Milburn Lake Hydrotechnical Assessment

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Submitted to: Ministry of Transportation and Infrastructure
Prepared by McElhanney

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1. Background

Flooding has occurred along Milburn Lake during the spring freshet of past recent years, damaging adjacent properties. The BC Ministry of Transportation and Infrastructure (MoTI) retained McElhanney Ltd. (McElhanney) to provide hydrotechnical services for the preliminary design of drainage improvements to mitigate flooding damage. The work was requested through As and When Contract 831CS1094.

Milburn Lake is located 20 km northwest of Quesnel, BC as shown in Figure 1. Two tributary streams flow into Milburn Lake on the west shore. Bouchie Creek is the main outlet, located at the southern tip of Milburn Lake. An existing 900 mm diameter culvert allows Milburn Lake Road to cross over Bouchie Creek at the outlet of the lake, shown in Figure 2. Downstream of Milburn Lake, an existing 1200 mm diameter culvert allows Rawlings Road to cross over Bouchie Creek, where Bouchie Creek then drains into Bouchie Lake.

Figure 1: Location of Milburn Lake

Figure 2: Inlet of 900 mm Diameter Culvert to Bouchie Creek

2. Site Visit

Amr Fathalla (McElhanney) accompanied by Derek Kitamura (MoTI) completed a site visit on October 23, 2020. The following is a summary of the site observations:

Milburn Lake Road Culvert

- The culvert crossing is at the lake outlet.
- One of the residents provided observations regarding the flooding.
- The road at the culvert crossing is not overtopped during peak flows. However, a low spot on the road further to the north is overtopped. Two residential properties are flooded. One is on the lakeside and the other one is across the road.
- About 30 m of the road was overtopped during the peak flows with approximately 0.3 m depth at the middle of the overtopped section.
- The water level at the culvert during the site visit was approximately 0.2 m above the inlet invert level.
- The low reach of the road is approximately 1.0 m above the invert of the culvert inlet.
- There is no flow in the culvert for extended periods.
- High water levels are associated with the freshet snowmelt.
- When the road was flooded, the water level was approximately 0.3m above the culvert crown.
- Observed peak flow from the lake is passed by both the culvert and the road. The road starts flooding when the water level is approximately at the culvert crown.

- The lakeside property starts flooding when the road is flooded, and the water level is approximately 1.2 m above the culvert inlet.

- Beaver activity is observed immediately upstream of the culvert. The middle section of the beaver dam was cleared.

Rawling Road Culvert

- The culvert is approximately 1.2 m diameter. The road fill on the top of the culvert is approximately 2.5 m.

- There is a second culvert (smaller) north of the main culvert crossing.

- Properties close to the crossing are likely high enough not to be flooded. Only the road may be overtopped.

- The culvert receives flows from Milburn Lake Road culvert, the low spot on Milburn Lake Road and the local catchment. Water may be above the crown during peak flows indicating inadequate capacity.

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s.13 A diagram of water levels during the 2020 spring freshet based on observations made during fall 2020 site visit is shown in Figure 3.

During freshet, the water level of the Milburn Lake increased, causing flooding at an existing public boat launch on the east shore (Figure 4). The water flooded the boat launch area and overtopped a low point in Milburn Lake Road. The water then flowed along Milburn Lake Road and floods the adjacent lakeside properties, south of the boat launch. During the 2020 freshet, the water level was observed to be approximately 0.3 m above the outlet culvert at Bouchie Creek. Beavers have been noted to be active near the outlet culvert.

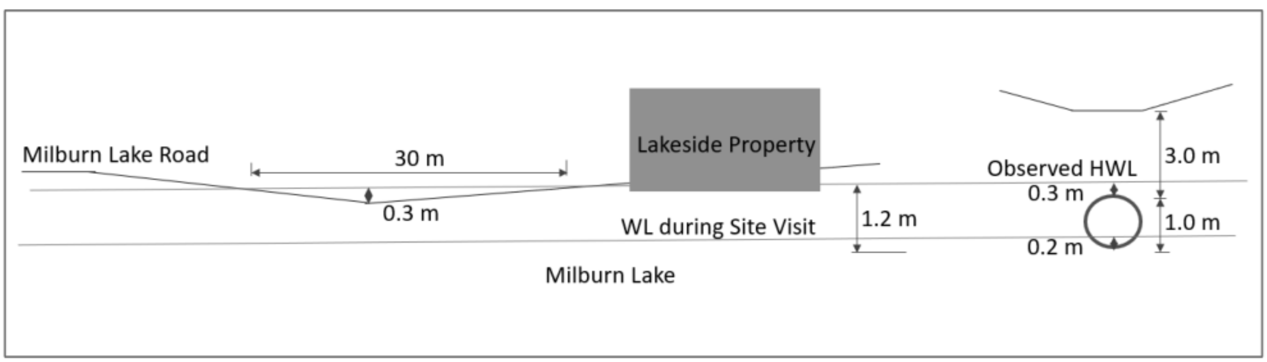

Figure 3: Diagram of flood water along the profile of Milburn Lake Road.

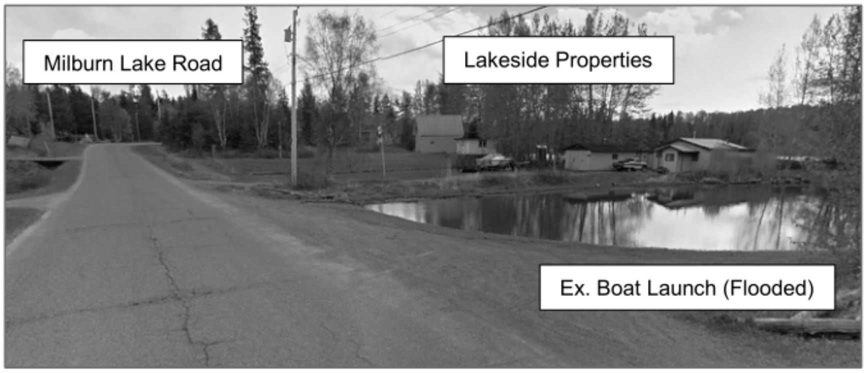

Figure 4: Low spot at Milburn Lake Road where flooding was observed.

3. Scope of Work

The scope of work required for this hydrotechnical assessment consist of the following:

- Complete a hydrologic analysis s.13
- Develop design flows incorporating climate change considerations;
- Conduct a hydraulic analysis of crossings s.13
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- Assess culvert and road configuration s.13
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4. Design Codes and References

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5. Hydrology

5.1. SITE LOCATION AND HYDROLOGIC REGIME

Milburn Lake is located 20 km northwest of Quesnel, BC. The drainage area and general topography is shown in Figure 5. Milburn Lake flows into Bouchie Creek, where it then drains into Bouchie Lake. The drainage area of Milburn Lake is over low foothills. Bouchie Creek is a shallow channel through a forested area. Woody debris was noted across Bouchie Creeks channel.

Milburn Lake watershed has the following baseline physical characteristics:

- Watershed area to Milburn Lake: 24.05 km^2
- Median watershed elevation: El. 1011 m
- Elevation at lake outlet: El. 818 m
- Lake morphology: Curved shoreline, constant low forested area
- Shoreline area: 3.0 km^2
- Lake fetch: 1.5 km
- Lake width: 500 m
- Bed material D_{50}: 10 mm (estimated)

Bouchie Creek watershed has the following baseline physical characteristics:

- Watershed area to the crossing: 1.4 km^2
- Median watershed elevation: El. 796 m
- Elevation at crossing: El. 752 m
- Channel morphology: Single, meandering channel within forested area
- Channel slope: 4.2 %
- Existing channel bottom width: 2 m
- Bed material D_{50}: 20 mm (estimated)

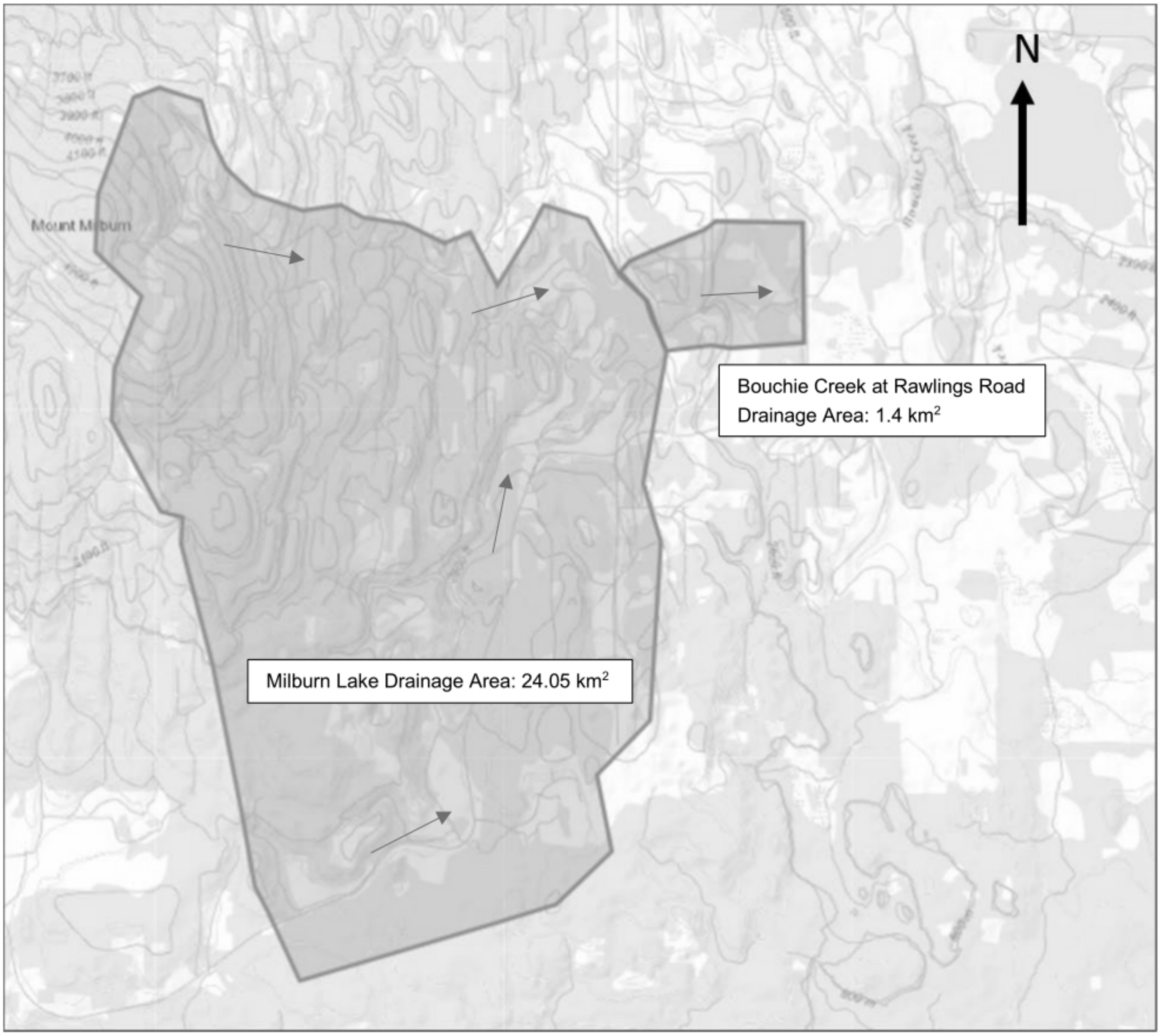

Figure 5: Milburn Lake and Bouchie Creek drainage areas and general topography

5.2. REGIONAL ANALYSIS

A regional analysis is required to estimate the instantaneous peak flows because neither Milburn Lake nor Bouchie Creek has a WSC gauge. Regional analysis relies on flow data form the Water Survey of Canada (WSC) stream gauging stations near or in the study area and applies the information to the watercourse of interest. The process for conducting a regional hydrologic analysis is as follows:

- Identify WSC stations near or in the study area, with similar physiographic characteristics and with sufficient periods of record;
- Delineate the WSC stations' catchments and determine physiographic properties (GIS analysis);
- For annual instantaneous peak flow and annual maximum average daily flow data, perform flood frequency analysis to predict flows for various return periods;

- Plot flow versus watershed area and perform a regression analysis to derive a regional curve for each return period;
- Delineate upstream watershed area (catchment) for the proposed crossing and determine physiographic properties; and
- Apply the regression curve equation to each site's catchment to predict flows for specified return periods.

Nearby stations identified for potential use in regional analysis are listed in Table 1.

Table 1: Water Survey of Canada stations considered in regional hydrologic analysis

Station Number	Name	Watershed Area (km^2)	Period of Record	Years of Record	Used in Analysis
08KE009	COTTONWOOD RIVER NEAR CINEMA	1910	1956-1998	43	Yes
08KE024	LITTLE SWIFT RIVER AT THE MOUTH	41	1972-2013	18	Yes
08KE032	TABOR CREEK ABOVE SWEDE CREEK	60	1981-1998	17	Yes
08MC045	SHERIDAN CREEK ABOVE MCLEESE LAKE	93.6	1987-2014	16	Yes
08KH019	MOFFAT CREEK NEAR HORSEFLY	554	1964-2018	51	Yes

Active stations and most inactive stations generally provide both annual peak instantaneous and annual peak average daily flows. For some years, the instantaneous values are not reported. To provide a larger dataset, for years where the instantaneous values are missing, the instantaneous flow was interpolated based on the average ratio of peak instantaneous to peak daily flow for the station.

The flows were then entered in the frequency analysis software Hyfran+ which estimates flow for 10 different distribution types. The estimates for each distribution were then entered into the Data and Frequency Analysis Spreadsheet developed by the City of Calgary, which ranks the distribution based on how well the data fits each distribution. The distribution that which was selected for modeling the region is Generalize Extreme Value Distribution. The estimated instantaneous peak flows for the 100-year and the 200-year return periods are summarized in Table 2.

Table 2: Flood frequency analysis for WSC stations.

Station Number	Name	Watershed Area (km^2)	100-year Peak Instantaneous Flow (m^3/s)	200-year Peak Instantaneous Flow (m^3/s)
08KE009	COTTONWOOD RIVER NEAR CINEMA	1910	455.6	567.5
08KE024	LITTLE SWIFT RIVER AT THE MOUTH	41	67.0	74.7
08KE032	TABOR CREEK ABOVE SWEDE CREEK	60	26.5	32.3
08MC045	SHERIDAN CREEK ABOVE MCLEESE LAKE	93.6	13.7	14.8
08KH019	MOFFAT CREEK NEAR HORSEFLY	554	61.8	67.3

5.2.1. Instantaneous Peak Flow

The estimated instantaneous peak flows were plotted against the watershed area, and a power regression analysis was performed. Graphical representation of the relationship between the 100-year instantaneous peak flow and watershed area is presented in Figure 6, and the 200-year instantaneous peak flow in Figure 7.

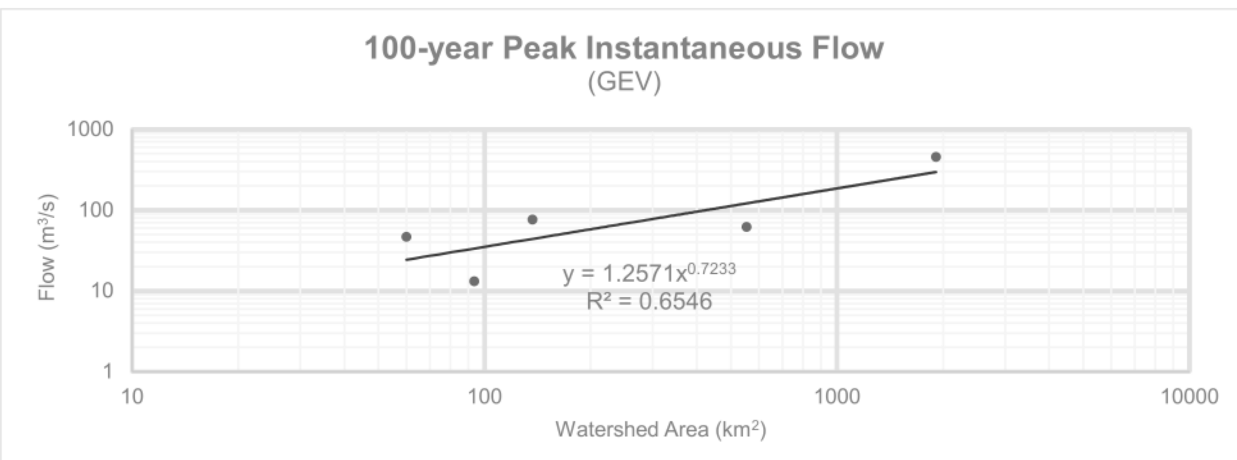

Figure 6: Regional Analysis 100-year peak instantaneous flow

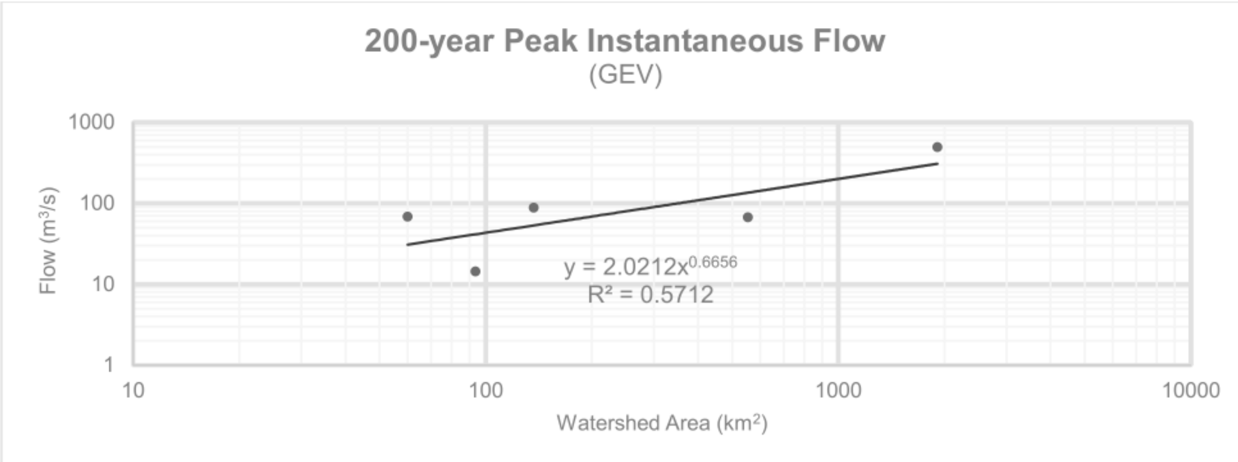

Figure 7: Regional Analysis 200-year peak instantaneous flow

5.2.2. Discussion of Results

All five watersheds show moderate correlation. The analysis from these flows is therefore considered to be representative of the flows in into for Milburn Lake and Bouchie Creek. The design flows at both crossings determined using regional analysis are summarized in Table 3.

Table 3: Regional analysis design flows at the project location

Return Period	Milburn Lake Design Flow (m^3/s)	Bouche Rawlings Road Culvert Design Flow (m^3/s)
200	16.8	17.4
100	12.5	13.1
10	4.6	4.8
2	1.9	2.0

Regional analysis flows were compared with an interpolation of BC Streamflow Inventory for the Cariboo Region. The selected stations within Hydrologic Zone 14 are included in Table 4.

Table 4: Stations from the Inventory of Streamflow

Hydrologic Zone	Stream	Hydrometric Station	Drainage Area (km^2)
14	Bowron-Box Canyon	08KD007	3371.42
14	Bowron-Wells	08KD001	452.41
14	Cariboo-Kangaroo	08KH003	3263.78
14	Cottonwood-Cinema	08KE009	1895.77
14	Horsefly-Quesnel Lake	08KH031	2758.27
14	Little Swift	08KE024	129.70
14	Penfold	08KH030	184.77
14	Quesnel-Likely	08KH001	5964.97
14	Quesnel	08KH006	11571.02
14	Willow	08KD006	2864.06

Interpolated peak flows for a watershed with a drainage area of 24.05 km^2 based on hydrometric stations in Zones 14 are summarized in Table 5.

Table 5: Interpolated Peak flows based on Peak Flows of Hydrometric Stations in Zones 14.

Return Period	Milburn Lake Road Culvert Design Flow (m^3/s)	Rawlings Road Culvert Design Flow (m^3/s)
200	14.7	15.1
100	13.1	13.5
10	9.1	9.4
2	7.0	7.2

The interpolated peak flow values from the streamflow inventory are generally reflective of the peak flows obtained in the regional analysis.

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5.3. CLIMATE CHANGE ANALYSIS

Adjustments were made to the design flows to take into consideration the effects of climate change. The results of the climate change analysis performed by McElhanney in the *2019 Hydrotechnical Report for Blackwater Riverbank Stabilization Works* were applied to the Bouchie Creek channel flows. Blackwater is very close to both Milburn Lake Road and Rawlings Road. The report recommends a 10% increase for the Blackwater River watershed. Smaller watersheds are more sensitive to increased flows than larger watersheds. The flows in the Bouchie Creek channel were adjusted by 20% to accommodate climate change. Adjusted flows are shown in Table 6.

Table 6: Bouchie Creek climate change adjusted design flows

Return Period	Milburn Lake Road Culvert Design Flow (m^3/s)	Rawlings Road Culvert Design Flow (m^3/s)
200	20.1	20.9
100	15.0	15.7
10	5.5	5.8
2	2.6	2.4

6. Hydraulic Modeling

A 2-D computational hydraulic model was developed for the Milburn Lake Road and Rawlings Road study areas. We employed the Hydrologic Engineering Center – River Analysis System (HEC_RAS) v5.0.7 computational modeling software for this assignment. Developed and maintained by the US Army Corps of Engineers, the software is recognized as an industry standard and is freely available to the public.

Primary inputs for the 2-D hydraulic model include a digital elevation model (DEM) of the study areas and their surrounding ground, flow information – in the form of input hydrographs – for the upstream extent of the model (upstream boundary condition), the downstream extent of Milburn Lake and the downstream boundary condition for the various scenarios examined, and the hydraulic roughness (Manning's "n") for areas in the model domain.

Using the primary inputs, the model performs a series of calculations over the model domain to predict the water surface elevation (and water depth), water velocities, and direction of flow (current vector) for areas within the model domain. The proposed options were simulated within the hydraulic model by adjusting the DEM and fitting in various culvert sizes at the two areas of interest in the model.

6.1. CALCULATION MESH AND ROUGHNESS

The model domain represents the area, including channels and flood plain, over which the model will perform the hydraulic calculations. The model domain is limited to areas where flow and potential flooding can occur to reduce the computational intensity and time required to run the model. Figure 8 shows the model domain and highlights the upstream and downstream boundary locations, as well as the culverts present in the study area. The total area captured in the model domain is 2.2 km^2.

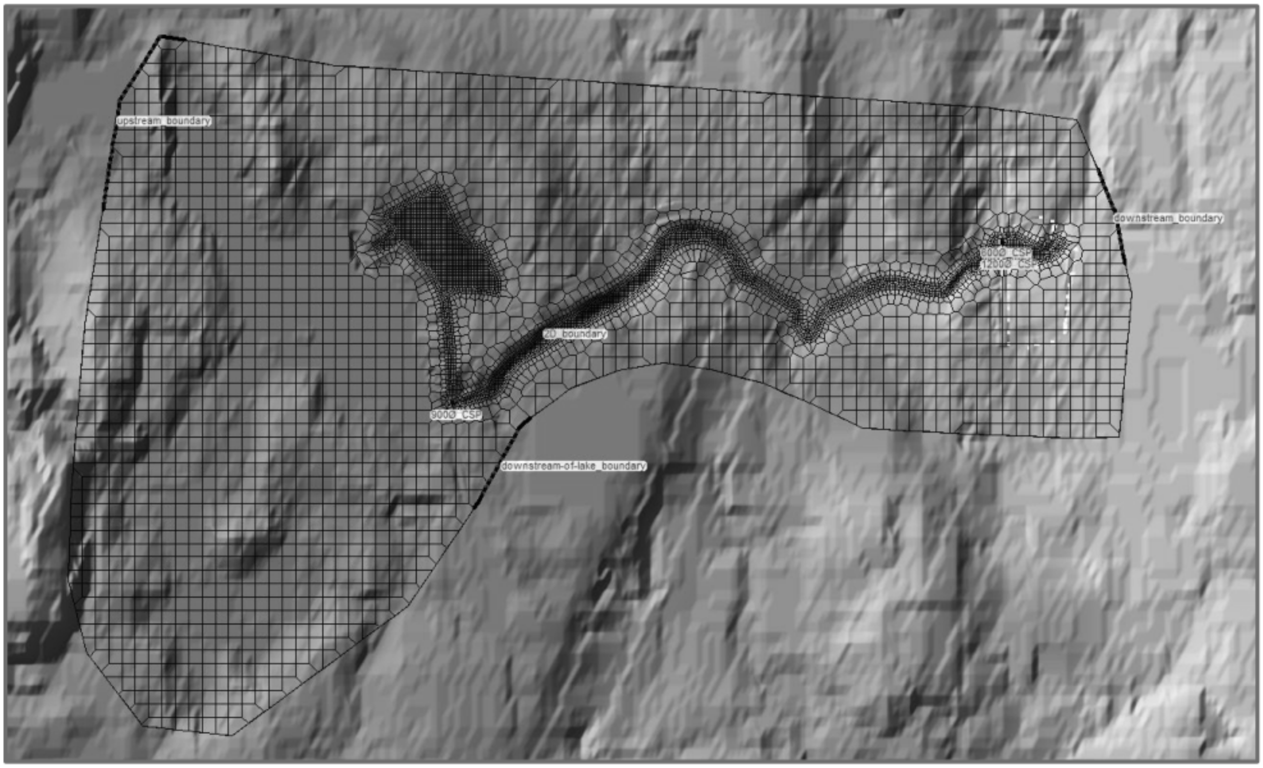

Figure 8: HEC-RAS 2-D Hydraulic Model Domain

6.1.1. Calculation Meshes and Regions

A 2-D hydraulic model uses a calculation mesh. The mesh, which is comprised of cells in a regular grid and irregular shaped cells, is used to calculate water surface elevation, water velocity, and flow direction within the model. Hydraulic calculations are completed for each cell. HEC-RAS allows further refinement of the calculation mesh by having different sized meshes within the model domain. These are referred to as regions. For the Milburn Lake model, we assigned an overall mesh size of 15 m x 15 m (the "domain mesh"). For the main channel (bank to bank) and the residential area located north of Milburn Lake Road and Tracy Road, the mesh size was reduced to 7 m x 7 m. Break lines were added for features such as local heights of land to ensure a division of computational cells at that location. Figure 9 shows an example of the calculation mesh, the channel refinement region, and the enforced break line superimposed on the DEM and aerial imagery.

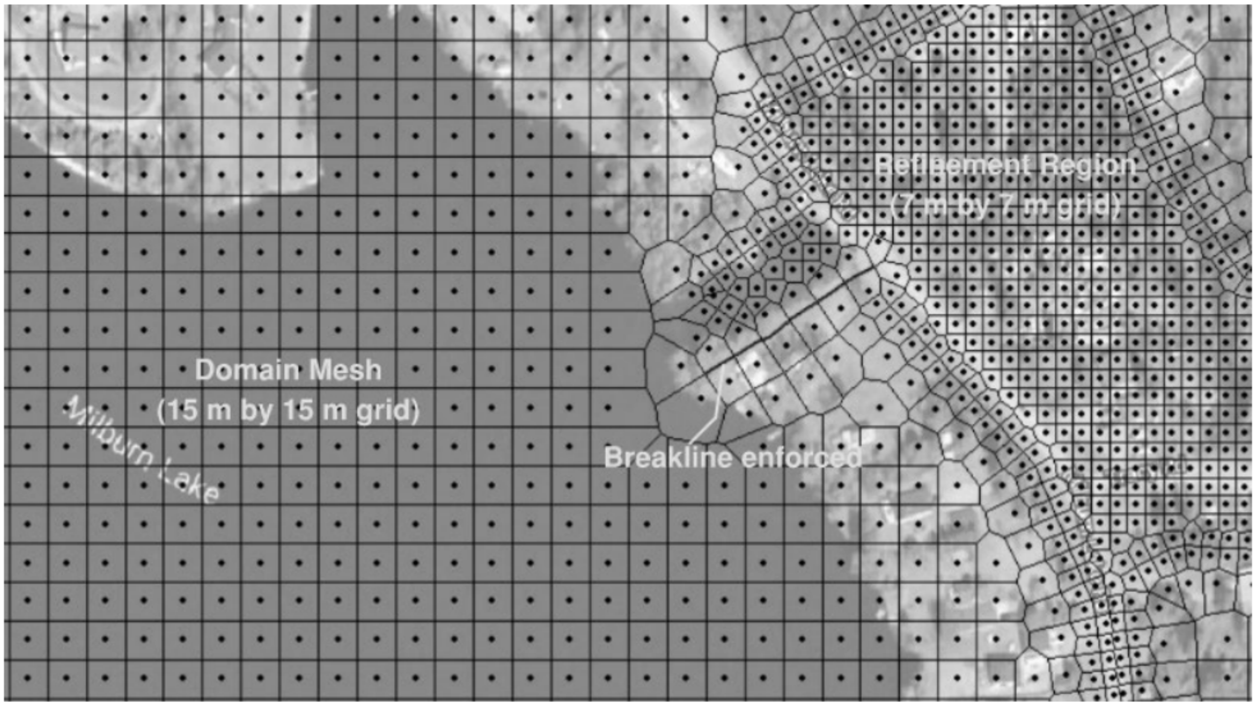

Figure 9: Example of the Calculation Mesh and Refinement Region.

6.1.2. Hydraulic Roughness

The hydraulic roughness, expressed as a Manning's "n" value, is used to characterize the physical resistance that a surface exerts on flowing water. The 2D model allows for multiple hydraulic roughness values to be assigned over the model domain. We delineated areas that exhibit different hydraulic roughness based on land cover identified from aerial imagery. Table 7 relates the land cover to a Manning's "n" value. The Manning's "n" value is based on published values for similar land cover.

Table 7: Manning's "n" values based on Landcover

Landcover	**Manning's "n"**
Channel	0.05
Lake Area	0.0001
Pond	0.0001
Dense Vegetation	0.09
Residential Areas – Sparse Density	0.07
Residential Areas – Low Density	0.1
Residential Areas – Medium Density	0.2

6.2. MODEL SCENARIOS

Two model scenarios were assessed. The first was to assess the conditions of the existing culverts. The second was to examine the associated conditions of the proposed culverts along with channel modifications and raising the elevation of Milburn Lake Road on the eastern side of the lake so water no longer floods the properties located at the north of the culvert crossing. The results of the modelled scenarios are presented in the subsections below.

6.2.1. Existing Conditions

The existing 900 mm culvert at Milburn Lake Road and the two culverts at Rawlings Road: a 600 mm and a 1200 mm were modelled to analyze and identify baseline site conditions. Figure 10 shows the results of the 2D hydraulic model of the entire study area. Water depths around the areas located north of the culvert crossing and through the culverts are highlighted in Figures 11 to Figure 13.

Figure 10: Depth profile for the existing conditions at Milburn Lake during the 100-year peak instantaneous flow overlain on Bing Imagery.

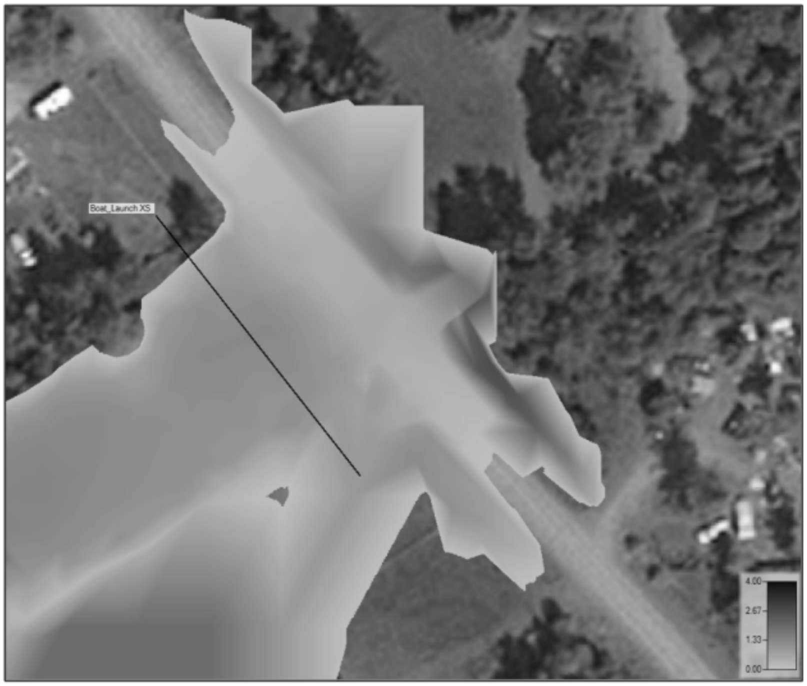

Figure 11: Depth profile of the area located at the north of the culvert crossing during the 100-year peak instantaneous flow overlain on Bing Imagery.

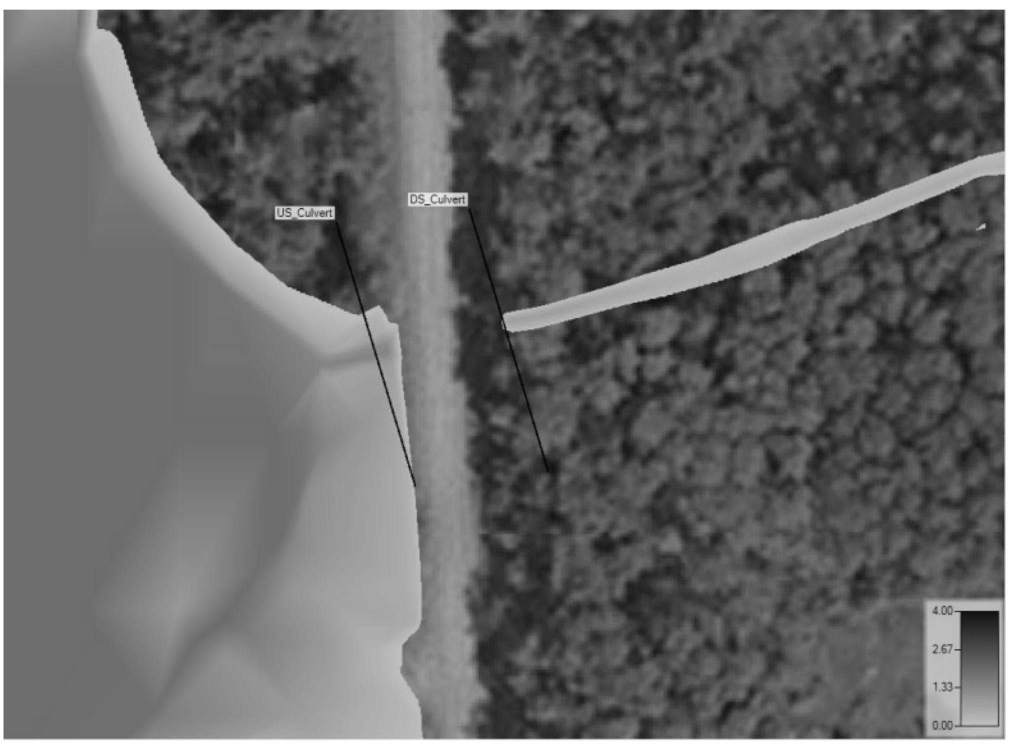

Figure 12: Depth profile of the existing 900 mm culvert at the Milburn Lake Road crossing during the 100-year peak instantaneous flow overlain on Bing Imagery.

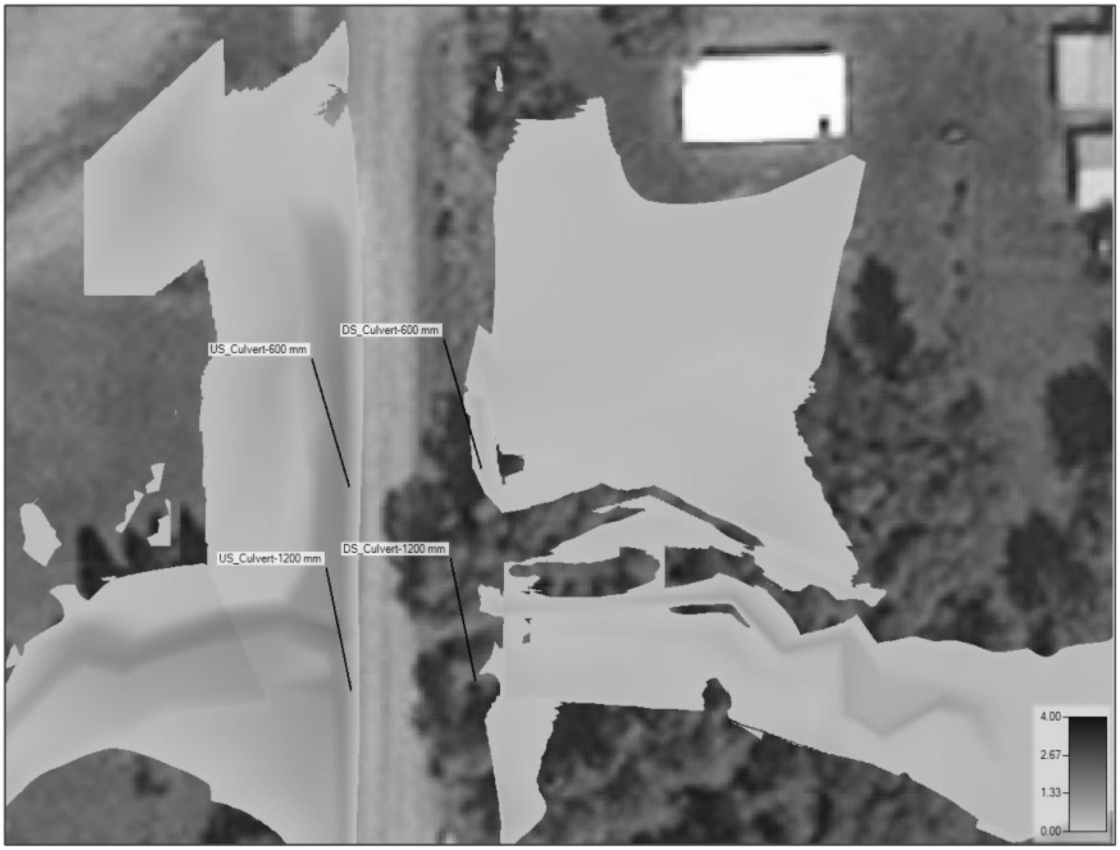

Figure 13: Depth profile of the existing 600 mm and 1200 mm culverts at Rawlings Road during the 100-year peak instantaneous flow overlain on Bing Imagery.

Table 8 summarizes the results of the hydraulic modelling based on the 100-year peak instantaneous flow. The values presented were extracted from sections cut in the model through the boat launch area, upstream, and downstream locations of the culverts as shown in Figures 11 to Figure 13.

Table 8: Hydraulic performance of the existing culverts during the 100-year instantaneous peak flow.

Parameter	Crossing located north of the culvert (Boat Launch)	Milburn Lake Road 900 mm Culvert		Rawlings Road 600 mm Culvert		Rawlings Road 1200 mm Culvert	
		Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Design Flow (Q_{100})	12.5 m^3/s	12.5 m^3/s	12.5 m^3/s	13.1 m^3/s	13.1 m^3/s	13.1 m^3/s	13.1 m^3/s
Water Surface Elevation	813.3 m	813.3 m	812.6 m	746.5 m	745.6 m	746.5 m	745.6 m
Maximum Channel Velocity	0.1 m/s	0.2 m/s	0.6 m/s	0.2 m/s	0.6 m/s	0.2 m/s	1.2 m/s

The Q_{100} water level is 813.3 m at the crossing located north of the culvert. The lowest elevation of the road at the crossing located north of the culvert is 812.8 m. Therefore, water from the lake spills onto the road.

The Q_{100} water level is 813.2 m at the upstream face of the 900 mm culvert at Milburn Lake Road. This culvert has a crown elevation of 812.9 m. The water is above the crown of the culvert. However, the road above the culvert is high and would not be overtopped.

The Q_{100} water level is 746.5 m at the upstream face of both culverts located at Rawlings Road. The 600 mm culvert has a crown elevation of 745.9 m while the crown elevation of the 1200 mm culvert is 747.4 m. Both culverts are under capacity and cannot pass the Q_{100} without surcharge and compromising the freeboard.

6.2.2. Proposed Flood Mitigation

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10. Recommendations

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11. Closing

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Yours truly,

McElhanney Ltd.

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APPENDIX A

Statement of Limitations

Statement of Limitations

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