 02 01

FIG. No.: A-025

KCB-R-MLA

Time: 17:36:59
Date: 3/31/2014
Scale: 1:2.5849(PS)
Drawing File: \\int.klohn.com\projdata\M\VCR\M09770A03-GovtYukon-2013 Faro\400 Drawings\OMS_Manual\FIG_A-025_CrossValleyDam_SpillwayRatingCurve.dwg (afischer)




Original Source: Figure 24 - 2009 Geotechnical Evaluation and Instrumentation Review, Volume 1

**NOTE**

1. ORIGINAL FIGURE PROVIDED BY BGC ENGINEERING INC. (2010).



CLIENT: Yukon Government

Klohn Crippen Berger

PROJECT: FARO MINE COMPLEX OMS MANUAL FOR DAMS

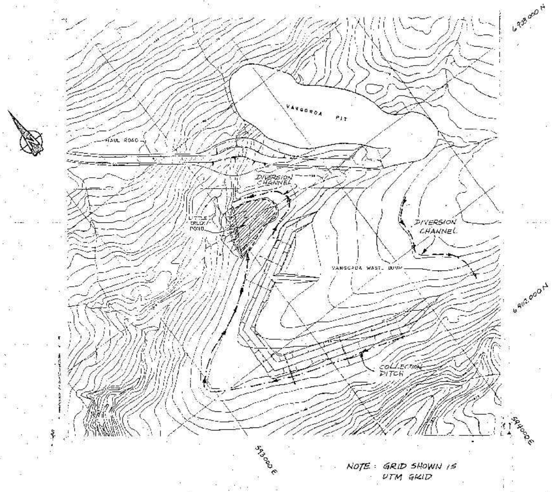
TITLE: CROSS VALLEY DAM INSTRUMENTATION PLAN AND SECTIONS

PROJECT No. M09770A03 02 01

FIG. No. B-026

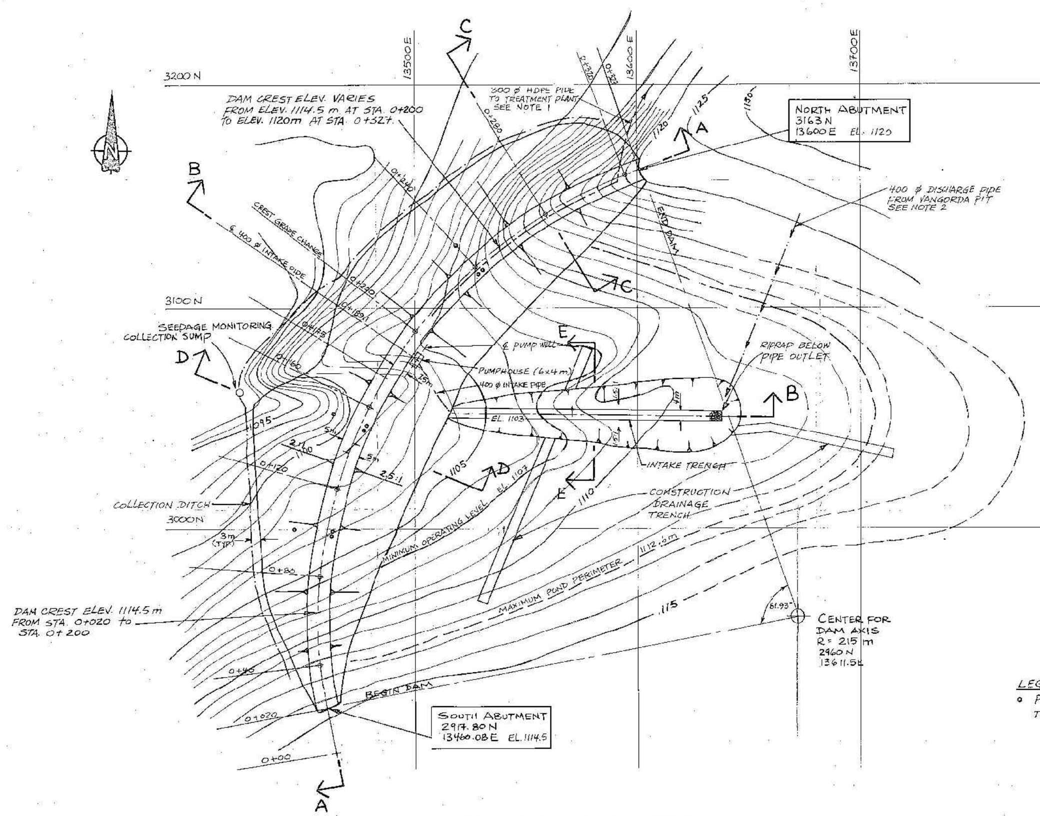
KCB-R-MLD

Date:1/29/2013 Time:13:25:10 Scale:1:2,585
Filename: \\INT.KLOHN.COM\PROJDATA\M\VCR\M09770A03-GOVTYUKON-2013 FARO\400 DRAWINGS\OMS_MANUAL\FIG_B-026_CROSSVALLEYDAM_INSTRUMENTATIONPLAN&SECTION.DWG




LOCATION PLAN

SCALE - 1:10 000




GENERAL ARRANGEMENT PLAN

SCALE - 1:1000

CONTOUR INTERVAL - 1 metre
GRID SHOWN IS MINE GRID

0 10 20 30 40 50 metres

LEGEND
- PIEZOMETERS AND THERMISTORS.

NOTES:

1. Intake trench not surveyed.
2. Collection sump and collection ditch not yet constructed as of Jan./91.
3. Piezometers and thermistors to be installed.
4. Refer to drawing 60627-04 for cross-sections through dam.
5. Survey data by Lamerton Assoc.
6. Pipeline dimensions are in mm.
7. Diversion channel location to be determined in field.

## NOTES

1. ORIGINAL SOURCE BY STEFFEN ROBERTSON & KIRSTEN CONSULTING ENGINEERS (1990).
2. MINE GRID.



CLIENT: Yukon Government

Klohn Crippen Berger

PROJECT: FARO MINE COMPLEX
OMS MANUAL FOR DAMS

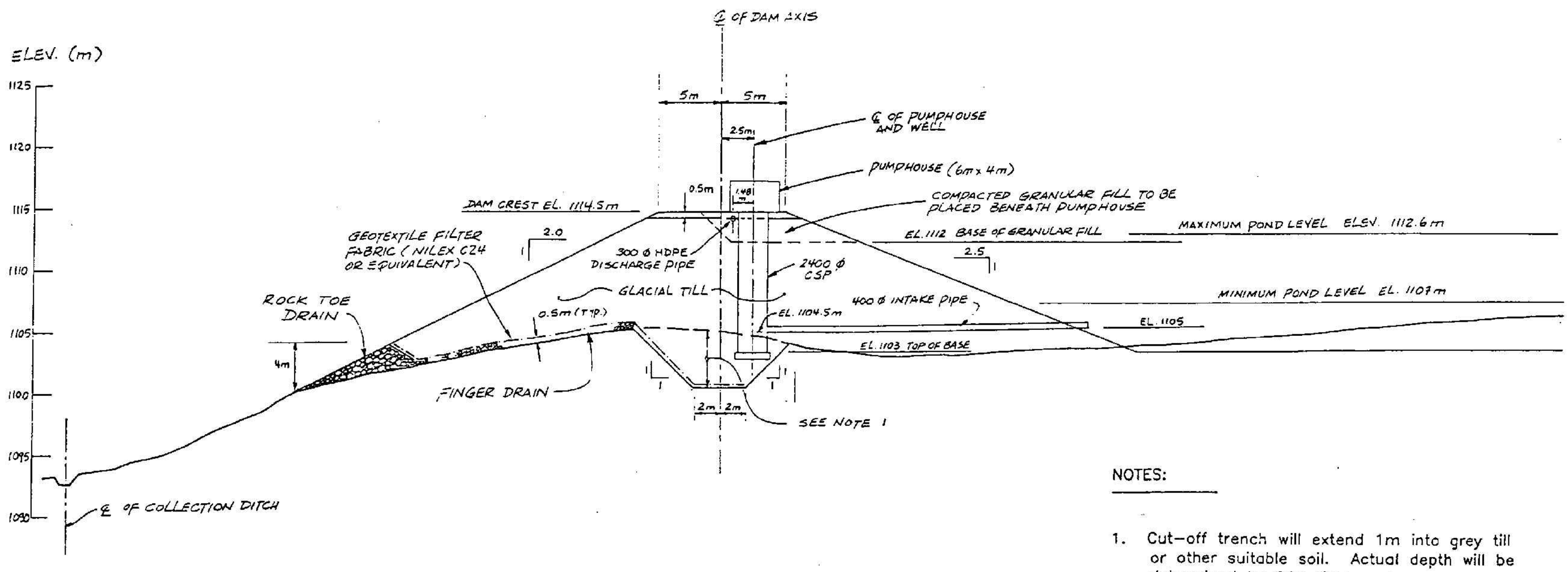
TITLE: LITTLE CREEK DAM
GENERAL ARRANGEMENT PLAN

PROJECT No. M09770A03 02 01

FIG. No. A-027

KCB-R-MLA

Time: 10:01:35
Date: 3/21/2014
Scale: 1:2.5849(PS)
Drawing File: \\int.klohn.com\projdata\M\VCR\M09770A03-GovtYukon-2013 Faro\400 Drawings\OMS_Manual\FIG_A-027_LittleCreekDam_GA.dwg (afischer)




NOTES:

1. Cut–off trench will extend 1m into grey till or other suitable soil. Actual depth will be determined by SRK field engineer.
2. The pumphouse, wet well and intake pipe were added to this section for illustrative purposes.

**NOTE**

1. ORIGINAL SOURCE BY STEFFEN ROBERTSON & KIRSTEN CONSULTING ENGINEERS (1990).



CLIENT: Yukon Government

Klohn Crippen Berger

PROJECT: FARO MINE COMPLEX
OMS MANUAL FOR DAMS

TITLE: LITTLE CREEK DAM
TYPICAL DAM SECTION

PROJECT No. M09770A03 02 01

FIG. No. A–028

KCB–R–MLA

Time: 17:40:34
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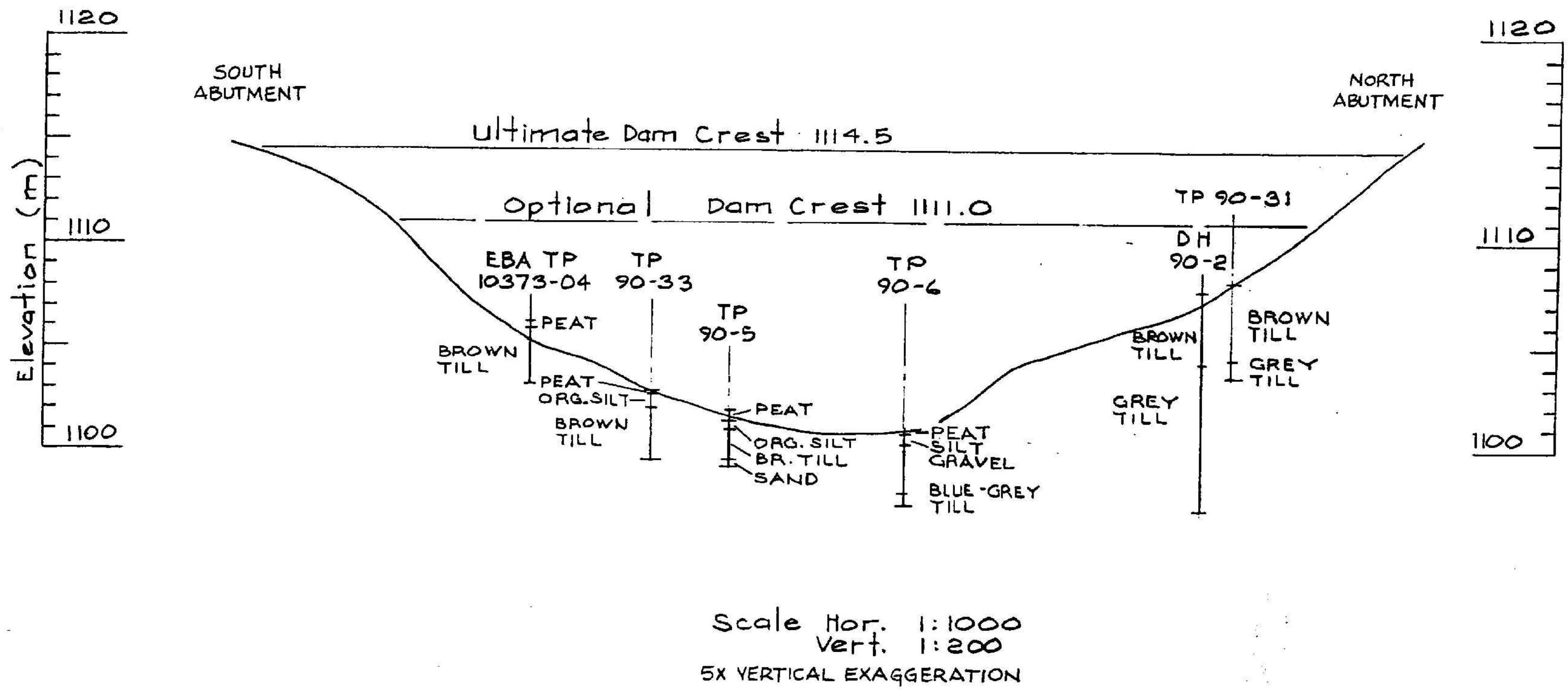
Scale: 1:2.5849(PS)
Drawing File: \\int.klohn.com\projdata\M\VCR\M09770A03–GovtYukon–2013 Faro\400 Drawings\OMS_Manual\FIG_A–028_LittleCreekDam_TypicalDamSection.dwg (afischer)




**NOTE**

1. ORIGINAL FIGURE PROVIDED BY BGC ENGINEERING.



CLIENT: Yukon Government

Klohn Crippen Berger

PROJECT: FARO MINE COMPLEX OMS MANUAL FOR DAMS

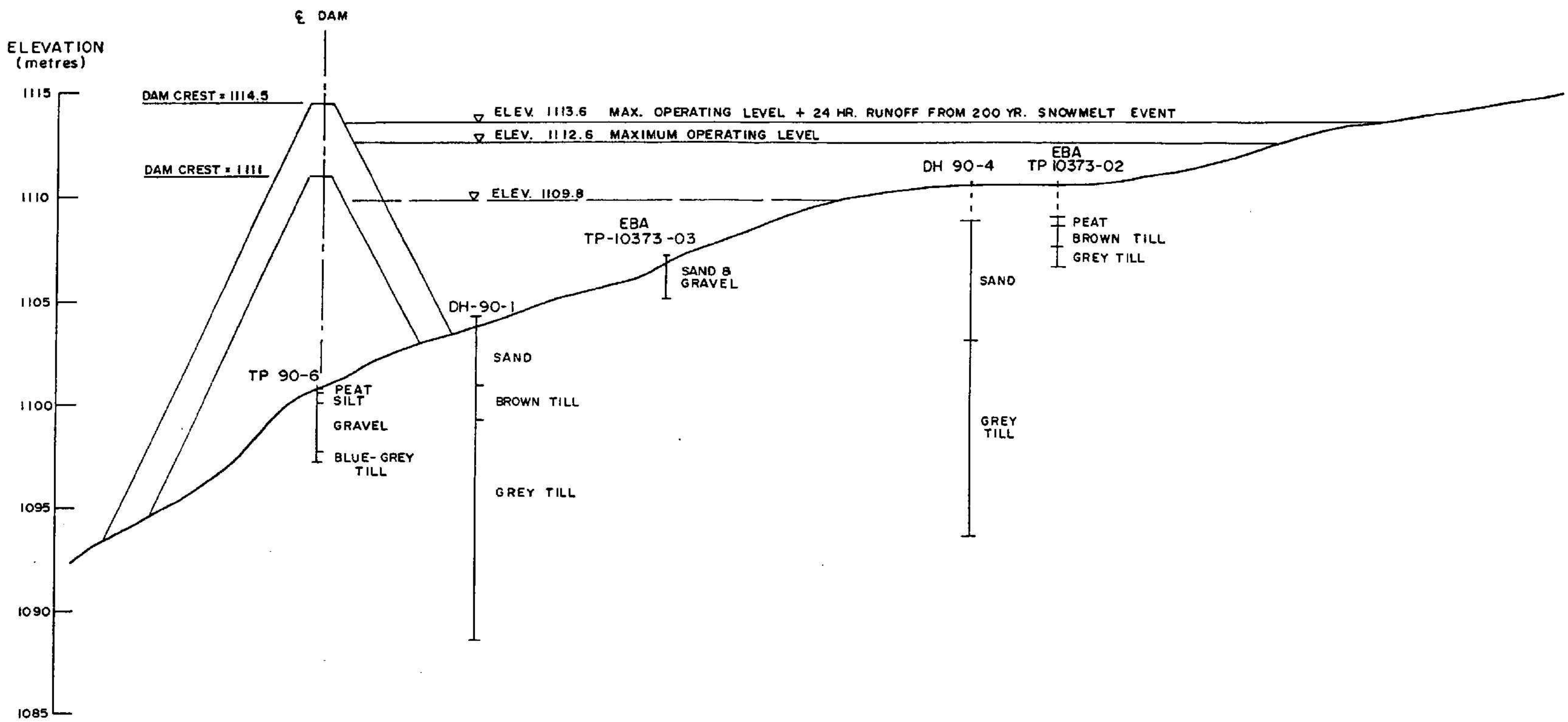
TITLE: LITTLE CREEK DAM LONGITUDINAL SECTION WITH DRILL HOLES AND TEST PITS

PROJECT No.: M09770A03 02 01

FIG. No.: A–029

KCB-R-MLA

Time: 17:46:14
Date: 3/31/2014
Scale: 1:2.5849(PS)
Drawing File: \\int.klohn.com\projdata\M\VCR\M09770A03–GovtYukon–2013 Faro\400 Drawings\OMS_Manual\FIG_A–029_LongitudinalSection_DHs&TPs.dwg (afischer)




## NOTES

1. ORIGINAL SOURCE BY STEFFEN ROBERTSON & KIRSTEN CONSULTING ENGINEERS (1990).
2. 5X VERTICAL EXAGERATION.



CLIENT: Yukon Government

Klohn Crippen Berger

PROJECT: FARO MINE COMPLEX
OMS MANUAL FOR DAMS

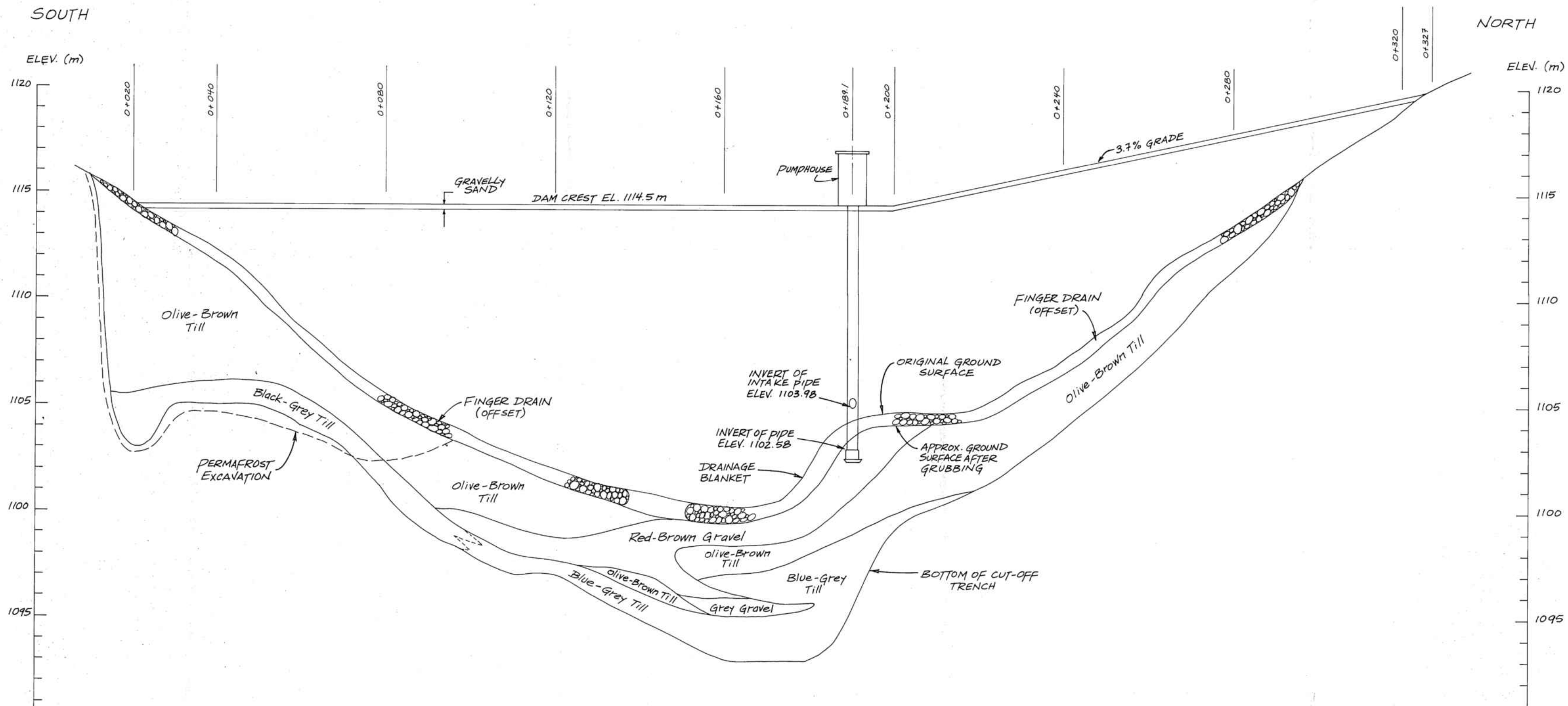
TITLE: LITTLE CREEK DAM
TRANSVERSE SECTION WITH
DRILL HOLES AND TEST PITS

PROJECT No. M09770A03 02 01

FIG. No. A–030

KCB–R–MLA

Time: 17:47:37
Date: 3/31/2014
Scale: 1:2.5849(PS)
Drawing File: \\int.klohn.com\projdata\M\VCR\M09770A03–GovtYukon–2013 Faro\400 Drawings\OMS_Manual\FIG_A–030_LittleCreekDam_TransverseSection.dwg (afischer)




LONGITUDINAL SECTION A-A

HORIZ. SCALE - 1:500
VERT. SCALE - 1:100

NOTES:

1. Stratigraphic profile is based on inspection of cut-off wall.
2. Drainage Blanket is offset 7-9 m downstream of section line.
3. Thickness of gravelly sand cover determined by CESL.
4. Wet well centerline is located 7.5 m upstream of dam centerline.

**NOTE**

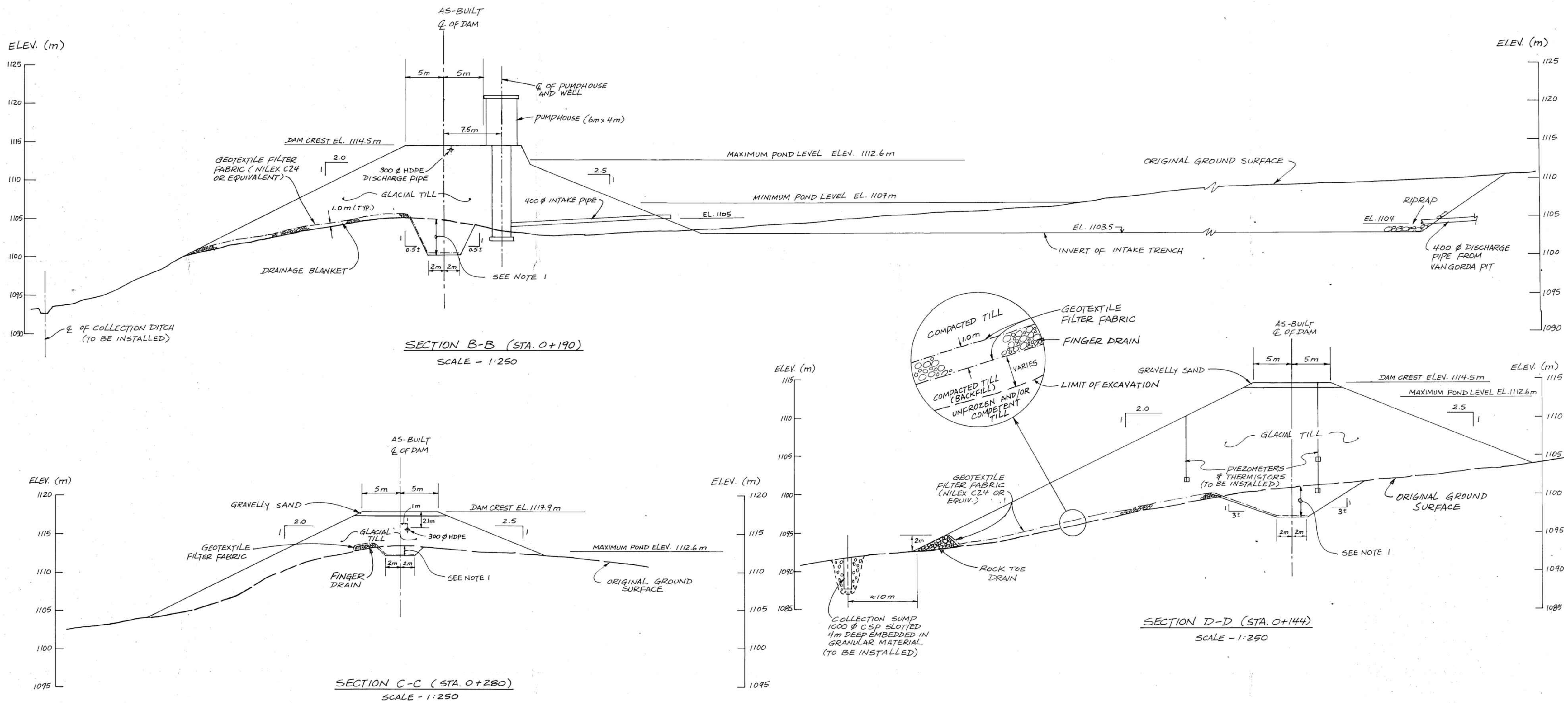
1. ORIGINAL FIGURE PROVIDED BY STEFFEN ROBERTSON & KIRSTEN CONSULTING ENGINEERS (1991).

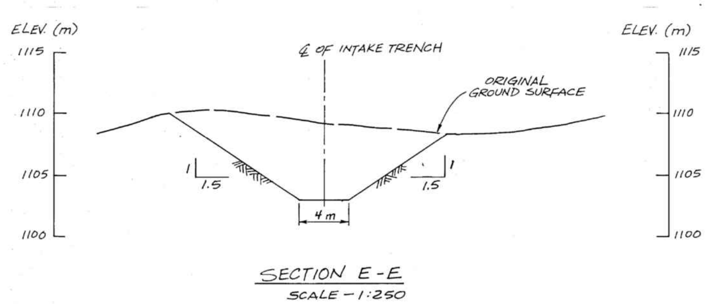


| | |
|---|---|
| CLIENT | Yukon Government |
| | Klohn Crippen Berger |
| PROJECT | FARO MINE COMPLEX OMS MANUAL FOR DAMS |
| TITLE | LITTLE CREEK DAM FOUNDATION STRATIGRAPHY |
| PROJECT No. | M09770A03 02 01 |
| FIG. No. | A-031 |

KCB-R-MLA

Time: 15:52:43
Date: 3/21/2014
Scale: 1:2.5849(PS)
Drawing File: \\int.klohn.com\projdata\M\VCR\M09770A03-GovtYukon-2013 Faro\400 Drawings\OMS_Manual\FIG_A-031_Foundation_Stratigraphy.dwg (afischer)




NOTES:

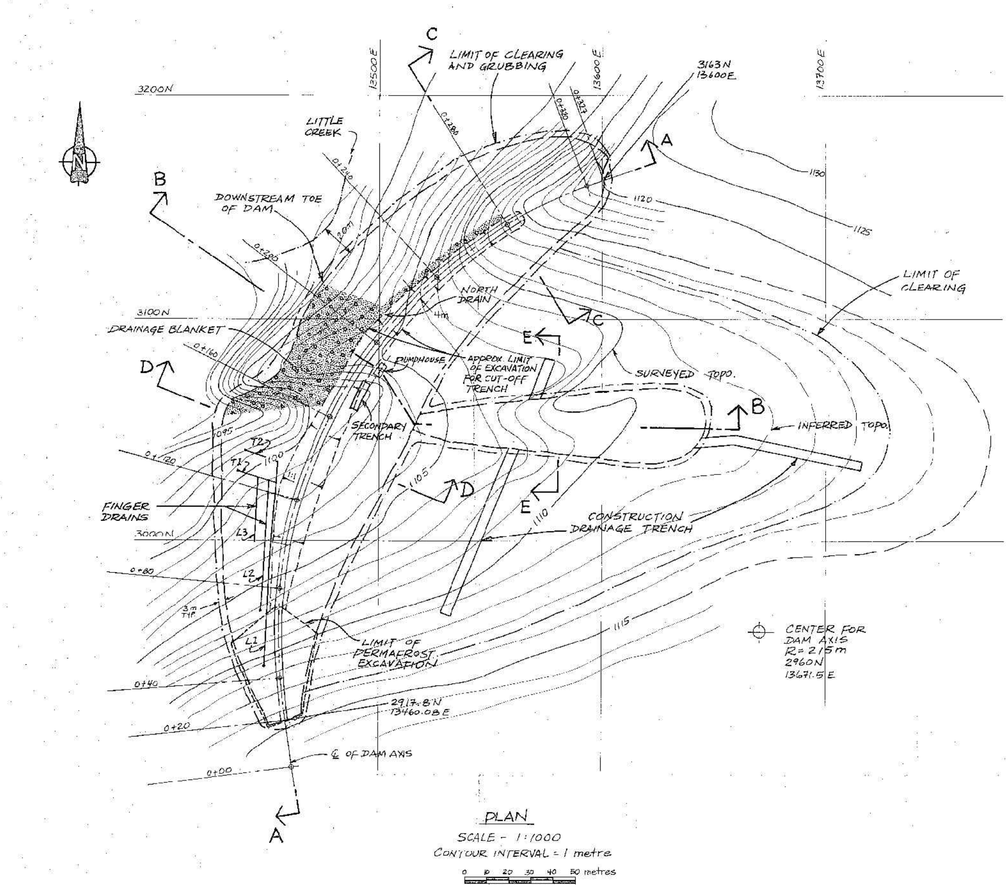
1. CUT-OFF TRENCH VARIES. SEE DRWG. NO. 60627-03. AS DETERMINED BY SRK FIELD ENGINEER.
2. GLACIAL TILL FILL MATERIAL COMPACTED TO 90 PERCENT OF THE MODIFIED PROCTOR MAXIMUM DRY DENSITY IN 0.3m LIFTS.
3. RIPRAP MATERIAL SHALL COMPLY WITH GRADATION REQUIREMENTS IN THE TECHNICAL SPECIFICATIONS.
4. PIEZOMETERS, THERMISTORS, COLLECTION DITCH AND COLLECTION SUMP NOT INSTALLED AS AT JAN. 1991.

**NOTE**

1. ORIGINAL FIGURE PROVIDED BY STEFFEN ROBERTSON & KIRSTEN CONSULTING ENGINEERS (1990).



| | |
|---|---|
| CLIENT | Yukon Government |
| | Klohn Crippen Berger |
| PROJECT | FARO MINE COMPLEX<br>OMS MANUAL FOR DAMS |
| TITLE | LITTLE CREEK DAM<br>CROSS SECTIONS AND DETAILS |
| PROJECT No. | M09770A03 02 01 |
| FIG. No. | B-032 |




AS-BUILT COORDINATES OF DAM

| ℄ AS-BUILT STATION | NORTHING | EASTING |
|---|---|---|
| 0+080 | 2977.48 | 13458.14 |
| 0+120 | 3016.19 | 13466.47 |
| 0+160 | 3052.89 | 13481.05 |
| 0+200 | 3085.38 | 13500.95 |
| 0+240 | 3114.07 | 13528.14 |
| 0+280 | 3135.26 | 13561.46 |
| 0+320 | 3152.23 | 13597.99 |

SURVEYED TRENCH FLOOR LOCATIONS

| STA. | ELEV. | NORTHING | EASTING |
|---|---|---|---|
| 0+070 | 1103.5 | 2967.7 | 13457.1 |
| 0+080 | 1100.9 | 2976.5 | 13457.2 |
| 0+100 | 1098.8 | 2995.6 | 13459.8 |
| 0+120 | 1097.6 | 3018.6 | 13457.2 |

**NOTE**

1. ORIGINAL SOURCE BY STEFFEN ROBERTSON & KIRSTEN CONSULTING ENGINEERS (1990).



CLIENT: Yukon Government

Klohn Crippen Berger

PROJECT: FARO MINE COMPLEX
OMS MANUAL FOR DAMS

TITLE: LITTLE CREEK DAM
LAYOUT FOR CUT-OFF TRENCH
EXCAVATION AND DRAINAGE BLANKET

PROJECT No. M09770A03 02 01

FIG. No. A-033

KCB-R-MLA

Time: 17:51:44
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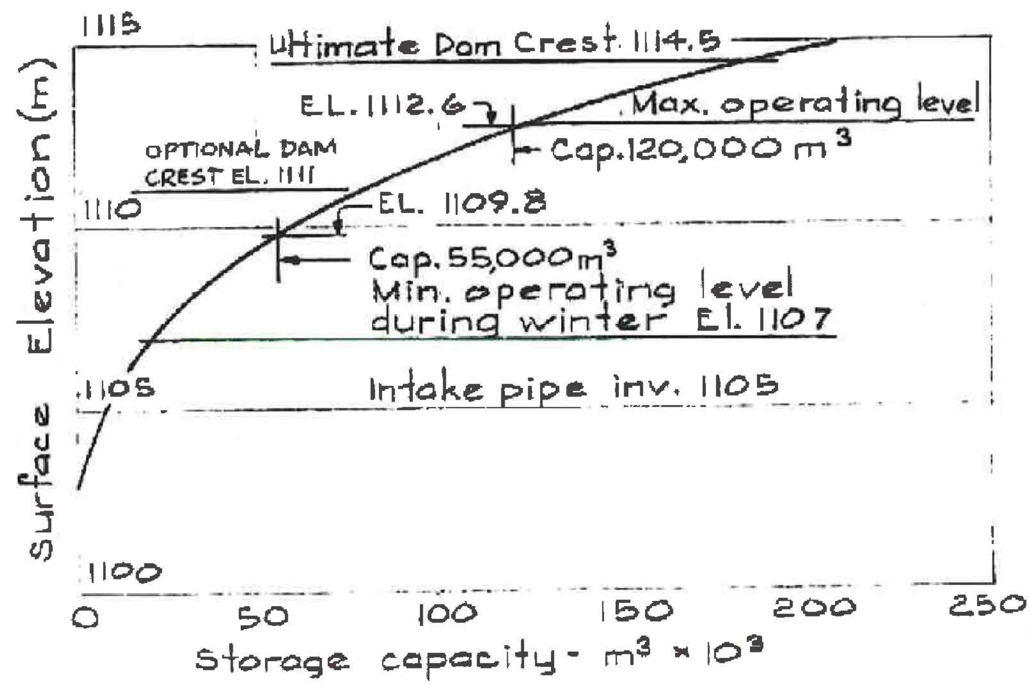
Drawing File: \\int.klohn.com\projdata\M\VCR\M09770A03-GovtYukon-2013 Faro\400 Drawings\OMS_Manual\FIG_A-033_LittleCreekDam_Layouts_CutoffTrench.dwg (afischer)




NOTE

Above EL. 1110, the topographic data used to establish this curve are approximate.

Source: SRK (1991)
"Vangorda Plateau Development As-Built Construction Report on Little Creek Dam"
Report 160636/1



NOTES

1. ORIGINAL SOURCE BY BGC ENGINEERING INC. (2008).
2. DATUM: NAD27.

CLIENT

Yukon Government

Klohn Crippen Berger

PROJECT

FARO MINE COMPLEX
OMS MANUAL FOR DAMS

TITLE

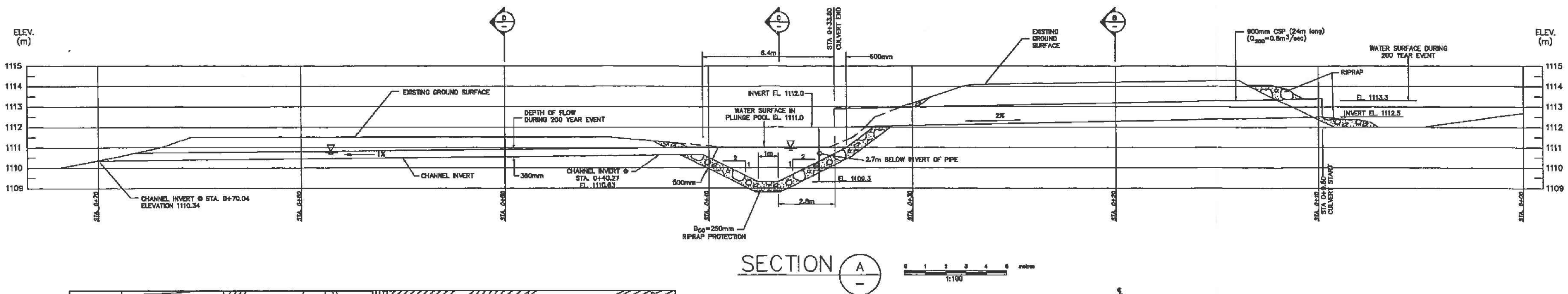
LITTLE CREEK DAM
STORAGE CAPACITY CURVE

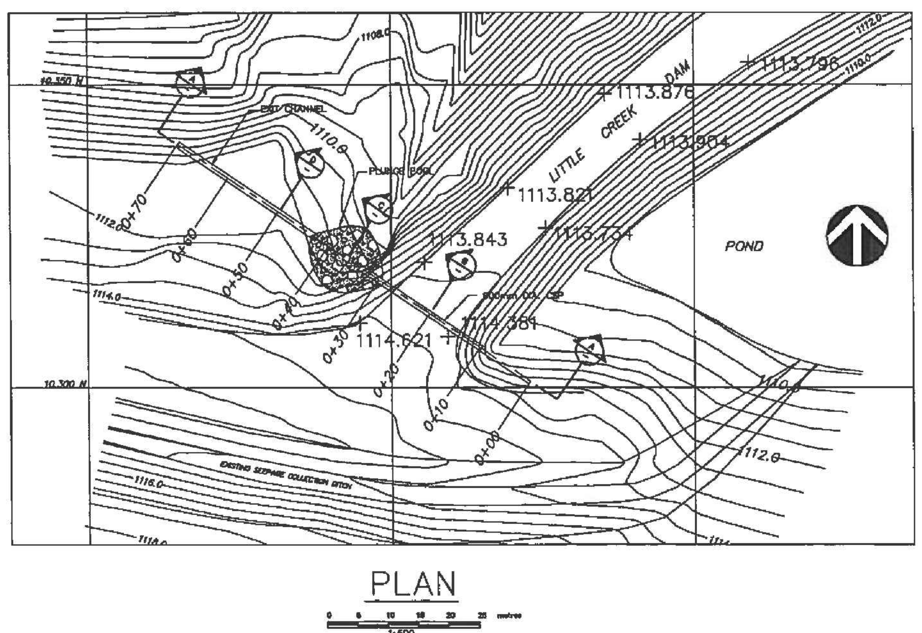
PROJECT No. M09770A03 02 01

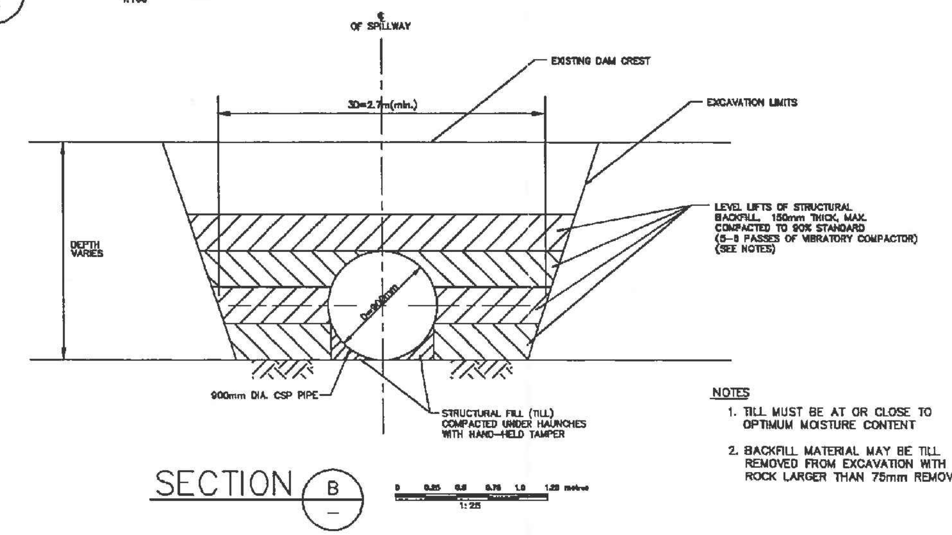
FIG. No. A-034

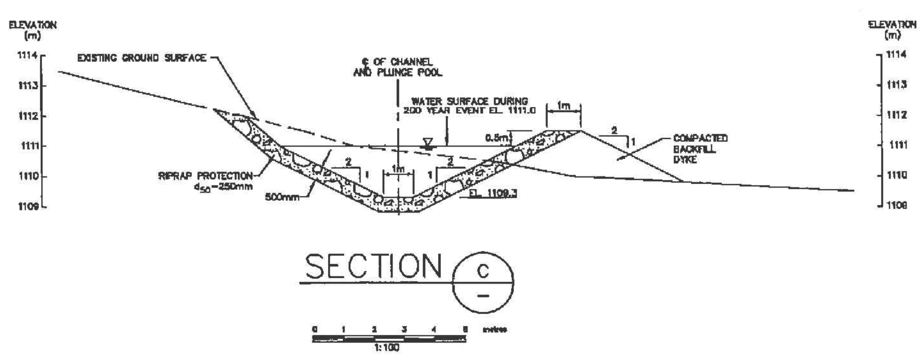
KCB-R-MPA

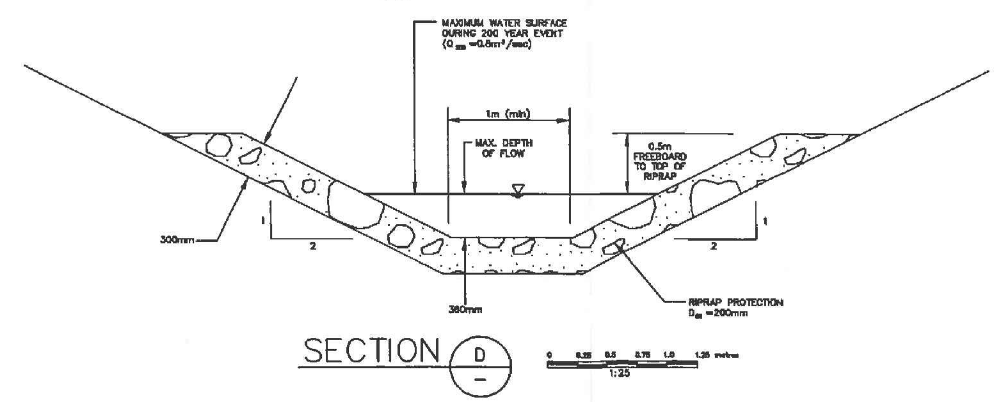
Time: 16:07:12
Date: 3/21/2014
Scale: 1:2.5849(PS)
Drawing File: \\int.klohn.com\projdata\M\VCR\M09770A03-GovtYukon-2013 Faro\400 Drawings\OMS_Manual\FIG_A-034_LittleCreekStorage_CapacityCurve.dwg (afischer)




**NOTE:**

1. ORIGINAL FIGURE PROVIDED BY STEFFEN ROBERTSON & KIRSTEN CONSULTING ENGINEERS.



CLIENT: Yukon Government

Klohn Crippen Berger

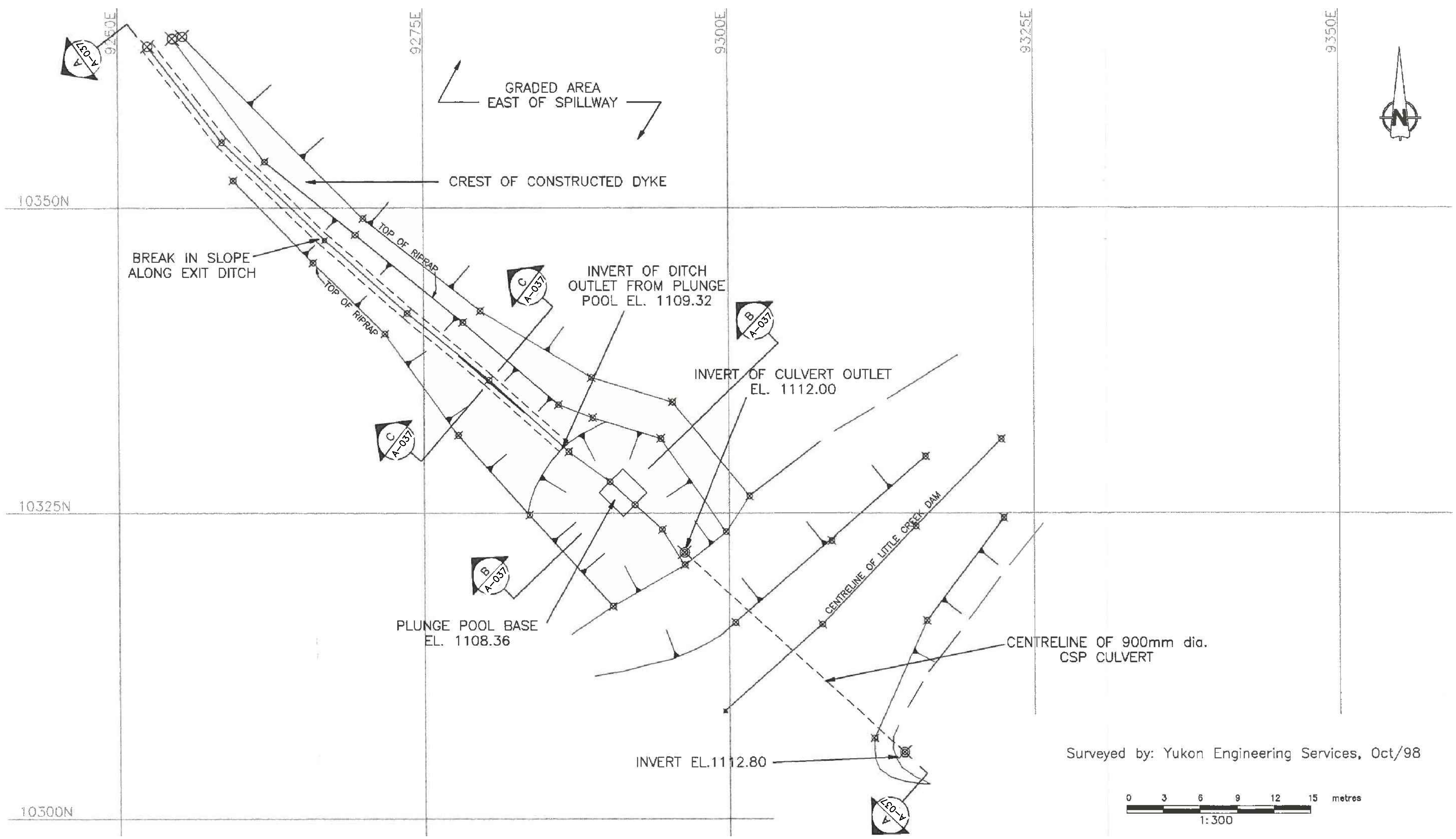
PROJECT: FARO MINE COMPLEX
OMS MANUAL FOR DAMS

TITLE: LITTLE CREEK DAM
SPILLWAY DESIGN
PLAN, SECTION AND DETAILS

| PROJECT No. | FIG. No. |
| --- | --- |
| M09770A03 02 01 | B-035 |

KCB-R-MLD

Date: 1/29/2013 Time: 13:25:10 Scale: 1:2,585
Filename: \\INT.KLOHN.COM\PROJDATA\M\VCR\M09770A03-GOVTYUKON-2013 FARO\400 DRAWINGS\OMS_MANUAL\FIG_B-035_LITTLECREEKDAM_SPILLWAYDESIGN_PLAN&SECTION.DWG




## NOTES

1. ORIGINAL SOURCE BY STEFFEN ROBERTSON & KIRSTEN CONSULTING ENGINEERS (1998).
2. SECTION VIEWS SHOWN ON FIGURE B-037 AND B-038.



CLIENT

Yukon Government

Klohn Crippen Berger

PROJECT

FARO MINE COMPLEX
OMS MANUAL FOR DAMS

TITLE

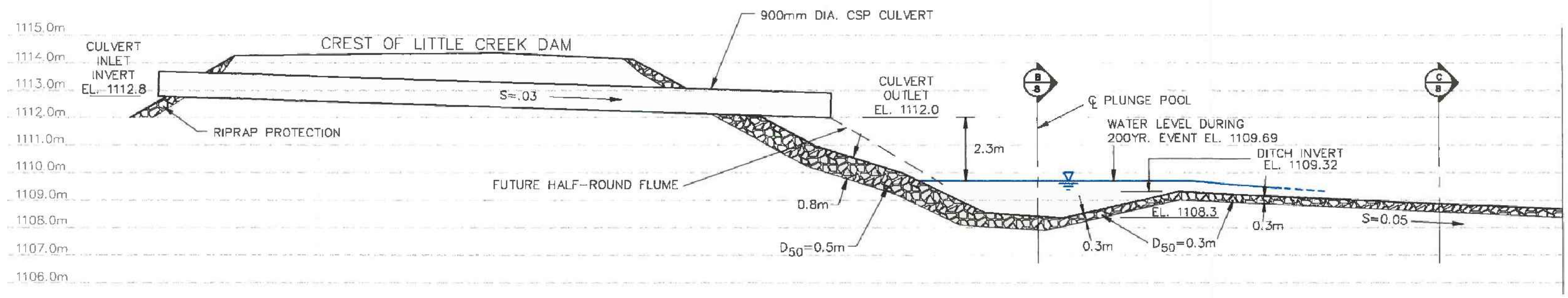
LITTLE CREEK DAM
AS-BUILT SPILLWAY IN PLAN

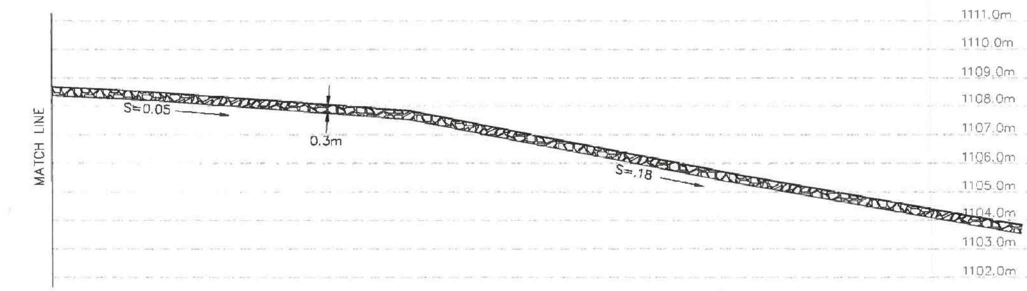
PROJECT No. M09770A03 02 01

FIG. No. A-036

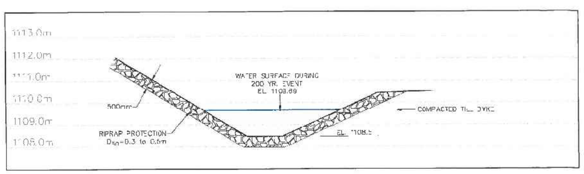
KCB-R-MLA

Time: 18:18:48
Date: 3/31/2014
Scale: 1:2.5849(PS)
Drawing File: \\int.klohn.com\projdata\M\VCR\M09770A03-GovtYukon-2013 Faro\400 Drawings\OMS_Manual\FIG_A-036_Spillway_in_Plan.dwg (afischer)



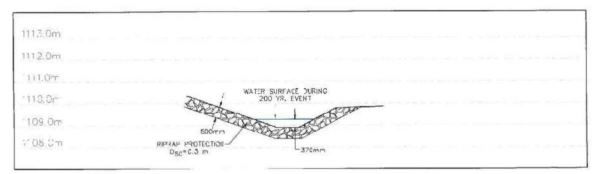




**SECTION A–A**
SCALE A




SECTION B–B – PLUNGE POOL

**SECTION B–B**
SCALE B




SECTION C–C – EXIT DITCH

**SECTION C–C**
SCALE B

SCALE A 0 1.5 3.0 4.5 6.0 7.5 metres

SCALE B

## NOTES

1. ORIGINAL SOURCE BY STEFFEN ROBERTSON & KIRSTEN CONSULTING ENGINEERS (1998).
2. DATUM: NAD27.
3. PLAN VIEW SHOWN ON FIGURE A–036.

LEGEND

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



CLIENT: Yukon Government

Klohn Crippen Berger

PROJECT: FARO MINE COMPLEX
OMS MANUAL FOR DAMS

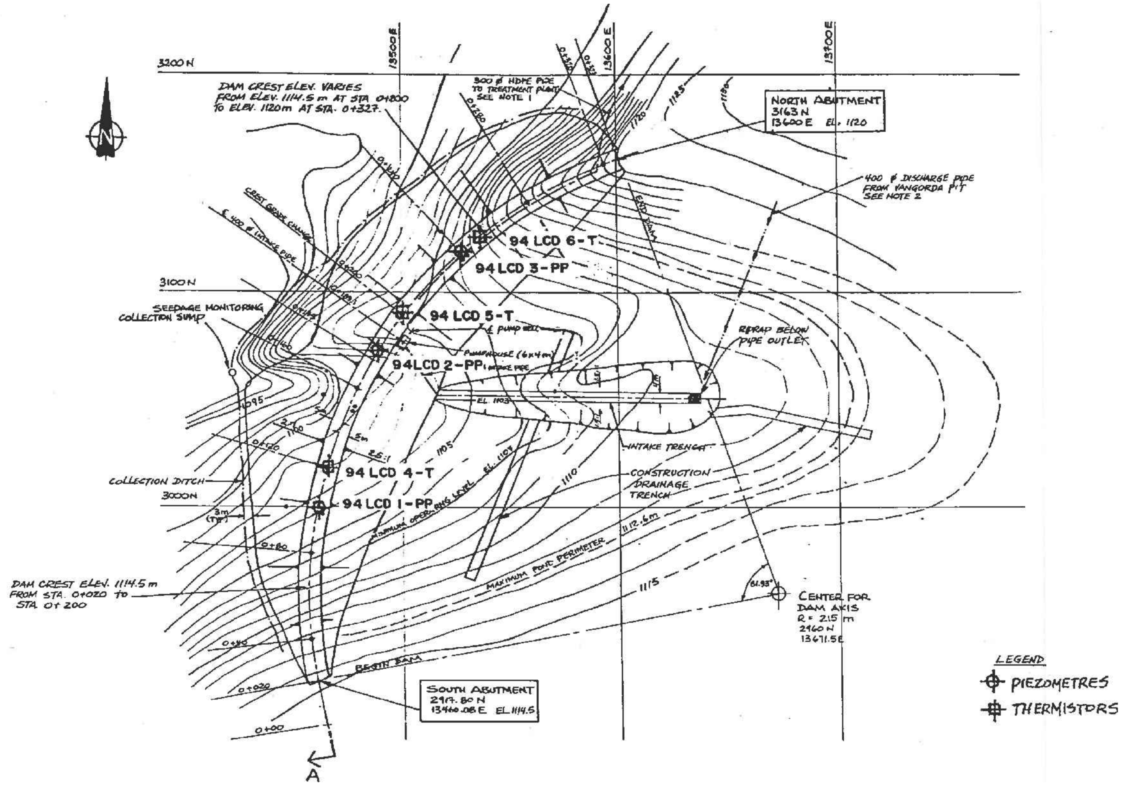
TITLE: LITTLE CREEK DAM
SPILLWAY CHANNEL SECTIONS

PROJECT No. M09770A03 02 01

FIG. No. A–037

KCB-R-MLA

Time: 18:11:00
Date: 3/31/2014
Scale: 1:2.5849(PS)
Drawing File: \\int.klohn.com\projdata\M\VCR\M09770A03-GovtYukon-2013 Faro\400 Drawings\OMS_Manual\FIG_A-037_LittleCreekDam_AsBuiltSpillway_in_Sections.dwg (afischer)




GENERAL ARRANGEMENT PLAN

CONTOUR INTERVAL = 1 metre
GRID SHOWN IS MINE GRID

## NOTES

1. ORIGINAL SOURCE BY STEFFEN ROBERTSON & KIRSTEN CONSULTING ENGINEERS (1998).
2. COORDINATE SYSTEM: MINE GRID.



CLIENT: Yukon Government

Klohn Crippen Berger

PROJECT: FARO MINE COMPLEX
OMS MANUAL FOR DAMS

TITLE: LITTLE CREEK DAM
INSTRUMENTATION LOCATION PLAN

PROJECT No. M09770A03 02 01

FIG. No. A-038

KCB-R-MLA

Time: 18:22:43
Date: 3/31/2014
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Drawing File: \\int.klohn.com\projdata\M\VCR\M09770A03-GovtYukon-2013 Faro\400 Drawings\OMS_Manual\FIG_A-038_LittleCreekDam_InstrumentationLocation.dwg (afischer)

# APPENDIX I

## Minister's Determination Re Faro Mine Complex Reclamation and Closure Activities (Section 37(1) of Waters Act)

Environment

Box 2703, Whitehorse,
Yukon Y1A 2C6

## Minister's Determination

(Subsection 37(1) of *Waters Act*)

### Re Faro Mine Complex Reclamation and Closure Activities

### A. Statement of Facts

1. On April 21, 1998, Deloitte & Touche Inc. was appointed by the Ontario Superior Court of Justice as interim receiver ("Interim Receiver") for the Faro Mine Complex (the "Mine") on behalf of Anvil Range Mining Corporation.

2. The Interim Receiver has focused on care and maintenance at the Mine, ensuring that the water flowing from the Mine meets the requirements of Water Licence QZ03-059.

3. On February 28, 2009, the Interim Receiver will be discharged by court order of the Ontario Superior Court of Justice, recognized by the Supreme Court of Yukon, from its responsibilities at the Mine. The assets and real property related to the Mine will be distributed according to the court order.

4. The Mine contains, or is adjacent to waters that include Faro Creek, Rose Creek, and Vangorda Creek (the "Surrounding Waters").

5. Due to the past operations and practices at the Mine, water has accumulated and been stored in pits at the Mine known as the Faro, Grum, and Vangorda pits (the "Waste Water"). The Waste Water is highly contaminated because it contains elevated concentrations of heavy metals and acids.

6. Due to the instability of the dams and diversion channels at the Mine, there continues to be a risk that the Waste Waters may release from the pits and thereby deposit waste into the Surrounding Waters

### B. Reasonable Grounds for Belief

I, Kevin McDonnell, acting on behalf of the Minister of the Department of Environment, have reasonable grounds to believe, based upon the facts above, that:

a. the works related to the use of waters or deposit of waste at the Mine have been permanently abandoned; and

b. that a danger to persons, property and the environment may result due to the past operation and the abandonment of the works at the Mine.

**C. Measures to be Taken**

I hereby authorize officials or agents of the Assessment and Abandoned Mines Branch, Department of Energy Mines and Resources, Government of Yukon ("Abandoned Mines") to use the following reasonable measures to prevent, counteract, mitigate, or remedy any resulting adverse effect on persons, property, or the environment, and in particular the Surrounding Waters:

1. Access the Mine and surrounding area, with the exception of any place being used as a temporary or permanent private dwelling-place.

2. Collection, testing, treatment, and discharge of treated Waste Water.

3. Maintaining, upgrading, inspecting and improving the diversions and dams at the Mine.

4. Re-sloping and covering and/or relocating waste rock to prevent further contamination of any of the waters at or around the Mine;

5. Construction of a water treatment plant at the Mine.

6. Any such other activities either directly or indirectly related to the use of waters or deposit of waste in waters that are necessary in order to undertake any of the above.

This determination is effective as of the date of signature.

Feb 27/09
Date of Signature

Kevin McDonnell
Director,
Water Resources Branch
Department of Environment,
Government of Yukon

# APPENDIX II

## Faro Mine Contact List

# Appendix II
# Contact List

| | | | |
|---|---|---|---|
| Geotechnical | Robert Lo | Klohn Crippen Berger | (604) 251-8455 (w)<br>(604) 278-7126 (h) |
| Geotechnical – Alternate | Jaco Esterhuizen | CH2MHILL | (541) 602-0309 |
| Hydrotechnical | Arvind Dalpatram | Klohn Crippen Berger | (604) 251-8511 (w)<br>(604) 434-3907 (h) |
| Environmental (YG) | Adrienne Turcotte | Assessment and Abandoned Mines | (867) 667-3153 (w)<br>(867) 334-9799 (c) |
| Environmental - Alternate | Steve Momeyer | CH2MHILL | (867) 668-2201 ext 2012 |
| Environmental Engineering | Leslie Gomm | Gomm Environmental | (867) 334-7237 |

# APPENDIX III

## Visual Inspection Forms

# Visual Inspection Form
# Faro Mine Structures

**Schedule**: Perform weekly, as required in the Water License. Additionally, perform immediately following a significant earthquake in the vicinity of the dam, and as appropriate during and following a major flood event.

**Structure:** ____________________________________________
**Inspector**: ______________________ **Date**: _________________
**Reservoir Elev.**: ________________m **Time**: _________________
**Weather**: _______________________ **Temperature**: __________ °C

For any question answered "YES" below, please provide additional information describing the situation as completely as possible under item 6, "Additional Information." Include hand drawn sketches or photographs when appropriate.

**1. Upstream Slope of the Structure:**

| | | |
|---|---|---|
| Any new evidence of significant erosion due to wave action? | No | Yes |
| Any new sinkholes, depressions, sloughs, or areas of unusual settlement? | No | Yes |
| Any evidence of whirlpools in the reservoir? | No | Yes |
| Any other changed conditions? | No | Yes |

**2. Crest of the Structure:**

| | | |
|---|---|---|
| Any new cracks, either transverse or longitudinal? | No | Yes |
| Any evidence of changed conditions in previously reported cracks? | No | Yes |
| Any new sinkholes, depressions, or areas of unusual settlement? | No | Yes |
| Any evidence of changed conditions in previously reported sinkholes, depressions, or settlement? | No | Yes |
| Any other changed conditions? | No | Yes |

**3. Downstream Slope of the Structure:**

| | | |
|---|---|---|
| Any new seepage areas or wet areas? | No | Yes |
| Any changes in conditions at existing seepage areas or wet areas? | No | Yes |
| Any evidence of materials being transported by seepage flows at new or existing seepage areas (such as discolored seepage water or sediment deposits)? | No | Yes |
| Any new sinkholes, depressions, sloughs, bulges, or areas of unusual settlement? | No | Yes |
| Any other changed conditions? | No | Yes |

**4. Downstream Toe Area, Abutments, and Areas Downstream of the Dam:**

| | | |
|---|---|---|
| Any evidence of materials being transported by seepage flows at existing seepage areas (such as discolored seepage water or sediment deposits)? | No | Yes |
| Any new seepage areas or wet areas? | No | Yes |
| Any changes in conditions at existing seepage areas or wet areas? | No | Yes |
| Any new sinkholes, sloughs, areas of unusual settlement or bulges? | No | Yes |
| Any evidence of seepage emerging in downstream river channels, such as turbid water or unusual flow patterns? | No | Yes |
| Any other changed conditions? | No | Yes |

**5. Spillway/Diversion Channel:**

Note: Document spillway/Diversion Channel performance during periods of high discharge rates using videos and/or photos (preferably obtained from consistent locations) that indicate flow conditions in the upstream channel, inlets and outlets, over the full length of the spillway/channel, and in the downstream channel.

| | | |
|---|---|---|
| Any new or enlarged cracks? | No | Yes |
| Any evidence of unusual deformations or displacements? | No | Yes |
| Any unusual flow patterns or conditions during releases? | No | Yes |
| Any evidence of erosion of the spillway? | No | Yes |
| Any other changed conditions? | No | Yes |

**6. Additional Information:**

**NOTE**: All descriptions should include specific location information and all other seemingly relevant information. Seepage area descriptions should include: estimated seepage amount and water clarity description (clear/cloudy/muddy, etc.). Crack descriptions should include orientation and dimensions.

# APPENDIX IV

## Faro Site Personnel OMS Pull-out Sheets

# Appendix IV
# Pull Out Sheets

## IV.1 Dam Monitoring Schedule

| Intermediate Dam | Cross Valley Dam | Little Creek Dam |
|---|---|---|
| **Weekly Monitoring**<br>*Pond level<br>*Surface Cracks<br>*Erosional Gullies<br>*Riprap Displacement<br>*Seepage | **Weekly Monitoring**<br>*Pond level<br>*Surface Cracks<br>*Erosional Gullies<br>*Riprap Displacement<br>*Seepage<br>Weir Flows (x13) | **Weekly Monitoring**<br>*Pond level<br>*Surface Cracks<br>*Erosional Gullies<br>*Seepage |
| **May. June and September Monitoring**<br>Piezometer Readings | **May. June and September Monitoring**<br>Piezometer Readings | **May. June and September Monitoring**<br>Piezometer Readings |
| | **Monthly Monitoring**<br>Weir Flows (x11, x12, and w3) | |

* Complete Visual Inspection Form for Faro Mine Complex - Dam Structures and place in corresponding dam binders for record keeping.

## IV.2 Intermediate Dam Operations, Maintenance and Surveillance Quick Reference Guide

| | |
|---|---|
| *Surficial Cracking* | Investigate potential causes and review with Geotechnical Consultant.<br>Do not cover cracks until instructed to do so by Geotechnical Consultant.<br>OMS manual outlines procedures for covering crack. |
| *Riprap* | Must be in good condition on the upstream slope.<br>Advise Geotechnical Consultant when placing riprap.<br>OMS manual outlines riprap sizing and placement. |
| *Erosional Issues* | Investigate potential causes and review with Geotechnical Consultant.<br>Do not backfill erosional gullies until instructed to do so by Geotechnical Consultant.<br>OMS manual outlines procedures for backfilling erosional gullies |
| *General Maintenance* | Maintenance where erosion or mining activities have altered the design configuration. |
| *Infrastructure:* | Needs to be kept in good operating condition for routine and emergency water discharges. |
| *Monitoring Equipment:* | Staff gauges in the Intermediate pond should be checked for stability in freeze-thaw process.<br>Piezometers should be checked for standing water at collar and infiltration to instrument.<br>OMS outlines procedures for correcting water infiltration to piezometers |

### Upstream Pond Water Levels

| | | |
|---|---|---|
| Normal | 1044.0 m – 1047.7 m (water at spillway bottom) | |
| Alert | 1047.7 m – 1048.2 m (spillway is discharging) | |
| Emergency | 1048.5 m – 1048.8 m (water above core but not overtopping dam) | **ERP Initiated Here!** |
| FAILURE | >1048.8 m (water overtopping dam) | |

### General Dam Alert Levels

| | |
|---|---|
| Dam Overtopping | Intermediate Pond level is at normal operating level and starts to rise to maximum operating level. |
| Dam Embankment Instability | Appearance of new cracks or the opening of existing cracks on dam crest or slopes. Significant increase of pore pressure in piezometers or high one-time reading of a single piezometer.<br>Slope slumping on either dam slope. |
| Piping | Small quantities of clear seepage flowing from the toe or abutment of the dam may be considered normal, but should be recorded as part of the regular visual inspection. The location and seepage rate, preferably measured by a weir or by the time required to fill a container of known volume, should be recorded. Changes in the location, rate of flow may be related to pond level, precipitation, snowmelt or thawing of ground ice. |
| Seismic Instability and Large Earthquake Event | Site staff should inspect the dam after a seismic event being felt at the site, regardless of the size of the event. Pore pressure readings should be taken on all piezometers. Information about the earthquake may be obtained from the Pacific Geoscience Centre website given in the ERP regarding recent seismic event in western and northern Canada and Alaska. |
| Piezometer Monitoring | A significant increase in piezometric level in any piezometer. A piezometer at the toe of the dam that reads a piezometric level higher than the Polishing Pond level |

## IV.3 Cross Valley Dam Operations, Maintenance and Surveillance Quick Reference Guide

| | |
|---|---|
| *Surficial Cracking* | Investigate potential causes and review with Geotechnical Consultant.<br>Do not cover cracks until instructed to do so by Geotechnical Consultant.<br>OMS manual outlines procedures for covering crack. |
| *Riprap* | Must be in good condition on the upstream slope.<br>Advise Geotechnical Consultant when placing riprap.<br>OMS manual outlines riprap sizing and placement. |
| *Erosional Issues* | Investigate potential causes and review with Geotechnical Consultant.<br>Do not backfill erosional gullies until instructed to do so by Geotechnical Consultant. OMS manual outlines procedures for backfilling erosional gullies |
| *General Maintenance*<br>*Infrastructure:* | Maintenance where erosion or mining activities have altered the design configuration.<br>Needs to be kept in good operating condition for routine and emergency water discharges.<br>Siphon pipes and valves need to be checked periodically occasionally for cracks and blockages etc.<br>Draining of siphon pipes in the fall helps alleviate potential blockages in the spring. |
| *Monitoring Equipment:* | Staff gauges in the Intermediate pond should be checked for stability in freeze-thaw process.<br>Piezometers should be checked for standing water at collar and infiltration to instrument.<br>OMS outlines procedures for correcting water infiltration to piezometers |

### Upstream Pond Water Levels

| | | |
|---|---|---|
| Normal | 1030.7 m – 1031.2 m (water below or spillway invert) | |
| Alert | 1030.78 m – 1031.07 m (spillway is discharging) | |
| Emergency | 1032.5 m – 1032.7 m (water above core but not overtopping dam) | **ERP Initiated Here!** |
| FAILURE | > 1032.7 m (water overtopping dam) | |

### General Dam Alert Levels

| | |
|---|---|
| Dam Overtopping | Polishing Pond level is at normal operating level and starts to rise to maximum operating level. |
| Dam Embankment Instability | Appearance of new cracks or the opening of existing cracks in crest or faces of dam. Significant warming trend in thermistors, increasing pore pressures in piezometers or high one-time reading from a single piezometer.<br>Surface slumping on face of dam. |
| Piping | Small quantities of clear seepage flowing from the toe or abutment of the dam may be considered normal, but should be recorded as part of the regular visual inspection. The location and seepage rate, preferably measured by a weir or by the time required to fill a container of known volume, should be recorded. Changes in the location, rate of flow may be related to pond level, precipitation, snowmelt or thawing of ground ice. |
| Seismic Instability and Large Earthquake Event | Site staff should inspect the dam after a seismic event being felt at the site, regardless of the size of the event. Pore pressure readings should be taken on all piezometers. Information about the earthquake may be obtained from the Pacific Geoscience Centre website given in the ERP regarding recent seismic event in western and northern Canada and Alaska. |
| Piezometer Monitoring | A significant increase in seepage rate or presence of murky seepage at installed weirs or elsewhere. A significant increase in piezometric level in any piezometer.<br>A piezometer at the toe of the dam that reads a piezometric level higher than the surface of the downstream drainage blanket. |

## IV.4 Little Creek Dam Operations, Maintenance and Surveillance Quick Reference Guide

| | |
|---|---|
| *Surficial Cracking* | Investigate potential causes and review with Geotechnical Consultant.<br>Do not cover cracks until instructed to do so by Geotechnical Consultant.<br>OMS manual outlines procedures for covering crack. |
| *Riprap* | Must be in good condition on the upstream slope.<br>Advise Geotechnical Consultant when placing riprap.<br>OMS manual outlines riprap sizing and placement. |
| *Erosional Issues* | Investigate potential causes and review with Geotechnical Consultant.<br>Do not backfill erosional gullies until instructed to do so by Geotechnical Consultant.<br>OMS manual outlines procedures for backfilling erosional gullies. |
| *General Maintenance*<br>*Infrastructure:* | Maintenance where erosion or mining activities have altered the design configuration.<br>Needs to be kept in good operating condition for routine and emergency water discharges.<br>Pumps and lines need to be checked periodically for cracks and blockages etc.<br>Floating barge maintenance should be done routinely in the winter when removed from pond. |
| *Monitoring Equipment:* | Staff gauges in the Intermediate pond should be checked for stability in freeze-thaw process.<br>Piezometers should be checked for standing water at collar and infiltration to instrument.<br>OMS outlines procedures for correcting water infiltration to piezometers. |

### Upstream Pond Water Levels

| | | |
|---|---|---|
| Normal | 1107.0 m – 1112.8 m (water at spillway bottom) | |
| Alert | 1112.8 m – 1113.8 m (spillway is discharging) | **ERP Initiated Here!** |
| Emergency | 1113.8 m – 1114.3 m (water above core but not overtopping dam) | |
| FAILURE | >1114.3 m (water overtopping dam) | |

### General Dam Alert Levels

| | |
|---|---|
| Dam Overtopping | Little Creek Pond level is at normal operating level and starts to rise to maximum operating level. |
| Dam Embankment Instability | Appearance of new cracks or the opening of existing cracks on dam crest or slopes. Significant increase of pore pressure in piezometers or high one-time reading of a single piezometer.<br>Slope slumping on either dam slope. |
| Piping | Small quantities of clear seepage flowing from the toe or abutment of the dam may be considered normal, but should be recorded as part of the regular visual inspection. The location and seepage rate, preferably measured by a weir or by the time required to fill a container of known volume, should be recorded. Changes in the location, rate of flow may be related to pond level, precipitation, snowmelt or thawing of ground ice. |
| Seismic Instability and Large Earthquake Event | Site staff should inspect the dam after a seismic event being felt at the site, regardless of the size of the event. Pore pressure readings should be taken on all piezometers. Information about the earthquake may be obtained from the Pacific Geoscience Centre website given in the ERP regarding recent seismic event in western and northern Canada and Alaska. |
| Piezometer Monitoring | A significant increase in piezometric level in any piezometer. |