Kugaaruk Sewage Lagoon Dam Safety Review

(FINAL)

Prepared for:
Government of Nunavut
Community and Government Services

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Sign-off Sheet

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Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Executive Summary

This draft report summarizes a Dam Safety Review (DSR) undertaken by Stantec for the Kugaaruk Lagoon, Nunavut. The visual inspection in fall 2016 of the Kugaaruk Lagoon indicated that the northwest and northeast berms do not show any visible indicators of slope instability. However, at the time of the inspection, four zones of seepage were observed between El. 22.0 and 22.7 m on the southwest berm. This seepage has been observed since October 2014.

It is concluded that the lagoon berm structure is not currently performing satisfactorily; is not water-tight as required for a retention lagoon; and it is currently releasing unauthorized, uncontrolled, and untreated sewage discharge into an area that is not a designated sewage discharge area. In addition, as a result of this seepage, internal erosion may be occurring within the berm that could lead to unstable conditions in the future.

It is recommended that the Kugaaruk Lagoon be classified as a **"significant"** consequence structure.

The 2016 inspection observed the absence of sagging, sloughing or other deformation of the perimeter berms, which suggests that the berms remain geotechnically stable. It is indeterminate how any instability may progress or over what timeframe. If seepage accelerates, the opportunity for material loss increases, which may negatively impact the geotechnical stability of the berms. The monitoring of the seepage flow, and the berm condition should be continued to determine any evidence of berm deterioration. It would be beneficial to implement a more accurate method to estimate the leakage from the lagoon, such as monitoring the change of the water level in the lagoon over a period of weeks.

The issues of concern that have been identified as part of this DSR are summarized below. The priority rating is a subjective assessment of issue seriousness from which the Owner should focus their short to longer term actions.

(**Table 4 from conclusions**)

Ref	Description	Action / Recommendation	Report Section	Priority Rating
1	Confirmation of consequence classification	Discussion and agreement with GN on the classification and the implications.	5.0	N/A
2	Difference of 2.35 m between benchmark survey elevations	Discrepancy clarified and noted on topographic survey information from Stantec.	6.1.1	Low
3	Seepage observed at toe of southwest berm	Investigation of the seepage and remediation of the berm.	6.1.2	High
4	Two animal borrows observed on upstream crest of southwest berm	Humanely remove the animals and infill the borrows. Discourage future denning.	6.1.2	High
5	Periodic discharge pipe not operational	Owner has abandoned discharge pipeline and is using a pumped discharge for the lagoon.	6.1.2	N/A
6	Drawdown capacity unknown	The design assumed a 300mm diameter discharge pipe. The Owner is currently using a pipe/pump system. The time for drawdown using the pumping system is 2 to 3 weeks.	6.1.2	Medium
7	No fences around lagoon	Install fencing around lagoon to restrict uncontrolled access due to proximity to public road and camping area.	6.1.2	High
8	Limited warning signs	Install additional warning signs around perimeter of lagoon in potential access areas (minimum 4 signs). Install additional sign near camping area south of lagoon to warn of sewage discharge.	6.1.2	High
9	No formalized emergency preparedness plan	Prepare a formalized process that provides roles, responsibilities, and clear lines of communication.	6.2	Medium
10	No formalized emergency response plan	Prepare a formalized process that provides roles, responsibilities, and clear lines of communication.	6.2	Medium
11	Operation and Maintenance Manual was not available for review during site inspection	Confirm availability of Operation and Maintenance manual for facility, and if no manual is available, proceed with the preparation of document	6.2	Medium

1.0 INTRODUCTION

1.1 BACKGROUND

The Kugaaruk Sewage lagoon was constructed by the Government of Nunavut (GN) to provide sewage treatment through retention, and a seasonal discharge to a wetland adjacent to the lagoon for the sewage from the Hamlet of Kugaaruk. Seepage was observed at the toe of the southwest berm in October 2014 by Hamlet staff. The GN retained the services of Stantec in 2015 to investigate the seepage and develop remedial options to control and stop the seepage. The options were presented to the GN in June 2016 (Stantec, 2016). An inspection of the WSL in mid-August 2016 was conducted by the GN. A visual review by Stantec of the findings and photographs of this inspection indicated that the seepage had 'substantially' increased.

Previous DSR's were conducted for the Kugaaruk lagoon in 2010 by AMEC and in 2014 by exp Services Inc. The typical frequency between DSRs for most water retention structures is every 10 years based on a significant consequence dam (CDA, 2013). However, the CDA Guidelines (2013) state"…*during the dam's operational life, any significant changes that might affect its safety should trigger a DSR or appropriate investigation*". The increased seepage at the toe can be defined as a "*discovery of unusual conditions*" under CDA Guidelines (2013; 2016) and therefore, is a justification for the GN retaining Stantec to undertake this DSR.

This project has been executed under the Standing Offer Agreement (SOA) 2013-33 between Stantec and the GN. The scope of this DSR is to:

- Review the available design and construction information
- Determine the consequence of dam failure
- Review the previous DSRs to determine if there has been any change in the condition of the lagoon or that previous recommendations have been implemented.
- Visually inspect the lagoon and the surrounding area
- Interview personnel from the GN and Hamlet of Kugaaruk
- Review the dam safety management system

The following tasks have not been undertaken for this DSR:

- Geotechnical investigation and analysis of the berm stability or seepage
- Dam breach and flood inundation analysis
- Inspection of the drainage outfall

1.2 REGULATORY CONTEXT

The regulation of dams in Canada is a provincial or territorial responsibility. For the purposes of the Kugaaruk DSR, in the absence of any other explicit regulations, the Nunavut Water Act was considered to be the appropriate regulatory reference. Through the Nunavut Water Act, the Nunavut Water Board (NWB) has "*responsibilities and powers over the use, management and regulation of inland water in Nunavut and its objects are to provide for the conservation and utilization of waters in Nunavut*". Its "*primary function is to license uses of water and deposits of waste*". The Kugaaruk WSL is classified as a "*waste disposal or water system for a municipality*".

The Nunavut Water Act does not provide a definition as whether the waste disposal system constitutes a 'dam' or describes a formalized dam safety management system that can be used within the Territory. In the absence of these, this assessment was undertaken in accordance with the best practices proposed by the CDA and dam safety management systems typically applied in Alberta and British Columbia.

2.0 AVAILABLE DATA

The documents made available for this DSR by the GN are listed in **Table 2-1.**

Table 2-1: Information review for DSR

Document Name	Date	Author
Sewage and Solid Waste Sites, Kugaaruk: Detailed Design Phase 2	July 10, 2007	Dillon Consulting Ltd (DCL)
Municipal Water Use Inspection Form	15 August 2008	Indigenous and Northern Affairs Canada (INAC)
Sewage and Solid Waste Sites, Kugaaruk: Detailed Design Phase 2: Appendix A - Revision 5 (7 sheets)	July 10, 2007	DCL
Municipal Water Use Inspection Form	15 August 2008	INAC
Water Use Inspection Report	August 8, 2009	INAC
Water Use Inspection Report	July 9, 2010	INAC
Dam Safety Review for the Kugaaruk Sewage Lagoon	November, 24, 2010	AMEC
Annual Report	2010	Not stated
Municipal Water Use Inspection Form	July 2014, 2011	INAC
Annual Report	2011	Not stated
Multi Year Municipal Compliance Summary	2012	Not stated
Annual Report	2013	Not stated
Renewal of license	May 15, 2014	Nunavut Water Board (NWB)
Water license inspection form	September 3, 2014	INAC
Dam Safety Review, Sewage Lagoon, Kugaaruk	November 14, 2014	exp Services Inc.

The following information was not available at the time of the inspection, and report preparation. This information should be located and distributed for review in association with any further action associated with remedial work on the lagoon, or future DSR's (**Table 2-2**).

Table 2-2: Information Gaps

Document Name	Date	Author
Geotechnical Investigation for Sewage Lagoon, Kugaaruk, NU	October 31, 2005	AMEC
Sewage Lagoon Cut-off Trench Construction Monitoring, Kugaaruk, NU	October 31, 2007	AMEC
Operations, Maintenance, and Surveillance Manual	Date unknown	DCL

3.0 DESCRIPTION OF THE DAM SYSTEM

3.1 LOCATION

The lagoon is located in the Hamlet of Kugaaruk, Nunavut. It is located on the western side of the Simpson Peninsula (**Figure 3-1**). The hamlet overlooks the Pelly Bay, which forms part of the Gulf of Boothia. The Bay is fed by the 'Kugaaruk', which is the traditional name of 'little stream' in Inuktitut. Cambridge Bay is located 525 km to the west. Yellowknife is 1,300 km to the southwest. Iqaluit is 1,080 km to the southeast. Access to the community is by air and by annual supply sealift. The hamlet has a typical elevation of 17 m above sea level (ASL). The longitude is 89°49'W and latitude is 68°31'N. The lagoon is located 1.1 km south of the Hamlet.

Figure 3-1: Location of Kugaaruk

3.1.1 Topography

The elevation of natural ground in the vicinity of the lagoon ranges between El. 21 m ASL at the northwest toe of the upper dam to El. 31 m ASL at the access road to the east of the lagoon. The site comprises undulating ground of monzogranite to granodiorite bedrock outcrops interspersed with areas of vegetation.

3.1.2 Climate

The region has an arctic climate defined as very cold winters, light snowfall, and cool summers. The mean daily temperature in July is 7 °C and in January is -33 °C.

3.1.3 Hydrology

The lagoon is a located at a higher elevation and 1.5 km to the south of the Kugaaruk River that drains into the Pelly Bay. There is an unnamed stream located to the southeast of the site. This is located at a higher elevation and drains into the bay to the south of the lagoon.

3.1.4 Geological Setting

Ryan et al. (2009) indicated that the geology at Kugaaruk comprises Archean-age monzogranite to granodiorite with localized tonalite variations. The fabric was variably foliated (massive to gneissic). The region is bisected by a swarm of broadly east-west (E-W) trending dykes (Dyke, 1984). The E-W trending Murchison River Fault, which was mapped on the Boothia Peninsula, may extend across the Pelly Bay into the site.

The regional Pleistocene history is influenced by north-flowing ice sheets that flowed from the Keewatin ice Divide. Tremblay et al. (2007) proposed a four-phase ice-flow history based on glacial landforms on the Boothia Peninsula. The first phase flowed north Keewatin ice Divide. The second phase rotated to the northeast during the Boothia Ice stream event. The third phase was an east-flowing event (probably not observed at Kugaaruk) before the last phase, which returned to a north-flowing event from the Keewatin ice Divide. The limit of flow is just off the coast of Simpson Peninsula.

The sea level would have been significantly higher in the region. Dyke (1984) indicated that the marine invasion was approximately 240 m ASL near Pelly Bay. Wave-washed outcrops, gravel beaches and ice-rafted debris are common in marine-inundated areas (Tremblay et al, 2007).

3.2 GENERAL ARRANGEMENT

The dam system comprises the following components (**Figure 3-2**).

Figure 3-2: Kugaaruk Dam System

1) Northwest Berm
2) Southwest Berm
3) Northeast Berm
4) Decant Cell
5) Tundra Wetland
6) Landfill site
7) Truck Discharge Flute
8) Southeast Bedrock High
9) Pelly Bay

3.3 OPERATION

The dam system comprises a single-cell sewage lagoon (Upper dam) with a smaller decant cell (Lower dam) located downstream, and a tundra treatment wetland downstream of the decant cell. Sewage from the Hamlet is collected and trucked to the sewage lagoon and discharged into the sewage lagoon. The wastewater effluent is pumped from the upper cell into the decant cell during late summer (original design was a discharge pipe). Effluent from the decant cell then seeps through the berm of the decant cell and is dispersed into the tundra treatment wetland before discharging into Pelly Bay.

3.4 DESIGN AND CONSTRUCTION

3.4.1 Upper Dam

The Kugaaruk Lagoon was constructed by Kudlik Construction between 2007 and 2008 to replace the previous lagoon. The designer was Dillon Consulting Ltd (DCL). The geotechnical

investigation and design was provided by AMEC. The construction drawings have been examined for this project.

3.4.1.1 Previous Dam

The layout of the previous lagoon is documented in Construction Drawing No: 100 (DCL, 2009) and on the GoogleEarth (**Figure 3-3**). The Lagoon utilized the existing topography with a U-shaped berm on the northwest and a separate linear berm on southwest side constructed in between the granodiorite outcrops. The berm side slopes were 1.5H:1V, which are steeper than the side slopes of the current lagoon. The base of the original reservoir footprint sloped from east at El. 27 m to west at El. 22 m. Construction drawing No: 201 (DCL, 2009) indicates that the previous berms are to be *'removed to allow for construction of the new berm with liner'*.

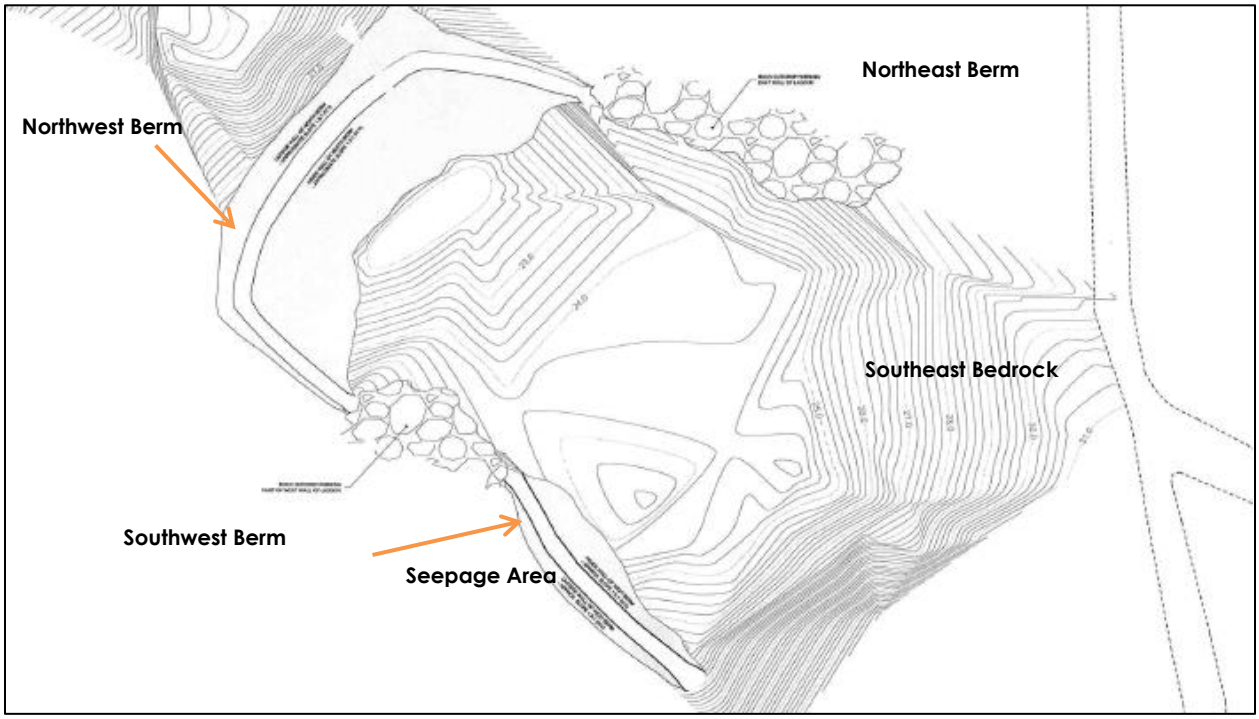

Figure 3-3: Previous Dam (Extract from Construction Drawing No: 100)

3.4.1.2 Current Dam

The layout of the new lagoon is documented in Construction Drawing No: 101 (DCL, 2009) and reproduced in **Figure 3-4**. Sections and construction details are provided in Construction Drawings No: 102, 200, 201 and 202. The upper dam was constructed in a U-shaped earthfill berm arrangement. It is formed by three (3) berms: southwest, northwest and northeast. The effluent reservoir is impounded on the southeast by bedrock.

AMEC (2005) proposed three approaches for the construction of the lagoon. The selected option comprised placement of sand fill, which was allowed to freeze in place. A typical section is presented in **Figure3-5**. The berm was designed with 3H:1V side slopes with specified Type II Granular material. The topographic survey completed by Stantec confirmed that the as constructed side slopes are 3H:1V on average.

The *'core'* of the berm was separated from the upstream zone of the berm by a *'granular (sic) clay liner'*[1] *or 'bentomate liner'*, which to be was placed at 1H:1V and embedded in a 2 m deep by 1 m wide excavated cut-off trench. AMEC (2010) noted that the liner was a *'Bentofix Thermal Lock Geosynthetic Clay Liner'*. The berm was to be protected by rock armour, which was won from the excavations for trenches.

The trench was excavated using drilling and blasting. AMEC (2010) reported that the trench excavation and backfill placement was split between 2007 and 2008. AMEC (2005) remarked that the bedrock is *'weathered, jointed and foliated'* and that *'discontinuities have created numerous large rock wedges that have been dislodged by repeated freeze-thaw cycles'*.

The trench was to be backfilled with sand and gravel fill compacted to a minimum 95% maximum dry density.

The 2010 DSR (AMEC, 2010) states that *"Based on the monitoring results, AMEC concluded that the cut-off trench was excavated into the hard frozen soils to depths specified in DCL design drawings" and that the "trenches will perform as designed, provided that the soils surrounding the cut-off trench remain in a frozen state"*.

[1] It is likely that the word 'granular' is an error, and the word was supposed to be 'geosynthetic'. 'Granular clay liners' do not exist.

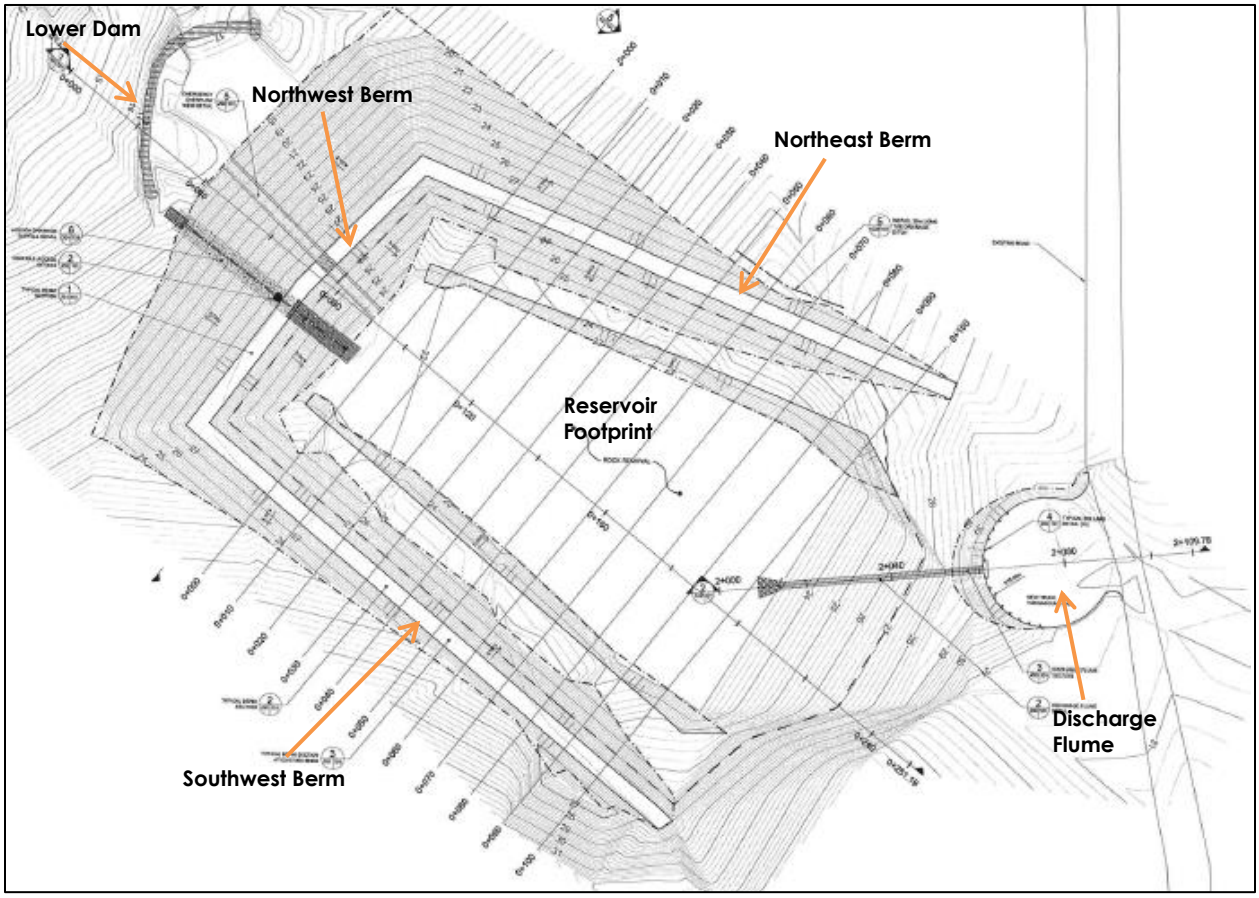

Figure 3-4: Current Dam Layout (Extract from Construction Drawing No: 101)

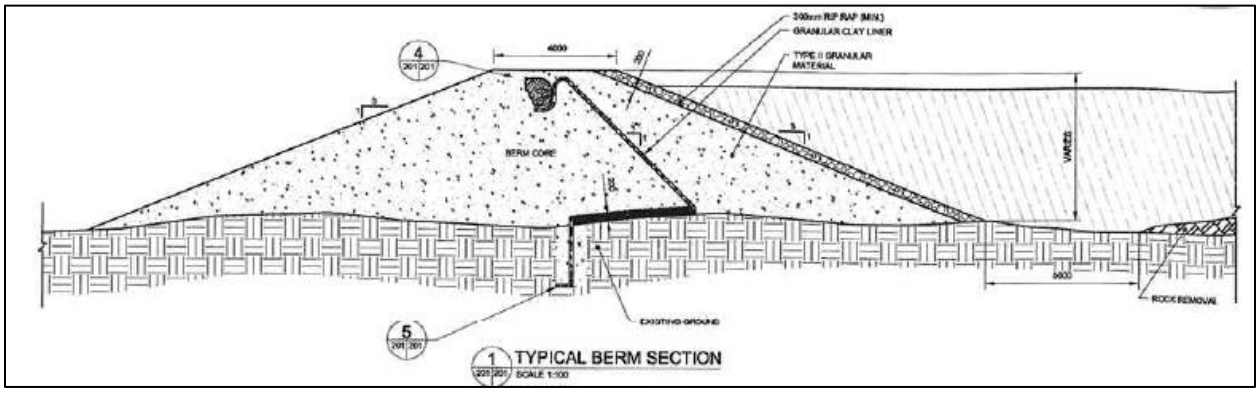

Figure 3-5: Typical Berm Section (Extracted from Construction Drawing No: 201)

The Construction Monitoring Report by AMEC (2007) was not made available to Stantec for this DSR. However, two construction photographs can be found on the Kudlik Construction Website:

http://kudlikconstruction.com/en/realisations/kugaaruk. These photographs reportedly show the excavation, placement of the berms and the liner on the northwest berm (**Figure 6a**) and the southwest berm (**Figure 6b**).

3.4.2 Lower Dam

The Lower dam comprises a U-shaped berm downstream of the upper dam. It is connected to the upper dam by the discharge pipe and the emergency overflow weir. No construction details can be found in the construction drawings (DCL, 2009).

Figure 3-6: Photos of the lagoon construction (from Kudlik Construction Website)

3.4.3 Emergency Overflow Weir

The overflow weir is located on the northwest berm. This invert is El. 27.7 m, which is approximately 300 mm below the crest elevation. The Construction Drawing No: 200 indicate that it comprises two (2) 300 mm thick sand layers either side of a bentomate liner. A 100 mm Geoweb layer was specified at the top of the berm. This was to be overlain by 200 mm dia. rockfill.

3.4.4 Discharge Pipe

The discharge pipe comprises a 300 mm diameter HDPE pipe beneath the northwest berm (**Figure 3-7**). It was designed with a 2 % slope between the lagoon at El. 24.5 m and the outfall

pipe at El. 22.2m. The pipe was surrounded by 300 mm layer of sand. The outfall on the downstream side of the berm comprises a 500 mm dia. corrugated steel pipe.

AMEC (2010) noted that the manhole access and discharge pipe were moved 19 m to the southeast from the original 2007 design.

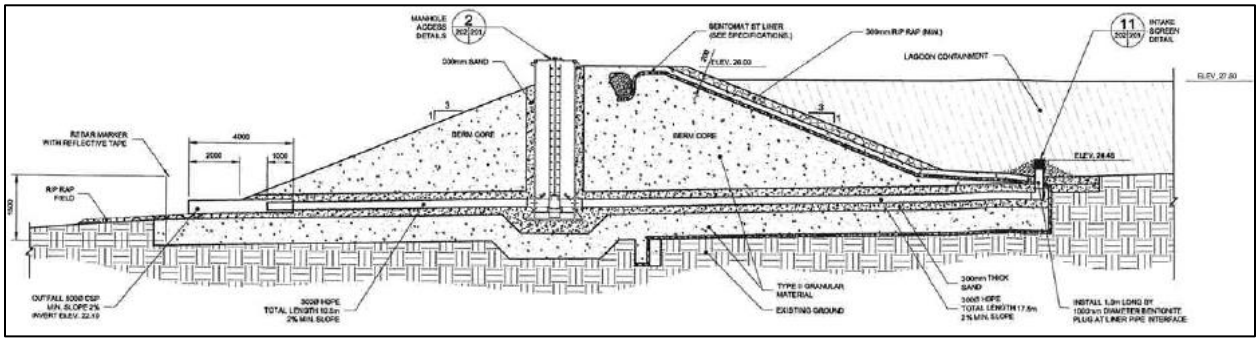

Figure 3-7: Discharge Pipe Section (Extracted from Construction Drawing No: 201)

3.4.5 Truck Discharge Flume

The truck discharge flume comprises an elevated platform located to the east of the lagoon (**Figure 3-4**). This comprises a chute formed from two (2) open faced 600 mm diameter corrugated steel pipes. This chute conveys effluent from trucks into the reservoir. The western perimeter of the trucking circle is surrounded by a series of bollards.

4.0 PREVIOUS DAM SAFETY REVIEWS

It is understood that there has been two DSR's prepared for the lagoon.

4.1 AMEC (2010)

AMEC was retained by DCL to undertake a DSR of the Lagoon in 2010. This was the first post-construction DSR undertaken for the lagoon. This comprised a field investigation and a review of two existing AMEC reports: geotechnical investigation (AMEC, 2005) and the cut-off trench construction monitoring report (AMEC, 2007), the construction drawings (DCL, 2009) and the license documentation (GN, 2007).

AMEC concluded that *"the dam berms were found in very good operating condition during the site visit"* and that *"no effluent seepage was identified along the three constructed sewage lagoon berms"*. However, AMEC noted that the effluent level was low at the time of the site visit.

AMEC (2010) made the following recommendations:

- The next site visit to be undertaken in two years' time when the effluent level is higher
- Hasp for the manhole lid should be replaced and kept locked
- The Operation and Maintenance manual should be supplied to the Hamlet Administration because they did not have a copy at the time of the inspection.

4.2 EXP SERVICES INC (2014)

The last DSR was undertaken by exp Services Inc. in 2014 under the authorization of the Hamlet of Kugaaruk. The final report issued on November 14, 2014. The intent of the DSR was *'to satisfy one of the requirements of the Nunavut Water Board for the upcoming renewal of the Hamlets' water license'*. The DSR comprised a review of the available information, site inspection between July 27 and 30, 2014; measurement of the sludge blanket and interview of staff.

exp Services Inc. concluded that the *"existing lagoon did not reveal any signs of seepage, slope instability or erosion"*, that *"there is no danger to humans in case of failure of the berms"* and that in their opinion *"the existing sewage lagoon is safe from a geotechnical and dam safety perspective for continual operation"*.

exp Services Inc. made the following recommendations in their report:

- The sludge blanket thickness be re-evaluated in the summer of 2016 to determine if cleanout is required.

- Discharge pipe be bought back into operation.

Stantec has reviewed this DSR report and has the following comments:

- There is no list showing the documents reviewed as part of this DSR. **Section 2** makes reference to the record drawings prepared by DCL and dated December 2009 only. There is no reference to the earlier DSR produced by AMEC in 2010, the geotechnical investigation report (AMEC, 2005) and the Construction monitoring report (AMEC, 2007). It is unknown of these documents were made available.
- Although the consequences of dam failure are discussed in Section 7, no consequence classification was assigned for the lagoon.

5.0 CONSEQUENCE CLASSIFICATION

The previous DSR's did not assign a consequence classification to the Kugaaruk lagoon. The assignment of a consequence classification for a dam is typically based on the population at risk, environment, cultural values, infrastructure and economics (CDA, 2016).

An advanced dam breach analysis and inundation mapping has not been undertaken for this DSR. However, the site inspection indicated that there are two potential inundation paths. These would occur due to a breach and release of fluid from the southwest and northwest berms. The topography on the northeast and southeast sides would restrict the flow. The flood wave would flow in a southwest or northwest (normal discharge path) direction towards the Pelly Bay (**Figure 5-1**).

It is recommended that the Kugaaruk Lagoon be classified as a **'significant'** consequence structure (see CDA Consequence Classification Rating table in Appendix). This is based on the following:

- Unspecified population at risk: There is no identifiable permanent population located in the areas that would be flooded as a result of a breach of the containment structure. There may be a temporary population at the time of a loss of containment; for example, people participating in fishing or recreational activities.
- Loss of life: See above. There would be limited exposure time for people temporarily at risk.
- Environmental: A dam breach would release effluent into the Pelly Bay. This would result in a localized loss and deterioration of marine environments in the area. The Hamlet would have to fish in areas away from the effluent plume until it has dissipated sufficiently.
- Loss of cultural values: discussion with the GN and SAO indicated that there were no cultural sites located downstream of the lagoon.
- Infrastructure and economics. There would be no damage to 3rd party infrastructure; however this facility is an important part of the Hamlet infrastructure. The loss of containment would result in loss of sanitation infrastructure; the potential for adverse health effects in the Hamlet and a costly re-build.

This consequence classification was discussed and agreed to by the GN.

Figure 5-1: Potential flow-paths from a dam breach

6.0 SITE VISIT

The Kugaaruk Lagoon site was visited by Stantec personnel (Andrew Bayliss and Leslie Merrithew) between September 21 and 23, 2016. The GN Representative (Shah Alam) was on site between September 22 and 23, 2016. The site visit comprised the following key components:

- Initial site walkover by Stantec and set up of GPS equipment on September 20, 2016
- Site walkover and survey by Stantec personnel between 8.30 am and 4.30 pm on September 21, 2016 followed by an additional site walkover with Shah Alam (GN) between 4.30 am and 5.30 pm September 22, 2016
- Interview with Shah Alam (GN) and John Ivey (SAO Kugaaruk) at 9 am September 23, 2016
- Decanting and sampling of the lagoon fluid started at 10 am September 23, 2016.
- Site walkover with Shah Alam at 11.30 am September 23, 2016.

The site walkovers comprised the following tasks:

- Undertake a topographical survey of the lagoon
- Visually review the components of the dam system and the surrounding area in accordance with the CDA Guidelines (2013; 2016).
- Visually review the previously observed seepage on the west berm and estimate the flow rates
- Observe the ground conditions through geological mapping only

The discharge outlet on the north berm was not inspected during this visit. This was considered a confined space and personnel did not have the appropriate training or safety equipment to inspect this.

6.1 OBSERVATIONS

6.1.1 Comment on Topographic Survey

A topographical survey was undertaken by Stantec personnel during the site visit. We noted a discrepancy of 2.35 m between the benchmark (El. 32.95 m) contained in GN CAD files supplied on September 22, 2016 and our measurement of the benchmark (El. 30.6 m).

All elevations stated in this DSR are measured on the topographical survey undertaken by Stantec.

6.1.2 Upper dam

This section summarizes the key issues observed during the site walkover of the upper dam. The dimensions based on the Stantec Survey are summarized in **Table 6-1**.

Table 6-1: Measured Geometry of the Upper Dam

Component	Southwest Berm	Northwest Berm	Northeast Berm
Length (centerline)	140 m	80 m	130 m
Slope angle (downstream)	3H:1V	3H:1V	3H:1V
Slope angle (upstream)	3H:1V	3H:1V	3H:1V
Crest width	4 m	4 m	4 m
Crest elevation	25.8 m ASL	25.8 m ASL	25.8 m ASL
Maximum height	3.8 m	10.5 m	Varies

A summary of field observations are below:

- The lagoon level was at El. 23.8 m, which was equivalent to 2 m freeboard. The sludge blanket could not be observed at the time of the inspection. (**Figure 6a**).
- No signs of cracking, bulging or sinkholes were observed. However, the presence of rock armour on the upstream and downstream slopes restricts visual confirmation of this.
- Numerous areas of grass vegetation (Figure 9b) were observed throughout the earthfill dam.
- Two animal borrows were observed on the upstream crest on the southwest berm (**Figure 6c**).
- The lagoon does not have an active geotechnical monitoring system in place.

The previously observed seepage was noted in the lower slope of the southwest berm (**Figures 6d and 6e**). This portion of the berm is 3.8 m high and was constructed across a valley between bedrock highs.

Site Visit
March 24, 2017

Figure 6-1: Observations from the site walkover

It is understood that seepage from the containment berm was first observed on October 2014 by Hamlet staff. This seepage has been ongoing for nearly two years. Although the rock armour restricts clear confirmation, there appears to be four zones of seepage (S1 to S4). The elevation of these seepage zones ranged between El. 22.0 and 22.8 m. The southernmost zones (S1 and S2) are flowing at a visually significantly higher rate than S3 and S4.

The seepage appeared to be clear and contained no sediment. This seepage was consistent and had formed a clearly defined surface flow-path towards Pelly Bay (Figure 6f).

Although, a public safety assessment is beyond the scope of this DSR, the site visit noted that there were no fences surrounding the lagoon, there was one warning sign by the discharge flume and there were no life-buoys on the site.

6.1.3 Lower Dam

The lower dam structure appeared to be in good condition, with no observed distress or seepage.

6.1.4 Emergency Overflow Weir

The overflow weir appeared to be in good condition, with no visual evidence of any deterioration.

6.1.5 Discharge Outfall

The manhole and pipe was not inspected as the DSR (Stantec) personnel did not have confined entry training or PPE to undertake this task safely. Discussions with Hamlet personnel on

September 23, 2016 indicated that the discharge outfall was still not operational and that decanting of the lagoon, which started that day, was undertaken using a pump and generator.

In an emergency, the drawdown time for the retained reservoir using this system is unknown. It is assumed that it will be different than the drawdown time using the 300 mm diameter discharge pipe.

6.1.6 Discharge Flume

The flume appeared to be in good condition **(See photos 6 g and 6 h)**.

6.2 INTERVIEW WITH PERSONNEL

Stantec personnel interviewed Shah Alam (GN) and John Ivey (SAO Kugaaruk) at 9 am September 23, 2016. The objectives were to discuss the findings to date and understand the operational and emergency response / preparedness of the WSL. The following items were discussed:

- No Operation, and Maintenance (O&M) manual was made available at the meeting. It was communicated that a copy is kept in the SAO office; however, this was not confirmed by Stantec personnel.
- There is no formalized emergency preparedness plan (EPP) or emergency response plan (ERP) for the lagoon. However, the contact procedure for a breach was communicated to Stantec Personnel.
- It was noted during the site visit that there was no fencing around the lagoon, limited signage and no life-buoys. Public Safety is not routinely covered in a DSR; however, this was communicated to the GN and SAO and will be included in the table of recommendations.

7.0 CONCLUSIONS AND RECOMMENDATIONS

It is concluded that the dam is not currently performing satisfactorily; is not water-tight as required for a retention lagoon and it is currently releasing unauthorized, uncontrolled and untreated sewage discharge into an area that is not a designated sewage discharge area. As a result of this seepage, internal erosion may be occurring within the berm that could lead to unstable conditions in the future.

The 2016 inspection observed the absence of sagging, sloughing or other deformation of the perimeter berms, which suggests that the berms remain geotechnically stable. It is indeterminate how any instability may progress or over what timeframe. If seepage accelerates, the opportunity for material loss increases, which may negatively impact the geotechnical stability of the berms. The monitoring of the seepage flow, and the berm condition should be continued to determine any evidence of berm deterioration. It would be beneficial to implement a more accurate method to estimate the leakage from the lagoon, such as monitoring the change of the water level in the lagoon over a period of weeks.

It is recommended that the Kugaaruk Lagoon be classified as a "significant" consequence structure.

The issues of concern that have been identified as part of this DSR are summarized below in **Table 7-1**. The priority rating is a subjective assessment of issue seriousness from which the Owner and Operators should focus their short to longer term actions.

Table 7-1: Issues of concern identified during this DSR

Ref	Description	Action / Recommendation	Report Section	Priority Rating
1	Confirmation of consequence classification	Discussion and agreement with GN on the classification and the implications.	5.0	N/A
2	Difference of 2.35 m between benchmark survey elevations	Discrepancy clarified and noted in topographic survey information submitted by Stantec.	6.1.1	Low
3	Seepage observed at toe of southwest berm	Investigation of the seepage and remediation of the berm.	6.1.2	High
4	Two animal borrows observed on upstream crest of southwest berm	Humanely remove the animals and infill the borrows. Discourage future denning.	6.1.2	High
5	Periodic discharge pipe not operational	Owner has abandoned discharge pipeline and is using a pumped discharge for the lagoon.	6.1.5	N/A
6	Drawdown capacity unknown	The design assumed a 300 mm diameter discharge pipe. The Owner is currently using a pipe/pump system. The time for drawdown using the pumping system is 2 to 3 weeks	6.1.5	Medium
7	No fences around lagoon	Install fencing around lagoon to restrict uncontrolled access due to proximity to public road and camping area.	6.1.2	High
8	Limited warning signs	Install additional warning signs around perimeter of lagoon in potential access areas (minimum 4 signs) . Install additional sign near camping area south of lagoon to warn of sewage discharge.	6.1.2	High
9	No formalized emergency preparedness plan	Prepare a formalized process that provides roles, responsibilities and clear lines of communication.	6.2	Medium
10	No formalized emergency response plan	Prepare a formalized process that provides roles, responsibilities and clear lines of communication.	6.2	Medium
11	Operation and Maintenance Manual was not available for review during site inspection	Confirm availability of Operation and Maintenance manual for facility, and if no manual is available, proceed with the preparation of document	6.2	Medium

8.0 REFERENCES

AMEC (2010) Dam Safety Review for the Kugaaruk Sewage Lagoon

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Appendix A CDA CONSEQUENCE CLASSIFICATION RATING FOR DAMS

Canadian Dam Association (CDA) Consequence Classification Ratings for Dams

Consequence Classification	Population at Risk	Consequences of Failure		
		Loss of Life	Environmental and Cultural Values	Infrastructure and Economics
Low	None[1]	There is no possibility of loss of life other than through unforeseeable misadventure	Minimal short-term loss or deterioration and no long-term loss or deterioration of: a) Fisheries or wildlife habitats b) Rare or endangered species, or c) Unique landscapes or sites of cultural significance	Minimal economic losses mostly limited to the dam owner's property, with virtually no pre-existing potential for development within the dam inundation zone.
Significant	Temporary only[2]	Low potential for multiple loss of life	No significant loss or deterioration of: a) Important fisheries or important wildlife habitats b) Rare or endangered species, or c) Unique landscapes or sites of cultural significance, and restoration or compensation in kind is highly possible	Low economic losses affecting limited infrastructure and residential buildings, public transportation or services or commercial facilities, or some destruction of or damage to locations used occasionally and irregularly for temporary purposes.
High	Permanent[3]	10 or fewer	Significant loss or deterioration of: a) Important fisheries or wildlife habitats b) Rare or endangered species, or c) Unique landscapes or sites of cultural significance, and restoration or compensation in kind is highly possible	High economic losses affecting infrastructure, public transportation or services or commercial facilities, or some destruction of or some severe damage to scattered residential buildings.
Very high	Permanent[3]	100 or fewer	Significant loss or deterioration of: a) Critical fisheries or wildlife habitats b) Rare or endangered species, or c) Unique landscapes or sites of cultural significance, an restoration or compensation in kind is possible but impractical	Very high economic losses affecting important infrastructure, public transportation or services or commercial facilities, or some destruction of or some severe damage to residential areas.
Extreme	Permanent[3]	More than 100	Major loss or deterioration of: a) Critical fisheries or wildlife habitats b) Rare or endangered species, or c) Unique landscapes or sites of cultural significance, and restoration or compensation in kind is impossible	Extremely high economic losses affecting critical infrastructure, public transportation or services or commercial facilities, or some destruction of or some damage to residential areas.

[1] There is no identifiable population at risk.
[2] People are only occasionally and irregularly in the dam breach inundation zone, for example stopping temporarily, passing through on transportation routes or participating in recreational activities.
[3] The population at risk is ordinarily or regularly located in the dam breach inundation zone, whether to live, work or recreate