Dam Safety Review (DSR)
Gullbridge Mine, Newfoundland

Report Prepared for:

Government of Newfoundland Labrador
Natural Resources
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1.0 INTRODUCTION

1.1 GENERAL

At the request of the Newfoundland and Labrador Department of Natural Resources (NLDNR), Stantec Consulting Ltd. (Stantec) has carried out a Dam Safety Review (DSR) of the existing tailings dam at the former Gullbridge Mine in Newfoundland. DSR's have also been conducted by Stantec for the former Whalesback Mine, and Consolidated Rambler Mine sites, and are reported under separate cover.

This report is a follow-up of our preliminary DSR Report, dated March 2, 2011. This report presents our findings for the Gullbridge tailings dam including results of the background information review, dam safety inspections, interviews with NLDNR staff, topographical and bathymetric survey, hydrotechnical assessment, geotechnical investigations, and geotechnical assessments. DSR conclusions and recommendations are provided at the end of this report for follow-up and implementation by NLDNR. The recommendations in this report include conceptual repair and rehabilitation to address geotechnical and hydrotechnical deficiencies of the subject tailings dam. Detailed design and construction drawings and specifications of the repair and rehabilitation of the subject tailings dam is provided under separate cover.

This DSR was undertaken in general accordance with the requirements of the Canadian Dam Association (CDA) - Dam Safety Guidelines (2007). This is the first comprehensive DSR for the Gullbridge tailings dam. This DSR is considered to be the initial stage of the tailings management system process for NLDNR.

1.2 SITE DESCRIPTION

The Gullbridge mine is an abandoned copper mine located in central Newfoundland, between the towns of South Brook and Badger, NL. We understand that the Gullbridge mine is classified under the Orphaned and Abandoned Mine (OAM) designation. The location of the Gullbridge tailings facility relative to the original mine site is shown on the Key Plan, Drawing No. 1, Appendix A. As shown on the Site Plan, Drawing No. 2, Appendix A, the tailings facility consists of one tailings embankment dam that runs in a north south direction with an upstream tailings impoundment to the east, and wetlands to the west.

1.2.1 Tailings Dam and Impoundment

The tailings dam is approximately 1,050 m in length, 5 m wide at the crest, and maximum 10 m in height from the crest to the downstream toe. The downstream slopes are at an angle of approximately 1.9H:1V. The tailings dam does not have an emergency spillway.

The tailings impoundment consists of both submerged and sub-aerial copper tailings contained within the tailings pond with deposited submerged tailings up against the upstream side of the tailings dam. Based on the bathymetric data, the submerged tailings have approximately 1 m of water above the tailings level, with the water level in the pond controlled by the invert elevation of the twin culverts. The twin culverts serve as the outlet discharge structure for the tailings pond. Moving upstream east within the tailings impoundment, the tailings become sub-aerial. The Site Plan, Drawing No. 2, Appendix A, shows the sub-aerial beach with an unnamed tributary or stream entering the tailings impoundment from the east and into the tailings pond.

As stated previously, the outlet structure for the tailings impoundment consists of twin culverts (900 mm diameter Corrugated Steel Pipe, CSP). The twin culverts are located at the north end of the tailings dam. Water from the tailings impoundment flows via the twin culverts to the wetland located immediately downstream of the tailings dam to the west. Water travelling through the wetland makes its way to South Brook located approximately 400 m downstream of the tailings dam.

2.0 SCOPE AND METHODOLOGY

Stantec's methodology for the Dam Safety Review (DSR) was consistent with the proposed scope of work that was outlined in our proposal 121613065, dated May 18, 2011. The purpose of the DSR was to identify potential issues relative to the physical stability of the dam from a geotechnical and hydrotechnical perspective following CDA standards. Any non-conformances or deficiencies relative to the physical stability were identified and recommendations made for correction of those deficiencies.

The work components of this DSR consisted of the following:

- Assessment and reporting of requirements for woody vegetation removal across the dam;
- Ensuring woody vegetation removal work was completed as per recommendations;
- Hydrological studies (including watershed delineation and flow measurements);
- Geotechnical studies (including intrusive testing);
- Assessment of blockages caused by beavers and consideration of this problem during the design of dam repairs and maintenance;
- Topographic and bathymetric surveys of the tailings dam and impoundment;
- Mapping the extent of any downstream inundation by tailings;
- Hydraulic assessment of all spillways and other flow control structures; and
- Visual inspection and assessment of the condition of the dam as outlined in the Dam Safety Guidelines (2007).

Detailed design and construction drawings and specifications of the repair and rehabilitation strategy, which is also part of our scope of work, are provided under separate cover.

It should be noted that analytical chemistry testing of water and tailings, and assessment of chemistry test results relative to potential environmental impacts and/or environmental consequences of failure from a hypothetical dam breach (for dam classification assessment) was not part of the scope of work. This follow-up chemistry testing and environmental assessment is recommended in the future by NLDNR, and is discussed in more detail in Section 7.2 of this report.

2.1 DEFINITION OF DSR (CDA 2007)

According to the CDA Dam Safety Guidelines 2007, a DSR is a systematic review of design, construction, operation, maintenance, processes, and other systems affecting a dam's safety, including the dam safety management system. The DSR encompasses all components of the dam system under evaluation including the dam, spillway, foundations, abutments, and reservoir. The DSR includes a site inspection and staff interviews, review of consequences of failure, review of Operations, Maintenance and Surveillance (OMS) and Emergency Preparedness Plans (EPP) and practices, and analysis of stability and performance. The results of the DSR are presented in a DSR Report. Any deficiencies or non-compliance, data gaps, *etc*., are prioritized and recommendations for corrective actions are provided in the DSR Report.

According to CDA, the scope and the level of detail of a DSR are conducted depending on the “dam classification” to demonstrate:

- the dam is safe;
- the dam/facility is operated safely;
- the dam/facility is maintained in a safe condition; and
- surveillance, procedures and processes are in place to detect any safety problems.

2.2 REVIEW OF BACKGROUND INFORMATION

This stage consisted of a review of available information, and historical records pertaining to the design, construction, operations, modifications, maintenance, and surveillance of the Gullbridge tailings dam and impoundment area. Findings from Stantec’s preliminary DSR Report, dated March 2, 2011 were also reviewed for planning and completion of this DSR Report. The results of the background information review are provided in Section 3.0 of this report.

2.3 VEGETATION REMOVAL

One of the main findings of Stantec’s preliminary DSR Report, dated March 2, 2011 was that vegetation removal would be required from the downstream slopes in order to complete dam safety inspection (DSI) and topographical survey.

Stantec conducted a site visit on June 11, 2011 to determine site conditions and the limits of the vegetation removal requirements. During the site visit, the limits of the vegetation removal were clearly marked with fluorescent spray paint and flagging tape. Stantec provided NLDNR with a brief letter entitled; *Detailed Dam Safety Review, Vegetation Removal Requirements at the Former Rambler, Whalesback and Gullbridge Copper Mine Sites*, dated June 22, 2011 outlining the requirements of the vegetation removal. This letter was used in a tender package prepared and issued by NLDNR for the vegetation removal. NLDNR was responsible for the tender award and supervision of the vegetation removal. As part of the vegetation removal, we understand that NLDNR also had all beaver lodges removed from the Gullbridge site.

Upon completion of the vegetation removal, Stantec conducted another site visit to ensure the vegetation removal was satisfactory. The vegetation removal was considered satisfactory; however the majority of the vegetation that was removed was stockpiled adjacent to the downstream toe. This was allowed under the NLDNR contract due to the difficulty of moving these materials to the top of the dam. Proper removal and disposal of these materials should be considered in any future tender/contract issued for repair and rehabilitation work required for the subject tailings dam.

2.4 PERMITS FOR FIELD WORK

To complete the various field work tasks associated with this DSR, Stantec obtained the following permits and letters:

- permit to work within 15 m of a water body was obtained from the Government of Newfoundland and Labrador, Department of Environment, Water Resources Division;
- a temporary water use license was obtained from Government of Newfoundland and Labrador, Department of Environment; and
- a letter of advice was obtained from the Department of Fisheries and Oceans, Fish Habitat Management Program.

All terms and conditions outlined in the above noted permits and letters were followed, and adhered to during the field investigations.

2.5 TOPOGRAPHIC AND BATHYMETRIC SURVEYS

Topographic and bathymetric surveys of the tailings dam and impoundment were completed by Stephen Burt Surveys Ltd. of King's Point, NL. The topographic survey included the crest, abutments, and upstream and downstream slopes of the tailings dam. The bathymetric survey included the upstream tailings impoundment side over a length of approximately 20 m to obtain the top of the submerged tailings profile. Depths to submerged tailings are unknown outside of the surveyed area. The survey included locating existing discharge culverts, historical discharge outlet structures, tension crack features, and beaver lodges, etc. The surveyor also installed two benchmark monuments, one at the north abutment and the other at the south abutment for future reference (*i.e.*, maintenance, repairs, and inspections). The survey also included the final elevations and locations of the geotechnical boreholes. No beached tailings were identified; therefore the survey was extended to approximately 5 m beyond the downstream toe, where possible.

2.6 GEOTECHNICAL INVESTIGATIONS

To support the geotechnical assessment of the subject tailings dam, a geotechnical investigation was undertaken to characterize the dam fill materials and foundation conditions below the dam. Thickness of the surficial organic layer in the wetland (immediately downstream of the dam) was also measured using bog probes. The investigation included measurement of water levels (phreatic surface) in the dam using piezometers/monitoring wells. The geotechnical investigation consisted of the following:

- Over the period from October 19 to 25, 2011, seven (7) boreholes (BH1 to BH7) were drilled along the top of the dam at the locations illustrated on Drawing No.1, Appendix B. The depths of the boreholes ranged from 6.7 m to 19.7 m below existing grade. The boreholes were drilled by hollow stem auger using a CME 75 rubber tired truck mounted drill supplied by Logan Geotech Inc. During borehole advancement, soils were continuously sampled using a 50 mm OD split spoon sampler during the performance of the Standard Penetration Test (SPT). The borehole records are provided in Appendix B.

- Three (3) piezometers/monitoring wells (MW2, MW4, and MW5) were installed in BH2, BH4, and BH5 for phreatic surface monitoring within the dam. The MW details are plotted on the borehole records in Appendix B.

- Over the period of November 7 to 9, 2011, thirteen (13) dynamic cone penetration tests (DCPT 1 to DCPT 13) were conducted to supplement and confirm the borehole information. The depth of the DCPT's ranged from 5.5 m to 12.5 m below existing grade. The DCPT's were conducted using a CME 75 rubber tire mounted drill supplied by Logan Geotech Inc. The DCPT results are provided in Appendix B following the borehole records. For reference, DCPT 1 to 7 are plotted on the nearby corresponding BH record (*i.e.,* DCPT 1 is plotted on BH 1 Borehole Record).

- Twenty-four (24) bog probes (BP's) were conducted immediately downstream of the toe of the dam in the wetland. Table 1, Appendix B provides a summary of the organic thickness at each BP location.

The lay-out of the above BH's, DCPT's, MW's and BP's are illustrated on the plan drawing, Appendix B.

The field work described above was conducted under the supervision of technical staff from Stantec who kept records of the subsurface conditions encountered and soil samples recovered. All soil samples were returned to our laboratory in St. John's for selected laboratory testing.

2.7 DAM SAFETY INSPECTIONS (DSI'S) AND INTERVIEWS

Dam Safety Inspections (DSI's) were conducted by Stantec following the vegetation removal program described above in Section 2.3. The DSI's were conducted during two field visits with the first visit by our hydrotechnical team, and the second visit by our geotechnical team.

Mr. Sheldon Smith, MES., P.Geo., and Mr. Andres Rodriguez, M.Sc., P.Eng., of Stantec conducted the hydrological and hydrotechnical field component review on September 1, 2011. The purpose of the site visit was to inspect the dam, tailings impoundment and discharge facilities and measure flow rates at key locations to develop an understanding of the hydrological and hydrotechnical conditions.

Mr. Jamie Powell, P.Eng., and Mr. Darrol Rice conducted the geotechnical field component inspection on November 16, 2011. The purpose of the site visit was to inspect the dam and impoundment including the crest, upstream and downstream slopes, abutments, and discharge facilities.

Interviews with NLDNR staff familiar with the site have been on-going. The interview process was very important to the DSR process, especially the historical aspects. The results of the interview process are described in more detail in Section 3.0 of this report.

2.8 GEOTECHNICAL ASSESSMENT

A geotechnical assessment of the subject tailings dam was conducted using the information collected from the DSI's and geotechnical investigation programs. The assessment considered the embankment dam, foundations and abutments. An analytical model of the dam was developed using the information collected from the geotechnical investigation program. The analytical model was used to conduct seepage and slope stability analysis. The results of the slope stability analysis were used to assess the stability of the dam under various loading conditions, including seismic (earthquakes), for comparison with the CDA acceptance criteria. Slope stability analysis was completed on the most critical dam section.

2.9 HYDROTECHNICAL ASSESSMENT

To support the data collected in the field by the hydrotechnical staff as described above in Section 2.7, a detailed desktop review of all available hydrological data was completed. Information on watershed boundaries, land use data, topography, drainage features, survey data, watercourses, waterbodies, wetlands, vegetation types, surface geology, aerial geo-referenced photographs, flow records, climate normals and Intensity-Duration-Frequency curves were obtained for this exercise from nearby stations operated by Environment Canada. The results of the hydrotechnical assessment were used for comparison with the CDA acceptance criteria for the dam class.

The following tasks were completed as part of the hydrological study and results and details can be found in the Hydrotechnical Report, Appendix C.

- organize the data using geographic information systems (GIS) and Excel spreadsheets as required;
- conduct a review of the watershed delineation layer (if available) or generate watershed layers for each mine based on available elevation contours;
- conduct flow proration estimations by area from nearby stations to the mine sites and if available, verify the validity of the flow estimations against the measured flows during the site visit;
- determine seasonal/annual trends with respect to precipitation amounts and other parameters of interest including snow cover;
- create an annual water balance of the site which includes annual average precipitation, evapotranspiration, infiltration and runoff;
- create an inventory of hydraulic structures including conveyance channels, conduits, spillways, ponds and dams and generate site flow schematics for each mine;
- determine inflow design flood (IDF) events for each mine dam site based on available precipitation and flow records using a hydrologic model and statistical methods;
- determine the probability of exceedance for the 1:2, 1:10, 1:25, and 1:100 year return storms based on proration methods and/or modeling results;
- conduct flood routing analysis of dams, spillways, channels and conduits for specified design flood events and the determined IDF; and
- determine the capacity of hydraulic structures for specified design flood events and the IDF.

3.0 REVIEW OF AVAILABLE INFORMATION

3.1 SOURCES OF INFORMATION

There are no background documents or reports available for the Gullbridge tailings dam and impoundment. The majority of information used in this DSR was obtained from interviews with NLDNR staff familiar with the site. A preliminary DSR was conducted by Stantec in 2010, and the results of this assessment were used for the planning and implementation of the field investigation work associated with this DSR. Historical air photos of the site were also reviewed to confirm historical timelines of the mine site development, and to review the pre-mine site features.

3.2 HISTORY OF SITE

A historical timeline was developed using the available information from 1967 to present day as follows:

- Gullbridge was first mined in 1967 by First Maritimes mining, before subsequent sale to K.C. Irving later that year to become Gullbridge Mines Limited. Approximately 2.8 million tonnes of copper ore were produced from the site before closure in 1971. There are no design, construction or operations records available for the tailings dam and impoundment areas over the time period from pre-1967 to 1971.

- It is unknown if there was any modification or maintenance to the tailings dam and impoundment areas between 1971 and 1996, except as noted below. In 1996, we understand from NLDNR that there was a "washout" of the original decant structure, and subsequent repairs were made in this area. It is unknown if this decant structure was put out of service in 1996 or sometime thereafter, and twin culverts installed for discharge (reservoir level control). There are no documents available concerning the repair or decommissioning of the decant structure or installation of the twin culverts.

- In 1999, we understand that rehabilitation work was initiated on the abandoned mine site, including demolition of buildings, sealing of shafts to underground workings, and removal of debris and chemicals from the site. There are no documents available concerning this rehabilitation work in 1999. It is unknown if the twin culverts were installed pre-1999 or was part of the 1999 rehabilitation work.

- We understand that NLDNR conducted a site visit on June 10, 2010, and eight (8) photographs were taken of the tailings dam, impoundment areas and twin culverts. We further understand that there have been repairs made in the culvert area in November, 2010.

- Stantec conducted a preliminary DSR in 2010 (preliminary DSR Report was issued on March 2, 2011, Appendix D).

3.3 DESIGN, CONSTRUCTION, MAINTENANCE, AND SURVEILLANCE RECORDS

There are no records available concerning design, construction, operations, modifications, maintenance, or surveillance of the tailings dam and impoundment areas.

3.4 PRELIMINARY DSR FINDINGS (STANTEC)

The Preliminary DSR Report, dated March 2, 2011, prepared by Stantec is provided in Appendix D. The following is a summary of the findings:

- It was concluded that vegetation removal is required to review the condition of the downstream slopes for later stages such as the DSI and topographical survey.
- Rip rap has been dislodged from ice-jacking on upstream side of reservoir.
- Erosion and shallow slope failures were observed on downstream slopes. Tension cracks parallel to slope noted at one location in particular. Seepage also noted on downstream slopes.
- Twin culverts were severely corroded at bottom, and erosion and washout surrounding the culverts was noted. Potentially acid generating (PAG) material also observed in the dam embankment near the culvert outlet.
- Recent repairs to address historical failures and washout observed at the discharge areas of the twin culverts were noted.
- Signs of beaver activity and blockage of the culverts were noted.
- Two potential historical discharge locations were noted.

3.5 REVIEW OF AERIAL PHOTOGRAPHS

To develop an understanding of the pre-mine development conditions and various timelines of the mine site development, a review of available air photos was undertaken. Five air photos were reviewed over the period from 1965 to 2002. Copies of the air photos are presented in Appendix E. Several of the highlights of the air photo review are provided below.

- Overall, the location of the tailings dam and impoundment area consists of poorly drained wetland terrain. Topographical relief across the site is from east to west. In general, surface drainage is directed west to the wetland, and continues to west through the wetland to South Brook, located approximately 400 m west of the tailings dam.
- A review of the 1965 (pre-mine development) air photo shows an unnamed stream located through the midpoint of the current tailings impoundment and tailings dam, and continued through the wetland bog and drained into South Brook. This same stream shows up in the post-dam construction air photos, so this stream is currently a major source of water into the tailings impoundment.
- The materials used to construct the dam appears to have been quarried from a source located approximately 1 km northeast of the site.
- Throughout the history of the structure, drainage of potential acidic effluent through the dam, via discharge structures and/or general seepage can be observed based on the coloration of the waters downstream of the dam.

- Three discharge locations can be observed in the air photos:
    - at the current twin culvert location at the north end of the tailings dam;
    - at approximately the mid-point of the dam, where the pre-mining stream once existed; and
    - at the southern end of the dam, just north of the tree line on the downstream side of the dam;
- Beached tailings also appear to be “reactive” or “acid-generating” based on the coloration of the tailings and the effluent.

4.0 DAM SAFETY INSPECTION (DSI) RESULTS

4.1 HYDROTECHNICAL

Mr. Sheldon Smith, MES., P.Geo., and Mr. Andres Rodriguez, M.Sc., P.Eng., of Stantec conducted the hydrological/hydrotechnical field component inspection on September 1, 2011. A Hydrotechnical Report outlining their findings and recommendations for repair and rehabilitation is provided in Appendix C. This report includes photographs that were taken by the hydrotechnical team. A summary of the field observations are provided below.

- The Gullbridge tailings facility includes a tailings beach extending into a permanently submerged tailings pond area and tailings dam.
- The outlet structure for the impoundment includes two 900 mm diameter culverts, the culverts are corrugated steel pipe (CSP) and galvanized. The culverts show evidence of oxidation to approximately 75% of their height with presence of woody debris and organic material in both culverts.
- The culvert on the left side (looking downstream) has approximately 90% blockage of its area, while the culvert on the right side is blocked approximately 30% of its area.
- The bottoms of both culverts are extensively deteriorated by iron oxidation with holes that allow water to flow under them, therefore eroding the culvert beds. This effect is more pronounced at the exit of the culverts.
- Very low flow was observed in the right side culvert which was estimated to be in the order of 1 – 2 L/s.
- Wave action erosion was observed at the culvert inlets with material eroding from the dam and loss of as much as 2 m of shoulder material from the culvert inlet. Erosion is likely increased by the length of the reservoir fetch which seems to be approximately 1 km on the longest straight line.
- A large beaver house was observed at the tailings pond side close to the NE dam abutment and other beaver houses were observed around the dam.
- There is evidence of water reaching the elevation of the crest of the dam near the outlet on a regular basis, it appears likely that dam overtopping has already occurred based on the lack of fines in the dam crest near the outlet.
- Significant red ochre staining on exposed rocks was observed suggesting that the pH in the water is low and resulting in iron oxidation.
- The existing culvert outlets are perched above the toe of the dam, with holes at the bottom of the culverts and as a result, the flow from the culverts will eventually erode the downstream toe of the dam.

- Erosion and overtopping are significant issues to dam stability, the current condition of the culverts is promoting piping effects in the culvert embedment material which may affect stability.

- A mine access road runs along the crest of the tailings embankment dam.

4.2 GEOTECHNICAL

Mr. Jamie Powell, P.Eng., and Mr. Darrol Rice conducted the geotechnical field component inspection on November 16, 2011. This inspection was conducted after the vegetation removal to allow visual inspection of the crest and downstream slopes of the dam. A geotechnical inspection report documenting the findings including photographs is provided in Appendix F. A summary of the field observations are provided below including photograph references from the November 16, 2011 inspection report.

- The vegetation removal was satisfactory to allow our DSI to be conducted. The vegetation was cleared to within 100 mm to 150 mm of the ground surface. Photos GB2011-1 and GB-through GB2011-4 shows the vegetation removal.

- Vegetation removed from the downstream slopes was stockpiled adjacent to the downstream toe of the dam (Photos GB2011-4, 8, 10, 11, 14, and 15).

- As noted in the 2010 inspection by Stantec (as reported in the preliminary DSR Report dated March 2, 2011), ice-jacking and removal of rip rap was observed at the crest and upstream slopes of the dam (see Photos GB2011-5, and GB2011-6). The surface at the crest of the dam also had an "undulating" appearance. These undulations may be from the way the dam was originally constructed, and/or differential settlements of the dam. Historical slope failures and repairs were also apparent on the downstream face of the dam (see Photo GB2011-7).

- Some erosion and relatively shallow failures were noted on the downstream slopes along the entire length of the dam. There is evidence that some failures occurred while the facility was in operation as mounds of fill material were apparent on the downstream crest of the dam where 'rough' repairs appear to have been made (see GB2011-7), as well as apparent failure scarps/mounds at the toe with a corresponding fill zone of slightly different materials near the crest of the slope (see GB2011-8). Other failure areas appear to have occurred post-operations as evidenced by failure scarps/mounds at the toe with corresponding 'void' areas near the crest of the slopes.

- There are no indications of recent slope failures, within the last several years, based on the vegetation growth on the failure scarps observed. Photos provided by NLDNR that were taken on June 10, 2010 (see Photo GB-5, in preliminary DSR report, dated March 2, 2011, Appendix D) show a tension crack near the downstream crest of the dam approximately 225 m north of the south end of the dam. This tension crack was located by the surveyors. The tension crack was no longer obvious due to the disturbance of the loose materials on the shell or outside of the dam during vegetation removal activities.

- Seepage along the downstream toe was observed at various locations (see Photos GB2011-8, 10, 14, and 15) along the length of the dam. The seepage was observed as measurable, surface flow at several locations along the toe of the dam, from the center of the dam to the south end. Two (2) of these areas of flow appear to correspond to locations that are interpreted to have been used as decant locations over the history of the dam. At one (1) of these locations, presence of wood indicated a historical structure at this location (Photos GB2011-16 and 17). In general, where seepage could be observed, the zone of seepage at the toe of the dam extended up the downstream face between 300 mm and 900 mm.

- Also, as noted in the preliminary DSR Report, dated March 2, 2011, the twin 900 mm diameter culvert bottoms were severely corroded (rusted). Due to the severe corrosion of the twin culverts, flow through and erosion of the dam structure is occurring below the culverts. Potentially acid generating (PAG) rock was also observed in the dam embankment near the culvert inlets, approximately 3 m to 4 m on either side of the culverts. The culverts are partially blocked at the upstream inlet end by organic materials placed by beavers.

- As noted in the preliminary DSR Report, dated March 2, 2011, sediment washed downstream of the dam from a relatively recent wash-out of the dam at the culvert (outflow) locations were observed and the repair area was also evident. Upon consultation with NLDNR, it is understood the area was repaired in November 2010, and that these materials are the result of the erosion from this repair and a washout of the original decant structure in 1996.

- A beaver house(s), previously observed in the 2010 inspection (as reported in the preliminary DSR Report, dated March 2, 2011) located approximately 40 to 50 m from the southwest end of the dam was removed. Several small beaver dams located immediately downstream of the dam extending approximately from the northeast abutment downstream to the existing culverts have been exposed as a result of the vegetation removal. These beaver dams are pooling the water at or above the toe of the dam along this section of dam as shown in Photo GB2011-19.

- Two (2) potential historical decant/discharge locations were observed on the upstream side of the tailings dam in the form of a standpipe, an old wood frame, and a minor inlet/channel with some timber. These structures were located by the surveyors and are shown in Photo(s) GB-20 and 21 of the 2010 inspection report (as reported in the preliminary DSR Report, dated March 2, 2011, Appendix D).

- A pH meter was used to measure the pH of the impounded water above the tailings level on the upstream side of the dam. Measurements were taken at several locations. The pH ranged from 5.3 to 5.5 on November 16, 2011.

5.0 GEOTECHNICAL INVESTIGATION FINDINGS

As stated in Section 2.6, a geotechnical investigation was undertaken to characterize the dam fill materials, and foundation conditions below the dam. The investigation consisted of 7 boreholes (BH's), 3 piezometers/monitoring wells, 21 dynamic cone penetration tests (DCPT's), and 24 bog probes (BP's).

5.1 SOIL CONDITIONS

In general, soil conditions encountered in the boreholes consisted of heterogeneous fills of variable thickness ranging from 4.2 m to 10.6 m thick, overlying organic peat and topsoil with thicknesses in the range of 0.15 m to 1.6 m, overlying sand and silt. A summary of the soil conditions encountered is provided in the Geotechnical Design Brief, Appendix B. Detailed descriptions of the soil conditions encountered in the boreholes are provided on the borehole records in Appendix B. The soils on the borehole records were classified in accordance with the Unified Soil Classification System (USCS) ASTM D2487 and D2488.

5.2 SOILS LABORATORY TESTING

Laboratory testing was conducted on soil samples that were retrieved during the borehole drilling program. Laboratory testing included moisture content determination and gradation analyses. The results of the laboratory testing are presented in the Geotechnical Design Brief, Appendix B.

5.3 PHREATIC SURFACE (WATER LEVELS)

Water level measurements in the dam were collected from three (3) monitoring wells BH/MW2, BH/MW4, and BH/MW5 on November 9, 2011. The levels were measured as follows: 3.3 m, 5.7 m and 2.7 m below crest of the dam, respectively.

6.0 CONSEQUENCES OF FAILURE, CLASSIFICATION, AND CRITERIA

6.1 CONSEQUENCES OF DAM FAILURE

The consequences of tailings dam failure were reviewed in order to classify the dam according to Table 2-1 of the 2007 CDA Dam Safety Guidelines. Table 2-1 is provided in Appendix G. The following consequences were reviewed for potential dam breach scenarios:

- **Population at Risk:** None (not applicable) as the mine site is remote.
- **Loss of Life:** None (not applicable) as the mine site is remote.
- **Loss of Environmental and Cultural Values:** Impacts to the downstream wetland and South Brook is the main consequence of failure for the Gullbridge tailings dam. South Brook is understood to be a salmon bearing tributary.
- **Infrastructure and Economic Loss:** Infrastructure and economic loss as defined by the 2007 CDA Guidelines includes potential impacts to hospitals, bridges and other related infrastructure. This Economic Loss category does not apply as there is no infrastructure in the vicinity of the mine site.

Due to the close proximity of the Gullbridge tailings dam and reservoir to the downstream wetland, and tributary (South Brook), “Environmental Loss” is considered to be the main consequence category that is applicable to a hypothetical dam breach.

6.2 DAM CLASSIFICATION

The dam class is determined by the highest potential impact for any of the consequence categories given in Section 7.1. The dam class is used to provide guidance on the standard of care expected by dam owners and designers for management, prioritization, and decision-making. The dam class also provides a basis for design flood (hydrotechnical), and earthquake (seismic) levels used in the deterministic method of analysis as described in Section 7.0. According to the consequences of failure described above, we recommend the following dam class in Table 1.

Table 1 Dam Classifications (CDA 2007)

Dam	Highest Consequence Category (Environmental)	Class
Gullbridge Tailings Dam	Minimal short-term loss. No long-term loss.	Low

The issue of dam classification was discussed with NLDNR in February 2012. It was reported by Stantec that this DSR report was being prepared based on the scope of work approved for which it was decided to classify the dam as “Low” consequence category. It was however noted that it is very likely that the classification will have to be changed to “Significant” due to the potential environmental impacts, and a reassessment of the dam classification should be made after results of chemistry analysis of water and tailings are available. The future review of dam classification should include a hypothetical dam breach scenario review, and the potential consequences from such a failure.

6.3 CDA ACCEPTANCE CRITERIA

Based on the dam classification of “Low” for the Gullbridge tailings dam, the following acceptance criteria in Table 2 are recommended by CDA, 2007.

Table 2 CDA Acceptance Criteria for “Low” Dam Class

Parameters	Suggested Annual Exceedance Probability (AEP)
Inflow Design Flood (IDF)	1/100
Earthquake Design Ground Motion (EDGM)	1/500
Critical Wind Frequency for Calculation of Freeboard during IDF	1/100

7.0 ANALYSIS AND ASSESSMENT RESULTS

7.1 GENERAL

A traditional deterministic method of analysis was used to analyze and assess the geotechnical, seismic and hydrotechnical aspects of the tailings dam and impoundment relative to dam safety. With this approach, the risks are managed implicitly, by application of the dam classification scheme described previously that reflects potential consequences of failure. In the assessment of dam safety, Factor of Safety (FOS) for slope stability, and annual exceedance probabilities (AEP's) for earthquake design ground motion (EDGM), inflow design flood (IDF) were used to confirm and demonstrate CDA compliance. Repair and rehabilitation measures are provided for the case where the suggested CDA criteria are not satisfied. This section is organized into three main topics as follows: geotechnical, seismic and hydrotechnical.

7.2 GEOTECHNICAL ASSESSMENT

7.2.1 Literature Review of Hazards and Failure Modes

For embankment dams, the most common hazards and modes of failure fall within one of the following four categories (CDA, 2007):

- Overtopping 48 %;
- Internal Erosion and Piping 46 %;
- Slope and Foundation Instability 5.5 %; and
- Earthquake Liquefaction 1.5 %.

The age of a dam also has an influence on the potential of failure. There is a higher likelihood of failure just after the first impoundment of the reservoir. After approximately the first five years following initial impoundment, embankment dams are generally less likely to exhibit potentially serious problems, although slow progressive processes such as internal erosion may be occurring which can manifest itself many years after impoundment.

- **Overtopping** as a result of flooding has been identified as the most common mode of failure for embankment dams. This failure mode is generally considered to be a hydrotechnical storage/discharge capacity adequacy issue.

- **Internal Erosion and Piping:** Dams and their foundations are never totally impervious. As a result, the water stored in a reservoir may find its way through the dam and/or foundation and abutments, resulting in seepage. If seepage is not controlled it can lead to internal erosion or piping of the embankment materials and ultimately to failure. Seepage problems can be masked for many years following the construction of a dam, culminating in an unexpected catastrophic failure if adequate protective measures are not provided.

- **Slope Instability:** Instability of the upstream and downstream slopes can occur when the activating shear forces on a particular plane exceed the maximum shear resistance available along the same plane. Slope instability can occur during construction, under normal reservoir storage conditions, or during extreme loading conditions such as rapid reservoir drawdown or seismic event. Pore water pressures within the embankment and foundation can play an integral role relative to stability of embankment slopes.

- **Foundation Irregularities:** This includes undesirable materials (weak materials, compressible materials, *etc*.) below the dam.

- **Surface Erosion:** Surface erosion can occur on the upstream or downstream embankment slopes, as well as along the inlet or outlet channels. Surface erosion can be caused by reservoir wave action, runoff and ice action. Human activities such as vehicle traffic and removal of vegetation can contribute to erosion.

- **Earthquakes:** Earthquake ground motions can cause embankment dams to settle or spread laterally. Under severe earthquake loading, one or all of the following failure mechanisms can be initiated:

  - slope instability leading to overtopping;
  - permanent deformations leading to overtopping;
  - cracking leading to internal erosion; and
  - liquefaction (dam or foundation).

7.2.2 Staged Construction of Tailings Dam

Based on the results of the geotechnical investigation, the Gullbridge tailings dam was likely constructed in stages using downstream construction methods. The available information suggests that the dam was built up and out on the downstream side, while the tailings were being deposited on the upstream side of the dam. In general, the upper 3 m of the dam profile (and likely the downstream slopes) consists of a sand and gravel with relatively low fines contents as compared to the internal core of the dam, which consists of a sand and gravel with relatively high fines contents. The downstream slopes of the dam were built steep of the order of 1.9H:1V, which is likely the angle of repose (dry) of the materials. Also, the upper 3 m of the dam profile is at a higher density than the internal core of the dam. It is unknown if the observed “zoning” was the intention of the original designers or construction contractor, or if this was a function of the materials that were available at the time of the original construction. Either way, the apparent zoning of the tailings dam materials appears to be one of the main factors influencing the seepage and stability of the dam.

With the apparent staged embankment construction method described above, the internal higher fines materials within the dam may be acting to slow down seepage through the dam, and the outer downstream cleaner sand and gravel materials may be acting like a drainage blanket allowing seepage to occur at a higher rate due to the higher permeability. That being said, the dam safety inspection results after vegetation removal has shown that the downstream slopes are showing signs of instability and seepage on the face of the dam as noted in the inspections provided in Appendix F.

7.2.3 Potential Failure Modes of Gullbridge Tailings Dam

Overtopping, slope instability, internal erosion and piping, and surface erosion are considered to be the main potential failure modes influencing the subject tailings dam. The following provides more details concerning the modes of failure:

- **Overtopping:** Currently, the only pond level control for the tailings impoundment is via twin culverts located in the tailings dam at the northwest corner. Overtopping could occur if the twin culverts are not able to handle the flow rates associated with a particular flood event, especially for the case of blocked or partially blocked culverts. Based on the hydrotechnical assessment conducted as part of this DSR, the existing twin culverts (*i.e.,* assumed unobstructed flow) are not able to accommodate the 1:100 year storm event and at the same time maintain the minimum required freeboard.

  There is evidence of overtopping of the tailings dam in the past (and wash-out and erosion of the discharge culvert area) likely due to blocked culverts from beaver activity. Therefore, any future repair and rehabilitation strategy for the tailings dam should include a provision to minimize the potential for blockage of the twin culverts from beaver or other animal activity.

  The current tailings dam does not have an emergency spillway, therefore there is no contingency in place to prevent dam overtopping for the case of a particular storm event exceeding the twin culvert discharge capacity. Therefore, any future repair and rehabilitation strategy should include the addition of an emergency spillway.

- **Slope Instability:** The combination of relatively steep downstream slopes, and very loose to loose dam fill materials, coupled with a relatively high phreatic surface within the dam, results in the potential for slope instability issues. Currently, based on the results of the DSI, the downstream slopes of the dam are showing signs of slope instability and localized slumping.

- **Piping and Internal Erosion** is also considered to be a potential due to the very loose to loose nature of the internal core of the dam. It is unknown if there is adequate "filter" compatibility between the finer grained internal dam materials, and the outer coarser grained materials. The above conditions can result in the potential of a high phreatic surface with high exit gradients, thus placing the tailings dam at potential risk of piping and internal erosion.

  Internal erosion has also been identified as a potential issue in the area of the existing twin culverts, where wash-out and removal of the surface coarser materials and rip rap layers has already occurred potentially leaving the very loose internal core of the dam exposed. Also, preferential seepage can occur through more permeable fills (i.e. coarse rock fill layers) placed during previous culvert replacement/remediation works, which will further increase the internal seepage potential.

  Based on the above, seepage and internal erosion are potential failure modes that require consideration for the rehabilitation strategy of the tailings dam.

- **Surface Erosion:** Surface erosion is another important element that needs to be addressed as part of the rehabilitation strategy. Surface erosion is particularly important on the upstream slopes of the dam exposed to wave action, around the inlet and outlet of the discharge facilities (*i.e.*, future twin culvert replacement), areas where the dam will be increased in grade, downstream slopes, and any other area with exposed erodible soils.

7.2.4 Slope Stability Analysis

A slope stability analysis was conducted for the downstream and upstream slopes of the tailings dam. Details concerning development of the analytical model for the analysis, assumptions used in the analysis, and stability analysis results are provided in the Geotechnical Design Brief, Appendix B. The following are several highlights of the analytical model development and results obtained:

- Seepage and slope stability analyses were carried out using finite element seepage, and limit equilibrium slope stability modeling software (SEEP/W and SLOPE/W 2007 by GEO-SLOPE International).

- The analytical model was developed using the results of the geotechnical investigations, topographical survey, water level measurements in the piezometers/monitoring wells, and observations during the dam safety inspections. The analytical model considered geometry, soil stratigraphy, strength parameters of the dam and foundation materials, and phreatic surface.

- With the limit equilibrium method of slope stability analysis, the Factor of Safety (FOS) was calculated for the particular slope being analyzed. The calculated FOS was then compared to the FOS CDA acceptance criteria.

- The slope stability analysis was conducted in two stages. The first stage was a slope stability analysis of the current dam geometry. If the current dam geometry did not meet the FOS CDA acceptance criteria, then a rehabilitation strategy was designed to meet the FOS CDA acceptance criteria. Therefore, the second stage was an analysis of the proposed rehabilitated dam cross-section.

- The results of the first stage of the slope stability analysis (<u>Current Dam Condition</u>) is as follows:

    - the FOS for the downstream slopes has been estimated to be 1.0, which does not meet the CDA acceptance criteria of 1.5. Therefore, the downstream slopes require rehabilitation as described in more detail below; and

    - the FOS for upstream slopes for the rapid drawdown condition also does not meet the CDA acceptance criteria. Therefore, the upstream slopes also require rehabilitation as described below.

It should be noted that the above dam stability non-conformances are for the static condition, and are not the result of earthquake (seismic) loading conditions.

- The results of the second stage of the slope stability analysis (<u>Rehabilitated Dam Condition</u>) is as follows:

- the FOS for the rehabilitated downstream slopes (with the addition of the toe berm as shown on Drawing SSA-02 of the Geotechnical Design Brief, Appendix B), has been estimated to be 1.63 for static conditions and 1.57 for pseudo-static seismic conditions, which meets the CDA acceptance criteria; and

- the FOS for the rehabilitated upstream slopes (by flattening the upstream slopes to 3H:1V as shown on Drawing SSA-03 of the Geotechnical Design Brief, Appendix B), has been estimated to be 1.5 for static and 1.1 for pseudo-static seismic conditions, which meets the CDA acceptance criteria.

7.2.5 Liquefaction Potential

Based on the results of the liquefaction potential analysis, there is a very low probability that the foundations or dams would experience liquefaction for the expected seismic loading conditions, and as such a pseudo-static method of analysis was appropriate for assessing seismic loading as described in Section 7.2.4. Results of the liquefaction potential analysis, are described in detail in the Geotechnical Design Brief, Appendix B.

7.3 SEISMIC ASSESSMENT

As described in Section 7.2.4, the seismic slope stability of the dam was completed based on a pseudo-static approach. The seismic events were modeled using the 2004 National Building Code seismic peak ground acceleration (PGA) for the site. In terms of consequence of failure, the dam has been classified as “Low”. According to CDA, the Earthquake Design Ground Motion (EDGM) acceptance criteria for a “low” consequence dam is AEP = 1/500. However, for the pseudo-static analysis, a PGA was selected based on a “Significant” consequence dam. The reported PGA at the site for a return period of 1 in 1,000 years (5% probability of exceedance in 50 years) is 0.045 g. According to the published literature, the fraction of the PGA to be used in a pseudo-static slope stability analysis varies from 1/3 to 2/3. In our analysis 1/2 of the PGA was used.

7.4 HYDROTECHNICAL ASSESSMENT

A hydrological and hydrotechnical assessment of the Gullbridge tailings dam and impoundment area was conducted by Stantec. The assessment consisted of both field work and desktop study and analysis. A summary of the tasks that were completed as part of the hydrotechnical study can be found in Section 2.9. Details concerning development of the hydrological and hydrotechnical models used in the analysis, assumptions, and results are presented in the Hydrotechnical Report, Appendix C.

The following are highlights of the assessment:

- The purpose of the hydrotechnical assessment was to review if the current tailings dam, impoundment, and flow control structures are able to handle the IDF storm event and maintain the minimum freeboard recommended by CDA. “Overtopping” is considered to be the main failure mode to prevent as described in Section 7.2.3.

- To support the hydrotechnical assessment, a site visit was conducted by Stantec hydrotechnical staff on September 1, 2011. Observations made during this site visit are described in detail in the Hydrotechnical Report, Appendix C, and are summarized in Section 4.1. Several of the findings relative to the existing 900 mm diameter twin culverts include:

    - the existing culverts are heavily corroded;
    - the existing culverts were full of woody and organic debris and sediment;
    - wave action erosion was observed at the culvert inlets with materials eroded from the upstream face of the dam surrounding the culverts; and
    - the outlet area of the culvert is also showing signs of erosion due to culverts being located above the toe of the dam and the lack of erosion control on the outlet end.

- The hydrotechnical assessment considered the subject tailings dam as a “low” consequence category dam (in accordance with the scope of the study) with the following CDA acceptance criteria:
    - Inflow Design Flood (IDF), AEP = 1/100; and
    - Critical Wind Frequency for Calculation of Freeboard during IDF, AEP = 1/100
- The hydrological models were developed to simulate precipitation frequency storm events up to the 1:100 year flood. The 1:100 year flood hydrograph was developed for the site characteristics, and used to assess the ability of the flow control structures to handle the 1:100 year flood event.
- Currently, the only reservoir level control structure is via the twin 900 mm CSP diameter culverts located at the north end of the tailings dam. Therefore, the hydrotechnical assessment focused on the ability of the twin culverts to safely convey a series of storm events up to the 1:100 year flood without compromising the dam structure (*i.e.* prevent overtopping), and to satisfy the minimum freeboard recommended by CDA.
- The main findings of the hydrotechnical assessment are as follows:
    - The existing twin 900 mm diameter culverts do not satisfy the CDA hydrotechnical requirements. The results of analysis suggest that the existing twin culverts are undersized, and result in insufficient freeboard during the 1:100 year storm event. During the 1:100 year storm event, the freeboard has been estimated to be approximately 0.5 m, which is less than the minimum freeboard of 0.65 m required during the IDF storm event.
    - The current dam does not have an emergency spillway structure. Therefore, for extreme flood events for unobstructed culverts and/or smaller storm events for the case of blocked culverts, the current dam does not have the ability to safely route the flow to prevent dam overtopping. From observations made during the dam safety inspections, there is evidence of dam overtopping in the past.

- Based on the above findings, the following repair and rehabilitation recommendations to correct the hydrotechnical deficiencies are provided below. More details can be found in the Hydrotechnical Report, Appendix C.

    - Add a low profile fordable emergency spillway with proper armour for erosion protection. The purpose of the emergency spillway is to handle the storm events in excess of the IDF.

    - Replace the existing 900 mm diameter twin CSP culverts with new 1200 mm diameter twin CPP culverts installed with an animal entry prevention grate often referred to as "beaver deceivers". Culvert inlets and outlets should have proper rip rap armoring for erosion protection. The new culverts should be installed with seepage collars. An open flow channel is not recommended for replacement of the culverts as described in more detail in the Hydrotechnical Report, Appendix C.

    - Increase the dam height to minimum elevation 153.25 m to accommodate the minimum freeboard requirement of 0.65 m. Based on the topographical survey, the north end of the tailings dam in particular requires an increase in grade.

    - The addition of a rip rap layer across the entire face of the upstream slopes to improve the wave action erosion protection.

8.0 REVIEW OF DAM SAFETY MANAGEMENT SYSTEM

8.1 GENERAL

As defined by CDA 2007, the Dam Safety Management System for a dam should have the following six elements:

- **Dam Safety Policy:** owner's commitment to safety management;
- **Planning:** procedures, resources, roles and responsibilities, standards, and schedules;
- **Implementation:** Operations, Maintenance and Surveillance (OMS) Manuals, and Emergency Preparedness Plans (EPP);
- **Checking and Reviewing:** dam surveillance, DSR's, regular inspections, peer review, audits;
- **Supporting Processes:** staff training, communications, record keeping; and
- **Corrective Actions and Reporting:** peer review, audits, reporting and follow-up.

An overview schematic of a typical Owner's Dam Safety Management System from CDA is presented in Appendix G.

8.2 CURRENT DAM SAFETY MANAGEMENT SYSTEM

Currently, NLDNR does not have a dam safety management system for the Gullbridge tailings dam and impoundment area. It is recommended for NLDNR to develop a dam safety management system including all of the above elements given in Section 8.1. The following provides more detail concerning several of the elements:

- The Operations, Maintenance and Surveillance (OMS) manual should be developed following the principles of CDA and Mining Association of Canada (MAC). MAC specifically has a guideline for developing an OMS Manual for tailings management facilities.
- The Emergency Protection Plan (EPP) should also be developed following the principles of CDA and MAC.
- An Emergency Response Plan (ERP) is recommended to be developed by NLDNR for the case where surveillance identifies an emergency condition (*i.e.,* dam breach or impending dam breach, *etc.*).
- An on-going training program is recommended for NLDNR staff involved with monitoring dams and dam safety. The training should include surveillance, monitoring, record keeping, and visual signs of instabilities and seepage, *etc*.

9.0 CONCLUSIONS

The conclusions of this Dam Safety Review (DSR) are presented below:

- The Gullbridge mine is an abandoned mine site, and is understood to be classified by NLDNR under the Orphaned and Abandoned Mines (OAM) designation.

- This is the first comprehensive DSR for the Gullbridge tailings dam. This DSR is the initial stage of the tailings management system process for NLDNR.

- It has been assumed that the tailings dam and impoundment will undergo a full closure strategy by NLDNR sometime in the future. Until then it is recommended that NLDNR should manage their risks associated with this abandoned tailings dam and impoundment. The recommendations below provide further guidance in this regard.

- Based on the potential consequences of failure review, the Gullbridge tailings dam has been assigned a "Low" dam classification for this DSR Report. It is noted however, that this dam class may have to be changed to "Significant", pending results of the chemical analysis of the water and tailings as described in this report. This may have an impact on the future closure strategy.

- Historical records concerning design, construction, operations, modifications, maintenance, and surveillance for the Gullbridge tailings dam and impoundment are non-existent. However, we understand from interviews with NLDNR that there have been some repairs to the discharge culverts by NLDNR in 2010.

- The Dam Safety Inspection (DSI), after vegetation removal, identified no major dam safety issues requiring immediate attention. However, the DSI identified several performance, operational, maintenance, and surveillance issues that require follow-up corrective actions by NLDNR. The following are the main points:

  - Signs of historical local failures (*i.e.,* slumping and erosion), and historical repairs of the downstream slopes were apparent.

  - The tailings dam is currently showing signs of performance issues at the crest of the dam as well as seepage and sloughing conditions on the downstream slopes at several locations. The downstream slopes of the dam appear to have been built very steep. Upstream slopes are also showing signs of rip rap removal from ice jacking. The above performance issues are physical stability (geotechnical) in nature and require corrective action.

  - Existing discharge culverts are in poor condition. The culverts are severely corroded at their bottoms. The culverts also had significant debris build-up possibly from beaver activity and sediment build-up (or some combination of the two), resulting in obstruction of flow through the culverts. There is no rip rap protection surrounding the culvert inlet end. There was significant wave action erosion on the upstream side of the tailings dam at the inlet end surrounding the culverts. The above performance issues are hydrotechnical in nature, and require corrective action.

- The tailings dam does not have an emergency spillway.
- The potential of PAG (Potentially Acid Generating) rock used in the construction of the dam was also identified.
- There appears to be no specified (scheduled) surveillance and monitoring program in place to identify areas of the dam and discharge facilities requiring corrective action and/or maintenance.

- Additional information was collected by Stantec as part of the DSR process including geotechnical investigations using boreholes, piezometers, dynamic cone penetration tests, and bog probes. A topographic and bathymetric survey of the tailings dam was also conducted. Following is the summary of findings:
    - Areas of the tailings dam are in a very loose to loose state of relative density, coupled with a relatively high water level (phreatic surface). These conditions are unfavorable from a slope stability perspective. The above conditions likely explain the geotechnical performance issues observed at the time of the DSI.
    - Downstream slopes of the tailings dam were measured to be 1.88H:1V, which is considered to be very steep. These steep downstream slope angles are also unfavorable from a slope stability perspective, and likely explain the geotechnical performance issues observed in the tailings dam at the time of the DSI.
- The tailings dam does not meet the <u>geotechnical</u> requirements according to CDA. The downstream slopes of the tailings dam do not meet the CDA Factor of Safety (FOS) acceptance criteria. The recommended dam repair and rehabilitation work to correct these geotechnical deficiencies are described in more detail in Section 10.0.
- The tailings dam does not meet the <u>hydrotechnical</u> requirements according to CDA. The required freeboard to prevent dam overtopping is not currently satisfied. Also, the current flow control structures (i.e. discharge culverts) are an issue and needs to be addressed. The recommended dam repair and rehabilitation work to correct these hydrotechnical deficiencies are described in more detail in Section 10.0.
- A review of the current Dam Safety Management System identified several non-conformances that require follow-up corrective action as follows.
    - Specific Operations, Maintenance and Surveillance (OMS) manuals or guidelines do not exist for the tailings dam and impoundment areas.
    - Emergency Preparedness Plans (EPP) for the tailings dam also does not exist.

10.0 RECOMMENDATIONS

The following recommendations are provided for review before issuing the final report.

- It is recommended for NLDNR to confirm that Stantec's "environmental" sensitivities assumptions are correct and consistent with NLDNR's perspective in terms of dam failure consequences. It is further recommended for NLDNR to review the dam classification of "Low" assumed in this DSR Report to make sure it is consistent with NLDNR's position.

- It is recommended for NLDNR to develop an Operations, Maintenance and Surveillance (OMS) manual, and an Emergency Protection Plan (EPP) following the principles of CDA and MAC. MAC specifically has a guideline for developing an OMS Manual for tailings management facilities.

- An Emergency Response Plan (ERP) is also recommended to be developed by NLDNR for the case where surveillance identifies an emergency condition (*i.e.,* dam breach or impending dam breach, *etc*.).

- An on-going training program should be developed for NLDNR staff involved with monitoring dams and dam safety. The training should include surveillance, monitoring, record keeping, and visual signs of instabilitiies and seepage, *etc*.

- As per CDA, the suggested frequency for DSR's is as follows:

  - Significant Dam Class – every 10 years ; and

  - Low Dam Class – not required for low-consequence category dams unless there is a change.

  However, due to the many non-conformances and deficiencies encountered in this first DSR, annual DSI's by Stantec is recommended, until such time that the repair and rehabilitation is complete. The above suggested frequency for DSR's is only a guide, and any modifications, unsual conditions, new standards, etc. that might affect dam safety should result in a DSR.

- Between now and the time the repair and rehabilitation work is completed, an on-going surveillance and maintenance plan should be developed by NLDNR to address blockage of culverts, erosion of culvert inlets, slumping, slope movements, seepage and piping of downstream slopes, etc. The on-going surveillance should define the priority areas requiring maintenance and corrective action. For instance, if a monthly dam inspection by NLDNR encounters a blocked culvert, then this should result in clean-out of the culvert immediately by a local contractor.

10.1 SPECIFIC RECOMMENDATIONS

The following recommendations are provided:

- In spring 2012, clean out the existing culverts, and add rip rap slope protection surrounding the culverts at the inlet and outlet ends.
- Chemical analysis of water and tailings samples should be undertaken to properly assess the potential "environmental" impact to downstream receptors for the case of a hypothetical dam breach scenario. The results of the above chemical analysis and hypothetical dam breach review will allow a proper assessment of "dam classification".
- NLDNR to develop and implement a Dam Safety Management System for the Gullbridge tailings dam and impoundment:
    - policy and plan;
    - implementation of the plan (OMS, EPP);
    - checking using the on-going inspections by NLDNR and annual DSI's by Stantec;
    - corrective actions (including maintenance);
    - training of NLDNR staff; and
    - reporting and documentation.
- NLDNR to provide on-going dam inspections (minimum monthly) between now and the time the repair and rehabilitation work is completed. After the repair work has been completed, the monthly dam inspections should continue until NLDNR is satisfied that the constructed repair work is performing as intended. After this stage, it is recommended for NLDNR to do annual dam inspections preferably after spring freshet. The annual dam inspections should be considered the minimum after the repair and rehabilitation work for the condition of intended performance.
- Recommend that Stantec conduct annual DSI's until the dam gets repaired and rehabilitated. The annual DSI's would be conducted concurrently with the monthly dam inspections by NLDNR. This annual DSI should be conducted in the spring/summer after spring freshet and is part of the above "Checking" category in the Dam Safety Management System.
- Repair and rehabilitation recommendations to correct the <u>geotechnical</u> deficiencies are provided in more detail in the Geotechnical Design Brief, Appendix B. The following is a summary of the geotechnical repair and rehabilitation strategies.
    - As stated in Section 2.3, the stockpiled vegetation at the toe of the existing dam should be moved to an approved location off site.

- The addition of a stabilization toe berm combined with slope flattening across the entire downstream slope of the dam. The materials should consist of free draining coarse rock fill (processed blasted rock). This stabilization berm will increase the global stability of the dam, and will help to minimize seepage erosion and piping over the remediated downstream face of the dam. The transition between the existing downstream dam face, and the stabilization toe berm should have a properly designed filter.

- For erosion protection, the addition of a coarse rip rap layer across the entire downstream face of the dam above the stabilization berm.

- The materials used for the stabilization work should consist of durable sound rock, and should not pose any environmental issues (*i.e.,* no PAG rock, *etc*.).

- Repair and rehabilitation recommendations to correct the <u>hydrotechnical</u> deficiencies are provided in more detail in the Hydrotechnical Report, Appendix C. The following is a summary of the hydrotechnical repair and rehabilitation strategies.

    - Add a low profile fordable emergency spillway with proper armour for erosion protection. The purpose of the emergency spillway is to handle the storm events in excess of the IDF.

    - Replace the existing twin 900 mm diameter twin CSP culverts with new 1200 mm diameter twin CPP culverts installed with an animal entry prevention grate often referred to as “beaver deceivers”. The new culverts should be installed with seepage collars. Culvert inlets and outlets should have proper rip rap armoring for erosion protection. An open flow channel is not recommended for replacement of the culverts as described in more detail in the Hydrotechnical Report, Appendix C.

    - Increase the dam height to minimum elevation 153.25 m to accommodate the minimum freeboard requirement of 0.65 m. Based on the topographical survey, the north end of the tailings dam in particular requires an increase in grade.

    - The addition of a rip rap layer across the entire face of the upstream slopes to improve the wave action erosion protection.

11.0 CLOSURE

Use of this report is subject to the Statement of General Conditions provided in Appendix H. It is the responsibility of Newfoundland and Labrador Department of Natural Resources (NLDNR), who is identified as "the Client" within the Statement of General Conditions, and its agents to review the conditions and to notify Stantec Consulting Ltd., should any of these not be satisfied. The Statement of General Conditions addresses the following:

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