SRK CONSULTING LIMITED
(ON BEHALF OF DELOITTE AND TOUCHE INC.)

FARO PIT PLUG DAM

CONCEPTUAL DESIGN REPORT

(DRAFT)

PROJECT NO.: 0257-019-01

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Cam Scott, M.Eng. P.Eng.
Principal Engineer
SRK Consulting
Suite 800,1066 West Hastings St.
Vancouver, BC
V6E 3X2

Re: Faro Pit Plug Dam-Draft Conceptual Design Report

Dear Cam:

Please find attached one copy of our above referenced draft report dated December 19, 2003. This report presents a conceptual design for a plug dam at the south end of the Faro Pit, based on a brief reconnaissance inspection earlier this fall. The report has included your comments on the earlier draft. We will finalize this report following receipt of comments from Deloitte and Touche Inc.

We trust that this information meets with your requirements at this time. Should you have any questions or comments, please do not hesitate to contact me at the number listed above.

Yours truly,
BGC Engineering Inc.
per:

Holger Hartmaier, M.Eng., P.Eng.
Senior Geotechnical Engineer

HHH/slf

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LIMITATIONS OF REPORT

This report was prepared by BGC Engineering Inc.(BGC) for the account of SRK Consulting, on behalf of Deloitte and Touche Inc., Interim Receiver for Anvil Range Mining Corporation. The material in it reflects the judgement of BGC staff in light of the information available to BGC at the time of report preparation. Any use which a Third Party makes of this report, or any reliance on decisions to be based on it are the responsibility of such Third Parties. BGC Engineering Inc. accepts 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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1.0 INTRODUCTION

1.1 Background and Study Objective

As part of the assessment of closure options for the Faro Mine, it may be necessary to construct an in-pit plug dam (the "Plug Dam) within the Faro open pit. The purpose of this dam would be to retain pit water (and possibly tailings solids and/or waste rock) within the main open pit and prevent any overflow and/or seepage from entering the adjacent Zone II pit, located to the south. Seepage that enters the Zone II pit later seeps out towards the north fork of Rose Creek and must be controlled with groundwater collection wells.

As reviewed in the closure-planning workshop of June 24-26, 2003 in Whitehorse, the plug dam may be required for various closure approaches. As a result, Deloitte and Touche Inc. (Deloitte) and the Type II Mine Management team, through SRK Consulting (SRK) requested that BGC Engineering Inc. (BGC) undertake a conceptual design study of the Plug Dam to facilitate closure planning assessments and costing.

1.2 Scope of Work and Authorization to Proceed

On September 17, 2003, BGC prepared a proposal for SRK outlining the proposed scope of work and budget for the conceptual design for the plug dam. Authorization to proceed with the work was given by Mr. Cam Scott, P.Eng. of SRK on September 17, 2003, with the view that field mapping could be completed at the dam site before exposures were covered by snow.

The program of work undertaken by BGC included the following major tasks:

- Collection and compilation of relevant topographical and geological information with respect to the Plug Dam.
- A site reconnaissance of the proposed dam location to inspect existing conditions, review foundation and abutment conditions, map exposed bedrock and assess access points and conditions for drilling equipment for later site investigations.
- Plotting of geological data collected onto stereonets and base maps of the dam area.
- A conceptual level design study including:
    - Compilation of Faro pit topography and a storage capacity curve for the retained volume behind the proposed plug dam and a height-volume curve for the proposed embankment.
    - Assessment of rock mass hydraulic conductivity and potential seepage volumes. Conceptual design of seepage cut-off elements.
    - Determining the requirements and testing protocols for a proposed site investigation program and associated costs.
    - Summary of material quantities and cost estimate required to construct the dam.
- Preparation of draft report for review by SRK and Deloitte. Preparation of final report.

2.0 BACKGROUND INFORMATION

2.1 Location and Topography

The Faro pit is located 15 km north-northwest of Faro, Yukon, in the Anvil Range Mountains, about 192 km northeast of Whitehorse. Access to the mine is via a 23 km long mine access road from the Town of Faro, as shown in Figure 1.

Topography in the region consists of smoothly rounded, dissected uplands, separated by broad valleys, with moderate relief. Faro pit straddles the valleys of Faro Creek and Rose Creek. Figure 2 shows the topographic features of the Faro Pit area in more detail. The drainage of Faro Creek was diverted around the northeast side of the pit to allow mining of the open pit. The pit was mined in three zones. Zones I and III are located within the main pit boundary. The Zone II Pit was located south of the Main Pit as shown in Figure 2 and was subsequently completely filled in and covered with waste rock.

Waste rock piles from the open pit mine are draped over the valley slopes of Rose Creek, along the southeast sides of the pit. The original Faro Creek drainage course forms a notch into the pit wall crests on the west and north sides. The pit is currently filled with water to about elevation 1142 m (all elevations are geodetic in metres above mean sea level (m amsl), unless noted otherwise). The notch along the former Faro Creek channel has been partially filled in with waste rock, with the lowest topographical point being at about elevation 1181.6 m at the top of the access road to the pump barge. A bedrock low, at elevation 1158.24 m occurs in this area (see Section 2.4). The location this topographic and bedrock low is indicated on Figure 5.

On the southeast corner of the pit, a haul road ramp forms a narrow slot through the Faro Pit crest. This road used to connect the main Pit to the Zone II Pit and was abandoned during mining of the Zone III orebody. The maximum bedrock elevation in the base of the haul road is about elevation 1158.9 m (SRK, 1991). This elevation tentatively represents another bedrock low on the rim of the Faro Pit. The bedrock has been covered by waste rock dumps, which have a maximum elevation of about 1254 m on the southeast side, between Faro Pit and Rose Creek. The minimum saddle elevation on the haul road out of the main pit, located on rockfill cover over the former Zone II pit area, is about 1175 m.

The purpose of the plug dam is to prevent loss of pit water through the southern haul road connection to the former Zone II pit, as well as preventing seepage through the overlying waste rock dumps into Rose Creek. Figure 3 presents a more detailed topographic plan of the proposed Plug Dam location. Figure 4 shows representative cross-sections through the proposed plug dam area, including the Faro and Zone II pits

Figure 5 is an aerial photograph of the site taken in July 2003, showing current conditions. These photos were used to create a new digital elevation model for the Anvil Range property, and were the basis for the topographic maps used in this report.

A storage capacity curve for the Faro pit was derived from the recent topographic data up to elevation 1180 m (Figure 6). Currently, a barge-mounted pump located near the northwest corner of the pit regulates pit water levels. Water is periodically pumped from the pit to a water treatment plant located in the mill. Current water level is maintained around elevation 1142 m. Impounding the pit water level to elevation 1180 m represents an additional storage volume of about 29,800,000 m^3 of water within the Faro Pit.

Water level within the buried Zone II pit is controlled by pumping from a well located along the access road south of the plug dam (Figures 2 and 3). Figure 7 presents a summary plot of water levels in the Zone II pit since pumping began in 1997. Further details on the hydrogeology of the Zone II pit are provided in Section 2.4.

2.2 Geology

2.2.1 Regional Setting

The area has been extensively glaciated during the Quaternary period. Tills and outwash deposits fill the lower parts of most valleys. Overburden, consisting of till-like deposits, sands, silts and gravels were found to exist up to depths of 60 m in the Faro Creek valley, in the vicinity of the open pit. (Piteau, Gadsby, Macleod Ltd., 1975)

The Faro Pit is the most westerly of a series of several concordant, stratiform, massive sulphide lead-zinc orebodies, which occur within the Anvil Arch, on the north side of the Tintina Trench. The main orebodies of the Anvil Range, from west to east are the Faro, Grum and Vangorda deposits (Figure 1). The main bedrock units hosting the Faro deposit are deformed sequence of late Precambrian to Upper Paleozoic metasedimentary and metavolcanics, intruded by a Cretaceous granitic plutonic suite (SRK, 1988).

The geology of the plug dam site is relatively complex and could not be fully appreciated during the brief reconnaissance inspection. The following sections summarize geological details obtained from various references, which described the geology of the Faro orebody. Many of these details will become important during final design, when site-specific drilling and better mapping data are obtained after the foundation has been exposed and the abutments cleaned of accumulated colluvial debris. In Section 3, the field reconnaissance data has been correlated with the detailed stratigraphy presented herein.

2.2.2 Bedrock Geology

The Anvil Range orebodies occur at the contact between the Mt. Mye Formation and the Vangorda Formation.

The Mt. Mye Formation is the oldest map unit in the area, ranging in age from Late Proterozoic to Lower Cambrian (Jennings and Jilson, 1986) and forms the basal stratigraphic unit of the region. Mt. Mye strata comprise non-calcareous phyllite and schist, marble and calc-silicate lenses, carbonaceous schist, minor psammitic schist and metabasite. The typical non-calcareous phyllite of the Mt. Mye Formation is a medium to dark medium grey, weathering rusty brown, with a rust flecked foliation surface (Jennings and Jilson, 1986). The rocks are commonly banded with dark grey micaceous folia, 1 mm to 10 mm thick, separating lighter grey, finely crystalline quartz-rich layers 2 to 50 mm thick. Metabasites are either flows or sills, occurring mainly near the top of the formation. They comprise mainly dark green amphibole, plagioclase, quartz schists that are strongly foliated, lacking relict igneous structure. These units are relatively thin (a few metres to several tens of metres thick), and discontinuous, with lateral dimensions up to a few hundred metres.

The Vangorda Formation consists of calcareous phyllite and calc-silicate, metabasites, carbonaceous phyllite, chloritic phyllite and minor marble (Jennings and Jilson, 1986). The unit has been strongly deformed, making it difficult to estimate its overall thickness. Estimates of 1000m were indicated from cross-sections based on exposures in the Anvil Range (Jennings and Jilson, 1986). The best exposures of the calc-silicate units are in the northwest side of the Faro Pit. A carbonaceous unit exists near the base of the formation and can also be seen within the Faro Pit. The Vangorda Formation is characterized by medium grey phyllite, very thinly interlayered with light grey quartz and calcite rich bands. The phyllitic bands are 0.5 to 1 cm thick and the quartz and calcite bands are 1 cm to several cm thick. The thin bands are typically intricately folded at the hand-specimen scale, with an axial plane crenulation cleavage forming the dominant plane of fissility of the phyllites.

In addition to the above major phyllite units there are four subordinate phyllite units that may represent up to 15% (by volume) of the formation: (Jennings and Jilson, 1986):

a) Black, variably calcareous and commonly dolomitic, thinly layered, quartzose phyllite;
b) Soft, medium grey to black, homogeneous, non-calcareous phyllite lacking in quartz siltstone layers.
c) Medium grey, non-calcareous phyllite, thinly interlayered with quartz siltstone.
d) Medium grey phyllite with thin quartz dolomite layers

A variety of the black phyllite is found in association with the sulphide orebodies, and near the base of the Vangorda Formation. This unit is pervasively foliated, homogeneous, variably siliceous, hard, fine grained, with minor (1%) disseminated pyrite and pyrrhotite.

Metabasites or “greenstones” are the most abundant subordinate rock unit within the Vangorda Formation. Compositionally, these rocks are of basaltic composition. This meta-igneous rock accounts for about 15%-20 % of the Vangorda Formation, but is conspicuous because of its resistance. Local crosscutting contact relationships and fine grained texture support an intrusive origin. This unit is associated with a green phyllite that may represent tuffs or mafic flows.

The ore deposits are confined to an approximately 150 m thick interval straddling the Mount Mye-Vangorda formation contact zone. This stratigraphic position indicates that the mineralization is Cambrian in age (Pigage, 1990). The deposits consist of one to five sheets of sulphide mineralization, with interbanded metasedimentary rocks. All ore types in the Anvil districts are described as completely recrystallized metamorphic tectonites containing well developed foliations. The main ore types consist of massive and quartzose ores (Pigage, 1990):

<u>Massive Sulphide Ores:</u>

The entire right abutment of the dam and a portion of the downstream left abutment is composed of massive sulphide ore. The following descriptions provide details on the nature of these rock units:

- Massive pyritic sulphides consisting of banded to homogeneous, usually weakly foliated and or lineated massive pyrite with lesser sphalerite and galena. Total sulphide content is at least 60% and may be up to 100%. Accessory minerals include pyrrhotite, chalcopyrite, magnetite, arsenopyrite and marcasite. Gangue minerals include quartz, barite and carbonates.
- Baritic, massive pyritic sulphides is a strongly to thinly banded massive sulphide/sulphate rock consisting of pyrite, galena, sphalerite and commonly magnetite in a gangue of barite and lesser carbonates. Barite content ranges up to 50%. Pyrrhotite is not commonly associated with this facies except at the Faro deposit where pyrrhotite is more abundant overall.
- Carbonate bearing, massive pyritic sulphide is similar to the massive pyritic sulphides but contains 10% carbonate and is a relatively minor facies.
- Pyrrhotitic massive sulphides consisting of massive, finely crystalline, usually well foliated pyrrhotite with less than 50% pyrite and highly variable amounts of sphalerite and galena. Minor chalcopyrite is characteristic of this copper rich facies. This is a minor facies except at the Faro deposit.

Post-metamorphic breccias are common within the massive sulphides (Pigage, 1990), especially in the massive pyritic and pyrrhotitic facies. The origin of the breccias may be related to ductility contrasts between the sulphides and adjacent lithologies during sulphide flow induced by deformation and metamorphism (Pigage, 1990). Friable and porous massive sulphides are relatively common and when strongly developed, degenerate to a pyrite sand. These units are commonly carbonate or barite bearing and originated by post-metamorphic groundwater leaching and oxidation, especially near faults (Pigage, 1990).

<u>Quartzose Disseminated Sulphide Ores:</u>

- Ribbon banded, “graphitic”, pyritic quartzite is a dark grey, well banded sulphide-bearing quartzite. The dark grey bands consist of very fine grained, carbonaceous phyllitic quartzite to siliceous phyllite. The light grey bands consist of more coarsely crystalline, quartz-sulphide (pyrite-sphalerite-galena) interbands. Total sulphide content is between 2%-60%, with pyrite being the dominant sulphide.

- Pyritic quartzite is a light grey, generally poorly banded, moderately to weakly foliated micaceous quartzite with a highly variable base metals and pyrite content. Pyrite content ranges from 2% to 60%, with a complete gradation from massive sulphide to quartzose ores. Barite, chalcopyrite, pyrrhotite and magnetite bearing varieties are common. Sphalerite may be present in high-grade varieties. A thick interval of this unit is found at the northeast edge of the Faro deposit, containing elevated copper and magnetite.

The Anvil batholith was intruded during the Cretaceous into the metamorphic sequence. The dominant rock type ranges from a biotite-muscovite granite to a hornblende-biotite granodiorite.

The Anvil batholith and surrounding metasedimentary rocks were intruded by late and post-metamorphic intrusive rocks of Cretaceous age as large plutonic bodies, dikes, sills and plugs. Three major intrusions are recognized and are collectively termed the Anvil Plutonic Suite, ranging in composition from granite to granodiorite (Jennings and Jilson, 1986). Within the Faro Pit, a prominent set of northeast trending, porphyritic, medium to dark green hornblende diorite dikes are commonly associated with faults and fractures. A large diorite body was found within the north end of the Faro Pit and northeast of the Zone 2 Pit. (Jennings and Jilson, 1986). This unit has produced an extensive zone of brecciation locally involving the sulphide deposit.

Intrusive rocks in the mine area consist of the following (Piteau Gadsby Macleod, 1975):

- Hornblende- biotite quartz diorite dikes (also forms large plug in north end of Faro Pit)
- Fine grained, grey, biotite diorite dikes.
- Quartz feldspar porphyry dikes (late stage-undated)
- Fine grained, dark green chloritic metamorphosed andesite dikes.

Figure 8 is a geological plan showing the major bedrock units inferred from the above descriptions as well as structural mapping data obtained during the reconnaissance investigation.

2.2.3 Structural Geology

The Anvil deposits occur on the south limb of the Faro Anticline. Five phases of deformation are recognized within the meta sedimentary and metavolcanic rocks hosting the orebodies (Pigage, 1990). The first two phases occurred in mid-Mesozoic time and involved intense deformation and metamorphism that resulted in establishing the gross overall structure of the mineral deposits. The remaining deformational phases were only locally developed and did not tend to form large or significant structures.

The original bedding (S_0) appeared to control the deposition of the sulphide orebodies. The first deformation (D_1) produced a regional metamorphic foliation (S_1) axial planar to tight to isoclinal mesoscopic folds (F_1) within the bedding (S_0). The larger scale folds associated with D_1 have fold axes that plunge to the northwest or southeast and are either vertical or inclined to the northeast.

The second deformation event (D_2) strongly crenulated the S_1 foliation and produced tight folds in S_1. The S_0 primary bedding was aligned nearly parallel with the S_1 foliation. Parallel to the axial planes of the D_2 folds is a crenulation cleavage (S_2). The F_2 axial planes and the S_2 axial plane foliations dip shallowly to the southwest in the pit area.

The subsequent deformation events (D_3 to D_5) generally produced open folds and weak crenulations in S_2 related to broad regional structures. In the vicinity of the Faro Pit, D_4 produced tight folds within the S_2 and associated axial plane crenulation cleavages.

The Anvil Batholith was intruded in the later stages of this deformation sequence, further deforming the metamorphic sequence into a northwest-southeast elongated dome, cored by the batholith. The later stages of emplacement were accompanied by large scale extensional faulting along the margins of the batholith. The faults developed in association with late D_2 deformation and delimited several of the deposits (Pigage, 1990). The quartz diorite dikes appear to be associated with these faults.

Metamorphic grade ranges from upper amphibolite facies (sillimanite- muscovite) to lower greenschist facies (muscovite- chlorite). Metamorphic isograds are roughly concentric around the Anvil batholith and are truncated by the late D_2 extensional faults (Pigage, 1990). The Faro deposit is the closest deposit to the batholith and is metamorphosed to amphibolite facies.

2.2.3.1 Faults

The Tintina and Vangorda Fault Zones form the southwest boundary of the Anvil District. Within the mine area, numerous smaller faults are locally important. These faults tend to be grouped into two major trends 60^{o} and 340^{o} (Jennings and Jilson, 1986). Most of these faults are moderately to steeply dipping normal faults that appear to be related to the post-metamorphic extensional fault system, possibly related to the emplacement of the Anvil batholith. Some faults show strike-slip displacement, possibly related to offset on the Tintina Fault. Some older faults, possibly related to the D_1 deformation phase are present locally (Jennings and Jilson, 1986).

In the Faro deposit, the central Zone 3 is bounded by several faults forming a graben structure. These normal faults are inferred to be post-D_2 (and D_3?) (Jennings and Jilson, 1986). Numerous other sets, mapped at the pit scale are known, with relatively small displacements.

Locally, in the vicinity of the plug dam, several faults have been mapped that pass through the right abutment. Limited information is available on these features, which are described in Section 2.3, which summarizes Faro Pit design information.

2.3 Faro Pit Design Information

Previous engineering geological studies for design of the Faro Pit wall provide some details regarding discontinuities that may be applied to assessing the abutments and foundation of the proposed plug dam. A major source of information was a report prepared by Piteau Gadsby Macleod Limited (PGML) (1975) on the analysis and design of the open pit slopes. Subsequently, SRK (1988) assessed the feasibility of underground mining in the southwest corner of the pit. Prior to mining, there was limited exposure of the rocks hosting the Faro Pit. Therefore detailed information had to be obtained from exposures within the pit itself as it was mined.

2.3.1 Jointing and Structural History

During the reconnaissance mapping, gathering of joint set data was difficult due to colluvial cover and inability to access some of the slopes. As a result the data set is rather sparse. Previous investigations and mapping in the pit during active mining revealed the complex deformational history and structure of the rock units. The following details are pertinent to assessing the overall rockmass characteristics at the plug dam site.

The main metamorphic event (D_2) produced a well-defined foliation, which generally strikes 110^o to 120^o and dips 20^o to 60^o SW (PGML, 1975), but has a wide range of orientations depending on location within the pit. Major faults were used to subdivide the pit into structural domains. Each structural domain has approximately similar structural geology characteristics. With respect to pit wall stability, the orientation of the foliation was the prime factor used to delineate the final structural domain boundaries. The variation in joint populations was not considered to be as significant in this regard (PGML, 1975). Foliation dipping into the pit constituted a major discontinuity set along which instability could develop. Due to the regional dip of the foliation, stability of the east wall of the pit is adversely affected. The orientation of the foliation rotated such that it dips to the south in the vicinity of the Faro Creek valley, southwest between Faro Creek and the Faro Fault and west in the calc-silicate gneisses and associated rocks south of the Faro Fault, in the south end of the pit. Hence the foliation dips towards the pit over the entire east wall of the pit, resulting in several large-scale pit wall instabilities.

PGML (1975) processed and summarized joint data from geological mapping as stereographic plots for each domain. Core orientation data was also analyzed but proved to be inconclusive (PGML. 1975). Five pronounced joint sets plus a few inconsistent or randomly distributed groups were found within the pit limits. The faults within the pit area were found to be generally similar in attitude as the main joint sets. The following is a summary of the joint set data compiled by PGML (1975):

- Joint Set A: Joints formed parallel to sub-parallel to the foliation and compositional layering. The average dip of these joints may be slightly steeper than foliation. These joints are very prominent and control the stability of the slopes on the east side of the pit.

- Joint Set B: Joints that strike approximately east-northeast to east and dip steeply to the south. These joints are particularly well developed in the intrusive rocks and are probably related to the emplacement of the intrusion.
- Joint Set C: Joints that strike approximately southeast to south and dip vertical to sub vertical. These joints are also well developed in the intrusive rocks and are probably related to intrusion.
- Joint Set D: Joints that strike approximately east- west and dip steeply north. These joints may be related to joints of Joint Set B.
- Joint Set E: Joints that strike approximately east-southeast and dip about 60^{o} to 70^{o} south. These joints are not present in all structural domains.
- Miscellaneous Sets: These sets occur throughout the pit and may be significant on a local basis only.

Joint frequency and persistence varies considerably depending on lithology and, possibly on proximity to major faults. Joints and faults of Joint Set A are well developed in the schistose rocks. Cross joints of Joint Sets B, C, and D are well developed in the brittle intrusive dikes, calc-silicate gneiss and massive sulphide rocks, but not as prevalent in the more ductile and deformable schists (PGML. 1975).

In 1988, SRK undertook structural mapping in the southwest corner of the pit to assess the rock mass for underground mining. The site is characterized by a dominant foliation (S_2) dipping to the southwest at 14^{o} to 22^{o}. Two prominent joint sets were identified. The first had a vertical dip and a strike of 168^{o}, which corresponds to Joint Set C mapped by PGML (1975). The other set had a strike of 78^{o} and a dip of 50^{o} to the south, comparable to Joint Set B. A third set had a strike of 95^{o} with vertical dip, possibly corresponding to Joint Set D. Fault sets comparable to these joint sets were also mapped.

2.3.2 Faults

Numerous small-scale fault sets were mapped that were approximately parallel to the above noted joint sets. Most of the mapped sets were moderately to steeply dipping and parallel to Joint Set A.

Fault Set A is common in the schists or in the schist bands within the more competent gneissic or ore rocks. The fault zones contain very soft, fine-grained micaceous clay gouge, up to 30 cm wide. In some faults the micas are closely aligned and it is often not clear whether the gouge zones are due to movement or to intense alteration of the softer schist bands in the sequence. For engineering purposes, the implications of the gouge zones are similar, regardless of origin. Some of these faults extend over the entire slope and are significant to the overall stability of the slope. There is little evidence for fault breakage or brecciation along the margins of the faults and the sense of movement is difficult to determine. Undulations on the fault planes are generally conformable with the waves of the foliation (PGML, 1975).

Faults Sets B to D are steeply dipping and related to the intrusive events or to cross jointing in the pit. These faults are present in all rock units, but are especially prevalent in the harder gneisses, massive sulphides and dike rocks and may extend over two or more benches. Fault zones contain both gouge and breccia and often have a zone of intensified fracturing in the adjacent rocks. Movement and offset across the faults is usually obvious. In schists, the gouge zones contain micaceous clay filling. In stronger rocks, the fault gouge is usually a stiff clay matrix with fine to coarse-grained fragments.

The most significant fault in the pit is the Faro Fault. The fault has an average strike of 106^o and a dip of 40^o south and appears to offset the south part of the orebody by about 46 m (PGML, 1975). Drag folding and offset of the orebody indicates a normal displacement with the south block being displaced downwards relative to the north block. The fault zone consists of a conspicuous 1 m to 3 m wide zone of extremely soft and sheared graphitic schist material. The fault is well defined on the east wall of the pit but was difficult to locate in the ore zone or on the west wall (PGML, 1975). Its attitude within the pit was highly variable due to the effects of dikes and rock strength variations.

Additional data on the description of faults within the Faro pit were obtained from a series of reports prepared by Piteau Associates Engineering Ltd. between 1991 and 1992 (Piteau 1991(a), (b), (c), (d), 1992). These reports reviewed geological mapping as the pit was developed, with respect to slope stability, particularly the east pit wall. Ten major faults were identified within the pit:

- North Bound (NB)
- North Bound Splay (NBS)
- Lower Bound (LB)
- AY
- Big Indian Splay (BIS)
- JB
- Faro (FRO)
- Graben A (GFA)
- Graben B (GFB)
- South (SOU)

As mining progressed, mapping of these structures revealed the following details:

- The overall dip of the structures was steeper than the pit slope, but could flatten with depth resulting in planar or wedge failures that could daylight on the slope at lower elevations. Several large potential wedge failures were identified in the northern portion of the east wall.
- The NB fault is a wide fault zone that strikes obliquely to the east wall has a dip ranging from 60^o to 87^o to the west (275^o to 300^o)

- The Big Indian fault dips about 55^{o} southeast. This structure is responsible for the "south slump area" in the southern portion of the east wall.
- The Faro fault strikes almost perpendicular to the east wall and dips moderately steeply to the south, having an average dip direction/dip of $195^{o}/57^{o}$ (Piteau, 1992).
- The Faro Fault and NB Fault intersect and were considered to have a potentially significant affect on slope stability.

The traces of mapped faults in the vicinity of the plug dam are shown in Figure 8. The locations of these structures were obtained from SRK (1991), based on fault locations mapped by Curragh Resources Inc in 1988. Based on the fault traces shown, with respect to the topography, the dip of most of these structures appears to be sub-vertical as they cross through the pillar of rock between the Faro and Zone II pits.

2.3.3 Rock Mass Properties

The SRK assessment included point load strength tests on samples of drill core. A "Mining Rock Mass Rating" (MRMR) system was used to classify each of the rock units on the basis of intact rock strength, fracture frequency and fracture condition. In general, phyllites received MRMR ratings between 30 and 40 ("POOR"), graphitic quartzites rated values between 40 and 50 ("FAIR") and massive sulphides were rated at 50-65 ("FAIR-GOOD"). The massive sulphides lacked foliation, but the high rating did not account for the hidden, healed fractures revealed by point load testing. Broken or fractured sulphide zones rated at 30 to 50 ("POOR-FAIR"). Unconfined compressive strengths of massive sulphide rock units ranged from 56 MPa to 175 MPa, compared to footwall and hanging wall rocks, which ranged from 8 MPa to 193 MPa.

2.4 Hydrogeology

Much of the assessment of groundwater conditions in the Faro Pit was carried out in conjunction with concerns regarding the stability of the east pit wall. In 1986, Piteau Associates Engineering Ltd. (Piteau) carried out a drilling and piezometer installation program to determine groundwater conditions in the pit, to estimate the contribution of this water to pit accumulations and to determine if wells or drains could relieve the water pressures. Although these investigations were carried out in a different section of the pit than the area of the plug dam, the following important observations were made regarding the hydrogeological characteristics of the rock mass (Piteau, 1986):

- The soft intrusive rocks near the bedrock overburden contact appeared to be relatively impervious.
- Falling head tests in a zone of altered schist below a dike contact yielded a hydraulic conductivity of 6.4×10^{-5} cm/s. Higher hydraulic conductivities were found in an adjacent hole (> 1×10^{-4} cm/s). The contact zones of the dike may serve as a significant conduit for groundwater.

- The Big Indian Fault system was found to act as a drain to the less permeable rocks in the immediate vicinity.
- A second hole designed to intersect the Big Indian Fault zone intersected impervious phyllites and only a small seep of water at the phyllite-massive sulphide contact.
- Water levels in all piezometers in the east wall were relatively high, indicating that the east wall does not drain freely towards the pit. Some of the structural features that maintain high groundwater levels in the east wall are the porphyry intrusive dikes, which have gouge-filled planar contacts striking parallel to the pit wall. Seepage flow is directed laterally and upward along these contacts.
- Gouge filled structures in phyllite associated with the Big Indian Fault impede groundwater flow towards the pit in the same manner as intrusive contacts.
- An average hydraulic conductivity of 3 x10^{-6} cm/s was determined from the piezometer nests in the east wall. The piezometers were selectively set in permeable structures within the boreholes, resulting in a high average value for the bulk material. The direction of greatest permeability is sub-parallel to the east wall.
- Only a few small isolated seeps are contributing groundwater accumulations of water in the pit.
- No significant yields of groundwater were experienced from any of the boreholes, indicating that relief wells would not be and effective means of reducing groundwater pressures.
- Dewatering wells can be successful in well defined structures in the massive sulphide orebody.

In 1991, SRK studied various plug dam options in conjunction with the assessment of tailings disposal within the Faro pit. As part of these studies, the hydrogeology of the Faro and adjacent Zone II pit were assessed. The prime concern was the potential for seepage from the Main pit to the Zone II pit, and from the Zone II pit to the North Fork of Rose Creek.

Water enters the Zone II pit by direct seepage from the Main pit and by infiltration through the waste rock piles, which completely cover the pit. The Zone II pit is partially flooded and pumping is carried out from a well installed by Curragh Resources in 1991 into the deepest point of the pit, as shown in Figures 2, 3 and. 8. This pump well is operated intermittently, as discussed in the previous section to remove accumulated water from the Zone II pit and return it to the Faro pit via a water line that lies in the ditch adjacent to the haul road, as shown in Figure 2.

The quality of water from the Zone II pit is poor, therefore the pump well discharge is fed back into the Main Pit via a pipeline that is laid along the access road into the main pit. Figure 7 is a graph showing water levels in the Zone II pit. The overflow point at which Zone II pit water will flow into the North Fork of Rose Creek is at about elevation 1128 m amsl. In general, the Zone II water levels have been maintained below elevation 1105 by intermittent pumping. Average pumping rate is 0.024 m^3/s (375 USGPM).

SRK identified three locations within the pit that are likely to have some permeability of significance:

- The north wall in the vicinity of the Faro Creek valley;
- The southwest wall, also related to Faro Creek;
- The southeast corner of the pit, adjacent to the Zone II pit.

The first location is a zone of seepage into the pit. Although important from the perspective of overall pit hydrology, this area is not impacted by the construction of the plug dam.

The other two sites are potential areas of seepage loss, and will be impacted by the flooded pit.

The south wall of the pit near the former Faro Creek valley was not investigated by SRK in 1991. They report however that the lowest bedrock elevation "…is thought to be approximately 3800 feet UTM" (1158.24 m amsl), "… with a maximum 50 foot thickness of porous sediments on top of this". This would put the original ground surface at elevation 1173 m amsl within the Faro Creek valley. Waste rock covers the original ground so that the minimum elevation in the area is 1181 m amsl, along the barge access roadway into the pit. Flooding of the pit above elevation 1158 would therefore be expected to result in some seepage through the sediments as well as the rockfill, depending on pit water level. The seepage would lead to an increase in base flow in Faro Creek. SRK assumed that the maximum thickness of sediments extended over a 122 m (400 ft.) length of pit perimeter. Applying Darcy's Law and with assumed representative values for hydraulic conductivity and gradient of 1×10^{-4} cm/s and 0.1 respectively, the estimated seepage through this zone was calculated to be about 8 m^3/day.

The SRK report essentially summarized the data collected by Piteau (1986), which was described above.

The proposed plug dam will close off the potential seepage zone between the Main pit and the Zone II pit. The location of the Zone II pit is shown in Figures 2 and 3. Cross-sections between the Main Pit and the Zone II pit are given in Figure 4.

SRK (1991) reported that very little information existed regarding the geology of the Zone II pit. Competent quartzite and sulphide rocks are common around the pit outline, with sulphides concentrated along the southern and eastern boundaries. The condition of these wall rocks will dictate the volume of seepage from the main pit after it is flooded.

The following information was obtained from SRK (1991) regarding the hydrogeology of the Main Pit-Zone II pit area:

- During mining of the Main pit, seepage in to the Zone II pit is thought to be minimal owing to the depression of groundwater levels as a result of mining and dewatering continuing in the Main pit.

- In March 1989, a higher than average concentration of zinc was reported in the X2 monitoring station on the North Fork of Rose Creek above the mine access road. At the time, water levels in the Zone II pit were rising and reached about elevation 1125 m amsl in October of 1989. It was suggested that seepage had occurred from the Zone II pit into the Rose Creek drainage. Note that the overflow "lip" of the pit is at about elevation 1118 m amsl.
- Pumping of the Zone II pit began in early 1991 to reduce the potential for seepage as a temporary precautionary measure.
- Four monitoring boreholes were installed in the area between the Zone II pit and Rose Creek to investigate pathways for potential seepage migration to the creek. The boreholes encountered 3-5 m of silty sand and gravel resting on phyllite bedrock. The lower metre or so of the overburden was saturated.
- The plug dam area is characterized by a high degree of fracturing and jointing in the floor and wall rocks, and several individual and mapable fractures of the Big Indian fault system are in close proximity. The potential for seepage from the Main pit via fracture flow in this area is therefore considered to be high and warrants consideration of control measures.
- Below elevation 1143 m amsl, the wall rocks are predominantly schists and phyllites, which do not maintain open fractures to any great depth. Based on this assessment SRK assumed that there would be no seepage out of the main pit below elevation 1143 m amsl.
- Flooding of the pit above elevation 1143 m amsl would expose the southern and south-eastern corners of the pit to seepage loss through the rock mass. SRK assumed hydraulic conductivities ranging from 1×10^{-3} to 1×10^{-4} cm/s as likely for the rock below the dam, necessitating some type of seepage cut-off.

Seepage out of the pit through the sediments along the former Faro Creek will occur with any impoundment of water above elevation 1158 m amsl. BGC has not assessed the requirements for seepage control in this area under the current terms of reference. Further work will be required to confirm bedrock elevations and the hydraulic conductivities of overburden and bedrock units in this area at a subsequent phase of study. Potential treatment measures for controlling seepage through this area include grouting of the alluvium, constructing a slurry wall cutoff trench down to bedrock or constructing an impervious blanket over the area to prevent infiltration. The selection of an appropriate seepage control option will require an extensive program of geotechnical investigations to determine bedrock topography and the hydraulic properties and distribution of the overburden units.

3.0 FIELD RECONNAISSANCE

3.1 Site Conditions

The physical dam site area comprises the south wall of the Faro pit, the Zone II pit, the waste rock dumps and the North Fork Rose Creek channel. These elements are shown in plan on Figure 2

BGC carried out a geological reconnaissance of the plug dam site between September 20 and 22, 2003. At the time of the site visit, a minor dusting of snow covered the exposures of bedrock and overburden in the dam area. Daily temperatures fluctuated between -5^{o} C to 5^{o} C. A limited amount of bedrock mapping was carried out due to restricted access to benches and the pit wall slopes and accumulation of ravelled rock and colluvium along the toes of individual benches. The field mapping was complimented by airphoto interpretation of recent (July 25, 2003) airphotos flown of the Anvil Range area at a scale of 1:20,000.

Selected photographs of the dam site are included in Appendix I. A geological plan showing the distribution of the major surficial geology map units and bedrock structural data is presented in Figure 8

At the time of mapping, water level in Faro pit was at about elevation 1141 m amsl. At this elevation, the pit water is completely contained by the surrounding bedrock within the pit walls. The haul road forming the foundation of the plug dam area is founded on bedrock, which rises to a maximum elevation of about 1158 m amsl, just before the edge of the Zone II pit. The Zone II pit has been completely filled with waste rock, which reaches a maximum elevation of about 1208 m on the right abutment.

Bedrock is exposed up to elevation 1180 m on the right abutment and about 1178 m on the left abutment, where it steadily rises to above elevation 1200 m amsl further to the east, along the east wall of the pit.

The left abutment is overlain by up to 12 m of overburden, on top of which waste rock has been piled in localized areas.

3.2 Geological Conditions

Details of the dam site geology are presented on Figure 8. The dam site is located in a rock cut 40 m wide along a mine haul road that traverses the saddle between the Main pit and the Zone II pit. The haul road slopes at an average grade of about 4% towards Faro pit. The road is founded entirely on bedrock, which is covered with rockfill and sand and gravel road base materials. The depth of the road fill is unknown, but appears to be less than 1 m within the dam site area. Bedrock elevations within the haul road cut range from about 1152 m amsl at the edge of the Faro pit wall towards the north and to about 1158 m amsl at the edge of the Zone II pit to the south.

Beyond the southern edge of the bedrock in the haul road cut, the road is founded on waste rock fill within the former Zone II pit. The waste rock dumps form the slopes on either side of the roadway through the former Zone II pit area. The road grade continues to rise to about elevation 1165 at the junction of the mine road to the Faro Creek Diversion Channel. At this point, the waste dumps cover the deepest part of the Zone II pit. Pit bottom is at elevation 1060 at this point.

Three major geological units were identified within the dam site area:

- Mine disturbed (Unit MD) units, including waste rock, fills and colluvial debris from man-made excavations in overburden and rock.
- Undisturbed, native overburden materials (Unit Q).
- Bedrock (Unit R)

The following sections describe each of these units in more detail.

3.2.1 Mine Disturbed Units (MD)

These are units associated with man-made disturbance due to mining related activities. Three major sub-units were distinguished:

- Undifferentiated colluvial debris (Unit MDc).
- Undifferentiated waste rock (Unit MDw)
- Undifferentiated fill (Unit MDf)

3.2.1.1 Undifferentiated Colluvial Debris (Unit MDc)

This is an unconsolidated, heterogeneous unit comprising various proportions of ravelled and weathered bedrock fragments (talus), overburden and waste rock. Grain size ranges from silt to large boulders of detached bedrock up to 1 m in dimension. This unit typically drapes the toes of individual rock benches excavated during mining. In some areas, the entire slope face may be covered with colluvial debris resulting from erosion of exposed overburden and waste rock higher up the slope. Thickness varies from a thin veneer on individual benches up to several metres where a large talus cone has formed.

3.2.1.2 Undifferentiated Waste Rock (Unit MDw)

Waste rock dumps cover an extensive area around the crest of the Faro pit. Waste rock is primarily phyllite, with minor amounts of sulphide rich material. The unit comprises mainly blasted bedrock fragments with a wide range of sizes, typically up to 0.5 m in maximum dimension. Some of the phyllite has broken down in the dumps due to weathering, producing finer grained detrital material. The foliated structure of the metamorphic rock units making up the waste rock imparts a tabular to slabby shape to the individual rock particles. Rock strength of individual fragments is highly variable. The strongest units are the massive sulphides and quartzites, which are very strong (unconfined compressive strengths (UCS) > 100 Mpa) and hard (R6). The weakest units are the schists and carbonaceous phyllites (UCS < 25 Mpa), which also tend to decompose in situ.

The waste rock has been placed by end dumping and has an average angle of repose of 34^{o}. The depth of waste rock is highly variable. On the right abutment, the waste rock slope is about 20 m high above the top of bedrock. The maximum thickness within the Zone II pit is about 140 m.

A small waste rock dump, 10 m high covers undisturbed overburden on top of the left abutment.

3.2.1.3 Undifferentiated Fill (Unit MDf)

This unit includes all constructed fill such as, embankments, dikes and road bedding. Dikes and embankments associated with water diversion ditches may contain a geomembrane liner composed of high-density polyethylene (HDPE) as well as geotextiles. Within the dam site area, this unit includes the haul road fill, the diversion ditch embankment on the left abutment and the haul road on top of the left abutment.

3.2.2 Undifferentiated Native Overburden (Unit Q)

Native, undisturbed overburden units in the vicinity of the mine site are inferred to be of Quaternary age, deposited during or subsequent to the last Pleistocene glaciation. At the dam site, this unit is exposed along the top of the left abutment, where it overlies weathered bedrock above elevation 1178 m amsl. The unit consists primarily of a heterogeneous mixture of silt, sand, gravel, cobbles and boulders. The unit is inferred to be, at least in part, colluvial in origin, based on the presence of embedded woody debris and angular clasts of weathered bedrock detritus. The exposed slopes are dry. The dominantly silty matrix is non-plastic, light brownish grey (dry) to dark brown (moist), and dense to compact.

3.2.3 Bedrock (Unit R)

Detailed bedrock mapping was not possible during the reconnaissance investigation carried out at the dam site. Nevertheless, at least four major rock types were distinguished within the dam site area. These units were correlated with previous mapping done in the Faro Pit by SRK (1991), shown in Figure 8.

The rock units straddle the contact zone between the Mt. Mye Formation, of Lower Cambrian age and the overlying Vangorda Formation of Cambrian to Lower Ordivician age. The sulphide bearing units of the Faro deposit occur in the lowermost section of the Vangorda Formation.

3.2.3.1 Vangorda Formation (Unit RV)

At the reconnaissance mapping level, two sub-units were distinguished at the dam site:

- Unit RV1: Comprising calc-silicate gneiss, carbonaceous schist, schist, chlorite schist and calc-silicate. This unit is exposed at the top of the right abutment, under the waste rock and extends south into the Zone II pit and west along the crest of the Faro pit wall. The calc-silicate strata within this unit tend to be resistant to weathering, compared to the schist units, which are recessive. As a result, detrital material from the schist units form colluvial aprons over the lower benches of the right abutment. Loosened blocks of the more resistant units become undercut by recessive weathering and roll down the slope. Undercutting of the crest of the pit wall has resulted in localized slides of the overlying waste rock into the pit.
- Unit RV2: These units are part of the Faro deposit and comprise two units, which were not mapable as independent units;
    - Ribbon banded graphitic pyritic quartzite and undifferentiated non-graphitic sulphide bearing quartzite.
    - Barren massive pyrite and massive pyritic sulphides.

On the right abutment, these units are exposed along the toe from upstream of the dam axis along the Faro pit wall to downstream of the dam axis. On the left abutment, sulphide bearing rock is exposed downstream of the dam axis to the edge of rock at the Zone II pit margin. In general, these units are very strong and hard, with blocky jointing in the right abutment, but become earthy where faulted and sheared in the left abutment, downstream of the dam.

3.2.3.2 Mt. Mye Formation (Unit RM)

Two major rock units were distinguished:

- Unit RM1: Consists of fine biotite-muscovite-andalusite schist, dark grey carbonaceous schist, chlorite schist, altered meta-basic intrusive, grades downward into biotite-muscovite-garnet-staurolite-andalusite schist. This unit is the dominant rock type in the right abutment, extending upstream of the dam and eastward along the south pit wall. The upper 4-5 m of this unit is highly weathered, almost to a residual soil consistency.
- Unit RM2: Altered quartz muscovite schist (white mica envelope). This unit is in faulted contact with the sulphides (Unit RV2) on the right abutment where it is mapped between the sulphides (Unit RV2) and the overlying calc-silicate gneiss (Unit RV1). On the left abutment it was mapped in fault contact and/or interbedded with Unit RV2 downstream of the dam (SRK, 1991), but these details were not discerned during reconnaissance mapping. This unit is considered a marker horizon with respect to the sulphide ore bodies of the Anvil Range.

3.2.4 Bedrock Structural Data

Figure 9 presents a lower hemisphere stereoplot of the bedrock structural measurements taken in the exposed rock cuts in the vicinity of the dam site. A total of 26 measurements were made. Collection of structural data was limited due to colluvial cover along the toes of individual rock benches, as well as danger of rockfall from degrading slopes overhead. The main discontinuities were the foliation and various joint sets. Although pit geology maps show that the right abutment is cut by several branches of the Big Indian Fault system, these features could not be discerned during the reconnaissance inspection. This is due mainly to the colluvial cover on the slopes- likely generated as a result of the faulted nature of the rock.

The dominant rock structure is the shallow southwest dipping foliation. On the left abutment, the bench slopes are parallel to sub-parallel with the dip of the foliation, which ranges from 15^o to 43^o on the right abutment, the foliation dips into the abutment, with bench faces formed along the dominant cross-joints intersecting the foliation.

The measured joint sets are consistent with previous mapping carried out in the pit (PGML, 1975). At least 5 sets exist, including foliation joints, which lie in the plane of the foliation. Intersecting joints form unstable wedges in the left abutment. At least three wedge failures have resulted in slides affecting the lower bench between the haul road and elevation 1170 m amsl. These failures have destroyed part of the diversion ditch embankment on the 1172 bench resulting in portions of the HDPE liner becoming breached. Water from the diversion ditch flows down the left abutment face, downstream of the dam centreline.

Average joint spacing in the left abutment is about 30 to 50 cm, with persistence of up to 2m. The left abutment joint pattern is blocky-rhombohedral due to the intersection of the foliation joints with steeply dipping cross-joint sets. The joints are dilated on the bench faces due to weathering and frost action, but are expected to be tight at depth.

On the right abutment, joints were not well developed in the schistose rock units. Blocky joints spaced 20-30 cm apart are well developed within the sulphide units upstream of the dam (Unit RV2), but not prominent elsewhere. The uppermost bedrock on the right abutment is suspected of being heavily disturbed by blasting from both the Faro pit and Zone II pit sides. As a result, the narrow pillar of rock separating the two pits, which is also transacted by several branches of the Big Indian Fault system, is expected to contain a network of open discontinuities that will require grouting in order to prevent seepage around the dam.

4.0 CONCEPTUAL DAM DESIGN

4.1 Previous Design Work

SRK (1991) conducted a conceptual design study of two plug dam alternatives:

- A central core dam using compacted till and rock fill.
- A slimes plug dam consisting of two rock fill dikes enclosing an interior section containing slimes (tailings).

Material quantities were calculated for each alternative and a preliminary capital cost estimate was prepared for each alternative.

Both concepts were designed in conjunction with a spillway outlet for the Faro Pit located in the Faro Creek valley on the west side of the pit. Maximum pit water level was set at 1173 m amsl. The spillway should have the capacity to pass the design flood at decommissioning without overtopping the plug dam.

The till core dam consists of an earth and rockfill dam with a central till core and rockfill shells. A core trench was proposed if the rock was rippable. Blasting was not recommended. A grout curtain was considered as an alternative to the core trench. The dam was located across the narrowest section of the rock cut. Final dam location would be selected to minimize the volume of fill required, while taking advantage of the most favourable rock conditions in the foundation and abutments.

The slimes dam alternative consists of tailings slimes being spigotted into an area enclosed by two plug dams. The upstream plug dam was located just inside the Main pit, with the second plug dam to the south to prevent the tailings from spilling into the Zone II pit. The slimes would seal the bedrock surface between the dams and in the abutments. The upstream dam was designed to retain the slimes only and not water. The dam would be constructed of compacted rockfill with a filter zone on the slope facing the interior tailings zone to prevent the spigotted tailings from washing through the rockfill.

The dam at the southern end of the rock cut would consist of a rockfill shell with a sloping layer of compacted till on the upstream face to retain both slimes and water. A filter zone between the rock and till would be provided.

The slimes were supposed to be cycloned from the mill discharge line. Although the mine is no longer in operation, using tailings in this manner to construct the dam could still be an option. In the original scheme, the slimes from the mill were potentially acid generating. A compacted till cover was required to limit oxygen entry and potential acid generation. Another alternative would be to create slimes by milling barren waste rock, free of sulphides, to create an inert core. In the original scheme, no core trench or grout curtain was included. A grout curtain is considered necessary to prevent seepage losses into the Zone II pit through the right abutment above elevation 1143 m.

SRK also considered a roller compacted concrete (RCC) dam option, but did not prepare a conceptual design or cost estimate for it. SRK mentioned that although the unit cost of the fill is greater than earth and rockfill, the total volume required is substantially less and the total costs could be comparable. Another advantage of the RCC option is the shorter period for construction, which would be an advantage due to the short construction season at the site. The RCC structure could also withstand overtopping in contrast to an earthfill dam option.

4.2 Design Criteria

The main site constraints governing the conceptual layout of the dam are the bedrock elevations in the abutments, the geometry of the excavated bedrock slopes, the properties of the dam construction materials and the depth of foundation treatment required. Overall, as a water retention structure, the design must meet the dam safety requirements for the appropriate class of dam as described in the Dam Safety Guidelines (CDA, 1999).

4.2.1 Retained Pit Water Level

From a topographic perspective, the overall length of dam increases significantly above about elevation 1180 m amsl, which is the top of the natural ground surface on both abutments. On the right abutment, the top of the waste rock pile is about elevation 1208 m amsl, however consideration for any dam height above elevation 1180 is impractical because it would require sealing the entire pit perimeter on the south and west sides. As mentioned in Section 2.4, the lowest topographic point on the west side of the pit is 1173 m amsl in the former Faro Creek valley. Bedrock is estimated to be at elevation 1158 m amsl at this location.

These factors would further constrain the maximum reservoir level to less than elevation 1173 m amsl, assuming some seepage is acceptable through the overlying sediments in the Faro Creek valley. At the dam site, the upper 4-6 m of rock on the left abutment is very highly weathered and would likely require a positive cut-off in the form of a core trench for at least 10 m into the abutment. Assuming top of rock at elevation 1178 m amsl, this would constrain the maximum reservoir level to about 1173 m amsl. On the right abutment, the narrow pillar of rock between the Faro Pit and the Zone II pit is suspected of being heavily damaged by blasting as well as cut by several upstream-downstream trending faults. Maintaining reservoir water level below 1173 m amsl would avoid having to treat the upper 7 m of poor quality rock along 120 m of pit wall perimeter in the right abutment pillar area.

As a result of these constraints, the maximum reservoir level was selected to be at 1173 m amsl, which is in agreement with the previous design concepts, assuming seepage is acceptable through the Faro Creek valley sediments on the west side of the Faro Pit. The additional storage in the Faro pit above current water level (elevation 1141 m amsl) amounts to about 23,500,000 m^3 (see Figure 6). If this is not acceptable, maximum pit water level would be constrained to 1158 m amsl. Further investigations will be required in a subsequent phase of work to assess conditions in the Faro Creek valley and design appropriate seepage control measures..

4.2.2 Dam Height

Based on a maximum pit water level of 1173 m amsl. The dam height was established by providing a freeboard of 1 m to the top of the core or main water retention element. The crest of the dam will be 2 m above the top of the core to allow for frost protection of the core and settlement. The maximum pit water level assumes that this includes any surcharges due to floods and any wind generated wave setup and run up. Consideration of these factors will define the normal operating water level or full supply level (FSL) of the pit water.

Based on the above requirements, the top of the dam will be at elevation 1176 m amsl, with the top of core at elevation 1174 m amsl.

4.2.3 Dam Stability

The stability of the upstream and downstream slopes must meet static and pseudo-static factors of safety based on two-dimensional limit equilibrium methods of analysis. All embankment slopes must have a factor of safety equal to or greater than the minimum factors of safety listed for the various stability cases given in Table 1

Table 1 Plug Dam Slope Stability Analysis Minimum Required Factors of Safety

Loading Conditions	Minimum Factor Of Safety	Slope
1. Reservoir at full supply level and steady state seepage conditions.	1.5	Downstream
2. Reservoir at full supply level and steady state seepage with MDE[1] horizontal pseudo-static[2] seismic loading.	1.0	Downstream
3. Rapid reservoir drawdown from full supply level to minimum supply level.	1.3	Upstream
4. Rapid reservoir drawdown from full supply level with MDE horizontal pseudo-static loading.	1.0	Upstream
5. End of construction pore water pressures in the dam.	1.3	Upstream
6. Reservoir at design flood level[3] and steady state seepage conditions.	1.2	Downstream

Notes:

1.) MDE= Maximum Design Earthquake, based on consequence classification of dam as per CDA Dam Safety Guidelines.

2.) Pseudo-static methods may be used to assess stability of dams founded on bedrock and with no liquefiable materials in the foundation.

3.) Design flood return period to be based on consequence classification of dam, as per CDA Dam Safety Guidelines.

4.2.4 Stability of Excavated and Existing Slopes

The existing pit wall slopes forming the dam abutments along the south side of the Faro Pit and the superimposed waste dumps on top of the right abutment must satisfy the factors of safety required for the dam as listed in Table 1. Based on the observations made during the site reconnaissance, there are no areas of active instability within the dam abutments, although minor, bench-scale wedge failures are evident. As part of the final design, an assessment should be made of the overall pit wall stability adjacent to the dam site, under the proposed pit water levels and operating conditions.

4.2.5 Material Properties

A selection of assumed material properties are presented in Table 2. These properties remain to be confirmed by laboratory testing in subsequent design phases.

Table 2 Assumed Material Properties for Foundation and Compacted Fill Materials

Material	Effective Cohesion c' (kPa)	Effective Angle Of Shearing Resistance (ϕ')	Unit Weight(kN/m^3)
Colluvium	0	28^o	21.6
Waste Rock	0	34^o	
Bedrock	0	40^o	
Compacted Core (Zone 1)	0	25^o	19.6
Rockfill Shells (Zones 2-8)	0	35^o	21.6

4.2.6 Settlement

Most of the settlement within the dam fill will take place during construction. There is not expected to be any significant settlement due to consolidation within the foundation bedrock as the dam will be constructed on a prepared bedrock foundation as described below. A minor amount of settlement may take place during initial impoundment as the rockfill becomes saturated. Subsequently, minor long-term settlement may be associated with rapid drawdown and filling events. The freeboard allowance for the core and dam crest is expected to be adequate to accommodate these deformations and no additional surcharge has been included to compensate for the effects of settlement in the dam.

4.3 Embankment Section and Construction

The plug dam section chosen for this evaluation is a rockfill dam with a central impervious core with upstream and downstream filter and transition zones and a single line grout curtain down to elevation 1137 m, as shown in Figure 10 This section was chosen based on the following considerations:

- Simple design that can be constructed using readily available construction equipment, with a minimal amount of technical supervision in a short construction season.
- Construction materials include waste rock, till and sand and gravel, which are readily available at the site.
- The rockfill side slopes can readily be flattened or steepened to accommodate any type of material. Previous design concepts allowed for the use of sulphide bearing waste in the upstream shell, below the minimum water level elevation.
- Minimal abutment foundation preparation required, which can be done over the late winter- early spring before the summer construction season.
- Grout curtain to seal potential water transmitting fractures in the bedrock above elevation 1143 m.

Prior to fill placement, the entire footprint of the dam will be stripped of colluvial debris and scaled of loose rock. The road base covering the foundation will be removed under the entire dam footprint. Minor rock excavation will be required in the right abutment to shape the core contact area. Ideally the impervious fill should be placed on a slope no greater than 45^{o} from the horizontal to ensure that during compaction, the lowermost lifts, in contact with rock are adequately compacted. Steeper rock slopes will be trimmed or concrete fillets placed in order to create smooth transitions on the core contact surface. The core contact area will be hand scaled and blown clean with compressed air prior to fill placement. Dental concrete and slush grouting of open surface cracks may be required, especially in the right abutment area.

During construction of the plug dam, two additional items of work will be required:

- Relocation of the water discharge pipeline from the Zone II pump well, which passes through the dam footprint along the toe of the left abutment.
- Removal and reconfiguration of the water diversion ditch on the 1173 bench on the left abutment.

Relocation and re-arrangement of these facilities (see Figures 2 and 3) should be done with extensive mine site staff input and may be done under a separate contract or work activity by Deloitte and Touche, in their capacity of interim receiver.

4.3.1 Zone 1 Impervious Fill

The central impervious core will be constructed using till obtained from borrow areas located on the Vangorda Plateau, a one-way haul distance of about 15 km. Other borrow sources may be located closer to the site, but remain to be identified. It was assumed that prior to construction, an extensive program of investigations would be carried out to identify potential borrow areas for dam construction materials.

It is anticipated that the till will consist of a well-graded mixture with a high percentage of clay and silt sized particles. In future studies, the sources, quantities and quality of till must be confirmed. A deposit of glacial material overlies bedrock on the left abutment. This material appears to be colluvial in origin, consisting of a heterogeneous mixture of silt, sand, gravel, and occasional cobbles and boulders that may be suitable as core material. There is at least 3 m depth of this material exposed in the rock cut at the dam site, with a portion covered by waste rock at the top of the left abutment. A preliminary volume estimate would indicate that about 30,000 m^3 of material may be available, which would be sufficient to construct the dam if it was suitable. Investigation of this deposit is recommended if further design studies proceed.

The till will be placed in lifts and compacted at optimum moisture content to a dry density equal to or greater than the maximum dry density obtained in the Standard Proctor Test. The bedrock contact zone will be placed at slightly wet of optimum moisture content, to ensure that the till is squeezed into the surface irregularities of the bedrock, without voids or areas of low compaction.

4.3.2 Zone 3 and Zone 5 Transition and Filter Materials

The gradation and number of filters will depend on the distribution of grain size curves obtained for the Zone 1 impervious core material and the gradation of the rockfill. Processed sand and gravel will be used to provide a material that meets the filter gradations. Granular borrow sources are located within 6 km of the dam site, in the Rose Creek valley adjacent to the Down Valley tailings disposal area.

The filter zones were generously sized in order to facilitate placement and compaction with a limited range of equipment that may be available or brought to site. Filter materials will be placed in lifts as the impervious core and rockfill shells are raised, and compacted to a dry density between 95% and 98 % of the maximum dry density. The 2 m depth of cover of granular materials over the impervious core was intended to offer thermal protection for the core and may be augmented by a road base for traffic if required.

4.3.3 Zone 7 Rockfill

It was assumed that sufficient rockfill would be obtained from the adjacent Faro waste rock dumps. Some of this material contains potentially acid generating (PAG) rock units, such as pyrite bearing quartzites, massive sulphide ores or disseminated sulphides. The SRK plug dam options considered using PAG material in the upstream shell, below the water line. This is still a valid option, as long as the future water levels in the pit do not change. Further consideration of the location of PAG materials within the dam section will be dependent on the final operational conditions for the Faro pit water level.

Rockfill will consist of metamorphic rock units such as phyllite, schist, gneiss and minor volcanics. Since the waste rocks have been exposed to weathering for a period of time, it should be possible to selectively excavate materials that are strong, durable and not subject to chemical or physical breakdown due to weathering. Maximum particle size will be 300 mm. The rockfill will be placed in lifts, with nominal compaction by the bulldozer or spreading equipment. The rockfill will be raised in lifts concurrent with the filters and till core.

4.4 Seepage Assessment and Cut-off Elements

4.4.1 Seepage Assessment

As discussed in Section 2.4, besides some minor seepage losses through the core of the proposed plug dam itself, there are two areas of potential seepage losses from the Faro Pit:

- The south corner of the pit, adjacent to the Zone II pit; and
- The southwest wall, also related to Faro Creek.

As described in the following two sub-sections, the total estimated seepage losses from these two areas ranges between approximately 100 m^3/day and 920 m^3/day.

<u>South Corner</u>

The Zone II pit will act as a local groundwater sink along the south perimeter of the Faro Pit (or below the right abutment and central portion of the proposed plug dam). Figure 7 shows that depending on the drawdown and recovery rates of the observation well near the Zone II pit pumping well, the water level in the Zone II pit has fluctuated between approximately 1106m and 1116m amsl, between March 14, 1997 and September 30, 2003.

Estimates of seepage losses from the Faro Pit into the Zone II pit have been carried out based on information obtained from the SRK (1991) report and field observations including:

- Below 1143m amsl, wall rocks are predominantly schists and phyllites, do not maintain open fractures to any great depth and have a hydraulic conductivity less than 1 x 10^{-6} cm/s (or are essentially impervious)
- Along the southern pit perimeter, above 1143m amsl, wall rocks are comprised of a highly fractured, blast damaged rock mass. Hydraulic conductivity above 1143m amsl ranges between approximately 1x10^{-3} cm/s and 1 x 10^{-4} cm/s.
- An average hydraulic conductivity of 3 x10^{-6} cm/s was determined from the piezometer nests in the east wall.

For the purposes of estimating seepage losses through the southern perimeter, we have assumed that:

- Because of the impervious rock mass below 1143m amsl, the majority of seepage losses will occur through the blast damaged upper wall rocks; and that
- As the observed range of water of water levels in the Zone II pit is well below 1143m amsl, a free flowing water face will develop in the blast damaged wall rocks of the Zone II pit, above 1143m amsl.
- Very little flow will occur below the left abutment, through wall rocks along the eastern perimeter of the Faro Pit.

A series of simple, hand drawn flow nets, were constructed using cross section BB' from Figure 4, to estimate seepage losses in this area. The approximate seepage loss per metre length was calculated to range between approximately 0.38 m^3/day and 3.8 m^3/day. Assuming seepage occurs over a perpendicular distance of approximately 240m, measured from the toe of the left abutment, the resulting estimated total seepage quantity is approximately 90 m^3/day to 910 m^3/day.

Based on the assumption that a free flowing water surface develops on the upper wall of the Zone II pit, the hydraulic gradient along this cross section was calculated to be approximately 0.22.

<u>Southwest Wall (Faro Creek Sediments)</u>

As discussed in Section 2.4, an approximately 15 m (50 ft.) thickness of porous sediments extends over a 122 m (400 ft.) length of the south-western wall of the Faro Pit. These sediments are related to the former Faro Creek valley. Applying Darcy's Law and with assumed representative values for hydraulic conductivity and gradient of 1 x 10^{-4} cm/s and 0.1, respectively, the estimated seepage through this zone was calculated to be about 8 m^3/day.

These sediments are overlain by at least another 8 m of waste rock (to el. 1181$\pm$). The hydraulic conductivity of the waste rock is expected to be at least two order of magnitude higher than the in situ sediments.

4.4.2 Seepage Cut-off Elements

A single line grout curtain is proposed under the dam and extending for about 120 along the right abutment to prevent seepage between the Main pit and the Zone II pit to the south (Figure 3). The rock mass is characterized by at least five joint sets, generally inclined from the vertical to varying degrees. Therefore the proposed orientation of the grout holes is vertical, which will result in the grout holes intersecting all fracture systems. Grout hole orientation must be confirmed by drilling investigation to determine if there are preferred flow paths through the rock mass. In general, a rock mass having a hydraulic conductivity of about 1 $X10^{-5}$ cm/s or greater is considered “groutable” with Portland cement based grouts. Previous investigations have determined that the rock mass above elevation 1143 m amsl has hydraulic conductivities ranging from 1 $X10^{-3}$ cm/s to 1 x 10^{-4} cm/s. Below this elevation, hydraulic conductivities of 1 $x10^{-6}$ cm/s or less were observed.

The grout curtain will tie in to the zone of relatively impermeable rock located below elevation 1143 m amsl. The bottom of the grout curtain has been set at elevation 1137, giving at least 6 m of overlap into the lower impervious rock mass. The depth of the grout curtain must be confirmed by water pressure testing in future site investigations, as described in Section 5.

The grout curtain is expected to decrease seepage losses into the Zone II pit by one to two orders of magnitude (0.9 m^3/day to 90 m^3/day).

4.5 Quantities and Cost Estimate

Table 3 presents a summary of the estimated quantities, unit prices and costs for the plug dam and grout curtain, based on the central impervious core section shown in Figure 10. In summary, the estimated cost is $1,752,360, excluding mobilization/demobilization, escalation and extra work allowances. A lump sum allowance of $60,000 was included to cover the cost of relocating the discharge pipeline from the Zone II pit and the diversion ditch on the left abutment. This work could be done in advance under a separate contract or by mine site staff.

The unit rates used for the various items are based on rates, which have been used for previous estimates at the site. As a starting point, the following rates were used by BGC for Faro earthworks in the past:

- Unit prices assume use of large-scale equipment.
- Excavate and load soil- $1.50/$m^3$.
- Haul- $0.18/tonne-km
- Dump and spread- $0.50/$m^3$
- Compact- $0.50/$m^3$
- Excavate and load rockfill- same as for soil

After an initial unit rate was derived based on the above factors, further adjustments were made on the basis of recent bid prices for the Fresh Water Supply dam, currently being breached at the site.

Table 3 Faro Pit Plug Dam Construction Cost Estimate

The following sections summarize each of the items in more detail.

4.5.1 Excavation

Excavation includes bulk overburden excavation and stripping and core trench rock excavation.

4.5.1.1 Bulk Overburden Excavation and Stripping.

Bulk overburden excavation and stripping includes removal of the mine haul road base under the dam footprint, removal of the left bank diversion ditch berm and liner as well as the accumulated colluvial debris and loose rock on the abutment slopes. An average thickness of 0.5 m was assumed over the entire dam footprint. The excavated material would be hauled to a designated waste dump site assumed to be on the existing waste rock dumps, within 1 km of the dam site.

4.5.1.2 Core Trench Rock Excavation

Although the dam does not have a core trench per se, there is some bedrock trimming required on the right abutment in order to prepare the bedrock slopes for placement of the Zone 1 impervious core material. This excavation is expected to involve a very limited amount of blasting. The excavated material will be hauled to the designated waste site, assumed to be within 1 km of the dam.

4.5.2 Foundation Preparation

Foundation preparation includes all the work required to prepare the contact area prior to placement of the impervious fill. This includes scaling and cleaning, followed by slush grouting and dental concrete as required.

Scaling and cleaning involves a lot of hand labour to remove loosened pieces of rock and debris after the completion of the rock excavation in the core contact area. Any cracks or voids filled with unconsolidated materials must be cleaned out, at least to a depth equal to three times their width. The open cracks are then backfilled with dental concrete or slush grout depending on their width. In areas where steep side “steps” of rock remain, concrete fillets must be placed to achieve a 1:1 slope.

Prior to placement of impervious fill, the core contact area must be blown clean of loose debris using compressed air.

This item also includes lump sum allowances for relocating the pipeline from the Zone II pumping well, and re-directing the left abutment runoff diversion ditch. Currently the diversion ditch is breached in the vicinity of the dam site and water is flowing over the left abutment rock slope, across the dam foundation and into the Faro pit. Water in the diversion ditch comes from the waste dumps and slopes south of the dam. It may be possible to widen the bench at the crest of the dam and have the water flow directly into the Faro pit with the increased water level behind the plug dam. The pump well discharge could then be routed across the waste dump material and discharge into the diversion ditch. Mine site staff will be required to further assess these issues

4.5.3 Foundation Grouting

The proposed grout curtain extends from the crest of the dam at the left abutment, across the rock cut to the crest on the right abutment. The centreline of the grout curtain is located at the upstream one-third point of the core contact width (Figure 10). From the right abutment crest, the grout curtain extends for another 110-120 m to the west, along the rock pillar between the Main pit and the Zone II pit.

Foundation grouting will be carried out soon after the bulk excavation and stripping is completed and before final foundation preparation. Grouting involves a progressive sequence of drilling and grouting. A primary hole spacing of 3 m was assumed. It was assumed that a split spacing closure sequence would be followed, in which holes are initially drilled at a wider spacing, say 12 m c-c, then grouted. Next, holes are drilled halfway in between the first set of holes and grouted. The process is repeated until all the holes are at a 3 m c-c primary spacing. Depending on the grout takes in this stage of holes, additional (secondary) holes spaced 1.5 m from high taking primary holes will be drilled and grouted as required. High taking secondary holes will require at least one more split spaced hole (tertiary) to be drilled and grouted. For estimating purposes it was assumed that all primary holes (3 m c-c) will be drilled and grouted. One-half (50%) of the secondary holes will be drilled and grouted and 25 % of the tertiary holes (0.75 m c-c) will be drilled and grouted.

Cement takes in the primary holes were assumed to be “Moderate” (75 kg/m). Takes in the secondaries was assumed to be “Moderately Low” (37 kg/m), with “low” takes (15 kg/m) in the tertiary holes. The use of sulphate resistant cement is recommended due to the presence of sulphides in the dam foundation rocks.

Drill holes are expected to be 75 mm diameter rotary drilled vertical holes up to about 40 m deep. In the left abutment and dam foundation, it was assumed that the entire hole would be drilled. Vertically drilled holes are expected to intersect all of the discontinuities in the rock mass, and will help to maintained stable hole conditions. It is expected that drilling of inclined grout holes will be problematical, especially in the right abutment.

In the right abutment, the upper 6m of hole are expected to be in poor rock conditions. Therefore top down grouting was assumed in this section of the hole. In this method, the hole is only drilled to a depth of one grout stage (3 m), then, grouted. When the grout has set, the hole is re-drilled to the bottom of the first stage and deepened by another 3 m. The lower 3 m stage is then grouted. Below 6 m it is expected that ground conditions will improve to allow drilling to the bottom of the grout curtain. The rest of the hole is then grouted from the bottom up in 3 m stages, as proposed for the left abutment and dam foundation grout holes.

As an option, drilling and grouting of the right bank holes in the pillar area, to the right of the dam crest, can be done after the dam is constructed. Access to the top of the right abutment can then be provided over the top of the completed dam. Otherwise a temporary access road will be required from the top of the right abutment down to the grout curtain centreline.

Prior to grouting, each grout hole will be water pressure tested in 3 m intervals. This will serve as a check on rock mass permeability and the effects of closure as grouting progresses.

Grouting is one of the largest cost items on the project, totalling $717,000. It is anticipated that the site investigation program will provide better information on rock mass hydraulic conductivities so that this cost item can be confirmed.

4.5.4 Embankment Materials

The unit prices for the dam embankment materials were derived from the assumptions listed at the beginning of this section.

The Zone 1 impervious core material is assumed to be obtained from till borrow areas located on the Vangorda Plateau. Unit prices reflect a 15 km one-way haul distance, plus the price for excavating, loading, hauling, placing and compacting the fill.

The Zone 3 and 5 fine and coarse filters are assumed to come from existing granular borrow areas located in the Rose Creek valley adjacent to the down valley tailings disposal area, within 6 km of the dam. The unit price covers bulk excavation of the granular material, processing (washing and screening), loading, hauling, placing, spreading and compacting.

The Zone 7 rockfill assumes clean, non-acid generating rockfill to be obtained from the waste rock dumps around the Faro pit within a 2 km one way haul distance. The price includes excavation, loading, hauling, placement and compaction. No costs have been included for environmental testing and monitoring of the rockfill material, assuming that a clean, acceptable source has been identified prior to construction.

4.6 Constraints and Uncertainties

The conceptual design of the plug dam has considered only one option, a rockfill dam with a central impervious core and single line grout curtain. This option was selected on the basis of the practicality of construction using the materials readily obtainable at the site. Previous studies (SRK, 1991) included a slimes plug dam, using spigotted tailings from the mill discharge. The use of tailings or milled clean rock is not precluded as an alternative option. Consideration of other options may be possible in the next stage, after additional data has been obtained from site investigations, as discussed in Section 5. Alternative schemes may be generated through the need to satisfy other closure priorities as determined by the Type II Mine Management Team.

The major constraints on the plug dam are the bedrock elevation at the dam site and along the west side of the Faro pit, which limit the maximum water level in the pit to about elevation 1173 m amsl. Further investigations are required in the Faro Creek valley to define geological conditions and assess the potential for seepage out of the pit and the design of seepage control measures.

In the plug dam area, confirmation of bedrock elevation is required in both abutments. In the right abutment, the geometry of the rock pillar between the Faro Main pit and the Zone II pit needs to be defined. Bedrock quality and rock mass hydraulic conductivity needs to be defined, especially across the mapped fault structures traversing the right bank pillar area, to assess potential leakage from the pit.

Sourcing the rockfill for the dam will require assessment of the waste rock dump materials in terms of acid rock drainage and metals leaching potential. BGC understands that SRK has undertaken these types of studies already and may be in a position to recommend potential borrow sources of “clean” rockfill. These sources could also be considered for use in creating inert slimes for the alternative slimes dam concept explored previously by SRK.

Confirmation of the impervious and granular borrow sources assumed to be available for dam embankment materials will be required to assess the quality and quantity of materials available.

Construction of the plug dam may result in ponding of runoff water along the downstream toe of the dam, within the rock cut, due to the grade of the road towards the Faro Pit. No consideration has been given as to what implications this would have, but pond levels may rise to the point where seepage occurs back into the Zone II pit. This “tail water” against the downstream slope should not be detrimental to the stability or operation of the dam, but requires consideration within the overall mine site surface water management plan. The relocation of the pump well discharge line and the left bank diversion channel should be included in these considerations.

5.0 PROPOSED SITE INVESTIGATION PROGRAM

5.1 Requirements

Further geotechnical investigations at the plug dam site are recommended in the following areas to provide additional information for future design phases of the plug dam:

- Bedrock core drilling and water pressure testing to assess rock mass quality and hydraulic conductivity in the abutments and dam foundation to confirm the depth and lateral extent of the grout curtain.
- Geophysical surveys to delineate the bedrock surface under the cover of surficial materials, particularly the rock profile in the pillar area between the Faro Main pit and the Zone II pit
- Test pitting to assess the quality of the overburden materials on the top of the left abutment for use as Zone 1 core material.

The scope and cost of a regional borrow materials investigation to identify and confirm dam construction materials have not been considered at this stage. It is anticipated that this work would be required to satisfy the needs of other mine site reclamation activities, in addition to those for the plug dam construction.

5.2 Drilling Investigations

The proposed locations of nine boreholes are shown in Figure 3. Each hole will be drilled using a triple-tube core barrel. In overburden, drilling will be done using mud-rotary methods. Overburden sampling will be done with a split spoon sampler. Due to the poor rock conditions that may be encountered, drilling and water testing should be done using a coring system incorporating a down hole packer inside the core barrel. Testing could be done in 3 m increments using a single packer to seal the hole.

The objectives for each of the holes shown on Figure 3 is provided below:

- Hole Number 1 is a vertical hole located along the left bank centreline and will be drilled to at least elevation 1137, the bottom of the grout curtain under the dam. The purpose of this hole is to confirm bedrock elevations and hydraulic conductivity in the southeast side of the pit.

- Hole Number 2 is a vertical hole located along the dam centreline and will confirm the thickness of the overburden in the left abutment. The hole will be drilled to the bottom of the grout curtain at elevation 1137 and confirm the lateral extent of the grout curtain in the left abutment.

- Hole Number 3 is a vertical hole located at the crest of the left abutment slope, near the present end of the grout curtain. This hole will be drilled to elevation 1137 to confirm rock conditions and hydraulic conductivity in the left abutment of the dam.

Holes 1 and 2 are accessible by truck-mounted equipment. Hole 3 can be made truck accessible by constructing a roadway along the bench.

- Hole Number 4 will be inclined at 60^{o} to the horizontal at the toe of the left abutment. This hole will be drilled to elevation 1137 and will confirm the rock conditions and hydraulic conductivity under the left abutment. If water pressure testing indicates that the rock mass at 1137 has a hydraulic conductivity greater than 1 $x10^{-5}$ cm/s, the hole depth will be extended at least another 6 m to confirm that the grout curtain can be tied into a rock mass of lower hydraulic permeability. This hole is expected to be normal to the foliation.

- Hole Number 5 is a vertical hole located in the base of the dam. This hole should be drilled to at least elevation 1130 to confirm that the rock mass under the grout curtain is tight.

- Hole Number 6 is an inclined hole at 60^{o} from the horizontal into the toe of the right abutment. As with Hole Number 4, this hole will assess rock conditions and hydraulic conductivity of the right abutment down to elevation 1137.

Holes 4, 5 and 6 may be drilled with a truck mounted rig, as they are located along the haul road.

- Hole Number 7 is located near the top of the rock on the right abutment on a narrow bench adjacent to the waste dump toe. This hole will be inclined at 60^{0} from the horizontal in a westerly azimuth and drilled to elevation 1137 to check the permeability of the rock pillar between the Faro and Zone II pits. The inclined hole will intersect the sub-vertical fault zones traversing the pillar area.

- Hole Number 8 is another inclined hole along the right abutment grout curtain. This hole is inclined at 60^{o} from the horizontal on an easterly azimuth to intercept fault zones in the pillar area. The hole will be drilled to elevation 1137.

- Hole Number 9 is a vertical hole drilled at the west end of the grout curtain. This hole will confirm the lateral extent and depth of the grout curtain.

Holes 7, 8 and 9 will require a skid mounted drill rig and an access road to be constructed so that the drills can be skidded into position onto the benches of the right abutment slope.

5.3 Geophysical Surveys

Confirmation of bedrock levels under the waste rock dumps in the right abutment is required to assess the thickness of bedrock in the pillar between the Faro and Zone II pits, and confirm the grout curtain layout. In the left abutment, at least one line should be run along the dam centreline to Hole 1 to confirm the thickness of overburden and weathered rock. Details of this program will be developed with the geophysical consultant as to the best method to be used in each case.

5.4 Left Bank Borrow Materials Investigations

This item includes a program of test pitting to assess the quantity and quality of the deposit of Quaternary material overlying bedrock in the left abutment. Samples will be obtained from the test pits and sent to soils laboratory for geotechnical index testing, including grain size, Atterberg Limits, moisture content and Proctor density.

5.5 Cost Estimate

The total estimated cost of the recommended site investigation program is about $278,800 as follows for the various programs:

- Drilling, including water pressure testing, core logging and overburden sampling in the left bank borrow area- $170,640
- Geophysical surveys- $19,940
- Test Pitting and Lab Testing- $3200
- Engineering field supervision (including travel and disbursements)- $62,000
- Engineering reporting- $23,020.

6.0 CONCLUSIONS AND RECOMMENDATIONS

A conceptual design for a plug dam was developed on the basis of a brief geological reconnaissance assessment. The proposed concept is an earth and rockfill dam with a central impervious core, founded on bedrock. A grout curtain will be required to elevation 1137 to tie-in to low permeability rock below elevation 1143.

The right abutment is a critical element of the design due to the proximity of the Zone II pit. The pillar of rock between the Faro Pit and the Zone II pit is traversed by several fault zones, which were mapped in the open pit. The rock mass is expected to be of poor quality due to the presence of these faults and the fact that the pit walls on both sides of the pillar are affected by blast damage.

The proposed design of the dam utilizes locally obtainable materials, and is relatively easy to construct within one construction season. The estimated capital cost of this alternative is

$1,752,360, excluding mobilization, demobilization, escalation and extra work allowances.
Further assessment is required of the potential seepage zone through the Faro Creek valley if the pit water level is raised to the proposed level of 1173 m.

7.0 CLOSURE

We trust that this information will meet with your requirements at this time. Should you have any questions or require any additional information, please do not hesitate to contact the undersigned.

Yours truly,
BGC Engineering Inc.
Per

Holger Hartmaier, M.Eng., P.Eng.	James W. Cassie, M.Sc. P.Eng.
Senior Geotechnical Engineer	Specialist Geotechnical Engineer

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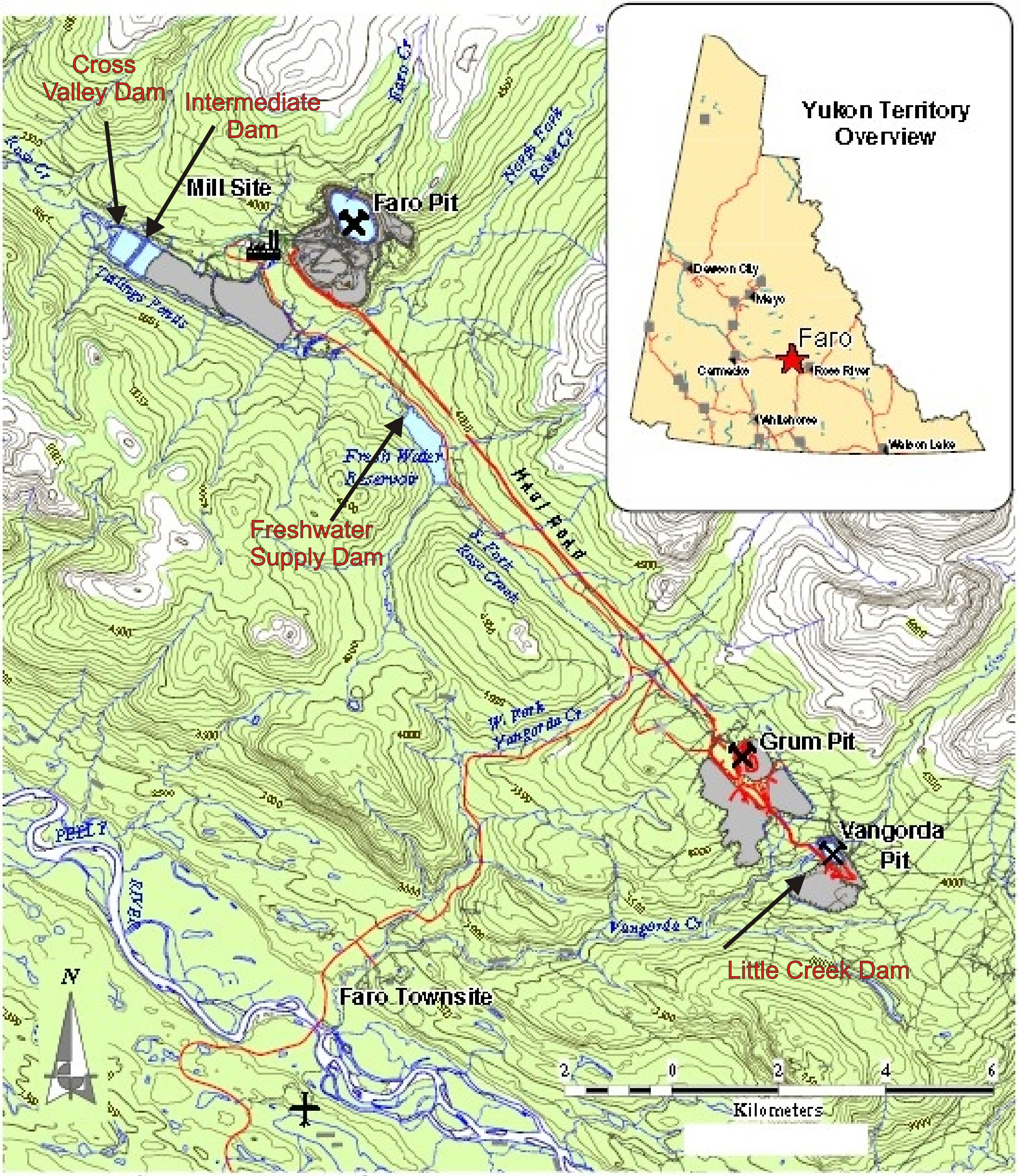
FIGURES



Note: Base map figure provided by Gartner Lee Limited.

SCALE:	As Shown	DESIGNED:	KFM
DATE:	October 2003	CHECKED:	HHH
DRAWN:	SLF	APPROVED:	JWC

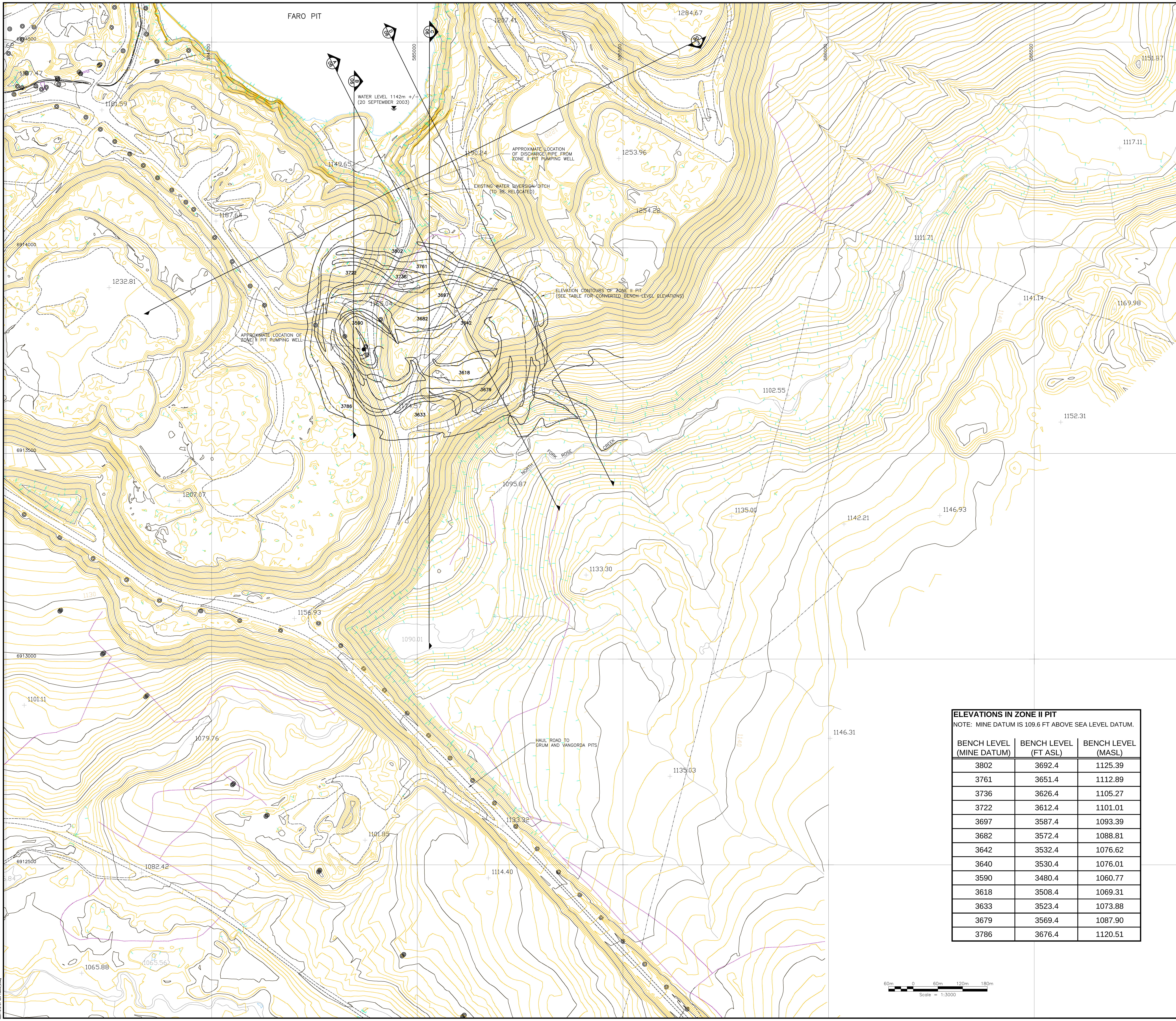
CLIENT: Deloitte & Touche

BGC Engineering Inc.
AN APPLIED EARTH SCIENCES COMPANY
BGC
Calgary, Alberta. Phone: (403) 250-5185

PROJECT
Anvil Range Property
Faro Pit Plug Dam

TITLE
Site Location Plan

PROJECT No.	Figure number	REV.
0257-019-01	Figure 1	0



ELEVATIONS IN ZONE II PIT

NOTE: MINE DATUM IS 109.6 FT ABOVE SEA LEVEL DATUM.

BENCH LEVEL (MINE DATUM)	BENCH LEVEL (FT ASL)	BENCH LEVEL (MASL)
3802	3692.4	1125.39
3761	3651.4	1112.89
3736	3626.4	1105.27
3722	3612.4	1101.01
3697	3587.4	1093.39
3682	3572.4	1088.81
3642	3532.4	1076.62
3640	3530.4	1076.01
3590	3480.4	1060.77
3618	3508.4	1069.31
3633	3523.4	1073.88
3679	3569.4	1087.90
3786	3676.4	1120.51

CLIENT: Deloitte & Touche

REV.	DATE	REVISION NOTES	DRAWN	CHECKED	APPROVED

SCALE: 1:3000
DATE: DEC 2003
DRAWN: CJT
DESIGNED: GRB
CHECKED: HHH
APPROVED:

PROJECT: ANVIL RANGE PROPERTY FARO PIT PLUG DAM

TITLE: GENERAL SITE PLAN

PROJECT No. 0257-019-01 | DWG. No. 02 | REV. 0

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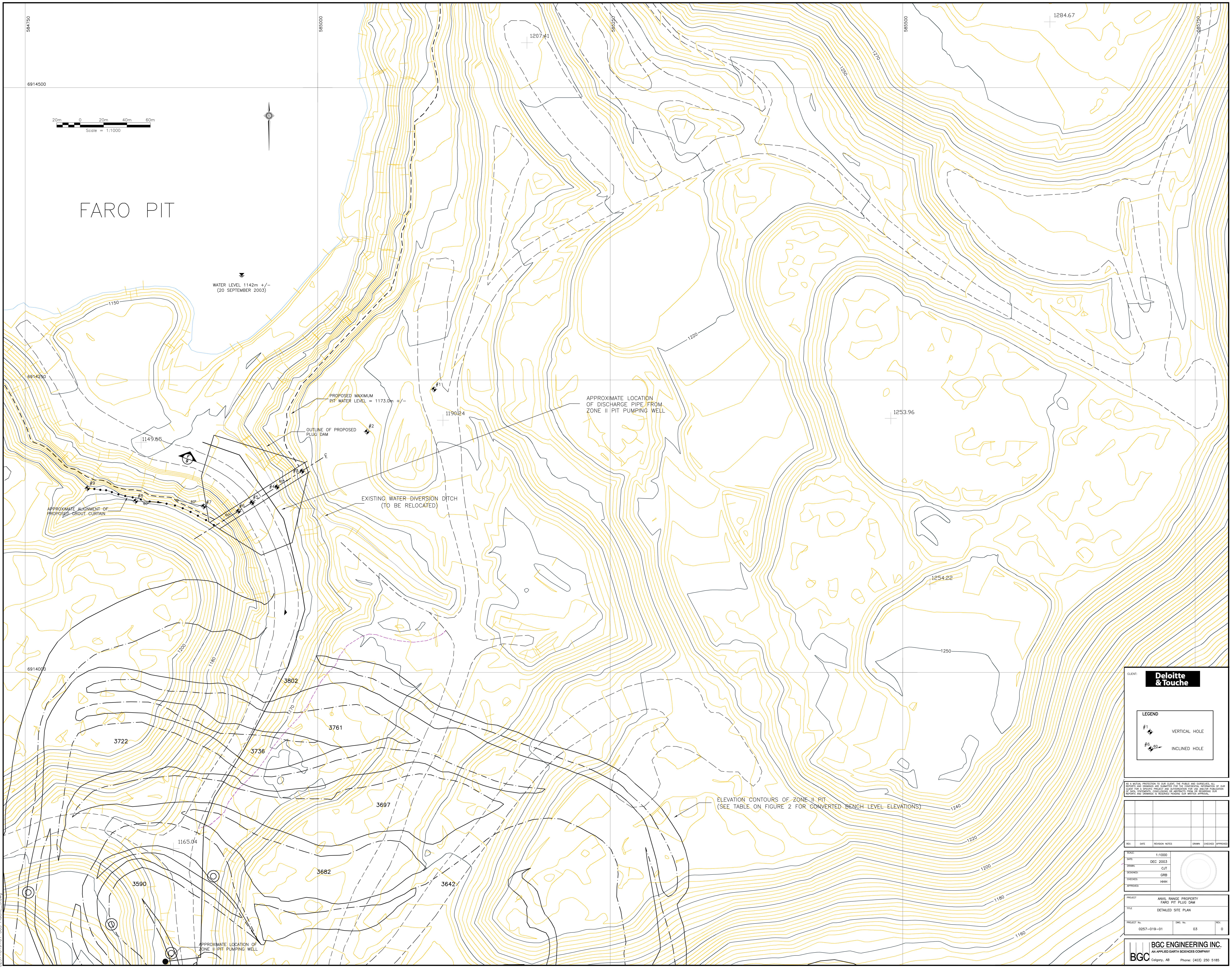

FARO PIT
Scale = 1:1000
20m 0 20m 40m 60m
WATER LEVEL 1142m +/- (20 SEPTEMBER 2003)
PROPOSED MAXIMUM PIT WATER LEVEL = 1173.0m +/-
OUTLINE OF PROPOSED PLUG DAM
APPROXIMATE LOCATION OF DISCHARGE PIPE FROM ZONE II PIT PUMPING WELL
EXISTING WATER DIVERSION DITCH (TO BE RELOCATED)
APPROXIMATE ALIGNMENT OF PROPOSED GROUT CURTAIN
ELEVATION CONTOURS OF ZONE II PIT (SEE TABLE ON FIGURE 2 FOR CONVERTED BENCH LEVEL ELEVATIONS)
APPROXIMATE LOCATION OF ZONE II PIT PUMPING WELL
1207.41
1284.67
1190.24
1253.96
1149.65
1254.22
1165.04
3802
3761
3722
3736
3697
3682
3642
3590
6914500
6914250
6914000
584750
585000
585250
585500
585750
CLIENT:
Deloitte & Touche
LEGEND
#1 VERTICAL HOLE
#6 60 INCLINED HOLE
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.
REV. DATE REVISION NOTES DRAWN CHECKED APPROVED
SCALE: 1:1000
DATE: DEC 2003
DRAWN: CJT
DESIGNED: GRB
CHECKED: HHH
APPROVED:
PROJECT ANVIL RANGE PROPERTY FARO PIT PLUG DAM
TITLE DETAILED SITE PLAN
PROJECT No. 0257-019-01
DWG. No. 03
REV. 0
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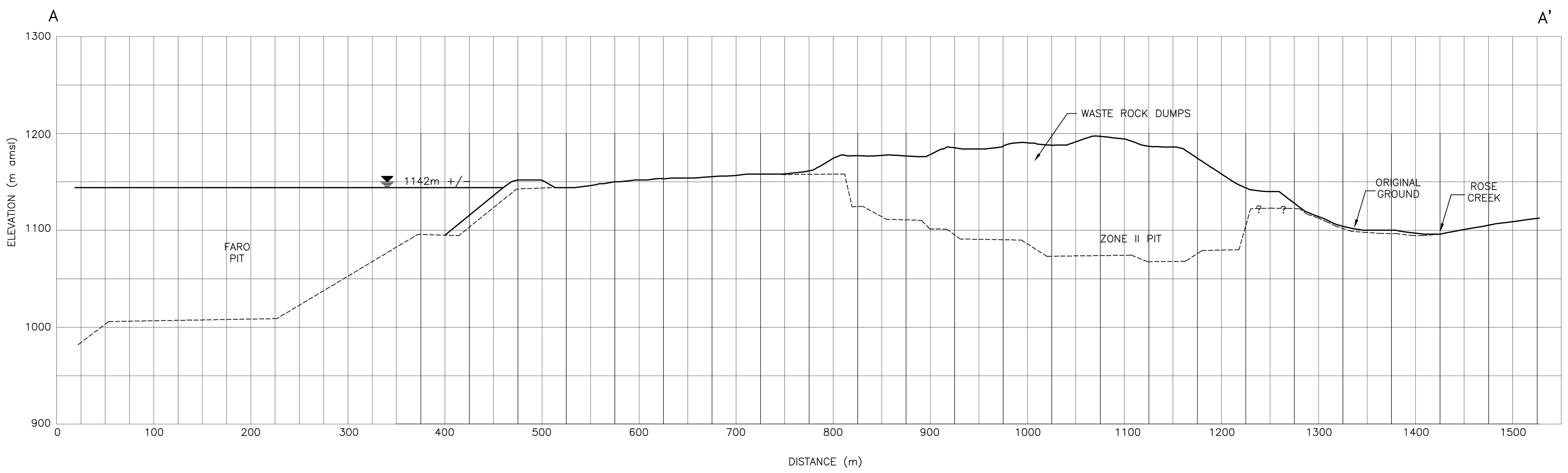

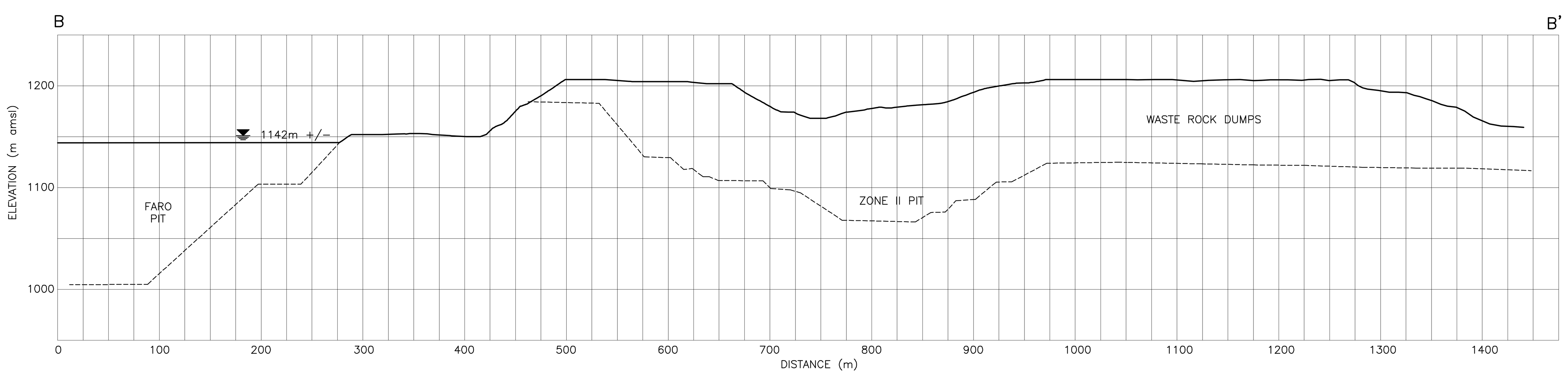

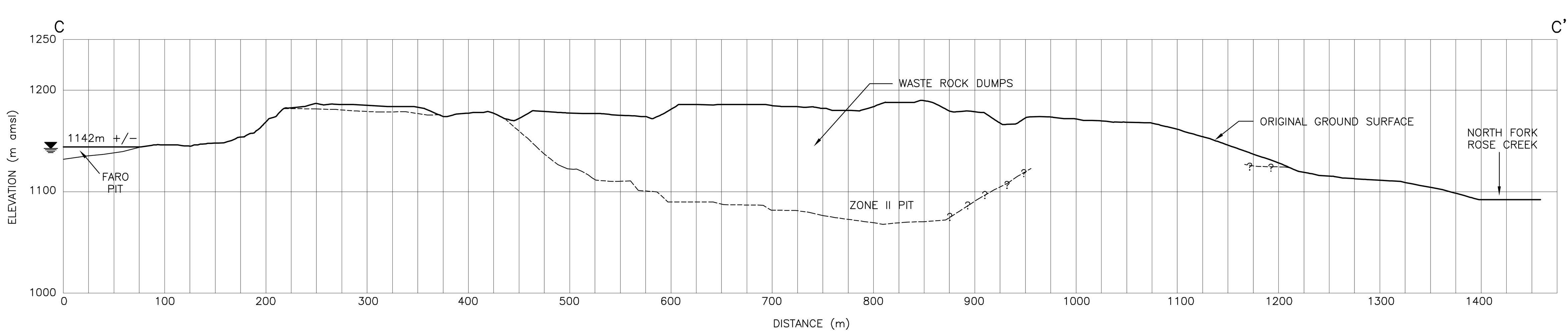

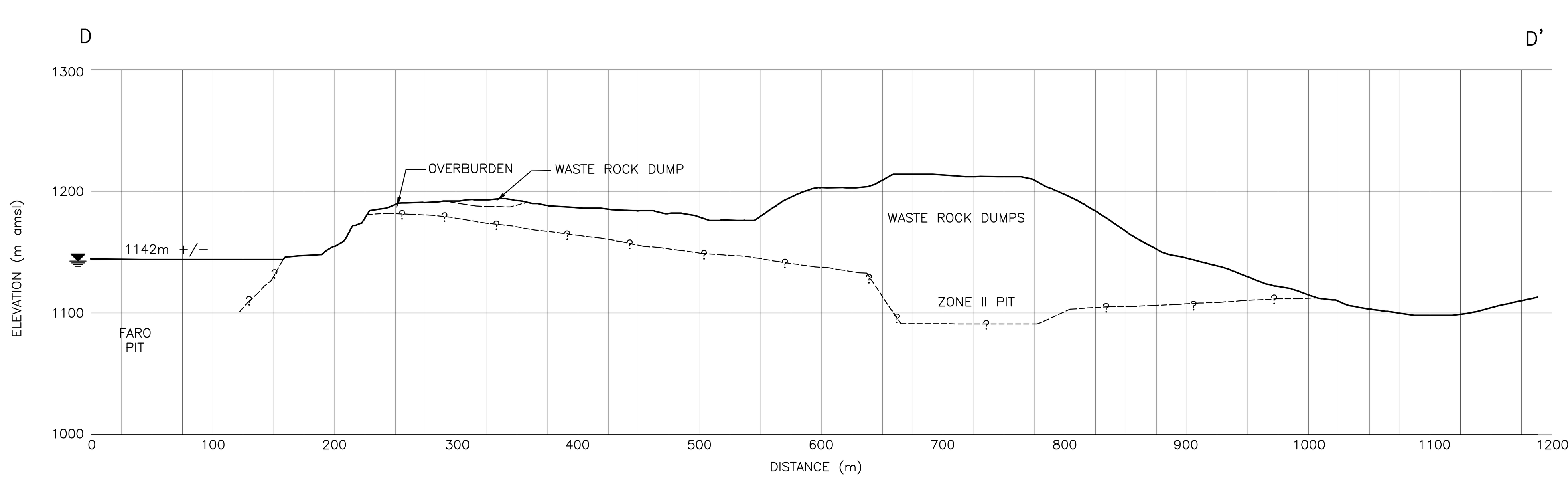

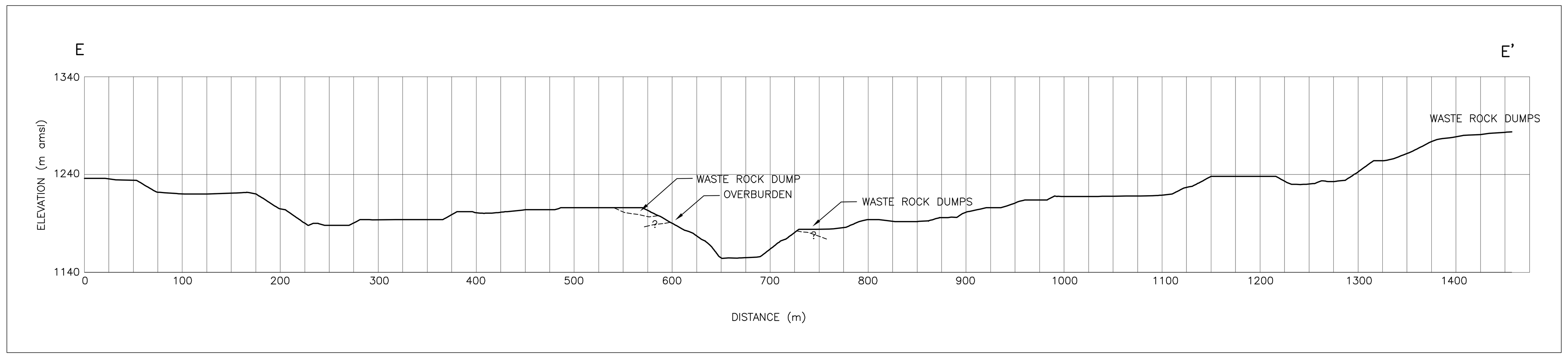

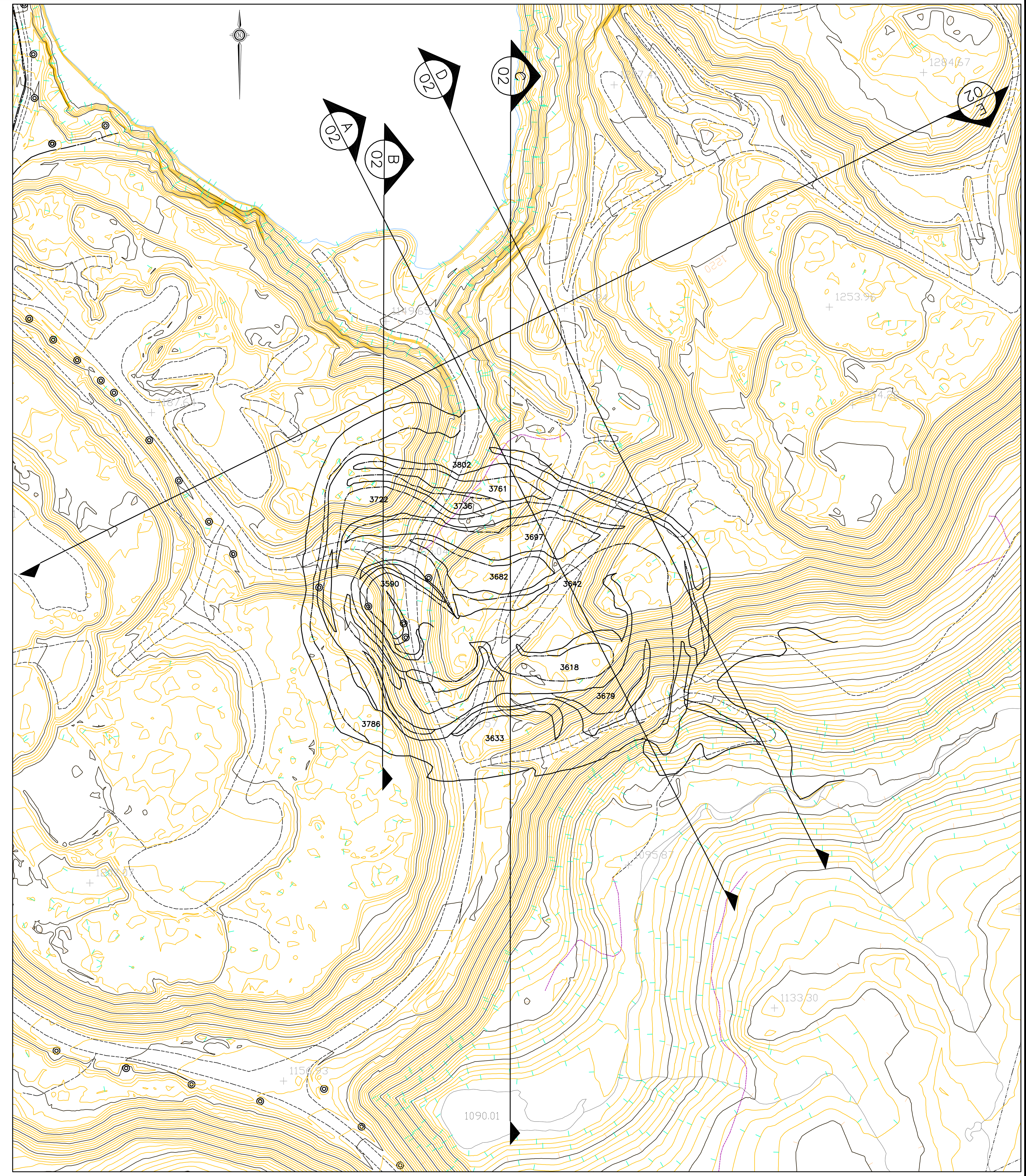

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Scale = 1:3000

CLIENT: Deloitte & Touche

REV.	DATE	REVISION NOTES	DRAWN	CHECKED	APPROVED

SCALE: 1:3000
DATE: DEC 2003
DRAWN: CJT
DESIGNED: GRB
CHECKED: HHH
APPROVED:

PROJECT: ANVIL RANGE PROPERTY FARO PIT PLUG DAM

TITLE: REPRESENTATIVE CROSS SECTIONS

PROJECT No.	DWG. No.	REV.
0257-019-01	04	0

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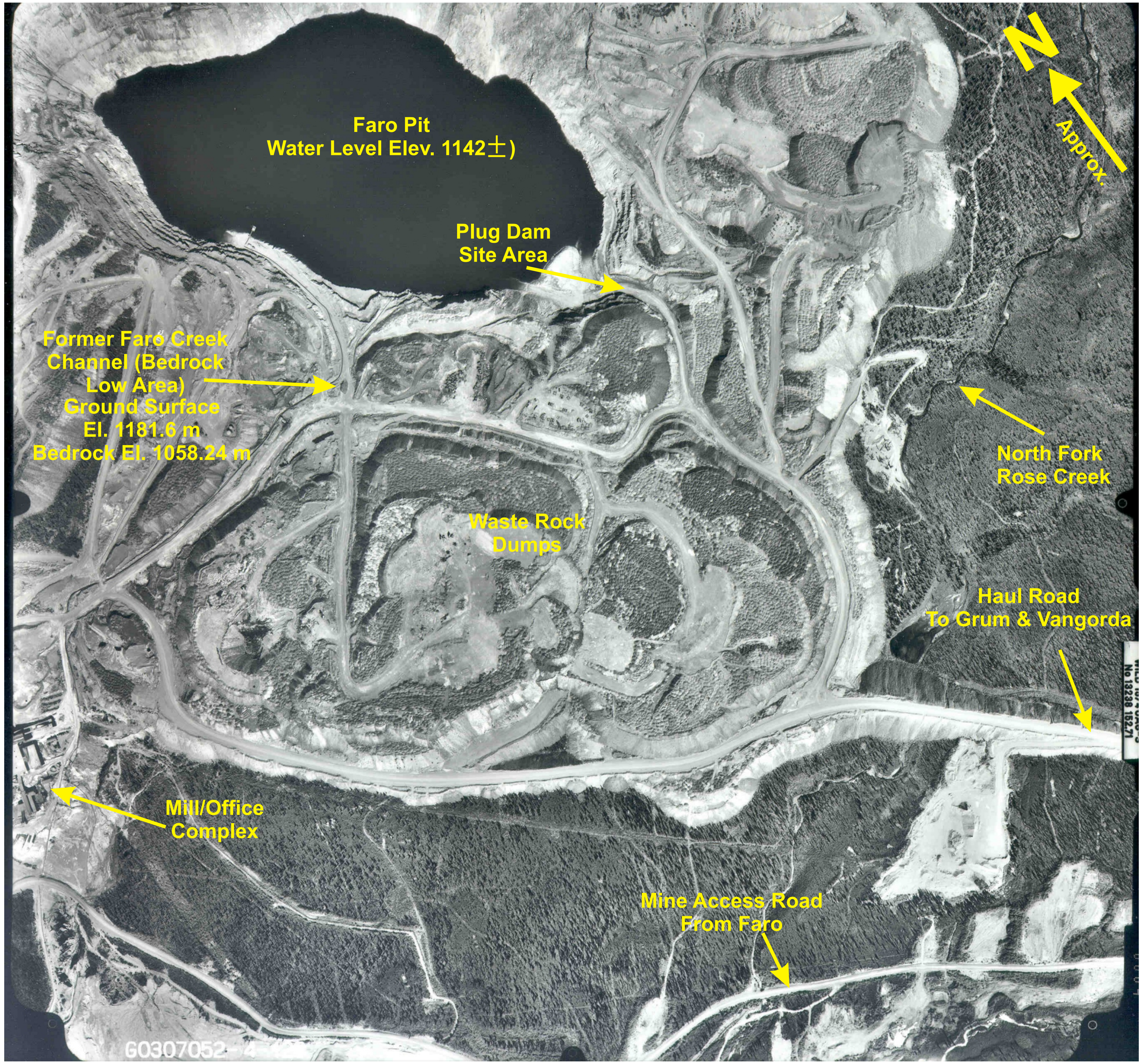

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Date: July 25, 2003
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CLIENT:

Deloitte & Touche

REV.	DATE	REVISION NOTES	DRAWN	CHECKED	APPROVED
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SCALE:	As Shown
DATE:	November 2003
DRAWN:	SLF
DESIGNED:	HHH
CHECKED:	HHH
APPROVED:	

PROJECT
ANVIL RANGE PROPERTY - FARO PIT PLUG DAM

TITLE
AERIAL PHOTOGRAPH SHOWING
CURRENT SITE CONDITIONS

PROJECT No.	DWG. No.	REV.
0257-019-01	FIGURE 5	0

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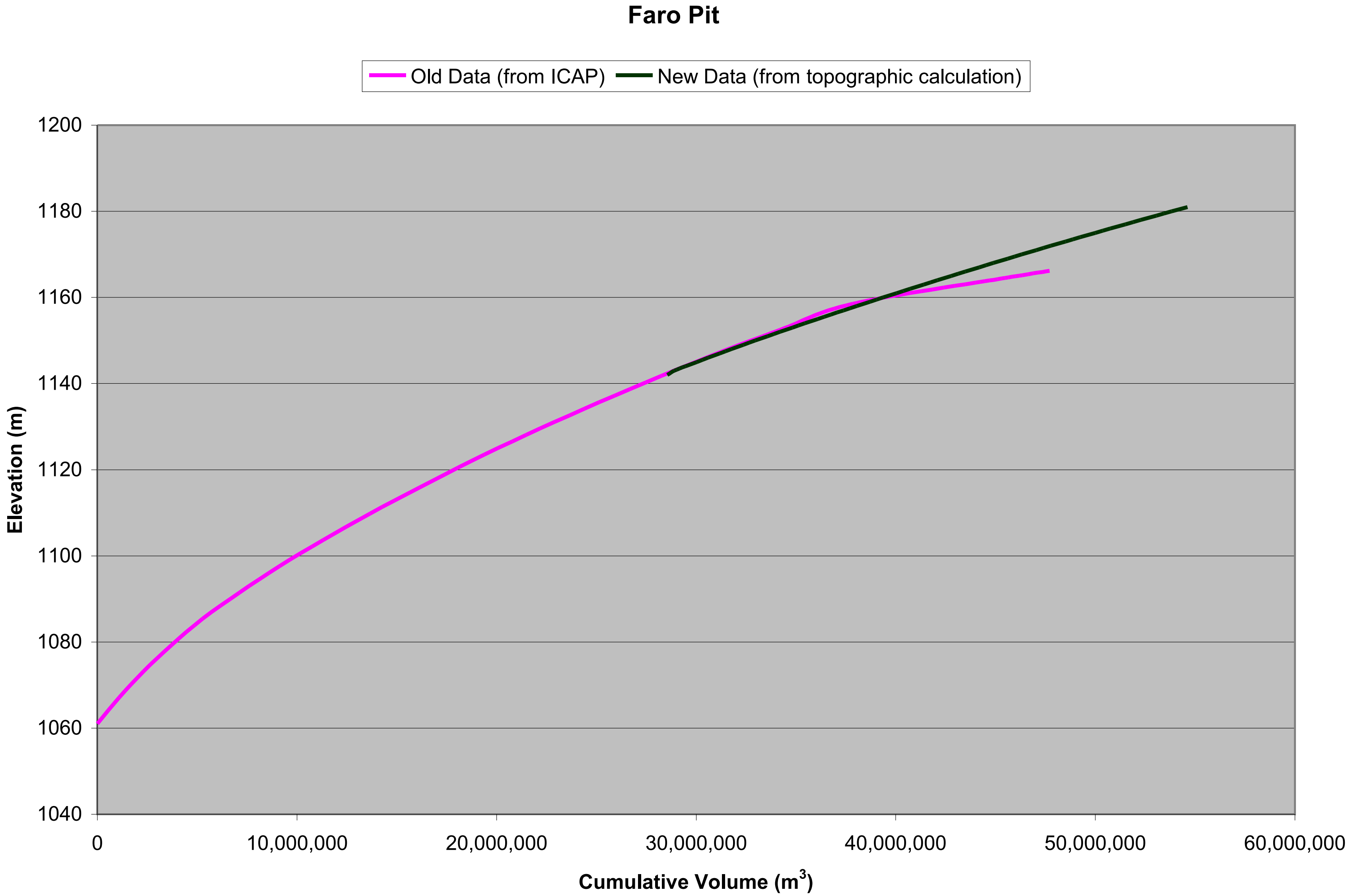
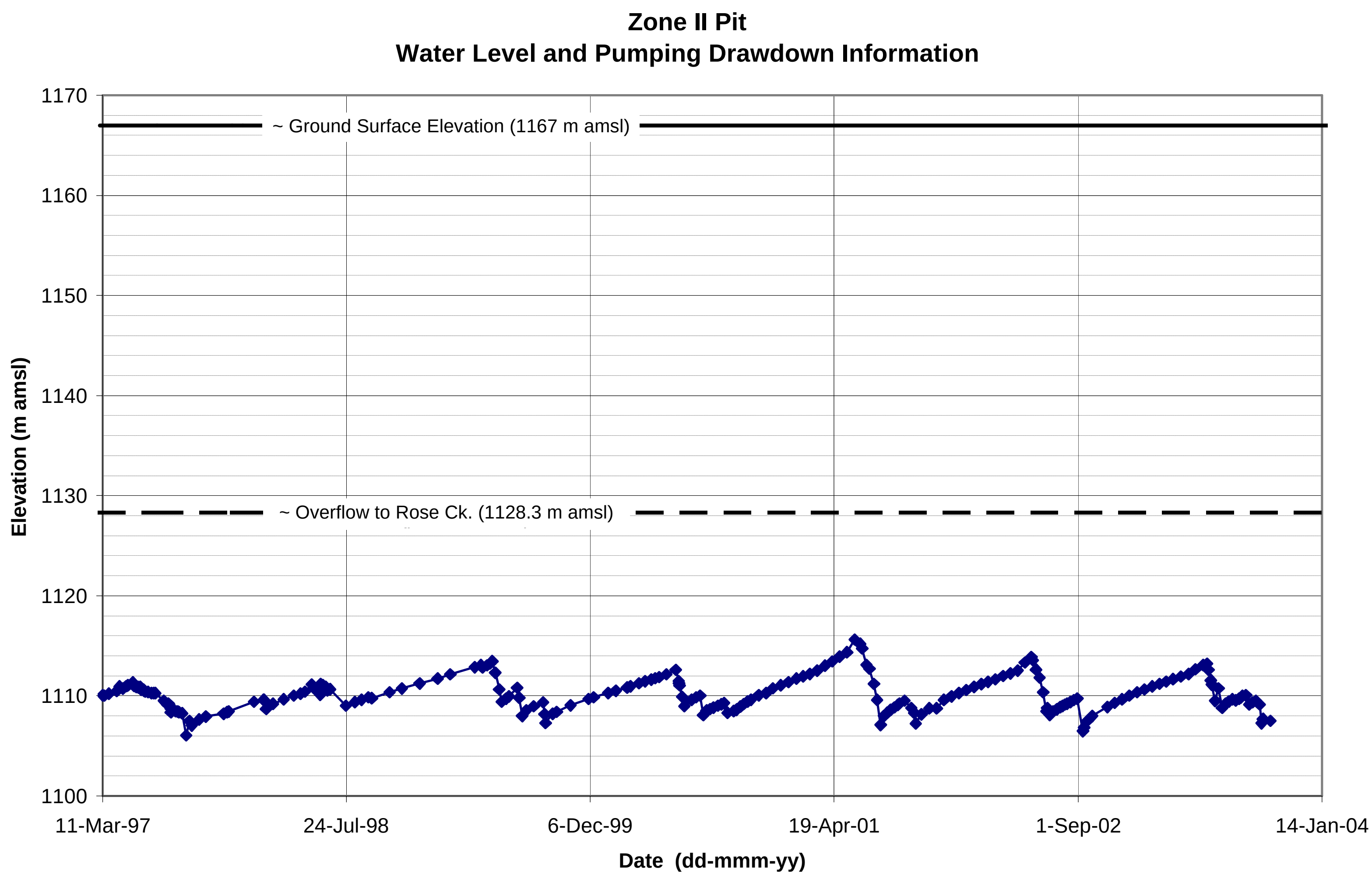


Source: Prepared by SRK, November 2003

DATE: DEC 2003	DRAWN SLF	BGC ENGINEERING INC. AN APPLIED EARTH SCIENCES COMPANY Calgary, Alberta Phone: (403) 250-5185	PROJECT ANVIL RANGE PROPERTY - FARO PIT PLUG DAM
REFERENCED DRAWING DESCRIPTION		CLIENT Deloitte & Touche	TITLE FARO PIT STORAGE CAPACITY CURVE
			PROJECT No. 0257-019-01 · DWG. No. FIGURE 6 · REV. 0

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.



SCALE: NTS	DATE: DEC 2003	DRAWN: CJT	DESIGNED: GRB	CHECKED: HHH	APPROVED:

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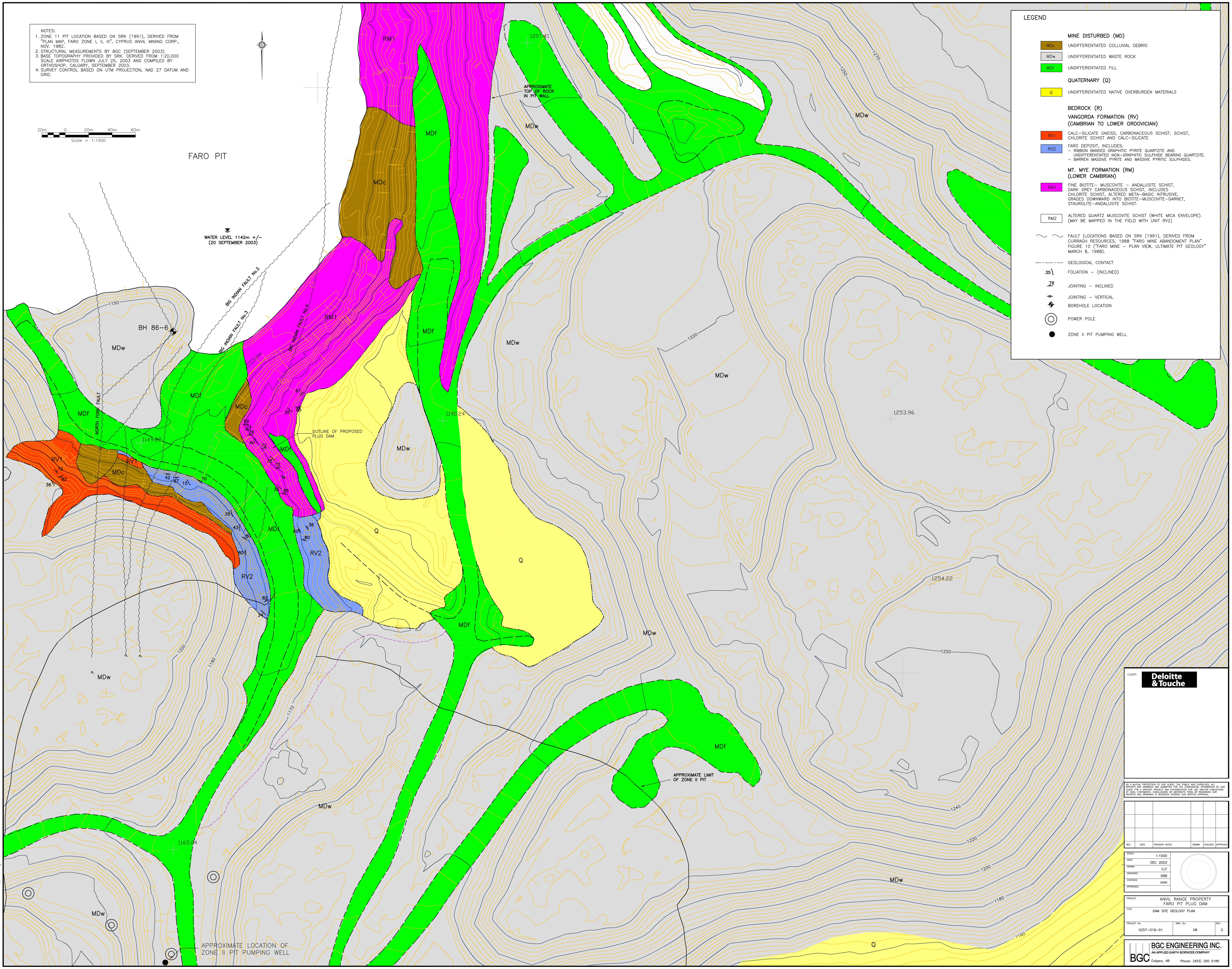
CLIENT: Deloitte & Touche

PROJECT: ANVIL RANGE PROPERTY FARO PIT PLUG DAM

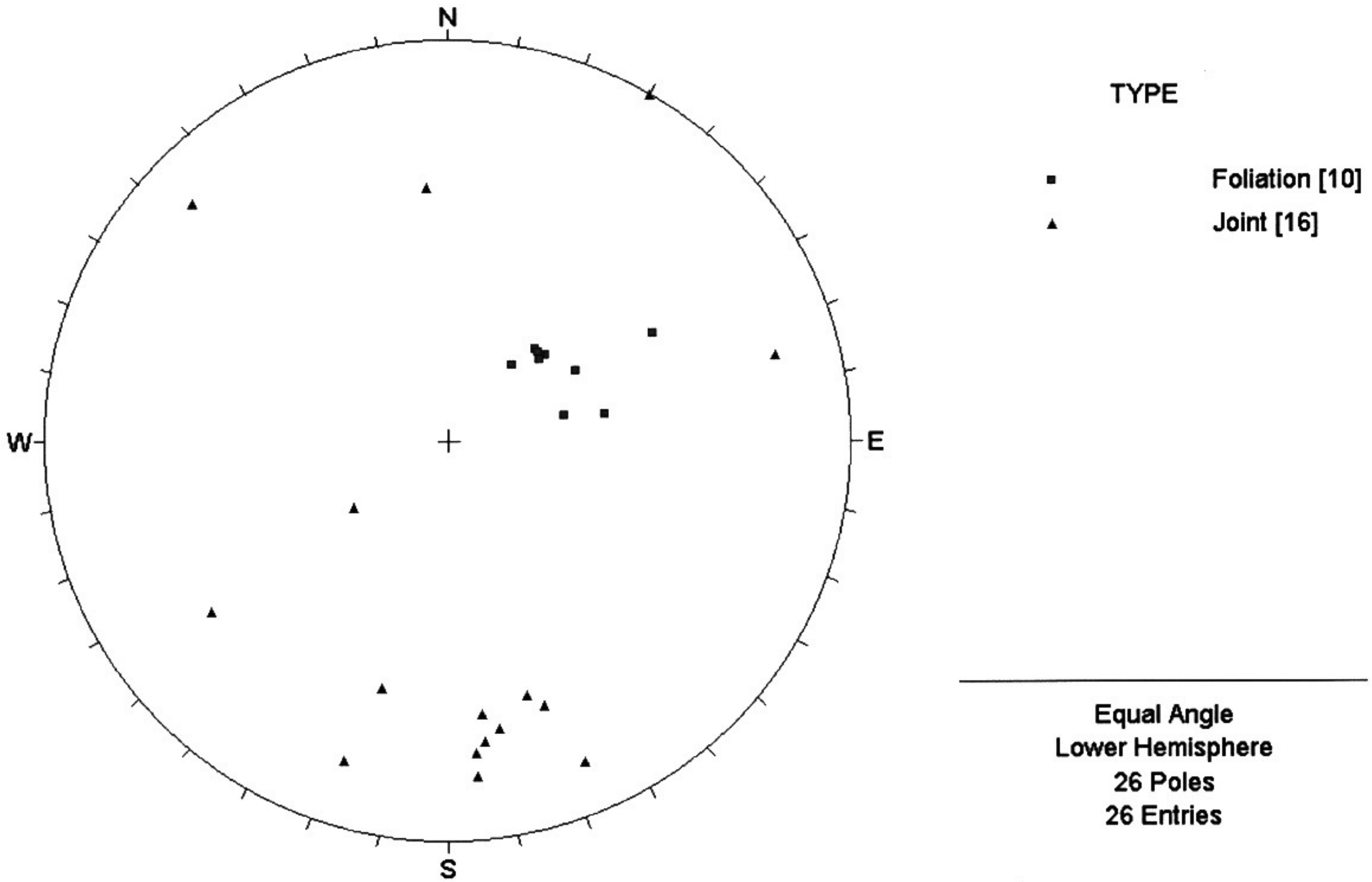
TITLE: ZONE II PIT WATER LEVEL INFORMATION GRAPH

PROJECT No.	DWG No.	REV.
0257-019-01	07	0

0257-019-01 006 FIGURE_7.dwg



0257-019-01 002 FIGURE_8.dwg



DATE: DEC 2003	DRAWN SLF

REFERENCED DRAWING DESCRIPTION

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CLIENT Deloitte & Touche

PROJECT
ANVIL RANGE PROPERTY - FARO PIT PLUG DAM

TITLE
JOINT MAPPING DATA

PROJECT No.	DWG. No.	REV.
0257-019-01	FIGURE 9	0

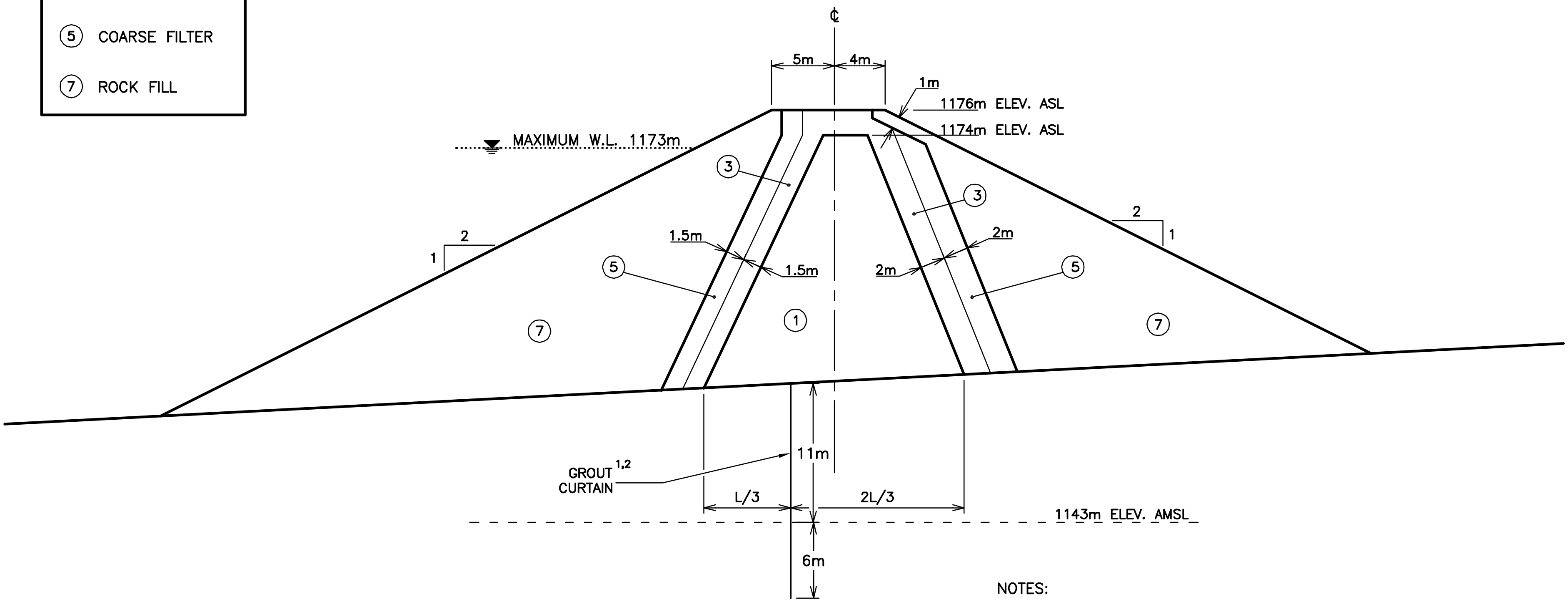
MATERIAL TYPES

(1) IMPERVIOUS FILL

(3) FINE FILTER

(5) COARSE FILTER

(7) ROCK FILL



5m 0 5m 10m 15m

NOTES:

1. SHOWN PENETRATING ~6m INTO "TIGHT" ROCK BELOW 1143m ELEV. ON RIGHT ABUTMENT AND THROUGH CENTRAL LENGTH OF THE PROPOSED PLUG DAM.
2. ACTUAL DESIGN DEPTH TO BE CONFIRMED BY FOUNDATION INVESTIGATION INCLUDING: DIAMOND DRILL CORING AND HYDRAULIC CONDUCTIVITY TESTING.

SCALE: 1:500	DATE: DECEMBER 2003	DRAWN: GEJ	DESIGNED: GRB	CHECKED: HHH	APPROVED:

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CLIENT: Deloitte & Touche

PROJECT: ANVIL RANGE PROPERTY FARO PIT PLUG DAM

TITLE: CONCEPTUAL PLUG DAM SECTION

PROJECT No.	DWG No.	REV.
0257-019-01	10	0

0257-019-01 003 FIGURE_10.dwg

APPENDIX I - SELECTED SITE PHOTOS

View of Plug Dam site from top of right abutment, looking downstream.

Plug Dam site looking downstream along haul road.

Looking upstream along toe of right abutment.

Looking upstream along toe of left abutment.

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REV.	DATE	REVISION NOTES	DRAWN	CHECKED	APPROVED
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SCALE:	N/A
DATE:	DECEMBER 2003
DRAWN:	SLF
DESIGNED:	HHH
CHECKED:	HHH
APPROVED:	

PROJECT

ANVIL RANGE PROPERTY - FARO PIT PLUG DAM

TITLE

SELECT SITE PHOTOS

PROJECT No.	DWG. No.	REV.
0257-019-01	FIGURE I-1	0

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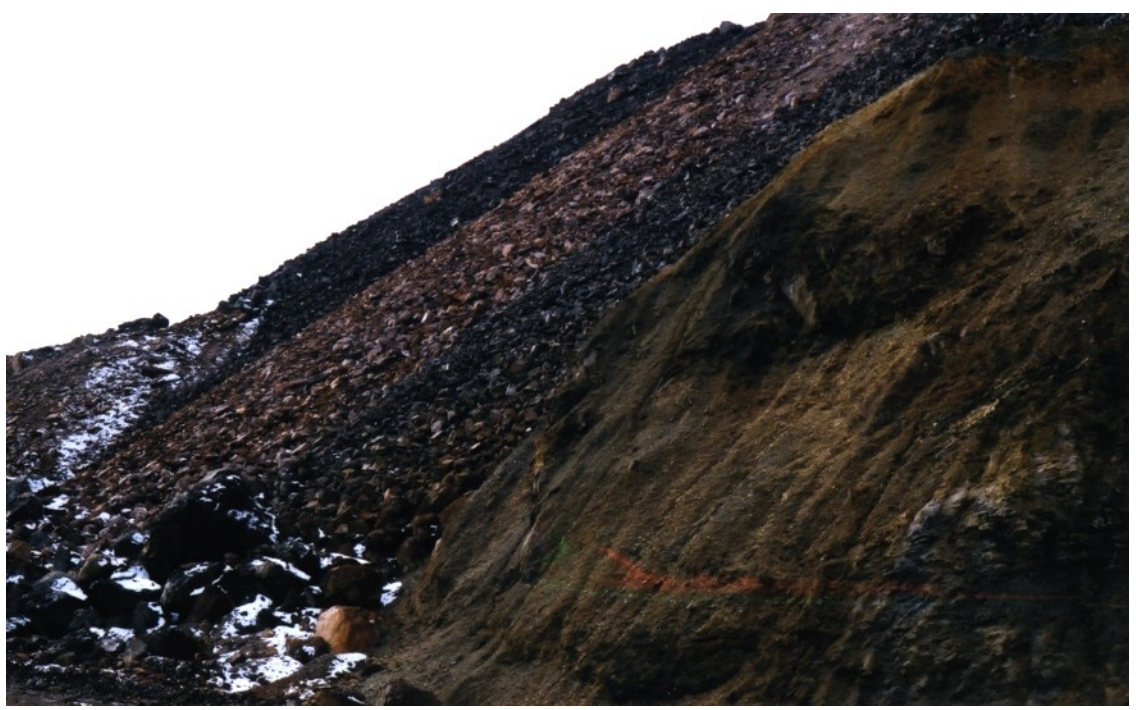
View of right abutment from top of left abutment.

Looking upstream along top of left abutment. Diversion ditch and berm on bench.



Edge of bedrock on right abutment at edge fo Zone II pit filled with waste rock.

Small - scale wedge failure in left abutment has breached diversion ditch and liner on upper bench

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REV.	DATE	REVISION NOTES	DRAWN	CHECKED	APPROVED
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SCALE:	N/A
DATE:	DECEMBER 2003
DRAWN:	SLF
DESIGNED:	HHH
CHECKED:	HHH
APPROVED:	

PROJECT

ANVIL RANGE PROPERTY - FARO PIT PLUG DAM

TITLE

SELECT SITE PHOTOS

PROJECT No.	DWG. No.	REV.
0257-019-01	FIGURE I-2	0

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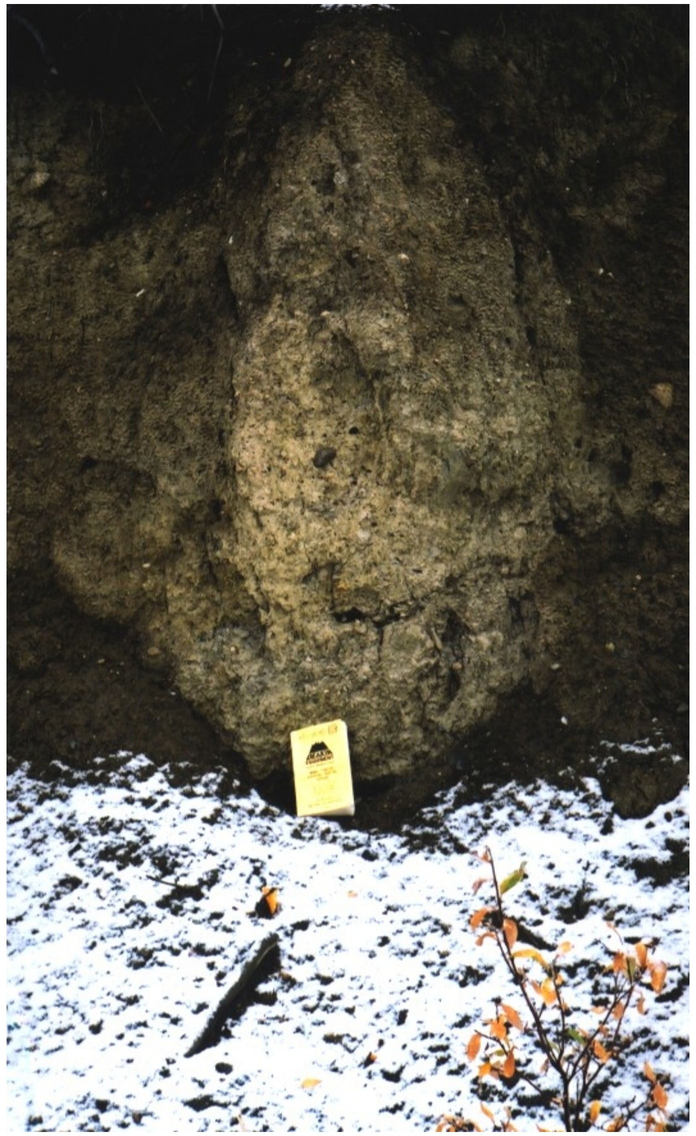

Exposure of Quaternary colluvial material in left abutment.

Toe of waste rock dump on top of bedrock in right abutment.

View of right bank bedrock pillar separating Faro Pit from Zone II Pit.

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REV.	DATE	REVISION NOTES	DRAWN	CHECKED	APPROVED
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SCALE:	N/A
DATE:	DECEMBER 2003
DRAWN:	SLF
DESIGNED:	HHH
CHECKED:	HHH
APPROVED:	

PROJECT
ANVIL RANGE PROPERTY - FARO PIT PLUG DAM

TITLE
SELECT SITE PHOTOS

PROJECT No.	DWG. No.	REV.
0257-019-01	FIGURE I-3	0

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