APPENDIX A
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Public Works and Government Services Canada
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Big Chaudiere Dam
Geotechnical Study Report
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Prepared By:

Holly Hampton FOR

J. Iqbal, P.Eng.
Senior Geotechnical Engineer

Approved By:

Holly Hampton

H. Hampton, P.Eng.
Project Manager

KGS GROUP
CONSULTING ENGINEERS

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EXECUTIVE SUMMARY

KGS Group was retained by Public Works and Government Services Canada (PWGSC) to carry out a geotechnical investigation program at Big Chaudiere Dam, located on the French River at Dokis, Ontario. The results and recommendations of this program are presented in this report.

Big Chaudiere Dam is one of three dams that control the water level in Lake Nipissing. The dam was built between 1914 and 1916 and consists of two nearby but independent gate structures on split channels near the head of the French River. Gate #1 is on the South Channel and Gates #2 and #3 are located together on the North Channel. The structures consist of four concrete gravity abutments on both channels and a pier on the North Channel side and steel sluice gates that constrict the flow of the natural channels.

A geological discontinuity (i.e., crevice or depression) exists along the centerline of the South Channel Dam, including beneath the South Channel Dam and upstream and downstream of the dam. The discontinuity in the vicinity of the dam is filled with “rubble” (loose rock and granular material). It is anticipated that the “rubble” is a result of glacial deposition as well as previous construction work at the site, and construction of cofferdams. The full extent of the discontinuity is not known. Seepage is evident under the South Channel Dam, and is a result of the geological discontinuity. It is reported that the extent of seepage has remained consistent over the years at a rate of approximately 1 to 2 m^3/s. A cement-based grouting program was performed in the 1980s to block the flow of water under the dam, but it was not successful.

The purpose of the geotechnical investigation program was to determine the extent of the discontinuity, the effects that the leakage is having on the structural stability of the dam and to determine alternative methods to mitigate the leakage under the dam.

Consideration is presently being given by PWGSC to replace the Big Chaudiere Dam in the near future with a new dam immediately downstream of the existing dam. The results of this investigation will impact the decision process. This geotechnical investigation program was developed based upon the following considerations and concerns:

- Assess if the structural stability of South Channel Dam is being compromised due to the seepage under the sill.

- Public and personnel safety is a concern because the undertow at the sill is significant due to the high flow rate under it. Therefore, it is unsafe for divers to carry out inspections or work in the vicinity and it is a safety risk should a swimmer be in the vicinity of dam.

- The leakage requires mitigation if the existing dam is to be used as a cofferdam for the construction of the new dam that is proposed to be constructed 16 m downstream of the existing dam.

The flow under the sill has been consistent for the past several years and does not appear to be having any negative impact on the structural stability of the sill and dam. With regards to public and personnel safety, dive inspections are not permitted in the vicinity of the seepage area. In addition, signage and safety booms could minimize the risk of swimmers approaching the dam. The predominant consideration for this investigation is to determine the feasibility and options to mitigate the south dam gate sill leakage so that the existing South Channel Dam can be used as a cofferdam for the construction of the proposed new south dam.

The geotechnical investigation program consisted of the following:

- Review of historical data.
- Seismic refraction survey upstream and downstream of the South Channel Dam.
- Drilling of boreholes and collection of continuous core samples upstream of the South Channel Dam.
- Downhole water pressure testing to measure in-situ permeabilities of any bedrock “rubble” zones and of the underlying intact bedrock.
- Downhole digital video camera work.
- Dye tracer testing.

The key findings from the investigation are:

The borehole core samples and the seismic refraction survey confirms that there is a deep crevice within the bedrock that is completely filled with “rubble” (i.e., loose rockfill and granular material) on the upstream side of the South Channel Dam. The maximum depth of the “rubble” filled crevice is approximately 12 m.

No borehole core samples were obtained downstream of the dam but based upon the seismic refraction results the crevice (and/or fractured upper bedrock) continues downstream of the dam and is filled with the “rubble”, or highly fractured bedrock. It is estimated that this condition is present as far as 20 m to 30 m downstream of the existing dam axis.
The intact bedrock formations are very tight and the “rubble” zone is the principal permeability zone, as confirmed by both drilling operations and water pressure tests.

Flow velocities are relatively high (0.15 m/s) through the “rubble” zone below the South Dam.
Based on the findings and the evaluation of various available options to mitigate the South Channel Dam seepage, KGS has determined that a hot bitumen grouting program is the most viable method to mitigate the leakage. The estimated cost for this grouting program is $1,570,000. Even though this method is the preferred method it may be cost prohibitive if the purpose to mitigate the leakage is strictly so that the South Channel Dam can be used as a cofferdam for the new dam. However, construction of earthfill cofferdams will require foundation preparations (i.e. grouting) as well to minimize water handling/pumping on the “dry side” of the cofferdam. While it carries some risk, the successful implementation of a South Dam rock rubble zone grouting program is likely the best option to mitigate significant flows into the proposed work areas for the construction of a new South Dam. When determining if the cost for the grouting program is acceptable PWGSC needs to also consider the benefits of mitigating leakage for personnel and public safety, and for the purpose to permit dive inspections to monitor and assess the underwater condition of the South Channel dam.

1.0 INTRODUCTION

1.1 Project Location and Site Description

Big Chaudiere Dam is located on the French River at Dokis, Ontario, near Dokis First Nation, approximately 30 km east of the town of Noelville, Ontario and approximately 47 km directly south-west of North Bay, Ontario, **Figure 1**. Access to the Dam is via the Public Works and Government Services (PWGSC) service road, which passes through the Dokis reserve.

Big Chaudiere Dam is one of three dams that control the water level in Lake Nipissing. Available records for the dam indicate that it was built during the period between 1914 and 1916. The site consists of two nearby but independent gate structures on separate bedrock channels, situated at the head of the French River. Gate # 1 is on the South Channel and Gates #2 and #3 are located together on the North Channel. The structures consist of a total of four concrete gravity abutments, with an additional pier required for the two gates on the North Channel side. Each structure utilizes steel sluice gates to control flow.

The project brief indicates that the dam is scheduled to be replaced, or potentially rehabilitated, with a proposed construction start date of July 2011. At present, PWGSC has decided to defer the replacement or rehabilitation work until they review findings that will presented in a Dam Safety Review report and an Options Analysis report that will be completed in 2011 by KGS Group. Originally, the construction work was planned to proceed over two years. The first year would consist of the replacement of the South Dam and the construction of the service road and control building. The second year would consist of the replacement of the North Dam and potentially deepening of the North Channel by two meters.

The project brief also indicates that a geological discontinuity (i.e. lineament or depression) exists along the centerline axis of the South Channel, including beneath the South Dam, and in upstream areas. The full extent of the fault is not known, and geotechnical information is generally limited. Historically observed seepage under the South Channel Dam, which is likely through the rockfill beneath the dam gate sill, is estimated to be approximately 1 to 2 m^3/s, and the degree of seepage through time appears to be constant. A cement-based grouting program was performed in the 1980’s on the south dam rockfill/gate sill areas to restrict the flow of water under the dam, but this program was not successful. Based on the limited information available, it is interpreted that the bedrock discontinuity is filled with course granular materials and/or broken rockfill.

In general terms, the KGS Group work program included the following tasks:

- Review historical construction records and geotechnical investigations / geological assessments completed to date.

- Undertake a geological and geotechnical investigation to characterize, and to the extent practicable, delineate any pervious bedrock discontinuities affecting seepage at the South dam.

- Provide various options, with Class C cost estimates, to mitigate the leakage beneath the South Channel Dam, and through the bedrock discontinuities within the area to be dewatered during the construction phase of the proposed new South Dam.

1.2 Detailed Scope of Work

The detailed KGS Group scope of work under the geotechnical study phases of the project is as follows:

Review existing construction documentation, geotechnical and geological information/reports pertaining to the bedrock discontinuity which exists under the South Dam, soundings and survey information, and the construction drawings for the proposed new South Dam.

Research and review other relevant data sources available, addressing the kind of seepage problem associated with bedrock discontinuities such as at the Chaudiere Dam site, including the infill granular deposits, and the various techniques used to delineate the pervious bedrock discontinuity.

Assess the overall challenges and difficulties associated with the requirement to permanently mitigate the seepage flow of water through the bedrock discontinuity zones during the construction activities for the proposed new South Dam.

Investigation using any non-intrusive testing method that can be used to determine the extent of the bedrock discontinuity zone, or used as a preliminary means to establish a drilling/coring investigation and testing program (e.g. ground penetrating radar or other geophysical techniques).

Field investigation consisting of core drilling, sampling, field observations, recording of core conditions, laboratory testing and reporting.

- This report details the Chaudiere Dam Geotechnical study as defined by PWGSC. It provides a summary of the field investigations, includes recommendations with respect to groutability of the rockfill and/or bedrock discontinuity zone(s), and discusses options to mitigate the flow of water through the rockfill and/or bedrock discontinuities located at the South dam.

1.3 Study Objectives

The KGS Group investigation was designed to meet the following objectives:

To determine the dimensions and rock infill characteristics of the bedrock discontinuity zone(s) under the existing South dam, and at locations upstream and downstream of the dam.

To determine the preferred methodology or technique for mitigating the flow of water through the bedrock within the construction area of the proposed new South dam.

2.0 REGIONAL GEOLOGY AND SEISMOLOGY

2.1 Regional Geology

The regional geology of the area has been mapped by the Ontario Department of Mines and Northern Affairs as shown in preliminary Map P.681, Burwash Area (East Half) as shown on **Figure 2**. The Big Chaudiere Dam is located within the Grenville Province of the Canadian Shield. The bedrock in the vicinity of the dam is comprised of middle Precambrian aged early granitic intrusive rocks, migmatitic and gneissic quartz monzonite, granodiorite, and migmatitic biotite gneiss units. The quartz monzonite unit forms a band (at least 1.2 km in width) oriented northwest-southeast, with the dam site located within the middle of the unit. The regional area is also associated with a diabase dyke, at least 2.1 km in length, oriented generally east-west. Numerous faults or “lineaments” are also shown on the map, which are generally oriented west-southwest and west-northwest. One lineament oriented at approximately AZ 240^{o} is shown passing adjacent to the Chaudiere Dam site. The overburden in the vicinity of the dam comprised of Quaternary aged glacial/glaciolacustrine deposits, typically comprised of sand, gravel, bouldery sand, clay, and silt..

2.2 Regional Seismology

The seismic hazard map of median peak ground acceleration (PGA) values from the Geological Survey of Canada (GSC) is shown on **Figure 3**. Based on the seismicity zoning map, the Big Chaudiere Dam is located within an area of relatively low seismicity (i.e. approximately <0.15 g).

3.0 KGS GROUP GEOTECHNICAL INVESTIGATION

3.1 Original Construction Details and Previous Site Investigations

3.1.1 Original Construction Reports

Based on Big Chaudiere Dam Construction Report and Pictures (1914 – 1916), (Ref. 1) the abutments of the South Channel dam were founded on competent bedrock. The current site of the North and South dams is a secondary location, chosen following cofferdam construction and unwatering for construction of the originally designed single dam structure, proposed to be situated in an area several hundred meters upstream of the current North and South dam locations. The original dam construction site in the upstream location was abandoned following cofferdam unwatering, due to the foundation conditions of large boulder and cobble fill, versus intact bedrock. Excavation in the base of the unwatered portion of the cofferdam revealed at least 3.0 m of basal coarse granular fill, and no exposed bedrock. Because of this foundation condition, the dual structures of the North and South dam locations, as constructed, were chosen.

The bedrock excavation on the south channel side was relatively minimal, with bedrock removal for each abutment sufficient to place concrete around the gate checks. During construction, open water below the cofferdam to approximately El. 628.5 ft (El. 191.57 m) was noted on the “dry side”, and concrete for the South dam and the gate sill had to be placed under water for a distance of about 1.5 m (four feet) from either side of the bedrock channel. Beyond this gate sill area, the bedrock surface sloped very quickly (steeply) to the river bed. Approximately 40 ft (12.2 m) of rock trimming by drilling was done in this sill area, and the broken rock was toppled downslope into the river bed to create rockfill, used to fill a deep bedrock depression at the South Dam location below the gate sill. The cofferdam was leaking badly before the pouring of concrete of the sill. Gravel and earth was hauled from Restoule Bay and was placed along the face of the cofferdam, which stopped the leakage and lowered the water level on the “dry side” of the cofferdam to approximately El. 625.0 ft (El.190.6 m). A steel beam was placed on hard rock foundations of the abutments, and concrete was then poured around it and over the underlying rockfill to form the sill. The completed top of the South Dam gate sill was at El. 627.0 ft, (El. 191.2 m) approximately five feet (1.5 m) below the sill elevation of the North Channel dam.

3.1.2 Dam Repairs in 1986

In 1986, PWGSC performed repair work on the Big Chaudiere Dam (South and North Channel dams). A granular fill cofferdam with a steel sheet pile core was constructed across the river immediately upstream of the North and South Channel dams. The cofferdam extended from the south bank of the South Channel dam to the tip of the central island (Small Island) and then across the river to the far shoreline near the North Channel dam. Only the work carried out on the South Channel dam will be briefly discussed since it has a bearing on the current investigations.

The proposed work for the South Channel Dam involved repairs to the concrete and steel gate. In order to evaluate the overall concrete condition, some investigation boreholes were advanced in the north concrete abutment and sill areas. Core samples of the concrete and foundation materials were obtained. One borehole (BH-A) was drilled through the north concrete abutment and five boreholes (CH-1 to CH-5) were drilled through the concrete sill of the South Channel Dam. The holes drilled through the sill were advanced while the steel gate was out and being repaired. The borehole locations, summary data and cross sections along with repair work carried out are shown on Dwg. No. MC-3 Project no. 620337, **Figure 4**.

Based on these investigations, the rubble below the sill ranges in depth from 6.5 to 16.4 ft (1.98 m to 5.0 m). These depths may only be minimum values since the confirmation of intact bedrock within this program was not clear. Confirmation of bedrock underlying the “rubble zone” (shot rock and other granular materials) cannot be made by coring only a few feet of “rock”, as the bedrock within the rubble zone is of the same lithology as the native intact bedrock below. At minimum of 10 to 15 ft (3 to 5 m) of intact cored bedrock is necessary to “confirm bedrock”, and the base of the overlying rubble rock/infill zone. In the case of the 1986 core drilling, the bedrock may not have been confirmed conclusively in this manner. Details of the core logging and photos of the cores were not available to confirm the details of the rubble zone collected during the 1986 program.

3.1.3 Phase I and Phase II investigations in 1998

In 1998, PWGSC performed Phase I and Phase II investigations on the Big Chaudiere Dam for the purpose of dam safety review. The drilling program was concentrated on the dam abutments and piers, whereas the underwater survey could not be performed on south channel dam due to safety issues. As such, this investigation program added little additional information relative to the seepage condition and pervious bedrock discontinuity below the South dam. The details of the investigations can be found in references 2, 3 and 4.

3.2 Geological Mapping

3.2.1 Previous Site Mapping

Site geology mapping was conducted by Trow Consulting Engineers Ltd. in 1998, as part of the Condition Assessment study of the Big Chaudiere Dam. Much of the site is underlain by pink to grey quartzofeldspathic gneiss, particularly at both abutments at the South Channel Dam, as well as much of the south abutment on the North Channel. Underlying the North Channel is a grey diorite/gabbro dyke, found at the pier and at the north abutment, with a contact to the gneissic unit in the proximity of the south abutment of the channel.

Foliation in the gneissic rock is variably developed from weakly to very well foliated and banded. The diorite unit is generally massive. A fault or lineament, shown from the regional geological maps, is approximately coincident with the South Channel, striking at AZ 240^o. Small changes in bedrock lithology and morphology of the bedrock channels are proposed to support evidence for a fault structure beneath the South Dam, as detailed within the Trow report.

Joint or discontinuity measurements taken at the site predominantly strike north-easterly to easterly, with steep (subvertical) dips to both the northwest and southeast. Joints with other orientations are present, but are less common. Small dyke structures are noted along the north and south edges of the south channel, striking at AZ 060^o.

Terraprobe Limited, as part of the Big Chaudiere Dam replacement study (2001), provided an overview of the geology at the existing dam site. The Terraprobe work shows a trace of a fault or lineament transferred from the regional geological maps, as well as some local joint measurements and mapping. The foliation and associated jointing of the gneissic rocks at the site suggests a steep dip to the north and north east, with a predominant joint set trending northwest to southeast. Downstream of the dam sites along the south channel, joint sets oriented at AZ 070^o to AZ 090^o (with a third less obvious at approximately AZ 045^o) were measured.

3.2.2 KGS Group Site Geological Mapping

KGS Group performed some mapping of bedrock structure in the south channel area in October

2010, both on the downstream and upstream sides of the structure. A set of 80 bedrock measurements were collected in the field, using a geological compass. The measurements are provided in **Appendix A**.

DIPS (version 5.0.5.1) computer software, from Rocscience, was used for the analysis of main joint families, as well as to look at the main joint sets measured, relative to the south channel and other bedrock controlled channel orientations. The stereonet plot of the structural joint measurements and the joint sets, along with the main channel orientations, is shown in **Figure 5**. Field bedrock structural measurements are also shown in plan on a map in **Figure 6**. A series of four joint set families are identified in the data. Following is the summary of the analysis and field observations:

The joint sets measured in the field generally align with regional scale joint patterns as observed/interpreted from the orientation of the structurally controlled bedrock channels.

Specifically:

- Bedrock channel orientations of approximately AZ 50^{o} to 60^{o} (or AZ 230^{o} to 240^{o}) align with Joint Set 1;
- Bedrock channel orientations of approximately AZ 155^{o} (or AZ 335^{o}) align with Joint Set 3;
- Bedrock channel orientations of approximately AZ 100^{o} (or AZ 280^{o}) align with Joint Set 4; and
- Joint Set 2 does not appear to align to any predominant structurally controlled bedrock channel local to the Chaudiere dam site; however, it is generally orthogonal to Joint Set 4.

Many areas of the observed bedrock channel sides are failing by wedges moving out from the channel sidewalls, due to frost jacking/weathering, and generally due to the steep dips of the joint sets, often dipping into the channel wall (i.e. northward), which enhances the movement of rock slabs toward the open channels. The noticeable displacement (predominantly aperture widening) along joints present at the bedrock channel sides has likely added to the spread in some of the orientation data, as presented on the DIPS plot.

Based on the analysis of the bedrock jointing measurements collected at the Big Chaudiere Dam site, the observed structurally controlled bedrock channels appear to be a reflection of regional jointing patterns. The presence of a fault parallel to the south channel, sourced from regional scale bedrock maps, has been postulated by other investigators, based on regional scale bedrock mapping. It is likely that a bedrock discontinuity or other structurally controlled bedrock feature, related to the formation of the bedrock channels, is present within these bedrock channel areas, based on the close correlation of measured bedrock joint patterns with bedrock channel orientations observed at the site.

Flow molded bedrock was observed in areas of the south channel, well downstream of the south dam. High pressure and velocity glacial (i.e. subglacial) water flows, likely in concert with ice flows, may have eroded the structurally controlled bedrock channels along planes of weakness (i.e. subglacial erosion along jointing pattern or due to intrusion of weaker rock along the regional jointing pattern, followed later by subglacial erosion). There are S-forms and other eroded bedrock forms in the intact bedrock, within downstream-channel areas of the south channel, suggesting flows through these rock areas of significant pressure and velocity, likely under subglacial conditions. In addition, there are large rounded boulders of approximately 1.8 m diameter, forming a base armor of some of the low-lying, eroded bedrock channels. These boulders would be placed in these areas by very high base-flow conditions, likely related to glacial or subglacial flow conditions.

As observed within previous site studies, the north side of the south dam channel is blocky, and the south side is rounded, previously postulated to indicate fault movements along the south channel. The north side of the south channel is on the lee side of ice flow, and the south side of the south channel would be hit directly by oncoming ice flow. This would tend to rip the ice-upflow side (North Channel side) and contour or round the south (i.e. down-ice flow) side of the channel. In addition, the nearly vertical joints on the north side of the south channel tend to dip to the north (or into the channel side). This orientation of bedrock structure would predispose the channel wall to topple towards the open channel. Over time wedge failures would result in the "blockyness" on this side of the channel observed today. Finally, along the south channel, there are large-scale discontinuities (structurally controlled bedrock lows) that lie at about AZ 100^{o} to 105^{o} orientation (i.e. cross channels). These cross channels are not noticeably laterally off-set across the main south channel (which is at about AZ 050^{o}), which does not strongly support significant lateral movement along the south channel via fault displacements (see **Figure 6**).

3.3 KGS Group Geophysical Investigation

A seismic refraction survey of the South Channel dam was completed as a part of the current geotechnical study on the upstream and downstream sides of the dam as shown on **Figure 7**. In total, approximately 420 m of seismic refraction lines were setup, shot, and results recorded using combinations of geophones (on land) and hydrophones (in water). A black powder, 8 gauge seismic shotgun was used as a source, and multiple shots were used to record data along each line of geophones/hydrophones. A five meter geophone/hydrophone spacing was utilized, which generally reflects the scale of bedrock features that could be easily resolved by this type of survey, and sensor layout. A 5 m spacing allows resolution of a feature that is approximately 1/3 the width of the south channel, for example. This spacing was deemed appropriate in the field based on the use of the geophysical work as a screening tool to assess to the bedrock conditions within the South Channel, and overall site logistics and challenging accessibility, with steep channel sides, and difficult access to the South Channel along steep rock slopes. The hydrophones placed in the water on the downstream side of the South dam were also terminated at the base of the steep rockface on the south side of the south channel, to minimize reflections of energy back to the survey area from the vertical rockface. These types of reflections would induce difficult to interpret “noise” within the collected data.

The purpose of the seismic refraction survey was to assist with defining the geological conditions and the structural nature of the bedrock within the South Channel in close proximity to the South dam. Specifically, structural weaknesses, or other pervious bedrock discontinuities such as a fault, shear zone or steeply sloped rock infilled depression of the South Channel and southern shore of French River were of interest.

The survey was conducted between October 25 and October 29, 2010. Geophysical survey services were provided by Frontier Geosciences Inc. of Vancouver, BC, with continuous on-site supervision by KGS Group. Frontier Geosciences submitted a seismic refraction investigation report, including details about the equipment used, survey procedure, interpretive method and geophysical results. The report is included in **Appendix B**, and a summary of the results is provided below.

3.3.1 Upstream of the South Channel Dam – Lines SL1 to SL3

The seismic refraction survey results indicate that the river surface upstream of the South Channel Dam is underlain by two distinct compressive wave velocity layers (approximately 1600 m/sec and 4000 to 5000 m/sec). The lower velocity zone is interpreted to be primarily the water column, underlain by a thin layer of high water content sediments on the river bed. These high water content sediments showed no appreciable difference in seismic velocities in comparison to the overlying water column; as such they are interpreted to be comprised of a fine grained (i.e. clay to silt sized), loose and liquefiable sediment present above the dense materials which make up the river bed areas proper. The high velocity zone (i.e. >4000 m/sec) is indicative of the river bottom, and is generally consistent with crystalline bedrock velocities.

The interpreted bedrock surface along seismic lines on the upstream side of the South Channel Dam is generally continuous, with high compressive velocity (approximately 4000 to 5000 m/sec), and no extreme changes in bedrock topography were detected. No low, basal velocities were detected, indicative of a fault or shear zone in the bedrock, at the scale of the survey.

The interpreted bedrock surface/base of river channel is approximately 13 m below the reservoir on the furthest upstream side of the South Channel Dam (i.e. seismic line SL-1). Nearest to the South dam, water depth is in the order of approximately 4 to 5 m (i.e. seismic line SL-3). It is important to note that densely packed rockfill or previously emplaced glacial cobbles and boulders within till soils, directly above the competent bedrock, would have a velocity signature that is overall similar to the underlying competent bedrock as measured in this area (i.e. 4000 m/sec to 5000 m/sec). At the scale of the surveys completed, these zones, particularly as a veneer or infill over bedrock, may be difficult to differentiate from the competent bedrock velocities noted during the seismic study.

Information within the original construction documentation for the South Dam indicates that the foundation condition for the upstream cofferdam was certainly leaky, with flows beneath the cofferdam either through the shallow fractured bedrock, or along the bedrock/sediment interface, within sediment-infilled bedrock low areas. Anecdotal evidence from the 1980's cofferdam construction period suggests that most seepage below that cofferdam was related to areas where the bedrock surface dipped slightly and fractured rock and/or sediment filled rock depressions were present (Pers. Comm.). Seepage during this construction period was handled by pumping from the dry side of the cofferdam, while most flows continued unimpeded through the rock rubble zone below the South Dam gate sill.

3.3.2 Downstream of the South Channel Dam – Lines SL4 to SL7

There is a thin surficial or overburden low velocity zone (approximately 500 to 600 m/sec) , with a maximum thickness of approximately 2 m, on the land portions (i.e. on Small Island) of the seismic lines run on the downstream side of the South Channel Dam. This relatively low velocity layer corresponds to surface exposures and shallow shothole intersections of organics and loose silts, sands and gravels.

A thicker intermediate layer was also identified on the downstream side of the dam with intermediate compressive velocities (approximately 2000 m/sec). Interpreted thicknesses for this layer vary from approximately 0 to 5 m outside the South Channel and 0 to 3 m inside the South Channel. This intermediate layer corresponds to less dense, weathered and open jointed bedrock typically found at shallow depth in the outcrop, and may be related to relatively loose rockfill, fractured bedrock, and/or cobble and boulder glacial infills within the South Channel itself. The apparent thickness of the intermediate velocity zone decreases in a down stream direction from seismic lines SL-6, SL-4, SL-7, to SL-5, from approximately a minimum of 2 m to 3 m in thickness at SL-6, SL-4, and SL-7, to approximately 1 m (or less) approximately 25 m to 30 m downstream of the existing South Dam at SL-5. This implies that the depth to competent bedrock within the base of the South Channel is minimized at a distance of approximately 25 m to 30 m downstream of the current South Dam.

The interpreted bedrock surface, or basal layer, on seismic lines on the downstream of the South Channel Dam is also continuous, with high compressive velocity (approximately 6000 m/sec). This velocity indicates massive, very competent, crystalline bedrock, and is somewhat higher than the bulk velocities (e.g. 4000 m/sec to 5000 m/sec) measured on the upstream side of the South Dam.

There were no low velocity zones evident in the data that would be representative of shear or larger scale discontinuity zones in the bedrock

3.4 KGS Group Geotechnical and Drilling Investigation

3.4.1 Introduction and Methodology

Following review of all available historical data, KGS Group field geological mapping, and seismic refraction study, an intrusive geotechnical investigation program was designed. Based on information available, it appeared that the target for investigations was a pervious, rubble rock infilled bedrock low area, positioned directly upstream of the South dam. Barge mounted diamond drilling along transects in close proximity to the South dam were chosen to provide the best chance for delineating any bedrock discontinuity features contributing to the seepage condition noted at the base of the South dam. The KGS Group drilling and testing program included:

- Drilling of boreholes and collection of continuous core samples.
- Downhole water pressure testing to measure in-situ permeabilities of any bedrock rubble zones and of the underlying intact bedrock.
- Downhole digital video camera work.
- Dye tracer testing.

Drilling services were provided by Walker Drilling Ltd., of Utopia, Ontario with continuous on-site supervision by KGS Group. The fieldwork involved drilling eight NQ size vertical boreholes on the upstream of the south channel dam as shown Drawing No. 10-0006-51 G01, **Figure 8**. The drilling was performed using a barge mounted drill rig with a 25 ft x 14 ft (7.6 m x 4.3 m) barge; photographs of the barge setup are provided in **Appendix C**. The drill was located approximately 10 ft (3.0 m) from the front of the barge, and centered on the barge. The barge was secured by ropes and anchors during the drilling. Due to the size of the barge, some of the original proposed boreholes could not be drilled since they were too close to the dam structure, and the drill and barge setup could not be maneuvered into the correct position to advance the desired boreholes.

The diamond drill boreholes were drilled using casing as required and advanced periodically in order to maintain an open borehole. Without borehole casing, loose material above the bedrock surface within bedrock rubble zones caved into the hole after the core barrel was removed.

Elevation references for the drilling operation were calculated from existing elevations of the top of the concrete abutments. Core samples from the rubble zone and bedrock were retrieved from the core barrel and laid out in core boxes for the field engineer to log. Photographs of core samples and other site operations were also taken and are provided in **Appendix C.** The core boxes for each hole were labelled and taped shut and stored on site. The boxes are stored upstream of the dam on the south bank of the South Channel dam, as per instructions from the on-site dam operator (Mr. Peter Restoule).

Following completion of the boreholes and water pressure testing, PVC (51 mm inside diameter) pipes were placed in the holes in order to secure the holes for downhole camera inspections and dye tracer testing. After all of the testing was completed, the PVC pipes were removed from all of the holes. The holes were not grouted and were left to cave in and fill naturally over time.

3.4.2 Core logging

The rubble/bedrock cores recovered from the boreholes were visually inspected, photographed and logged by the KGS field engineer. Field logs for each borehole were prepared in accordance with standard industry practice. Data and information recorded on the logs include:

- Borehole location;
- Elevations and depths;
- Core recovery (%);
- Rock quality designation (RQD) of rock (%);
- Description and classification of rock and discontinuities;
- Water pressure test results;
- Drilling comments and observations;

The information and observations from the field logs were transcribed to final borehole logs using Microsoft Excel. The logs and color digital core photographs are included in **Appendix D.**

The rock cores extracted showed that the rubble zone generally consists of a mixture of granite and diabase boulders. The rubble appears to be in the order of coarse grained gravel sizes, approximately 0.1 m to 0.3 m in size (up to perhaps 0.6 m in size). Sections of loose granular material, sand, and gravel were also encountered in the rubble zone. A considerable amount of caving was experienced in the zone during drilling, when the core barrel was retrieved. The bedrock generally consisted of quartz-feldspar rich (light coloured mineral) gneissic monzonite, diabase and mica rich lamprophyre intrusive (dykes), comprised of very dark coloured minerals. There was no water return during drilling in the rubble zone whereas the returns were generally 100% in the bedrock with RQD ranging from 40 to 95%.

3.4.3 Water Pressure Testing

Water pressure tests were performed in boreholes BC11-2, BC11-3 and BC11-8. Boreholes were washed prior to the water pressure testing being carried out. Photographs of the test setup are provided in **Appendix C**. Testing was carried out in the bedrock first then the casing was raised up to near the top of the rubble zone where a second pressure test was carried out. Water pressure testing was done in stages (i.e. 30, 40, 50 psi) depending on the depth of the test. Test pressures were generally based on the rule of thumb of 1 psi of injection pressure per ft of cover. At each pressure stage the water acceptance or “take” was measured by the field engineer over a 5 to 10 minute period. The test continued depending on the water take. If it was obvious that there was no water acceptance then the test would be cut short. The testing continued in the reverse pressures (i.e. 50, 40, 30 psi) with the associated water acceptances over time. Only a single inflatable packer was used for these tests.

The injection rate of water (water take) was recorded at each pressure interval for a minimum of five minutes or until the injection rate was stabilized. The injection pressures and water takes were then used to compute the hydraulic conductivity in Lugeon values (Houlsby, 1971) and in units of permeability (cm/s). The head losses were factored into the computations using the friction loss charts from literature, based on test results that were performed with similar testing equipment and configuration. The water pressure test results are provided in **Appendix E** and the permeability values are also included on the field geologic logs, **Appendix D**. The results showed that the rubble zone has a very high permeability with permeability values ranging from approximately 145 to 200 Lugeons whereas the bedrock is tight.

3.4.4 Dye Tracer Testing

Environmentally friendly green dye was introduced into selected boreholes, as shown in a photograph, Dye Tracer Testing – 1 in **Appendix C**, at various depths in order to determine the length of time that it took for water to flow from certain borehole locations to the tailrace seepage area (i.e. average velocity). Dye was introduced into the rubble zone in borehole BC11-8 through the steel casing and the dye was introduced into borehole BC11- 3 at specific depths through the PVC pipe. The presence of the dye downstream was confirmed by visual inspection and the travel time of the dye was measured with a stopwatch by the field engineer in cooperation with the drilling staff. **Table 1** summarizes the tracer testing that was completed.

Table 1: Dye Tracer Test Results – Big Chaudiere Dam

Test No.	Borehole No.	Depth from t/o Barge FL. (m)	Time (@ the initial location)	Vertical Distance (m)	Horizontal Distance (m)	Distance Travelled (hypotenuse) (m)	Velocity (m/s)
1	BC11-8	13.1	2 min. 19 sec.	10.89	18.7	21.64	0.16
2	BC11-8	7	2 min. 10 sec.	4.79	18.7	19.30	0.15
3	BC11-3	7	2 min. 10 sec.	4.79	6.55	8.11	0.06
4	BC11-3 (Rice Krispies)	7.62	30 sec	3.81	6.10	7.19	0.24

An alternate tracer method was also devised using Rice Krispies cereal. The test was carried out successfully in borehole BC11-3. The result of the tests is also summarized in Table 2. The results showed that the water flow through the rubble zone is very fast as the velocity ranged from 0.06 m/s to 0.24 m/sec (average value 0.15 m/s).

3.5 Confirming Rubble Zone Thickness and Bedrock

The borehole locations were designed to determine the distribution of the rubble zone and to verify its thickness by confirming bedrock.

3.5.1 Rubble Zone

The term "rubble zone" is used to identify the loose rock and granular material found in the upstream channel of the South Channel Dam. This material rests directly on bedrock. As previously discussed, the uppermost portions of this loose rockfill material consists of shot rock that was placed during original construction as a foundation for the concrete sill. Since this material is derived from the blasting of bedrock at the site, it was felt that the lithological differences between the rubble rock and the bedrock could be difficult to identify in core samples, as the source of the materials is identical.

As a result, some general characteristics of the rubble zone material were considered prior to the drilling investigation. It was reasoned that the blast rock placed for fill rock would have been disturbed by the blasting and onsite construction handling to the point where any weakness planes (i.e. joints or thin layers) would have been broken and the resulting rock fragment would be very competent. Based on the onsite blast rock that is piled up on the north bank of the North dam, the pieces of the blast rock would be generally no larger than about 0.6 m (2 ft) in diameter. In addition, there would also be many void spaces between the randomly laid blast rock. These voids are the pathways for the water flowing beneath the dam and are significant in understanding the permeability and ultimately the groutability of the rubble zone. It was anticipated that drilling within this zone would show water loss throughout this zone due to the void spaces, which was in fact observed during drilling at site.

It was also anticipated that there would be granular materials present (coarse to fine gravel, sand) within this zone because of natural glacial deposition as well as previous construction work at the site, and construction of cofferdams. Granular material in the cofferdams would be drawn down into the open voids within the zone by flowing water. Some of this material would be trapped between boulders etc. and remain within the interstitial space between larger rock fragments. During drilling these areas of sand and gravel would be probably washed by drilling water or possibly partially recovered in core samples. Any infill granulars used would likely have rounded gravel sized clasts, and if recovered in the core could be identifiable on that basis.

3.5.2 Bedrock

Because the rubble zone rock types are identical to native bedrock at the South dam site, lithology alone was not used as a diagnostic indicator of the intact bedrock surface. Bedrock was confirmed in each borehole when at least 15 ft (4.6 m) of core showed consistent intact bedrock characteristics. Some of the main diagnostic characteristics used for bedrock confirmation included:

Consistent joint orientations and fitting of joint surfaces together within recovered cores.

Presence of small features like wafer thin layers that fit together within recovered cores.

Evidence of fine and weak brittle fracturing (i.e. faulted or sheared rock) that would not likely be typical of a disturbed rubble zone rock

There was 100% water return during the drilling of all bedrock sections, whereas within the rubble zone there was always 100% water loss.

3.6 Downhole Camera survey

The downhole camera surveys were carried out at boreholes BC11-2 and 8 by Camspec (a downhole camera specialist from Sudbury, Ontario). The camera allows for a “forward looking” view of the borehole as shown in a photograph, Downhole Video Survey – 1 in **Appendix C.** The inspection was recorded on DVD. The recorded images of the inspections were reviewed by the KGS field engineer in order to compare the core samples with the in situ conditions.

The camera inspected the bedrock and the rubble zone in borehole BC11-8. However, due to caving conditions, observations of the rubble zone were limited. The removal of the casing allowed the unconsolidated granular materials to collapse into the borehole. The casing protected the camera as the casing was pulled up through the rubble zone. A copy of the DVD recorded has been submitted to PWGSC and a report on the observations made during the downhole video survey is included in **Appendix F.**

The inspection of borehole BC11-2 was carried out through the PVC pipe. The camera was positioned at the bottom of the pipe and the cable was taped to the top of the pipe. The pipe was then removed slowly and the camera recorded the image of the material in the borehole.

4.0 FINDINGS OF INVESTIGATION

4.1 Characteristics of Rubble Zone

The geophysical survey, drilling investigation, bedrock cores, downhole camera inspection, dye tracer testing, and water pressure testing within the rubble zone provided data regarding the depth and distribution, composition, and permeability of the rubble infill zone. While the geophysical survey was not capable of clearly defining a bedrock "low" adjacent to the South Channel Dam, it did generally confirm the top of bedrock on the upstream side of the South Channel Dam structure, as well as suggest that the rock infill in that area has generally similar velocity profile as the shallow bedrock. On the downstream side of the South Channel Dam structure, the geophysical survey suggests that there is several meters (i.e. 3 m or more) of fractured bedrock and/or rock fill materials within the base of the South Channel.

On the upstream side of the South Channel Dam, the rubble zone thickness is confirmed in boreholes BC11-1, BC11-2, BC11-3, BC11-4, and BC11-8. The thickness of the zone ranges from 1.4 ft to 39 ft (0.42 m to 12 m) above competent bedrock. The deepest portion of the rubble rock zone is found approximately 15.2 m upstream of the south dam at borehole BC11-8. Within areas closest to the South Dam (i.e. within approximately 3.0 m of the dam on the upstream side), the depth of the rubble rock zone below the riverbed is approximately 7.0 m to 8.3 m (at boreholes BC11-3 and BC11-2, respectively).

These cored depths of the rubble rock zone are generally comparable to data collected in 1986 where minimum thicknesses of the bedrock rubble infill zone were interpreted to be between 2.0 m and 5.0 m. The lateral limits of the rubble zone near the dam structure are delineated at boreholes BC11-1 and BC11-4 where only bedrock was encountered, with no overlying rubble zone. Boreholes BC11-1, BC11-2, and BC11-3 encountered between approximately 0.3 m and 1.47 m of concrete/mixed concrete and rockfill at the riverbed, in close proximity to the South Dam gate sill. This material is related to the concrete poured for forming the South Dam gate sill, and for encapsulating the steel beam placed between the abutments at the South Dam.

The longitudinal limits of the rubble zone are not explicitly defined, but are inferred or dimensions confirmed within the limits of investigations from the geophysical testing on the downstream side of the South dam, and from drilling on the upstream side at BH11-8. The outcrop visible at the South dam abutments would define the limits of the rubble zone at the dam axis location. A cross section of the riverbed just upstream of the South Channel dam is shown on Drawing No. 10-0006-51 G02, **Figure 9**.

The drilling operations at BC11-5, BC11-6 and BC11-7 encountered difficulty keeping proper alignment of the casing while the casing was advanced through the rubble zone. Although the barge was secured with ropes, the boreholes did not reach bedrock and had to be terminated in the rubble zone due to hole misalignment and associated binding. The final depths of BC11-5, BC11-6 and BC11-7 below the river bottom are 1.5 m, 0.3 m and 2.9 m respectively. Recovered cores in the rubble zone from BC11-5, BC11-6, and BC11-7 have similar characteristics as rubble zones observed within boreholes BC11-1, BC11-2, BC11-3, BC11-4 and BC11-8. Photographs of the cores recovered are included in **Appendix C**.

The rubble zone consists of a mixture of granite, and diabase boulders up to a total depth of 12m (39 ft). There is no way of determining which boulders are blast rock and which ones are naturally occurring, other than for possible contact faces which would be expected to be angular in the blast rock, and possibly rounded for other naturally occurring rock sources. Sections of loose granular material, including sand and gravel, was also encountered (some material may have been washed away during drilling and was not recovered). Coarse grained gravel was well rounded and clearly glacio-fluvial in origin. These gravels could have been part of the granular material used to stop the leakage from the cofferdams, or these deposits could be natural, based on the observation of thick basal granular fills at the upstream cofferdam site originally constructed at the prime single structure upstream location, in the early 1900's. Considerable amount of caving was experienced during drilling when the core barrel was retrieved within the rubble zone. Consequently, material falling to the bottom of the hole was recorded until the casing was advanced to cover the caved zone material.

The most important aspect of the rubble zone is the occurrence of voids and the permeability of this zone. During the drilling operations, water return to surface was zero throughout the rubble zone as a result of drilling water escaping through open voids or pervious granular sections. Water pressure testing also confirmed that the rubble zone has a very high permeability with permeability values ranging from approximately 145 to 200 Lugeons. The actual dimensions of some voids are not known but their size could vary throughout the rubble zone, as some of the void spaces have been found filled with grout. Grout infill zones appear to be very localized and are located nearest to the South dam. Voids are distributed within the entire rubble zone and are interconnected hydraulically. Voids could range widely in size from millimeter scale to as much as 0.1 to 0.3 m, depending upon the distribution and packing of the rocks in the rubble zone, based on drilling observations and available camera video.

The dye tracer testing showed that the water flow through the rubble zone is very fast with the range of velocity from 0.06 m/s to 0.24 m/sec (average value 0.15 m/s).

Visual observations of the downstream leakage of water under the sill of the dam shows considerable upwelling of water and the large volume of water coming through the rubble zone that exists under the sill. Personal communications with Peter Restoule (onsite dam Tender) regarding the leakage under the dam indicated that his records show that when all of the gates are closed, the residual leakage (only coming through the South Channel dam) is measured at 1 to 2 cubic meters per second (35 to 70 cubic feet per second). The records also show that the amount of seepage under the sill is consistent over the years. This discharge rate is however considered to be very high and will affect the groutability of the rubble zone.

In summary :

- The bedrock rubble zone on the immediate upstream side of the South Dam (i.e. 3 m upstream of the gate sill), has a maximum depth of between 7.0 and 8.3 m based on boreholes advanced as part of this investigation program (i.e. boreholes BC11-2 and BC11-3).

- Laterally, the rubble zone does not extend into the outcrop abutment areas of the south dam, based on cores drilled at boreholes BC11-1 and BC11-4. This is consistent with intact bedrock observed at the South Dam abutment areas.

- The deepest portion of the rubble zone thalweg was noted at borehole BC11-8, located approximately 15 m upstream of the South Dam gate sill. The bedrock rubble zone depth in this area is approximately 12 m.

- Geophysical information collected on the downstream side of the South Dam indicates that there is a zone of at least 3 m thickness of fractured bedrock, and/or fractured bedrock and rubble infills within the base of the south channel. This zone extends at least 20 to 30 m downstream of the South Dam gate sill. The seismic data collected at seismic line SL-5 implies that the thickness of the fractured bedrock/rubble bedrock intermediate velocity zone thins to approximately 1 m or so at this distance of 25 m to 30 m downstream of the South Dam. Further intrusive investigation would be required to confirm this interpretation of the seismic data.

- The permeability of the rubble rock zones is very high (e.g. 200 Lugeons), and flow velocities through this zone beneath the South Dam gate sill are also quite high (average 0.15 m/s). Constant discharge below the South Dam gate sill is estimated between 1 m^3/sec to 2 m^3/sec.

4.2 Characteristics of Bedrock

Bedrock is exposed along the upstream and downstream areas of the dam site. However, the drilling investigations confirmed that there is a deep crevice within the bedrock (associated with the some local discontinuity or lineament in this area) that is filled with loose rockfill and granular material. Bedrock in the upstream area was confirmed in boreholes BC11-1, BC11-2, BC11-3, BC11-4, and BC11-8. In the case of borehole BC11-1 and BC11 4, it was obvious that after drilling 4 m and 3 m (13 and 10 ft) respectively with consistent rock type, consistent jointing and no water loss that the true bedrock surface had been intersected.. These holes were terminated by the field engineer.

The bedrock type consisted of quartz-feldspar rich (light coloured mineral) gneissic monzonite, diabase and mica rich lamprophyre intrusive (dykes), comprised of very dark coloured minerals. The monzonite rock formation is very massive with very few joints. However, the dyke formations showed closely spaced steeply dipping joints (10 to 20 degrees to the core axis). These joints are likely related to the local discontinuity or lineament in this area. However, these joints are generally tight and there was 100% water return during drilling of all bedrock sections. In some cases where a piece of core got jammed in the core barrel some grinding of the closely fractured bedrock was encountered.

The rock formations are very tight with little to no water flow through the fractures intersected as confirmed by water pressure testing and the fact that there was no water lost during drilling. Even though there are fractures in the bedrock these fractures are tight and consequently do not allow water to flow readily through the rock mass.

5.0 GROUTING

5.1 Grouting Methods

Traditionally, there are three basic methods used for grouting stable rock masses:

- Downstage (descending stage) with top hole packer.
- Downstage with downhole packer.
- Upstage (ascending stage).

For extremely weathered and/or collapsing ground conditions (as experienced during the current geotechnical study at BCD), even descending stage methods can prove impractical, and the Multiple Packer Sleeve Pipe (MPSP) Method could be the method of choice. This rockfill medium at the Big Chaudiere site is generally very difficult to drill, and none of the conventional grouting methods can be made to work due to the high flow velocities through the rock fill zone. The MPSP system is similar to the sleeved tube principle in common use for grouting soils and the softest rocks (rockfills) (reference 13). The sleeve grout in the conventional system is replaced by concentric polypropylene fabric collars, slipped around sleeve ports at specific points along the tube (**Figure 10**). After placing the tube in the hole, the collars are inflated with cement grout, via a double packer and so the grout pipe is centered in the hole, and divides the hole into stages. Each stage can then be grouted with whatever material is judged appropriate, through the intermediate sleeved ports. Considerable use has been made of MPSP in loose, incompetent, or voided rock masses and rockfills, in recent major projects in Canada, and U.S.

5.2 Grouting Materials

Three categories of grouting materials considered for grouting the rubble zone are the following:

- Cement based;
- Polyurethane (Chemical); and
- Hot bitumen.

5.2.1 Cement Based

Additives and admixtures can be used to minimize wash out of the cement based grouts and typically can be adjusted to be suitable for flow conditions that are less than 0.1 m/s. The higher the flow rate the more thixotropic the grout is required to be and therefore the shorter the penetration distance and the more closely spaced the grout holes will have to be to create a continuous grout curtain.

The flow velocity through the rubble zone (approximately 0.2 m/s) is significantly higher than is practical for cement based grouts. In order for cement based grouts to be effective for this project the flow velocity would be required to be reduced prior to carrying out the grouting activities.

5.2.2 Polyurethane (Chemical)

Pure water reactive polyurethane grouts can also be used to minimize wash-out of the grouts. Although very expensive, these products are effective to cut off inflows under significant flow conditions provided resident tubes are used. Grouting with "resident tubes" pertains to a system in which water is injected into the polyurethane grout flow, causing the grout to foam as soon as it enters the rock formation to prevent wash-out. As more apertures are being cut off, the flow paths are becoming more direct, prompting adjustments to the resident pipe system. Grouting with resident tubes is a difficult operation, involves extensive experience and a lot of grout holes (as many as 5 per lineal meter of curtain). This operation is not practical for the Big Chaudiere grouting program due to the extensive number of grout holes required.

5.2.3 Hot Bitumen Grout

Hot bitumen in conjunction with cement based grout is effective in creating grout curtains under extreme flow conditions. Moreover, blown (oxidized) bitumen is an environmentally friendly grout (see Section 5.3).

The advantage of bitumen over other grouting systems to stop or control water flow, especially under high pressure and at high flow rates, is that blown bitumen will not wash-out. Another advantage of the hot bitumen grouting is that fewer grout holes are required for grouting. It should however be noted that for long-term success, experience, knowledge and a sound engineering design must be applied. The use of hot bitumen for this project is the preferred grout to be used.

5.3 Environmental Issues

Environmental issues are a major concern in the construction of grout curtains under extreme flow conditions. Some quantities of grouts inevitably do wash out under a variety of conditions, in spite of the selected technologies and methods. The waters polluted with grout ingredients will end up in the surface or sub-surface fresh water system one way or another, even if they are being retained in a surface pond for a period of time.

Even minute spills of regular cement based grouts can cause serious environmental issues and the suspension of the grouting operations.

With increased awareness of environmental matters, most polyurethanes offer a solution of grouting in potable water environments but as discussed in Section 5.2.2 polyurethane grouts are not practical products to use for this project.

The injection of hydrocarbons into soil, rock or structures immediately raises environmental concerns. There are, however, many types of bitumen grouts available with a wide range of characteristics. The desirable type for use in grouting is a hard oxidized environmentally friendly type of bitumen with a high solidification point. Oxidized blown bitumen has a long history of successful use for lining of potable water reservoirs in California (over 40 years) and in 1987 Washington and Oregon State wildlife authorities have used it for lining fish hatcheries ponds. Oxidized bitumen has proven to be in compliance with the American Water Works Association (AWWA) standards for leachate resistance of materials for use in potable water applications (reference 17).

5.4 Alternative Methodologies to Seal South Channel Dam

The current drilling investigation showed that the rubble zone, within the crevice and under the sill, starts at approximately one meter from the faces of the concrete abutments with a maximum depth of approximately 12 m roughly at the centre of the channel. The extent of the crevice on the upstream and downstream sides of the dam is not known. The water pressure tests conducted during the investigation showed that the rubble zone is the principal permeability zone and that the bedrock is tight. The water flows through the rubble zone with a high flow rate and velocity (approximately 1 to 2 m^3/sec and up to 0.24 m/sec, respectively). This indicates that the rubble zone may contain large voids. The high flow rate and velocity through the rubble zone will make the conventional cementitious grouting very problematic since the grouting volumes and the pumping rates required would not be able to overcome the water flow through the rubble zone. Even with a fast set grout would not be effective.

The field investigations revealed that there are significant challenges with performing a grouting program with the goal to permanently mitigate the seepage of water through the bedrock discontinuity zones below the existing South Dam. A successful grouting program advanced to mitigate flows below the existing South Dam would also have the largest benefit to minimizing risk for construction of the new South Dam in downstream areas. Specifically, the grouting program would have to be designed to perform under the following site conditions:

- Drilling through the rubble zone, with borehole collapsing conditions.
- High rate of water flow and velocity in the rubble zone.
- A maximum rubble zone depth of approximately 12 m.
- Large voids (0.1m to 0.3 m in size) within the rubble zone.
- Environmental issues related to the grouting materials dispersing due to high rate of water flow.

The rubble zone could be grouted using a staged grouting approach. At first the water flow rates are reduced to minimize wash-out of the grout, followed by the actual cement based grouting.

The following three options have been considered for grouting the rubble zone and sealing the South Channel Dam:

5.4.1 Option 1: Cofferdam & Cementitious Grout

Option 1: Install an upstream cofferdam to minimize the water flow rate / velocity through the rubble zone and then grout with a cementitious grout.

To construct an effective cofferdam would involve the following:

- Excavate, in the wet, the full depth of rubble wide enough to accommodate installing a 5 m to 6 m thick layer of 5% bentonite/sand mixture against the exposed rubble face. Excavation can be carried out using a backhoe with an extended arm or clam shells or both. The soil / bentonite mix would be mixed on shore using bob cats / front end loaders and dumped in the channel and compacted. It might be necessary to place this fill in geotextile bags (to prevent washout and erosion from the flow rate). The excavation activities will be carried out sufficiently far enough upstream to ensure that rubble under the South Dam sill is not destabilized.

- Once the berm is in place, install sheet piles along the centerline of the berm (perpendicular to the flow) extending to the river bottom. There will be gaps between the sheets and the rock contours that will be required to be grouted.

- Steel sleeve grouting pipes are to be installed at each joint (between the sheets) for the injection of hydrophobic, water reactive MDI, semi-rigid polyurethane prepolymer. This is done to stop erosion in the contact zone between the sheet piles and the rock formation.

- Where necessary, inject hydrophobic, water reactive, MDI, semi-rigid, polyurethane prepolymer in each sleeve pipe to create a seal between the rock contours at the base of the berm and the sheet piles.

A high risk cost is associated with constructing this cofferdam because of the difficulties that may be encountered with the working in the high flow conditions and with the rubble. The cost of such a cofferdam could be in the order of $1,000,000 but further design and constructability evaluations are required to provide a reliable cost estimate. Furthermore, if sealing the South Channel Dam is strictly so that it can be used as a cofferdam for the construction of a new dam downstream of the South Channel Dam it would be more cost effective and technically sound to construct a cofferdam downstream of the South Channel Dam (see Section 6.3).

This is NOT the preferred option.

5.4.2 Option 2: Fill Voids & Cementitious Grout

<u>Option 2:</u> Gravity fill the voids in the rubble zone both upstream and immediately downstream of the dam using sand and graded aggregate to minimize the water flow rate / velocity and grout with a cementitious grout.

This operation should be carried out under a low head condition with the installation of a well graded aggregate filter on the downstream side to minimize the wash-out of sand and fine aggregate. This material could then be progressively dumped into the upstream area of the dam to progressively plug the void spaces within the rubble zone. Coarse sand and fine gravel would be ideal in the initial stages of grouting so that the water flow could carry the material deeper into the rubble zone. The sand, gravel and coarse aggregate could be progressively built up to form a large blanket extending from the dam to about 15 to 20 m upstream. Then, a cementitious grout can be used to provide an impervious grout curtain in the rubble zone.

To effectively fill the rubble zone with the sand and aggregate may involve significant trial and error costs and delays and still there is a high risk that this method may not be successful.

This option is NOT preferred.

5.4.3 Cementitious Grouting Procedure for Options 1 and 2

Peter White of Multiurethanes Ltd. who is a cementitous grouting specialist who carries out water cut-off operations to control major water inflows through rock was consulted regarding appropriate cementitious grouting procedures for this project.

Should PWGSC choose to either construct an effective cofferdam or effectively gravity fill the rubble voids with aggregate to reduce the flow then the following cementitious grouting procedures can be used:

5.4.3.1 Drilling Activities

- Drill three rows of holes upstream of the concrete sill, at a spacing of 1.5 m between adjacent holes, and to a sufficient depth that penetrates between 1 to 2 m into solid bedrock. Based on the anticipated width and depth of the rubble zone, it is expected that 12 holes will be required.

- Drilling equipment would be self-contained on a barge situated upstream of the South Channel Dam.

- Upon completion of drilling and casing each hole to the appropriate depth, a 3 inch PVC sleeve pipe shall be installed to the bottom of each hole prior to recovery of the drill casing.

- The PVC sleeve pipe shall be equipped with grouting ports and outer rubber sleeves at 0.5 m intervals.

5.4.3.2 Cement Grouting Operations

- The objective of the grouting operations will be to place a thixotropic, low-mobility cement grout into the rubble zone beneath the concrete sill of the South Channel Dam with minimum loss of cement to the downstream environment.

- Cement grouting operations will commence at the lowest elevation in holes with the greatest depth within the rubble formation. Grouting operations will proceed in sequence through adjacent holes to place cement grout systematically in ascending horizontal layers.

- Cement grouting equipment and materials shall be self-contained on a barge situated upstream of the South Channel Dam.

- Cement grouting work should proceed in controlled stages of limited grout volumes using a thick cement grout with accelerators and thixotropic additives as appropriate for various site conditions to coagulate cement particles within the rubble zone and minimize wash out of the cement.

5.4.4 <u>Option 3</u>: Hot Bitumen & Cementitious Grout

Hot bitumen can be used effectively for grouting the rubble zone along with a cement based “mattress” to confine the top surface of the rubble zone during the grouting operations. A cement based grout will also be used to compensate for the shrinkage of the cooling bitumen.

This is the recommended option.

5.4.4.1 Hot Bitumen Grouting Procedures

The biggest challenge with this project is the fact that the rubble extends all the way to the floor of the channel. There is no confinement at the top. Typically, grouting the upper 2 meters of a soil or rubble zone is very difficult, even in the absence of flow.

In consultation with a Hot Bitumen consulting specialist (Alex Naudts of ECO Grouting Specialists) the following Hot Bitumen grouting procedure is recommended:

5.4.4.1.1 Drilling and Confinement Activities

- Install 3 rows of grout holes from a barge:

  - The upstream row (3 holes) would be used to create some (deep) upstream confinement for the grout.

  - The downstream row (4 holes), located very close to and just upstream of the sill is the row that has to ensure no flow enters between the sill and the grout curtain. Some artificial confinement is to be created at this location (double layered flexible form, 2- 3 m wide, filled with a water repellant, stable cement based suspension grout).

- The central row (3 holes) is used to perform the final grouting pass, once the confinement has been created by the other 2 grout curtains and the confining grout mattress.

5.4.4.1.2 Piping and Grouting Operations

- Install the in-hole grout delivery pipe system in each of the holes. The system will be somewhat different in each of the holes, depending on where the plan is to target the inflow. The lower part of the delivery system will be a single pipe steel stinger, with the upper part of the delivery system being a concentric pipe system (to facilitate the heating of the circuits). The intent is to inject from the bottom up, starting at the deepest point.

- Install the hot bitumen grout plant and heating system for the preparation of the insulated surface circuits. Once these circuits are hot, hot bitumen shall be sent down into and through the in hole pipe delivery system of the first grout hole, until this one is warm enough to start the actual grouting.

- Start grouting through the first grout hole from the bottom up. Bring more holes on line as the operation progresses. Perform real time monitoring and assessment to follow the "growth" of the bitumen/rubble conglomerate. Initially, the injection rates will be very high. (15 to 30,000 liters per hour).

- Eventually, some holes will be taken offline and others will be brought on line. The bitumen will migrate through the rubble to the floor of the South Channel and flow like a lava, being re-melted from the inside. This operation continues until all seepage has stopped. Some cement grouting will take place to compensate for the shrinkage of the cooling bitumen. The hot bitumen grouting operation shall be maintained for several days at lower injection rates.

5.5 Estimated Costs – Grouting of Existing Rubble Zone at the South Dam

The following Table 2 provides estimated costs to carry out the Cementitious Grouting work as part of Options 1 and 2 and the Hot Bitumen Grouting (Option 3). The Cementitious Grouting cost estimate was provided by Peter White of Multiurethanes Ltd. and the Hot Bitumen Grouting cost estimate was provided by Alex Naudts of ECO Grouting Specialists.

The costs for the Cementitious Grouting method does not include the costs for the construction of a cofferdam (Option 1) or for the costs to gravity fill the voids in the rubble zone with sand / aggregate to effectively reduce the velocity of the flow in the rubble zone to less than 0.1 m/sec. The risk costs for the cofferdam and filling the rubble zone voids with aggregate are very high and therefore Options 1 and 2 are not preferred.

Hot Bitumen Grouting (Option 3) is the most reliable method and therefore the preferred option but the total cost is estimated to be $1,570,000 which may be cost prohibitive for this project.

Table 2: Grouting Cost Estimates

Task	Cost	
	Cementitious Grouting (part of Options 1 & 2)[1]	Hot Bitumen Grouting[2] (Option 3)
Mobilization (drill rigs, grout plant, and barges) & Site Preparation	$ 200,000	$ 200,000
Drilling Activities	$ 250,000	$ 300,000
Installation of grout filled mattress (divers and grout crew)	$ -	$ 80,000
Grouting Work	$ 180,000	$ 380,000
Materials	$ 40,000	$ 480,000
Clean-up and Demobilization	$ 65,000	$ 50,000
Design of grouting program - Site Engineering and Direction	$ 50,000	$ 80,000
TOTAL	**$ 785,000**	**$ 1,570,000**

[1] Costs do not include for installation of cofferdam (Option 1) or gravity filling rubble voids with aggregate (Option 2).

[2] Preferred option.

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6.0 ALTERNATIVES TO MITIGATE LEAKAGE DURING CONSTRUCTION OF NEW SOUTH DAM

In Section 5.0 alternatives were presented to stop leakage under the sill of the existing South Channel Dam primarily so that the existing South Channel Dam be used as a cofferdam for the construction of a new South Channel Dam proposed to be located 16 m downstream of the existing dam. This Section provides alternatives to mitigating leakage during construction of the new dam and leaving the leakage under the existing South Channel Dam as is.

6.1 Relocating the New Proposed South Dam South of the Existing Channel

One option requested by PWGSC was to evaluate the option of relocating the South Channel Dam south of the existing bedrock channel. This option carries additional costs related to pre-construction investigations, as well as bedrock drill and blast excavation costs during construction, and costs related to abandonment of the existing south channel, which would still require grouting/sealing of the existing bedrock rubble zone to mitigate the existing baseflow conditions through the rubble bedrock zones. For example, prior to moving ahead with this option, certain investigation/design elements would have to be addressed, such as:

- Quality/coverage of existing topographic survey within the proposed area of construction

- Drilling/investigation to confirm depth to bedrock, as there is sediment cover over bedrock south of the current location of the South Dam. The shape and bedrock surface elevation would require confirmation prior to moving ahead with this option.

- Drilling/investigation to confirm bedrock structure/condition for new channel excavation design and dam abutments. Depending on channel excavation design, and location of the new bedrock channel, excavation costs could escalate rapidly. Optimizing the location of the new channel to minimize bedrock excavation, and use of an earthfill dam to decommission the existing south channel could be investigated, however this would require significant re-design from the currently proposed south dam reconstruction.

- Grouting of the existing south channel bedrock rubble zone would be required, regardless of relocation of the South Dam, unless continued baseflow through the bedrock rubble zone is allowable.

- Design and installation of an earthfill berm to decommission the existing South Channel and allow for dismantling of the current South Dam.

This kind of an option is likely not advantageous for PWGSC, since there are investigation and design elements that would need to be addressed, possibly significant increases in construction costs, and increased schedule duration, due to additional design and rock excavation required. In addition, the requirement to grout off the existing south channel bedrock rubble zone likely remains with this scenario.

6.2 Relocate the New Proposed South Dam Downstream of Rubble Leakage Area

Geophysical information collected on the downstream side of the South Dam implied that there is a zone of at least 3 m thickness of fractured bedrock, and/or fractured bedrock and rubble infills within the base of the south channel and that the thickness of the fractured bedrock/rubble bedrock intermediate velocity zone thins to approximately 1 m or so at this distance of 25 m to 30 m downstream of the South Dam. Further intrusive investigation would be required to confirm this interpretation of the seismic data.

Further geophysical investigations (and particularly intrusive investigation) should be considered to be carried downstream of the existing South Dam to determine the extent and thickness of the fractured bedrock/rubble. If the fractured bedrock / rubble terminates or the depth becomes minimal approximately 30 to 40 m downstream of the existing South Dam then consideration could be given to constructing the new dam further downstream than currently proposed outside of the fractured bedrock/ rubble zone. Further hydraulic analysis and cost analysis would be required to be carried to determine the extent of additional bedrock that would be required to be excavated to achieve the required spill capacity of the new Dam.

6.3 Construct Cofferdam Downstream of Existing South Dam and Upstream of New Dam

Another alternative for consideration is to construct a cofferdam between the existing South Dam and the new Dam. The proposed type of cofferdam would be a soil/bentonite berm complete with sheet piles and polyurethane grouted at the base of the cofferdam at the interface between the sheet piles and bedrock. The proposed type of cofferdam and method of installation is similar to the method presented in Section 5.4.1. (i.e., cofferdam for cementitous grouting the South Dam leakage).

Depending upon the depth of the fractured bedrock / rubble that would be required to be excavated this cofferdam could be significantly less (i.e., less than $1M) than sealing the existing South Dam with hot bitumen and cementitious grout (see Section 5.4.4). However, there is a high risk associated with constructing this cofferdam because of the difficulties that may be encountered with working in the high flow conditions and with the fractured bedrock / rubble. Excavation of any rubble from the channel base to improve foundation conditions for the sand-bentonite berm would have to be undertaken carefully, without destabilizing the rubble rock fill below the existing South Dam gate sill. As noted above, further investigation would be required to determine the depth of the fractured bedrock / rubble on the downstream side of the existing South Dam, to allow for finalizing the cofferdam construction methodology

7.0 SUMMARY AND RECOMMENDATIONS

The geotechnical investigation of the South Channel Dam seepage at the Big Chaudiere site has revealed the following:

- The channel orientation of the South Channel Dam bedrock channel, and distribution/orientations of surrounding bedrock channels, are structurally controlled by the predominant bedrock joint families measured at the Chaudiere site.

- There is a pervious “V shaped” bedrock discontinuity beneath the South dam gate sill that is filled with loose rockfill above intact bedrock, with dimensions in the order of 9 m lateral width nearest to the intact bedrock surface, and in the order of 0.4 m depth along the sides, to as much as 12 m in depth within the thalweg of the feature.

- The longitudinal limits of the pervious rockfill zone parallel to the south channel were not delineated definitively, though geophysical investigations suggest at least 3.0 m depth of fractured rock/rockfill may be present on the downstream side of the South dam, as far as 20 m to 30 m downstream of the dam axis. The in-filled bedrock discontinuity extends in an upstream direction at least as far as borehole BC11-08, located approximately 15 m upstream of the South dam. These limits are sufficient to work with in designing for a remedial grouting program, if desired by PWGSC.

- Permeability of the rockfill zone varies between approximately 145 Lugeons and 200 Lugeons. Bedrock permeabilities were much lower, with results <60 Lugeons, with most <5 Lugeons.

- Voids within the rockfill zone may be millimeter in scale to as much as 0.1 m to 0.3 m in size. Grout filled voids were observed within limited areas closest to the South Channel Dam sill.

- Flow velocities are relatively high through the rubble infill zone below the South Channel Dam, and vary between approximately 0.06 m/s to 0.24 m/sec (average value 0.15 m/s).

- Current seepage flows below the South Channel Dam gate sill are between approximately 1 m^3/s and 2 m^3/s.

Based on the site characteristics as described within this report, the grouting Option 3, hot bitumen in conjunction with a cement based grout, is likely the most reliable option to mitigate seepage flows below the South Channel Dam gate sill and therefore is the preferred option. Option 1 (cofferdam and cementitious grouting) and Option 2 (fill rubble zone voids with sand / aggregate and cementitious grouting) are also potentially viable options however these options have a higher risk associated with their successful implementation. It is important to determine the key objectives for grouting the rubble zone, and careful detailed design and costing would be required prior to initiating any grouting program at the Big Chaudiere Dam site. The following should be considered:

- Structural stability of South Channel Dam sill: The flow under the sill has been consistent for the past several years and does not appear to be having any negative impact on the structural stability / integrity of the sill.

- Public and personnel safety: The undertow at the sill is significant due to the high flow rate under it. Therefore, it is unsafe for divers to carry out inspections or work in the vicinity of the sill and it is a safety risk should a swimmer be in the vicinity of the dam. Currently no diving activities are permitted in the vicinity of the sill. Signage and safety booms could minimize the risk of swimmers approaching the dam.

- Mitigate leakage for construction of a new dam: If the intent to grout the rubble zone is to only stop leakage so that the existing South Channel Dam can be used as a cofferdam dam for the construction of a new structure, then grouting of the rubble zone may be cost prohibitive. These costs would have to be analyzed against the cost of installing an upstream cofferdam, such as completed during the 1980's work, and the associated pumping costs that would accompany this option in order to maintain the "dry side" of the cofferdam. A cofferdam on the upstream side of the existing South Dam with no foundation treatment of the rock rubble zone below the South Dam gate sill will allow large flows of water into the new construction site in downstream areas. If successful, the grouting of the South Dam rock rubble zone is likely the best option for mitigating dewatering risk for construction of the new South Dam, and minimizing water handling and pumping costs associated with controlling the site for the construction of the proposed new South Dam.

- Further investigation to determine the depth of the fractured bedrock / rubble downstream of the South Dam and the extent of the fractured bedrock / rubble should be considered to determine the cost effectiveness to construct a cofferdam dam between the existing South Dam and the new Dam versus sealing the South Dam. This investigation would also be necessary for analyzing any potential cost benefits to constructing the new Dam further downstream potentially outside of the fractured bedrock / rubble zone versus its currently proposed location.

- Cofferdam locations on the upstream and downstream side of the existing South Dam, in order to facilitate construction of the proposed new South Dam should be placed in the closest allowable proximity to the structures to facilitate construction of the new Dam, and decommissioning of the existing South Dam. Based on the presence of the rock rubble zone defined on the upstream side of the existing South Dam, the presence of at least 3 m of fractured rock and/or fractured rock and rubble on the downstream side of the existing South Dam, and the experience noted in the 1980's construction program, to mitigate leakage in the construction/decommissioning areas the fractured bedrock / rubble would be required to be excavated in the cofferdam areas to facilitate the installation of sand / bentonite cofferdams complete with sheet piling and sealed at the sheet piling / bedrock interface with polyurethane grout. Detailed intrusive investigation would be required within the proposed downstream cofferdam area to delineate rock fill/fractured rock conditions, and to determine what amount of rockfill might be allowable for removal for the cofferdam foundation preparation without destabilizing the remaining rock fill nearest to the South Dam gate sill areas.

- Based upon the currently known conditions the rubble rockfill grouting program at the existing South Dam is the most reliable option. However, It is acknowledged that there is some risk involved with providing a successful grouting operation within the existing South Dam rubble rock zone, based on conditions assessed during this investigation program. Detailed grouting program design and cost estimation should be completed prior to mobilizing this option for South Dam leakage mitigation.

- A successful rubble rock grouting program at the existing South dam mitigates most risk associated with construction of the new South Dam in downstream areas, which is to be constructed "in the dry". Some additional pumping and/or grouting will likely be required within site specific construction areas in addition to the south dam rock rubble zone, as the site is developed and prepared for construction of the new South Dam.

- Rubble zone rock fill materials on the upstream side of the existing South Dam appear to be in the order of coarse grained gravel sizes, up to possibly 0.1 m to 0.3 m in size (up to perhaps 0.6 m in size), with void spaces in the order of 0.1 m to 0.3 m. Areas downstream of the existing South Dam were not directly observed, however based on channel observations elsewhere at the site, there is good possibility for boulder sized material to be present, which could be in the order of 0.5 m to 1.5 m in size, depending on origin. Meter scale wedge failures from the north side of the south channel are likely present within the bottom of the south channel, based on general site observations.

- Acceptable residual leakage: Depending upon what PWGSC considers being an acceptable leakage limit under the South Channel Dam, consideration may be given to reducing the leakage by filling the voids immediately upstream and downstream of the South Channel dam with graded aggregate and sand and not carry out any grouting activities. However, this approach would directly impact the path forward for controlling water for construction of the new South Dam, as possibly significant water handling would be required within the construction site, for the duration of construction.

8.0 REFERENCES

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FIGURES

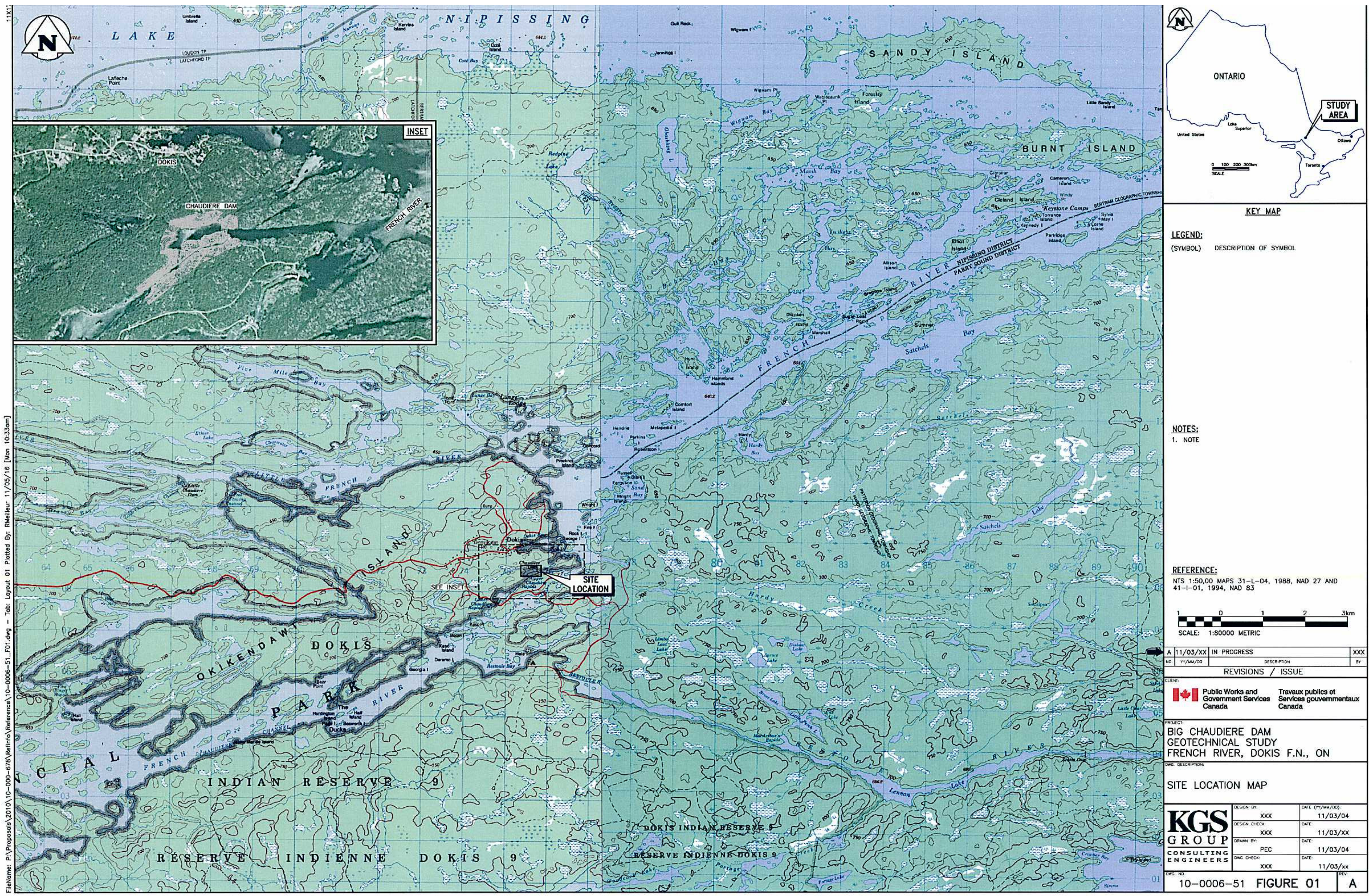
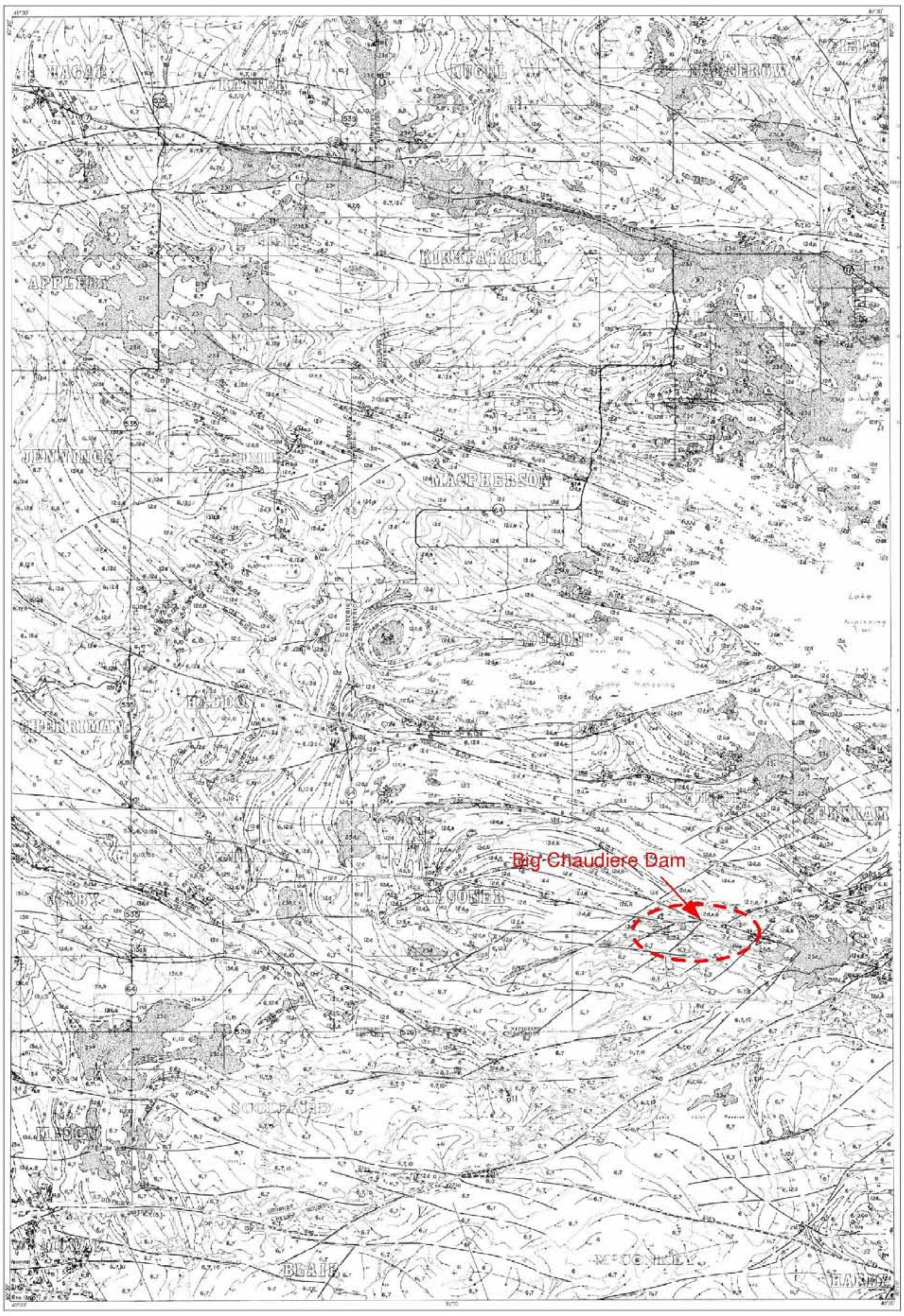


FIGURE 1: Location of Big Chaudiere Dam and Surrounding Area

8.5x11

FileName: P:\Projects\2010\10-0006-51\dwg\geo\FIG.3, 4 & 6.dwg - Tab: LAYOUT Plotted By: JCarlos 05/19/2011 [Thu 5:16pm]
8.5"X11" PLOT SCALE: 1:2



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REVISIONS / ISSUE

KGS GROUP CONSULTING ENGINEERS

Canada

PWGSC—ONTARIO REGION
FRENCH RIVER BIG CHAUDIERE
SOUTH AND NORTH DAM

GEOLOGICAL MAP P.681, BURWASH AREA BY ONTARIO DEPARTMENT OF MINES AND NORTHERN AFFAIRS

MAY 2011 | FIGURE 2 | REV: A

FIGURE 2: Geological Map P.681, Burwash Area (East Half) by Ontario Department of Mines and Northern Affairs– Big Chaudiere Dam**.**

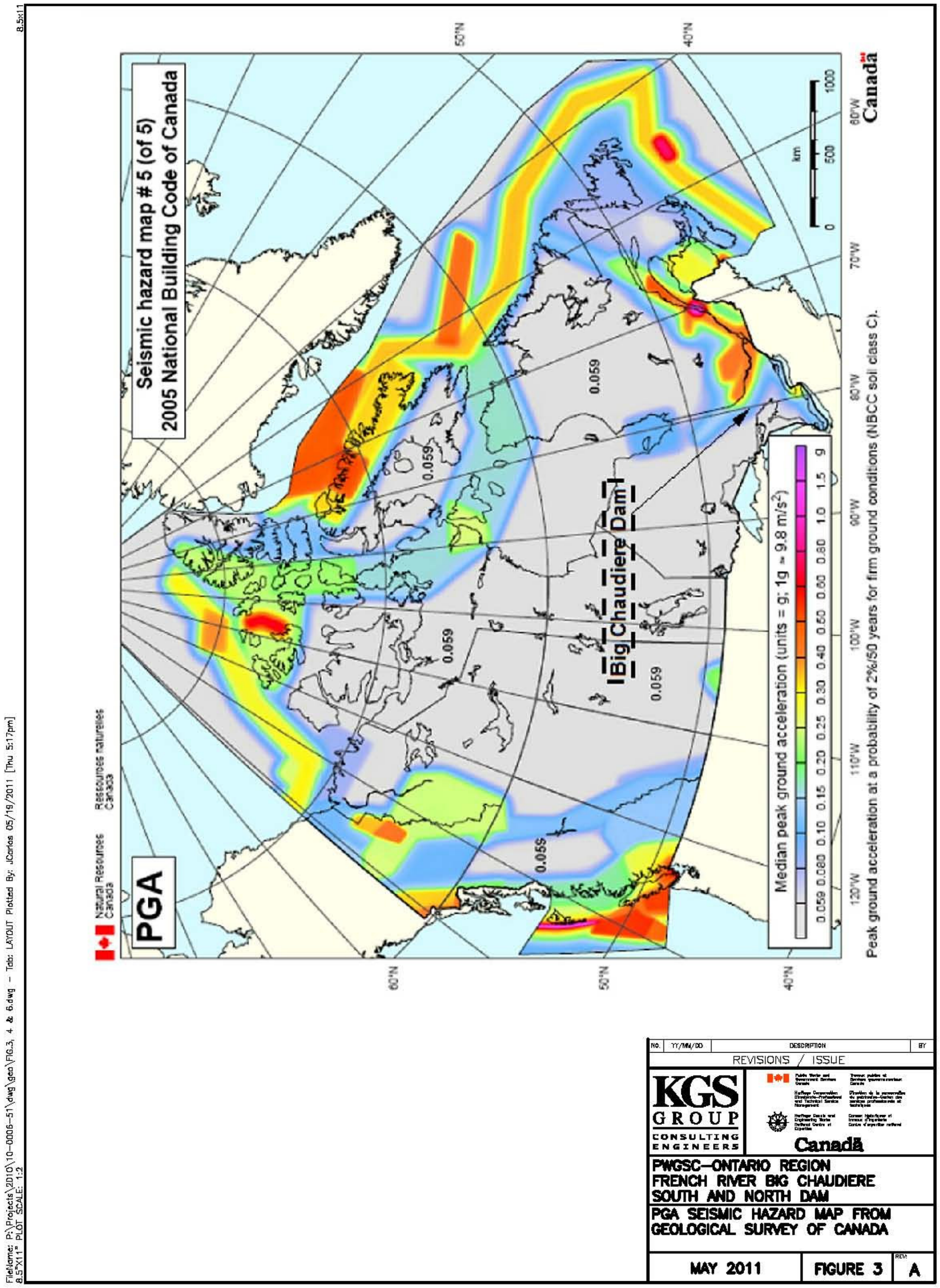

FIGURE 3: PGS Seismic Hazard From Geological Survey of Canada.

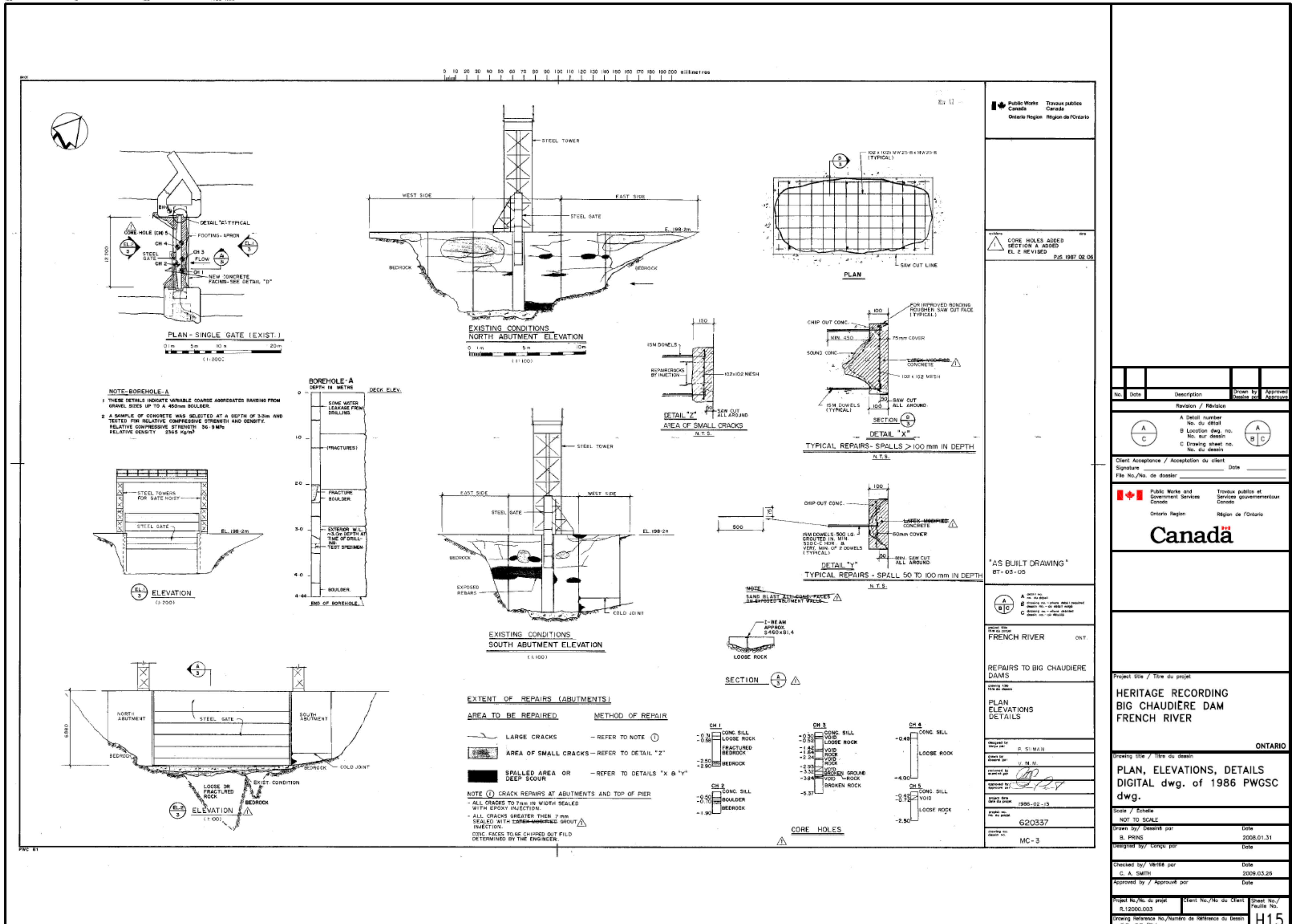

FIGURE 4: Site Investigation and Dam Repair 1986 – Big Chaudiere Dam.

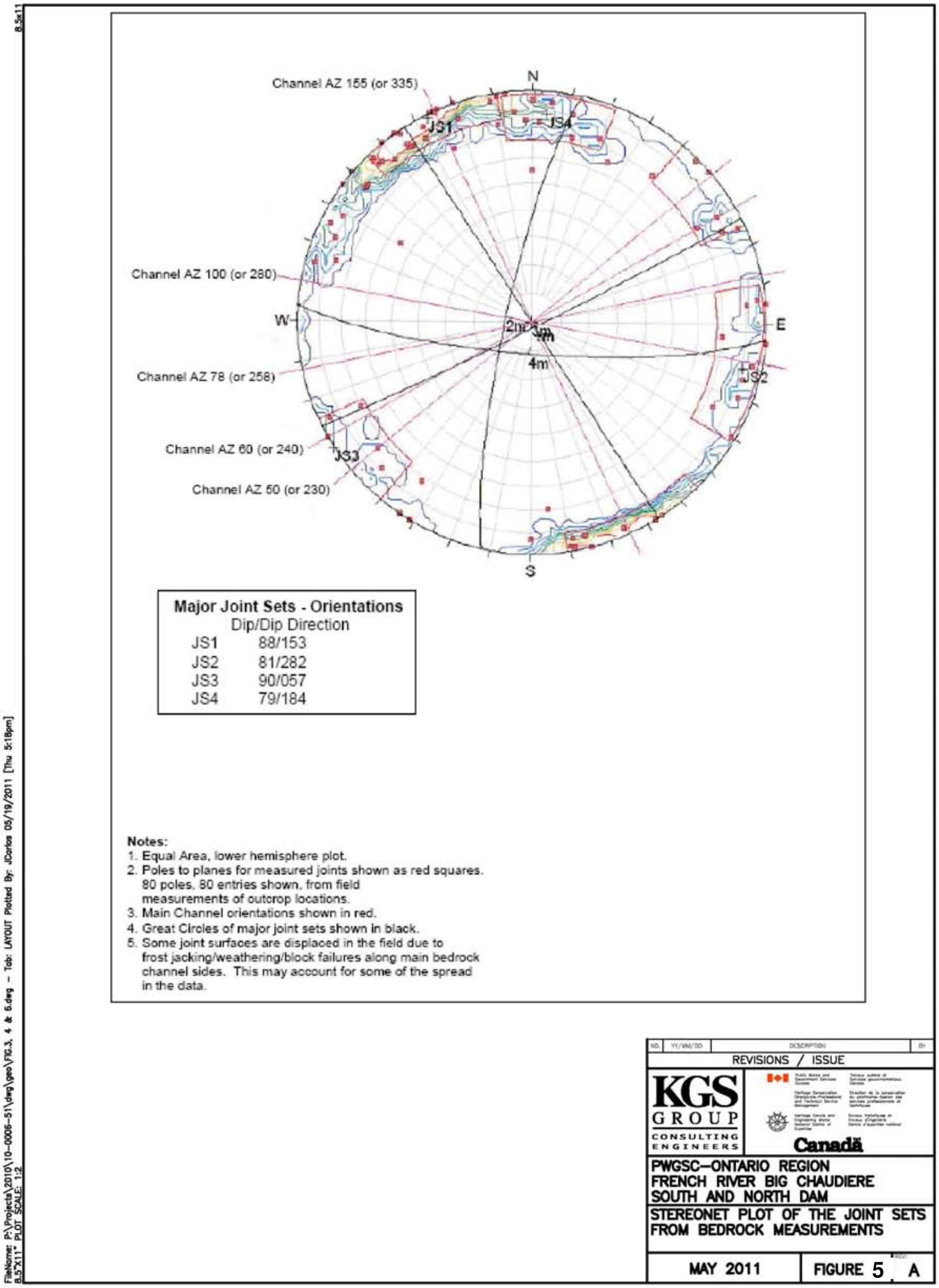

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FIGURE 5: Stereonet Plot of the Joint Sets from Bedrock Measurements – Big Chaudiere Dam

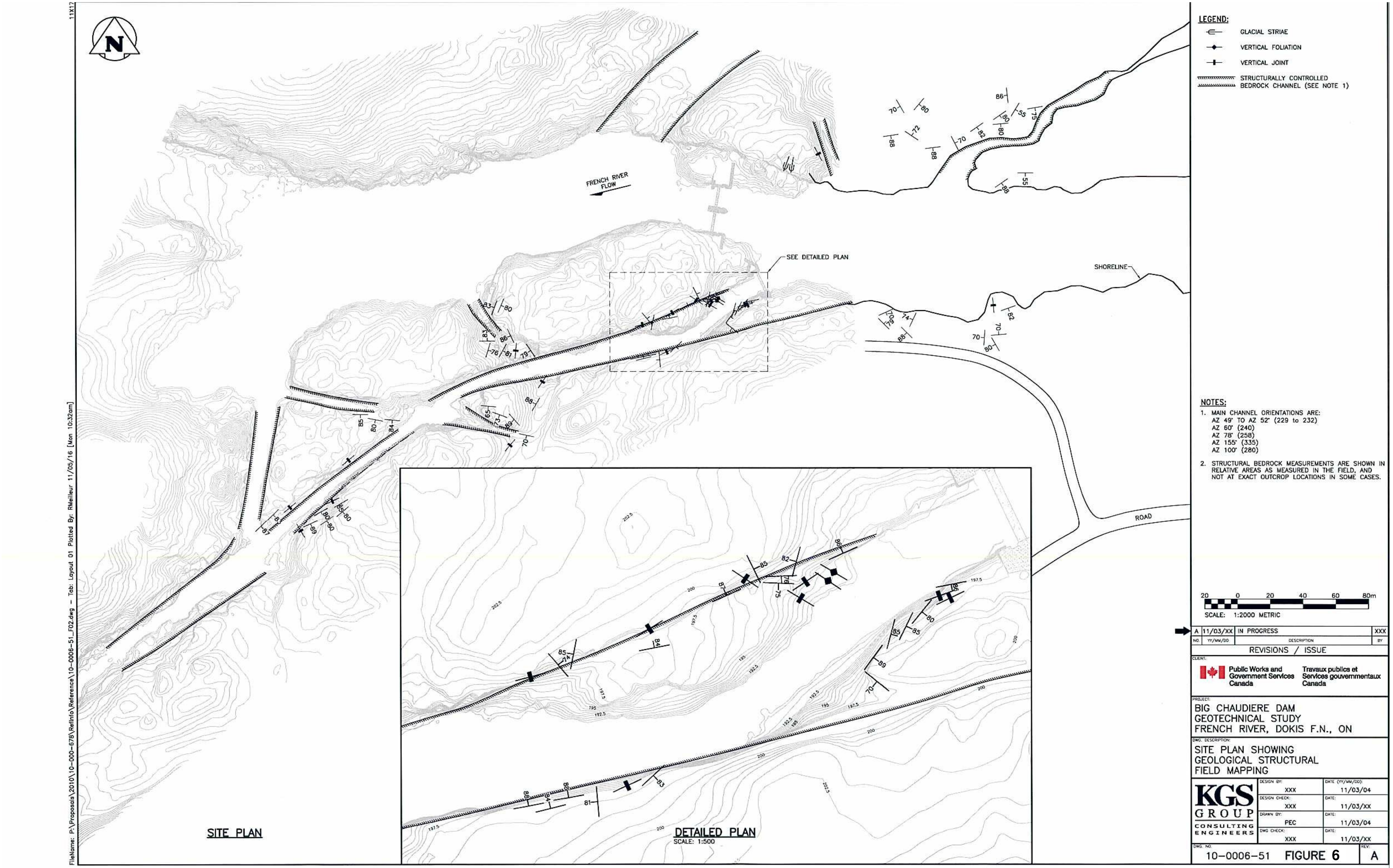

FIGURE 6: Site Plan Showing Geological Structural Field Mapping

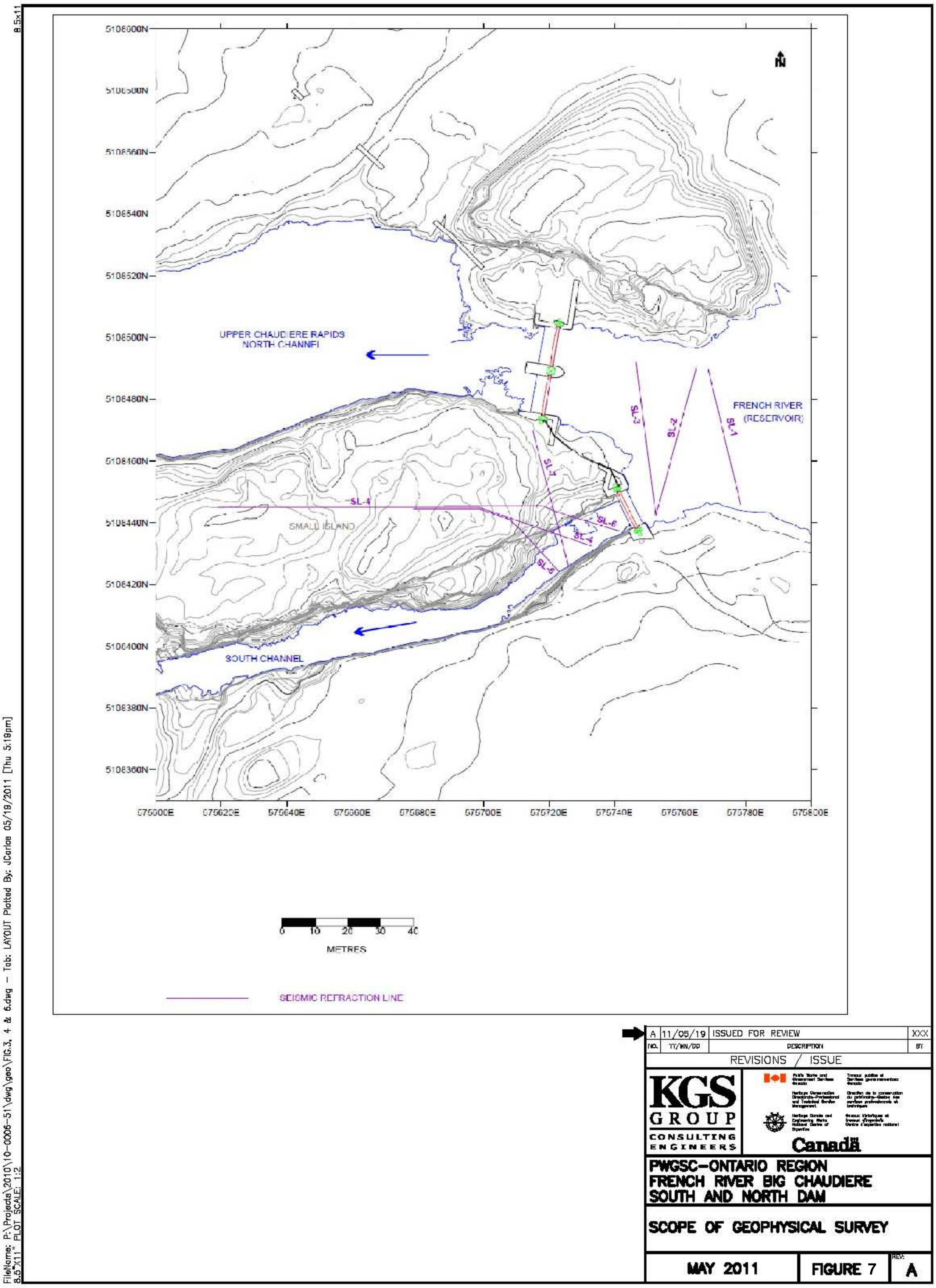

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FIGURE 7: Scope of Geophysical Survey – Big Chaudiere Dam

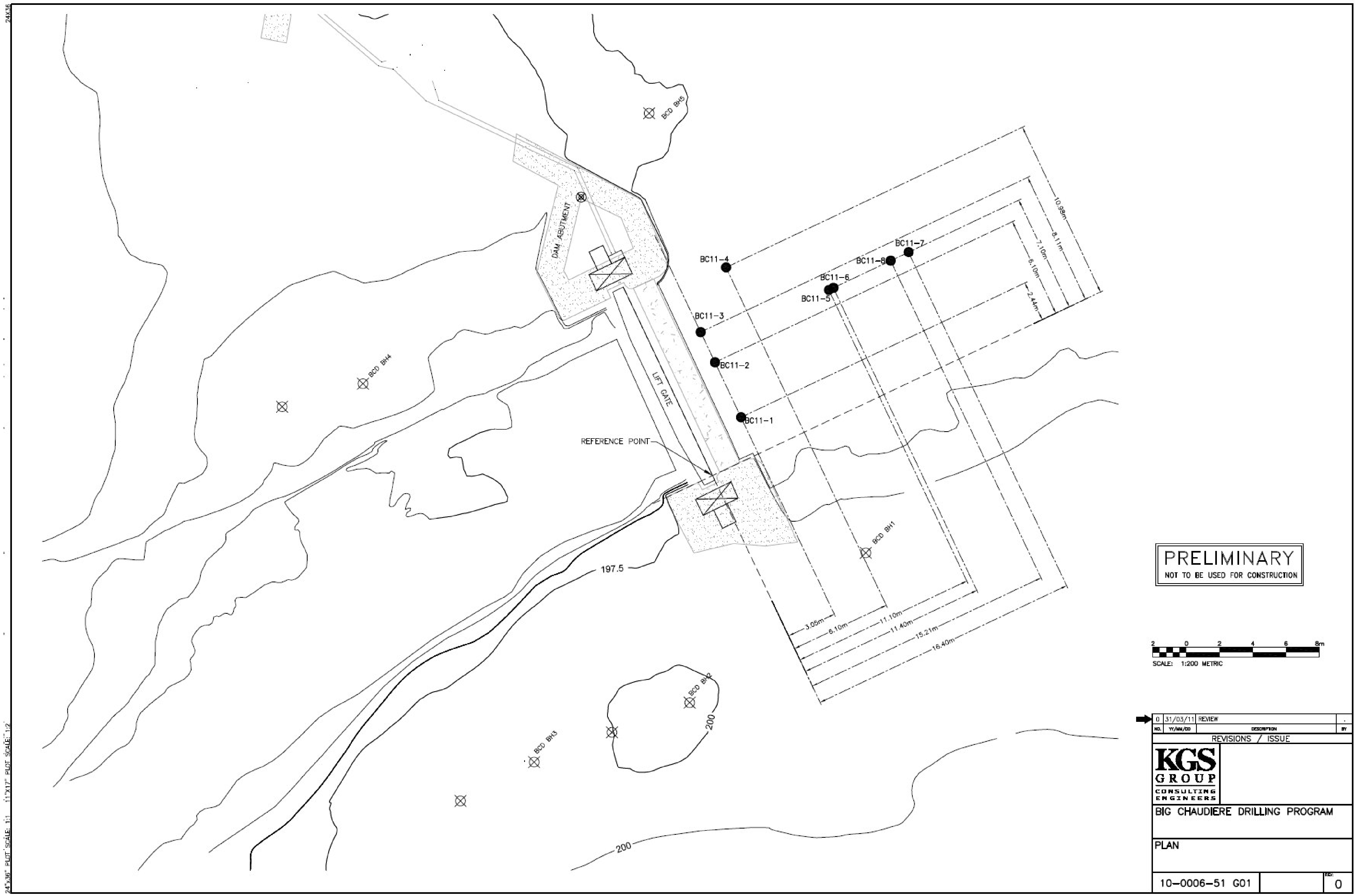


FIGURE 8: KGS Group Drilling Investigation Program 2011 – Big Chaudiere Dam.

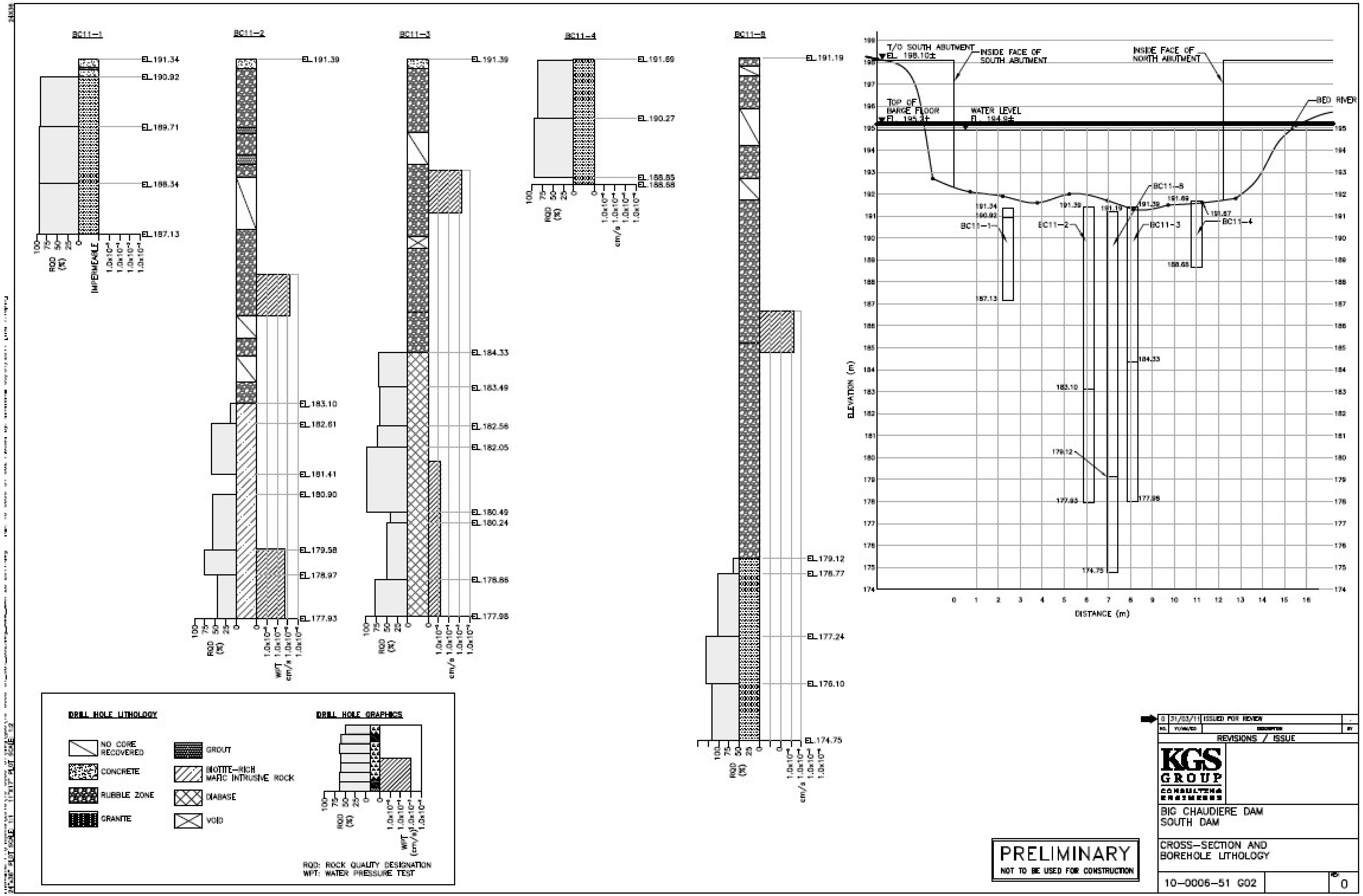


FIGURE 9: Cross Section of River Bed upstream of South Channel Dam - Drilling Investigation Program 2011.

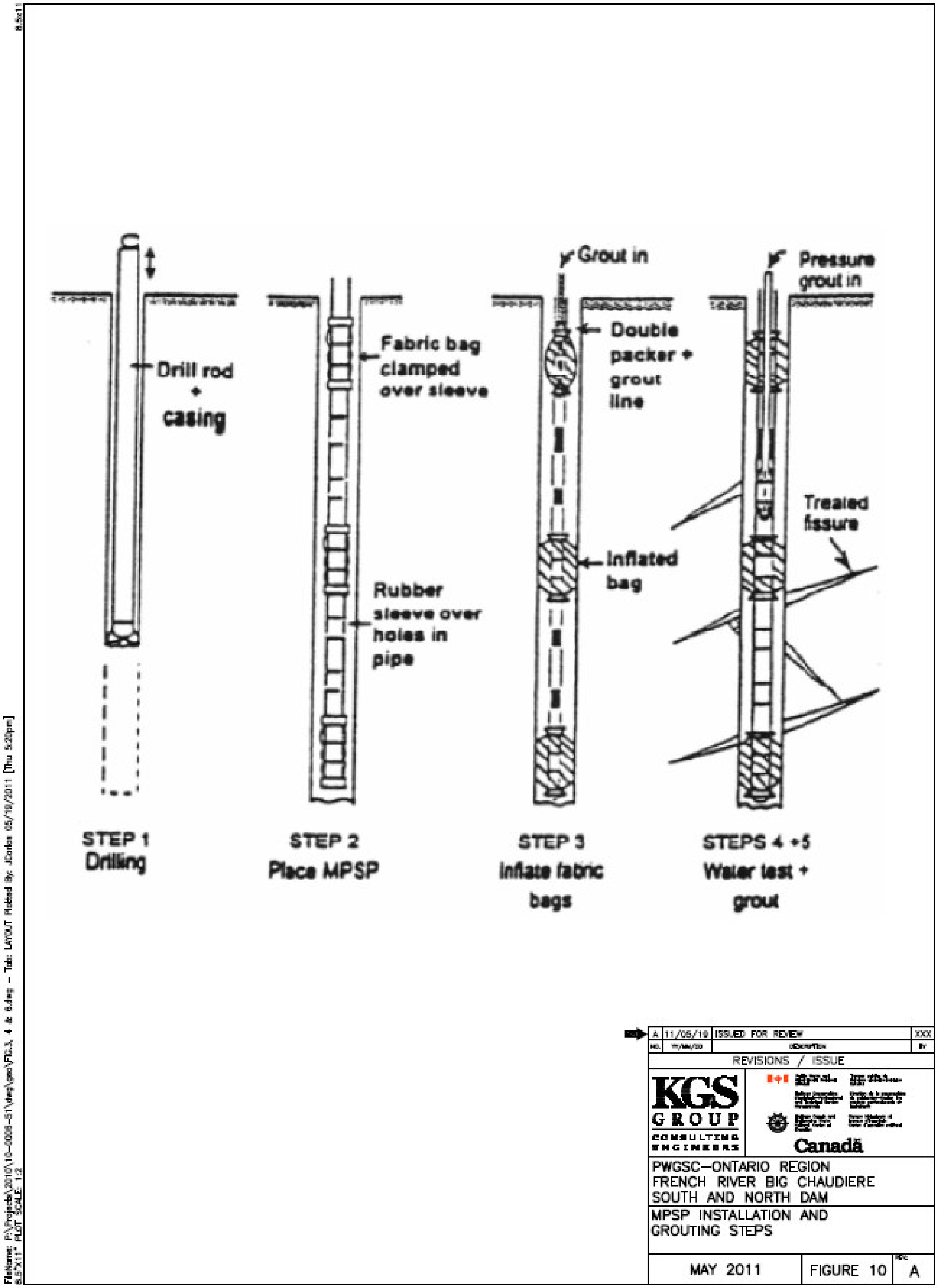


FIGURE 10: Multiple Packer Sleeve Pipe (MPSP) Installation and Grouting Steps - Drilling Investigation Program 2011.

APPENDIX – A
Geological Mapping- Bedrock Measurements
Big Chaudiere Dam

South Dam - U/S - North Bank						
UTM Zone	UTM E	UTM N	Strike (deg.)	Dip (deg.)	General Orientation (deg.)	Notes
17T	575759	5108526			200 to 210	Glacial striae on bedrock surface
17T	575773	5108536			152	Deep water filled discontinuity, subvertical to vertical slopes, approx. 20 m wide by 10 - 12 m deep
17T	575855	5108536	304	72		Major JT
17T	575855	5108536	81	88		Major JT
17T	575886	5108530	333	70		Major JT
17T	575886	5108530	83	88		Major JT
17T	575923	5108543	85	80		Major JT
17T	575923	5108543	31	55		Major JT
17T	575923	5108543	55	80		Major JT
17T	575923	5108543	80	75		Major JT
17T	575923	5108543	174	86		Major JT
17T	575924	5108538			60 or 240	Channel orientation looking d/s at south dam, vertical walls, wedging out of rock mass noticeable on channel sides
17T	575916	5108512	90	55		Major JT looking d/s at north dam
17T	575916	5108512	55	88		
17T	575904	5108542	55	82		Major JT - block displacement
17T	575857	5108551	40	80		Major JT
17T	575857	5108551	150	70		Major JT

South Dam - U/S - South Bank						
UTM Zone	UTM E	UTM N	Strike (deg.)	Dip (deg.)	General Orientation (deg.)	Notes
17T	575827	5108429	66	70		Major JT
17T	575827	5108429	315	79		Major JT
17T	575827	5108429	205	74		Major JT
17T	575827	5108429	135	88		Major JT
17T	575883	5108411	184	70		Major JT
17T	575883	5108411	150	80		Major JT
17T	575883	5108411	265	70		Major JT
17T	575898	5108437	175	90		Major JT
17T	575898	5108437	70	82		Major JT
South Dam - D/S - North Bank						
17T	575697	5108424	238	90		Major JT
17T	575697	5108424	259	84		Major JT
17T	575709	5108431	246	87		Major JT
17T	575709	5108431	334	85		Major JT
17T	575709	5108431	304	90		Foliation
17T	575727	5108432	246	86		Major JT
17T	575718	5108428	88	76		Major JT

South Dam - D/S - North Bank (Continued)						
UTM Zone	**UTM E**	**UTM N**	**Strike (deg.)**	**Dip (deg.)**	**General Orientation (deg.)**	**Notes**
17T	575718	5108428	92	75		Major JT
17T	575718	5108428	236	90		Major JT
17T	575718	5108428	195	82		Major JT
17T	575718	5108428	301	90		Foliation
17T	575680	5108415	255	90		Major JT
17T	575680	5108415	191	85		Major JT
17T	575680	5108415	320	74		Major JT
17T	575584	5108421	200	83		Major JT
17T	575584	5108421	155	86		Major JT
17T	575586	5108400	185	90		Major JT
17T	575586	5108400	154	79		Major JT
17T	575587	5108398	23	80		Major JT
17T	575587	5108398	270	83		Major JT
17T	575587	5108398	29	81		Major JT
17T	575587	5108398	17	76		Major JT
17T	575535	5108375			105	Discontinuity, south side of south channel, 8-10 m wide by 6-8 m deep
17T	575509	5108363			105	Discontinuity, cuts the point of the island between the n and S channel, 6-9 m wide by 4-5 m deep, subvertical walls

South Dam - D/S - North Bank (Continued)						
UTM Zone	**UTM E**	**UTM N**	**Strike (deg.)**	**Dip (deg.)**	**General Orientation (deg.)**	**Notes**
17T	575509	5108363	95	84		Major JT
17T	575509	5108363	90	85		Major JT
17T	575509	5108363	101	80		Major JT
17T	575436	5108295			50	Excavated channel. Waterfall to main S channel
17T	575436	5108295	46	83		JT/channel side
17T	575436	5108295	46	87		JT/channel side
17T	575436	5108295	50	90		JT/channel side
17T	575489	5108338	50	90		JT opening subparallel main S channel; continuous over 50 m, 0.3 - 0.4 m wide
South Dam - D/S - South Bank						
17T	575726	5108440	15	85		Channel side/JT
17T	575726	5108440	39	80		Channel side/JT
17T	575726	5108440	129	70		Channel side/JT
17T	575726	5108440	26	85		Channel side/JT
17T	575726	5108440	36	89		Channel side/JT
17T	575726	5108440			220 (40) to 265 (85)	General channel side orientation, moving d/s
17T	575713	5108480	64	90		Major JT
17T	575713	5108480	70	90		Major JT

South Dam - D/S - South Bank (Continued)						
UTM Zone	UTM E	UTM N	Strike (deg.)	Dip (deg.)	General Orientation (deg.)	Notes
17T	575713	5108480			255 (75) to 270 (90)	Channel side orientation, moving d/s
17T	575713	5108480	79	86		Channel side/JT
17T	575676	5108410			250 (70)	Smooth wall of d/s channel, south wall
17T	575676	5108410	259	88		Major JT
17T	575676	5108410	260	88		Major JT
17T	575676	5108410	256	84		Major JT
17T	575676	5108410	175	81		Major JT
17T	575676	5108410	47	83		Major JT
17T	575676	5108410	65	90		Major JT
17T	575608	5108394	54	90		Down channel area, low rock slope, possible access area
17T	575601	5108356	210	88		Major JT
17T	575601	5108356	102	70		Major JT
17T	575601	5108356	110	73		JT, discontinuity channel
17T	575601	5108356	139	89		Major JT
17T	575601	5108356	40	90		Major JT
17T	575601	5108356	115	65		Major JT
17T	575461	5108296	60	80		Major JT

South Dam - D/S - South Bank (Continued)						
UTM Zone	UTM E	UTM N	Strike (deg.)	Dip (deg.)	General Orientation (deg.)	Notes
17T	575461	5108296	65	89		Major JT
17T	575461	5108296	66	90		Major JT
17T	575461	5108296	56	80		Major JT
17T	575461	5108296	330	90		Major JT
17T	575461	5108296	50	80		Major JT
17T	575461	5108296	61	85		Major JT

APPENDIX – B
Geophysical Investigation Report

KGS GROUP CONSULTING ENGINEERS

REPORT ON

SEISMIC REFRACTION INVESTIGATION

BIG CHAUDIERE DAM PROJECT

FRENCH RIVER

NOELVILLE AREA, ONTARIO

By

Beth Friesen, B.Sc.

Russell A. Hillman, P.Eng.

October, 2010 **PROJECT FGI-1171**

Frontier Geosciences Inc. 237 St. Georges Avenue, North Vancouver, B.C., Canada V7L 4T4
Tel: 604.987.3037 Fax: 604.984.3074

CONTENTS

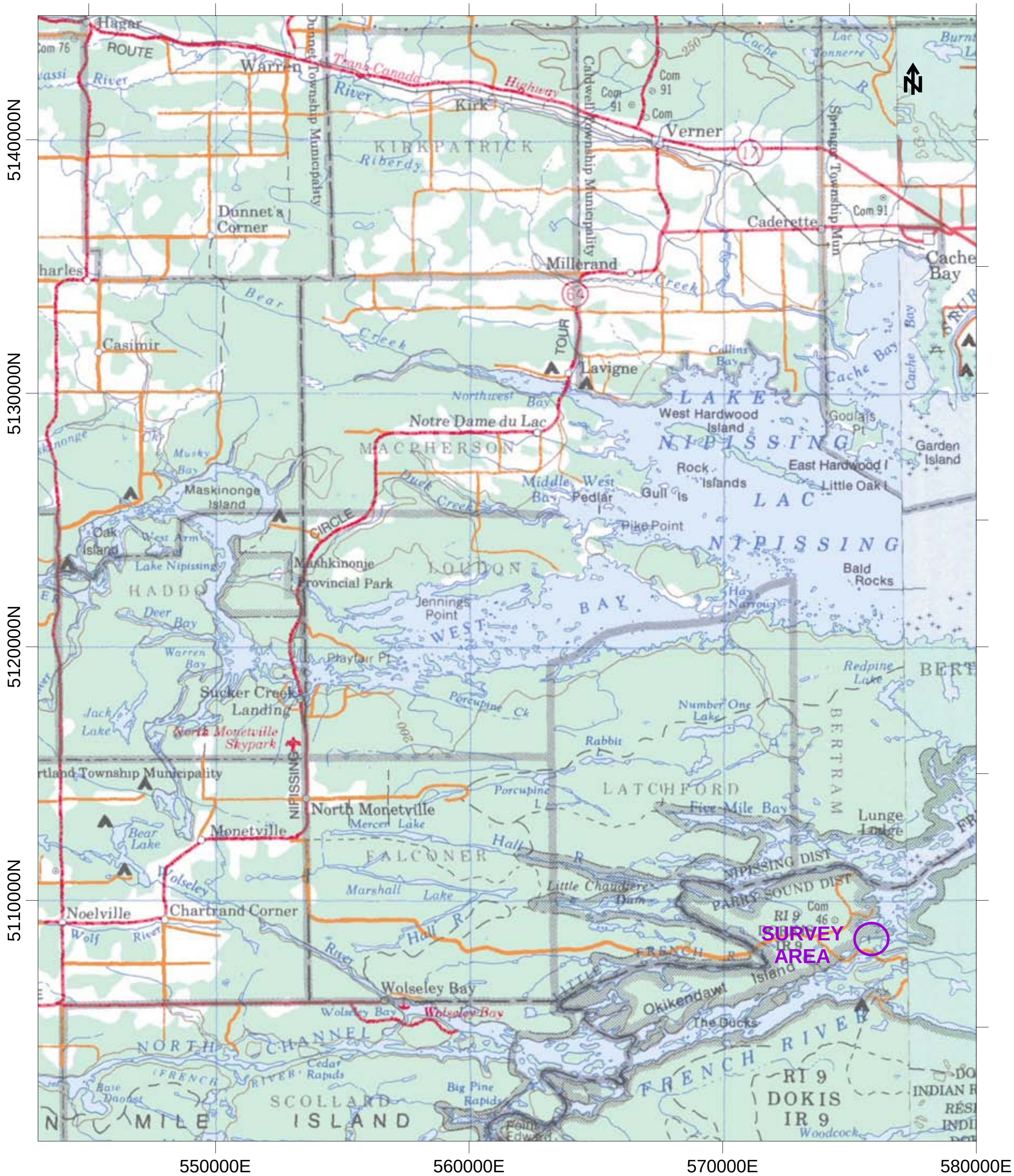
ILLUSTRATIONS

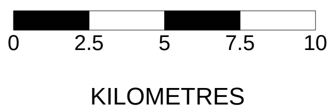
1. INTRODUCTION

In the period October 25 to October 29, 2010, Frontier Geosciences Inc. carried out a seismic refraction survey for KGS Group Consulting Engineers at the Big Chaudiere Dam site. The survey area is located approximately 30 km east of Noelville, Ontario. A Survey Location Plan of the area is shown at a scale of 1:250,000 in Figure 1.

The purpose of the seismic refraction survey was to determine geological conditions and the structural nature of the south channel of the French River. Specifically, structural weaknesses such as a fault, shear zone or sharp depression of the south channel and southern shore of French River were of interest. Seismic lines SL-1, SL-2, and SL-3 were conducted overwater on the upstream side of the Big Chaudiere Dam, extending across the French River. Seismic lines SL-4 through SL-7 were conducted on the downstream side of the dam, extending across the south channel of Upper Chaudiere rapids and onto Small Island. A Site Plan of the seismic lines and survey area is presented at a scale of 1:1,000 in Figure 2, of the Appendix.

In all, a total of approximately 420 metres of detailed seismic refraction surveying was carried out at the Big Chaudiere Dam site, along seven separate traverses.





KGS GROUP CONSULTING ENGINEERS BIG CHAUDIERE DAM PROJECT		
SEISMIC REFRACTION SURVEY		
SURVEY LOCATION PLAN		
FRONTIER GEOSCIENCES INC.		
DATE: OCT. 2010	SCALE 1:250,000	FIG. 1

2. THE SEISMIC REFRACTION SURVEY METHOD

2.1 Equipment

The seismic refraction investigation was carried out using a Geometrics, Geode, 24 channel, signal enhancement seismograph and Oyo Geo Space, 10 Hz geophones or Mark Product Ltd. hydrophones. Geophone (hydrophone) intervals along the multicored seismic cables were maintained at 5 metres in order to obtain high resolution data on subsurface layering. Energy input was provided by a seismic shotgun, firing blank, black powder, 8 gauge industrial shells into hand-excavated shotholes or into the water. Shot initiation or zero time was established by metal to metal contact of a striking hammer contacting the firing pin of the shotgun.

2.2 Survey Procedure

For each spread, the seismic cable was stretched out in a straight line and the geophones implanted. For spreads overwater, the seismic cable was tied to a rope equipped with floats. Hydrophones were attached to the seismic cable and placed one metre below the water surface. Six separate 'shots' were then initiated: one at either end of the geophone array, two at intermediate locations along the seismic cable, and one off each end of the line to ensure adequate coverage of the basal layer. The shots were detonated individually and arrival times for each geophone were recorded digitally in the seismograph. Data recorded during field surveying operations was generally of fair to good quality.

Throughout the survey, notes were recorded regarding seismic line positions in relation to topographic and geological features in the area. Line locations were surveyed with a Garmin 60Cx handheld GPS unit. Relative elevations along the seismic lines were recorded by an inclinometer with absolute elevations taken from mapping of the site provided by KGS Group Consulting Engineers.

2.3 Interpretive Method

The final interpretation of the seismic data was arrived at using the method of differences technique. This method utilises the time taken to travel to a geophone from shotpoints located on either side of the geophone. Using the total time, a small vertical time is computed which represents the time taken to travel from the refractor up to the ground surface. This time is then multiplied by the velocity of each overburden layer to obtain the thickness of each layer at that point.

3. GEOPHYSICAL RESULTS

3.1 General

The results of the seven seismic refraction traverses carried out at the Big Chaudiere Dam site are shown at a scale of 1:500 in Figures 3 through 9 in the Appendix. The survey area was sub-divided into the Upstream and Downstream areas. The Upstream area was surveyed with three sub-parallel lines using overwater hydrophones and a small boat for deployment. The Downstream area was surveyed with four seismic lines using a combination of on-land and overwater techniques. The survey area is characterised by frequent bedrock exposures, primarily next to the river channels.

3.2 Discussion

3.2.1 Upstream

The results of the interpretations for seismic lines SL-1, SL-2, and SL-3 are shown in Figures 3 through 5. The results indicate the river upstream of the dams is underlain by two distinct velocity layers. The dark blue line indicates the river surface, with the hydrophones shown at water depths of about one metre. The layer underlying the hydrophones exhibits a compressional (P) wave velocity of 1550 m/s. This layer is interpreted to be primarily the water column, possibly underlain by a thin layer of saturated sediments. As the saturated sediments have a compressional wave velocity similar to the water, the sediment-water interface could not be defined.

The interpreted bedrock surface is indicated by the basal red line on the sections. Seismic line SL-1 exhibits a bedrock compressional wave velocity of 3870 m/s consistent with competent crystalline rock. The interpreted bedrock surface is a maximum 13 metres below the reservoir, at station 15 N on the traverse.

The interpreted bedrock surface on seismic lines SL-2 and SL-3 is much shallower than line SL-1 and averages about 5 metres in depth below the water surface. Seismic line SL-2 has a compressional wave velocity of 3985 m/s with line SL-3 exhibiting a somewhat higher compressional wave velocity of 5055 m/s. These velocities reflect competent to very competent crystalline rock.

The interpreted bedrock surface on lines SL-1, SL-2 and SL-3 is continuous and high velocity, with no extreme changes in bedrock topography. No low, basal velocities were detected indicative of a fault or shear zone in the bedrock.

3.2.2 Downstream

The Downstream area was surveyed with seismic lines SL-4 through SL-7. The first three phones of each line were placed in the water of Upper Chaudiere Rapids, with the balance of the lines extending up onto Small Island.

There is a thin, surficial layer underlying the land portions of the traverses with compressional wave velocities of 500 m/s to 610 m/s. This layer which is a maximum 2 m in thickness, corresponds to surface exposures and shallow shothole intersections of organics and loose silts, sands and gravels.

A thicker intermediate layer was identified in the data with velocities in the narrow range of 2150 m/s to 2250 m/s. Interpreted thicknesses for this layer vary from 0.2 m to 5 metres. This layer is consistent with looser, moderately weathered, competent bedrock with open joints in the rock mass.

The basal layer with velocities from 5725 m/s to 5820 m/s is the competent bedrock surface. This velocity range indicates massive, very competent, crystalline rock. There were no low velocity zones evident in the data that would be representative of shear or fault zones in the bedrock.

4. LIMITATIONS

The depths to subsurface boundaries derived from seismic refraction surveys are generally accepted as accurate to within ten percent of the true depths to the boundaries. In some cases, unusual geological conditions may produce false or misleading data points with the result that computed depths to subsurface boundaries may be less accurate. In seismic refraction surveying difficulties with a ‘hidden layer’ or a velocity inversion may produce erroneous depths. The first condition is caused by the inability to detect the existence of a layer because of insufficient velocity contrasts or layer thicknesses. A velocity inversion exists when an underlying layer has a lower velocity than the layer directly above it. The interpreted depths shown on drawings are to the closest interface location, which may not be vertically below the measurement point if the refractor dip direction departs significantly from the survey line location.

Structural discontinuities occurring on a scale less than the geophone/hydrophone spacing would go undetected in the interpretation of the data. For this survey, a five metre geophone/hydrophone spacing was employed on all seven seismic traverses. At few locations in the downstream area, wider phone spacings were employed to maximize survey coverage within the channel.

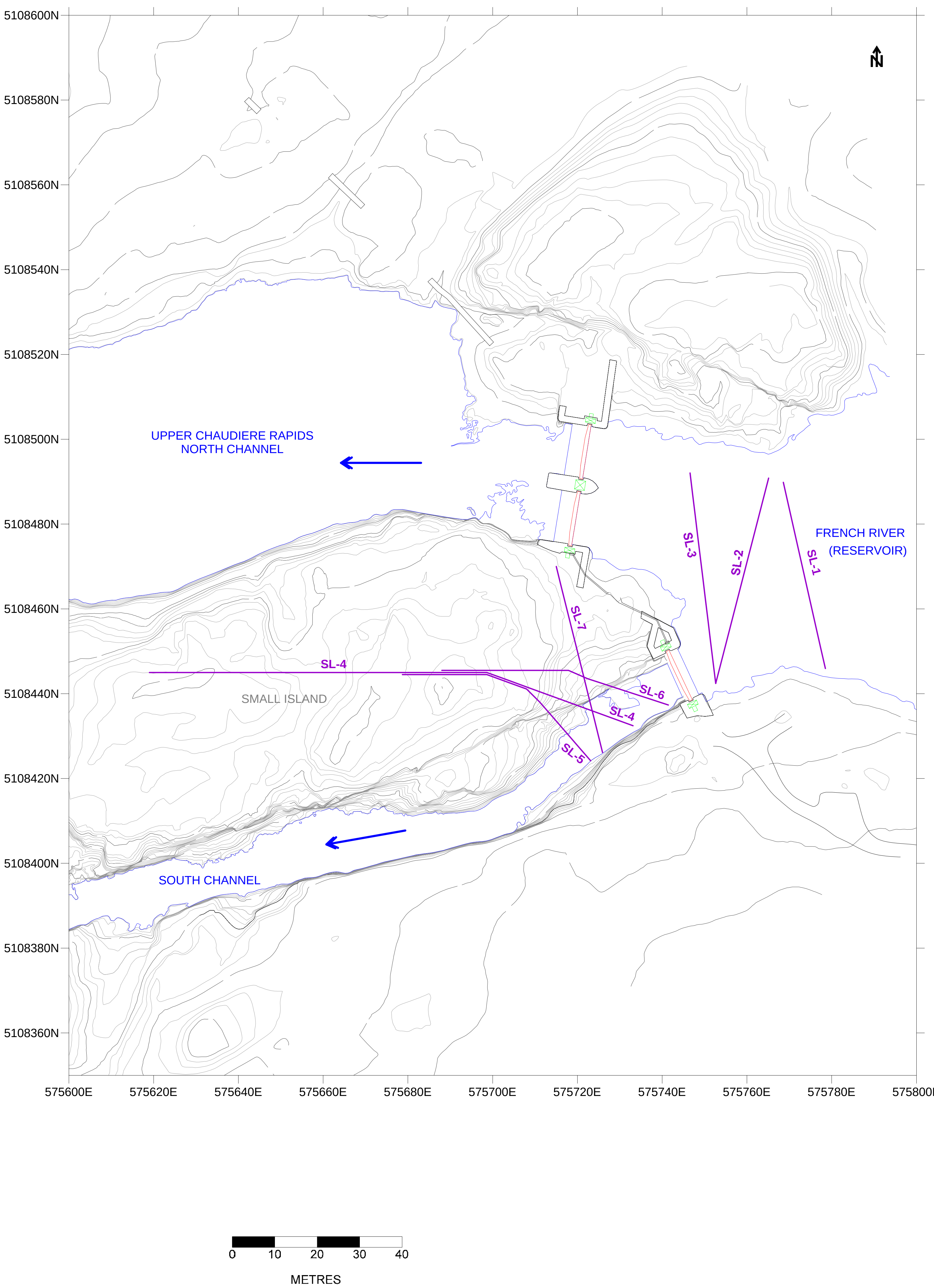
The results are interpretive in nature and are considered to be a reasonably accurate representation of existing subsurface conditions within the limitations of the seismic refraction method.

For: Frontier Geosciences Inc.

Beth Friesen, B.Sc.

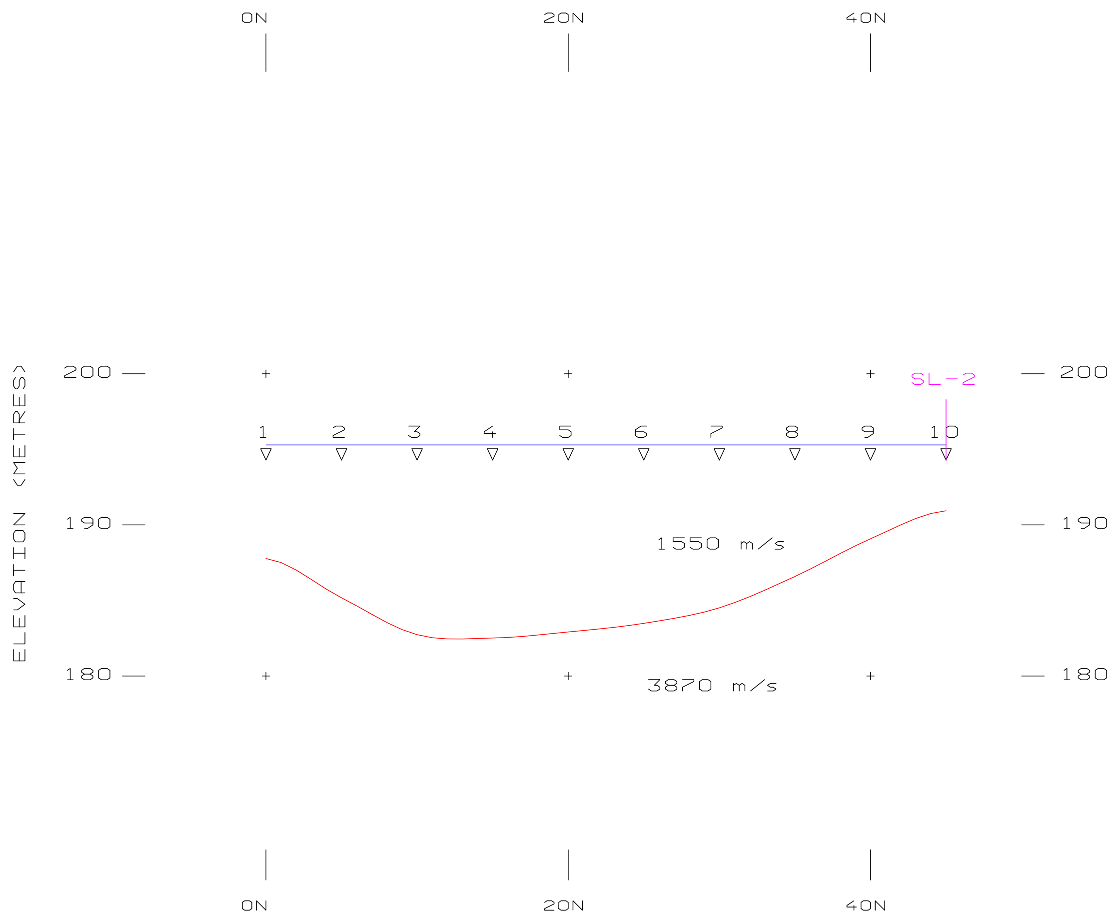
Russ Hillman

Russell Hillman, P.Eng.



SEISMIC REFRACTION LINE

KGS GROUP CONSULTING ENGINEERS BIG CHAUDIERE DAM PROJECT		
SEISMIC REFRACTION SURVEY		
SITE PLAN		
FRONTIER GEOSCIENCES INC.		
DATE: OCT. 2010	SCALE 1:1,000	FIG. 2



SEISMIC LINE SL-1

INSTRUMENT: GEOMETRICS GEODE

KGS GROUP CONSULTING ENGINEERS

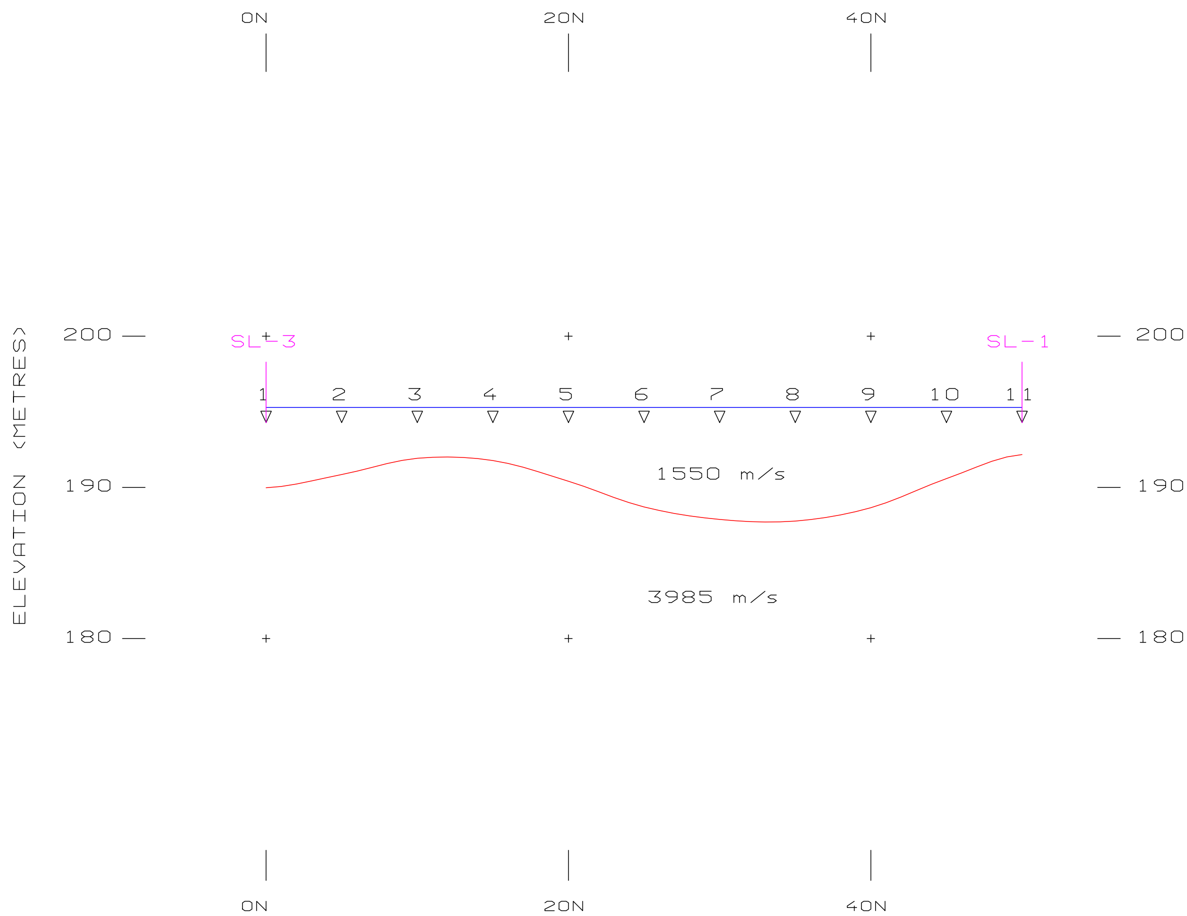
BIG CHAUDIERE DAM PROJECT

SEISMIC REFRACTION SURVEY

INTERPRETED DEPTH SECTION SL-1

FRONTIER GEOSCIENCES INC.

DATE: OCT. 2010	SCALE 1:500	FIG. 3

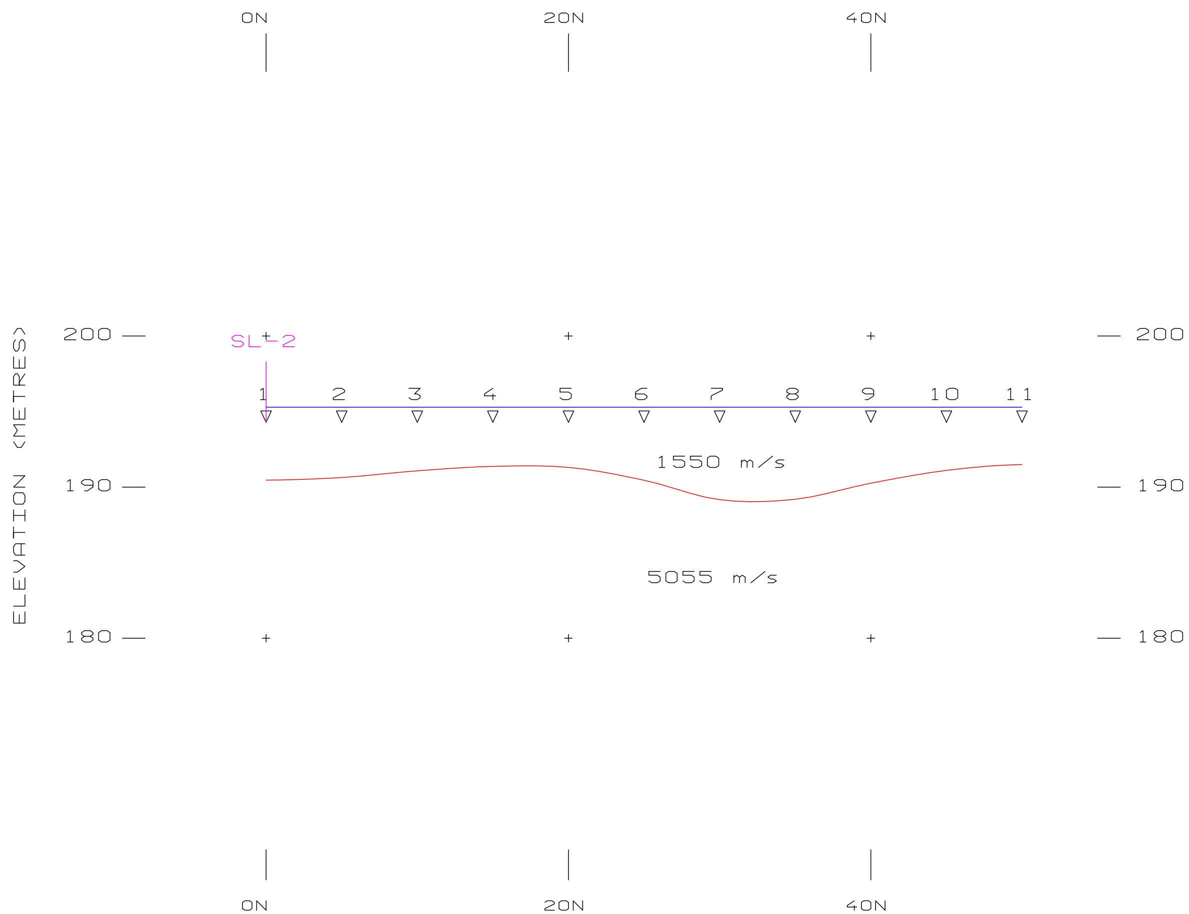


SEISMIC LINE SL-2

INSTRUMENT: GEOMETRICS GEODE

KGS GROUP CONSULTING ENGINEERS BIG CHAUDIERE DAM PROJECT
SEISMIC REFRACTION SURVEY
INTERPRETED DEPTH SECTION SL-2
FRONTIER GEOSCIENCES INC.

DATE: OCT. 2010	SCALE 1:500	FIG. 4



SEISMIC LINE SL-3

INSTRUMENT: GEOMETRICS GEODE

KGS GROUP CONSULTING ENGINEERS

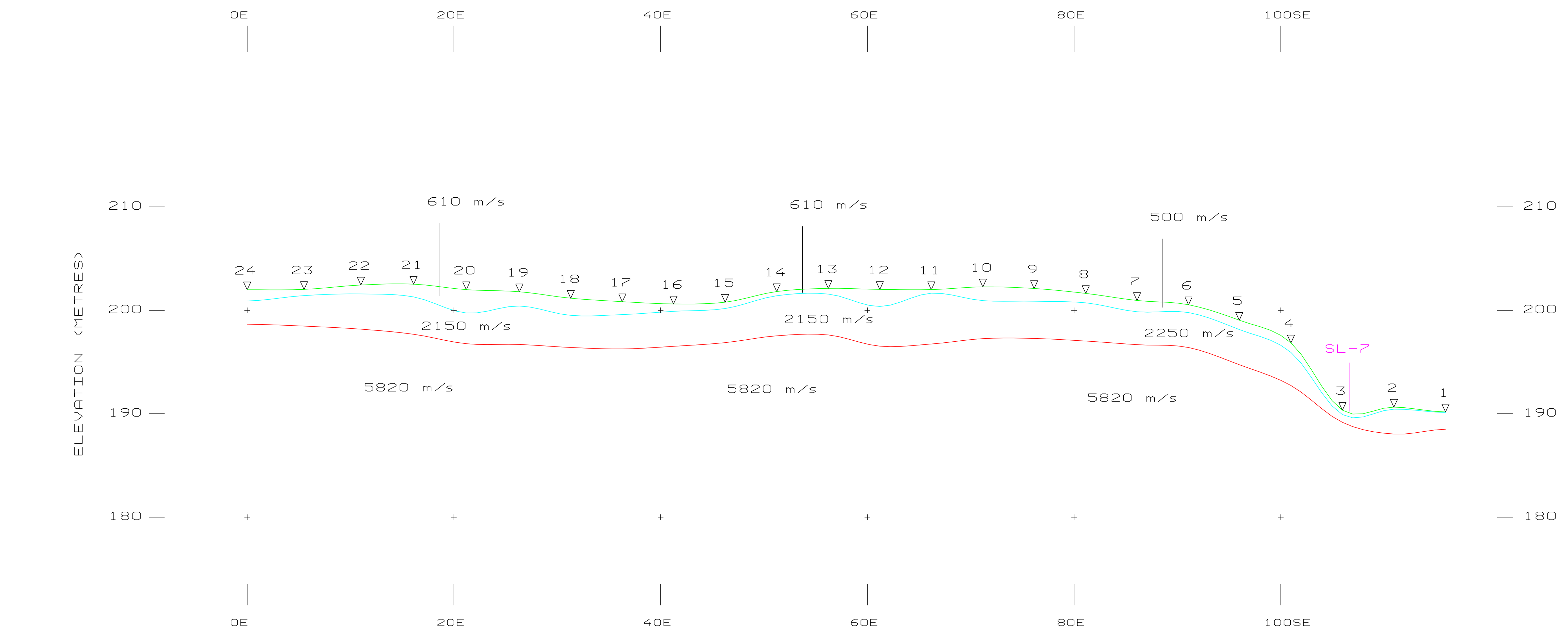
BIG CHAUDIERE DAM PROJECT

SEISMIC REFRACTION SURVEY

INTERPRETED DEPTH SECTION SL-3

FRONTIER GEOSCIENCES INC.

DATE: OCT. 2010	SCALE 1:500	FIG. 5



SEISMIC LINE SL-4

INSTRUMENT: GEOMETRICS GEODE

KGS GROUP CONSULTING ENGINEERS

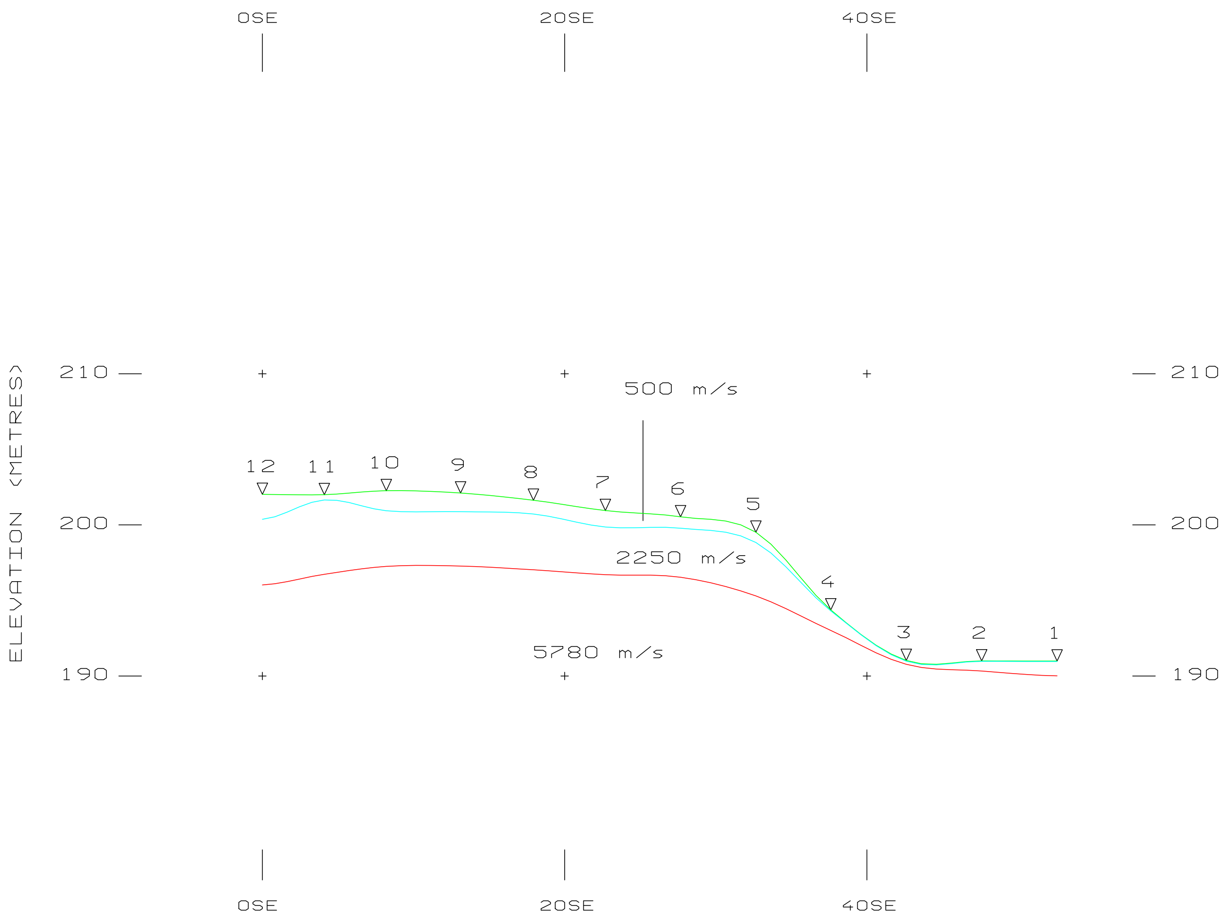
BIG CHAUDIERE DAM PROJECT

SEISMIC REFRACTION SURVEY

INTERPRETED DEPTH SECTION SL-4

FRONTIER GEOSCIENCES INC.

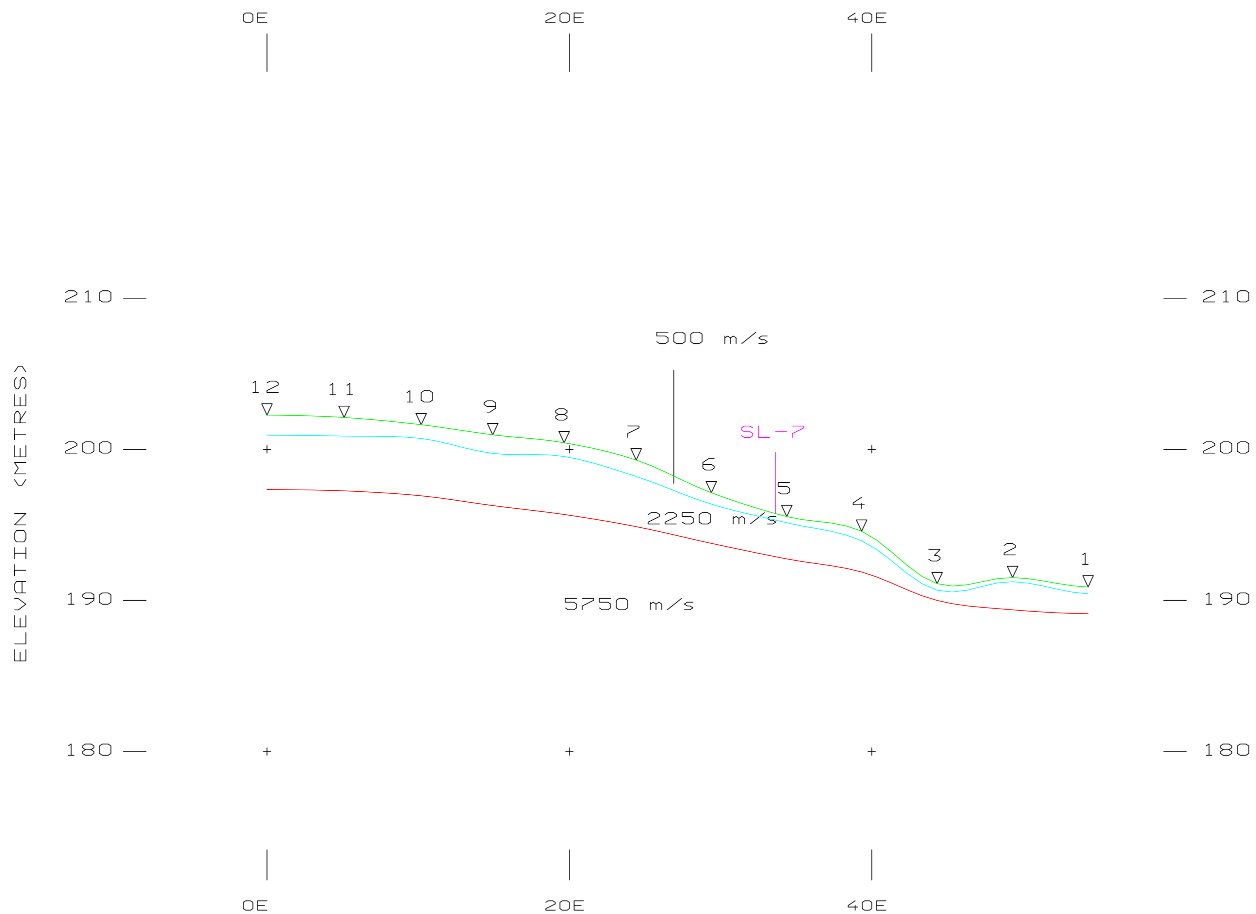
DATE: OCT. 2010	SCALE 1:500	FIG. 6



SEISMIC LINE SL-5

INSTRUMENT: GEOMETRICS GEODE

KGS GROUP CONSULTING ENGINEERS BIG CHAUDIERE DAM PROJECT		
SEISMIC REFRACTION SURVEY		
INTERPRETED DEPTH SECTION SL-5		
FRONTIER GEOSCIENCES INC.		
DATE: OCT. 2010	SCALE 1:500	FIG. 7

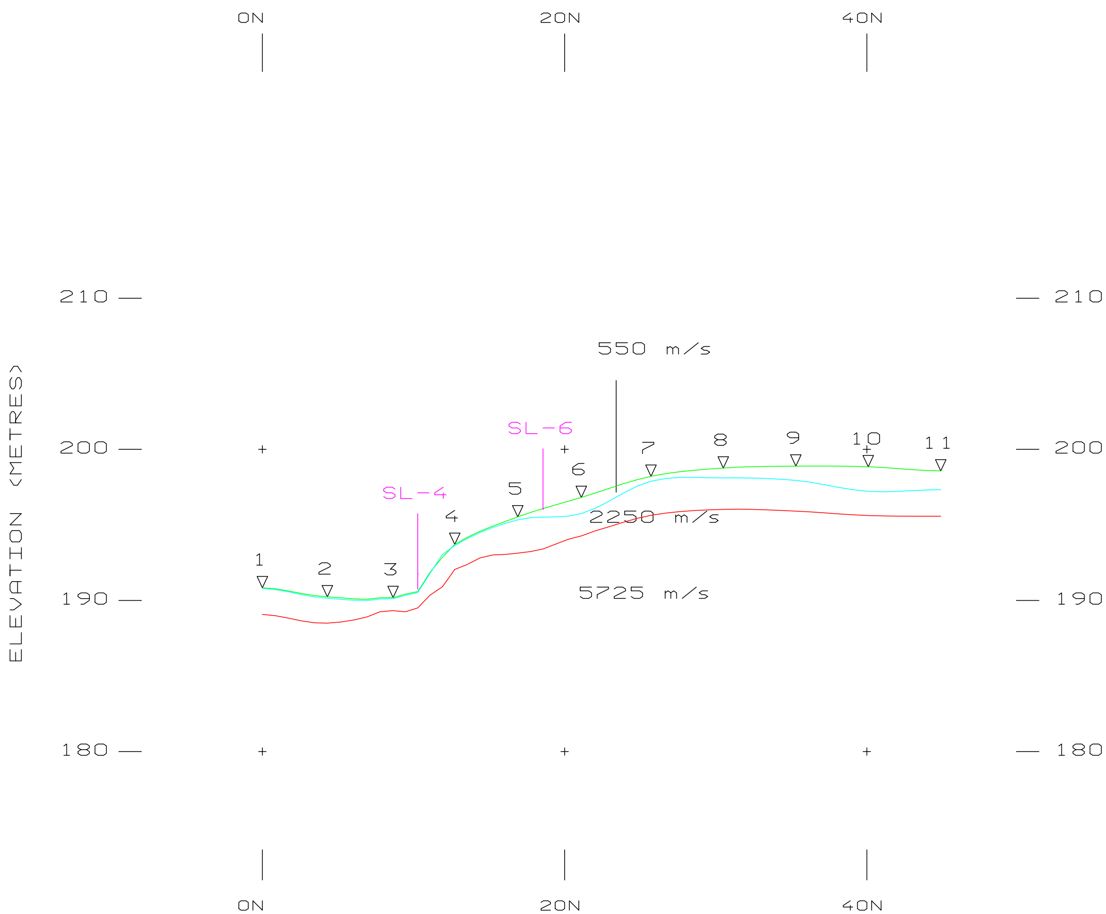


SEISMIC LINE SL-6

INSTRUMENT: GEOMETRICS GEODE

KGS GROUP CONSULTING ENGINEERS BIG CHAUDIERE DAM PROJECT
SEISMIC REFRACTION SURVEY
INTERPRETED DEPTH SECTION SL-6
FRONTIER GEOSCIENCES INC.

DATE: OCT. 2010	SCALE 1:500	FIG. 8



SEISMIC LINE SL-7

INSTRUMENT: GEOMETRICS GEODE

KGS GROUP CONSULTING ENGINEERS BIG CHAUDIERE DAM PROJECT
SEISMIC REFRACTION SURVEY
INTERPRETED DEPTH SECTION SL-7
FRONTIER GEOSCIENCES INC.

DATE: OCT. 2010	SCALE 1:500	FIG. 9

APPENDIX – C
Photographs

Drilling Procedures - 1

Drilling Procedures - 2

Drilling Procedures - 3

Drilling Procedures - 4

Barge Setup – Borehole BC11-1

Barge Setup – Borehole BC11-2

Barge Setup – Borehole BC11-3

Barge Setup – Borehole BC11-4

Barge Setup – Borehole BC11-8 -1

Barge Setup – Borehole BC11-8 -2

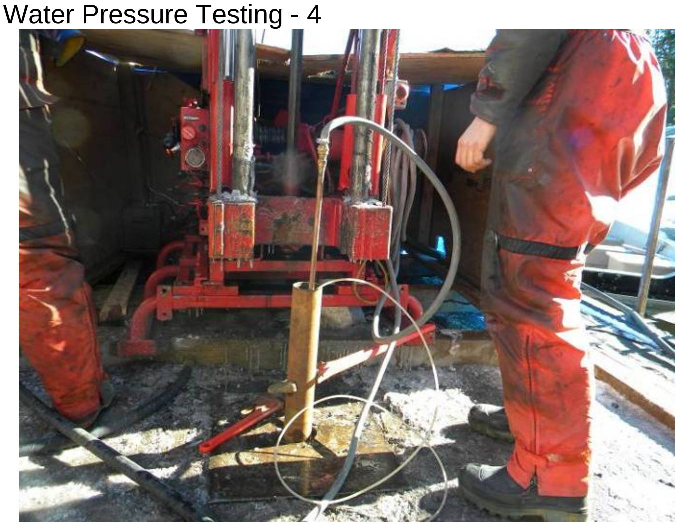
Barge Setup – Borehole BC11-8 -3

Water Pressure Testing - 1

Water Pressure Testing - 2

Water Pressure Testing - 3

Water Pressure Testing - 4



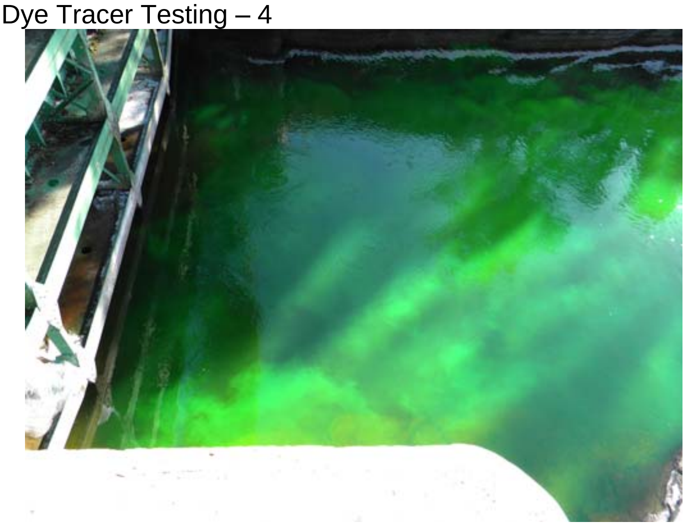
Water Pressure Test Testing -5

Dye Tracer Testing -1

Dye Tracer Testing - 2

Dye Tracer Testing -3

Dye Tracer Testing – 4



Downhole Video Survey -1

Downhole Video Survey -2

Downhole Video Survey -3

Downhole Video Survey -4

Downhole Video Survey -5


Mobilization and Barge Assembly -1

Mobilization and Barge Assembly -2

Mobilization and Barge Assembly 3

Mobilization and Barge Assembly 4

Mobilization and Barge Assembly - 5

Mobilization and Barge Assembly - 6

A View from Downstream of the South Channel - 1

A View from Downstream of the South Channel - 2

Demobilization -1

Demobilization -2

Core Photographs

Core Sample Photo BC11-1 BOX 1 of 1

Core Sample Photo BC11-2 Box 1 of 4

Core Sample Photo BC11-2 Box 2 of 4

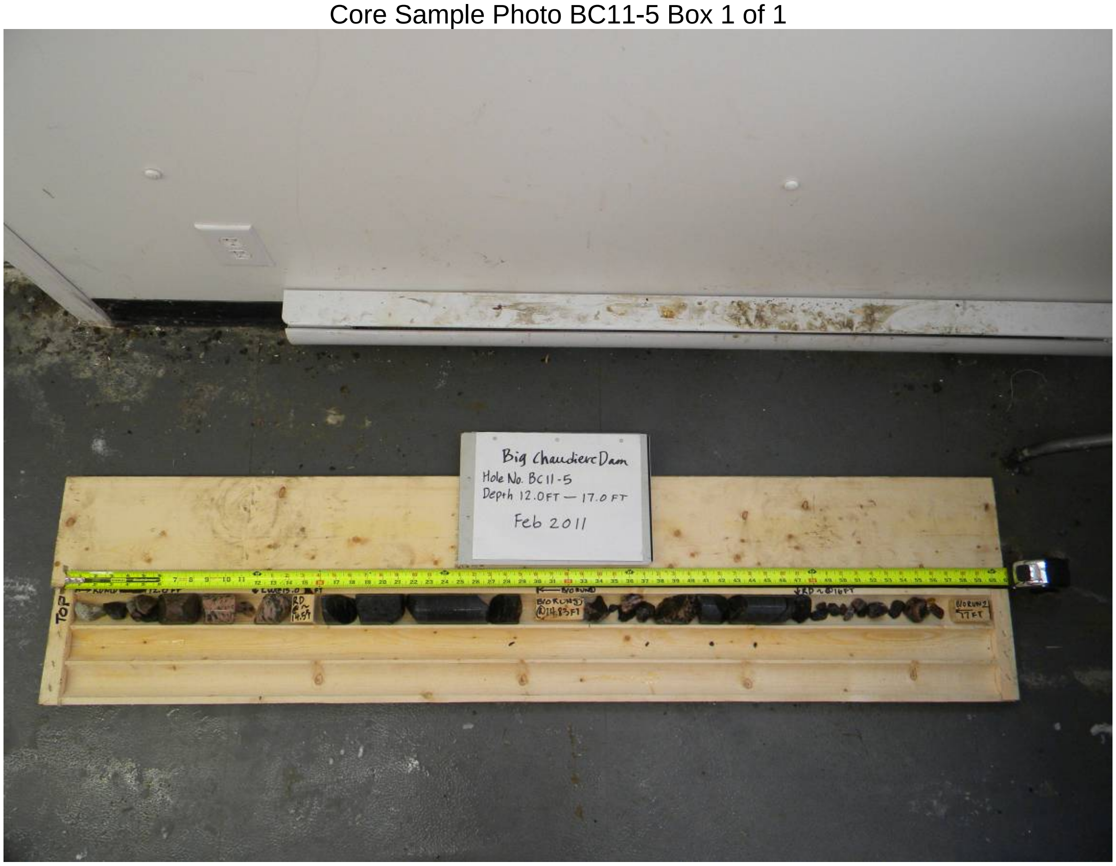
Core Sample Photo BC11-2 Box 3 of 4

Core Sample Photo BC11-2 Box 4 of 4

Core Sample Photo BC11-3 Box 1 to 4 of 4

Core Sample Photo BC11-4 Box 1 of 1

Core Sample Photo BC11-5 Box 1 of 1



Core Sample Photo BC11-6 Box 1 of 1

Core Sample Photo BC11-7 Box 1 of 1

Core Sample Photo BC11-8 Box 1 to 4 of 4

Core Boxes Stored on Site

APPENDIX – D
Borehole Logs

DRILL HOLE FIELD LOG

Big Chaudiere Dam

SYMBOLS:

Concrete

Grout

Rubble zone

Biotite-rich mafic intrusive rock

Granitic Gneiss

No core recovery

ABBREVIATIONS:

BLK - blocked
LW - Lost water
RD - Rod drop
LWTO - Lost water throughout
RDA - Rapid drill advance
WR - Water Returned
WRTO - Water Returned Throughout

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DRILL HOLE FIELD LOG

SUMMARY SHEET

Big Chaudiere Dam

Hole Number **BC11-1**

Feature: ______

Total Depth (m): 8.07
Angle from Horiz.: 90 deg.
Bearing: ______

N (m):	2.44
E (m):	3.05
Ground Elev (m).	191.34

Date Started: January 13, 2011
Date Completed: January 17, 2011

Water Level Upon Completion (m): 194.90

Converted to Piezometer: ~~Yes~~ No
Hole Backfilled/Grouted: ~~Yes~~ No ______

Drilling Company: Walker Drilling Ltd.
Driller: David Moser
Drill Rig Type: ______
Drill Rig Model: ______

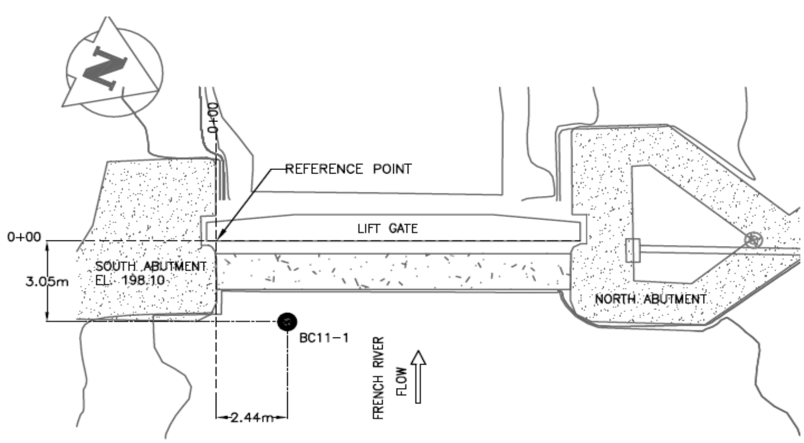
Length of Conc. Sill: 0.42 m
Samp. Method: Diamond Core
Length of Rock Coring: 3.78 m
Rock Coring Bit Sizes: NQ
Length of Casing Used: 1.52 m
Problems Encountered: N/A

Number of Core Boxes: 1

Logged By: AMM
Date Logged: 19-Jan-11
Note:

WPT	~~Yes~~	No
Other Permeability	~~Yes~~	No
Other in situ tests	~~Yes~~	No
Downhole Survey (Camera)	~~Yes~~	No
Point Load Index	~~Yes~~	No
Unconfined compressive strength	~~Yes~~	No
Splitting tensile (Brazilian) strength	~~Yes~~	No
Direct shear	~~Yes~~	No
Other	~~Yes~~	No

Borehole Location:



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FIELD GEOLOGIC LOG

Big Chaudiere Dam

PWGSC

Sheet No. 1 of 2
Date Logged: 19-Jan-2011
Logged by: AMM

HOLE NUMBER	**BC11-1**	N (m) :	2.44
Total Depth (m): 8.07	Feature:	E (m):	3.05
Angle (from horiz.): 90°	Depth to Rock (m): 4.28	Ground Elev. (m):	191.34 MSL
Bearing:	Started: 13/01/2011	Finished:	17/01/2011

Depth (m)	Recovery (%)	RQD %	Run No.	Lithology	Structure	Attitude	Classification and Physical Condition	WPT (L:cm/s)	Remarks
0.3							↑ EL. 195.2 m T/O Barge FL.		
0.3 – 3.86 (1, 2, 3)		N/A		Water			↑ EL. 194.9 m Water Level ↓EL. 191.34 m	N/A	
3.86 – 4.10 (4)		N/A	1				Pieces of Concrete, max. 10 cm and a piece of diabase rock. ↓ EL. 191.10 m	N/A	Run#1 End of Run - BLK.
4.10 – 5.49 (5)		91	2		80°	⚹ ⚹	Two pieces of concrete (~10 cm) **(Bedrock) Granitic Gneiss (Quartz-feldspar rich)** **very coarse grained, hard, competent, tight, lightly fractured.** **from 4.28 m (EL. 189.37 m)** - Coarse grained rock, gneissosity poorly defined - @ 4.4 m MB - @ 5.18 m JT 90° weathered fracture. - @ 5.21 m MB, @ 5.26 m Joint 80° ↓ EL. 189.71 m	N/A	Run#2 Drilled ~ 3.5 hrs. No LW **Bedrock@ 4.28 m (EL. 190.92 m)**
5.49 – 6.86 (6)		92	3	80°	40° 70° 70°	⚹	- @ 6.08 m MB - @ 6.31 m WJ 40° - @ 6.52 m JT 70° - @ 6.82 m JT 70° EL. 188.34 m	N/A	Run #3 Drilled ~3.5 hrs. WRTO
6.86 – 8.07 (7, 8)		94	4		60° 60° 60° 40° 60°	⚹ ⚹	- @ 7.29 m 60° - @ 7.38 & 7.40 m 60°, 2 friable layers separated by a 51 mm rock - @ 7.67 & 7.72 m MB - @ 7.81 m JT40° - @ 7.90 m MB and Joint 60° ↓ EL. 187.13 m	N/A	Run #4 WRTO
8.07 – (9)									

Note: ⚹ = Mechanical break in core
The datum elevation is taken at the top of barge floor at EL. 195.2 m. Depth is measured from the datum elevation.
Measurements are in metres and elevations are based on Canadian Geodetic Datum.
Natural joints in the bedrock are measured in degrees relative to the core axis

KGS GROUP

FIELD GEOLOGIC LOG

Big Chaudiere Dam

PWGSC

Sheet No. 2 of 2
Date Logged: 19-Jan-2011
Logged by: AMM

HOLE NUMBER		**BC11-1**		N (m) :	2.44
Total Depth (m):	8.07	Feature:		E (m):	3.05
Angle (from horiz.):	90°	Depth to Rock (m):	4.28	Ground Elev. (ft):	191.34 MSL
Bearing:		Started:	13/01/2011	Finished:	17/01/2011

CORE PHOTOGRAPHS

Box 1 of 1 - Depth from 3.86 m to 8.07 m (from 12.67 ft to 26.46 ft)

DRILL HOLE FIELD LOG

SUMMARY SHEET

Big Chaudiere Dam

Hole Number **BC11-2** Feature: ______

N (m):	6.10
E (m):	3.05
Ground Elev.	191.39

Total Depth (m): 13.46
Angle from Horiz.: 90 deg.
Bearing: ______

Date Started: January 18, 2011 Date Completed: January 27, 2011

Water Level Upon Completion (m): 194.90

Converted to Piezometer: ~~Yes~~ No
Hole Backfilled/Grouted: ~~Yes~~ No

Drilling Company: Walker Drilling Ltd. Driller: David Moser
Drill Rig Type: ______ Drill Rig Model: ______

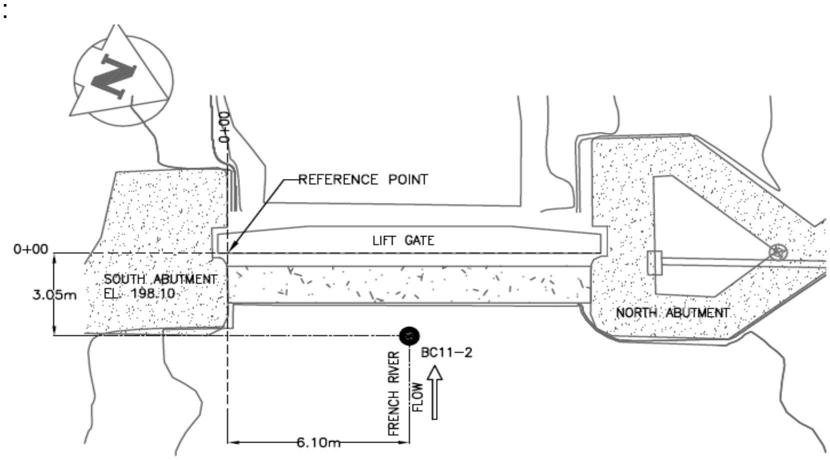
Length of Rubble: 8.29 m Samp. Method: Diamond Core
Length of Rock Coring: 5.17 m Rock Coring Bit Sizes: NQ
Length of Casing Used: 1.52 m/ea. casing
Problems Encountered: Loss of cores in the rubble zone (the possible of soft zone).

Number of Core Boxes: 4

Logged By: AMM Date Logged: 30-Jan-11

WPT	Yes	~~No~~	
Other Permeability	~~Yes~~		
Other in situ tests	~~Yes~~		
Downhole Survey (Camera)	~~Yes~~		
Point Load Index	~~Yes~~		
Unconfined compressive strength	~~Yes~~		
Splitting tensile (Brazilian) strength	~~Yes~~		
Direct shear	~~Yes~~	No	
Other	Yes	~~No~~	Downhole Video Survey

Borehole Location:



KGS GROUP

FIELD GEOLOGIC LOG

Big Chaudiere Dam

PWGSC

Date Logged: 30-Jan-2011

Logged by: AMM

HOLE NUMBER	**BC11-2**	N (m):	6.10
Total Depth (m): 17.27	Feature:	E (m):	3.05
Angle (from horiz.): 90°	Depth to Rock (m): 12.10	Ground Elev. (m):	191.39 MSL
Bearing:	Started: 18/01/2011	Finished:	27/01/2011

Depth (m)	Recovery (%)	RQD %	Run No.	Lithology	Structure	Attitude	Classification and Physical Condition	WPT (L:cm/s)	Remarks
0.3							↑ EL. 195.2 m T/O Barge FL		
3.81		N/A		Water			↑ EL. 194.9 m Water Level ↓EL. 191.39 m	N/A	
4.56		N/A	1				A mixture of concrete, diabase and granite. Concrete (sill), 7 cm to 12 cm. Diabase ~20 cm Granite ~ 15 cm ea. ↓EL. 190.64 m	N/A	Run#1 The bottom of Run #1 - BLK.
6.34		N/A	2				A mixture of granite and grout pieces. Granite: 35 cm max. 1 cm min. (broken cores). Grout: 13 cm max. ↓ EL. 188.86 m	7.9×10^{-6}	Run#2 LW @~5.2 m
7.92*		N/A	3				Broken cores (1.25 to 2.5 cm in dia.) and some grout pieces ~ 7.5 cm max. Poor core recovery Soft materials (unconsolidated and/or gravels) may not be lost. then went through soft materials. The possibility of voids. ↓ EL. ~ 187.28 m*	N/A	Run#3 *LWTO* *RD between Run#3 and #4 but no measurement was possible.
9.14		N/A	4				A mixture of granite and diabase rock. Granie 0.19 m max. Diabase rock (very dark colour), lightly fractured. ↓ EL. 186.06 m	N/A	Run#4 *LWTO*
9.91		N/A	5				A mixture of quartzite and granitic rocks. Quartzite, min. 5 cm, max. 17 cm. some grout were stuck at the bottom of the core surface. Granitic rock , very dark colour, min. 2.5 cm, max. 18 cm. ↓ EL. 185.29 m	N/A	Run#5 *WR* at the end of the run.

Note: ⚹ = Mechanical break in core
The datum elevation is taken at the top of barge floor at EL. 195.2 m. Depth is measured from the datum elevation.
Measurements are in metres and elevations are based on Canadian Geodetic Datum.
Natural joints in the bedrock are measured in degrees relative to the core axis

KGS GROUP

FIELD GEOLOGIC LOG

Big Chaudiere Dam

PWGSC

Date Logged: 30-Jan-2011

Logged by: AMM

HOLE NUMBER BC11-2

Total Depth (m): 17.17

Angle (from horiz.): 90°

Bearing:

Feature:

Depth to Rock (m): 12.10

Started: 18/01/2011

N (m): 6.10

E (m): 3.05

Ground Elev. (m): 198.10 MSL

Finished: 27/01/2011

Depth (m)	Recovery (%)	RQD %	Run No.	Lithology	Structure	Attitude	Classification and Physical Condition	WPT (L:cm/s)	Remarks
10.52			6				Smooth rounded gravels 1.3 cm to 3.8 cm dia., poor core recovery. ↓EL. 184.68 m	N/A	Run#6 Rapid drill advance - finer materials may have been washed out.
11, 11.58			7				A mixture of roken cores (diabase and quartzite) with some rounded pebbles, poor core recovery. ↓EL. 183.62 m	N/A	Run #7 The possibility of loss of finer materials (gravels).
11.89			8 & 9				See Notes below. ↓EL. 183.31		
12		14	10				Gravels 11.89 → 12.10 m, well rounded. **BEDROCK EL. 183.10 m, Depth = 12.10 m** Coarse grained, biotite-rich mafic intrusive rock 12.10 → 12.59 m ↓EL. 182.61 m	N/A	
12.59, 13, 13.79		60	11			⚹ ⚹	No core recovered about 0.46 m, possible soft zone. - @13.15 m MB - @13.22 m MB - @13.56 m Healed joint - @13.69 m Healed joint ↓EL. 181.41 m	N/A	Run#11 WRTO
14		0	12				Highly fractured. Large crystals observed in the rock. ↓EL. 180.93 m	N/A	Run#12 WRTO
14.27, 15, 15.62		55	13		70°, 60°, 60°, 60°		- From 14.27 to 14.42 m, sheared, highly fractured. - From 14.6 to 14.8 m, some iron deposit (hematite) on the rock. - @ 14.80 JT 70º from the CA. - From ~14.81 to 15.19 m - vertical fracture (shear zone) @14.86, 14.94 and 15.01 m JT 60º from the CA. ↓EL. 179.58 m	N/A	Run#13 WRTO
16, 16.23		75	14			⚹	- From 15.62 to 15.85, highly fractured. - @16.05 m MB ↓EL. 178.97 m	2.0×10^{-9} / 3.2×10^{-7}	Run#14 WRTO.
17, 17.27		46	15			⚹	- Highly fractured (the top, middle and bottom sections of the recovered core). - From 16.66 m to 16.79 m, a vertical fracture - @16.79 m MB ↓EL. 177.93 m		Run#15 WRTO. ←16.8 m
18, 19									

NOTE:
Run #8
Quartzite boulder (~13 cm) with rounded surfaces & diabase boulder (~8.9 cm) with smooth surface exposed in the core. Rounded pebbles from the above (i.e. caved in, core recovery > depth)

Run #9
No drill advancement but recovered some broken cores, probably 'caved in' cores from the above.

WPT:
From 15.6 m to 17.27 m
2.0×10^{-9} CM/s
From 16.82 m to 17.27 m
3.2×10^{-7} CM/s

Note: ⚹ = Mechanical break in core
The datum elevation is taken at the top of barge floor at EL. 195.2 m. Depth is measured from the datum elevation.
Measurements are in metres and elevations are based on Canadian Geodetic Datum.
Natural joints in the bedrock are measured in degrees relative to the core axis

KGS GROUP

FIELD GEOLOGIC LOG

Big Chaudiere Dam

PWGSC

Date Logged: 30-Jan-2011

Logged by: AMM

HOLE NUMBER	**BC11-2**			N (m):	6.10
Total Depth (m):	17.17	Feature:		E (m):	3.05
Angle (from horiz.):	90°	Depth to Rock (m):	12.1	Ground Elev. (ft):	198.10 MSL
Bearing:		Started:	13/01/2011	Finished:	17/01/2011

CORE PHOTOGRAPHS

Box 1 of 4 - Depth from 3.81 m to 7.92 m (from 12.50 ft to 26.0 ft)

Box 2 of 4 - Depth from 7.92 m to 11.89 m (from 26.0 ft to 38.7 ft)

Box 3 of 4 - Depth from11.89 m 16.23 m to (from 38.7 ft to 53.25 ft)

FIELD GEOLOGIC LOG

Big Chaudiere Dam
PWGSC

Sheet No. 4 of 4
Date Logged: 30-Jan-2011
Logged by: AMM

HOLE NUMBER	**BC11-2**			N (m):	6.10
Total Depth (m):	17.17	Feature:		E (m):	3.05
Angle (from horiz.):	90°	Depth to Rock (m):	12.1	Ground Elev. (ft):	198.10 MSL
Bearing:		Started:	13/01/2011	Finished:	17/01/2011

CORE PHOTOGRAPHS

Box 4 of 4 - Depth from 16.23 m to 17.27 m (53.25 ft to 56.67 ft)

DRILL HOLE FIELD LOG

KGS GROUP

SUMMARY SHEET

Big Chaudiere Dam

Hole Number **BC11-3**

Feature:

Total Depth (m): 17.22
Angle from Horiz.: 90 deg.
Bearing:

N (m):	8.11
E (m):	3.05
Ground Elev.	191.39

Date Started: January 31, 2011 Date Completed: February 4, 2011

Water Level Upon Completion (m): 194.90

Converted to Piezometer: ~~Yes~~ No
Hole Backfilled/Grouted: ~~Yes~~ No

Drilling Company: Walker Drilling Ltd. Driller: David Moser
Drill Rig Type: Drill Rig Model:

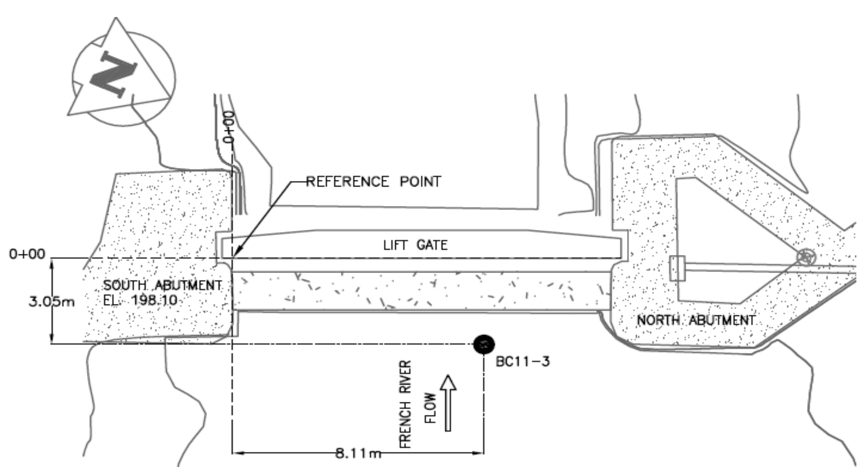
Length of Rubble: 7.06 m Samp. Method: Diamond Core
Length of Rock Coring: 6.35 m Rock Coring Bit Sizes: NQ
Length of Casing Used: 1.52 m/ea. casing
Problems Encountered: N/A

Number of Core Boxes: 4

Logged By: AMM Date Logged: 11-Feb-11

WPT	Yes	~~No~~	
Other Permeability	~~Yes~~	No	
Other in situ tests	~~Yes~~	No	
Downhole Survey (Camera)	~~Yes~~	No	
Point Load Index	~~Yes~~	No	
Unconfined compressive strength	~~Yes~~	No	
Splitting tensile (Brazilian) strength	~~Yes~~	No	
Direct shear	~~Yes~~	No	
Other	Yes	~~No~~	Dye Test

Borehole Location:



KGS GROUP

FIELD GEOLOGIC LOG

Big Chaudiere Dam

PWGSC

Sheet No. 1 of 3
Date Logged: 10-Feb-2011
Logged by: AMM

HOLE NUMBER **BC11-3**

Total Depth (m): 17.22
Angle (from horiz.): 90°
Bearing:
Feature:
Depth to Rock (m): 10.87
Started: 31/01/2011

N (m): 8.11
E (m): 3.05
Ground Elev. (m): 191.39 MSL
Finished: 04/02/2011

Depth (m)	Recovery (%)	RQD %	Run No.	Lithology	Structure	Attitude	Classification and Physical Condition	WPT (L:cm/s)	Remarks
0.3							↑ EL. 195.2 m T/O Barge floor		
1, 2, 3, 3.81		N/A		Water			↑ EL. 194.9 m Water level ↓EL. 191.34 m	N/A	
4, 5, 5.33		N/A	1				A mixture of concrete, diabase and granite. Concrete 12 cm ea. Diabase min. 1.2 cm, max. 13 cm. Diabase Rock ~ 0.25 m ↓EL. 189.87 m		Run #1 LW @4.57m, void dimension is unknown.
6, 6.86		N/A	2				A mixture of granite and diabase rock, poor core recovery*. Granite - broken 1.2 cm ~ 5 cm and a 22 cm piece. Diabase ~13 cm. ↓ EL. 188.34 m		Run #2 *Poor core recovery - no LW and no sign of void found. LW @6.32 m RDA @~ 6.70 m
7, 8, 8.38		N/A	3				A mixture of broken cores (granite and diabase). Granite 1.3 to 13 cm Diabase rock, max. 13 cm, some pieces with rusted surfaces. ↓ EL. 186.82 m	9.5×10^{-6}	Run #3 LWTO
9, 9.91		N/A	4				Pebbles and a mixture of broken cores (granite and diabase), poor core recovery. Granite 18 cm Pebble 1.25 cm in dia. Diabase 2.5 cm to 15 cm max. ↓ EL. 185.29 m	N/A	Run #4 Voids expected within this run, LWTO.

Note: ✕ = Mechanical break in core
The datum elevation is taken at the top of barge floor at EL. 195.2 m. Depth is measured from the datum elevation.
Measurements are in metres and elevations are based on Canadian Geodetic Datum.
Natural joints in the bedrock are measured in degrees relative to the core axis

KGS GROUP

FIELD GEOLOGIC LOG

Big Chaudiere Dam

PWGSC

Date Logged: 10-Feb-2011

Logged by: AMM

HOLE NUMBER	**BC11-3**	N(m):	8.11
Total Depth (m): 17.22	Feature:	E (m):	3.05
Angle (from horiz.): 90°	Depth to Rock (m): 10.87	Ground Elev. (m):	191.39 MSL
Bearing:	Started: 31/01/2011	Finished:	04/02/2011

Depth (m)	Recovery (%)	RQD %	Run No.	Lithology	Structure	Attitude	Classification and Physical Condition	WPT (L:cm/s)	Remarks
10.30			5				Rounded pebbles and broken cores (QF and diabase rocks) fell down from the above, probably sequence from Run #4. ↓EL. 184.90 m * measured value after retrieving the core barrel.		Run #5 - Drill stopped advancing→retrieved the core barrel.
10.84			6				Broken cores (diabase), stained and weathered surfaces. Two pieces of QF fragments and small gravels fond in the recovered cores. ↓EL. 184.36 m * measured value after retrieving the core barrel		Run #6 - broken cores were not fitted together well in the slot of the core box.
11 11.71		70	7		20°	⚹⚹⚹	Broken cores (diabase), possibly caved in from the above. Some small QF pieces found. **BEDROCK@ EL. 184.33 m; Depth = 10.87 m** @11.05 m and 11.18 m MB @11.38m MB and JT 20º from CA @ 11.49 and 11.55 m MB ↓EL. 183.49 m	N/A	Run #7
12 12.64		68	8		30° 30°	⚹	Broken cores No core recovered approximately 0.3 m, no sign of void and LW, possible ground cores. Bedrock ↓ @11.87 m JT 30º @12.01 m MB, @12.17 m MB and @12.38 m MB & JT 30º ↓EL. 181.01 m		Run #8
13 13.15		73	9			⚹⚹	@0.20 m from t/o core MB ~ 0.13 m broken cores from the bottom of the run. ↓EL. 182.56 m* measured		Run #9 - drilled ~ 10 min, WRTO.
14 14.71		98	10		80° 80° 80° 80° 20° 45°		Redrilled surfaces ~ 0.05 m @ 13.25 m JT 80º @ 13.53 m JT 80º @ 13.81 m JT 80º @ 14.14 m JT 20º, 45º and 80º @ 14.67 m MB @ 14.78 m* MB ↓EL. 180.94 m		Run #10 - core recovery is more than 1.52 m (5 ft), the bottom of the core may be broken below the bottom of the core barrel.
14.96		40	11				No drill advancement occurred and stopped the run. ↓EL. 180.24 m		
15 16 16.34		51	12		80° 80° 80° 15°		broken cores about 0.09 m, one piece of the core has redrilled surfaces. @ 15.21 m JT 80º @ 15.32 m JT 80º @ 15.48 m NJ 80º @ 15.70 m MB @ 15.72 →15.89 m Healed joint @16.28 m → bottom JT 15º ↓EL. 178.86 m	9.2×10^{-8}	
17 17.22		78	13		30° 80° 60°		@ 16.43 m JT 30º @ 16.64 m JT 80º and 90º @ 16.92 m JT 60º ↓EL. 177.98 m		
18									
19									

Note: ⚹ = Mechanical break in core

The datum elevation is taken at the top of barge floor at EL. 195.2 m. Depth is measured from the datum elevation.

Measurements are in metres and elevations are based on Canadian Geodetic Datum.

Natural joints in the bedrock are measured in degrees relative to the core axis

GROUP

FIELD GEOLOGIC LOG

Big Chaudiere Dam

PWGSC

Sheet No. 3 of 3
Date Logged: 10-Feb-2011
Logged by: AMM

HOLE NUMBER		**BC11-3**		N (m):	8.11
Total Depth (m):	17.22	Feature:		E (m):	3.05
Angle (from horiz.):	90°	Depth to Rock (m):	10.87	Ground Elev. (ft):	191.39 MSL
Bearing:		Started:	31/01/2011	Finished:	04/02/2011

CORE PHOTOGRAPHS

BC11-3 From 3.81 m to 17.22 m (From 12.5 FT to 56.5 FT)

DRILL HOLE FIELD LOG

SUMMARY SHEET

Big Chaudiere Dam

KGS GROUP

Hole Number **BC11-4**

Feature: ____________

Total Depth (m): 6.52
Angle from Horiz.: 90 deg.
Bearing: ____________

N (m):	10.98
E (m):	6.10
Ground Elev.	191.69

Date Started: February 7, 2011 Date Completed: February 8, 2011

Water Level Upon Completion (m): 194.90

Converted to Piezometer: ~~Yes~~ No
Hole Backfilled/Grouted: ~~Yes~~ No

Drilling Company: Walker Drilling Ltd. Driller: David Moser
Drill Rig Type: ____________ Drill Rig Model: ____________

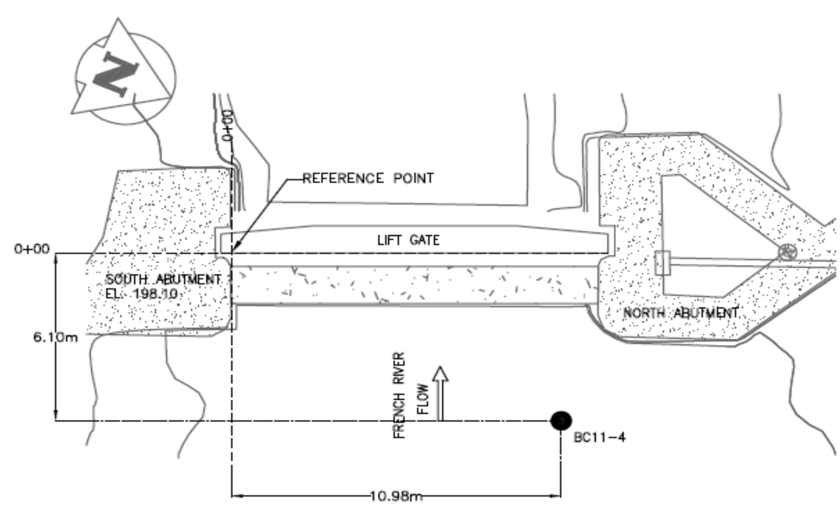
Length of Rubble (m) ____________ Samp. Method: Diamond Core
Length of Rock Coring: 6.52 Rock Coring Bit Sizes: NQ
Length of Casing Used: 1.52 m/ea. casing
Problems Encountered: N/A

Number of Core Boxes: 1

Logged By: AMM Date Logged: 10-Feb-11

WPT	~~Yes~~	No
Other Permeability	~~Yes~~	No
Other in situ tests	~~Yes~~	No
Downhole Survey (Camera)	~~Yes~~	No
Point Load Index	~~Yes~~	No
Unconfined compressive strength	~~Yes~~	No
Splitting tensile (Brazilian) strength	~~Yes~~	No
Direct shear	~~Yes~~	No
Other	~~Yes~~	No

Borehole Location:



KGS GROUP

FIELD GEOLOGIC LOG

Big Chaudiere Dam

PWGSC

Sheet No. 1 of 2
Date Logged: 10-Feb-2011
Logged by: AMM

HOLE NUMBER **BC11-4**

Total Depth (m):	6.52	Feature:	
Angle (from horiz.):	90°	Depth to Rock (m):	3.53
Bearing:		Started:	07/02/2011

N (m):	10.98
E (m):	6.10
Ground Elev. (m):	191.69 MSL
Finished:	08/02/2011

Depth (m)	Recovery (%)	RQD %	Run No.	Lithology	Structure	Attitude	Classification and Physical Condition	WPT (L:cm/s)	Remarks
0.3							↑ EL. 195.2 m T/O Barge FL.		
0.3 – 3.51				Water			↑ EL. 194.9 m Water level ↓EL. 191.69 m	N/A	
3.51 – 4.93		86	1		60º, 50º		**BEDROCK (Granitic Gneiss, coarse grain, very hard, lightly fractured)** **@ EL.191.69, Depth = 3.51 m** @ 3.63 m JT with fine sands 60º @ 3.99 m JT with fine sands 50º @ 4.59 m MB @ 4.69 m weathered surfaces, rusted. @ 4.87 m MB A bottom 0.05 may not be retrieved. ↓EL. 190.27 m	N/A	Run #1 WRTO A piece of cobble (~ 1.5 cm), multiple cutting lines by the casing on top of the core.
4.93 – 6.35		95	2		60º, 80º, 70º, 70º		From 4.93 to 4.95 m, multiple drilled surfaces, probably left from Run 1. @ 5.25 m JT, weathered, 60º @ 5.73 m NJ, rusted surfaces, 80º @ 6.15 m JT, weathered surfaces, 70º @ 6.28 m JT, weathered surfaces, 70º @ 6.3 m MB ↓ EL. 188.85 m	N/A	Run #2 WRTO
6.35 – 6.52		0	3 & 4				Run #3 and #4 - broken at NJ	N/A	Run 3 & 4 WRTO
6.52							↑EL. 188.68 m		

Depth scale: 1, 2, 3, 4, 5, 6, 7, 8, 9

Note: ⚹ = Mechanical break in core
The datum elevation is taken at the top of barge floor at EL. 195.2 m. Depth is measured from the datum elevation.
Measurements are in metres and elevations are based on Canadian Geodetic Datum.
Natural joints in the bedrock are measured in degrees relative to the core axis

KGS GROUP

FIELD GEOLOGIC LOG

Big Chaudiere Dam

PWGSC

Date Logged: 10-Feb-2011

Logged by: AMM

HOLE NUMBER	**BC11-4**	N (m):	10.98
Total Depth (m): 6.52	Feature:	E (m):	6.10
Angle (from horiz.): 90°	Depth to Rock (m): 3.53	Ground Elev. (ft):	191.69 MSL
Bearing:	Started: 07/02/2011	Finished:	08/02/2011

CORE PHOTOGRAPHS

BC11-4 From 3.51 m to 6.52 m (11.5 ft to 21.40 ft)

DRILL HOLE FIELD LOG

SUMMARY SHEET

Big Chaudiere Dam

Hole Number **BC11- 5**

Feature:

Total Depth (m):	1.52	N (m):	7.1
Angle from Horiz.:	90 deg.	E (m):	11.10
Bearing:		Ground Elev.	191.46

Date Started: February 9, 2011 Date Completed: February 9, 2011

Water Level Upon Completion (m): 194.90

Converted to Piezometer:	~~Yes~~	No
Hole Backfilled/Grouted:	~~Yes~~	No

Drilling Company: Walker Drilling Ltd. Driller: David Moser

Drill Rig Type: Drill Rig Model:

Length of Rubble: 1.52 m Samp. Method: Diamond Core

Length of Rock Coring: 0.00 m Rock Coring Bit Sizes: NQ

Length of Casing Used: 1.52 m

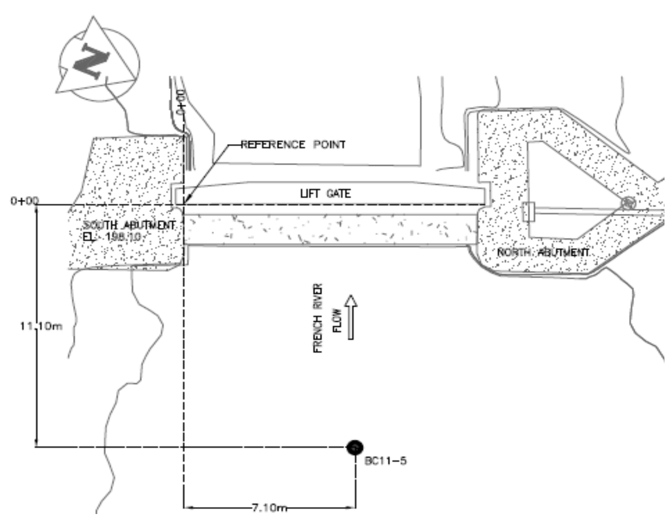
Problems Encountered: Encountered alignment problems with the casing and terminated the drilling operation at the depth of 5.18 m.

Number of Core Boxes: 1

Logged By: AMM Date Logged: 15-Feb-11

WPT	~~Yes~~	No
Other Permeability	~~Yes~~	No
Other in situ tests	~~Yes~~	No
Downhole Survey (Camera)	~~Yes~~	No
Point Load Index	~~Yes~~	No
Unconfined compressive strength	~~Yes~~	No
Splitting tensile (Brazilian) strength	~~Yes~~	No
Direct shear	~~Yes~~	No
Other	~~Yes~~	No

Borehole Location:



KGS GROUP

FIELD GEOLOGIC LOG

Big Chaudiere Dam

PWGSC

Sheet No. 1 of 1
Date Logged: 15-Feb-2011
Logged by: AMM

HOLE NUMBER	**BC11-5**	N (m):	7.1
Total Depth (m): 1.52	Feature:	E (m):	11.10
Angle (from horiz.): 90°	Depth to Rock (m): N/A	Ground Elev. (m):	191.46 MSL
Bearing:	Started: 09/02/2011	Finished:	09/02/2011

Depth (m)	Recovery (%)	RQD %	Run No.	Lithology	Structure	Attitude	Classification and Physical Condition	WPT (L:cm/s)	Remarks
0.3							↑ EL. 195.2 m		T/O Barge FL EL. 195.2 m; Depth = 0 m
3.66				Water			↑ EL. 194.9 m ↓EL. 191.46 m		WT EL.194.9 m; Depth = 0.3 m
4.52			1				Some concrete pieces and broken cores (QF and Diabase rocks) ↓EL. 190.06 m		Run#1- FEB 9, 2011 LW @ 3.96 m RD @4.42 m
5.18			2				Broken cores with rusted surfaces (QF, Diabase rocks) and gravel ↓EL. 189.94 m		Run#2 - FEB 9, 2011 RD @4.88 m

Depth scale: 1, 2, 3, 4, 5, 6, 7, 8, 9

DRAFT

Note: ⚹ = Mechanical break in core
The datum elevation is taken at the top of barge floor at EL. 195.2 m. Depth is measured from the datum elevation.
Measurements are in metres and elevations are based on Canadian Geodetic Datum.
Natural joints in the bedrock are measured in degrees relative to the core axis

KGS GROUP

FIELD GEOLOGIC LOG

Big Chaudiere Dam

PWGSC

Sheet No. 2 of 2
Date Logged: 15-Feb-2011
Logged by: AMM

HOLE NUMBER	**BC11-5**			N (m):	7.1
Total Depth (m):	1.52	Feature:		E (m):	11.10
Angle (from horiz.):	90°	Depth to Rock (m):	N/A	Ground Elev. (ft):	191.46 MSL
Bearing:		Started:	09/02/2011	Finished:	09/02/2011

CORE PHOTOGRAPHS

Box 1 of 1 - Depth from 3.66 m to 5.18 m (from 12 ft to 17 ft)

DRILL HOLE FIELD LOG

SUMMARY SHEET

Big Chaudiere Dam

Hole Number **BC11- 6**

Feature:

Total Depth (m): 0.35
Angle from Horiz.: 90 deg.
Bearing:

N (m):	7.1
E (m):	11.40
Ground Elev.	190.88

Date Started: February 10, 2011
Date Completed: February 10, 2011

Water Level Upon Completion (m): 194.90

Converted to Piezometer: ~~Yes~~ No
Hole Backfilled/Grouted: ~~Yes~~ No

Drilling Company: Walker Drilling Ltd.
Driller: David Moser
Drill Rig Type:
Drill Rig Model:

Length of Rubble: 0.35 m
Length of Rock Coring: 0.00 m
Length of Casing Used: 1.52 m
Problems Encountered: N/A

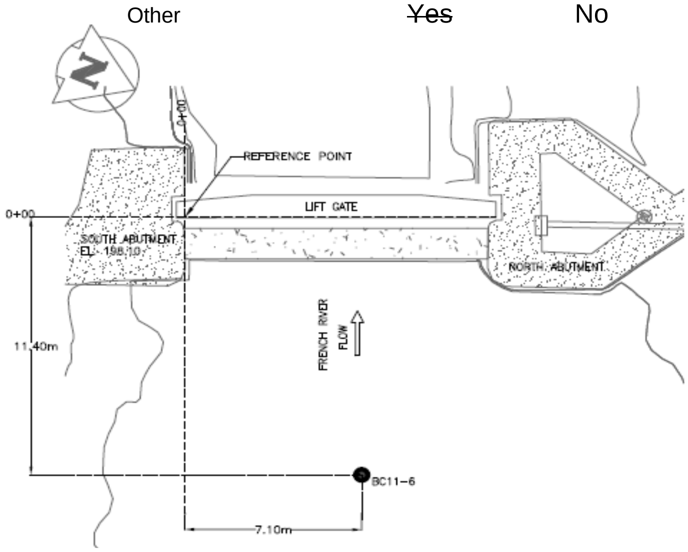
Samp. Method: Diamond Core
Rock Coring Bit Sizes: NQ

Number of Core Boxes: 1

Logged By: AMM
Date Logged: 15-Feb-11

WPT	~~Yes~~	No
Other Permeability	~~Yes~~	No
Other in situ tests	~~Yes~~	No
Downhole Survey (Camera)	~~Yes~~	No
Point Load Index	~~Yes~~	No
Unconfined compressive strength	~~Yes~~	No
Splitting tensile (Brazilian) strength	~~Yes~~	No
Direct shear	~~Yes~~	No
Other	~~Yes~~	No

Borehole Location:



KGS GROUP

FIELD GEOLOGIC LOG

Big Chaudiere Dam

PWGSC

Sheet No. 1 of 1
Date Logged: 15-Feb-2011
Logged by: AMM

HOLE NUMBER	**BC11-6**	N (m):	7.10
Total Depth (m):	1.52	E (m):	11.40
Angle (from horiz.):	90°	Ground Elev. (m):	190.88 MSL
Bearing:			
Feature:		Depth to Rock (m):	N/A
Started:	09/02/2011	Finished:	09/02/2011

Depth (m)	Recovery (%)	RQD %	Run No.	Lithology	Structure	Attitude	Classification and Physical Condition	WPT (L:cm/s)	Remarks
0.3							↑ EL. 195.2 m		T/O Barge FL EL. 195.2 m; Depth = 0 m
1, 2, 3, 4				Water			↑ EL. 194.9 m ↓EL. 190.88 m		WT EL.194.9 m; Depth = 0.3 m
4.32 – 4.66							A mixture of granite and diabase rocks min. 1.25 cm to max. 10 cm ↓EL. 190.54 m		Run#1 - FEB 9, 2011 LWTO
5, 6, 7, 8, 9							The core barrel stopped advancing at the depth of 4.66 m. Advanced the casing for another 1.52 m but encountered alignment problems with the casing and terminated the drilling operation at the depth of 4.66 m.		

DRAFT

Note: ⚹ = Mechanical break in core
The datum elevation is taken at the top of barge floor at EL. 195.2 m. Depth is measured from the datum elevation.
Measurements are in metres and elevations are based on Canadian Geodetic Datum.
Natural joints in the bedrock are measured in degrees relative to the core axis

FIELD GEOLOGIC LOG

Big Chaudiere Dam

PWGSC

Sheet No. 2 of 2
Date Logged: 15-Feb-2011
Logged by: AMM

HOLE NUMBER	**BC11-5**	N (m):	7.10
Total Depth (m): 0.35	Feature:	E (m):	11.40
Angle (from horiz.): 90°	Depth to Rock (m): N/A	Ground Elev. (ft):	190.88 MSL
Bearing:	Started: 01/01/1900	Finished:	09/02/2011

CORE PHOTOGRAPHS

Box 1 of 1 - Depth from 4.32 m to 4.66 m (from 14.17 ft to 15.30 ft)

DRILL HOLE FIELD LOG

SUMMARY SHEET

Big Chaudiere Dam

Hole Number **BC11- 7**

Feature: ____________

Total Depth (m): 2.89
Angle from Horiz.: 90 deg.
Bearing: ____________

N (m):	7.10
E (m):	16.40
Ground Elev.	190.89

Date Started: February 11, 2011 Date Completed: February 11, 2011

Water Level Upon Completion (m): 194.90

Converted to Piezometer: ~~Yes~~ No
Hole Backfilled/Grouted: ~~Yes~~ No ____________

Drilling Company: Walker Drilling Ltd. Driller: David Moser
Drill Rig Type: ____________ Drill Rig Model: ____________

Length of Rubble: 2.89 m
Length of Rock Coring: 0.00 m
Length of Casing Used: 1.52 m
Problems Encountered: N/A

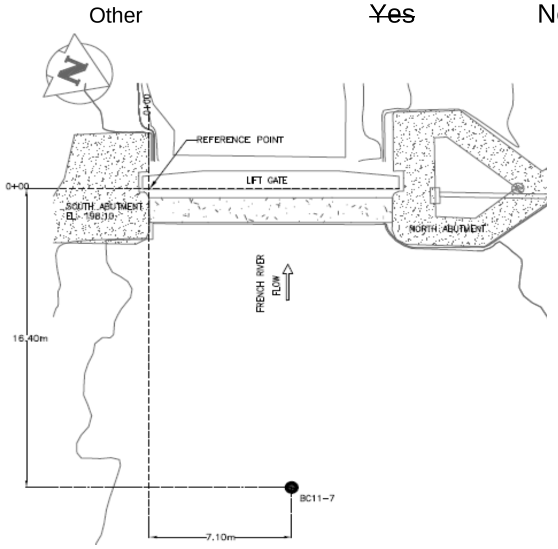
Samp. Method: Diamond Core
Rock Coring Bit Sizes: NQ

Number of Core Boxes: 1

Logged By: AMM Date Logged: 15-Feb-11

WPT	~~Yes~~	No
Other Permeability	~~Yes~~	No
Other in situ tests	~~Yes~~	No
Downhole Survey (Camera)	~~Yes~~	No
Point Load Index	~~Yes~~	No
Unconfined compressive strength	~~Yes~~	No
Splitting tensile (Brazilian) strength	~~Yes~~	No
Direct shear	~~Yes~~	No
Other	~~Yes~~	No

Borehole Location:



FIELD GEOLOGIC LOG

KGS GROUP

Big Chaudiere Dam
PWGSC

Sheet No. 1 of 1
Date Logged: 15-Feb-2011
Logged by: AMM

HOLE NUMBER **BC11-7**

Total Depth (m): 2.89
Angle (from horiz.): 90°
Bearing:
Feature:
Depth to Rock (m): N/A
Started: 11/02/2011

N (m): 7.10
E (m): 16.40
Ground Elev. (m): 190.89 MSL
Finished: 11/02/2011

Depth (m)	Recovery (%)	RQD %	Run No.	Lithology	Structure	Attitude	Classification and Physical Condition	WPT (L:cm/s)	Remarks
0.3							↑ EL. 195.2 m		T/O Barge FL EL. 195.2 m; Depth = 0 m
4.31				Water			↑ EL. 194.9 m ↓EL. 190.89 m		WT EL.194.9 m; Depth = 0.3 m
4.66 5.68							QF ~ 0.12m Broken cores (QF) with vegetations (moss) on some surfaces on the cores ↓EL. 189.52 m		Run#1 - FEB 11, 2011 LWTO RD @4.82 m RDA @5.37 m RD @5.53 m
7.20							Broken cores (QF and Diabase rocks with rusted surfaces) ↓EL. 188.00 m		Run#12- FEB 11, 2011 LWTO RDA @6.1 m RDA @6.9 m RD @7.1 m
							The casing fell into the water when it was advanced for the 3rd run. Further operation was not possible.		

Depth scale: 1, 2, 3, 4, 5, 6, 7, 8, 9

DRAFT

Note: ⚹ = Mechanical break in core
The datum elevation is taken at the top of barge floor at EL. 195.2 m. Depth is measured from the datum elevation.
Measurements are in metres and elevations are based on Canadian Geodetic Datum.
Natural joints in the bedrock are measured in degrees relative to the core axis

FIELD GEOLOGIC LOG

KGS GROUP

Big Chaudiere Dam
PWGSC

Sheet No. 2 of 2
Date Logged: 15-Feb-2011
Logged by: AMM

HOLE NUMBER	**BC11-7**			N:	?
Total Depth (m):	2.89	Feature:		E:	?
Angle (from horiz.):	90°	Depth to Rock (m):	N/A	Ground Elev. (ft):	190.89 MSL
Bearing:		Started:	11/02/2011	Finished:	11/02/2011

CORE PHOTOGRAPHS

Box 1 of 1 - Depth from 4.31 m to 7.20 m (from 14.13 ft to 23.63 ft)

KGS GROUP

DRILL HOLE FIELD LOG

SUMMARY SHEET

Big Chaudiere Dam

Hole Number **BC11-8**

Feature:

Total Depth (m): 20.45
Angle from Horiz.: 90 deg.
Bearing:

N (m):	7.10
E (m):	15.21
Ground Elev.	191.19

Date Started: February 14, 2011   Date Completed: February 22, 2011

Water Level Upon Completion (m): 194.90

Converted to Piezometer: ~~Yes~~ No
Hole Backfilled/Grouted: ~~Yes~~ No

Drilling Company: Walker Drilling Ltd.   Driller: David Moser
Drill Rig Type: Drill Rig Model:

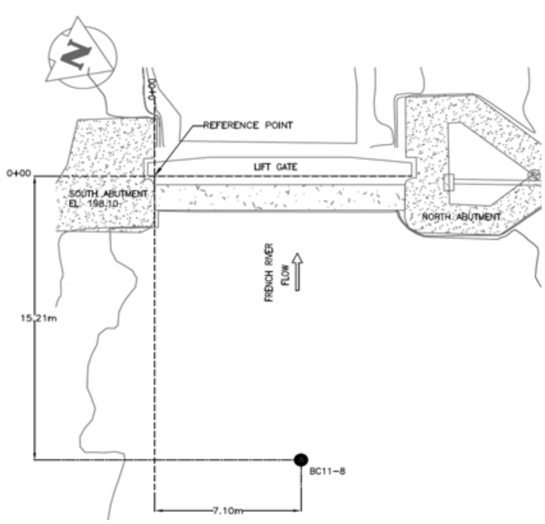
Length of Rubble (m) 12.07   Samp. Method: Diamond Core
Length of Rock Coring: 8.38   Rock Coring Bit Sizes: NQ
Length of Casing Used: 1.52 m/ea. casing
Problems Encountered: Redrilling of caved materials in the rubble. (From Run # 9 to #19).

Number of Core Boxes: 4

Logged By: AMM   Date Logged: 24-Feb-11

WPT	Yes	~~No~~	
Other Permeability	Yes	~~No~~	Dye Test
Other in situ tests	Yes	~~No~~	Downhole Video Survey
Downhole Survey (Camera)	~~Yes~~	No	
Point Load Index	~~Yes~~	No	
Unconfined compressive strength	~~Yes~~	No	
Splitting tensile (Brazilian) strength	~~Yes~~	No	
Direct shear	Yes	No	
Other	Yes	~~No~~	

Borehole Location:



FIELD GEOLOGIC LOG

KGS GROUP

Big Chaudiere Dam
PWGSC

Sheet No. 1 of 4
Date Logged: 24-Feb-2011
Logged by: AMM

HOLE NUMBER	BC11-8	N (m):	7.10
Total Depth (m): 20.45	Feature:	E (m):	15.21
Angle (from horiz.): 90°	Depth to Rock (m): 16.08	Ground Elev. (m):	191.19 MSL
Bearing:	Started: 14/02/2011	Finished:	22/02/2011

Depth (m)	Recovery (%)	RQD %	Run No.	Lithology	Structure	Attitude	Classification and Physical Condition	WPT (L:cm/s)	Remarks
0.3							↑ EL. 195.2 m T/O Barge FL EL. 195.2 m		
0.3 – 4.01 (1, 2, 3, 4)				Water			↑ EL. 194.9 m Water Level ↓EL.191.19 m	N/A	
4.01 – 4.90			1				Broken cores (granite) and some gravels Granite 1.3 cm to 13 cm ↓EL. 190.30 m		Run # 1 LW @ 4.22 m, Void approx. 0.2 m RD @ 4.54 m about 2.5 cm
4.90 – 5.23 (5)			2				Granite 0.36 m, rusted surface on the top. Box 1 of 4. ↓EL. 189.97 m		Run # 2 LWTO
5.23 – 5.51							↓ Beginning of run after the casing was advanced Depth 5.51 m, void space? ↓EL. 189.69 m		
5.51 – 7.03 (6, 7)			3				A mixture of broken granite and diabase rock, <Poor core recovery> Granite 1.25 cm min. /10 cm max. with weathered surfaces Diabase 1.25 cm to 3.5 cm with weathered surfaces ↓ EL. 188.17 m		Run #3 No WR below ~ 5.67 m RDA @ 6.1 m
7.03 – 8.46 (8)			4				Gravels, granite and diabase rocks. Gravels: most of them may be lost below the bottom of casing loose materials can be possibly washed away. Granite: ~ 8 cm, rusted surface (top) Diabase rock: min. 2.5 cm max. 25 cm ↓ EL. 186.74 m	N/A	Run #4 LWTO RD @7.3 m & void approx. 2.5 cm.
8.46 – 9.98 (9)			5				Broken cores (diabase) with some gravels. Diabase: min. 1.25 cm max. 25 cm, rusted surfaces. ↓ EL. 185.22 m		Run #5 LW @8.9 m RD @7.3 m

Note: ⤫ = Mechanical break in core
The datum elevation is taken at the top of barge floor at EL. 195.2 m. Depth is measured from the datum elevation.
Measurements are in metres and elevations are based on Canadian Geodetic Datum.
Natural joints in the bedrock are measured in degrees relative to the core axis

FIELD GEOLOGIC LOG

KGS GROUP

Big Chaudiere Dam
PWGSC

Date Logged: 24-Feb-2011
Logged by: AMM

HOLE NUMBER **BC11-8**
Total Depth (m): 20.45
Angle (from horiz.): 90°
Bearing:
Feature:
Depth to Rock (m): 16.08
Started: 14/02/2011

N (m): 7.10
E (m): 15.21
Ground Elev. (m): 198.10 MSL
Finished: 22/02/2011

Depth (m)	Recovery (%)	RQD %	Run No.	Lithology	Structure	Attitude	Classification and Physical Condition	WPT (L:cm/s)	Remarks
10.88			6				A mixture of granite and diabase (broken cores), poor core recovery. Diabase: 1.25 cm to 10 cm Granite: 1.25 cm to 12 cm ↓ EL. 184.32 m	N/A	Run #6 LW @ 10.24 m
11 11.45			7				Run #7 - Broken cores, mainly diabase rocks and gravels. QF about 14 cm, weathered surfaces. ↓ EL. 183.75 m	8.4 x 10^{-6}	Run #7 - LWTO
11.52			8				Run #8 - Two pieces of diabase rocks, 7.5 cm max. ↓ EL. 183.68 m		
12 12.06			9 & 10				Run 9 - Diabase rocks 2.5 cm to 18 cm. Run 10 - Diabase rocks 2.5 cm to 15 cm. ↓ EL. 183.10 m (b/o Run #10)		Run #9 - drilled caved in materials from the above. WR after approx. 0.1 m of the core barrel advancement. Run #10 LW @0.97 m
12.40			11				Broken cores (diabase rocks) 1.25 cm to 7.5 cm.		Run #11 - LWTO.
12.57			12				Broken cores (diabase) and pebbles. Diabase 20 cm max. (boulder).		Run #12 - LWTO.
13 13.18							Possible void ? Beg. of Run #13 was measured @13.18 m after the casing was advanced. ↓ EL. 182.02 m		
13.44			13				No core recovered for this run, possible void. ↓ EL. 181.76 m		Run #13 - drilled 0.25 m.
14 14.14			14				A mixture of granite and diabase. Granite 0.43 m max. Broken cores approx. 1.25 cm in dia. Diabase min. 1.25 cm to max. 15 cm ↓EL. 181.06 m		Run #14 - LWTO, RD @13.90 m, the core barrel stopped advancing @14.44 m.
14.94			15				A mixture of granite and diabase with some pebbles. Granite 5 cm min. 15 cm max. Diabase rock 15 cm max. ↓EL.180.26 m	N/A	Run #15 LWTO
15 15.13			16				A 0.38 cm diabase rock and pebbles. See notes on page 3 ↓EL.180.07 m		Run #16, drilled caved in materials.
16 16.43		16	17 & 18 & 19				Run #17 - Pebbles and broken cores: these may fell in from the above. **(BEDROCK@179.12 m; Depth = 16.08 m)** **Biotite rich mafic intrusive rock** severely fractured. Run #18 - Rounded rocks (pebbles) and a 7.6 cm diabase rock. Run #19 - Rounded rocks (pebbles). ↓EL. 178.77 m **B/O RUN #19**		Run #17, #18 and #19 - LWTO Drilled caved in materials from the above.
16.64					85° 85°		↓BOR measured @16.64 m (Run # 18) EL. 178.56 m		Run #19 - WRTO
17 17.96		53	20		85° 80° 85° 85° 45°		@16.66 m JT 85°, @16.69 m JT 85° @16.71 m 85° , @ 16.79 MB, @17.11 m JT 80° from CA, @ 17.20 m JT 85° & a vertical fracture @17.76 m JT 85°, @17.88 m multiple JTs, 45° @18.01 and 18.06 m MB ↓EL.177.24 m		Run #20 - WRTO - ~ 3 hrs. in total to core for Run #19 and #20 The bottom section of the core - broken. NOTE: some fractured rocks did not fit together, cores in the box are more than the length of Run #20 (a 1.52m (5-ft) run).
18 19 19.10		81	21		80° 45° 80° 30° 85°		Double cut cores @ 18.04 m JT 80° @ 18.11 m JT 45°, @18.20 m JT 45° and MB, @ 18.32 m JT 80°, @18.38 JT 30° and 85°, @18.50 m JT 85° ↓ EL. 176.10 m	0	Run #21 WRTO Double cut cores due to the casing advancement. ↓ BOR measured for @18.97 m (caved in)
		65	22		85° 85° 15°	45°	Run #22 From 18.92 to 19.40 m Broken cores (double cut by the casing advancement). @19.53 m JT 85° @19.63 to 19.84 m, vertical fractures (shear) @19.84 m JT 85°		Run #22 - WRTO Some materials caved in from the above after the casing advancement.

Note: ⚹ = Mechanical break in core
The datum elevation is taken at the top of barge floor at EL. 195.2 m. Depth is measured from the datum elevation.
Measurements are in metres and elevations are based on Canadian Geodetic Datum.
Natural joints in the bedrock are measured in degrees relative to the core axis

KGS GROUP

FIELD GEOLOGIC LOG

Big Chaudiere Dam

PWGSC

Sheet No. 3 of 4
Date Logged: 24-Feb-2011
Logged by: AMM

HOLE NUMBER	**BC11-8**	N (m):	7.10
Total Depth (m): 20.45	Feature:	E (m):	15.21
Angle (from horiz.): 90°	Depth to Rock (m): 16.08	Ground Elev. (m):	198.10 MSL
Bearing:	Started: 14/02/2011	Finished:	22/02/2011

Depth (m)	Recovery (%)	RQD %	Run No.	Lithology	Structure	Attitude	Classification and Physical Condition	WPT (L:cm/s)	Remarks
20.45				0			↓ EL. 174.75 m	0	
21									
22									
23									
24									
25									
26									
27									
28									
29									

Note: ⚹ = Mechanical break in core
The datum elevation is taken at the top of barge floor at EL. 195.2 m. Depth is measured from the datum elevation.
Measurements are in metres and elevations are based on Canadian Geodetic Datum.
Natural joints in the bedrock are measured in degrees relative to the core axis

KGS GROUP

FIELD GEOLOGIC LOG

Big Chaudiere Dam
PWGSC

Sheet No. 4 of 4
Date Logged: 24-Feb-2011
Logged by: AMM

HOLE NUMBER	**BC11-8**			N (m):	7.10
Total Depth (m):	20.45	Feature:		E (m):	15.21
Angle (from horiz.):	90°	Depth to Rock (m):	16.08	Ground Elev. (ft):	198.10 MSL
Bearing:		Started:		Finished:	

CORE PHOTOGRAPHS

BC11-8 From 4.01 m to 20.45 m (13.16 ft to 67.10 ft)

APPENDIX – E
Water Pressure Tests

KGS GROUP

WATER PRESSURE TEST 1

Big Chaudiere Dam

PWGSC

Sheet No. 1 of 2

Date Tested 27-Jan-11

Hole Number BC11-2

Total Depth: 44.07 ft

Angle (from horiz.): 90 deg.

Bearing:

Height of Gauge: 1 ft

Feature:

Depth to Rock: ft

Water depth before test: 1 ft

Actual Packer IP used = psi

N: ?

E: ?

Ground Elev. 635.33 FT

Tested By: A.MARSHALL

	Interval Tested (ft)			Take (m³/min)					Pressure (psi)				Permeability	
Test Number	From	To	**Length**	Start	Finish	Water Loss	Elapse Time (min.)	**Take**	Gauge	Column	Friction Loss	**Net**	**Lugeons**	**cm/s**
1	55.2	56.7	1.5	0.06150	0.06150	0.0000	1	0.000	30.0	0.4	0.007	30.4	0.000	0.0E+00
				0.06150	0.06150	0.0000	2							
				0.06150	0.06150	0.0000	3							
				0.06150	0.06150	0.0000	4							
				0.06150	0.06150	0.0000	5							
2	55.2	56.7	1.5	0.06150	0.06150	0.0000	1	0.000	40.0	0.4	0.007	40.4	0.000	0.0E+00
				0.06150	0.06150	0.0000	2							
				0.06150	0.06150	0.0000	3							
				0.06150	0.06150	0.0000	4							
				0.06150	0.06150	0.0000	5							
3	55.2	56.7	1.5	0.06150	0.06150	0.0000	1	0.000	50.0	0.4	0.007	50.4	0.317	4.1E-06
				0.06150	0.06160	0.0001	2							
				0.06160	0.06170	0.0001	3							
				0.06170	0.06180	0.0001	4							
				0.06180	0.06190	0.0001	5							
				0.06190	0.06210	0.0002	6							
				0.06210	0.06220	0.0001	7							
				0.06220	0.06230	0.0001	8							
				0.06230	0.06225	-0.0001	9							
				0.06225	0.06200	-0.0003	10							
4	55.2	56.7	1.5	0.06205	0.06205	0.0000	1	0.000	40.0	0.4	0.007	40.4	0.0395	5.1E-07
				0.06205	0.06205	0.0000	2							
				0.06205	0.06205	0.0000	3							
				0.06205	0.06215	0.0001	4							
				0.06215	0.06210	0.0000	5							
				0.06210	0.06210	0.0000	6							
				0.06210	0.06210	0.0000	7							
				0.06210	0.06210	0.0000	8							
				0.06210	0.06210	0.0000	9							
				0.06210	0.06210	0.0000	10							

Refer to accompanying Geologic Logs and separate P-Q plots.

WATER PRESSURE TEST 1

KGS GROUP

Big Chaudiere Dam

PWGSC

Sheet No. 2 of 2

Date Tested 27-Jan-11

Hole Number **BC11-2**

Total Depth: 44.07 ft

Angle (from horiz.): 90 deg.

Bearing:

Height of Gauge: 1 ft

Feature:

Depth to Rock: ft

Water depth before test: 1 ft

Actual Packer IP used = psi

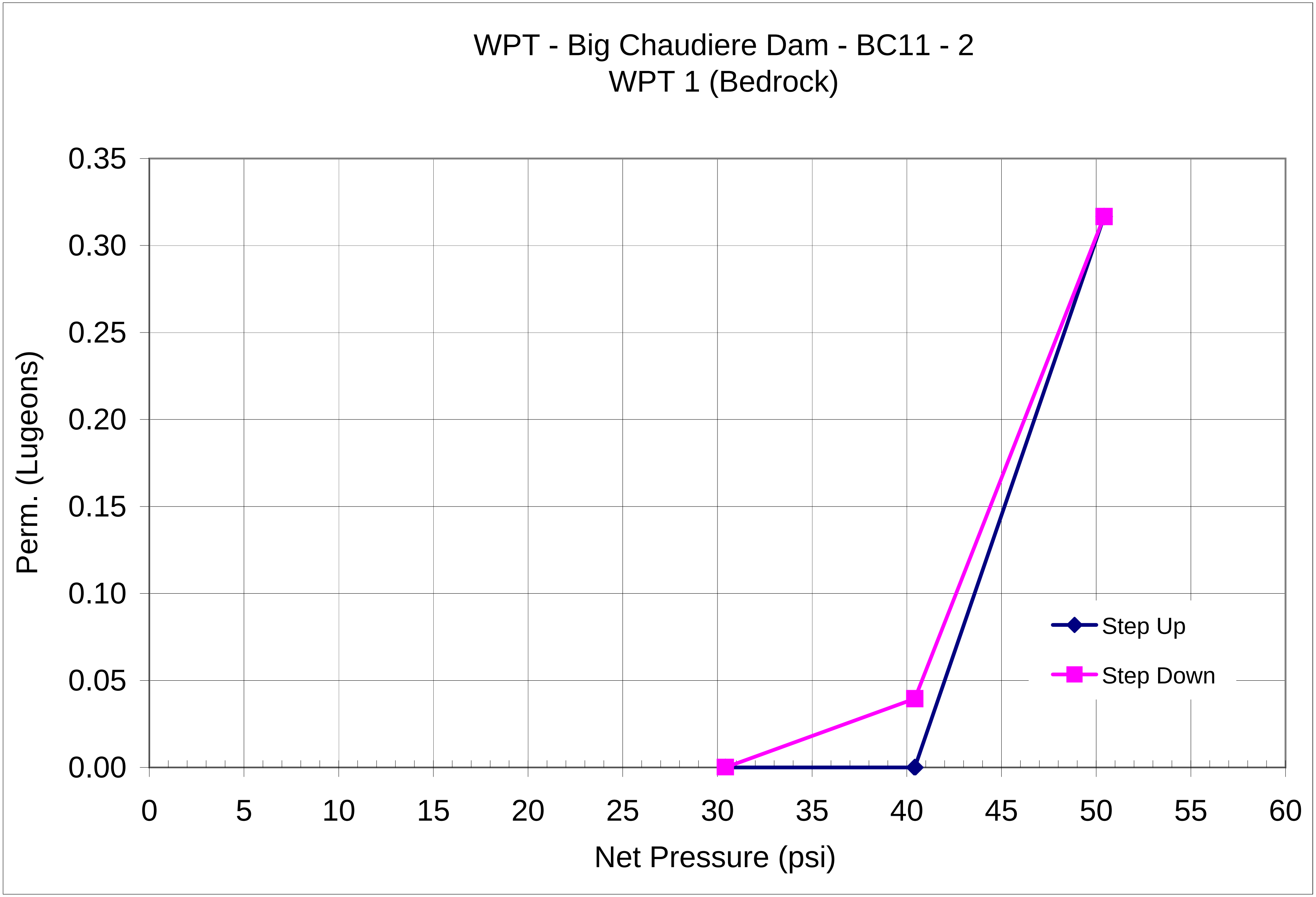
N: ?

E: ?

Ground Elev. 635.33 FT

Tested By: A.MARSHALL

	Interval Tested (ft)			Take (m³/min)					Pressure (psi)				Permeability	
Test Number	From	To	**Length**	Start	Finish	Water Loss	Elapse Time (min.)	**Take**	Gauge	Column	Friction Loss	**Net**	**Lugeons**	**cm/s**
5	55.2	56.7	1.5	0.06155	0.06155	0.0000	1	0.000	30.0	0.4	0.007	30.4	0.0000	0.0E+00
				0.06155	0.06155	0.0000	2							
				0.06155	0.06155	0.0000	3							
				0.06155	0.06155	0.0000	4							
				0.06155	0.06155	0.0000	5							
				0.06155	0.06155	0.0000	6							
				0.06155	0.06155	0.0000	7							
				0.06155	0.06155	0.0000	8							
				0.06155	0.06155	0.0000	9							
				0.06155	0.06155	0.0000	10							


WPT - Big Chaudiere Dam - BC11 - 2
WPT 1 (Bedrock)
Perm. (Lugeons)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
5
10
15
20
25
30
35
40
45
50
55
60
Net Pressure (psi)
Step Up
Step Down

KGS GROUP

WATER PRESSURE TEST 2

Big Chaudiere Dam

PWGSC

Sheet No. 1 of 2

Date Tested 27-Jan-11

Hole Number **BC11-2**

Total Depth: 44.07 ft

Angle (from horiz.): 90 deg.

Bearing:

Height of Gauge: 1 ft

Feature:

Depth to Rock: ft

Water depth before test: 1 ft

Actual Packer IP used = psi

N: ?

E: ?

Ground Elev.

Tested By: A.MARSHALL

Test Number	Interval Tested (ft)			Take (m³/min)					Pressure (psi)				Permeability	
	From	To	**Length**	Start	Finish	Water Loss	Elapse Time (min.)	**Take**	Gauge	Column	Friction Loss	**Net**	**Lugeons**	**cm/s**
1	51.2	56.7	5.5	0.06350	0.06640	0.0029	1	0.002	30.0	0.4	0.007	30.4	6.44	8.4E-05
				0.06640	0.06980	0.0034	2							
				0.06980	0.07360	0.0038	3							
				0.07360	0.07620	0.0026	4							
				0.07620	0.07780	0.0016	5							
				0.07780	0.07950	0.0017	6							
				0.07950	0.08060	0.0011	7							
				0.08060	0.08240	0.0018	8							
				0.08240	0.08420	0.0018	9							
				0.08420	0.08600	0.0018	10							
2	51.2	56.7	5.5	0.08800	0.09190	0.0039	1	0.020	40.0	0.4	0.007	40.4	43.73	5.7E-04
				0.09190	0.10900	0.0171	2							
				0.10900	0.13300	0.0240	3							
				0.13300	0.15500	0.0220	4							
				0.15500	0.17800	0.0230	5							
				0.17800	0.20000	0.0220	6							
				0.20000	0.22300	0.0230	7							
				0.22300	0.24600	0.0230	8							
				0.24600	0.26900	0.0230	9							
				0.26900	0.29100	0.0220	10							
3	51.2	56.7	5.5	0.31000	0.33800	0.0280	1	0.026	50.0	0.4	0.007	50.4	0.17	2.2E-06
				0.33800	0.36400	0.0260	2							
				0.36400	0.39000	0.0260	3							
				0.39000	0.41500	0.0250	4							
				0.41500	0.44200	0.0270	5							
				0.44200	0.46800	0.0260	6							
				0.46800	0.49300	0.0250	7							
				0.49300	0.51900	0.0260	8							
				0.51900	0.54600	0.0270	9							
				0.54600	0.57200	0.0260	10							
4	51.2	56.7	5.5	0.58300	0.60700	0.0240	1	0.023	40.0	0.4	0.007	40.4	48.69	6.3E-04
				0.60700	0.63000	0.0230	2							
				0.63000	0.65300	0.0230	3							
				0.65300	0.67500	0.0220	4							
				0.67500	0.69700	0.0220	5							
				0.69700	0.72000	0.0230	6							
				0.72000	0.74200	0.0220	7							
				0.74200	0.76400	0.0220	8							
				0.76400	0.78600	0.0220	9							
				0.78600	0.80900	0.0230	10							

WATER PRESSURE TEST 2

Big Chaudiere Dam

PWGSC

Sheet No. 2 of 2

Date Tested: 27-Jan-11

Hole Number **BC11-2**

Total Depth: 44.07 ft

Angle (from horiz.): 90 deg.

Bearing:

Height of Gauge: 1 ft

Feature:

Depth to Rock: ft

Water depth before test: 1 ft

Actual Packer IP used = psi

N: ?

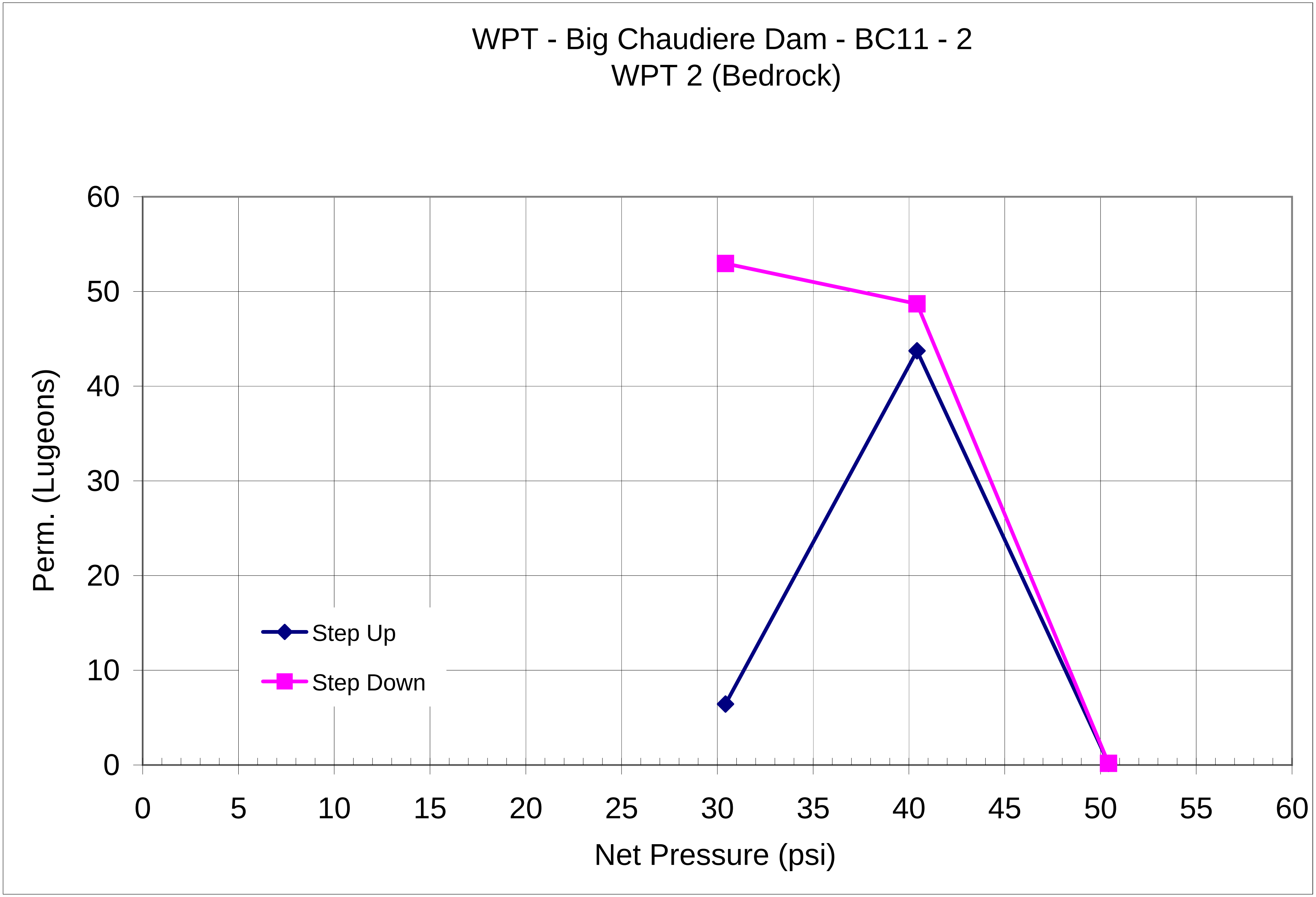
E: ?

Ground Elev.

Tested By: A.MARSHALL

	Interval Tested (ft)			Take (m³/min)					Pressure (psi)				Permeability	
Test Number	From	To	**Length**	Start	Finish	Water Loss	Elapse Time (min.)	**Take**	Gauge	Column	Friction Loss	**Net**	**Lugeons**	**cm/s**
5	51.2	56.7	5.5	0.81700	0.83500	0.0180	1	0.019	30.0	0.4	0.007	30.4	52.95	6.9E-04
				0.83500	0.85400	0.0190	2							
				0.85400	0.87200	0.0180	3							
				0.87200	0.89000	0.0180	4							
				0.89000	0.90800	0.0180	5							
				0.90800	0.92700	0.0190	6							
				0.92700	0.94500	0.0180	7							
				0.94500	0.96500	0.0200	8							
				0.96500	0.98200	0.0170	9							
				0.98200	1.00200	0.0200	10							

Refer to accompanying Geologic Logs and separate P-Q plots.


WPT - Big Chaudiere Dam - BC11 - 2
WPT 2 (Bedrock)
Perm. (Lugeons)
Net Pressure (psi)
0
10
20
30
40
50
60
0
5
10
15
20
25
30
35
40
45
50
55
60
Step Up
Step Down

KGS GROUP

WATER PRESSURE TEST 3

Big Chaudiere Dam

PWGSC

Sheet No. 1 of 1

Date Tested: 28-Jan-11

Hole Number **BC11-2**

N: ?

E: ?

Ground Elev.

Total Depth: 44.07 ft

Angle (from horiz.): 90 deg.

Bearing:

Height of Gauge: 1 ft

Feature:

Depth to Rock: ft

Water depth before test: 1 ft

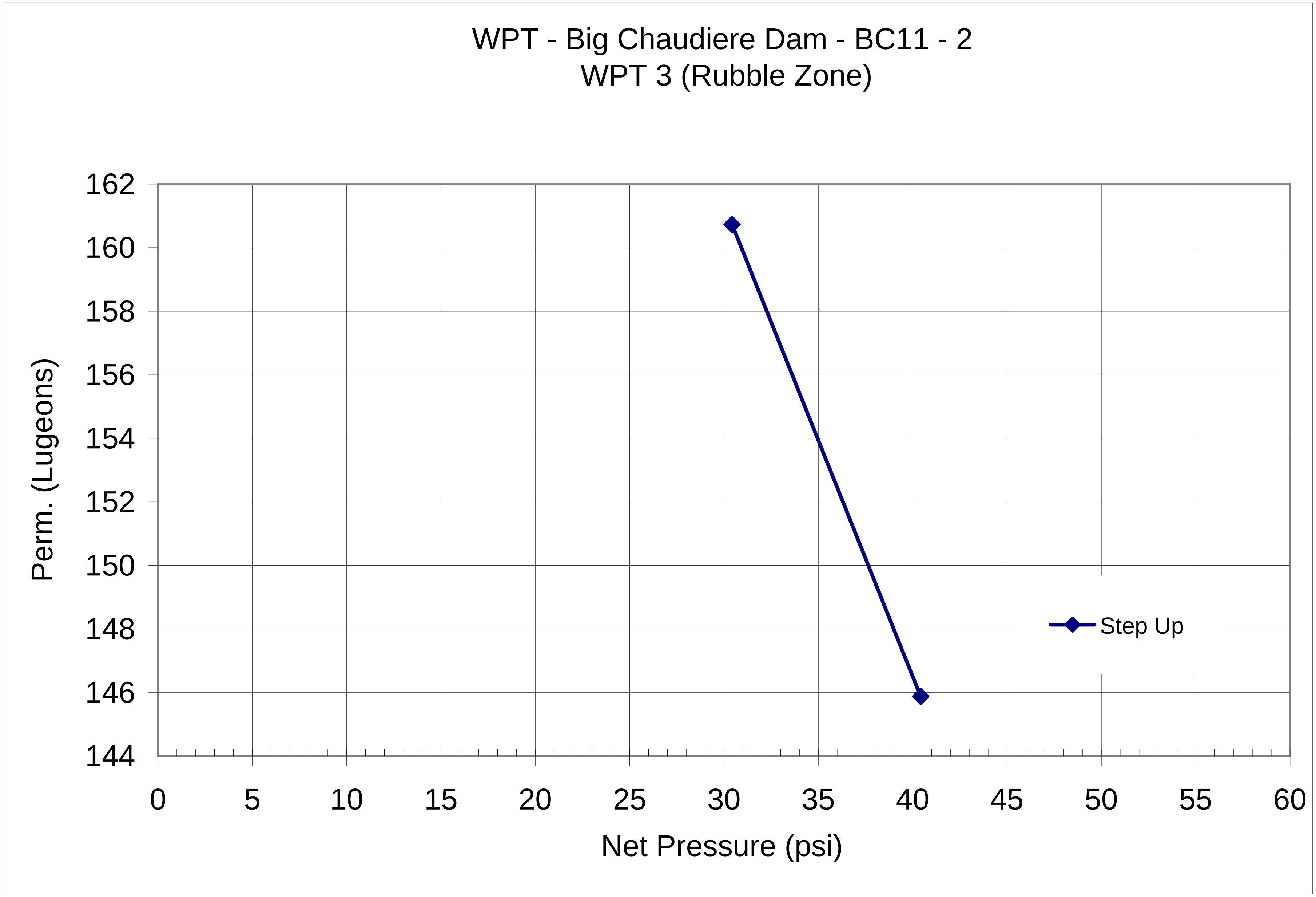
Actual Packer IP used = psi

Tested By: A.MARSHALL

	Interval Tested (ft)			Take (m³/min)					Pressure (psi)				Permeability	
Test Number	From	To	**Length**	Start	Finish	Water Loss	Elapse Time (min.)	**Take**	Gauge	Column	Friction Loss	**Net**	**Lugeons**	**cm/s**
1	17.0	20.3	3.3	1.02500	1.06100	0.0360	1	0.034	30.0	0.4	0.007	30.4	160.74	2.1E-03
				1.06100	1.09400	0.0330	2							
				1.09400	1.12800	0.0340	3							
				1.12800	1.16300	0.0350	4							
				1.16300	1.19800	0.0350	5							
				1.19800	1.23100	0.0330	6							
				1.23100	1.26400	0.0330	7							
				1.26400	1.29800	0.0340	8							
				1.29800	1.33000	0.0320	9							
				1.33000	1.36500	0.0350	10							
2	17.0	20.3	3.3	1.42300	1.46100	0.0380	1	0.041	40.0	0.4	0.007	40.4	145.88	1.9E-03
				1.46100	1.50200	0.0410	2							
				1.50200	1.54300	0.0410	3							
				1.54300	1.58400	0.0410	4							
				1.58400	1.62500	0.0410	5							
				1.62500	1.66700	0.0420	6							
				1.66700	1.70800	0.0410	7							
				1.70800	1.75000	0.0420	8							
				1.75000	1.79100	0.0410	9							
				1.79100	1.83300	0.0420	10							

Remarks:

Refer to accompanying Geologic Logs and separate P-Q plots.



WPT - Big Chaudiere Dam - BC11 - 2
WPT 3 (Rubble Zone)
Perm. (Lugeons)
162
160
158
156
154
152
150
148
146
144
0
5
10
15
20
25
30
35
40
45
50
55
60
Net Pressure (psi)
Step Up

WATER PRESSURE TEST 1

Big Chaudiere Dam

PWGSC

Sheet No. 1 of 1
Date Tested 4-Feb-11

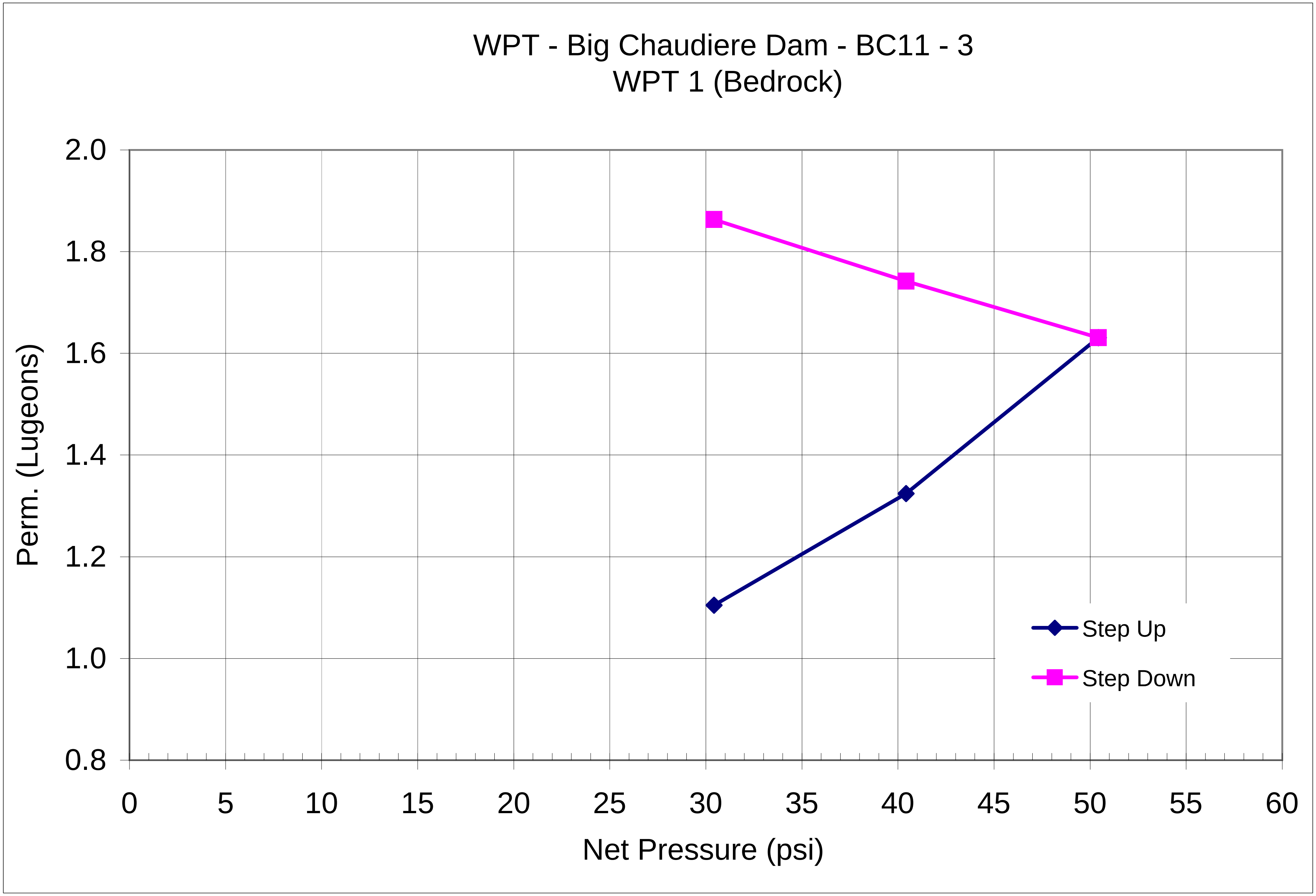
Hole Number **BC11-3**
Total Depth: 44 ft
Angle (from horiz.): 90 deg.
Bearing:
Height of Gauge: 1 ft

Feature: **Bed Rock**
Depth to Rock: ft
Water depth before test: 1 ft
Actual Packer IP used = psi

N: ?
E: ?
Ground Elev. 635.33 FT
Tested By: A.MARSHALL

	Interval Tested (ft)			Take (m³/min)					Pressure (psi)				Permeability	
Test Number	From	To	**Length**	Start	Finish	Water Loss	Elapse Time (min.)	**Take**	Gauge	Column	Friction Loss	**Net**	**Lugeons**	**cm/s**
1	44.3	56.5	12.2	2.05567	2.05650	0.0008	1	0.001	30.0	0.4	0.007	30.4	1.10	1.4E-05
				2.05650	2.05720	0.0007	2							
				2.05720	2.05795	0.0008	3							
				2.05795	2.05895	0.0010	4							
				2.05895	2.05995	0.0010	5							
2	44.3	56.5	12.2	2.06180	2.06250	0.0007	1	0.001	40.0	0.4	0.007	40.4	1.32	1.7E-05
				2.06250	2.06400	0.0015	2							
				2.06400	2.06560	0.0016	3							
				2.06560	2.06710	0.0015	4							
				2.06710	2.06860	0.0015	5							
3	44.3	56.5	12.2	2.07000	2.07220	0.0022	1	0.002	50.0	0.4	0.007	50.4	1.63	2.1E-05
				2.07220	2.07460	0.0024	2							
				2.07460	2.07650	0.0019	3							
				2.07650	2.07895	0.0025	4							
				2.07895	2.08120	0.0023	5							
4	44.3	56.5	12.2	2.08200	2.08400	0.0020	1	0.002	40.0	0.4	0.007	40.4	1.74	2.3E-05
				2.08400	2.08590	0.0019	2							
				2.08590	2.08770	0.0018	3							
				2.08770	2.08960	0.0019	4							
				2.08960	2.09140	0.0018	5							
5	44.3	56.5	12.2	2.09220	2.09360	0.0014	1	0.001	30.0	0.4	0.007	30.4	1.86	2.4E-05
				2.09360	2.09450	0.0009	2							
				2.09450	2.09650	0.0020	3							
				2.09650	2.09890	0.0024	4							
				2.09890	2.09940	0.0005	5							

Refer to accompanying Geologic Logs and separate P-Q plots.



WPT - Big Chaudiere Dam - BC11 - 3
WPT 1 (Bedrock)
Perm. (Lugeons)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0
5
10
15
20
25
30
35
40
45
50
55
60
Net Pressure (psi)
Step Up
Step Down

WATER PRESSURE TEST 2

Big Chaudiere Dam

PWGSC

KGS GROUP

Sheet No. 1 of 1
Date Tested 4-Feb-11

Hole Number **BC11-3**

Total Depth: 44 ft
Angle (from horiz.): 90 deg.
Bearing:
Height of Gauge: 1 ft

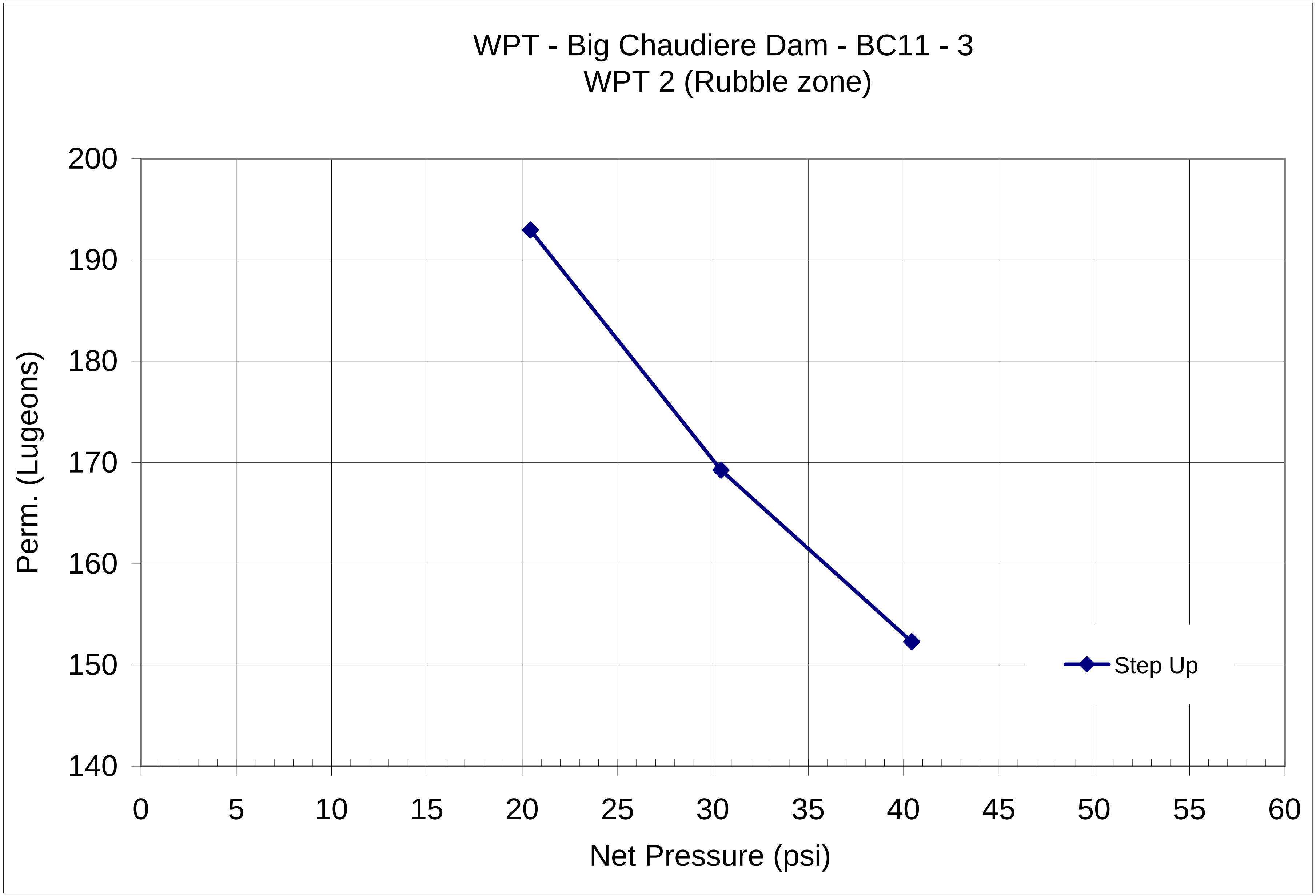
Feature: **Bed Rock**
Depth to Rock: ft
Water depth before test: 1 ft
Actual Packer IP used = psi

N: ?
E: ?
Ground Elev. 635.33 FT

Tested By: A.MARSHALL

	Interval Tested (ft)			Take (m³/min)					Pressure (psi)				Permeability	
Test Number	From	To	**Length**	Start	Finish	Water Loss	Elapse Time (min.)	**Take**	Gauge	Column	Friction Loss	**Net**	**Lugeons**	**cm/s**
1	21.3	24.7	3.3	2.115	2.145	0.030	1	0.027	20.0	0.4	0.007	20.4	192.96	2.5E-03
				2.145	2.171	0.026	2							
				2.171	2.198	0.027	3							
				2.198	2.225	0.027	4							
				2.225	2.252	0.027	5							
2	21.3	24.7	3.3	2.299	2.337	0.038	1	0.036	30.0	0.4	0.007	30.4	169.25	2.2E-03
				2.337	2.372	0.035	2							
				2.372	2.406	0.034	3							
				2.406	2.443	0.037	4							
				2.443	2.478	0.035	5							
3	21.3	24.7	3.3	2.527	2.569	0.042	1	0.043	40.0	0.4	0.007	40.4	152.29	2.0E-03
				2.569	2.613	0.044	2							
				2.613	2.657	0.044	3							
				2.657	2.698	0.041	4							
				2.698	2.741	0.043	5							

Refer to accompanying Geologic Logs and separate P-Q plots.


WPT - Big Chaudiere Dam - BC11 - 3
WPT 2 (Rubble zone)
Perm. (Lugeons)
200
190
180
170
160
150
140
0
5
10
15
20
25
30
35
40
45
50
55
60
Net Pressure (psi)
Step Up

WATER PRESSURE TEST 1

Big Chaudiere Dam

PWGSC

KGS GROUP

Sheet No. 1 of 1
Date Tested 23-Feb-11

Hole Number **BC11-8**
Total Depth: ft
Angle (from horiz.): 90 deg.
Bearing:
Height of Gauge: 1 ft

Feature: **Bedrock**
Depth to Rock: ft
Water depth before test: 1 ft
Actual Packer IP used = psi

N: ?
E: ?
Ground Elev. 635.33 FT
Tested By: A.MARSHALL

	Interval Tested (ft)			Take (m³/min)					Pressure (psi)				Permeability	
Test Number	From	To	**Length**	Start	Finish	Water Loss	Elapse Time (min.)	**Take**	Gauge	Column	Friction Loss	**Net**	**Lugeons**	**cm/s**
1	0.0	67.1	67.1	2.7883	2.7883	0.000	1	0.000	30.0	0.4	0.007	30.4	0.00	0.0E+00
				2.7883	2.7883	0.000	2							
				2.7883	2.7883	0.000	3							
				2.7883	2.7883	0.000	4							
				2.7883	2.7883	0.000	5							
2	0.0	67.1	67.1	2.7883	2.7883	0.000	1	0.000	40.0	0.4	0.007	40.4	0.00	0.0E+00
				2.7883	2.7883	0.000	2							
				2.7883	2.7883	0.000	3							
				2.7883	2.7883	0.000	4							
				2.7883	2.7883	0.000	5							
3	0.0	67.1	67.1	2.7883	2.7883	0.000	1	0.000	50.0	0.4	0.007	50.4	0.00	0.0E+00
				2.7883	2.7883	0.000	2							
				2.7883	2.7883	0.000	3							
				2.7883	2.7883	0.000	4							
				2.7883	2.7883	0.000	5							
4	0.0	67.1	67.1	2.7883	2.7883	0.000	1	0.000	40.0	0.4	0.007	40.4	0.00	0.0E+00
				2.7883	2.7883	0.000	2							
				2.7883	2.7883	0.000	3							
				2.7883	2.7883	0.000	4							
				2.7883	2.7883	0.000	5							
5	0.0	67.1	67.1	2.7883	2.7883	0.000	1	0.000	30.0	0.4	0.007	30.4	0.00	0.0E+00
				2.7883	2.7883	0.000	2							
				2.7883	2.7883	0.000	3							
				2.7883	2.7883	0.000	4							
				2.7883	2.7883	0.000	5							

Refer to accompanying Geologic Logs and separate P-Q plots.

WATER PRESSURE TEST 2

Big Chaudiere Dam

PWGSC

Sheet No. 1 of 1
Date Tested 23-Feb-11

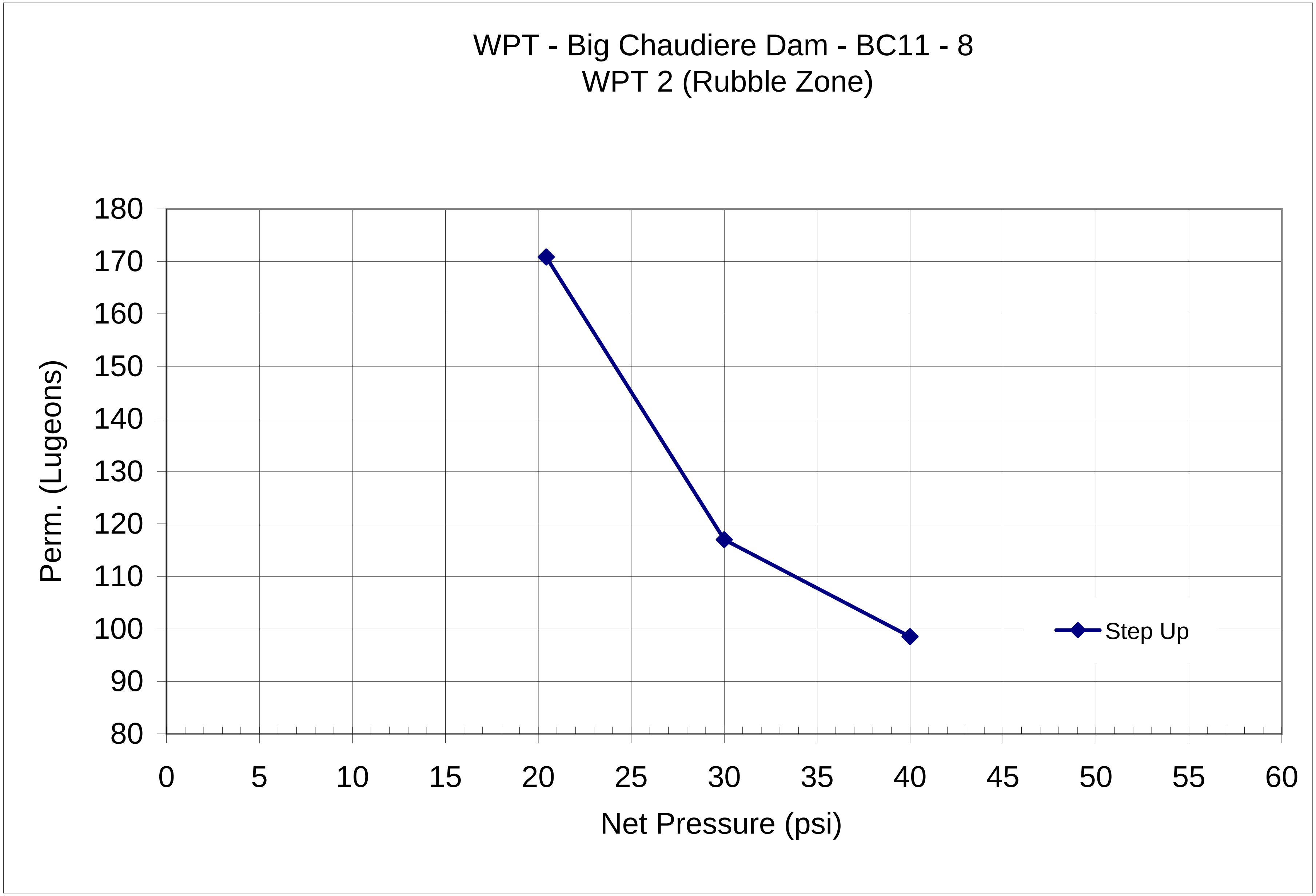
Hole Number **BC11-8**
Total Depth: ft
Angle (from horiz.): 90 deg.
Bearing:
Height of Gauge: 1 ft

Feature: **Rubble Zone**
Depth to Rock: ft
Water depth before test: 1 ft
Actual Packer IP used = psi

N: ?
E: ?
Ground Elev. 635.33 FT
Tested By: A.MARSHALL

	Interval Tested (ft)			Take (m³/min)					Pressure (psi)				Permeability	
Test Number	From	To	**Length**	Start	Finish	Water Loss	Elapse Time (min.)	**Take**	Gauge	Column	Friction Loss	**Net**	**Lugeons**	**cm/s**
1	33.0	36.3	3.3	4.090	4.120	0.0303	1	0.024	20.0	0.4	0.007	20.4	170.85	2.2E-03
				4.120	4.144	0.0240	2							
				4.144	4.167	0.0230	3							
				4.167	4.189	0.0220	4							
				4.189	4.211	0.0220	5							
2	33.0	36.3	3.3	4.220	4.243	0.0230	1	0.024	40.0	0.4	0.007	30.0	116.98	1.5E-03
				4.243	4.270	0.0270	2							
				4.270	4.295	0.0250	3							
				4.295	4.318	0.0230	4							
				4.318	4.342	0.0240	5							
3	33.0	36.3	3.3	4.353	4.381	0.0280	1	0.027	50.0	0.4	0.007	40.0	98.52	1.3E-03
				4.381	4.409	0.0280	2							
				4.409	4.437	0.0280	3							
				4.437	4.465	0.0280	4							
				4.465	4.490	0.0250	5							

Refer to accompanying Geologic Logs and separate P-Q plots.


WPT - Big Chaudiere Dam - BC11 - 8
WPT 2 (Rubble Zone)
180
170
160
150
140
130
120
110
100
90
80
Perm. (Lugeons)
0
5
10
15
20
25
30
35
40
45
50
55
60
Net Pressure (psi)
Step Up

APPENDIX – F
Downhole Video Survey

KGS GROUP ENGINEERING & CONSULTING

PROJECT NUMBER

J-4-11

BORE HOLE INSPECTIONS

BIG CHAUDIERE DAM, NOELVILLE
(DOKIS RESERVE)

(REQUESTED BY HOLLY HAMPTON)

CamSpec
P.O. BOX 129, 1475 HWY. 69 N., VAL CARON, ONT. P3N 1N6

February 23, 2011
Big Chaudiere Dam, Noelville
KGS Group Engineering & Consulting.

1) Hole #1 - From barge, 3.5 inches steel casing
51 feet 8 inches, steel casing ends, rock begins.
53 feet water is dirty, poor visibility
58 feet 7 inches survey stopped.

2) Hole #1 - from barge, will pull casing up 10 feet and recamera
46 feet 2 inches steel casing ends, rock begins. Open cavity.
48 feet 6 inches large cavity, it appears that hole filled in with silt.
Survey stopped.

3) Hole #1 - pulled casing up another 10 feet, recamera
33 feet 8 inches steel casing ends. Rock begins. Loose rocks camera obstructs.

4) Hole #2 - (BC 11-2). PVC 2 inches
21 feet PVC pipe ends, large cavity
Survey stopped.

5) Hole #1 from barge
33 feet from top of barge, 10 feet more of casing was removed.
This camera inspection was done after die test
25 feet 6 inches steel casing ends, rock begins, open cavity
26 feet 4 inches large cavity
27 feet large rocks, camera obstructs.

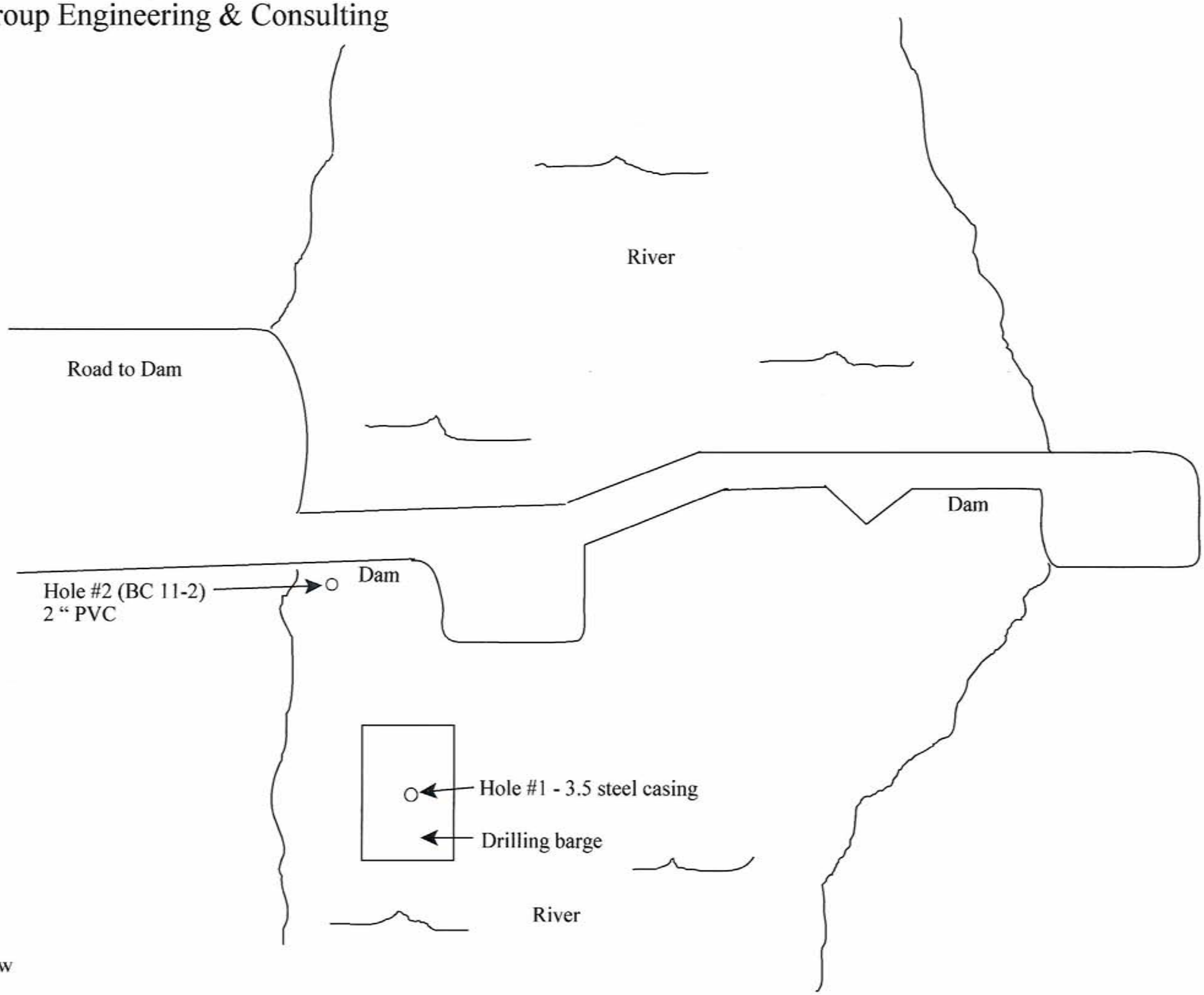
6) Hole #1 - from barge, removed 10 feet of casing.
12 feet 9 inches steel casing ends, rock begins and loose rocks.
15 feet 6 inches rocks open cavity
Survey stopped.

7) Hole #1 - from barge, removed 5 feet of casing.
12 feet casing ends, rock begins. Loose rocks, camera obstructs.

8) Hole #2 - (BC-11-2) 2 inch PVC. Will camera down to end of PVC will hold camera at this point and pull up PVC pipe to surface

Note : Could not get footage coming back out
Bottom is 25 feet.

February 23, 2011
Big Chaudiere Dam, Noelville
KGS Group Engineering & Consulting



41103.A.drw

CamSpec
P.O. BOX 129, 1475 HWY. 69 N., VAL CARON, ONT. P3N 1N6