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October 20, 2011
File No: 8-5782-1

Gardom Pond Dam & Works Stakeholders
6604 Harbour Hill Road
Pender Island, BC
V0N 2M1

Attn: [redacted]

Dear [redacted]

Re: Dam Safety Review – **Addendum 1**
Gardom Dam – North Pender Island, BC

As requested, we have reviewed portion of the Dam Safety Review submitted on August 31, 2011. Please find herein the associated Addendums.

Addendum to Section 5.3 Dam Crest Conditions

On first paragraph of page 8, after the last sentence the following text should be added:

The freeboard was observed to be approximately 1.2 m at the time of our investigation. The level of freeboard is difficult to assess without a complete survey of the spillway and the dam crest, however, we understand that a mark point was installed on 6604 Harbour Hill Road in 1994. On the marker there is a high water mark and a low water mark. The high water mark corresponds to when the water reaches the level of the spillway high point. At the time of inspection, the pond level was noted to be about 0.3 m below the high water mark. Such is consistent with the freeboard designed at the time of construction, which was 0.9 m.

Addendum to Section 5.6 Low Level Outlet Conditions

On second paragraph of page 9 the following text should be added:

At that time, however, no inspection of the upstream concrete chamber and/or the outlet pipe had been undertaken due to legal and liable constraints. At the time of the Review no definitive authorization from Razor Point Improvement District (the owner of record) has been given to inspect the pipe, which would have made the Reviewer and Gardom Pond Stakeholders liable in the event of failure of the pipe or valve during the inspection process.

<u>Addendum to section 6.1 Flood capacity Analysis</u>

On paragraph 1 of page 11 the following text should be added:

... *Therefore, using available data, the spillway is only capable of passing approximately 80% of the IDF flow.* The calculation of the IDF is based on the Canadian Dam Association (CDA) guidelines that suggest to use an IDF between 1/3 of a 1/1000 return period and the Probable Maximum Flood (PMF) for a High Dam Classification. The 1/1000 return period of a rainfall event was estimated based on the Rainfall Intensity-Duration-Frequency curves mentioned above combined with the Rational Method, which is used to assess the water flow. The PMF was derived from the Probable Maximum Flood Estimator for British Columbia as proposed to the Simplified Method for Assessing Flood Capacity and Seismic Stability for Dams under 10 Meters in Height provided by the Ministry of Forests, Lands & Natural Ressources Oprerations. The above calculation are undertaken for a 15 minute event and as such, we have calculated the IDF to be 27.72 ft^3/s or 0.79 m^3/s for an hour duration event and 25.6 ft^3/s or 0.73 m^3/s for a 24 hour duration event. Given the spillway capacity, we have calculated that the associated rise of the water level is 0.09 m for a 1 h rainfall event and 1.3 m for a 24 h rainfall event. In the case of a 24 h event it may be expected that the dam will be overtopped, since the design freeboard is 0.9 m.

<u>Addendum to section 10.2 Piping</u>

On paragraph 4 of page 20 the following text should be added:

...*it will require more frequent inspections.* The lack of maintenance and inspection history from Razor Point Improvement District, the rust noted on the valves (which are believed to be constantly under water), the potential leak of one of the valves noted during our field review, in addition of the age of the pipe which has been subjected to constant pressure are additional factors that point to a complete decommission of the pipe instead of spending money to inspect a pipe that has obviously reached or would in the next few years reach the end of its life. *The decommissioning would involve...*

On paragraph 5 of page 20 the following text should be added:

As such, we recommend a full internal inspection of these pipes by a qualified professional every 5 years, however, the valve system should be checked for potential leakage at least once a year. As mentioned in our report, we do believe that the water lines are an additional hazard to the stability of the dam, and if such is safely feasible, they should be removed. Removal of these should be undertaken under the direction of a geotechnical professional to ensure that the dam is not potentially compromised.

Addendum to Section 10. Recommendations

The following section should be added to the report under a new section 10.4 Recommended Actions:

Based on our field review and on the recommendations provided above, we recommended to take these noted actions in the following order to improve the level of safety of the Dam:

1. Decommission the low level outlet or if such is not judged acceptable by the designated authorities further inspection of the valves and pipe conditions
2. Removal or further inspection of the upper water lines
3. Improvement of the spillway capacity
4. Visual inspection below water level of the upstream slope
5. Installation of a staff gauge/water level monitoring station
6. Complete decommissioning of the dam if the actions above are judged too costly, over the long term.

We hope the preceding is suitable for your purposes at present, however if you have any questions with respect to the above, please contact us.

Yours very truly,
Ryzuk Geotechnical

Isabelle Maltais, EIT
Project Engineer

S. W. Moore, P.Geo.
Geoscientist

PROFESSIONAL PROVINCE OF S. W. MOORE #30949 BRITISH COLUMBIA GEOSCIENTIST

DAM SAFETY REVIEW

GARDOM DAM

NORTH PENDER ISLAND, BC

Report To:

Gardom Pond Dam & Works Stakeholders
6604 Harbour Hill Road
Pender Island, BC
V0N 2M1

Attention:

[redacted]

Prepared By:

Ryzuk Geotechnical
Victoria, B.C.

August 31, 2011

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1. Introduction

As requested by the Gardom Pond Stakeholders, we have completed a Dam Safety Review of the Gardom Dam system. The following report summarizes the results of our review and provides associated recommendations. Our work in this regard has been carried out in accordance with, and is subject to, the attached Statement of Terms of Engagement contained in Appendix A.

2. Site Description

The site is located on the north side of Razor Point Road on North Pender Island. The dam is located in its entirety on lot #6 - 6606 Harbour Hill Road and access is provided through a private road named Gardom Lane. The road/driveway extends across the dam further to the east, as indicated in Figure 1 below taken from Capital Regional District (CRD) Natural Atlas.

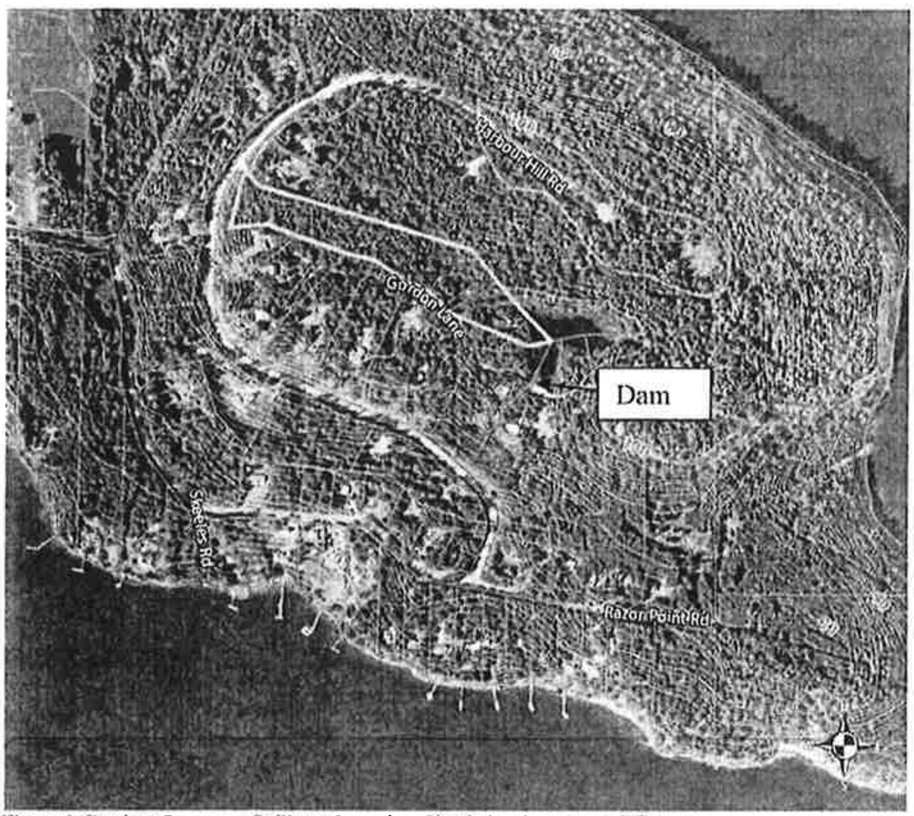


Figure 1-Gardom Dam and Spillway Location, North Pender Island, BC (taken from CRD Natural Atlas)

The dam consists of an earthen embankment and is approximately 4 m in height and extends over a length of roughly 30 m. The spillway is located some 65 m northwest of the dam itself, extending west then turning 90 degrees to the south.

3. Background Review

The Dam Safety Review involved the review of aerial photos, soil and geology mapping and documentation provided by the Gardom Pond Stakeholders. The Stakeholders also provided complete historical documentation of various letters and correspondences relating to the dam, which they obtained from the BC Ministry of Natural Resources.

The dam retains water, which is stored in a man-made pond originally designed as a potable water source. The pond was excavated in an existing low depression cleared of vegetation, as shown below in an aerial photo of the area taken in 1975. The scale of the air photo is large, and as such we are not able to observe the presence of a pre-existing water course. Based on imapBC and comments from the dam Stakeholders, an intermittent water course existed prior to the construction of the dam.

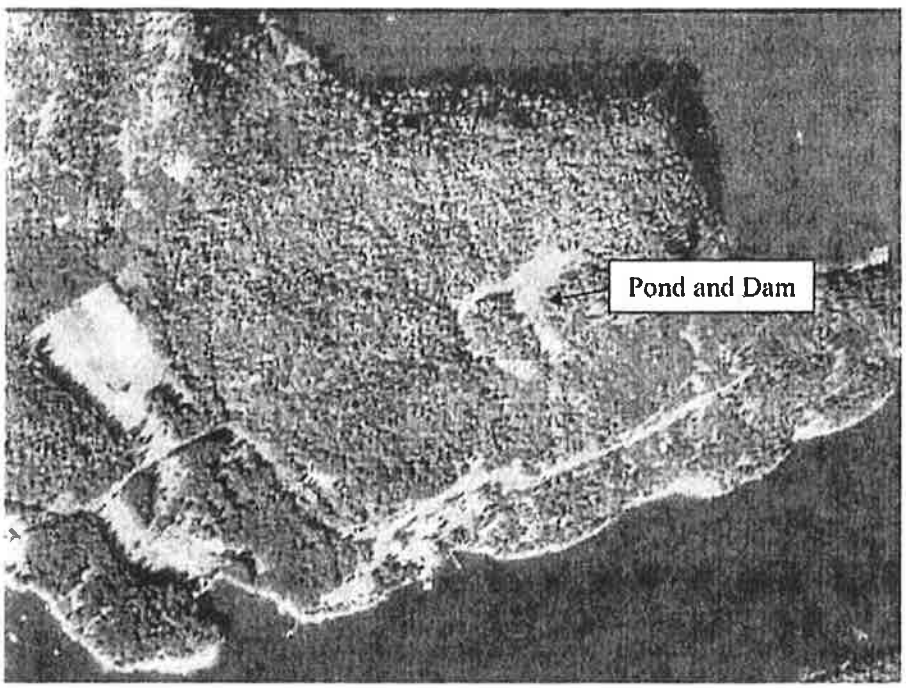


Figure 2 - Aerial Photograph taken in 1975

The regional quaternary mapping indicates that the soil in the area of the dam consists of colluvium soils over bedrock. The bedrock in this area is part of the Nanaimo Group deposited during the Late Cretacious period (70 to 65 Million years ago), and specifically from the De Courcy Formation, which reportedly consists of sedimentary rock such as sandstone, conglomerate, minor siltstone and shale.

The documentation provided by the owners included various photographs taken at the time of construction, as well as an as built drawing prepared in 1978 by Island Geotechnical Services. Below is a historical summary of the dam life activities up to present:

1977	Construction/Installation of the sluice pipe (6" diameter A.C.), the pipe was backfilled with clay, and the work appears to have been supervised by Graeme Engineering Ltd. The dam inspector engineer, Mr. G. F. Cox, noted that the left abutment is atop solid bedrock with some outcropping on the right abutment. The reservoir area was stripped of all topsoil down to clayey material (from dam inspection report).
1977-1979	Construction of the dam and associated spillway.
1979	Construction of the dam completed. According to the inspector, Mr. G. F. Cox, and Mr. Y. I. Fellman (Senior Hydraulic Engineer) the dam appears to have been built of glacial till. No compaction equipment was used, except for a tractor with a full front end bucket and the loaded truck traffic over the dam. They noted, however, that supervision has been provided by a geotechnical engineering firm from Nanaimo. The spillway was apparently cut to "hardpan" and designed to handle 14 ft^3/s at capacity, based on an Inflow Design Flood (IDF) of 4 ft^3/s. The total reservoir storage potential was about 10 acre-ft.
1989?	Installation of the upper services pipe of Razor Point District.
1993	Two inch valve replaced in the low level outlet.
1994-1995	Geotechnical assessment of the dam by C.N. Ryzuk & Associates Ltd. The report was submitted after a visual assessment of the dam, including suitability to support traffic loading over its crest, retention pond slopes, emergency spillway, existing well, etc. At the time of the assessment, no seismic provision was made regarding the stability of the dam.
1995	Application for licensing the dam.
1997	Classification of the Downstream Dam Failure Consequences of the dam as High by dam inspector, Mr. John Baldwin.
2002	Dam inspection was performed by Mr. John Baldwin. He noted that seepage has been reported 5 m south of the embankment and that the low level outlet chamber was partially filled with water. The major recommendations consisted of undertaking further investigation of the low level outlet and to have the spillway inspected after a flood or earthquake event.
2003	Inspection of the low level outlet pipe by Razor Point Improvement District and Mr. Garth Campbell from Capital Regional District (CRD). The procedure consisted of

opening and closing the valve several times (No mention of which valve was opened). No leakage was observed, although Mr. Campbell acknowledged himself that he was unable to assess if the low level outlet conduit had any deterioration at this time.

2011 Ryzuk Geotechnical is retained by the Gardom Pond Stakeholders to complete a Dam Safety Review.

We understand the low level outlet was installed before the construction of the dam, and that it was supposed to be used as the water supply for a proposed 40 lot subdivision. However, the low level outlet was only used for the first 10 years. After this period, the water used by the residents below was supplied via a groundwater well located west of the pond. There are two pipes that run along the bottom of the pond and go through the top part of the dam (just below the pond water level). The two pipes on the south side of the dam become connected into one pipe that carries the well water down the hill to the properties along Razor Point Road. Razor Point District apparently bought the rights to the water water system in 1989, and as such we can make the assumption the lower outlet has not been used since around that time.

There is a well on the extreme edge of the right abutment of the dam, which supplies the residence at 6606 Harbour Hill Road. The well drilling records were examined in 1994, and since the well is extending through rock, it was believed that it would not affect the stability of the dam, as per C. N. Ryzuk and Associates Ltd. report prepared in 1995.

4. Site Investigation

The site investigation initially consisted of a visual assessment of the crest of the dam, the upstream slope, the downstream slope, the low level outlet downstream chamber, the upper pipe downstream chamber and the spillway structure.

Following the visual assessment, we completed a subsurface soil investigation. The upper 1.2 m of the soil was augered and from the cutting returns, we could visually assess the soil conditions. We undertook four Standard Penetration Tests (SPT) at 1.2 m (4') elevation, from which a sample was retrieved with a split spoon. Due to the earthen nature of the dam, the density of the soils at depth below 1.2 m from the crest was assessed by Dynamic Cone Penetration Test (DCPT) to avoid excessive soil disturbance. The locations of the test holes are indicated in our attached drawing 8-5782-1-1 contained in Appendix A. The samples were then tested in the laboratory for moisture content.

5. Surface and Subsurface Dam Conditions

The surface and subsurface structure and appurtenant structures of the dam were taken from the as built drawing prepared by Island Geotechnical Services attached in Appendix B, historical data collected in the past 34 years, and our site investigation.

5.1 General Dam Structure

Based on the as built drawing, the earthen dam is built of compacted brown silt with some clay, over undisturbed compact to dense brown silt with some clay. The upstream and downstream slopes were originally graded at 3H:1V (Horizontal: Vertical). The crest was about 2.4 m wide at the time of the construction, but was widened to approximately 9 m some years after the construction of the dam to create a driveway atop the dam structure. Due to this widening, the downstream slope is now steeper and is generally at 1H:1V, with steeper localized portions of the slope above the low level outlet chamber graded at 0.5H:1V. Accordingly to the as built drawing, a cut-off trench was excavated to bedrock and/or dense glacial material at the base of the dam.

There is a low level outlet located approximately through the mid-portion of the earthen dam, which consists of an asbestos concrete pipe and steel valve. The control valves are located downstream.

5.2 Dam Embankment Conditions

The subsurface soil conditions exposed during the investigation consisted of a thin layer of 19 mm minus crush road base over 0.6 to 1.2 m of dry silty gravelly sand, overlying approximately 3 m of clayey fill material, in turn overlying inferred dense glacial till and/or bedrock. From the cutting returns and the split spoon samples, the clayey fill material is brown, firm, silty clay with a minor amount of sand followed by firm grey, sandy silty clay. The glacial material (inferred till) was assumed to be encountered at 3.3 m depth where blow counts were above 30 per 300 mm, (see attached results in Appendix C). Refusal on inferred bedrock occurred at depths ranging from 1.8 to 4.8 m. The moisture content results from samples taken from Test Holes 2 though 6 (taken at elevations between 1.2 and 1.5 m) vary between 26% and 31%. No seepage was noted in the test holes during testing.

The findings of our soil investigation are consistent with the observations of the Dam Engineer that reviewed the dam during construction in the 1970's. The dam appears to be constructed upon a dense layer of glacial till or bedrock. The blow counts in the clay fill, which vary between 1 and 17, confirms that the clay was not compacted or only slightly compacted at the time of construction and has somewhat consolidated at depth over the years under the weight of the fill itself. The bedrock depth varies between 1.8 to 4.8 m at the deepest and is consistent with the observations and pictures taken at the time of construction (Appendix D) indicating that bedrock was present at the abutments of the dam.

5.3 Dam Crest Conditions

The crest conditions appeared relatively good at the time of our visit, as indicated in the photos provided in Appendix E. The crest is partially vegetated with sparse grass areas. A thin layer of crushed road base covers the crest. No erosion, intrusive vegetation or settlement was observed on the crest. In addition, no cracks and/or signs of significant instability were noted. The freeboard was observed to be approximately 1.2 m at the time of our investigation.

The only negative impact identified was some minor rutting created by vehicle traffic along the dam crest. The rutting, although not extremely deep, may channel the surficial runoff water which can lead to erosion of the dam crest.

5.4 Dam Upstream Slope Conditions

We were only able to assess the uptream slope above the water line, which was approximately 1.2 m lower than the crest at the time of our investigation. The slope exposed was covered with grass above the water line, and at the water level with typical pond plants, as indicated in the photos provided in Appendix E. No signs of erosion, slope instability, or cracks were observed on the exposed portion. Low depressions were observed along the length of the dam. However, it is difficult to determine how long these depressions have been there.

5.5 Dam Downstream Slope Conditions

The downstream slope was generally covered with grass, with no intrusive vegetation, as indicated in the photos provided in Appendix E. No erosion, cracks or slope instability was noted. No seepage was observed at the time of our visit, but according to the dam inspection performed in 2005, seepage was noted within 5 m of the downstream slope. The Gardom Pond Stakeholders also noted seepage over the years about 18 m downstream from the dam.

5.6 Low Level Outlet Conditions

The low level outlet consists of an asbestos concrete pipe installed near the base of the dam, which crosses the dam perpendicularly at the mid-portion. The low level outlet has two concrete chambers, one upstream of the dam and one downstream. The upstream chamber is believed to be ungated. Two valves with diameters of 10 cm (4") and 5 cm (2") respectively, are present as a control device in the downstream chamber, as illustrated in the photos provided in Appendix E. The low level outlet is believed to have been in use until 1989, when the pond was still being used as a potable water source.

At the time of our inspection, the downstream chamber was full of water. To assess if the system was leaking, the water in the chamber was completely pumped out. After 3 days the chamber was again filled with approximately 50 cm of water. We measured the level of water after 1 week, and it remained stable at 50 cm. No rain events were recorded during this time, and as such it seems unlikely that the water is from rain accumulating in the chamber. Furthermore, we expect some evaporation would have occurred during this period and therefore there is likely some minor seepage into the chamber.

The downstream valves are extremely rusty, likely due to their submersion under water. There is no record of the last time the pipe was inspected, although apparently one of the valves was opened and closed several times during an inspection in 2003. At that time, however, no inspection of the upstream concrete chamber and/or the outlet pipe had been undertaken.

5.7 Spillway Structure and Conditions

The spillway is located some 70 m northwest of the dam. The general section of the spillway is about 1.5 m wide by 1.5 m deep. Side slopes are inclined at about 1H: 1V and the inlet is ungated. The spillway was generally clear of vegetation and/or obstructions, such as woody debris, as shown in the photos provided in Appendix E. The spillway is excavated through hard clay, but its shape and path rapidly becomes less defined as it reaches closer to the Razor Point District driveway and Gardom Lane.

We understand that the pond was originally designed for storage and was used as a potable water source for Razor Point residents. In order to maintain the storage volume necessary to supply the residents, the spillway was reportedly designed for "reverse flow action" which redirects the runoff water from the marsh located on Gardom Park property, which collects rainwater from a western upslope watershed. We are told that the system was designed so that when the pond reaches its capacity, the flow of the spillway is reverts and flows through the spillway, down the seasonal creek. No design details of the spillway were available for review, however.

According to the Gardom Pond Stakeholders records, the system worked as intended from 1996 through 2001. In the winters of 2002-2003 and 2003-2004, we understand that the system failed and that the collected marsh water was flowing down the seasonal creek instead of being directed to the pond. Apparently, during this period the pond did not reach the high water mark. The spillway was repaired with a board dam to facilitate the flow to the pond in 2006, however, the board dam has failed again in the winter of 2010-2011 and was allowing the collected water from the marsh to flow once again directly to the creek. The pond, however, did reach the high water mark this past winter.

The high water is monitored with two markers located at 6604 Harbour Hill Road. There is no gradation on the markers, and as such the level of water is measured relative to the high water mark on each marker.

The water flow observed in the spillway in the winter season during the owner's inspections is low and only reaches moderate flow in intense rain activity. The maximum depth of water reported in the spillway is 15 cm (6").

6. Hydraulic Assessment

6.1 Flood Capacity Analysis

To carry out the flood capacity analysis of the dam and accompanying spillway we began by reviewing the available design information to determine what type of rainfall event the dam was originally designed to withstand. We also walked and photographed the spillway and took measurements of its dimensions as they are today because plant growth, erosion and sediment buildup can often change the spillway's dimensions over time, which can ultimately reduce flood conveyance capacity. From available contour mapping, we derived the rainfall catchment area for Gardom Pond which we estimated to be around 74,000 square meters; this catchment is shown in Figure 4 below. Note this area does not include the catchment for the marshy area surrounding the spillway to the west of the pond.

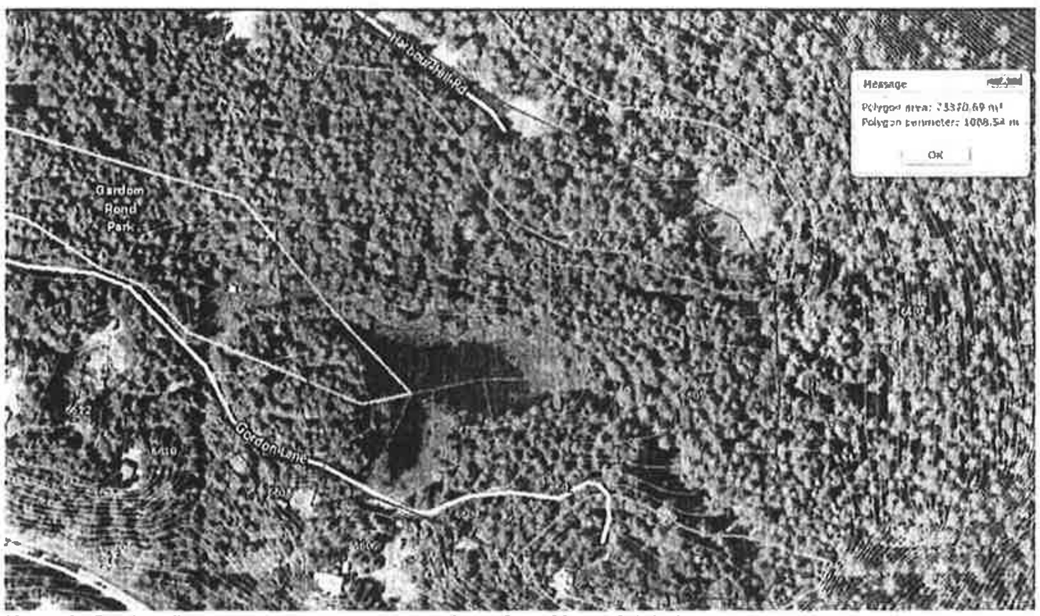


Figure 3- Gardom Pond Catchment Area (Taken from CRD Natural Atlas)

The ability of a dam to safely handle a rainfall flood event is based on two things: how much rainwater is expected to be flowing into the reservoir from its entire catchment area at any one time during a design rainfall event; and how much water the spillway can safely convey out of the reservoir. Making sure the spillway has a greater flow capacity than the IDF is of vital importance when assessing the safety of a dam. When the dam was originally designed the IDF was estimated to be around 4 cubic feet per second (ft^3/s) or 0.11 cubic meters per second (m^3/s) and the capacity of the spillway was calculated to be 14 ft^3/s or 0.4 m^3/s. Using current design standards for a High Consequence Dam combined with historical rainfall data taken from the Rainfall Intensity-Duration-Frequency curves of Victoria International Airport, we found the IDF to be 30.7 ft^3/sec

or 0.87 m^3/sec, about 8 times larger than the IDF used during the original design in the 1970's. Based on the spillway's physical dimensions and vegetated state, the flow capacity was found to be approximately 22.6 ft^3/s or 0.64 m^3/s. Therefore, using available data, the spillway is only capable of passing 74% of the IDF flow.

6.2 Breach Assessment and Flood Routing

The breach assessment was completed utilizing the data collected during our Dynamic Cone Penetration Testing to estimate the compaction of the clay material the dam is comprised of. Once we assessed the level of compaction identified at various depths in the dam structure, we estimated at what elevation the dam would breach if a breach were to occur. As shown in the DCPT results in Appendix B, there appears to be a soil density interface around 3.3 m below the crest of the dam, coinciding with the interface between undisturbed foundation materials, and the clay material placed to construct the dam. This information leads us to believe that there is a remote chance of a full breach of the dam.

We then calculated the probable size of a breach based on the storage volume and height of the dam as well as the material of which the dam was built. With this probable breach size, we calculated the peak breach discharge that would be flowing out of the dam if a failure occurred. This value was calculated to be around 85 m^3/s.

We routed the potential flood downstream of the dam using the available contour maps and aerial photographs. This routing is shown in Figure 4 and represents the potential inundation zone in the unlikely event of dam failure. Furthermore, the estimated peak flow velocities and peak flood wave heights are shown in Table 1 at various points along the flood route. The inundation zone covers approximately eight properties each with residences, and two public roads.

"C"

Figure 4 - Potential Flood Routing based on contours taken from CRD Natural Atlas.

Table 1- Estimated peak flow velocities and peak flow water depths at various points along the flood route.

Flood Zone	Width of Flood Zone (m)	Peak Flow Velocity (m/s)	Peak Flow Depths (m)
A	20	3.7	1.1
B	70	2.0	0.65
C	160	1.6	0.35

Figure 4 - Potential Flood Routing based on contours taken from CRD Natural Atlas.

Table 1- Estimated peak flow velocities and peak flow water depths at various points along the flood route.

Flood Zone	Width of Flood Zone (m)	Peak Flow Velocity (m/s)	Peak Flow Depths (m)
A	20	3.7	1.1
B	70	2.0	0.65
C	160	1.6	0.35

7. Assessment of Probable Mode of Dam Failure

Earthen dams have many different potential failure modes, and based on the Hazards and Failure Modes Matrix provided by BC MoE we have selected and focused our investigation on the most relevant and probable modes of failure for the conditions of the Gardom Dam in our analysis. These failure modes include: both static and seismic slope instability, piping (internal erosion), overtopping erosion and failure of the spillway. These four failure modes were chosen based on information we gathered during our site investigation as well as documentation provided by the Gardom Pond Stakeholders. An explanation of each failure mode and reasons why we recognize it as a hazard follows.

7.1 Static and Seismic Slope Instability

Slope instability of the upstream and downstream slope of the dam may occur under normal reservoir storage conditions and more suddenly during and/or after an earthquake or a rapid drawdown of the reservoir.

Some of the main factors influencing slope instability are:

- Poor foundation material and/or irregularities in the foundations
- Surface erosion
- Earthquakes

We believe the dam was designed without a foundation and that the clayey embankment fill was placed directly upon either bedrock or glacial till. Although some joints or fractures may be present within the rock, we expect that the bedrock or till are suitable as the foundation and are not significantly increasing the risk of slope instability.

No surface erosion was noted on the downstream face or the upper meter of the upstream slope of the dam. However, the surface under the water was not assessed at the time of our visit. We do not expect at this time that surface erosion is a significant risk to the slope in stability.

The dam is located in an area that may be affected by a Cascadia Subduction event, and if such was to occur the resulting slope instability, permanent deformation and fissuring/cracking could potentially lead to overtopping and/or internal erosion of the dam.

We carried out a slope stability analysis under normal and extreme loading conditions using an elasto-plastic finite element stress analysis program called Phase 2. The geometry of the dam and soil parameters were taken from the as built drawing and the results of our investigations. The determination of the seismic loading used in the analyses was based upon the Earth Design Ground Motion provided for the location of the dam by National Building Code of Canada (NBCC 2005) for a 2 % probability of exceedance in 50 years, which converts to a median annual exceedance probability of approximately 0.0004. The NBCC 2005 hazard values represent a median hazard value as opposed as to the mean hazard value generally recommended for typical seismic hazard computations by the Canadian Dam Association (CDA). However, the "Simplified Method For Assessing Flood Capacity and Seismic Stability for Dams under 10 Meters in Height" recommends using the seismic hazard values provided by NBCC 2005. As such, we have used two-thirds of the peak ground acceleration provided for a seismic design with a 2% probability of exceedance in 50 years, which corresponds to 0.4 g at the dam location.

The slope stability analysis indicates that the dam is stable under normal loading conditions. However, when seismic loading is added to the analysis the model fails. The model appears to be failing where the granular fill portion was added to accommodate the driveway. This may be explained in part by the steeper sloped portion above the low level outlet chamber, and by the poor compaction of the clay material used in the earthen dam construction.

The finite element analyses indicate that the dam would sustain permanent deformation in the order of centimeters when subjected to extreme loading such as that associated with a large earthquake. Based on the results of the analysis and our experience, such may be sufficient to create fissures/cracks that may lead to internal erosion and subsequent failure of the dam.

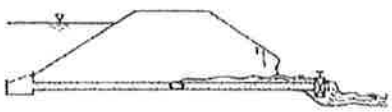
7.2 Piping

Although built with relatively impervious material, a dam is never totally impermeable and water can still migrate through the embankment material, especially through the weakest and more erodible material. Seepage through the dam is generally controlled with an impervious core, drainage and filter layer.

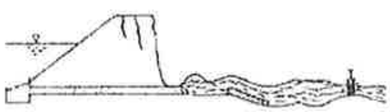
Piping failure in dams may occur many years after the dam has been in full operation and often occurs instantaneously without any warning signs, particularly when seepage is uncontrolled and internal erosion of the embankment occurs. The water begins carrying material out of the dam, creating a small void which further allows water to enter and begin to flow, leading to erosion of the dam. This usually begins at the downstream side of the dam and progressively works its way to the upstream end where a breach occurs. It is referred to as piping not because it is a failure of a pipe inside of a dam, although this can often cause piping to occur, but because as the water erodes the material away it effectively leaves a tunnel or 'pipe' where the water flows freely out of the reservoir.

Based on the soil conditions of the embankment of the Gardom Dam, which is built of relatively impervious clayey material, we expect that the most likely location that piping would occur is along the existing low level outlet. The piping around the pipe may either develop following consolidation of poorly compacted material around the pipe and/or defects from deterioration, deformation or joint separation of the pipe itself. The mechanism of piping is presented visually in Figure 5 below.

A - Hole develops in conduit with downstream valve which is under constant pressure from reservoir head.



B - Hole enlarges allowing increased flow and a piping failure begins.



C - Reservoir drains through the conduit

Figure 5 - Development of a Piping Failure Resulting from a Hole in a Conduit with a Dowstream Valve.

The Gardom Dam has a very similar low level outlet control system as the one pictured above, known as downstream valve control. This method of low level outlet control is generally not acceptable in current dam designs as it causes the entire conduit running through the dam to be under constant pressure caused by the reservoir head. The significance of this is that if there is a crack or corroded seam in the conduit, the water will be forced out under pressure into the surrounding soil which could lead to a piping failure and eventually a breach of the dam. Safer low level outlet controls have a valve or sluice gate placed at the upstream entrance to the conduit or near the midway portion of the conduit in a drywell allowing for easy visual inspection for possible internal erosion.

Although we have not undertaken a probabilistic assessment of piping occurring at the site, we believe that the presence of the low level outlet and the upper pipe going through the crest of the dam increase the probability of piping failure. The low level outlet has not been inspected since 2003 and the operation of only one valve was assessed at that time. The pipe has been in the dam for 34 years and has in general, a life expectancy of between 50 to 60 years. Based on the observations of standing water in the downstream chamber, we can conclude that the system (pipe or valve) is slightly leaking.

We understand that the upper pipes were installed through the dam around 1989, and that they were installed just below the water level of the dam. Although shallow, the pipes are a weak point in the dam, and if the pipes were to fail, this may potentially breach the upper portion of the dam. Although minor, the breach may lead to erosion of the dam embankment and significant failure of the dam.

7.3 Overtopping

Overtopping failure is one of the most common modes of failure for earthen dams. It generally occurs when the reservoir inflow surpasses the outflow/discharge capacity of the system for a significant period of time. Settlement of the crest may potentially be a factor as well. In rare occasions, waves caused by an earthquake or landslide into the reservoir can lead to overtopping.

Once the overtopping occurs, it may cause the dam to breach. The breach will develop in time as a function of the erodibility of the materials, and further embankment failure and release of water can occur if the erosion is not dealt with immediately.

Overtopping failure at Gardom Dam is not perceived likely to occur, although if the spillway was to get fully blocked, it is possible that the inflow of water could surpass the outflow capacity. In addition, as mentioned above, the current capacity of the spillway is slightly less than the IDF, which increases the probability of a chance that the reservoir could rise above the dam and overtop the crest, which could lead to a breach of the earthen dam. We have calculated that this scenario could develop, leading to a catastrophic full breach, in less than 30 minutes.

The key to preventing this from happening is ensuring that the water level in the reservoir will never reach the crest of the dam. Proper freeboard (difference in elevation between maximum reservoir height and minimum crest elevation), adequate spillway capacity and a correctly calculated IDF all help to ensure the water level never reaches the crest. The freeboard for the Gardom Dam was intended to be approximately 0.9 m based on calculations done in the 1970's for the IDF and spillway capacity. Both the IDF and the spillway capacity have changed since that time due to changes in codes and regulations, which specify how to determine the IDF as well as changes to the spillway's geometry and flow surface caused by erosion, sediment buildup and plant growth.

7.4 Spillway Failure

The main purpose of a spillway is to safely and effectively route water out of the reservoir and away from the dam. Spillway failures can occur in many different ways but the one we are concerned about is inadequate conveyance capacity, which can lead to overtopping and downstream flooding. As mentioned previously inadequate capacity can be caused by such things as improper or outdated spillway calculations, changes to the geometry and flow surface and natural and man-made blockages.

We have concern about the possibility of downstream flooding because of the undefined route of the flows after they leave the gulley that runs through 6610 and 6608 Gardom Lane and also the inadequate capacity of the 50 cm (20 in) diameter culvert under Gardom Lane. If the flow cannot be fully passed under Gardom Lane (flow capacity of 0.2 m^3/s) it will back up and possibly flood or wash out the road. Further downstream, as the flow leaves the gulley it intersects with the ditch on the eastern edge of Harbour Hill Road. The flow then follows Harbour Hill Road down until the intersection with Razor Point Road. Once at the intersection, the flow merges into the ditch to a culvert that runs beneath Harbour Hill Road and outlets into 6601 Harbour Hill Road, and from here the flow path is unknown. Once the remaining water in the ditch reaches the intersection with Razor Point Road, it passes through a culvert beneath the road and follows a small creek down into the ocean. Again, if the capacity of the culvert below Razor Point Road is not equal to or greater than that of the spillway expected peak flow (less the diverted flow into the culvert at 6601 Harbour Hill Road), flooding and or/ washout of Razor Point Road is a possibility. The flow path of the spillway and possible flooded areas due to spillway failure are highlighted in Figure 6 below.

Figure 6 - Spillway Route and Potential Flooded/Washout Areas

8. Downstream Dam Failure Consequences Classification Review

As part of our work we were asked to review the Downstream Dam Failure Consequences Classification. This classification system only takes into account what would happen if the dam did fail by looking at what lies downstream in the inundation zone where a theoretical flood wave would travel. It does not consider the probability of the dam failing or the various possible failure modes of the dam. For a dam to be given a Low Consequence Classification, there must be no possibility of loss of life if the dam fails whereas for a High Consequence Classification, for example, the potential loss of life if the dam fails must be less than ten persons. Secondary to the risk to human life is the risk to infrastructure and property in the inundation zone. Low Classification is given when the losses would mostly only occur to the dam owner's property. High Classification is given when damage to downstream properties would represent some destruction of or severe damage to scattered residential buildings. Our study has shown that the damage to property and infrastructure would not be limited to just the owner's property meaning the Low Classification is not warranted.

It should be noted that the Dam Failure Consequences Classification System was amended on June 9, 2011 and now includes a "Significant" class between Low and High; this class however is only given to dams when the downstream populations at risk are a temporary population. For a summary of each Dam Failure Consequences Classification and the characteristics of each see Appendix F.

From the flood routing shown in Figure 5, it is clear that if the dam were to fail, multiple lives would be at risk and the damage to people's homes and public roads would be quite significant. Based on this, it is our professional opinion that the Dam Failure Consequences Classification should not be adjusted to Low and is correctly rated as High for the Gardom Dam.

9. Dam Safety Management

9.1 Owner's Commitment to Safety

In the process of carrying out our Dam Safety Review, we have had numerous correspondences with the representatives of the Gardom Pond Stakeholders and reviewed several inspection documents. From these documents, we have formed a good sense of the position the owners have taken towards the stability of the dam and the safety of the people living in the area. In tracking the inspection records and history of the dam, it is evident that the owners have been very compliant with all regulations and guidelines related to properly managing the Gardom Dam.

9.2 Regular Inspection

Inspection requirements vary from dam to dam depending on the Downstream Dam Failure Consequences Classification and also the Operation, Maintenance and Surveillance Manual (OMS). The Gardom Dam was given a High Downstream Dam Failure Consequences Classification in the year 1997. The provincial Water Act Dam Safety Regulation mandates that dams with a High Classification have a Dam Safety Review done every 10 years and be inspected formally every year. The Act also mandates that site surveillance be carried out every week. From discussions and documents provided to us by the Gardom Pond Stakeholders, we understand that inspections have been completed annually since 1997 and almost daily site surveillance of the dam system has been carried out by one of the Gardom Pond Stakeholders.

9.3 Emergency Procedures Plan

We have reviewed the Gardom Pond Dam Emergency Procedures Plan dated April 2011 and consider it sufficiently detailed in terms of contact information. The plan lists who should be notified and their phone numbers in order of first to last to be contacted; this list includes neighbors, local fire department, local RCMP, Ministry of Highways, the Regional Dam Saftey Officer and the Provincial Emergency Program's regional and provincial offices. However, we believe it lacks the required list of actions that would need to be carried out in times of emergency. The only action mentioned in the plan is to call Gulf Island Excavating Ltd. for a load of rock to be dumped into the breach. We believe this plan should be further updated to include recommended actions and procedures for such urgent situations as crest overtopping by floodwater, overtopping due to blocked spillway, landslides on the embankment and piping erosion. The Province has created a guide of suggested emergency procedures and we have included a copy of this document in Appendix G.

10. Recommendations

Following our extensive assessment of Gardom Dam, we conclude that the dam does not meet all the safety requirements. We have outlined below in Table 2, our recommendations regarding the actions that will need to be taken to increase the level of safety of the dam.

Table 2 – Summary of Recommendations

Potential Failure Mode	Recommendations
Slope Stability	• No recommendations feasible for seismic induced slope instability (please refer to detailed comments below)
Piping	
Low Level Outlet	• Further inspection of the low level valve conditions • Further inspection of the pipe conditions • Decommissioning the low level outlet
Upper Pipes	• Further Inspection of the pipe conditions
Upstream Slope	• Visual inspection below water level of the upstream slope
Overtopping and Spillway	
Spillway	• Improvement of the spillway capacity

10.1 SLOPE STABILITY

As mentioned above, the global stability of the dam is not at risk considering the normal and extreme loading conditions. However, the deformation analysis of the dam indicated that under extreme loading conditions, such as a large earthquake, movement in the order of centimeters may be experienced in the embankment, which may be sufficient to create transversal and longitudinal fissures/cracks in the dam structure. Such fissures/cracks could potentially result in internal seepage routes through the dam that would increase the risk of internal erosion. Internal erosion may potentially lead to partial or full breach of the dam. The time for the breach to develop is unpredictable and may be instantaneous following a large earthquake.

The dam was built in the late 1970's and as such, the dam was not designed to sustain large earthquakes. Due to the High Downstream Dam Failure Consequences Classification and the small size of the dam, we believe that the cost associated with such mitigation and even full reconstruction to today's standards would be prohibitive. We would recommend, if the risk is acceptable to the owners and representatives of BC Ministry of Natural Resources, to incorporate an emergency reservoir evacuation plan as part of an Emergency Preparedness Plan (EPP) in the event of an earthquake.

10.2 PIPING

The first recommendation would consist of having the low level outlet completely inspected to ensure that the pipe and valves do not have any major defects and function properly. We are not specialists in pipe inspection, and this work should be undertaken by a professional in this area of practise. The valves would also require inspection to ensure that they operate properly.

The low level outlet is believed to have reached more than half of its design life, and as such it may be more economical in the long term to decommission the low level outlet, as approching closer to the end of its life expectancy it will require more frequent inspections. The decommissioning would involve high pressure grouting of the pipe and its surroundings, which would require temporary localized dewatering of the upstream chamber. Based on the BC Ministry of Natural Resources specifications, we understand that a low level outlet is required on all dams obstructing a stream channel or lake outlet. However, pond dams that are licensed under the Water Act may not require a low level outlet if emergency reservoir evacuation plans are outlined in the OMS Manual and EPP.

The upper pipes crossing the dam are owned and used by Razor Point District. These may have disastrous consequences if the dam was to start eroding after a small breach creating by a piping failure of these upper pipes. As such we recommend a full internal inspection of these pipes by a qualified professional.

The clay comprising the dam is not considered an erodible material, however, it will be necessary to have a professional diver inspect the submerged portion of the upstream slope, in order to assess if the slope presents indication of erosion and/or piping.

10.3 Overtopping and Spillway Failure

The risk of overtopping of the dam is primarily governed by a failure of the spillway. The spillway capacity, as calculated, is less than the current estimated IDF. In order to accommodate the current design flow, we recommend improving the spillway channel. Increasing the size, the gradient of the channel, and placement of some scour protection would necessitate the spillway to be redesigned, as well as the culvert crossing Gardom Lane.

We understand that, although the pond is no longer in use as a potable water storage source, it is desired to maintain the "reverse flow action" of the spillway to allow the dam to be maintained at the desired high water mark. We do not consider that such a system is safe with the current IDF, and does not allow for proper drainage in the event of a flood event.

An alternative to the recommendations above is to lower the pond to a safer level and/or completely decommission the dam.

11. Closing

Ryzuk Geotechnical was engaged to undertake a Dam Safety Review of Gardom Dam. Our involvement consisted of a geotechnical and hydraulic assessment, probable failure mode assessment and associated recommendations to increase the level of safety of the dam to meet the safety requirements outlined in the Dam Safety Program.

We trust the preceding Dam Safety Review fulfills the requirements outlined by the Dam Safety Review Guidelines provided by Dam Safety Section of the provincial legislature of Victoria, BC, and that it is suitable for your purposes at present. If you have any questions with respect to the above, or require further information or clarification, please contact us.

Yours very truly,
Ryzuk Geotechnical

Isabelle Maltais, EIT
Project Engineer

Shane Moore, P.Geo.
Principal / Geoscientist

APPENDIX A

Statement of Terms of Engagement

STATEMENT OF TERMS OF ENGAGEMENT

GENERAL

C.N. Ryzuk & Associates Ltd. (The Consultant) shall render the Services, as specified in the attached Scope of Services, to the Client for this Project in accordance with the following terms of engagement. The Services, and any other associated documents, records or data, shall be carried out and/or prepared in accordance with generally accepted engineering practices in the location where the Services were performed. No other warranty, expressed or implied is made. The Consultant may, at its discretion and at any stage, engage subconsultants to perform all or any part of the Services.

COMPENSATION

All charges will be payable in Canadian Dollars. Invoices will be due and payable by the Client on receipt of the invoice without hold back. Interest on overdue accounts is 24% per annum.

TERMINATION

Either party may terminate this engagement without cause upon thirty (30) days' notice in writing. On termination by either party under this paragraph, the Client shall forthwith pay to the Consultant its Charges for the Services performed, including all expenses and other charges incurred by the Consultant for this Project.

If either party breaches this engagement, the non-defaulting party may terminate this engagement after giving seven (7) days' notice to remedy the breach. On termination by the Consultant under this paragraph, the Client shall forthwith pay to the Consultant its Charges for the Services performed to the date of termination, including all fees and charges for this Project.

ENVIRONMENTAL

The Consultant's field investigation, laboratory testing and engineering recommendations will not address or evaluate pollution of soil or pollution of groundwater. The Consultant will cooperate with the Client's environmental consultant during the field work phase of the investigation.

PROFESSIONAL RESPONSIBILITY

In performing the Services, the Consultant will provide and exercise the standard of care, skill and diligence required by customarily accepted professional practices and procedures normally provided in the performance of the Services contemplated in this engagement at the time when and the location in which the Services were performed.

LIMITATION OF LIABILITY

The Consultant shall not be responsible for:

(a) the failure of a contractor, retained by the Client, to perform the work required for the Project in accordance with the applicable contract documents;
(b) the design of or defects in equipment supplied or provided by the Client for incorporation into the Project;
(c) any cross-contamination resulting from subsurface investigations;
(d) any damage to subsurface structures and utilities which were identified and located by the Client;
(e) any Project decisions made by the Client if the decisions were made without the advice of the Consultant or contrary to or inconsistent with the Consultant's advice;
(f) any consequential loss, injury or damages suffered by the Client, including but not limited to loss of use, earnings and business interruption;
(g) the unauthorized distribution of any confidential document or report prepared by or on behalf of the consultant for the exclusive use of the Client

The total amount of all claims the Client may have against the Consultant or any present or former partner, executive officer, director, stockholder or employee thereof under this engagement, including but not limited to claims for negligence, negligent misrepresentation and breach of contract, shall be strictly limited to the amount of any professional liability insurance the Consultant may have available for such claims.

No claim may be brought against the Consultant in contract or tort more than two (2) years after the Services were completed or terminated under this engagement.

DOCUMENTS AND REPORTING

All of the documents prepared by the Consultant or on behalf of the Consultant in connection with the Project are instruments of service for the execution of the Project. The Consultant retains the property and copyright in these documents, whether the Project is executed or not. These documents may not be used on any other project without the prior written agreement of the Consultant.

The documents have been prepared specifically for the Project, and are applicable only in the case where there has been no physical alteration to, or deviation from any of the information provided to the Consultant by the Client or agents of the Client. The Client may, in light of such alterations or deviations, request that the Consultant revise and review these documents.

The identification and classification as to the extent, properties or type of soils or other materials at the Project site has been based upon investigation and interpretation consistent with the accepted standard of care in the engineering consulting practice in the location where the Services were performed. Due to the nature of geotechnical engineering, there is an inherent risk that some conditions will not be detected at the Project site, and that actual subsurface conditions may vary considerably from investigation points. The Client must be aware of, and accept this risk, as must any other party making use of any documents prepared by the Consultant regarding the Project.

Any conclusions and recommendations provided within any document prepared by the Consultant for the Client has been based on the investigative information undertaken by the Consultant, and any additional information provided to the Consultant by the Client or agents of the Client. The Consultant accepts no responsibility for any associated deficiency or inaccuracy as the result of a misstatement or receipt of fraudulent information.

JOBSITE SAFETY AND CONTROL

The Client acknowledges that control of the jobsite lies solely with the Client, his agents or contractors. The presence of the Consultant's personnel on the site does not relieve the Client, his agents or contractors from their responsibilities for site safety. Accordingly, the Client must endeavor to inform the Consultant of all hazardous or otherwise dangerous conditions at the Project site of which the Client is aware.

The client must acknowledge that during the course of a geotechnical investigation, it is possible that a previously unknown hazard may be discovered. In this event, the Client recognizes that such a hazard may result in the necessity to undertake procedures which ensure the safety and protection of personnel and/or the environment. The Client shall be responsible for payment of any additional expenses incurred as a result of such discoveries, and recognizes that under certain circumstances, discovery of hazardous conditions or elements requires that regulatory agencies must be informed. The Client shall not bring about any action or dispute against the Consultant as a result of such notification.

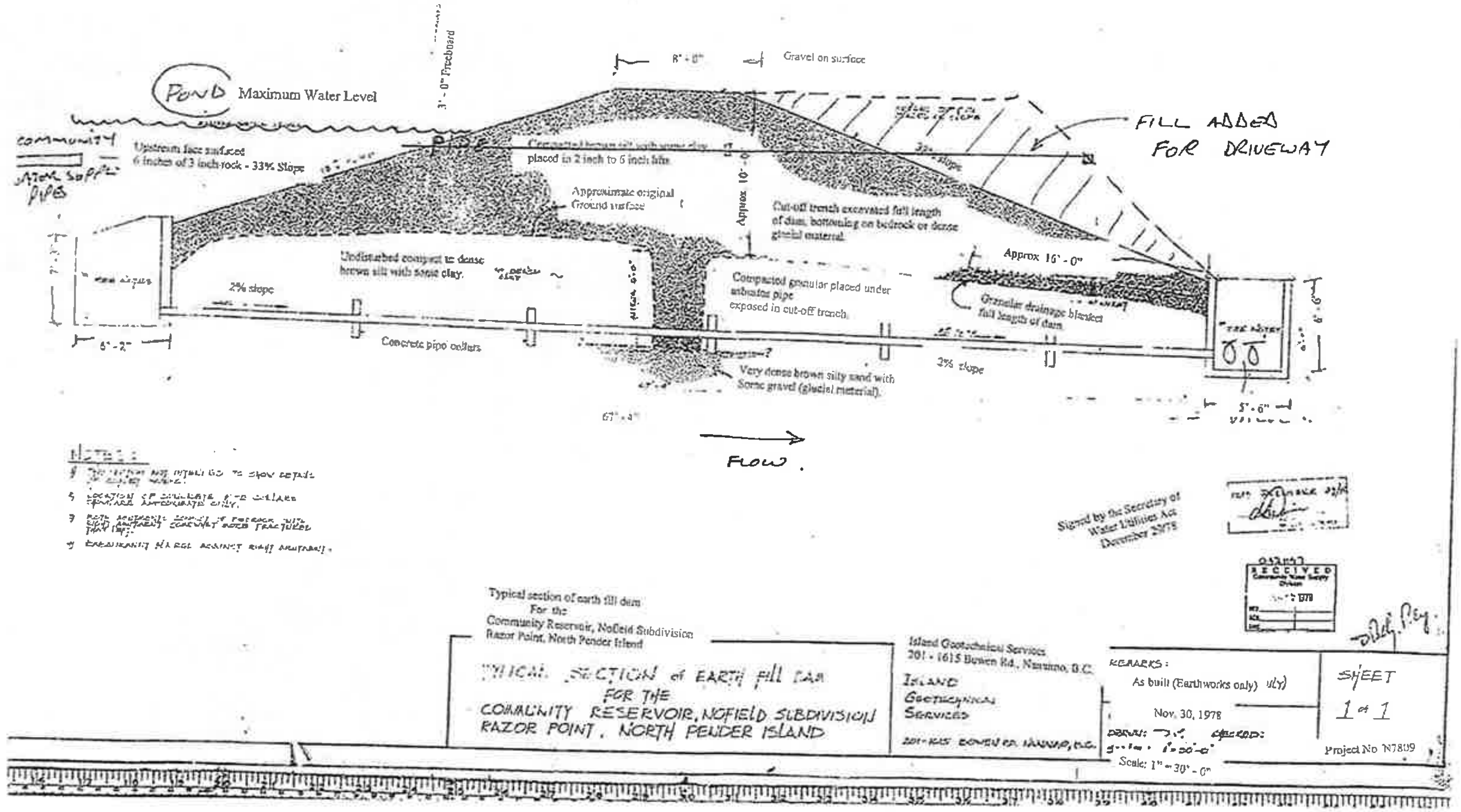
APPENDIX B

Location and Section Plans

Notes:

1. Base plan taken from CRD Regional Community Atlas.
2. Test holes drilled on site by Ryzuk Geotechnical and located relative to existing site features. Estimated accuracy ± 1.0 m.

	Gardom Pond Stakeholders	DRAWN PMS
	LOCATION PLAN **Dam Safety Review**	DATE August, 2011
		APPROVED
	Gardom Dam — North Pender Island, B.C.	SCALE 1:500
	RYZUK GEOTECHNICAL — Engineering & Materials Testing	DRAWING No. 8-5782-1-1

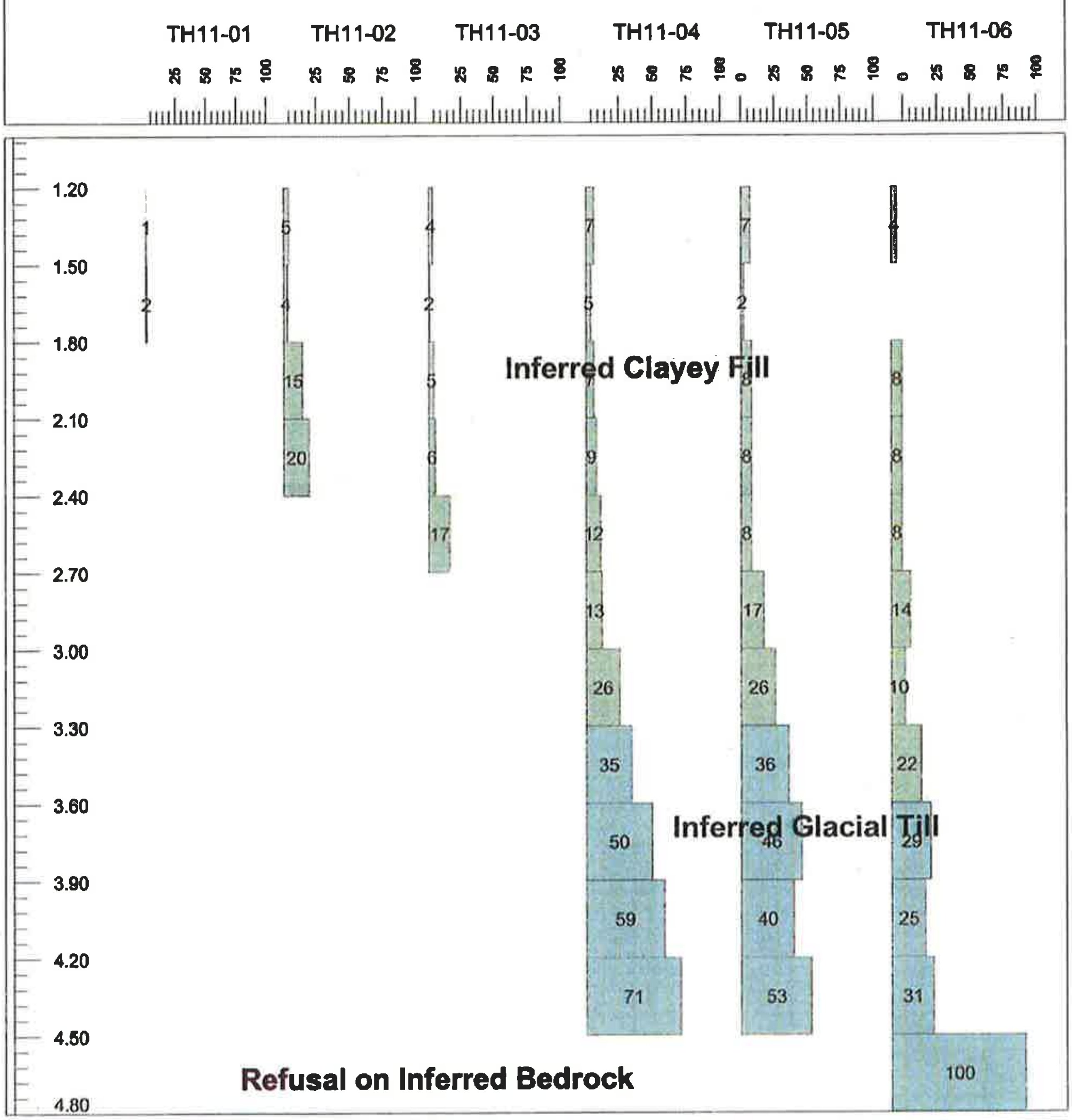


POND
Maximum Water Level
3' - 0" Freeboard
8' - 0"
Gravel on surface
FILL ADDED FOR DRIVEWAY
COMMUNITY WATER SUPPLY PIPES
PIPE
Upstream face surfaced 6 inches of 3 inch rock - 33% Slope
Compacted brown silt with some clay placed in 2 inch to 6 inch lifts
Approximate original Ground surface
Approx 10' - 0"
Cut-off trench excavated full length of dam, bottoming on bedrock or dense glacial material.
Approx 16' - 0"
Undisturbed compact to dense brown silt with some clay.
2% slope
Compacted granular placed under asbestos pipe exposed in cut-off trench.
Granular drainage blanket full length of dam.
6' - 2"
Concrete pipe collars
Very dense brown silty sand with some gravel (glacial material).
2% slope
5' - 6"
67' - 0"
FLOW
NOTES:
Signed by the Secretary of Water Utilities Act December 1978
RECEIVED
Typical section of earth fill dam For the Community Reservoir, Nofield Subdivision Razor Point, North Pender Island
TYPICAL SECTION of EARTH FILL DAM FOR THE COMMUNITY RESERVOIR, NOFIELD SUBDIVISION RAZOR POINT, NORTH PENDER ISLAND
Island Geotechnical Services 201 - 1615 Bowen Rd., Nanaimo, B.C.
ISLAND GEOTECHNICAL SERVICES
REMARKS:
As built (Earthworks only)
Nov. 30, 1978
DRAWN:
CHECKED:
Scale: 1" = 30' - 0"
SHEET 1 of 1
Project No N7809

APPENDIX C

Dynamic Cone Penetration Test (DCPT) Results

Dynamic Cone Penetration Test (DCPT)



RYZUK GEOTECHNICAL
ENGINEERING & MATERIALS TESTING

Project: Dam Safety Review
Client: Gardom Dam Stakeholders
Location: Gardom Dam - North Pender Island, BC
Date: August 2, 2011
Job #: 8-5782-1
Operator: Western Grater
Inspector: IMDM

APPENDIX D

Photographs Taken During Time of Construction

Panorama Centered Over Sluice Trench - December 1, 1977

Right Abutment - December 1, 1977

Left Abutment - December 1, 1977

View Across Reservoir Looking Toward Intake - December 1, 1977

	Gardom Pond Stakeholders	DRAWN AAM
	PHOTOS Dam Safety Review	DATE August, 2011
		APPROVED
	Gardom Dam North Pender Island, B.C.	SCALE Not to Scale
	RYZUK GEOTECHNICAL Engineering & Materials Testing	DRAWING No. B-5782-1-2

Clay Material Found All Around Reservoir - December 1, 1977

Intake Channel - December 1, 1977

Intake Works - December 1, 1977

Outlet Works - December 1, 1977

RYZUK GEOTECHNICAL	Gardom Pond Stakeholders	DRAWN [illegible]
	PHOTOS Dam Safety Review	DATE August, 2011
		APPROVED
	Gardom Dam — North Pender Island, B.C.	SCALE Not to Scale
	RYZUK GEOTECHNICAL — Engineering & Materials Testing	DRAWING No. [illegible]

Panorama Crest, Downstream Face of Dam and Reservoir from Left Abutment - March 20, 1979

Downstream Face of Dam - March 20, 1979

Spillway Cut Viewed From Upstream End - March 20, 1977

Gardom Pond Stakeholders		DRAWN AAM
PHOTOS Dam Safety Review		DATE August, 2011
		APPROVED
Gardom Dam	North Pender Island, B.C.	SCALE Not to Scale
RYZUK GEOTECHNICAL	Engineering & Materials Testing	DRAWING No. 6-0760-1-4

APPENDIX E

Photographs taken in 2011