



November, 2016

REPORT ON

Inventory and Assessment of Dams in Eastern Newfoundland

Submitted to:

Paula Dawe, P. Eng.
Water Resources Management Division
Department of Environment and Conservation
4th Floor, West Block
Confederation Building
PO Box 8700
St. John's, NL

REPORT



Report Number: 1533903-01-Rev1

Distribution:

1 Copy - WRMD
1 Copy - Golder Associates Ltd.





Executive Summary

A larger emphasis is starting to be placed on dam safety by many Provincial Governments throughout Canada in an attempt to limit, and ideally eliminate, the occurrence of dam failures and the risk they can pose to people, infrastructure, and the environment. The Department of Environment and Conservation, Water Resources Management Division of the Government of Newfoundland and Labrador has undertaken an initiative to strengthen the province's Dam Safety Program. The first step in completing this initiative is to update the provincial dam inventory registry and database, and to provide the Government with a comprehensive and accurate catalogue of all dams within the province. This will then help the Government develop the necessary tools to ensure the effective regulation of the province's dams. Golder was retained by the Water Resources Management Division to complete this inventory update for the eastern portion of the island of Newfoundland and has provided this report to summarize the process taken, its findings, and recommendations to the Government.

The execution of the project was divided into several phases which are all discussed in detail in this report. The first and largest phase involved verifying that the records presently in the database were current and accurate. This meant contacting every dam owner in the region and requesting that they provide up to date information through the use of a dam inventory form. The information received was then compared with the information in the database and the necessary updates were made. In total, out of the two hundred seventy-eight (278) dams that dam inventory forms were requested for, seventy-three (73) dam inventory forms were received from dam owners (two of these dams that forms were received for were later removed from the inventory). In addition to the forms received, informal notification (email) was also received by other owners that nine (9) dams no longer existed. This equates to a 29% response rate on a per dam basis. A total of eighty-four (84) owners were contacted and responses were received from forty-seven (47) of them, whether this was by way of a dam inventory form, indication that a dam no longer existed, or that they had no records for the dam and were unable to complete a form. This equates to a 56% response rate on a per owner basis.

The second phase was similar to the first and involved identifying any new dams not already in the database. When receiving responses from dam owners it would sometimes happen that they indicated they owned more dams than just the ones on record for them in the database. On a few occasions, a new dam was also discovered from a site visit to another dam. In this case the dam owner was contacted and asked to complete a dam inventory form. In total, eighteen (18) new dams were added to the inventory. Of these new dams, indication was provided by the owner for ten (10) of them (56%), by the Water Resources Management Division for six (6) of them (33%), and two (2) were discovered from site visits (11%). Once indication of these dams was received, information requests were sent to the respective owners. Information was received for fourteen (14) of the new dams, or 78% of them. The new dams for which information was not received for had only their name and owner (if known) added to the database.

The third phase required collecting any dam breach inundation mapping that had been completed for the study area. It turned out that the vast majority of dams in the region did not have any dam breach inundation mapping completed; Golder only received inundation mapping for six (6) developments. These developments contain thirteen (13) dams with inundation mapping, which is only 4% of the two hundred eighty-three (293) dams in the inventory for the region (considering additions and subtractions of new and no longer existing dams as of the conclusion of this project). The inundation mapping that was collected, was digitized when possible, i.e., the



quality of some of the maps was poor. This equated to three (3) inundation maps being digitized. Another part of this phase was to develop criteria to identify which dams should have dam failure inundation mapping completed. This was not a straight forward task because to properly classify a dam, even a dam that is believed to be low risk, some basic type of inundation mapping or assessment study should be completed. If a dam is in a remote area with no threat to population or infrastructure, for example, then detailed inundation mapping with flood wave arrival times, etc. might not be required. However, some focus still needs to be paid to the ecological components of the system, particularly for tailings dams.

The fourth phase was to gather information on any dam failures that have occurred within the entire province. For the eastern region this request was made when contacting the dam owners for the phase one information, but for dams outside of the eastern region dam owners were additionally contacted to provide this dam failure information only. Brief summary write-ups of all recorded dam breach events were then completed to capture all of the information provided. A total of thirty-one (31) dam failures were identified, spanning from 1907 to 2015. These failures resulted in three (3) known fatalities and an estimated \$64 million in damage. It is important to note that this cost only accounts for fourteen (14) of the failures as the costs of the damage resulting from the remaining seventeen (17) failures is unknown.

The fifth phase involved making site visits to various dams. The dams that were visited were those that did not have any pictures in the dam inventory database. Having pictures in the database of each dam is an important piece of information, so this needed to be addressed. During the site visits pictures were taken, but coordinates of the dam and, when possible, measurements of length, width, and height were also taken to further verify the accuracy of the information in the database. In total, fifty-one (51) dams were visited. Of the two hundred ninety-three (293) dams in the inventory, as of the conclusion of this project, two hundred thirty (230) dams have pictures attached to their entries, this equates to 78% of the dams in the inventory having pictures.

The sixth phase was to review all dam safety reviews and other dam safety related documents to determine if the dam safety review frequency advocated by the Canadian Dam Association was being met and if any deficiencies found during a review had or were being addressed by dam owners. Documents were received for seventeen (17) developments, containing a total of one hundred twenty-four (124) dams, and a dam safety audit sheet was completed for each. These audit sheets helped to assign a risk level for each dam. Nineteen (19) of the dams were assigned a risk level of 1 – Alert (15%), twenty-eight (28) were assigned a risk level of 2 – Caution (23%), sixty-seven (67) were assigned a risk level of 3 – Stable (54%), and ten (10) were assigned a risk level of 4 – No Concerns (8%).

The seventh phase was to identify any monitoring equipment that was installed on any of the dams and to provide general details on the types of monitoring instruments that could be used for a given type of dam, etc. This was done by reviewing the reports obtained during phase six and reviewing records and replies from dam owners. It was found that there were seven (7) developments that had dams with monitoring equipment installed. This is a total of fourteen (14) dams in the region having monitoring equipment installed; or about 5% of all dams in the region.

The eighth phase of the project was to take all of the information gathered in the previous phases and physically update the Government dam registry and database. In total, seventy-two (72) of the dams already in the database were updated and fourteen (14) dams were removed. This means that 30% of the two hundred eighty-nine (289) dams already in the database, prior to the start of this project, were either updated or removed based on information provided by the owners. It is important to note that Newfoundland Power owns one hundred forty-nine



(149) of these dams and they did not provide any responses. If this one owner had to have provided information on their dams, this number would increase significantly to 81%.

This report presents the results of the various surveys and includes recommendations to the Water Resources Management Division on how the dam inventory database and dam inventory form can be improved upon. The nature of these recommendations varies, but they were all developed from Golder's experience in using both of these tools throughout the project. The recommendations mainly focus on the ease of a dam owner to understand the form they are being asked to complete and on the ease of making edits to the dam inventory database.

As previously stated, dam safety is taking on more importance and has become a significant focus for many provinces in Canada. This is very important to ensure that dams are being operated safely and efficiently. Conforming to guidelines such as those of the Canadian Dam Association will help ensure dam owners that their dams are being designed and operated in a safe and effective manner and will significantly limit the risk to people, infrastructure, and the environment. However, the generally low response rates from this study indicate that there is still much work to be done to raise awareness on dam safety in our province. Currently only about 4% of the dams have inundation mapping, which is a hugely important aspect of a dam safety program. This must increase to better classify dams and to ensure that appropriate emergency preparedness and response plans are in place. Monitoring equipment can be quite effective in preventing dam failures if read and monitored regularly. The survey found that only 5% of all dams in the region have monitoring equipment. Even discounting small dams with a low risk of failure, such a rate is still too low. With more willingness to participate and more understanding of dam safety requirements from dam owners, the dam safety program in Newfoundland and Labrador has the potential to be tremendously effective and would significantly limit the potential for dam failures and the risks associated with them.



Table of Contents

| | |
|--|-----------|
| 1.0 INTRODUCTION..... | 1 |
| 2.0 EXISTING RECORDS VERIFICATION AND UPDATING | 2 |
| 3.0 IDENTIFICATION OF NEW DAMS..... | 3 |
| 4.0 DAM FAILURE INUNDATION MAPPING | 3 |
| 5.0 DAM FAILURES | 5 |
| 5.1 Dam Failure Inventory | 5 |
| 6.0 SITE VISIT | 42 |
| 7.0 DAM SAFETY REVIEWS | 42 |
| 7.1 DSR Recommendations and Follow up Actions | 43 |
| 7.2 Dam Safety Audit Tool..... | 47 |
| 8.0 EMERGENCY PREPAREDNESS AND RESPONSE PLAN REVIEWS..... | 47 |
| 8.1.1 CDA Guidelines for EPP | 48 |
| 8.1.2 Newfoundland Power Dam Safety Emergency Preparedness Plan..... | 48 |
| 8.1.3 Newfoundland and Labrador Hydro – Victoria Dam | 49 |
| 9.0 MONITORING EQUIPMENT FOR SAFE DAM OPERATION | 49 |
| 9.1 Failure Modes..... | 50 |
| 9.2 Existing Instrumentation | 54 |
| 9.3 Recommended Instrumentation..... | 55 |
| 10.0 UPDATING DAM INVENTORY DATABASE..... | 56 |
| 11.0 RECOMMENDATIONS..... | 56 |
| 12.0 CLOSURE..... | 60 |

TABLES

| | |
|---|----|
| Table 1: Dam Safety Audit Breakdown | 47 |
|---|----|

FIGURES

| | |
|---|---|
| Figure 1: Goodyear's Dam – showing the two failed sections..... | 6 |
| Figure 2: Dam 1 (Merrymeeting Pond) – looking along the crest. | 7 |



FINAL REPORT - EASTERN NEWFOUNDLAND DAM INVENTORY

| | |
|--|----|
| Figure 3: Dam 1 (Merrymeeting Pond) - cracking in spillway | 8 |
| Figure 4: Joe Dennis Pond - aerial view of the dam from downstream. | 10 |
| Figure 5: Joe Dennis Pond Dam - remains of the former dam just upstream of the new structure. | 10 |
| Figure 6: Mclvers Reservoir Dam – showing the gabion wall..... | 12 |
| Figure 7: Sheaves Cove Dam - Showing the upstream side of the main dam. | 13 |
| Figure 8: Sheaves Cove Dam – showing deterioration of the downstream side of the main dam..... | 13 |
| Figure 9: Sheaves Cove Dam – showing the small reserve dam and failed area. | 14 |
| Figure 10: Well Cove Brook Dam – showing reservoir. | 15 |
| Figure 11: Well Cove Brook Dam – showing spillway (photo 1). | 15 |
| Figure 12: Well Cove Brook Dam – showing spillway (photo 2). | 16 |
| Figure 13: Well Cove Brook Dam showing spillway on the upstream side. | 16 |
| Figure 14: Dike GJ-11A – showing aftermath of the washout. | 17 |
| Figure 15: Gullbridge Tailings Dam – showing the breached section..... | 19 |
| Figure 16: North Embankment Dam - circa 2010-2012, looking northwest towards the breach..... | 20 |
| Figure 17: North Embankment Dam - circa 2010-2012, looking south towards the dam. | 20 |
| Figure 18: West Dam – showing the breached section. | 21 |
| Figure 19: West Dam – showing the material within the dam..... | 22 |
| Figure 20: Nugget Pond Polishing Pond Dam – showing repairs to the dam. | 23 |
| Figure 21: Central Control Dike – showing extent of the failed tailings. | 25 |
| Figure 22: Jody's Dike – showing the location of the dike failure and the IOC Tailings System..... | 26 |
| Figure 23: Jody's Dike – showing the extent of the 2012 breach. | 27 |
| Figure 24: Jody's Dike – showing the extent of the 2013 breach. | 27 |
| Figure 25: Lawn Forebay Dam – showing eroded abutments. | 29 |
| Figure 26: Lawn Forebay Dam - showing cracked and displaced concrete. | 29 |
| Figure 27: Flooding in Lawn caused by Hurricane Igor. | 30 |
| Figure 28: Port Union Hydroelectric Development - showing erosion along the dam and the dam's steel core. | 31 |
| Figure 29: Sunny Side Water Supply Dam - showing damage to the dam..... | 32 |
| Figure 30: Bully's Pond Dam - showing the dam failure in 1995. | 34 |
| Figure 31: Granfer's Pond Dam – showing showing the dam washout and the stoplogs in the spillway..... | 35 |
| Figure 32: Hender's Brook Dam – showing dam failure in 1991. | 36 |
| Figure 33: Terra Nova Mining Water Supply Dam – showing damage to the water supply dam..... | 37 |
| Figure 34: Concrete Products Berm – showing section of the berm that breached..... | 38 |
| Figure 35: Little Bay Copper Mine Tailings Dam – showing tailings that were deposited due to the dam failure (Photo courtesy of DFO) | 39 |



APPENDICES

APPENDIX A

Listing of Dams Removed from Database

APPENDIX B

Listing of Dams Added to Database

APPENDIX C

Dam Safety Audit Sheet

APPENDIX D

Listing of Dams Updated in Database

APPENDIX E

Listing of Dams in Database with No Pictures



1.0 INTRODUCTION

Golder Associates Ltd. (Golder) was retained by the Department of Environment and Conservation, Water Resources Management Division (WRMD) to conduct an inventory and assessment of all the dams in eastern Newfoundland east of the Town of Badger. The purpose of the project was to help strengthen the province's dam safety program by updating the provincial dam inventory database. Having a comprehensive and accurate database will assist Government in developing the necessary regulatory tools to prevent dam failures in the province. The main objectives of the study included the following:

- Verify information in the current dam inventory database;
- Compile missing information for the existing records;
- Identify new dams and create records for each;
- Identify and reference dams where dam failure inundation mapping has been developed;
- Identify dams where inundation mapping should be developed;
- Identify both known and previously unknown dam failures in the province and collect associated information on the failure;
- Determine if Dam Safety Review frequency requirements according to the Canadian Dam Association (CDA) Dam Safety Guidelines and recommendations are being met by dam owners;
- Determine if Dam Safety Inspections are being undertaken and at what frequency;
- Determine if Emergency Preparedness and Response Plans have been developed according to the CDA Dam Safety Guidelines; and,
- Identify the different types of monitoring instrumentation that can be used to provide data, which can aid in evaluating the safety and operation of a dam.

The study began in late June 2015 and consisted of compiling available data, requesting information from dam owners, creating records of previously unidentified dams, verifying and updating the existing information contained within the database, identifying known and unknown dam failures in the province and performing site visits. Once these tasks were initiated the information obtained was used to complete the following: digitize the inundation mapping provided and create a GIS layer for each set of mapping, determine if dam safety reviews and inspections are being completed and at what frequency, determine if emergency preparedness plans have been developed, identify various types of monitoring instrumentation and update the WRMD dam inventory database. All of these tasks are described in further detail in the following sections.



2.0 EXISTING RECORDS VERIFICATION AND UPDATING

This phase of the project consisted of contacting dam owners, compiling received and available information, and verifying and updating existing dam inventory database records.

This phase was the most time consuming portion of the project. Tasks within this phase were being completed for the majority of the project duration. The starting point was taking the inventory given to Golder by the WRMD and reviewing each entry to verify that the contact information provided was current. To do this, the phone number for the dam owner on file was called and a request was made for an updated email address, phone number, and fax number. Through this action it was found that most of the contact information listed in the inventory was current and correct, but there were a number of listings with no contact information given, phone numbers that were out of service, or wrong phone numbers. For these cases a Google search of the owner was completed, Government listings of municipalities and local service districts were checked, and the WRMD was consulted. Most of the remaining contact information was collected by following this process. Within the entire eastern region only three (3) dam owners were unable to be contacted which include the following: the Peter's River Water Committee who owns dam #1230 Peter's River Water Supply Dam, the Trinity-Placentia Development Association who owns dam #657 Mother's Brook Dam and dam #717 Piper's Hole River Dam (although both of these dams were removed from the database after a site visit determined they were no longer existing), and the owner of dam #736 Bremigens Pond Dam. It is also important to mention that when the owners were contacted by phone they were informed that Golder was calling them in reference to the Government of Newfoundland's Dam Inventory Project and that they would be receiving a brief letter from Golder requesting information on a dam that was listed under their ownership.

Once the contact information was gathered, letters were drafted to each owner indicating what information was being requested from them for this project. Attached to Golder's letter was an additional letter to dam owners provided by Government, a map indicating the dams in each region, and the dam inventory form that they were asked to complete and return to Golder. These letters were sent to the owners via email, or in some cases by fax or postal mail if the owner did not have an email address. A target date was given in each letter based on when it was sent in an attempt to receive the replies in a timely manner. If there was no communication back from the owner within approximately one (1) month of the letter being sent, a follow-up phone call was made. If after the follow-up call there was still no reply from the owner, then a further follow-up email was sent.

Of the 289 eastern region dams in the inventory as of the start of this project, Golder received dam inventory forms for seventy-three (73) dams and notification that fourteen (14) dams should be removed from the inventory. It should be noted that of the seventy-three (73) dams that forms were received for, two (2) of these were later removed from the database and hence are also included in the fourteen (14) dams mentioned above. The information received was then reviewed and further verified with the WRMD to ensure that a dam could actually be removed from the database. A list of the dams that were removed from the database can be seen in **Appendix A**. Of all the dam owners, Newfoundland Power Inc. was the only one that did not provide any current information. Newfoundland Power is responsible for one hundred forty-nine (149) of the eastern region dams in the Government's database. It is also important to note that of all the dam owners who responded, no dam inundation mapping, dam safety inspection reports, emergency preparedness plans, emergency response plans, or an indication of any monitoring equipment was received directly from Newfoundland Power.

All information received was filed electronically and hardcopies of forms, reports, pictures, drawings, etc. received were kept as well. The forms received from the owners were first compared with the existing entries in the



database to determine any new or updated information, as well as any discrepancies. If any discrepancies were found, the owner was contacted to confirm the correct information. The dam inventory forms received were used to update the WRMD dam inventory database. To help complete this task, a binder was created that contained an updated dam inventory form for the applicable dams. All the information for a given dam was handwritten on a form in the binder with any new information to be updated in the database highlighted on each. This made for a more efficient process when updating the database.

3.0 IDENTIFICATION OF NEW DAMS

This phase of the project included identification of new dams in eastern Newfoundland, compiling the available information and creating new records for each dam.

During the project, there were eighteen (18) dams discovered in the eastern region that weren't currently in the database. A list of these dams can be found in **Appendix B**. These dams were discovered in numerous ways including: conversations with dam owners, from dam owner email replies, from site visits, and from the WRMD. Once Golder learned of a new dam, the dam owner was contacted similar to the process described in Section 2.0. The owner was sent a letter via email requesting information on the dam. Dam inventory forms were received for fourteen (14) of these new dams and were added to the binder used to update the database. The remaining four (4) new dams were also added to the inventory, but the only information entered was the dam name, its location, and in some cases the dam owner. Golder was unable to determine the owner of two (2) of these new dams: #1809 Great Rattling Brook Dam and #1810 Concrete Pool & Weir - Waterford River. Similar to the previous task, all information received was filed electronically and hardcopies of forms, reports, pictures, drawings, etc. received were kept as well.

4.0 DAM FAILURE INUNDATION MAPPING

The dam owners were asked to provide inundation mapping for each dam, if it was completed. None of the dam owners provided this information and in the vast majority of cases there was never any inundation mapping ever completed. Inundation mapping for six (6) developments were provided to Golder by the WRMD through various reports and dam safety reviews. These developments are the Barry Group Fish Plant, Cape Broyle – Horse Chops Hydroelectric Development, Heart's Content Hydroelectric Development, Port Union Hydroelectric Development, Sandy Brook Hydroelectric Development, and Bay d'Espoir Hydroelectric Development. Three (3) of these maps, dam #1348 Barry Group Water Supply Dam, dam #190 Rocky Pond Control Dam and Spillway, and dam #86 VD-3 (Victoria Dam) were digitized into GIS layers and updated into the dam inventory database by the following processes. Many of the other maps provided were not of sufficient quality to digitize.

The available inundation maps were exported as jpeg files. Using ArcGIS, UTM grid lines were created for each map that matched the existing grid lines provided on the topographical maps. The intersections of these grid lines were georeferenced and were then used as control points within ArcGIS. To create inundation flooding layers, a polygon feature class was created in ArcGIS. Flood plains that were provided on topographic maps were digitized using the CanVec Waterbody data layer. This enabled the digitizing of the shorelines to be more efficient and accurate. All the flooding data that was created for each dam from the various maps were merged together. The digitized data was then QA/QC'ed against data obtained from Google Earth and Bing Maps as well as Government NTS topographic map sheets that were downloaded from GeoGratis. Once it was determined that there were no inconsistencies in the data, it was output into a shapefile format and submitted to the WRMD via email.



One of the tasks associated with this study was to develop criteria for identifying which dams should have dam failure inundation mapping completed. The classification of a dam is intrinsically linked to the consequence of a dam failure and the incremental losses or, in some cases, the total losses. Even at the lowest level of complexity, without dam failure inundation mapping it is almost impossible to quantify in any meaningful way what the environmental loss associated with a dam failure would be; the environmental effects are equally important when trying to determine a dam classification. For example, if a dam is in a completely remote area and there is no obvious threat to population or infrastructure then detailed dam failure inundation mapping would not be required, however, the potential for environmental damage associated with a dam failure is not as easy to dismiss. The release of a reservoir could have an impact on both upstream and downstream ecosystems. Qualitative desktop studies could be performed to gather information on the types of ecosystems that could potentially be affected and may provide enough information to support the decision not to undertake inundation mapping. However, in most cases, it would be expected that there would be some identifiable effect on upstream aquatic habitats and/or terrestrial and aquatic habitats downstream and some level of additional study would likely be required to help quantify the effects, unless very conservative estimates are made. This in turn can result in increased cost to the dam owner by increasing the frequency of Dam Safety Reviews, etc. Therefore, unless it can be clearly demonstrated that the qualification of the potential environmental damages is enough to accurately characterize the incremental loss or total loss then some degree of inundation mapping may need to be completed in order to assign an accurate dam classification. The 2007 CDA Dam Safety Guidelines do not provide specific criteria regarding when inundation mapping should be completed but do provide the following statement with respect to a hypothetical dam breach, flood wave routing, inundation mapping and evaluation of impacts:

"In general, a preliminary assessment using simple and conservative procedures should be done to obtain a first approximation of the level of consequences. Complexity and accuracy should be increased if there is a need for greater detail to confirm the dam classification, support a detailed emergency response plan, or to inform risk management decisions. This approach allows for consequence classification to be used for small or obviously low consequence structures where the cost and complexity of larger, more detailed studies may not be required."

Complex and detailed dam breach analyses are only warranted for higher consequence dams, where it is clear that there is a population at risk and/or critical infrastructure or the potential for high economic losses, however, in some circumstances it may also be required for Significant consequence dams as well. These analyses are often included with and form an important part of a dam owner's dam safety management system. Decisions on whether or not a detailed dam breach analysis needs to be conducted are best left for a case by case basis where there is open communication and consultation between the dam owner and the relevant stakeholders. Very rarely are such analyses performed for dams where the consequence of failure is anticipated to be low. In these cases a dam classification can usually be supported by carefully considering the downstream environment and the likely failure flow path and downstream topography, although some basic level of inundation mapping may be required as previously discussed.

Detailed inundation mapping is more critical when there is a population at risk and there is critical infrastructure downstream of the dam. For many tailings dams the more important driver is usually the environment. With that in mind, consideration should be given to the impact of tailings and water on the receiving ecosystem; the flooding stage and limits are less critical. Tailings dams that impound a significant amount of water can have far reaching impacts like a water dam. Non-flowable tailings dams typically only impact the immediate area of failure. As a screening level estimate there are simple empirical and semi-quantitative methods for estimating the tailings discharge associated with a dam failure.



5.0 DAM FAILURES

This phase of the project included reviewing and compiling data received from dam owners and from the WRMD and completing a Google search for publicly available reports of dam failures and safety inspections. This phase of the project included all the dams in the province, not just eastern Newfoundland.

The information available for the dam failures was reviewed and brief summaries were compiled including the following information:

- Name of the dam;
- Name of the dam owner;
- Date and time of dam failure;
- Description of the dam;
- Description of the mechanism of failure and extent of breach;
- Description of damage caused by dam failure including if any lives were lost as a result of the dam failure;
- Chronological changes or repairs to the dam structure;
- Cost of dam failure;
- Pictures of failed dam; and,
- References.

This information was added to a list of dam failures that was provided by the WRMD. In some cases, additional information was found for previously identified failures. This information was added to the entries. The list and summaries of the dam failures are compiled and are presented in the following section.

Through this exercise, thirty-one (31) dams were identified that have breach or failed in the past, some of which have failed multiple times.

5.1 Dam Failure Inventory

021 Goodyear's Dam

Name: Goodyear's Dam

Owner: Nalcor Energy

The failure was observed on Friday May 15, 2015 at approximately 16:00. Exact time of failure is unknown, however it was suspected to have occurred two to three weeks prior during heavy rains and high flows in the river.

The Goodyear's dam is located approximately 2 km upstream of the Grand Falls Main Dam on the Exploits River. This is a low head dam (4.5 – 5.5 metres in height) consisting of a concrete ogee dam (~1.5 m) with a rockfill timber crib structure (~3.0 m) built on top of it. It is intended to slow down water flow to prevent frazil ice from entering the generating station intake.



The rockfill timber crib failed in two (2) locations on the south side of Goodyear's Dam. One breach was approximately 22 m in width and the second was approximately 18 m in width. The mechanism of failure is unknown but it is suspected that the heavy rains, high flows, and large chunks of ice flowing down the river weeks prior to the identification of the failure were the cause, i.e., upstream loading.

This failure caused the water levels upstream of the dam to lower for approximately 4 to 5 km and rendered the fishways on the north and south sides of the dam inoperable. There was no effect downstream and there was no risk to public safety or loss of life. The failed dam can be seen below in Figure 1.

In order for repairs to take place the water level in the Exploits River would have to be significantly lowered to undertake remedial work and all emergency repairs needed to be completed prior to winter to prevent the loss of power production at the Grand Falls Hydroelectricity Facility. It is known with some confidence that emergency repairs were completed, however the details of these repairs have not been provided to Golder.

The cost to permanently repair the damages caused by the failure was estimated to be on the order of \$20 million. In April, 2016 Nalcor issued an RFP for the detailed design of the Goodyear's Dam.



Figure 1: Goodyear's Dam – showing the two failed sections.

Third party information supplied by Department of Environment and Conservation Dam Safety Program Manager, Paula Dawe.

717 Fermeuse Water Supply Dam

Name: Dam 1- Merrymeeting Pond Fermeuse Water Supply



Owner: Town of Fermeuse

The exact time of failure is unknown however the failure was observed on January 23, 2000 by Harris and Associates and later inspected on March 14, 2000 by Newfoundland Geosciences Limited.

Dam 1 is an earth fill dam with an impervious core material and cut off trench. The side slopes are faced with rip rap and there is a concrete spillway with a corrugated overflow pipe. The dam can be seen below in Figure 2.

There was water seepage observed at the toe of the dam below the concrete spillway. A small gap had formed in the wall, allowing overflow water to pass through, underneath the control structure.

This seepage was considered evidence of a minor failure and was caught before anything more significant could have happened. There was minimal damage to the dam and there was no risk to public safety or loss of life. Figure 3 shows cracking in the concrete spillway.

It is unknown if the recommended repairs were completed to the dam. The cost to repair the seepage was estimated at approximately \$21,000.



Figure 2: Dam 1 (Merrymeeting Pond) – looking along the crest.



Figure 3: Dam 1 (Merrymeeting Pond) - cracking in spillway

The information was obtained from the report “Department of Municipal & Provincial Affairs Fermeuse Industrial Water Supply Evaluation Study” prepared by Harris & Associates Limited. This report was provided to Golder by the Department of Environment and Conservation Water Resources.

236 Joe Dennis Pond Dam and Spillway

Name: Joe Dennis Pond Dam and Spillway

Owner: Newfoundland Power

Failed between 10:00 to 11:30 am May 20, 1992

Joe Dennis Pond Dam was a homogeneous, earth fill dam with gravel and rockfill rip rap on the upstream slope for erosion protection. The dam was approximately 5.5 m in height. The water release structure included a timber bulkhead and gate set between two abutting timber cribs on the river bed. The spillway consisted of rip rap protection along the slopes with an interlocked steel sheeting in the centre of the embankment adjacent to the timber cribwork. There was a timber walkway over the spillway that is supported on steel columns set in the embankment to provide access to the crib structure. Figure 4 shows an aerial view of the original dam.

The mechanism of failure is believed to be the reoccurrence of undercutting to the upstream timber cutoff membrane of the timber cribwork outlet structure at the foundation and the subsequent washing out of the ballast.

This failure caused damage to the forebay structures, washouts and damage to a fibreglass penstock, washouts on the main access road, undermining steel penstock supports, soil washouts and infilling at the powerhouse and tailrace discharge channels. The main access road to the powerhouse was also washed out.

The chronological changes or repairs leading up to the dam failure are as follows:



- November 1990 after construction was completed in October 1990, severe leakage was noted at the gated timber cribwork outlet structure;
- The gate was left open and the leakage monitored;
- April 1991 piping was observed and temporary and permanent repairs to the outlet structure were recommended;
- Temporary repairs were completed in January 1991 which consisted of installing an improved cutoff at the upstream toe and placement of rockfilled gabion erosion protection;
- The north abutment timber cribwork was empty of rockfill ballast and was refilled;
- Rockfilled gabions were also placed at the downstream toe to allow drainage and prevent the migration of ballast material within the cribwork;
- The permanent repair was constructed in August to September 1991 which consisted of excavating the upstream face of the cribwork and the construction of a deeper timber cutoff facing which was then filled with glacial till and protected with filter cloth and riprap;
- The dam operated with the gate fully opened until the week of May 10-16, 1992 in order to impound snowmelt. The gate remained opened 10-15 mm due to an obstruction in the gate sill; and,
- Observations of increased flow and murky water were made by operators on the morning of May 19, 1992.

It is unknown if repairs were made to the original dam after the failure. Figure 5 shows the remnants of the old structure.

The cost of this failure has not been provided, but it is estimated to be in the millions of dollars range.



Figure 4: Joe Dennis Pond - aerial view of the dam from downstream.



Figure 5: Joe Dennis Pond Dam - remains of the former dam just upstream of the new structure.

This information was provided in the report "A Report on the Failure of Joe Dennis Dam Lookout Brook Development" prepared by ShawMont Newfoundland Limited in 1992 for Newfoundland Power. Additional information was provided by the Department of Environment and Conservation Dam Safety Program Manager, Paula Dawe.



453 Uncle Arthur's Brook Dam

Name: Uncle Arthur's Brook Dam

Owner: Local Service District of St. Jude's

The date and time of failure are not known, best estimates from a local representative suggest that the failure occurred approximately six (6) years ago (2010). The dam is a concrete dam with earth sides and it is used as a water supply.

The chronological changes or repairs leading up to the dam failure are as follows:

- Water was leaking through the dam and lowered the water level below the pipe intake.
- The residents that used Uncle Arthur's Brook Dam for water had little to no water.
- The leak was repaired by one of the residents of the local district who maintains this dam on a regular basis.

The cost of this failure is unknown. Pictures of the failed dam are unavailable.

Information was provided by Kelly Rubia who is a representative for the Local Service District of St. Jude's council.

648 McIvers Reservoir Dam

Name: McIvers Reservoir Dam

Owner: Town of McIvers

The original McIvers Reservoir Dam was constructed of gabion baskets and there were a few occurrences of minor failure prior to 2010, i.e., prior to 2010, when the water level was high in the brook, one or two of the gabion baskets would get dislodged in the dam. However, there was no damage caused by the failure and no loss of life or danger to the public. The gabion baskets in place prior to 2010 are seen below in Figure 6.

There were no chronological changes and the only repair to the dam structure was repositioning the gabion baskets prior to replacing the original dam structure in 2010 with a concrete structure. The cost of dam failure is unknown.



Figure 6: McIvers Reservoir Dam – showing the gabion wall

This information was provided by Warren Blanchard on behalf of the Town of McIvers.

900 Sheaves Cove Dam

Name: Sheaves Cove Dam

Owner: The Local Service District of Sheaves Cove

The exact date of failure is unknown but the dam has been experiencing issues since 2005.

The Sheaves Cove Dam consists of two structures, one is the main dam and the second is a reserve off the main structure, both are constructed out of wood. The dam can be seen below in Figure 7.

The failure mechanism was washouts caused by the rotting of the dam. This rendered one section of the dam non-functional. There was a blockage of the dam on one side and there was evidence of seepages on the downstream side. There is also erosion and shallow slope failures on the downstream slopes and sides of the dam, as well as tension cracks along the dam. The foundation is severely eroded and erosion and washouts are occurring around the dam. Figures 8 and 9 show the poor condition of the dam after the failure.

This failure has caused pollution in the surface water supply. There has been a boil order in effect since 2008

There have been no chronological changes or repairs to the dam structure and it is continuing to deteriorate.

The cost to replace the dam would be approximately \$250,000.



Figure 7: Sheaves Cove Dam - Showing the upstream side of the main dam.



Figure 8: Sheaves Cove Dam – showing deterioration of the downstream side of the main dam.



Figure 9: Sheaves Cove Dam – showing the small reserve dam and failed area.

This information was provided by Marilyn Rowe who is a representative of the Local Service District of Sheaves Cove

894 Well Cove Brook Dam

Name: Well Cove Brook Dam

Owner: Town of Anchor Point

There was a breach on February 7, 2013, the exact time of the failure is unknown.

The dam is an earth filled dam with an impermeable PVC film membrane. It is approximately 3 m high, 3 m wide at the crest and 50 m long. There is also a spillway associated with this dam. The dam is used as a water supply for the Town. Figures 10 – 13 show different areas of the dam.

The chronological changes or repairs leading up to the dam failure are as follows:

- The water levels in the reservoir went below the pipe intake due to a leak and the Town didn't have water for 24 hours.
- The location of the breach was repaired and the water was restored to the Town.

There was no damage caused by the failure and there were no injuries or lives lost. The cost of the failure was not provided. There is a Capital Works Project underway to make the necessary repairs to the dam.



Figure 10: Well Cove Brook Dam – showing reservoir.



Figure 11: Well Cove Brook Dam – showing spillway (photo 1).



Figure 12: Well Cove Brook Dam – showing spillway (photo 2).



Figure 13: Well Cove Brook Dam showing spillway on the upstream side.

This information was provided by the Town Clerk/Manager for the Town of Anchor Point and the Department of Environment and Conservation Dam Safety Program Manager, Paula Dawe.



1131 GJ-11A

Name: Dike GJ-11A

Owner: Churchill Falls (Labrador) Corporation Ltd.

The failure occurred at 8:50 pm August 10, 1971

GJ-11A is a homogeneous, till embankment dam with downstream rock protection. The structure is 175 m long and has a maximum height of 21.3 m above the bottom core trench. The maximum depth of the core trench is 5.2 m.

The dike failed as a result of ineffective grouting during construction. Flow occurred through a system of cracks in the foundation under the transition and into the downstream rock zone. The flow of water caused fine sand in the glacial till embankment to wash into the coarser transition and rockfill materials and form sinkholes. The dike after the washout can be seen in Figure 14 below.

This failure occurred during original reservoir filling, therefore the damage was minimal. Little water was released to the downstream and there was no loss of life or damage to other infrastructure. The main control structure was closed and the flow was able to be released through the adjacent spillway.

Cofferdams were constructed upstream and downstream of the area that required repairs. The dike section was excavated to bedrock which was determined to be acceptable as a foundation. A grout curtain was installed up to 12 m into the rock and was followed by reconstruction of the dike embankment. The repairs were effective and there haven't been any other issues with this dike since the project began power production in 1971.

The cost of the repair is not available. It was included in the original construction cost.



Figure 14: Dike GJ-11A – showing aftermath of the washout.



This information was provided by a representative of the Churchill Falls (Labrador) Corporation Ltd and the Department of Environment and Conservation Dam Safety Program Manager, Paula Dawe.

1201 Gullbridge Tailings Dam

Name: Gullbridge Tailings Dam

Owner: Department of Natural Resources (Mines Branch)

The failure occurred on December 17, 2012 at 7:45 am.

The dam is an earth filled dam approximately 1050 m long, 8 m high, and 6-16 m wide at the crest.

The failure was the result of slope instability, which occurred while efforts were underway to stabilize the dam, which was holding back tailings. The failure caused the pond to drain completely and a small amount of tailings were also released. The breach section was approximately 500 m away from South Brook which is a scheduled salmon river and the source of drinking water for the community of South Brook. The breached dam can be seen below in Figure 15.

The changes and/or repairs to the dam after the dam failure are as follows:

- In January 2013, Tetrattech was hired for design engineering and field inspection of repairs to the failure area of the dam to mitigate the erosion of tailings during spring runoff;
- In March 2013, Marine Contractors completed the repairs to the failure area, however, the remaining dam structure did not meet the stability requirements of the Canadian Dam Association;
- AMEC was awarded a contract for the review of alternatives and preliminary design of long term solutions for Gullbridge tailings management area;
- AMEC submitted a report that provided a description and evaluation of the closure options and recommended a preferred closure option and phased rehabilitation;
- AMEC completed the detailed design, tender packages and construction supervision for Phase I of the closure works. This work included flattening the slopes of the dam to safe slopes and widening and lowering the dam crest. This was completed in December 2013 by P&B Trucking & Rentals Inc.; and
- In 2014, AMEC was awarded a contract for site inspection and development of an action plan and cost estimate for Phase II of rehabilitation work.

The cost of the failure was not provided.



Figure 15: Gullbridge Tailings Dam – showing the breached section.

The information was provided by the Newfoundland and Labrador Department of Natural Resources (Mines Branch) and from the Department of Environment and Conservation Dam Safety Program Manager, Paula Dawe.

675 North Embankment Dam

Name: North Embankment Dam for the Consolidated Rambler Mines Project (AKA North Dam)

Owner: Department of Natural Resources

The exact date of the failure is unknown. The breach was noted by Stantec in their 2011 DSR of the Consolidated Rambler Mine. They mentioned that this breach was first reported in 2006 by AMEC.

The dam is a 350 m long earth filled dam that was constructed out of material from local borrow sites and non-acid generating rock material from the mine development. It is located at the north end of the tailings impoundment and separates the sub-aerial tailings from Muskrat Pond. At the breach location a synthetic liner was exposed at the surface and was in a deteriorated condition with numerous perforations.

It is unknown what caused the dam breach. The breach allows discharge from Muskrat Pond to the tailings area. It creates the potential for non-contact external surface water to come in contact with potentially contaminated tailings water during high water levels. The breached dam can be seen in Figures 16 and 17.

Stantec noted that the liner should be repaired and that the breach should be modified to create a stable spillway configuration that can allow water to flow without further compromising the structure. It is not known if this was ever completed.



There is no cost or lives lost associated with this minor dam breach.



Figure 16: North Embankment Dam - circa 2010-2012, looking northwest towards the breach.



Figure 17: North Embankment Dam - circa 2010-2012, looking south towards the dam.

This information was obtained from Stantec's Dam Safety Review – Consolidated Rambler Mine Newfoundland 2012 and from communications with Department of Environment and Conservation Dam Safety Program Manager, Paula Dawe.

687 West Dam

Name: Consolidated Rambler Mines West Dam

Owner: Department of Natural Resources



The exact time of the failure is unknown. The dam failure was noted during an inspection on October 16, 2013 conducted by SNC-Lavalin. It is also known that the breaches in the dam have occurred in the past and were previously repaired.

The dam is an earth filled dam that was constructed out of material from local borrow sites and non-acid generating rock material from the mine development.

The exact mechanism of failure is unknown but it is assumed to have been caused by internal erosion of the dam material or from overtopping. The breach is approximately 8 m wide near the center of the dam. There is also a section of the upstream slope on the north side of the breach that is being undermined. The breached dam is shown in Figures 18 and 19.

The breach in the dam has not created any damage other than to its structure. The breach however is allowing non-contact water from Little Rambler Pond to mix with tailings impoundment water in the tailings impoundment area, i.e. water from Little Rambler Pond is entering into the tailings area but tailings water isn't entering into Little Rambler Pond.

It was reported by the Department of Natural Resources that the breach in this dam at this location has occurred at least twice before and has been repaired twice, in 1995 and 1999. It is unknown if any remedial work has occurred since it was reported in 2013.

The cost of this dam failure is unknown.



Figure 18: West Dam – showing the breached section.



Figure 19: West Dam – showing the material within the dam.

This information was obtained from SNC-Lavalin Dam Safety Inspection 2013 Consolidated Rambler Mine, NL Report supplied by Darren Pittman from the Department of Natural Resources. Additional information was also received from the Department of Environment and Conservation Dam Safety Program Manager, Paula Dawe.

1468 Nugget Pond Polishing Pond Dam

Name: Dam #3 Polishing Pond

Owner: Rambler Metals and Mining Canada Ltd.

The exact date of the failure is unknown, however it is known that it occurred sometime between 2:00 pm January 20 and 5:00 am January 22, 2013.

Nugget Pond Dam #3 is an earth filled dam. It is constructed out of compacted impermeable till core and topped with a liner and heavy crushed stone. It is approximately 2 m high and 5.4 m wide at the crest. There is an associated spillway with this dam.

Since there was no observation of the failure, it is unknown what the exact mechanism of failure was. The breach was approximately 4.5 m long by 2.5 m deep by 3 m wide and released approximately 220,000 m³ of water.

The only damage caused by the failure was to the dam itself. There was no danger to the public or lives lost during this failure.

After the breach occurred, the following steps were taken to repair the damage:

- Core material (till) was taken from a local quarry and layered in 0.5 m increments;
- Layers were compacted with a 200 John Deere excavator to within 2 feet of the top of the dam;
- Coarser rock material was used to cap off a geotextile liner that was installed in the dam;



- The geotextile was used over the full length of the damaged section of the dam and had a 1.5 m overlay; and
- Rip rap boulders were placed on the upstream face of the dam.

The repaired dam can be seen below in Figure 20.

The cost for the dam failure is unknown.



Figure 20: Nugget Pond Polishing Pond Dam – showing repairs to the dam.

This information was taken from *Nugget Pond- Repair to Polishing Pond Dam Breach Report (Rev 1)* by West Coast Engineering Limited, 2013 which was supplied by Rambler Metals and Mining. Additional information was also provided by the Department of Environment and Conservation Dam Safety Program Manager, Paula Dawe.

424 Western Tailings Dike

Name: Western Tailings Dike

Owner: Iron Ore Company of Canada

The failure occurred on March 23, 2015 at 12:00 am.

The dike is earth filled and is composed of tailings and waste rock. It measures approximately 550 m in length, up to a maximum of 20 m in height, and is 15 m wide at the crest. The dike was not intended to be an impoundment structure, but rather a diversion structure to control the coarse tailings flow direction and deposition.

The flow from tailings lines breached the control dike. Due to the breach, the structure no longer contained the coarse tailings and the tailings flowed in a southerly direction.



Emergency repairs commenced immediately by mobilization of a local contractor. Additional height (< 2 m) was added to the dam over a period of a couple months (May and June, 2015).

The cost for the failure was approximately \$700,000.

Pictures of the failed dike are unavailable.

This information was provided by personal communication with Patrick Lauziere, Iron Ore Company of Canada, Environment and Sustainable Development Manager.

655 Central Control Dike

Name: Central Control Dike

Owner: Iron Ore Company of Canada

The failure occurred on March 20, 2015 at 12:00 am.

The dike is earth filled and is composed of tailings and waste rock. It measures approximately 2 km in length, up to a maximum of 20 m in height, and is 15 m wide at the crest. The dike is not intended to be an impoundment structure, but rather a diversion structure to control the coarse tailings flow direction and deposition.

The flow from two tailings lines eroded and breached the Central Control Dike and the Fines Trench. The failed dike is seen in Figure 21.

Due to the breach, the structure no longer contained the coarse tailings flow and the tailings flowed in the easterly direction and also breached the Fines Trench channel which carries the fines portion of the tailings discharge.

Emergency repairs commenced immediately by mobilization of a local contractor. Additional height (< 2 m) and length (< 200 m) was added to the dam over a period of a few months (March to October, 2015).

The cost for the failure was approximately \$2,000,000.



Figure 21: Central Control Dike – showing extent of the failed tailings.

This information was provided by personal communication with Patrick Lauziere, Iron Ore Company of Canada, Environment and Sustainable Development Manager.

1268 Jody's Dike

Name: Jody's Dike

Owner: Iron Ore Company of Canada

Two breach events occurred. The first occurred on September 30, 2012 and the exact date of the second breach is unknown, but it occurred during the spring of 2013.

Jody's Dike is not an engineered structure, so the construction details of the dam are unknown. It is an earth filled dike composed of tailings and waste rock to confine the coarse tailings deposition and surface water from migrating south into a fish habitat area. Figure 22 shows the location of Jody's Dike.

The summer of 2012 experienced above average rainfall during the months of August and September. Along with the additional water from the tailings, the area between the dikes (Jody's and the Northern Dike) became a catchment for water with no method of escape or disbursement of the water. Thus, a large accumulation of water occurred behind Jody's Dike, putting hydraulic pressure on the dike which caused internal erosion and seepage. A second failure in 2013 occurred during the spring melt and is assumed to have occurred from water seeping from the tailings cone through the old tailings beach southwards of the west dike and run-off raised the water level in the west part of the basin formed on the north side of Jody's Dike, increasing the hydraulic gradient in Jody's dike and/or overtopped the crest of the dike.



The 2012 failure caused an estimated 15 m long area where the dike meets the west hillside to become breached. This breach can be seen below in Figure 23. The 2013 breach occurred approximately 45 m from its west abutment (hillside). This breach can also be seen below in Figure 24.

Repairs were made to the first breach that occurred on September 30, 2012 using rock/gravel. The 2013 breach was repaired with a permanent rock-lined spillway between late August and early October of 2015. This work was performed under NL Department of Environment and Conservation, Water Resources Management division, permit number ALT7764-2014 dated Nov. 17, 2014.

The cost of repairing the 2012 failure is unknown as it was repaired using IOC internal resources. The cost of the repairs to the 2013 failure was \$1,280,000.



Figure 22: Jody's Dike – showing the location of the dike failure and the IOC Tailings System.



Figure 23: Jody's Dike – showing the extent of the 2012 breach.



Figure 24: Jody's Dike – showing the extent of the 2013 breach.

This information was provided through personal communication with Paula Dawe, Department of Environment and Conservation, Dam Safety Program Manager, and by Patrick Lauziere, Iron Ore Company of Canada, Environment and Sustainable Development Manager.



218 Lawn Forebay Dam

Name: Lawn Dam

Owner: Newfoundland Power Inc.

The exact time of the failure is unknown but it did occur while Hurricane Igor passed over Newfoundland on September 21, 2010.

The Lawn Forebay Dam is a rock masonry dam with a concrete base and an upstream and downstream concrete face. The downstream face is covered with a layer of mesh reinforced shotcrete. The dam is approximately 9 m in height. There is a penstock that is associated with this dam.

The failure was caused when extreme weather (heavy rain and wind; Hurricane Igor) forced water over the concrete dam.

The overtopping caused the abutments to be severely eroded and cracks developed in the concrete displacing sections entirely, this is seen in Figure 25. The mesh reinforced shotcrete on the crest and downstream face was damaged due to the overtopping and completely washed away the dam's downstream rockfill. The damaged concrete is seen in Figure 26. There were also damages to the penstock supports and sections of guard rail and security fence were damaged or destroyed. Flooding conditions in the area during Hurricane Igor can be seen in Figure 27.

Temporary repairs were made to the Lawn Dam in 2010 which included temporary timber cribbing to support the penstock, and a temporary water recirculation system was installed to ensure ice build-up would not be an issue during the winter.

Additional longer term repairs to the dam structure were planned which included the following:

- Construct new penstock supports;
- Replace the mesh reinforced concrete decking and walkway; and,
- Reinstate the downstream rockfill and multi-plate culvert.

This work was planned to be completed during the summer of 2011, however it is unknown if this work was completed.

The estimated cost to repair the dam was approximately \$450,000.



Figure 25: Lawn Forebay Dam – showing eroded abutments.



Figure 26: Lawn Forebay Dam - showing cracked and displaced concrete.



Figure 27: Flooding in Lawn caused by Hurricane Igor.

The above information was obtained from Department of Environment and Conservation, Dam Safety Program Manager, Paula Dawe, and the report “Port Union and Lawn Rehabilitation April 2011” by Newfoundland Power Inc., requests for information PUB-NP-189 accessed on March 21, 2016 at the following web address: <http://www.pub.nf.ca/applications/IslandInterconnectedSystem/files/rfi/PUB-NP-189.pdf>

207, 209, 210, 211, 212 (Port Union Hydroelectric Development)

Name: Whirl Pond Dam, Whirl Pond Freeboard Dike No. 1, 2, and 3 and Long Pond Dam

Owner: Newfoundland Power Inc.

The exact time of the failure is unknown. The failure occurred on September 21, 2010 during Hurricane Igor.

The impacted dams were earth filled/rock dams. The Whirl Pond Dam has a steel core. The Long Pond Dam is a rockfilled timber crib.

The failures were caused by extreme weather (heavy rain and wind; Hurricane Igor) resulting in overtopping of the dam structures.

The overtopping water caused heavy erosion along the abutments at the control gate at Long Pond Dam. The Whirl Pond Spillway exceeded the design flow (1:1,000 year flood) by 2.5 times, this caused overtopping of the Whirl Pond Dam which eroded the crest and downstream side so severely that the steel core was exposed in some areas. This can be seen below in Figure 28. The three freeboard dikes were damaged; two of them were significantly eroded by water overtopping and the third experienced minor damages from the flood wave actions. The flood waters flooded the power house damaging generators, governors, switchgear, control panels, metering panels, battery bank, battery charger, DC distribution panel, AC distribution panel, protection and control equipment as well as the building structure. The rising water levels caused damage to the downstream plant access road. The flood damaged a diesel generator beyond repair. There was no loss of life as a result of the dam failure.



Repairs to the access road were completed in 2010 to allow access to the plant during the winter season. Additional repairs that were completed to address the damage caused by the dam failure are mainly to the electrical infrastructure and are as follows:

- Civil restoration of the powerhouse building and downstream retaining wall;
- Mechanical overhaul of the two generators;
- Replacement of hydraulic governors;
- Replacement of the generator stator winding, rotor winding and exciter on G1;
- Refurbishment of the generator stator windings, rotor windings and exciter on G2;
- Refurbishment of the switchgear and circuit breakers;
- Replacement of the G1 and G2 control panels; and,
- Replacement of the battery bank and charger.

Details on the repairs to the dams has not been provided, however it was mentioned in the report that this was completed as part of the hurricane clean up in 2010. The above work was planned to be completed by September 2011.

The cost of these dam failures was estimated at \$1.65 million. This includes an estimated \$320,000 that was spent in 2010 to refurbish various dams, site cleanup and securing the site for the winter.



Figure 28: Port Union Hydroelectric Development - showing erosion along the dam and the dam's steel core.

The information was provided by the Department of Environment and Conservation, Dam Safety Program Manager, Paula Dawe and the report "Port Union and Lawn Rehabilitation April 2011" by Newfoundland Power Inc., requests for information PUB-NP-189 accessed on March 21, 2016 at the following web address: <http://www.pub.nf.ca/applications/IslandInterconnectedSystem/files/rfi/PUB-NP-189.pdf>



438 Sunnyside Water Supply

Name: Sunnyside Water Supply Dam

Owner: Town of Sunnyside

The exact time of the failure is unknown. The failure occurred on September 21, 2010 during Hurricane Igor.

The dam is a reinforced concrete earth backed structure. The dam is 4.2 m in height and the crest is 32.7 m long

The failure was caused by extreme weather (heavy rain and wind; Hurricane Igor). The floodwaters overtopped the structure along the entire length.

The dam breach caused significant damages to municipal infrastructure. The water from the breach washed away all the earthen embankments, and undermined the spillway and pump house. The damage to the dam can be seen below in Figure 29.

The repairs to the dam structure are unknown.

The cost of the dam repairs is unavailable.



Figure 29: Sunnyside Water Supply Dam - showing damage to the dam.

The information was provided by the Department of Environment and Conservation, Dam Safety Program Manager, Paula Dawe.

1348 Water Supply Dam Barry Group Inc. Fish Plant

Name: Water Supply Dam



Owner: Barry Group Inc. (Clareville)

The exact time of the failure is unknown, however it did occur on September 21, 2010 during Hurricane Igor.

The dam is an earth filled dam with a height of approximately 5 m, width of 3 m, and is 97 m long. There is an associated 3.1 m long spillway.

The dam breached due to extreme weather (heavy rains and winds; Hurricane Igor).

No significant damages occurred due to the breach. The Town of Clareville evacuated residents downstream as a precaution.

The repairs to the dam are unknown, the cost of the dam failure is unavailable and pictures of the dam are unavailable.

The information was provided by the Department of Environment and Conservation, Dam Safety Program Manager, Paula Dawe.

727 Bulley's Pond Dam

Name: Bulley's Pond Dam- King's Point Water Supply

Owner: Town of King's Point

There were two failure events. The first occurred at 4:00 pm June 8, 1995 and the second occurred during the spring of 1999.

The Bulley's Pond Dam is an earth filled dam with a concrete spillway, gate and intake structure. The dam is approximately 4.5 m high, 4.7 m wide at the crest, and 102 m long.

The first failure was caused by heavy rains from the tail end of a hurricane which was compounded with snow melt in the mountainous terrain where the headwaters originate, contributing to the runoff and overtopping of the dam. The second failure was caused by the wash out of the substandard repairs of the first failure.

The first failure in 1995 involved a 10 m section of the earth filled dam on the north side of the concrete spillway and left the community without drinking water. This failure can be seen below in Figure 30. The second failure in 1999 occurred when a 30 m section of earthen dam was washed out.

The repairs from the first failure in 1995 included backfilling of the washed out section of the dam. This work was completed by the residents of King's Point. There was no approval from the Department of Environment and Conservation or any engineering work completed because they could not secure the funds for the emergency repairs. The repairs from the second failure included repairing the existing dam structure and grouting along the underside of the spillway.

The cost of the dam failure is unavailable.



Figure 30: Bully's Pond Dam - showing the dam failure in 1995.

The information was provided by the Department of Environment and Conservation, Dam Safety Program Manager, Paula Dawe.

490 Granfer's Pond Dam

Name: Granfer's Pond Dam- Hermitage-Sandyville Water Supply

Owner: Town of Hermitage-Sandyville

The failure occurred April 13/14, 1998

The dam is a concrete faced rockfill dam approximately 3 m high, 3 m crest width, and 29 m long. The dam does have a spillway and intake structures.

The dam was washed out due to significant rainfall amounts. The exact mechanisms of failure are unknown but it is believed to have overtopped or had experienced excessive seepage, causing undermining and breaching of the structure. It should also be noted that there were three stop logs installed in the spillway to increase reservoir capacity which ultimately reduced the spillway capacity. The dam after the washout can be seen in Figure 31.

The failure caused the town to be without a water supply and have no access outside of the community.

The chronological changes or repairs to the dam are unknown. The dam was replaced then abandoned.

The cost of the failure is approximately \$3 million.



Figure 31: Granfer's Pond Dam – showing showing the dam washout and the stoplogs in the spillway.

The information was provided by the Department of Environment and Conservation Dam Safety Program Manager, Paula Dawe.

509 Hender's Brook Dam

Name: Hender's Brook Dam – Governor's Park Salmonier Line

Owner: The Wilds

There were two failures of this dam. The first occurred February 15/16, 1991 and can be seen below in Figure 32. The date and time of the second failure is unknown. In 1997, it was reported that this dam was experiencing leakages.

This is a rockfilled timber crib dam that is approximately 3 m in height, and 21 m long. There is a spillway and gates associated with this dam but the details of both are not available.

The first failure was caused by undermining of the dam structure due to the dam not being constructed to design specifications. During heavy rains, the water surged around the west dam abutment. The only details provided for the second failure in 1997 were that there were leakages in the dam.

The extent of the damages caused by the dam failures are unknown.

There were repairs completed in 1991 and 1997 to fix the failures however the details of the repairs are unavailable and the cost to repair the dam is unknown.

There are no pictures of the 1997 dam failure.



Figure 32: Hender's Brook Dam – showing dam failure in 1991.

The information was provided by the Department of Environment and Conservation, Dam Safety Program Manager, Paula Dawe.

671 Terra Nova Mining Water Supply Dam

Name: Terra Nova Mining Water Supply Dam

Owner: Department of Natural Resources (formerly Terra Nova Mining, but company is no longer in operation)

The failure occurred at approximately 3:00 am on May 16, 1992.

The dam is approximately 25 m long, 6 m high, and has a crest width of approximately 2 m. From the picture of the failure (Figure 33), the dam appears to be an earth filled dam.

The mechanism of the failure is unknown. The breach flooded the Mill quickly and the damage caused by the breach was to the Mill building and the water supply.

The details regarding the changes and/or repairs to the dam are unavailable.

The cost of the dam failure was estimated to be \$270,000.



Figure 33: Terra Nova Mining Water Supply Dam – showing damage to the water supply dam.

The information was provided by the Department of Environment and Conservations, Dam Safety Program Manager, Paula Dawe.

Concrete Products Berm

Name: Concrete Products Berm

Owner: Concrete Products (the owner at the time of the failure was Concrete Products, the current owner of this berm is unknown).

The failure occurred on August 23, 1991. The exact time is unknown. The failure can be seen below in Figure 34.

The specifications of the berm are not available, but from photographs it appears that the dam is earth filled.

The flood wave caused by the failure wave washed away the material along the hillside and exposed bedrock. The amount of damage caused by the failure is unknown. The flood wave deposited silt and debris into a community park and pool area in Holyrood.

The details of the repairs are unknown and the cost of the dam failure is unknown.



Figure 34: Concrete Products Berm – showing section of the berm that breached.

The information was provided by the Department of Environment and Conservations Dam Safety Program Manager, Paula Dawe.

Little Bay Copper Mine Tailings Dam

Name: Little Bay Copper Mine Tailings Dam

Owner: Consolidated Mining Co. (the owner of the Copper Mine at the time of the failure was Consolidated Mining Co., the current owner is unknown)

The exact date and time of the failure is unknown but it did occur in 1989; all that is known about the dam is that it was a tailings pond dam.

The mechanism of the failure was the dam washed out or “ruptured”. This failure released 30 to 50% of the tailings into Little Bay Arm marine area, as can be seen in Figure 35. The tailings were heavily contaminated with copper, nickel, zinc, iron, and manganese.

The damage caused by this failure was to the marine environment in Little Bay Arm.

Repairs to stabilize the tailings and develop a water diversion as well as rehabilitate the site were planned and began in 2004. The status of this work was not available.

The cost to rehabilitate the site was \$500,000.



Figure 35: Little Bay Copper Mine Tailings Dam – showing tailings that were deposited due to the dam failure (Photo courtesy of DFO)

The information was provided by the Department of Environment and Conservation Dam Safety Program Manager, Paula Dawe and the Department of Natural Resources publication Minfo Volume 10, No.2 Fall 2004 accessed on March 23, 2016 at the following web address:

<http://www.nr.gov.nl.ca/mines&en/publications/minfo/vol10no2.pdf>

711 L'Anse Au Clair Water Supply

Name: Park Pond Dam

Owner: Town of L'anse au Clair

The exact date and time of the failure is unknown but it did occur in 1985; the Park Pond Dam is an earth filled dam with a concrete spillway.

The dam failed because the spillway was inadequately designed for the volume of water it was required to spill.

The damage caused by the dam failure is unknown and the cost of the failure is unknown. The details on the repairs to the dam structure are unknown, but repairs were made in 1985.

Pictures of the failure are unavailable.



The information was supplied by the Department of Environment and Conservation Dam Safety Program Manager, Paula Dawe.

017 Bishop's Falls Dam

Name: Abitibi Price Dam (the current name on the dam is Bishop's Falls Dam).

Owner: Nalcor Energy (the owner at the time of the failure was Abitibi Price).

The failure occurred between 2:00 am and 6:00 am on January 14, 1983.

The dam is an earth filled and Ambersen concrete gravity dam. There are also spillways associated with the dam.

The dam failed due to phenomenal flooding that overtopped the dam and eroded the left abutment.

The damage caused by this failure was significant. 1.2 million cubic meters of material eroded, residential properties and subdivisions were damaged, the power plant was damaged, and power transformers containing PCB's were washed into the Exploits River. No loss of lives occurred as a result of the dam failure.

The details on the repairs to the dam structure are unavailable, but it is known that the entire dam was refurbished after the failure.

The cost of the dam failure was approximately \$34 million which includes the cost for the loss of Bishop's Falls Power Plant and replacement energy.

Pictures of the failure are not available.

The information was provided by the Department of Environment and Conservation Dam Safety Program Manager, Paula Dawe, and a report titled "Ice Analysis and Flood Risk Mapping Study of Bishop's Falls" prepared by Fenco Newfoundland (1990) for the Canada-Newfoundland Flood Damage Reduction Program.

The report was accessed on March 23, 2016 at the following web address:

http://www.canal.gov.nl.ca/reports/frm/FRM_Bishops_Falls/Ice_Analysis_and_Flood_Risk_Mapping_Study_of_Bishops_Falls_Main_Report.pdf

037 Newfoundland Hydro Power Canal Dike Failure

Name: HD-2 No Name Brook Diversion Dike

Owner: Newfoundland and Labrador Hydro

The exact time and date of the failure is unknown however it occurred in December 1982.

The construction of the canal was completed in 1980. The dam is an earth filled dam approximately 4 m high, 4 m wide along the crest and 920 m long.

The main mechanism of failure was caused by previous flooding which caused the liner to erode which in turn led to piping. The extent of the breach is not available. "No Name Brook" flooded, filling the canal and eventually overflowing at the spillway. This flooding occurred on several occasions.

The damage caused by the failure is unavailable and the cost of the failure is unknown.

Details of the repairs to the dam structure are unknown and pictures of the failure are unavailable.



The information was provided by the Department of Environment and Conservation Dam Safety Program Manager, Paula Dawe.

United Towns Electric Company Little St. Lawrence Dam

Name: Little St. Lawrence Dam

Owner: United Towns Electric Company

The failure occurred on August 3, 1941, the exact time of the failure is unknown.

The description of the dam is unavailable.

The failure occurred due to torrential rains. The rains caused the dam to be overtopped which then caused approximately 50 m of spillway to be washed away.

The failure caused the death of two employees of the United Towns Electric Company.

The repairs to the dam structure are unavailable and the cost of the dam failure is unavailable.

Pictures of the dam failure are unavailable.

The information was provided by the Department of Environment and Conservation Dam Safety Program Manager, Paula Dawe and from the Department of Natural Resources website which was accessed on March 23, 2016. (<http://www.nr.gov.nl.ca/nr/mines/outreach/disasters/flooding/1941.html>)

United Towns Electric Company Fall Pond Dam

Name: Fall Pond Dam

Owner: United Towns Electric Company

The exact date or time for the failure is unavailable. The failure did occur around 1939.

The dam was a timber crib forebay dam, but further description is unavailable.

The mechanism of failure and extent of the breach is unavailable.

The failure of the dam caused one person to drown.

The details of repairs to the dam structure are unavailable and the cost of the failure is unavailable.

Pictures of the failure are unavailable.

The information was provided by the Department of Environment and Conservation Dam Safety Program Manager, Paula Dawe.

Harmsworth Co. Dam Failure

Name: Harmsworth Co. Dam

Owner: Anglo-Newfoundland Development Company

The exact time of the failure is unknown, but it occurred overnight on November 1, 1907.



The main dam was a concrete structure which was used for logging. At the time, there was also a temporary cofferdam in place upstream of the main dam, while work was being completed on the main dam. The cofferdam was built from logs and was ballasted with rock and plank on its upstream side.

Heavy rain from the previous two days caused the water level of the Exploits River to rise by over 2 ft. The increased water caused two 30 ft sections of the cofferdam to break from its foundation and to be swept away with large force into the forebay dam flood gates. Water entered along the whole upstream side of the dam on the north side of the river (approximately 500 ft in length) and flooded the forebay. Water rushed down the incline at the upper end of the penstock line of excavation with great force.

The only damage caused by this failure was that approximately 100 ft of crib work being constructed along the front of the concrete dam as an apron to protect from heavy ice rafting was floated out of place. During the day, thirty men had been working on the riverbed between the cofferdam and the main dam. Any injuries or fatalities to these men were avoided due to the failure occurring at night.

Details on the repair work to the dam and the associated costs are unavailable. It was noted that the cofferdam and crib work would be replaced, the delay in work on the main dam would not be serious, and the resulting costs were not expected to be very high.

Pictures of the failure are unavailable.

This information was provided by the Department of Environment and Conservation Dam Safety Program Manager, Paula Dawe and from two news archive pages of the NL GenWeb website (http://nl.canadagenweb.org/dailynews_nov1907.htm and http://nl.canadagenweb.org/nd_freepress1907-1911.htm) which were accessed on May 19, 2016.

6.0 SITE VISIT

In the month of November and into early December of 2015, Golder completed site visits to several dams which had no pictures in the government database. It is important to note that as instructed by the WRMD, these visits did not include any Newfoundland Power dams. In total, fifty-one (51) dams were visited where pictures and coordinates of each were taken and, if possible, measurements of crest width, crest length, and maximum height were also taken, along with signs of deterioration. This task played a key role in collecting information for the inventory update. While on these site visits, if possible and practical, dam owners which had not sent Golder the requested information were visited and discussions were held about the request. These in-person discussions helped Golder receive additional responses from dam owners that may not have been received otherwise. Also during the site visits, in-person discussions with the dam owners revealed multiple dams that were not currently in the database.

7.0 DAM SAFETY REVIEWS

As part of the information request sent to the dam owners, the inventory form asked if and when a dam safety review was completed, when the next one is scheduled for, and if an emergency preparedness plan has been completed. They were asked to provide these documents to Golder for review. Golder received dam safety related documents for seventeen (17) developments. These documents included thirteen (13) dam safety reviews, three (3) flood and dam break studies, two (2) dam condition assessments, one (1) inflow design flood study, and one (1) design flood and freeboard review. Golder was also provided with two (2) emergency preparedness plans. All of these documents were provided by WRMD and not the dam owners.



From the information provided, it was Golder's mandate to determine whether the dam safety review (DSR) frequency was being met, if the dam owners addressed deficiencies and issues that were identified during the (DSR), and if emergency preparedness plans were developed and compliant with CDA guidelines. The findings of review are discussed in the following sections.

7.1 DSR Recommendations and Follow up Actions

A summary of the recommendations from the DSR's and whether the dam owners have addressed the issues are presented below. It should be noted that nine (9) of the DSR's that were provided to Golder are from Newfoundland Power Inc (NP). Newfoundland Power did not return the completed inventory form therefore the status of many of the maintenance issues is unknown. The majority of the information regarding Newfoundland Power's dams was collected through permit applications on file with the WRMD.

Bay Bulls Big Pond Dam (Dam Inventory Number 091)

This dam is owned and operated by Newfoundland Power Inc. A DSR was completed in 2004 and recommended numerous improvements to the dam structure and studies to be completed such as an inflow design flood and freeboard study. Newfoundland Power did complete this study in 2011 and Golder was given a copy of this report by the WRMD. Newfoundland Power was issued a permit (ALT8008-2015) in 2015 to complete the structural improvements to the dam which included:

- Flattening of the upstream spillway slope;
- Capping the metal spillway cut off wall;
- Replacement of the spillway riprap;
- Re-grading of the dam crest;
- Rehabilitation of the spillway channel; and,
- Public safety work.

It is unknown if this work was completed in 2015, however, Newfoundland Power did make some efforts to address the deficiencies that were identified in the 2004 DSR.

Cape Broyle – Horse Chops (Dam Inventory Numbers 139, 140, 141, and 156)

This hydroelectric development is owned and operated by Newfoundland Power Inc. A dam safety review was completed on this system in 2011. This DSR included inspections and recommendations for the structures located at Cape Broyle Pond, Horse Chops Pond and Mount Carmel Pond. Included in the DSR was a review of the issues identified in a previous 2002 review. In the 2002 report there were thirty-five (35) recommendations, seven (7) were regarding emergency preparedness plans, fifteen (15) were completed and thirteen (13) were outstanding at the time of the 2011 DSR.

In 2014, Newfoundland Power was issued a permit (ALT7634-2014) to replace the existing Cape Broyle Pond Spillway with a reinforced concrete ogee crest spillway, make improvements to the retaining walls and abutments, and add a sluice gate. These items were identified in the 2011 DSR to be fixed. However, there were also a number of items to be addressed at the Horse Chops and Mount Carmel Ponds structures as well. It is unknown



if the work to the Cape Broyle Pond Spillway was completed and if there were any actions undertaken to address the remaining issues identified in the DSR.

Cochrane Pond (Dam Inventory Numbers 92 and 93)

These structures are owned and operated by Newfoundland Power Inc and a DSR was completed in 2004. There were a number of recommendations given, however it is unknown if any action has been taken to address the recommendations.

Sandy Brook Development (Dam Inventory Numbers 229, 230, 231, 232, 233, and 234)

The Sandy Brook Development is owned and operated by Newfoundland Power Inc. and includes Sandy Brook Forebay Dam, Sandy Brook Forebay Emergency Spillway, Island Pond Diversion Dam, Sandy Lake Dam and West Lake Dam. The DSR was completed for this development in 2009. The DSR presented recommendations for all of the dams in this system. Newfoundland Power was issued a permit (ALT7659-2014) in 2014 to replace the outlet of West Lake Dam with a reinforced concrete outlet structure, make repairs to the walkway, replace rip rap and make upgrades to the metal cut off wall. It is unknown if this work was completed and if there were any attempts to complete the recommendations for the other dams in the system.

Heart's Content Hydroelectric Development (Dam Inventory Numbers 187, 188, 189, 190, 191, 192, and 193)

The Heart's Content Hydroelectric Development is owned and operated by Newfoundland Power Inc. and it includes the Heart's Content Forebay Dam, Southern Cove Pond Canal Embankment, Southern Cove Pond Dam, Rocky Pond Control Dam and Spillway, Long Pond Control Dam and Spillway, Seal Cove Pond Dam, and Packs Pond Diversion Dam. The DSR was completed in 2013. Recommendations were given for all of the dams and one recommendation mentioned that the Southern Cove Pond (Forebay) dam was scheduled to be replaced in 2014. Newfoundland Power was issued a permit (ALT7337-2014) in 2014 to replace the penstock and intake at Southern Cove Pond. It is unknown if the replacement was completed or if any efforts have been made to address the other recommendations.

Lemanche Tors Cove Hydroelectric Development (Dam Inventory Numbers 107, 108, 115 to 122, 128, and 348)

The Lemanche Tors Cove Hydroelectric Development is owned and operated by Newfoundland Power Inc. and it includes Tors Cove Pond East and West Dams and Spillway, Lemanche Canal Spillways No. 1 through 7, Lemanche Canal Embankment, and Cape Pond Dam and Spillway.

A DSR was completed in 2011. The DSR recommended a number of physical improvements that needed to be made to the spillways and other structures and it also recommended to complete geotechnical studies on the embankments. Newfoundland Power was issued a permit (ALT7654-2014) in 2014 to complete rehabilitation on spillways 1, 2, 4, 5, 6, and 7 along the Lemanche Canal, clearing of vegetation along Lemanche and Cluney's canals, re-grading and widening of the Lemanche Canal crest and downstream slope, installation of filters and drains on the downstream slope of the Lemanche Canal embankment and removal of a timber crib upstream from the canal embankment. These items addressed many of the recommendations in the DSR. It is unknown if this work was completed and if there were any efforts made to address the remaining recommendations.



Paradise River – PD-2 Paradise River Cut-Off Dam (Dam Inventory Number 69)

This dam is owned and operated by Newfoundland and Labrador Hydro. A study of the inflow design flood and freeboard requirements was completed in 2010. The recommendation from the study was to raise the perimeter embankment dam by approximately 0.6 m. A permit (ALT7498-2014) was issued to Newfoundland & Labrador Hydro in 2014 to complete this work. From the completed inventory form, it was noted that this work was completed in 2014.

Port Union Hydroelectric Development (Dam Inventory Numbers 205 to 212)

The Port Union Development is owned and operated by Newfoundland Power Inc. and includes the Second Storage Pond Dam, Port Union Canal Embankment, Whirl Pond Dam, Whirl Pond Spillway, Whirl Pond Freeboard Dikes No. 1 through 3, and Long Pond Dam.

A DSR was completed for this system in 2009. There were a number of recommendations for the system which included physical improvements to the structures and required studies. It is unknown if any of these recommendations were addressed.

Seal Cove Hydroelectric Development (Dam Inventory Numbers 180, 181, 182, 183, 184, and 1370)

The Seal Cove Hydroelectric Development is owned and operated by Newfoundland Power Inc. and includes six (6) structures which are: White Hills Pond Dam (SCV Forebay Dam), Fenelons Pond Dam, Soldiers Pond Dam/Spillway, Soldiers Pond Outlet Dam, Soldiers Pond East Freeboard Dam, and Soldiers Pond West Freeboard Dam.

The DSR was completed in 2004. There were a number of recommendations regarding the condition of the dams, some of which were noted to be in a state of disrepair. It is unknown if any actions were taken to address these recommendations.

The City of St. John's Water Supply Dams (Dam Inventory Numbers 436, 674, 754, 903, and 904)

The City of St. John's owns and operates a number of water supply dams which include Windsor Lake Dam, Beer Pond North Dam, Petty Harbour – Long Pond Dam, Beer Pond Southeast Dam, and Beer Pond Northeast Dam.

A condition assessment for the dams was completed in 2011. The assessment indicated that a number of structural repairs were needed to the dams, such as repairs to the concrete along some eroded sections, and it was recommended that a DSR be completed along with stability analyses on some of the dams. The information that was received from the City on the completed inventory form stated that permits are in place to complete the rehabilitation work that is needed. This rehabilitation work is currently underway.

Topsail Hydroelectric Development (Dam Inventory Numbers 172 to 179)

The Topsail Hydroelectric Development is owned and operated by Newfoundland Power Inc. and includes Topsail Pond (Forebay) Dam, Three Island Pond Dam, Three Arm Pond Dam, Paddy's Pond Dam, Paddy's Pond Freeboard Dam, Paddy's Pond Outlet Structure, and Thomas Pond Dam.

A DSR was completed in 2004. It provided recommendations for the dams, however it is unknown if any of these recommendations have been addressed.



Beaver Brook Antimony Mine – Old Tailings Facility (Dam Inventory Number 1192)

Beaver Brook Antimony Mine – Old Tailings Facility is owned and operated by Beaver Brook Antimony Mine Inc. A DSR of the old tailings pond dam was completed in 2012 and provided a number of recommendations. It is unknown if any of these recommendations have been addressed. It was noted in the information provided that the Old Tailings Facility is no longer in operation and all the tailings are being directed to a new facility as of September 2012.

Grand Bank Dam (Dam Inventory Number 673)

The Grand Bank Dam is owned and operated by the Town of Grand Bank as a water supply dam. A condition assessment was completed in 2014. The recommendations of the assessment were to complete a DSR, inundation studies and a review of the reservoir storage. It is unknown if these studies have been completed. Upgrades to the dam to prevent leakage are currently underway.

Barry Group Inc. Water Supply Dam (Dam Inventory Number 1348)

The Water Supply Dam is owned and operated by Barry Group Inc. as a water supply for their fish plant in Clareville.

A study was completed in 2011 which indicated that some remedial work was required for the dam. It was also recommend that geotechnical, seismic and structural studies should be undertaken and that emergency plans and an operation, maintenance and surveillance manual needed to be developed. A further recommendation was made to complete a DSR and to perform routine inspections.

Information received from the completed inventory form indicated that the remedial work of removing stop logs and raising the crest was completed in 2012. It is unknown if any of the other recommendations have been completed.

Exploits River Development (Dam Inventory Numbers 6, 21, 23, and 24)

The Exploits River Development is operated by Nalcor Energy and includes Grand Falls Main Dam, Goodyear's Dam, North Twin Dam, and South Twin Dam.

A DSR was completed on these structures in 2011. The DSR recommended further studies and remediation work to be completed on some of the dams. Upgrades to the system are currently undergoing Environmental Assessment.

Exploits Generation Dams (Dam Inventory Numbers 7, 12, 14, and 16)

The Exploits Generation Dams are operated by Newfoundland and Labrador Hydro and include a number of dams, but only the following three are in Eastern Newfoundland: Grand Falls Original Forebay Intake Structure, Grand Falls Power Canal Embankments, and Grand Falls RCC Spillway.

A DSR was completed for these dams in 2015. The recommendations were for remedial work and additional geotechnical and topographic surveys to be completed. Upgrades to the system are currently undergoing Environmental Assessment.

Minworth Tailings (Dam Inventory Number 740)

The Minworth Tailings Dam is owned by the Department of Natural Resources.



A DSR was completed in 2015 for this dam. The information that was received on the completed inventory form stated that a preliminary repair design had been submitted with the DSR but these repairs have not been completed yet. There was no indication of when these repairs would be addressed.

7.2 Dam Safety Audit Tool

In order to provide comment on the probability of occurrence of a potential dam failure, a literature review was undertaken to obtain relevant studies/methodologies which address this topic. During the review process, a document was identified which is currently in use by the Government of British Columbia and forms an important part of the government's dam safety program. The audit tool assigns a failure probability rating based on a number of criteria. This tool was modified for use with this project by including some additional questions, but the overall functionality of the tool remained unchanged. A copy of the modified audit tool has been included in **Appendix C**. Using the audit tool and the various reports that have been provided to Golder, a preliminary assessment of several of the dams contained within the eastern dam inventory database has been completed. In total, one hundred twenty-four (124) dams were assessed using the audit tool. A breakdown of the assessment results is shown in Table 1.

Table 1: Dam Safety Audit Breakdown

| Risk Level | # of Dams | Percentage |
|-----------------|-----------|------------|
| 1 – Alert | 19 | 15% |
| 2 – Caution | 28 | 23% |
| 3 – Stable | 67 | 54% |
| 4 – No Concerns | 10 | 8% |
| 5 – Effectual | 0 | 0% |

The audit tool also helps address the question of whether or not the dam safety review status is acceptable. It should be noted that in the majority of cases this question was marked as requiring further follow up. For instance, many of the DSRs indicated that the dam classification provided was provisional and required additional dam break and inundation studies in order to validate the provisional classification. Without knowing what the actual classification should be it is difficult to provide additional comment on the adequacy of the review frequency. Also, in some cases the classifications that were provided were based on an older version of the CDA guidelines and had not been updated into the new classification system. Another issue that was encountered was that most of the DSRs completed only dealt with issues that the owner requested in the scope of work that was provided to the consultant, so in some instances, aspects of a dam safety review that should have been addressed or reviewed were not, therefore it was difficult for Golder to provide confirmation that the dam safety review status was acceptable when relevant aspects of the DSR were not completed or re-evaluated using current CDA guidelines.

8.0 EMERGENCY PREPAREDNESS AND RESPONSE PLAN REVIEWS

As part of the inventory form that was sent to dam owners, it was asked if an emergency preparedness plan (EPP) and emergency response plan (ERP) had been developed. Of the completed inventory forms, only seven (7) dam owners indicated that an EPP had been completed. Golder did not receive copies of these EPPs to review. Two (2) EPPs were provided to Golder by the WRMD for review, Newfoundland Power and Newfoundland and Labrador



Hydro – Victoria Dam. Golder reviewed both of these EPPs to see if they follow the CDA guidelines. A general overview of the CDA guidelines and each of the EPPs reviewed are presented in the following sections.

8.1.1 CDA Guidelines for EPP

The 2007 CDA Dam Safety Guidelines (2013) outline requirements for EPPs. An EPP should be developed by the dam owner for use by external agencies and should define the hazards posed by the dam, the roles and responsibilities of all parties and the notifications to be made. The EPP is not a response document, but it should contain essential information such as:

- Project description including dam owner, on site personnel responsible and 24 hour telephone numbers;
- Effects of inundation, including maps with approximate travel times of flood wave/waters;
- Description of the dam including maps, figures and general overview/timing of hazardous conditions developing downstream;
- Overview of the emergency response structure; and,
- Administration and maintenance procedures for the document including review processes, testing, training and revision.

8.1.2 Newfoundland Power Dam Safety Emergency Preparedness Plan

The Newfoundland Power EPP is a general document that covers the twenty-three (23) hydroelectric developments they own and operate.

The EPP does not include specific dam details such as locations, dam type, figures, hazardous conditions downstream, etc. and inundation mapping is not included. Within the EPP there are no procedures outlined for training so that copy holders understand their roles and responsibilities in the administration and maintenance process. However, it is indicated in the EPP that Newfoundland Power has developed a Corporate Operational Procedure entitled “Testing of a Dam Safety Emergency Preparedness Plan” and that Procedure covers all aspects of test exercise, including preparation, execution, monitoring and reporting. Some additional comment on training may be included in that document.

The EPP does include notification charts, personnel responsible, alternates, and phone numbers for each of the various locations where their hydroelectric developments are located. The emergency response structure is included in the document. It includes general failure scenarios, mitigation measures, appropriate response measures and notification protocols. There is also a communications directory that includes contact information for contractors, government officials, and consultants that may need to be notified during an emergency.

There are revision and testing records included in the appendices as well as a copy of an emergency report form that is required to be filled out after an emergency.

This EPP has most of the required information as outlined in the 2007 CDA guidelines. However, it is missing inundation mapping and site specific information, both of which are required.

It should be noted that the EPP was last reviewed in 2005 before the 2007 CDA Dam Safety Guidelines were released.



8.1.3 Newfoundland and Labrador Hydro – Victoria Dam

This EPP is comprehensive. It includes a description of the project, maps, cross sections, inundation maps, and effects of inundation downstream with estimated arrival times and peak flood times.

It discusses the various types of training and testing required by employees, the review and revision process for the document, notification flow charts and communication directories. It does not mention the frequency at which the document is reviewed.

Their emergency response is summarized which includes various dam failure scenarios, notification procedures, preventative and mitigation measures, site access, and required contact numbers for outside agencies, contractors and consultants who possibly need to be contacted in case of emergencies.

Revision records and documents that are required to be filled out by outside agencies essential to support the EPP document and to be completed after an emergency response are included in the appendices.

As mentioned above, this EPP does include inundation mapping, however, the mapping was only completed for fair weather failure at full supply level (FSL).

Overall this EPP follows the CDA 2007 guidelines. However, the frequency of the review and revision of the document was not specified, which it should be.

9.0 MONITORING EQUIPMENT FOR SAFE DAM OPERATION

Surveillance of dam structures is an important aspect of their operation. Surveillance activities include both visual and instrumentation monitoring. Since each dam is unique and has specific purposes, the surveillance requirements including instrumentation are also unique.

The surveillance program and requirements are based on the failure modes of each dam. To have an effective surveillance program the person inspecting the dam should understand the hazards present, how the dam could fail, the warning signs for failure, and what should be monitored to detect a developing failure. As such, the Canadian Dam Association (CDA) does not have any minimum requirements for instrumentation monitoring, however the CDA recommends that the need for instrumentation should be systematically based on the expected dam performance and identification of parameters that need to be measured quantitatively. It should be noted that instrumentation monitoring in no way replaces visual inspections. Rather, the instrumentation is an aid to augment ongoing assessment of dam performance. According to the CDA any instrumentation installed should provide data that is necessary for the following:

- Analytical assessment and verification of design parameters related to dam behaviour, dam safety review calculations, etc.;
- Observing performance of known geologic and structural anomalies;
- Predicting future performance;
- Establishment of baseline data for determination of causes and effects; and,
- Refinement of future design.



If instrumentation is installed in a dam, it must be monitored on a regular schedule and the data must be interpreted by qualified staff on a routine basis.

There are a number of different types of monitoring instrumentation available to help assess the ever changing condition of a dam. These instrumentation methods can range from very basic to high tech and completely autonomous. The methods also vary depending on the type of dam structure present and potential failure modes. In the following sections, the instrumentation methods for different failure modes are described further.

9.1 Failure Modes

As discussed above, surveillance programs should be developed around possible failure modes of the dam. The use of instrumentation should be in addition to visual routine monitoring and provide quantitative data that can provide additional information regarding dam performance and potential failures.

The majority of dams in eastern Newfoundland are earth fill or concrete dams. Possible failure modes for these kinds of dams include the following:

- Overtopping the crest or impervious core;
- Internal erosion, specifically piping through the embankment material or foundation;
- Seismic shaking;
- Deep seated rotational failures in embankment dams;
- Sliding and overturning stability in concrete dams;
- Concrete integrity;
- Bedrock foundation stability; and,
- Bedrock abutment stability.

The above failure modes are very broad, however they all have warning signs that can be monitored using instrumentation. Some of these warning signs are as follows;

- Pore pressure and uplift pressure changes;
- Horizontal or translational movement;
- Vertical movements;
- Rotational movement;
- Crack and joint size changes;
- Stress and strain changes; and
- Water flow and quality changes.

In the following section some of the available instrumentation to monitor the failure modes will be discussed.



Overtopping the Crest or Impervious Core

Overtopping of the crest or impervious core of an embankment dam is caused by the water level in the reservoir exceeding the height of the dam or core. This can be easily monitored by using water level monitoring instrumentation. The most basic tool is a staff gauge that can be installed at the dam, however, it needs to be manually read. Other automated options include a float type water level gauge, an ultrasonic water level sensor, and a bubble water level sensor. These instruments can be easily installed near the dam.

Piping

Piping is the erosion of material either internally in the dam, or through the foundation and abutment material. It can be detected as; seepage along the face of the dam or toe (especially if the water is turbid), whirlpools upstream, boils on the surface of the dam or downstream, wet spots or leakage and the formation of sinkholes or depressions. Piezometers and flow measurements can be used to monitor the extent of piping.

Piezometers are used to monitor the phreatic level. They can be of very simple construction, consisting of a stand pipe, and require manual measurements. They can also be more technical and have data loggers installed that can be remotely monitored. There are also other types of piezometers that can be installed such as twin tube hydraulic piezometers, pneumatic piezometers, and vibrating wire piezometers.

If there is seepage or leakages around the dam caused by piping, the volume of flow should be monitored and measured. The volume can be measured using a weir. These instruments can be designed and constructed for site specific use. Other methods that can be used for measuring volume are flumes, pipe methods, and flow meters. The measuring device should be placed wherever there is evidence of seepages or leakages. This is usually close to the toe of the downstream side of the dam. If there are multiple seepages that need to be measured, the device can be placed downstream where the flow converges to measure a cumulative flow.

The quality of any water that is leaking around the dam should also be monitored. The turbidity, temperature, electro-conductivity and pH are just a few of the parameters that can be monitored. Instrumentation can be installed at the weir or other measuring device and can be remotely monitored with near real time data if necessary, similar to the water quality stations that are established throughout the province by the Department of Environment and Conservation.

It should be noted that piezometers, flow and water quality measuring devices also monitor other potential failure modes such as stability issues in slopes, concrete, abutments and bedrock foundations of dams. The wide variety of monitoring uses for piezometer and flow monitoring equipment makes these instruments versatile and cost effective for most dam owners.

Hydrometric monitoring stations can accomplish the required monitoring as described above and they can also be used to monitor inflows to the dam area to give advanced warning of potential high water levels and influx of water from spring melt, etc. These stations can be installed both upstream, to monitor inflowing water, and downstream, to monitor seepages or downstream flow, of the dams. The hydrometric stations can be remotely monitored with near real time data if necessary.

Seismic Shaking

Seismic shaking is caused by large scale earth movements such as earthquakes. Newfoundland is in a relatively low seismic area. The Geological Survey of Canada operates a Canadian National Seismograph Network Station in St. John's and Deer Lake. The information from both of these stations is adequate for the needs of dam owners.



Blasting near a dam could cause similar failures as seismic activity. It is recommended if blasting is taking place close to a dam that seismic instrumentation such as a vibrometer and accelerometer, be installed to monitor the effect on the dam.

Stability – Slope, Concrete, and Bedrock

Slope stability failures are caused by movement within the slope or foundation. This can occur on both the upstream and downstream slopes. Concrete stability failures can occur at contact boundaries that create a sliding plane or stresses on the contact boundaries and could cause a sliding or overturning failure. Bedrock stability failures can occur along a weak plane in the foundation or abutment. Both concrete and bedrock could have integrity issues and cause the materials to deteriorate and become weak. All three of these stability failure modes are grouped together in this section because they have similar warning signs such as movement and cracks and therefore have the same instrumentation requirements.

There are different types of movements that occur within a dam that may signal a potential instability in the slope, concrete or rock, such as horizontal or translational movement, vertical movement, rotational movement, and lateral movement. The formation of cracks and joints can also indicate instability. Various types of monitoring equipment that could be used to identify some of the early warning signs are described in the following sub-sections.

Horizontal Movement

Horizontal movement involves the total movement of the dam relative to its abutments or foundation. This movement can be monitored with the following instrumentation:

- Extensometers including probe (electrical and mechanical), fixed embankment, and fixed borehole which measure the change in length;
- Inclinometers including probe and in-place which measure the subsurface movements and deformations;
- Survey methods including horizontal control stations, surface measuring points and benchmarks; and,
- Time domain reflectometry.

In concrete structures, the above methods can be used but there are additional methods which are:

- Tape gauges;
- Plumb lines;
- Foundation deformation gauges;
- Tilt meters; and,
- 2D and 3D joint movement indicators.

Vertical Movement

Vertical movement is usually the result of consolidation of the embankment or foundation materials that causes settlement in the dam. Vertical movement can also be the result of heave at the toe of the dam which is caused by hydrostatic uplift pressure. Vertical movement can be monitored by the following instruments:



- Settlement plates and sensors;
- Extensometers including probe (electrical and mechanical), fixed embankment, and fixed borehole;
- Survey methods including embankment monuments, and structural measuring points;
- Inclinometers including probe and in place;
- Liquid level gauges including single point and full profile; and
- Piezometers (for hydrostatic pressures).

Rotational Movement

Rotational failure is the downward and outward movement of a mass on top of a concave upward failure surface and is typically the result of low shearing strength within the embankment materials or the foundation itself. This type of movement can be measured by the following instruments:

- Inclinometers including probe and in place;
- Tilt meters;
- Extensometers including probe, fixed embankment and fixed borehole;
- Electro level beam sensors; and,
- Surface measurement points.

Lateral Movement

Lateral movement is movement parallel with the crest of the dam and these types of movements are common in concrete arch and gravity dams. Movements can be monitored by the following instruments:

- Structural measurement points;
- Tilt meters;
- Extensometers including probe, fixed embankment and fixed borehole;
- Crack measurement devices;
- Plumb lines;
- Strain meters;
- Stress meters;
- Inclinometers including probe and in place;
- Joint meters; and,
- Load cells.



Cracks and Joints

Cracks and joints in dams are caused by movement, seasonal freeze thaw processes, and other possible failure modes such as piping. It is important to monitor these cracks and joints to determine if they are increasing or decreasing in width and length and if any displacement is occurring. Cracks and joints can be monitored using the following instruments:

- Tape gauges;
- Dial gauges;
- Crack meters;
- Reference survey points; and,
- Plaster or grout patches.

Other Instrumentation

Instrumentation can be installed in and around the dam to monitor other conditions not necessarily associated with specific failure modes. Web camera stations can be installed at dam sites to provide remote monitoring of the structure and near real time surveillance. Weather stations that monitor precipitation, snow, wind, temperature, etc. can be installed at the dam site to provide site conditions and notifications when there are heavy rains forecasted. Some of the weather stations can also be monitored remotely and have near real time data. Water quality monitoring stations can also be installed in the reservoir or in areas of concern with respect to seepage. These stations can be remotely monitored and provide near real time information if necessary. These stations would normally be installed in places such as tailings dams where contamination seepage is a concern.

9.2 Existing Instrumentation

As part of the requested information, dam owners were asked to provide Golder with dam safety review (DSR) reports. From these reports, Golder was to summarize the existing instrumentation. There were only thirteen (13) DSR's that were provided to Golder for review. Summarized below are the dams that have existing instrumentation.

Paradise River Arch Dam

The Paradise River Arch Dam is operated by Newfoundland and Labrador Hydro. This dam has six (6) piezometers installed to measure pore pressure. Three (3) are located on the left abutment and three (3) are located on the right abutment. Settlement and displacement are monitored by a forced centre setup location on the left abutment sights, two back sights in the rock face back from the dam at the right abutment. Readings are taken on three (3) collimation points, two (2) on the crest and one (1) on the cutwater in the middle of the spillway. (NLH, 2007). Seepage measurements are measured through a notched weir at the end of the apron slab and through the under-drains. NLH had also installed twelve (12) concrete thermocouples and five (5) rock thermocouples, however all of these thermocouples have been abandoned.

Heart's Content Development

The Heart's Content Development is owned and operated by Newfoundland Power Inc. and consists of Southern Cove Pond, Seal Cove Pond, Long Pond, Packs Pond, and Rocky Pond. Of these ponds, Packs Pond has a weir located adjacent to the left abutment on the right section of the dam to measure seepage. There is also a weir



located in the vicinity of a marshy area at the toe of Southern Cove Pond Dam and adjacent to the Forebay Dam right abutment to measure seepage water.

Beaver Brook Antimony Mine

The Beaver Brook Antimony Mine in Glenwood, NL has the Old Tailings Management Facility that underwent a dam safety review in 2012. There are two (2) sealed pneumatic piezometers installed to monitor water pressure in the tailings pond.

Exploits River System

The Exploits River System is operated by Nalcor Energy and consists of the following six (6) structures:

- South Twin Dam;
- North Twin Dam;
- Buchans Forebay Dam;
- Buchans Main Dam;
- Goodyear's Dam; and,
- Grand Falls Main Dam.

In the DSR report, the instrumentation installed is not listed, however it is reported that there are over 300 instruments in the database. These instruments include piezometers for pore pressure measurement, weir and flow pipes for seepage measurement, and deformation monuments for measuring horizontal and vertical movements.

Minworth Dam

The Minworth Dam is an old tailings dam that is currently owned by the Department of Natural Resources. There are currently five (5) piezometers installed in the dam to monitor water levels.

Victoria Dam

The Victoria Dam is a hydroelectric dam owned and operated by Newfoundland and Labrador Hydro. There are currently two (2) flow pipes and one (1) weir to measure seepage.

Vale Processing Plant, Long Harbour

A DSR for Long Harbour was not received for review, however, from email correspondence regarding water control failure monitoring with Long Harbour personnel, it was established that Vale has installed piezometers on some of their dams on site.

9.3 Recommended Instrumentation

There are currently no requirements to have instrumentation installed on dams. The CDA guidelines do not have specific guidance on dam instrumentation. However, there is an expectation to have instrumentation on all dams except for the lowest dam classes; i.e., Low. Keeping this in mind, the minimum instrumentation any dam should have is a water level monitor such as a staff gauge or automated level monitors as described above. Piezometers are versatile instruments that can monitor a variety of potential issues. These should also be installed in and around dams to monitor groundwater levels, upstream and downstream, and internal water levels. If there are



seepages or leaks in the dam, a weir or other flow monitoring device should be installed to measure the volume of water.

There is a growing trend that quantitative performance objectives should be defined for each dam and then they would be measured in the field. These can include trigger levels for water reservoirs and instruments installed. Quantifiable performance objectives can also help identify areas that need instrumentation for better surveillance and monitoring.

There are no requirements or general rules regarding geotechnical instrumentation. This type of instrumentation is determined on a case by case basis. The cost of the instrumentation can also be quite variable depending on the supplier, quantities, locations/accessibility and installation techniques.

10.0 UPDATING DAM INVENTORY DATABASE

Once Golder received and compiled the information from dam owners, it was possible to update the Government's Dam Inventory Database. As discussed previously, this was completed using a binder containing information on the dams that required updating, removal or addition. For dams that had information to be updated, the dam inventory forms within the binder were populated using both the information that was available in the database and new information that was received from owners in their completed dam inventory forms that they had sent to Golder. Any information on the forms that was new and should be incorporated into the database was highlighted so that it was easily identifiable. A total of seventy-two (72) dams were updated in the database. A list of these dams can be seen in **Appendix D**.

Any dam entry that was to be removed from the database had its dam inventory number recycled, meaning that all of the information for that dam was cleared from that index number and the new dam being added to the database had its information added under that same number. This limited the index numbers in the inventory and avoided adding unnecessary new entries.

The other substantial portion of the inventory update was adding pictures and relevant documents to each dam entry. Throughout the project if there were any drawings, maps, or reports received for a dam these were saved electronically. They were then attached to the respective dam entry in the Government database. Pictures were also gathered for each dam. They were collected from Government, dam safety reviews, owner replies, and site visits. There were fifty-seven (57) dams that pictures were not collected for, forty-three (43) of which were Newfoundland Power dams. A list of the dams that do not have any pictures associated with them in the database can be found in **Appendix E**. Of the dams that pictures were collected for, representative pictures of each showing the main dam structure, upstream slope, downstream slope, and any associated structures were selected to be attached to the database entries. The pictures and files already in the inventory were checked as the new pictures and files were being added to avoid including any duplicates.

The database was only accessible for updating from a Government computer so Golder personnel travelled to the WRMD's office and completed the updates there.

11.0 RECOMMENDATIONS

While completing the project, Golder developed a list of recommendations for the WRMD in relation to the Dam Inventory Database as well as the Dam and Reservoir Inventory form that was submitted to dam owners. These recommendations arise from both Golder's own experiences with the project and from speaking with dam owners.



Dam Inventory Database

The following is a list of updates and issues that we would like to bring to the attention of the WRMD for further consideration with respect to the database:

- Currently when adding/updating information in the database the user must click a button to save each section of a dam entry page individually. If the button for a given section is not clicked, that section will not be updated. For example, after entering the information in the General section of the page (project name, dam name, owner name and contact information), the user must click the “Update General Info” button before moving on and updating the Operator section. After entering the Operator information the user must then click the “Update Operator Info” button before moving on to the next section, and so on. It is easy to forget to click these buttons after every section, as they are located to the left side of the data fields, near the section title, and not below the section's data fields. They would be more easily noticed below the last data field of every section as this is in the line of sight and follows the order of the data entry fields as the user progresses through the database entry. It would be helpful to move these buttons to the end of each section so that they are easily noticed and not accidentally forgotten by the user, or to remove these buttons at each section and only have one at the end of the page to update the entire entry.
- It was noticed that some fields only accepted numerical entries and not text. If text was entered into these fields, an error page would be displayed when the “Update” button was pressed. This would result in the user having to reload the database, log back in, and relocate the dam entry they were working on from the drop down menu in the database. A good example of this issue is the Operation Parameters section. In this section, for water level, surface area, and storage volume the “Normal” field accepted both text and numbers, but the “Minimum” and “Maximum” fields did not accept text. This became problematic when entering water levels because some owners provided water levels as an elevation and some provided them as measured heights. For those given as elevations it was intended to enter these with “EL” before the number to distinguish these from a measurement, but this wasn't possible due to the error. Hence, enabling all data fields to accept both numerical and text entries to avoid future issues with circumstances such as this would be helpful.
- In certain dam entries, when entering a year into the “Date of Next Update to Dam Safety Review” field of the Dam Safety Review section, the same error as discussed above would result. To overcome this issue, the date of the next update to a dam safety review was noted in the “Remarks” field further down in the same section. It would be nice if this could be addressed so that the information can be entered into the intended field instead of the field for general remarks.
- The database currently has the 1999 CDA dam classifications in the drop down menus for both the Life Safety and Socio-Economic classifications in the Dam Safety Review section. It is our understanding that the WRMD is already aware of this and are going to update the menus with respect to the current 2007 CDA classifications.
- On a few occasions while adding file attachments to dam entries in the database, a file was added to an incorrect dam by mistake. It was also noticed that some of the attached photos that had been previously added to the database were attached to the wrong dam entry. There is currently no way for the user to correct one of these mistakes and remove an attached file from an incorrect entry; rather, a list of these cases was made and given to the WRMD to provide to the database administrator who can then delete the files. It



would save time if an option to delete incorrect file attachments was added to the database to allow the user to easily correct mistakes such as these. However, we can also appreciate that giving users the ability to delete attachments could prove problematic if the person accessing the database is not fully aware of what they are doing.

- It is recommended to include some additional sections in the database to provide more information on each dam. These sections could include Structural Design, Geotechnical Design, Dam Risk Level, and Dam Monitoring. The first two sections would provide valuable insight on the history of a dam and its initial design. A dam is given a risk level based on its failure consequence and failure probability ratings; it provides a good high level view of the status of the dam in terms of if there is any work that needs to be done to reduce its risk of failure and the urgency of the work. Dam monitoring is important in dam safety as it can help to provide a dam operator with a warning of any issues within a dam, such as seepage, which can allow for the operator to complete necessary actions to prevent a breach from occurring. Having an indication in the database of any monitoring equipment that a dam has would be very useful information in terms of dam safety.

Dam and Reservoir Inventory Form

The following is a list of updates that Golder recommends to be implemented to improve the dam and reservoir inventory form. For the most part these updates are to benefit the dam owner representatives completing the forms who may not have a technical background in this area and may not be familiar with many of the terms used on the form.

- Many owners asked to be sent an editable pdf file of the form because it would be easier, more efficient, and environmentally friendly to electronically fill out the pdf form as opposed to having to print the form, complete it, and scan it back onto their computer. For this reason, developing the form into an editable pdf format is recommended.
- It is recommended that in Section C (Dam) of the form, some reference information be provided or a link to reference information for such things as different dam types and appurtenant structures, an explanation of design criteria (return period, PMF, etc.), and clarification of the three desired dimensions along with a possible diagram to illustrate them. This would help the dam owners to gain a better understanding of the request, which would lead to a more consistent and better quality response.
- In the Operation Parameters portion of Section D (Reservoir) of the form, it was found that some owners would report water levels as elevations while other owners would report them as measured heights. It is recommended that the form indicate the desired format for reporting the water levels. This would eliminate confusion and allow for consistency in the responses.
- Also in Section D (Reservoir) of the form, it is recommended including definitions of freeboard and catchment area so that the dam owners gain a better understanding of the request. The desired freeboard, i.e., minimum or normal, should be indicated on the form as well.
- In Section E (Dam Safety Review) of the form, it was noticed that many owners did not accurately indicate the CDA classifications for a dam because they weren't aware of the considerations that are involved in classifying a dam. For this reason, it is recommended to include an excerpt from the 2007 CDA guidelines outlining the criteria for each classification and possibly some guidance on how a dam is classified. This



would ensure that the responses are much more accurate and hopefully avoid false information being reported.

- Also in Section E (Dam Safety Review) of the form, it is recommended to include points asking if Dam Safety Inspections (DSI), Operation, Maintenance & Surveillance (OMS) manuals, and Flood Inundation Mapping have been completed. It was noticed that information from these various documents would be helpful for use in this project. Along with this, it is recommended to include a statement requesting that a copy of any DSR, EPP, ERP, DSI, OMS manual, or flood inundation mapping be provided as proof of completion and to ensure that the dam owner has indicated the correct classification on the form.
- For this project, dam failure information was also requested from dam owners, but not through the use of the dam and reservoir inventory form. The request for failure information was made through a letter drafted to dam owners from Golder. Some dam owners only noticed the dam and reservoir inventory form as a priority and neglected to provide any failure information. Hence, it is recommended to include a new section on the dam and reservoir inventory form for dam failure information to ensure it is acknowledged by the dam owner. The first question in the section could request the dam owner to indicate if the dam has ever experienced a failure and, for the owner's reference, the form could briefly outline what qualifies as a failure. It could then further request the date and time of the failure, a brief description of the failure and the resulting damage, a brief description of any repair work and the associated cost, and any available pictures of the failed dam.
- Monitoring instrumentation information was also requested from dam owners during this project. Similar to the dam failure information, this request was not made through the use of the dam and reservoir inventory form, but rather through a letter drafted to dam owners from Golder. Again, some dam owners only noticed the dam and reservoir inventory form as a priority and neglected to provide any monitoring instrumentation information. Hence, it is recommended to also include a new section on monitoring instrumentation to ensure it is acknowledged by the dam owner as well. The section could first ask if there is any monitoring instrumentation associated with the dam. It could then list various types of instrumentation and request the owner to indicate which types are in use. It could also request information such as if the instrumentation is manual or automated, who operates it, and a sample of the acquired data or maintenance records.
- It was noted during the review of the documentation provided that some dam owners had failed to fill out portions of the form correctly, i.e., an owner would indicate that a DSR was completed, when in fact it was actually a dam break study, condition assessment, etc. These reports lacked some of the fundamental information that would have been provided as part of a full DSR. This was not done on purpose by the owners, but illustrates the fact that many dam owners are very unfamiliar with the questions that are being asked of them. The quality of the information in the database is largely dependent on the information provided in the dam owner's response. This also illustrates the importance of making a clear request for copies of all available documents on the inventory form itself so that the information that the dam owners provide can be further verified or follow up can be made. For example, a series of new questions on the inventory form might be; (1) has a dam safety inspection been performed? (2) if so, then when? (3) has a copy of the most recent DSI been provided with your response? If the owner indicates that a DSI was performed but is unable to provide a copy then follow up might be warranted to determine the basis for the initial confirmation and to further judge the quality and validity of the inspection. Another example where follow up would be required is if a dam owner indicates that the classification is High, but then goes on to indicate that an EPP is not required; some additional clarification should be obtained in such instances.



- To help improve the accuracy of the information one recommendation is to have a follow up call with dam owners who may have struggled with the required information or who have reported discrepancies between the original information contained in the database and what is currently being reported. This would be very worthwhile in order to have a quick QA/QC with respect to the information provided. It should also be indicated in the introductory letter that owners requiring assistance are welcome to contact the consultant's representative.
- During the process Golder also learned that several municipalities, service districts, etc., were unaware of the number of dams registered to them or that they had any dams at all. Therefore it is recommend that the initial letter also include the list of dams that are registered to the owner. This is something that Golder started to include part way through the project and it made things a lot easier going forward.
- Public Safety Assessments are another aspect of dam safety which dam owners, e.g., Nalcor, are starting to complete. Therefore a set of questions regarding Public Safety Assessments should be added to the inventory form.

12.0 CLOSURE

We trust this report meets with your current requirements. Should additional information be required, please do not hesitate to contact the undersigned at your convenience.

Yours truly,

GOLDER ASSOCIATES LTD.

Michael Morris, B. Eng., EIT.
Junior Geotechnical Engineer

Kam Shiu, P. Eng.
Principal, Senior Geotechnical Engineer

Andrew Peach, P. Geo., EP.
Senior Engineering Geologist

MM/AP/SK/ob

n:\actif\2015\3 proj\1533903 docc dams eastern nfld\5 preparation of deliverables\final report docc dam inventory_mm_ap_sk november 3, 2016.docx

Golder, Golder Associates and the GA globe design are trademarks of Golder Associates Corporation.



REFERENCES

- AMEC, 2002. Newfoundland Power Cape Broyle/ Horse Chops Hydro System Flood and Dam Break Study. Report # RD-115793-C-11.03 Rec C. Prepared for Newfoundland Power.
- AMEC, 2002. Newfoundland Power Sandy Brook Hydroelectric Development Flood and Dam Break Study. Prepared for Newfoundland Power.
- AMEC, 2002. Newfoundland Power Tors Cove/ Rocky Pond Hydro System Flood and Dam Break Study. Report Number RD-115793-C-11-06 Rev B. Prepared for Newfoundland Power.
- AMEC Foster Wheeler, 2015. Exploits Generation Dam Safety Review Final Report. Prepared for Newfoundland and Labrador Hydro.
- Canadian Dam Association (CDA), 2007. Dam Safety Guidelines.
- Department of Natural Resources, 2015. Department of Natural Resources website. For the Public/Outreach-Geological Hazards-Flooding. Accessed March 23, 2016 at <http://www.nr.gov.nl.ca/nr/mines/outreach/disasters/flooding/1941.html>
- Department of Natural Resources, 2004. Minfo Volume 10 No. 2 Fall 2004 Mine Rehabilitation Little Bay Copper Mine (Springdale Area). Accessed March 23, 2016 at <http://www.nr.gov.nl.ca/mines&en/publications/minfo/vol10no2.pdf>
- Federal Energy Regulatory Commission, 2015. Engineering Guidelines for the Evaluation of Hydropower Projects. Chapter 9 Instrumentation and Monitoring. Access on March 28, 2015 at <https://www.ferc.gov/industries/hydropower/safety/guidelines/eng-guide/chap9.pdf>
- Fenco Newfoundland, 1990. Ice Analysis and Flood Risk Mapping Study of Bishop's Falls, prepared for Canada-Newfoundland Flood Damage Reduction Program. Accessed March 23, 2016 at http://www.canal.gov.nl.ca/reports/frm/FRM_Bishops_Falls/Ice_Analysis_and_Flood_Risk_Mapping_Study_of_Bishops_Falls_Main_Report.pdf
- Harris & Associates Ltd, 2000. Department of Municipal and Provincial Affairs Fermeuse Industrial Water Supply Evaluation Study.
- Hatch, 2011. Paradise River IDF Study Final Letter. Report Prepared for Nalcor Energy.
- Hatch, 2011. Review of Design Flood and Freeboard for Bay Bulls Pig Pond- Final Letter Report. Prepared for Newfoundland Power.
- Hatch, 2011. Nalcor Energy Exploits River Dam Safety Review final Report February 2011.
- Hatch Mott MacDonald, 2011. Flood and Dam Break Study Final Report Barry Group Inc.
- Mitchelmore Engineering, 2005. 2004 Dam Safety Review Petty Harbour System. Prepared for Newfoundland Power.
- Mitchelmore Engineering, 2005. 2004 Dam Safety Review Seal Cove Hydroelectric Development. Prepared for Newfoundland Power.



FINAL REPORT - EASTERN NEWFOUNDLAND DAM INVENTORY

Mitchelmore Engineering, 2005. 2004 Dam Safety Review Topsail Hydroelectric Development. Prepared for Newfoundland Power.

Mitchelmore Engineering, 2010. 2009 Dam Safety Review Program Port Union Hydroelectric Development Final Report. Prepared for Newfoundland Power.

Mitchelmore Engineering, 2010. 2009 Dam Safety Review Program Sandy Brook Hydroelectric Development Final Report. Prepared for Newfoundland Power.

Mitchelmore Engineering, 2012. 2011 Dam Safety Review Program Cape Broyle/Horse Chops Hydroelectric Development Final Report. Prepared for Newfoundland Power.

Mitchelmore Engineering, 2012. 2011 Dam Safety Review Program Tors Cove/Rocky Pond Hydroelectric Development Final Report. Prepared for Newfoundland Power.

Mitchelmore Engineering, 2013. 2012 Dam Safety Review Newfoundland Power Heart's Content Development Heart's Content, NL. Prepared for Newfoundland Power.

Mitchelmore Engineering, 2013. 2012 Dam Safety Review Old Tailings Management Facility, Beaver Brook Antimony Mine, NL. Prepared for Beaver Brook Antimony Mine.

Newfoundland Design Associates Limited Consulting Engineers, 2012. City of St. John's 2011 Condition Assessment of Water Supply Dams. Prepared for the City of St. John's.

Newfoundland and Labrador Hydro, 2000. Dam Safety Emergency Preparedness Plan, Bay d'Espoir Hydroelectric Development Victoria Dam. Registered Copy # 27.

Newfoundland and Labrador Hydro, 2007. Dam Register

Newfoundland Power Inc., 2011. Port Union and Lawn Rehabilitation, April 2011. Requests for Information PUB-NP-189. Accessed on March 21, 2016 at <http://www.pub.nf.ca/applications/IslandInterconnectedSystem/files/rfi/PUB-NP-189.pdf>.

Newfoundland Power, 2005. Dam Safety Emergency Preparedness Plan, Standard procedures Revision # 2005-11.

Personal Correspondence with Paula Dawe, Department of Environment and Conservations, Water Resources Management Division, Dam Safety Program Manager.

Personal Correspondence with Kelly Rubia, Local Service District of St. Jude's Council Representative. December 3, 2015.

Personal Correspondence with Warren Blanchard, Town of McIvers Representative. October 30, 2015

Personal Correspondence with Marilyn Rowe, Local Service District of Sheaves Cove Representative. November 27, 2015.

Personal Correspondence with Town Clerk/Manager of Town of Anchor Point. October 15, 2015.

Personal Correspondence with Gord Hynes, Churchill Falls (Labrador) Corporation Ltd. Representative. October 19, 2015.



FINAL REPORT - EASTERN NEWFOUNDLAND DAM INVENTORY

Personal Correspondence with Darren Pittman, Department of Natural Resources (Mines Branch) representative. November 25, 2015.

Personal Correspondence with Patrick Lauziere, Iron Ore Company of Canada, Environment and Sustainable Development Manager. June 1, 2016.

ShawMont Newfoundland Ltd. 1992. A Report on the Failure of Joe Dennis Dam Lookout Brook Development. Prepared for Newfoundland Light and Power Co. Ltd.

SNC-Lavalin, 2013. Dam Safety Inspection 2013 Consolidated Rambler Mine, NL. Prepared for Department of Natural Resources.

SNC-Lavalin, 2014. Grand Bank Dam Assessment. Town of Grand Bank, NL.

SNC-Lavalin, 2015. Minworth Dam Safety Review St. Lawrence, NL Final Report. Prepared for the Department of Natural Resources.

Stantec Consulting Ltd., 2012. Dam Safety Review (DSR) Consolidated Rambler Mine Newfoundland. Prepared for Department of Natural Resources.

Texas Commission on Environmental Quality, Guidelines for Operation and Maintenance of Dams in Texas. Chapter 6 Instrumentation and Monitoring Guidelines. Accessed on March 28, 2016 at https://www.tceq.texas.gov/publications/gi/gi_357

US Army Corps of Engineers, 1995. Engineering and Design, Instrumentation of Embankment Dams and Levees, EM 1110-2-190. Accessed on March 28, 2016 at http://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/EM_1110-2-1908.pdf

West Coast Engineering Ltd., 2013. Nugget Pond- Repair to Polishing Pond Dam Breach Report (Rev.1). Prepared for Rambler Metals and Mining Canada Limited.



APPENDIX A

Listing of Dams Removed from Database



Dams Removed from Database

| Dam Index # | Project Name | Dam Name | Owner |
|--------------------|---|---|---|
| 434 | St. John's (Windsor Lake Watershed) | Little Powers Pond Dam | City of St. John's - Public Works |
| 456 | Portugal Cove - St. Philip's Water Supply | Blast Hole Pond Dam and Canal | Town of Portugal Cove - St. Philip's |
| 536 | Bull Arm Little Mosquito Pond | Impoundment Dam | Hibernia Management and Development Company Ltd. |
| 657 | Piper's Hole River Salmon Counting Fence | Mother's Brook | Trinity - Placentia Development Association |
| 676 | Bishop's Falls Stream Diversion | Unnamed Dam | Enaid Limited |
| 680 | Calvert Water Supply | Juniper Knot Brook Dam | Local Service District of Calvert |
| 692 | Indian Bay | Little Bear Cove Pond Dam | Forestry and Agrifoods Agency, Forestry Services Branch |
| 717 | Piper's Hole River Park Fishway | Piper's Hole River Dam | Trinity - Placentia Development Association |
| 734 | Hickman's Harbour Water Supply | Deans Cove Pond Dam | Local Service District of Hickman's Harbour |
| 745 | Whiteway Berm Misc | Jim Rows Pond Outlet Dam | Drover, Craig |
| 747 | Indian Bay | Indian Bay Big Pond | Forestry and Agrifoods Agency, Forestry Services Branch |
| 755 | Bull Arm | Flow Control Structure between Upper Pond and Middle Pond | Hibernia Management and Development Company Ltd. |
| 848 | Heart's Content Water Supply and Hydro | Southern Cove Pond Dam | Town of Heart's Content |
| 1570 | Quidi Vidi Lake | Fishway Channel | City of St. John's - Public Works |



APPENDIX B

Listing of Dams Added to Database



Dams Added to Database

| Assigned Dam Index # | Project Name | Dam Name | Owner |
|----------------------|---|--|--|
| 680 | Argentia Pond | Argentia Pond Dam 1 | Argentia Management Authority |
| 434 | Argentia Pond | Argentia Pond Dam 2 | Argentia Management Authority |
| 456 | Harbour Grace Water Supply | Bannerman Lake Dam and Spillway | Town of Harbour Grace |
| 536 | Placentia Backup Water Supply | Barrons Pond Dam | Town of Placentia |
| 657 | Benton Marsh (DUC Project #6864) | Benton Marsh Dam | Ducks Unlimited Canada |
| 676 | Bowring Park Duck Pond Restoration Water Control Structures | Bowring Park Fishway | City of St. John's - Public Works |
| 692 | Corduoy Brook (DUC Project #6867) | Corduoy Brook Dam | Ducks Unlimited Canada |
| 717 | Fermeuse Water Supply | Dam 1 | Town of Fermeuse |
| 734 | Fermeuse Water Supply | Dam 2 | Town of Fermeuse |
| 745 | Marystown Old Water Supply | Fox Hill Reservoir Dam No. 2 | Town of Marystown |
| 747 | Placentia Backup Water Supply | Gull Pond Dam | Town of Placentia |
| 755 | Kiwanis Pool - Conception Bay Highway | Kiwanis Pool - Conception Bay Highway | Town of Conception Bay South |
| 848 | Placentia Water Supply | Larkins Pond Dam | Town of Placentia |
| 1570 | Placentia (Dunville) Water Supply | Wyse Pond Dam | Town of Placentia |
| 1808 | Unknown | Big Long Pond Dam | Local Service District of Lower Lance Cove |
| 1809 | Unknown | Great Rattling Brook Dam | Unknown |
| 1810 | Unknown | Concrete Pool & Weir - Waterford River | Unknown |
| 1811 | Unknown | Water Supply Dam | MUN Ocean Sciences Centre |



APPENDIX C

Dam Safety Audit Sheet

PRELIMINARY

DAM SAFETY AUDIT

AUDIT CHECK SHEET

Dam: _____

Date: _____

CDA Failure Consequence Rating:

| | | | | |
|---|----|---|---|---|
| E | VH | H | S | L |
|---|----|---|---|---|

Failure Probability Rating:

| | | | |
|-----|-----|----|-----|
| Lrg | Mod | Sm | VSm |
|-----|-----|----|-----|

Risk Level:

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|

This audit is not an inspection of the dam. The dam owner is responsible for dam surveillance and inspections. This is an audit of the dam owner's dam safety program. All requested documentation must be submitted to the Department of Environment and Conservation, Water Resources Division or their representative.

DAM SAFETY REGULATION REQUIREMENTS

| | Yes | No | N/A | Follow up? |
|--|--------------------------|--------------------------|--------------------------|--------------------------|
| 1. Consequence rating appropriate? | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Alterations or hazards occurred recently? | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Owner reported any recent alterations or hazards? | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Emergency plan prepared? | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Emergency plan submitted and updated? | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Dam failure inundation mapping completed? | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 7. OMS plan prepared? | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 8. OMS plan submitted and updated? | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 9. Reservoir operation as per OMS manual? | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 10. Maintenance suitable? | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 11. Surveillance/monitoring equipment suitable? | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 12. Inspection frequency adequate? | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 13. Public safety assessment complete? | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 14. Public safety signs posted? | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 15. Dam safety review status acceptable? | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

Comments and site observations: _____

Dam owner/agent present for audit? Y ☐ N ☐

Copy given to dam owner/agent? Y ☐ N ☐

| | | |
|---|-----------|------|
| Printed name of Dam Safety Consultant/Inspector | Signature | Date |
| Printed name of Dam Owner/Agent | Signature | Date |

FAILURE PROBABILITY RATING GUIDELINES

| RATING | GENERAL GUIDELINES FOR ALLOCATING RATINGS (NOTE: Apply highest rating, only one bullet required) |
|-------------------|---|
| LARGE | <ul style="list-style-type: none"> Uncorrected design, construction, structural and/or operational deficiencies that could clearly lead to uncontrolled reservoir release. If the dam owner is actively working on an approved project to correct the deficiency the rating can be reduced to MODERATE. Owner exhibits reluctance to operate in a safe and timely manner, or is incapable of doing so; all unlicensed dams are allocated this rating. |
| MODERATE | <ul style="list-style-type: none"> Uncorrected design, construction, structural and/or operational deficiencies that could potentially lead to uncontrolled reservoir release. Owner exhibits reluctance to undertake and report on annual inspection, or is incapable of doing so. Design and operation lacks redundancy, e.g., no back-up power for electrical gates. |
| SMALL | <ul style="list-style-type: none"> Design and/or performance deficiencies may exist, but are actively monitored and are not expected to significantly increase failure potential over the near term. Design and operation exhibits redundancy |
| VERY SMALL | <ul style="list-style-type: none"> Dams that are breached, partially breached, reservoir drained or otherwise safeguarded. Failure modes analysis indicates very low probability of failure (e.g., robust concrete gravity dam). |

RISK LEVEL CHART*

| Failure Probability Rating | Failure Consequence Rating | | | | |
|----------------------------|----------------------------|-----------|------|-------------|------------------|
| | Extreme | Very High | High | Significant | Low ¹ |
| Large | 1 | 1 | 1 | 2 | 3 |
| Moderate | 2 | 2 | 2 | 3 | 4 |
| Small | 3 | 3 | 4 | 4 | 5 |
| Very Small | 3 | 4 | 4 | 5 | 5 |

1) ALERT (immediate action required):

Enhanced monitoring / consultants involved / repairs ASAP / may restrict reservoir operation / EPP reviewed / CWR or RWM notified, possible Order

2) CAUTION (considerable work to do):

Increased monitoring / planning for rehab / may modify reservoir operation / EPP reviewed / may request submission of Inspection Report (perhaps weekly), OMS, or early DSR / CWR or RWM made aware of situation

3) STABLE:

Regular owner inspections plus monitoring operation under peak loading / rehab hazardous conditions / may request submission of Annual Inspection Report, OMS, or early DSR / may audit on an increased frequency

4) NO CONCERNS:

Included in regular audit program to identify any changes / normal operation

5) EFFECTUAL (significant and low consequence dams ONLY):

Significant consequence dams included in regular audit program to monitor failure consequence only / normal operation

***Note:** The risk level chart is only a guide. If the Dam Safety Consultant deem the risk level of the dam to be different than that prescribed by the risk level chart, the rationale for the variation should be provided by the Dam Safety Consultant in the Comments & Site Observations field on the first page.

¹Low consequence dams are not included in the audit program at this time.



APPENDIX D

Listing of Dams Updated in Database



Dams Updated in Database

| Dam Index # | Project Name | Dam Name | Owner |
|--------------------|-----------------------------------|---|---------------------------------|
| 6 | Grand Falls Generating Station | Grand Falls Main Dam | Government of NL |
| 7 | Grand Falls Generating Station | Grand Falls Forebay Dam | Government of NL |
| 10 | Grand Falls Generating Station | Grand Falls Power Canal - ASB Embankment Dam | Government of NL |
| 11 | Grand Falls Generating Station | Grand Falls Power Canal - East Concrete Gravity | Government of NL |
| 12 | Grand Falls Generating Station | Grand Falls Power Canal - East Embankment Dam | Government of NL |
| 13 | Grand Falls Generating Station | Grand Falls Power Canal - Intake Dams #1, 2 & 4 | Government of NL |
| 14 | Grand Falls Generating Station | Grand Falls Power Canal - RCC Spillway | Government of NL |
| 15 | Grand Falls Generating Station | Grand Falls Power Canal - West Concrete Gravity | Government of NL |
| 16 | Grand Falls Generating Station | Grand Falls Power Canal - West Embankment Dam | Government of NL |
| 17 | Bishop's Falls Generating Station | Bishop's Falls Dam | Government of NL |
| 21 | Grand Falls Generating Station | Goodyear Dam | Government of NL |
| 23 | Grand Falls Generating Station | North Twin Dam | Government of NL |
| 24 | Grand Falls Generating Station | South Twin Dam | Government of NL |
| 68 | Paradise River | PD-1 (Paradise River Arch Dam) | Newfoundland and Labrador Hydro |



FINAL REPORT - EASTERN NEWFOUNDLAND DAM INVENTORY

| Dam Index # | Project Name | Dam Name | Owner |
|-------------|--|-----------------------------------|---|
| 69 | Paradise River | PD-2 (Paradise River Cut-Off Dam) | Newfoundland and Labrador Hydro |
| 70 | Holyrood Thermal Generating Station | QD-1 (Quarry Brook Dam) | Nalcor Energy |
| 349 | Marystown Old Water Supply | Fox Hill Reservoir Dam No. 1 | Town of Marystown |
| 350 | Clarenville Water Supply - Andrew's Pond Control Structure | Andrew's Pond Dam | Town of Clarenville |
| 351 | Torbay Water Supply | North Pond Dam | Town of Torbay |
| 359 | Fogarty's Wetland (DUC Project #6945) | Fogarty's Wetland Dam | Ducks Unlimited Canada |
| 414 | Clarenville Water Supply | Shoal Harbour River Intake | Town of Clarenville |
| 416 | Point Lance Water Supply | Point Lance Dam | Town of Point Lance |
| 423 | Bay L'Argent Water Supply | Sugarloaf Dam | Town of Bay L'Argent |
| 430 | Brighton Water Supply | Hyne's Pond Dam | Town of Brighton |
| 436 | St. John's (Windsor Lake Watershed) Water Supply | Windsor Lake Dam | City of St. John's - Public Works |
| 457 | Black Ridge Construction Pit | Black Ridge Settling Pond Dyke | Robert W. Crowley - Black Ridge Construction Ltd. |
| 510 | St. Bride's Water Supply | Northside Dam | Town of St. Bride's |
| 514 | Lushes Bight - Beaumont Water Supply | Gull Pond (Milkboy) Dam | Town of Lushes Bight - Beaumont |
| 530 | Clarenville Old Water Supply | Lower Shoal Harbour River Intake | Town of Clarenville |
| 533 | Beachside Water Supply | Anchor Brook Dam | Town of Beachside |
| 535 | Placentia Water Supply | Clarkes Pond Dam | Town of Placentia |
| 539 | Placentia (Dunville) Water Supply | Second Pond Dam | Town of Placentia |



FINAL REPORT - EASTERN NEWFOUNDLAND DAM INVENTORY

| Dam Index # | Project Name | Dam Name | Owner |
|-------------|---|-------------------------------|---|
| 548 | Clarenville Old Water Supply | Club Pond Dam | Town of Clarenville |
| 651 | Little St. Lawrence Water Supply | Butler's Brook Dam | Local Service District of Little St. Lawrence |
| 654 | Otter Pond (DUC Project #6385) | Highway Marsh Dam | Ducks Unlimited Canada |
| 669 | Jumper Brook (DUC Project #6362) | Jumper Brook Dam | Ducks Unlimited Canada |
| 670 | Arnold's Cove Water Supply | Steve's Pond Dam | Town of Arnold's Cove |
| 673 | Grand Bank Water System Extension | Grand Bank Dam | Town of Grand Bank |
| 674 | St. John's (Petty Harbour - Long Pond Watershed) Water Supply | Beer Pond North Dam | City of St. John's - Public Works |
| 678 | Municipal Pool - Legion Road | Municipal Pool - Legion Road | Town of Conception Bay South |
| 679 | Shag Pond - Argentia | Shag Pond Weir | Argentia Management Authority |
| 684 | Tizzard's Harbour Water Supply | Rocky Pond Dam | Local Service District of Tizzard's Harbour |
| 688 | Lethbridge Gully (DUC Project #6361) | Lethbridge Gully Dam | Ducks Unlimited Canada |
| 716 | Pool's Cove Water Supply | Widgeon Pond Dam | Town of pool's Cove |
| 723 | Terra Nova Resort & Golf Community | Reservoir Dam | Sports Villas Resorts Inc. |
| 726 | Queen's Cove Water Supply | Queen's Cove Water Supply Dam | Local Service District of Random Sound West |
| 739 | Milltown - Head of Bay d'Espoir Water Supply | Jersey Pond Dam | Town of Milltown - Head of Bay d'Espoir |



FINAL REPORT - EASTERN NEWFOUNDLAND DAM INVENTORY

| Dam Index # | Project Name | Dam Name | Owner |
|-------------|---|--|--|
| 740 | Minworth Flourspar Mine (OAM) | Minworth Tailings Dam | Department of Natural Resources |
| 742 | Robert's Arm Water Supply | Young's Pond Dam | Town of Robert's Arm |
| 750 | Hebron Project - Bull Arm Site | Back Cove Brook Retention Dam | Nalcor Energy - Bull Arm Fabrication Site |
| 752 | Come By Chance Water Supply | Boutcher's Brook Dam | Town of Come By Chance |
| 753 | Come By Chance Water Supply | Siding Pond Dam | Town of Come By Chance |
| 754 | St. John's (Petty Harbour - Long Pond Watershed) Water Supply | Petty Harbour Long Pond Dam | City of St. John's - Public Works |
| 808 | Fortune Water Supply | Inside Reservoir | Town of Fortune |
| 828 | Bellevue Beach Water Supply | Unnamed Dam | Local Service District of Bellevue Beach |
| 849 | Arnold's Cove Water Supply | Concrete Dam and Reservoir on Steve's Pond Brook | Town of Arnold's Cove |
| 902 | Bauline Water Supply | Bauline Dam | Town of Bauline |
| 903 | St. John's (Petty Harbour - Long Pond Watershed) Water Supply | Beer Pond Southeast Dam | City of St. John's - Public Works |
| 904 | St. John's (Petty Harbour - Long Pond Watershed) Water Supply | Beer Pond Northeast Dam | City of St. John's - Public Works |
| 905 | St. Bride's Water Supply | Southside Dam (Conway's Brook) | Town of St. Bride's |
| 928 | Exploits Regional Services Board WTP | Northern Arm Pond Dam | Exploits Regional Services Board (Host community: Grand Falls - Windsor) |
| 1192 | Beaver Brook Antimony Mine - Old Tailings Facility | Old Tailings Pond Dam | Beaver Brook Antimony Mine Inc. |



FINAL REPORT - EASTERN NEWFOUNDLAND DAM INVENTORY

| Dam Index # | Project Name | Dam Name | Owner |
|--------------------|---|---|--|
| 1348 | Barry Group Inc. Fish Plant | Water Supply Dam | Barry Group Inc. |
| 1408 | Beaver Brook Antimony Mine - New Tailings Pond Dam | Southwest Horseshoe Dam | Beaver Brook Antimony Mine Inc. |
| 1528 | Bowring Park Duck Pond Restoration Water Control Structures | Bowring Park Spillway | City of St. John's - Public Works |
| 1568 | Quidi Vidi Lake Dam & Fishway Upgrade | Quidi Vidi Flood Control Structure | City of St. John's - Public Works |
| 1569 | Quidi Vidi Lake Control Structure | Quidi Vidi Original Flood Control Structure | City of St. John's - Public Works |
| 1608 | Cottrell's Cove Water Supply | Manuels Pond Dam | Local Service District of Cottrell's Cove/Moore's Cove |
| 1609 | Harbour Breton Water Supply | Connaigre Pond Dam | Town of Harbour Breton |
| 1630 | Ocean Pond Dam | Ocean Pond Dam | Ocean Pond Projects Association |
| 1668 | Botwood Old Water Supply | Peter's River Dam | Town of Botwood |
| 1708 | Terrenceville Water Supply | Terrenceville Dam | Town of Terrenceville |



APPENDIX E

Listing of Dams in Database with No Pictures



Dams in Database with No Pictures

| Dam Index # | Project Name | Dam Name | Owner |
|--------------------|---|---|---------------------------------------|
| 13 | Grand Falls Generating Station | Grand Falls Power Canal - Intake Dams #1, 2 & 4 | Government of NL |
| 95 | Pierres Brook Hydroelectric Development | Gull Pond Freeboard Dam | Newfoundland Power Inc. |
| 96 | Pierres Brook Hydroelectric Development | Big Country Pond Dam | Newfoundland Power Inc. |
| 97 | Pierres Brook Hydroelectric Development | Big Country Pond Spillway | Newfoundland Power Inc. |
| 98 | Pierres Brook Hydroelectric Development | Rocky Pond Freeboard Dam No. 1 (North) | Newfoundland Power Inc. |
| 99 | Pierres Brook Hydroelectric Development | Rocky Pond Freeboard Dam No. 2 (South) | Newfoundland Power Inc. |
| 100 | Pierres Brook Hydroelectric Development | West Country Pond Dam | Newfoundland Power Inc. |
| 101 | Pierres Brook Hydroelectric Development | West Country Pond Spillway | Newfoundland Power Inc. |
| 103 | MOP/MRP Hydroelectric Development | Mobile Canal Embankment | Newfoundland Power Inc. |
| 105 | MOP/MRP Hydroelectric Development | Mobile Big Pond Spillway | Newfoundland Power Inc. |
| 106 | MOP/MRP Hydroelectric Development | Morris Canal Embankment | Newfoundland Power Inc. |
| 113 | TCV/ROP Hydroelectric Development | Long Pond - Middle Pond Control Structure | Newfoundland Power Inc. |
| 117 | TCV/ROP Hydroelectric Development | Lemanche Canal Spillway No. 2 | Newfoundland Power Inc. David Ball |
| 122 | TCV/ROP Hydroelectric Development | Lemanche Canal Spillway No. 7 | Newfoundland Power Inc. David Ball |



FINAL REPORT - EASTERN NEWFOUNDLAND DAM INVENTORY

| Dam Index # | Project Name | Dam Name | Owner |
|-------------|--|-------------------------------------|-------------------------|
| 140 | CAB / HCP Hydroelectric Development | Cape Broyle Freeboard Dam | Newfoundland Power Inc. |
| 141 | CAB / HCP Hydroelectric Development | Cape Broyle Intake Dam | Newfoundland Power Inc. |
| 142 | CAB / HCP Hydroelectric Development | Beaver Pond Freeboard Dam | Newfoundland Power Inc. |
| 143 | CAB / HCP Hydroelectric Development | Horsechops Canal Embankment | Newfoundland Power Inc. |
| 147 | CAB / HCP Hydroelectric Development | Fly Pond Diversion Dam | Newfoundland Power Inc. |
| 148 | CAB / HCP Hydroelectric Development | Two Arm Pond Diversion Dam | Newfoundland Power Inc. |
| 186 | Victoria Hydroelectric Development | Rocky Pond Dam | Newfoundland Power Inc. |
| 188 | Hearts Content Hydroelectric Development | Southern Cove Pond Canal Embankment | Newfoundland Power Inc. |
| 196 | NCH / PIT Hydroelectric Development | Pitman's Pond West Dyke | Newfoundland Power Inc. |
| 197 | NCH / PIT Hydroelectric Development | Ocean Pond Dyke | Newfoundland Power Inc. |
| 198 | NCH / PIT Hydroelectric Development | Moose Pond Diversion Dyke | Newfoundland Power Inc. |
| 199 | NCH / PIT Hydroelectric Development | Crooked Pond Dyke | Newfoundland Power Inc. |
| 201 | Lockston Hydroelectric Development | Rattling Pond Spillway | Newfoundland Power Inc. |
| 202 | Lockston Hydroelectric Development | Lockston Canal Embankment | Newfoundland Power Inc. |
| 203 | Lockston Hydroelectric Development | Trinity Pond Outlet Structure | Newfoundland Power Inc. |
| 204 | Lockston Hydroelectric Development | Copeley's Pond Diversion Dyke | Newfoundland Power Inc. |
| 213 | Port Union Hydroelectric Development | Wells Pond Dam | Newfoundland Power Inc. |
| 214 | Port Union Hydroelectric Development | Halfway Pond Dam - Decommissioned | Newfoundland Power Inc. |
| 217 | West Brook Hydroelectric Development | West Brook Canal Embankment | Newfoundland Power Inc. |



FINAL REPORT - EASTERN NEWFOUNDLAND DAM INVENTORY

| Dam Index # | Project Name | Dam Name | Owner |
|-------------|---|------------------------------------|--|
| 219 | Lawn Hydroelectric Development | Lawn Forebay Spillway | Newfoundland Power Inc. |
| 221 | Rattling Brook Hydroelectric Development | Rattling Brook Forebay Spillway | Newfoundland Power Inc. |
| 222 | Rattling Brook Hydroelectric Development | Rattling Lake Dam | Newfoundland Power Inc. |
| 223 | Rattling Brook Hydroelectric Development | Rattling Lake Spillway | Newfoundland Power Inc. |
| 224 | Rattling Brook Hydroelectric Development | Amy's Lake Dam | Newfoundland Power Inc. |
| 225 | Rattling Brook Hydroelectric Development | Amy's Lake Freeboard Dyke No. 1 | Newfoundland Power Inc. |
| 226 | Rattling Brook Hydroelectric Development | Amy's Lake Freeboard Dyke No. 2 | Newfoundland Power Inc. |
| 227 | Rattling Brook Hydroelectric Development | Amy's Lake Freeboard Dyke No. 3 | Newfoundland Power Inc. |
| 228 | Rattling Brook Hydroelectric Development | Frozen Ocean Lake Dam | Newfoundland Power Inc. |
| 232 | Sandy Brook Hydroelectric Development | Island Pond Diversion Dam | Newfoundland Power Inc. |
| 233 | Sandy Brook Hydroelectric Development | Island Pond Outlet Dam | Newfoundland Power Inc. |
| 365 | Terra Nova | | Town of Terra Nova |
| 415 | St. Bernard's-Jacques Fontaine Water Supply | Rattle Brook Dam | Town of St. Bernard's-Jacques Fontaine |
| 417 | Jean de Baie Girl Guide Campsite | Unnamed Dam | Jessie Shave Memorial Campsite - Craig Bennett |
| 431 | Comfort Cove Water Supply | Steady Cove Dam | Town of Comfort Cove |
| 708 | Jean de Baie Water Supply | Colleen's Pond Dam (Backup Supply) | Town of Jean de Baie |



FINAL REPORT - EASTERN NEWFOUNDLAND DAM INVENTORY

| Dam Index # | Project Name | Dam Name | Owner |
|--------------------|------------------------------------|--------------------------|--|
| 717 | Fermeuse Water Supply | Dam 1 | Town of Fermeuse |
| 734 | Fermeuse Water Supply | Dam 2 | Town of Fermeuse |
| 1328 | Whitbourne Fire Pump System | Unnamed Wooden Dam | Newfoundland and Labrador Hydro |
| 1388 | Vale Long Harbour Processing Plant | Dam 1 | Vale Newfoundland and Labrador Limited |
| 1389 | Vale Long Harbour Processing Plant | Dam 2 | Vale Newfoundland and Labrador Limited |
| 1390 | Vale Long Harbour Processing Plant | Dam 3 | Vale Newfoundland and Labrador Limited |
| 1809 | Unknown | Great Rattling Brook Dam | Unknown |
| 1811 | Unknown | Water Supply Dam | MUN Ocean Sciences Centre |

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

For more information, visit golder.com

| | |
|---------------|-------------------|
| Africa | + 27 11 254 4800 |
| Asia | + 86 21 6258 5522 |
| Australasia | + 61 3 8862 3500 |
| Europe | + 44 1628 851851 |
| North America | + 1 800 275 3281 |
| South America | + 56 2 2616 2000 |

solutions@golder.com
www.golder.com

Golder Associates Ltd.
11 Austin Street - Suite 101
St. John's, NL
A1B 4C1 Canada
T: +1 (709) 722 2695

