DILLON CONSULTING

HAMLET OF ARVIAT

The Hamlet of Arviat Drainage Plan

Drainage Plan Report – FINAL

March 2020 | 19-9737

DILLON
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March 17, 2020

The Hamlet of Arviat
PO Box 150
Arviat, NU
X0C 0E0

Attention: Steve England
Senior Administrative Officer

The Hamlet of Arviat Drainage Plan Final Report

Dear Mr. England:

Please find enclosed one electronic copy of our Drainage Plan Final Report for the Hamlet of Arviat, Nunavut.

Our Drainage Plan is based on discussions with the Hamlet staff, as well as site investigations and desktop assessments. Areas of drainage concern were identified and a topographic site plan was developed to establish conceptual drainage strategies. This document is to assist in developing drainage infrastructure to alleviate drainage concerns in the Hamlet of Arviat.

We appreciate the opportunity to work with the Hamlet on this interesting project. Should you have any questions or immediate comments, please contact the undersigned at 403.215.8885, ext. 4328 or at plopez@dillon.ca.

Sincerely,

DILLON CONSULTING LIMITED

Pablo Lopez, P. Eng., Associate
Project Manager

AYS:clm

Our file: 19-9737

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1.0 Introduction

The Hamlet of Arviat is contained within the Kivalliq region of Nunavut, which is comprised of flat open tundra, and numerous lakes and wetlands. The general site location is presented in **Figure 1**. Arviat has a subarctic climate, characterized by long cold winters and comparatively short warmer summers. Over the past several decades, the effects of climate change have become a prominent concern in northern Canadian communities. Climatological variability, in addition to changing animal migration patterns, the introduction of new animal and insect species, melting permafrost, and sea ice changes, threaten the Nunavummiut people and culture. Arviat lacks a dedicated and complete drainage system. The Hamlet has raised concerns relating to challenges with seasonal drainage, requiring improvements to the existing infrastructure and drainage system. In recent years, Arviat has experienced significant temperature fluctuations during the spring freshet, which have cause widespread flooding throughout the Hamlet. Furthermore, the spring freeze-thaw conditions have resulted in substandard road conditions and increased municipal operations expenses. The purpose of this report is to provide guidance to the Hamlet of Arviat in the selection and implementation of a Drainage Plan and Long-Term Asset Management Plan.

1.1 Scope of Work

This Drainage Plan was intended to include the following objectives:

- Watershed and water flow mapping;
- Recommendations and specifications for ditching and for culvert placement, both within the community, and on the boundaries to control drainage flows in and around the community;
- Ditching/culvert maintenance and thawing techniques;
- Snow removal management plan, including options for snow dumping/storage and push-out areas;
- Identification of training needs for staff to implement and maintain the plan on an ongoing basis; and
- A complete implementation and Asset Management Plan to guide the Hamlet's planning and budgeting processes for the foreseeable future, including identification of additional equipment that the Hamlet requires (immediately or in the future) to implement the plan, ongoing maintenance and inspection checklists, annual work calendars, etc.

HAMLET OF ARVIAT

DRAINAGE PLAN

SITE PLAN

FIGURE 1

STUDY AREA

N
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0 0.25 0.5 1 km

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1.2 Report Layout

The structure of this report is intended to provide clearly illustrated Drainage Plan concepts. Appendices were selected to supplement the content of this report. Sketches and photographs are also included in the appendices to assist in the visual representation of the drainage concerns for the community of Arviat. The appendices, along with their brief description, are shown in **Table 1**.

Table 1: Appendix Information

Appendix	Title	Description
A	Site Inspection Photos	Complete set of photos taken during the various site visits.
B	Design Calculations	Tabulated design calculations for proposed ditches and culverts.
C	Lifecycle Strategy	Detailed lifecycle strategy and considerations.
D	Asset Inventory Sheets	Asset inventory sheets for culverts, ditches and equipment.
E	Operations and Maintenance Forms	These procedures contain information on the proper operation and maintenance of drainage ditches and culverts.
F	Alternative Ditch Access Way Details	Geoweb® product details.

2.0 Background

2.1 Location

The Hamlet of Arviat is located along the western shore of Hudson Bay within the Kivalliq region of Nunavut. It is located at Longitude 94° 04' W, Latitude 61° 07' N and has an approximate elevation of 10 m. It is estimated that 2,514 individuals reside within the Hamlet of Arviat (according to the 2016 Canadian Census conducted by Statistics Canada) and the population density is estimated at 1,000 individuals/km^2.

2.2 Background Information

Existing mapping, aerial photographs and community plans were acquired from the ATLAS website for review. GIS information and Canada Lands Survey data was downloaded and was used to construct the base plans for all mapping and figures used throughout this report. The topographic survey data was provided by the Government of Nunavut, and consisted of a Digital Elevation Model (DEM) with 1 m horizontal accuracy. Due to the flat terrain in the community, the DEM was deemed to only be suitable for conceptual designs. More discussion on this point is provided in the following sections.

2.3 Site Investigations

Dillon Consulting Limited (Dillon) personnel were on-site in the community for three separate site investigations. The focus of the site investigations was to identify drainage problems and determine the cause of those problems.

The first site investigation was performed at the end of April 2019. During this visit, problem areas were inspected and the visible existing infrastructure was documented. The multiple areas of concern were found to be related to the lack of existing infrastructure and connected drainage system. This site investigation also allowed for Dillon personnel to witness the existing snow management plan for the Hamlet. During this trip, a council meeting was also held where Dillon personnel heard the concerns of the council members, as well as the main constraints they faced.

At the request of the Hamlet, a second site investigation was performed by Dillon personnel at the end of May 2019. This site investigation was to assess the existing infrastructure that was buried under the snow and ice during the first site visit, and to witness firsthand the effects of the spring freshet on the community. The majority of existing infrastructure within the community was damaged and/or filled with debris and silt. The drainage system was found to be non-existent within some parts of the community and some of the roadways had pooling water from the snow melt with no outlet nearby to drain the water. During this site visit the constraints of the spring freshet were also witnessed, where it was found that as snow melt started to fill the existing ditches the culverts were still frozen, consequently restricting the flow of the snow melt.

Dillon personnel performed a third site visit to the community at the end of September in 2019. This site visit was to assess the existing infrastructure and roadways, prior to the fall freeze-up, as well as perform a site survey of one of the problem areas (8^{th} Avenue) highlighted by the Hamlet. The site survey was completed to identify the general drainage patterns, or lack thereof, in the problem area, and to provide a base line of information to inform the development of the conceptual Drainage Plan. The site survey was limited to primarily the 8^{th} Avenue problem area roads and ditches, and did not cover the entire community.

A complete set of site investigation photos are included in **Appendix A**.

3.0 Drainage Plan Development

The Hamlet of Arviat is in need of a Drainage Plan to mitigate the local flooding issues they experience. The following sections describe the local conditions, constraints, considerations and rationale for a proposed Drainage Plan. Included in this Drainage Plan, are strategies that address short and long-term drainage goals and the required drainage infrastructure to accomplish those goals.

3.1 Urban and Rural Drainage Systems

There are two primary types of drainage systems that communities can elect to use: 1) curb/gutter roads with a storm sewer system; and 2) roadside ditch and culvert system. Curb and gutter type systems are primarily used in urban centres with higher vehicular and pedestrian traffic, while the ditch and culvert type systems are more commonly used in rural communities. Curb and gutter road systems allow for better pedestrian accessibility, as there is no open ditch barriers, but typically include higher up front capital costs compared to open ditch/culvert systems. Ditch systems typically include dedicated driveway crossings at each property with culverts to convey flows across the driveways. Driveway culverts can lead to blockage issues, which then lead to damages and also higher maintenance costs. Local site conditions can also dictate the viability of drainage systems (e.g., flat vs. steep terrain, minimal cover, greenfield vs. brownfield (retrofit) applications), and in the case of northern communities the avoidance of permafrost. While each system has its merits, they each also have deficiencies. A certain and common element between any type of drainage system is the need to maintain it in operational conditions to ensure it performs as intended. Without a properly implemented maintenance program, the best drainage systems will lead to a reduced level of service (LOS). The following sections describe the rationale for the proposed Arviat drainage system.

3.2 Local Conditions and Constraints

The Hamlet of Arviat currently uses a small network of defined ditches, culverts and swales to drain stormwater runoff and snow melt away from the community. Currently, many of the existing culverts and ditches have limited functionality due to being severely damaged or capacity restricted. Along with the lack of defined ditches and damaged culverts, the terrain in Arviat is relatively flat, which makes conveying the stormwater from the low-lying areas to the designated outfalls a challenge. Due to the flat terrain, some existing ditches do not have positive drainage (i.e., do not drain away but rather pond water) to dedicated locations outside the community. In addition, the majority of existing roads are dirt roads and do not have a normal-crown cross section; thus, leading to standing water on the roads. Other constraints consist of the high permafrost table that leads to high saturation of soils which then leads to ground and roadway structural issues.

The poor drainage conditions in the community were evident during the various site visits. **Figures 2** and **3** demonstrate the local conditions. While on-site, Hamlet staff identified the local drainage issues as a range from public inconveniences to health and safety concerns. Common drainage issues observed throughout the community are summarized in **Table 2**. Along with this, standing water can have other potential drawbacks and disadvantages as highlighted in **Table 3**.

In addition to the existing drainage problem area in the south-east part of the community along 8th Avenue, as described in **Section 2.3**, another drainage problem area identified by Hamlet staff is the area behind the community hall building in the south-west part of the community. Due to previous concerns relating to the existing wetland behind the community hall building flooding the building, the Hamlet constructed a ditch to convey flows away from the building. The ditch can be seen in **Figure 6**, and situated within catchments W01 and W02. Due to the limited survey data accuracy, further investigation and additional survey is required to assess the existing condition and functionality of that ditch system.

Figure 2: Example of Standing Water within the Community

Figure 3: Example of Lack of Road-Crowning and Proper Ditching

Table 2: Common Drainage Issues

Common Element	Issue	Probable Causes
Culverts	Excessive damage and/or restrictions to culvert entrances and/or exits decrease functionality, and reduce flow conveyance capacity.	Lack of maintenance – insufficient clearing of materials deposited in or around culvert pathways. Vehicle damage – vehicle damage to ends of culverts due to poor visibility during snow/ice conditions.
Ditches	Undefined edges and poor grading decrease the flow conveyance effectiveness.	Improper installation techniques and lack of maintenance.
Grading	Flat terrain limits the ability to have positive drainage and leads to standing water and ponding.	Flat terrain and improper grading techniques.
Connectivity	Much of the pooling and standing water does not have a dedicated drainage system to move water away. Many roadways and embankments without ditching and/or culverts.	A general lack of a drainage system.

Table 3: Standing Water Drawbacks and Disadvantages

Drawback	Description
Safety	Standing water can create safety issues for both pedestrian and vehicle travel, should the extent of the ponding reach or spill onto a roadway.
Insects	The presence of standing water provides an area for mosquitoes and other insects to thrive.
Aesthetics	Standing water tends to collect and store wind-blown garbage and other debris.

3.2.1 Snow Melt

During the spring freshet, the main contributor to standing water is snow and ice melt within the community. This is caused by the snow and ice melting within the roadways and properties before frozen culverts have thawed, exacerbating the problem areas. In recent years, this problem has worsened, as the spring freshet appears to occur more rapidly than historically. Continuous freeze-thaws of culverts and ditches from one day to the next are leading to restricted flow paths and standing water throughout the community. This is a nuisance and safety concern that the Hamlet maintenance staff has to address and mitigate daily during the spring freshet.

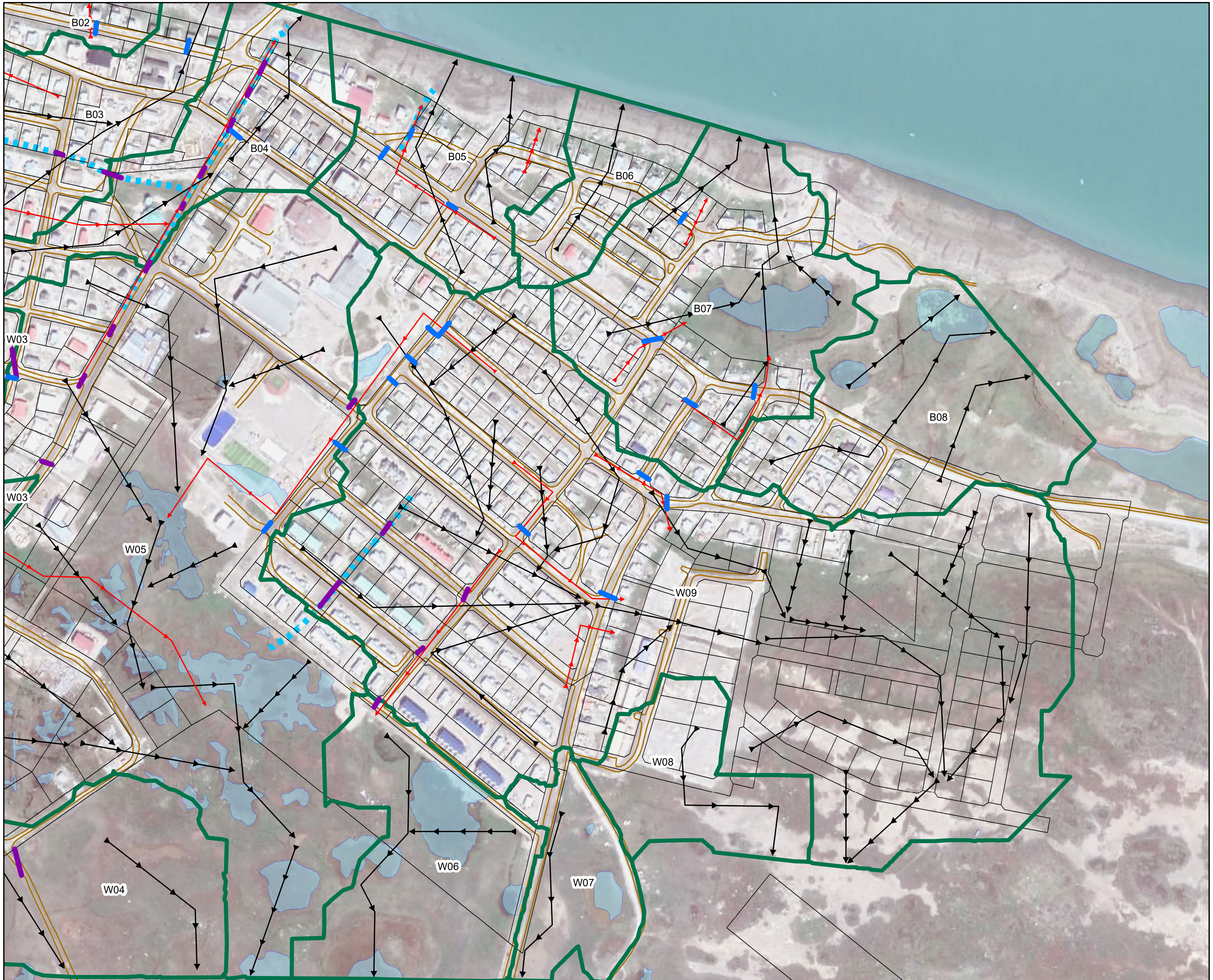
3.2.2 Damaged/Blocked Culverts

While frozen culverts, relatively flat terrain and an incomplete drainage system seem to be the main reason for standing water and restricted flow, the excess damage to the inlets and outlets of culverts by vehicular traffic (including maintenance and snow removal vehicles) further limits the capacity of the existing drainage system. Shown in **Figure 4** is an extreme example of culvert damage and blockage within the community that is restricting flow at the outlet. Culverts with damage or restrictions have a greatly reduced flow capacity and inhibits a connected drainage system from performing properly.

Figure 4: Extreme Example of Damaged/Blocked Culvert

3.2.3 Existing Drainage Pathways

Based on the data obtained from the Government of Nunavut's GIS data for the Hamlet of Arviat and anecdotal evidence from Hamlet staff, some of the existing drainage pathways within the community are conveyed through residential parcels without properly established utility or drainage easements. Furthermore, some roads and corresponding drainage systems (i.e., culverts) are also not within road rights-of-way and encroach across property lines. Existing catchment boundaries, ditches, flow directions and culverts are shown in **Figures 5** and **6**.



HAMLET OF ARVIAT

DRAINAGE PLAN

EXISTING FLOW MAPPING EASTERN HALF OF SITE

FIGURE 5

- EXISTING CULVERTS - (SOURCE - HAMLET STAFF)
- EXISTING CULVERTS - (SOURCE - GN)
- EXISTING BRIDGE - (SOURCE - GN)
- EXISTNG FLOW DIRECTION - (SOURCE - HAMLET STAFF)
- EXISTING DITCHES - (SOURCE - GN)
- EXISTING FLOW DIRECTIONS FROM LIDAR
- EXISTING CATCHMENTS
- WATER BODIES
- EXISTING GRAVEL ROADS
- B00 CATCHMENT ID

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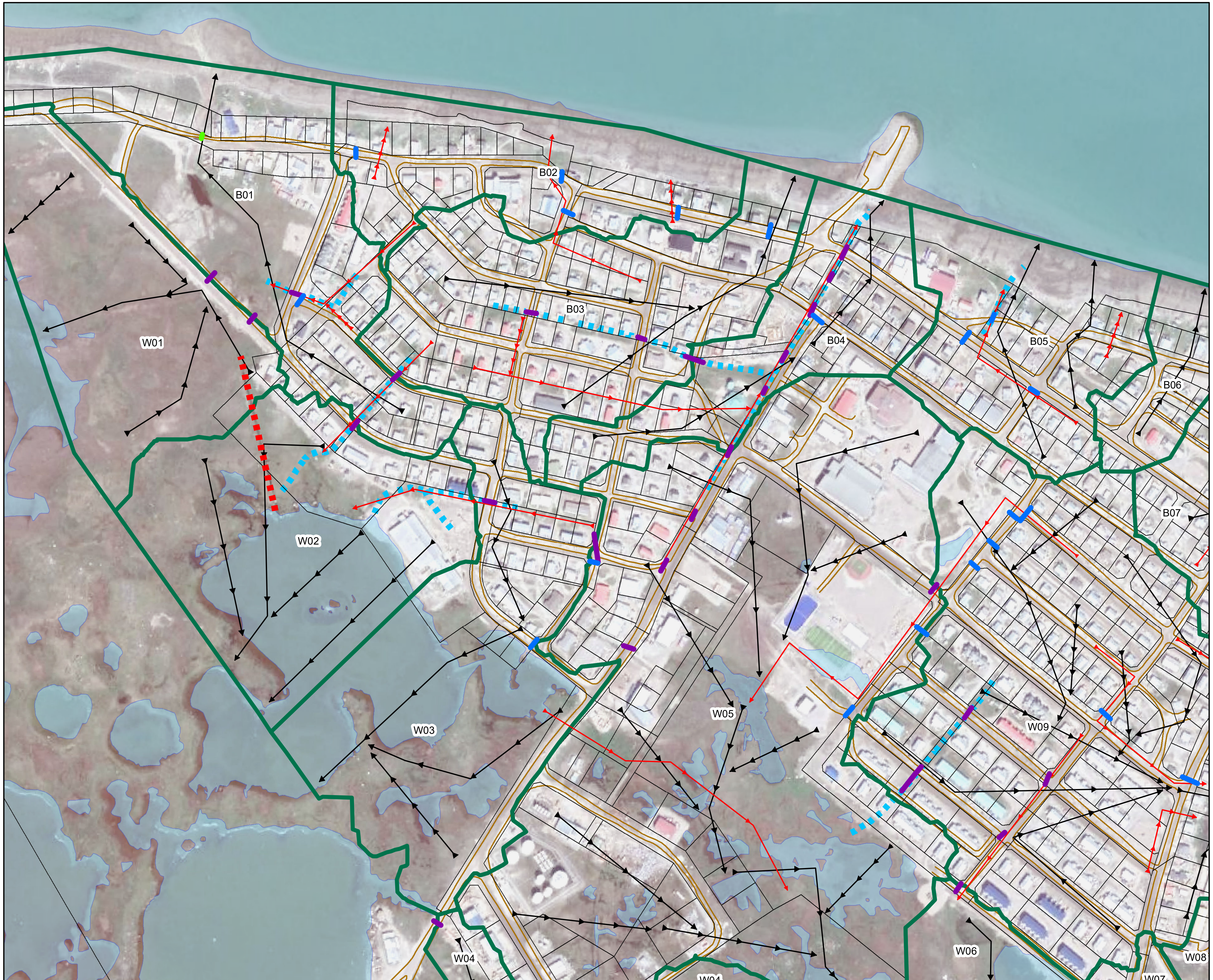
HAMLET OF ARVIAT

DRAINAGE PLAN

EXISTING FLOW MAPPING WESTERN HALF OF SITE

FIGURE 6



- EXISTING DITCH - (SOURCE - HAMLET STAFF)
- EXISTING CULVERTS - (SOURCE - HAMLET STAFF)
- EXISTING CULVERTS - (SOURCE - GN)
- EXISTING BRIDGE - (SOURCE - GN)
- EXISTNG FLOW DIRECTION - (SOURCE - HAMLET STAFF)
- EXISTING DITCHES - (SOURCE - GN)
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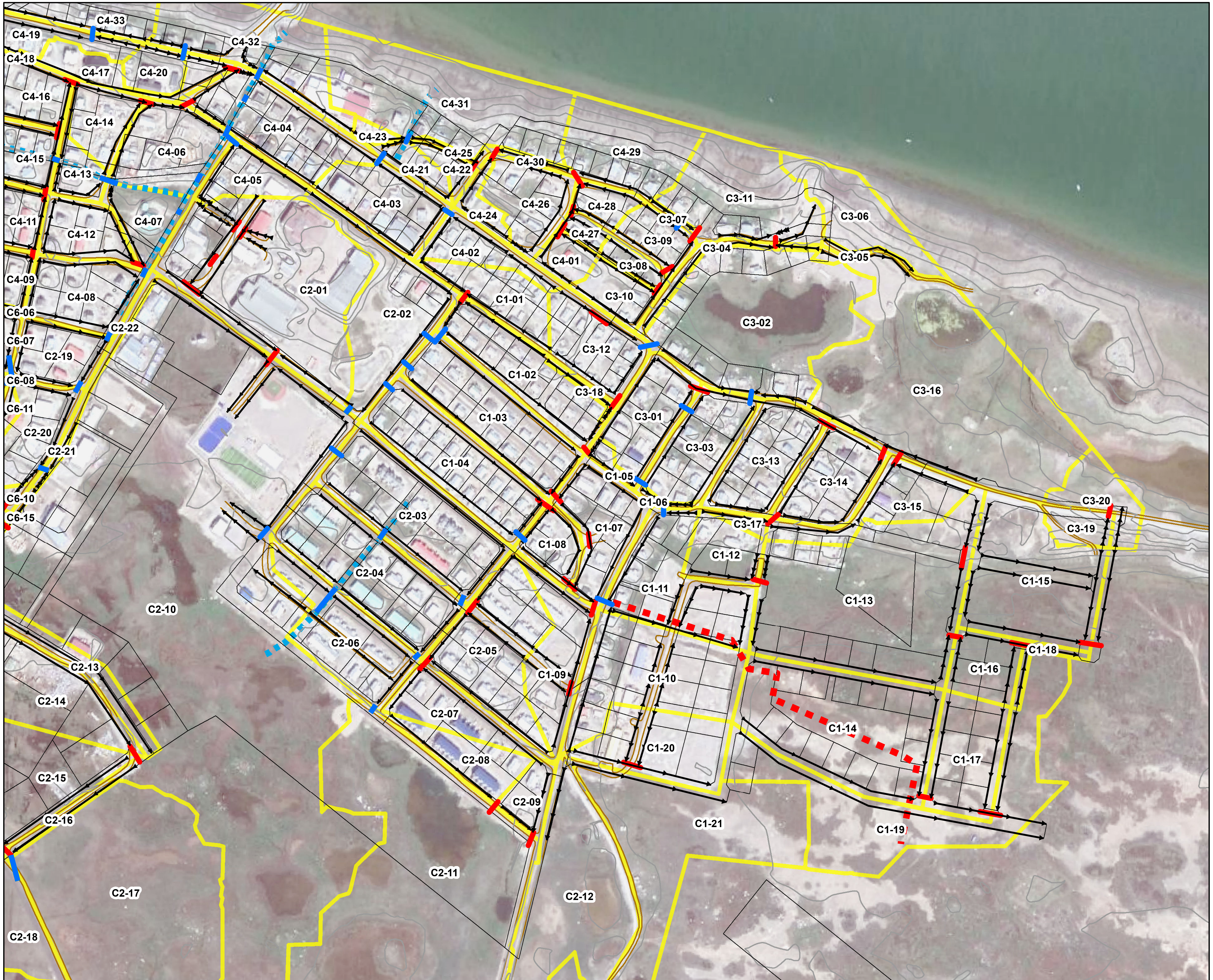
3.3 Recommended Approach

The following describes the recommended Drainage Plan approach for the Hamlet of Arviat to achieve an improved level of service based on existing conditions and objectives established by the Hamlet. The Hamlet's preferred drainage system is a low cost, low maintenance system that will mitigate local drainage issues. A rural drainage system of functional gravel roads with adjacent ditches and culverts is recommended. The plan entails rebuilding all existing roads with a gravel normal-crown cross section that will drain into adjacent road-side ditches. The ditches are intended to be contiguous and drain away from the community through designated culverts at road intersections, and in some locations, through designated drainage ways. See **Figures 7** and **8** for a conceptual Drainage Plan showing all proposed ditches, flow directions, culverts, dedicated drainage ways and corresponding catchments. It is noted that the proposed drainage system design is conceptual and was limited by the accuracy of the existing DEM provided by the Government of Nunavut. More detailed community wide survey data will be required to properly design the ditch and culvert network, under subsequent phases of the Drainage Plan.

Road-side ditch design concepts include moderate side slopes (5:1 on the road-side and 10:1 on the property side) and shallow depths to allow accessibility of vehicles, pedestrian and ATV traffic without the need of ditch blocking driveways. Ditch filled driveways are not preferred by the Hamlet, as they will require more culvert crossings and more maintenance. The ditch design allows pedestrians and vehicles to cross anywhere along the ditch during dry conditions. In anticipation of wet conditions, the design concepts include designated access ways to allow vehicle crossings without getting stuck in the mud. The designated access ways include additional gravel in the ditch to provide structural support of vehicles without blocking ditch flows. A drawback of not using filled in driveways is that pedestrian traffic will not have a dry walkway across the ditches during wet conditions. All proposed and salvaged existing culverts will include culvert delineators to prevent vehicular damage during winter conditions. See **Figure 7** for conceptual design details.



HAMLET OF ARVIAT

DRAINAGE PLAN

PROPOSED DRAINAGE PLAN EASTERN HALF

FIGURE 7

- EXISTING CULVERTS
- EXISITNG BRIDGE
- EXISTING DITCHES
- PROPOSED DITCHES
- PROPOSED CULVERTS
- PROPOSED CATCHMENT
- EXISTING GRAVEL ROADS
- PROPOSED DRAINAGE EASEMENT
- C0-0 CATCHMENT ID

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HAMLET OF ARVIAT

DRAINAGE PLAN

PROPOSED DRAINAGE PLAN WESTERN HALF

FIGURE 8

- EXISTING CULVERTS
- EXISTING BRIDGE
- EXISTING DITCHES
- PROPOSED DITCHES
- PROPOSED CULVERTS
- PROPOSED CATCHMENT
- EXISTING GRAVEL ROADS
- C0-0 CATCHMENT ID

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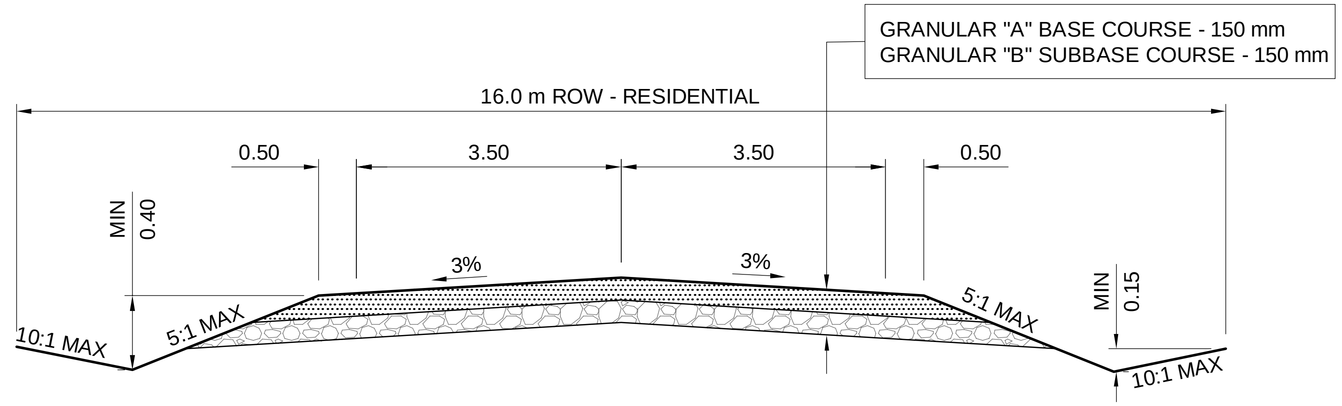
DRAINAGE PLAN

CROSS SECTIONS

FIGURE 9



A - TYPICAL NORMAL CROWN ROADWAY

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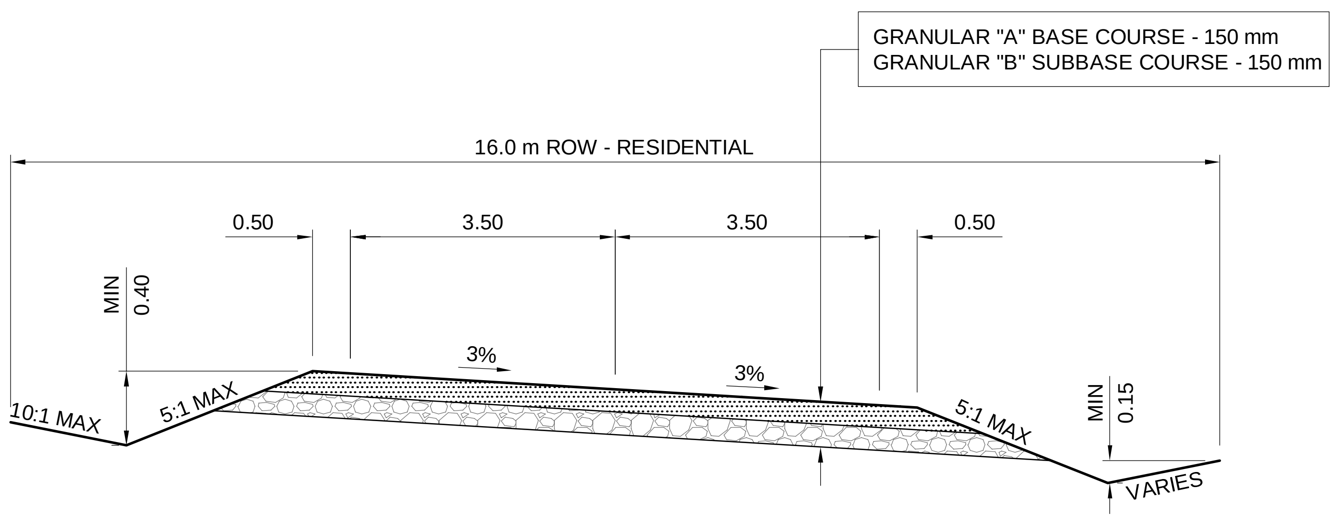
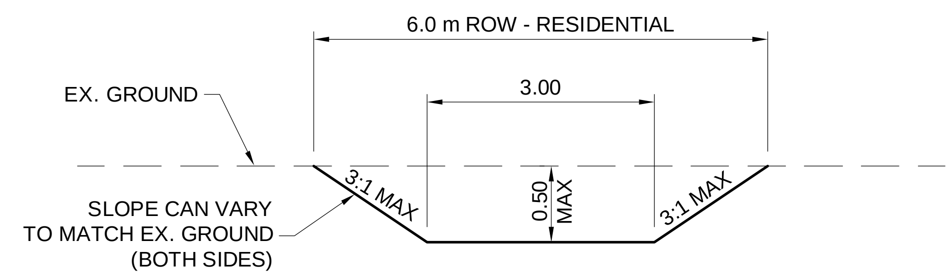


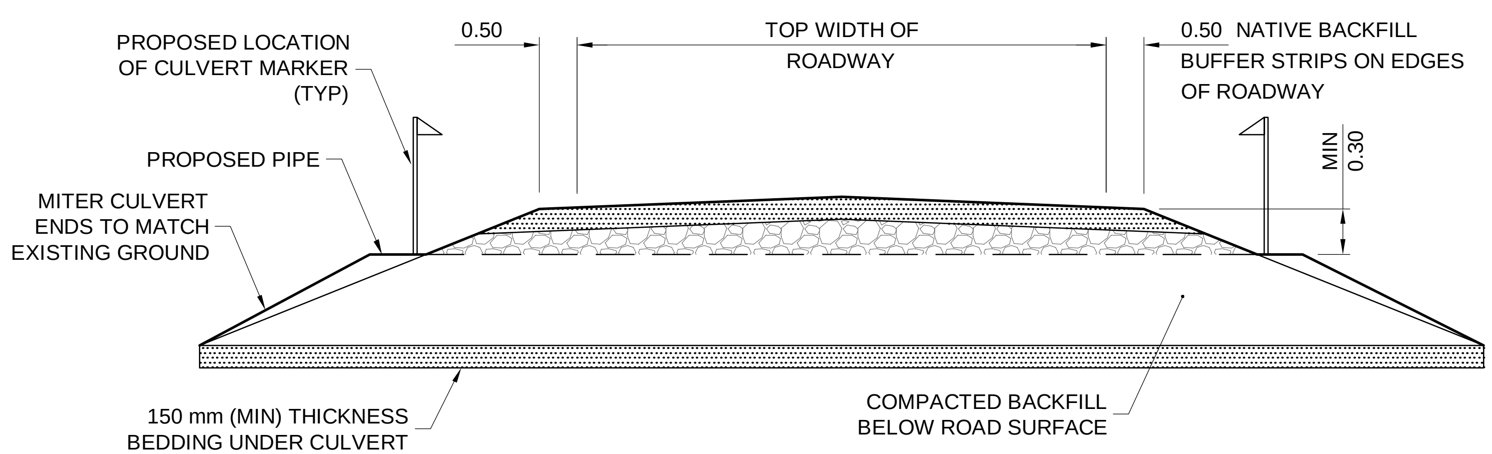
B - SUPER ELEVATED ROADWAY

SCALE HORZ 1:100 VERT 1:50



C - PROPOSED DESIGNATED DRAINAGE DITCH

SCALE HORZ 1:100 VERT 1:50



D - CULVERT

SCALE HORZ 1:100 VERT 1:50

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DECIMALIZED NUMBERS INDICATE METRES

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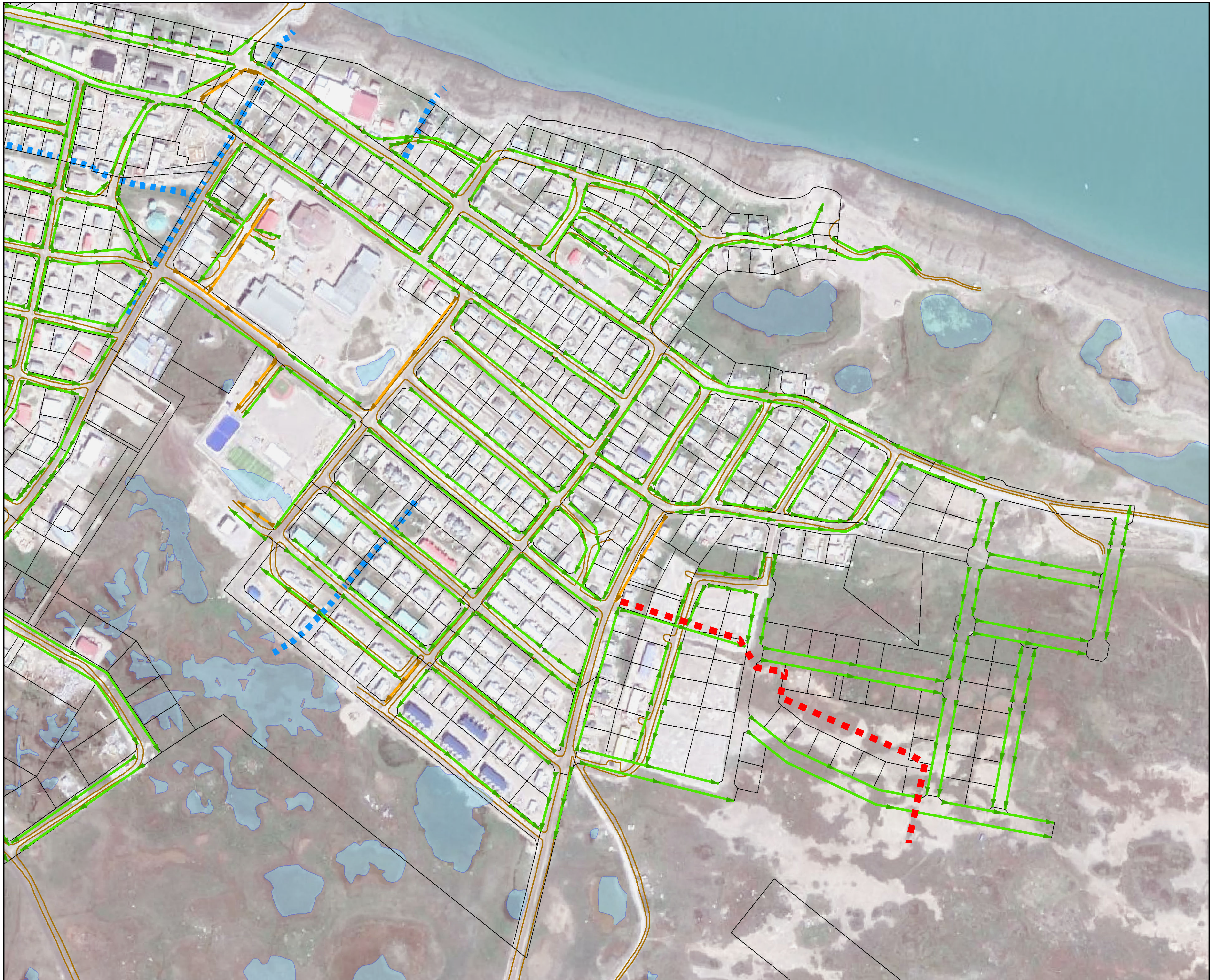
4.0 Basis of Design

4.1 Proposed Drainage System

The intention of the proposed Drainage Plan is to develop an effective drainage network to prevent or reduce the impact of future flooding events in the Hamlet of Arviat. As part of the proposed plan, several infrastructure improvements have been recommended in order to improve the drainage system. The proposed conceptual Drainage Plan requires it to be retrofitted throughout most of the community with the exception of a few projected growth areas. Retrofitting rural drainage infrastructure like that in the proposed ditch/culvert drainage system comes with some challenges, especially considering the existing flat terrain. Unlike in greenfield applications, where the site can be designed and graded to accommodate desired drainage design standards, the flow design capacity (i.e., LOS) in retrofit applications is often limited to what the local conditions can accommodate. Based on the conceptual design, the majority of the proposed ditches will be able to convey runoff flows from a storm event with a 1:2 year probability (also referred to as a 2-year storm return period). The proposed drainage system is expected to be able to also convey runoff flows during significant freshet conditions, provided the culverts are free of debris and ice blockages. See **Figures 10** and **11** for the proposed drainage system capacities.

Some of the ditches with larger corresponding catchment areas will only be able to provide approximately a six month storm capacity. The new development area, not yet constructed, south-east of the 8^{th} Avenue problem area, is expected to convey a relatively larger catchment that currently flows through this future development. To accommodate the larger anticipated flows, rather than relying on the lower capacity roadside ditches to convey these larger flows, a dedicated drainage easement is proposed between future residential properties to adequately convey the 2-year storm flows. This will require planning and consideration during the design of the new sub-division. See **Figure 10** for proposed drainage options through the new development area.

See **Appendix B** for design capacity calculations and assumptions.



HAMLET OF ARVIAT

DRAINAGE PLAN

PROPOSED DRAINAGE PLAN DESIGN CAPACITIES EASTERN HALF

FIGURE 10

EXISTING DITCHES
WATER BODIES
EXISTING GRAVEL ROADS

PROPOSED DITCHES

2 YEAR OR GREATER RAINFALL EVENT
6 MONTH RAINFALL EVENT
PROPOSED DRAINAGE EASEMENT

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PROPOSED DRAINAGE PLAN DESIGN CAPACITIES WESTERN HALF

FIGURE 11

EXISTING DITCHES

WATER BODIES

EXISTING GRAVEL ROADS

PROPOSED DITCHES

2 YEAR OR GREATER RAINFALL EVENT

6 MONTH RAINFALL EVENT

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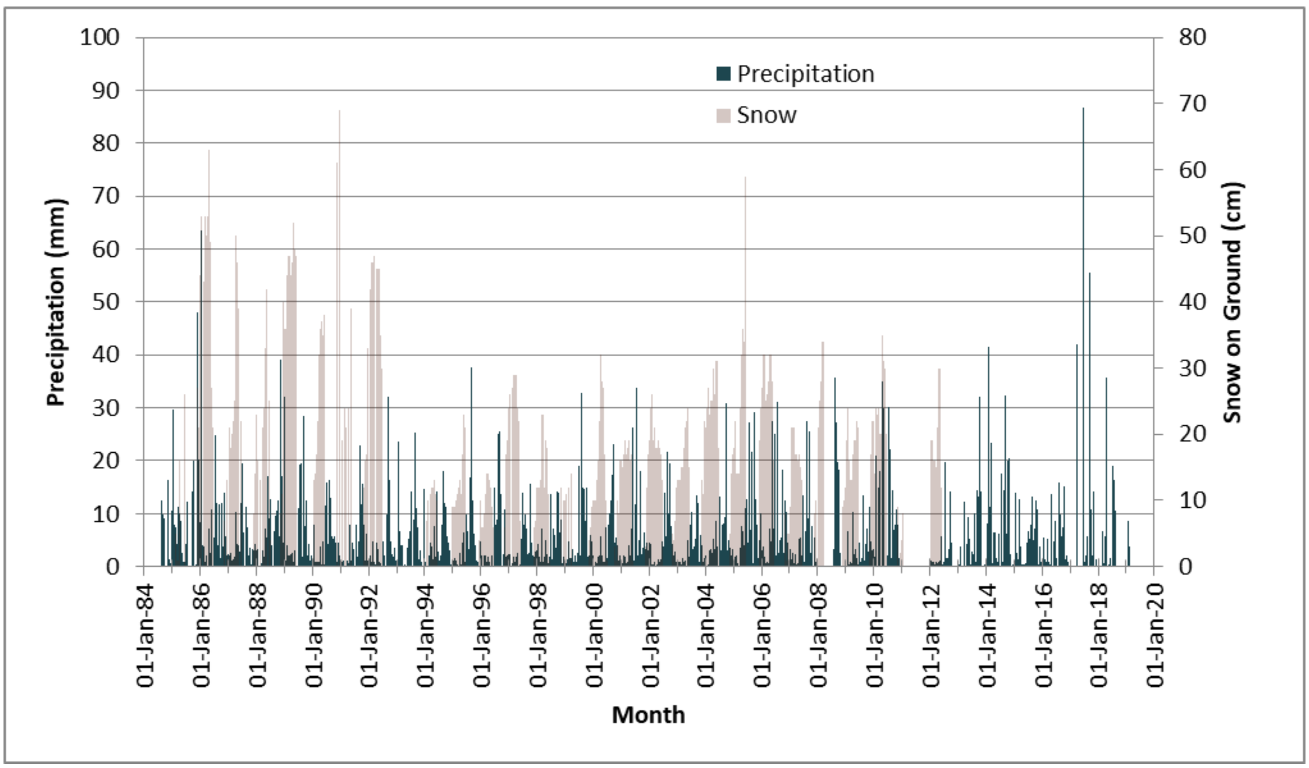
4.2 Climate Change

4.2.1 Climate Change Analysis

According to the Environment and Climate Change Canada's climate normal for 1980 to 2010 at the Arviat A climate station (#2300MFK and #2300278), average temperatures are above zero from July to September, with average monthly rainfall between 40 mm and 56 mm, and August experiencing the largest yearly precipitation amounts. For the remainder of the year, precipitation is dominated by snow, with an average annual snow accumulation in the order of 110 cm. Most of this snow falls as trace amounts, with single event snowfall accumulations greater than 5 cm being infrequent. Localized blowing snow over the winter months is common when winds are strong.

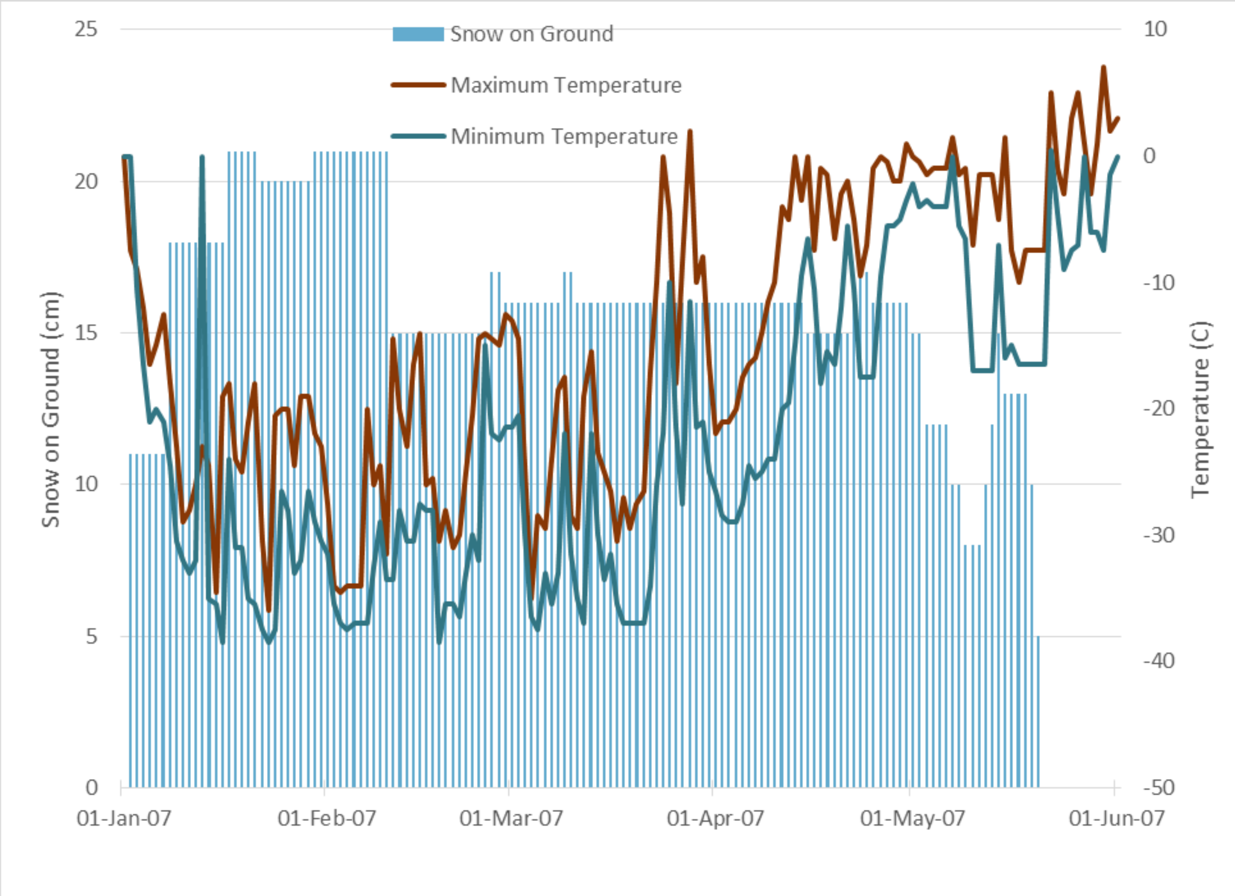
The Arviat A climate station (#2300MFK) contains records for "snow on ground" between 1987 and 2012; data is unavailable for the periods between 1984 to 1986, 1993 to 1994, 2011, and 2013 to 2019. While the data set is incomplete, it does provide some indication of the type of spring and freshet experienced on a yearly basis. **Figure 12** shows the daily precipitation and snowpack measurements from 1984 to 2019. Precipitation is defined as the water equivalent of all types of precipitation, including rain, drizzle, freezing rain, freezing drizzle, hail and snowfall.

Figure 12: Precipitation and Snow on Ground for Arviat A Climate Station (1984 to 2019)



As shown in **Figure 13**, spring 2007 exhibited a slow freshet or snow melt period. A maximum snow on ground depth of 21 cm was measured from January 17, 2007 to February 4, 2007. Reductions to the snow depth in February, March and early April were likely the result of wind action. Near the end of April, maximum daily temperatures above 0 C were recorded. The minimum daily temperatures also increased from -17.5 C (April 25) to -3.5 C (April 30) to 0 C (May 7). This warming pattern in minimum daily temperatures had a noticeable impact on the snow melt. Recorded depths of snow on ground fell from 16 cm (April 25) to 10 cm (May 7). The snow depth decreased to 0 cm by May 21, 2007.

Figure 13: Temperature and Snow on Ground for Arviat A Climate Station (2007)



To inform the potential climate change impacts on the Hamlet of Arviat, the Canadian Water Network's Intensity-Duration-Frequency (IDF) Climate Change Computerized Tool (IDF_CC tool), Version 4.0 (August 2019), developed at the University of Western Ontario (UWO), was employed for the creation of the 24-hour IDF statistics for various return period events (http://www.idf-cc-uwo.ca). The Arviat climate station (Climate ID: 2301153), containing 12 years of data from 2005 to 2016, was utilized by the IDF_CC tool to prepare a 50-year climate change projection from 2020 to 2070.

Table 4 provides a summary of the historical IDF and projected future IDF curve data expected under climate change. Three different climate change scenarios / representative concentration pathway (RCP) scenarios were modelled:

- RCP 2.6: Lowest climate change severity scenario;
- RCP 4.5: Moderate climate change severity scenario; and
- RCP 8.5: Most severe climate change scenario.

Table 4: Summary of Historical and Estimated Future Rainfall Depths in Arviat, Nunavut (Climate ID: 2301153)

Return Period (Years)		2	5	10	25	50	100
Historically Derived Rainfall Depth (mm)		30.76	36.32	38.72	40.79	41.85	42.62
Estimated Future (2020 – 2070) Climate Change Rainfall Depth (mm)	Scenario RCP 2.6	34.87	42.01	46.40	51.67	59.50	59.50
	Scenario RCP 4.5	34.76	41.21	44.84	49.06	52.23	52.23
	Scenario RCP 8.5	34.45	42.29	46.84	50.46	53.62	56.62
Percent Increase (%)	Scenario RCP 2.6	13%	16%	20%	27%	40%	40%
	Scenario RCP 4.5	13%	13%	16%	20%	23%	23%
	Scenario RCP 8.5	12%	16%	21%	24%	26%	26%

Notes:

1. IDF values calculated using the bias corrected (ensemble) option.
2. Generalized Extreme Value distribution utilized, as it provides a more conservative estimate of future rainfalls depths.

All rainfall depth estimates are quite conservative based on the statistical approaches used for their calculation. As shown in **Table 4**, the total rainfall depth for the 100-year, 24 hour return period is estimated to increase the most under the RCP 2.6 scenario. Considering all climate change scenarios, future rainfall depths in Arviat are expected to increase by approximately 12% to 40% within the next 50 years.

Similarly, ClimateData.ca, a climate information platform developed by Environment and Climate Change Canada, the Computer Research Institute of Montréal, Ouranos, the Pacific Climate Impacts Consortium, the Prairie Climate Centre, and HabitatSeven, estimates a 29% increase in average annual precipitation for Arviat for the 2051 to 2080 time period under the RCP 8.5 scenario (most severe climate change scenario).

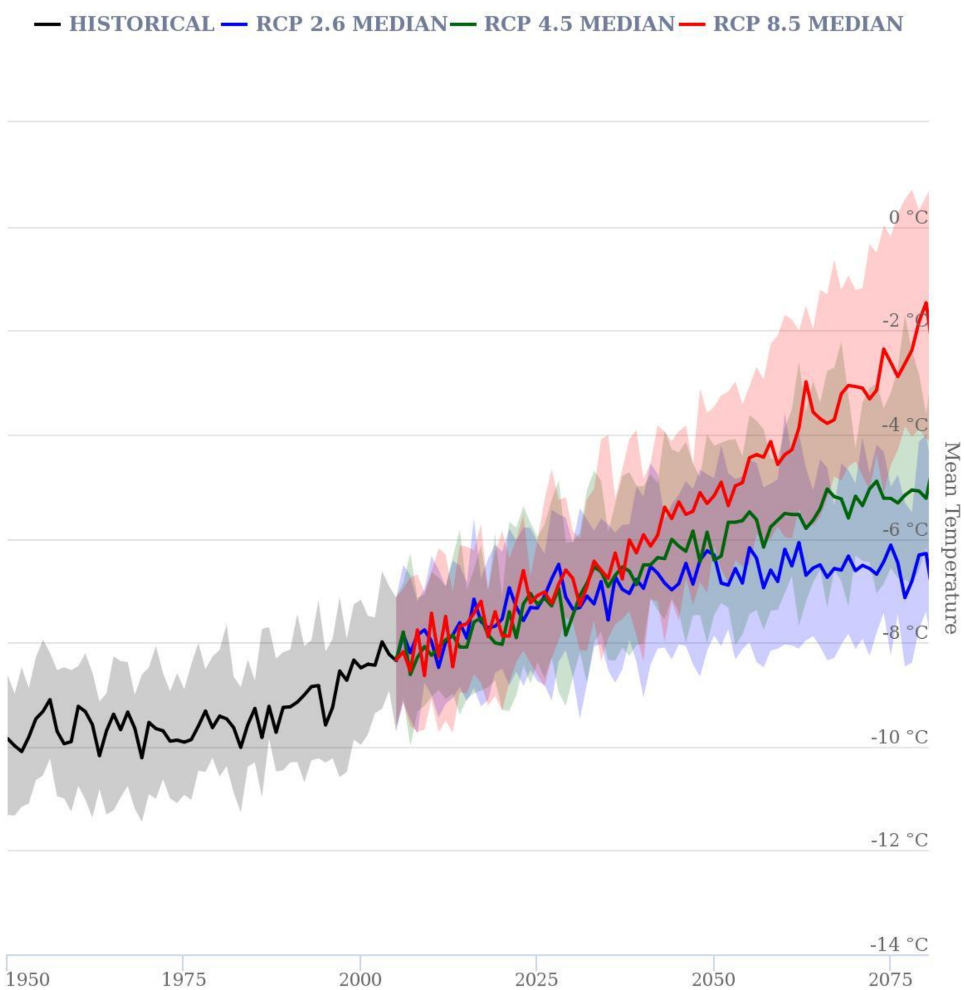
As per summary information available on ClimateData.ca for Arviat, Nunavut:

Average annual precipitation for the 1951-1980 period was 339 mm. Under a high emissions scenario, this is projected to change by 9% for the 2021-2050 period, by 22% for the 2051-2080 period and by 29% for the last 30 years of this century.

For the 1951-1980 period, the annual average temperature was -9.3 ºC; for 1981-2010 it was -9 ºC. Under a high emissions scenario, annual average temperatures are projected to be -6.3 ºC for the 2021-2050 period, -3.8 ºC for the 2051-2080 period and -1.8 ºC for the last 30 years of this century.

This is shown graphically in **Figure 14** below.

Figure 14: Average Annual Mean Temperature (Historical and Future Estimates, 1950 to 2080)



In addition to potential impacts associated with increased rainfall amounts, it is expected that changes to snow accumulation and increases in spring temperatures may also contribute to future flood risks in Arviat. Under current drainage conditions, areas of standing water will likely limit the mobility of residents, and pose an even greater health and safety concern if present-day surface water drainage issues are not addressed in the immediate future.

Surface water ponding may also lead to increased thawing of the permafrost layer as areas of standing water absorb heat from the sun and warm up the frozen soils below. Future predictions for a warming climate in Arviat may lead to thawing of the permafrost, and uneven ground settlement (thaw subsidence) may result. While uneven ground settlement poses more of a structural issue for the construction of houses and other buildings, it may also affect the future connectivity of the proposed drainage system within Arviat.

4.2.2 Climate Change Impacts on Proposed Drainage Plan

The system capacity computations described in **Section 4.1** were prepared using historical data and not the above expected climate change values. The reasons being there is a lot of uncertainty in how and when the climate change conditions will manifest over time. When the Hamlet does experience the projected climate change rainfall conditions, the proposed ditch-culvert system capacity will be reduced, thereby the LOS will also be decreased. At that time, the Hamlet can assess next steps and may possibly consider more robust stormwater management options than those currently proposed. As mentioned in the previous section, the proposed ditch-culvert system is expected to adequately convey runoff flows from significant freshet conditions, as long as the culverts and ditches are maintained free of ice blockage.

The proposed drainage system is expected to have a degree of resiliency to the effects of climate change. The proposed ditch-culvert system will be better able to accommodate potential ground settlement (thaw subsidence) than a curb and gutter drainage system. This proposed drainage system is designed to convey water and limit instances of standing water. As such, the potential for thawing of permafrost as a result of standing water will be reduced in the future. It is recommended that the performance of the proposed drainage system be monitored (anecdotally and systematically via the use of flow monitoring) to properly assess the performance of the system over time. Uneven ground settlement in the future should be assessed for its impact to the connectivity of the proposed drainage system.

5.0 Implementation and Long-Term Asset Management Plan

5.1 Mitigation Prioritization

The Hamlet can consider two implementation options of the proposed Drainage Plan:

1. Experienced **contractor builds all of the improvements** and includes time to train Hamlet staff; or
2. Experienced **contractor builds a portion of improvements** and includes time to train Hamlet staff. Hamlet staff constructs the rest of the improvements.

The implementation of the proposed Drainage Plan depends on the availability of materials, equipment and labour forces within the Hamlet. It is recommended that all drainage ditches, culverts and road profiles be laid out by an experienced surveyor or competent contractor who is adept at using auto level, differential or other survey equipment. If the Hamlet elects Option 1, barring favourable weather conditions, this Drainage Plan may be conceivably implemented at a faster pace than Option 2 as the contractor will supply their own crew to complete the work with the use of the Hamlet equipment. If Option 2 is elected, the implementation plan is expected to occur over the course of approximately five years as Hamlet staff will need to accommodate this work amongst other community needs. Option 2, with the use of Hamlet staff and equipment, is recommended to be coordinated and overseen by an experienced contractor that is expected to reside within the community during the construction season. With the Drainage Plan being phased out over multiple years, regardless of which option is preferred, the higher risk areas should be prioritized first. To guide the Hamlet in the sequencing of the Drainage Plan, a prioritization map has been prepared, as shown in **Figure 15**, and is further described in **Table 5**.

Regardless of which implementation option is chosen, all construction activities should begin at the downstream drainage outlet and should proceed working upstream through the drainage network. This allows all surficial runoff water to flow away from the community through the ditches during construction, alleviating the difficulties that standing water would impart upon excavation and construction operations. Construction should occur during the dry season to eliminate the excessive flooding occurred during the spring snow melt. Erosion and sediment control best management practices are recommended to minimize the amount of sedimentation into the adjacent wetlands and into the Hudson Bay.

Figure 15 and **Table 5** show area of concern 'A' being prioritized over area 'D' which is downstream of area 'A'. This area is prioritized for immediate action as area 'D' is for phased future development within the community. If any development is to occur within area 'D' prior to Year 4, the drainage network should begin at the downstream outfall of the development and proceed upstream as described above to alleviate the potential for a bottle-neck where areas 'A' and 'D' meet.

Table 5: Phasing of Implementation Plan

	Year				
	1	2	3	4[2]	5[3]
Area of Concern	A	B	C	D	-
New Culverts	13	19	19	13	4
Existing Culverts to be Replaced[1]	8	12	6	10	16
Total Culverts to be Installed	21	31	25	23	20

1. Existing culverts to be replaced within the priority areas is based on the existing asset condition further explained in Section 5.5.4 Asset Condition. This assumes that 60% of the existing culverts within the priority area are in need of replacement.
2. Area of Concern 'D' does not currently have any existing culverts to be replaced; the estimate of 10 culverts to be replaced is to address any critical culverts within the community that are in need of immediate replacement.
3. Implementation for Year 5 would be to install any outstanding culverts within the community that did not fall under any of the four areas of concern, and replace any additional culverts that are in need of replacement.

The following sections provide further details on cost considerations for each implementation option and staff training considerations.

HAMLET OF ARVIAT

DRAINAGE PLAN

IMPLEMENTATION MAP

FIGURE 15

PHASING AREAS
WATER BODIES
EXISTING GRAVEL ROADS

N
W E
S

0 0.1 0.2 0.4 Kilometres

MAP DRAWING INFORMATION:
DATA PROVIDED BY DILLON CONSULTING LIMITED,
ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR GEOGRAPHICS,
CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN,
AND THE GIS USER COMMUNITY

MAP CREATED BY: PMW
MAP CHECKED BY: JH
MAP PROJECTION: NAD 1983 UTM Zone 15N

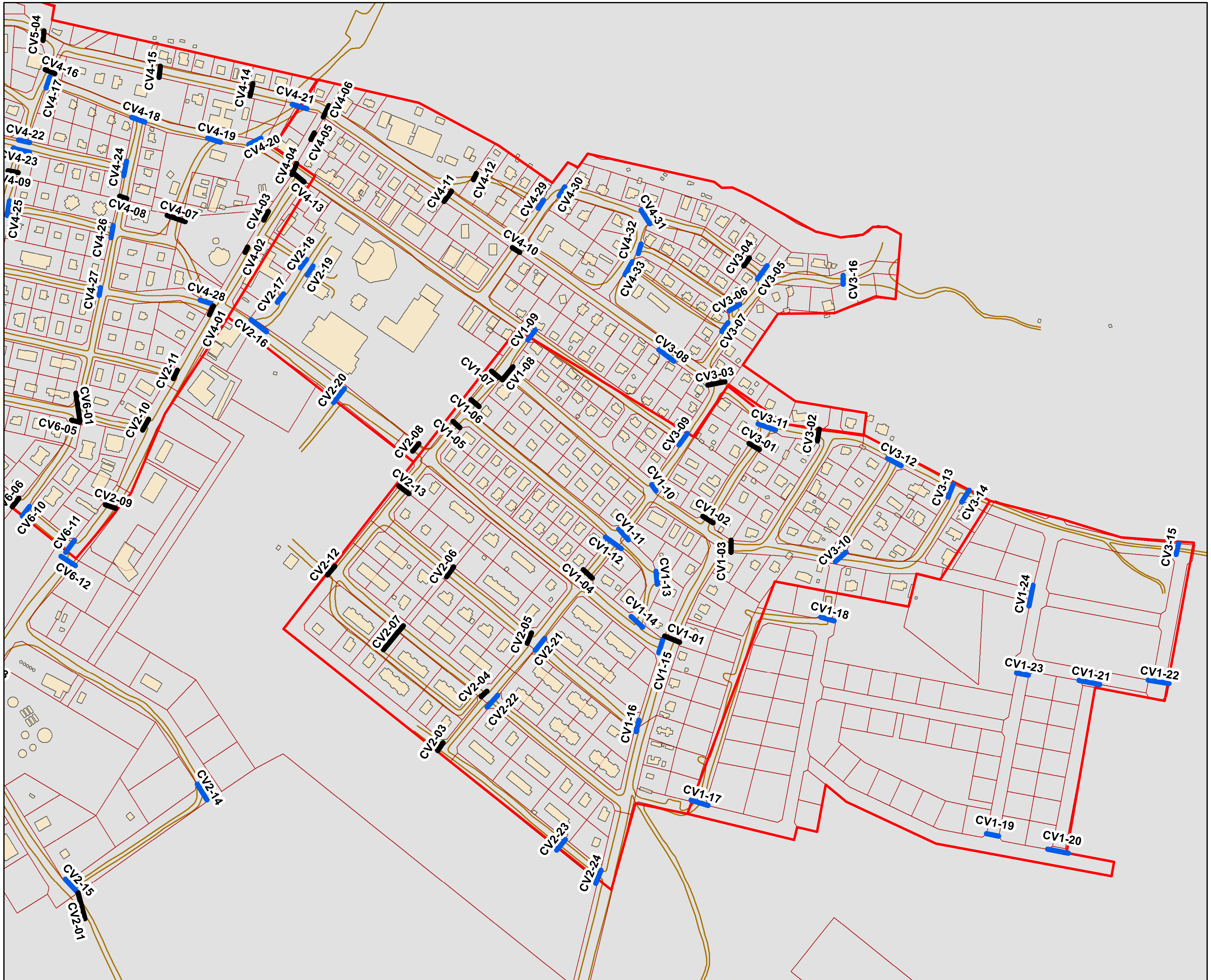
FILE LOCATION: \\DILLON.CA\DILLON_DFS\WINNIPEG
\G:\GIS\199737 CALGARY\MXD

DILLON CONSULTING

PROJECT: 19-9737

STATUS: FINAL

DATE: MARCH 2020



HAMLET OF ARVIAT

DRAINAGE PLAN

CULVERT MAPPING

FIGURE 16

- PROPOSED CULVERT
- EXISTING BRIDGE
- EXISTING CULVERT
- BUILDINGS
- PARCELS
- EXISTING GRAVEL ROADS
- PHASING AREAS

N
W E
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0 0.05 0.1 0.2 Kilometres

MAP DRAWING INFORMATION:
DATA PROVIDED BY DILLON CONSULTING LIMITED,
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CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN,
AND THE GIS USER COMMUNITY

MAP CREATED BY: JJH
MAP CHECKED BY: PL
MAP PROJECTION: NAD 1983 UTM Zone 15N

FILE LOCATION: \\DILLON.CA\DILLON_DFS\WINNIPEG
\G:\GIS\199737 CALGARY\MXD

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PROJECT: 19-9737

STATUS: FINAL

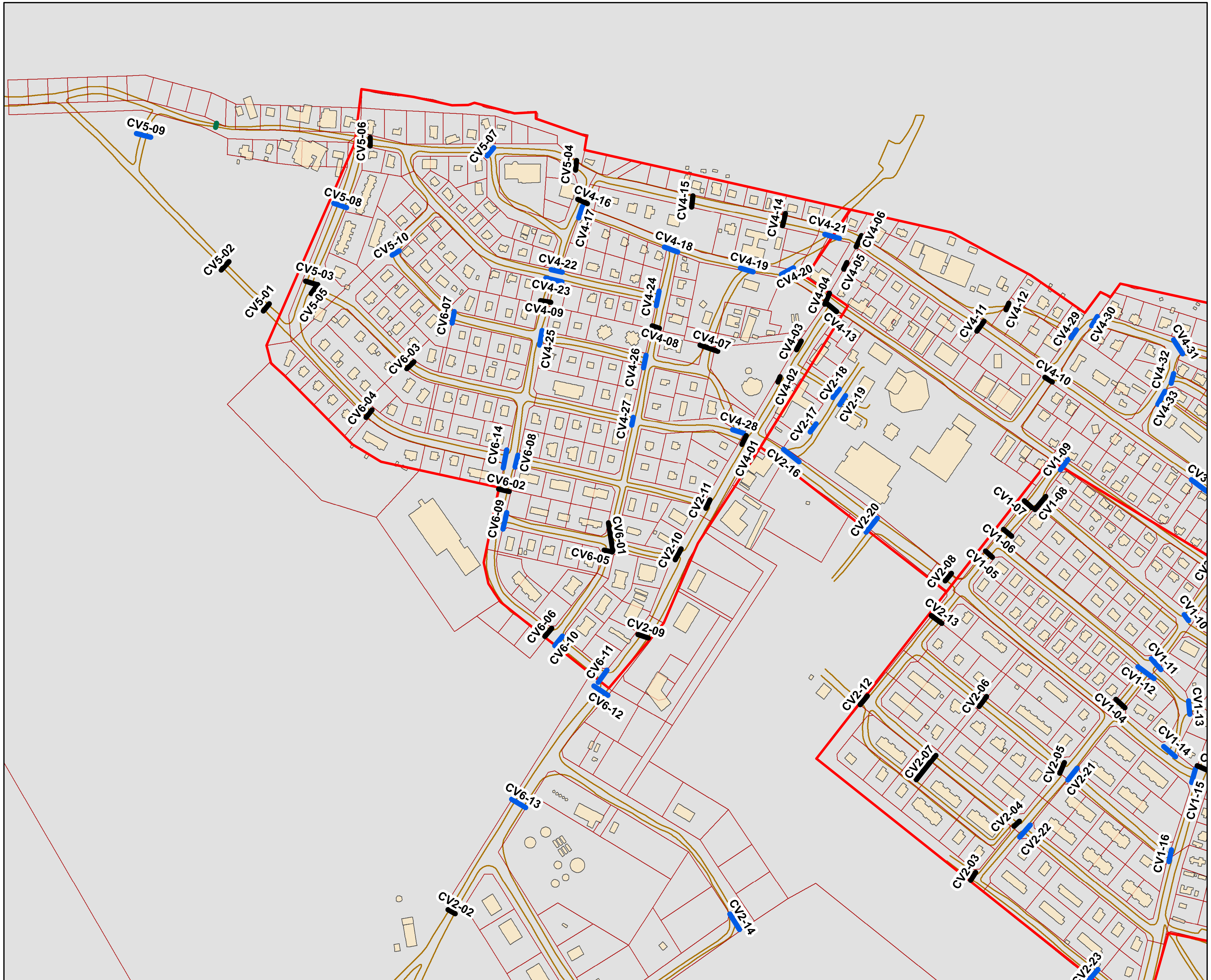
DATE: MARCH 2020

HAMLET OF ARVIAT

DRAINAGE PLAN

CULVERT MAPPING

FIGURE 17



- PROPOSED CULVERT
- EXISTING BRIDGE
- EXISTING CULVERT
- BUILDINGS
- PARCELS
- EXISTING GRAVEL ROADS
- PHASING AREAS

N
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0 0.05 0.1 0.2 Kilometres

MAP DRAWING INFORMATION:
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CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN,
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\G:\GIS\199737 CALGARY\MXD

DILLON CONSULTING

PROJECT: 19-9737

STATUS: FINAL

DATE: MARCH 2020

5.2 Cost Considerations

In the development of proposed mitigation measures, high-level (Class D) cost estimates were also prepared. The timeline for implementation of solutions will be dependent on available funding, materials and workforce, and may extend over several years. As such, the cost for implementation is expected to fluctuate according to inflation, availability of materials and other factors. The provided cost estimate assumes the phased implementation plan will be followed and completed over a period of five years.

For the development of the proposed high-level cost estimates, the following construction materials and implementation assumptions were made:

- Material unit costs include assumed annual sealift delivery costs.
- Unit costs for corrugated metal pipe (CMP) culverts were estimated on a per culvert basis. The assumed average culvert length was 10 m. It is advisable that the Hamlet confirm culvert length requirements in the field prior to ordering culverts.
- It is assumed that suitable aggregate will be supplied by the Hamlet of Arviat.
- The cleaning and maintenance of existing culverts and ditch infrastructure is assumed to be done by Hamlet staff.
- The implementation of Option 1 as described in **Section 5.1**, the contractor building all of the improvements, is based on the contractor supplying a surveyor, foreman and two operators to complete the work over a period of five years with the construction season of each year having a duration of two months. Hamlet equipment to be used during the implementation. Hamlet to purchase all materials required for the project. This also takes into account contractor expenses such as airfare and accommodations, as well as the cost of training the Hamlet staff.
- The implementation of Option 2 as described in **Section 5.1**, the contractor building a portion of the improvements with their own crew, is based on the contractor's crew only being on-site for the first of five construction seasons. After Year 1 the contractor will only provide an experienced foreman to coordinate and oversee the execution of the Drainage Plan with the use of Hamlet staff and equipment over the following four construction seasons.

Also listed in the cost estimate is a line item for the supply of surface stabilization mat (Geoweb®) proposed to be an alternative option for the property access ways through the ditches, as described in **Section 3.3**. The Geoweb® panels within the ditch can be filled with aggregate, soil and/or sand, and compacted to provide a more structurally stable surface to reduce rutting caused by vehicles. This line item and product are provided as an alternative approach to the proposed ditch material of local aggregate. For cost planning purposes, it is assumed to be placed at all driveway entrances. More information on the design and specifications can be found in **Appendix F**.

A summary of the estimated costs are included in **Table 6**.

Table 6: Estimated Costs for the Drainage Plan Implementation

Mitigation	Unit of Measure	Unit Price ($)[1]	Estimated Quantity	Total Estimated Cost
Culverts				
300 mm dia. CMP	l.m.	$ 120	150	$18,000
500 mm dia. CMP	l.m.	$ 180	800	$ 144,000
600 mm dia. CMP	l.m.	$210	250	$52,500
Culvert markers	each	$60	240	$ 14,400
Bedding aggregate	cu. m.	Assumed that suitable material will be provided by the Hamlet		
Sub-Total				**$228,900**
Contractor Building Improvements (100%)[2]				
Foreman	day	$1500	200	$ 300,000
Surveyor	day	$1200	200	$ 240,000
Operator (2)	day	$1000	400	$ 400,000
Aggregate	cu.m	Assumed that suitable material will be provided by the Hamlet		
Expenses (Accommodations & Food)	day	$350	800	$280,000
Airfare	each	$3,000	20	$60,000
Sub-Total				**$1,280,000**
Alternative Property Ditch Access Ways				
Geoweb®	sq. m.	$ 45.00	7,000	$ 315,000
Aggregate to fill Geoweb®	cu. m.	Assumed that suitable material will be provided by the Hamlet		

1. Unit prices include supply and delivery costs only.
2. 100% refers to the contractor building all the improvements as per Option 1 in **Section 5.1**.
3. Unit prices are based on 2020 values. If significant project delays are experienced, inflation costs should be taken into account.

If Option 1, presented in **Section 5.1**, is selected the total labour/ accommodation costs are estimated at $1,280,000. If Option 2 is selected, a portion of the work to be completed by contractor, the labour/ accommodation costs would be reduced to 20% (assumed to be required only in Year 1 of the five year plan) for the operators and surveyor, while the foreman cost would remain the same as they are expected to return each year to coordinate and oversee the work as mentioned in **Section 5.1**.

Option 1: Total Project Construction Cost Estimate

- Materials / Labour / Training: $1,508,900
- 50% Contingency (Class D): $754,450
- Sub-Total: $2,263,350
- 15% Engineering / Administration: $339,503

- **Total: $2,602,853**

Option 2: Total Project Construction Cost Estimate

- Materials / Labour / Training: $792,900
- 50% Contingency (Class D): $396,450
- Sub-Total: $1,189,350
- 15% Engineering / Administration: $178,403
- **Total: $1,367,753**

5.3 Identification of Staff Training Requirements

In order for the Hamlet to implement and maintain the recommended Drainage Plan, additional staff training will be required. As stated above in **Section 5.1**, it is recommended that all drainage ditches and culverts be laid out by an experienced surveyor or competent contractor. It is also recommended that the selected competent contractor work with the Hamlet maintenance staff to provide on-site training, while implementing the Drainage Plan. This will allow for the Hamlet staff to properly maintain the proposed infrastructure once the initial installation is completed. Staff training requirements include, but are not limited to:

- Road Building Techniques:
  - Building the roads up in lifts,
  - Selecting the proper aggregate for each lift,
  - Compacting in-between lifts, and
  - Crowning the roads to convey water off of the roads;
- Ditching Techniques:
  - Maintaining grade though ditches,
  - Forming front and back slopes, as well as ditch bottoms, and
  - Tying into existing properties and roads; and
- Installation of Culverts:
  - Setting culvert inverts,
  - Installing culvert delineators, and
  - Providing proper cover over the culvert.

5.4 Recommended Implementation Option

The two implementation options as described in **Sections 5.1** to **5.3**, were discussed with Hamlet staff and the preferred option is **Option 2** as it will create employment opportunities for local residents and it is the lower cost option. It also creates an opportunity for Hamlet staff to gain experience in constructing the drainage system. That experience and knowledge can then be applied to operate and maintain the drainage system. Therefore, **Option 2** is the recommended implementation option.

5.5 Long-Term Asset Management Plan

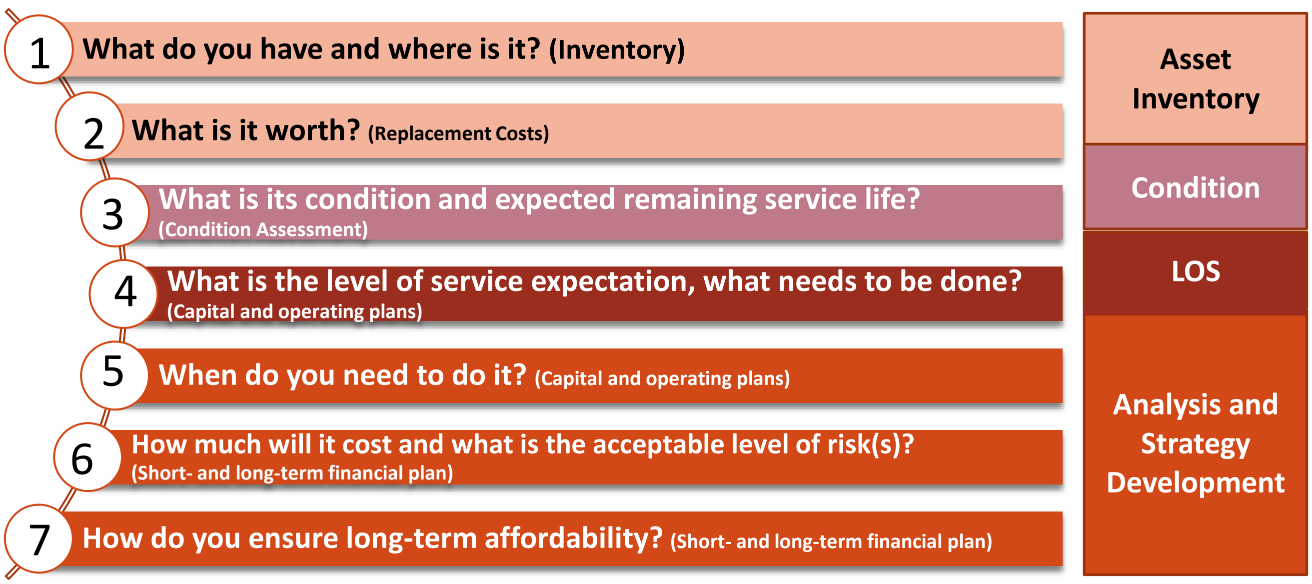
5.5.1 Asset Management Framework

The framework of essential questions from the InfraGuide: Managing Infrastructure Assets (Federation of Canadian Municipalities, October 2005) is shown below in **Figure 18**. These questions form the basis of the asset management approach, in alignment with ISO 55000.

Questions 1 through 5 will be assessed within the scope of the Asset Management Plan. These questions consider the current assets within the Hamlet's drainage system, establish current LOS, provide guidance on establishing desired LOS, and demonstrate a framework for capital and operational plan development. Short and long-term financial plans considering risk and funding sources for the proposed implementation and asset management activities were not requested within the Request for Proposal, and have been determined out of scope for this assignment.

The following sections provide the Hamlet with an understanding of its current assets, and establish best practices and planning for asset management within the drainage system.

Figure 18: Framework of Asset Management Questions (Federation of Canadian Municipalities, October 2005)



5.5.2 Asset Inventory

What do you have and where is it?

The Hamlet of Arviat currently maintains a drainage network providing surface water drainage for the community. The drainage network relies on several components to operate, such as culverts, bridges, ditches and equipment. The following components will be considered in the Asset Management Plan:

- Culverts;
- Ditches; and
- Equipment.

Table 7 provides a summary of culvert, ditch and equipment assets currently owned by the Hamlet.

Table 7: Inventory List of Drainage System Assets

Asset Type	Number of Assets
CMP Culverts	66
Ditches	Several hundred meters of ditches:6 major ditches; 21 other identified ditches
D8 Bulldozers	1
D6 Bulldozers	2
Wheeled Loaders	4
Motor Graders	2
Excavators	3
Dump Trucks	3
Aggregate Crushing Machine	1
Steel Drum Compactor	1
Kubota Skid Steer	1
Steam Jet with Culvert Thawing Kit	1

The maintenance and management of these assets is imperative to the performance and service delivery of the current and future drainage network of the Hamlet. See **Appendix D** for the complete list of asset inventory for culverts, ditches and equipment. The tables will be provided electronically so they can be updated as new information becomes available.

5.5.3 Replacement Cost

What is it worth?

Based on the data provided for the Hamlet's current inventory of drainage system assets, an approximate replacement cost can be calculated for some asset categories.

Culverts

The Hamlet of Arviat used both 300 mm and 600 mm culverts throughout the existing drainage system. As per **Section 5.1** a standard range of culvert sizes are recommended for the implementation of drainage improvements. Where possible, it is recommended that the Hamlet use 500 mm culverts to replace existing culverts as required by the implementation plan and replacement strategy. Utilizing a 500 mm culvert will allow the Hamlet to achieve adequate cover of the culvert obvert and improve the ability for staff to maintain and clear culverts during the spring thaw. Therefore, a 500 mm standard culvert size will be used to estimate the replacement cost of existing assets. A standard of 10 m was used as the estimated average length for all existing culverts. Cost estimates should be considered Class D estimates (Joint Federal Government / Industry Cost Predictability Taskforce, 2012).

Table 8: Culvert Replacement Costs

Approximate Number of Culverts	Unit Cost ($/asset)[1]	Total Culvert Material Replacement Cost
66	$1,800	$118,800

1. Unit cost include supply and delivery costs only.

Ditches

The replacement value for ditches could not be calculated as the depth and total length of existing ditches for the Hamlet was not known.

Equipment

The approximate replacement cost of existing equipment was estimated based on the Hamlet's current equipment inventory related to the drainage network. Replacement cost estimate assumptions:

- In current Canadian Dollars;
- Include the approximate base price for the asset type and estimated sealift shipping costs; and
- Do not include equipment accessories, tax, inflation or price variability considerations.

All replacement cost estimates should be considered Class D estimates.

Estimated useful life for equipment is provided based on information provided by manufacturers. The estimated useful life assumes good maintenance practices as recommended by the manufacturer.

Table 9: Estimated Equipment Useful Life and Replacement Costs

Equipment Asset Type	Number of Assets	Estimated Useful Life	Estimated Replacement Value (Unit Cost)	Equipment Asset Total
D8 Bulldozers	1	15-20 years	$ 1,020,000	$ 1,020,000
D6 Bulldozers	2	15-20 years	$ 520,000	$ 1,040,000
Wheeled Loaders	4	15-20 years	$ 445,000	$ 1,780,000
Motor Graders	2	15-20 years	$ 470,000	$ 940,000
Excavators	3	15-20 years	$ 620,000	$ 1,860,000
Steel Drum Compactor	1	15-20 years	$ 220,000	$ 220,000
Aggregate Crushing Machine	1	15-20 years	$ 2,020,000	$ 2,020,000
Kubota Skid Steer	1	7 years	$ 80,000	$ 80,000
Dump Trucks	3	10-12 years	$ 220,000	$ 660,000
Steam Jet with Culvert Thawing Kit	1	10-15 years	$ 20,000	$ 20,000
			TOTAL	**$ 9,640,000**

5.5.4 Asset Condition

What is the asset condition and expected remaining useful life?

Culverts

During site visits in April, May and September of 2019, Dillon personnel collected photos of the existing drainage system to assess the current condition and performance. Photos of culvert ends were collected to provide information on the general condition and performance of the structures. From the available data, culvert conditions were evaluated to provide the Hamlet with information on the condition of their existing assets. Only culverts visible at the time of inspection were photographed and assessed. The structural integrity of culverts was not included as part of the visual condition assessment.

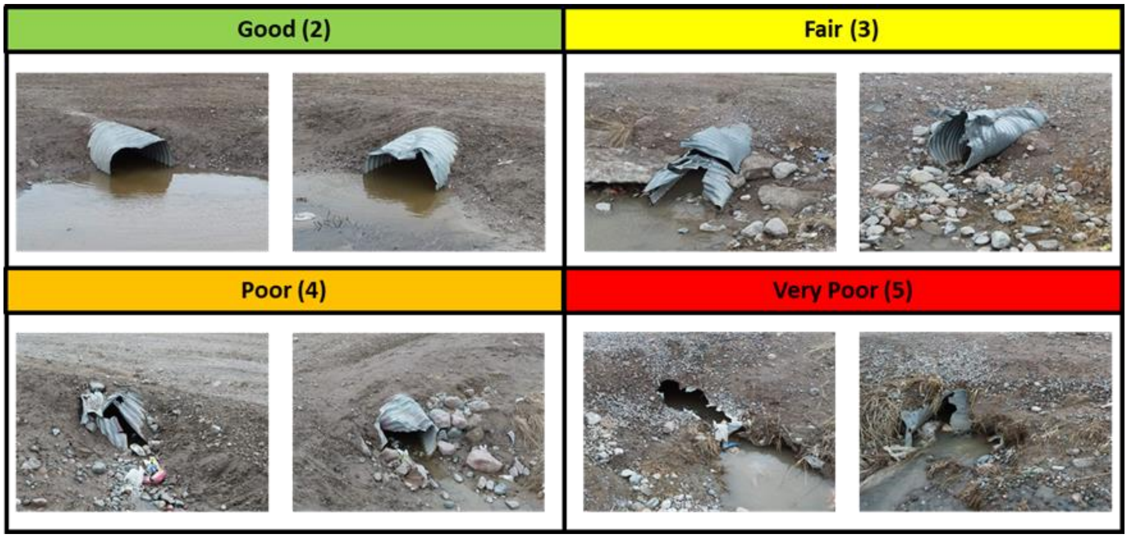
A condition rating for each culvert was established based on set appearance criteria. Five condition categories were used to rate the condition of assets, which aligns with condition categories presented in the Canadian Infrastructure Report Card (Federation of Canadian Municipalities, 2019). The five condition categories are Very Good, Good, Fair, Poor and Very Poor. Each condition category was given a condition score, which is a whole number from 1 to 5, with 1 representing Very Good condition assets and 5 representing Very Poor condition assets.

The condition rating system is available in **Table 10**, with descriptions for the condition of culverts within each category. Examples of the Hamlet of Arviat's culverts classified under each condition rating are provided in **Figure 19**.

Table 10: Culvert Condition Rating Table

Condition Score	Condition Rating	Description
1	Very Good	• Like new, very little or no deterioration. • Culvert markers and/or end protection installed. • No crushing of culvert ends, little or no blockage of upstream/downstream invert, opening is approximately 100% of actual culvert diameter. • Appropriate cover provided. • Culvert supported at base and properly aligned. • Culvert functioning normally.
2	Good	• Some deterioration or damage. • Inadequate culvert markers and/or end protection installed. • Minor crushing of culvert ends, some blockage of upstream and/or downstream invert, opening is approximately 75% of actual culvert diameter. • Some areas requiring additional culvert cover. • Minor washout of culvert end base or minor misalignment. • Minor reduction in function.
3	Fair	• Moderate deterioration or damage. • No culvert markers and/or end protection installed. • Moderate crushing of culvert ends, significant blockage of upstream and/or downstream invert, opening is approximately 50% of actual culvert diameter. • Several areas requiring additional culvert cover. • Culvert end not adequately supported or moderate misalignment. • Culvert is partially functioning. • Maintenance required.
4	Poor	• Significant deterioration. • No culvert markers and/or end protection installed. • Significant crushing of culvert ends, significant blockage of upstream and/or downstream invert, opening is approximately 25% of actual culvert diameter. • Inadequate cover provided for approximately 50% of culvert. • Culvert end not adequately supported or significant misalignment. • Culvert function significantly reduced. • Repair or replacement recommended.
5	Very Poor	• Culvert is failed or failure imminent. • No culvert markers and/or end protection installed. • Significant crushing of culvert ends, significant blockage of upstream and/or downstream invert, opening is significantly less than 25% of actual culvert diameter. • Inadequate cover provided over the majority of the culvert, sections of pipe top may be exposed in roadway. • Culvert end not adequately supported and significant misalignment. • Culvert is not functioning and/or blocked. • Requires repair or replacement immediately.

Figure 19: Example Culvert Condition Ratings



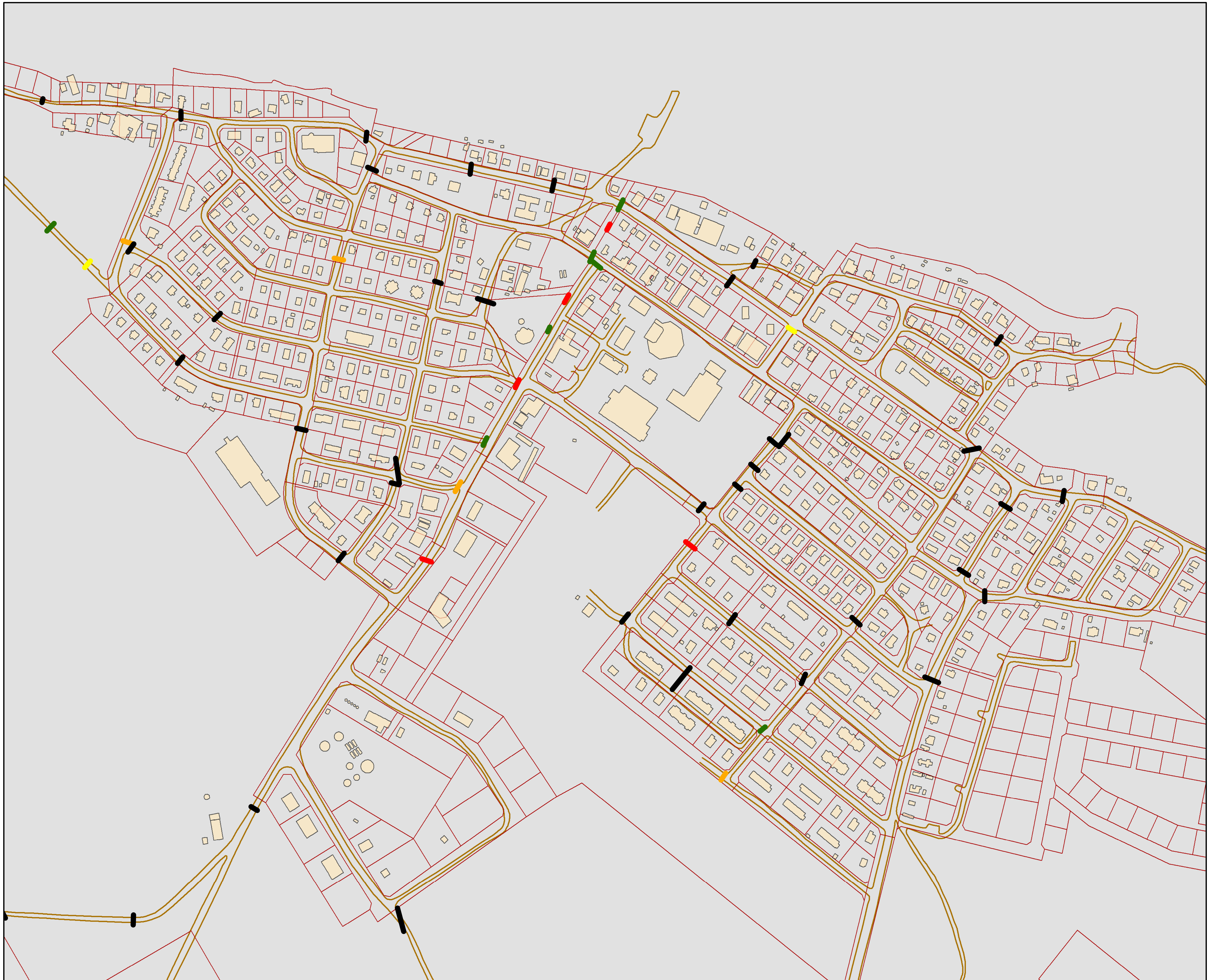
A map of all known Hamlet existing culverts is available in **Figure 20** with each asset colour coded based on the assessed condition rating.

HAMLET OF ARVIAT

DRAINAGE PLAN

EXISTING CULVERT CONDITION ASSESSMENT

FIGURE 20



- BUILDINGS
- PARCELS
- GRAVEL ROADS
- GOOD
- FAIR
- POOR
- VERY POOR
- NOT ASSESSED

N
W E
S

0 0.05 0.1 0.2 Kilometres

MAP DRAWING INFORMATION:
DATA PROVIDED BY DILLON CONSULTING LIMITED,
ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR GEOGRAPHICS,
CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN,
AND THE GIS USER COMMUNITY

MAP CREATED BY: JJH
MAP CHECKED BY: PL
MAP PROJECTION: NAD 1983 UTM Zone 15N

FILE LOCATION: \\DILLON.CA\DILLON_DFS\WINNIPEG
\G:\GIS\199737 CALGARY\MXD

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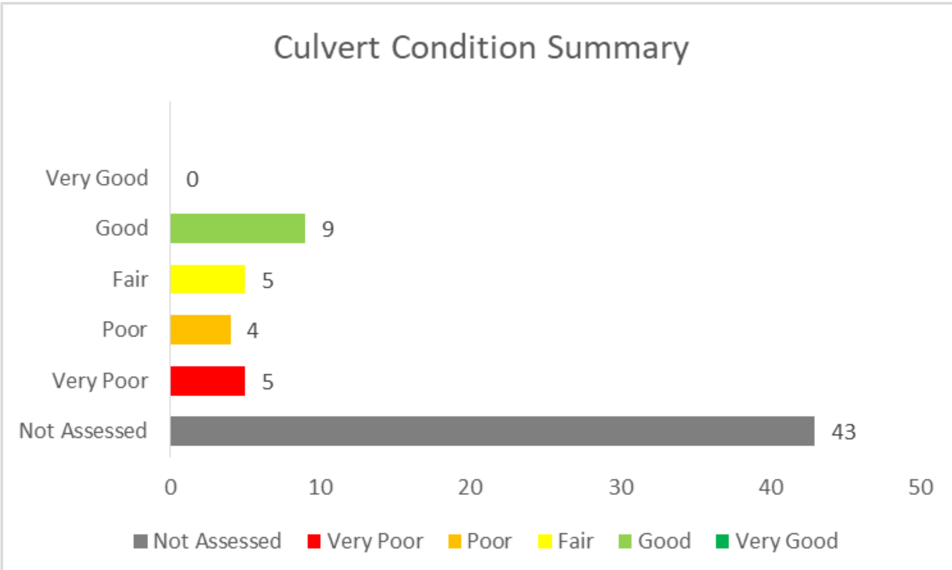
PROJECT: 19-9737

STATUS: FINAL

DATE: MARCH 2020

A summary of culvert condition is also provided in **Figure 21**, which displays the distribution of culvert condition across all known culverts within the Hamlet of Arviat. The average condition of assessed culverts in the Hamlet of Arviat is 3.2, falling between the rating of Fair and Poor condition classifications.

Figure 21: Hamlet of Arviat Culvert Condition Summary



Forty-three (43) of the Hamlet's 66 culverts did not receive a condition assessment rating due to the inability to see the culvert openings as a result of snow/ice cover or submersion at the time of site visits.

Ditches & Equipment

Condition for ditches and equipment was not assessed or provided.

It is recommended the Hamlet complete an assessment of culverts not yet assessed, ditches and equipment to determine individual asset condition. As with culverts, the condition of ditches and equipment may be used to determine their performance in meeting the desired LOS of the drainage network and identifying the estimated remaining useful life of the equipment.

5.5.5 Level of Service

What is the level of service?

A key aspect of asset management is the identification of the LOS being provided by the assets in the system currently, and what is the desired LOS in the future. The LOS for the Hamlet of Arviat drainage system is established following ISO 55000 for determining the key parameters to use in measuring the LOS for the community drainage system.

Capacity and Reliability have been identified as the LOS parameters for the drainage system. Capacity accounts for the ability of the system to effectively convey surface runoff, as designed. Reliability captures the consistency with which the system is expected to perform, which includes:

1. Responsiveness – How quickly can we clear or repair damaged system components?
2. Availability – Are the components maintained in a state to which they are able to perform when required?

5.5.5.2 Current Level of Service

The drainage system LOS and performance is directly affected by the condition of assets within the system. The LOS parameters for the drainage system, Capacity and Reliability, are measurable from each asset's ability to perform to the designed flow capacity and consistently operate, as required. The condition of culverts is used to estimate the overall LOS for the drainage system. As indicated in **Section 5.5.4**, the average condition score for the culverts was found to be between Fair and Poor on the established condition scale. Applying this condition rating to the entire drainage system asset portfolio, classifies the entire system rating between Fair and Poor.

The Hamlet of Arviat has begun to experience drastic differences in normal seasonal temperatures over the last decade. These changes have caused drainage issues within the community, contributing to flooding events, which have damaged residents' property, deteriorated roadways, increased maintenance costs to mobile water/sewer fleet and increased operating budgets of the Public Works Department. **Figures 22** and **23** display the drainage issues experienced by the Hamlet, during the spring 2018 melt.

Figure 22: 9th Avenue in Arviat during the 2018 Spring Melt

Figure 23: 8th Avenue in Arviat during the 2018 Spring Melt

From the understanding of current system performance provided in the Hamlet, the LOS does not meet the expectations of the community.

5.5.5.3 Desired Level of Service

Proposed LOS establishes a target for the desired service delivery and performance of the drainage network. Defining a desired LOS will allow for the Hamlet to develop an implementation plan (an Asset Management Plan) as a guide to achieving the desired LOS.

The intention of the proposed Drainage Plan is to develop an effective drainage network to reduce the impact of future flooding events in the Hamlet of Arviat. As part of the proposed plan, several infrastructure improvements have been recommended in order to improve the drainage system LOS. As described in previous sections, the implementation of the proposed Drainage Plan depends on the availability of materials, equipment and labour forces within the Hamlet, as well as availability of funding.

The long-term desired LOS can be established as Good. It is recommended the Hamlet adopt a continuous improvement process to prioritize projects, based on impact to the community, and successively raise the LOS by managing and increasing individual asset performance and overall system performance, as resources allow.

5.5.6 Lifecycle Strategy

During the implementation of the proposed Drainage Plan and as part of the Hamlet's continuous improvement process, Dillon recommends the Hamlet consider the employment of several strategies and best practices in the management of their drainage system. The suggested strategies and best practices are based on the standard practices outlined in Section 6 of CAN/CSA-S503-15 *Community Drainage System Planning, Design, and Maintenance in Northern Communities*. These strategies should be implemented as soon as possible, based on the current infrastructure and be actively maintained to incorporate changes as the Drainage Plan is implemented.

See **Appendix C** for a detailed Lifecycle Strategy.

See **Appendix D** for template Asset Inventory Sheets. The Hamlet should use the provided templates to develop and maintain asset inventories for drainage network assets. Missing data should be completed by the Hamlet where possible.

5.5.7 Summary of Implementation and Asset Management Plan

A high level summary of implementation and asset management activities is provided below in **Table 11**, capturing activities recommended as part of the 10-year capital and operations plans as presented in **Appendix C**.

Table 11: Implementation and Asset Management Plan Summary

Activity	Year									
	1	2	3	4	5	6	7	8	9	10
Area of Concern Focus[1]	A	B	C	D	-	-	-	-	-	-
New Culverts to be Installed[1]	13	19	19	13	4	No Further Action for Implementation Plan				
Existing Culverts to be Replaced[1]	8	12	6	10	16	Determine from Annual Inspection and Prioritization Strategy				
Total Culverts in Network (at end of year)	79	98	117	130	134	134	134	134	134	134
Inspection Activities[2]	**Spring** - Culvert Inspection **Spring** - Runoff/Rain Event System Inspection **Summer** - Complete Drainage System Inspection **Summer** - Pre-Season Steam Jet Inspection **Winter** - Inspection of Drainage System for Snow Removal Damage									
Reporting Activities[2]	**Summer/Fall** - Update Asset Inventory **Summer/Fall** - Update Drainage Network Map									
Planning Activities[2]	**Spring/Summer** - Prioritize and Select Maintenance and Replacement Projects **Spring/Summer** - Schedule Maintenance and Replacement Projects **Winter** - Define Inspection Schedule									
Maintenance Activities[2]	**All Seasons** - Equipment Maintenance **Spring** - Culvert Thawing **Spring** - Clearing of Litter/Debris from Drainage Network **Spring** - Erosion Control **Summer/Fall** - Ditch and Culvert Maintenance/Repairs **Summer/Fall** - Culvert Replacement **Fall** - Repair/Replace Culvert Markers **Winter** - Snow Removal and Storage									

Activity	Year									
	1	2	3	4	5	6	7	8	9	10
Total Capital Cost[3]	$ 946	$ 785	$ 795	$ 771	$ 765	Determine from Annual Inspection and Prioritization Strategy				
Inspection, Reporting and Planning Resource Estimates[4]	59 hours	71 hours	88 hours	105 hours	116 hours	120 hours	120 hours	120 hours	120 hours	120 hours
Maintenance Resource Requirements[2]	Determine from Annual Inspection and Prioritization Strategy									

1. For additional information see **Section 5.1 Mitigation Prioritization**
2. For additional information see Operating Plan in **Appendix C - Lifecycle Strategy** and **Appendix E - Operations and Maintenance Plan**
3. For additional information see Capital Plan in **Appendix C- Lifecycle Strategy**
4. As drainage improvements are implemented and network expanded resource requirements will increase, the increase in culverts was applied to estimate the network expansion and required increases in activity resources. Resource requirements estimated by total number of planned existing culverts in the network at end of previous implementation year (i.e.,Year 1 requires resources for 66 culverts, Year 2 requires resources for 79 culverts, Year 3 requires resources for 98 culverts, etc.).
5. Costs presented in $,000.

6.0 Operations and Maintenance

After the implementation of the Drainage Plan it will be essential to maintain the system, in order to keep it operating as intended and in optimal condition. The proposed system will be retrofitted into the existing community; therefore, will have a reduced design capacity, when compared to greenfield drainage systems. To maintain the optimal LOS in the new drainage system, it is advisable for the Hamlet to follow and implement operations and maintenance plans. The following sections provide operations and maintenance considerations and strategies. Over time, the maintenance plans should be updated to more accurately reflect the specific needs of the community.

6.1 Ditch and Culvert Maintenance and Thawing

As mentioned in previous sections, the Hamlet has been experiencing drastic temperature changes that cause multiple thaws and fast freezes. Both ranges of these temperatures cause major drainage issues within the community, as the culverts and ditches freeze-up, restricting flow. This then leads to flooding of community roads and residential properties, as the restricted flow has no outlet.

The Hamlet has addressed this problem by using a self-contained Power Eagle culvert thawing machine that is able to thaw entire culverts within five to 10 minutes compared to the hours it was taking the Public Works Department, prior to the purchase of the machine. While this process has been effective in the thawing of culverts, a maintenance and monitoring plan must be implemented to increase the efficiency of culvert thawing and maintenance within the community.

Using CAN/CSA-S503-15 "*Community Drainage System Planning, Design, and Maintenance in Northern Communities",* Dillon was able to adapt the seasonal inspection and maintenance guidelines into an operator friendly maintenance and monitoring plan (found in **Appendix E**), to be used in conjunction with **Figure 9**, to identify and track any maintenance or repairs needed within the community. An estimated cost and effort for the identified maintenance and repairs can then be applied based on the information provided in **Section 5.0**.

6.1.1 Ditch Maintenance

Some key elements of the maintenance program can be found summarized below in **Table 12**. More details of the maintenance and monitoring plan and corresponding template forms are provided in **Appendix E**.

Table 12: Key Elements of a Ditch Maintenance Program

Key Elements	Suggested Frequency
Trash and debris removal to prevent blockages within drainage network.	As needed
Avoid working around drainage structures with heavy equipment to prevent damage.	-
Utilize shallower shoulder slopes to prevent sloughing of ditch sides. Inspect for sloughing or material deposition on ditch base.	Annually or semi-annually
Ditch inspection; regrade as required.	Annually
Do maintenance in a dry ditch. This means doing the annual maintenance items in the summer or fall, not the spring when the ditches are flooded.	-

6.2 Gravel Road Building and Crowning Techniques

Road grading should be implemented throughout the community to maintain road quality and drainage patterns. Road conditions should be inspected on an annual basis and regarded, as necessary, to maintain the proposed road-way cross sections provided in **Figure 9 Section A**. During the process of road grading, ditch cross sections and profiles should also be maintained as per the proposed cross sections in **Figure 9 Section A**.

For the Hamlet of Arviat, Dillon has proposed two types of road cross sections. These include normal-crown and super-elevated sections. The majority of the community will have normal-crown roads, where water can runoff to either side of the road centerline. A few roads will require super-elevated cross sections to allow water to runoff across the entire road cross section. The proposed cross sections for both of these sections are shown in **Figure 9**.

6.2.1 Normal-Crown Roads

Grading roads with a centreline crown is a typical practice, and unless otherwise noted, roads within the community should be graded to this cross section. Road cross-fall slopes can range between 2% and 6%, based on the topography at the location of the grading. As shown in **Figure 9 Section A**, we recommend that the cross-fall slopes throughout the Hamlet of Arviat be typically graded to 3%.

6.2.2 Super-Elevated Roads

Where indicated, the road should be constructed to a super-elevated cross section, as shown in **Figure 9 Section B**. Cross-fall slopes for this type of construction should be within the range of 2% and 6%, and a grade of 3% is recommended throughout the community. Super-elevated roads are typically used in road curves, but can also be used within the Hamlet to convey flows across the entire road.

6.3 Site Grading

Site grading is not necessarily required by the Hamlet staff, as site grading pertains to the grading of properties, but can be applied when grading is required at Hamlet owned properties. Site grading is required in locations where the topography is not consistent with proposed drainage patterns, and runoff retention or poor drainage occurs. Site grading will require placement of fill or cutting of existing ground to achieve a minimum site grade of 2% away from buildings and structures. The slope of the graded sites should tie into existing grades on adjacent lands.

When conducting grading, the following best practices are recommended:

- **General:**
    - Clearing of the area for grading, including removal of weeds, exposed boulders and debris as required.
    - Protect natural and man-made features required to remain undisturbed (unless otherwise indicated or located in an area to be occupied by new construction).
    - Do not obstruct flow of surface drainage or natural watercourses.
- **Fill:**
    - Remove snow, ice, debris, organic soil and standing water from spaces to be filled.
    - Place fill material in 150 mm lifts.
    - Compact the fill material to 90% compaction or in accordance with ASTM D698.
- **Cut:**
    - Dispose of surplus and unsuitable excavated material off-site.
    - Maintain a maximum (not to exceed) slide slope of 4:1 in cut areas.

6.4 Alternative Property Ditch Access Ways

As described in **Section 3.3**, property ditch access ways were designed into the conceptual Drainage Plan to allow vehicular access across ditches without rutting or getting stuck in the mud. The proposed approach for the access ways is to use extra gravel to provide structural support at the designated access ways. If that option proves to be ineffective, the Hamlet could elect to use alternative proprietary products. One example of alternative products include the use of cellular confinement systems (such as Geoweb® or a similar product). Geoweb® panels consist of three-dimensional cells that can contain, confine and reinforce a variety of fill material, such as aggregate, soil and sand. If alternatives are used, it is recommended that the Hamlet pilot the option on several properties before applying it over the entire community. See **Appendix F** for more information and details relating to the Geoweb® product.

6.5 Construction of Culverts

The sizing of culverts should generally be undertaken based on the size of area it is servicing, and the anticipated quantity of runoff from the contributing area. There are limitations on sizing and depth of culverts, due to the climate and in-situ ground conditions. The following typical design and construction practices should be considered during a culvert installation and be implemented, where possible, during construction for future developments:

- Culvert bedding thickness to be no less than 150 mm;
- If possible, minimum 300 cm of cover over the culvert;
- Culvert will not be installed below the active soil layer;
- Minimum culvert slope should be 0.1%;
- Culverts will be CMP material;
- Culverts should have sloped, tapered ends at 2:1 slopes, if possible;
- If sloped end sections are to be used, couplers will be required. Tapered culvert ends increase capacity efficiencies and will reduce potential crushing if tapered to match adjacent ground; and
- No clay seal around the ends of the culvert.

Culverts have been recommended at locations where flow paths cross existing roadways. Culvert lengths should be determined at each location, in consideration of the width of the roadway, side slopes of adjacent ditching and depths of adjacent ditching. Recommended design practices are shown in **Figure 9 Section D**.

In the case where expected flow is too large for the capacity of culvert that is feasible to construct, we recommend constructing twin culverts. These can have two smaller sized culverts operating in parallel, to allow for sufficient flow capacity, without compromising the construction methodology of the culverts. Currently, there are no proposed culvert crossings that require multiple pipes but this practice can be used, if during construction the local conditions warrant the use of them.

In addition, flexible high-density polyethylene culvert markers are recommended to be installed on existing and proposed culverts within the Hamlet, to identify the location of culvert ends. Refer to the picture in **Figure 24**. As culverts are buried under snow during the winter months, culvert markers will alert snow removal operators and Hamlet residents to their location; thus, reducing the likelihood of damage to the culverts from snow removal operations, and snowmobile or vehicular traffic. Culvert markers also act as safety devices to warn drivers of the location of obstacles and can help reduce the chance of accidents and/or injuries, as drivers will not drive directly over top of the culvert ends after markers are installed. Culvert markers are fairly inexpensive and simple to install, requiring only a metal clamp and metal plate that will be bolted to the surface of the culvert.

Figure 24: Example of Culvert Marker

6.6 Snow Removal and Storage

Current Hamlet snow removal practices include the removal of snow and then stored in multiple locations across the community. While the Hamlet has designated snow pads close to the harbour, the snow pads are not being utilized by all contractors involved in snow clearing activities within the Hamlet.

Placement of removed snow should be in locations with sufficient drainage outlet. Improvements to runoff routing from snow storage locations should be prioritized due to the expected volume of runoff during the melting period. Snow clearing activities should also take into consideration the proposed drainage network (ditches and culverts) to ensure the accumulation of snow will not cause complications during the freshet. Dedicated snow pads are shown in **Figure 25**.

To ensure that all snow removal contractors are following consistent snow removal practices and properly dispose of the snow in dedicated locations, it is recommended that the Hamlet introduce a Bylaw that includes enforcement protocol.

HAMLET OF ARVIAT

DRAINAGE PLAN

SNOW MANAGEMENT PLAN

FIGURE 25

PROPOSED SNOW PADS

N
W E
S

0 0.1 0.2 0.4 Kilometres

MAP DRAWING INFORMATION:
DATA PROVIDED BY DILLON CONSULTING LIMITED,
ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR GEOGRAPHICS,
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DILLON CONSULTING

PROJECT: 19-9737

STATUS: FINAL

DATE: MARCH 2020

7.0 Future Recommendations/Closure

7.1 Key Findings and Conclusions

Key study findings and conclusions are as follows:

- The Hamlet of Arviat experience drainage problems throughout the community and is in need of a drainage system that effectively drains surface drainage flows away from the community. A rural type drainage system is proposed to be retrofitted into the community.
- The proposed drainage system consists of building/regrading existing dirt roads into normal-crowned gravel roads with retrofitted road side ditches and culverts. The road side ditch concepts do not include ditch-filled driveways to reduce the amount of culverts the Hamlet will need to maintain and operate. Rather, the ditch design concept includes moderate side slopes and a dedicated rock travel access way to allow safe and effective vehicular crossing.
- The proposed drainage system is conceptual and limited by the survey data accuracy.
- The proposed retrofitted ditch / culvert system will have a 2-year storm LOS (capacity) in most of the system.
- The proposed ditch drainage system is expected to be more resilient to climate change impacts associated with ground stability issues as a result of melting permafrost levels. Rigid closed stormdrain systems would be more susceptible to ground movements, leading to higher operational needs.
- Two proposed drainage system implementation options:
    - **Option 1**: Experienced **contractor builds <u>all of the improvements</u>** and includes time to train Hamlet staff – Capital Costs (Class D): **$2,602,853**
    - **Option 2**: Experienced **contractor builds a <u>portion of improvements</u>** and includes time to train Hamlet staff. Hamlet staff constructs the rest of the improvements. – Capital Costs (Class D): **$1,367,753**
- Implementation **Option 2 is recommended** for the following reasons:
    - Makes use of local resources and employs local residents;
    - Lower capital costs; and
    - Provides drainage system construction experience transferable to operations and maintenance needs.
- An Asset Management Plan is included in this study for existing and proposed drainage system and relevant equipment.
- Operations and maintenance considerations are provided to inform the operational needs of the proposed drainage system.

7.2 Key Recommendations

Based on the findings and conclusions of this study, the following recommendations are proposed:

1. Prior to construction of the proposed drainage system, more detailed community wide survey data will be required to properly design the gravel road, ditch and culvert network.
2. All culverts, existing and new, should include flexible culvert markers on each end to reduce vehicular damage during winter conditions.
3. Any new development that takes place is recommended to implement a dedicated drainage system similar to or superior to the proposed retrofitted drainage system, and must work in conjunction to the proposed system in this study.
4. To assess the longer term effects of climate change, it is recommended that the performance of the proposed drainage system be monitored (anecdotally and systematically via the use of flow monitoring) to properly assess the performance of the system over time.
5. Due to weather conditions during the various site visits, the condition assessment of existing culverts was limited to only the culverts with exposed ends not covered in snow or ice. The remaining existing culverts and ditches should be inspected as soon as possible to inform the implementation and Asset Management Plan strategies as described in this study.
6. The implementation plan should follow the priority sequence as presented in **Sections 5.1** to **5.4** and **Figure 15**.
7. All other Asset Management Plan recommendations presented in **Section 5.4** and **Appendix C** should be followed.
8. To ensure that all snow removal contractors are following consistent snow removal practices and properly dispose of the snow in dedicated locations, it is recommended that the Hamlet introduce a Bylaw that includes enforcement protocol.

7.3 Closure

This report was prepared exclusively for the purposes, project and site location(s) outlined in the report. The report is based on information provided to, or obtained by Dillon Consulting Limited (Dillon) as indicated in the report, and applies solely to site conditions existing at the time of the site investigation(s).

This report was prepared by Dillon for the sole benefit of the Hamlet of Arviat. The material in it reflects Dillon's best judgement in light of the information available to it at the time of preparation. Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. Dillon accepts no responsibilities for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

Respectfully Submitted,

Dillon Consulting Limited

Pablo Lopez, P. Eng.
Project Manager

Keith Barnes, P. Eng.
Project Coordinator

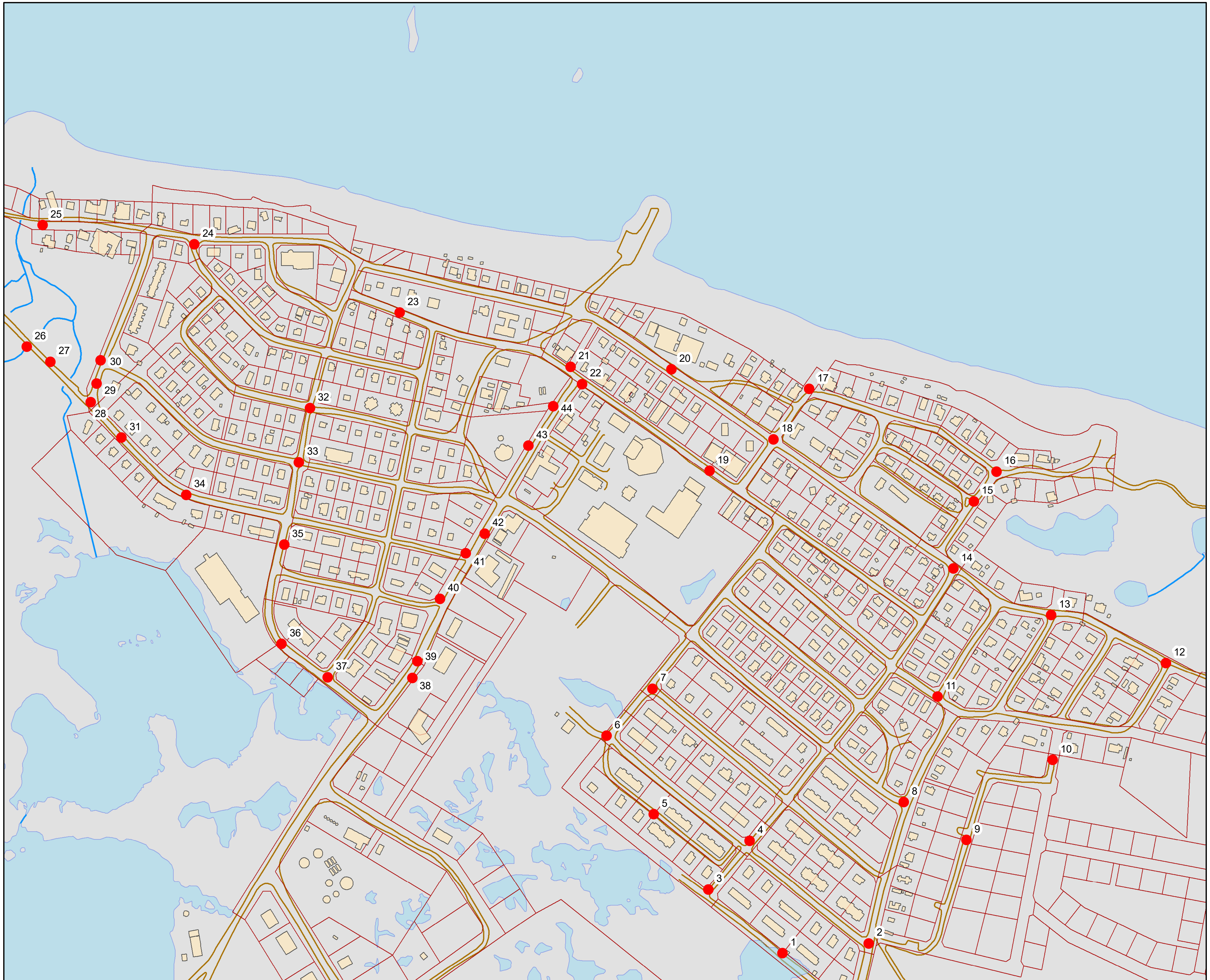
Darla Campbell, P.Eng., CSR-P
Asset Management Specialist

Appendix A

Site Inspection Photos

HAMLET OF ARVIAT

DRAINAGE PLAN



SITE PHOTO INDEX

APPENDIX A

PHOTO LOCATION
BUILDINGS
PARCELS
WATERCOURSES
WATER BODIES
GRAVEL ROADS

N
W E
S

0 0.05 0.1 0.2 Kilometres

MAP DRAWING INFORMATION:
DATA PROVIDED BY DILLON CONSULTING LIMITED,
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DILLON CONSULTING

PROJECT: 19-9737

STATUS: DRAFT

DATE: 2020/02/18

Figure 1: Ditch and end of culvert condition looking northeast

Figure 2: Looking northwest down 9th Avenue

Figure 3: Blocked culvert at playground looking southwest

Figure 4: Condition of ditch on northwest side of 8th Street at 9th avenue intersection

Figure 5: Condition of empty lot (looking north from photo location)

Figure 6: Condition of ditch on northwest side of 7th Street at 9th Avenue intersection

Figure 7: Looking southeast down 8th avenue

Figure 8: Looking north on 9th street from 7th avenue intersection

Figure 9: Looking east at drainage ditch near new development

Figure 10: Standing water near new development and 11th street

Figure 11: Looking northwest down 5th avenue

Figure 12: Looking south down 12th street

Figure 13: Culvert going north across 3rd avenue

Figure 14: Looking south down 8th street from 3rd avenue

Figure 15: Looking west down 2nd avenue from 8th street

Figure 16: Looking west down 1st avenue from 8th street

Figure 17: Snowpad location at end of 1st avenue

Figure 18: Looking west down 3rd avenue

Figure 19: Looking east down 4th avenue

Figure 20: Looking west down 3rd avenue

Figure 21: End of culvert at end of 6th street

Figure 22: Ditch condition on west side of 6th street near 4th avenue

Figure 23: Looking east down 4th avenue

Figure 24: Water sitting at intersection of 3rd avenue and 5th avenue

Figure 25: Looking east down 3rd avenue

Figure 26: End of twin culverts, looking south off of 8th avenue

Figure 27: North end of culvert on 8^{th} avenue looking south

Figure 28: Looking north up 2^{nd} street

Figure 29: Looking east near 8th avenue from 2nd street

Figure 30: Looking east down 7th avenue from 2nd street

Figure 31: Looking east down 8th avenue

Figure 32: Looking south down 4th street

Figure 33: Looking west up 7^{th} avenue

Figure 34: Looking north in-between properties on 8^{th} avenue

Figure 35: Looking east between properties at end of culvert off of 4th street

Figure 36: Looking northwest up 4th street

Figure 37: Looking north up 5th street

Figure 38: End of blocked culvert looking west from side of 6th street

Figure 39: Looking north up 6th street

Figure 40: End of culvert at 9th avenue and 6th street intersection

Figure 41: End of culvert at 8th avenue and 6th street intersection

Figure 42: Looking north on 6th street

Figure 43: Looking north up 6th street from end of culvert at Elders Centre

Figure 44: Ditch on west side of 6th street looking north towards 4th avenue intersection

Appendix B

Design Calculations

1.0 Existing Catchments

1.1 Parameters used for the Rational Method

Parameter	Value	Units	Intensity Duration	Notes
$I_{@2years}$	5.29	mm/hr	@ 2hr	*taken from Arviat IDF for intensity rates
$I_{@2years}$	7.16	mm/hr	@ 60min	*taken from Arviat IDF for intensity rates
$I_{@2years}$	9.69	mm/hr	@ 30min	*taken from Arviat IDF for intensity rates
$I_{@2years}$	20.35	mm/hr	@ 10min	*taken from Arviat IDF for intensity rates
$I_{@2years/2}$	2.645	mm/hr	@ 2hr	
$I_{@2years/2}$	3.58	mm/hr	@ 60min	
$I_{@2years/2}$	4.845	mm/hr	@ 30min	
$I_{@2years/2}$	10.175	mm/hr	@ 10min	
C	0.9			(Earth Shoulders)
K_U	360			

1.2 Design Discharge, Q (m^3/s)

Catchment	Area (ha)	$Q_{2,2hr}$	$Q_{2,60min}$	$Q_{2,30min}$	$Q_{6Month,2hr}$	$Q_{6Month,60min}$	$Q_{6Month,30min}$
B01	11.29691	0.1494	0.2022	0.2737	0.0747	0.1011	0.1368
B02	6.7577	0.0894	0.1210	0.1637	0.0447	0.0605	0.0819
B03	10.6623	0.1410	0.1909	0.2583	0.0705	0.0954	0.1291
B04	6.1587	0.0814	0.1102	0.1492	0.0407	0.0551	0.0746
B05	6.9569	0.0920	0.1245	0.1685	0.0460	0.0623	0.0843
B06	2.8986	0.0383	0.0519	0.0702	0.0192	0.0259	0.0351
B07	10.4058	0.1376	0.1863	0.2521	0.0688	0.0931	0.1260
B08	8.1398	0.1076	0.1457	0.1972	0.0538	0.0729	0.0986
W01	9.3110	0.1231	0.1667	0.2256	0.0616	0.0833	0.1128
W02	10.6345	0.1406	0.1904	0.2576	0.0703	0.0952	0.1288
W03	12.0564	0.1594	0.2158	0.2921	0.0797	0.1079	0.1460
W04	8.3105	0.1099	0.1488	0.2013	0.0550	0.0744	0.1007
W05	34.9054	0.4616	0.6248	0.8456	0.2308	0.3124	0.4228
W06	6.6267	0.0876	0.1186	0.1605	0.0438	0.0593	0.0803
W07	3.0545	0.0404	0.0547	0.0740	0.0202	0.0273	0.0370
W08	3.8287	0.0506	0.0685	0.0928	0.0253	0.0343	0.0464
W09	39.0842	0.5169	0.6996	0.9468	0.2584	0.3498	0.4734

2.0 Post Catchments

2.1 Parameters for using the Rational Method

Parameter	Value	Units	Intensity Duration	Notes
$I_{@2years}$	5.29	mm/hr	@ 2hr	*taken from Arviat IDF for intensity rates
$I_{@2years}$	7.16	mm/hr	@ 60min	*taken from Arviat IDF for intensity rates
$I_{@2years}$	9.69	mm/hr	@ 30min	*taken from Arviat IDF for intensity rates
$I_{@2years}$	20.35	mm/hr	@ 10min	*taken from Arviat IDF for intensity rates
$I_{@2years/2}$	2.645	mm/hr	@ 2hr	
$I_{@2years/2}$	3.58	mm/hr	@ 60min	
$I_{@2years/2}$	4.845	mm/hr	@ 30min	
$I_{@2years/2}$	10.175	mm/hr	@ 10min	
C	0.9			(Earth Shoulders)
K_U	360			

2.2 Design Discharge, Q (m^3/s)

Catchment	Area (ha)	$Q_{2,2hr}$	$Q_{2,60min}$	$Q_{2,30min}$	$Q_{6Month,2hr}$	$Q_{6Month,60min}$	$Q_{6Month,30min}$
C1-01	0.8230	0.0109	0.0147	0.0199	0.0054	0.0074	0.0100
C1-02	1.3835	0.0183	0.0248	0.0335	0.0091	0.0124	0.0168
C1-03	1.7061	0.0226	0.0305	0.0413	0.0113	0.0153	0.0207
C1-04	1.8006	0.0238	0.0322	0.0436	0.0119	0.0161	0.0218
C1-05	0.1805	0.0024	0.0032	0.0044	0.0012	0.0016	0.0022
C1-06	0.0741	0.0010	0.0013	0.0018	0.0005	0.0007	0.0009
C1-07	1.1924	0.0158	0.0213	0.0289	0.0079	0.0107	0.0144
C1-08	0.5211	0.0069	0.0093	0.0126	0.0034	0.0047	0.0063
C1-09	1.1588	0.0153	0.0207	0.0281	0.0077	0.0104	0.0140
C1-10	2.1818	0.0289	0.0391	0.0529	0.0144	0.0195	0.0264
C1-11	1.7794	0.0235	0.0319	0.0431	0.0118	0.0159	0.0216
C1-12	0.6488	0.0086	0.0116	0.0157	0.0043	0.0058	0.0079
C1-13	4.5421	0.0601	0.0813	0.1100	0.0300	0.0407	0.0550
C1-14	3.1844	0.0421	0.0570	0.0771	0.0211	0.0285	0.0386
C1-15	2.4427	0.0323	0.0437	0.0592	0.0162	0.0219	0.0296
C1-16	0.6819	0.0090	0.0122	0.0165	0.0045	0.0061	0.0083
C1-17	1.2365	0.0164	0.0221	0.0300	0.0082	0.0111	0.0150
C1-18	0.1605	0.0021	0.0029	0.0039	0.0011	0.0014	0.0019
C1-19	3.1734	0.0420	0.0568	0.0769	0.0210	0.0284	0.0384
C1-20	1.3709	0.0181	0.0245	0.0332	0.0091	0.0123	0.0166

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Catchment	Area (ha)	$Q_{2,2hr}$	$Q_{2,60min}$	$Q_{2,30min}$	$Q_{6Month,2hr}$	$Q_{6Month,60min}$	$Q_{6Month,30min}$
C1-21	3.3384	0.0442	0.0598	0.0809	0.0221	0.0299	0.0404
C2-01	5.8817	0.0778	0.1053	0.1425	0.0389	0.0526	0.0712
C2-02	1.8158	0.0240	0.0325	0.0440	0.0120	0.0163	0.0220
C2-03	2.2092	0.0292	0.0395	0.0535	0.0146	0.0198	0.0268
C2-04	2.0779	0.0275	0.0372	0.0503	0.0137	0.0186	0.0252
C2-05	1.8449	0.0244	0.0330	0.0447	0.0122	0.0165	0.0223
C2-06	1.4824	0.0196	0.0265	0.0359	0.0098	0.0133	0.0180
C2-07	0.8518	0.0113	0.0152	0.0206	0.0056	0.0076	0.0103
C2-08	0.7276	0.0096	0.0130	0.0176	0.0048	0.0065	0.0088
C2-09	0.4035	0.0053	0.0072	0.0098	0.0027	0.0036	0.0049
C2-10	20.6875	0.2736	0.3703	0.5012	0.1368	0.1852	0.2506
C2-11	6.5675	0.0869	0.1176	0.1591	0.0434	0.0588	0.0795
C2-12	2.7495	0.0364	0.0492	0.0666	0.0182	0.0246	0.0333
C2-13	0.7293	0.0096	0.0131	0.0177	0.0048	0.0065	0.0088
C2-14	2.0504	0.0271	0.0367	0.0497	0.0136	0.0184	0.0248
C2-15	2.8463	0.0376	0.0509	0.0690	0.0188	0.0255	0.0345
C2-16	0.1655	0.0022	0.0030	0.0040	0.0011	0.0015	0.0020
C2-17	4.8991	0.0648	0.0877	0.1187	0.0324	0.0438	0.0593
C2-18	3.7731	0.0499	0.0675	0.0914	0.0249	0.0338	0.0457
C2-19	0.7800	0.0103	0.0140	0.0189	0.0052	0.0070	0.0094
C2-20	0.8926	0.0118	0.0160	0.0216	0.0059	0.0080	0.0108
C2-21	0.1197	0.0016	0.0021	0.0029	0.0008	0.0011	0.0015
C2-22	0.1360	0.0018	0.0024	0.0033	0.0009	0.0012	0.0016
C3-01	1.0295	0.0136	0.0184	0.0249	0.0068	0.0092	0.0125
C3-02	3.7262	0.0493	0.0667	0.0903	0.0246	0.0333	0.0451
C3-03	1.1235	0.0149	0.0201	0.0272	0.0074	0.0101	0.0136
C3-04	0.2727	0.0036	0.0049	0.0066	0.0018	0.0024	0.0033
C3-05	0.0957	0.0013	0.0017	0.0023	0.0006	0.0009	0.0012
C3-06	1.0976	0.0145	0.0196	0.0266	0.0073	0.0098	0.0133
C3-07	0.0450	0.0006	0.0008	0.0011	0.0003	0.0004	0.0005
C3-08	0.2464	0.0033	0.0044	0.0060	0.0016	0.0022	0.0030
C3-09	0.5203	0.0069	0.0093	0.0126	0.0034	0.0047	0.0063
C3-10	0.5027	0.0066	0.0090	0.0122	0.0033	0.0045	0.0061
C3-11	1.8871	0.0250	0.0338	0.0457	0.0125	0.0169	0.0229
C3-12	1.0700	0.0142	0.0192	0.0259	0.0071	0.0096	0.0130
C3-13	1.2497	0.0165	0.0224	0.0303	0.0083	0.0112	0.0151
C3-14	1.0911	0.0144	0.0195	0.0264	0.0072	0.0098	0.0132
C3-15	1.0437	0.0138	0.0187	0.0253	0.0069	0.0093	0.0126
C3-16	5.7598	0.0762	0.1031	0.1395	0.0381	0.0516	0.0698
C3-17	0.1208	0.0016	0.0022	0.0029	0.0008	0.0011	0.0015
C3-18	0.1059	0.0014	0.0019	0.0026	0.0007	0.0009	0.0013

Catchment	Area (ha)	$Q_{2,2hr}$	$Q_{2,60min}$	$Q_{2,30min}$	$Q_{6Month,2hr}$	$Q_{6Month,60min}$	$Q_{6Month,30min}$
C3-19	0.3603	0.0048	0.0064	0.0087	0.0024	0.0032	0.0044
C3-20	0.6540	0.0086	0.0117	0.0158	0.0043	0.0059	0.0079
C4-01	0.3254	0.0043	0.0058	0.0079	0.0022	0.0029	0.0039
C4-02	0.5111	0.0068	0.0091	0.0124	0.0034	0.0046	0.0062
C4-03	1.1070	0.0146	0.0198	0.0268	0.0073	0.0099	0.0134
C4-04	1.5663	0.0207	0.0280	0.0379	0.0104	0.0140	0.0190
C4-05	0.5871	0.0078	0.0105	0.0142	0.0039	0.0053	0.0071
C4-06	1.2225	0.0162	0.0219	0.0296	0.0081	0.0109	0.0148
C4-07	0.6617	0.0088	0.0118	0.0160	0.0044	0.0059	0.0080
C4-08	1.0897	0.0144	0.0195	0.0264	0.0072	0.0098	0.0132
C4-09	0.8727	0.0115	0.0156	0.0211	0.0058	0.0078	0.0106
C4-10	0.4901	0.0065	0.0088	0.0119	0.0032	0.0044	0.0059
C4-11	0.5905	0.0078	0.0106	0.0143	0.0039	0.0053	0.0072
C4-12	0.7211	0.0095	0.0129	0.0175	0.0048	0.0065	0.0087
C4-13	0.4085	0.0054	0.0073	0.0099	0.0027	0.0037	0.0049
C4-14	0.6493	0.0086	0.0116	0.0157	0.0043	0.0058	0.0079
C4-15	1.0782	0.0143	0.0193	0.0261	0.0071	0.0096	0.0131
C4-16	0.9353	0.0124	0.0167	0.0227	0.0062	0.0084	0.0113
C4-17	0.6492	0.0086	0.0116	0.0157	0.0043	0.0058	0.0079
C4-18	0.0727	0.0010	0.0013	0.0018	0.0005	0.0007	0.0009
C4-19	0.6128	0.0081	0.0110	0.0148	0.0041	0.0055	0.0074
C4-20	0.3880	0.0051	0.0069	0.0094	0.0026	0.0035	0.0047
C4-21	0.3238	0.0043	0.0058	0.0078	0.0021	0.0029	0.0039
C4-22	0.2145	0.0028	0.0038	0.0052	0.0014	0.0019	0.0026
C4-23	0.1207	0.0016	0.0022	0.0029	0.0008	0.0011	0.0015
C4-24	0.2778	0.0037	0.0050	0.0067	0.0018	0.0025	0.0034
C4-25	0.0783	0.0010	0.0014	0.0019	0.0005	0.0007	0.0009
C4-26	0.9122	0.0121	0.0163	0.0221	0.0060	0.0082	0.0110
C4-27	0.1655	0.0022	0.0030	0.0040	0.0011	0.0015	0.0020
C4-28	0.3439	0.0045	0.0062	0.0083	0.0023	0.0031	0.0042
C4-29	1.4751	0.0195	0.0264	0.0357	0.0098	0.0132	0.0179
C4-30	0.1038	0.0014	0.0019	0.0025	0.0007	0.0009	0.0013
C4-31	2.9614	0.0392	0.0530	0.0717	0.0196	0.0265	0.0359
C4-32	1.9051	0.0252	0.0341	0.0462	0.0126	0.0171	0.0231
C4-33	1.6245	0.0215	0.0291	0.0394	0.0107	0.0145	0.0197
C4-34	0.3713	0.0049	0.0066	0.0090	0.0025	0.0033	0.0045
C4-35	0.6290	0.0083	0.0113	0.0152	0.0042	0.0056	0.0076
C4-36	0.8600	0.0114	0.0154	0.0208	0.0057	0.0077	0.0104
C5-01	9.2856	0.1228	0.1662	0.2249	0.0614	0.0831	0.1125
C5-02	1.0204	0.0135	0.0183	0.0247	0.0067	0.0091	0.0124
C5-03	0.4795	0.0063	0.0086	0.0116	0.0032	0.0043	0.0058

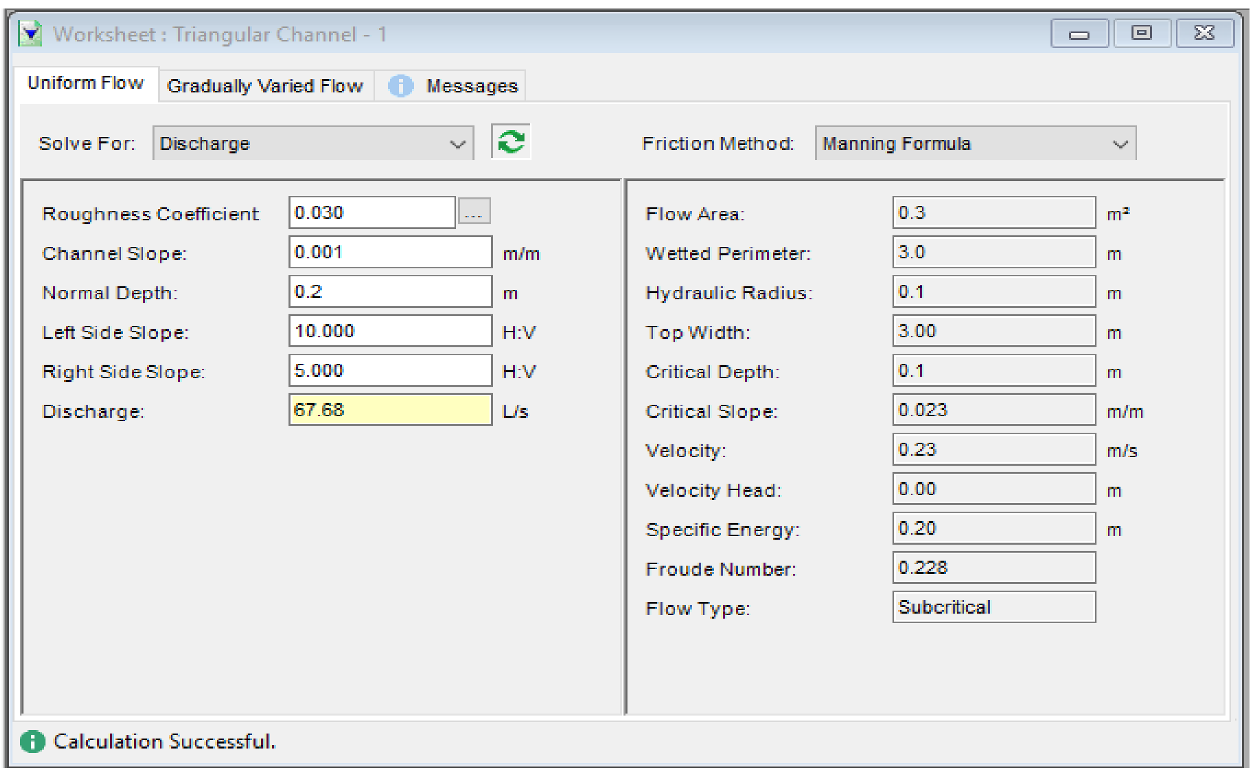
Catchment	Area (ha)	$Q_{2,2hr}$	$Q_{2,60min}$	$Q_{2,30min}$	$Q_{6Month,2hr}$	$Q_{6Month,60min}$	$Q_{6Month,30min}$
C5-04	0.4113	0.0054	0.0074	0.0100	0.0027	0.0037	0.0050
C5-05	4.1353	0.0547	0.0740	0.1002	0.0273	0.0370	0.0501
C5-06	0.8291	0.0110	0.0148	0.0201	0.0055	0.0074	0.0100
C5-07	0.5517	0.0073	0.0099	0.0134	0.0036	0.0049	0.0067
C5-08	0.4739	0.0063	0.0085	0.0115	0.0031	0.0042	0.0057
C5-09	2.3758	0.0314	0.0425	0.0576	0.0157	0.0213	0.0288
C5-10	3.4732	0.0459	0.0622	0.0841	0.0230	0.0311	0.0421
C6-01	0.5053	0.0067	0.0090	0.0122	0.0033	0.0045	0.0061
C6-02	1.5228	0.0201	0.0273	0.0369	0.0101	0.0136	0.0184
C6-03	1.0855	0.0144	0.0194	0.0263	0.0072	0.0097	0.0131
C6-04	0.8326	0.0110	0.0149	0.0202	0.0055	0.0075	0.0101
C6-05	0.4266	0.0056	0.0076	0.0103	0.0028	0.0038	0.0052
C6-06	0.2334	0.0031	0.0042	0.0057	0.0015	0.0021	0.0028
C6-07	1.0499	0.0139	0.0188	0.0254	0.0069	0.0094	0.0127
C6-08	0.2380	0.0031	0.0043	0.0058	0.0016	0.0021	0.0029
C6-09	0.1077	0.0014	0.0019	0.0026	0.0007	0.0010	0.0013
C6-10	0.1011	0.0013	0.0018	0.0024	0.0007	0.0009	0.0012
C6-11	0.3519	0.0047	0.0063	0.0085	0.0023	0.0031	0.0043
C6-12	1.1190	0.0148	0.0200	0.0271	0.0074	0.0100	0.0136
C6-13	0.1674	0.0022	0.0030	0.0041	0.0011	0.0015	0.0020
C6-14	0.1496	0.0020	0.0027	0.0036	0.0010	0.0013	0.0018
C6-15	8.5994	0.1137	0.1539	0.2083	0.0569	0.0770	0.1042

3.0 Ditch Level of Service (LOS)

3.1 Parameters for using Rational Method

Parameter	Value	Units	Intensity Duration	Notes
$I_{@2years}$	5.29	mm/hr	@ 2hr	*taken from Arviat IDF for intensity rates
$I_{@2years}$	7.16	mm/hr	@ 60min	*taken from Arviat IDF for intensity rates
$I_{@2years}$	9.69	mm/hr	@ 30min	*taken from Arviat IDF for intensity rates
$I_{@2years}$	20.35	mm/hr	@ 10min	*taken from Arviat IDF for intensity rates
$I_{@2years/2}$	2.645	mm/hr	@ 2hr	
$I_{@2years/2}$	3.58	mm/hr	@ 60min	
$I_{@2years/2}$	4.845	mm/hr	@ 30min	
$I_{@2years/2}$	10.175	mm/hr	@ 10min	
C	0.9			(Earth Shoulders)
K_U	360			

3.2 Ditch Capacity



3.3 Max Contributing Area per Intensity Rates

Parameter	Value	Units	Value	Units
$Q_{2,2hr}$	0.067448	m^3/s	67.4475	L/s
$A_{2,2hr}$	5.1	ha		
$Q_{2,60min}$	0.067125	m^3/s	67.125	L/s
$A_{2,60min}$	3.75	ha		
$Q_{2,30min}$	0.06783	m^3/s	67.83	L/s
$A_{2,30min}$	2.8	ha		
$Q_{2,10min}$	0.066138	m^3/s	66.1375	L/s
$A_{2,10min}$	1.3	ha		
$Q_{6Month,2hr}$	0.067448	m^3/s	67.4475	L/s
$A_{6Month,2hr}$	10.2	ha		
$Q_{6Month,60min}$	0.067125	m^3/s	67.125	L/s
$A_{6Month,60min}$	7.5	ha		
$Q_{6Month,30min}$	0.06783	m^3/s	67.83	L/s
$A_{6Month,30min}$	5.6	ha		
$Q_{6Month,10min}$	0.066138	m^3/s	66.1375	L/s
$A_{6Month,10min}$	2.6	ha		

Notes:

1. Flow length from 0 metres to 150 metres using 10min intensity rates
2. Flow length from 150 metres to 600 metres using 30min intensity rates
3. Flow length greater than 600 metres using 60min intensity rates

3.4 Catchment Ditches LOS

Catchment	Intensity	LOS
C1-01	10min	2 year
C1-02	30min	2 year
C1-03	30min	2 year
C1-04	30min	2 year
C1-05	30min	2 year
C1-06	30min	2 year
C1-07	30min	2 year
C1-08	30min	2 year
C1-09	10min	2 year
C1-10	30min	2 year
C1-11	60min	none *To be changed to Drainage Ditch (easement recommended)*
C1-12	10min	2 year
C1-13	60min	none *To be changed to Drainage Ditch (easement recommended)*

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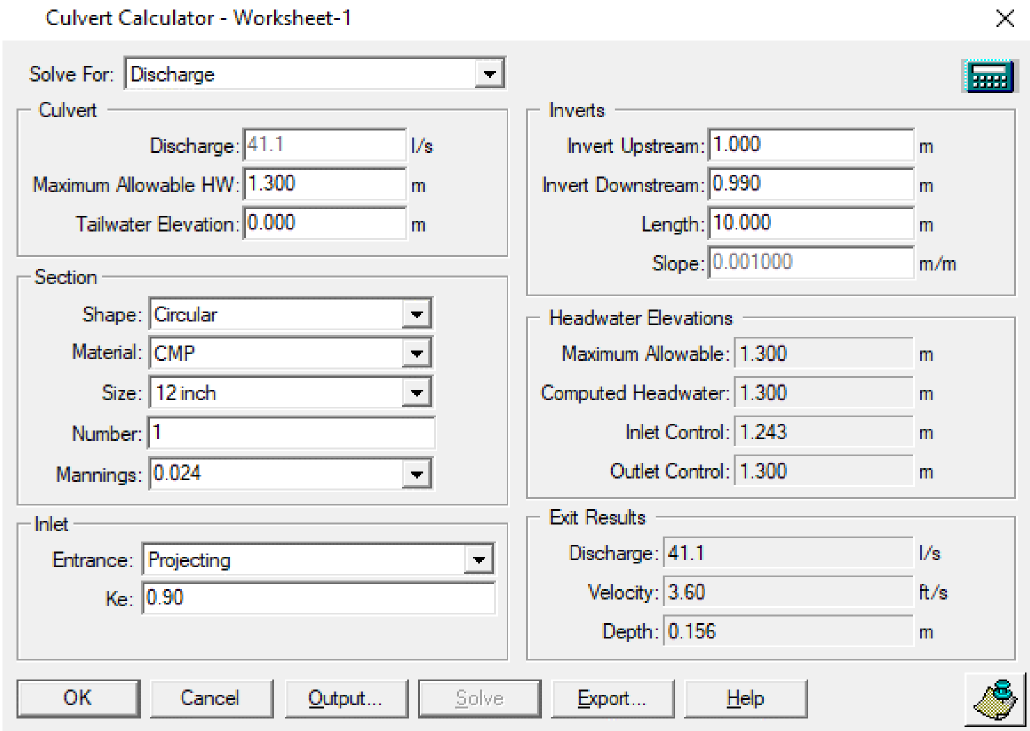
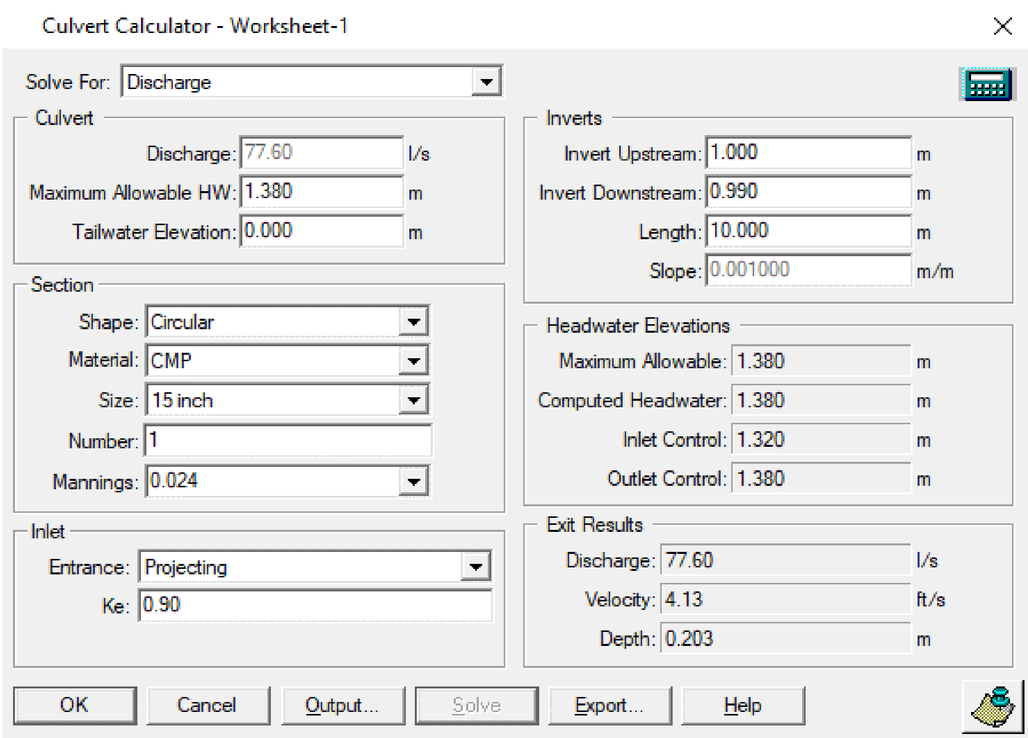
Catchment	Intensity	LOS
C1-14	60min	none *To be changed to Drainage Ditch (easement recommended)*
C1-15	30min	2 year
C1-16	60min	none *To be changed to Drainage Ditch (easement recommended)*
C1-17	60min	none *To be changed to Drainage Ditch (easement recommended)*
C1-18	60min	none *To be changed to Drainage Ditch (easement recommended)*
C1-19	30min	2 year
C1-20	10min	2 year
C1-21	10min	2 year
C2-01	30min	6 month
C2-02	10min	6 month
C2-03	30min	2 year
C2-04	30min	6 month
C2-05	30min	2 year
C2-06	30min	6 month
C2-07	30min	2 year
C2-08	10min	2 year
C2-09	10min	2 year
C2-10	60min	6 month
C2-11	30min	2 year
C2-12	30min	2 year
C2-13	30min	2 year
C2-14	30min	2 year
C2-15	30min	2 year
C2-16	10min	2 year
C2-17	-	no ditches within catchment area
C2-18	10min	2 year
C2-19	10min	2 year
C2-20	30min	2 year
C2-21	10min	2 year
C2-22	10min	2 year
C3-01	10min	2 year
C3-02	30min	2 year
C3-03	10min	2 year
C3-04	30min	2 year
C3-05	10min	2 year
C3-06	-	no ditches within catchment area
C3-07	10min	2 year
C3-08	10min	2 year
C3-09	30min	2 year
C3-10	10min	2 year
C3-11	10min	2 year

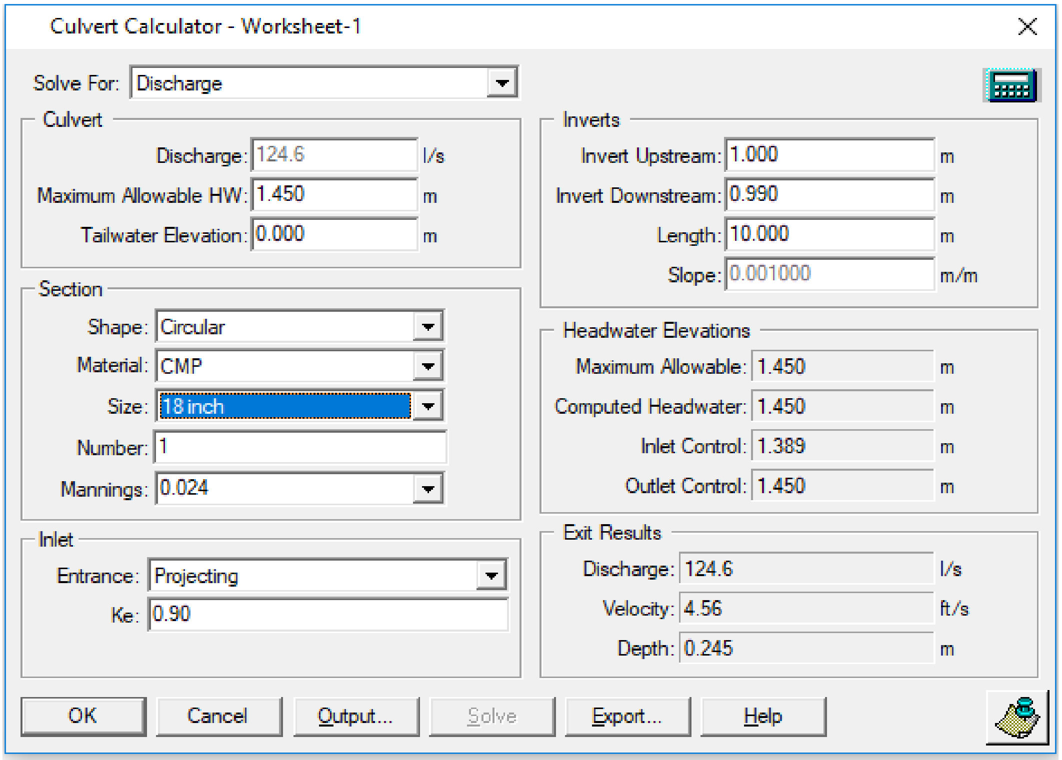
Catchment	Intensity	LOS
C3-12	10min	2 year
C3-13	10min	2 year
C3-14	30min	2 year
C3-15	10min	2 year
C3-16	30min	2 year
C3-17	10min	2 year
C3-18	10min	2 year
C3-19	10min	2 year
C3-20	10min	2 year
C4-01	10min	2 year
C4-02	10min	2 year
C4-03	10min	2 year
C4-04	60min	6 month
C4-05	10min	2 year
C4-06	30min	6 month
C4-07	30 min	6 month
C4-08	10min	2 year
C4-09	10min	2 year
C4-10	10min	2 year
C4-11	10min	2 year
C4-12	10min	2 year
C4-13	30min	6 month
C4-14	30min	2 year
C4-15	30min	2 year
C4-16	30min	2 year
C4-17	10min	2 year
C4-18	10min	2 year
C4-19	10min	2 year
C4-20	10min	2 year
C4-21	10min	6 month
C4-22	10min	2 year
C4-23	10min	2 year
C4-24	10min	2 year
C4-25	10min	2 year
C4-26	30min	2 year
C4-27	10min	2 year
C4-28	10min	2 year
C4-29	10min	2 year
C4-30	30min	2 year
C4-31	-	no ditches within catchment area
C4-32	10min	2 year

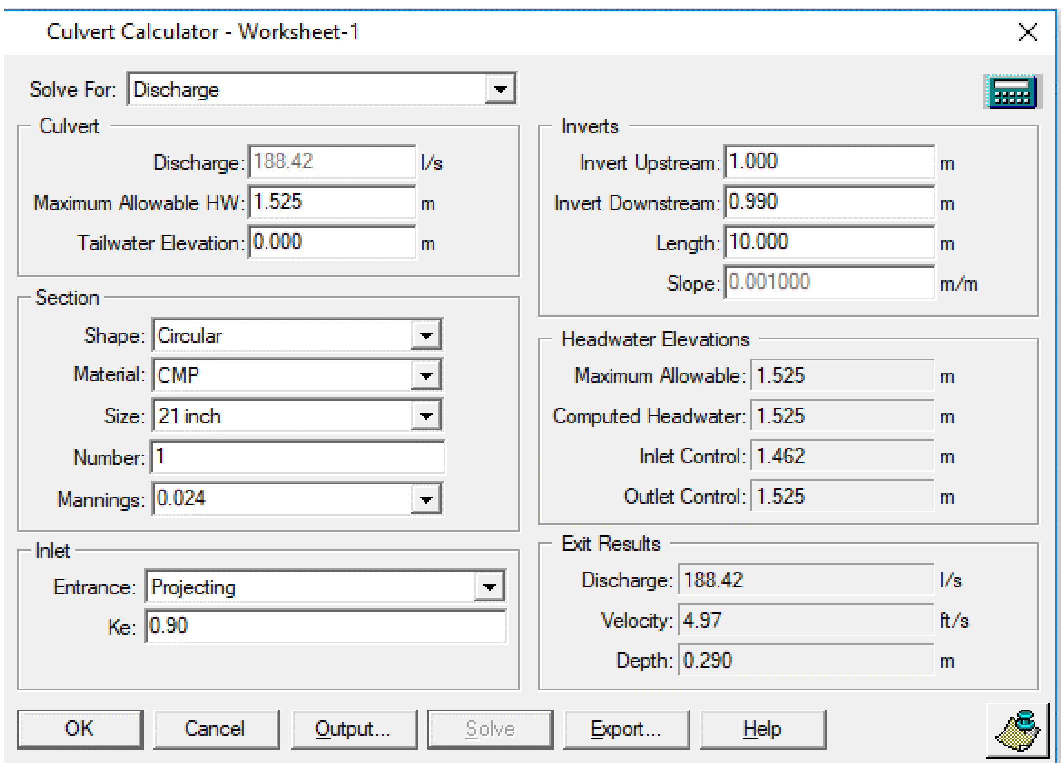
Catchment	Intensity	LOS
C4-33	10min	2 year
C4-34	10min	2 year
C4-35	10min	2 year
C4-36	10min	2 year
C5-01	-	no ditches within catchment area
C5-02	10min	2 year
C5-03	10min	2 year
C5-04	-	no ditches within catchment area
C5-05	30min	2 year
C5-06	10min	2 year
C5-07	10min	2 year
C5-08	10min	2 year
C5-09	30min	2 year
C5-10	10min	2 year
C6-01	10min	2 year
C6-02	30min	2 year
C6-03	30min	6 month
C6-04	10min	2 year
C6-05	10min	2 year
C6-06	10min	2 year
C6-07	10min	2 year
C6-08	10min	2 year
C6-09	10min	2 year
C6-10	10min	2 year
C6-11	30min	2 year
C6-12	10min	2 year
C6-13	10min	2 year
C6-14	10min	2 year
C6-15	30min	2 year
C6-16	30min	6 month

4.0 Culvert Sizing









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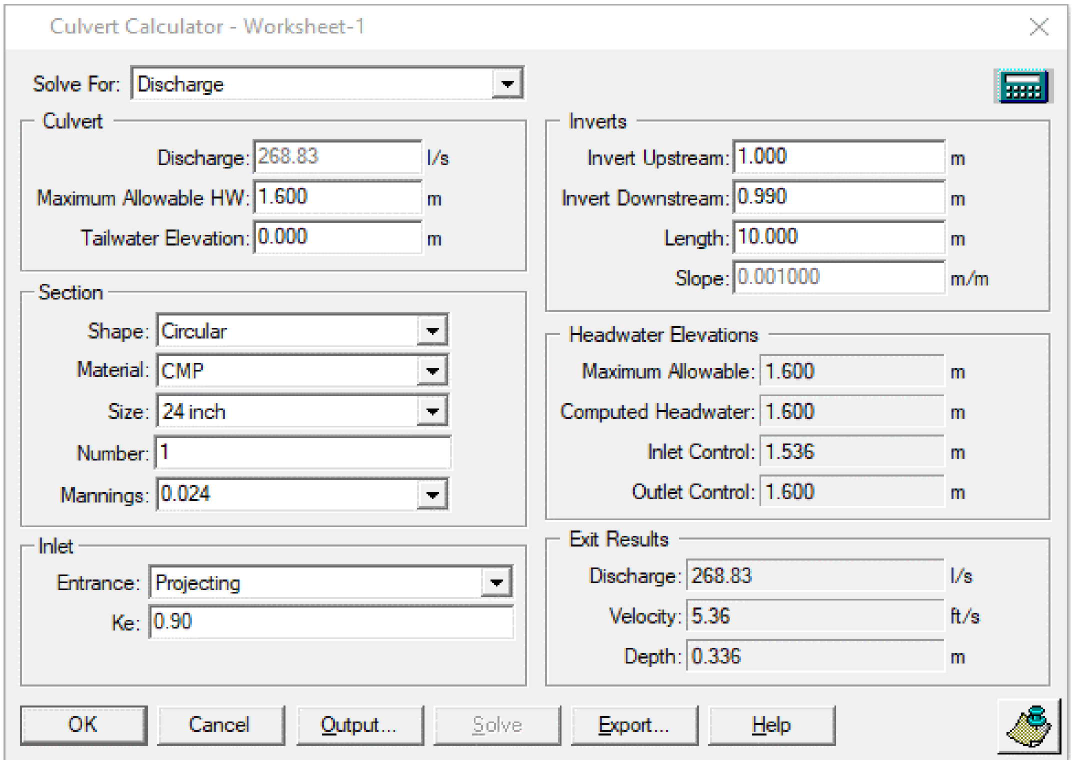

Culvert Calculator - Worksheet-1
Solve For: Discharge
Culvert
Discharge: 268.83 l/s
Maximum Allowable HW: 1.600 m
Tailwater Elevation: 0.000 m
Section
Shape: Circular
Material: CMP
Size: 24 inch
Number: 1
Mannings: 0.024
Inlet
Entrance: Projecting
Ke: 0.90
Inverts
Invert Upstream: 1.000 m
Invert Downstream: 0.990 m
Length: 10.000 m
Slope: 0.001000 m/m
Headwater Elevations
Maximum Allowable: 1.600 m
Computed Headwater: 1.600 m
Inlet Control: 1.536 m
Outlet Control: 1.600 m
Exit Results
Discharge: 268.83 l/s
Velocity: 5.36 ft/s
Depth: 0.336 m
OK
Cancel
Output...
Solve
Export...
Help

Appendix C

Lifecycle Strategy

Appendix C: Lifecycle Strategy

C1.0 Update Asset Inventory

The Hamlet should maintain a detailed inventory of assets including culverts, ditches and equipment. Each asset should have a unique identifier and tracked information on location, size, type/description, condition, install/purchase date and last inspection date. Asset information should be regularly updated based on changes to the asset information, disposal of assets or addition of new assets.

Asset inventories should be maintained by the Public Works Director or a designated staff member.

See **Appendix D** for full Asset Inventory Sheets for culverts, ditches and equipment. A Microsoft Excel workbook with asset inventory sheets has also been provided. Asset inventory sheets should be used to develop and maintain an asset inventory for culverts, ditches and equipment owned by the Hamlet. Blank cells/boxes should be completed by the Hamlet.

C1.1 Asset Inventory - Culverts

An example of an asset inventory specific to culverts can be found below in **Table C-1**.

Table C-1: Sample Culvert Asset Inventory

Culvert Catchment Area	Culvert ID No.	Existing / Proposed	Culvert Location	Culvert Size (mm)	Culvert Type

Culvert Length (m)	Culvert Condition	Culvert Marker Installed	Install Date	Last Inspection Date	Comments

1. The table is presented in two lines to display within the report. Table headings should be along a single line as in **Appendix D**.

A list of known existing and proposed culverts has been developed as part of the Drainage Plan, available in Figures 16 and 17 of the Drainage Plan Report. The Hamlet should utilize this list as a starting document for their culvert asset inventory. The culvert asset inventory is to be updated based on:

1. Any changes to an existing culvert that would affect the recorded information in **Table C-1**, including repair or replacement activities. The information should be updated in the master asset inventory.
2. Installation of a new culvert. The new asset should be added to the asset inventory with a unique identifier and all information required as per **Table C-1**. The condition of the asset is to be recorded as Very Good at time of installation, unless a post construction condition evaluation determines otherwise.

Effort should be made to update the asset inventory as soon as possible after the repair/replacement or new installation work is complete. The culvert asset inventory should be assessed and updated during the recommended complete drainage system inspection, per Section 6 Operations and Maintenance of the Drainage Plan Report and **Appendix E**, completed at the beginning of every summer. The culvert asset inventory will be an essential tool in the planning of culvert maintenance, repair and replacement activities, and provide the Hamlet with a detailed view and valuation of existing culvert infrastructure.

Confirmed installation of culvert markers is included within the culvert asset inventory. Culvert markers are considered a component of the culvert asset.

C1.2 Asset Inventory – Ditches

An asset inventory for ditches should be developed by the Hamlet. A sample ditch asset inventory is provided in **Table C-2**. The Hamlet should utilize the ditch asset inventory template provided in **Table C-2** to develop and implement an asset inventory for existing ditches. Effort should be made to update the asset inventory as soon as possible after the repair or new installation work is complete. The ditch asset inventory should be assessed and updated during the recommended complete drainage system inspection, per Section 6.0 of the Drainage Plan Report and **Appendix E**, completed at the beginning of every summer.

Table C-2: Sample Ditch Asset Inventory

Ditch Segment Catchment Area	Ditch Segment ID No.	Existing / Proposed	Adjacent Roadway	Upstream Culvert	Downstream Culvert	Condition	Geo-textile Installed	Last Inspection Date	Comments

C1.3 Asset Inventory – Equipment

An asset inventory for equipment should be developed by the Hamlet. A sample equipment asset inventory is provided in **Table C-3**. The Hamlet should utilize the equipment asset inventory template provided in **Table C-3** to develop and implement an asset inventory for existing equipment. Effort should be made to update the asset inventory as soon as possible after the replacement or purchase of any equipment. The equipment asset inventory should be updated annually to ensure information accuracy and track the usage and condition of assets.

Table C-3: Sample Equipment Asset Inventory

Equipment ID No.	Name	Description	Equipment Type	Model	Serial No.	Purchase Date

Hours or Odometer	Replacement Value	Expected Useful Life	Remaining Useful Life	Estimated Year of Replacement	Last Inspection Date

1. The table is presented in two lines to display within the report. Table headings should be along a single line as in **Appendix D**.

C1.4 Asset Inventory – Other

Inventories for other assets may be developed as necessary based on changes to the drainage network. At this time no additional asset inventories are recommended.

C2.0 Ditch and Culvert Network Mapping

A map of existing and proposed ditches and culverts has been developed as part of the drainage plan, available in Figures 7 and 8 of the Drainage Plan Report. The Hamlet should utilize this map as a basis for developing and maintaining a detailed and accurate map of the existing ditch and culvert network. It is recommended that the map be updated with any changes to the drainage network in order to provide an accurate information source to be used in inspection and maintenance activities. Effort should be made to update the ditch and culvert network map as soon as possible after the repair/replacement or new installation work is complete. Accuracy of the map should be evaluated during the recommended complete drainage system inspection, per Section 6.0 of the Drainage Plan Report and **Appendix E**, completed at the beginning of every summer.

The drainage network map should be modified and maintained by the Public Works Director or a designated staff member.

The asset inventory and drainage network mapping will aid in the tracking of assets, infrastructure priority planning and conducting maintenance.

C3.0 Inventory of Critical Spares

The Hamlet should maintain adequate supply of critical spares for drainage system assets. At least 5% of CMP materials used in the drainage system should be kept in stock. Materials include spare couplers, CMP pipe, repair clamps and culvert markers. Zinc-rich primer, as supplied by the CMP manufacturer, should be kept in supply to coat cut culvert pipe ends. Maintaining a supply of critical spares will allow the Hamlet to quickly respond to emergency repair or replacement requirements.

It is assumed that all proposed Drainage Plan improvements will be completed as per the schedule outlined in Section 5.1 of the Drainage Plan Report. It is recommended the Hamlet attempt to standardize the size of culvert utilized in their drainage system if possible, and an inventory of the recommended culvert size per Section 5.1 of the Drainage Plan Report be established in accordance with the criteria above. Utilizing a standard culvert size across the majority of the drainage system will allow the Hamlet to maintain a more uniform supply of critical spares, improving their ability to respond to emergency repairs or replacements.

The existing inventory of critical spares can continue to be used in the repair and replacement of existing culverts until the supply is exhausted.

The Hamlet should ensure repair clamps and couplers are of the appropriate size, as well as take care not to mix up metric and imperial sized clamps and couplers. Universal couplers may be used, provided a rubber gasket or coating is used between the joints to ensure an appropriate seal. The manufacturer instructions should be followed when cutting, repairing and joining CMP culverts, and installing repair clamps or couplers.

C4.0 Asset Maintenance and Inspection

C4.1 Maintenance and Inspection Scheduling

The Hamlet should maintain an up-to-date maintenance plan and inspection schedule for all asset types. These plans and schedules can be categorized based on time of year and developed from the recommended maintenance provided in Section 6.0 of the Drainage Plan Report and **Appendix E**, and should take into account the criticality of each asset, as described in **Section C8.0**. The annual work plan provided in **Table C-4** outlines an approximate schedule for inspection and maintenance activities.

The Hamlet should ensure new or replaced assets are included in maintenance schedules and routines.

It is recommended the Director of Public Works complete all updates and modifications to the maintenance and inspection schedule.

C4.2 Maintenance and Inspection Procedure – Culverts and Ditches

When conducting asset condition inspections, the Hamlet should complete condition ratings in a consistent fashion and record the condition rating and any pertinent notes for each asset. Inspection data should be used to update the asset inventory and plan for maintenance and repair/replacement activities.
Inspection log sheets have been developed and are available in **Appendix E** for culvert and ditch inspections.

Hamlet staff completing inspection and maintenance activities should be aware of the following signs which may indicate decreased LOS:

- Flooding, standing or ponding water;
- Slow drainage;

- Ground subsidence;
- Erosion;
- Damming, blockages or excessive debris (e.g., leaves, litter, grass, rocks and silt, and other debris);
- Crushed culvert ends;
- Excessive vegetation impeding flow; and
- Material blocking drainage paths within area.

C4.3 Maintenance and Inspection Procedure – Equipment

Condition of equipment assets should be assessed during regular maintenance and inspection intervals as recommended by the manufacturer. Hours or odometer readings and inspection date should be recorded in equipment maintenance logs. Good maintenance practices are recommended for equipment, following the recommendations of the manufacturer. Further recommendations on equipment best practices and management are provided in **Section C6.0**.

C5.0 Asset Replacement Schedules

Culverts, ditches and equipment replacement schedules are based on the results of periodic inspections and observation during maintenance activities. Replacement and repair of assets will be determined in accordance with meeting the Hamlet's desired LOS. Assets which have reached the end of their useful life (i.e., no longer performing to a standard that delivers the required LOS) should be replaced. Condition is an indicator of asset performance; condition assessments will guide replacement or repair requirements.

The current LOS rating for the drainage system is estimated between Fair and Poor based on the condition of the assets. The desired LOS is an overall average condition of Good.

Prioritization of culvert and ditch major repair or replacement should be completed considering the factors outlined in **Section C7.0** to determine the criticality of the infrastructure. The most critical infrastructure should be replaced first, within the considerations of available resources.

C5.1 Asset Replacement Schedule – Culverts

To improve the LOS for the existing drainage system to a Good rating, it is recommended that all Very Poor, Poor and Fair culverts be repaired or replaced, as necessary, to improve their condition to Very Good.

A proposed replacement schedule of existing culverts has been developed and included in the implementation plan as part of Section 5.1 of the Drainage Plan Report. As previously stated, the replacement schedule was based on the assumption that the 43 culverts which did not received condition ratings have a condition rating distribution similar to the 23 culverts that have been condition rated.

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At the end of the five year implementation strategy, it is recommended that the Hamlet repair and replace culverts as identified by the annual inspections. Culverts which are performing below what is required to maintain a Good LOS for the community should be identified as candidates for replacement. The number of culverts replaced beyond the 5-year implementation plan cannot be recommended at this time and will be based on the future drainage network LOS and the annual inspections.

The estimated useful life of a CMP culvert is over 25 years, if maintained as recommended in Section 6.0 of the Drainage Plan Report. It is assumed that all culverts will receive maintenance and operations as established by the best practices established in Section 6.0 of the Drainage Plan Report and. Therefore, all new culverts should last beyond the 10-year planning horizon established within the report.

Based on field observations, the Hamlet's culverts appear to have a greater likelihood of damage, typically due to blockage or the crushing of culvert ends. Culvert end crushing is likely due to vehicles driving over culvert ends during the winter when culverts are not visible due to snow cover. The installation of culvert markers is recommended to reduce the rate of damage from vehicles crushing culvert ends. The increased risk of damage of culverts within the Hamlet demonstrate the need for consistent and thorough inspection and maintenance as recommended in **Section C4.0** and Section 6.0 of the Drainage Plan Report.

A guide for repair and replacement of damaged culverts is available in **Appendix E.**

C5.2 Asset Replacement Schedule – Ditches

Following initial construction and under normal conditions ditches should only require periodic maintenance in accordance with the best practices as outlined in Section 6.0 of the Drainage Plan Report. Ditch construction is recommended to be completed as described in Section 6.0 of the Drainage Plan Report.

C5.3 Asset Replacement Schedule – Equipment

The Hamlet should develop replacement schedules for equipment assets. Dillon has provided approximate replacement costs and estimated useful lives in Table 9 of the Drainage Plan Report for Hamlet equipment assets based on information provided by manufacturers. The Hamlet should complete a condition assessment, estimate the remaining useful life of equipment and update the schedule for planned equipment replacement. The age of the equipment was unknown at the time of developing the Drainage Plan.

C5.4 Asset Replacement Schedule – Other Assets in Drainage Network

Culvert markers are considered as an important component of culverts. Culvert markers shall be stocked as per **Section C3.0** and any damaged or missing culvert markers should be replaced.

Geo-textiles are presented as an option for driveway crossing of ditches. If installed, replacement schedule for geo-textiles should be prepared as instructed by the manufacturer.

C6.0 Equipment Management

C6.1 Existing Equipment

All equipment should be operated, inspected and maintained as recommended by the manufacturer. A detailed equipment inspection schedule should be developed for weekly, monthly and annual inspection and maintenance activities based on instructions from the manufacturer. Good maintenance extends equipment life and reduces the likelihood of unexpected break-downs that may result in a reduced LOS for the community drainage system.

As part of the annual work plan, the following recommendations are key to a successful program:

1. **Steam Jet Annual Inspection**: This inspection serves as a thorough check of equipment function, in order to identify problems prior to the culvert thawing season, as well as allowing time for replacement parts and additional maintenance to be completed. This inspection is recommended in addition to the ongoing maintenance as recommended by the manufacturer.
2. **Stock Spare Parts:** It is recommended the Hamlet stock spare parts for equipment that will address common modes of failure. The Hamlet should consult with the equipment manufacturer to identify which parts to keep in stock as spares.
3. **Equipment Replacement Reserve Fund:** An equipment replacement reserve fund has been included in the proposed Capital Plan, **Section C10.0**.

C6.2 Purchase of Additional Equipment

As proposed drainage improvements are implemented and the scale of the drainage network increases within the community, additional equipment may be necessary. As presented in **Section C10.0**, the purchase of an additional steam jet with culvert thawing kit is recommended within a three to five year period. If all recommended drainage improvements are implemented, the Hamlet will significantly increase the number of existing culverts, from 66 to 134. The additional steam jet is intended to maintain the Hamlet's ability to clear and thaw culverts, if the appropriate staffing resources are provided. The efficient clearing and thawing of culverts during periods of melt is imperative to maintaining the performance of the drainage network and limiting the effects of flooding on the community. The purchase of a second steam jet with culvert thawing kit will provide 100% redundancy to the Hamlet's culvert thawing equipment, decreasing the risk of service disruption and decrease in the drainage network LOS.

At this time, no other additional equipment is recommended.

C7.0 Record Keeping and Reporting

A record of inspection and maintenance performed on the drainage system shall be maintained by the Hamlet as well as kept on file.

Maintain a system of internal reporting documents including:

- Asset inventory – including asset condition;
- Drainage network maps;
- Asset Management Plan;
- Maintenance logs;
- Inspection reports; and
- Reports on drainage issues or flooding.

Documents provide historical data on the drainage network and aid in the management of assets.

C8.0 Critical Infrastructure Prioritization Strategy

The Hamlet should identify the most critical assets to deliver the desired LOS to the community and prioritize efforts to improve drainage and maintain those assets. By identifying the most critical assets for delivering the LOS, the Hamlet can implement improvements and conduct maintenance activities that will have the greatest improvement on the drainage system LOS.

To identify the most critical infrastructure in the drainage system the Hamlet should consider the following framework.

Consideration #1	Consideration #2	Consideration #3
Identified Priority Areas (per Section 5.1 of the Drainage Plan Report)	**Condition of Asset**	**Considering Downstream Infrastructure and Condition**
Good performance of drainage network infrastructure serving the identified Priority Areas are to be considered critical to limit the impacts of flooding in the areas.	Condition of assets is used as an indicator of performance. Assets which are not performing at a level which meets the desired LOS should be considered for maintenance or replacement. Very Poor assets to be considered for repair or replacement first, then Poor and then Fair.	Confirm functional capacity of downstream culverts and ditches to ensure discharge of water from the community. When considering the repair or replacement of ditches and culverts, the Hamlet must confirm downstream infrastructure has the capacity to receive flow.

As stated in Section 5.1 of the Drainage Plan Report, work should be completed on the outfall infrastructure first and then working upstream from that point.

The prioritization strategy applies to the consideration of both capital projects and operations and maintenance activities.

When thawing culverts during the spring season, prioritize the thawing of culverts in Priority Areas (identified in Section 5.1 of the Drainage Plan Report). Staff will identify areas of standing water and use the drainage network maps to determine the approximate direction of flow. The outfall of the flow path must then be determined and the Hamlet should begin thawing culverts from the outfall, moving upstream until the blockages are removed and standing water is able to flow to the outfall.

To identify which culverts take priority for replacement, look at culverts in Poor and Very Poor condition and consider the importance of the culvert on the LOS of the system. For example:

- **Lower Priority:** Is it in an area on the edge of the community or outside a priority area where flooding is unlikely and the impact low so the replacement would have little impact on the LOS? or
- **Higher Priority:** Is it in the centre of the community or in a priority area downstream of several large drainage areas where flooding could be more likely and damaging, and replacement would significantly increase the LOS?

And also consider downstream effects:

- **Lower Priority:** The downstream culverts and ditches are also in poor condition and will not be able to handle the increased flow from this culvert, resulting in potential flooding and decreased LOS; or
- **Higher Priority:** The downstream culverts and ditches have the capacity to handle increased flows from this culvert.

The same process can also be applied to determine priority for ditch reconstruction or maintenance activities.

In applying the recommended framework of prioritization the Hamlet can refine implementation strategies for specific asset investment.

C9.0 Annual Work Plan

Recommended annual work plan for operations and capital activities for drainage system improvement and maintenance is presented below in **Table C-4**. The timing of tasks identified in **Table C-4** may change with annual weather variability, and more detailed scheduling to be completed by the Hamlet should be adjusted to take these variations into account. The timing provided are estimates for planning purposes only.

Table C-4: Annual Work Plan

Activity Type Maintenance (M) or Capital (C)	Task	Month[1]										
		January	February	March	April	May	July	August	September	October	November	December
M	Snow Removal and Storage	X	X	X	X							X
M	Inspection of Drainage System for Snow Removal Damage	X	X	X	X							X
M	Culvert Inspection – Looking for Back-up Melt Water				X	X						
M	Culvert Cleaning/Thawing				X	X						
M	Outlet Litter/Debris Inspection and Removal				X	X	X					
M	Runoff/Rain Event System Inspection					X	X					
M	Erosion Control						X					
M	Complete Drainage System Condition Inspection						X	X				
M	Ditch and Culvert Maintenance						X	X	X	X		
C	Gravel Road Building							X	X	X		
C	Site Grading							X	X	X		
C	Construction of Ditches							X	X	X		
C	Culvert Construction							X	X	X		
M	Pre-Season Equipment Inspection – Steam Jet								X			
M	Culvert Marker Post Inspection and Replacement									X	X	

1. Timing of tasks subject to change due to annual weather variability.

C10.0 Capital Plan

The presented capital plan, **Table C-5**, provides a basis for the Hamlet to develop budgets for proposed improvements and asset management.

The estimated costs are provided in present day Canadian Dollars, and do not include inflation or increases for potential cost volatility. Cost estimates should be considered Class D estimates.

Table C-5: Proposed 10-Year Capital Plan

Activity	Year									
	1	2	3	4	5	6	7	8	9	10
5-year Phased Implementation Plan – New Culvert and Ditch Construction										
Implementation of Drainage Plan[1]	$ 183	$ 83	$ 95	$ 68	$ 23	No Further Action for Implementation Plan				
Asset Management – Culvert Replacement Plan										
Replacement Plan[1]	$ 113	$ 52	$ 30	$ 53	$92	Determine from Annual Inspection and Prioritization Strategy				
Asset Management – Equipment Replacement										
Purchase of Additional Steam Jet[2]	-	-	$ 20	-	-	-	-	-	-	-
Reserve Fund Contribution for Replacement of Equipment[3]	$ 650	$ 650	$ 650	$ 650	$ 650	$ 650	$ 650	$ 650	$ 650	$ 650
Total Annual Capital Cost										
Total Capital Cost	$ 946	$ 785	$795	$771	$765	Determine from Annual Inspection and Prioritization Strategy				

1. Capital cost estimated based on Option 2, recommended implementation approach.
2. Capital cost estimated based on purchase and delivery for steam jet of similar type to current (Power Eagle DC-3505 with culvert thaw kit).
3. Capital cost estimate calculated as the average annual investment when all equipment assumed to be new at start of Year 1 and replaced at the lower range for estimated useful life per Table 9 of the Drainage Plan Report. Age of equipment not provided by Hamlet. Hamlet to refine annual reserve fund contribution based on asset estimated remaining useful life and planned replacement year.
4. Presented in $,000.

C10.1 Culverts & Ditches

The Capital Plan captures the estimated planned expenditures involved in the implementation of improvements presented in the Drainage Plan, and major repairs or replacement of existing infrastructure to achieve the desired LOS. The proposed 10-year Capital Plan is presented in **Table C-5**.

It is assumed the implementation of proposed drainage solution will be completed as recommended within the implementation plan, Section 5.1 of the Drainage Plan Report. Beyond the five year implementation plan it is recommended that replacement of existing culverts be based on the recommendation outlined in **Section C5.0**.

C10.2 Equipment

Consideration for annual equipment replacement is also captured in the Capital Plan, **Table C-5**, to allow for planned periodic replacement of equipment. It is recommended the Hamlet maintain a reserve fund to purchase required replacement equipment as necessary. The annual planned equipment replacement cost was based on an estimated replacement cost and useful life for the Hamlet's existing drainage equipment as per Table 9 of the Drainage Plan Report.

The replacement schedule and Capital Plan should be updated when new information becomes available on the condition and the estimated useful life of the equipment.

With considerable expansion of the drainage system as part of the Drainage Plan and to reduce risk of LOS decrease due to equipment failure, an additional steam jet with culvert thawing kit is recommended as per **Section C6.2**. The purchase of the steam jet has been included in the Capital Plan.

C11.0 Operating Plan

The proposed operating plan captures the estimated annual resource requirements to conduct maintenance activities on the drainage system to sustain the desired LOS of the Hamlet. Estimated resource requirements are for the existing drainage network and are to be adjusted as drainage network infrastructure is increased per the implementation plan, Section 5.1 of the Drainage Plan Report. The operating plan is developed based on the best practices for recommended maintenance found in Section 6.0 of the Drainage Plan Report and **Appendix E**. The proposed annual operating plan is presented below in **Table C-6** with descriptions and estimated resource allocations for the activities.

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Table C-6: Proposed Annual Operations Plan

Season	Activity	Description	Resources	Frequency
Spring	Culvert Inspection	Inspection for presence of back-up melt water and identify the cause.	Public Works Director Approximately 1 hour to complete inspection Approximately 1 hour to record findings	Weekly
	Culvert Clearing/Thawing	Clear culvert ends of ice/snow and thaw culverts to allow flow of melt water.	2 Public Works Staff Approximately 5 hours	As required. To be completed when snow melt occurs during the day and nighttime temperatures are below freezing.
	Outlet Litter/Debris Inspection and Clearing	Outlets of drainage system near discharge location inspected for litter and debris. Any present to be removed.	2 Public Works Staff Approximately 1 hour	Every two weeks
	Runoff/Rain Event System Inspection	Complete drainage system inspection during runoff and rain events. Identify deficiencies for summer repair.	Public Works Director Approximately 2 hours to complete inspection Approximately 1 hour to record findings	During 2 spring rain events
	Erosion Control	Providing erosion control in response to spring runoff and rain events.	2 Public Works Staff As required	As required
Summer	Complete Drainage System Condition Inspection	Completed drainage system inspection. Identify asset conditions and any deficiencies. Complete condition assessment. Confirm accuracy of asset inventory and drainage network map.	Public Works Director Approximately 4 hours to complete inspection Approximately 2 hour to record findings	Annually
	Ditch and Culvert Maintenance	Complete minor ditch and culvert maintenance as required. Determined through spring and summer inspections.	3 Public Works Staff As required	As required
Fall	Pre-Season Equipment Inspection – Steam Jet	Complete thorough inspection of steam jet to ensure proper operation prior to spring season.	Public Works Director or trained staff Approximately 1 hour	Annually
	Ditch and Culvert Maintenance	Complete minor ditch and culvert maintenance as required. Determined through spring and summer inspections.	3 Public Works Staff As required	As required

Season	Activity	Description	Resources	Frequency
	Culvert Marking Post Inspection and Replacement	Complete inspection of all culverts to ensure marking posts properly installed. Replace marking posts as required.	2 Public Works Staff Approximately 4 hours	Annually
Winter	Snow Removal and Storage	Complete snow removal and storage as per community requirements. Ensure storage and removal completed as per Section 6.6 Remove snow and ice blockages from culvert entrances.	As required	As required
	Inspection of Drainage System for Snow Removal Damage	Inspection of ditches and culverts for damage caused by snow removal activities or other factors during winter.	Public Works Director or trained staff Approximately 1 hour to complete inspection Approximately 1 hour to record results and make recommendations	Monthly

Appendix D

Asset Inventory Sheets

Culvert Catchment Area	Culvert ID No.	Exisitng / Proposed	Culvert Location	Culvert Size (mm)	Culvert Type	Culvert Length (m)	Culvert Condition	Marker Marker Installed	Install Date	Last Inspection Date	Comments / Issues
Airport Area	CV0-01	Existing			CMP		Not Assessed	No			
Airport Area	CV0-02	Existing			CMP		Not Assessed	No			
Airport Area	CV0-03	Existing			CMP		Not Assessed	No			
Airport Area	CV0-04	Existing			CMP		Not Assessed	No			
Airport Area	CV0-05	Existing			CMP		Not Assessed	No			
Airport Area	CV0-06	Existing			CMP		Not Assessed	No			
Airport Area	CV0-07	Existing			CMP		Not Assessed	No			
Airport Area	CV0-08	Existing			CMP		Not Assessed	No			
Airport Area	CV0-09	Existing			CMP		Not Assessed	No			
Airport Area	CV0-10	Existing			CMP		Not Assessed	No			
Airport Area	CV0-11	Existing			CMP		Not Assessed	No			
Airport Area	CV0-12	Existing			CMP		Not Assessed	No			
Airport Area	CV0-13	Existing			CMP		Not Assessed	No			
1	CV1-01	Existing			CMP		Not Assessed	No			
1	CV1-02	Existing			CMP		Not Assessed	No			
1	CV1-03	Existing			CMP		Not Assessed	No			
1	CV1-04	Existing			CMP		Not Assessed	No			
1	CV1-05	Existing			CMP		Not Assessed	No			

1	CV1-06	Existing			CMP		Not Assessed	No			
1	CV1-07	Existing			CMP		Not Assessed	No			
1	CV1-08	Existing			CMP		Not Assessed	No			
1	CV1-09	Proposed			CMP						
1	CV1-10	Proposed			CMP						
1	CV1-11	Proposed			CMP						
1	CV1-12	Proposed			CMP						
1	CV1-13	Proposed			CMP						
1	CV1-14	Proposed			CMP						
1	CV1-15	Proposed			CMP						
1	CV1-16	Proposed			CMP						
1	CV1-17	Proposed			CMP						
1	CV1-18	Proposed			CMP						
1	CV1-19	Proposed			CMP						
1	CV1-20	Proposed			CMP						
1	CV1-21	Proposed			CMP						
1	CV1-22	Proposed			CMP						
1	CV1-23	Proposed			CMP						
1	CV1-24	Proposed			CMP						

2	CV2-01	Existing			CMP		Not Assessed	No			
2	CV2-02	Existing			CMP		Not Assessed	No			
2	CV2-03	Existing			CMP		Poor	No		1-Apr-19	
2	CV2-04	Existing			CMP		Good	No		1-Apr-19	
2	CV2-05	Existing			CMP		Not Assessed	No			
2	CV2-06	Existing			CMP		Not Assessed	No			
2	CV2-07	Existing			CMP		Not Assessed	No			
2	CV2-08	Existing			CMP		Not Assessed	No			
2	CV2-09	Existing			CMP		Very Poor	No		1-Apr-19	
2	CV2-10	Existing			CMP		Poor	No		1-Apr-19	
2	CV2-11	Existing			CMP		Good	No		1-Apr-19	
2	CV2-12	Existing			CMP		Not Assessed	No			
2	CV2-13	Existing			CMP		Very Poor	No		1-Apr-19	
2	CV2-14	Propsed			CMP						
2	CV2-15	Propsed			CMP						
2	CV2-16	Propsed			CMP						
2	CV2-17	Propsed			CMP						
2	CV2-18	Propsed			CMP						
2	CV2-19	Propsed			CMP						

2	CV2-20	Propsed			CMP						
2	CV2-21	Propsed			CMP						
2	CV2-22	Propsed			CMP						
2	CV2-23	Propsed			CMP						
2	CV2-24	Propsed			CMP						
3	CV3-01	Existing			CMP		Not Assessed	No			
3	CV3-02	Existing			CMP		Not Assessed	No			
3	CV3-03	Existing			CMP		Not Assessed	No			
3	CV3-04	Existing			CMP		Not Assessed	No			
3	CV3-05	Propsed			CMP						
3	CV3-06	Propsed			CMP						
3	CV3-07	Propsed			CMP						
3	CV3-08	Propsed			CMP						
3	CV3-09	Propsed			CMP						
3	CV3-10	Propsed			CMP						
3	CV3-11	Propsed			CMP						
3	CV3-12	Propsed			CMP						
3	CV3-13	Propsed			CMP						
3	CV3-14	Propsed			CMP						
3	CV3-15	Propsed			CMP						
3	CV3-16	Propsed			CMP						

4	CV4-01	Existing			CMP		Very Poor	No		1-Apr-19	
4	CV4-02	Existing			CMP		Good	No		1-Apr-19	
4	CV4-03	Existing			CMP		Very Poor	No		1-Apr-19	
4	CV4-04	Existing			CMP		Good	No		1-Apr-19	
4	CV4-05	Existing			CMP		Very Poor	No		1-Apr-19	
4	CV4-06	Existing			CMP		Good	No		1-Apr-19	
4	CV4-07	Existing			CMP		Not Assessed	No			
4	CV4-08	Existing			CMP		Not Assessed	No			
4	CV4-09	Existing			CMP		Poor	No		1-Apr-19	
4	CV4-10	Existing			CMP		Fair	No		1-Apr-19	
4	CV4-11	Existing			CMP		Not Assessed	No			
4	CV4-12	Existing			CMP		Not Assessed	No			
4	CV4-13	Existing			CMP		Good	No		1-Apr-19	
4	CV4-14	Existing			CMP		Not Assessed	No			
4	CV4-15	Existing			CMP		Not Assessed	No			
4	CV4-16	Existing			CMP		Not Assessed	No			
4	CV4-17	Proposed			CMP						
4	CV4-18	Proposed			CMP						
4	CV4-19	Proposed			CMP						
4	CV4-20	Proposed			CMP						
4	CV4-21	Proposed			CMP						

4	CV4-22	Proposed			CMP						
4	CV4-23	Proposed			CMP						
4	CV4-24	Proposed			CMP						
4	CV4-25	Proposed			CMP						
4	CV4-26	Proposed			CMP						
4	CV4-27	Proposed			CMP						
4	CV4-28	Proposed			CMP						
4	CV4-29	Proposed			CMP						
4	CV4-30	Proposed			CMP						
4	CV4-31	Proposed			CMP						
4	CV4-32	Proposed			CMP						
4	CV4-33	Proposed			CMP						
5	CV5-01	Existing			CMP		Fair	No		1-Apr-19	
5	CV5-02	Existing			CMP		Good	No		1-Apr-19	
5	CV5-03	Existing			CMP		Poor	No		1-Apr-19	
5	CV5-04	Existing			CMP		Not Assessed	No			

5	CV5-05	Existing			CMP		Not Assessed	No			
5	CV5-06	Existing			CMP		Not Assessed	No			
5	CV5-07	Proposed			CMP						
5	CV5-08	Proposed			CMP						
5	CV5-09	Proposed			CMP						
5	CV5-10	Proposed			CMP						
6	CV6-01	Existing			CMP		Not Assessed	No			
6	CV6-02	Existing			CMP		Not Assessed	No			
6	CV6-03	Existing			CMP		Not Assessed	No			
6	CV6-04	Existing			CMP		Not Assessed	No			
6	CV6-05	Existing			CMP		Not Assessed	No			
6	CV6-06	Existing			CMP		Not Assessed	No			
6	CV6-07	Proposed			CMP						
6	CV6-08	Proposed			CMP						
6	CV6-09	Proposed			CMP						
6	CV6-10	Proposed			CMP						
6	CV6-11	Proposed			CMP						
6	CV6-12	Proposed			CMP						
6	CV6-13	Proposed			CMP						
6	CV6-14	Proposed			CMP						

Ditch Segment Catchment Area	Ditch Segment ID No.	Existing / Proposed	Adjacent Roadway	Upstream Culvert	Downstream Culvert	Condition	Geo-textile Installed	Last Inspection Date	Comments / Issues

Equip. ID No.	Name	Description	Equipment Type	Model	Serial No.	Purchase Date	Hours or Odometer	Replacement Value	Expected Useful Life	Remaining Useful Life	Estimated Year of Replacement	Last Inspection Date
E1	Bulldozer_1		Bulldozer	CAT D8				$ 1,020,000	15-20 years			
E2	Bulldozer_2		Bulldozer	CAT D6				$ 520,000	15-20 years			
E3	Bulldozer_3		Bulldozer	CAT D6				$ 520,000	15-20 years			
E4	Loader_1		Wheeled Loader					$ 445,000	15-20 years			
E5	Loader_2		Wheeled Loader					$ 445,000	15-20 years			
E6	Loader_3		Wheeled Loader					$ 445,000	15-20 years			
E7	Loader_4		Wheeled Loader					$ 445,000	15-20 years			
E8	Grader_1		Motor Grader					$ 470,000	15-20 years			
E9	Grader_2		Motor Grader					$ 470,000	15-20 years			
E10	Excavator_1		Excavator					$ 620,000	15-20 years			
E11	Excavator_2		Excavator					$ 620,000	15-20 years			
E12	Excavator_3		Excavator					$ 620,000	15-20 years			
E13	Compactor_1	Steel Drum Compactor	Drum Compactor					$ 220,000	15-20 years			
E14	Crusher_1	Includes jaw, cone and screen	Aggregate Crushing Machine					$ 2,020,000	15-20 years			
E15	Skid Steer_1		Kubota Skid Steer					$ 80,000	7 years			
E16	Steam Jet_1	With culvert thaw kit	Steam Jet	PowerEagle DC-3505				$ 20,000	10-15 years			

Appendix E

Operations and Maintenance Forms

1.0 General

1.1 Inspection and Maintenance Personnel

Inspection and maintenance activities shall be carried out by a competent individual. This competent individual can include the director of public works, or equipment and utility operators.

1.2 Culvert Mapping

As mentioned above the inspection and maintenance plan should be used in conjunction with Figure 18 – Culvert Mapping, which indicated the location of culverts throughout the community.

2.0 Spring Season

- Culverts shall be inspected to determine if back-up melt water is present. The cause of any backed-up melt water shall be identified (i.e. frozen snow and water, ice, debris etc.) and removed.
- Culvert ends shall be cleared when blocked with ice or snow. A back hoe, excavator, or hand tool may be used. Blocked culverts shall be cleared to allow melt water to flow freely. A culvert thawing machine can be used to melt frozen blockage from the downstream end of the culvert. When using the culvert thawing machine, equipment specific operating procedures should be followed.
- A priority system shall be used to thaw and unblock culverts. Maintenance personnel should begin at the end of the drainage system and work upstream. Frozen culverts might need to be reopened over periods where temperatures are below freezing at night and above zero during the day. Melt water overflowing a road or driveway approach can erode the structure if left unchecked.
- After a rain event and during spring runoff, the outlets of the drainage system closest to the discharge location should be inspected for litter and other debris from the community that has been carried by drainage water. If litter and debris are present, it shall be collected and disposed of in accordance with the community's regulations.
- The drainage system shall be inspected at some point during runoff and rain events to identify deficiencies for repair over the spring and summer.

3.0 Summer Season

- Following the spring runoff, at the beginning of the summer season, the complete drainage system should be inspected by a competent person and any deficiencies should be identified.
- Any deficiencies should be documented in Table 1 or 2 (below) and a corrective plan of action shall be developed.

3.1 Corrective Action Plan

- Ponding in ditches shall be identified and corrective action taken. This can include re-sloping the ditch bottom or lowering the downstream culvert;
- In areas where overgrown vegetation is prevalent around culverts and other drainage channels, the vegetation shall be cut back;
- Blocked culverts should be flushed to remove sediment, rocks and other debris;
- Where practicable, damaged culvert ends shall be cut back, replaced, or else collapsed ends bent open to allow for flow to travel through culvert until replacement can be performed ;
- Culverts that have shifted or moved shall be replaced or re-installed on a priority basis.
- Riprap protection should be installed around culvert outlets to protect from scour and erosion;
- Proper placement and compaction of material around and over culverts is required to protect the crown of the pipe from contact resulting in damage to the pipe.

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4.0 Fall Season

- Maintenance and repair of saturated areas of the drainage system should be carried out in the fall when water levels are typically the lowest.
- Culvert marking posts shall be inspected and replaced if damaged.
- Maintenance personnel should have completed all work that was identified during the spring inspection.

5.0 Winter Season

- An inspection should be undertaken to ensure that the drainage system elements are not damaged or blocked during the snow removal and storage process.
- The following components of the community drainage system shall be clearly marked and identifiable before the first snow fall to inform snow removal equipment operators of their location:
    - Outfalls;
    - Drainage ditches;
    - Culvert ends; and
    - Culvert marking posts

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Table 1: Culvert Identification Log Sheet

Culvert Catchment Area	Culvert ID No.	Existing / Proposed	Culvert Location (Street / Intersection)	Culvert Size (mm)	Culvert Type	Culvert Length (m)	Culvert Condition	Culvert Marker Installed	Install Date	Last Inspection Date

Table 2: Ditch Repair Log Sheet

Ditch Location (Highlight on Map)	Problem	Date Repaired

Appendix F

Alternative Ditch Access Way Details

If native soil is elected as the infill material of choice, it should be tested on a few pilot sites first to test the effectiveness. If proven to be ineffective with native soil infill, local crush aggregate can be used as an alternative. If granular infill is used, geotextile under the cell structure is recommended to ensure a physical barrier is in place to prevent migration of fines into the granular fill material. It is recommended that granular infill layer consists of aggregate material containing less than 9% total fines.
Geoweb® panels are shipped in their flattened state, making them easier and more cost effective to transport and handle than other heavier alternative products.

As shown in **Figures F-1**, **F-2** and **F-3** below, Geoweb® will laterally distribute point loading from vehicles to surrounding cells, thereby reducing the likelihood of rutting within the ditch structure.

Figure F-1: Geoweb® (Aerial view)

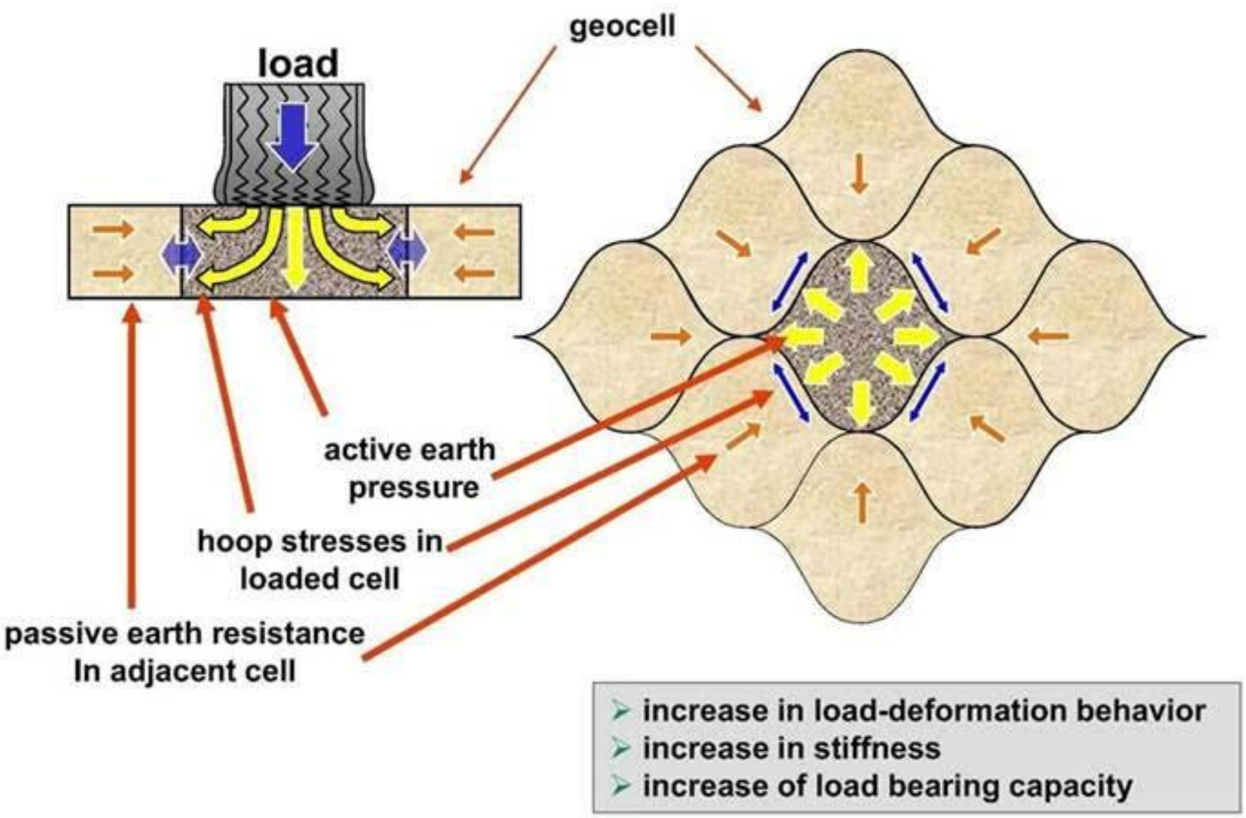

Figure F-2: Gravel Road Deformation (with and without Geoweb®)

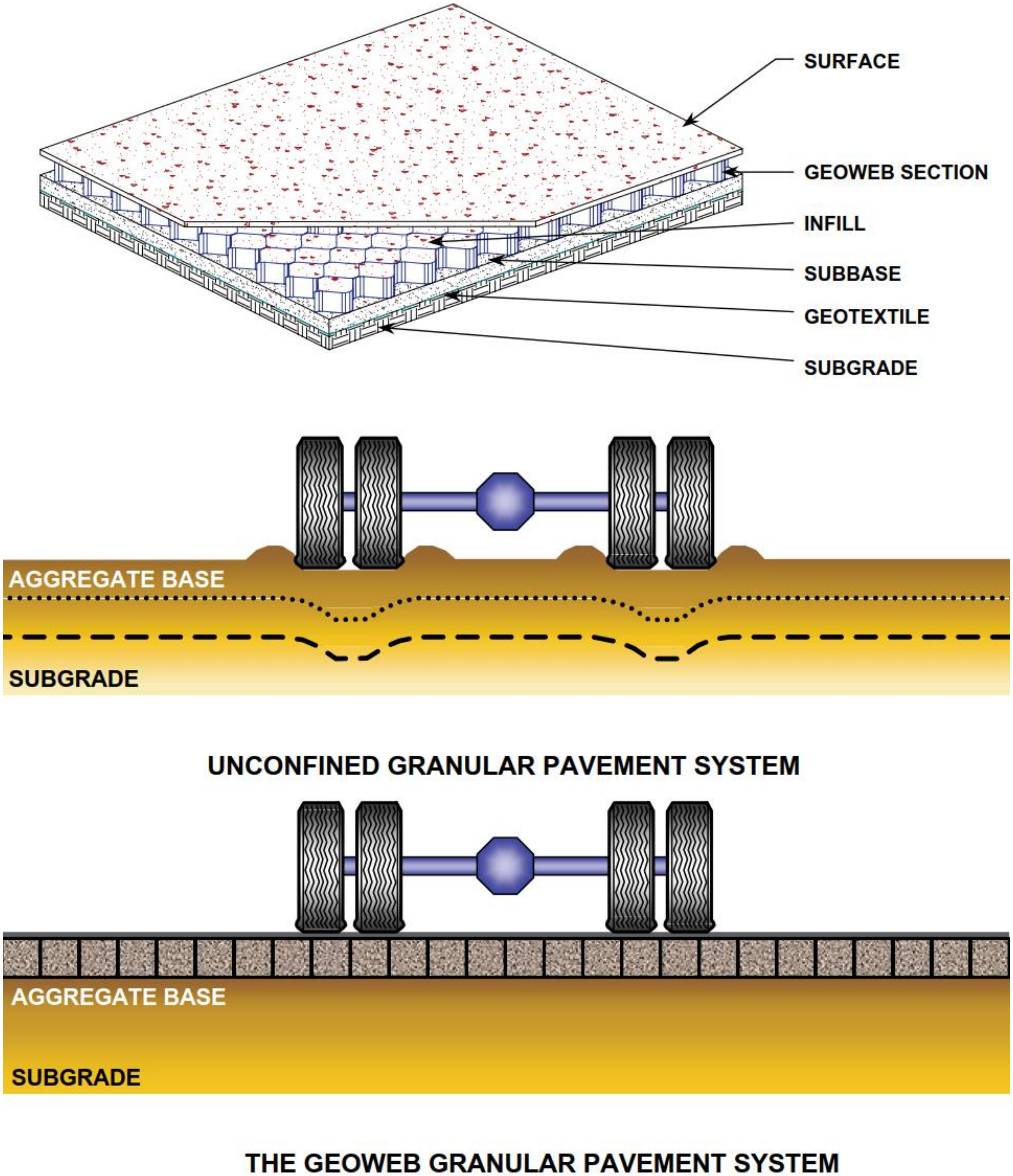

Figure F-3: Geoweb® Installation and Infilling with Aggregate

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