Appendix D.1

Moose River Consolidated Phase II Preliminary Engineering Hydrometeorology Report, Knight Piésold Ltd

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MOOSE RIVER CONSOLIDATED PHASE II

PRELIMINARY ENGINEERING HYDROMETEOROLOGY REPORT

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Knight Piésold
CONSULTING

EXECUTIVE SUMMARY

Atlantic Gold Corporation is in the early stages of developing the Moose River Consolidated Phase II Expansion located approximately 100 km north-east of Halifax, in central Nova Scotia. The Expansion comprises two mine sites: Fifteen Mile Stream Project and Cochrane Hill Project. Knight Piésold Ltd. completed a preliminary engineering hydrometeorology analysis for the Project area. There have been no site-specific hydrological or meteorological data collected at the Project sites, and as such, the meteorological and hydrological parameters have been estimated based on available regional data.

Climate

There are several climate stations in the region operated by Environment Canada. The Halifax Stanfield International Airport climate station was selected as an active station representative of the climatic conditions at the Fifteen Mile Stream and Cochrane Hill projects. The results of the climate analysis at Halifax Airport that are applicable to the Project area are as follows:

- The mean annual temperature is estimated to be 6.5°C, with minimum and maximum mean monthly temperatures of -5.8°C and 18.7°C occurring in January and July, respectively.
- The mean annual precipitation (MAP) is estimated to be 1,440 mm and fairly evenly distributed throughout the year, with mean monthly values ranging from a low of 93 mm in July to a high of 164 mm in December. The majority of precipitation falls as rainfall, with 83% of precipitation as rain and 17% of precipitation as snow.
- The 24 hour extreme precipitation 100 year, 200 year, and PMP values for the Project area are estimated to be 168 mm, 184 mm, and 531 mm, respectively.
- The 1 in 200 year wet annual precipitation value is estimated to be 1,962 mm, and the 1 in 200 year dry annual precipitation is estimated to be 918 mm.
- The estimated mean annual wind speed is approximately 4.6 m/s, with the wind direction being predominantly from the northwest in the winter and from the south in the summer.
- No solar radiation data are available in the region.
- The mean annual relative humidity is estimated to be 76.8%, with a minimum of 74.2% in March and a maximum of 80.6% in December.
- Atmospheric pressure is fairly consistent year round with a mean annual of 99.7 kPa, a low of 99.5 kPa in late winter, and a high of 99.9 in autumn.
- The mean annual lake evaporation, or potential evapotranspiration is estimated to be 564 mm, while the actual evaporation is estimated to be in the range of 340 mm to 450 mm.

Hydrology

There are several hydrometric stations operated by Water Survey of Canada (WSC) in the region. The St. Mary's River at Stillwater station (01EO001) was selected as the station representative of the hydrologic conditions at the Fifteen Mile Stream and Cochrane Hill projects. Hydrology estimates applicable to the Project area are as follows:

- The long-term mean annual unit discharge (MAUD) for the Project area was estimated to be 31.8 L/s/km^2, which equates to an annual runoff depth of approximately 1,000 mm.

- The effective annual runoff coefficient for natural drainage areas is estimated to be 0.70 based on the ratio of mean annual runoff to mean annual precipitation.
- The annual hydrograph is bimodal with the lowest flows occurring in the late summer and winter, and the peak flows occurring during the spring freshet and during the fall storm season.
- The 10 year wet and dry annual unit discharges are estimated to be 54.8 L/s/km^2 and 13.5 L/s/km^2, respectively.
- The 10 year 7-day low unit discharge is estimated to be 0.5 L/s/km^2.
- Peak freshet flows in the spring are due to snowmelt, or combined rainfall and snowmelt events, and peak flows in the fall are due to cyclonic storm events affecting the eastern seaboard. The 100 and 200 year return period instantaneous peak unit discharge are estimated to be 824 L/s/km^2 and 924 L/s/km^2, respectively.

Climate Change

- Based on the available regional climate data, it is not possible to make strong conclusions about future climatic conditions. There appears to be a general trend towards slightly warmer temperatures, while precipitation trends are less apparent, as they are increasing at some stations, but decreasing at others.
- Based on the available regional hydrologic data, it is not possible to make strong conclusions about future streamflow conditions. There is no strong indication on whether mean annual discharge and annual peak flows are increasing or decreasing.
- The available climate change models predict increased storm intensity in the Project area, which suggests annual peak flows may also increase.
- It is recommended that peak design flows are increased by 15% for structures with a design life longer than 30 years.

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ABBREVIATIONS

Atlantic Gold	Atlantic Gold Corporation
Halifax Airport	Halifax Stanfield International Airport
MRC Phase II Expansion	Moose River Consolidated Phase II Expansion Project
AET	Actual Evapotranspiration
EC	Environment Canada
IDF	Intensity-Duration-Frequency
IDF_CC Tool	Intensity-Duration-Frequency Climate Change Tool
km	kilometres
KP	Knight Piésold Ltd.
kPa	kilopascals
L/s/km2	litres per second per square kilometre
MAD	Mean Annual Discharge
MAP	Mean Annual Precipitation
MAT	Mean Annual Temperature
MAUD	Mean Annual Unit Discharge
MAUR	Mean Annual Unit Runoff
masl	metres above sea level
m/s	metres per second
m^3/s	cubic metres per second
MOECC	Ministry of the Environment and Climate Change
MRC	Moose River Consolidated
PET	Potential Evapotranspiration
PMP	Probable Maximum Precipitation
RCP 8.5	Representative Concentration Pathways 8.5
SWE	Snow Water Equivalent
WSC	Water Survey of Canada

1.0 INTRODUCTION

1.1 PROJECT DESCRIPTION

Atlantic Gold Corp. (Atlantic Gold) is in the early stages of developing the Moose River Consolidated Phase II Expansion Projects (MRC Phase II Expansion); a turbidite-hosted mesothermal gold deposit located approximately 100 km northeast of Halifax, in central Nova Scotia (Staples et al., 2018). MRC Phase II Expansion consists of two project sites, Fifteen Mile Stream and Cochrane Hill. The Project locations are shown on Figure 2.1. The Moose River Consolidated Phase I Projects (MRC Phase I) consisting of the Touquoy Mine and planned Beaver Dam Mine, are located in the same general area and are also shown on Figure 2.1 for reference.

Fifteen Mile Stream is situated 100 km northeast of Halifax in Halifax County, while Cochrane Hill is located 13 km north of Sherbrooke in Guysborough County, 43 km east of the Fifteen Mile Stream Project. Both properties can be accessed via paved or gravel roads. The closest international airport is the Halifax Stanfield International Airport (Halifax Airport) located approximately 25 km north of Halifax, while the closest major port is the Port of Halifax.

The climatic conditions for the Project area are representative of the Northern temperate zone, and mining operations are expected to be conducted year-round.

1.2 SCOPE OF REPORT

This report provides meteorological and hydrological characterizations for the Project area, in terms of expected long-term climatic and hydrologic conditions that are based on analyses of regional data from Environment Canada (EC) and Water Survey of Canada (WSC).

1.2.1 CLIMATOLOGY

No site specific climate data are available for the Project. As a result, a regional climate study was conducted using data available from EC. Temperature and precipitation data were compared between stations, in order to determine estimates most appropriate for the Project area.

Additional climate parameters such as wind speed, relative humidity, and atmospheric pressure are only available for the Halifax Airport station, and as such, no analysis has been done to compare these parameters between stations. The climate parameters are discussed in Section 2.

1.2.2 HYDROLOGY

No site specific hydrology data are available for the Project. As a result, a regional hydrology study was conducted using data available from WSC, a Ministry of the Environment and Climate Change (MOECC) agency responsible for all national hydrometric monitoring work in Canada. Data from the stations were compared to determine the most appropriate estimates for the Project area. The hydrology is discussed in Section 3.

1.2.3 CLIMATE CHANGE

Potential climate change trends and the predicted climate change effects for the Project area are discussed in Section 4. The regional climate trends in terms of air temperature and precipitation were assessed using long-term historical records from EC climate stations, while the regional streamflow trends were assessed using the long-term historical data from WSC stations. Predicted possible future climate conditions based on global climate models were also considered and discussed.

2.0 CLIMATE

2.1 REGIONAL STATIONS

Considering no site specific climate data are available for the Project, a regional climate study was conducted using data available from EC. The available regional climate stations are shown on Figure 2.1, and the station details are provided in Table 2.1.

Temperature and precipitation data were compared between several regional stations, in order to determine estimates most appropriate for the Project area. Each of the following stations has a period of record of at least 30 years, and a maximum distance from the Project of 50 km:

- Collegeville
- Upper Stewiacke
- Middle Musquodoboit
- Halifax Airport
- Stillwater, and
- Malay Falls.

The climate stations at Halifax Airport, Stillwater and Malay Falls have been reinstalled within the period of record; however, the locations for the new stations either did not change (Halifax Airport and Malay Falls), or changed by a small distance (Stillwater). For the purposes of this study, the old and new installations are considered to be the same station, and the data from these stations were combined in the analysis.

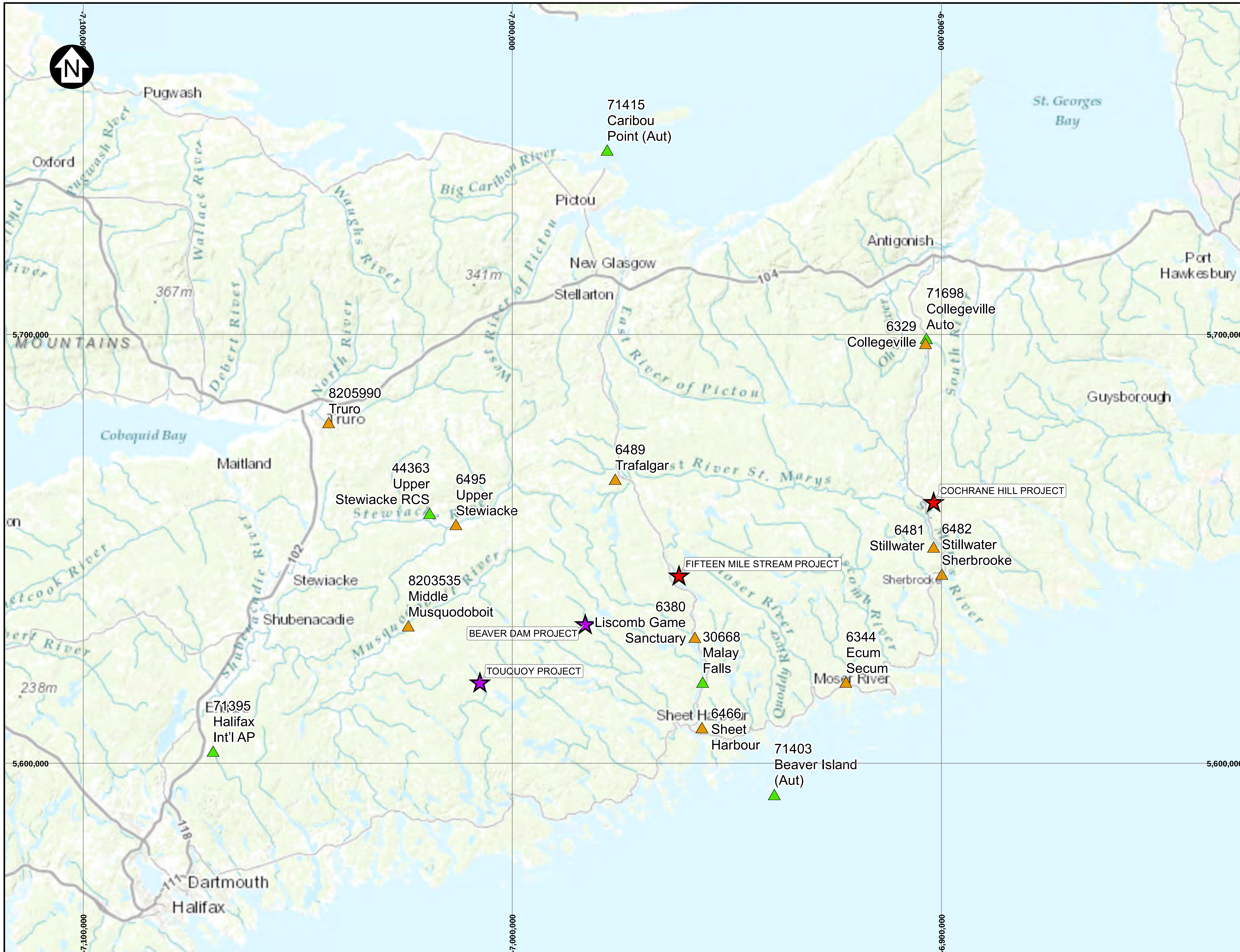
Additional climate parameters such as wind speed, relative humidity, and atmospheric pressure are only available for the Halifax Airport station, and as such, no analysis has been done to compare these parameters between stations.

Table 2.1 Summary of Available Regional Climate Stations

Station Name	ID	Active or Inactive	Years of Record	Start Year	End Year	Latitude	Longitude	Elevation (m)
Beaver Island (Aut)	71403	Active	25	1994	2018	44.82	-62.33	16.0
Collegeville Auto	71698	Active	4	2015	2018	45.49	-62.01	69.0
Collegeville	6329	Inactive	101	1916	2016	45.48	-62.02	76.2
Caribou Point (Aut)	71415	Active	25	1994	2018	45.77	-62.68	2.4
Malay Falls[1]	6399	Inactive	51	1950	2000	44.98	-62.48	39.6
Malay Falls[1]	30668	Active	20	1999	2018	44.98	-62.48	39.6
Liscomb Game Sanctuary	6380	Inactive	9	1962	1970	45.05	-62.50	61.0
Stillwater[2]	6481	Inactive	65	1915	1979	45.18	-62.00	17.1
Stillwater Sherbrooke[2]	6482	Inactive	38	1967	2004	45.14	-61.98	14.0
Trafalgar	6489	Inactive	63	1919	1981	45.28	-62.67	152.4
Upper Stewiacke	6495	Inactive	91	1915	2005	45.22	-63.00	22.9
Upper Stewiacke RCS	44363	Active	14	2005	2018	45.23	-63.06	23.5
Sheet Harbour	6466	Inactive	13	1950	1962	44.92	-62.48	9.1
Ecum Secum	6344	Inactive	47	1940	1986	44.98	-62.18	15.3
Middle Musquodoboit	8203535	Inactive	56	1961	2016	45.07	-63.10	47.8
Truro	8205990	Inactive	27	1960	1986	45.37	-63.27	39.9
Halifax Stanfield Int'l AP[3]	6358	Inactive	60	1953	2012	44.88	-63.50	145.4
Halifax Int'l AP[3]	71395	Active	7	2012	2018	44.88	-63.51	145.4

NOTES:

1. THE ACTIVE MALAY FALLS STATION IS AT THE SAME LOCATION AND SAME ELEVATION AS THE INACTIVE MALAY FALLS STATION. THESE TWO STATIONS ARE CONSIDERED THE SAME FOR DATA COMPARISON PURPOSES.
2. THE STILLWATER SHERBROOKE STATION IS 4,320 m AWAY FROM THE STILLWATER STATION, AND 3 m BELOW THE STILLWATER STATION ELEVATION. THESE TWO STATIONS ARE CONSIDERED THE SAME FOR DATA COMPARISON PURPOSES.
3. THE ACTIVE HALIFAX INT'L AP STATION IS AT THE SAME LOCATION AND SAME ELEVATION AS THE INACTIVE HALIFAX STANFIELD INT'L AP STATION. THESE TWO STATIONS ARE CONSIDERED THE SAME FOR DATA COMPARISON PURPOSES.



LEGEND:

- PHASE 2 PROJECT LOCATIONS
- PHASE 1 PROJECT LOCATIONS
- ACTIVE REGIONAL CLIMATE STATION
- INACTIVE REGIONAL CLIMATE STATION

NOTES:

1. BASE MAP: ESRI ONLINE WORLD TOPOGRAPHIC MAP.
2. COORDINATE GRID IS IN METRES.
COORDINATE SYSTEM: WGS 1984 WEB MERCATOR AUXILIARY SPHERE.
3. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:900,000 FOR 11x17 (TABLOID) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.
4. THE INACTIVE 6399 MALAY FALLS STATION IS LOCATED AT THE SAME COORDINATES AND ELEVATION AS THE ACTIVE 30668 MALAY FALLS STATION.

10 5 0 10 20 30 40 50 km

ATLANTIC GOLD CORPORATION

MOOSE RIVER CONSOLIDATED PHASE II

REGIONAL CLIMATE STATIONS

Knight Piésold CONSULTING

P/A NO.	REF NO.
VA101-708/04	1

FIGURE 2.1 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
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2.2 TEMPERATURE

The mean monthly temperatures recorded at the selected regional stations are provided in Table 2.2 and Figure 2.2 for the full period of record. The data represent mean monthly temperatures for each station based on the entire period of record. The data are consistent between the stations, with some variability evident in the mean monthly values. The mean annual temperature (MAT) from these stations ranges from 5.5°C at Stillwater to 6.5°C at Halifax Airport.

Table 2.2 Mean Monthly Air Temperatures for Regional Stations for the Full Period of Record

Station Name	Mean Temperature (°C)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Collegeville	-6.4	-6.8	-2.3	3.1	9.0	14.3	18.3	17.9	13.8	8.6	3.3	-2.9	5.8
Upper Stewiacke	-6.6	-6.6	-1.7	3.7	9.5	14.6	18.3	17.8	13.7	8.4	3.2	-3.3	5.9
Middle Musquodoboit	-6.4	-5.6	-1.2	4.3	9.7	14.8	18.4	18.3	13.9	8.3	3.4	-2.6	6.3
Halifax Airport	**-5.8**	**-5.6**	**-1.5**	**3.9**	**9.8**	**14.9**	**18.7**	**18.6**	**14.5**	**8.9**	**3.5**	**-2.4**	**6.5**
Stillwater	-6.4	-6.9	-2.3	3.1	8.5	13.5	17.6	17.6	13.6	8.3	3.1	-3.3	5.5
Malay Falls	-5.5	-5.5	-1.4	3.8	8.9	14.1	18.0	18.1	14.3	8.7	3.7	-2.1	6.3

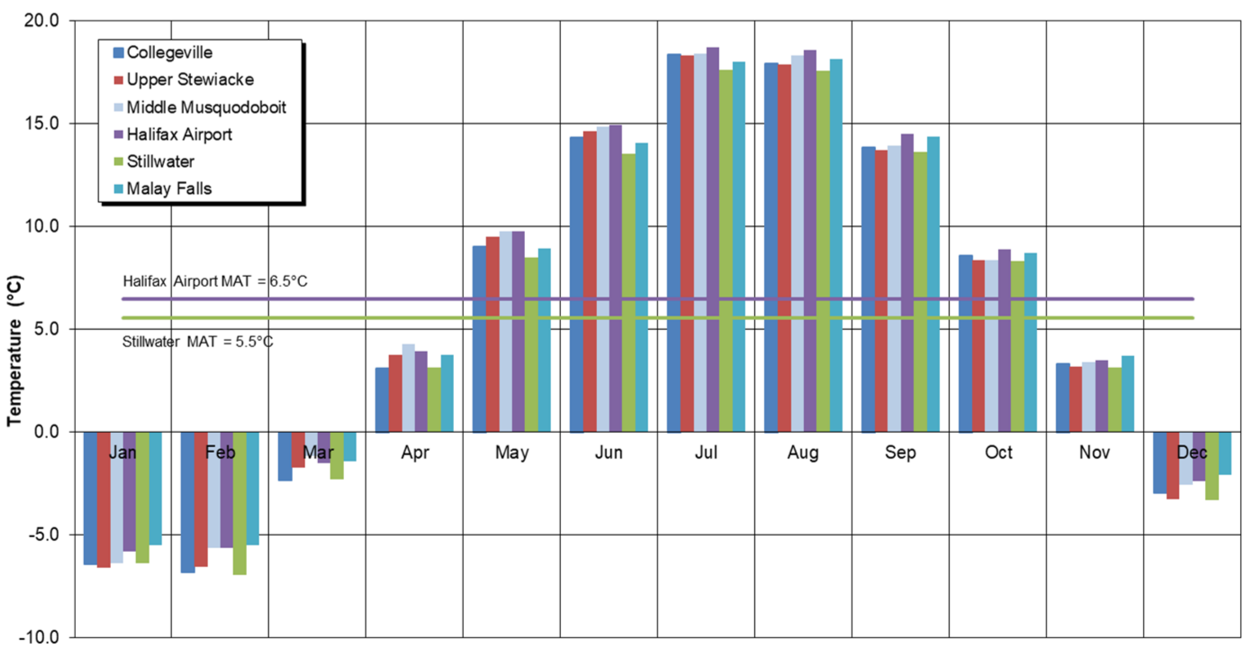


Figure 2.2 Mean Monthly Temperatures for Regional Stations for the Full Period of Record

The difference in elevation between the stations is small, as shown in Table 2.1; therefore, lapse rate effects are assumed to be negligible between stations and are unlikely to be the cause of temperature variations between the stations. However, the difference in the period of record for each station may influence the mean monthly values.

In order to investigate whether the variability between the stations is caused by differences in the periods of record, a comparison of all stations was conducted using the concurrent period of record from 1988 to 2004, as shown on Figure 2.3. The comparison indicates a smaller difference between the MAT for all stations, as well as a tighter distribution of mean monthly temperatures. The MAT is the lowest for the Collegeville station at 5.9°C, and the highest for the Stillwater station at 6.6°C. This analysis indicates that temperatures at various regional stations are similar and that the variability between the data sets evident on Figure 2.2 is mostly due to differences in their periods of record.

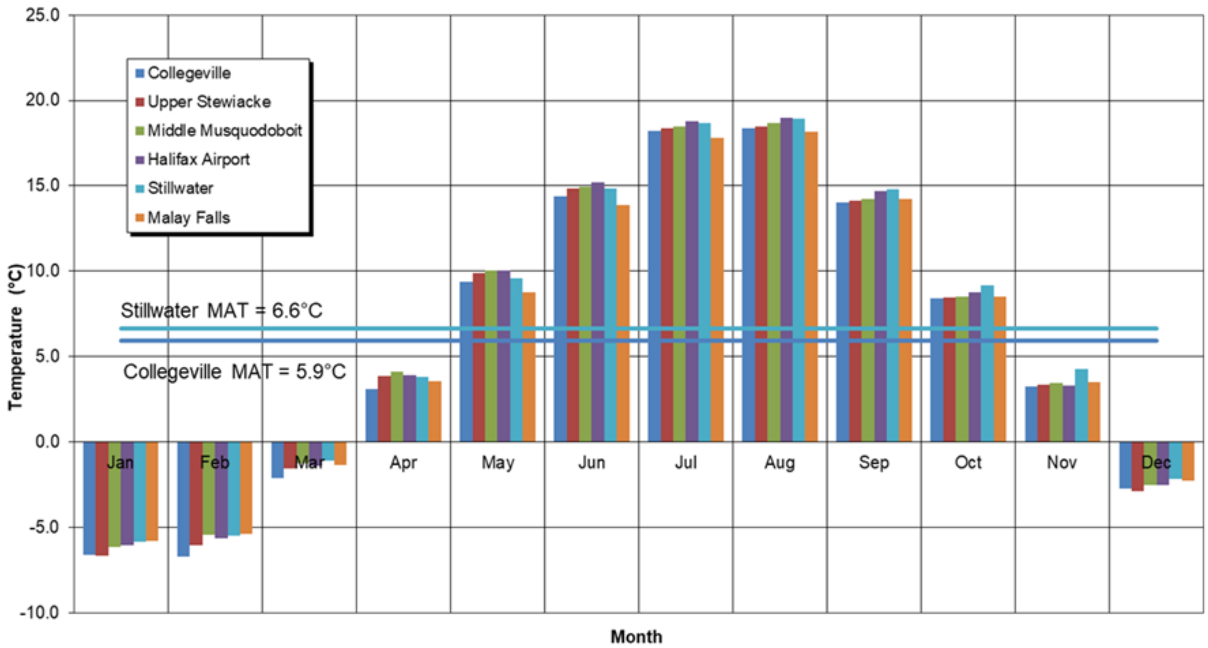


Figure 2.3 Mean Monthly Temperature Comparison for Concurrent Period 1988 to 2004

There is very little difference in the long-term conditions between the sites selected for comparison. Halifax Airport has one of the longest and most complete records of all the active stations and is approximately the same distance away from the coast as the Projects. This station is selected to be representative of the climate conditions in the Project area, and as such, the temperature values for this station are shown in bold in Table 2.2.

The mean monthly, maximum monthly mean, and minimum monthly mean temperatures for the Project area based on Halifax Airport based on the full period of record from 1953 to 2018 are presented in Table 2.3. The MAT was 6.5°C, and the minimum and maximum mean monthly temperatures were - 5.8°C and 18.7°C occurring in January and July, respectively. The monthly mean temperatures for January during the observed record period ranged from a minimum of -10.3°C to -1.5°C, and the monthly mean temperatures for July ranged from 15.3°C to 21°C.

Table 2.3 Long-Term Mean Monthly Air Temperatures for the Project Area Based on Halifax Airport

Station Name	Value	Temperature (°C)												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Halifax Airport	Max Monthly Mean	-1.5	-1.1	2.6	7.3	13.0	17.4	21.0	20.7	18.5	12.4	6.0	1.5	21.0
	Mean Monthly	**-5.8**	**-5.6**	**-1.5**	**3.9**	**9.8**	**14.9**	**18.7**	**18.6**	**14.5**	**8.9**	**3.5**	**-2.4**	**6.5**
	Min Monthly Mean	-10.3	-10.0	-5.0	0.7	6.5	13.2	15.3	16.2	11.8	5.6	1.0	-9.6	-10.3

NOTES:

1. THE MEAN MONTHLY VALUE REPRESENTS THE MEAN TEMPERATURE FOR A GIVEN MONTH FOR THE ENTIRE PERIOD OF RECORD.
2. THE MIN AND MAX MONTHLY MEAN REPRESENTS THE MINIMUM AND MAXIMUM VALUE OF THE MEAN TEMPERATURE IN A SINGLE MONTH WITHIN THE PERIOD OF RECORD.

2.3 PRECIPITATION

2.3.1 REGIONAL DATA

Mean monthly precipitation values for the selected climate stations listed in Section 2.1 are presented in Table 2.4 and Figure 2.4 for the full period of record. These data suggest that precipitation in the region is fairly evenly distributed throughout the year; however, precipitation is the lowest in mid-summer and the highest in early-winter.

Table 2.4 Mean Monthly Precipitation for Regional Stations for the Full Period of Record

Station Name	Mean Total Precipitation													
	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Collegeville	mm	110	89	102	84	88	91	84	103	100	128	137	127	1,244
	% annual	9%	7%	8%	7%	7%	7%	7%	8%	8%	10%	11%	10%	100%
Upper Stewiacke	mm	112	97	96	84	88	83	87	94	101	103	119	114	1,179
	% annual	9%	8%	8%	7%	7%	7%	7%	8%	9%	9%	10%	10%	100%
Middle Musquodoboit	mm	125	99	123	105	104	95	99	101	100	123	135	137	1,347
	% annual	9%	7%	9%	8%	8%	7%	7%	7%	7%	9%	10%	10%	100%
Halifax Airport	**mm**	**138**	**118**	**122**	**113**	**108**	**97**	**93**	**99**	**103**	**134**	**150**	**164**	**1,440**
	% annual	**10%**	**8%**	**8%**	**8%**	**7%**	**7%**	**6%**	**7%**	**7%**	**9%**	**10%**	**11%**	**100%**
Stillwater Sherbrooke	mm	128	106	115	111	112	103	88	115	122	137	142	136	1,416
	% annual	9%	8%	8%	8%	8%	7%	6%	8%	9%	10%	10%	10%	100%
Malay Falls	mm	135	125	129	127	127	101	99	92	114	133	174	135	1,491
	% annual	9%	8%	9%	9%	9%	7%	7%	6%	8%	9%	12%	9%	100%

NOTES:

1. ASSUMES 1 CENTIMETER OF SNOW IS EQUIVALENT TO 1 MILLIMETER OF RAIN.

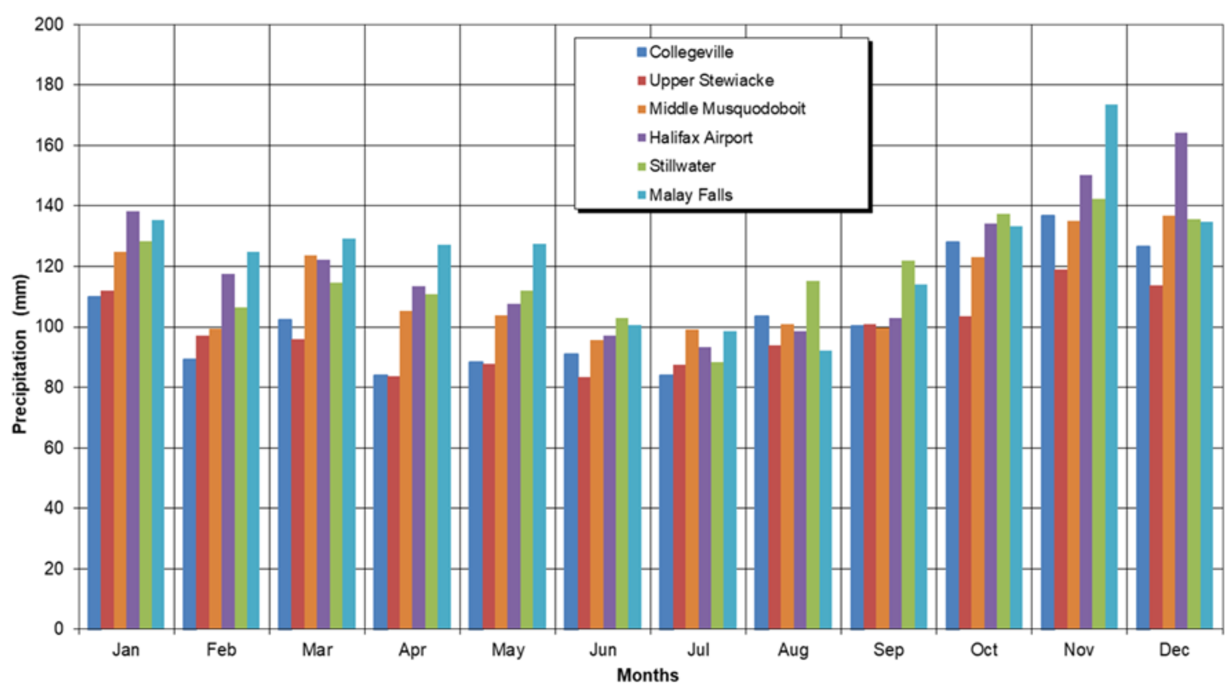
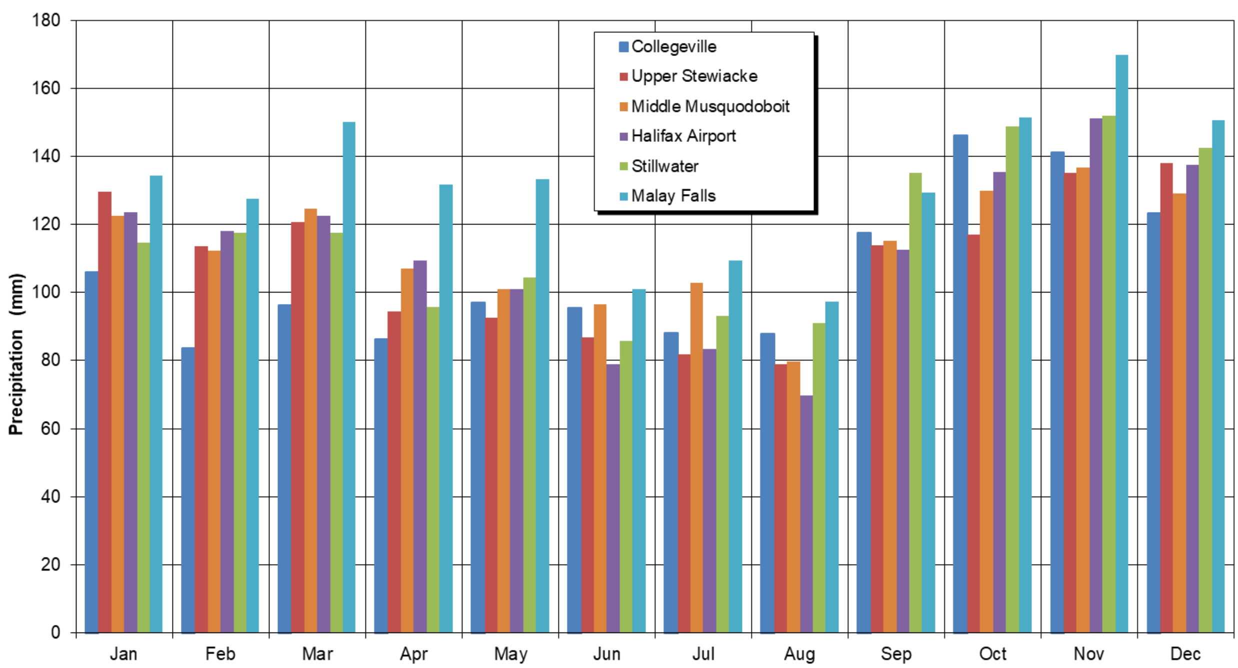


Figure 2.4 Mean Monthly Precipitation for Regional Stations for the Full Period of Record

In order to investigate whether the variability between the stations is caused by differences in the periods of record, Figure 2.5 shows a comparison of concurrent years of data arranged by distance from the east coast. The Collegeville station is the farthest from the coast at approximately 50 km, and the Malay Falls station is the closest to the coast at approximately 12 km. The comparison shows that, in general, precipitation decreases as the distance from the ocean increases, although there is some variability evident in this trend. The precipitation is distributed reasonably evenly throughout the year, with the highest precipitation occurring from October through January, and the lowest occurring from June through August.

Orographic effects resulting from air masses moving up the sides of elevated land formations, are typically characterized by increases in precipitation with increases in elevation. The terrain slope in Nova Scotia is gentle, and increase in precipitation due to orographic effects is considered negligible compared to increase in precipitation caused by air masses moving from the ocean to the land. This trend is reflected in the regional data, where stations lower in elevation but closer to the Atlantic Ocean receive more precipitation compared to higher stations further inland.

The precipitation distribution at Halifax Airport is selected to be representative of the precipitation patterns in the Project area, and as such, the values for this station are shown in bold in Table 2.4. This station was selected due to its similar distance to the coast (about 30 km) and similar elevation to the Project area. The mean annual precipitation (MAP) estimate for the Project area is equivalent to 1,440 mm with mean monthly values ranging from a low of 93 mm in July to a high of 164 mm in December, as shown in Table 2.5.



NOTES:

1. THE STATIONS ARE ALIGNED FROM THE FURTHEST FROM THE COAST ON THE LEFT TO THE CLOSEST ON THE RIGHT.

Figure 2.5 Regional Mean Monthly Precipitation Comparison for Period 1988 to 2004

Table 2.5 Long-Term Mean Monthly Precipitation for the Project Area Based on Halifax Airport

Station Name	Value	Precipitation (mm)												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Halifax Airport	Max Monthly Mean	313	210	263	228	319	307	190	387	309	335	268	295	1,931
	Mean Monthly	**138**	**118**	**122**	**113**	**108**	**97**	**93**	**99**	**103**	**134**	**150**	**164**	**1,440**
	Min Monthly Mean	21	30	19	30	26	18	8	17	18	28	37	44	1,048

NOTES:

1. THE MEAN MONTHLY VALUE REPRESENTS THE MEAN PRECIPITATION FOR A GIVEN MONTH FOR THE ENTIRE PERIOD OF RECORD.
2. THE MIN AND MAX MONTHLY MEAN REPRESENTS THE MINIMUM AND MAXIMUM VALUE OF THE MEAN PRECIPITATION IN A SINGLE MONTH WITHIN THE PERIOD OF RECORD.

2.3.2 MONTHLY PRECIPITATION DISTRIBUTION

Precipitation is reported by EC as rain or snow for the stations of interest. The rain and snow distribution for the various stations is presented in Table 2.6. The majority of precipitation falls as rain even in the winter months, which is expected for a moderate coastal region such as Nova Scotia. The rain to snow distribution is similar for all stations with 83-90% rain and 17-10% snow annually, indicating consistent pattern throughout the region. Based on the Halifax Airport station, 83% of the precipitation falls as rain, and the remaining 17% falls as snow annually.

Table 2.6 Mean Monthly Rain and Snow Distribution

Station Name	Precipitation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Collegeville	Rain	57%	53%	66%	83%	98%	100%	100%	100%	100%	99%	92%	65%	84%
	Snow	43%	47%	34%	17%	2%	0%	0%	0%	0%	1%	8%	35%	16%
Upper Stewiacke	Rain	61%	55%	67%	86%	99%	100%	100%	100%	100%	99%	93%	69%	85%
	Snow	39%	45%	33%	14%	1%	0%	0%	0%	0%	1%	7%	31%	15%
Middle Musquodoboit	Rain	63%	59%	76%	90%	99%	100%	100%	100%	100%	99%	95%	76%	87%
	Snow	37%	41%	24%	10%	1%	0%	0%	0%	0%	1%	5%	24%	13%
Halifax Airport	**Rain**	**59%**	**54%**	**66%**	**83%**	**98%**	**100%**	**100%**	**100%**	**100%**	**99%**	**91%**	**71%**	**83%**
	Snow	**41%**	**46%**	**34%**	**17%**	**2%**	**0%**	**0%**	**0%**	**0%**	**1%**	**9%**	**29%**	**17%**
Stillwater Sherbrooke	Rain	73%	61%	74%	88%	99%	100%	100%	100%	100%	100%	94%	75%	89%
	Snow	27%	39%	26%	12%	1%	0%	0%	0%	0%	0%	6%	25%	11%
Malay Falls	Rain	77%	68%	72%	94%	100%	100%	100%	100%	100%	100%	98%	79%	90%
	Snow	23%	32%	28%	6%	0%	0%	0%	0%	0%	0%	2%	21%	10%

2.3.3 SNOWMELT

The timing of spring snowmelt has a significant impact on the magnitude and timing of spring runoff (freshet). Snowmelt rates are impacted by numerous factors, such as temperature, slope, aspect, solar radiation, wind speed, and elevation. In order to understand the likely snowmelt patterns in the Project area, knowledge of when the maximum snow water equivalent (SWE) generally occurs is needed. However, snow course survey stations and SWE data are not available for the Project area or for any of the regional stations. Periods of rainfall exist throughout the winter months, as indicated in Table 2.6, and in these periods, both the higher temperatures and the rainfall would contribute to periodic partial or full melting of the snowpack, which may result in a moderate spring freshet (further discussed in Section 3). The snowpack in coastal regions typically melts over a shorter period of time, and a consistent snowpack may not exist throughout the winter period.

2.3.4 EXTREME PRECIPITATION

Estimates of extreme precipitation are required for many aspects of design, and are subsequently presented in several formats. The most common and useful information is the 24 hour extreme precipitation, given for different return periods, as well as for the probable maximum precipitation (PMP).

Extreme 24 hour precipitation values were estimated for the Project area using a frequency factor approach, as presented in the Rainfall Frequency Atlas (RFA) for Canada (Hogg and Carr, 1985). This approach involves using estimates of the mean and standard deviation of the annual 24 hour extreme precipitation, and utilizes frequency factors based on the Extreme Value Type I (Gumbel) distribution. Estimates of the mean and standard deviation were derived directly from the RFA. Additionally, the mean and standard deviations of the annual 24 hour extreme precipitation were calculated based on the precipitation record from Halifax Airport station presented in Section 2.3.1. A factor of 1.13 was applied to the daily precipitation record to account for potential differences between the daily and 24 hour precipitation (Hershfield, 1961). The resulting mean and standard deviation values are 71 mm and 27 mm from the RFA, and 80 mm and 28 mm from the Halifax Airport recorded data, respectively.

The resulting return period estimates based on the two methods are provided in Table 2.7. Given the uncertainty inherent in the two sets of estimates, the larger return period values were selected as appropriately conservative. Accordingly, the values generated using the measured record at the Halifax Airport station are recommended to be used for the design of various structures in the Project area.

The 100 year, 200 year, and PMP 24 hour extreme precipitation values for the Project area are estimated to be 168 mm, 184 mm, and 531 mm, respectively.

Table 2.7 Estimated 24 Hour Extreme Precipitation in the Project Area

Return Period (years)	RFA 24 Hour Extreme Event (mm)	Halifax Airport Data (mm)
2	67	**75**
5	90	**100**
10	106	**116**
15	115	**126**
20	121	**132**
25	126	**137**
50	141	**153**
100	156	**168**
200	170	**184**
500	190	**204**
1,000	204	**219**
PMP[2]	509	**531**

NOTES:

1. RAINFALL FREQUENCY ATLAS OF CANADA (RFA) (HOGG AND CARR, 1985).
2. PROBABLE MAXIMUM PRECIPITATION (PMP) EVENT IS BASED ON HERSHFIELD'S EQUATION (HERSHFIELD, 1961).
3. THE HALIFAX AIRPORT STATION DATA VALUES ARE RECOMMENDED TO BE USED AS DESIGN VALUES FOR THE PROJECT.

2.3.5 WET AND DRY YEAR PRECIPITATION

Estimates of wet and dry year annual precipitation are required to assess the range of probable precipitation conditions at the site. Wet and dry year annual precipitation totals were calculated based on a normally distributed probability of occurrence. The calculations require mean and standard deviation values for annual precipitation, which were determined from the long-term historical climate records for the Halifax Airport station to be 1,440 mm and 203 mm, respectively (Section 2.3.1). The wet and dry annual precipitation values for various return periods are presented in Table 2.8, which indicates a 1 in 200 year wet annual precipitation of 1,981 mm and a 1 in 200 year dry annual precipitation of 895 mm.

During the full period of record, the maximum annual precipitation was 1,931 mm at the Halifax Airport station, which is between the 1 in 100 and 1 in 200 year wet event, and the minimum annual precipitation was 1,048 mm, which is between the 1 in 20 and 1 in 50 dry event. This reasonable match between the extremes in the site record and the estimated return period event suggests that the assumption of a normal distribution is appropriate.

Table 2.8 Estimated Wet and Dry Year Precipitation in the Project Area

Return Period	Halifax Airport (mm)
1 in 200 year **wet**	1,962
1 in 100 year **wet**	1,912
1 in 50 year **wet**	1,856
1 in 20 year **wet**	1,773
1 in 10 year **wet**	1,700
Mean Annual Precipitation	**1,440**
1 in 10 year **dry**	1,180
1 in 20 year **dry**	1,107
1 in 50 year **dry**	1,024
1 in 100 year **dry**	968
1 in 200 year **dry**	918

NOTES

1. YEARS WITH ONE OR MORE MONTHS OF MISSING DATA ARE CONSIDERED INCOMPLETE AND ARE NOT INCLUDED IN THIS ANALYSIS.
2. ESTIMATED VALUES ASSUME A NORMAL DISTRIBUTION OF ANNUAL PRECIPITATION.
3. THE HALIFAX AIRPORT STATION DATA VALUES ARE RECOMMENDED TO BE USED AS DESIGN VALUES FOR THE PROJECT.

2.4 WIND SPEED AND DIRECTION

Wind speed and wind direction are important parameters used in the design of various structures, as they impact evaporation and dust transportation capacity. Wind speed and wind direction are available in the Canadian Climate Normals for the Halifax Airport station for period from 1981 to 2010. The data are presented in terms of mean monthly wind speed, maximum hourly speed, and maximum gust speed, including their respective directions. The mean monthly wind speeds and directions are summarized in Table 2.9 along with the maximum hourly wind speeds and direction of maximum wind speeds. The mean annual wind speed is 4.6 m/s, and the predominant wind direction is from the south.

As wind speed data can vary significantly between locations, it may be advantageous to install a site specific wind gauges where more accurate site specific wind speed data are required.

Table 2.9 Wind Speed and Wind Direction at Halifax Airport

Station Name	Value	Wind Speed (m/s)												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Halifax Airport	Maximum Hourly Speed	22.2	24.7	21.4	19.7	17.8	18.1	21.9	18.1	23.6	18.9	25.8	23.6	25.8
	Mean Wind Speed	4.9	5.1	5.1	5.1	4.6	4.2	3.9	3.7	4.0	4.4	4.9	5.1	4.6

Station Name	Value	Wind Direction												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Halifax Airport	Maximum Hourly Speed	S	E	S	E	S	N	SE	S	SE	SE	SE	S	S
	Most Frequent Direction	NW	NW	N	N	S	S	S	S	S	W	NW	NW	S

NOTES:

1. VALUES FROM CANADIAN CLIMATE NORMALS FOR THE HALIFAX AIRPORT STATION DATA FROM 1981 TO 2010.

2.5 SOLAR RADIATION

No solar radiation data are available in the region.

2.6 RELATIVE HUMIDITY

Humidity is a measure of the partial pressure of water vapour in the air, and it can be measured and presented in several different ways, with relative humidity being the most common. Relative humidity is typically presented as a percentage and represents the ratio of the partial pressure of water vapour in a packet of air to the saturated vapour pressure of water in the same packet of air. Relative humidity depends on temperature because the saturation pressure of air increases as the temperature increases. It differs from absolute humidity, which is measured in grams of water vapour per cubic meter of air.

Relative humidity climate data are available in the Canadian Climate Normals for the Halifax Airport station for period from 1981 to 2010. A monthly summary of relative humidity is provided in Table 2.10. The mean annual relative humidity is 76.8%, with a minimum of 74.2% in March and a maximum of 80.6% in December.

Table 2.10 Mean Relative Humidity at Halifax Airport

Station Name	Value	Relative Humidity												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Halifax Airport	Average Vapour Pressure (kPa)	0.4	0.4	0.5	0.6	0.9	1.3	1.6	1.7	1.4	1	0.7	0.5	0.9
	Mean Relative Humidity (%)	78.4	75.1	74.2	74.2	74.5	75.4	76.3	76.9	78.0	78.4	80.1	80.6	76.8

NOTES

1. VALUES FROM CANADIAN CLIMATE NORMALS FOR THE HALIFAX AIRPORT STATION. DATA FROM 1981 TO 2010.

2.7 ATMOSPHERIC PRESSURE

Atmospheric pressure is the pressure exerted by the weight of the earth's atmosphere. Typically, the atmospheric pressure decreases as elevation increases; however, atmospheric pressure is also affected by weather systems. While average atmospheric pressure data are only available at the Halifax Airport station, these data are expected to be reasonable estimates of conditions in the Project area due to the similar elevations and similar distance from the coast. Atmospheric pressure data are available in the Canadian Climate Normals for the Halifax Airport station for period from 1981 to 2010. The data are summarized as monthly averages in Table 2.11. Atmospheric pressure is fairly consistent year round, with a mean of 99.7 kPa, a low of 99.5 kPa in late winter, and a high of 99.9 in autumn. For comparison, the atmospheric pressure is typically around 101.3 KPa at sea level.

Table 2.11 Mean Atmospheric Pressure at Halifax Airport

Station Name	Value	Atmospheric Pressure												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Halifax Airport	Average Atmospheric Pressure (kPa)	99.5	99.5	99.5	99.6	99.7	99.6	99.7	99.8	99.9	99.9	99.8	99.5	99.7

NOTES

1. VALUES FROM CANADIAN CLIMATE NORMALS FOR THE HALIFAX AIRPORT STATION. DATA FROM 1981 TO 2010.

2.8 EVAPORATION

Evaporation is an important climate parameter, particularly for water balance studies. However, there are no pan evaporation estimates given for any of the regional climate stations, which is not unusual given the difficulty inherent in reliably collecting these types of data. Monthly Potential Evapotranspiration (PET) data were estimated using the Thornthwaite equation (Thornthwaite and Mather, 1955). PET is defined as the amount of evapotranspiration that would occur given an infinite supply of water from a crop surface, and these values are believed to be reasonably representative of lake evaporation conditions (Ponce, 1989; Maidment, 1993).

The benefit of the Thornthwaite equation over other methods is that the equation only requires inputs of temperature and of the daylight factor, which depends on the month and latitude. A limiting factor of the Thornthwaite equation is that 12 months of data in a year are always required; otherwise the respective year must be ignored. Considering that long-term regional temperature values from the Halifax Airport station were selected as representative of the Project area (Section 2.2), the Thornthwaite equation was used for calculating PET estimates for the Project.

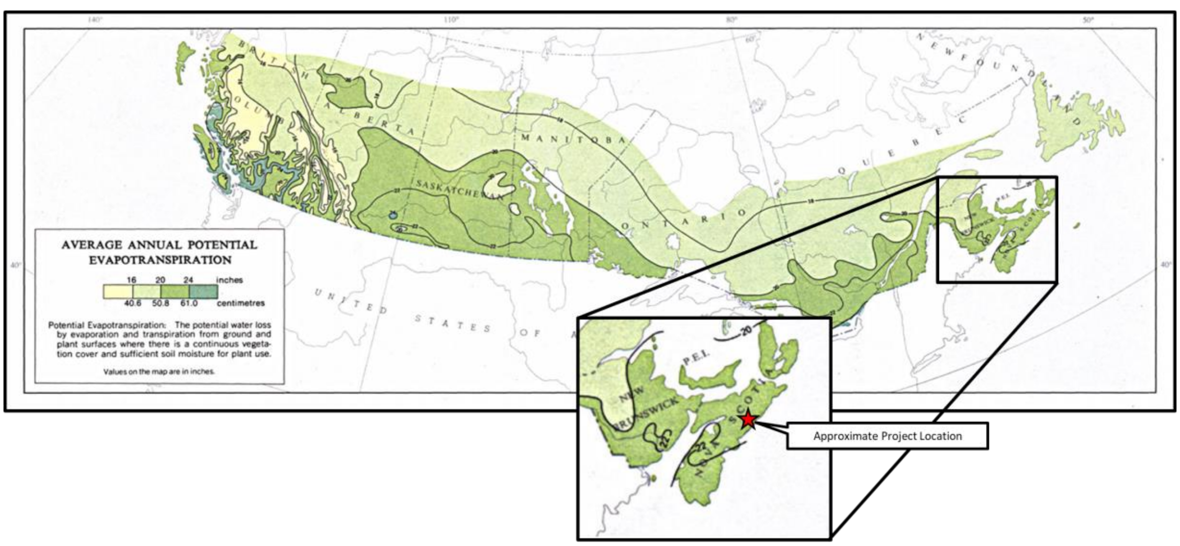
Temperature data from the Halifax Airport station were used as inputs to the Thornthwaite equation. Resultant monthly and annual estimates of PET are summarized in Table 2.12. The estimated long-term annual PET value for the Project is 564 mm, with little to no evapotranspiration occurring during winter months. This estimate is supported by the 4th Edition (1974) of the Atlas of Canada Potential Evapotranspiration map, shown on Figure 2.6, which estimates PET as approximately 550 mm. Actual evapotranspiration (AET) is typically in the order of 60% to 80% of PET, and therefore AET is estimated to be between 340 mm to 450 mm.

Table 2.12 Estimated Long-Term Potential Evapotranspiration

Station Name	Unit	Evapotranspiration (mm)												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Halifax Airport	mm	0	0	0	23	64	99	126	116	78	43	14	0	564
	% annual	0%	0%	0%	4%	11%	18%	22%	21%	14%	8%	3%	0%	100%

NOTES:

1. THE LONG-TERM PET VALUES ARE BASED ON THE LONG-TERM MEAN MONTHLY TEMPERATURE VALUES AT THE HALAIFAX AIRPORT STATION USING THE THORNTHWAITE EQUATION.
2. THE THORNTHWAITE EQUATION ASSUMES THAT WHEN THE MEAN MONTHLY TMEPERATURE IS EQUAL TO OR LESS THAN ZERO, PET IS ZERO.



NOTES:

1. FIGURE BASED ON THE PET MAP FROM THE ATLAS OF CANADA (4TH EDITION), 1974.

Figure 2.6 Atlas of Canada Potential Evapotranspiration Map

2.9 SUBLIMATION

Sublimation is the process by which moisture is returned to the atmosphere directly from snow and ice without passing through the liquid phase (Liston and Sturm, 2004). Sublimation can play a significant role in the annual hydrologic water balance in areas where winter precipitation comprises a large proportion of annual precipitation. Many estimates and methods of estimating sublimation found in the literature, are site-specific, subject to significant uncertainty, and not easily extrapolated. Sublimation may be considered negligible compared to the daily melt rates in the Project area considering that a long-term snowpack typically does not occur in the region, as discussed in Section 2.3.3.

3.0 HYDROLOGY

3.1 REGIONAL STATIONS

A regional hydrology study was conducted using data available from WSC. The available regional hydrometric stations are shown on Figure 3.1, and station details are provided in Table 3.1. The majority of the stations have been deactivated for a prolonged period of time or are located sufficiently far from the Project area, such that the hydrological conditions are expected to be different from conditions within the study area.

Data from three WSC stations were compared to determine the most appropriate runoff estimates for the Project area. Each station has a period of record of at least 30 years and a maximum distance from the Project area of 50 km. These stations were:

- Liscomb River at Liscomb Mills
- Musquodoboit at Crawford Falls, and
- St. Mary’s River at Stillwater.

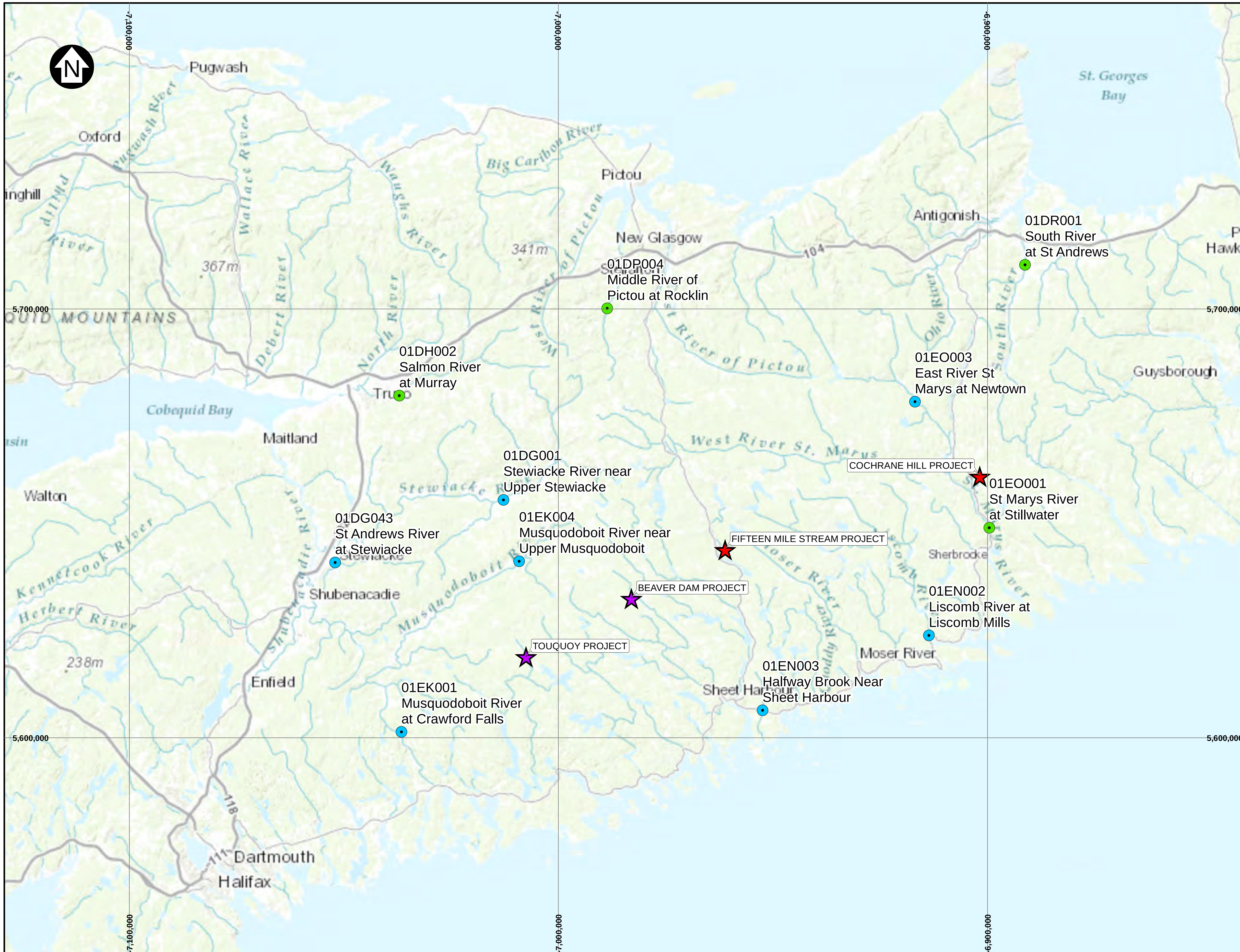
The WSC lists flow on the Musquodoboit River at Crawford falls as being regulated; however, the streamflow record was considered in the analysis due to proximity to the Project area.

Table 3.1 Summary of Regional Hydrology Stations

Station Name	ID	Active or Inactive	Drainage Area (km^2)	Years of Record	Start Year	End Year	Latitude	Longitude
St Marys River at Stillwater	01EO001	Active	1,350	104	1915	2018	45.17	-61.98
Halfway Brook Near Sheet Harbour	01EN003	Inactive	16.9	8	1988	1995	44.90	-62.45
Middle River of Pictou at Rocklin	01DP004	Active	92.2	54	1965	2018	45.50	-62.78
Stewiacke River near Upper Stewiacke	01DG001	Inactive	420	12	1915	1926	45.22	-63.00
Musquodoboit River near Upper Musquodoboit	01EK004	Inactive	141	10	1974	1983	45.12	-62.96
Musquodoboit River at Crawford Falls	01EK001	Inactive	650	82	1915	1996	44.87	-63.21
East River St Marys at Newtown	01EO003	Inactive	282	15	1965	1979	45.36	-62.14
Salmon River at Murray[1]	01DH002	Active	363	12	1964	2018	45.37	-63.22
South River at St Andrews[2]	01DR001	Active	177	69	1917	2018	45.56	-91.90
Liscomb River at Liscomb Mills	01EN002	Inactive	389	35	1962	1996	45.02	-62.11
St Andrews River at Stewiacke	01DG043	Inactive	98.2	8	2011	2015	45.12	-63.35

NOTES:

1. DATA COLLECTED FROM 1964 - 1972 AND 2016 – 2018.
2. DATA COLLECTED FROM 1918 - 1925, 1927 - 1933, AND 1965 – 2018.



LEGEND:

- PHASE 2 PROJECT LOCATIONS
- PHASE 1 PROJECT LOCATIONS
- ACTIVE REGIONAL HYDROLOGY STATION
- INACTIVE REGIONAL HYDROLOGY STATION

NOTES:

1. BASE MAP: ESRI ONLINE WORLD TOPOGRAPHIC MAP.
2. COORDINATE GRID IS IN METRES.
COORDINATE SYSTEM: WGS 1984 WEB MERCATOR AUXILIARY SPHERE.
3. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:900,000 FOR 11x17 (TABLOID) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.

10 5 0 10 20 30 40 50 km

ATLANTIC GOLD CORPORATION

MOOSE RIVER CONSOLIDATED PHASE II

REGIONAL HYDROLOGY STATIONS

Knight Piésold CONSULTING

P/A NO. VA101-708/04 | REF NO. 1

FIGURE 3.1 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	06SEP'18	ISSUED WITH REPORT	DAA	KK	VM

3.2 STREAMFLOW ESTIMATES

3.3 FLOW STATISTICS AND FREQUENCY ANALYSIS

Understanding the magnitude and frequency of hydrologic events is important to help inform the design and operations of the Project. The following sections describe the results of various statistical analyses performed on the long-term regional stream flow record to generate hydrologic design estimates for the Project.

3.3.1 DISCHARGE AND UNIT RUNOFF

Three hydrology stations located near the Project area were identified as relevant regional stations, as noted in Section 3.1. The mean annual unit discharge (MAUD) for each station is summarized in Table 3.2. The Musquodoboit station may not be suitable given that it is listed as a regulated waterway but it has been included due to its proximity to the Project and in consideration that the Fifteen Mile Stream Project is also located in a regulated watershed.

The MAUD varies from 30.8 L/s/km^2 for Musquodoboit River to 41.2 L/s/km^2 for Liscomb River, as indicated in Table 3.2. This variation can be explained by differences in basin location, vegetative cover, slope, aspect, and basin elevation; however, a detailed analysis of catchment characteristics has not been completed in this report. The stations with the longest records, Musquodoboit River and St. Mary's River, both suggest the Project area has a mean annual unit runoff (MAUR) of approximately 1,000 mm, which is generally consistent with the estimates of precipitation (1,440 mm) and AET (340 mm to 450 mm).

Table 3.2 Mean Monthly Unit Discharge

Station Name	Mean Monthly Unit Discharge (L/s/km^2)												MAUD (L/s/km^2)	MAUR (mm)	MAD (m^3/s)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec			
Liscomb River at Liscomb Mills	45.4	38.3	54.7	77.9	50.2	24.8	17.5	19.1	16.2	35.1	56.3	58.6	41.2	1,299	15.9
Musquodoboit River at Crawford Falls	38.4	30.2	44.3	60.9	35.1	17.7	10.7	12.7	11.9	23.3	41.3	43.6	30.8	973	20.1
St Mary's River at Stillwater	**37.3**	**30.2**	**41.8**	**65.8**	**40.1**	**17.9**	**10.9**	**11.0**	**13.2**	**25.8**	**43.2**	**44.3**	**31.8**	**1,003**	**42.9**

The mean daily discharge hydrographs for the three stations are presented on Figure 3.2, and a comparison of the concurrent unit discharge records is shown on Figure 3.3. Regional runoff patterns are characterized as follows:

- Moderate flows during winter months from November to March
- An increase in flows during the spring freshet season in April and May
- Lower flows in the summer months from July to September
- June and October being the transitional shoulder months, and
- Sustained flows in response to storm systems can be observed throughout the year.

All three unit hydrographs are relatively similar. The Liscomb River data is slightly higher throughout the year, leading to the higher annual unit runoff compared to the other two rivers, as shown in Table 3.2. Although WSC notes that discharge is regulated for the Musquodoboit River, flows appear to follow the same pattern as the St. Mary's River, which suggests that the regulation has limited effect on the overall distribution of flow.

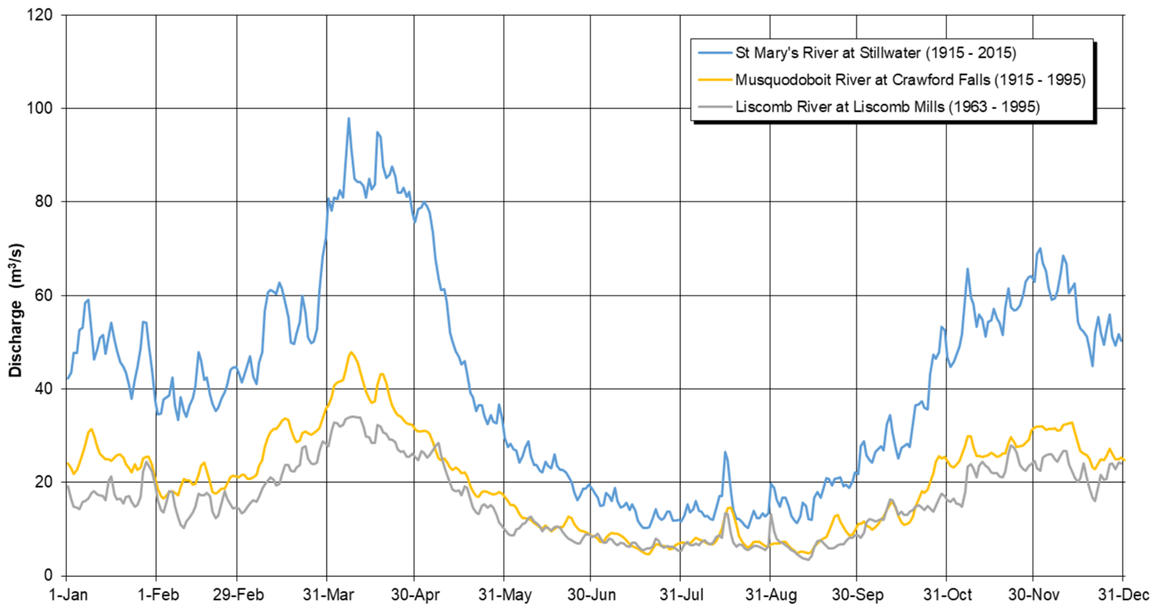
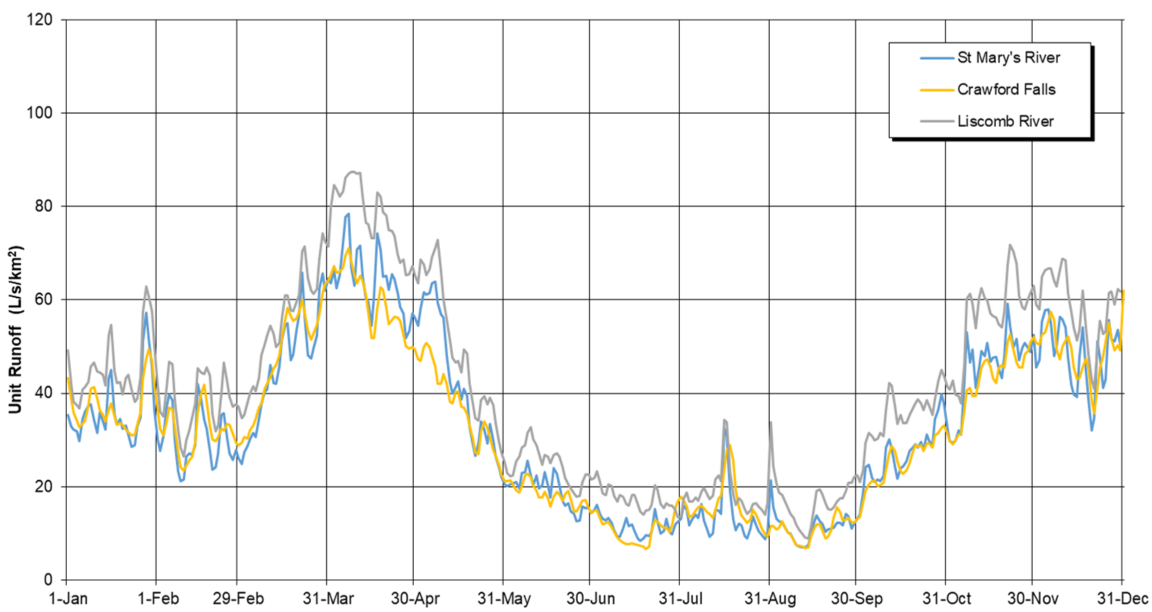


Figure 3.2 Mean Daily Discharge Hydrograph



NOTES:

1. YEARS WITH MISSING MONTHS WERE OMMITED FROM THE ANALYSIS.

Figure 3.3 Mean Daily Unit Discharge Hydrograph for the Concurrent Period from 1963 to 1995

The Liscomb River station is likely not representative of the conditions at the Project area as the MAUR of 1,299 mm is not consistent with estimates of precipitation (1,440 mm) and AET (340 mm to 450 mm). Furthermore, the above figures suggest that regulation of the Musquodoboit River has little effect on the MAUD and MAUR; however, the regulation would likely impact both peak instantaneous flows and low flows. Additionally, both stations have been discontinued for more than 20 years, and as such are not considered suitable as representative for the Project area.

The St. Mary's River station has the longest period of record of the three stations, and is currently an active station. It was determined that streamflow data from the St. Mary's River is the most applicable to the Project area, and as such, the mean monthly unit discharge, MAUR, MAUD and MAD for this station are shown in bold in Table 3.2. The Cochrane Hill Project is within the St. Mary's River catchment, while the Fifteen Mile Stream Project is approximately 43 km east of this hydrology station.

3.3.2 RUNOFF COEFFICIENT

The runoff coefficient is a dimensionless number that defines the annual ratio of precipitation to runoff. The results of the precipitation, streamflow, and evaporation analysis suggest an annual runoff coefficient of approximately 0.70 (70%), which is consistent with regional runoff estimates. This estimate should be refined seasonally following site specific data collection and analysis.

3.3.3 WET AND DRY RETURN PERIOD FLOWS

Wet and dry monthly flow values were estimated for the St. Mary's River for recurrence intervals of 5, 10, and 20 years, by fitting statistical distributions to the monthly mean flow values. The results are presented in Table 3.3 and shown on Figure 3.4. The monthly return period values were estimated using the distribution fitting application provided in the Palisade Decision Tools @RISK statistical software program. The best fit distribution type was selected for each month. For most months a lognormal distribution was selected, noting that the wet and dry monthly flow values do not differ greatly between various distributions.

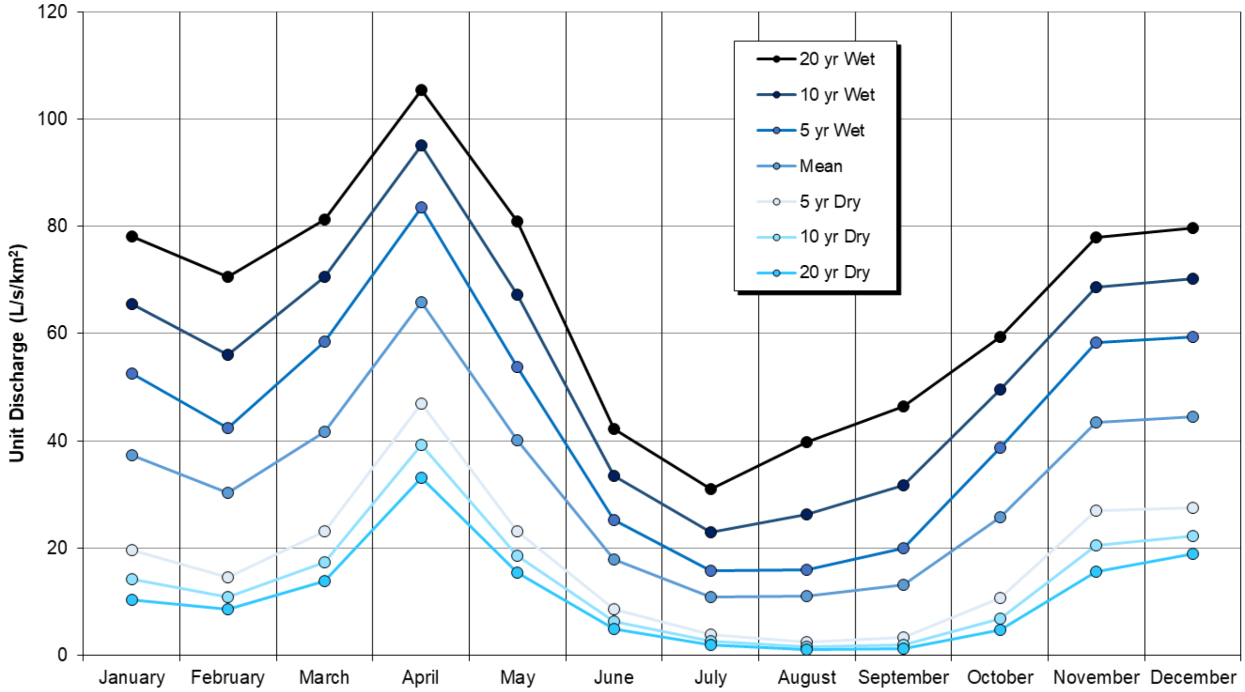
Table 3.3 Wet and Dry Return Period Streamflow for St. Mary's River

Month	Estimated Return Period Monthly Discharge (m^3/s)						
	Dry			Mean	Wet		
	20 yr	10 yr	5 yr		5 yr	10 yr	20 yr
January	14.1	19.2	26.6	**50.3**	70.9	88.4	105.5
February	11.6	14.7	19.6	**40.8**	57.3	75.7	95.3
March	18.6	23.4	31.2	**56.3**	79.0	95.4	109.8
April	44.8	52.9	63.4	**88.8**	112.7	128.4	142.4
May	20.9	25.0	31.1	**54.0**	72.6	90.8	109.3
June	6.7	8.6	11.5	**24.2**	34.2	45.2	56.9
July	2.6	3.5	5.1	**14.7**	21.3	30.9	41.9
August	1.4	2.1	3.3	**14.8**	21.5	35.5	53.8
September	1.7	2.7	4.4	**17.7**	26.9	42.8	62.7
October	6.3	9.2	14.4	**34.6**	52.3	66.9	80.2
November	21.1	27.7	36.4	**58.5**	78.7	92.6	105.2
December	25.5	29.9	37.1	**60.0**	80.2	94.7	107.5
Mean Annual	**14.6**	**18.2**	**23.7**	**42.9**	**59.0**	**73.9**	**89.2**

Month	Estimated Return Period Monthly Unit Discharge ($L/s/km^2$)						
	Dry			Mean	Wet		
	20 yr	10 yr	5 yr		5 yr	10 yr	20 yr
January	10.4	14.2	19.7	**37.3**	52.5	65.5	78.1
February	8.6	10.9	14.5	**30.2**	42.5	56.1	70.6
March	13.8	17.3	23.1	**41.8**	58.5	70.6	81.3
April	33.2	39.1	46.9	**65.8**	83.5	95.1	105.5
May	15.5	18.5	23.1	**40.1**	53.8	67.3	81.0
June	5.0	6.4	8.5	**17.9**	25.3	33.5	42.2
July	1.9	2.6	3.8	**10.9**	15.8	22.9	31.1
August	1.0	1.5	2.4	**11.0**	15.9	26.3	39.8
September	1.3	2.0	3.3	**13.2**	20.0	31.7	46.4
October	4.7	6.8	10.6	**25.7**	38.8	49.5	59.4
November	15.7	20.5	27.0	**43.4**	58.3	68.6	77.9
December	18.9	22.2	27.5	**44.5**	59.4	70.2	79.6
Mean Annual	**10.8**	**13.5**	**17.5**	**31.8**	**43.7**	**54.8**	**66.1**

NOTES

1. WET AND DRY VALUES CALCULATED USING PALISADE'S @RISK ANALYSIS TOOL IN MICROSOFT EXCEL.



NOTES

1. WET AND DRY VALUES CALCULATED USING PALISADE'S @RISK ANALYSIS TOOL IN MICROSOFT EXCEL.

Figure 3.4 Wet and Dry Return Period Unit Runoff Comparison

3.3.4 7-DAY LOW FLOWS

There is a single low flow period evident annually within the St. Mary's River data, which typically occurs in the summer between June and September. Stream flows are primarily due to groundwater recharge during this low flow period, when prolonged periods of lower precipitation and higher evaporation result in a reduction of flows to base flows.

A frequency analysis was used to determine the 7-day annual low flows with return periods ranging from 2 to 200 years for the St. Mary's River station. Return period 7-day low flows were generated using the US Army Corps of Engineers' HEC-SSP statistical software. The HEC-SSP uses a Log-Pearson Type III distribution to model return period low flows from these inputs, and the resultant return period values are presented in Table 3.4. Please note that the flow values in this table are shown in L/s, compared to other tables that show flows in m^3/s.

Table 3.4 Estimated Annual 7-Day Low Flows

Station Name	Drainage Area (km^2)	Value	2 yr	5 yr	10 yr	20 yr	50 yr	100 yr	200 yr
St. Mary's River at Stillwater	1,350	Flow (L/s)	2,010	976	651	459	303	228	173
		Unit Runoff (L/s/km^2)	1.5	0.7	0.5	0.3	0.2	0.2	0.1

3.3.5 PEAK FLOWS

Peak flows on the St. Mary's River typically occur during two periods annually; the spring, and the early winter. The peak flows are likely due to snowmelt in the spring or snowmelt combined with rainfall events. Early winter peak flows are likely caused by sustained storm events.

A flood frequency analysis was conducted using daily average discharge from the WSC streamflow record from the St. Mary's River station. Daily average flows were converted to equivalent instantaneous peak flow values by applying a conversion factor of 1.15 specific to the hydrology station. The conversion factor was then applied to the daily flows from the long-term record to produce a maximum instantaneous flow series.

The flood frequency analyses was completed using the HEC-SSP software. A Log Pearson Type III distribution was fit to the data set to generate return period peak flow values, which are summarized in Table 3.5. The log Pearson Type III distribution is commonly used in flood frequency analysis and was appropriate for this study as it fits the peak flow data well.

Table 3.5 Estimated Peak Instantaneous Flows

Station Name	Drainage Area (km^2)	Value	2 yr	5 yr	10 yr	20 yr	50 yr	100 yr	200 yr
St. Mary's River at Stillwater	1,350	Peak Flows (m^3/s)	444	602	714	828	985	1,112	1,247
		Peak Unit Runoff ($L/s/km^2$)	329	446	529	613	730	824	924

NOTES:

1. THE PEAK FLOW ESTIMATES PRESENTED ARE BASED ON THE HISTORICAL RECORD.
2. THE DESIGN FLOOD ESTIMATES FOR THE PROJECT SHOULD INCLUDE AN UPLIFT CLIMATE CHANGE ADJUSTMENT FACTOR OF 15%.

A climate change adjustment factor should be applied to the peak flow estimates to account for the uncertainty, and potential greater volatility, of future climatic conditions, given that the flood estimates are based on historic events. For example, the Engineers and Geoscientists of British Columbia (EGBC) guidelines (EGBC 2018) indicate that if no climate change trend is detectable when analyzing historic streamflow trends, a 10% upward adjustment factor should be used to account for future change in water input from precipitation. Conversely, a 20% upward adjustment factor should be applied in smaller drainage basins if a statistically significant trend is detected in historic streamflow trends.

An analysis of regional climate trends within the Project area is presented in Section 4 of this report and indicates that due to the strong scatter in the data, no strong conclusions can be derived on potential climate change at this time. Accordingly, there is no compelling evidence to suggest that the climate is changing in a manner that will materially affect peak flows. However, it is generally expected by regulators and the public that climate change is addressed in peak flow analyses, and a 15% climate change factor has evolved in engineering practice as a somewhat "de facto" standard to address this concern. The need to apply such a factor is dependent on the design life of the structure in question and the justification for its use is left to the judgment of the design engineer. For structures with a reasonably long design life (e.g., 30 years or more), projected climate change effects might be expected to occur over that period, so a 15%

uplift should be applied in determining peak design flow values. However, if a structure has a short design life (e.g., less than 30 years), a climate change adjustment is not warranted.

To conclude, it is recommended that peak instantaneous design flows for the Project be determined using the values in Table 3.5, and that an additional 15% climate change adjustment factor is added to these estimates if it is warranted by the design life of the structure in question.

4.0 CLIMATE CHANGE

4.1 TEMPERATURE AND PRECIPITATION TRENDS

The Halifax Airport station has been selected as the most representative of the Project area; however, the climate stations at Stillwater, Stewiacke and Collegeville each have over 80 years of record, and as such are valuable in determining potential long-term temperature and precipitation trends in the region. These four stations were used to evaluate various climate trends for the Nova Scotia region where the projects are located.

4.1.1 NORTH ATLANTLIC OSCIALLATION

The North Atlantic Oscillation (NAO) represents an index of the difference in the strength of the normalized sea level pressure between Iceland and the Azores (Bonsal and Shabbar, 2010), which may potentially impact any observed trends in the data. The NAO shows monthly, annual, and decadal variations over the last century; however, there is no indication of an apparent long-term trend.

The NAO affects winter weather (December through March) more noticeably, with a positive winter index related to colder winter temperatures and less precipitation, and a negative index related to the opposite. Typical regions of Canada affected by NAO temperature trends extend from Baffin Island to the northern coast of Nova Scotia, with the Project area on the border of the affected zone. The effect on precipitation of the NAO is much smaller (than the effect on temperatures) with the region extending from the south half of Baffin Island to the east end of Labrador.

Since the 1970s, the NAO has been dominated by a positive winter index (colder temperatures with less precipitation). Given the Project area is on the border of the affected zones, the temperatures and precipitation may not be heavily influenced from the positive NAO, which is suggested by the data trends at various climate stations. It is recommended that NAO effects are not included in the climate change analysis for this Project due the unpredictability of the oscillations and the lack of historic regional temperature and precipitation response to the index trend.

4.1.2 TEMPERATURE

Three temperature data subsets (mean annual, annual maximum mean monthly, and annual minimum mean monthly) were assessed for the Halifax Airport and Stillwater stations. The significance of any trends observed in the data sets were confirmed by the P-value test. The P-value, or calculated probability, is the probability of finding the observed results when the null hypothesis, which assumes no difference, is true. If the P-value is less than a selected value (typically 0.01, 0.05 or 0.10, or 1%, 5% and 10%, respectively) the null hypothesis is rejected, meaning that the findings are statistically significant; however, if the P-value is greater than the selected value, the results are not statistically significant. Years with missing months were omitted from the statistical analysis.

Temperature data for the Halifax Airport and Stillwater stations are presented on Figure 4.1 and Figure 4.2, respectively. All three data subsets for the Halifax Station indicate temperature increases of approximately 0.03°C per year. The trends are considered to be statistically significant at 1% level.

The maximum mean monthly temperature data for the Stillwater station shows a 0.01°C per year trend that is significant at a 5% significance level. The mean annual temperature data show a 0.03°C per year increase and the minimum mean monthly temperature data show a 0.04°C per year increase; both of which are statistically significant at a 1% significance level.

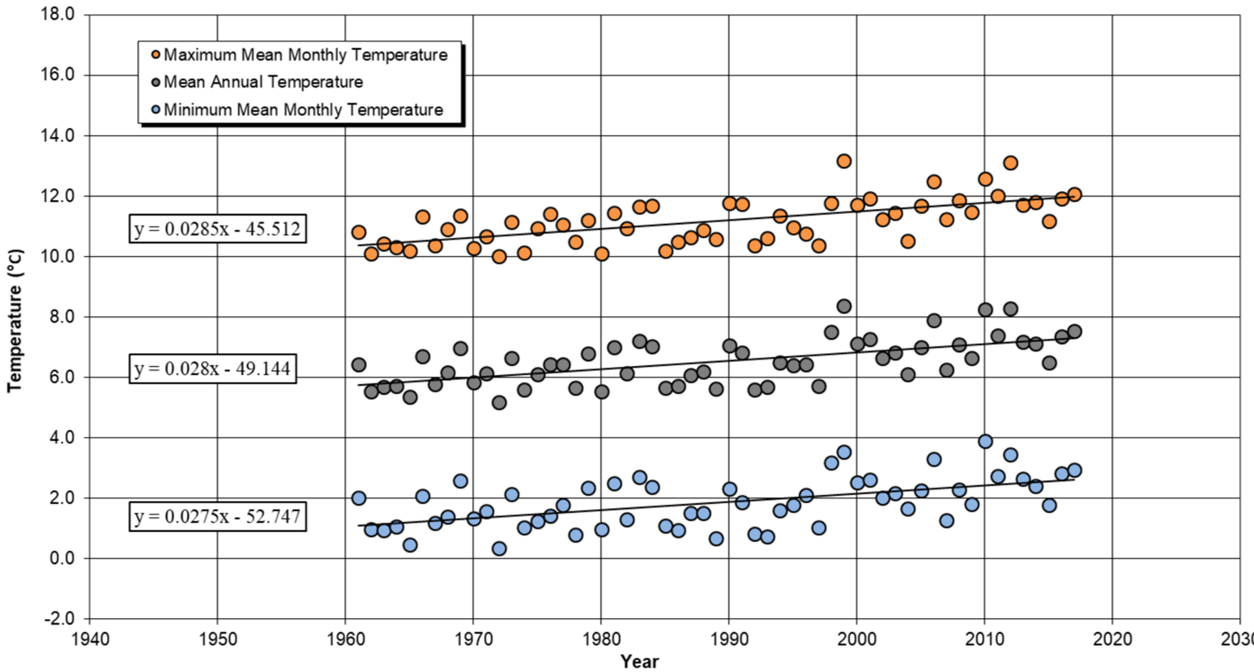


Figure 4.1 Annual Temperature Trends at Halifax Airport Station

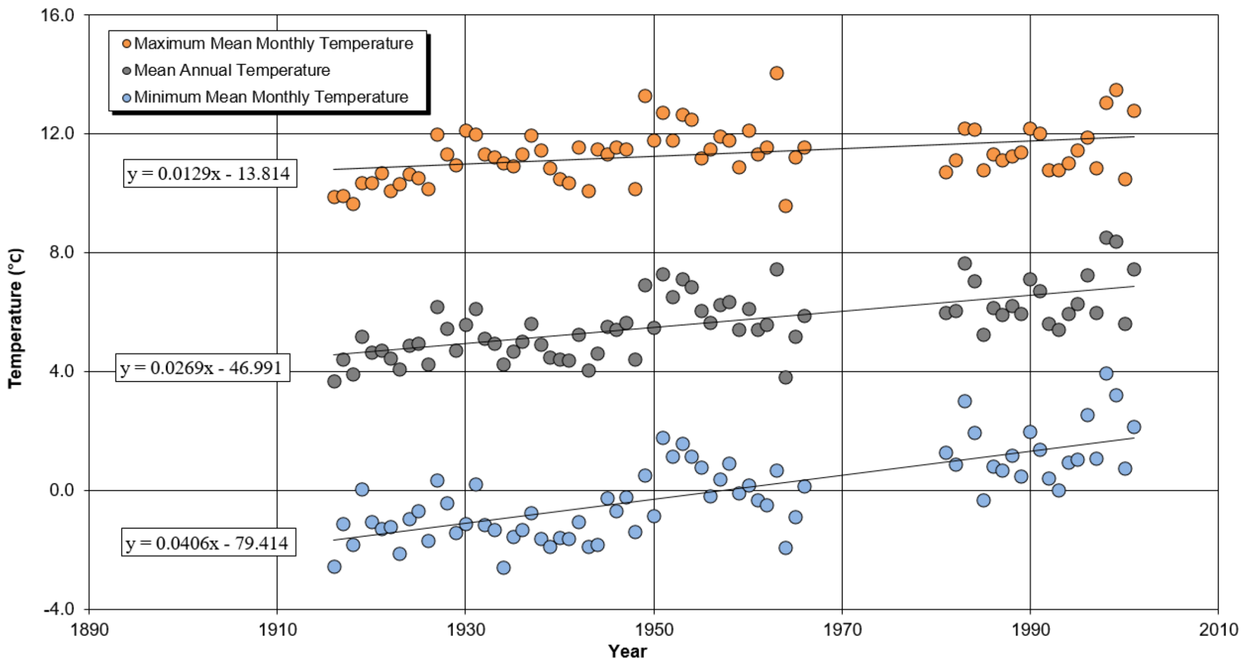


Figure 4.2 Annual Temperature Trends at Stillwater Station

Both stations show that the mean annual temperature is increasing at a rate of around 0.03°C per year at a 1% significance level. As such, it is recommended that this increase in temperature be accounted for when completing engineering analysis using these data.

4.1.3 PRECIPITATION

Three data types (annual precipitation, annual rainfall, and annual snowfall) were assessed for each of the stations noted above. As with the temperature data, the significance of any trends observed in each data set were confirmed using the P-value test. Annual precipitation data for the Halifax Airport station are presented on Figure 4.3 and data for the Stillwater station are presented on Figure 4.4.

Data at the Halifax Airport indicate a slight increase in annual rainfall, and decreases in both annual snowfall and total precipitation. The decrease in the annual snowfall trend is significant at a 5% significance level; however, annual precipitation and annual rainfall trends are not statistically significant. The decrease in the snowfall trend is consistent with the increase in temperature observed at this station.

Data at the Stillwater station indicate increases in annual precipitation, rainfall, and snowfall; however, the trends were determined not to be statistically significant due to the scatter in the data. Furthermore, the very low values observed in the annual precipitation in the 1960s, followed by the very high values in the 1990s are not identified at other stations. Given the relative consistency of the rainfall distribution in the region, the data for the Stillwater station precipitation may not be valid. Due to the differences in the precipitation trends observed between the Halifax Airport and Stillwater stations, additional analysis was completed for Stewiacke and Collegeville stations. Data for the Stewiacke and Collegeville stations are presented on Figure 4.5 and Figure 4.6, respectively.

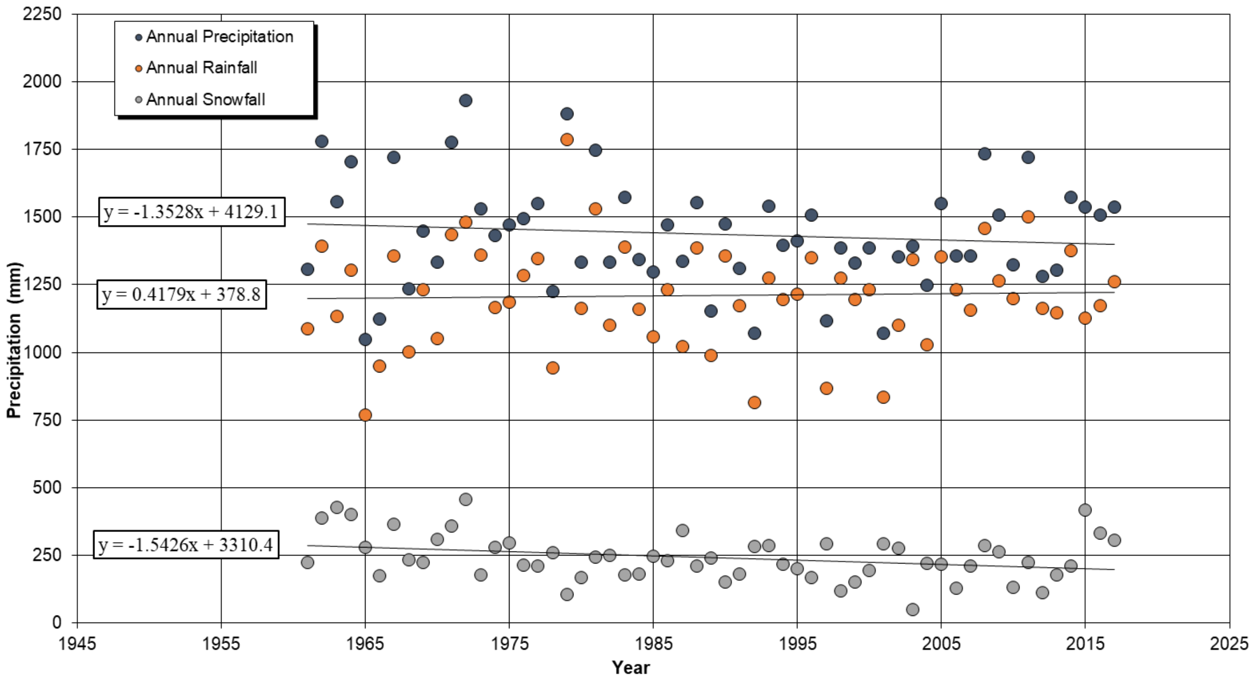


Figure 4.3 Annual Precipitation Trends at Halifax Airport Station

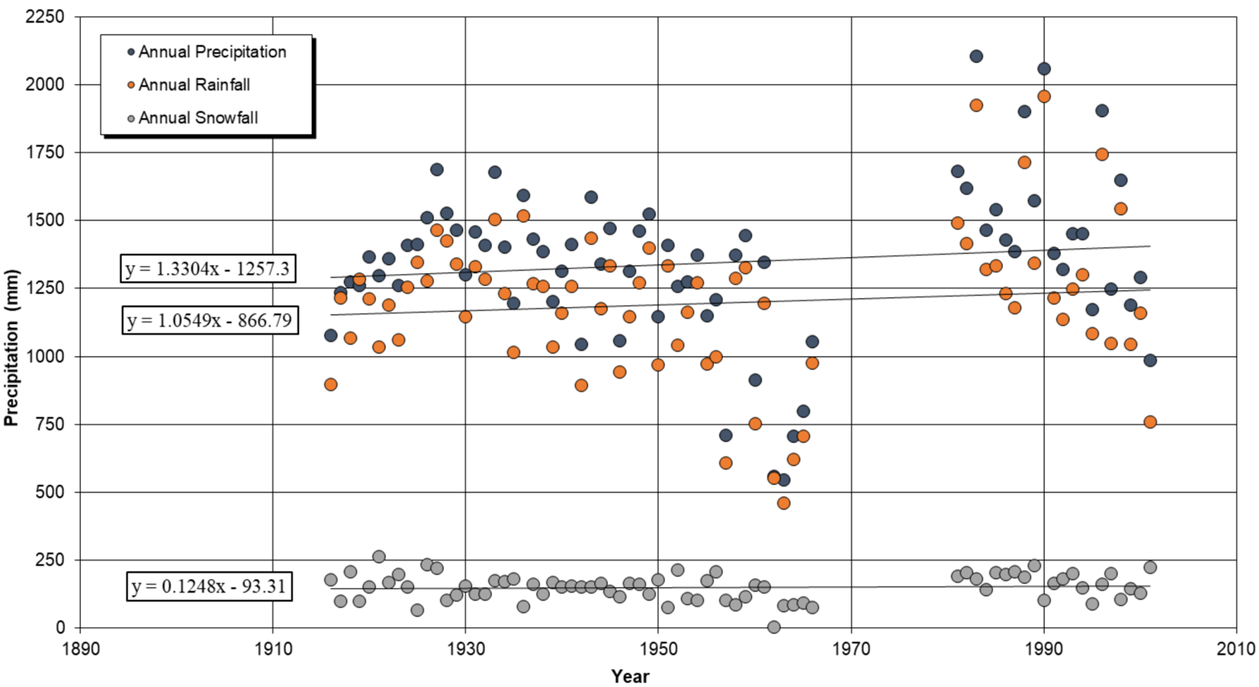


Figure 4.4 Annual Precipitation Trends at Stillwater Station

Data from the Stewiacke station suggest that annual precipitation, rainfall, and snowfall are increasing. The annual precipitation is increasing at 4.8 mm per year, the annual rainfall is increasing at 3.6 mm per year, and the annual snowfall is increasing at 1.1 mm per year. All of these trends are significant at a 1% significance level.

Data from the Collegeville station suggest that annual precipitation, rainfall, and snowfall are increasing. The annual precipitation is increasing at 1.8 mm per year, and the annual rainfall is increasing at 1.6 mm per year and are both significant at a 5% significance level. Annual snowfall appears to be increasing over time; however, the trend is not statistically significant.

The precipitation and rainfall trends indicate decrease or no change at the Halifax Airport station and increase at both the Stewiacke and Collegeville stations, which are both located further inland from the east coast than the Halifax Airport or the Projects sites. Given the discrepancies in the trends for the Halifax Airport, Stewiacke, and Collegeville stations, no strong conclusion can be made at this time regarding whether the precipitation is generally increasing or decreasing in the Project area.

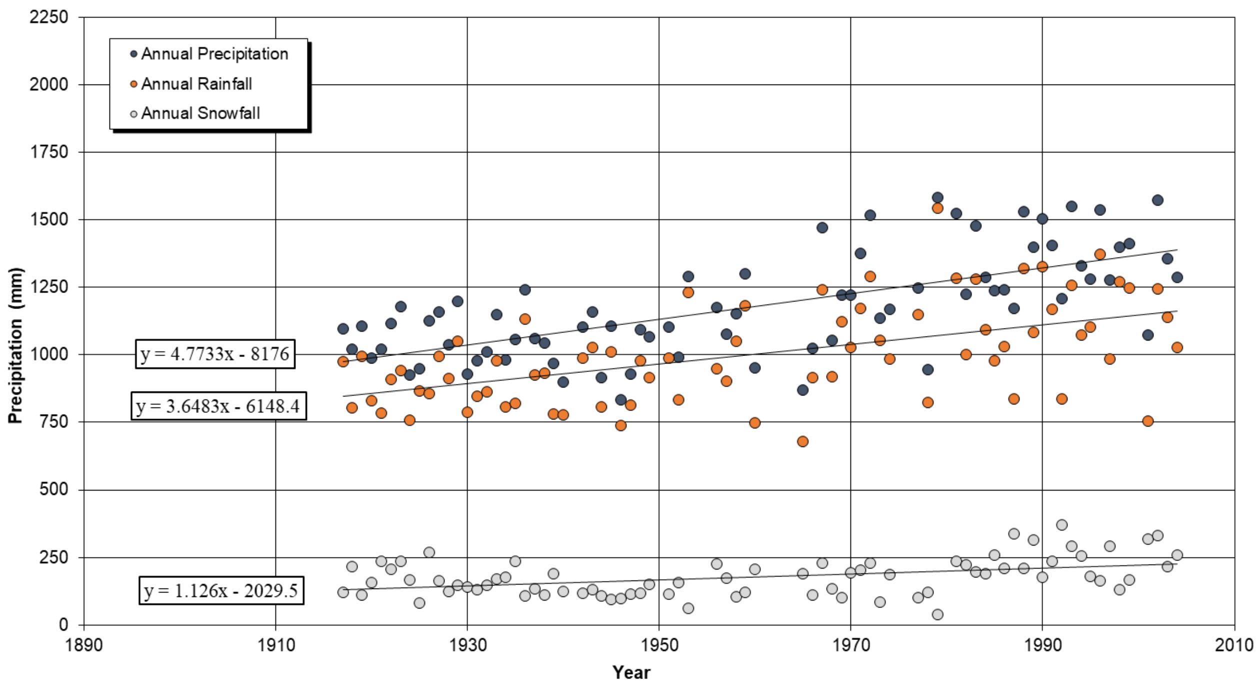


Figure 4.5 Annual Precipitation Trends at Upper Stewiacke Station

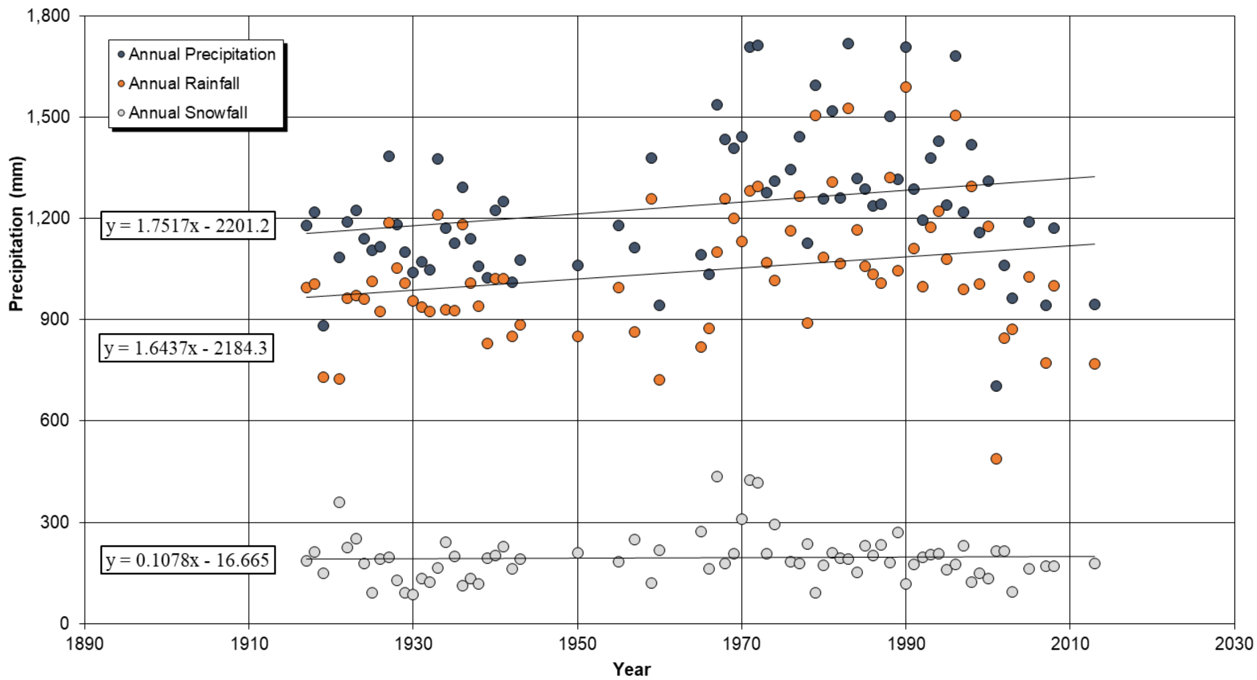


Figure 4.6 Annual Precipitation Trends at Collegeville Station

4.2 STREAMFLOW TRENDS

The potential effects of long-term climate patterns on stream flows in the Project area were assessed by examining the WSC flow records for the longest operating and most relevant regional stream gauging stations available. These stations are St. Mary's at Stillwater (01EO001), which began operations in 1916 (first year of complete flow data) and is still active, and Liscomb River at Liscomb Mills (01EN002), which began operations in 1962 and was discontinued in 1996. The mean annual unit discharge and the annual peak flows for these stations were assessed. Even though the Musquodoboit River was assessed for determining annual runoff patterns, it was not assessed for climate change trends, as the regulation creates an added layer of uncertainty to interpreting the results.

The mean annual unit discharge values for St. Mary's River and Liscomb River are presented on Figure 4.7 and Figure 4.8, respectively. A slight increasing trend is observed for both the St. Mary's River and the Liscomb River unit flows; however, there is considerable scatter in the data, and the trends are not statistically significant. As a result, no strong conclusions can be made on whether or not annual flows are expected to change with time within the Project area.

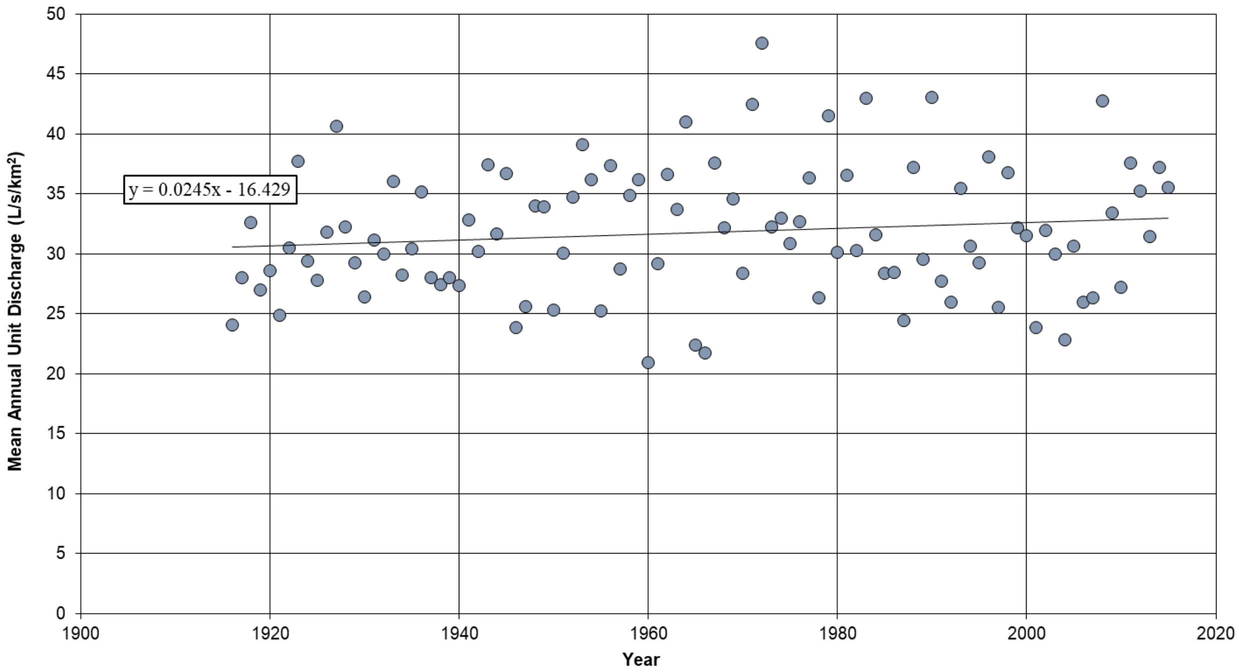


Figure 4.7 Mean Annual Unit Discharge Trend at St. Mary's River Station

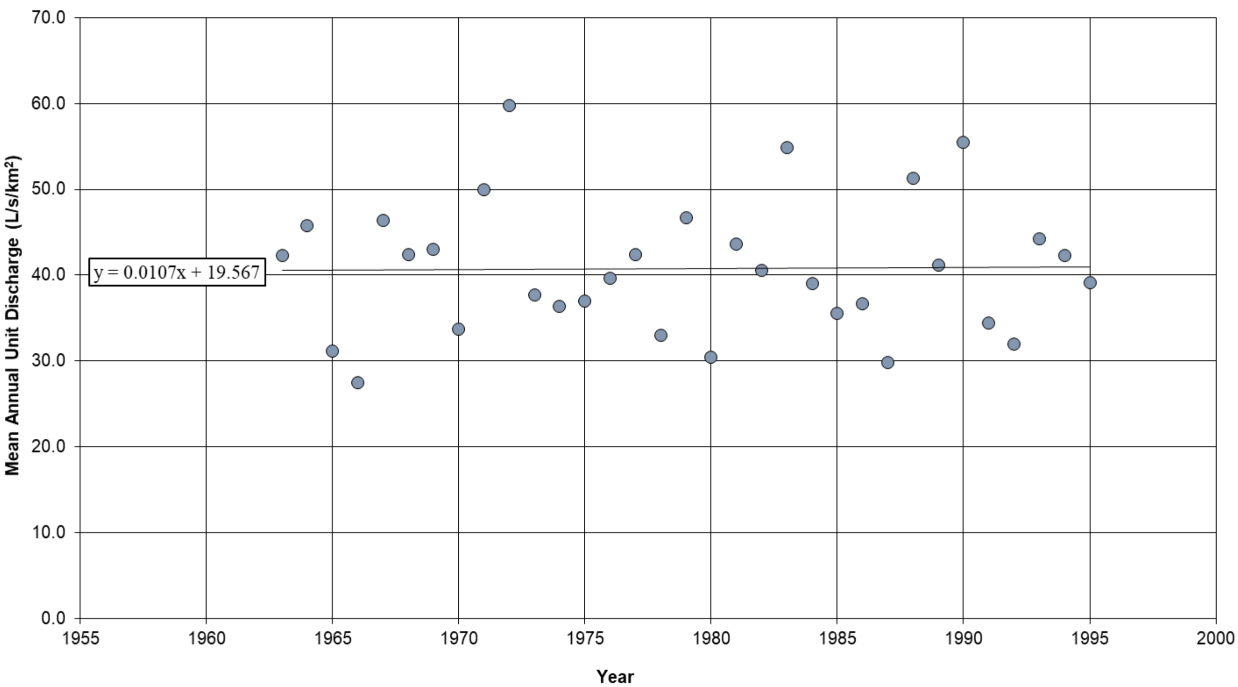


Figure 4.8 Mean Annual Unit Discharge Trend at Liscomb River Station

Figure 4.9 and Figure 4.10 present the annual peak flows in the St. Mary's River and the Liscomb River, respectively. The St. Mary's peak flow data shows an increasing trend; however, the trend is not statistically significant. The peak flow data for the Liscomb River shows a decrease of around 1.9 m^3/s per year, at a

5% significance level. Given the differences observed between these two stations, no strong conclusions can be made about whether or not peak flows are changing with time within the Project area.

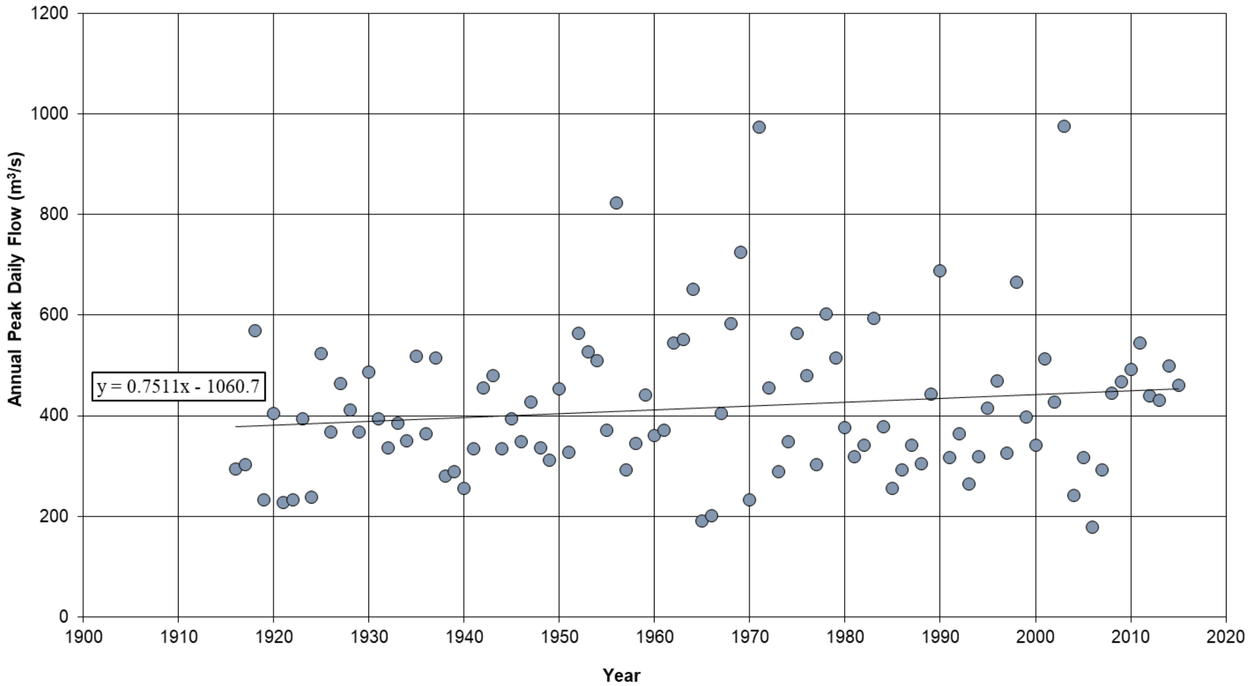


Figure 4.9 Annual Peak Flow Trend at St. Mary's River Station

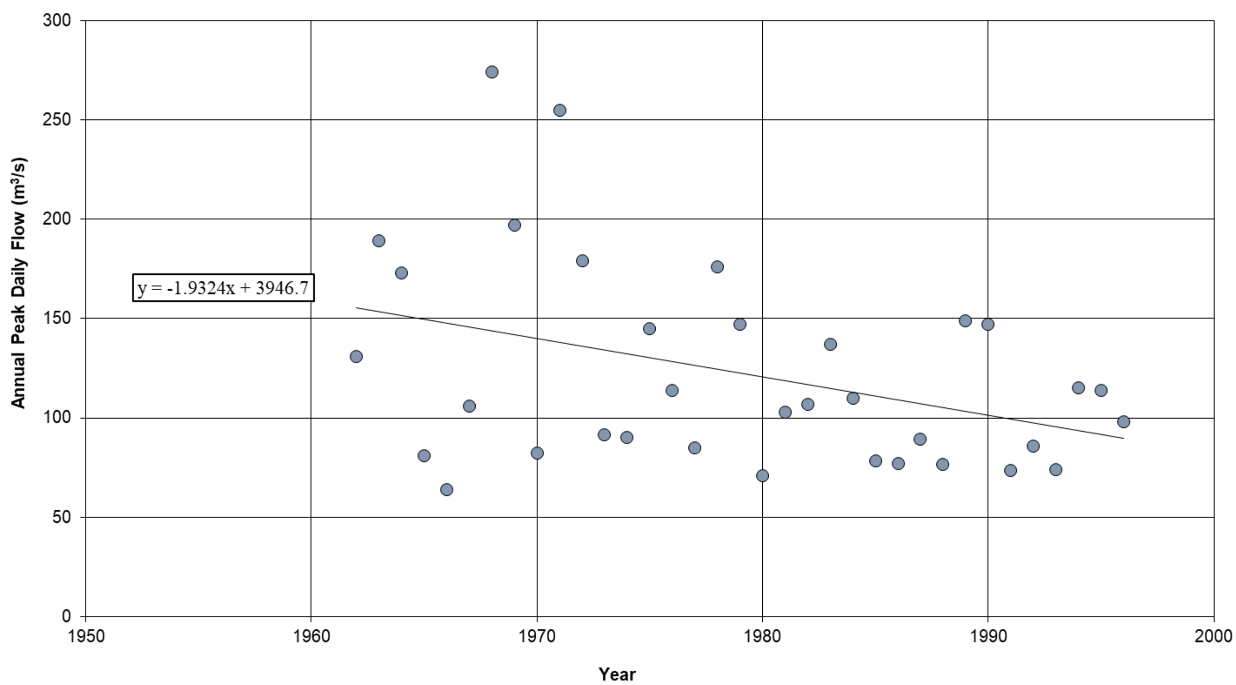


Figure 4.10 Annual Peak Flow Trend at Liscomb River Station

4.3 CLIMATE CHANGE SCENARIOS

There is a general consensus in the scientific community that the global atmosphere is warming and that worldwide climate patterns are changing as a result. There is some concern about whether or not historical flow and climate records reasonably represent conditions that might be expected through Project operations, or even longer time scales through Project closure and post-closure. Therefore, an assessment of climate change was also conducted using predicted climate change patterns for Nova Scotia, in addition to considering historic data from the Project area discussed in preceding sections.

Potential changes to mean annual precipitation and extreme precipitation events in the Project region were investigated using the University of Western Ontario's Intensity-Duration-Frequency Climate Change Tool (IDF_CC Tool). Precipitation values for the Halifax Airport station were compared to simulated values for future predicted climate conditions for the year 2056 under scenario RCP 8.5 (Representative Concentration Pathways 8.5), corresponding to the pathway with the highest greenhouse gas concentrations, which represents the upper bound of the various climate change scenarios available in the IDF_CC Tool. The resulting 24 hour storm depths and 24 hour rainfall intensity rates summarized in Table 4.1. The results suggest the region will receive more intense storms and higher total annual precipitation for different return period events.

Table 4.1 Halifax Airport Station IDF Climate Change Projections for 2056

IDF Results		Return Period (Years)					
		2	5	10	25	50	100
Based on Historical Data	Total Storm Precipitation (mm)	71	86	97	112	125	138
	24 Hour Intensity Rates (mm/h)	3.0	3.6	4.0	4.7	5.2	5.8
Under Climate Change	Total Annual Precipitation (mm)	84	107	126	159	188	222
	24 Hour Intensity Rates (mm/h)	3.5	4.4	5.2	6.6	7.8	9.2

NOTES:

1. IDF VALUES GENERATED WITH THE UNIVERSITY OF WESTERN ONTARIO'S IDF_CC TOOL.
2. A GENERALIZED EXTREME VALUE DISTRIBUTION WAS USED IN THE ANALYSIS FOR THE HISTORICAL DATA.

4.4 SUMMARY

It is not possible to make strong conclusions about future climate conditions based on the measured climate and flow data available. There appears to be a general trend towards slightly warmer temperatures in the region, while the precipitation trends between the stations are not consistent. Climate change modelling tools indicate the precipitation would increase in the future. The annual streamflow trends appear to be slightly increasing, while the trends in peak flows are not consistent between the stations. There is no compelling evidence to suggest that the climate is changing in a manner that will materially affect peak flows. However, it is generally expected by regulators and the public that climate change is addressed in peak flow analyses. The EGBC guidelines suggest that if no climate change trend is detectable in historic streamflow trends, a 10% upward adjustment factor should be used to account for future change in water input from precipitation. Conversely, a 20% upward adjustment factor should be applied in smaller drainage basins if a statistically significant trend is detected in historic streamflow trends (EGBC 2018). Considering that the trend was not statistically significant for the increase in historic peak flows, while precipitation varied and the trend analysis indicated increasing trend for some stations, a 15% uplift is suggested to be applied to the peak design flow values for design of structures that are expected to be in place for longer periods of time (e.g., longer than 30 years).

5.0 CONCLUSIONS

This report presents the climate and hydrology characterization for the MRC Phase II Expansion Projects. The analysis presented in this report is suitable for continued Project development. Site specific hydrometric monitoring should be included in the baseline monitoring program to potentially improve the understanding of hydrometric characterization of the project sites.

The assessment of the long-term meteorological conditions in the Project area is based on regional climate stations with records ranging from durations of several decades to nearly a century. After analysis of several stations, the Halifax Airport station data were selected to reasonably represent actual conditions in the Project area.

The assessment of the long-term streamflow and runoff conditions in the Project area is based on regional streamflow records spanning several decades to a century. The long-term average and statistical variability of hydrological values were assessed based on these records. After analysis of several stations, the St. Mary's at Stillwater station data are believed to reasonably represent actual conditions in the Project area.

Potential climate change trends in the Project area were assessed through a review of regional climate and streamflow trends using long-term historical records. There is a statistically significant trend towards slightly warmer temperatures, while the increases in annual stream flows are not statistically significant. Some of the stations indicate increase in precipitation, which would be consistent with annual stream flow increases; however, this trend is not evident for all the stations investigated. Despite these general increases in temperatures and streamflow, there is no compelling indication that peak flows will materially change.

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7.0 CERTIFICATION

This report was prepared and reviewed by the undersigned.

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