GOVERNMENT OF NUNAVUT

Kimmirut Wastewater Treatment Facility

Pre-Design Report DRAFT

February 2022 – 20-2790

February 16, 2022

Department of Community and Government Services
Government of Nunavut
Iqaluit, Nunavut
X0A 0H0

Attention: Mr. Justin Kim

Kimmirut Wastewater Treatment Facility DRAFT Pre-Design Report

Dear Mr. Justin Kim:

Please find attached an electronic copy of the draft Pre-Design Report for the Kimmirut Wastewater Treatment Facility located in the Hamlet of Kimmirut, Nunavut. This document is intended as an initial overview of the proposed design options to optimize the layout of the site in addressing the Hamlet needs.

Please contact the undersigned if you have any questions or concerns with regards to this submission.

Sincerely,

DILLON CONSULTING LIMITED

Keith Barnes, P. Eng.
Project Manager

JJH:sls

Our file: 20-2790

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1.0 Introduction

Dillon Consulting Limited (Dillon) has been retained by the Government of Nunavut (GN), Department of Community and Government Services (CGS) to provide Engineering Services for a New Sewage Lagoon in Kimmirut, Nunavut.

The intent of the project is to provide the Hamlet of Kimmirut (the Hamlet or Kimmirut) with a new sewage lagoon that has an overland discharge path that meets or exceeds applicable environmental and regulatory guidelines and regulations. This report presents the preliminary design for the lagoon, including: previous investigations; site selection; design considerations; site infrastructure; climate change impacts; and required site investigations and recommendations.

1.1 Background

Kimmirut is a small community located on the southern end of Baffin Island with a population of less than 500. Kimmirut is only accessible year-round by plane, while boat (sealift) access to the community is available throughout the summer. The community is served by local roads, with power being supplied through central diesel generators.

The community is currently serviced by a trucked system for both water delivery and sewage collection. For the past 30 years, the Hamlet has discharged its untreated wastewater into a trench near the community's solid waste facility. The wastewater then drains over a steep embankment into the ocean through Lake Harbour. The current system only provides preliminary treatment, with some further primary and secondary treatment occurring during the summer months when vegetation is present and active. Due to the inadequate effluent quality, the current sewage treatment method has been considered unacceptable by the Nunavut Water Board (NWB) and Indigenous and Northern Affairs Canada.

A new Wastewater Treatment Facility (WWTF) was constructed in 2001, under the approval of the NWB. The completed facility was subsequently rejected by the community upon discovering that it discharged into fish habitats throughout the wetlands and adjoining lakes.

1.2 Previous Studies and Investigations

In 2015, Stantec Inc. (Stantec) completed a feasibility study, Kimmirut Wastewater Treatment Feasibility Study Final Report that identified potential locations throughout the community and recommended the new WWTF be constructed at Site 9, which has been approved by the Hamlet.

Following a topographical survey, land use application and Airport-Bird Hazard Risk Assessment, Stantec provided the GN with the Phase 1 of Regulatory Approvals for a Wastewater Treatment Facility in

Kimmirut, NU report. Included within the report was the Airport Zoning Regulations approval from Transport Canada for the proposed Site 9.

A geotechnical investigation was completed by Canadrill Limited Geotechnical Division (Canadrill) in 2019 in two phases: the first at the end of August 2019 and the second at the end of September 2019. Their report, dated December 3, 2019, Geotechnical Investigation New Wastewater Treatment Facility, Kimmirut, NU stated that based on their findings, the Stantec design was considered feasible at Site 9. On February 24, 2020, Canadrill Limited (Canadrill) submitted a revised report (Canadrill Limited, 2020) that stated: due to the groundwater flow, open fractures of bedrock and the proposed options for the lagoon, a hydrological study would be likely necessary to support design decisions.

Canadrill visited the current gravel crushing operations in Kimmirut in August of 2019 to discuss production types/rates and obtains samples of the available materials. It is their understanding that borrow material is readily available throughout the community and typical crushing operations include borrowing local overburden as crusher feed with no blasting required. Based on Canadrill's investigation, the borrow sources and crushing capacities in the community are expected be sufficient to produce the granular required for the proposed new WWTF.

2.0 Site Selection and Further Investigation

During project initiation, the GN requested that Dillon re-evaluate the alternative sites proposed by Stantec in their Feasibility Study (Nunami Stantec, 2015), prior to selecting Site 9 as the preferred site location. Dillon conducted a desktop review and produced a summary report outlining the basis of design, evaluation of the alternative sites and discussion of the potential risks. The report identified that, while low probability, the potential could exist for impacted groundwater in the vicinity of the future lagoon to flow in the direction of Fundo Lake (Hamlet water source) under specific conditions. As a result of this potential, further work was completed to better understand the site conditions and associated risk.

2.1 Hydrogeological Review

2.1.1 Drilling Program

Dillon retained Canadrill to complete an additional field investigation of Site 9, which included drilling three core holes along the topographic high of the area in November 2020. In March 2021, monitoring wells were subsequently installed at each of the core hole locations, along with an additional monitoring well that was installed closer to the natural pond at Site 9. Locations of the monitoring wells are shown in Figure 1.

The core holes were drilled with a geotechnical coring rig to allow for the collection of rock core for logging, as well as to allow for the installation of thermistor arrays. The monitoring well holes were drilled with an air rotary rig to the planned depth (15 m) and to provide sufficient diameter to install the monitoring wells.

Figure 1: Location of Monitoring Wells installed by Canadrill in March 2021

2.1.2 Results

Results of the core logging confirm the findings of the 2019 investigation (that the bedrock does contain fractures), and it can be expected that these fractures are connected and will allow the flow of groundwater within the active zone when not frozen.

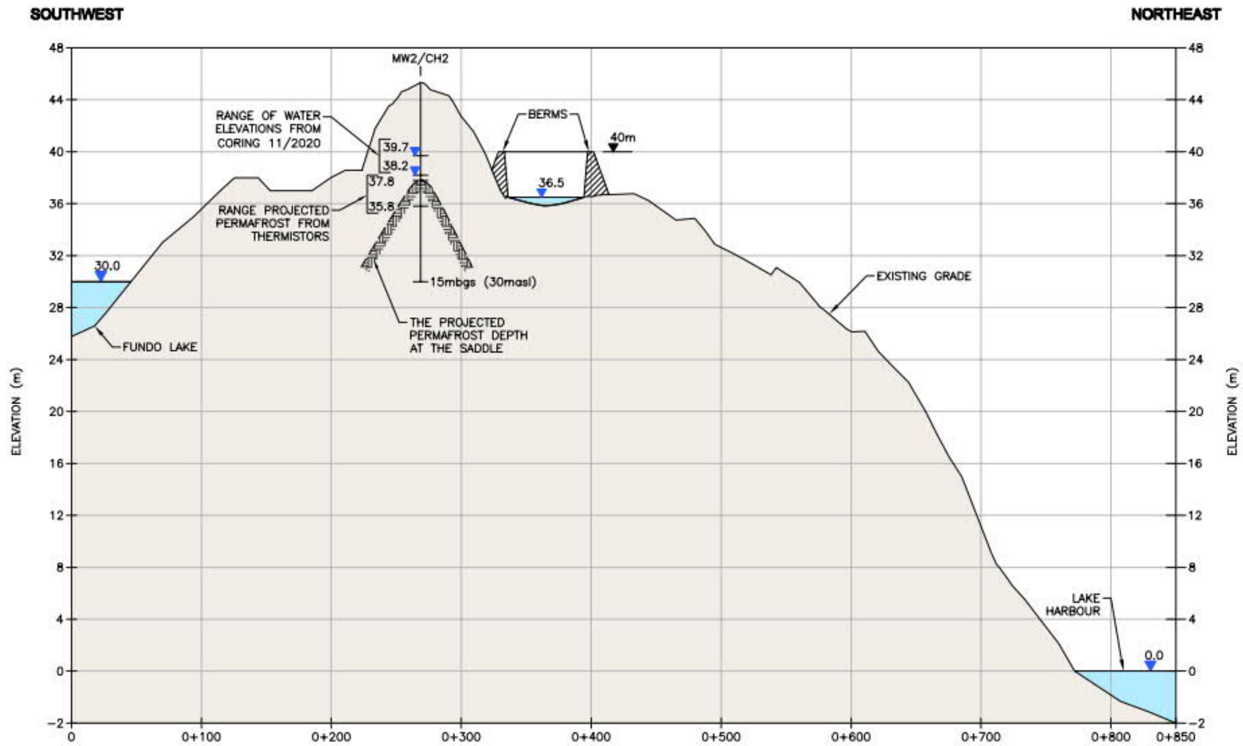
Results of the thermistor testing indicated that the depth to permafrost along the saddle was approximately 8 m below ground (permafrost elevation at the three core hole locations ranged from 35.8 to 37.8 metres above sea level [masl]).

2.1.3 Interpretation

A schematic cross-section through the site was prepared to aid in the visualization of the subsurface conditions, topography and locations of the noted waterbodies. The location of the cross-section is shown as line A-A' on Figure 1 and the schematic cross-section is shown on Figure 2.

As can be seen, the pond at Site 9 is separated from Fundo Lake by the topographic high. This high point is the location of the core holes/monitoring wells (with MW2 shown on the Figure 1). Also shown on Figure 2 is the projected depth of permafrost beneath the high point.

Figure 2: Cross-Section of Site 9 Area



The projected permafrost depth is at, or higher, than the elevation of the water in the pond at Site 9. While equilibrium groundwater levels have not been measured, it is expected that, during the thaw, groundwater would occur above permafrost in the active zone. This would raise the hydraulic head further above the pond. Under the current conditions, with the pond elevation at approximately 36.5 masl, there is a hydraulic divide at the high point (permafrost and/or groundwater above permafrost) preventing groundwater beneath the pond from flowing toward Fundo Lake. Therefore, under current conditions and based on the available information, it is not possible for groundwater beneath the pond at Site 9 to flow toward Fundo Lake. As a reminder, the natural drainage for the pond at Site 9 is to the northeast, away from Fundo Lake, to sea level at Lake Harbour.

With the addition of berms at Site 9, the anticipated final elevation of the effluent is to be near 40 masl. Theoretically, this elevation could create a hydraulic gradient between Site 9 and Fundo Lake. However, the conditions that would allow subsurface flow from the lagoon at Site 9 to Fundo Lake remain at a very low probability due to proposed design considerations detailed later in Section 3.0.

Due to these proposed design considerations, in the worst case scenario of a liner breach when the lagoon is at full capacity, there will be both natural conditions (permafrost depth and hydraulic divide) and engineered controls that greatly reduce the already low probability of impacted groundwater flowing toward Fundo Lake.

2.2 Hamlet of Kimmirut Council Meeting and Approval

Along with project background, Dillon presented the hydrogeological concerns and design considerations to the Hamlet's Council on October 21, 2021. From this presentation, Kimmirut's Council approved the motion to move forward with the new sewage lagoon at Site 9, with the effluent decanted yearly to the receiving water body of Lake Harbour.

3.0 Design Considerations

The lagoon will be designed to meet the long-term needs of Kimmirut, the regulatory requirements of Kimmirut's water license, as well as the required safeguards to prevent impacted groundwater flow towards Fundo Lake. Design standards will be based on Planning, design, operation and maintenance of wastewater treatment in northern communities using lagoon and wetland systems (CSA Group [CSA] W203:19). According to this standard, the lagoon will be designed for a 20 year design horizon, to the year 2043. The lagoon system will be designed to contain 12 months of storage, prior to being decanted to the receiving environment.

3.1 Risk Mitigation

The lagoon will be fully lined such that the head, or height, in the lagoon is independent and separated from the natural head in the groundwater. Monitoring pipes will be placed adjacent to and beneath the liner to monitor water quality, and allow collection of samples in the event of a liner breach.

An underdrain system will be constructed to actively drain the natural pond water (during construction) and underlying shallow groundwater (post-construction) to the northeast away from the Fundo Lake watershed. In addition to the underdrain, a piped collection system is proposed that can be used to pump water from beneath the liner system in case the underdrain toe becomes frozen and prohibits the flow of groundwater, which could lead to pressure underneath the liner and 'whale backs'. In addition to removing water beneath the liner, the pipe collection system can be used to collect water samples and act as an early warning leak detection system.

The lagoon will not be at design capacity until late summer, just before it is decanted to the wetland treatment system; as such, there would only be a relatively short duration when the lagoon could be at a higher head and the subsurface is thawed to allow groundwater to move within the active layer.

If for some reason the lagoon were to overflow, the overflow would discharge from the lagoon and flow towards Lake Harbour. The overflow would have partial primary treatment completed from retention time in the lagoon and would flow through the downstream existing wetland for partial secondary treatment, prior to discharge to Lake Harbour. Once the pond discharges to the wetland system, there is a possibility that overland flow could seep into fractures in the bedrock and potentially find a path back to Fundo Lake. It is considered that this risk is low as the further the discharge gets from Site 9, the head gradient lessens relative to Fundo Lake, resulting in less potential for contamination to reach Fundo Lake.

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3.2 Treatment Method

The treatment facility will be designed to meet the effluent water quality parameters set out in the community's water licence (3BM-KIM1929). The system will be constructed at the same area as the existing pond located at Site 9 and will be designed based on the CSA Standard W203:19.

3.3 Lagoon Cell and Berm Design

The following design criteria will be followed for the cells and berms design:

- Berms to be constructed with granular material available locally;
- Berms must have at minimum an interior side slope of 3H:1V;
- Berms must have at minimum an exterior side slope of 3H:1V;
- Berms must have an impermeable liner keyed into a depth suitable to ensure no seepage;
- Berm shall allow for maintenance vehicle access on top of the berms (i.e., F350 or similar); and
- 1 m of freeboard.

3.4 Capacity Analysis

3.4.1 Population Projections and Wastewater Generation Rates

Kimmirut's population projections were developed using the Baffin Community Population Projections, 2014 to 2035, while an actual 2016 population value of Kimmirut was referenced from the 2016 Census Canada data. The population projections were adjusted using the 2016 Census data and population increases were extrapolated from 2035 to the proposed design year of 2043.

The sewage generation rate was calculated using standard design equations from CSA Standard W203:19. The assumed residential water use (RWU) for a trucked water and sewage system is 90 litres per person per day. An allowance is made for non-residential water uses, such as commercial, institutional and industrial demands. The total water use (TWU) per capita was estimated using the following equation:

$$TWU = RWU\ x\ [1.0 + (0.00023\ x\ population)]$$

The annual wastewater generation to the year 2043 is presented in Table 1.

Table 1: Population and Wastewater Generation Rates 2023-2043

Year	Population	Total Water Use Per Capita (L/c/day)	Daily Wastewater Volume (L/d)	Annual Wastewater Generation (m^3)
2023	479	99.9	47,912	17,488
2028	495	100.3	49,631	18,115
2033	501	100.4	50,300	18,360
2038	511	100.6	51,445	18,777
2043	520	100.8	52,442	19,141

3.4.2 Sludge Accumulation

The lagoon will be sized to store sludge accumulation for the 20 year design life of the treatment system. It is assumed that sludge will not be dredged from the lagoon during the 20 year design life, and the design volume will include sludge buildup till 2043. As referenced from CSA Standard W203:19, a generation rate of 0.35 L/person/day will be considered to estimate sludge accumulation volumes. The annual sludge accumulation estimates are shown in Table 2.

Table 2: Annual Sludge Accumulation to 2043

Year	Daily Sludge Generated (L/day)	Annual Sludge Generated (m^3)	Total Sludge Accumulation (m^3)
2023	167.8	61.3	61.3
2028	173.3	63.3	373.4
2033	175.4	64.0	692.0
2038	179.0	65.3	1016.1
2043	182.1	66.5	1346.3

3.4.3 Annual Precipitation and Evaporation

The lagoon will be sized to accommodate storage of precipitation for a 12 month period. Consideration for climate change has been included as part of the precipitation data analysis. Evaporation is not currently included as part of the Pre-Design, as it is expected to be minimal.

Climate information for this study was obtained from Environment and Climate Change Canada (ECCC) archives for the latest climate normals period of 1981-2010. Historical precipitation data was referenced from Iqaluit Airport from 1981-2010 to estimate an average annual precipitation volume in the area of the lagoon. Although Kimmirut does have historical and even current observations of weather parameters, the data from the archive does not currently include precipitation, which is critical for this project. A projected precipitation increase by 11% annually for the 2035's period (2021-2050) was estimated and accounted for in the annual precipitation volume and is further discussed in Section 5.0.

- Average annual precipitation (1981-2010) 390 mm
- Annual precipitation with 11% allowance for climate change 433 mm
- Annual precipitation volume captured by lagoon 6,268 m^3

3.4.4 Lagoon Working Volume

The lagoon system will be sized to accommodate storage of wastewater, sludge accumulation, precipitation and surface runoff for a 12 month storage period.

- Annual wastewater generation to 2043 19,141 m^3
- Annual sludge accumulation to 2043 1,346 m^3
- Annual precipitation volume (snow and rain) captured by lagoon 6,268 m^3
- Lagoon working volume 26,755 m^3

3.5 Influent Loading Characteristics

The characteristics of sewage in the community are dependent on the type of municipal wastewater system. The type of wastewater conveyance (piped, trucked or combination) and water usage in a municipality is considered when estimating influent wastewater quality. As referenced from CSA Standard W203:19, the following influent loading criteria shown in Table 3 will be assumed for Kimmirut based on a trucked wastewater system.

Table 3: Typical Raw Wastewater Quality for Trucked Wastewater System

Parameter	Typical Raw Wastewater Quality	Units	Source
$cBOD_5$	450	mg/L	CSA Standard W203:19
TSS	400	mg/L	CSA Standard W203:19
TAN	100	mg/L	CSA Standard W203:19
TP	15	mg/L	CSA Standard W203:19
E. coli	1 x 10^8	CFU/100 mL	CSA Standard W203:19

3.6 Effluent Requirements Review

The GN considers, based on the research completed by Dalhousie University and ongoing discussions with NWB regarding wastewater regulations in the north, that effluent quality limits for a lagoon/wetland discharging into a well flushed receiving environment should be $cBOD_5$ of 100 mg/L and TSS of 120 mg/L.

While the GN is pursuing updates to the water license (3BM-KIM1929) to increase the $CBOD_5$ and TSS limits, Dillon has assumed that the current, more stringent effluent parameters will need to be met for the purposes of this predesign report. As stated in the license, all effluent discharged from the Sewage Disposal Site at Monitoring Program Station KIM-3 and the Enhanced Sewage Disposal Facility at Monitoring Program Station KIM-5 shall not exceed the effluent quality standards shown in Table 4 below.

Table 4: Effluent Quality for Trucked Wastewater System

Parameter	Effluent Quality	Units
$CBOD_5$	80	mg/L
TSS	100	mg/L
pH	Between 6 and 9	-
Oil and Grease	No visible sheen	-
E. coli	1×10^4	CFU/100 mL

3.7 Lagoon System Kinetics

The overall level of treatment achieved by a lagoon system can be estimated using the following first order kinetic formula (Atlantic Canada, 2006):

$$\frac{L_e}{L_i} = \frac{1}{1 + K_t T}$$

Where,

L_e = Concentration ($cBOD_5$) in lagoon effluent (mg/L)
L_i = Concentration ($cBOD_5$) in lagoon influent (mg/L)
T = Residence time of sewage in lagoon during treatment period (days)
K_t = kinetic rate constant ($days^{-1}$)

The kinetic rate constant, K_t varies according to temperature:

$$K_t = K_{20}\theta^{t-20}$$

Where,

K_t = $cBOD_5$ kinetic rate constant ($days^{-1}$)
K_{20} = standard $cBOD_5$ kinetic rate constant ($days^{-1}$) for 20^0C
θ = temperature coefficient
t = temperature of lagoon contents in the critical or warmest months (^{0}C)

3.7.1 Storage Cell

Typical temperature coefficients (θ) as referenced from Wastewater Engineering Fifth Edition (Metcalf and Eddy, 2004) are 1.02-1.10. A typical value for θ of 1.035 was used in the preliminary sizing calculations based on past experience while typical values for K_{20} range from 0.04 – 0.06 $days^{-1}$ for anaerobic lagoon cells. For the new system in Kimmirut Dillon has used 0.06 $days^{-1}$ due to the proposed cell being at an operating depth of 2 m, making it closer to a facultative cell than an anaerobic cell. Using these assumed values, the effluent quality from the constructed lagoon was estimated for a variety of conservative temperatures and retention times (Table 5).

The treatment system was considered as a whole, using the published literature values for $CBOD_5$ in northern trucked raw wastewater. Although the lagoon cells will hold sewage for one year, the effective treatment time used in these calculations only accounts for the length of time sewage is completely thawed to facilitate biological treatment during the summer months. Since freeze-up can vary and occur anytime from October – December, a range of 80-100 days of treatment were analyzed for the storage cell and is based on a treatment window from mid-May to mid-August, with winter treatment assumed to be negligible. These were chosen to provide a conservative effluent modelling approach.

Table 5: Estimate of Effluent $cBOD_5$ from Primary Cell using Lagoon Kinetics

T (days)	K_{20} (days^{-1})	θ	t (°C)	K_t[1] (days^{-1})	C_e/C_i	L_i (mg/L)	L_e (mg/L)
100	0.06	1.035	3	0.033	0.2302	450	104
100	0.06	1.035	4	0.035	0.2242	450	101
100	0.06	1.035	5	0.036	0.2183	450	98
100	0.06	1.035	6	0.037	0.2125	450	96
100	0.06	1.035	7	0.038	0.2068	450	93
90	0.06	1.035	3	0.033	0.2494	450	112
90	0.06	1.035	4	0.035	0.2431	450	109
90	0.06	1.035	5	0.036	0.2368	450	107
90	0.06	1.035	6	0.037	0.2306	450	104
90	0.06	1.035	7	0.038	0.2246	450	101
80	0.06	1.035	3	0.033	0.2721	450	122
80	0.06	1.035	4	0.035	0.2654	450	119
80	0.06	1.035	5	0.036	0.2587	450	116
80	0.06	1.035	6	0.037	0.2522	450	113
80	0.06	1.035	7	0.038	0.2458	450	111

At an operating depth of 2 m, the lagoon is at the deeper range of a facultative lagoon and the shallower end of an anaerobic lagoon. Based on this, the lagoon may operate similar to a facultative lagoon, which allows for aerobic treatment near the top of the lagoon with the bottom of the lagoon being treated similar to anaerobic. Although the cell may operate as a facultative lagoon for the preliminary design we have assumed the system acts as an anaerobic lagoon in the treatment kinetics to be conservative.

3.8 Wetland Area

At the request of the GN to provide a more conservative design, the wetland treatment area downstream of the decant location will not be included with treatment calculations and the effluent quality parameters will be met through lagoon treatment prior to decant. It is important to note though that the wetland area will provide further polishing of the effluent, prior to it entering the receiving marine body and is typically included within treatment calculations.

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4.0 Site Infrastructure

4.1 Arctic Rated HDPE Liner System

Geomembrane liners have been proven to be successful for use in Arctic environments as impermeable membranes, as they are highly durable, resistant to the intense stresses of weather and resilient to chemicals. There are several liner options available on the market for extreme weather applications. Reinforced polyethylene membranes (Arctic-grade) are common, which present superior puncture resistance at low temperatures and lower thermal coefficient of expansion than traditional HDPE liner systems. Some reinforced polyethylene membranes will retain flexibility at low temperatures (up to -40°C/-40°F). This feature is particularly important as it enables the geomembrane to be installed during extreme weather conditions.

Taking into consideration cold crack, brittleness failure and low-temperature impact, an 80 mil thick liner has been preliminarily recommended. As with any lining system, the materials must be installed properly, following the manufacturer's guidelines to ensure the overall integrity of the system is maintained.

4.2 Inlet Structure

As recommended in CSA Standard W203:19, the inlet structure will include a discharge chute, constructed from a section of corrugated steel pipe and secured on the inside berm of the lagoon over rip-rap to protect the berm from erosion. A truck turn-around pad above the discharge chute will be levelled and identified by bollards. The discharge chute will extend through the fence so that the truck operator does not have to open a gate to discharge the truck contents.

4.3 Decant Pump

Effluent from the lagoon will be discharged annually to the existing wetland area east of the site, prior to entering the receiving marine body of Lake Harbour. Decant from the lagoon will be completed with the use of a portable pump and generator that is to be situated on the top of the east berm during decant. This simple, reliable, and low-cost decanting method was chosen to allow the community to control the time and rate of discharge. A self-priming suction lift pump complete with a foot valve will be transported to the discharge location on top of the berm and monitored throughout the decant process. A dispersion pipe will be used downstream of the pumping system to evenly disperse the effluent over the wetland area.

It is recommended that the decanting operations take place over a 30 day interval to not overwhelm the receiving body. It is also recommended to start the decanting process near the end of summer to early fall to allow for the freshet to take place through the wetland and allow for biological treatment to occur within the lagoon through the warmer summer months.

4.4 Emergency Overflow Channel

An emergency overflow channel will be included in the lagoon berm design. This will consist of a shallow, open channel located at the top of the berm. The channel will be protected from erosion and should divert effluent to a specified release point that minimizes impacts on downstream infrastructure and receiving environments.

4.5 Drainage/Venting System

Gas formation under the liner is unusual, but it occurs when a liner is placed over a surface previously covered with decomposable organic material. Biogas formation will also readily form if minor amounts of wastewater flow through small pin holes or imperfect seams in the liner during construction or during operation. Biogas pockets may lead to the creation of large gas bubbles under the liner, which results in "whale backs" extending beyond the surface of liquid in HDPE lined cell and stressing the material. Hydraulic uplift potential must also be considered in areas where the excavated cell or portions of the excavated cell are at a depth where a phreatic surface of groundwater is present or piezometric pressures are present.

To mitigate this risk, a pipe vent will be installed to promote passive ventilation and will be large enough to allow the introduction of a submersible pump, should water accumulation become a problem. The vent pipe will consist of a 250 mm pipe extending from underneath the liner along the height of the berm and will daylight at the east end of the lagoon.

4.6 Access Road

Construction of the lagoon will require an access road from the existing road to the north of the site. The access road will connect the east side of the lagoon to the existing road. The access road must meet the following conditions:

- The access road width will be 4 m;
- The maximum grade will be 5.1%;
- Road side delineators will be install to assist in snow clearing; and
- Side slopes of the road will be governed by the stability of the granular material used for the road construction. Geotechnical recommendation will be used to determine the minimum side slope. For safety reasons, a minimum slope of 3:1 will also govern.

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5.0%

4.7 Truck Turnaround Pad

The truck turning access pad will need to be constructed to the east of the lagoon to allow for gravity discharge from the truck into the lagoon. The location of the pad must provide for a cost effective construction that balances earthworks and allows for safe operation of the truck in winter conditions. The truck pad will have the following elements:

- A turning radius of 17.5 m;
- 3:1 (H:V) side slopes;
- Discharge culvert at discharge location;
- Stop logs at the discharge location to give the truck driver a physical indicator to stop the truck;
- Delineators along the edge of the truck pad to indicate the edge of the embankment in winter conditions; and
- The side slopes of the truck pad will be protected against erosion with a layer of granular material. The erosion protection will have a minimum gradation of a 50 mm minus material. Coarser material may be used, if economically available.

4.8 Signage

The lagoon should be provided with a suitable fence placed at the top of the berm, with a locked access gate. The truck discharge into the primary cell will be designed to penetrate through the site fence to allow for sewage truck operators to access the site and discharge into the lagoon, without requiring an access gate.

It is recommended that warning signs be placed along the perimeter of the site and at least one per side in local languages to designate the nature of facility, the risk to human health, and advise against trespassing. Signs should also be posted at appropriately spaced intervals along the perimeter of the proposed wetland treatment area (WTA) and at the final discharge compliance point of the WWTF.

4.9 Upstream Flow Diversion

Based on the site location, there will be minimal upstream flow diversion required, but all upstream runoff will be diverted around the lagoon footprint using ditches, and directed towards the valley and existing wetland area. A factor of safety will be applied to the sizing of ditching and culverts to account for future climate change conditions and changing precipitation patterns for the lifespan of the sewage treatment system.

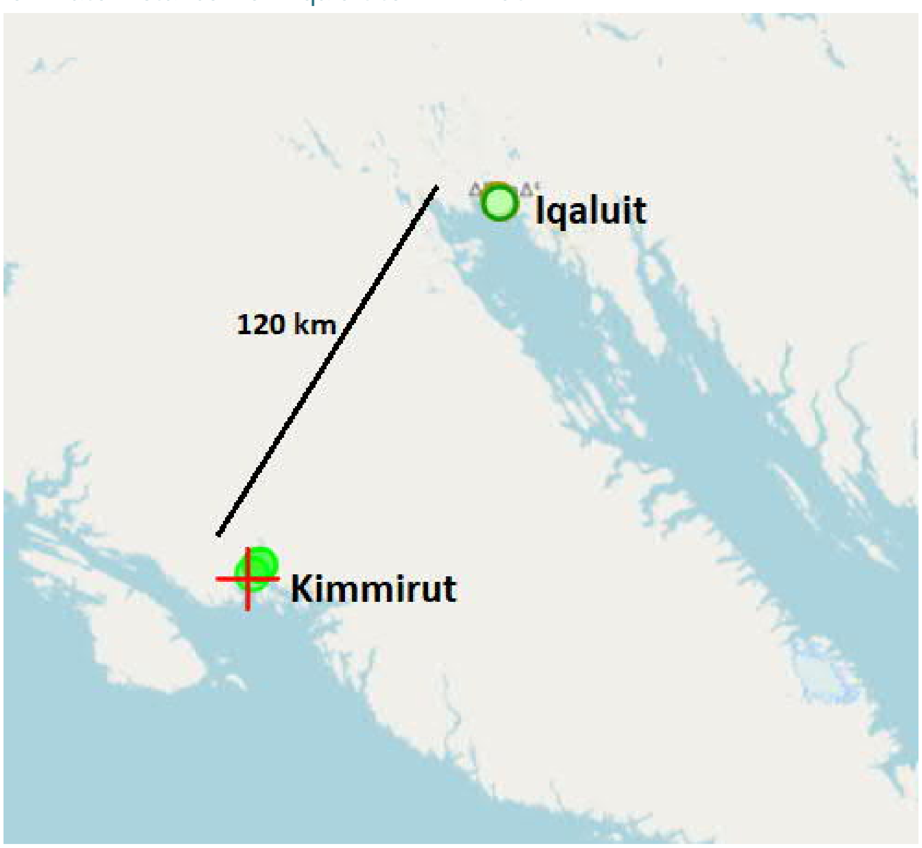
5.0 Climate Change Impacts

5.1 Historical Precipitation Conditions

An important consideration for the design of Arctic wastewater lagoons is the amount of precipitation that can be expected under current and future climate conditions. Of most relevance to the Kimmirut lagoon are the historical and projected total precipitation amounts during the storage period (before decanting at the end of the warmer season).

Climate information for this study was obtained from the ECCC national archives. Although Kimmirut does have historical and even current observations of weather parameters, the data from the archive does not currently include precipitation, which is critical for this project. Previous observations of precipitation are sporadic and non-continuous for Kimmirut, which limit their use to determine a reliable historical climate record. As a result, this report focuses on the more reliable climate record of Iqaluit, some 120 km to the northwest of Kimmirut. This alternate location can be considered relatively climatologically similar and a reliable proxy for average climate conditions of Kimmirut due to its proximity, similar coastal conditions, and weather/climatic influences.

Figure 3: Approximate Distance from Iqaluit to Kimmirut



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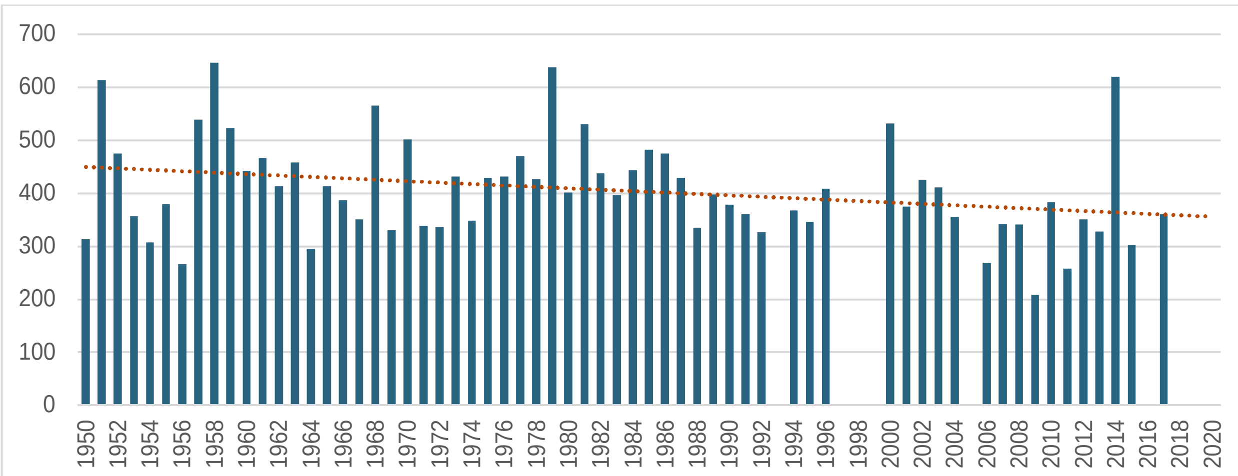
The currently available normal period of 1981-2010 for Iqaluit was used for precipitation baseline and future climate change projection differences. Only those years with sufficient precipitation data were included in the analysis.

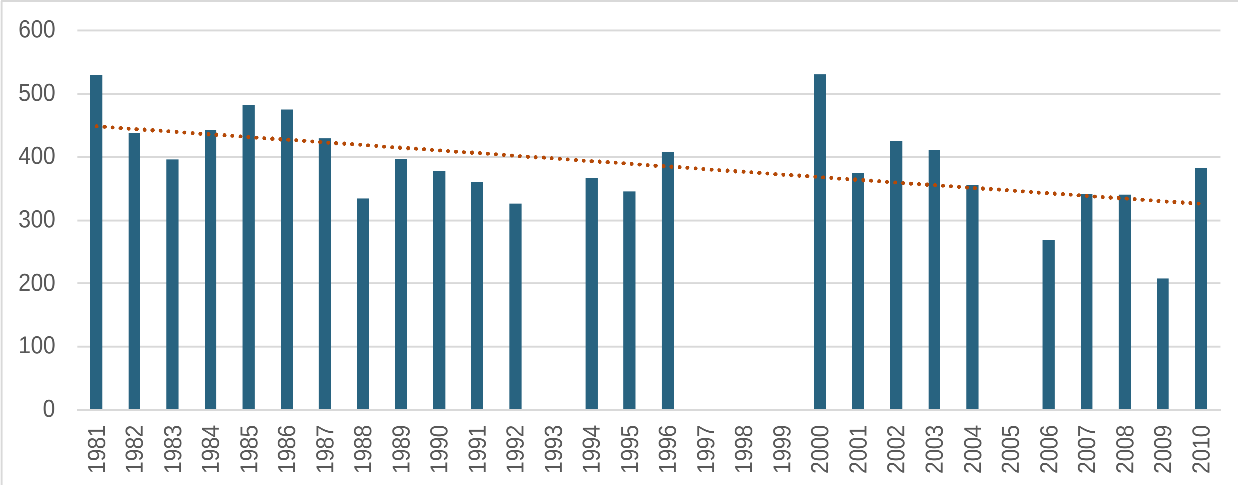
For the Iqaluit Airport station, long-term precipitation observations are available from 1950 to 2017, which meet minimum data requirements. The long-term trend indicates a decreasing trend in precipitation over this period, averaging from about 450 mm/yr in the 1950s to near 350 mm/yr currently, as shown in the Graph 1 below. The last full year of data in 2017 recorded 359.3 mm of total precipitation (including both rain and snow). For this long climate data record of over 60 years, the average annual precipitation amount was 390.1 mm.

Graph 1: Iqaluit A – Annual Precipitation (mm)



Given the rates of climate change in Arctic regions, only the most recent period of precipitation conditions are relevant for climate analysis. For climate change projections of the future, this would be the last available 30 year normal period of 1981-2010. The upcoming 1991-2020 normals period data is not yet officially available from ECCC.

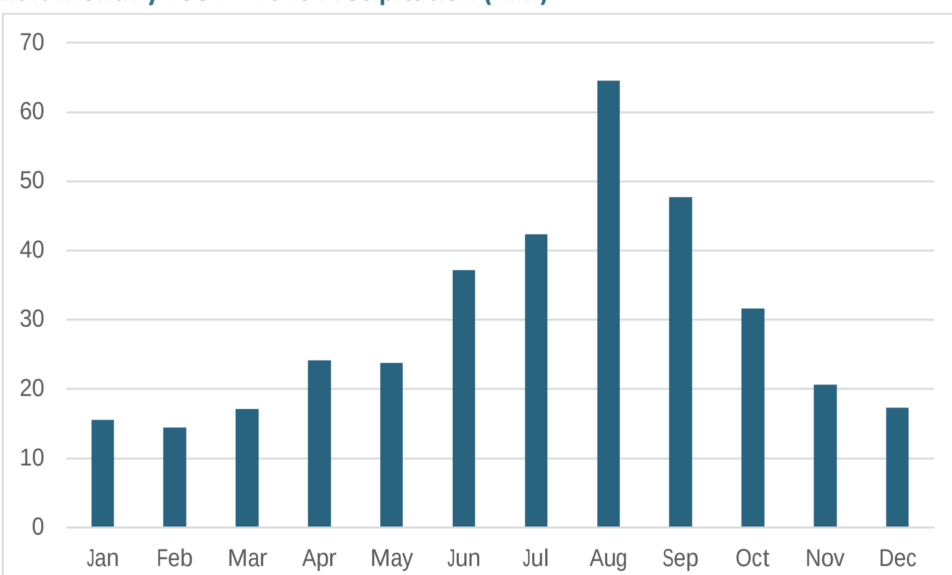
Graph 2: Iqaluit A – Annual Precipitation 1981 - 2010



For this recent 30-year climate normals period, shown in Graph 2 above, the trend is downward or decreasing from about 450 mm/yr to near 330 mm/yr, with an average annual precipitation amount of 389.7 mm. Years with insufficient data are omitted, as shown above. Preliminary analysis of the most recent climate normal period of 1991-2020 indicates a lower average annual amount of 364.6 mm (a continued drop), but it is important to note that nine years of the representative recent 30 year normal period have insufficient data. No matter the averaging period, it seems evident that Iqaluit (and by proxy Kimmirut) is experiencing a downward trend in annual precipitation.

Seasonally, the summer months are the wettest (August highest), while winter months are the driest.

Graph 3: Iqaluit Monthly 1981 – 2010 Precipitation (mm)



5.2 Projected Precipitation Conditions

Future projections of precipitation were obtained on a monthly and annual basis from the Dillon Climate Analytical System, using an ensemble of 35 Global Climate models for this proxy location. All projections were based on the IPCC AR5 climate change model series using a conservative emissions assumption or scenario where greenhouse gas (GHG) emissions are assumed to increase with continued burning of fossil fuels. This GHG assumption is known as the 'business as usual' Representative Concentration Pathway or RCP8.5. In the past, this has been the emissions pathway closest to replicating actual observations of GHG concentrations in the atmosphere. In the relatively short-term service life period considered for this project, a continued use of fossil fuels globally is anticipated. GHG concentrations will continue to increase during the lifetime of this development project. Projections are provided as a 'change' in percent from the historical period of 1981-2010 (current conditions) to represent the future 30 year averaged period of '2035s' (from 2021-2050).

The 1981-2010 precipitation average of near 390 mm/yr at Iqaluit (and hence our proxy value for Kimmirut) is projected to increase by 11% annually for the 2035s period to 433 mm/yr on average. Precipitation change is not uniform over the entire year, as shown below in the monthly projected changes to precipitation based on the average of all models. Note that the climate change projections for all months show expected increases in precipitation, with the least increase in the summer months (near 6%) and the greatest increases in the winter months (near 18%).

The projected change in precipitation going forward is almost the inverse of the existing precipitation distribution, meaning that the historically wetter summers will see the least increases in the future, while the drier winter months are expected to see the largest increases. This implies, as shown in the Graphs 4 and 5 below, the seasonality of precipitation will not change from historical conditions, with summers remaining the wettest of all seasons.

With increasing temperatures through all seasons, earlier thawing and decanting may become options. Evaporation rates should also increase during the longer daylighting periods, with both impacts potentially adding buffering to some of the lagoon capacity requirements.

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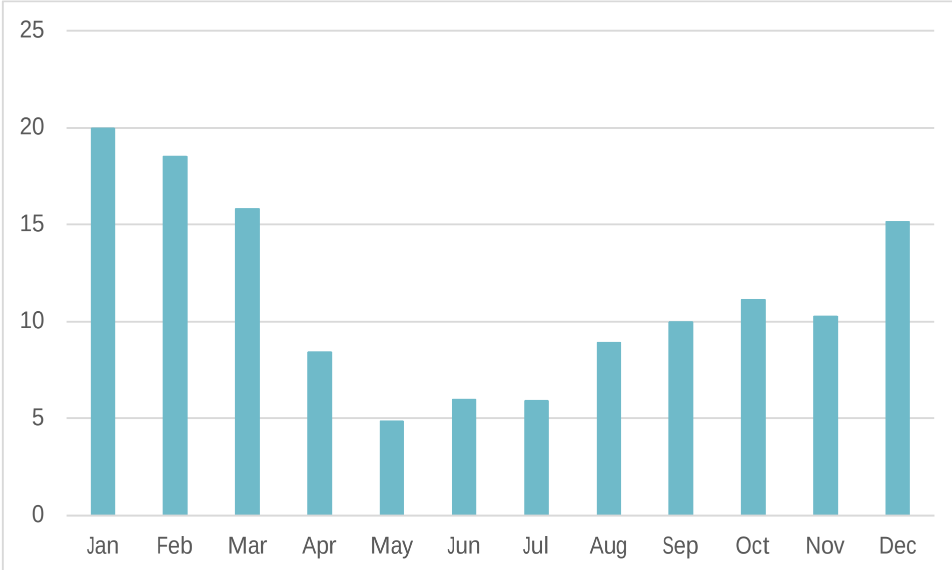
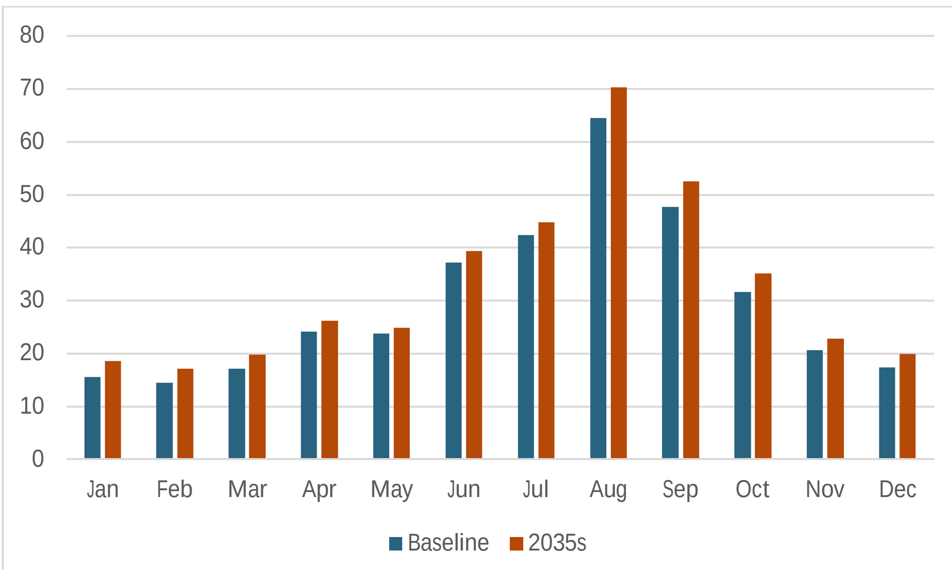
Graph 4: Kimmirut Projected Precipitation Change (%) from Historical in '2035s'



Graph 5: Iqaluit Monthly Historical and Projected Precipitation (mm) – AR5 RCP8,5



5.3 Commentary on Diverging Historical Trend and Projections from both AR5 and newest AR6

Historical trends show that precipitation totals have been increasing in many western Arctic regions, while decreasing in parts of eastern Nunavut, including this location. Similar downwards trends have been documented for the western Greenland ice sheet for the period 1996-2016 and have been attributed to shifting storm tracks as a result of stronger atmospheric blocking over Greenland, especially in summer (Lewis et al, 2019). Other studies have linked the declining precipitation in the eastern Arctic (Greenland) to teleconnections between tropical and Arctic atmospheric and ocean circulations (Matsumura et al, 2021; Zou et al, 2020). Further research may help to improve future projections in the Arctic, especially for the eastern Arctic, and clarify the differences between historical and future projected trends in precipitation.

Precipitation trend analysis for Nunavut is made more challenging by its limited precipitation measurements, and the reality from the past decade or two that many of the existing precipitation and climate stations are automated, and no longer differentiate rainfall and snowfall contributions to total precipitation. More work is needed to understand the causes of this long declining trend in precipitation and to understand its future implications under climate change, which currently is at odds with projections. Nevertheless, model consensus is for an increasing precipitation pattern under climate change overall, which would require future planning to account for this projected change going forward in spite of historical downward trends.

Under climate change, the Arctic hydrological cycle is projected to intensify throughout this century as a result of increased evaporation from expanding open water areas and more precipitation. The latest projections from the sixth phase of the new Coupled Model Inter-comparison Project (CMIP6) point to more rapid Arctic warming and sea-ice loss by the year 2100 than the AR5 models used in this report. The new models (CMIP6) show earlier rainfall dominance over snowfall, particularly in autumn, for most of the Arctic Ocean and the Canadian Archipelago. In winter, the latest models project that snowfall will continue to increase and still remain the dominant precipitation type, even at the end of the century across much of the Arctic. In essence, the Arctic generally remains largely snow-dominated in winter and spring throughout this century but rainfall amounts will also increase. Many of the changes in precipitation will not be consistent from year-to-year. Instead, it is likely that both the means and variability of Arctic precipitation will increase, and that years and seasons with excessive or more extreme precipitation will occur more often than currently experienced.

6.0 Preliminary Design Drawings

Dillon has completed preliminary design drawings for a lagoon at Site 9. The preliminary design drawings include a proposed footprint for the lagoon system with the cell configuration to be determined within the schematic design phase. Treatment would be achieved within the proposed footprint, prior to the effluent reaching the existing wetland system and receiving water body. The following has also been included within the design drawings found in Appendix A:

- Site plan of the development showing locations of the proposed lagoon, berm, approach road and truck turn area;
- Total volume, working volume, sludge allowance and freeboard;
- Cross-sections; and
- Contours developed from DEM data and associated elevations of berms, lagoon bed, and access road.

7.0 Recommended Site Investigations

The following site investigations are recommended through the schematic design phase to move the project into detailed design, based on the selection of Site 9.

7.1 Phase I/II Environmental Site Assessment

A Phase I Environmental Site Assessment (ESA) will be required at Site 9 and it is also recommended at the existing discharge location for decommissioning purposes. Dillon will gather background information on the selected site through review of available documentation and photos from Dillon's previous site visit on October 21, 2021. This information includes reviewing available information provided by GN CGS and utilizing Environmental Risk Information Services (ERIS). Dillon will contact the Kimmirut Senior Administrative Officer to provide knowledge regarding the historical uses of the site.

ERIS will be contacted and retained to conduct a search of databases for information on the site and surrounding area (250 m radius), and will obtain aerial photographs of the site from the extensive collection at the National Aerial Photography Library (i.e., one aerial photo per decade, if available).

The results of the Phase I ESA will determine if a Phase II ESA is required at Site 9 and/or the existing discharge location.

7.2 Snow and Wind Analysis

A snow and wind analysis is recommended for Site 9. An initial overview of the snowdrift conditions were provided by Rowan Williams Davies and Irwin Inc. in December of 2014. This overview included a high level summary of all the potential sites discussed by Stantec in their 2015 Feasibility Study and compared to projected drift zones of each option.

With approval from the GN, Dillon would retain hire Gradient Wind as a subconsultant to perform a snow and wind analysis of Site 9; more specifically, the proposed truck discharge location. The principal tool in both studies is 3D computer modelling based on computational fluid dynamics to assess snow drifting and odour dispersion from the lagoon. The snow drift and accumulation study would estimate the drift sizes and locations that may cause operational problems for site access, and recommend snow clearing operations or snow storage areas, as may be required.

7.3 Fish Habitat Study

A fish habitat study will be required on the existing pond at Site 9. Dillon's biologists will perform a desktop study of the site using existing data, available background information, as well as a community consultation. The results of the desktop study will determine if a field assessment and survey is required.

7.4 Wetland Field Assessment

As mentioned above at the request of the GN, the wetland treatment area downstream of the decant location will not be included within the treatment calculations and the effluent quality parameters are designed to be met entirely through lagoon treatment, prior to decant.

If the GN does decide that they would like to include the existing wetland area within treatment calculations and estimate the effluent quality entering the receiving marine body after further polishing through the wetland area, it is recommended that wetland field assessment be completed. This can be further discussed, if required. We recommend that as the wetland develops over the years, a study be conducted to determine the polishing effects of the wetland treatment area as it is anticipated that the polishing through the wetland will further treat the lagoon effluent.

8.0 Project Schedule

Table 6: Revised Project Schedule

Phase	Tasks	Site Trip #	Revised Schedule
Proposal Submission			March 12, 2020
Project Award			May 1, 2020
A. Basic Services			
Phase 1: Pre-Design Services	Task 1 - Project Initiation Meeting		May 6, 2020
	Task 2 - Background Review		May 15, 2020
	Task 3 – Site 9 Review		May 22, 2020
	Task 4 – Pre-Design Meeting and Site Visit	1	October 19, 2021
	Task 4A – Geotechnical Investigation and Reporting		June 30 – Jul 31, 2020
	Task 5 – Regulatory Review		Aug 7, 2020
	Task 6 – Capacity Analysis		May 29, 2020
	Task 7 – Effluent Requirements Review		Aug 7, 2020
	Task 8 – Pre-Design Report		February 9, 2022
	Task 9 – Regulatory Agency Submission		March 16, 2022
Phase 2: Schematic Design Report	Task 1 – Schematic Design		March 9, 2022
	Task 2 – Class 'D' Cost Estimate		March 18, 2022
	Task 3 – Schematic Design Report – Community Consultation	2*	March 18, 2022
Phase 3: Design Development Phase	Task 1 – Design Development Report with updated Class 'C' estimate by a Professional Quantity Surveyor (PQS)		April 15, 2022
Phase 4: Construction Document Phase	Task 1 – 75% Design and Specifications with Class 'B' estimate by a PQS		April 22, 2022
	Task 2 – 100% Design and Specifications with Class 'A' estimate by a PQS		May 13, 2022
	Task 3 – Verification Plan		TBD
Phase 5: Procurement Phase	Task 1 – Tender Ready Documents		TBD
	Task 2 – Tender Process Support • Tender Advertising • Tender Open/Close • Recommendation of Award		TBD
	Task 1 – Construction Administration		TBD

Phase	Tasks	Site Trip #	Revised Schedule
Phase 6: Construction Phase	Task 2- On-Site Construction Monitoring Services • Site Trip #5 • Site Trip #6 • Site Trip #7 • Site Trip #8 • Certificate of Substantial Performance	5 6 7 8	TBD
Phase 7: Post Construction & Warranty	Task 1 – Commissioning • Submission of Operation and Maintenance Manual		TBD
	Task 2 – Preparation of As-built Drawings • Complete Record (As-built) Drawings		TBD
	Task 3 – Warrant Inspection		TBD
B. Additional Services			
Phase I/II Environmental Site Assessment		3*	TBD
Fish Habitat Study		4*	TBD
Snow and Wind Analysis			TBD
Wetland Assessment (if required)			TBD

*If required based on desktop investigations

9.0 Recommendations

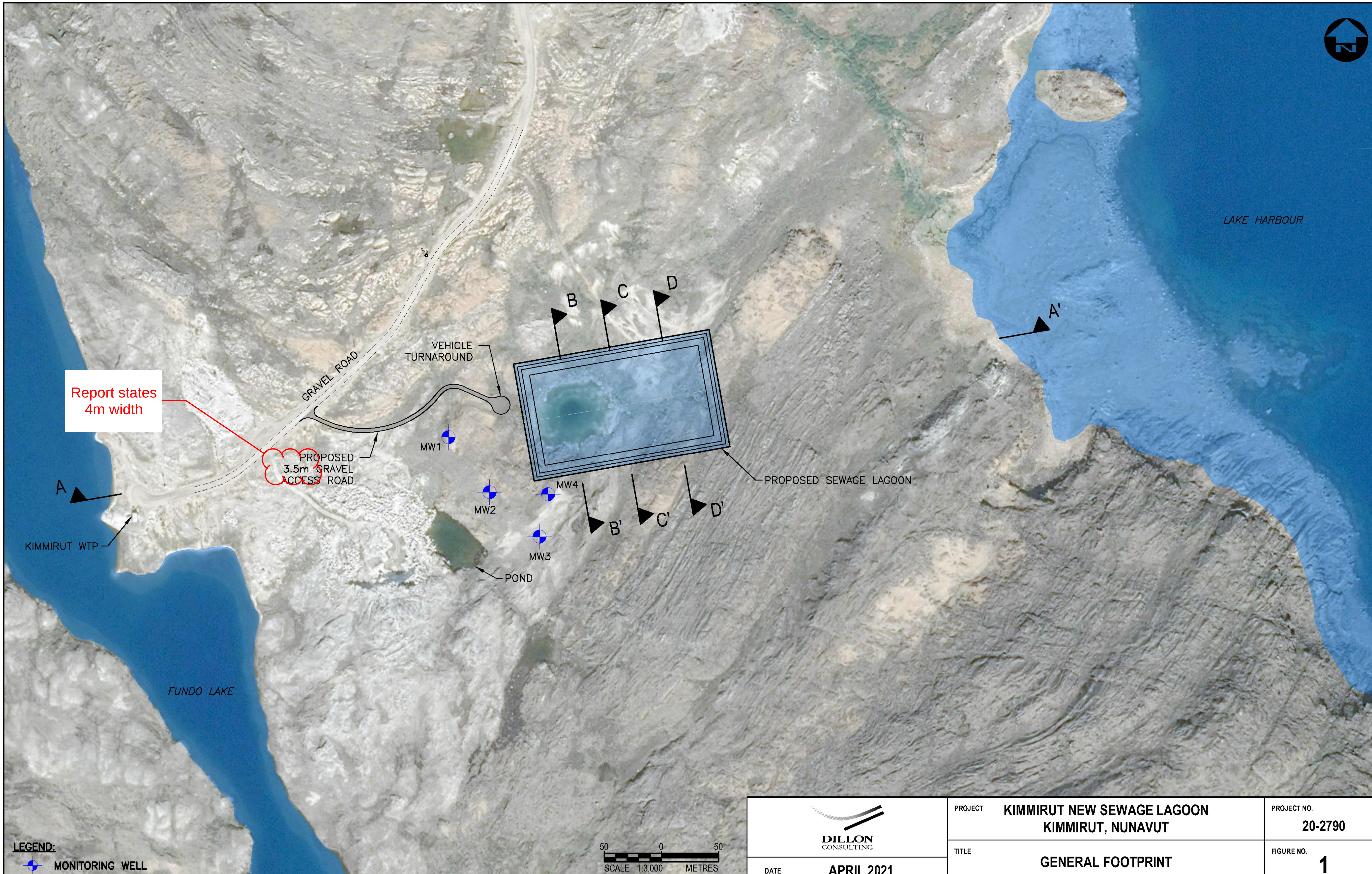
Dillon recommends proceeding to schematic design for Site 9 and providing the GN with a minimum of two variations that will compare ease of operation, maintenance, capital and lifecycle cost, and treatment kinetic predictions. Dillon will identify potential conceptual strategies for management of community wastewater for an additional 10 years beyond 2043. Based on the comparison of the design variations during the schematic design phase, Dillon will recommend a preferred design to proceed to detailed design.

The following site investigations will be required at Site 9, prior to the project moving into detailed design:

- Phase I/II ESAs;
- Snow and Wind Analysis; and
- Fish Habitat Study.

Appendix A

Preliminary Design Drawings



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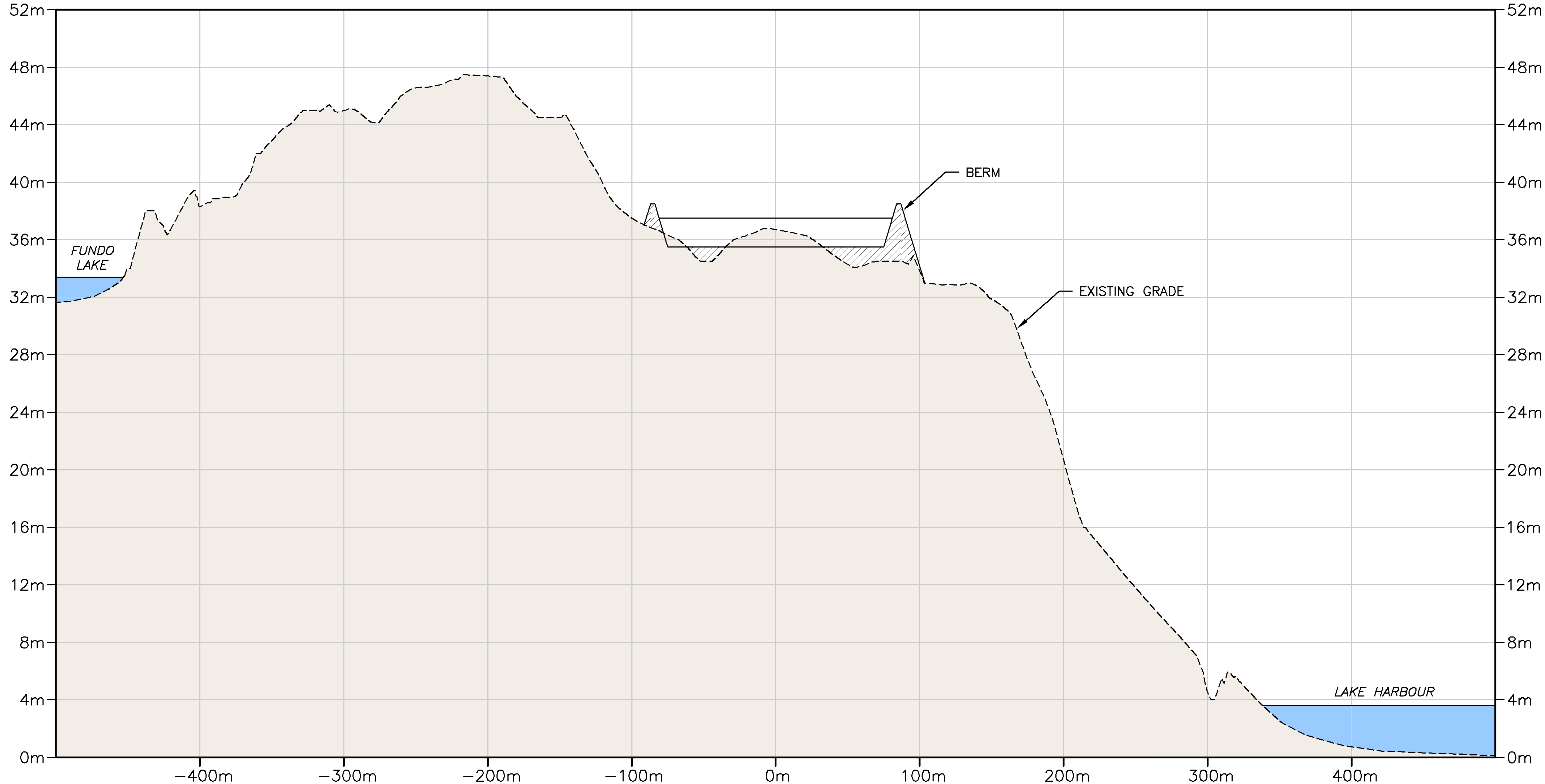
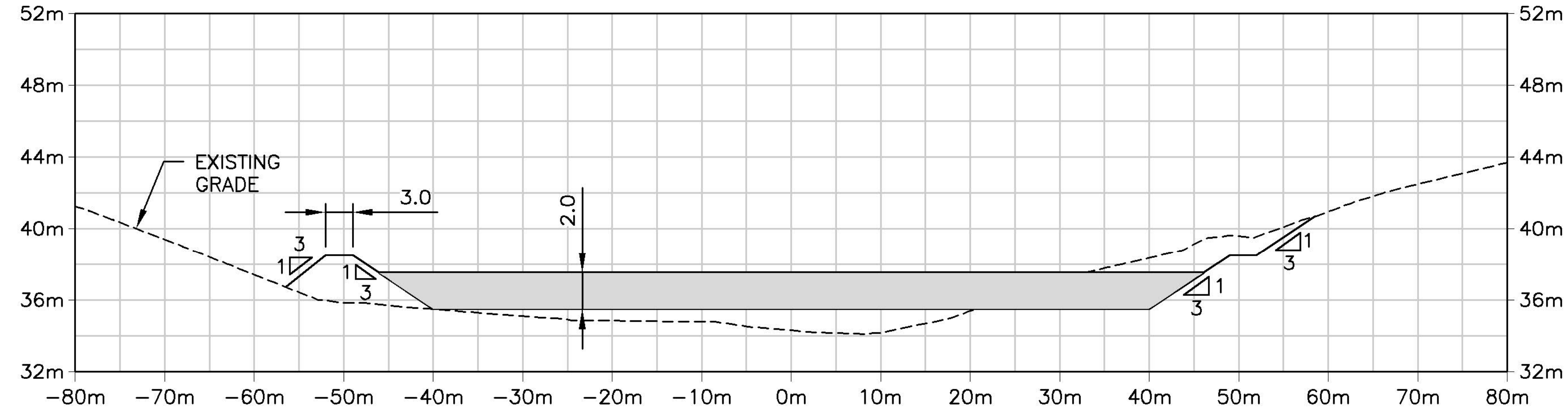
PROJECT	KIMMIRUT NEW SEWAGE LAGOON KIMMIRUT, NUNAVUT	PROJECT NO.	20-2790
TITLE	GENERAL FOOTPRINT	FIGURE NO.	1
DATE	APRIL 2021		

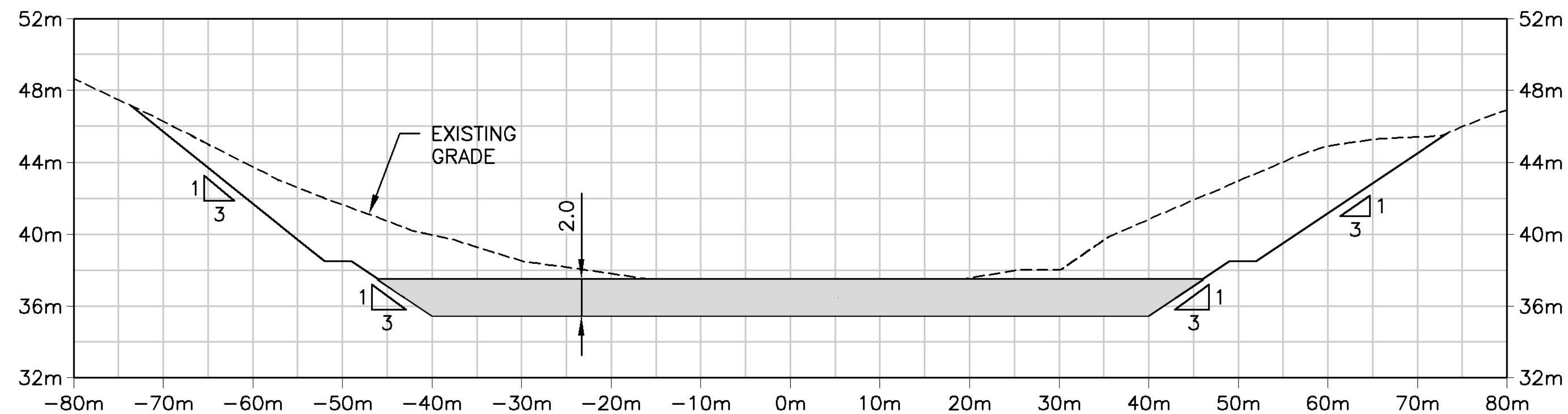


DILLON CONSULTING	PROJECT: KIMMIRUT NEW SEWAGE LAGOON KIMMIRUT, NUNAVUT		PROJECT NO. 20-2790
DATE: APRIL 2021	TITLE: CROSS SECTION A-A'		FIGURE NO. 2

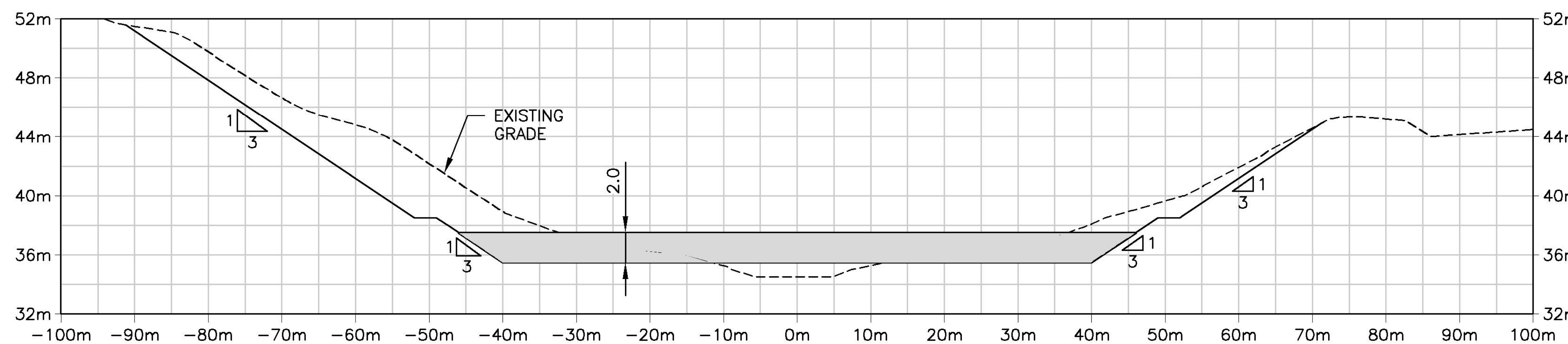
FileName:c:\pw working directory\projects 2020\40skb\dms95646\202790-10-www-des.dwg



CROSS SECTION D-D'



CROSS SECTION C-C'



CROSS SECTION B-B'

DILLON CONSULTING	PROJECT	KIMMIRUT NEW SEWAGE LAGOON KIMMIRUT, NUNAVUT	PROJECT NO. 20-2790
DATE APRIL 2021	TITLE	LAGOON CROSS SECTIONS	FIGURE NO. 3

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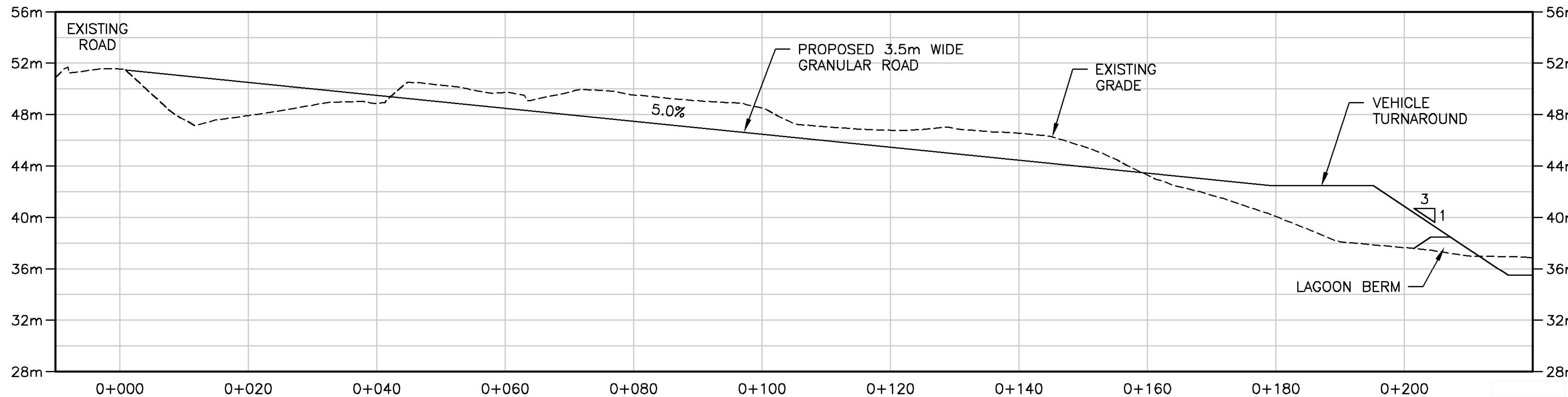

PROFILE

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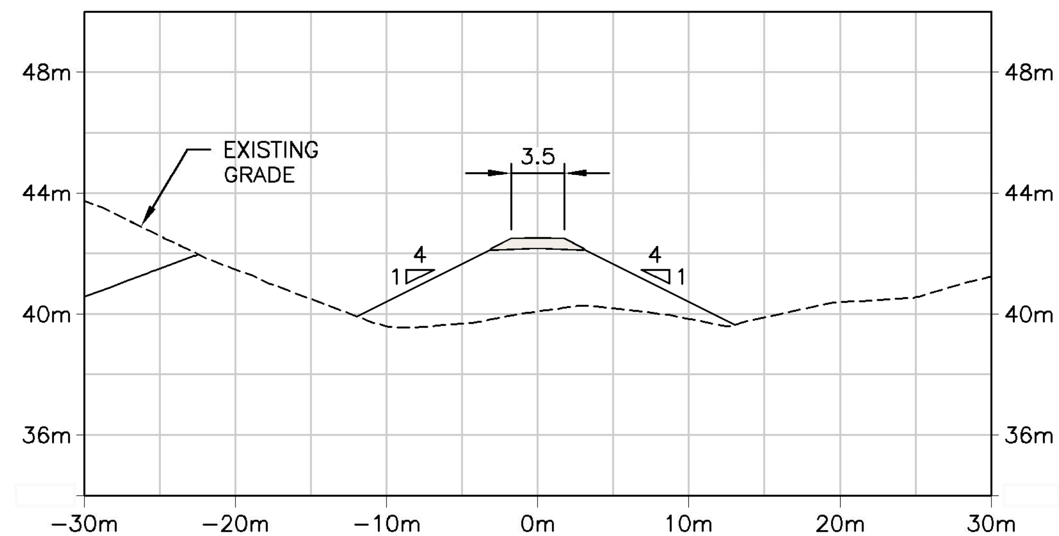
DILLON CONSULTING

PROJECT	KIMMIRUT NEW SEWAGE LAGOON KIMMIRUT, NUNAVUT	PROJECT NO. 20-2790
DATE APRIL 2021	TITLE ACCESS ROAD PROFILE	FIGURE NO. 4



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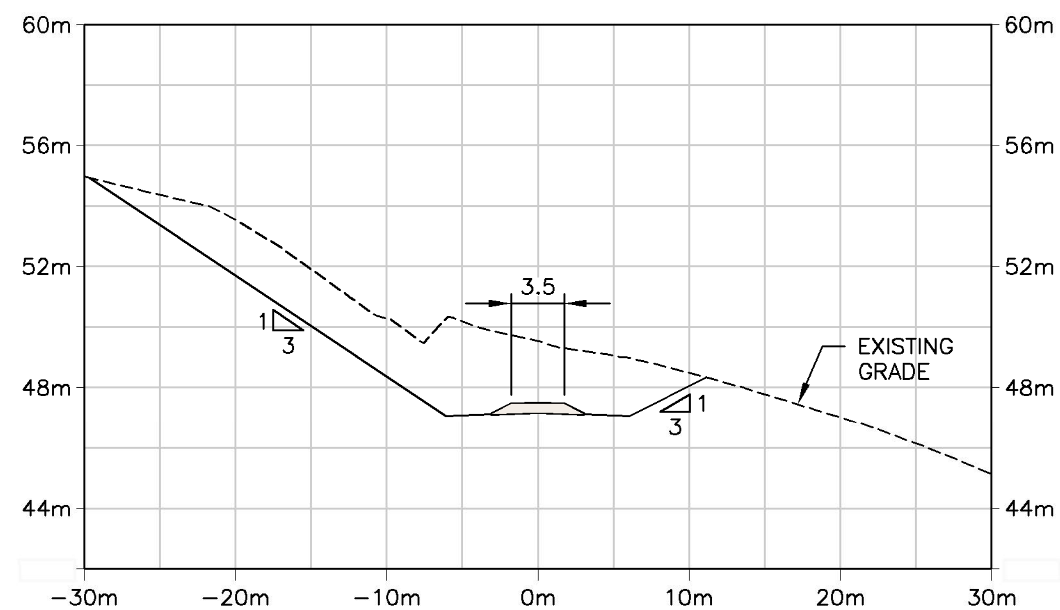

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PROJECT	KIMMIRUT NEW SEWAGE LAGOON KIMMIRUT, NUNAVUT	PROJECT NO.	20-2790
TITLE	ACCESS ROAD CROSS SECTIONS	FIGURE NO.	5
DATE	APRIL 2021		

FileName:c:\pw working directory\projects 2020\40skb\dms95646\202790-10-www-des.dwg

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