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WAREHAM DAM INTERIM SPILLWAY REPAIRS

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ONTARIO AUDITOR GENERAL 2022 REPORT

Wareham Dam Interim Spillway Repairs

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ABSTRACT

This project consisted of the interim repairs of the Wareham Dam spillway chute slab located in the Town of Mayo, Yukon. The photo on the cover of this magazine shows the spillway on the left abutment of Wareham Dam. The scope of the work included site investigation, interim design drawings and construction. The works were carried out in 2021 and 2022. The site investigation was to ensure that no imminent failure of the spillway was going to occur. The interim design and construction were to protect the spillway from further degradation. Interim measures will be applied until a permanent solution can be engineered and constructed.

BACKGROUND

Yukon Energy (YEC), which is a publicly owned utility and operates at an arms length from the Yukon Government, is the primary generator and transmitter of power for the Yukon. The Mayo Generation Station (MGS) is one of three hydro stations within YEC and is an integral part of the overall power supply. The Yukon grid is an isolated grid and, therefore, requires all its systems and assets to remain working for the benefit of the people of the Yukon. The MGS generates approximately 12.5 MWh from two hydro plants that are connected to the overall grid. The MGS is located approximately 10 km north of the Town of Mayo, and 400 km north of Whitehorse.

The Department of Mines and Resources, Canada retained the Montreal Engineering Company (Monenco) in 1949 to design a 3000 HP (two 1.1 MWh units) hydro-electric power plant on the Mayo River to provide power for the mining activities in Elsa, YT. The construction began in 1950 and was completed by 1952. The MGS consisted of the formation of Wareham Lake (along the Mayo River), Wareham Dam, spillway, intake, penstock, powerhouse, substation, and transmission lines.

Over the years, several issues have been identified in relation to the spillway. During the winter of 1965/66, there was leakage through the gates that caused glaciation at the dissipator and led to an overtopping event that eroded away part of the right embankment (looking downstream) and cracking of the spillway and chute. Repair works were enacted in 1966 to repair the cracking and the erosion underneath. The erosion of the foundation under the chute and wearing of the concrete surface had been noted since the early 1960s and continued to be an ongoing issue. The spillway chute has been in constant repair, and projects in 1970, 1973, 1979, 1985, and 1987 were executed to grout cracks. Movement of the spillway walls was noted in 1970 and addressed in 1976.

In the 2002 Dam Safety Review, it was identified that a concrete overtopping would be required over the spillway chute because the aggregate and joints of the chute had deteriorated to a point where there was a potential for failure of the spillway. The concrete overtopping project began in the late summer/fall of 2004, as shown in Figure 1 on page 17. Winter conditions were experienced by mid-September which led to delays in concrete pouring and requirements for constructing heating and hoarding shelters. There were also delays in the delivery of the concrete from Whitehorse and issues with the bonding agents.

The hoarding and construction techniques implemented in the overtopping project did not provide for an adequate bond to the existing concrete, even with additional reinforcing bars drilled into the existing concrete. All these effects would unknowingly lead to a catastrophic failure during the Labour Day weekend in 2020, as seen in Figure 2 on page 18.

A project was executed in the late summer of 2020 to rehabilitate one of the spillway gates as identified by a report stating that the gates required repairs to extend their useful life. The project required that only one of the gates would be operational during this period. Stoplogs were placed in front of the one gate being rehabilitated and the discharge flow was concentrated through the other gate. Within a 24-hour period, the flows increased from 39 cms to 67 cms. The shape of the spillway and the concentration of flow through one gate potentially caused enough uplift on the 2004 overtopping slab that it failed catastrophically around 3 p.m. on Sept 5, 2020. Most of the spillway overtopping ended up in the plunge pool. Andrew Bayliss of Stantec was called to come to site to perform an emergency inspection to ensure that the spillway would not fail any further. Global Rope Access (GRA) arrived a couple of days later to remove the concrete and rebars that remained, as shown in Figure 3 on page 19.

MANAGING RISK, DESIGN AND CONSTRUCTION OF INTERIM REPAIR AND WAY FORWARD

Wareham spillway provides the *Inflow Design Flood (IDF)* capacity to the Wareham Lake system. There is no other spilling structure at Wareham Lake which can pass IDF or spring freshet. If the spillway is not operatable during flood, the lake water levels would rise and eventually overtop the Wareham dam. Being an earthfill dam, the overtopping of the dam is not an option, as this is main failure mode of earthfill dams. Therefore, the inoperability of the spillway during flood increases the risk profile of the Wareham dam significantly.

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To avoid any further damage and manage failure risk before next spring freshet, YEC planned an interim repair and monitoring until the permanent repairs could be completed. To complete these repairs, YEC had three major tasks to complete in just seven months (October 2020 to April 2021), before the spring freshet of 2021. The first task was to procure the services of a consulting engineer (the engineer) and a contractor to carryout the design and construction of the repair. The second was to investigate the root causes of this failure, which would be the design basis of the repairs. The third was to design and construct the interim repairs. One of the main challenges was the procurement of the services of a capable engineer and contractor who could complete the project within tight deadlines.

As mentioned earlier, the root cause analysis indicated that the major cause of failure during the 2020 event was likely stagnant pressure. This pressure might have built up due to water ingress into the two layers of new overtopping (2004 repair) concrete and old concrete (original construction in 1952) through unsealed expansion joints. The inadequate bond between new and old concrete due to poor construction practises and high concentrated flow conditions through one gate also contributed to the failure of the chute slab. The sealant in the expansion joints was deteriorated to the extent that it was not effective anymore. No waterstops were installed in the joints during 2004 repairs. These waterstops are great defence against water infiltration. The chute slab does not have a drainage system to dissipate uplift pressure. This stagnant pressure or hydraulic jacking is suspected to have caused structural failures at other chute spillways in North America as well, the most notable being the Oroville Dam spillway (Wahl and Frizell, 2020; Wahl, 2020).

The 2020 event exposed the old concrete of the chute slab which was suspected to be in unacceptable condition and was repaired with an overlay layer in 2004 repairs. Therefore, the old concrete is more susceptible to damage under flow conditions. This event also exposed large voids and rebars in the old slab. At some places, these voids were deep enough that they exposed the bedrock to flow. Monenco indicated in their 1990 investigation of the stability of the structure that the foundation bedrock is mostly quartzite, interbedded with thin shales and muscovite.

The bedrock at the downstream end was weathered and deteriorated under the dissipation structure. There were some remnants of the new overlay concrete layer from the 2004 repairs which did not rip apart during the 2020 event and was very much intact.

The water infiltering from the joints and through the deep voids may also damage the thinly bedded foundation rock and cause failure of the dissipation structure and walls. The overall condition of the bedrock under the spillway was unknown at the time of these repairs. The toe of the earthfill dam is on the right side of the chute and dissipation structure. The failure of the spillway chute and dissipation structure may also undermine the toe of the dam and cause dam failure.

The engineer and contractor visited the site in early October to collect data for the design basis. Based on root cause analysis and site observations, the project team decided to carry out the repair of the areas of deep voids and spalled areas of the slab, sealing the open joints and installing steel protection to protect the edges of the leftover overlay concrete layer from further damage.

To meet project schedule deadlines and site conditions, the project team came up with an innovative solution rather than using conventional concrete repair methods. The project team designed steel plates on rubber pads for all major voids and spalled areas with grouting afterwards instead of conventional concrete. Large plates with shear studs were installed over the deep voids, which were grouted from the top in the cold weather. The project team accepted the risk of low strength concrete due to some

Figure 2. 2020 Flood Event | *Crue de 2020*

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freezing, as the primary objective of this grout was to fill the void and avoid any excessive vibration of the plates due to discharge flow.

The engineer estimated all the flow regimes and estimate the maximum water velocity and static head in the chute slab. These estimates of the velocity and static head were the basis of the design the steel plate sizes and anchors. The anchor nuts were torqued to avoid any fatigue damage and vibration.

The engineer completed the design of the repairs before December 2020 and issued design sketches with enough details for construction. This saved the time of preparing standard construction drawings. YEC mobilized the contractor in December to complete the work in two stages (December 2020 and April 2021) as the temperature was relatively mild in April. However, this window in April is short due to spring freshet, therefore some work was completed early in December 2020 (Figure 4). The works in December were hampered by extreme cold and leakage through the gates. The construction team did not have all the adequate tools to perform the works and were much better prepared in April.

The steel plates on rubber pads were installed on the joints to provide joint sealing. Hydrotite waterstops were also

Figure 4. Work of Interim Repair in progress December 2020 | *Travaux de réparations temporaires en cours en décembre 2020*

installed in all open joints to prevent further water infiltration to the foundation below. Bevelled nuts with some torque were used to avoid loosening of the nuts and fatigue damage. Due to construction challenges and supply issues, the idea of countersunk nuts was dropped (see Figure 5 on page 21).

A two-steel angle section pair with field welding was used along the vertical edges of the concrete that remained intact during 2020 event. Grinding of the existing concrete to receive the steel plate/ steel angles was a great challenge for the construction team due to harsh winter conditions and water leaking from the gates and falling from the sides due to spring thaw in April.

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The project team faced many challenges and some of them are discussed here. Wareham spillway is located at a remote site near the village of Mayo in Yukon and supply of concrete in winter in this area is quite a challenge. The winter concreting with all the heating and hoarding would have been difficult and very expensive to accomplish within the project deadlines.

The project was completed during the peak of the COVID-19 pandemic, at a time when no vaccine was available. YEC managed all the necessary government approvals for the travel of the team and managed the safe site visits during design and construction. COVID-19 also slowed down the supply of some of the project materials, and the project team had to select materials that had relatively short lead times.

Collaboration and trust among the team of the engineer, contractor, and the owner was very important to meet the tight deadlines of these emergency repairs. The owner built and led the team of the engineer, contractor and their own personnel effectively. They provided the necessary resources for the success of the project. The owner's leadership and role were key here to achieve the goals of this emergency project. The owner's valuable experience at site, especially during the winter, helped the team understand in advance what challenges the project might face.

One of the key factors of the success of this project was to bring the engineer, the contractor, and the owner's project and operational team to the table early and let them find the solutions to the project challenges as one team. The team carried out many modifications and scope changes during the design and construction phases to meet the project objectives and deadlines.

As this was an interim repair, carried out to avoid any immediate damage, it is important to carry out a comprehensive site visit every year after spring freshet and plan any additional repairs to keep the spillway operational. YEC also planned regular site visits to continue monitoring of the spillway throughout the year.

The 2022 post spring freshet site visit indicated new areas of damage due to non uniform flow and uneven chute surface. However, the earlier repair was deemed to be intact and performing as expected. In 2022, YEC completed the repairs of the new areas with the help of the same team of the engineer and contractor. Based on lessons learned and the experience of the team, this repair was completed relatively quicker and early in schedule and at a cost savings for both time and materials.

YEC plans to do either permanent repairs or to replace this spillway, which is a tremendous undertaking from both a project planning and financial perspective. Therefore, YEC will continue their interim repairs each year based on the damage indicated by the engineering inspection after each spring freshet until a more permanent solution is implemented. ■