Niagara Region

REGIONAL MUNICIPALITY OF NIAGARA
SOUTH NIAGARA FALLS WASTEWATER SOLUTIONS

V3.5 – Assimilative Capacity Studies

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V3.5.1

REGIONAL MUNICIPALITY OF NIAGARA
SOUTH NIAGARA FALLS WASTEWATER SOLUTIONS

Assimilative Capacity Studies

ACS Modelling Approach

TECHNICAL MEMORANDUM

DATE February 2, 2022 **Project No.** 18104462

TO Barbara Slattery, EA Coordinator
Ministry of Environment, Conservation and Parks

CC GM BluePlan, Regional Municipality of Niagara
Project File

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SOUTH NIAGARA WASTEWATER SOLUTIONS CLASS ENVIRONMENTAL ASSESSMENT– SURFACE WATER DATA REVIEW AND PROPOSED ASSIMILATIVE CAPACITY MODELLING APPROACH

The Regional Municipality of Niagara (Niagara Region) is currently conducting a Municipal Class Environmental Assessment (EA) for a proposed Waste Water Treatment Plant (WWTP) in the vicinity of Chippewa Creek, Niagara. The scope of this EA also considers the potential benefits of decreasing the network flow to the existing Stanley Avenue Plant and reducing the frequency and magnitude of Combined Sewer Overflows (CSOs). As well as providing other ancillary services, Golder Associates Ltd. (Golder) has been retained to conduct an Assimilative Capacity Study (ACS) in support of the EA.

In response to a request by the Ontario Ministry of Environment, Conservation and Parks (MECP) on February 19, 2019, this technical memorandum specifically documents the water quality and flow data available to support, as well as the proposed methodology to complete, the ACS.

1.0 STUDY AREA OVERVIEW

The study area covers the southern portion of the Hydro Electric Power Canal (HEPC), the eastern portion of the Welland River East, Chippewa Creek and Canadian shoreline of the Niagara River upstream of the International Control Dam (ICD) shown on Figure 1. The geographic extent of this study area was identified as the preferred location for siting a second WWTP for the City of Niagara Falls (GMBP, 2019).

The study area is highly modified and regulated from the natural predevelopment conditions that existed prior to the 1950s. During the 1950s, the power canal was constructed from the Welland River (upstream of the Horseshoe Falls) to the Sir Adam Beck Generating Station (GS) which discharges to Niagara Gorge. As a result, the flow in last 6.5 km of the Welland River was reversed to provide water from the Niagara River to the HEPC. The amount of flow that is diverted is primarily determined by two factors that include (i) the operation of the ICD in the Niagara River that can be closed to increase the water level in the Niagara River at the mouth of Chippewa Creek and (ii) water levels at the outlet of Lake Erie that are influenced by both long-term weather patterns and through meteorological event based seiching.

In addition, construction of the Welland Canal to the west of the study area has changed the hydrology and drainage area of the Welland River as well as several small tributaries. The Welland River passes under the Welland Canal at two locations via sumps that may alter the flow in the river during high flow events. The Lyons Creek watershed area was also decreased by the Welland Canal to the extent that water is pumped from Welland Canal into Lyons Creek to maintain a minimum flow requirement.

For the purposes of maintaining consistent terminology, the key surface water features referred to in this EA and supporting studies use a naming convention typically used by MECP, the Niagara Peninsula Conservation Authority (NPCA), and Ontario Power Generation (OPG). Specifically, these features include;

- **International Control Dam (ICD):** This multi-gated dam in the Niagara River built in 1954 is located approximately 800 m above the Horseshoe Falls and is used to control flows to the Sir Adam Beck GS operated by OPG, the Robert Moses GS operated by the New York Power Authority (NYPA) and the American Falls operated according to Niagara River Treaty (1950). In other literature and documentation, the ICD has sometimes also been referred to as the International Niagara Control Works (INCW).
- **Chippewa–Grassy Island Pool (GIP):** This is the area of the Niagara River upstream of the ICD where water levels vary with upstream flow and the operation of the ICD.
- **Chippewa Creek:** This is a former portion of the Welland River between the Niagara River and the HEPC that flows from the Niagara River to the HEPC when the HEPC is in operation (e.g., reverse flow to natural conditions).
- **Hydro Electric Power Canal (HEPC):** This is a canal that conveys diverted flow from the Niagara River (via Chippewa Creek) to the Sir Adam Beck Generating Station.
- **Earth Cut Section:** This is the wide portion of the HECP dug into soil between Triangle Island and the Rock Cut Section of the HEPC.
- **Rock Cut Section:** This is the narrower and deeper section of the HECP cut into bedrock below the Earth Cut Section.
- **Welland River East:** This is the portion of the Welland River upstream of triangle island. MECP / NPCA use this convention to distinguish the sections of the Welland River east or west of the Welland Canal.

2.0 DATA REVIEW

2.1 Definition of Seasons

The ACS will be completed on a seasonal basis. Water quality and flows will be characterized for winter, spring, summer, and fall. For purposes of the ACS, the seasons will be defined as follows;

- Winter will be represented by data collected in December, January, and February,
- Spring will be represented by data collected in March, April, and May,
- Summer will be represented by data collected in June, July, and August, and,
- Fall will be represented by data collected in September, October, and November.

2.2 Summary of Data Availability

Tables 1 and 2 summarise the wealth of available flow and water quality data for the ACS, respectively.

Table 1: Summary of Available Flow Data

Source	Stations	Duration	Frequency	Source
Niagara River	USGS 04216000	1926 to 2018	Daily	USGS
Welland River West	02HA007	1957 to 2017	Daily	Water Survey of Canada
Stanley Avenue WWTP	-	2015 to 2018	Daily	Niagara Region
HEPC	Estimated[1]	2016 to 2018	Hourly	OPG

Notes:
[1] Estimated flow in HEPC provided by OPG (Kowolski, 2019).

Table 2: Summary of Available Water Quality Data

Location	Station Number	Duration	Number of Samples	Source
Welland River East at Welland Canal	WR010	2003-2018	118	NPCA
Welland River East at Montrose Road	WR011	2011-2018	55	NPCA
Power Canal near Stanley Ave. WWTP	PR001	2012-2018	50	NPCA
Lyons Creek	LY003	2003-2018	127	NPCA
Niagara River at Fort Erie	ON02HA0045	1981-1999	245	Environment Canada
Eastern Basin of Lake Erie		2012-2018	193	Environment Canada
Niagara Falls Drinking Water Plant Raw Intake Water		2016-2018	156	Niagara Region
Stanley Avenue WWTP	-	2015-2018	1,461	Niagara Region
Stanley Avenue WWTP Primary Bypass	-	2015-2018	48	Niagara Region
Stanley Avenue WWTP Secondary Bypass	-	2015-2018	103	Niagara Region

2.3 Bathymetric Data

Bathymetric data for the Welland River East and Chippewa Creek near Triangle Island are available in the form of selected transects (see Figure 2) derived from a river survey conducted by Golder on June 20 and 21, 2017 (Golder, 2018) for OPG in support of the Sir Adam Beck 1 Canal Rehabilitation Project. Currently, Golder has verbal permission to use this bathymetric data. Written approval will be obtained before the detailed modelling commences.

The primary objective of the study was to characterize the flow pattern around Triangle Island; however, incidental collection of high quality bathymetric data was also completed. A cross-sectional characterization of selected transects is included in Table 3. The transects measured by Golder were collected in the areas open to publicly access (e.g., outside safety barriers at Triangle Island).

Transects US1 and US2 were measured in the Welland River East upstream of Triangle Island while transects US3, US4, and US5 were measured around Triangle Island. Transects labelled DS1 through DS5 were measured in Chippewa Creek between Triangle Island and the Niagara River.

Based on the measured data, on the date and time when the survey was completed, flow on the south channel of Triangle Island is to the west (i.e. from Chippewa Creek).

Additional bathymetric data was collected by ASI in 2018 in the HEPC below the safety barriers. This data has been made available to Golder for completion of this study.

Table 3: Summary of Chippewa Creek & Welland River Survey (Golder, 2018)

Transect ID	Maximum Water Depth (m)	Channel Width (m)	Channel Flow (m^3/s)	Average Water Level at Fort Erie[1] (ft)
US1	3.7	86.8	14.4±3.4	561.378
US2	5.2	79.1	23.1±0.3	561.276
US3	5.8	75.3	31.1±0.6	561.276
US4	2.6	69.3	11.5±1.0	561.276
US5	12.4	127.2	361.4±9.7	561.175
DS1	12.6	125.7	436.4±8.4	561.470
DS2	12.5	124.2	430.1±9.0	561.378
DS3	12.1	100.3	404.3±3.2	561.276
DS4	11.6	88.8	386.7±5.1	561.276
DS5	10.6	87.3	385.4±11.0	561.276

Notes:

[1] Provisional data at material dock in Fort Erie provided by OPG. Water levels reported in feet relative to IGLD 1955.

2.4 Flow Data

2.4.1 Water Management in Study Area

The flow in Chippewa Creek and the HEPC has been controlled by the operation of the ICD since 1954. The ICD is jointly controlled by OPG and NYPA in accordance with the 1950 Niagara Treaty (Canada, 1950). The treaty between Canada and the United States was intended to maximize the beneficial use of the hydroelectric potential of the Niagara River while maintaining the scenic value of Niagara Falls for tourism. The treaty stipulates that;

- Any river flow diverted for hydroelectric power is to split equally between both counties.
- During tourist times, the flow over the falls must be at least 2,832 m^3/s (100,000 cfs). Tourist times are defined as 8 AM to 10 PM from April 1 to September 15 and 8 AM to 8 PM from September 16 to October 31.
- The specified minimum flow over the falls is at least 1,416 m^3/s (50,000 cfs) at all other times.
- If the upstream flow in the Niagara River is less than the specified minimum flows, no river flow is to be diverted to the power canals.

Water levels in the Chippewa-Grassy Island Pool are regulated in accordance with the 1993 Directive of the International Niagara Board of Control.

In addition, OPG is required to maintain a minimum flow of 40 m^3/s to the HEPC via Chippewa Creek to ensure that water from the Niagara River reaches the drinking water intake of the City of Niagara Falls Water Supply plant located near the junction of Chippewa Creek and the Niagara River (Kowalski, 2019). Golder believes that this minimum flow requirement does not supersede the Niagara Treaty.

2.4.2 Welland River

Regional station data was used to estimate flows for the Welland River East. Flow data for the Welland River West near Caistor Corners (station 02HA007) from Water Survey of Canada (WSC) are available from 1957 to 2017. Flows at site are calculated based on the prorated watershed area of the site (906 km^2) and the total watershed area of the gauged station (223 km^2). The Figure 3(a) presents the average, maximum, minimum and seasonal values of prorated flow for the Welland River East.

The average flow for the Welland River East is 9.3 m^3/s, and typical summer flow is 1.79 m^3/s. The peak daily flows for the period of record for fall, winter, summer, and spring are 229.47 m^3/s, 335.07 m^3/s, 172.61 m^3/s, and 391.12 m^3/s, respectively.

In addition to natural inflows from upstream drainage areas, supplemental flow is provided to the Welland River from the Old Welland Canal immediately downstream of the old siphon located approximately 15 km upstream of Triangle Island. Under normal operation, a series of ports allow approximately 14.2 m^3/s of flow from the Old Welland Canal into the Welland River (AquaSource, 2009). The water quality entering the Welland River from the canal is expected to be similar to that of Lake Erie.

2.4.3 Niagara River

Daily flow data for Niagara River at Buffalo, New York has been obtained from the USGS for Station 04216000 located in the Niagara River at Buffalo, New York for the years 1926 to 2018. Figure 3(b) shows the minimum, average, and maximum seasonal values of the flow in Niagara River.

The average flow for the Niagara River at this location is 5,804 m^3/s, and typical summer flow is 6,015 m^3/s. The peak daily flow over the period of record for fall, winter, summer, and spring are 8,466 m^3/s, 9,825 m^3/s, 7,957 m^3/s, and 8,410 m^3/s, respectively.

The average daily flow in the Niagara River did not fall below the tourist time minimum flow requirement of 2,832 m^3/s (see Section 2.4.1) over the 93-year data period.

2.4.4 Hydro Electric Power Canal (HEPC)

Flow from the Niagara River is diverted to the Sir Adam Beck GS from the Chippewa-Grassy Island Pool via four conveyances; three tunnels and the HEPC. Under normal operating conditions, each of these conveyances carries approximately one quarter of the total diverted flow.

The flow in the HEPC can vary hourly due to flow variations in the Niagara River, minimum flow requirements over the falls (See Section 2.4.1), electrical demand, and the market price for electricity.

Hourly flow data provided by OPG for a three-year period (2016 to 2018) was used as a basis for the following observations regarding the flow in the HEPC;

- The hourly flow rate ranged from 292 m^3/s to 624 m^3/s with an average of 429 m^3/s.
- Flow rates are typically highest during the summer months (446 m^3/s) and lowest in the fall (411 m^3/s).
- Typically, the flows are lowest at 4:00 AM (402 m^3/s) and highest at 6:00 PM (456 m^3/s).

2.4.5 Stanley Ave WWTP

The daily volume of the water from the Stanley Avenue WWTP was reported from 2015 to 2018. The flow rate was calculated assuming that the effluent flow rate remains constant throughout the day. The graph in Figure 3(c) presents the average, maximum and seasonal values of the calculated flow from Stanley Avenue WWTP. The average flow is 0.24 m^3/s, and typical summer flow is 0.24 m^3/s. The peak daily flow over the period of record for fall, winter, summer, and spring are 0.55 m^3/s, 0.45 m^3/s, 0.49 m^3/s, and 0.53 m^3/s, respectively.

2.4.6 Combined Sewer Overflows (CSOs) and WWTP Bypass

Niagara Region has a total of five Regional combined sewer outflows (CSOs) discharging into the HEPC from regional pumping stations. Discharges from the CSOs into the HEPC are primary triggered by storm events. The pumping stations associated with these Regional CSOs are Dorchester Road, Drummond Road, Royal Manor, and High Lift.

The Stanley Avenue WWTP is further differentiated in terms of water quality as direct overflow (i.e. no treatment) and secondary bypass (i.e. primary treatment)

The City of Niagara Falls has a total of three municipal CSO discharging to the HPEC from their sanitary and storm sewer collection systems. The locations associated with these municipal CSOs are Sinnicks Avenue, Bellevue Street, and McLeod Road.

Measured CSO flows were provided by Niagara Region for 2015 through 2018. The measured seasonal frequency and magnitude of overflows from these regional CSOs was analyzed for the period of record. The average monthly overflow volumes are shown on Figure 4 while the average number of seasonal events and the average event volumes are summarized in Table 4.

In general, the majority of CSO events occur in spring and summer, coinciding with the largest overflow magnitudes. The secondary bypass from the Stanley Avenue WWTP (receiving primary treatment) yields the largest volume and frequency, followed by those from the Stanley Avenue WWTP Overflow.

Table 4: Summary of Measured CSO Discharges (2015 to 2018)

	Dorchester Road	Drummond Road	Royal Manor	High Lift	Stanley Ave. WWTP Primary Bypass	Stanley Ave. WWTP Secondary Bypass
Average Overflow Volume (m^3/event)						
Winter	211	0	0	133	1,919	3,513
Spring	1,503	56	162	1,913	4,232	5,324
Summer	306	36	0	646	1,226	1,386
Fall	476	27	0	1,261	2,972	2,855
Average Number of Overflow Events (events/month)						
Winter	2	0	0	2	2	5
Spring	3	1	1	3	5	9
Summer	5	5	0	1	4	8
Fall	2	1	0	2	2	6

2.5 Water Quality Data

Water quality data for the Stanley Avenue WWTP and receivers were available for several locations. Most of these locations included parameters suitable to the ACS (e.g., basic chemistry, nutrients, metals, temperature, etc.).

For the initial phases of the ACS, the parameters of concern include total ammonia, unionized ammonia, nitrate, phosphorous, and e-coli. The assessment will also consider pH and water temperature as they are used to estimate unionized ammonia.

The fraction of total ammonia present in the unionized form ammonia is dependent on pH and water temperature. The equation presented by Emerson et al. (1975) permits the calculation of the unionized ammonia from the total ammonia measured in freshwater based on pH and temperature data of the samples. The method first calculates the pKa, which is the ionization constant of the ammonium ion as below:

$$pKa = 0.09018 + \frac{2729.92}{T} \quad \text{and} \quad f = {}^{1}/_{\left(10^{(pKa-PH)}+1\right)}$$

$$Unionized\ ammonia = Total\ ammonia \times f$$

Where T is the temperature in Kelvin. The equation for pKa is invalid outside the temperature range of 0-30°C.

Applicable PWQOs for the parameters discussed in this memorandum are presented in the table below. Since the study area is effectively a river, the PWQO for the avoidance of excessive plant growth in rivers and streams (0.03 mg/L) was used.

Table 5: Summary of Applicable Provincial Water Quality Objectives

Parameter	PWQO or CCME Guideline
Unionized Ammonia	0.02 mg/L as N[1]
Nitrate	3 mg/L as N[2]
pH	6.5 to 8.5[1]
E.coli.	100 cfu/100mL[1]
Total Phosphorous	■ 0.01 mg/L for protection of naturally velar lakes, ■ 0.02 mg/L to avoid nuisance algae in lakes, ■ 0.03 mg/L to avoid excessive plant growth in rivers and streams[1]
Water Temperature	10ºC above background or 30ºC for thermal discharges[1]

Notes:
1. Provincial Water Quality Objectives
2. Guideline for freshwater aquatic life in CCME Guidelines

2.5.1 Welland River East

For water quality assessment of the Welland River East, data from two monitoring stations are used.

- Immediately west (upstream) of Triangle Island at Montrose Road (WR011) with available data from 2011 to 2018; and,
- further west (upstream), where the Welland River crosses at the Welland Canal (WR010) with data from 2003 to 2018.

Water quality data for the Welland River was provided by NPCA. A summary of the seasonal water quality values for WR010 and WR011 are presented in Table 6.

Comparing the 75th percentile concentrations for both stations (Figure 5) showed that ammonia concentrations are higher at WR011 during winter/spring and that overall, the concentration of phosphorous is higher upstream in the Welland River (WR010).

The remaining parameters do not show significant differences between upstream (WR010) and downstream (WR011) monitoring stations.

Based on the data, there are frequent exceedances of the PWQOs for phosphorous and *E. coli.* in the Welland River East.

Table 6: Summary of Seasonal Water Quality Concentrations for Welland River

Parameter		Winter		Spring		Summer		Fall	
		WR010	WR011	WR010	WR011	WR010	WR011	WR010	WR011
Number of Samples		5	2	34	17	38	16	41	20
Total Ammonia (mg/L)	Geo-mean	0.21	0.47	0.16	0.16	0.14	0.07	0.11	0.10
	75th	0.23	0.59	0.21	0.28	0.23	0.09	0.20	0.16
Unionized Ammonia (mg/L)	Geo-mean	0.001	0.003	0.003	0.004	0.009	0.003	0.004	0.004
	75th	0.001	0.007	0.006	0.007	0.018	0.004	0.009	0.007
Nitrate (mg/L)	Geo-mean	1.78	2.32	0.76	0.62	0.32	0.33	0.50	0.50
	75th	2.29	2.38	1.11	0.91	0.49	0.48	1.05	0.82
E. coli. (cfu/100 mL)	Geo-mean	-	**2,473**	-	66	-	25	-	64
	75th	-	**6,920**	-	**308**	**-**	**105**	**-**	**170**
Total Phosphorous (mg/L)	Geo-mean	**0.09**	**0.12**	**0.07**	**0.05**	**0.06**	**0.04**	**0.06**	**0.04**
	75th	**0.14**	**0.13**	**0.16**	**0.09**	**0.08**	**0.06**	**0.10**	**0.08**
Water Temperature (ºC)	Geo-mean	1.78	3.39	7.54	10.4	22.6	14.2	13.5	20.9
	75th	2.10	7.72	14.4	13.9	24.2	22.9	19.7	24.1
pH	Geo-mean	7.82	7.73	8.08	7.98	8.17	8.08	8.18	8.02
	75th	7.82	7.81	8.23	8.16	8.26	8.23	8.27	8.15

Notes:

1. **Bold** values indicate exceedances of applicable PWQO.
2. Data provided by NPCA.

2.5.2 Niagara River

The water quality in the Niagara River was quantified by compiling data from three sources. Three sources were required since none of these locations offered a full complement of data for all the required parameters. The data sources were;

- The Niagara River at Fort Erie (ON02HA0045) from 1991 to 1999;
- The eastern basin of Lake Erie from 2012 to 2018; and,
- The raw water intake data for the Niagara Falls Drinking Water Supply Plant from 2016 to 2018.

Water quality data for the eastern basin of Lake Erie and the Niagara River at Fort Erie were obtained from the Environment Canada website while the water intake data was provided by Niagara Region.

The 75th percentile of seasonal values of different parameters for Niagara River and Lake Erie are presented in Table 7 below. Since *E. coli.* was not included in the measured parameters for Niagara River and Lake Erie, data collected at the drinking water intake was used.

Table 7: Summary of Seasonal Water Quality Concentrations for Niagara River and Lake Erie

Parameter		Winter			Spring			Summer			Fall		
		Niagara River[2]	Lake Erie[2]	Raw Water Intake[3]	Niagara River[2]	Lake Erie[2]	Raw Water Intake[3]	Niagara River[2]	Lake Erie[2]	Raw Water Intake[3]	Niagara River[2]	Lake Erie[2]	Raw Water Intake[3]
Number of Samples		92	192	39	92	158	39	24	157	39	37	131	39
Total Ammonia (mg/L)	Geo-mean	0.004	0.011	-	0.015	0.013	-	0.023	0.011	-	0.014	0.011	-
	75th	0.008	0.017	-	0.038	0.019	-	0.043	0.020	-	0.022	0.017	-
Unionized Ammonia (mg/L)	Geo-mean	<0.001	0.001	-	<0.001	0.001	-	0.001	<0.001	-	<0.001	0.001	-
	75th	<0.001	0.001		0.001	0.001	-	0.003	0.000	-	<0.001	0.002	-
Nitrate (mg/L)	Geo-mean	0.24	-	0.36	0.252	-	0.30	0.38	-	0.20	0.14	-	0.12
	75th	0.26	-	0.54	0.276	-	0.20	0.46	-	0.12	0.16	-	0.07
E. coli. (cfu/ 100 mL)	Geo-mean	-	-	5	-	-	3	-	-	3	-	-	5
	75th	-	-	50	-	-	12	-	-	8	-	-	26
Total Phosphorous (mg/L)	Geo-mean	0.019	0.014	-	0.017	0.016	-	0.014	0.011	-	0.015	-	-
	75th	0.025	0.020	-	0.021	0.022	-	0.015	0.019	-	0.021		-
pH	Geo-mean	7.80	8.35	-	7.90	8.27	-	8.10	7.90	-	7.90	8.38	-
	75th	8.00	8.44	-	8.10	8.49	-	8.10	8.13	-	8.00	**8.57**	-

Notes:
1. **Bold** values indicate exceedances of applicable PWQO.
2. Data obtained from Environment Canada.
3. Data provided by Niagara Region.

2.5.3 Power Canal

A summary of the measured water quality in the HEPC near the Stanley Avenue WWTP is provided in Table 8. Data were provided by NPCA for station PR001 between 2012 and 2018. Based on these data, there are frequent exceedances of the PWQOs for phosphorous and *E. coli.* in the HEPC.

Table 8: Summary of Seasonal Water Quality Concentrations in the HEPC

Parameter		Winter	Spring	Summer	Fall
Number of Samples		3	17	17	15
Total Ammonia (mg/L)	Geo-mean	0.078	0.264	0.186	0.209
	75th	0.179	0.375	0.250	0.280
Unionized Ammonia (mg/L)	Geo-mean	0.001	0.004	0.008	0.008
	75th	0.001	0.006	0.015	0.012
Nitrate (mg/L)	Geo-mean	0.37	0.21	0.14	0.12
	75th	0.51	0.27	0.22	0.16
E. coli. (cfu/100 mL)	Geo-mean	**5,780**	**283**	**115**	**570**
	75th	**7,550**	**440**	**220**	**4,200**
Total Phosphorous (mg/L)	Geo-mean	**0.042**	**0.013**	**0.015**	**0.022**
	75th	**0.059**	0.018	0.020	**0.040**
Water Temperature (°C)	Geo-mean	4.60	6.45	17.2	18.2
	75th	9.49	9.89	22.0	22.5
pH	Geo-mean	7.86	8.00	8.12	8.03
	75th	7.99	8.16	8.22	8.14

Note:
1. **Bold** values indicate exceedances of applicable PWQO.
2. Data provided by NPCA.

2.5.4 Lyons Creek

A summary of measured water quality in Lyons Creek is provided in Table 9. Data were provided by NPCA for station LY003 between 2003 and 2018. As expected for a small watershed that drains agricultural areas, the total phosphorous concentrations in Lyons Creek are elevated well above the PWQO.

Table 9: Summary of Seasonal Water Quality Concentrations for Lyons Creek

Parameter		Winter	Spring	Summer	Fall
Number of Samples		3	35	44	44
Total Ammonia (mg/L)	Geo-mean	0.059	0.051	0.047	0.041
	75th	0.059	0.110	0.079	0.060
Unionized Ammonia (mg/L)	Geo-mean	-	0.002	0.002	0.003
	75th	-	0.005	0.004	0.008
Nitrate (mg/L)	Geo-mean	0.75	0.13	0.07	0.06
	75th	0.87	0.20	0.20	0.20
E. coli. (counts/100 mL)	Geo-mean	**137**	56	44	34
	75th	**520**	95	57	88
Total Phosphorous (mg/L)	Geo-mean	**0.147**	**0.127**	**0.132**	**0.141**
	75th	**0.255**	**0.160**	**0.160**	**0.140**
Water Temperature (ºC)	Geo-mean	0.30	3.83	9.86	11.9
	75th	0.30	14.9	26.1	24.7
pH	Geo-mean	7.43	7.77	7.86	7.87
	75th	7.65	7.99	8.02	7.95

Note:

1. **Bold** values indicate exceedances of applicable PWQO.
2. Data provided by NPCA.

2.5.5 Existing Stanley Ave. WWTP, Primary Bypass, and Secondary Bypass

Water quality data and laboratory analysis were provided for the Stanley Avenue WWTP Final Effluent from 2015 to 2018 by the Niagara Region. Water quality data for the Plant Bypass (Sewage receives no treatment prior to release) and the Secondary Bypass (Sewage receives primary treatment prior to release) were also provided. The water quality data are summarized in Table 10 and presented on Figure 6.

Table 10 Summary of Seasonal Water Quality Concentrations for the Stanley Avenue WWTP Effluent, Primary Bypass and Secondary Bypass

Parameter		Winter			Spring			Summer			Fall		
		Effluent	Primary Bypass	Secondary Bypass	Effluent	Primary Bypass	Secondary Bypass	Effluent	Primary Bypass	Secondary Bypass	Effluent	Primary Bypass	Secondary Bypass
Number of Samples		361	7	18	368	18	34	368	14	31	364	9	20
Total Ammonia (mg/L)	Geo-mean	4.03	17.1	19.0	2.91	10.2	15.9	3.66	10.5	20.2	3.69	5.7	14.6
	75th	9.61	33.3	22.8	7.36	19.6	23.5	8.42	19.8	27.8	8.01	18.4	19.7
Unionized Ammonia (mg/L)	Geo-mean	0.014	-	-	0.013	-	-	0.026	-	-	0.021	-	-
	75th	**0.032**	-	-	**0.032**	-	-	**0.058**	-	-	**0.046**	-	-
Nitrate (mg/L)	Geo-mean	**6.53**	0.47	0.22	**5.91**	0.84	0.32	**5.38**	0.24	0.22	**5.71**	0.29	0.24
	75th	**9.64**	2.03	0.20	**8.61**	1.70	0.21	**7.65**	0.20	0.21	**7.82**	0.47	0.20
E. coli. (cfu/100 mL)	Geo-mean	7	-	**4,102,012**	9	**1,395,510**	**1,972,611**	6	**4,177,722**	**4,447,867**	8	**2,800,601**	**5,047,209**
	75th	13	-	-	13	**2,550,000**	**3,650,000**	10	**5,802,500**	**8,160,000**	11	**6,995,000**	**8,422,500**
Total Phosphorous (mg/L)	Geo-mean	**0.30**	**3.60**	**5.12**	**0.28**	**2.26**	**3.05**	**0.40**	**3.21**	**3.50**	**0.35**	**2.53**	**3.39**
	75th	**0.38**	**5.87**	**8.08**	**0.36**	**2.98**	**5.18**	**0.52**	**4.35**	**4.40**	**0.47**	**4.60**	**4.53**
Water Temperature (ºC)	Geo-mean	10.0	-	-	11.9	-	-	20.2	-	-	17.3	-	-
	75th	11.7	-	-	14.5	-	-	21.9	-	-	20.2	-	-
pH	Geo-mean	7.25	-	-	7.29	-	-	7.25	-	-	7.24	-	-
	75th	7.35	-	-	7.40	-	-	7.36	-	-	7.31	-	-

Note:

1. **Bold** values indicate exceedances of applicable PWQO.
2. Data provided by Niagara Region.

2.6 Data Conclusions and Generalizations

Based on the preceding characterisation of available flow and water quality data, the following conclusions are provided:

- There are no significant seasonal variations in Niagara River flow. Variations in Niagara River flow are likely related to changes in the water level in Lake Erie. These variations can either be long-term due to seasonal or interannual changes in the regional hydrology and precipitation (e.g., over entire Great Lakes basin) or short-term due to wind related events (e.g. longitudinal seiching) along Lake Erie.
- Flows in the HEPC and Chippewa Creek are controlled by the operation of the ICD and should not be represented as a natural flow regime in the ACS.
- Seasonal variations of most water quality parameters are not pronounced.
- The Niagara River has lower concentrations of ammonia, unionized ammonia and phosphorous when compared to the Welland River and Lyons Creek.
- Concentrations of *E. coli* in the CSO from the Stanley Avenue WWTP are higher than other CSOs and are typically over 100,000 times higher than concentration in WWTP effluent.
- The Welland River East and Lyon’s Creek are sizeable contributors of phosphorous in the HEPC. Dilution with water from the Niagara River results in lower phosphorous levels in the HEPC.

3.0 PROPOSED MODELLING APPROACH

The proposed modelling approach has been designed with the following objectives;

- Estimate the remaining capacity of the receiving waters to accept WWTP effluent without exceeding applicable criteria;
- Estimate the recommended effluent objectives for each of the discharge locations and compare those limits to feasible limits based on the available treatment technology;
- Provide input to the EA process regarding the selection of two preferred discharge locations based on the results of the ACS as well as hydrodynamic and bathymetric considerations;
- Provide a suitable discharge location for each of the two selected discharge locations that will ideally optimize the mixing provided by the outfall based on hydrodynamic and bathymetric considerations;
- Develop a conceptual design for the selected discharge locations and configurations based on expected plant discharge rates and hydrodynamic conditions in the study area; and,
- Estimate the lateral and downstream distance required for the effluent to become completely mixed with the flow in the receiving water.

Based on a review of the available water quality data, the modelling approach will primarily consider ammonia (total and unionized), *E. coli.* and total phosphorous. The modelling will also include water temperature and pH which are needed to estimate unionized ammonia.

Given the short retention time in Chippewa Creek and the HEPC, it is expected that most parameters will be modelled as conservative parameters (e.g., no decay or reactions). Given the complex calculations needed to represent pH, the pH in the receiving water will be based on measured seasonal values.

The modelling approach has been divided into phases, where the first phase is a simplified modelling approach to short-list the most favourable discharge locations while the second phase completes a detailed assessment of the mixing zone. The first phase of the modelling will be incorporated into the EA screening process for determining the preferred discharge location.

The first phase involves mass balance modelling to identify one to two preferred locations based on the assimilative capacity of the receiving water and the estimated effluent requirements for each location. It is expected that the recommended effluent objectives for one or more location(s) may not be preferred from a wastewater treatment perspective. The mass balance model makes several simplifying assumptions to allow the modelling approach to consider numerous scenarios in a short time frame.

The two phases of the modelling are discussed in the following sections.

3.1 Mass Balance Modelling

The mass balance modelling will consider the following four potential discharge locations;

- The Welland River East in the vicinity of Montrose Road;
- Chippewa Creek;
- The Earth Cut Section of the HEPC; and,
- The Niagara River below the ICD.

The mass balance modelling will be used to identify two preferred locations based on the assimilative capacity of the receiving water and the estimated effluent limits for each location. It is expected that the recommended effluent objectives for one or more location(s) may not be feasible limits from a water treatment perspective.

Given the complexity of the hydrodynamic conditions in the study area, the first three discharge locations (Chippewa Creek, Welland River East and HEPC) will be modelled using a stochastic approach. The fourth location, evaluating a discharge to the Niagara River, is relatively simple by comparison and will be modelled using a simple spreadsheet model.

Niagara River Location

The potential discharge of effluent to the Niagara River considers a relatively simple river discharge condition. The factors related to mixing and transport of the effluent are related to the flow in the river below the ICD. While the river flow is regulated, the expected conditions are relatively simple to quantify by using the terms of the Niagara Treaty and a nominal low flow condition in the river (e.g., $7Q_{20}$).

Since the Niagara River is wide and shallow within the study area, the mass balance modelling cannot assume that the effluent will become immediately mixed with the entire flow in the river upstream of the Horseshoe Falls. As an initial estimate, the mass balance model will assume that the effluent mixes with 10% of the total flow in the Niagara River below the ICD (e.g., do not include flow diverted to power canals) and will likely remain attached to the Canadian shoreline.

This assumption will be verified using a Gaussian Plume model that predicts the lateral mixing extent under steady state conditions as the plume moves downstream. If the Gaussian Plume shows that the effluent does not mix with at least 10% of the river flow before reaching the falls, the mass balance model will be adjusted accordingly. Alternately, the lateral mixing could also be estimated using CORMIX.

The mass balance model will be used to estimate the recommended effluent objectives for the Niagara River discharge option based on seasonal upstream water quality (75th percentile) for several flow conditions. At a minimum, the flow scenarios will include the flows outlined in the Niagara Treaty and a $7Q_{20}$ flow if it is found to be less than the flows in the treaty.

Chippewa Creek, Welland River East and HEPC

Given the highly regulated hydraulic conditions in Chippewa Creek, the HEPC, and the Welland River East, a typical low flow analysis cannot be used. The major factors controlling flow and water levels are;

- Water levels in the Niagara River at the Chippewa-Grassy Island Pool are controlled by the operation of the ICD and upstream flow.
- The operation of the ICD is determined by the terms of the Niagara Treaty and electrical power demand.
- The upstream flow in the Niagara River is controlled by the water levels in Lake Erie at Fort Erie. The water levels in Lake Erie can vary hourly during wind events (e.g., wind seiches) and can vary due to long term water balance fluctuations over the Great Lakes Basin.
- The flow in the Niagara River does not change significantly as a result of local precipitation.
- The upstream flow in the Welland River is influenced by local rainfall and snow-melt.
- The flow in Lyons Creek is also influenced by local rainfall, but the flow is augmented by pumping from the Welland Canal.

In general, the major factors controlling flow and water levels are largely independent of each other. Applying low flow conditions for each factor for a finite number of scenarios may result in overly conservative results. Since the distributions of flow, water level and water quality are neither dependent nor independent, defining suitable multi-parameter combinations from individual probability density functions is not appropriate, and, instead, a stochastic approach is warranted.

A stochastic water quantity and water quality model will be developed using GoldSim version 12.1. GoldSim is a graphical, object-oriented mathematical model where all input flows, constituents and functions are defined by the user and are built as individual objects or elements linked together by mathematical expressions. The object-based nature of the model is designed to facilitate understanding of the various factors, which control an engineered or natural system and predicted the future performance of the system. Additional information regarding GoldSim and stochastic modelling is provided in Appendix B.

In GoldSim, each flow (e.g., river flows, discharges, etc.) entering the area of interest and potentially, affecting water quantity and/or quality of the system will be itemized and assigned a source term chemical profile for selected constituents, based on measured water quality data. Inflow volumes and concentrations will be included as inputs to the system to account for loadings from major watersheds, CSOs, and WWTPs draining into the study area.

The stochastic approach was selected to account for the variability and/or uncertainty of the input parameters controlling the model associated with flow. Therefore, the seasonal probability distribution for each flow will be used as an input to the GoldSim model. The results will capture this uncertainty and provide an expected range of results.

Water quality concentrations for inflows will be based on the 75th percentile from measured water quality data.

Stochastic modelling in GoldSim is achieved using a Monte Carlo simulation approach. This approach consists of running the model for a selected number of iterations (i.e. realizations). For each realization, the stochastic inputs are randomly sampled based on their statistical distributions. At this time, it is assumed that at least 2,000 iterations will be sufficient to reach a representative and convergent distribution of results.

Recommended effluent objectives will be estimated by iteratively running the model to identify an effluent concentration that results in the water quality in the HEPC meeting a criterion (e.g., PWQO) for each of the water quality parameters at the discharge of the HEPC into the Niagara River (e.g., at Sir Adam Beck GS) at a specific frequency.

In a typical assimilative capacity assessment, the recommended effluent objectives are estimated for a low flow condition that occurs for one week every 20 years (i.e., 7Q20) or one out of every 1,040 weeks (e.g., 0.1% of the time). GoldSim will be used to estimate the allowable effluent objectives that will result in exceedances of the criteria no more that 0.1% of the. This target percentage should be confirmed by MECP before the modelling commences.

Golder has evaluated the statistical distribution of flows and considered that seasonal distributions would be required to capture the variability of most of the inflows. For water quality, the amount and variability of water quality data suggests using an annual distribution is appropriate.

The majority of the flows will be statistically characterized by using a seasonal log-normal distribution. Given the low seasonal variably in the discharge from the Stanley Avenue WWTP, a unique log-normal distribution will be used to characterize this inflow for the entire year.

Given the high variability in discharge magnitude and frequency from CSOs, its characterization was based on probability of occurrence, itself based on the frequency of bypasses for each individual CSO. CSO discharge events will be based on a seasonal distribution of event magnitudes, the effects of the CSOs will not be considered when estimating the recommended effluent objectives. However, the CSOs will be included in the evaluation of the options to be included in the EA.

A schematic of the GoldSim model is included in Figure 7. The model will represent the following elements for flow and water quality:

- Welland River East
- Thompsons Creek
- Chippewa Creek
- Lyon’s Creek
- Hydro Electric Power Canal (HEPC)

- Niagara River
- Existing Niagara Falls Waste Water Treatment Plant (WWTP)
- CSOs discharging to HEPC (not used for estimation of recommended effluent objectives)
  - Niagara Region CSOs: Drummond Road PS; Royal Manor PS; Dorchester Road PS; High Lift PS; and Niagara Falls Waste Water Treatment Plant (overflow and by-pass)
  - City of Niagara Falls CSOs: Sinnicks Ave.; Bellevue Rd.; and McLeod Rd

Seasonal concentrations will be used to characterize the chemistry of inflows. The model allows the user to select average concentration (e.g., geometric mean) or 75th percentile for the water quality prediction. The model was designed to predict results for the following water quality constituents:

- Conventional constituents: TDS, TSS, and water temperature
- Nutrients: Nitrate, total ammonia, un-ionized ammonia (calculated), and total phosphorous
- Fecal coliforms (*E. coli.*)

Given the complex calculations required to predict pH, the model will assume seasonal averages based on measured values at selected locations.

The flow and water quality models are designed to predict constituent concentrations on a daily timestep.
The model is run iteratively for 200 realizations using the aforementioned Monte Carlo simulation. At each time step and iteration, a unique value is calculated based on randomly selected values for each of the stochastic inputs 200 times. Following the model run, average and range between the 1st and 99th percentile estimated concentrations is calculated based on the 200 values calculated at each time step, to assess the range of conditions that could occur in each source.

3.2 Detailed Dispersion Modelling

Detailed hydrodynamic and dispersion modelling will be completed for the short-listed discharge locations (one to two locations) that have been identified following the mass balance approach outlined above together with other socio-economic considerations.

The detailed modelling component will provide a comprehensive assessment of the proposed discharge. The detailed modelling will assess the mixing characteristics of the effluent in the receiving water as a result of time varying flow conditions, outfall design, and effluent buoyancy. Key outcomes of the detailed modelling will include effluent concentrations at selected locations in the area, the lateral spreading of the effluent (e.g., mixing zone), and an assessment of the effects of potential flow reversals.

The detailed modelling will be completed in two phases. The first phase includes the development and application of a 2-D hydrodynamic model to predict the current speeds and directions in the study area as a result of variations in flow and water levels. The second phase includes the use of a mixing zone model to predict the performance of the proposed outfall and the mixing of the effluent in the immediate area around the outfall location based on selected diffuser configurations.

3.2.1 Scenario Selection

While the stochastic method used in the mass balance modelling will consider many combinations of flow conditions, the detailed modelling will be limited to a finite number of scenarios. The selection of these scenarios will depend on several factors including but not limited to;

- Average and low-flow conditions in unregulated water courses (e.g., Welland River East and Lyons Creek)
- Minimum, typical, and maximum possible flows in the HEPC;
- Seasonal variations in the allowable flow diverted to the HEPC under the Niagara Treaty;
- Measured water levels in the Chippewa-Grassy Island Pool;
- Possible backwater effects upstream into the Welland River East as a result of operation of the ICD (e.g., a sudden increase in water level in the Niagara River may cause a flow reversal in the Welland River East upstream of Triangle Island);
- Seasonal temperatures in the Welland and Niagara Rivers, and,
- Expected effluent discharge rates from the proposed WWTP.

The scenarios will also include the selection of the outfall location that specify the depth of water and the distance from shore. The selection of the location will consider bathymetry, sediment type, and the currents in the area estimated using the 2-dimensional hydraulic model (see following section).

The selection of the final scenarios considered in the detailed modelling will be developed based on subsequent data analysis and will be documented in a technical memorandum for discussion. Agreement of the final scenarios from the MECP and Niagara Region is preferred before detailed modelling begins.

3.2.2 2-Dimensional Hydraulic Modelling

A 2-dimensional hydraulic model will be developed to predict the current speed and direction in the study area based on varying water levels in the Niagara River and inflows. HEC-RAS 2D is the proposed software for completion of the 2-D hydraulic modelling.

The hydrodynamic model will encompass Chippewa Creek, the Earth Cut Section of the HEPC, and at least 2 km of the Welland River East. The model will also include a section of the Rock Cut Section of the HEPC (e.g., just below the Montrose Gate).

The model will be verified using the flow measurements collected in 2017 by Golder in Chippewa Creek and the Welland River East.

The model output will be used to;

- Estimate the low, typical, and high current speeds at the selected discharge locations (to be used in the mixing zone assessment);
- Estimate the duration of current speed events (e.g., how long specific current speeds persist before they change); and,

- Identify conditions that may result in the accumulation of effluent due to stagnant, slow moving, or reversing flows.

3.2.3 CORMIX Modelling

A mixing zone study will be completed to assess the near-field water quality effects of the proposed WWTP discharge. For this study, the near-field area is defined as the area where the mixing of the effluent with the receiving water is influenced by the outfall design and effluent quality. The mixing zone assessment will be completed using CORMIX. CORMIX is a commercially available software package (MixZon) that was originally developed by the USEPA to predict the mixing of a discharge into a water body based on the design of the outfall, effluent quality, and ambient conditions.

The mixing zone assessment considers the following two defined mixing zones:

- The turbulent mixing zone is the region where the dissipation of energy from the discharge (e.g., exit velocity) results in turbulence and rapid mixing of the effluent. The turbulent mixing zone is predominantly determined by the design of the outfall and is considered in this assessment to consider any potential interaction of the plume with the water surface and sediment or velocity effects on aquatic species. The size of the turbulent mixing zone is not typically defined by regulations or guidelines.
- The regulated mixing zone is a region defined by applicable regulations or guidelines as an area where the water quality is permitted to exceed applicable criteria. Water quality at the edge or outside of the regulated mixing zone is expected to meet the criteria. The size of the regulated mixing zone can be determined as finite distance, a fraction of the surface area of the water body or defined by a regulatory agency. In most cases, the size of the regulated mixing zone is independent of the turbulent mixing zone.

The mixing zone assessment has three primary components:

- **Conceptual Outfall Design:** A conceptual design for the outfall will be developed to maximize the initial mixing of the effluent, minimize the size of the mixing zone, reduce the potential for the plume contacting the sediment, and reduce the potential for interference recreational use (e.g., navigation, thin ice cover due to surface currents). The design will also consider design constraints provided by other disciplines (e.g., sensitive habitat) and the design team. The conceptual design will be documented in a separate memorandum that outlines the location of the outfall (depth, distance offshore, height above bottom), outfall configuration (number of ports, port diameter, port orientating), and design flow (minimum and maximum flows to ensure proper operation).
- **Predicted Effects of Effluent Discharge:** Based on the conceptual outfall design and the predicted effluent quality is provided by the design team, the extent of the water quality of the discharge will be estimated using CORMIX. The effects will be assessed at the edge of the regulated mixing zone and other key locations that lie within the predictions provided by CORMIX. The model results will also be used to produce a figure showing the dilution of the effluent with distance from the outfall.
- **Estimation of Recommended Effluent Objectives:** The CORMIX model will be used to provide a second estimate of the recommended effluent objectives on a seasonal basis such that the predicted water quality at the edge of the regulated mixing zone meets the applicable criteria. This analysis will also support subsequent discussions regarding the permitting of the project.

4.0 CLOSURE

We trust that this technical memorandum meets your needs at this time. If you have any questions, please do not hesitate to contact the undersigned.

Yours truly,

Greg Rose, BSc (Hons) MSc
Associate, Senior Water Resources Specialist

Gerard Van Arkel, MEng, PEng
Associate, Senior Water Resources Engineer

GR/MLE/GVA/SK/mp

Attachments:	Appendix A – Figures
	Appendix B - Stochastic Modelling in GoldSim

https://golderassociates.sharepoint.com/sites/29902g/deliverables/01_data_review_&_modelling_approach_to_mecp/final/18104462-tm-rev0-data review modelling approach-02feb2022.docx

REFERENCES

AquaSource. 2009. Water Availability Study for the Central Welland River, Big Forks Creek, and Beaverdams Shriners Creeks Watershed Plan Areas Niagara Peninsula Source Protection Area. A report prepared for the Niagara Peninsula Conservation Authority. January 23, 2009.

Canada. 1950. Treaty Between Canada and the United States of America Concerning the Diversion of the Niagara River (E100418). Signed October 10, 1950.

GMBP. 2017. City of Niagara Falls Pollution Prevention & Control Plan Study Update. GM BluePlan Engineering Limited. November 2017.

Golder. 2018. Welland River Survey, Sir Adam Beck 1 Canal Rehabilitation Project. Golder Associates Ltd., June 26, 2018.

Kowolski, P. 2019. Personal communication with Peter Kowolski (Peter Kowolski Consulting Inc.) on February 11, 2019.

APPENDIX A

Figures

SOUTH NIAGARA WASTEWATER SOLUTIONS CLASS ENVIRONMENTAL ASSESSMENT

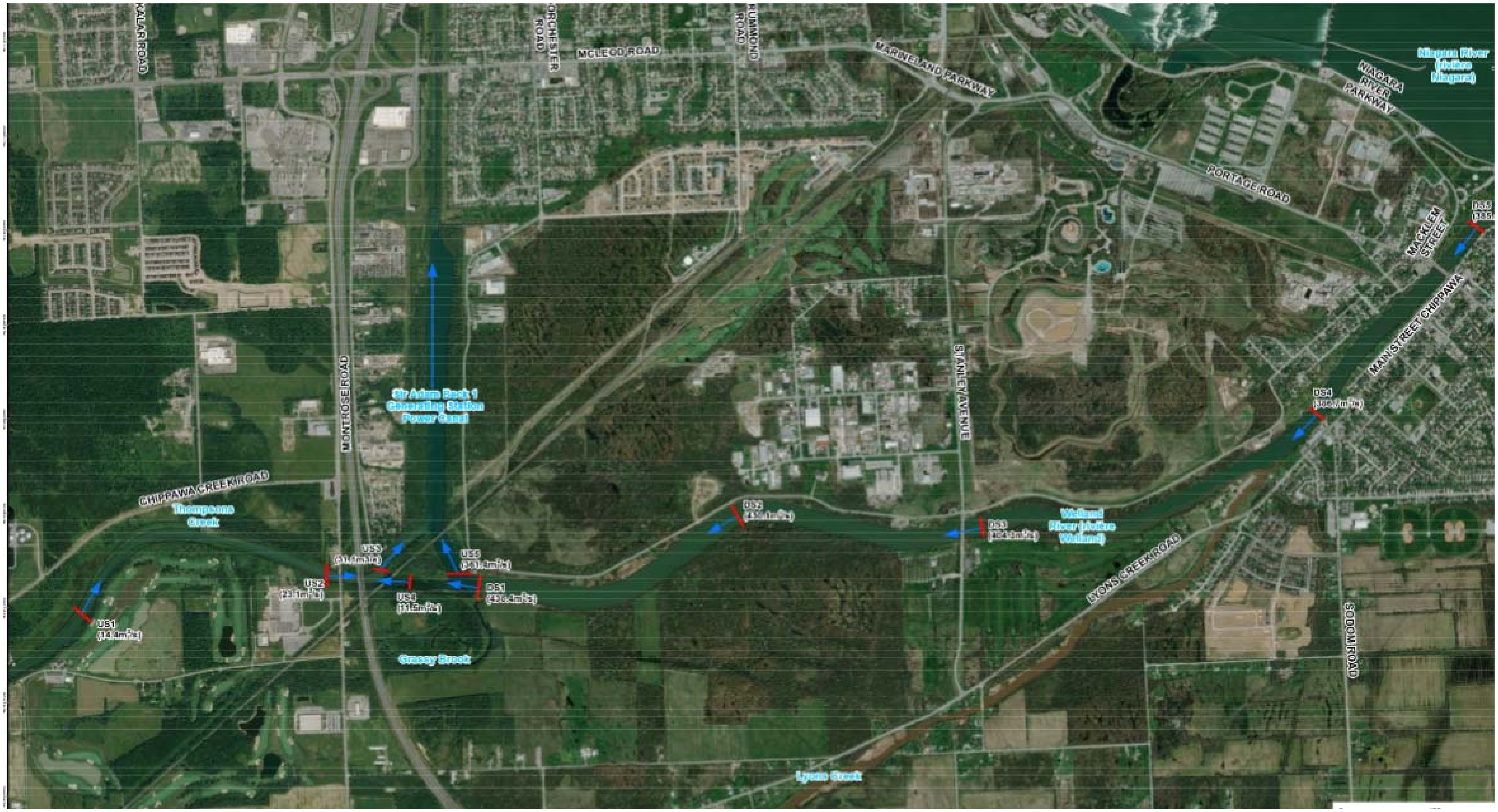
GOLDER

FIGURE: 1

Project Study Area Showing Key Surface Water Features

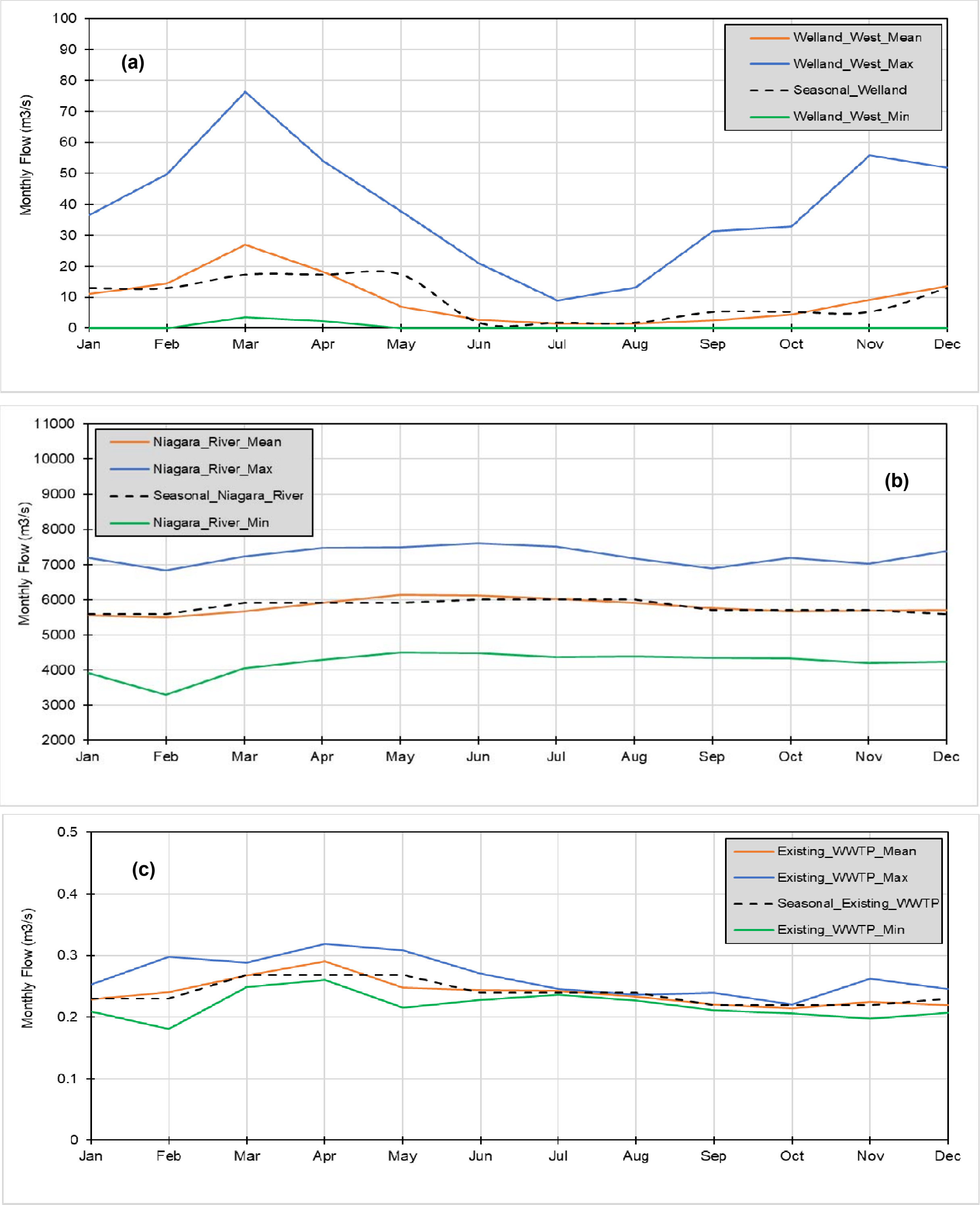
DATE: March 2019	
PROJECT NO: 18104462	
DRAWN: MLE	CHECK: GR

NIAGARA



GOLDER	FIGURE: 2	DATE: February 2019	
	GoldSim model schematic	PROJECT NO: 18104462	
		DRAWN: MLE	CHECK: GR

SOUTH NIAGARA WASTEWATER SOLUTIONS CLASS ENVIRONMENTAL ASSESSMENT



GOLDER

FIGURE: 3

Monthly and seasonal variation of flows of (a) Welland River (b) Niagara River (c) Old WWT

DATE: March 2019

PROJECT NO: 18104462

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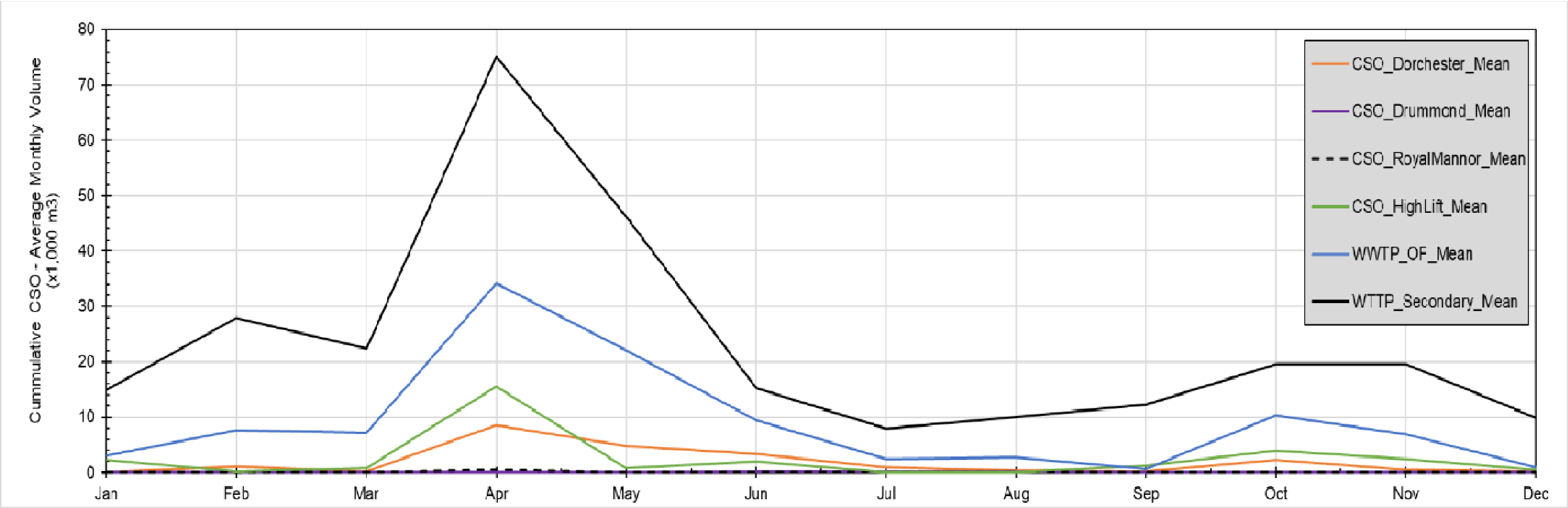
SOUTH NIAGARA WASTEWATER SOLUTIONS CLASS ENVIRONMENTAL ASSESSMENT



GOLDER

FIGURE: 4

CSO and Bypass flow estimates

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PROJECT NO: 18104462
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SOUTH NIAGARA WASTEWATER SOLUTIONS CLASS ENVIRONMENTAL ASSESSMENT

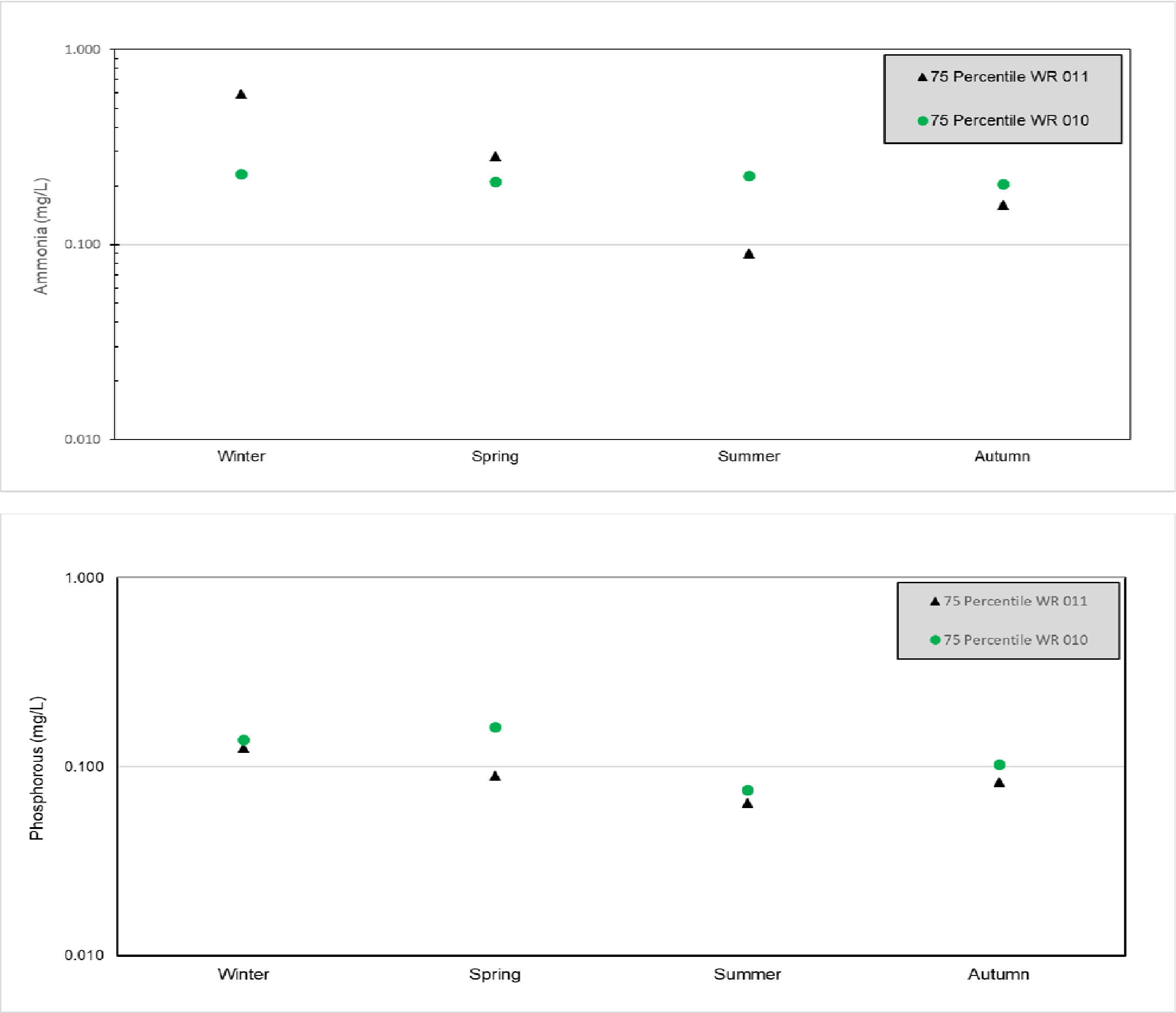

FIGURE: 5

Monthly and seasonal variation of flows of (a) Welland River (b) Niagara River (c) Old WWT

DATE: March 2019

PROJECT NO: 18104462

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SOUTH NIAGARA WASTEWATER SOLUTIONS CLASS ENVIRONMENTAL ASSESSMENT

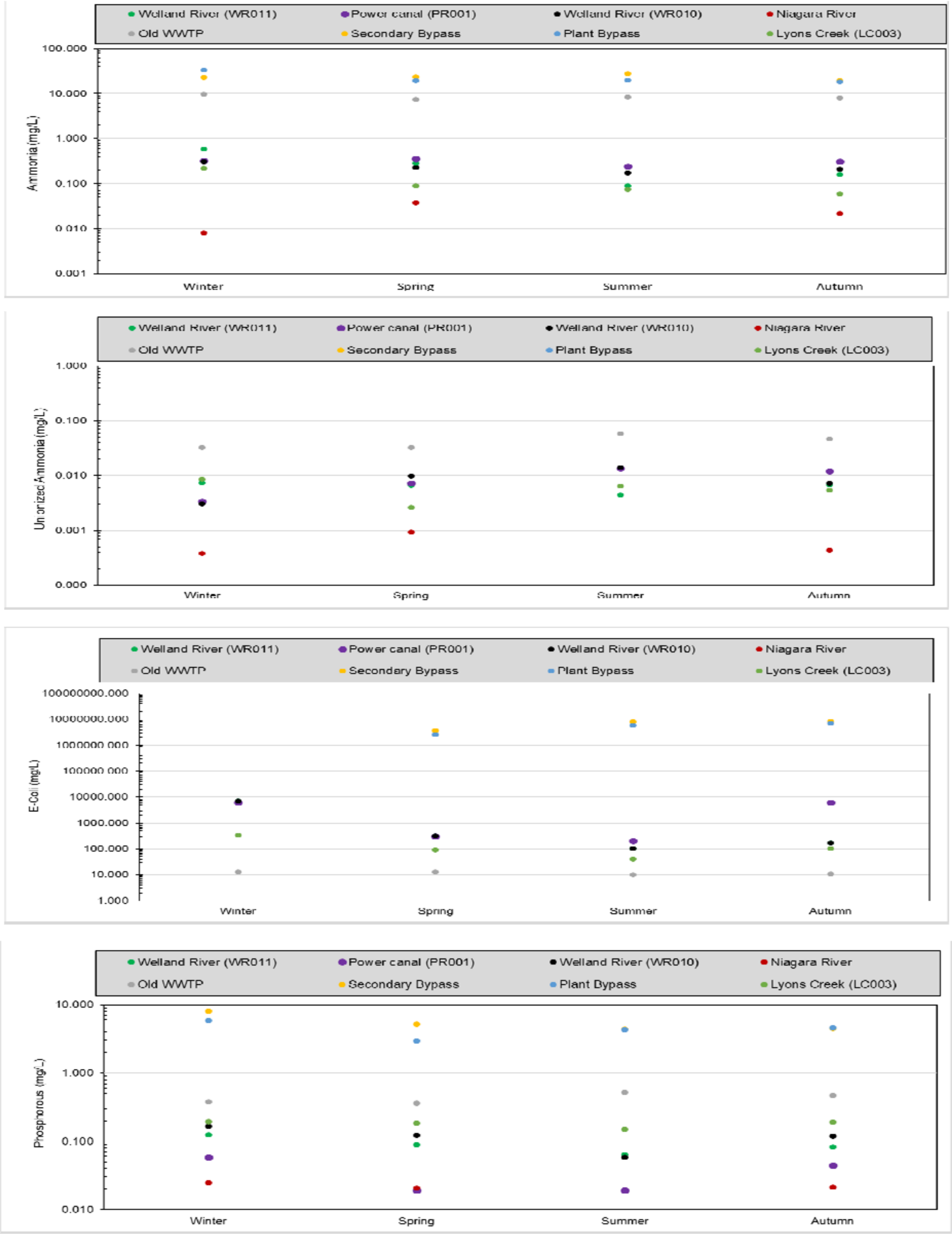

FIGURE: 6

Comparison of different parameters amount in different sources

DATE: March 2019

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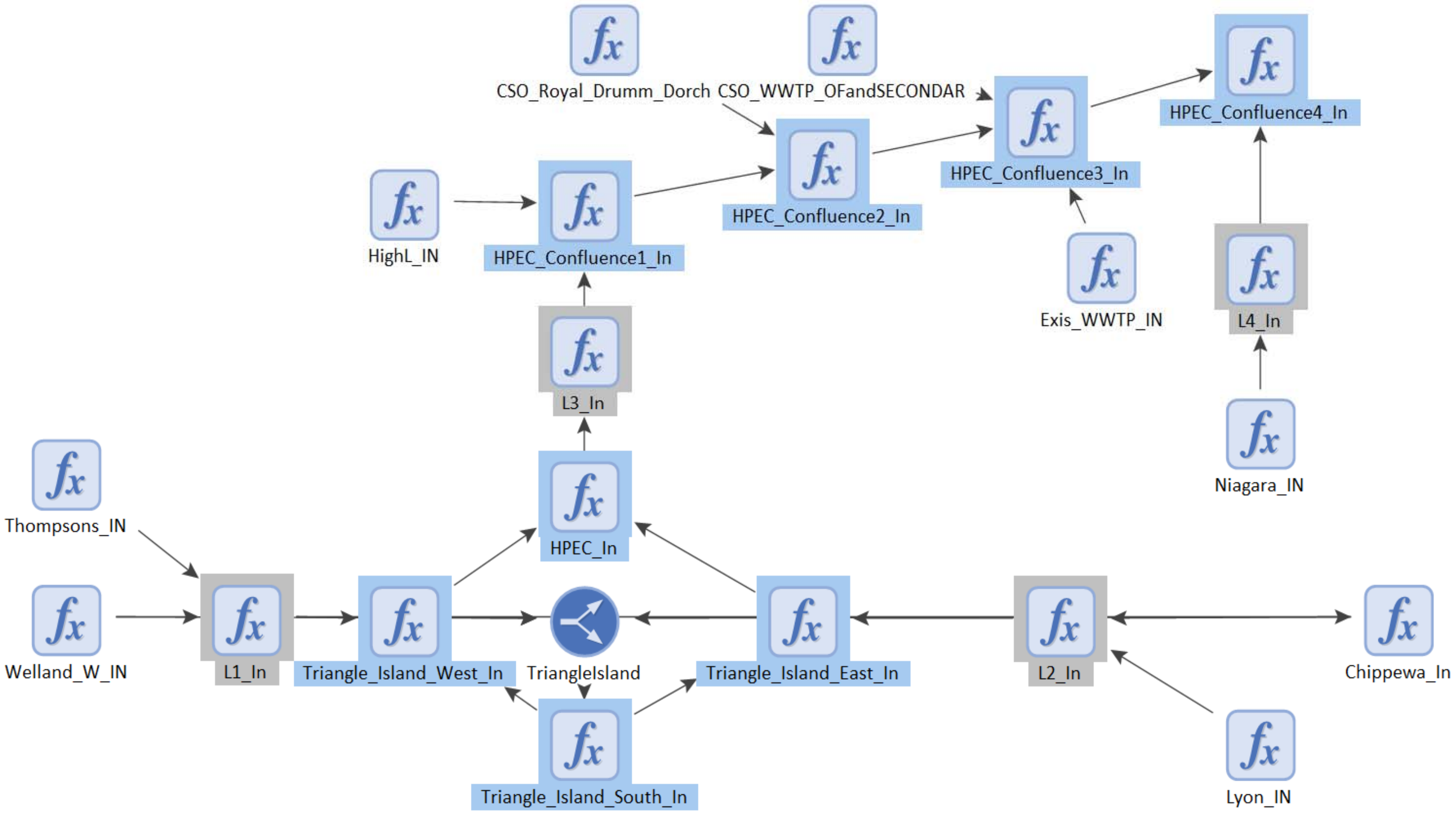
SOUTH NIAGARA WASTEWATER SOLUTIONS CLASS ENVIRONMENTAL ASSESSMENT



GOLDER

FIGURE: 7

GoldSim model schematic

DATE: March 2019

PROJECT NO: 18104462

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APPENDIX B

Stochastic Modelling in GoldSim

Appendix A: Introduction to Probabilistic Simulation

Appendix Overview

This appendix provides a very brief introduction to probabilistic simulation (the quantification and propagation of uncertainty). Because detailed discussion of this topic is well beyond the scope of this appendix, readers who are unfamiliar with this field are strongly encouraged to consult additional literature. A good introduction to the representation of uncertainty is provided by Finkel (1990) and a more detailed treatment is provided by Morgan and Henrion (1990). The basic elements of probability theory are discussed in Harr (1987) and more detailed discussions can be found in Benjamin and Cornell (1970) and Ang and Tang (1984).

In this Appendix

This appendix discusses the following:

- Types of Uncertainty
- Quantifying Uncertainty
- Propagating Uncertainty
- A Comparison of Probabilistic and Deterministic Analyses
- References

Types of Uncertainty

Many of the features, events and processes which control the behavior of a complex system will not be known or understood with certainty. Although there are a variety of ways to categorize the sources of this uncertainty, for the purpose of this discussion it is convenient to consider the following four types:

- Value (parameter) uncertainty: The uncertainty in the value of a particular parameter (e.g., a geotechnical property, or the development cost of a new product);
- Uncertainty regarding future events: The uncertainty in the ability to predict future perturbations of the system (e.g., a strike, an accident, or an earthquake).
- Conceptual model uncertainty: The uncertainty regarding the detailed understanding and representation of the processes controlling a particular system (e.g., the complex interactions controlling the flow rate in a river); and
- Numerical model uncertainty: The uncertainty introduced by approximations in the computational tool used to evaluate the system.

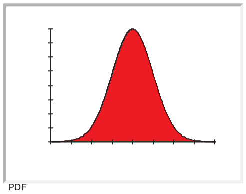
Incorporating these uncertainties into the predictions of system behavior is called *probabilistic analysis* or in some applications, *probabilistic performance assessment*. Probabilistic analysis consists of explicitly representing the uncertainty in the parameters, processes and events controlling the system and propagating this uncertainty through the system such that the uncertainty in the results (i.e., predicted future performance) can be quantified.

Quantifying Uncertainty

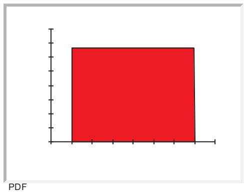
Understanding Probability Distributions

When uncertainty is quantified, it is expressed in terms of ***probability distributions***. A probability distribution is a mathematical representation of the relative likelihood of an uncertain variable having certain specific values.

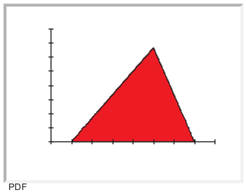
There are many types of probability distributions. Common distributions include the normal, uniform and triangular distributions, illustrated below:



Normal Distribution



Uniform Distribution

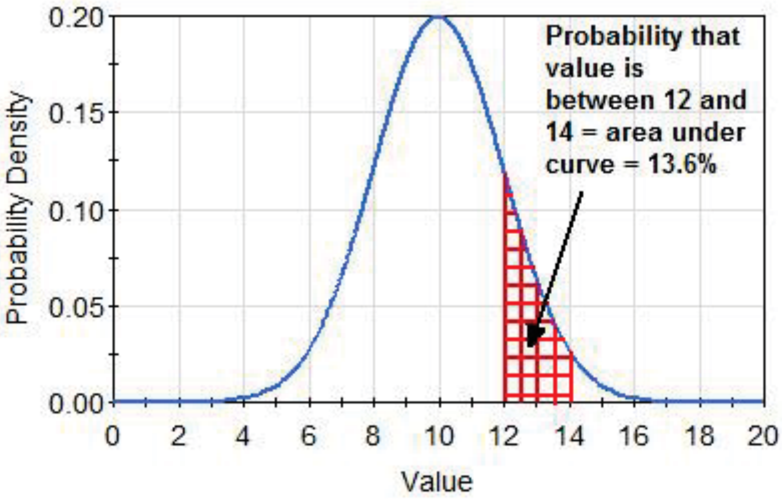


Triangular Distribution

All distribution types use a set of *arguments* to specify the relative likelihood for each possible value. For example, the normal distribution uses a ***mean*** and a ***standard deviation*** as its arguments. The mean defines the value around which the bell curve will be centered, and the standard deviation defines the spread of values around the mean. The arguments for a uniform distribution are a minimum and a maximum value. The arguments for a triangular distribution are a minimum value, a most likely value, and a maximum value.

The nature of an uncertain parameter, and hence the form of the associated probability distribution, can be either *discrete* or *continuous*. Discrete distributions have a limited (discrete) number of possible values (e.g., 0 or 1; yes or no; 10, 20, or 30). Continuous distributions have an infinite number of possible values (e.g., the normal, uniform and triangular distributions shown above are continuous). Good overviews of commonly applied probability distributions are provided by Morgan and Henrion (1990) and Stephens et al. (1993).

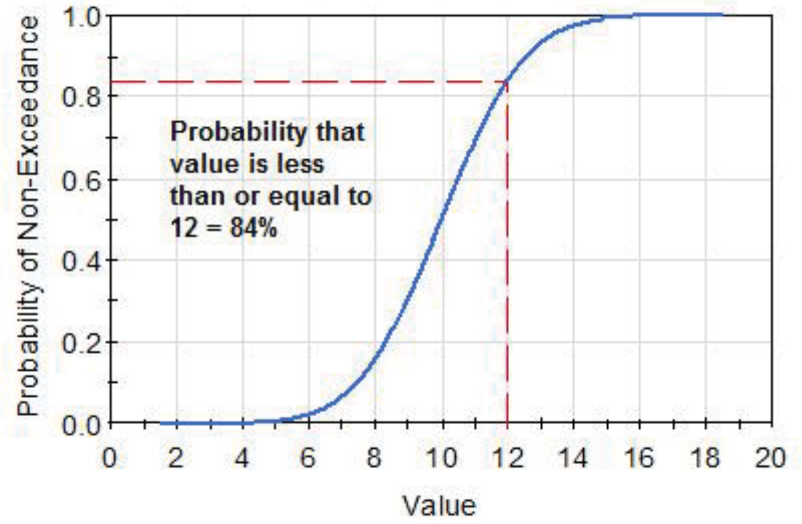
There are a number of ways in which probability distributions can be graphically displayed. The simplest way is to express the distribution in terms of a ***probability density function*** (PDF), which is how the three distributions shown above are displayed. In simple terms, this plots the relative likelihood of the various possible values, and is illustrated schematically below:



Note that the “height” of the PDF for any given value is *not* a direct measurement of the probability. Rather, it represents the *probability density*, such that integrating under the PDF between any two points results in the probability of the actual value being between those two points.

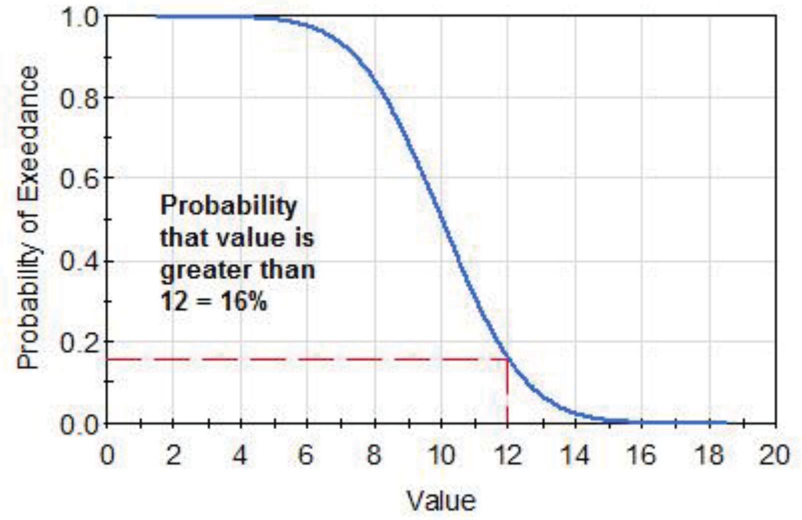
Note: Discrete distributions are described mathematically using probability mass functions (pmf), rather than probability density functions. Probability mass functions specify actual probabilities for given values, rather than probability densities.

An alternative manner of representing the same information contained in a PDF is the ***cumulative distribution function*** (CDF). This is formed by integrating over the PDF (such that the slope of the CDF at any point equals the height of the PDF at that point). For any value on the horizontal axis, the CDF shows the cumulative probability that the variable will be less than or equal to that value. That is, as shown below, a particular point, say [12, 0.84], on the CDF is interpreted as follows: the probability that the value is less than or equal to 12 is equal to 0.84 (84%).



By definition, the total area under the PDF must integrate to 1.0, and the CDF therefore ranges from 0.0 to 1.0.

A third manner of presenting this information is the ***complementary cumulative distribution function*** (CCDF). The CCDF is illustrated schematically below:



A particular point, say [12, 0.16], on the CCDF is interpreted as follows: the probability that the value is greater than 12 is 0.16 (16%). Note that the CCDF is simply the complement of the CDF; that is, in this example 0.84 is equal to 1 – 0.16.

Probability distributions are often described using *quantiles* or *percentiles* of the CDF. Percentiles of a distribution divide the total frequency of occurrence into hundredths. For example, the 90th percentile is that value of the parameter below which 90% of the distribution lies. The 50th percentile is referred to as the ***median***.

Characterizing Distributions

Probability distributions can be characterized by their *moments*. The first moment is referred to as the ***mean*** or ***expected value***, and is typically denoted as μ. For a continuous distribution, it is computed as follows:

$$\mu = \int x\ f(x)\ dx$$

where f(x) is the probability density function (PDF) of the variable. For a discrete distribution, it is computed as:

$$\mu = \sum_{i=1}^{N} x_i p(x_i)$$

in which $p(x_i)$ is the probability of x_i, and N is the total number of discrete values in the distribution.

Additional moments of a distribution can also be computed. The nth moment of a continuous distribution is computed as follows:

$$\mu_n = \int (x - \mu)^n \ f(x) \ dx$$

For a discrete distribution, the nth moment is computed as:

$$\mu_n = \sum_{i=1}^{N} (x_i - \mu)^n \ p(x_i)$$

The second moment is referred to as the ***variance***, and is typically denoted as σ^2. The square root of the variance, σ, is referred to as the ***standard deviation***. The variance and the standard deviation reflect the amount of spread or dispersion in the distribution. The ratio of the standard deviation to the mean provides a dimensionless measure of the spread, and is referred to as the ***coefficient of variation***.

The ***skewness*** is a dimensionless number computed based on the third moment:

$$\text{skewness} = \frac{\mu_3}{\sigma^3}$$

The skewness indicates the symmetry of the distribution. A normal distribution (which is perfectly symmetric) has a skewness of zero. A positive skewness indicates a shift to the right (and example is the log-normal distribution). A negative skewness indicates a shift to the left.

The ***kurtosis*** is a dimensionless number computed based on the fourth moment:

$$\text{kurtosis} = \frac{\mu_4}{\sigma^4}$$

The kurtosis is a measure of how "fat" a distribution is, measured relative to a normal distribution with the same standard deviation. A normal distribution has a kurtosis of zero. A positive kurtosis indicates that the distribution is more "peaky" than a normal distribution. A negative kurtosis indicates that the distribution is "flatter" than a normal distribution.

Specifying Probability Distributions

Given the fact that probability distributions represent the means by which uncertainty can be quantified, the task of quantifying uncertainty then becomes a matter of assigning the appropriate distributional forms and arguments to the uncertain aspects of the system. Occasionally, probability distributions can be defined by fitting distributions to data collected from experiments or other data collection efforts. For example, if one could determine that the uncertainty in a particular parameter was due primarily to random measurement errors, one might simply attempt to fit an appropriate distribution to the available data.

Most frequently, however, such an approach is not possible, and probability distributions must be based on *subjective assessments* (Bonano et al., 1989; Roberds, 1990; Kotra et al., 1996). Subjective assessments are opinions and judgments about probabilities, based on experience and/or knowledge in a specific area, which are consistent with available information. The process of developing these assessments is sometimes referred to as *expert elicitation*. Subjectively derived probability distributions can represent the opinions of individuals or of groups. There are a variety of methods for developing subjective probability assessments, ranging from simple informal techniques to complex and time-consuming formal methods. It is beyond the scope of this document to discuss these methods. Roberds (1990), however, provides an overview, and includes a list of references. Morgan and Henrion (1990) also provide a good discussion on the topic.

A key part of all of the various approaches for developing subjective probability assessments is a methodology for developing (and justifying) an appropriate probability distribution for a parameter in a manner that is logically and mathematically consistent with the level of available information. Discussions on the applicability of various distribution types are provided by Harr (1987, Section 2.5), Stephens et al. (1993), and Seiler and Alvarez (1996). Note that methodologies (Bayesian updating) also exist for updating an existing probability distribution when new information becomes available (e.g., Dakins, et al., 1996).

Correlated Distributions

Frequently, parameters describing a system will be *correlated* (inter-dependent) to some extent. For example, if one were to plot frequency distributions of the height and the weight of the people in an office, there would likely be some degree of positive correlation between the two: taller people would generally also be heavier (although this correlation would not be perfect).

The degree of correlation can be measured using a ***correlation coefficient***, which varies between 1 and -1. A correlation coefficient of 1 or -1 indicates perfect positive or negative correlation, respectively. A positive correlation indicates that the parameters increase or decrease together. A negative correlation indicates that increasing one parameter decreases the other. A correlation coefficient of 0 indicates no correlation (the parameters are apparently independent of each other). Correlation coefficients can be computed based on the actual values of the parameters (which measures linear relationships) or the rank-order of the values of the parameters (which can be used to measure non-linear relationships).

One way to express correlations in a system is to directly specify the correlation coefficients between various model parameters. In practice, however, assessing and quantifying correlations in this manner is difficult. Oftentimes, a more practical way of representing correlations is to explicitly model the cause of the dependency. That is, the analyst adds detail to the model such that the underlying functional relationship causing the correlation is directly represented.

For example, one might be uncertain regarding the solubility of two contaminants in water, while knowing that the solubilities tend to be correlated. If the main source of this uncertainty was actually uncertainty in pH conditions, and the solubility of each contaminant was expressed as a function of pH, the distributions of the two solubilities would then be explicitly correlated. If both solubilities increased or decreased with increasing pH, the correlation would be positive. If one decreased while one increased, the correlation would be negative.

Ignoring correlations, particularly if they are very strong (i.e., the absolute value of the correlation coefficient is close to 1) can lead to physically unrealistic simulations. In the above example, if the solubilities of the two contaminants were positively correlated (e.g., due to a pH dependence), it would be physically inconsistent for one contaminant's solubility to be selected from the high end of its possible range while the other's was selected from the low end of its possible range. Hence, when defining probability distributions, it is critical that the analyst determine whether correlations need to be represented.

Variability and Ignorance

When quantifying the uncertainty in a system, there are two fundamental causes of uncertainty which are important to distinguish: 1) that due to inherent variability; and 2) that due to ignorance or lack of knowledge. IAEA (1989) refers to the former as "Type A uncertainty" and the latter as "Type B uncertainty". These are also sometimes referred to as *aleatory* and *epistemic* uncertainty, respectively.

Aleatory uncertainty results from the fact that many parameters are inherently variable (random or noisy) over time such that their behavior can only be described statistically. Examples include the flow rate in a river, the price of a stock or the temperature at a particular location.

Variability in a parameter can be expressed using *frequency distributions*. A frequency distribution displays the relative frequency of a particular value versus the value. For example, one could sample the flow rate of a river once an hour for a week, and plot a frequency distribution of the hourly flow rate (the x-axis being the flow rate, and the y-axis being the frequency of the observation over the week).

Other parameters are not inherently variable over time, but cannot be specified precisely due to epistemic uncertainty: we lack sufficient information or knowledge to specify their value with certainty. Examples include the strength of a particular material, the mass of a planet, or the efficacy of a new drug.

A fundamental difference between these two types of uncertainty is that epistemic uncertainty (i.e., resulting from lack of knowledge) can theoretically be reduced by studying the parameter or system. That is, since the variability is due to a lack of knowledge, theoretically that knowledge could be improved by carrying out experiments, collecting data or doing research. Aleatory uncertainty, on the other hand, is inherently irreducible. If the parameter itself is inherently variable, studying the parameter further will certainly not do anything to change that variability. This is important because one of the key purposes of probabilistic simulation modeling is not just to make predictions, but to identify those parameters that are contributing the most to the uncertainty in results. If the uncertainty in the results is due primarily to epistemic parameters, we know that we could (at least theoretically) reduce our uncertainty in our results by gaining more information about those parameters.

It should be noted that parameters which have both kinds of uncertainty are not uncommon in simulation models. For example, in considering the flow rate in a river, we know that it will be temporally variable (inherently random in time so it can only be described statistically), but in the absence of adequate data, we will have uncertainty about the statistical measures (e.g., mean, standard deviation) describing that variability. By taking measurements, we can reduce our uncertainty in these statistical measures (i.e., what is the mean flow rate?), but we will not be able to reduce the inherent variability in the flow.

Note that some quantities are variable not over time, but over space or within a collection of items or instances. An example is the age of population. If you had a group of 1000 individuals, you could obtain the age of each individual and create a frequency distribution of the age of the group. This kind of distribution is similar to the example of the flow rate in a river discussed above in that both are described using frequency distributions (one showing a frequency in time, and one showing a frequency of occurrence within a group). The age example, however, is fundamentally different from an inherently random parameter. Whereas a distribution representing an inherently random parameter truly is describing uncertainty (we cannot predict the value at any given time), a distibution representing the age distribution is not describing uncertainty at all. It is simply describing a variability within the group that we could actually measure and define very precisely.

It is critical not to combine variability like this with uncertainty and represent both using a single distribution. For example, suppose that you needed to represent the efficacy of a new drug. The efficacy is different for different age groups. Moreover, for each age group, there is scientific uncertainty regarding its efficacy. A common mistake would be to define a single probability distribution that represents both the variability due to age and the uncertainty due to lack of knowledge. Not only would it be difficult to define the shape of such a distribution in the first place, this would produce simulation results that would be difficult, if not impossible, to interpret in a meaningful way. The correct way to handle such a situation would be to disaggregate the problem (by explicitly modeling each age group separately) and then define different probability distributions for each age group (with each distribution representing only the scientific uncertainty in the efficacy for that age group).

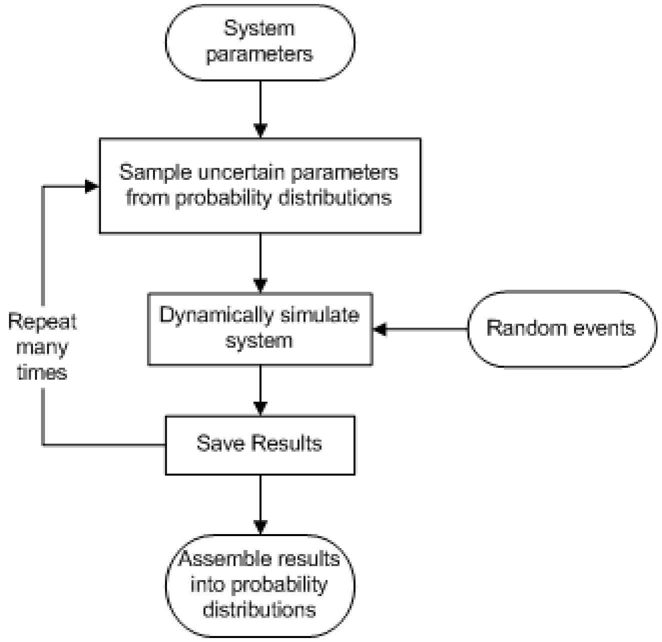
Propagating Uncertainty

If the inputs describing a system are uncertain, the prediction of the future performance of the system is necessarily uncertain. That is, the result of any analysis based on inputs represented by probability distributions is itself a probability distribution.

In order to compute the probability distribution of predicted performance, it is necessary to *propagate* (translate) the input uncertainties into uncertainties in the results. A variety of methods exist for propagating uncertainty. Morgan and Henrion (1990) provide a relatively detailed discussion on the various methods.

One common technique for propagating the uncertainty in the various aspects of a system to the predicted performance (and the one used by GoldSim) is ***Monte Carlo simulation***. In Monte Carlo simulation, the entire system is simulated a large number (e.g., 1000) of times. Each simulation is equally likely, and is referred to as a ***realization*** of the system. For each realization, all of the uncertain parameters are sampled (i.e., a single random value is selected from the specified distribution describing each parameter). The system is then simulated through time (given the particular set of input parameters) such that the performance of the system can be computed.

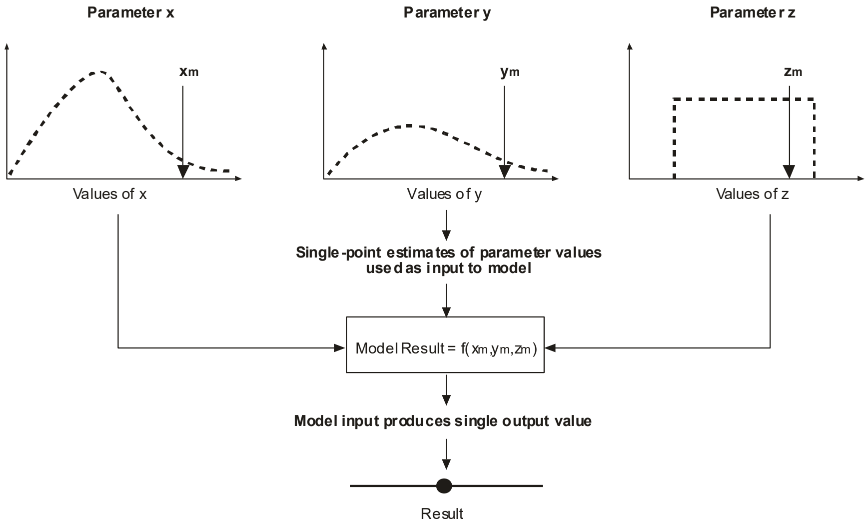
This results in a large number of separate and independent results, each representing a possible “future” for the system (i.e., one possible path the system may follow through time). The results of the independent system realizations are assembled into probability distributions of possible outcomes. A schematic of the Monte Carlo method is shown below:



A Comparison of Probabilistic and Deterministic Simulation Approaches

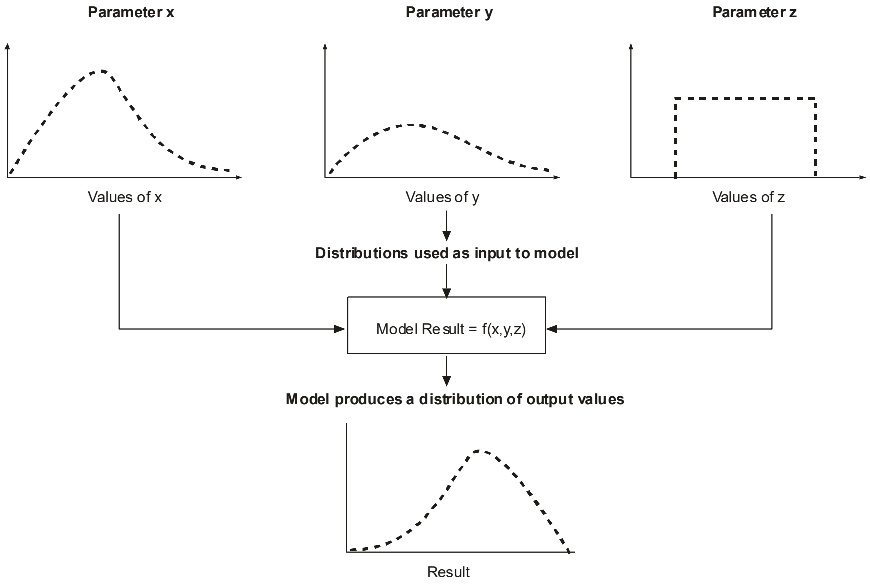
Having described the basics of probabilistic analysis, it is worthwhile to conclude this appendix with a comparison of probabilistic and ***deterministic*** approaches to simulation, and a discussion of why GoldSim was designed to specifically facilitate both of these approaches.

The figure below shows a schematic representation of a deterministic modeling approach:



In the deterministic approach, the analyst, although he/she may implicitly recognize the uncertainty in the various input parameters, selects single values for each parameter. Typically, these are selected to be "best estimates" or sometimes "worst case estimates". These inputs are evaluated using a simulation model, which then outputs a single result, which presumably represents a "best estimate" or "worst case estimate".

The figure below shows a similar schematic representation of a probabilistic modeling approach:



In this case the analyst explicitly represents the input parameters as probability distributions, and propagates the uncertainty through to the result (e.g., using the Monte Carlo method), such that the result itself is also a probability distribution.

One advantage to deterministic analyses is that they can typically incorporate more detailed components than probabilistic analyses due to computational considerations (since complex probabilistic analyses generally require time-consuming simulation of multiple realizations of the system).

Deterministic analyses, however, have a number of disadvantages:

- *"Worst case" deterministic simulations can be extremely misleading*. Worst case simulations of a system may be grossly conservative and therefore completely unrealistic (i.e., they typically have an extremely low probability of actually representing the future behavior of the system). Moreover, it is not possible in a deterministic simulation to quantify how conservative a "worst case" simulation actually is. Using a highly improbable simulation to guide policy making (e.g., "is the design safe?") is likely to result in poor decisions.
- *"Best estimate" deterministic simulations are often difficult to defend*. Because of the inherent uncertainty in most input parameters, defending "best estimate" parameters is often very difficult. In a confrontational environment, "best estimate" analyses will typically evolve into "worst case" analyses.
- *Deterministic analyses do not lend themselves directly to detailed uncertainty and sensitivity studies*. In order to carry out uncertainty and

sensitivity analysis of deterministic simulations, it is usually necessary to carry out a series of separate simulations in which various parameters are varied. This is time-consuming and typically results only in a limited analysis of sensitivity and uncertainty.

These disadvantages do not exist for probabilistic analyses. Rather than facing the difficulties of defining worst case or best estimate inputs, probabilistic analyses attempt to explicitly represent the full range of possible values. The probabilistic approach embodied within GoldSim acknowledges the fact that for many complex systems, predictions are inherently uncertain and should always be presented as such. Probabilistic analysis provides a means to present this uncertainty in a quantitative manner.

Moreover, the output of probabilistic analyses can be used to directly determine parameter sensitivity. Because the output of probabilistic simulations consists of multiple sets of input parameters and corresponding results, the sensitivity of results to various input parameters can be directly determined. The fact that probabilistic analyses lend themselves directly to evaluation of parameter sensitivity is one of the most powerful aspects of this approach, allowing such tools to be used to aid decision-making.

There are, however, some potential disadvantages to probabilistic analyses that should also be noted:

- *Probabilistic analyses may be perceived as unnecessarily complex, or unrealistic*. Although this sentiment is gradually becoming less prevalent as probabilistic analyses become more common, it cannot be ignored. It is therefore important to develop and present probabilistic analyses in a manner that is straightforward and transparent. In fact, GoldSim was specifically intended to minimize this concern.
- *The process of developing input for a probabilistic analysis can sometimes degenerate into futile debates about the "true" probability distributions*. This concern can typically be addressed by simply repeating the probabilistic analysis using alternative distributions. If the results are similar, then there is not necessity to pursue the "true" distributions further.
- *The public (courts, media, etc.) typically does not fully understand probabilistic analyses and may be suspicious of it*. This may improve as such analyses become more prevalent and the public is educated, but is always likely to be a problem. As a result, complementary deterministic simulations will always be required in order to illustrate the performance of the system under a specific set of conditions (e.g., "expected" or "most likely" conditions).

As this last point illustrates, it is important to understand that use of a probabilistic analysis does not preclude the use of deterministic analysis. In fact, deterministic analyses of various system components are often essential in order to provide input to probabilistic analyses. The key point is that for many systems, deterministic analyses *alone* can have significant disadvantages and in these cases, they should be complemented by probabilistic analyses.

References

The references cited in this appendix are listed below.

Ang, A. H-S. and W.H. Tang, 1984, Probability Concepts in Engineering Planning and Design, Volume II: Decision, Risk, and Reliability, John Wiley & Sons, New York.

Bonano, E.J., S.C. Hora, R.L. Keaney and C. von Winterfeldt, 1989, Elicitation and Use of Expert Judgment in Performance Assessment for High-Level Radioactive Waste Repositories, Sandia Report SAND89-1821, Sandia National Laboratories.

Benjamin, J.R. and C.A. Cornell, 1970, Probability, Statistics, and Decision for Civil Engineers, McGraw-Hill, New York.

Dakins, M.E., J.E. Toll, M.J. Small and K.P. Brand, 1996, *Risk-Based Environmental Remediation: Bayesian Monte Carlo Analysis and the Expected Value of Sample Information*, Risk Analysis, Vol. 16, No. 1, pp. 67-79.

Finkel, A., 1990, Confronting Uncertainty in Risk Management: A Guide for Decision-Makers, Center for Risk Management, Resources for the Future, Washington, D.C.

Harr, M.E., 1987, Reliability-Based Design in Civil Engineering, McGraw-Hill, New York.

IAEA, 1989, Evaluating the Reliability of Predictions Made Using Environmental Transfer Models, IAEA Safety Series No. 100, International Atomic Energy Agency, Vienna.

Kotra, J.P., M.P. Lee, N.A. Eisenberg, and A.R. DeWispelare, 1996, *Branch Technical Position on the Use of Expert Elicitation in the High-Level Radioactive Waste Program*, Draft manuscript, February 1996, U.S. Nuclear Regulatory Commission.

Morgan, M.G. and M. Henrion, 1990, Uncertainty, Cambridge University Press, New York.

Roberds, W.J., 1990, *Methods for Developing Defensible Subjective Probability Assessments*, Transportation Research Record, No. 1288, Transportation Research Board, National Research Council, Washington, D.C., January 1990.

Seiler, F.A and J.L. Alvarez, 1996, *On the Selection of Distributions for Stochastic Variables*, Risk Analysis, Vol. 16, No. 1, pp. 5-18.

Stephens, M.E., B.W. Goodwin and T.H. Andres, 1993, *Deriving Parameter Probability Density Functions*, Reliability Engineering and System Safety, Vol. 42, pp. 271-291.

V3.5.2

REGIONAL MUNICIPALITY OF NIAGARA
SOUTH NIAGARA FALLS WASTEWATER SOLUTIONS

Assimilative Capacity Studies

ACS Screening

REPORT

South Niagara Falls Wastewater Solutions Schedule C Class Environmental Assessment

Screening Level Assimilative Capacity Study of Discharge Location Alternatives

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ACRONYMS AND ABBREVIATIONS

Acronym or Abbreviation	Description
ACS	Assimilative Capacity Study
BOD_5	Biochemical Oxygen Demand
$CBOD_5$	Carbonaceous Biochemical Oxygen Demand
CCME	Canadian Council of Ministers of the Environment
CSO	Combined Sewer Overflow
E. coli	*Escherichia coli*
EA	Environmental Assessment
ECA	Environmental Compliance Approval
GS	Generating Station
HEPC	Hydro Electric Power Canal
ICD	International Control Dam
INCW	International Niagara Control Works
MECP	Ministry of the Environment, Conservation and Parks
MOEE	Ministry of Energy and Environment
NOAA	National Oceanic and Atmospheric Administration
NPCA	Niagara Peninsula Conservation Authority
NYPA	New York Power Authority
OPG	Ontario Power Generation
the Project	South Niagara Falls Wastewater Solutions Schedule C Class EA
PWQMN	Provincial Water Quality Monitoring Network
PWQO	Provincial Water Quality Objectives
SLSMC	St. Lawrence Seaway Management Corporation
TSS	Total Suspended Solids
USGS	United States Geological Survey
WSC	Water Survey of Canada
WWTP	Wastewater Treatment Plant

UNITS OF MEASURE

Symbol or Unit	Description
cfs	Cubic feet per second
cfu	Colony-forming unit
kg/d	kilograms per day
km	kilometre
km^2	Square kilometres
m	metre
µg/L	Microgram per litre
mg/L	Milligrams per litre
MLD	Megalitres per day
m^3/s	Cubic metres per second
mL	Millilitre
ºC	Degrees Celsius
%	Percent

1.0 INTRODUCTION

The Regional Municipality of Niagara (Niagara Region) is currently conducting a Schedule “C” Municipal Class Environmental Assessment (EA) for a proposed Wastewater Treatment Plant (WWTP) in the vicinity of Chippewa Creek, Niagara. As well as providing other ancillary services, Golder Associates Ltd. (Golder) has been retained to conduct an Assimilative Capacity Study (ACS) in support of the South Niagara Falls Wastewater Solutions Schedule C Class EA Project (the Project), which is the subject of this technical report.

1.1 Study Background

With significant future regional growth and urban intensification forecast for the area, the 2017 Niagara Region Master Servicing Plan provided a long-term wastewater solutions strategy to improve the existing collection system and add a new, second wastewater treatment facility in South Niagara Falls that can accommodate phased growth, provide wastewater service to currently subserviced areas, reduce pressure on existing wastewater infrastructure, decrease the magnitude and frequency of untreated combined sewer overflows and WWTP bypasses and, in doing so, enhance overall environmental performance.

Wastewater collection within Niagara Falls is currently facilitated through a number of collection systems and pumping stations. These systems convey the wastewater to the existing Niagara Falls WWTP (sometimes referred to as the Stanley Avenue WWTP). Many of the components of the collection system are nearing their design capacity.

The 2017 Master Servicing Plan identified a number of candidate discharge location for a new WWTP in South Niagara Falls that could potentially accept an effluent discharge rate of up to 30 Megalitres per day (30 MLD).

1.1.1 Study Area Overview and Nomenclature

The extent of this study area was identified as the preferred geographical context for siting the new WWTP for the City of Niagara Falls (GMBP, 2019). As depicted on Figure 1, the study area features a number of potential discharge receivers for assimilating the new WWTP discharge, including:

- the Hydro Electric Power Canal (HEPC);
- the eastern portion of the Welland River East;
- Chippewa Creek; and
- The Canadian shoreline of the Niagara River upstream of the International Control Dam (ICD).

The hydrology of the study area has been highly modified and regulated from the natural predevelopment conditions that existed prior to the 1950s. During the 1950s, the HEPC was constructed from the Welland River (upstream of Horseshoe Falls) to the Sir Adam Beck Generating Station (GS) which discharges to Niagara Gorge. As a result, the flow within last 6.5 km of the Welland River was reversed to direct a small portion of Niagara River flows towards the HEPC. The section from the Niagara River to Triangle Island is referred as Chippewa Creek. The amount of flow that is diverted is primarily determined by the following factors:

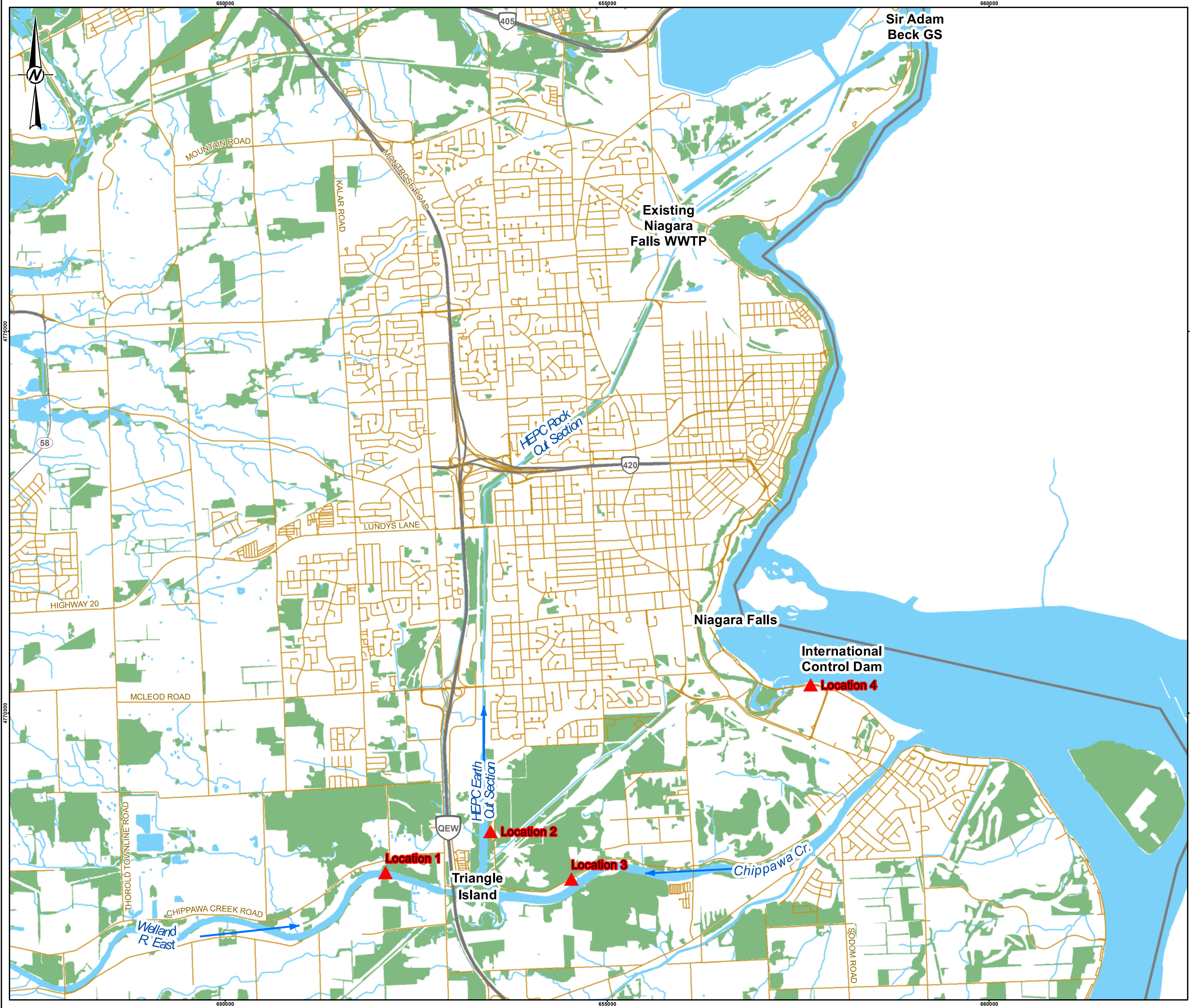
- the operation of the ICD in the Niagara River; which can alternatively increase or decrease the water level in the Niagara River at the mouth of Chippewa Creek; and
- upstream flows in the Niagara River which are determined by water levels at the outlet of Lake Erie, that are influenced by both long-term weather patterns and short-term meteorological events (such as seiching).

The daily operation of the ICD is influenced by the electrical demands and markets in both Ontario and New York State as well as maintaining minimum flow over the falls during tourist periods.

In addition, construction of the Welland Canal to the west of the study area has modified the hydrology and drainage area of the Welland River and several small contributing tributaries. The Welland River passes under the Welland Canal at two locations via siphons that may alter the flow in the river during high flow events. The Lyons Creek watershed area was also decreased by the Welland Canal to the extent that water must now be pumped from the Welland Canal into Lyons Creek to maintain a minimum flow requirement.

For the purposes of maintaining consistent terminology, key surface water features referred to in this ACS use a naming convention adopted by the Ministry of the Environment, Conservation and Parks (MECP), the Niagara Peninsula Conservation Authority (NPCA), and Ontario Power Generation (OPG). Specifically, these key surface water features include:

- **International Control Dam (ICD):** This multi-gated dam in the Niagara River built in 1954 is located approximately 800 m above the Horseshoe Falls and is used to control flows to the Sir Adam Beck GS operated by OPG, the Robert Moses GS operated by the New York Power Authority (NYPA) and the American Falls operated according to Niagara River Treaty (1950). In other literature and documentation, the ICD has sometimes also been referred to as the International Niagara Control Works (INCW).
- **Chippewa–Grass Island Pool (GIP):** This is the area of the Niagara River upstream of the ICD where water levels vary with upstream flow and the operation of the ICD.
- **Hydro Electric Power Canal (HEPC):** This is a canal that conveys diverted flow from the Niagara River (via Chippewa Creek) to the Sir Adam Beck Generating Station.
- **Chippewa Creek:** This is a former portion of the Welland River that flows from the Niagara River to the HEPC when the HEPC is in operation (e.g., reverse flow to natural conditions). During the construction of the HEPC, the width and depth of this section of river were increased to accommodate the increased flow.
- **Triangle Island:** this is a small, constructed island at the junction of the Welland River East, Chippewa Creek, and the HEPC. During normal operation of the HEPC, the diverted flow from the Niagara River flows past the northeast side of Triangle Island from Chippewa Creek into the HEPC while flow from the Welland River East flows past the northwest side of Triangle Island into the HEPC. The channel to the south of Triangle Island is narrower and shallower than the other channels and does not typically have significant flows. Triangle Island is also the location of the safety booms (northeast and northwest sides) used to prevent boat traffic from entering the HEPC.
- **Earth Cut Section:** This is the wide portion of the HECP dug into soil between Triangle Island and the Rock Cut Section of the HEPC and is approximately 1.5 km long.
- **Rock Cut Section:** This is the narrower and deeper section of the HECP cut into bedrock below the Earth Cut Section. The rock cut section of the HEPC is approximately 12 km long and ends at the Sir Adam Beck GS.
- **Welland River East:** This is the portion of the Welland River upstream of triangle island. MECP / NPCA use this convention to distinguish the sections of the Welland River east or west of the Welland Canal.



LEGEND

▲	APPROXIMATE DISCHARGE LOCATON
→	FLOW DIRECTION
—	LOCAL ROAD
—	PRIMARY HIGHWAY
—	SECONDARY HIGHWAY
—	WATERCOURSE
☐	INTERNATIONAL BORDER
🟩	WOODED AREA
🟦	WATERBODY

0 1 2

1:50,000 KILOMETRES

NOTE(S)

1. ALL LOCATIONS ARE APPROXIMATE.

REFERENCE(S)

BASE DATA COURTESY OF MNRF LIO. PRODUCED BY GOLDER ASSOCIATES UNDER LICENSE FROM ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY
PROJECTION: UTM ZONE 17N DATUM: NAD 83

CLIENT

REGIONAL MUNICIPALITY OF NIAGARA

PROJECT

SOUTH NIAGARA FALLS WASTEWATER SOLUTIONS
SCHEDULE C CLASS ENVIRONMENTAL ASSESSMENT

TITLE

LOCATION OF PROJECT AREA

CONSULTANT

GOLDER

YYYY-MM-DD	2020-05-19
DESIGNED	MM/PR
PREPARED	PR
REVIEWED	GVA
APPROVED	GVA

PROJECT NO.	CONTROL	REV.	MAP
18104462	0007	A	1

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1.1.2 Potential Discharge Locations

With reference to Figure 1, the ACS considered four different effluent discharge location alternatives for the purpose of receiving treated wastewater effluent discharges from the new WWTP, as follows:

- **Location 1 – Welland River East:** Located immediately west of Triangle Island, the discharge from the new WWTP would mix with flow from Welland River East.
- **Location 2 – Earth Cut Section of HEPC:** Located immediately north of Triangle Island, the discharge from the new WWTP would mix with flow from Chippewa Creek and Welland River East.
- **Location 3 – Chippewa Creek:** Located immediately east of Triangle Island, the discharge from the new WWTP would mix with flow from Chippewa Creek (composed mainly by water from the Niagara River diverted into the HEPC based on flow demand and flow from Lyons Creek) and occasionally with water from Welland River East when the HEPC is not operational.
- **Location 4 – Niagara River:** Located immediately downstream of the ICD and below Chippewa, the WWTP would discharge directly into the Niagara River via a shoreline discharge.

1.2 Study Purpose

The purpose of this ACS is to provide alternatives assessment input in support of the Municipal Class EA by:

1) Evaluating the assimilative capacity of each considered discharge location, considering the seasonal characteristics of key water quality parameters that could be affected by treated effluent discharges at local and system compliance points.
2) Determining the environmental constraints of each discharge location with respect to assimilating a treated wastewater discharge of 30 MLD.
3) Identifying the discharge concentration limits of key water quality parameters to meet Provincial Water Quality Objectives (PWQOs), to meet Canadian Council for Ministers of the Environment criteria (where PWQOs are not available), or to maintain water quality in accordance with MECP Policy 2 requirements conditions at the discharge location.

This study assesses the assimilative capacity and water quality effects at two compliance points for each discharge option. The local compliance point is located immediately downstream of the discharge. In order to consider the cumulative effects of existing discharges to the HEPC, the system compliance point is located in the HEPC immediately downstream of the existing Niagara Falls WWTP and upstream of the confluence with the power tunnels.

1.3 General Study Approach and Report Outline

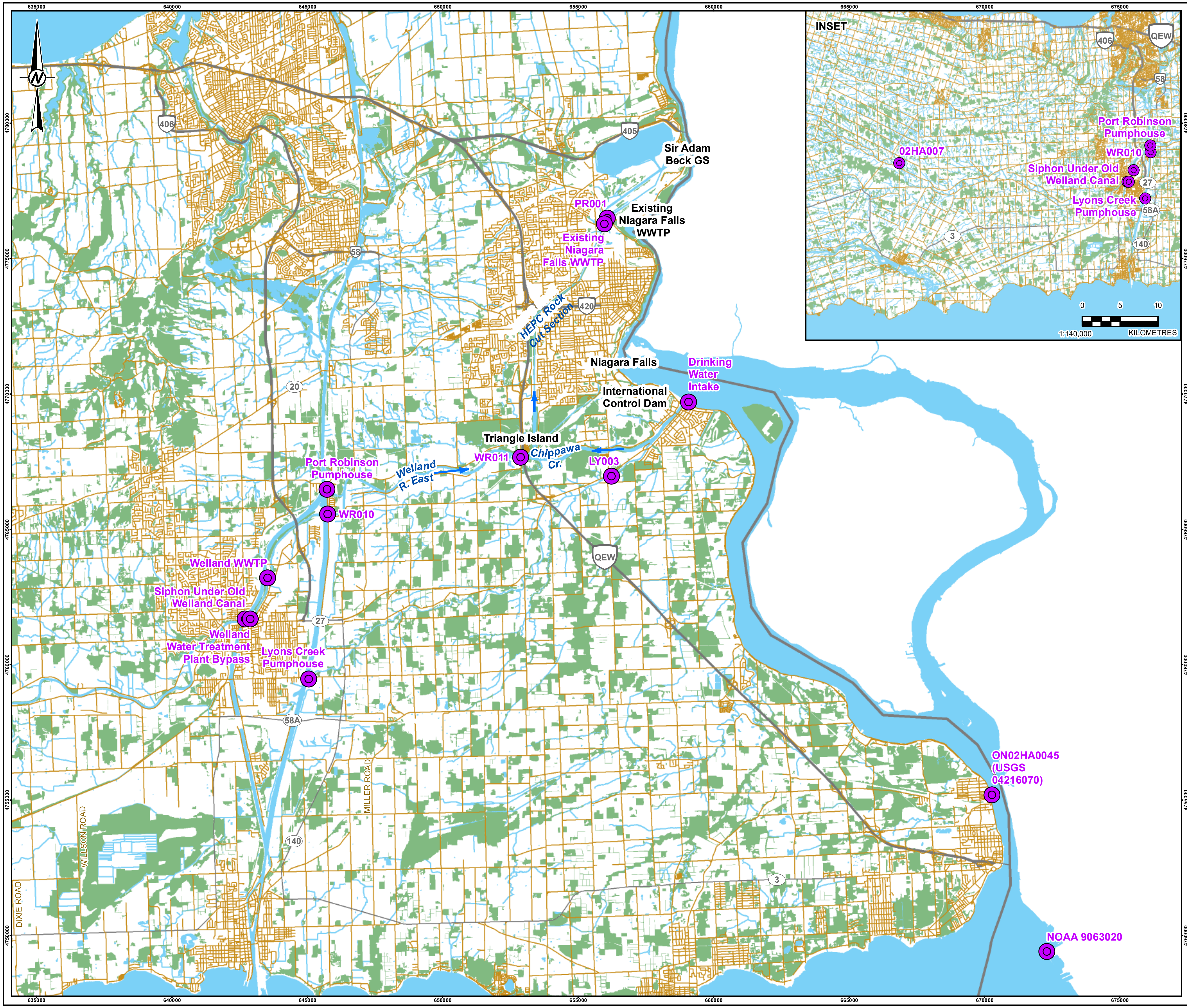
The characterisation of discharge locations considered in this study were based on a number of corporate and publicly available sources including water quality obtained from the MECP Provincial Water Quality Monitoring Network (PWQMN), the US Geological Survey (USGS), The National Oceanic and Atmospheric Administration (NOAA), and the NPCA. Flow data for the Welland River was obtained from the Water Survey of Canada (WSC), flow data for the Niagara River were obtained from the USGS, and flow data for the HEPC were provided by OPG. The structure of this ACS report is presented in the following order:

- Section 2 details the background information obtained and used to characterise seasonal water quality and flow conditions for each of the four discharge locations.

- The hydrological nature of the four locations considered in this study required a slightly modified approach compared to conventional Assimilative Capacity Studies. Namely, system flows at three of the locations (Welland River East, Chippewa Creek and HEPC) are heavily regulated, which meant that the conventional 7Q20 approach to flow derivation was replaced with a stochastic approach. Secondly, the fact that effluent discharges to the Niagara River would only mix with a limited portion of river flow prior to reaching Niagara Falls meant that the mixing potential of effluent discharges at this location were assumed to be limited to only 3% of the Niagara River flows. Section 3 introduces the modelling approach adopted for each discharge location and identifies relevant seasonal and/or environmental constraints, as well as identifying the maximum allowable effluent concentrations at each discharge location to achieve regulatory compliance.
- Based on the constraints identified in Section 3, Section 4 identifies the appropriate treatment technology for each discharge location, presents the ensuing water quality results at each location and provides a high-level discussion of the overall implications on the Project. Section 4 also recommends effluent limits and limits for each location and parameter.
- Section 5 estimates the effects of the Project on the receiving water at selected locations in terms of total phosphorus, nitrate, fecal coliforms (*E. coli*), Carbonaceous Biochemical Oxygen Demand ($CBOD_{5)}$, and ammonia (total and unionized).
- Section 6 summarises the key conclusions and recommendations of the ACS.

2.0 BACKGROUND INFORMATION AND DATA REVIEW

This section provides details and summaries of the data used in the ACS. The locations of the monitoring locations where the data were collected are shown in Figure 2.



LEGEND

- ◎ REGIONAL SAMPLING STATION LOCATION
- → FLOW DIRECTION
- LOCAL ROAD
- PRIMARY HIGHWAY
- SECONDARY HIGHWAY
- WATERCOURSE
- ▭ INTERNATIONAL BORDER
- 🟩 WOODED AREA
- 🟦 WATERBODY

0 5 10

1:140,000 KILOMETRES

NOTE(S)

1. ALL LOCATIONS ARE APPROXIMATE.

REFERENCE(S)

BASE DATA COURTESY OF MNRF LIO. PRODUCED BY GOLDER ASSOCIATES UNDER LICENSE FROM ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY
PROJECTION: UTM ZONE 17N DATUM: NAD 83

CLIENT
REGIONAL MUNICIPALITY OF NIAGARA

PROJECT
SOUTH NIAGARA FALLS WASTEWATER SOLUTIONS
SCHEDULE C CLASS ENVIRONMENTAL ASSESSMENT

TITLE
DATA COLLECTION AND MONITORING LOCATIONS

CONSULTANT
GOLDER

YYYY-MM-DD	2020-05-19
DESIGNED	MM/PR
PREPARED	PR
REVIEWED	GVA
APPROVED	GVA

PROJECT NO.	CONTROL	REV.	MAP
18104462	0007	A	2

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2.1 Hydrology and Flow Data

2.1.1 Water Management in Study Area

The flow in Chippewa Creek and the HEPC has been controlled since 1921. The ICD has been in operation since 1954 and is jointly funded and controlled by OPG and NYPA in accordance with the 1950 Niagara Treaty (Canada, 1950) and a Memorandum of Understanding between the two power companies which are intended to maximize the beneficial use of the hydro electric potential of the Niagara River, while maintaining the scenic value of Niagara Falls for tourism and other uses of water in the Niagara River. The treaty stipulates that:

- Scenic flow is allocated first, domestic use second, navigational requirements third, and power generation fourth.
- Any river flow diverted for hydro electric power is to split equally between both countries.
- During tourist times, the flow over the falls must be at least 2,832 m³/s (100,000 cfs). Tourist times are defined as 8 AM to 10 PM from April 1 to September 15 and 8 AM to 8 PM from September 16 to October 31.
- The specified minimum flow over the falls is at least 1,416 m³/s (50,000 cfs) at all other times.
- If the upstream flow in the Niagara River is less than the specified minimum flows, no river flow is to be diverted to the power canals.

Water levels in the Chippewa-Grass Island Pool are regulated in accordance with the 1993 Directive of the International Niagara Board of Control.

In addition, OPG is required to maintain a minimum flow of 240 m³/s to the HEPC via Chippewa Creek to ensure that water from the Niagara River reaches the existing drinking water intake of the City of Niagara Falls Water supply plant located near the junction of Chippewa Creek and the Niagara River (Kowalski 2019). Niagara Region is currently in the process of relocating the water supply intake to the Niagara River upstream of Chippewa Creek.

2.1.2 Welland River East

In general, low flow frequency analysis of natural flows is used to generate the low-flow conditions (7Q20) to assess the assimilative capacity of the receiving water body (MOE 1994a). The Welland River East, however, is a complex hydrologic system characterized by natural flows and supplemental flows and the low-flow conditions are dominated by the supplemental flows. As a result, the 7Q20 would not be applicable for this specific assessment. Previous Assimilative Capacity Studies in the Welland River East have successfully applied an approach where the low flows conditions are based on combination of natural and supplemental flows as shown in the ACS completed for the Welland Wastewater Treatment Plant (XCG 2007).

2.1.2.1 Natural Flows in the Welland River East

Regional station data was used to estimate natural flow for the Welland River East. Flow data for the Welland River below Caistor Corners (station 02HA007) from the WSC are available from 1957 to 2017. Flows at the site are calculated based on the prorated watershed area of the site (906 km²) and the total watershed area of the gauged station (223 km²). Natural flows in the system are generally low with punctual peak flows recorded during storm events and snowmelt.

Since supplemental flows are significantly higher than average natural flows in the system (i.e., approximately double the annual average flows), natural flows in the Welland River East become relevant only under peak flow conditions. Therefore, flows were prorated between the gauging station (223 km²) and the area at the site

($906 km^2$) according to the Transposition of Flood Discharges Method (MTO, 1997) applying a coefficient of 0.75 to represent peak flows (the coefficient used for average and low flows is 1.0).

The estimated natural flows yield an average annual flow of 6.50 m^3/s with estimated maximum and minimum flows in the range of 132.41 m^3/s and 0.046 m^3/s. The 7Q20 for the natural flows based on the Log Pearson Type III distribution would yield 0.004 m^3/s.

2.1.2.2 Supplemental Flow from Welland Canal into Welland River East

Supplemental flows enter the Welland River East from the Welland Canal (St. Lawrence Seaway Management Corporation [SLSMC] 2019) as follows:

- A series of ports in the roof of the old syphon provide flow from the canal into the river. Depending on the season and water levels in the canal, the total flow ranges from 5 to 7 m^3/s.
- A pump at Port Robinson provides a flow of 0.97 m^3/s to a side channel of the Welland River East, which was cut-off from the main branch of the river during the straightening of the canal in the 1950s.
- The bypass of the Welland Water Treatment Plant provides a flow between the canal and the river that ranges from 4 m^3/s to 6 m^3/s.
- The effluent from the Welland Wastewater Treatment Plant provides a flow of 0.8 m^3/s (XCG 2007).

In general, the supplemental flows from the Welland Canal are from Lake Erie and have better water quality than that of the upstream areas of the Welland River.

Monthly estimates of the supplemental flows for the siphon ports, Port Robinson Pump, the Welland Water Treatment Plant and the Welland WWTP were provided by the SLSMC (SLSMC 2019) for the period 2014 to 2019 and are summarized in Table 1.

Table 1: Summary of Supplemental Flows from Welland Canal into the Welland River East

Source	Winter		Spring		Summer		Fall	
	Min	Avg	Min	Avg	Min	Avg	Min	Avg
Old Welland Canal at Old Siphon[1]	5.17	5.82	5.85	6.61	6.68	6.88	5.56	6.88
Welland Water Treatment Plant[1]	4.45	5.05	4.61	5.65	5.19	5.87	5.64	5.92
Port Robinson Pump[1]	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Welland WWTP[2]	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Total[3]	**11.39**	**12.64**	**12.23**	**14.03**	**13.64**	**14.52**	**12.97**	**14.57**

Notes:

1. SLSMC 2019.
2. XCG 2007.
3. All flow values in Table 1 are presented in m^3/s.

2.1.3 Niagara River

Daily flow data for Niagara River at Buffalo, New York (opposite Fort Erie, Ontario) were obtained from the USGS for Station 04216000 located in the Niagara River at Buffalo, New York for the years 1926 to 2018 (93 years).

As shown in Table 2, the monthly average flows for the Niagara River at Buffalo range from 5,501 m^3/s (February) to 6,139 m^3/s (May) with an average flow is 5,808 m^3/s. The peak daily flow over the period of record for fall, winter, summer, and spring are 8,466 m^3/s, 9,825 m^3/s, 7,957 m^3/s, and 8,410 m^3/s, respectively. In general, the flows are seasonally consistent year-round with only a slight increase during the spring.

The average daily flow in the Niagara River at Fort Erie did not fall below the tourist time minimum daytime (tourist hours) flow requirements of 2,832 m^3/s (see Section 2.1.1) over the 93-year data period suggesting that there is consistently excess flow available for power generation (e.g., excess flow above treaty requirements).

2.1.3.1 Flow Diversions

Flow diversions from the Niagara River into Chippewa Creek are controlled by OPG based on the requirements in the Treaty for equitable streamflow apportioning between OPG and NYPA. NYPA flows are adjusted upwards to reduce the benefit to OPG at Niagara for the Ogoki-Long Lac diversion south into Great Lakes watershed since mid-1940's

Total diversion flow (HEPC plus three tunnels) data was obtained from OPG for the period 2016 to 2018. As shown in Table 2, the monthly average total flow diversions by OPG range from 1,461 m^3/s (March) to 1,645 m^3/s (August) with an average flow of 1,540 m^3/s. As mentioned previously, the diverted flows by NYPA would be equal to the OPG diverted flows. Instantaneous (hourly) flows ranged from 1,014 m^3/s to 2,272 m^3/s.

Table 2: Average Flow Data for Niagara River at Fort Erie, Diverted Flow by OPG, and Flow Over Niagara Falls

Month	Season	Niagara River at Fort Erie[1] (m^3/s)		Total OPG Diverted Flow[2,3] (m^3/s)		Estimated Flow over Niagara Falls[4] (m^3/s)			
		Monthly Average	Season Average	Monthly Average	Season Average	Monthly Average	Season Average	Monthly Min	Season Min
Jan	Winter	5,573	5,583	1,562	1,521	2,627	2,687	2,124	2,124
Feb		5,501		1,541		2,598		2,124	
Mar		5,667		1,461		2,828		2,124	
Apr	Spring	5,908	6,055	1,493	1,499	2,993	3,101	2,242	2,242
May		6,139		1,479		3,210		2,242	
Jun		6,115		1,526		3,095		2,242	
Jul	Summer	6,023	5,899	1,637	1,619	2,836	2,762	2,242	2,124
Aug		5,909		1,645		2,735		2,242	
Sep		5,760		1,573		2,712		2,124	
Oct	Fall	5,672	5,690	1,464	1,519	2,799	2,738	2,124	2,124
Nov		5,685		1,498		2,763		2,124	
Dec		5,715		1,595		2,654		2,124	
Annual		**5,808**		**1,540**		**2,822**		**2,124**	

Notes:

1. Measured daily flows for Niagara River at Buffalo, New York (USGS Station 04216000) from 1926 to 2018.
2. Total diverted flow diverted by OPG for 2016 to 2018 (Kowolski, 2019).
3. As per the 1950 Niagara Treaty, diverted flows by NYPA would be equal to the OPG diverted flows.
4. Estimated flow over Niagara Falls based on Niagara River flow, diverted flows by OPG and NYPA, and 1950 Niagara Treaty requirements.

2.1.3.2 Estimated Flow Over Falls

For an evaluation of Location 4, the flow over Niagara Falls (e.g., below the ICD) was based on the following assumptions and methods:

- As per the Niagara Treaty, on any day the flow diverted by NYPA was assumed to be equal to that diverted by OPG.

- While the operation of the ICD may disproportionately affect the flow at Location 4 depending on which gates are closed, it was assumed that the flow downstream of the ICD is distributed equally across the width of the Niagara River.
- Monthly average total diverted flows were estimated based on the data provided by OPG (2016 to 2018).
- The minimum flow requirements of the Niagara Treaty were converted to a time-weighted daily average minimum flow requirement (2,242 m^3/s from April 1st to September 15th and 2,124 m^3/s from September 16th to March 31st).
- Daily average flows over the falls were estimated for the long-term flow record at Buffalo (1926 to 2018) by subtracting the average monthly total diverted flows. If the resulting flow was less than the appropriate daily average minimum flow requirement, then the minimum flow requirement was used (e.g., assumed reduction in diverted flow).

The estimated seasonal and monthly flows over Niagara Falls are also provided in Table 2. The monthly average flows over Niagara Falls range from 2,598 m^3/s (February) to 3,210 m^3/s (May) with an average flow is 2,822 m^3/s.

Restrictions in the total diverted flow by OPG and NYPA occurred approximately 22% of the time between 1926 and 2018 in order to meet the required minimum daily average flow over the falls. These restrictions occurred most frequently during January and February (approximately 33% of the time) and least frequently in May (approximately 8% of the time).

Since the flow over the falls is regulated, a statistical analysis of the flows to determine the 7Q20 low-flow condition is not appropriate. As such, the low-flow condition over the falls was assumed to be the minimum regulated daily average flow over the falls as outlined in the Niagara Treaty (2,242 m^3/s during the tourist season and 2,124 m^3/s during the non-tourist season) that occurs in each assessment season.

2.1.4 Lyons Creek

Historically, the drainage area of Lyons Creek extended into the City of Welland. However, during the construction of the Welland Canal, the watershed was split with the western section draining into the Welland Canal. While the eastern section of Lyons Creek still drains into Chippewa Creek, the drainage area was reduced to approximately 88 km^2. As a result of this reduction in drainage area, the natural flows in Lyons Creek are supplemented by the pumping of water from the Welland Canal at the location where the main channel of Lyons Creek was interrupted by the construction of the canal. From April to November, during the shipping season when the Welland Canal is full, the pumping rate is approximately 0.283 m^3/s (SLSMC 2019). From December to March, when sections of the canal are drained, the flow is reduced to approximately 0.142 m^3/s.

Regional station data was used to estimate the natural flows for the Lyons Creek. Flow data for the Welland River Below Castor Corners (station 02HA007) from the WSC are available from 1957 to 2017. Flows at site are calculated based on the prorated watershed area of the site (88 km^2) and the total watershed area of the gauged station (223 km^2).

2.1.5 Hydro Electric Power Canal (HEPC)

Flow from the Niagara River is diverted to the Sir Adam Beck GS from the Chippewa-Grass Island Pool via three tunnels and the HEPC. Under normal operating conditions, each of these conveyances carries approximately one quarter of the total diverted flow. The flow in the HEPC and tunnels can vary hourly and seasonally due to flow variations in the Niagara River, minimum flow requirements over the falls (see Section 2.4.1), electrical demand, and the market price for electricity.

The flow data provided by OPG (Kowalski 2019) represents the total flow diverted by OPG from the Niagara River to the HEPC and the three tunnels. Typically, the flow in the HEPC represents 27% of the total diverted flow.

Hourly flow data provided by OPG for a three-year period (2016 to 2018) was used as a basis for the following observations regarding the flow in the HEPC:

- The hourly flow rate ranged from 292 m^3/s to 624 m^3/s with an average of 429 m^3/s.
- Flow rates are typically highest during the summer months (446 m^3/s) and lowest in the fall (411 m^3/s).
- Typically, the flows are lowest at 4:00 AM (402 m^3/s) and highest at 6:00 PM (456 m^3/s).

2.1.6 Chippewa Creek

Water from the Niagara River is diverted into Chippewa Creek based on the water levels in the Chippewa-Grass Island Pool. Chippewa Creek extends approximately 6.5 km from the Niagara River to Triangle Island. Lyons Creek drains to the south shore of Chippewa Creek approximately 2km west of the Niagara River.

Given the highly regulated system, flow in Chippewa Creek was estimated in the model based on the flow demand in the HEPC and the estimated flows contributing to the system from the Welland River East and Lyons Creek. The estimated flow (diverted from Niagara River) was calculated in the modelling exercise.

2.1.7 Existing Niagara Falls Wastewater Treatment Plant

The daily volume of the water from the existing Niagara Falls WWTP was provided by Niagara Region for the period 2015 to 2018.

The measured daily flow over the period of record for fall, winter, summer, and spring are 0.55 m^3/s, 0.45 m^3/s, 0.49 m^3/s, and 0.53 m^3/s, respectively. For comparison, the existing Niagara Falls WWTP is rated for an average daily flow of 0.79 m^3/s (68,300 m^3/day), a peak flow rate of 1.58 m^3/s (136,400 m^3/day) during dry weather, and 2.37 m^3/s (205,000 m^3/day) during wet weather (MOE, 2010). These rates are well above the average and peak flows observed for the period 2015 to 2018, meaning that the plant was operating under capacity for the period of record.

The existing Niagara Falls WWTP operates at an average flow of approximately 0.472 m^3/s (40,810 $m^{3/}$day). For the ACS modelling, the effluent flow was maintained at the existing rated capacity of 0.79 m^3/s (68,300 m^3/d). The effluent from the plant to the HEPC and immediately upstream from the system compliance point (upstream of Sir Adam Beck GS).

2.1.8 Combined Sewer Overflows (CSOs) and Wastewater Treatment Plan Bypass

Niagara Region has a total of five Regional CSOs discharging into the HEPC from regional pumping stations. Discharges from the CSOs into the HEPC are primary triggered by storm events. The pumping stations associated with these Regional CSOs are Dorchester Road, Drummond Road, Royal Manor, High Lift and existing Niagara Falls WWTP. The existing Niagara Falls WWTP is further differentiated in terms of water quality as direct overflow (i.e., no treatment) and secondary bypass (i.e., primary treatment).

The City of Niagara Falls has a total of three municipal CSOs discharging to the HPEC from their sanitary and storm sewer collection systems. The locations associated with these municipal CSOs are Sinnicks Avenue, Bellevue Street, and McLeod Road. Volume and frequency of CSOs from the City of Niagara Falls has not been made available and therefore, are excluded from this analysis.

Measured CSO flows were provided by Niagara Region for 2015 through 2018. The measured seasonal frequency and magnitude of overflows from these regional CSOs was analyzed for the period of record. The average seasonal overflow volumes per overflow event (and volume% calculated over average CSO flow discharge over the season) and number of events are summarized on Table 3.

In general, the majority of CSO events occur in spring and summer, coinciding with the largest overflow magnitudes. The secondary bypass from the existing Niagara Falls WWTP yields the largest volume and frequency of CSO flows into the system, followed, by the overflow from the existing Niagara Falls WWTP. These two items yield approximately 94.0% (summer) to 99.6% (fall) of the total CSO flows in the system.

Table 3: Summary of Average Seasonal Flow per Event and Average Number of Events per Season

Season	Dorchester Road	Drummond Road	Royal Manor	High Lift	Existing Niagara Falls WWTP Primary Bypass	Existing Niagara Falls WWTP Secondary Bypass
Average Overflow Volume (m³/event)						
Winter	720(0.3%)	0(0%)	0(0%)	1,820(0.5%)	7,100(2.5%)	9,200(96.7%)
Spring	4,740(0.5%)	140(0%)	970(0%)	6,810(0.7%)	15,700(2.8%)	17,900(95.9%)
Summer	970(3.9%)	220(0.6%)	0(0%)	3,880(1.5%)	4,300(11.4%)	3,200(82.6%)
Fall	1,360(0.4%)	80(0%)	0(0%)	5,020(0.6%)	8,000(2.3%)	14,500(96.7%)
Annual	1,840(0.2%)	160(0%)	970(0.1%)	4,530(0.2%)	9,500(0.9%)	11,200(98.6%)
Average Number of Overflow Events (events/month)						
Winter	1.75	0	0	1.5	1.75	5.25
Spring	3	1.67	1	2.75	4.75	9
Summer	5.25	3.5	1	0.5	3.5	8
Fall	2	1	0	1	2.25	5.5
Annual	3	1.64	2	1.44	3.06	6.94

Notes:

1. Values in brackets indicate the approximate percentage of the total seasonal volume contributed by each source.

2.2 Water Quality Data

Water quality data for the existing Niagara Falls WWTP and receivers were available for several locations. Most of these locations included parameters suitable to the ACS (e.g., basic chemistry, nutrients, metals, temperature, etc.).

For the initial phases of the ACS, the parameters of concern include total ammonia, unionized ammonia, nitrate, phosphorus, *Escherichia coli* (*E. coli*), dissolved oxygen, Carbonaceous Biochemical Oxygen Demand ($CBOD_5$), and Total Suspended Solids (TSS). The assessment also used pH and water temperature estimate unionized ammonia concentration of the reported water quality data using the equations provided by the MECP (Ministry of Energy and Environment [MOEE], 1994).

The data summaries for the locations in the following sections present the 75th percentile values for all the parameters. These percentiles are used in subsequent analysis as follows:

- The 75th percentile values for total ammonia, nitrate, total phosphorus, *E. coli*, dissolved oxygen, $CBOD_5$, and TSS were used as the background concentrations when estimating the maximum allowable effluent concentrations.
- The 75th percentile values of pH and water temperature were used to estimate the maximum allowable concentration of total ammonia in the effluent based on the estimated maximum allowable effluent concentration for unionized ammonia.
- If more than one water quality monitoring station was available for any given flow source, the maximum reported 75th percentile value was used for conservatism in the modelling exercise.

2.2.1 Applicable Water Quality Guidelines

Applicable PWQOs for the parameters discussed in this memorandum are presented in the Table 4 and are discussed in the following points.

- Since the study area is effectively a river, the PWQO for phosphorus for the avoidance of excessive plant growth in rivers and streams (0.03 mg/L) was used.
- Since there is no PWQO for nitrate, the Canadian Council of Ministers of the Environment (CCME) guideline was selected.
- Seasonal temperature and pH values were used to determine the limits for total ammonia based on the PWQO for unionized ammonia.
- Since the Niagara River, Lyons Creek, and Welland River East are all considered warm water aquatic habitat (NPCA 2011), the dissolved oxygen guideline for warm water fisheries was used.
- The PWQO for fecal coliforms (*E. coli*) is for recreational use (e.g., beaches).
- Since the new WWTP is not expected to release a thermal discharge or alter the pH in the receiving waters, water temperature and pH were excluded from the modelling exercise.
- Since there is no PWQO for total suspended solids, the CCME guideline for clear flow (low flow) was selected.

Table 4: Summary of Applicable Water Quality Objectives

Parameter	PWQO or CCME Guideline
Unionized Ammonia	0.0164 mg/L as N[1]
Total Ammonia	Estimated from unionized ammonia criteria based on ambient water temperature and pH using equations in the Provincial Water Quality Objectives (MOEE 1994)
Nitrate	3 mg/L as N[2]
pH	6.5 to 8.5[1]
E. coli.	100 cfu/100mL[1,3]
Total Phosphorus	0.03 mg/L to avoid excessive plant growth in rivers and streams[1]
Dissolved Oxygen	47% of saturation or 4 mg/L above 20ºC for warm water fisheries[1,5]
Total Suspended Solids	During clear flow (low flow): Maximum average increase of 5 mg/L from background levels for longer term exposures (24 hours to 30 days).[2]
Water Temperature	10ºC above background or 30ºC for thermal discharges[1]

Notes:

1. Provincial Water Quality Objectives (MOEE, 1994).
2. Guideline for freshwater aquatic life in CCME Guidelines (CCME, 2014).
3. PWQO for *E. coli* is for recreational use (e.g., swimming beaches).
4. Since the new WWTP is not expected to release a thermal discharge or alter the pH in the receiving waters, water temperature and pH were excluded from the modelling exercise (explicitly) but used to assess capacity in the system for unionized ammonia.
5. Since the Niagara River, Lyons Creek, and Welland River East are all considered warm water aquatic habitat (NPCA 2011), the dissolved oxygen guideline for warm water fisheries was used.

2.2.2 Welland River East

For the water quality assessment of the Welland River East, data from two monitoring stations were used:

- immediately west (upstream) of Triangle Island at Montrose Road (WR011) with available data from 2011 to 2018; and
- further west (upstream), where the Welland River crosses at the Welland Canal (WR010) with data from 2003 to 2018.

Water quality data for the Welland River East was provided by NPCA. A summary of the seasonal water quality values for WR010 and WR011 are presented in Table 5. Water quality in the Welland River East consistently exceeds the PWQO guidelines for phosphorus and *E. coli*.

As mentioned in Section 0, the flows in the Welland River East are supplemented by flows from the Welland Canal. As a result, the water quality in the Welland River East is a combination of water from the Welland Canal which is effectively water from Lake Erie) and natural drainage from the upper sections of the Welland River Watershed. The water from the canal is typically of better quality than that of the upper Welland River (e.g., lower phosphorus concentrations). The contributions of the Welland Canal flows on the water quality in the Welland River East are demonstrated on Figure 3 when the natural flows are low and diluted by Welland Canal flows, the total phosphorus concentrations are low (e.g., less than 0.05 mg/L). During higher natural flows, the dilution by the canal flows are less pronounced and the total phosphorus concentration are elevated (e.g., up to 0.45 mg/L).

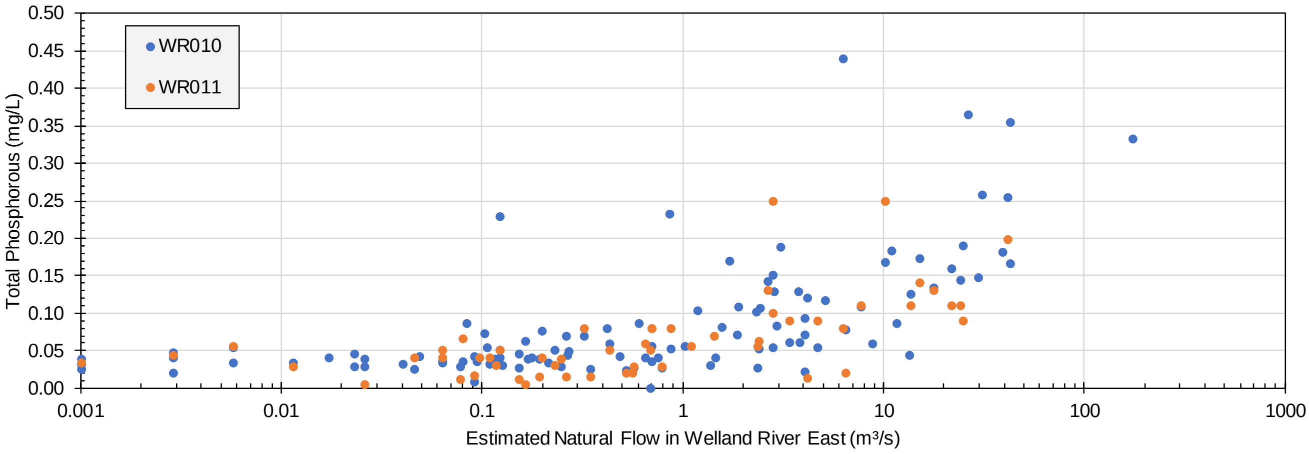

Figure 3: Total Phosphorus Concentration Against Estimated Natural Flow in Welland River East

Comparing the 75th percentile concentrations for both stations showed that ammonia concentrations are higher at WR011 during winter/spring and that overall, the concentration of phosphorus is higher upstream in the Welland River (WR010). The remaining parameters do not show significant differences between upstream (WR010) and downstream (WR011) monitoring stations. Based on the data, there are frequent exceedances of the PWQOs for phosphorus and *E. coli.* in the Welland River East.

The GoldSim model uses the monthly 75th percentile of ammonia, *E. coli*, nitrate, and total phosphorus. For each parameter, the highest 75th percentile value from WR011 and WR010 was selected. The decision to use this approach is based on the uncertainty of WR011 (as it would be influenced by flow from Niagara River) and the additional sources which could affect water quality in the reach between WR010 and WR011. Using the highest value of the two stations yields a conservative approach for prediction of assimilative capacity of the system. The assimilative capacity of the system for ammonia is based on the regulatory limit of unionized ammonia, ammonia in the system (based on 75th percentile), and 75th percentile values of pH and temperature.

The seasonal values selected to characterize the water quality in the Welland River East are presented in Table 5.

Table 5: Summary of Seasonal Water Quality Concentrations for Welland River East

Parameter		**Winter**		**Spring**		**Summer**		**Fall**	
		WR010	**WR011**	**WR010**	**WR011**	**WR010**	**WR011**	**WR010**	**WR011**
Number of Samples		**5**	**2**	**34**	**17**	**38**	**16**	**41**	**20**
Total Ammonia (mg/L)	Geo-mean	0.21	0.47	0.16	0.16	0.14	0.07	0.10	0.10
	75th	0.23	0.59	0.21	0.28	0.22	0.09	0.20	0.16
Unionized Ammonia (mg/L)	Geo-mean	0.001	0.003	0.003	0.004	0.009	0.003	0.004	0.004
	75th	0.001	0.007	0.006	0.007	0.018	0.004	0.009	0.007
Nitrate (mg/L)	Geo-mean	1.78	2.32	0.76	0.62	0.32	0.33	0.50	0.50
	75th	2.29	2.38	1.11	0.91	0.49	0.48	1.05	0.82
E. coli. (cfu/100 mL)	Geo-mean	-	**2474**	-	66	-	25	-	64
	75th	-	**6920**	-	**308**	-	**105**	-	**170**
Total Phosphorus (mg/L)	Geo-mean	**0.09**	**0.12**	**0.07**	**0.05**	**0.06**	**0.04**	**0.06**	**0.04**
	75th	**0.14**	**0.13**	**0.16**	**0.09**	**0.08**	**0.06**	**0.10**	**0.08**
Dissolved Oxygen (mg/L)	Geo-mean	13.73	14.48	11.64	12.04	9.17	9.78	9.84	9.85
	25th	12.68	13.81	10.66	11.48	8.12	8.66	8.51	8.97
CBOD$_5$ (mg/L)	Geo-mean	-	-	-	0.16	-	0.31	-	0.16
	75th	-	-	-	1.03	-	2.00	-	1.00
Total Suspended Solids (mg/L)	Geo-mean	20.2	26.1	12.6	7.4	8.9	5.6	6.6	4.7
	75th	34.9	28.8	20.9	21.0	11.4	11.8	9.7	6.0
Water Temperature (ºC)	Geo-mean	1.78	1.62	7.54	8.77	22.57	23.64	13.52	13.40
	75th	2.10	1.99	14.39	13.46	24.06	25.27	19.69	20.45
pH	Geo-mean	7.82	7.73	8.08	7.98	8.17	8.08	8.18	8.02
	75th	7.82	7.81	8.23	8.16	8.26	8.23	8.27	8.15

Notes:

1. **Bold** values indicate exceedances of applicable PWQO.
2. Data provided by NPCA.
3. Highlighted values correspond with input to the GoldSim model.

2.2.3 Niagara River

The water quality in the Niagara River was quantified by compiling data from three sources since no one location offered a full complement of data for all required parameters. The data sources were:

- The Niagara River at Fort Erie (ON02HA0045) from 1981 to 1999 (total phosphorus, total ammonia, unionized ammonia, nitrate, and pH).
- The Niagara River at Niagara-on-the-Lake (ON02HA0019) from 1975 to 1999 (total phosphorus only, not used as modelling input).
- The raw water intake data for the Niagara Falls Drinking Water Supply Plant from 2016 to 2018 (*E. coli*).
- Water temperatures in the Niagara River were based on hourly measurements taken at Buffalo, NY (Station 9063020) by NOAA between 2007 and 2018.
- Dissolved oxygen and TSS concentrations were obtained from the USGS for station 04216070 (Niagara River at Fort Erie) for the period 2014 to 2019.

Water quality data for the eastern basin of Lake Erie and the Niagara River at Fort Erie were obtained from the Environment Canada website while the water intake data was provided by Niagara Region. Data from NOAA and the USGS were obtained from their respective websites.

Although older than the Lake Erie data, the Niagara River data was selected since the Lake Erie data was collected sporadically and could not adequately define seasonal variations.

In general, the water quality in the Niagara River meets all of the applicable objectives. The only exception was total phosphorus where the 75th percentile concentration of 0.043 mg/L during winter months exceeds the PWQO (0.03 mg/L). This is a consistent annual pattern that occurs throughout the entire data record, with phosphorus below PWQO during all seasons with the exception of winter. The highest monthly total phosphorus concentrations typically occur in December and January.

Measured data regarding TSS and Carbonaceous Biochemical Oxygen Demand ($CBOD_5$) were not available in sufficient quantity to provide seasonal statistical summaries. However, since the water in the Niagara River is typically clear (NYPA, 2005), it is expected that concentrations of TSS and $CBOD_5$ are low. Sixteen samples collected by the USGS provide annual estimates for the geometric mean and 75th percentile TSS values of 5.2 mg/L and 11.3 mg/L, respectively.

The 75th percentile of seasonal values of different parameters for Niagara River and Lake Erie are presented in Table 6.

This study model uses the seasonal 75th percentile values for the Niagara River station for all parameters except dissolved oxygen. The seasonal 75th percentile values for pH and temperature were used to estimate unionized ammonia concentrations. The seasonal 25th percentile values for dissolved oxygen were used.

Table 6: Summary of Seasonal Water Quality Concentrations for Niagara River

Parameter		Winter		Spring		Summer		Fall	
		Niagara River[2]	Raw Water Intake[2]	Niagara River[2]	Raw Water Intake[2]	Niagara River[2]	Raw Water Intake[2]	Niagara River[2]	Raw Water Intake[2]
Number of Samples		596	39	361	39	346	39	375	39
Total Ammonia (mg/L)	Geo-mean	0.007	-	0.029	-	0.022	-	0.012	-
	75th	0.014	-	0.046	-	0.044	-	0.032	-
Unionized Ammonia (mg/L)	Geo-mean	<0.001	-	<0.001	-	0.001	-	<0.001	-
	75th	<0.001		0.001	-	0.002	-	<0.001	-
Nitrate (mg/L)	Geo-mean	0.25	0.20	0.26	0.19	0.19	0.10	0.14	0.07
	75th	0.31	0.36	0.31	0.30	0.26	0.20	0.18	0.12
E. coli. (cfu/100 mL)	Geo-mean	-	5	-	3	-	3	-	5
	75th	-	50	-	12	-	8	-	26
Total Phosphorus (mg/L)	Geo-mean	0.027	-	0.019	-	0.015	-	0.019	-
	75th	**0.043**	-	0.026	-	0.022	-	0.027	-
Dissolved Oxygen[3] (mg/L)	Geo-mean	11.1	-	9.81	-	10.5	-	10.4	-
	25th	10.4	-	8.60	-	8.98	-	8.75	-
Water Temperature (°C)[4]	Geo-mean	1.5	-	6.4	-	21.7	-	13.8	-
	75th	2.5	-	10.1	-	23.9	-	20.1	-
pH	Geo-mean	7.98	-	8.12	-	8.27	-	8.08	-
	75th	8.12	-	8.20	-	8.33	-	8.20	-

Notes:

1. **Bold** values indicate exceedances of applicable PWQO.
2. Data provided by Niagara Region.
3. Dissolved oxygen data obtained from USGS.
4. Data downloaded from NOAA (NOAA, 2019).
5. Average value – geometric mean could not be calculated due to water temperatures below zero.
6. Shaded cells correspond with input to the GoldSim and Mass Balance models.

The total phosphorus concentrations in the upper section of the Niagara River (Fort Erie) are compared to those on the lower section (Niagara-on-the-Lake) in Table 7 for the period 1981 to 1999. Apart from summer, the mean total phosphorus concentrations in the lower sections are lower than the concentrations in the upper section. In all seasons except winter, the difference in mean and 75th percentile concentrations are less than 0.03 mg/L (3 µg/L) suggesting that the effects of current direct phosphorus loads to the Niagara River (e.g., not from Lake Erie) are not measurable.

Table *7*: Comparison of Total Phosphorus in Niagara River Between Fort Erie and Niagara-on-the-Lake

Statistic	Location	Winter	Spring	Summer	Fall
Number of Samples	Fort Erie[1]	597	626	605	618
	Niagara-on-the-Lake[2]	819	865	846	839
Geometric Mean (mg/L)	Fort Erie	0.0346	0.0238	0.0196	0.0241
	Niagara-on-the-Lake	0.0249	0.0206	0.0200	0.0228
75th Percentile (mg/L)	Fort Erie	0.0427	0.0259	0.0215	0.0265
	Niagara-on-the-Lake	0.0345	0.0264	0.0204	0.0257

Notes:

1. Data for Fort Erie collected at Station ON02HA0045 (1981 to 1999).
2. Data for Niagara-on-the-Lake collected at Station ON02HA0019 (1981 to 1999).

2.2.4 Lyons Creek

A summary of measured water quality in Lyons Creek is provided in Table 8. Data were provided by NPCA for station LY003 between 2003 and 2018. $CBOD_5$ data was available only for the 2009 to 2014 period, while dissolved oxygen was not available in the dataset provided for this study.

As expected for a small watershed that drains agricultural areas, the total phosphorus concentrations in Lyons Creek are elevated well above the PWQO.

Table 8: Summary of Seasonal Water Quality Concentrations for Lyons Creek

Parameter		Winter	Spring	Summer	Fall
	Number of Samples	**3**	**35**	**44**	**44**
Total Ammonia (mg/L)	Geo-mean	0.059	0.051	0.041	0.035
	75th	0.059	0.120	0.080	0.060
Unionized Ammonia (mg/L)	Geo-mean	-	0.002	0.002	0.004
	75th	-	0.005	0.004	0.008
Nitrate (mg/L)	Geo-mean	0.75	0.08	0.07	0.10
	75th	0.87	0.20	0.20	0.20
E. coli. (counts/100 mL)	Geo-mean	**137**	45	32	44
	75th	**520**	95	57	88
Total Phosphorus (mg/L)	Geo-mean	0.147	0.124	0.141	0.103
	75th	**0.255**	**0.160**	**0.160**	**0.140**
$CBOD_5$ (mg/L)	Geo-mean	-	1.16	0.95	1.13
	75th	-	2.00	1.00	1.00
Water Temperature (ºC)	Geo-mean	0.30	6.4	15.1	18.4
	75th	0.30	14.9	26.1	24.7
pH	Geo-mean	7.43	7.83	7.87	7.78
	75th	7.65	7.99	8.02	7.95

Note:

1. **Bold** values indicate exceedances of applicable PWQO.
2. Data provided by NPCA.
3. Shaded correspond with input to the GoldSim and Mass Balance models.

2.2.5 Hydro Electric Power Canal (HEPC)

A summary of the measured water quality in the HEPC near the existing Niagara Falls WWTP is provided in Table 9. Data were provided by NPCA for station PR001 (HEPC at Whirlpool Road) between 2012 and 2018. Based on these data, there are exceedances of the PWQOs for phosphorus during fall and winter months and *E. coli.* in the HEPC.

The GoldSim model does not use this data as input, but these measurements are used to validate the model performance downstream of the existing Niagara Falls WWTP.

Table 9: Summary of Seasonal Water Quality Concentrations in the Hydro Electric Power Canal

Parameter		Winter	Spring	Summer	Fall
Number of Samples		3	17	17	15
Total Ammonia (mg/L)	Geo-mean	0.078	0.264	0.186	0.209
	75th	0.180	0.375	0.250	0.280
Unionized Ammonia (mg/L)	Geo-mean	0.001	0.004	0.008	0.008
	75th	0.001	0.006	0.015	0.012
Nitrate (mg/L)	Geo-mean	0.37	0.21	0.14	0.12
	75th	0.51	0.27	0.22	0.16
E. coli. (cfu/100 mL)	Geo-mean	**5,780**	**283**	**116**	**570**
	75th	**7,550**	**440**	**220**	**4,200**
Total Phosphorus (mg/L)	Geo-mean	**0.042**	0.013	0.015	0.022
	75th	**0.059**	0.018	0.020	**0.040**
Dissolved Oxygen (mg/L)	Geo-mean	16.37	12.46	10.00	9.07
	25th	13.56	9.88	8.26	6.62
$CBOD_5$ (mg/L)	Geo-mean	-	0.24	0.07	0.57
	75th	-	2.00	0.05	2.00
Total Suspended Solids (mg/L)	Geo-mean	15.4	2.6	2.5	4.7
	75th	19.5	2.8	2.2	14.8
Water Temperature (ºC)	Geo-mean	2.1	11.5	22.4	9.8
	75th	3.5	18.6	23.6	13.5
pH	Geo-mean	7.86	8.00	8.12	8.03
	75th	7.99	8.16	8.22	8.14

Note:

1. **Bold** values indicate exceedances of applicable PWQO.
2. Data provided by NPCA.

2.2.6 Existing Niagara Falls Wastewater Treatment Plant, Primary Bypass, and Secondary Bypass

Water quality data and laboratory analysis were provided for the existing Niagara Falls WWTP Final Effluent from 2015 to 2018 by the Niagara Region. Water quality data for the Plant Bypass (Sewage receives no treatment prior to release) and the Secondary Bypass (Sewage receives primary treatment prior to release) were also provided. The water quality data are summarized in Table 10.

For validation, the GoldSim model uses the largest between the geometric mean and the 75th percentile value to characterize the effluent to the existing Niagara Falls WWTP and the primary and secondary bypass data. The effects of CSOs were included and the water quality was assumed to correspond to values reported for the Plant Bypass. The assimilative capacity of the system was estimated by excluding all CSOs, and assuming that the water quality from the effluent at existing Niagara Falls WWTP correspond with the regulatory limits outlined in the Amended Environmental Compliance Approval (ECA) number 7962-7ZLKR6, issued on February 3, 2010. The regulated parameters which are outlined in the aforementioned ECA are total phosphorus and *E. coli*, with effluent limits specified as at 0.75 mg/L and 200 counts/100 ml, respectively.

The data presented in Table 10 indicates that the 75th percentile of total phosphorus during summer would be exceeding the regulatory requirement outlined in the ECA.

Table 10: Summary of Seasonal Water Quality Concentrations for the Existing Niagara Falls Wastewater Treatment Plant Effluent, Primary Bypass, and Secondary Bypass

Parameter		Winter			Spring			Summer			Fall		
		Effluent	Primary Bypass	Secondary Bypass	Effluent	Primary Bypass	Secondary Bypass	Effluent	Primary Bypass	Secondary Bypass	Effluent	Primary Bypass	Secondary Bypass
Number of Samples		**361**	**7**	**18**	**368**	**18**	**34**	**368**	**14**	**31**	**364**	**9**	**20**
Total Ammonia (mg/L)	Geo-mean	4.04	17.09	18.79	2.91	10.20	15.87	3.66	10.45	20.17	3.69	5.66	14.59
	75th	9.61	33.28	22.83	7.37	19.60	23.50	8.42	19.78	27.80	8.01	18.35	19.65
Unionized Ammonia (mg/L)	Geo-mean	**0.014**	-	-	**0.013**	-	-	**0.026**	-	-	**0.021**	-	-
	75th	**0.032**	-	-	**0.032**	-	-	**0.058**	-	-	**0.046**	-	-
Nitrate (mg/L)	Geo-mean	**6.53**	0.46	0.22	**5.91**	0.44	0.32	**5.38**	0.24	0.22	**5.71**	0.29	0.24
	75th	**9.64**	2.03	0.20	**8.61**	1.70	0.21	**7.65**	0.20	0.21	**7.82**	0.47	0.20
E. coli. (cfu/100 mL)	Geo-mean	7	-	**4,102,000**	9	**1,395,500**	**1,972,600**	6	**4,177,700**	**4,447,900**	8	**2,800,600**	**5,047,200**
	75th	13	-	-	13	**2,550,000**	**3,650,000**	10	**5,802,500**	**8,160,000**	11	**6,995,000**	**8,422,500**
Total Phosphorus (mg/L)	Geo-mean	**0.30**	**3.60**	**5.12**	**0.28**	**2.26**	**3.05**	**0.40**	**3.21**	**3.50**	**0.35**	**2.53**	**3.39**
	75th	**0.38**	**5.87**	**8.08**	**0.36**	**2.98**	**5.18**	**0.52**	**4.35**	**4.40**	**0.47**	**4.60**	**4.53**
$CBOD_5$ (mg/L)	Geo-mean	4.39	68.12	175.41	4.72	71.21	100.42	5.23	105.87	128.56	5.61	90.31	126.15
	75th	5.80	142.75	279.75	6.50	122.50	143.00	7.73	136.25	177.00	8.40	167.00	166.25
Water Temperature (ºC)	Geo-mean	10	-	-	11.9	-	-	20.2	-	-	17.3	-	-
	75th	11.7	-	-	14.5	-	-	21.9	-	-	20.2	-	-
pH	Geo-mean	7.25	-	-	7.29	-	-	7.25	-	-	7.24	-	-
	75th	7.35	-	-	7.4	-	-	7.36	-	-	7.31	-	-

Note:

1. **Bold** values indicate exceedances of applicable PWQO.
2. Data provided by Niagara Region.
3. Shaded cells correspond with input to the GoldSim for verification only

2.3 Total Phosphorus Loads in Study Area

The existing total phosphorus loads in the study area provided in Table 11 were estimated based on seasonal average flows and geometric mean concentrations for background. The estimates show that:

- Over 98% of the total phosphorus in the Niagara River comes from Lake Erie.
- The contributions from the Welland River East represent about 1% of the total phosphorus loads.
- Based on the rated capacity and effluent discharge limits, the existing Niagara Falls WWTP contributes approximately 19 tonnes/year (0.3% of the total).
- Total annual contributions from the primary secondary bypasses at the existing Niagara Falls WWTP and the CSOs are estimated to be less than 2 tonnes/year (less than 0.05% of the total loads in the Niagara River).

Table 11: Estimated Seasonal and Annual Total Phosphorus Loads in Study Area

Season	Winter (kg/d)	Spring (kg/d)	Summer (kg/d)	Fall (kg/d)	Annual (tonnes/year)
Niagara River at Fort Erie	15,066.2	11,036.0	8,952.9	10,748.6	4,173.1 (98.3%)
Niagara River into Chippewa Creek	960.4	622.2	554.9	654.1	254.3 (6.0%)
Lyons Creek	35.1	40.0	10.6	16.8	9.3 (0.2%)
Welland River East	114.7	173.0	88.0	106.3	44.0 (1.0%)
Existing Niagara Falls WWTP Effluent[2]	51.2	51.2	51.2	51.2	18.7 (0.3%)
Existing Niagara Falls WWTP Primary Bypass	0.5	1.6	0.5	0.5	0.3 (0.01%)
Existing Niagara Falls WWTP Secondary Bypass	3.0	4.8	1.3	1.9	1.0 (0.02%)
Combined Sewer Overflows	0.3	1.2	0.3	0.5	0.2 (<0.01%)
HEPC at Sir Adam Beck	1,165.2	893.9	706.9	831.3	327.8 (7.7%)
Total[3]	15,271.0	11,307.7	9,104.8	10,925.8	4,246.6 (100%)

Note:

1. Values in brackets represent percentage of total annual loads to Niagara River not including other inflows.
2. Based on ECA effluent limits (0.75 mg/L) and rated capacity of plant (68.3 MLD).
3. Total does not include contributions from other sources (e.g., other tributaries, discharges to Niagara River, etc.)

2.4 Data Conclusions and Generalizations

Based on the preceding characterisation of available flow and water quality data, the following conclusions are provided:

- There are no major seasonal variations in Niagara River flow. Variations in Niagara River flow are likely related to changes in the water level in Lake Erie. These variations can either be long-term due to seasonal or interannual changes in the regional hydrology and precipitation (e.g., over entire Great Lakes basin) or short-term due to wind related events (e.g. longitudinal seiching) along Lake Erie.
- Flows in the HEPC and Chippewa Creek are controlled by the operation of the ICD and should not be represented as a natural flow regime in the ACS.
- The background concentrations of two parameters, phosphorus and *E. coli*, are shown to exceed their respective water quality criteria within two or more watercourses discharging to the HEPC:
- While the Niagara River generally has lower concentrations of phosphorus when compared to the Welland River and Lyons Creek, it represents a far more significant loading source of this parameter due to the considerable difference in flows directed through the HEPC from all sources:
  - Niagara River approximates 95.1% of background HEPC flows;
  - Welland River (natural and supplemental flows) approximates 4.5% of background HEPC flows;
  - Lyons Creek contributes less than 0.3% of background HEPC flows; and
  - Existing Niagara Falls WWTP approximates 0.1% of background HEPC flows.
- Total phosphorus concentrations within the Niagara River tend to increase substantially outside the growing season; the winter 75th percentile phosphorus concentration in the Niagara River is almost twice that of other seasons (22 to 27 µg/L).
- A comparison of the total phosphorus concentrations in the upper and lower sections of the Niagara River suggest that the current direct phosphorus loads to the Niagara River (e.g., not from Lake Erie) are not measurable.
- Notably, it has recently been estimated that 57% of all phosphorus loads to Lake Ontario come from the Niagara River from upstream sources in Lake Erie (ECCC & USEPA, 2018).
- The Welland River East and Lyons Creek also have some local influence, particularly in spring when background phosphorus loading to the HEPC from these two watercourses alone can exceed 20%.
- Water quality in Welland River East, particularly total phosphorus, deteriorates as the natural flows increase. This correlation is likely attributed to the increased influence of poor land management practices during rainfall runoff compared to the beneficial dilution effects of consistent, supplemental inflows from the Welland Canal via the Port Robinson Pumping Station, ports in the old siphon, and the Welland WWTP bypass under low flow conditions.
- Relative to the Niagara River, bacteriological concentrations in the Welland River and Lyons Creek are so high that the Welland River and Lyons Creek are the dominant sources of *E. coli* throughout the winter and spring, despite order of magnitude differences in flow volume.
- As such, much of the water quality issues in the system are currently being influenced by background contributions from Lake Erie and smaller watersheds located upstream of the HEPC.

3.0 MODELLING APPROACH AND RESULTS

The modelling approach was designed with the following objectives:

- Estimate the remaining capacity of the receiving waters to accept the proposed WWTP effluent flows without exceeding applicable guidelines,
- Estimate the recommended effluent limits for each of the discharge locations and compare those limits to feasible limits based on the available treatment technology, and
- Estimate the existing and future concentrations in the receiving waters at selected locations based on the recommended effluent limit.

Given the complexity of the hydrodynamic conditions in the study area, the first three discharge locations (Location 1 – Welland River East, Location 2 – HEPC and Location 3 – Chippewa Creek) will be modelled using a stochastic approach. The fourth location, evaluating a discharge to the Niagara River, is relatively simple by comparison and was modelled using a mass balance approach.

The following points outline the methods used to complete the ACS at the four locations and for various parameters:

- Given the complex and regulated hydrodynamic conditions in Location 1 – Welland River East, Location 2 – HECP and Location 3 – Chippewa Creek, a stochastic model (GoldSim) was used to complete the ACS for total phosphorus, total ammonia, nitrate, and fecal coliforms (*E. coli*). Estimates for unionized ammonia were calculated based on modelled ammonia and measured 75th percentile temperature and pH.
- To provide an alternate estimate of the assimilative capacity, a mass balance model was developed to estimate the maximum allowable effluent concentrations for total ammonia, unionized ammonia, nitrate, fecal coliforms (*E. coli*), and total phosphorus for conditions where all the flows in the study area were assumed to be representative of low-flow conditions (e.g., 7Q20 or minimum regulated flow).
- The assimilative capacity was assessed at two compliance points; a local compliance point that is immediately downstream of the proposed discharge and a system compliance point in the HEPC downstream of the existing Niagara Falls WWTP to consider cumulative effects in the study area.
- For Location 4 – Niagara River, the effluent is not expected to mix with the entire width if the Niagara River before reaching Niagara Falls. As such a 2-Dimensional Gaussian Plume model was used to predict the lateral mixing of the proposed effluent in the Niagara River. This model was used to assess for total phosphorus, total ammonia, unionized ammonia, nitrate, and fecal coliforms (*E. coli*).
- For parameters associated with oxygen in the water (dissolved oxygen and $CBOD_5$), the maximum allowable effluent concentrations were estimated using a simplified and conservative dissolved oxygen mass balance model that included $CBOD_5$ decay for all the locations. Since a high rate of reaeration is expected in the Niagara River and HEPC due to current speeds, this assessment was only completed for a local compliance point.
- The assimilative capacity did not consider the depletion of dissolved oxygen associated with the nitrification of ammonia.
- A simple mass balance model was used to estimate the maximum allowable effluent concentrations for TSS based on the CCME recommended maximum increase of 5 mg/L over the background conditions (Table 4).

3.1 GoldSim Modelling for Locations 1 Through 3

A stochastic water balance and water quality model was developed using GoldSim version 12.1. GoldSim is a graphical, object-oriented mathematical model where all input flows, constituents and functions are defined by the user and are built as individual objects or elements linked together by mathematical expressions. The object-based nature of the model is designed to facilitate understanding of the various factors, which control an engineered or natural system and predict the future performance of the system.

In GoldSim, each flow that could influence water quality predictions for the Project was itemized and assigned a source term chemistry, for the constituents of interest, based on measured water quality in the system. The model was developed to allow the user to run specific scenarios, including baseline or future conditions (by specifying the desired location of the new WWTP).

3.1.1 Model Conceptualization

The water balance and water quality model were designed to estimate the assimilative capacity and future concentrations in the system. GoldSim runs calculations on a daily timestep for the season of interest.

In GoldSim, each flow (e.g., river flows, discharges, etc.) entering the area of interest and with potential to affect water quantity and/or quality of the system was itemized and assigned a source term chemical profile for selected constituents, based on measured water quality data. Inflow volumes and concentrations were included as inputs to the system to account for loadings from major watersheds, CSOs, and WWTPs draining into the study area.

The stochastic approach was selected to account for the variability and/or uncertainty of the input parameters controlling the model associated with flow. Stochastic modelling in GoldSim was achieved using a Monte Carlo simulation approach. This approach consists of running the model for a selected number of iterations (i.e., realizations). For each realization, the stochastic inputs are randomly sampled based on their statistical distributions. It was assumed that 1,000 realizations would be sufficient to reach a representative and convergent distribution of results. The probability distribution assumed a log-normal distribution for the flows, defined seasonally. By running the model stochastically, each flow will present a range rather than a single value, which accounts for the observed variability in the available dataset.

For the purpose of analysing the flows on a seasonal manner, the months were grouped as follows: March to May to represent spring, June to August to represent summer, September to November to represent fall; and December to February to represent winter. For the purpose of analysing the flows on a seasonal manner, the months were grouped as follows: March 1st to May 31st to represent spring, June 1st to August 31st to represent summer, September 1st to November 30th to represent fall; and December 1st to February 28th to represent winter. While the seasonal patterns varied between flows assessed, the seasonal definition remained unchanged between flow inputs. Average, standard deviation, maximum and minimum flows were used to characterize flow distribution. Flows which did not show seasonal variability were input as a constant value throughout the year.

Water quality concentrations for inflows were based on the 75th percentile seasonal concentrations from measured water quality data for total phosphorus, nitrate, and total ammonia.

Following the model run, the probability of exceedance was calculated based on the 1,000 values calculated at each timestep to assess the range of conditions that could occur in the local and system compliance point for each scenario and season. In a typical ACS, the recommended effluent limits are estimated for a low flow condition that occurs for one week every 20 years (i.e., 7Q20). GoldSim was used to estimate the allowable effluent limits that will result in exceedances of the criteria no more than 5.0% of the time.

Recommended effluent limits were estimated by iteratively running the model to identify a mass flow that results in the water quality in the HEPC meeting PWQO criterion for each of the water quality parameters at the discharge location of the HEPC into the Niagara River. Allowable mass was then converted to the allowable concentration according to the flow in the new WWTP.

3.1.2 Flow Implementation

Flow was implemented in the model based on the available data and the stochastic modelling using the GoldSim model for Welland River East, Lyons Creek, and the HEPC. Flow in Chippewa Creek was estimated using the HEPC flow as well as the flows coming from the Welland River East and Lyons Creek (Sections 2.1.4 and 2.1.5).

3.1.2.1 Welland River East

Table 12 shows the parameters associated with the log-normal distributions followed to characterize the seasonal flow in Welland River East in GoldSim. These distributions include all supplemental inflows from the Welland Canal into the Welland River East. Figure 4 shows the probability distribution of seasonal flows.

Table 12: Summary of Seasonal Flow Statistics for Welland River East Including Supplemental Flows

Parameter	Winter	Spring	Summer	Fall
Mean flow (m^3/s)	17.7	24.4	14.9	20.6
Maximum flow (m^3/s)	29.0	40.2	19.9	32.8
Minimum flow (m^3/s)	14.0	14.7	13.6	12.7
Standard deviation (m^3/s)	3.8	5.4	1.3	4.8

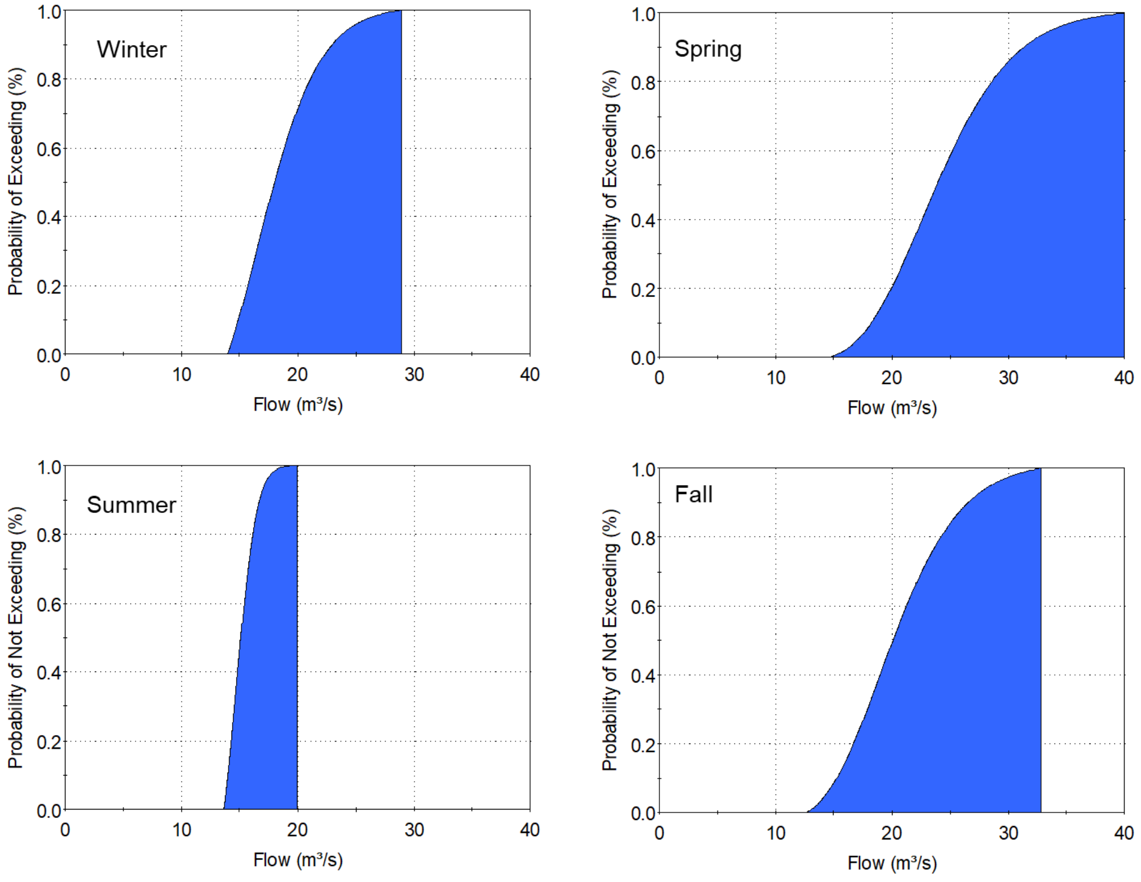

Figure 4: **Seasonal Log-Normal Distribution of Flows in the Welland River East Including Supplemental Inflows**

3.1.2.2 Lyons Creek

Table 13 shows the parameters associated with the seasonal log-normal distributions followed to characterize the flow in Lyons Creek in GoldSim. Figure 5 shows the probability distribution of seasonal flow.

Table 13: **Summary of Seasonal Flow Statistics for Lyons Creek**

Parameter	Winter	Spring	Summer	Fall
Mean flow (m^3/s)	1.4	2.0	0.5	0.7
Maximum flow (m^3/s)	3.1	4.0	1.2	2.2
Minimum flow (m^3/s)	0.2	0.6	0.3	0.3
Standard deviation (m^3/s)	0.7	0.7	0.2	0.5

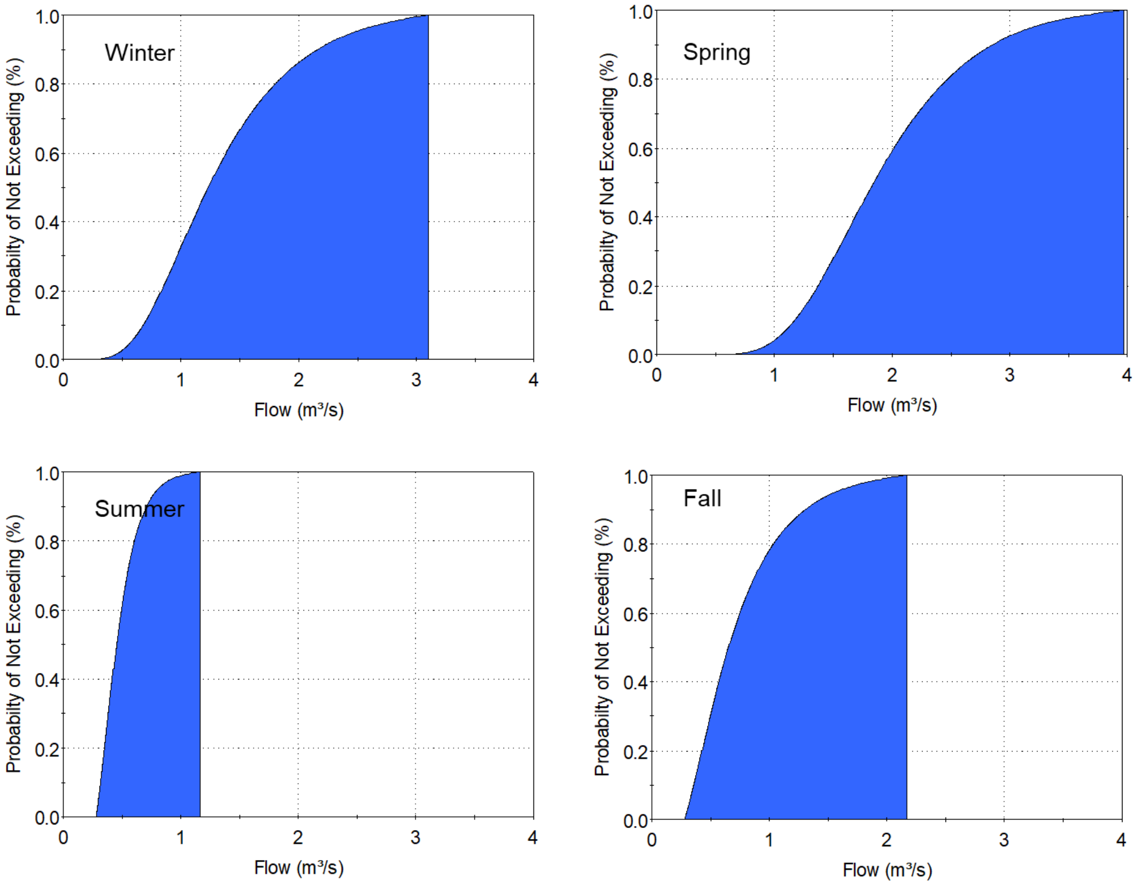

Figure 5: Seasonal Log-Normal Distribution of Flows in the Lyons Creek

3.1.2.3 *Hydro Electric Power Canal (HEPC)*

Table 14 shows the parameters associated with the log-normal distributions followed to characterize the flow in HEPC in GoldSim. Figure 6 shows the probability distribution of seasonal flow. The flow through Chippewa Creek was calculated based on the difference between the flow in the HEPC (input in GoldSim as per the distribution below) and the corresponding flow in Welland River East.

Table 14: Summary of Seasonal Flow Statistics for the Hydro Electric Power Canal

Parameter	Winter	Spring	Summer	Fall
Mean flow (m³/s)	429	411	446	421
Maximum flow (m³/s)	435	431	469	436
Minimum flow (m³/s)	420	401	419	403
Standard deviation (m³/s)	8.4	16.7	25.3	16.7

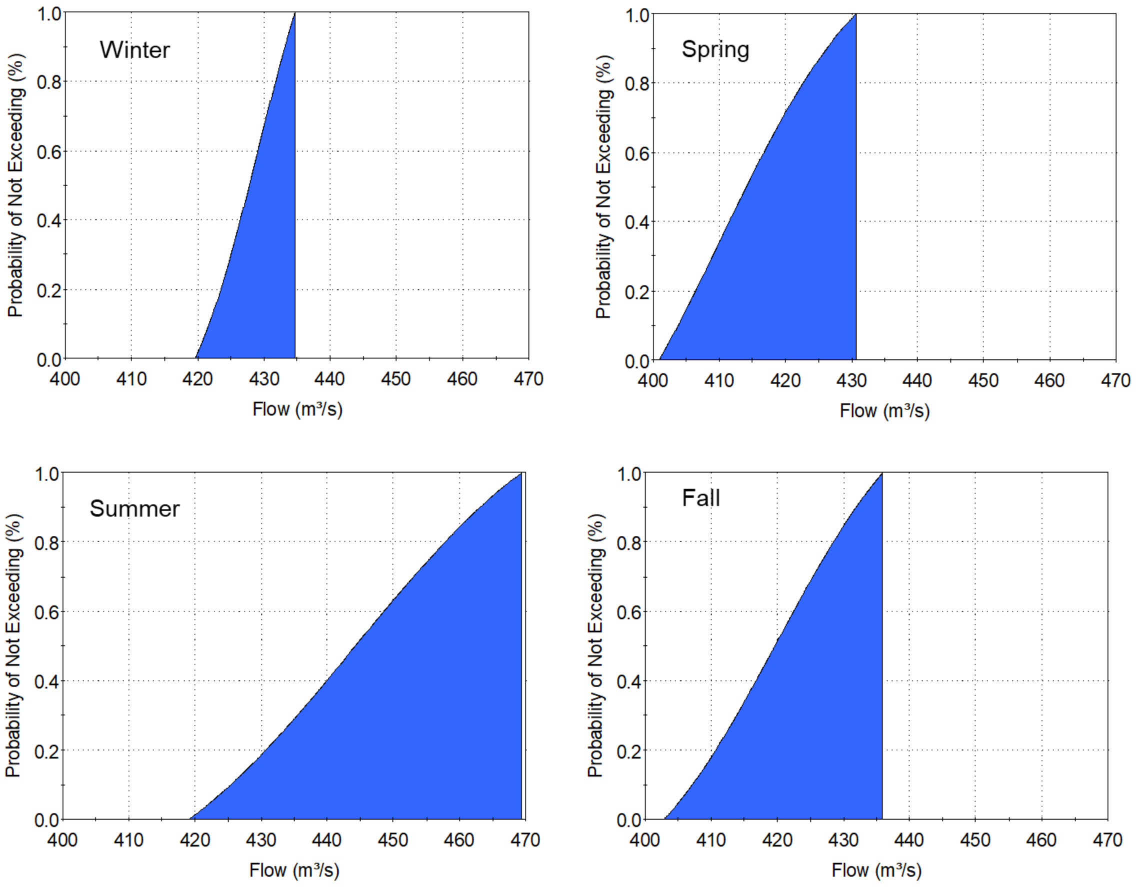

Figure 6: Seasonal Log-Normal Distribution of flows in the Hydro Electric Power Canal

3.1.2.4 *Existing Niagara Falls Wastewater Treatment Plant*

A statistical analysis of the flow data from the existing Niagara Falls WWTP showed little variation throughout the year. Table 15 shows the statistical flow distribution of existing Niagara Falls WWTP (based on data provided by Niagara Region), the flow limit based on existing ECA, and the assumed yearly mean flow used for modelling purposes in the GoldSim model.

Table 15: Summary of Seasonal Flow Statistics for Existing Niagara Falls Wastewater Treatment Plant, Environmental Compliance Approval Limit, and Assumed Mean Flow

Parameter	Winter	Spring	Summer	Fall	ECA Flow Limit	Assumed Mean Flow
Mean flow (m^3/s)	0.23	0.27	0.24	0.22	0.79[2]	0.47[3]
Minimum flow (m^3/s)	0.02	0.02	0.01	0.01	na[1]	na[1]
Maximum flow (m^3/s)	0.25	0.30	0.25	0.23	na[1]	na[1]
Standard deviation (m^3/s)	0.19	0.25	0.23	0.2	na[1]	na[1]

Notes

1. Mean flow which is assumed constant throughout the year (i.e., no probability distribution required).
2. Mean flow based on the ECA limit of 68,300 $m^{3/}$day.
3. Information provided by CIMA+.
4. Highlighted value corresponds with input to GoldSim model.

Given the above noted little variation throughout each season and between seasons, the mean value of 0.47 m^3/s was used to define the flow associated with the existing Niagara Falls WWTP. This fixed value was used instead of defining a probability distribution to characterize this input.

3.1.3 Model Validation

Model validation was done using the measured water quality data at the HEPC. The 75th percentile measurements at station PR001 was used for this purpose. Comparison were done considering two scenarios:

- excluding the CSOs from the model (No-CSO); and
- including the CSOs in the model (CSO).

The scenario that included the CSOs in the model also included, the overflow and secondary bypass from the existing Niagara Falls WWTP. As presented in Table 3, these flows represent approximately 94.0 to 99.6% of the total CSO flows. Water quality for each CSO (either overflow or secondary bypass) was allocated to each corresponding flow.

Table 16 compares the measured 75th percentile at PR001 with modelled (either CSO or No-CSO) 75th percentile concentration for the key parameters. These results show the effect of modelling CSO or No-CSOs does not affect the 75th percentile, which is to be expected given the low probability of occurrence of CSO events triggering high-load events...

Figure 7 though Figure 9 shows the box plots for comparing the measured and predicted concentration in the two scenarios as No-CSO and CSO for *E. coli*, total ammonia and phosphorus. These figures show how the consideration of CSOs in the model affects significantly the maximum modelled concentrations, specifically for *E. coli.*

When comparing the modelled results against the measured values, it is observed that total ammonia and *E. coli* are underpredicted by GoldSim. Generally, nitrate concentrations are well captured by GoldSim, with the later underpredicting winter concentrations by approximately 20%, and overpredicting nitrate concentrations for the rest of the year, with a maximum overestimation of 44% observed in fall. Phosphorus concentrations are also well captured in GoldSim, with general underprediction of phosphorus concentrations in winter and fall and overpredictions the rest of the year. The largest disagreement between measured and modelled concentration is observed in fall (23% underestimation) and spring (50% overprediction).

The differences between model predicted and measured concentrations are attributed to the following factors: exclusion of the variability of water quality in the model inputs, limited measured water quality data to better characterize chemistry in the system and exclusion of any other potential high-load sources which could affect water quality between the monitoring stations used to develop model inputs and monitoring station used to validate model output.

Table 16: Summary of GoldSim Model Verification

Parameter	Winter			Spring			Summer			Fall		
	PR001 Measured	Model without CSOs	Model with CSOs	PR001 Measured	Model without CSOs	Model with CSOs	PR001 Measured	Model without CSOs	Model with CSOs	PR001 Measured	Model without CSOs	Model with CSOs
Total Ammonia (mg/L)	0.18	0.05	0.05	0.38	0.07	0.07	0.25	0.05	0.05	0.28	0.05	0.05
E. coli (mg/L)	7,550	379	400	440	32	33	220	12	12	4,200	34	34
Nitrate (mg/L)	0.51	0.41	0.41	0.27	0.37	0.37	0.22	0.27	0.27	0.16	0.23	0.23
Total Phosphorus (mg/L)	0.059	0.049	0.049	0.018	0.036	0.036	0.020	0.024	0.025	0.040	0.031	0.032

Notes

1. All values in table are either measured or modelled 75th percentile concentrations.

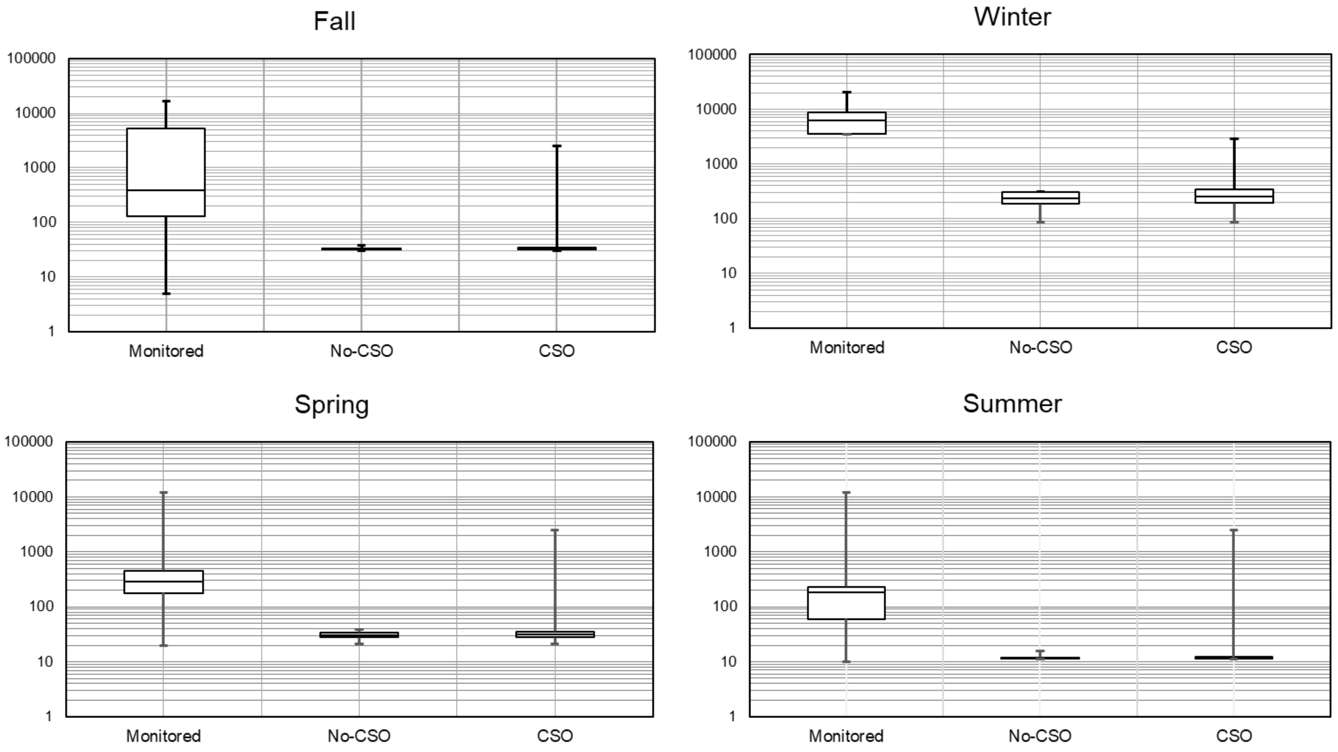

Figure 7: Box Plots Comparing Seasonal Measured and Modeled (No-CSO, CSO) *E. coli* Concentrations

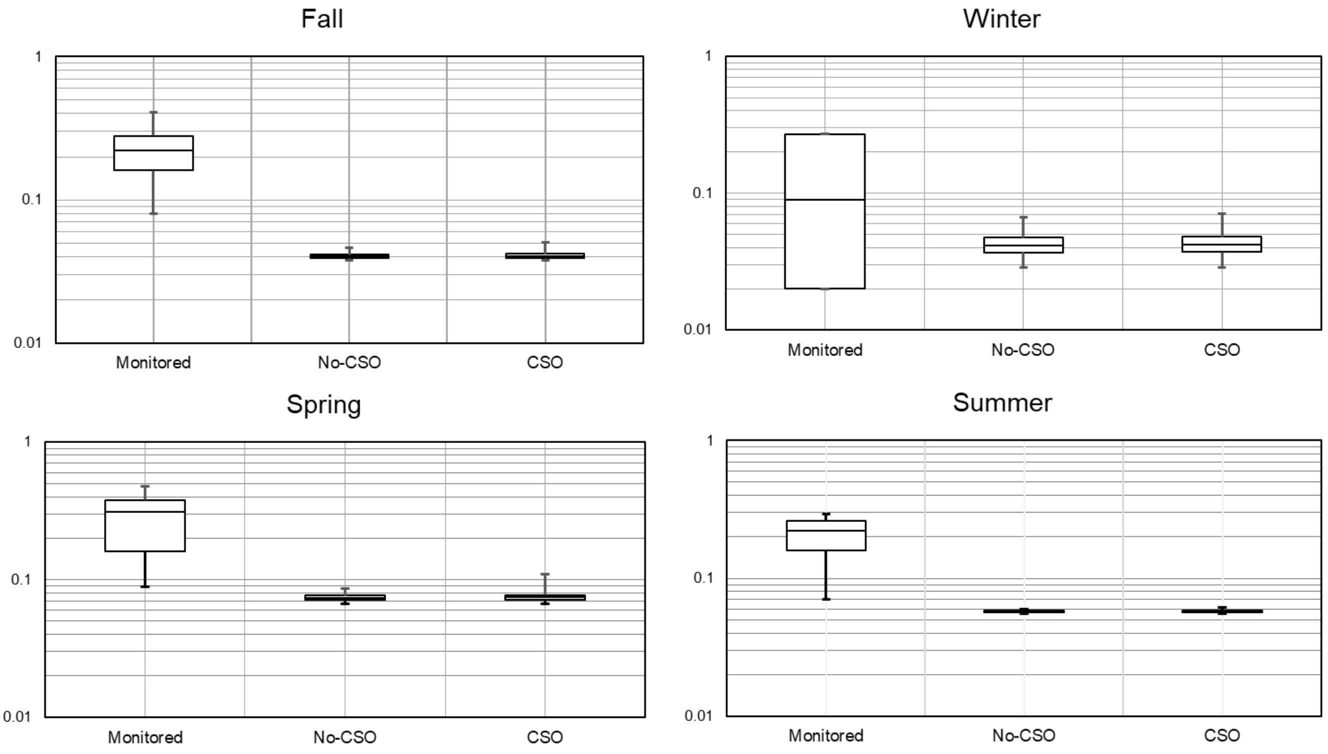

Figure 8: Box Plots Comparing Seasonal Measured and Modeled (No-CSO, CSO) Total Ammonia Concentrations

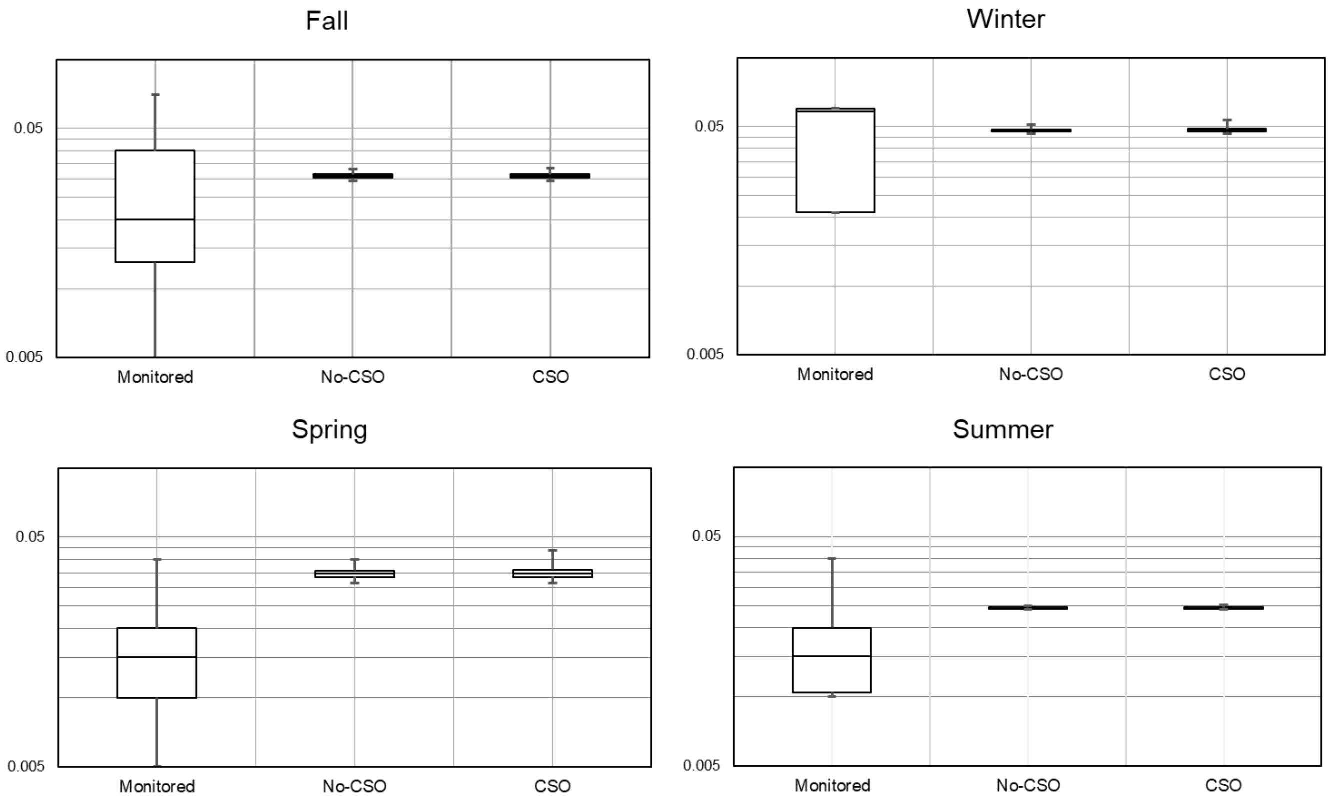

Figure 9: **Box Plots Comparing Seasonal Measured and Modeled (No-CSO, CSO) Total Phosphorus Concentrations**

3.1.4 Modelling Scenarios

Four different modelling scenarios were considered to assess assimilative capacity of the system under existing conditions, and under three potential locations of the new WWTP (Location 1 to Location 3). Each scenario was run independently for each season using a stochastic approach. These scenarios are described as follows:

- Baseline Scenario: To represent existing conditions, which includes the existing Niagara Falls WWTP but does not include the new WWTP.
- Scenario L1: Assumed the new WWTP discharges to the Welland River East, immediately upstream from Triangle Island.
- Scenario L2: Assumed the new WWTP discharges to the HEPC, downstream from Triangle Island and upstream from the existing Niagara Falls WWTP.
- Scenario L3: Assumed the new WWTP discharges to Chippewa Creek, immediately upstream from Triangle Island and downstream from the confluence with Lyons Creek.

3.1.5 Flow Implementation

As previously mentioned, the flow was implemented in the model based on the available data and the stochastic modelling using the GoldSim model for Welland River East, Lyons Creek and the HEPC. Flow in Chippewa Creek was estimated using the HEPC flow demand. The HEPC demand is provided by the flow coming from triangle west (Welland River East and the flow from new existing plant in case of Scenario L1) and flow coming from triangle east (Chippewa Creek, Lyons Creek and flow from new WWTP in case of scenario L2).
Therefore, flow in Chippewa Creek implemented in the model as the HEPC demand subtracted by flow coming from triangle west, Lyons Creek and L2. Flow from new WWTP was considered to be 0.347 m^3/s (30,000 m^3/d).

Effluent from the existing Niagara Falls WWTP was considered as per the average daily flow outlined in the ECA (i.e., 0.79 m^3/s equivalent to 68,300 m^3/day). CSOs associated with overflow and secondary bypass from the existing Niagara Falls WWTP were considered in this analysis.

3.1.6 Water Quality Implementation

The available data for water quality included ammonia, *E. coli*, nitrate, and total phosphorus. Water quality data associated with the 75th percentile was used for all inputs to the model with the exception of the effluent from the existing Niagara Falls WWTP, which considered water quality as per the ECA regulatory limits for total phosphorus and *E. coli*.

3.1.7 Water Quality Objectives

The allowable effluent concentration for the proposed WWTP were estimated by calculating the mass allowed in the system until reaching applicable water qualitive objectives. The threshold for *E. coli*, total phosphorus and nitrate were based on the guidelines provided in Table 4.

The GoldSim model does not incorporate accurate modelling of pH and water temperature. The fraction of the total ammonia that is unionized is a function of pH and temperature. The seasonal target values for total ammonia were back calculated from the PWQO limit of 0.0164 mg/L as nitrogen for unionized ammonia based on the monthly 75th percentile water temperature and pH in Chippewa Creek and the HEPC.

The seasonal thresholds for total ammonia, *E. coli*, nitrate and total phosphorus in the receiver used to estimate recommended effluent limits are summarized in Table 17.

Table 17: Summary of Water Quality Criteria used in GoldSim

Parameter	Winter	Spring	Summer	Fall
Total Ammonia (mg/L)[1]	1.150	0.288	0.142	0.176
E. coli. (cfu/100 mL)	100	100	100	100
Nitrate (mg/L)	3	3	3	3
Total Phosphorus (mg/L)	0.03	0.03	0.03	0.03

Note:

1. Total ammonia criteria based on target unionized ammonia concentration of 0.0164 mg/L as N and seasonal average water temperature and pH in receiving water.

3.1.8 Maximum Allowable Effluent Concentrations

The allowable mass modelled in the system was extracted for the local compliance point (immediate receiver where effluent from the new WWTP plant would enter the system) and at the system compliance point (downstream of the existing Niagara Falls WWTP). The recommended effluent concentrations were calculated by dividing the allowable mass by the flow from new WWTP. Large values in the table can be explained by the small flow rate in the proposed WWTP compared to the other flows in the system.

Table 18 shows the recommended effluent limits based on assimilative capacity at the local and system compliance points. These concentrations were calculated based on the GoldSim predictions for the 5% probability of exceedance.

These results show that the system is currently at capacity for *E. coli* in the summer and total phosphorus in the winter, spring, and fall.

The required effluent concentrations for total ammonia and total nitrate for the discharge into the Welland River East yielded the most restrictive treatment capacity, given the lower assimilative capacity of the immediate receiver. The differences between the discharges to the HEPC and Chippewa Creek are negligible in term required treatment.

Table 18: Summary of Maximum Allowable Effluent Concentrations from GoldSim Modelling

Parameter	Compliance Point	Winter			Spring			Summer			Fall		
		Location 1	Location 2	Location 3	Location 1	Location 2	Location 3	Location 1	Location 2	Location 3	Location 1	Location 2	Location 3
Total Ammonia (mg/L)	Local	24.5	1,347	1,312	0.7	262	261	nc	112	115	nc	157	159
	System	1,342			258			107			152		
E. coli (cfu/100 mL)	Local	nc	nc	55,235	nc	75,615	94,761	nc	107,736	107,869	nc	76,549	81,586
	System	nc			75,382			107,502			76,349		
Nitrate (mg/L)	Local	29	3,149	3,108	96	3,069	2,910	103	3,334	3,219	83	3,245	3,133
	System	3,142			3,062			3,328			3,238		
Total Phosphorus (mg/L)	Local	nc	nc	nc	nc	nc	3.28	nc	6.93	9.20	nc	nc	2.97
	System	nc			nc			6.28			nc		

Note:

1. “nc” denotes no capacity since existing background water quality exceeds applicable criteria (PWQO or CCME).

3.2 Mass Balance Modelling for Total Phosphorus, Ammonia, Nitrate, and *E. coli*

A secondary verification to the GoldSim model results, mass balance modelling was completed using 75th percentile background water quality concentrations and minimum supplemental flows. Mass balance modelling estimated the maximum allowable effluent concentrations for total phosphorus, E. coli, nitrate, total ammonia, CBOD5, and TSS and the minimum dissolved oxygen concentration. The mass balance models generally followed the same structure as the GoldSim model as shown on Figure 10 and provided seasonal estimates. One mass balance model was developed to assess total phosphorus, ammonia, nitrate, and *E. coli* such that both the local and system compliance points could be considered. Because dissolved oxygen and $CBOD_5$ are not independent, a specific mass balance model was developed for these two parameters simultaneously. A third mass balance model was developed for TSS since the water quality guideline for that parameter is based on an increase over ambient.

These models are intended to provide a secondary verification of the results provided by GoldSim by estimating the maximum allowable effluent concentrations for the worst-case conditions. The worst-case conditions were assumed to be the monthly cases where the low-flow conditions in each of the waterbodies occurred simultaneously.

The following points outline the inputs into the mass balance modelling:

- Total phosphorus, nitrate*, E. coli*, unionized ammonia, and TSS were modelled as conservative parameters and used the water quality limits provided in Table 4.
- The seasonal maximum allowable effluent concentrations for total ammonia were estimated based on the seasonal maximum allowable unionized ammonia concentration and 75th percentile values for water temperature and pH.
- The discharge of effluent from the existing Niagara Falls WWTP was assumed to be the rated capacity (68.3 MLD).
- The effluent discharge rate from the proposed WWTP was 30 MLD.
- Inflow concentrations from the Niagara River, Lyons Creek, and Welland River East were assumed to be equal to the 75th percentile of the measured seasonal concentrations.
- Where applicable, the existing effluent limits for the existing Niagara Falls WWTP were used (total phosphorus and *E. coli*).
- Since there are no effluent limits for the existing Niagara Falls WWTP for nitrate or ammonia, seasonal 75th percentile values based on measured data were used (Table 10).
- The effluent from both the existing Niagara Falls WWTP and the proposed plant was assumed to mix completely in the receiving water immediately after release.

Natural flows in the Welland River East were assumed to be negligible. The low-flow conditions in the Welland River East were assumed to be equal to the minimum supplemental flows from the Welland Canal as provided in Supplemental flows enter the Welland River East from the Welland Canal (St. Lawrence Seaway Management Corporation [SLSMC] 2019) as follows:

- A series of ports in the roof of the old syphon provide flow from the canal into the river. Depending on the season and water levels in the canal, the total flow ranges from 5 to 7 m^3/s.

- A pump at Port Robinson provides a flow of 0.97 m³/s to a side channel of the Welland River East, which was cut-off from the main branch of the river during the straightening of the canal in the 1950s.
- The bypass of the Welland Water Treatment Plant provides a flow between the canal and the river that ranges from 4 m³/s to 6 m³/s.
- The effluent from the Welland Wastewater Treatment Plant provides a flow of 0.8 m³/s (XCG 2007).

In general, the supplemental flows from the Welland Canal are from Lake Erie and have better water quality than that of the upstream areas of the Welland River.

Monthly estimates of the supplemental flows for the siphon ports, Port Robinson Pump, the Welland Water Treatment Plant and the Welland WWTP were provided by the SLSMC (SLSMC 2019) for the period 2014 to 2019 and are summarized in Table 1.

- Table 1Inflows from Lyons Creek were assumed to be equal to the pumping rates from the Welland Canal since naturally occurring low-flow conditions (e.g., 7Q20) are negligible (Section 2.1.4).
- Flows in the HEPC were assumed to be equal to the minimum daily average flow in the HEPC based on data provided by OPG between 2016 and 2018 (349 m³/s).
- Flow in Chippewa Creek was assumed be the same as the flow in the HEPC less the contributions from the Welland River East and Lyons Creek.
- Seasonal maximum allowable effluent concentrations were estimated at local compliance point specific to each discharge location as well as at the system compliance point below the existing Niagara Falls WWTP.

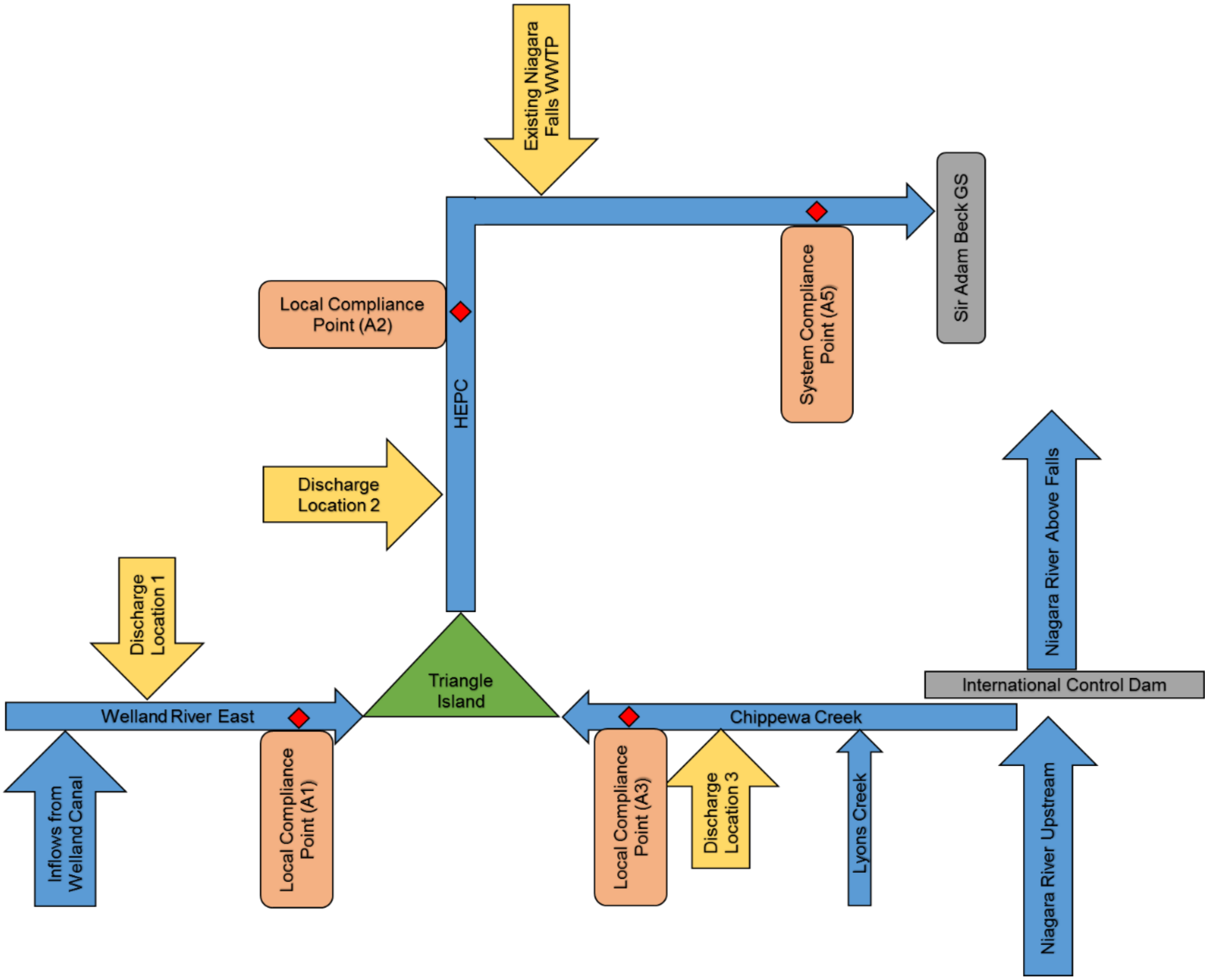

Figure 10: Schematic of Mass Balance Modelling for Total Phosphorus, Ammonia, Nitrate, and *E. coli*

The resulting estimates of the maximum allowable effluent concentrations are provided in Table 19.
The modelling results suggest that:

- Poor water quality in the Welland River East provide no additional capacity for effluent in terms of total phosphorus and *E. coli* year-round and unionized ammonia during the summer.
- Elevated total phosphorus concentrations in the Niagara River during the winter are above the guideline and will limit capacity in Chippewa Creek and the HEPC.
- High *E. coli* contributions from the Welland River East limit the available capacity in the HEPC during the winter.
- High phosphorus loads from the Welland River East also limit the available capacity in the HEPC during the spring.
- Contributions from the existing Niagara Falls WWTP limit the available capacity at the system compliance point (A5) during the fall.

Table 19: Summary of Maximum Allowable Effluent Concentrations from Mass Balance Modelling of Worst Case Low-Flow Conditions

Parameter	Compliance Point	Winter			Spring			Summer			Fall		
		Location 1	Location 2	Location 3	Location 1	Location 2	Location 3	Location 1	Location 2	Location 3	Location 1	Location 2	Location 3
Unionized Ammonia (mg/L)	Local	0.5	15.5	15.0	0.4	15.3	15.0	nc	13.9	13.9	0.3	14.2	14.0
	System	15.5			15.3			13.8			14.2		
Total Ammonia (mg/L)	Local	33	1,227	1,194	4.4	284	280	nc	113	115	2.8	254	251
	System	1,216			610			101			243		
E. coli (cfu/100 mL)	Local	nc	nc	48,567	nc	78,132	85,459	nc	88,800	88,996	nc	69,113	71,728
	System	nc			78,132			88,800			69,113		
Nitrate (mg/L)	Local	23	2,644	2,621	67	2,681	2,614	99	2,750	2,652	73	2,807	2,735
	System	2,629			2,668			2,740			2,796		
Total Phosphorus (mg/L)	Local	nc	nc	nc	nc	nc	3.80	nc	5.69	7.65	nc	0.23	2.84
	System	nc			nc			5.02			nc		

Note:

1. “nc” denotes no capacity since existing water quality exceeds applicable criteria.

3.2.1 Comparison of Mass Balance Model Results to GoldSim Results

The following observations were made while comparing the results of the mass balance modelling to those of GoldSim:

- In cases where both models predicted assimilative capacity, the results from the mass balance model were lower than the results of GoldSim. This was expected since the mass balance model assumed the worst-case conditions (e.g., all low flows occur at once), which is expected to occur less than 5% of the time in the GoldSim model.
- With only one exception, both models predicted no assimilative capacity for the same cases.
- In the case for a discharge into the HEPC during the fall, GoldSim predicts no capacity for total phosphorus, while the mass balance model estimates a maximum allowable effluent concentration of 0.23 mg/L. Further investigation indicates that the difference is attributed to phosphorus loads from Welland River East. The mass balance model assumes that natural flows in Welland River East are negligible, while GoldSim uses a distribution of flows that include some natural flows. This results in a lower total phosphorus load in the mass balance model compared to that in GoldSim. Sensitivity analysis using the mass balance model suggest that natural flows from Welland River East were as low as 2 m³/s increase the total phosphorus loads to the HEPC enough to eliminate any assimilative capacity in the fall.

3.3 Modelling for Niagara River Discharge (Location 4)

The following points summarize the approach used to assess the discharge to the Niagara River (Location 4):

- This discharge was assessed as a single port outfall (e.g., pipe) into a wide shallow river.
- The compliance point was assumed to be at the top of Niagara Falls along the Canadian shore approximately 1.6 km downstream of the ICD.
- The low-flow condition over the falls was assumed to be the minimum regulated daily average flow over the falls as outlined in the Niagara Treaty (2,242 m³/s during the tourist season and 2,124 m³/s during the non-tourist season). These flow conditions are the result of the operation of the ICD.
- The discharge location was assumed to be below the ICD and as such, water level fluctuations in the Grass Island Pool due to the operation of the ICD are not expected to affect the mixing of the effluent in the Niagara River.
- Since neither bathymetric data or current measurements are available for the Niagara River below the ICD, hydraulic modelling was completed to estimate the depth and current speed in that section of the Niagara River (see Section 3.3.1).
- Given that the Niagara River below the ICD is fast moving and wide, complete mixing with the effluent into the Niagara River flow cannot be expected before the compliance point. A Gaussian Plume model was used to estimate the width if the effluent plume at the compliance point to approximate the amount of river flow available for effluent dilution before passing the compliance point (See Section 3.3.2).
- Maximum allowable effluent concentrations were estimated for each season based on the available flow for dilution, upstream water quality, and ambient water temperature and pH.

3.3.1 Estimation of Hydraulic Conditions

Manning equation (Manning 1891) was iteratively solved to estimate the flow depth and current speed:

$$Q = UBH = \frac{1}{n}\left(\frac{BH}{B+2H}\right)^{2/3} S^{1/2}$$

Where: Q total flow in river (m³/s),
U current speed (m/s),
B river width (m),
H depth (m),
n Manning's roughness coefficient, and
S slope of river (m/m).

For this assessment, the average river width was assumed to be 887 m based on four width measurements (Google Earth) and the Manning's Roughness Coefficient was assumed to be 0.03.

The slope of the Niagara River was based on a downstream distance of 1,600 m and a reported river drop of 15 m between the ICD and the falls (Niagara Parks 2018). The slope for this section of the Niagara River was estimated to be 0.009 (0.9%).

The estimated low-flow hydraulic conditions in the Niagara River below the ICD for tourist and non-tourist periods are summarized in Table 20. For both periods, the estimated water depths are less than 1 m and the current speeds are greater than 2.8 m/s. Under these conditions, the effluent is expected to travel from the discharge location to the compliance point in less than 10 minutes.

Table 20: Summary of Estimated Low-Flow Hydraulic Conditions in Niagara River below the ICD

	Non-Tourist Season Winter Regulated Minimum Flow Over Falls	Tourist Season Spring/Summer/Fall Regulated Minimum Flow Over Falls
Flow over Falls (m^3/s)	2,124	2,242
Average Width (m)	887	
Depth (m)[1]	0.87	0.85
Current Speed (m/s)[1]	2.89	2.83
Lateral Dispersion Coefficient (m^2/s)[2]	0.146	0.139

Note:

1. Estimated using Manning's Equation.
2. Estimated using equations from Fischer (1979).

3.3.2 Gaussian Plume Modelling

A 2-dimensional Gaussian plume model is used to estimate the spread of the effluent in the Niagara River for the conditions provided in Table 20. The general form of a Gaussian plume for a continuous release from a shoreline discharge is:

$$C(x,y) = \frac{2W}{H\sqrt{4\pi D_y U x}} e^{\left(-Uy^2 / 4D_y x\right)}$$

Where: $C(x,y)$ predicted concentration at specified location (g/m³),
x downstream distance (m),
y distance from shoreline (m),
W effluent mass loading rate (flow x concentration) (g/s),
U current speed (m/s),
H depth (m), and
D_y lateral dispersion coefficient (m²/s).

The lateral dispersion coefficient was estimated as follows (Fischer et al. 1979):

$$D_y = 0.6HU^*$$

$$U^* = \sqrt{gHS}$$

Where: U^* shear velocity (m/s),
g acceleration due to gravity (m/s²), and
S river slope (m/m)

Based on the Gaussian plume modelling, at a distance of 1,600 m the width of plume that contains 95% of the effluent is predicted to be approximately 25 m or approximately 3% of the average river width. This suggests that the effluent will only mix with 3% of the total flow in the Niagara River below the ICD. This translates to available river flows for dilution of 72.7 m³/s during the tourist season and 63.7 m³/s during the non-tourist season.

3.3.3 Maximum Allowable Effluent Concentrations

A mass balance model was used to estimate the seasonal maximum allowable effluent concentrations for the Niagara River discharge option based on seasonal upstream water quality. For parameters listed in the ECA, the 75th percentile was used for the upstream water quality while for water temperature and pH seasonal averages were used.

Seasonal low-flow conditions were based on the minimum daily average flow requirements from the Niagara Treaty that occur in each of the assessment seasons. The mass balance assumed an effluent flow rate of 30 MLD (0.35 m^3/s).

The maximum allowable effluent concentration was estimated for each parameter (except total ammonia) and season using:

$$C_e = \frac{(Q_e + Q_r)C_g - Q_r C_r}{Q_e}$$

Where:	C_e	allowable effluent concentration (mg/L),
	C_r	river/background concentration (mg/L),
	C_g	water quality guideline/target (mg/L),
	Q_r	upstream river flow (m^3/s), and
	Q_e	effluent flow rate (m^3/s)

The maximum allowable total ammonia concentrations were based on the maximum allowable unionized ammonia concentrations, average seasonal water temperature, and average seasonal pH.

A summary of the mass balance modelling and the resulting maximum allowable effluent concentrations are provided in Table 21.

Table 21: Detailed Summary of Allowable Effluent Concentrations for Discharge to Niagara River

	Winter	Spring	Summer	Fall
Flow Conditions				
Total Flow Over Falls (m^3/s)	2,124	2,124	2,424	2,124
Flow Available for Dilution (m^3/s)	63.7	63.7	72.7	63.7
Effluent Flow	0.347	0.347	0.347	0.347
Ultimate Dilution	185:1	185:1	210:1	185:1
Total Phosphorus				
Background / Upstream Concentration (mg/L)	0.043	0.026	0.022	0.027
PWQO / Target at Flow over Falls (mg/L)	0.030	0.030	0.030	0.030
Allowable Effluent Concentration (mg/L)	No Capacity	0.764	1.705	0.581
Nitrate				
Background / Upstream Concentration (mg/L)	0.310	0.310	0.260	0.180
PWQO / Target at Flow over Falls (mg/L)	3.0	3.0	3.0	3.0
Allowable Effluent Concentration (mg/L)	497	497	577	521
E. coli				
Background / Upstream Concentration (cfu/100 mL)	50	12	8	26
PWQO / Target at Flow over Falls (cfu/100 mL)	100	100	100	100
Allowable Effluent Concentration (cfu/100 mL)	9,276	16,249	19,368	13,680
Unionized and Total Ammonia				
75th Percentile Water Temperature (ºC)	2.5	10.1	23.9	20.1
75th Percentile pH	8.1	8.2	8.3	8.2
Fraction Unionized Ammonia (%)	1.32%	2.88%	10.09%	5.95%
Upstream Total Ammonia Concentration (mg/L)	0.014	0.046	0.044	0.032
Upstream Unionized Ammonia Concentration (mg/L)	0.00018	0.00133	0.00444	0.00190
PWQO / Target at Flow over Falls (mg/L)	0.0164	0.0164	0.0164	0.0164
Allowable Effluent Unionized Ammonia Concentration (mg/L)	2.99	2.78	2.52	2.68
Allowable Effluent Total Ammonia Concentration (mg/L)	227	97	25.0	45

3.4 Mass Balance Modelling for Dissolved Oxygen, $CBOD_5$, and Total Suspended Solids

Allowable effluent concentrations were estimated for dissolved oxygen, CBOD5, and TSS using a spreadsheet-based mass-balance model. These parameters could not be modelled in GoldSim for the following reasons:

- dissolved oxygen and $CBOD_5$ are interconnected such that they could not be represented in GoldSim and,
- the criteria for TSS (see Section 2.2.1) is based on an increase over background.

The mass balance modelling was based on low flow conditions that represent the minimum regulated flows over the falls (Section 2.1.3.2), supplemental inflows in the Welland River (Section 0), and estimated 7Q20 flows in the HEPC (Section 2.1.5). For the discharge to the Niagara River, the available flow for dilution was assumed to be 3% of the total flow over the falls (Section 3.3.2). A summary of the flows used in the mass balance modelling for dissolved oxygen, $CBOD_5$, and TSS is provided in Table 22.

Table 22: Summary of Flows Used in Mass Balance Modelling

Season	Niagara River Below ICD		Chippewa Creek[3] (m^3/s)	Welland River East[4] (m^3/s)	HEPC[5] (m^3/s)
	Total[1] (m^3/s)	Available for Dilution[2] (m^3/s)			
Winter	2,124	63.7	338	11.4	349
Spring	2,142	63.7	337	12.2	349
Summer	2,224	67.3	335	13.6	349
Fall	2,124	63.7	336	13.0	349

Notes:

1. Minimum flows as defined in Niagara Treaty of 1950.
2. Only 3% of flow available for dilution before reaching falls (Section 3.3.2).
3. Flow in HEPC less flow from Welland River East.
4. Sum of all supplemental flows into Welland River East from Welland Canal.
5. Low flow condition (7Q20) for flow in HEPC.

3.4.1 Dissolved Oxygen and $CBOD_5$

Since dissolved oxygen and $CBOD_5$ of the effluent and background water all affect the downstream dissolved oxygen concentrations, these two parameters must me assessed together. The downstream dissolved oxygen at any downstream location is determined by the mixed (effluent and river) concentration of dissolved oxygen and the amount of oxygen consumed by the $CBOD_5$ in the time taken to reach that location. Other factors that affect the downstream dissolved oxygen include surface reaeration and algal growth/decay.

The assessment of dissolved oxygen and $CBOD_5$ provides a conservative estimate of allowable effluent concentrations based on the following assumptions:

- Although measurements of dissolved oxygen in the Niagara River and HEPC are frequently at or above saturation due to turbulent flow conditions that provide a high degree of surface reaeration, surface reaeration is not included in this assessment.
- Given the typical clarity of the water in the study area, the effects of algae are assumed to be negligible and are not included in the assessment.

- Given the short retention time in the system (e.g., less than a few hours), it is expected that only a fraction of the $CBOD_5$ will be consumed before leaving the study area. This assessment assumes that 50% of the $CBOD_5$ from upstream sources and the effluent will be consumed before leaving the system.
- $CBOD_5$ data was not available for the Niagara River. As such a background $CBOD_5$ concentration of 2 mg/L was assumed based on the highest seasonal 75th percentile $CBOD_5$ concentration found for the Welland River East (Table 5). These upstream conditions were applicable to the discharges into Chippewa Creek and the Niagara River.
- Upstream $CBOD_5$ concentrations in the Welland River East were based on the seasonal 75th percentile of the measured data.
- Upstream dissolved oxygen concentrations were based on the seasonal 25th percentile of the measured data.
- Upstream $CBOD_5$ and dissolved oxygen for the HEPC discharge were based on flow weighted values for Chippewa Creek and Welland River East.
- Water temperatures (required to estimate dissolved oxygen saturation concentrations) were based on the seasonal 75th percentile temperature values for Chippewa Creek, the HEPC, and Welland River East.
- Given the high degree of surface reaeration in the HEPC, dissolved oxygen and $CBOD_5$ were not assessed at the system compliance point (Sir Adam Beck GS).
- The assessment was based on the dissolved oxygen criteria for warm water fisheries (47% of saturation below 20ºC and 4 mg/L above 20ºC).

The allowable effluent $CBOD_5$ concentration was estimated by re-arranging the following equation:

$$Q_d D_d = Q_r D_r - f Q_r B_r + Q_e D_e - f Q_e B_e$$

Where:		
	Q_d	downstream flow (m^3/s) equal to sum of upstream and effluent flows,
	Q_r	upstream flow (m^3/s),
	Q_e	effluent flow (m^3/s),
	D_d	downstream dissolved oxygen concentration (mg/L) equal to guideline,
	D_r	upstream dissolved oxygen concentration (mg/L),
	D_e	effluent dissolved oxygen concentration (mg/L),
	B_r	upstream $CBOD_5$ concentration (mg/L),
	B_e	effluent $CBOD_5$ concentration (mg/L), and
	f	fraction of $CBOD_5$ consumed in study area (assumed to be 0.5).

Estimates of the allowable seasonal effluent $CBOD_5$ concentrations are provided in Table 23 for three levels of effluent dissolved oxygen saturation (10%, 50%, and 90%). Allowable concentrations for $CBOD_5$ are all greater than the minimum standard limit for secondary treated effluent of 15 mg/L.

The results indicate that allowable $CBOD_5$ concentrations are not sensitive to the dissolved oxygen levels in the effluent. Therefore, effluent dissolved oxygen concentration equal to 50% of the saturation concentration is recommended. The corresponding allowable seasonal effluent $CBOD_5$ concentrations will be carried forward in this assessment.

Table 23: Estimated Allowable $CBOD_5$ Concentrations Based on Effluent Dissolved Oxygen

Discharge Location	Season	Allowable Effluent $CBOD_5$ Concentration		
		Eff DO = 10% Sat[1]	Eff DO = 50% Sat[1]	Eff DO = 90% Sat[1]
Welland River East (Location 1)	Winter	360	371	382
	Spring	376	384	392
	Summer	239	**245**	252
	Fall	282	289	296
HEPC (Location 2)	Winter	6,758	6,768	6,779
	Spring	6,793	6,800	6,808
	Summer	7,934	7,940	7,947
	Fall	5,943	**5,952**	5,960
Chippewa Creek (Location 3)	Winter	6,370	6,380	6,391
	Spring	6,376	6,384	6,391
	Summer	7,682	7,689	7,695
	Fall	5,699	**5,707**	5,715
Niagara River (Location 4)	Winter	1,194	1,204	1,215
	Spring	1,201	1,275	1,283
	Summer	1,536	1,461	1,468
	Fall	1,074	**1,083**	1,091

Note:

1. Dissolved oxygen concentration in effluent expressed as percent of saturation.
2. **Bold** values indicate maximum allowable effluent concentrations carried forward in assessment.

3.4.2 Total Suspended Solids

The assessment of TSS was based on the following assumptions:

- Upstream TSS concentrations in the Welland River East were based on the seasonal 75th percentile of the measured data.
- Upstream TSS concentrations in the Niagara River, Chippewa Creek, and the HEPC were based on an annual 75th percentile of the measured data in the Niagara River (11.3 mg/L).

The allowable effluent TSS concentration was estimated by re-arranging the following equation:

$$(Q_r + Q_e)(C_r + \Delta C) = Q_r C_r + Q_e C_e$$

Where: Q_r upstream flow (m^3/s),
Q_e effluent flow (m^3/s),
C_r upstream TSS (mg/L),
C_e effluent TSS (mg/L), and
ΔC allowable TSS concentration increase (5 mg/L).

The estimated allowable seasonal effluent concentrations for TSS are provided in Table 24 and indicate that the allowable effluent TSS concentration show little seasonal variation. Allowable concentrations for TSS are all greater than the minimum standard limit for secondary treated effluent of 15 mg/L.

Table 24: Estimated Allowable Seasonal Effluent TSS Concentrations

Discharge Location	Season	Allowable Total Suspended Solids (mg/L)
Welland River East (Location 1)	Winter	204
	Spring	202
	Summer	213
	Fall	**201**
HEPC (Location 2)	Winter	5,047
	Spring	5,047
	Summer	**5,046**
	Fall	**5,046**
Chippewa Creek (Location 3)	Winter	4,880
	Spring	4,866
	Summer	**4,846**
	Fall	4,855
Niagara River (Location 4)	Winter	934
	Spring	985
	Summer	**934**
	Fall	**934**

Note:

1. **Bold** values indicate maximum allowable effluent concentrations carried forward in assessment.

4.0 DERIVATION OF RECOMMENDED EFFLUENT LIMITS

The following sections outline the development of the recommended effluent limits and limits based on the ACS and include the following details for each discharge location:

- the applicable water quality assessment points for each discharge location alternative,
- if specific parameters meet or exceed relevant criteria and whether a Policy 2 Condition applies,
- the critical season for each parameter and location, and
- an appropriate treatment technology for the location.

A quick summary of the adopted approach is provided below. Using this approach, the detailed evaluation of assimilative capacity and selection of treatment technologies is documented for each discharge location alternative in Section 4.1 through 4.4.

Water Quality Assessment Points

The water quality effects of introducing the new WWTP at each of four discharge location alternatives is evaluated at selected downstream assessment points. Referring to Section 0, the new WWTP effluent at each discharge location alternative is specifically evaluated at local assessment points (A1, A2, A3 or A4), located immediately downstream of each discharge location alternative, and at a system assessment point (A5) in the HEPC below the existing Niagara Falls WWTP (Locations 1, 2, and 3 only).

Available Assimilative Capacity

The available assimilative capacity for each assessment point is first considered without the effluent inputs from the new WWTP to determine if there is any for each of the parameters at the local compliance point. Where locations are shown to have capacity to assimilate effluent, a treatment technology was selected that could meet the maximum allowable effluent concentrations for each parameter. In cases were there was no available assimilative capacity (e.g., Policy 2), the effluent quality was selected such that the effluent concentration would be equal or less than the existing background conditions.

The typical effluent quality for the available treatment technologies considered in this study, based on information available from the MECP (MECP 2019), are summarized in Table 25.

Table 25: Typical Effluent Quality for Various Treatment Processes

Process	Effluent Parameter[1,2]			
	$CBOD_5$ (mg/L)	Total Suspended Solids (mg/L)	Total Phosphorus (mg/L)	Total Ammonia (mg/L as N)[3]
Conventional Activated Sludge System				
Without Phosphorus Removal	25	25	3.5	15 to 20
With Phosphorus Removal	25	25	<1.0	15 to 20
With Phosphorus Removal and Filtration	10	10	0.3	15 to 20
With Nitrification and Phosphorus Removal	25	25	<1.0	<3
Membrane Bioreactor				
Without Phosphorus Removal	2	1	3.0	15 – 20
With Phosphorus Removal	2	1	0.1	15 – 20
With Phosphorus Removal and Filtration	2	1	0.1	0.3

Notes:

1. Taken from “Design Considerations for Sewage Treatment Plants” (MECP 2019)
2. The above values are based on raw sewage with CBOD5 = 150-200 mg/L, Soluble CBOD5 = 50% of CBOD5, TSS = 150-200 mg/L, TP = 6-8 mg/L, TKN = 30-40 mg/L, TAN = 20-25 mg/L.
3. TAN (total ammonia nitrogen) concentrations may be lower during warm weather conditions if nitrification occurs.

With regard to parameters not listed in Table 25, the following assumptions have been used:

- Any treatment plant with disinfection can expect to have an *E. coli* concentration objective of less than 200 cfu/100 mL,
- If needed, aeration of the dissolved oxygen concentration in the final effluent can be provided to at least 80% of the saturation concentration.
- The expected effluent nitrate concentration from an activated sludge system without denitrification was assumed to be 20 mg/L.

4.1 Location 1 – Welland River East

4.1.1 Overview of Existing Conditions

The Welland East discharge would release effluent to Welland River East between Montrose Road and Triangle Island. Under normal conditions, the effluent is expected to travel downstream into the HEPC and eventually enter the Niagara River at the Sir Adam Beck GS. The local compliance point (A1), in the Welland River East just upstream of Triangle Island, and the system compliance point (A5), in the HEPC below the existing Niagara Falls WWTP (both shown on Figure 11).

The Welland River East discharge is not expected to affect water quality in Chippewa Creek or in the Niagara River upstream of the Sir Adam Beck GS.

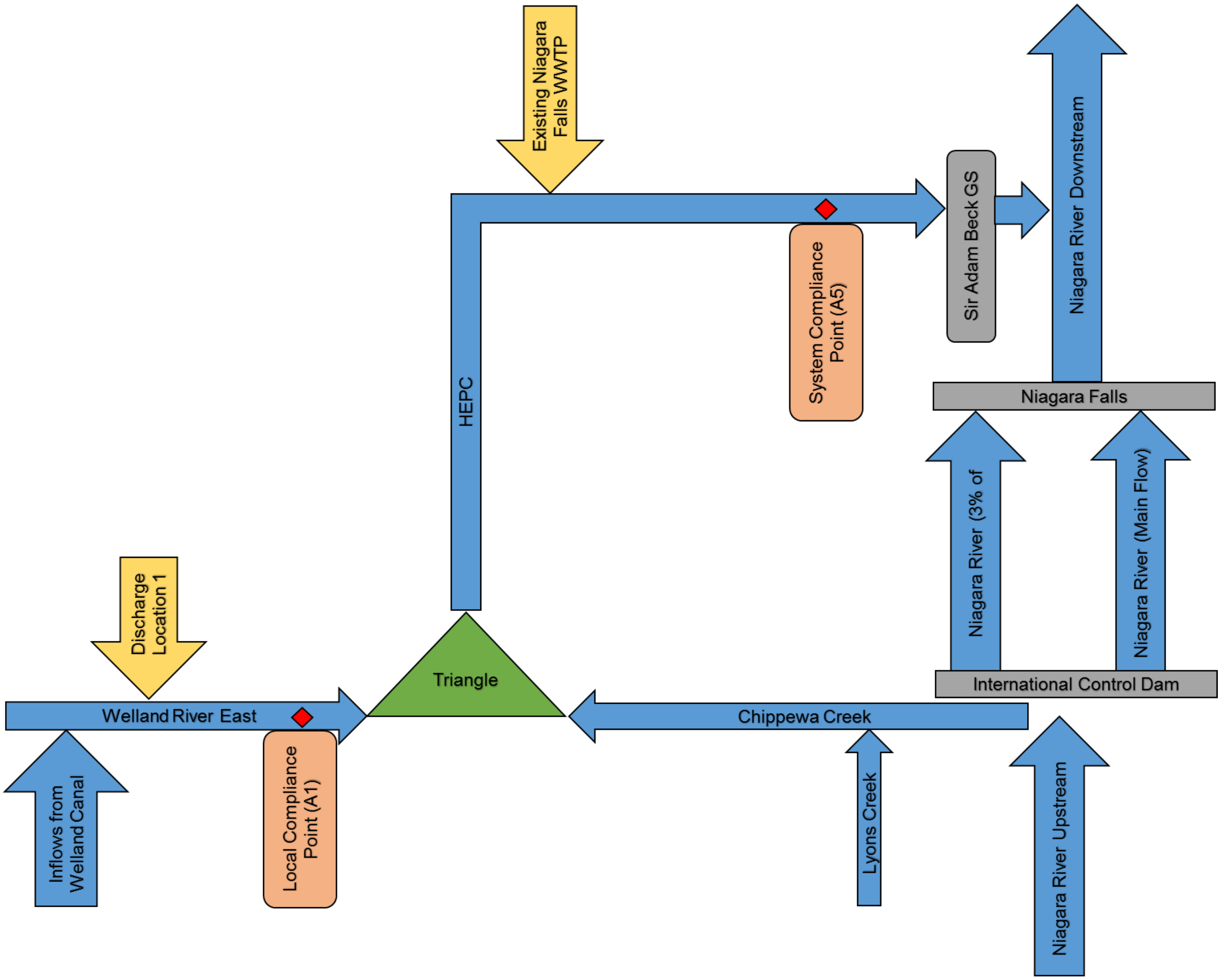

Figure 11: Local and System Compliance Points for Discharge at Location 1 – Welland River East

4.1.2 Phosphorus

The total phosphorus concentrations in the Welland River East are elevated and consistently exceed the applicable PWQO (0.03 mg/L). The seasonal geometric mean concentration ranges from 0.04 mg/L to 0.12 mg/L while the 75th percentile concentrations range from 0.06 mg/L to 0.14 mg/L. Total phosphorus concentrations are typically higher at Welland (WR010) than at Montrose Road (WR011). It is suspected that the water quality at Montrose Road is periodically affected flow reversals that occur due to the operation of the ICD (e.g., water from the Niagara River with better water quality is periodically samples at WR011).

The predicted maximum allowable effluent concentrations for phosphorus are presented in Table 26.
The elevated upstream total phosphorus concentrations result in Policy 2 conditions year-round at the local and system compliance points. Discharge from the existing Niagara Falls WWTP results in no additional capacity to receive phosphorus at the system compliance point in all seasons except summer.

Table 26: Maximum Allowable Seasonal Total Phosphorus Concentrations for Discharge at Location 1 – Welland River East

Season	Upstream[1] (mg/L)	Maximum Allowable Effluent Concentration (mg/L)	
		Local Compliance Point	System Compliance Point
Winter	0.140	No Capacity[2]	No Capacity[2]
Spring	0.160		
Summer	0.080		
Fall	0.100		

Notes:

1. 75th percentile of seasonal upstream concentrations.
2. No capacity due to elevated concentrations at the compliance point.

Since the upstream phosphorus concentration in Welland River East exceed the PWQO (0.03 mg/L), it is considered a Policy 2 receiver with respect to total phosphorus. As such, the effluent concentration is not to exceed background conditions. The seasonal 75th percentile phosphorus concentration varies from 0.075 mg/L to 0.125 mg/L. It is recommended that the annual average 75th percentile value be used (0.10 mg/L) as the effluent limit for phosphorus.

Based on the information provided in Table 25, in terms of total phosphorus discharge the recommended treatment technology at Location 1 is equivalent to a membrane bioreactor with phosphorus removal.

4.1.3 Nitrate

The seasonal geometric mean nitrate concentration ranges from 0.33 mg/L to 2.32 mg/L while the 75th percentile concentrations range from 0.48 mg/L to 2.38 mg/L. The highest nitrate concentrations, which typically occur during the winter, are approaching the CCME guideline (3 mg/L). This suggests that there may be seasonal limitations on the maximum allowable effluent concentration of nitrate.

The predicted maximum allowable effluent concentrations for nitrate are presented in Table 27. In general, the local compliance point provides the most restrictive conditions. Based on the modelling results, the most restrictive value is 29 mg/L.

Based on the assumptions in Section 4.0, a conventional activated sludge system without denitrification is expected to provide effluent nitrate concentrations of 20 mg/L. As a result, nitrate limits would not be required for Location 1.

Table 27: Maximum Allowable Seasonal Nitrate Concentrations for Discharge at Location 1 – Welland River East

Season	Upstream[1] (mg/L)	Maximum Allowable Effluent Concentration (mg/L)	
		Local Compliance Point	System Compliance Point
Winter	2.38	**29 (23)**	3,142 (2,629)
Spring	1.11	96 (67)	3,062 (2,668)
Summer	0.49	103 (99)	3,328 (2,740)
Fall	1.05	83 (73)	3,238 (2,796)

Notes:

1. 75th percentile of seasonal upstream concentrations.
2. Values in brackets refer to predictions from the mass balance modelling approach, if different from the GoldSim modelling approach.

4.1.4 Ammonia

The seasonal geometric mean total ammonia concentration ranges from 0.07 mg/L to 0.47 mg/L while the 75th percentile concentrations range from 0.09 mg/L to 0.59 mg/L. The corresponding unionized ammonia concentrations are below the applicable PWQO (0.0164 mg/L as N) for all the seasons except summer.

The maximum allowable effluent concentrations for total and unionized ammonia are presented in Table 28. In general, the local compliance point provides the most restrictive conditions. The elevated upstream unionized ammonia concentrations result in Policy 2 conditions in the summer.

Table 28: Maximum Allowable Seasonal Total and Unionized Ammonia Concentrations for Discharge at Location 1 – Welland River East

Season	Total Ammonia			Unionized Ammonia		
	Upstream	Maximum Allowable Concentration (mg/L)		Upstream	Maximum Allowable Concentration (mg/L)	
		Local Compliance Point	System Compliance Point		Local Compliance Point	System Compliance Point
Winter	0.59	25 (33)	1,342 (1,216)	0.001	0.3 (0.5)	12.5 (15.5)
Spring	0.28	0.7 (4.4)	258 (284)	0.007	0.4 (0.4)	14.0 (15.3)
Summer	0.22	No Capacity	107 (101)	0.018	No Capacity^2	11.8 (13.8)
Fall	0.20	No Capacity (2.8)	152 (243)	0.009	0.2 (0.3)	11.6 (14.2)

Notes:

1. 75th percentile of seasonal upstream concentrations.
2. No capacity due to elevated concentrations at the compliance point.
3. Values in brackets refer to predictions from the mass balance modelling approach, if different from the GoldSim modelling approach.
4. Unionized ammonia concentrations predicted in GoldSim based on modelled ammonia and average seasonal pH and temperature.
5. Unionized ammonia concentrations predicted using the mass balance approach based on measured concentrations and modelled as a conservative constituent.

According to Policy 2, during the summer, the effluent unionized ammonia concentration cannot exceed the upstream concentration of 0.018 mg/L. As such, the recommend effluent limits during the summer for unionized and total ammonia are 0.018 mg/L and 0.20 mg/L, respectively. Reliably achieving 0.20 mg/L total ammonia will be difficult for any nitrifying wastewater facility. Accordingly, 0.50 mg/L total ammonia concentration limits that are demonstrated in a nitrifying activated sludge system are recommended for summer conditions.

The predicted maximum allowable unionized ammonia concentrations listed in Table 28 for winter, spring, and fall exceed the acute toxicity guideline for unionized ammonia (0.10 mg/L as N). As such, it is recommended that the effluent limits for total ammonia be based on meeting the acute toxicity limit for unionized at end-of-pipe and 75th percentile water temperature and pH. Based on the resulting values presented in Table 29, the recommended total ammonia limit is recommended to be 1.4 mg/L for winter, spring, and fall. Accordingly, the recommended effluent limits for unionized and total ammonia in the summer are 0.50 mg/L and 1.4 mg/L, respectively.

Based on the information provided in Table 25, in terms of total ammonia discharge the required treatment level is equivalent to a membrane bioreactor at Location 1 is a membrane bioreactor with phosphorus removal and filtration.

Table 29: Maximum Allowable Seasonal Total Ammonia Concentrations for Discharge at Location 1 – Welland River East Based on Acute Toxicity Limits for Unionized Ammonia

Season	Ambient Conditions		Maximum Allowable Effluent Concentration (mg/L)	
	Water Temperature (ºC)	PH	Unionized Ammonia	Total Ammonia
Winter	2.1	7.82	0.1	15.2
Spring	14.4	8.23	0.1	2.36
Summer	25.3	8.26	0.018	**0.19**
Fall	20.5	8.27	0.1	**1.41**

Notes:

1. Lowest concentration reliably achievable in a nitrifying secondary treatment plant.

4.1.5 *E. coli*

The seasonal upstream geometric mean *E. coli* concentration ranges from 25 cfu/100 mL to 2,474 cfu/100 mL while the 75th percentile concentrations range from 105 cfu/100 mL to 6,920 cfu/100 mL. Since the upstream *E. coli* concentrations in the Welland River East consistently exceed the PWQO (100 cfu/100 mL), it is considered a Policy 2 receiver with respect to *E. coli*. As such, the effluent concentration is not to exceed background conditions. It is recommended that an effluent limit of 200 cfu/100 mL, consistent with other treatment plants in the area.

Table 30: Maximum Allowable Seasonal *E. coli* Concentrations for Discharge at Location 1 – Welland River East

Season	Upstream (mg/L)	Maximum Allowable Effluent Concentration (mg/L)	
		Local Compliance Point	System Compliance Point
Winter	6,920	No Capacity[2]	No Capacity
Spring	308		75,382 (78,132)
Summer	105		107,502 (88,800)
Fall	170		76,349 (69,113)

Notes:

1. 75th percentile of seasonal upstream concentrations.
2. No capacity due to elevated concentrations at the compliance point.
3. Values in brackets refer to predictions from the mass balance modelling approach, if different from the GoldSim modelling approach.

4.1.6 $CBOD_5$ and Dissolved Oxygen

The seasonal 25th percentile upstream dissolved oxygen concentrations range from 8.1 mg/L to 13.8 mg/L, which correspond to approximately levels in excess of 90% of the dissolved oxygen saturation concentration at the seasonal water temperatures. The upstream $CBOD_5$ values are typically less than 2 mg/L. This combination of conditions indicates that dissolved oxygen is not likely to restrict the discharge of oxygen consuming organic material.

The mass balance modelling suggests that the dissolved oxygen concentrations downstream of the discharge are not sensitive to the effluent dissolved oxygen concentrations.

The recommended annual maximum allowable $CBOD_5$ concentrations for effluent is based on the minimum value of 245 mg/L (fall) from Table 31. This value is well above the minimum secondary effluent standard limit of 25 mg/L (Table 25). As such, the recommended effluent limit for $CBOD_5$ is 25 mg/L. However, it should be noted that the treatment level required to achieve the phosphorus limits will result in an effluent $CBOD_5$ concentration of <5 mg/L.

Table 31: Maximum Allowable Seasonal $CBOD_5$ Concentrations for Discharge at Location 1 – Welland River East

Season	Upstream $CBOD_5$ (mg/L)[1]	Maximum Allowable Effluent Concentration (mg/L)[2]
Winter	1.3	371
Spring	1.0	384
Summer	2.0	**245**
Fall	1.0	289

Notes:

1. Upstream 75th percentile concentration.
2. Based on effluent dissolved oxygen concentration equal to 50% of saturation.

4.1.7 Total Suspended Solids (TSS)

The seasonal 75th percentile upstream TSS concentrations range from 9.7 mg/L to 34.9 mg/L suggesting that the receiving water is not heavily impacted by suspended sediment. Based on the mass balance modelling results provided in Table 33, the recommended annual maximum allowable TSS concentration for effluent is 202 based on the minimum value (fall) from the table below.

This value is well above the minimum secondary effluent limit of 15 mg/L (Table 25). As such, the recommended effluent limit for TSS is 15 mg/L.

Table 32: Maximum Allowable Seasonal TSS Concentrations for Discharge at Location 1 – Welland River East

Season	Upstream TSS (mg/L)[1]	Maximum Allowable Effluent Concentration (mg/L)[2]
Winter	34.9	204
Spring	20.9	202
Summer	11.4	213
Fall	9.7	**202**

Notes:

1. Upstream 75th percentile concentration.

4.1.8 Recommended Effluent Limits

Based on the preceding discussions, a summary of the recommended effluent limits for the Welland River East discharge is presented in Table 33.

Table 33: Summary of Development of Effluent Limits for Discharge at Location 1 – Welland River East

Parameter		Limiting Assimilative Capacity Concentration[1]	Typical Treatment Plant Effluent[2]	Proposed Effluent Limits
Total Phosphorus (mg/L)		0.10[3]	0.10	0.100
Nitrate (mg/L)		29	20	N/A[4]
Unionized Ammonia (mg/L)	Summer	0.018[3]	--	0.018
	Winter/Spring/Fall	0.1	--	0.10
Total Ammonia (mg/L)	Summer	0.2[3]	0.3	0.5
	Winter/Spring/Fall	1.4	0.3	1.4
E. coli (cfu/100 mL)		no capacity[3]	<100	200
Dissolved Oxygen (% of Saturation)		50%	>80%	N/A[4]
CBOD$_5$ (mg/L)		239	10	25
Total Suspended Solids (mg/L)		202	5	15

Notes:

1. lowest seasonal value from local and system compliance points.
2. typical effluent for a membrane bioreactor with phosphorus removal and filtration.
3. No capacity – Policy 2 receiver.
4. 4.Not applicable – typical effluent is expected to be better than the limiting assimilative capacity concentration.

4.2 Location 2 – Hydro Electric Power Canal (HECP)

4.2.1 Overview of Existing Conditions

The HEPC discharge would release effluent to the earth-cut section of the HECP between Triangle Island and the Montrose Gate (start of rock-cut section). The existing water in the HEPC is a combination of inflows from the Niagara River (Chippewa Creek), Lyons Creek, and Welland River East. Under normal conditions, the effluent is expected to travel downstream in the HEPC and eventually enter the Niagara River at the Sir Adam Beck GS. The local compliance point (A2) is in the HEPC just upstream of the Montrose Gate and the system compliance point (A5) is in the HECP below the existing Niagara Falls WWTP so that the combined effects of both plants are considered in the ACS. The HEPC discharge is not expected to affect water quality in Chippewa Creek, Welland River East, or in the Niagara River upstream of the Sir Adam Beck GS.

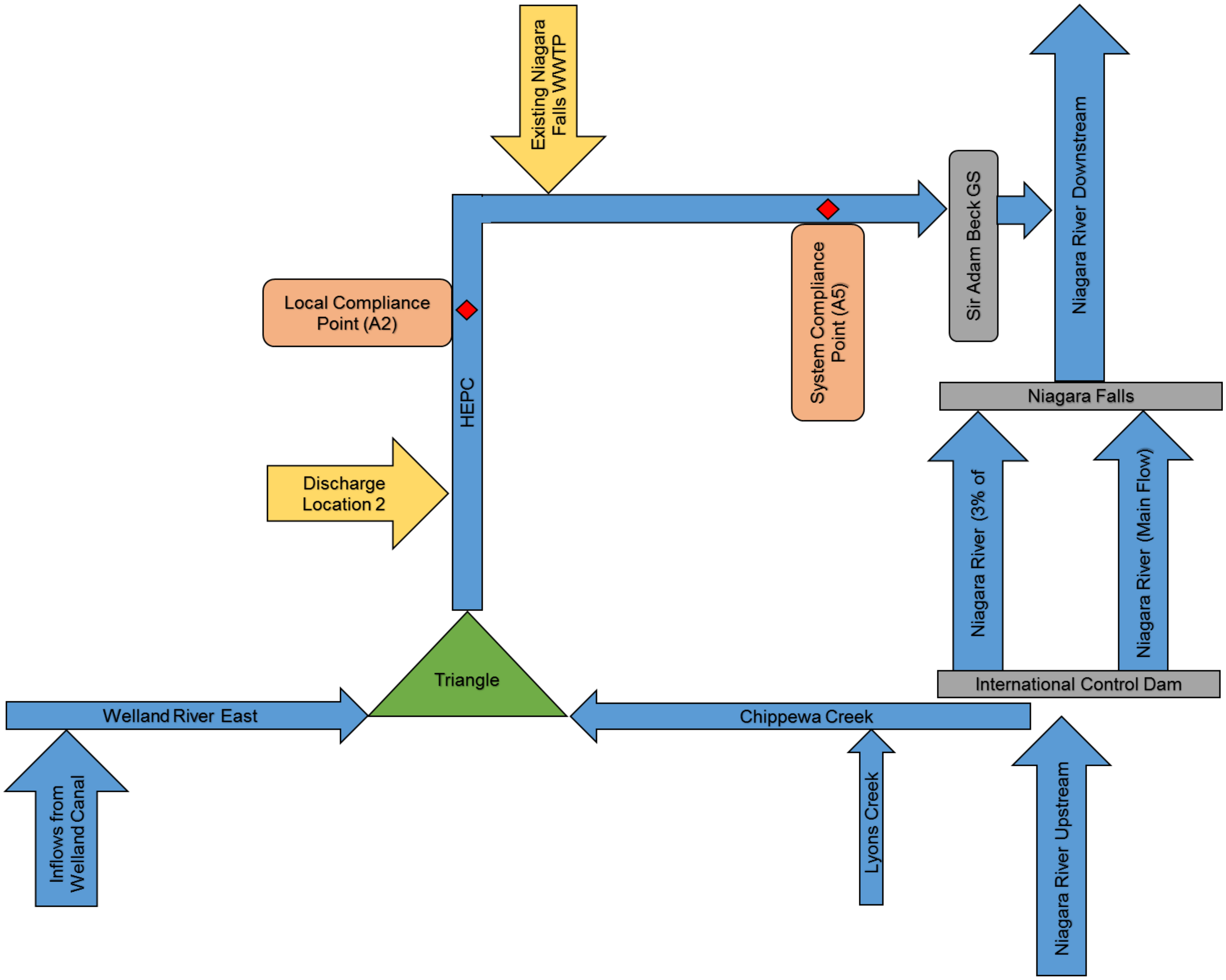

Figure 12: Local and System Compliance Points for Discharge at Location 2 – Hydro Electric Power Canal

4.2.2 Total Phosphorus

The total phosphorus concentrations in the HEPC are elevated in the winter, spring, and fall and consistently exceed the applicable PWQO (0.03 mg/L) in those seasons. The predicted seasonal 75th percentile concentrations range from 0.022 mg/L to 0.46 mg/L. Elevated total phosphorus concentrations in the HEPC are a result of elevated concentrations in the Niagara River during the winter and large phosphorus loads from Welland River East during the spring and fall. There are additional constraints at the system compliance point caused by the discharge of effluent into the HEPC from the existing Niagara Falls WWTP.

The predicted maximum allowable effluent concentrations for phosphorus are presented in Table 34. The elevated upstream total phosphorus concentrations result in Policy 2 conditions at the local and system compliance point in winter, spring, and fall. During summer, both the GoldSim and mass balance models show that effluent concentrations of 4.5 mg/L or more can be discharged to the HEPC without exceeding the total phosphorus target in the HEPC.

An effluent limit for total phosphorus of 0.75 mg/L is recommended based in the following rationale:

- The elevated phosphorus concentrations in the HEPC are the result of factors outside the study area (e.g., inflow from the Niagara River and Welland River East).
- The effluent flow rate represents less than 0.1% of the total flow in the HEPC and as such the contributions of the proposed discharge will cause negligible increases in the total phosphorus concentrations within the HEPC.
- Similarly, the effluent flow rate is insignificant when compared to the flow in the Niagara River below the Sir Adam beck GS.

Based on the information provided in Table 25, in terms of total phosphorus discharge the recommended treatment technology at Location 2 is a conventional activated sludge system with phosphorus removal and filtration.

Table 34: Maximum Allowable Seasonal Total Phosphorus Concentrations for Discharge at Location 2 – Hydro Electric Power Canal

Season	Upstream[1,2] (mg/L)	Maximum Allowable Effluent Concentration (mg/L)	
		Local Compliance Point	System Compliance Point
Winter	0.046 **(0.047)**	No Capacity	No Capacity
Spring	0.031 **(0.032)**	No Capacity	No Capacity
Summer	0.024 **(0.020)**	6.9 (5.7)	6.3 (5.0)
Fall	0.030 **(0.034)**	No Capacity	No Capacity

Notes:

1. Estimated value based on flow weighted average of inputs from Niagara River, Lyons Creek, and Welland River East at local compliance point during low flow conditions.
2. Values in bold indicate estimated value based on flow weighted average of inputs from Niagara River, Lyons Creek, and Welland River East at local compliance point during average conditions.
3. Values in brackets refer to predictions from the mass balance modelling approach, if different from the GoldSim modelling approach.

4.2.3 Nitrate

The predicted 75th percentile concentrations in the HEPC range from 0.18 mg/L to 0.37 mg/L. The highest nitrate concentrations typically occur during the winter. The predicted maximum allowable effluent concentrations for nitrate are presented in Table 35. In general, the local compliance point provides the most restrictive conditions. Based on the modelling results, the both the local and system compliance points can accept effluent nitrate concentrations in excess of 2,000 mg/L.

Based on the assumptions in Section 4.0, a conventional activated sludge system without denitrification is expected to provide effluent nitrate concentrations of 20 mg/L. As a result, nitrate limits would not be required for Location 2.

Table 35: Maximum Allowable Seasonal Nitrate Concentrations for Discharge at Location 2 – Hydro Electric Power Canal

Season	Upstream[1,2] (mg/L)	Maximum Allowable Effluent Concentration (mg/L)	
		Local Compliance Point	System Compliance Point
Winter	0.37 **0.31**	3,149 (2,644)	3,142 (2,629)
Spring	0.34 **0.31**	3,069 (2,681)	3,062(2,668)
Summer	0.27 **0.26**	3,334(2,750)	3,328 (2,740)
Fall	0.21 **0.18**	3,245(2,807)	3,238 (2,796)

Notes:

1. Estimated value based on flow weighted average of inputs from Niagara River, Lyons Creek, and Welland River East at local compliance point.
2. Values in bold indicate estimated value based on flow weighted average of inputs from Niagara River, Lyons Creek, and Welland River East at local compliance point during average conditions.
3. Values in brackets refer to predictions from the mass balance modelling approach, if different from the GoldSim modelling approach

4.2.4 Ammonia

The predicted 75th percentile concentrations for total ammonia in the HEPC range from 0.033 mg/L to 0.064 mg/L. The corresponding unionized ammonia concentrations are consistently below the applicable PWQO (0.0164 mg/L as N) for all the seasons. The maximum allowable effluent concentrations for total and unionized ammonia are presented in Table 36.

The predicted maximum allowable unionized ammonia concentrations listed in Table 36 exceed the acute toxicity guideline for unionized ammonia (0.10 mg/L as N). As such, it is recommended that the effluent limits for total ammonia be based on meeting the acute toxicity limit for unionized at end-of-pipe and seasonal water temperature and pH. The recommended effluent limit for unionized is 0.10 mg/L.

Based on the resulting values presented in Table 37, the recommended total ammonia limits are recommended to be 1.3 mg/L during the summer and 2.0 mg/L for the remainder if the year based on seasonal 75th percentile water temperature and pH in the HEPC.

Table 36: Maximum Allowable Seasonal Total and Unionized Ammonia Concentrations for Discharge at Location 2 – Hydro Electric Power Canal

Season	Total Ammonia			Unionized Ammonia		
	Upstream^{1,2}	Maximum Allowable Concentration (mg/L)		Upstream^{1,2}	Maximum Allowable Concentration (mg/L)	
		Local Compliance Point	System Compliance Point		Local Compliance Point	System Compliance Point
Winter	0.033 (**0.037)**	1.347 (1,227)	1,342 (1,216)	0.0011 **0.0010**	12.6 (15.5)	12.5 (15.5)
Spring	0.054 (**0.064)**	262 (284)	258 (275)	0.0013 **0.0012**	14.1 (15.3)	14.0 (15.3)
Summer	0.051 (**0.063)**	112 (113)	107 (101)	0.0028 **0.0014**	12.2 (13.9)	11.8 (13.8)
Fall	0.038 (**0.050)**	157 (254)	152 (243)	0.0024 **0.0012**	11.8 (14.2)	11.6 (14.2)

Notes:

1. Estimated value based on flow weighted average of inputs from Niagara River, Lyons Creek, and Welland River East at local compliance point.
2. Values in **bold** indicate estimated value based on flow weighted average of inputs from Niagara River, Lyons Creek, and Welland River East at local compliance point during average conditions.
3. Values in brackets refer to predictions from the mass balance modelling approach, if different from the GoldSim modelling approach.
4. Unionized ammonia concentrations predicted in GoldSim based on modelled ammonia and average seasonal pH and temperature.
5. Unionized ammonia concentrations predicted using the mass balance approach based on measured concentrations and modelled as a conservative constituent.

Table 37: Maximum Allowable Seasonal Total Ammonia Concentrations for Discharge at Location 2 – Hydro Electric Power Canal Based on Acute Toxicity Limits for Unionized Ammonia

Season	Ambient Conditions		Maximum Allowable Effluent Concentration (mg/L)	
	Water Temperature (ºC)	pH	Unionized Ammonia	Total Ammonia
Winter	3.5	7.99	0.1	9.39
Spring	18.6	8.16	0.1	**2.04**
Summer	23.6	8.22	0.1	**1.27**
Fall	13.5	8.14	0.1	3.08

4.2.5 *E. coli*

The predicted 75th percentile *E. coli* concentration in the HEPC ranges from 12 cfu/100 mL to 319 cfu/100 mL. The predicted *E. coli* concentration exceed the PWQO (100 cfu/100 mL) during the winter due to contributions from Welland River East at both the local and system compliance points. As such, the effluent concentration is not to exceed background conditions during the winter. As shown in Table 38, during the remaining seasons, there is capacity at both compliance points to accept effluent *E. coli* concentrations that exceed 60,000 cfu/100 mL. These allowable concentrations greatly exceed the expected effluent quality from a treatment plant.

It is recommended that an effluent limit of 200 cfu/100 mL be applied, consistent with other treatment plants in the area. With disinfection of the final effluent, any of the treatment plant can expect to meet these criteria.

Table 38: Maximum Allowable Seasonal *E. coli* Concentrations for Discharge at Location 2 – Hydro Electric Power Canal

Season	Upstream[1,2] (mg/L)	Maximum Allowable Effluent Concentration (mg/L)	
		Local Compliance Point	System Compliance Point
Winter	274 **319**	No Capacity	No Capacity
Spring	22 **36**	75,615 (78,132)	75,382 (78,132)
Summer	12 **13**	107,736 (88,800)	107,502 (88,800)
Fall	31 **34**	76,549 (69,113)	76,349 (69,113)

Notes:

1. Estimated value based on flow weighted average of inputs from Niagara River, Lyons Creek, and Welland River East at local compliance point.
2. Values in **bold** indicate estimated value based on flow weighted average of inputs from Niagara River, Lyons Creek, and Welland River East at local compliance point during average conditions.
3. Values in brackets refer to predictions from the mass balance modelling approach, if different from the GoldSim modelling approach

4.2.6 Biochemical Oxygen Demand (CBOD$_5$) and Dissolved Oxygen

The mass balance modelling suggests that the dissolved oxygen concentrations downstream of the discharge are not sensitive to the effluent dissolved oxygen concentrations.

The recommended annual maximum allowable CBOD$_5$ concentrations for effluent is based on the minimum value of 5,952 mg/L (fall) from Table 39. This value is well above the minimum secondary effluent standard limit of 25 mg/L (Table 25). As such, the recommended effluent limit for CBOD$_5$ is 25 mg/L.

Table 39: Maximum Allowable Seasonal CBOD$_5$ Concentrations for Discharge at Location 2 – Hydro Electric Power Canal

Season	Upstream CBOD$_5$ (mg/L)[1]	Maximum Allowable Effluent Concentration (mg/L)[2]
Winter	2.0	6,768
Spring		6,800
Summer		7,940
Fall		**5,952**

Notes:

1. Highest seasonal 75th percentile concentration in HEPC.
2. Based on effluent dissolved oxygen concentration equal to 50% of saturation.

4.2.7 Total Suspended Solids (TSS)

The annual 75th percentile upstream TSS is estimated to be 11.3 mg/L suggesting that the HEPC does not typically have high concentration od suspended solids. The mass balance modelling results provided in Table 40, the recommended annual maximum allowable TSS concentration for effluent is 5,046 based on the minimum value (summer and fall).

This value is well above the expected effluent from a conventional activated sludge system of 15 mg/L (Table 25). This value is well above the minimum secondary effluent standard limit of 25 mg/L (Table 25). As such, the recommended effluent limit TSS is 25 mg/L.

Table 40: Maximum Allowable Seasonal TSS Concentrations for Discharge at Location 2 – Hydro Electric Power Canal

Season	Upstream TSS (mg/L)[1]	Maximum Allowable Effluent Concentration (mg/L)[2]
Winter	11.3	5,047
Spring		5,047
Summer		**5,046**
Fall		**5,046**

Notes:

1. Annual 75th percentile concentration from Niagara River.

4.2.8 Recommended Effluent Limits

Based on the preceding discussions, a summary of the recommended effluent limits for the HEPC discharge is presented in Table 41.

Table 41: Summary of Development of Effluent Limits and Limits for Discharge at Location 2 – Hydro Electric Power Canal

Parameter		Limiting Assimilative Capacity Concentration[1]	Typical Treatment Plant Effluent[2]	Proposed Effluent Limits
Total Phosphorus (mg/L)		No capacity[3]	0.5	0.75
Nitrate (mg/L)		2,620	20	N/A[4]
Unionized Ammonia (mg/L)		0.1	--	0.1
Total Ammonia (mg/L)	Summer	1.3	<1	1.3
	Winter/Spring/Fall	2.0	<3	2.0
E. coli (cfu/100 mL)			<100	200
Dissolved Oxygen (% of Saturation)		50%	>80%	N/A[4]
$CBOD_5$ (mg/L)		5,097	25	25
Total Suspended Solids (mg/L)		5,046	25	25

Notes:

1. Lowest seasonal value from local and system compliance points.
2. Typical effluent for secondary effluent without filtration
3. No capacity – Policy 2 receiver.
4. 4.Not applicable – typical effluent is expected to be better than the limiting assimilative capacity concentration.

4.3 Location 3 – Chippewa Creek

4.3.1 Overview of Existing Conditions

The Chippewa Creek discharge would release effluent to the Chippewa Creek between Lyons Creek and Triangle Island. The existing water quality in Chippewa Creek is dominated by the water quality in the Niagara River. Under normal conditions, the effluent will travel downstream into the HEPC and eventually enter the Niagara River at the Sir Adam Beck GS. The local compliance point (A3) is in Chippewa Creek just upstream of Triangle Island and the system compliance point (A5) is in the HEPC below the existing Niagara Falls WWTP, so that the combined effects of both plants are considered in the ACS. The Chippewa Creek discharge is not expected to affect water quality in Welland River East or in the Niagara River upstream of the Sir Adam Beck GS.

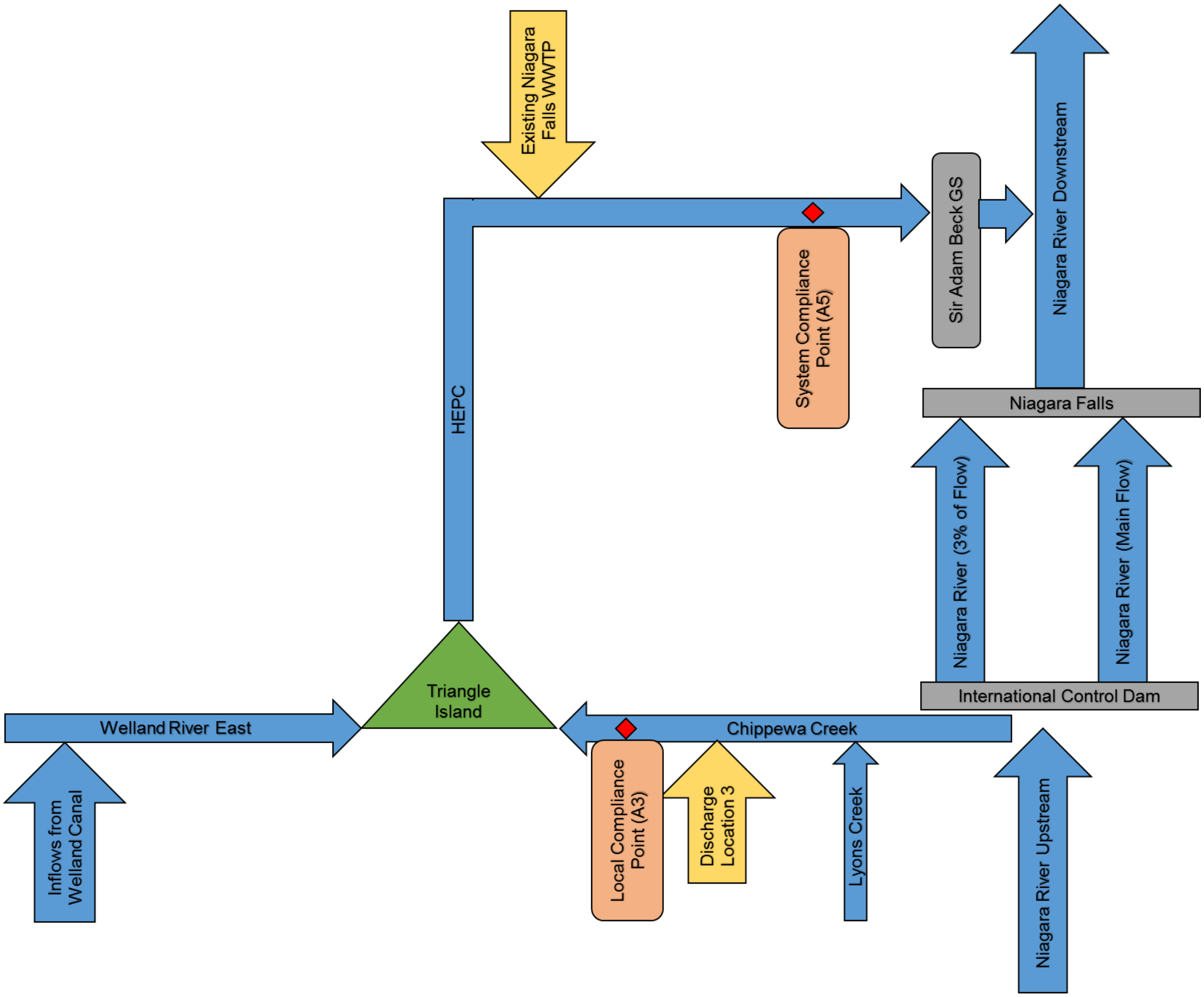

Figure 13: Local and System Compliance Points for Discharge at Location 3 – Chippewa Creek

4.3.2 Total Phosphorus

The measured seasonal 75th percentile concentrations of total phosphorus in Chippewa Creek range from 0.022 mg/L to 0.43 mg/L and are effectively the same as the measured conditions in the Niagara River. The total phosphorus concentrations in Chippewa are elevated in the winter as a result of elevated concentrations in the Niagara River during the winter. There are additional constraints at the system compliance point caused by the discharge of effluent into the HEPC from the existing Niagara Falls WWTP.

The predicted maximum allowable effluent concentrations for phosphorus are presented in Table 42. The elevated upstream total phosphorus concentrations result in Policy 2 conditions at the local compliance point in the winter months. At the local compliance point, Chippewa Creek can accept total phosphorus concentration of 2.8 mg/L or greater in the effluent in all the seasons except winter. At the system compliance point, elevated phosphorus concentrations are experienced in winter, spring and fall months due to inputs from the Welland River East and existing Niagara Falls WWTP.

An effluent limit for total phosphorus of 0.75 mg/L is recommended based in the following rationale:

- On an annual basis, there is sufficient capacity to accept an effluent concentration greater than 0.75 mg/L.
- The effluent flow rate represents less than 0.1% of the total flow in Chippewa Creek and as such the contributions of the proposed discharge will cause negligible increases in the total phosphorus concentrations within Chippewa Creek and the HEPC.
- The elevated phosphorus concentrations in Chippewa Creek are only experienced during the winter months, which is outside the algae growing season. The elevated winter background concentrations are the result of factors outside the study area (e.g., inflow from the Niagara River).
- Similarly, the effluent flow rate is insignificant when compared to the flow in the Niagara River below the Sir Adam beck GS.

Table 42: Maximum Allowable Seasonal Total Phosphorus Concentrations for Discharge at Location 3 – Chippewa Creek

Season	Upstream[1] (mg/L)	Maximum Allowable Effluent Concentration (mg/L)	
		Local Compliance Point	System Compliance Point
Winter	0.043	No Capacity	No Capacity
Spring	0.026	3.3 (3.8)	No Capacity
Summer	0.022	9.2 (7.7)	6.3 (5.0)
Fall	0.027	3.0 (2.8)	No Capacity

Notes:

1. Estimated value based on flow weighted average of inputs from Niagara River and Lyons Creek
2. Values in brackets refer to predictions from the mass balance modelling approach, if different from the GoldSim modelling approach

4.3.3 Nitrate

The measured 75th percentile nitrate concentrations in Chippewa Creek range from 0.18 mg/L to 0.31 mg/L. The highest nitrate concentrations typically occur during the winter. The predicted maximum allowable effluent concentrations for nitrate are presented in Table 43. In general, the local compliance point provides the most restrictive conditions. Based on the modelling results, the both the local and system compliance points can accept effluent nitrate concentrations in excess of 2,000 mg/L.

Based on the assumptions in Section 4.0, a conventional activated sludge system without denitrification is expected to provide effluent nitrate concentrations of 20 mg/L. As a result, nitrate limits would not be required for Location 3.

Table 43: Maximum Allowable Seasonal Nitrate Concentrations for Discharge at Location 3 – Chippewa Creek

Season	Upstream[1] (mg/L)	Maximum Allowable Effluent Concentration (mg/L)	
		Local Compliance Point	System Compliance Point
Winter	0.31	3,108 (2,621)	3,142 (2,629)
Spring	0.31	2,910 (2,614)	3,062 (2,668)
Summer	0.26	3,219 (2,652)	3,328 (2,740)
Fall	0.18	3,133 (2,735)	3,238 (2,796)

Notes:

1. Estimated value based on flow weighted average of inputs from Niagara River and Lyons Creek
2. Values in brackets refer to predictions from the mass balance modelling approach, if different from the GoldSim modelling approach

4.3.4 Ammonia

The measured 75th percentile concentrations for total ammonia in Chippewa Creek range from 0.014 mg/L to 0.032 mg/L. The corresponding unionized ammonia concentrations are consistently below the applicable PWQO (0.0164 mg/L as N) for all the seasons. The maximum allowable effluent concentrations for total and unionized ammonia are presented in Table 44.

The predicted maximum allowable unionized ammonia concentrations listed in Table 44: exceed the acute toxicity guideline for unionized ammonia (0.10 mg/L as N). As such, it is recommended that the effluent limits for total ammonia be based on meeting the acute toxicity limit for unionized at end-of-pipe and seasonal water temperature and pH.

Based on the resulting values presented in Table 45, the recommended total ammonia limits are recommended to be 1.0 mg/L during the summer and 1.7 mg/L for the remainder if the year based on seasonal average water temperature and pH in the HEPC.

Table 44: Maximum Allowable Seasonal Total and Unionized Ammonia Concentrations for Discharge at Location 3 – Chippewa Creek

Season	Total Ammonia			Unionized Ammonia		
	Upstream[1]	Maximum Allowable Concentration (mg/L)		Upstream[1]	Maximum Allowable Concentration (mg/L)	
		Local Compliance Point	System Compliance Point		Local Compliance Point	System Compliance Point
Winter	0.014	1,312 (1,294)	1,342 (1,216)	0.00012	12.12 (15.0)	12.52 (15.5)
Spring	0.046	261 (280)	258 (275)	0.00083	13.40 (15.0)	13.98 (15.3)
Summer	0.044	115 (115)	107 (101)	0.00339	12.24 (13.9)	11.82 (13.8)
Fall	0.032	159 (251)	152 (243)	0.00093	11.85 (14.0)	11.65 (14.2)

Notes:

1. Estimated value based on flow weighted average of inputs from Niagara River and Lyons Creek.
2. Values in brackets refer to predictions from the mass balance modelling approach, if different from the GoldSim modelling approach.
3. Unionized ammonia concentrations predicted in GoldSim based on modelled ammonia and average seasonal pH and temperature.
4. Unionized ammonia concentrations predicted using the mass balance approach based on measured concentrations and modelled as a conservative constituent.

Table 45: Maximum Allowable Seasonal Total Ammonia Concentrations for Discharge at Location 3 – Chippewa Creek Based on Acute Toxicity Limits for Unionized Ammonia

Season	Ambient Conditions		Maximum Allowable Effluent Concentration (mg/L)	
	Water Temperature (ºC)	pH	Unionized Ammonia	Total Ammonia
Winter	2.5	8.12	0.100	7.58
Spring	10.1	8.20	0.100	3.47
Summer	23.9	8.33	0.100	**0.99**
Fall	20.1	8.20	0.100	**1.68**

4.3.5 *E. coli*

The measured 75th percentile *E. coli* concentration in Chippewa Creek ranges from 8 cfu/100 mL to 50 cfu/100 mL and are consistently below the PWQO (100 cfu/100 mL). There are limitations on the discharge at the system compliance point during the winter due to contributions from Welland River East. As such, the effluent concentration is not to exceed background conditions during the winter. As shown in Table 46, during the remaining seasons, there is capacity at both compliance points to accept effluent *E. coli* concentrations that exceed 55,000 cfu/100 mL. These allowable concentrations greatly exceed the expected effluent quality from a treatment plant.

It is recommended that an effluent limit of 200 cfu/100 mL be used, consistent with other treatment plants in the area.

Table 46: Maximum Allowable Seasonal *E. coli* Concentrations for Discharge at Location 3 – Chippewa Creek

Season	Upstream[1] (mg/L)	Maximum Allowable Effluent Concentration (mg/L)	
		Local Compliance Point	System Compliance Point
Winter	50	55,235	No Capacity
Spring	12	94,761	75,382
Summer	8	107,502	107,502
Fall	26	81,586	76,349

Notes:

1. Estimated value based on flow weighted average of inputs from Niagara River and Lyons Creek
2. Values in brackets refer to predictions from the mass balance modelling approach, if different from the GoldSim modelling approach

4.3.6 Biochemical Oxygen Demand (CBOD$_5$) and Dissolved Oxygen

The mass balance modelling suggests that the dissolved oxygen concentrations downstream of the discharge are not sensitive to the effluent dissolved oxygen concentrations. As such, effluent dissolved oxygen concentrations equal to 50% of the saturation concentration are recommended as the effluent limit

The recommended annual maximum allowable CBOD$_5$ concentrations for effluent is based on the minimum value of 5,707 mg/L (fall) from Table 47. This value is well above the minimum secondary effluent standard limit of 25 mg/L (Table 25). As such, the recommended effluent limit for CBOD$_5$ is 25 mg/L.

Table 47: Maximum Allowable Seasonal CBOD$_5$ Concentrations for Discharge at Location 3 – Chippewa Creek

Season	Upstream CBOD$_5$ (mg/L)[1]	Maximum Allowable Effluent Concentration (mg/L)[2]
Winter	2.0	6,380
Spring		6,384
Summer		7,689
Fall		**5,707**

Notes:

1. Highest seasonal 75th percentile concentration in Welland River East.
2. Based on effluent dissolved oxygen concentration equal to 50% of saturation.

4.3.7 Total Suspended Solids (TSS)

The annual 75th percentile upstream TSS is estimated to be 11.3 mg/L suggesting that Chippewa Creek does not typically have high concentration od suspended solids. The mass balance modelling results provided in Table 48, the recommended annual maximum allowable TSS concentration for effluent is 4,846 based on the minimum value (summer and fall). This value is well above the minimum secondary effluent standard limit of 25 mg/L (Table 25). As such, the recommended effluent limit TSS is 25 mg/L.

Table 48: Maximum Allowable Seasonal TSS Concentrations for Discharge at Location 3 – Chippewa Creek

Season	Upstream TSS (mg/L)[1]	Maximum Allowable Effluent Concentration (mg/L)[2]
Winter	11.3	4,880
Spring		4,866
Summer		**4,846**
Fall		4,855

Notes:

2. Annual 75th percentile concentration from Niagara River.

4.3.8 Recommended Effluent Limits

Based on the preceding discussions, a summary of the recommended effluent concentrations for the Chippewa Creek discharge is presented in Table 49. In order to meet the limits and limits for each parameter, if the new WWTP discharges to Chippewa Creek the new plant would be designed as a membrane bioreactor with phosphorus removal and filtration. This advanced level of treatment is required in order to meet the end-of-pipe acute toxicity criteria during the summer.

Table 49: Summary of Development of Effluent Limits for Discharge at Location 3 – Chippewa Creek

Parameter		Limiting Assimilative Capacity Concentration[1]	Typical Treatment Plant Effluent[2]	Proposed Effluent Limits
Total Phosphorus (mg/L)		No capacity[3]	0.5	0.75
Nitrate (mg/L)		2,614	20	N/A[4]
Unionized Ammonia (mg/L)		0.1	--	0.10
Total Ammonia (mg/L)	Summer	1.0	<1	1.1
	Winter/Spring/Fall	1.7	<3	1.7
E. coli (cfu/100 mL)		55,235	100	200
Dissolved Oxygen (% of Saturation)		50%	>80%	N/A[4]
$CBOD_5$ (mg/L)		4,885	25	25
Total Suspended Solids (mg/L)		4,846	25	25

Notes:

1. Lowest seasonal value from local and system compliance points.
2. Typical effluent for a conventional activated sludge without filtration.
3. No capacity – Policy 2 receiver during winter months only.
4. Not applicable – typical effluent is expected to be better than the limiting assimilative capacity concentration.

4.4 Location 4 – Niagara River

4.4.1 Overview of Existing Conditions

The Niagara River discharge would release effluent to the Niagara River just downstream of the ICD approximately 1.8 km upstream of Niagara Falls. The effluent is expected to form a shoreline plume as it travels downstream to the falls. The effluent is expected to mix with approximately 3% of the total flow in the Niagara River in the 10-minute travel time. Below the falls, the effluent is expected to mix completely with the Niagara River flow. The local compliance point (A4) is located on the Canadian shoreline at the crest of the falls. There is no system compliance point for this location since the Niagara River discharge not expected to affect water quality in Welland River East, Chippewa Creek, in the HEPC where the existing Niagara Falls WWTP discharges into. There is no system compliance point for this location since the Niagara River discharge not expected to affect water quality in Welland River East, Chippewa Creek, in the HEPC where the existing Niagara Falls WWTP discharges into.

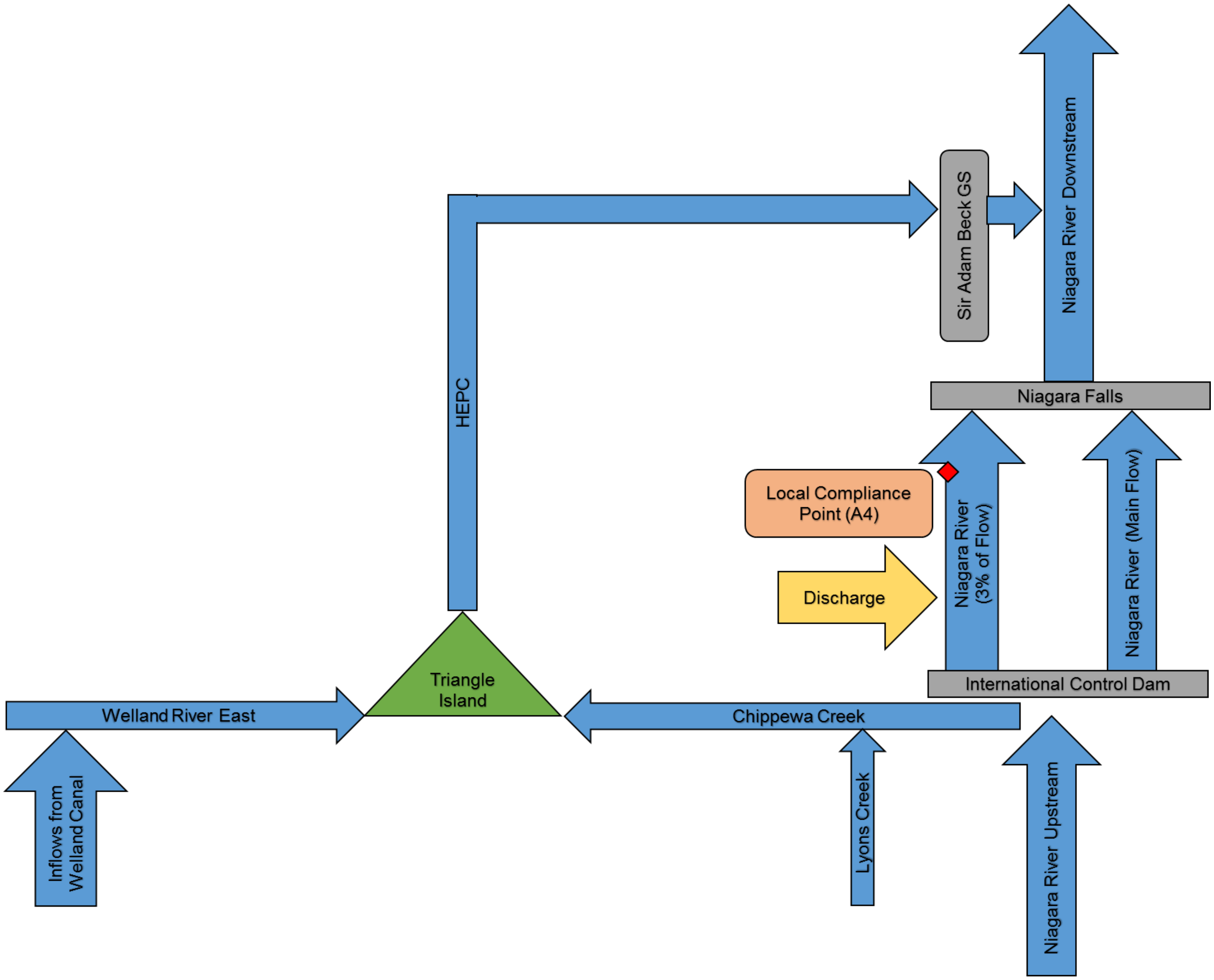

Figure 14: Local and System Compliance Points for Discharge at Location 4 – Niagara River

4.4.2 Total Phosphorus

The measured seasonal 75th percentile concentrations of total phosphorus in Niagara River range from 0.022 mg/L to 0.43 mg/L. The total phosphorus concentrations in Niagara River are elevated in the winter and result in discharge constraints in the winter.

The predicted maximum allowable effluent concentrations for phosphorus are presented in Table 50. The elevated upstream total phosphorus concentrations result in Policy 2 conditions at the local compliance during winter months. At the local compliance point, the Niagara River can accept total phosphorus concentration of 0.58 mg/L or greater in the effluent in all the seasons except winter.

An effluent limit for total phosphorus of 0.75 mg/L is recommended based in the following rationale:

- On an annual basis, there is sufficient capacity to accept an effluent concentration greater than 0.75 mg/L.
- The elevated phosphorus concentrations in the Niagara River are only during winter months and are the result of factors outside the study area (e.g., upstream in the Niagara River and Lake Erie).
- The effluent flow rate represents less than 0.01% of the total flow in Niagara River and as such the contributions of the proposed discharge will cause negligible increases in the total phosphorus concentrations downstream.

Table 50: Maximum Allowable Seasonal Total Phosphorus Concentrations for Discharge at Location 4 – Niagara River

Season	Upstream (mg/L)	Maximum Allowable Effluent Concentration (mg/L)
Winter	0.043	No Capacity
Spring	0.026	0.764
Summer	0.022	1.498
Fall	0.027	0.581

4.4.3 Nitrate

The measured 75th percentile nitrate concentrations in the Niagara River range from 0.18 mg/L to 0.31 mg/L. The highest nitrate concentrations typically occur during the winter. The predicted maximum allowable effluent concentrations for nitrate are presented in Table 53:. Based on the modelling results, the Niagara River can accept effluent nitrate concentrations in of 497 mg/L or greater.

Based on the assumptions in Section 4.0, a conventional activated sludge system without denitrification is expected to provide effluent nitrate concentrations of 20 mg/L. As a result, nitrate limits would not be required for Location 3.

Table 51: Maximum Allowable Seasonal Nitrate Concentrations for Discharge at Location 4 – Niagara River

Season	Upstream (mg/L)	Maximum Allowable Effluent Concentration (mg/L)
Winter	0.31	**497**
Spring	0.31	497
Summer	0.26	577
Fall	0.18	521

4.4.4 Ammonia

The measured 75th percentile concentrations for total ammonia in Niagara River range from 0.014 mg/L to 0.032 mg/L. The corresponding unionized ammonia concentrations are consistently below the applicable PWQO (0.0164 mg/L as N) for all the seasons. The maximum allowable effluent concentrations for total and unionized ammonia are presented in Table 52.

The predicted maximum allowable unionized ammonia concentrations listed in Table 52 exceed the acute toxicity guideline for unionized ammonia (0.10 mg/L as N). As such, it is recommended that the effluent limit for total ammonia be based on meeting the acute toxicity limit for unionized at end-of-pipe and seasonal water temperature and pH.

Based on the resulting values presented in Table 53:, the recommended total ammonia limits are recommended to be 1.0 mg/L during the summer and 1.7 mg/L for the remainder if the year based on seasonal average water temperature and pH in the HEPC.

Table 52: Maximum Allowable Seasonal Total and Unionized Ammonia Concentrations for Discharge at Location 4 – Niagara River

Season	Upstream (mg/L))		Maximum Allowable Effluent Concentration (mg/L)	
	Total	Unionized	Total	Unionized
Winter	0.014	0.00012	227	3.0
Spring	0.046	0.00083	97	2.8
Summer	0.044	0.00339	25	2.5
Fall	0.032	0.00093	45	2.7

Table 53: Maximum Allowable Seasonal Total Ammonia Concentrations for Discharge at Location 4 – Niagara River Based on Acute Toxicity Limits for Unionized Ammonia

Season	Ambient Conditions		Maximum Allowable Effluent Concentration (mg/L)	
	Water Temperature (ºC)	pH	Unionized Ammonia	Total Ammonia
Winter	2.5	8.12	0.100	7.58
Spring	10.1	8.20	0.100	3.47
Summer	23.9	8.33	0.100	**0.99**
Fall	20.1	8.20	0.100	**1.68**

4.4.5 *E. coli*

The measured 75th percentile *E. coli* concentration in the Niagara River ranges from 8 cfu/100 mL to 50 cfu/100 mL and are consistently below the PWQO (100 cfu/100 mL). There are no seasonal limitations on the discharge identified. As shown in Table 54, there is capacity in all seasons to accept effluent *E. coli* concentrations that exceed 9,000 cfu/100 mL. These allowable concentrations greatly exceed the expected effluent quality from a treatment plant.

It is recommended that an effluent limit of 200 cfu/100 mL be used, consistent with other treatment plants in the area.

Table 54: Maximum Allowable Seasonal Nitrate Concentrations for Discharge at Location 4 – Niagara River

Season	Upstream (cfu/100 mL)	Maximum Allowable Effluent Concentration (cfu/100 mL)
Winter	50	**9,276**
Spring	12	16,249
Summer	8	19,368
Fall	26	13,680

4.4.6 Biochemical Oxygen Demand ($CBOD_5$) and Dissolved Oxygen

The mass balance modelling suggests that the dissolved oxygen concentrations downstream of the discharge are not sensitive to the effluent dissolved oxygen concentrations.

The recommended annual maximum allowable $CBOD_5$ concentrations for effluent is based on the minimum value of 1,083 mg/L (fall) from Table 55. This value is well above the minimum secondary effluent standard limit of 25 mg/L (Table 25). As such, the recommended effluent limit for $CBOD_5$ is 25 mg/L.

Table 55: Maximum Allowable Seasonal $CBOD_5$ Concentrations for Discharge at Location 4 – Niagara River

Season	Upstream $CBOD_5$ (mg/L)[1]	Maximum Allowable Effluent Concentration (mg/L)[2]
Winter	2.0	1,204
Spring		1,275
Summer		1,461
Fall		**1,083**

Notes:

1. Highest seasonal 75th percentile concentration in Welland River East.
2. Based on effluent dissolved oxygen concentration equal to 50% of saturation.

4.4.7 Total Suspended Solids (TSS)

The annual 75th percentile upstream TSS is estimated to be 11.3 mg/L suggesting that the Niagara River does not typically have high concentration od suspended solids. The mass balance modelling results provided in

Table 56, the recommended annual maximum allowable TSS concentration for effluent is 934 based on the minimum value. This value is well above the minimum secondary effluent standard limit of 25 mg/L (Table 25). As such, the recommended effluent limit TSS is 25 mg/L.

Table 56: Maximum Allowable Seasonal TSS Concentrations for Discharge at Location 4 – Niagara River

Season	Upstream TSS (mg/L)[1]	Maximum Allowable Effluent Concentration (mg/L)[2]
Winter	11.3	**934**
Spring		985
Summer		**934**
Fall		**934**

Notes:

1. Annual 75th percentile concentration from Niagara River.

4.4.8 Recommended Effluent Limits

Based on the preceding discussions, a summary of the recommended effluent concentrations for the Niagara River discharge is presented in Table 57.

Table 57: Summary of Development of Effluent Limits for Discharge at Location 4 – Niagara River

Parameter		Limiting Assimilative Capacity Concentration[1]	Typical Treatment Plant Effluent[2]	Proposed Effluent Limits
Total Phosphorus (mg/L)		No capacity[3]	0.5	0.5
Nitrate (mg/L)		497	20	N/A[4]
Unionized Ammonia (mg/L)		0.10	0.1	0.1
Total Ammonia (mg/L)	Summer	1.0	<1	1.0
	Winter/Spring/Fall	1.7	<3	1.7
E. coli (cfu/100 mL)		9,276	<100	200
Dissolved Oxygen (% of Saturation)		50%	>80%	N/A[4]
$CBOD_5$ (mg/L)		927	25	25
Total Suspended Solids (mg/L)		934	25	25

Notes:

1. Lowest seasonal value.
2. Typical effluent for a conventional activated sludge without filtration.
3. No capacity – Policy 2 receiver during winter months only.
4. 4.Not applicable – typical effluent is expected to be better than the limiting assimilative capacity concentration.

5.0 CUMULATIVE EFFECTS OF THE PROJECT ON WATER QUALITY

The following subsections of this report present the projected cumulative effect of different discharge location alternatives on receiving water quality within the system at downstream assessment points with accompanying discussion of seasonal sensitivities, where relevant. It should be noted that presented results specifically consider the effects of the proposed effluent discharge under the 7Q20 flow and 75th percentile condition, meaning that water quality conditions would typically be better than presented. A schematic of the mass balance model including the assessment points used in the cumulative effects assessment is provided in Figure 10.

5.1 Total Phosphorus

Table 58 compares the water quality effects of proposed discharge location alternatives at each of six assessment points recognising that the phosphorus effluent limit for discharge location 1 is limited to 0.1 mg/L due to Policy 2 conditions while the phosphorus effluent limit for discharge locations 2, 3 and 4 is 0.75 mg/L which are achievable in conventional activated sludge system with phosphorus removal.

As observed in the tables below, the WWTP at discharge location 1 results in the smallest cumulative change in downstream phosphorus concentrations. Total phosphorus concentrations at Assessment Point A1 generally decrease due to the intensified level of treatment and poor background water quality in Welland River East. Marginal increases in phosphorus concentrations are observed further downstream at Assessment Point A2 during the winter and fall and, on average, over the course of the year.

Owing to the higher phosphorus effluent limit at discharge locations 2, 3 and 4, the effect of the new WWTP at each of these locations at downstream assessment points (A2, A5 and A6 for discharge location 2; A3, A2, A5 and A6 for discharge location 3; A4 and A6 for discharge location 4) is slightly higher than for discharge location 1. However, that these increases are typically less than 0.1 µg/L (approximately 1.5%) and do not result in exceedances of the PWQO for phosphorus during the summer when the risk of algal growth is elevated.

To further demonstrate the effect of the Project on the total phosphorus concentrations, GoldSim was used to predict the expected distribution of total phosphorus concentrations at each of the assessment locations. This was accomplished completing a Monte Carlo simulation for each season and discharge location using statistical distributions of inflows (same as used in to estimate maximum allowable effluent concentrations) and statistical distributions of the total phosphorus concentration in the Niagara River, Lyons Creek, and Welland River East. In all cases, a log-normal distribution was used.

The results of this analysis are provided in Appendix A. For the discharge options into the HEPC and Chippewa Creek, the predicted distributions at all the affected assessment points are nearly identical to the baseline condition. For the discharge option to Welland River East, there is a predicted change to the distribution at Assessment Point A1 (a shift of the distribution to the right) suggesting an increase in total phosphorus concentrations.

Based on these two assessments, it is expected that the change in phosphorus concentrations in the receiving waters as a result of the Project will not be measurable for all cases except for the discharge into the Welland River East.

Table 58: Predicted Total Phosphorus Concentrations at Assessment Points by Season and Discharge Location

	Winter	Spring	Summer	Fall	Annual
New WWTP Flow (m^3/s)	0.35				
New WWTP Total Phosphorus Limit	0.1 mg/L at L1; 0.75 mg/L at L2, L3, L4				
A1 – Welland River East at Triangle Island					
Existing Concentration (µg/L) – No Discharge	140.0	160.0	80.0	100.0	118.2
Future Concentration (µg/L) – Discharge at L1	138.8	158.3	80.5	100.0	117.7
Future Concentration (µg/L) – Discharge at L2	140.0	160.0	80.0	100.0	118.2
Future Concentration (µg/L) – Discharge at L3	140.0	160.0	80.0	100.0	118.2
Future Concentration (µg/L) – Discharge at L4	140.0	160.0	80.0	100.0	118.2
A2 – HEPC at Montrose Gate					
Existing Concentration (µg/L) – No Discharge	46.2	30.8	24.4	29.8	32.7
Future Concentration (µg/L) – Discharge at L1	46.3	30.9	24.5	29.9	32.8
Future Concentration (µg/L) – Discharge at L2	46.9	31.5	25.1	30.5	33.5
Future Concentration (µg/L) – Discharge at L3	46.9	31.5	25.1	30.5	33.5
Future Concentration (µg/L) – Discharge at L4	46.2	30.8	24.4	29.8	32.7
A3 – Chippewa Creek at Triangle Island					
Existing Concentration (µg/L) – No Discharge	43.1	26.1	22.1	27.1	29.6
Future Concentration (µg/L) – Discharge at L1	43.1	26.1	22.1	27.1	29.6
Future Concentration (µg/L) – Discharge at L2	43.1	26.1	22.1	27.1	29.6
Future Concentration (µg/L) – Discharge at L3	43.8	26.9	22.9	27.8	30.3
Future Concentration (µg/L) – Discharge at L4	43.1	26.1	22.1	27.1	29.6
A4 – Niagara River at Falls (Canadian Shore)					
Existing Concentration (µg/L) – No Discharge	43.0	26.0	22.0	27.0	29.4
Future Concentration (µg/L) – Discharge at L1	43.0	26.0	22.0	27.0	29.4
Future Concentration (µg/L) – Discharge at L2	43.0	26.0	22.0	27.0	29.4
Future Concentration (µg/L) – Discharge at L3	43.0	26.0	22.0	27.0	29.4
Future Concentration (µg/L) – Discharge at L4	47.1	29.9	26.1	31.1	33.4
A5 – HEPC at Sir Adam Beck GS					
Existing Concentration (µg/L) – No Discharge	47.8	32.4	26.0	31.4	34.4
Future Concentration (µg/L) – Discharge at L1	47.9	32.5	26.1	31.5	34.4
Future Concentration (µg/L) – Discharge at L2	48.5	33.1	26.7	32.1	35.1
Future Concentration (µg/L) – Discharge at L3	48.5	33.1	26.7	32.1	35.1
Future Concentration (µg/L) – Discharge at L4	47.8	32.4	26.0	31.4	34.4
A6 – Niagara River below Sir Adam Beck GS					
Existing Concentration (µg/L) – No Discharge	43.6	26.8	22.5	27.5	30.0
Future Concentration (µg/L) – Discharge at L1	43.6	26.8	22.5	27.6	30.0
Future Concentration (µg/L) – Discharge at L2	43.7	26.9	22.6	27.6	30.1
Future Concentration (µg/L) – Discharge at L3	43.7	26.9	22.6	27.6	30.1
Future Concentration (µg/L) – Discharge at L4	43.7	26.9	22.6	27.6	30.1

5.2 Unionized Ammonia

Table 59 compares the water quality effects of proposed discharge location alternatives at each of six assessment points recognising that the unionized ammonia effluent limit for discharge location 1 is limited to 0.018 mg/L during the summer (membrane bioreactor with phosphorus removal and filtration) because existing background water quality in this watercourse is close to the PWQO of 0.0164 mg/L as N. The unionized ammonia effluent limit that has been applied during all other seasons and at all other discharge locations is 0.1 mg/L.

The effect of introducing the new WWTP at discharge locations 1 and 4 on local assessment points is conspicuous when compared to siting the new WWTP at discharge locations 2 and 3. Only minor differences in water quality effects between the four discharge locations are in evidence by the time the mixed effluent stream reaches the system assessment point (A5) and final assessment point (A6) indicating that water quality effects for unionized ammonia are relatively localized.

Table 59: Predicted Unionized Ammonia Concentrations at Assessment Points by Season and Discharge Location

	Winter	Spring	Summer	Fall	Annual
New WWTP Flow (m^3/s)	0.35				
New WWTP Unionized Ammonia Limit	18 µg/L at L1 (summer); otherwise 100 µg/L				
A1 – Welland River East at Triangle Island					
Existing Concentration (µg/L) – No Discharge	1.00	6.00	18.00	9.00	8.94
Future Concentration (µg/L) – Discharge at L1	3.93	8.59	18.00	11.37	10.83
Future Concentration (µg/L) – Discharge at L2	1.00	6.00	18.00	9.00	8.94
Future Concentration (µg/L) – Discharge at L3	1.00	6.00	18.00	9.00	8.94
Future Concentration (µg/L) – Discharge at L4	1.00	6.00	18.00	9.00	8.94
A2 – HEPC at Montrose Gate					
Existing Concentration (µg/L) – No Discharge	1.00	1.18	2.63	2.26	1.77
Future Concentration (µg/L) – Discharge at L1	1.10	1.28	2.64	2.36	1.85
Future Concentration (µg/L) – Discharge at L2	1.10	1.28	2.72	2.36	1.87
Future Concentration (µg/L) – Discharge at L3	1.10	1.28	2.72	2.36	1.87
Future Concentration (µg/L) – Discharge at L4	1.00	1.18	2.63	2.26	1.77
A3 – Chippewa Creek at Triangle Island					
Existing Concentration (µg/L) – No Discharge	1.00	1.00	2.00	2.01	1.50
Future Concentration (µg/L) – Discharge at L1	1.00	1.00	2.00	2.01	1.50
Future Concentration (µg/L) – Discharge at L2	1.00	1.00	2.00	2.01	1.50
Future Concentration (µg/L) – Discharge at L3	1.10	1.11	2.10	2.11	1.60
Future Concentration (µg/L) – Discharge at L4	1.00	1.00	2.00	2.01	1.50
A4 – Niagara River at Falls (Canadian Shore)					
Existing Concentration (µg/L) – No Discharge	1.00	1.00	2.00	2.00	1.49
Future Concentration (µg/L) – Discharge at L1	1.00	1.00	2.00	2.00	1.49
Future Concentration (µg/L) – Discharge at L2	1.00	1.00	2.00	2.00	1.49
Future Concentration (µg/L) – Discharge at L3	1.00	1.00	2.00	2.00	1.49
Future Concentration (µg/L) – Discharge at L4	1.54	1.52	2.54	2.54	2.03
A5 – HEPC as Sir Adam Beck GS					
Existing Concentration (µg/L) – No Discharge	1.07	1.25	2.75	2.36	1.86
Future Concentration (µg/L) – Discharge at L1	1.17	1.35	2.77	2.46	1.94
Future Concentration (µg/L) – Discharge at L2	1.17	1.35	2.85	2.46	1.96
Future Concentration (µg/L) – Discharge at L3	1.17	1.35	2.85	2.46	1.96
Future Concentration (µg/L) – Discharge at L4	1.07	1.25	2.75	2.36	1.86
A6 – Niagara River below Sir Adam Beck GS					
Existing Concentration (µg/L) – No Discharge	1.01	1.03	2.09	2.05	1.54
Future Concentration (µg/L) – Discharge at L1	1.02	1.04	2.10	2.06	1.55
Future Concentration (µg/L) – Discharge at L2	1.02	1.04	2.11	2.06	1.55
Future Concentration (µg/L) – Discharge at L3	1.02	1.04	2.11	2.06	1.55
Future Concentration (µg/L) – Discharge at L4	1.02	1.04	2.11	2.06	1.55

5.3 Total Ammonia

Table 60 compares the water quality effects of proposed discharge location alternatives at each of six assessment points for total ammonia. In each case the total ammonia was estimated using the unionized ammonia effluent limits (discussed in Section 5.2), the average seasonal water temperature and pH within each receiver. The below water quality results for total ammonia thus reflect a variety of seasonal and location-based water quality and temperature characteristics.

The tabulated results indicate that water quality at local assessment points, particularly at A1, can be substantially influenced by introducing the new WWTP upstream. As would be expected, the magnitude of these influences decreases considerably with distance downstream as the influence of other loadings sources and flows becomes more dominant.

As no provincial water quality limit is tied directly to total ammonia, the significance of water quality effects of discharge location alternatives at each assessment is best evaluated for unionized ammonia (Section 5.2).

Table 60: Predicted Total Ammonia Concentrations at Assessment Points by Season and Discharge Location

	Winter	Spring	Summer	Fall	Annual
New WWTP Flow (m^3/s)	0.35				
New WWTP Total Ammonia Limit	1.4 mg/L (winter, spring, fall) & 0.5 mg/L (summer) at L1; 1.3 mg/L (winter, spring, fall) & 2.0 mg/L (summer) at L2; 1.0 mg/L (winter, spring, fall) & 1.7 mg/L (summer) at L3 & L4				
A1 - Welland River East at Triangle Island					
Existing Concentration - No Discharge (mg/L)	0.2300	0.2100	0.2200	0.2000	0.2146
Future Concentration - Discharge at L1 (mg/L)	0.2646	0.2428	0.2270	0.2313	0.2404
Future Concentration - Discharge at L2 (mg/L)	0.2300	0.2100	0.2200	0.2000	0.2146
Future Concentration - Discharge at L3 (mg/L)	0.2300	0.2100	0.2200	0.2000	0.2146
Future Concentration - Discharge at L4 (mg/L)	0.2300	0.2100	0.2200	0.2000	0.2146
A2 - HEPC at Montrose Gate					
Existing Concentration - No Discharge (mg/L)	0.0240	0.0518	0.0509	0.0238	0.0377
Future Concentration - Discharge at L1 (mg/L)	0.0253	0.0531	0.0513	0.0252	0.0389
Future Concentration - Discharge at L2 (mg/L)	0.0253	0.0531	0.0511	0.0252	0.0388
Future Concentration - Discharge at L3 (mg/L)	0.0256	0.0534	0.0518	0.0255	0.0392
Future Concentration - Discharge at L4 (mg/L)	0.0240	0.0518	0.0509	0.0238	0.0377
A3 - Chippewa Creek at Triangle Island					
Existing Concentration - No Discharge (mg/L)	0.0170	0.0461	0.0440	0.0170	0.0311
Future Concentration - Discharge at L1 (mg/L)	0.0170	0.0461	0.0440	0.0170	0.0311
Future Concentration - Discharge at L2 (mg/L)	0.0170	0.0461	0.0440	0.0170	0.0311
Future Concentration - Discharge at L3 (mg/L)	0.0187	0.0478	0.0450	0.0188	0.0327
Future Concentration - Discharge at L4 (mg/L)	0.0170	0.0461	0.0440	0.0170	0.0311
A4 - Niagara River at Falls (Canadian Shore)					
Existing Concentration - No Discharge (mg/L)	0.0170	0.0460	0.0440	0.0170	0.0313
Future Concentration - Discharge at L1 (mg/L)	0.0170	0.0460	0.0440	0.0170	0.0313
Future Concentration - Discharge at L2 (mg/L)	0.0170	0.0460	0.0440	0.0170	0.0313
Future Concentration - Discharge at L3 (mg/L)	0.0170	0.0460	0.0440	0.0170	0.0313
Future Concentration - Discharge at L4 (mg/L)	0.0263	0.0548	0.0494	0.0263	0.0395
A5 - HEPC at Sir Adam Beck GS					
Existing Concentration - No Discharge (mg/L)	0.0456	0.0683	0.0698	0.0419	0.0565
Future Concentration - Discharge at L1 (mg/L)	0.0470	0.0696	0.0702	0.0432	0.0576
Future Concentration - Discharge at L2 (mg/L)	0.0470	0.0696	0.0699	0.0432	0.0575
Future Concentration - Discharge at L3 (mg/L)	0.0472	0.0699	0.0707	0.0435	0.0580
Future Concentration - Discharge at L4 (mg/L)	0.0456	0.0683	0.0698	0.0419	0.0565
A6 - Niagara River Below Sir Adam Beck					
Existing Concentration - No Discharge (mg/L)	0.0205	0.0487	0.0472	0.0201	0.0344
Future Concentration - Discharge at L1 (mg/L)	0.0207	0.0488	0.0473	0.0203	0.0345
Future Concentration - Discharge at L2 (mg/L)	0.0207	0.0488	0.0472	0.0203	0.0345
Future Concentration - Discharge at L3 (mg/L)	0.0208	0.0489	0.0473	0.0203	0.0346
Future Concentration - Discharge at L4 (mg/L)	0.0208	0.0489	0.0473	0.0203	0.0346

5.4 Nitrate

Table 61 compares the water quality effects of proposed discharge location alternatives at each of six assessment points with the conventional secondary treatment effluent nitrate concentrations of 20 mg/L being applied consistently across seasons and locations. This concentration is consistent with a fully nitrifying facility without denitrification.

Notable from the results is that the new WWTP has a negligible effect on nitrate concentrations within receiving waters in all cases except at assessment point A1 when discharge location 1 is considered. In this case increases in nitrate concentrations of between 25% and 100% are observed, depending on season. Even so, these changes are not considered significant from a water quality perspective because instream nitrate concentrations remain below the Canadian Water Quality Guideline of 3 mg/L.

Table 61: Predicted Nitrate Concentrations at Assessment Points by Season and Discharge Location

A1 – Welland River East at Triangle Island	Winter	Spring	Summer	Fall	Annual
New WWTP Flow (m^3/s)	0.35				
New WWTP Nitrate Limit	20 mg/L				
A1 – Welland River East at Triangle Island					
Existing Concentration (mg/L) – No Discharge	2.29	1.11	0.49	1.05	1.19
Future Concentration (mg/L) – Discharge at L1	2.81	1.63	0.97	1.54	1.69
Future Concentration (mg/L) – Discharge at L2	2.29	1.11	0.49	1.05	1.19
Future Concentration (mg/L) – Discharge at L3	2.29	1.11	0.49	1.05	1.19
Future Concentration (mg/L) – Discharge at L4	2.29	1.11	0.49	1.05	1.19
A2 – HEPC at Montrose Gate					
Existing Concentration (mg/L) – No Discharge	0.37	0.34	0.27	0.21	0.30
Future Concentration (mg/L) – Discharge at L1	0.39	0.36	0.29	0.23	0.32
Future Concentration (mg/L) – Discharge at L2	0.39	0.36	0.29	0.23	0.32
Future Concentration (mg/L) – Discharge at L3	0.39	0.36	0.29	0.23	0.32
Future Concentration (mg/L) – Discharge at L4	0.37	0.34	0.27	0.21	0.30
A3 – Chippewa Creek at Triangle Island					
Existing Concentration (mg/L) – No Discharge	0.31	0.31	0.26	0.18	0.27
Future Concentration (mg/L) – Discharge at L1	0.31	0.31	0.26	0.18	0.27
Future Concentration (mg/L) – Discharge at L2	0.31	0.31	0.26	0.18	0.27
Future Concentration (mg/L) – Discharge at L3	0.33	0.33	0.28	0.20	0.29
Future Concentration (mg/L) – Discharge at L4	0.31	0.31	0.26	0.18	0.27
A4 – Niagara River at Falls (Canadian Shore)					
Existing Concentration (mg/L) – No Discharge	0.31	0.31	0.26	0.18	0.27
Future Concentration (mg/L) – Discharge at L1	0.31	0.31	0.26	0.18	0.27
Future Concentration (mg/L) – Discharge at L2	0.31	0.31	0.26	0.18	0.27
Future Concentration (mg/L) – Discharge at L3	0.31	0.31	0.26	0.18	0.27
Future Concentration (mg/L) – Discharge at L4	0.42	0.41	0.37	0.29	0.37
A5 – Niagara River below Sir Adam Beck GS					
Existing Concentration (mg/L) – No Discharge	0.40	0.36	0.29	0.23	0.32
Future Concentration (mg/L) – Discharge at L1	0.42	0.38	0.31	0.25	0.34
Future Concentration (mg/L) – Discharge at L2	0.42	0.38	0.31	0.25	0.34
Future Concentration (mg/L) – Discharge at L3	0.42	0.38	0.31	0.25	0.34
Future Concentration (mg/L) – Discharge at L4	0.40	0.36	0.29	0.23	0.32
A6 – Niagara River below Sir Adam Beck GS					
Existing Concentration (mg/L) – No Discharge	0.32	0.32	0.26	0.19	0.27
Future Concentration (mg/L) – Discharge at L1	0.32	0.32	0.27	0.19	0.27
Future Concentration (mg/L) – Discharge at L2	0.32	0.32	0.27	0.19	0.27
Future Concentration (mg/L) – Discharge at L3	0.32	0.32	0.27	0.19	0.27
Future Concentration (mg/L) – Discharge at L4	0.32	0.32	0.27	0.19	0.27

5.5 *E. coli*

Table 62 compares the water quality effects of proposed discharge location alternatives at each of six assessment points with the conventional secondary treatment with disinfection effluent limit for *E. coli* (200 cfu/100ml) being applied consistently across seasons and locations.

While the tabulated provide some insight into potential changes in *E. coli* concentrations it should be noted that there are no water quality concerns as the effluent objectives meet provincial guidelines for receiving water quality.

Table 62: Predicted *E. coli* Concentrations at Assessment Points by Season and Discharge Location

A1 – Welland River East at Triangle Island	Winter	Spring	Summer	Fall	Annual
New WWTP Flow (m^3/s)	0.35				
New WWTP *E. coli* Limit	200 cfu/100 mL				
A1 – Welland River East at Triangle Island					
Existing Concentration (cfu/100 mL) – No Discharge	6920.0	308.0	105.0	170.0	1695.1
Future Concentration (cfu/100 mL) – Discharge at L1	6721.2	305.0	107.4	170.8	1654.9
Future Concentration (cfu/100 mL) – Discharge at L2	6920.0	308.0	105.0	170.0	1695.1
Future Concentration (cfu/100 mL) – Discharge at L3	6920.0	308.0	105.0	170.0	1695.1
Future Concentration (cfu/100 mL) – Discharge at L4	6920.0	308.0	105.0	170.0	1695.1
A2 – HEPC at Montrose Gate					
Existing Concentration (cfu/100 mL) – No Discharge	274.2	22.4	11.8	31.4	84.1
Future Concentration (cfu/100 mL) – Discharge at L1	274.2	22.6	12.0	31.6	84.2
Future Concentration (cfu/100 mL) – Discharge at L2	274.2	22.6	12.0	31.6	84.2
Future Concentration (cfu/100 mL) – Discharge at L3	274.2	22.6	12.0	31.6	84.2
Future Concentration (cfu/100 mL) – Discharge at L4	274.2	22.4	11.8	31.4	84.1
A3 – Chippewa Creek at Triangle Island					
Existing Concentration (cfu/100 mL) – No Discharge	50.2	12.1	8.0	26.1	24.0
Future Concentration (cfu/100 mL) – Discharge at L1	50.2	12.1	8.0	26.1	24.0
Future Concentration (cfu/100 mL) – Discharge at L2	50.2	12.1	8.0	26.1	24.0
Future Concentration (cfu/100 mL) – Discharge at L3	50.4	12.3	8.2	26.2	24.2
Future Concentration (cfu/100 mL) – Discharge at L4	50.2	12.1	8.0	26.1	24.0
A4 – Niagara River at Falls (Canadian Shore)					
Existing Concentration (cfu/100 mL) – No Discharge	50.0	12.0	8.0	26.0	23.7
Future Concentration (cfu/100 mL) – Discharge at L1	50.0	12.0	8.0	26.0	23.7
Future Concentration (cfu/100 mL) – Discharge at L2	50.0	12.0	8.0	26.0	23.7
Future Concentration (cfu/100 mL) – Discharge at L3	50.0	12.0	8.0	26.0	23.7
Future Concentration (cfu/100 mL) – Discharge at L4	51.1	13.0	9.1	27.1	24.8
A5 – Niagara River below Sir Adam Beck GS					
Existing Concentration (cfu/100 mL) – No Discharge	274.1	22.8	12.3	31.8	84.3
Future Concentration (cfu/100 mL) – Discharge at L1	274.0	23.0	12.4	31.9	84.5
Future Concentration (cfu/100 mL) – Discharge at L2	274.0	23.0	12.4	31.9	84.5
Future Concentration (cfu/100 mL) – Discharge at L3	274.0	23.0	12.4	31.9	84.5
Future Concentration (cfu/100 mL) – Discharge at L4	274.1	22.8	12.3	31.8	84.3
A6 – Niagara River below Sir Adam Beck GS					
Existing Concentration (cfu/100 mL) – No Discharge	77.8	13.3	8.5	26.7	31.2
Future Concentration (cfu/100 mL) – Discharge at L1	77.8	13.3	8.6	26.7	31.2
Future Concentration (cfu/100 mL) – Discharge at L2	77.8	13.3	8.6	26.7	31.2
Future Concentration (cfu/100 mL) – Discharge at L3	77.8	13.3	8.6	26.7	31.2
Future Concentration (cfu/100 mL) – Discharge at L4	77.8	13.3	8.6	26.7	31.2

5.6 Biological Oxygen Demand ($CBOD_5$)

Table 63 compares the water quality effects of proposed discharge location alternatives at each of six assessment points with the conventional secondary treatment effluent limit for $CBOD_5$ (25 mg/L) being applied consistently across seasons and locations.

While the tabulated provide some insight into potential changes $CBOD_5$ concentrations it should be noted that there are no water quality concerns as the effluent objectives meet provincial guidelines for receiving water quality.

Table 63: Predicted CBOD$_5$ Concentrations at Assessment Points by Season and Discharge Location

A1 – Welland River East at Triangle Island	Winter	Spring	Summer	Fall	Annual
New WWTP Flow (m^3/s)	0.35				
New WWTP CBOD$_5$ Limit	25 mg/L				
A1 – Welland River East at Triangle Island					
Existing Concentration - No Discharge (mg/L)	1.34	1.03	2.00	1.00	1.36
Future Concentration - Discharge at L1 (m/L)	2.04	1.69	2.57	1.63	1.99
Future Concentration - Discharge at L2 (mg/L)	1.34	1.03	2.00	1.00	1.36
Future Concentration - Discharge at L3 (mg/L)	1.34	1.03	2.00	1.00	1.36
Future Concentration - Discharge at L4 (mg/L)	1.34	1.03	2.00	1.00	1.36
A2 - HEPC at Montrose Gate					
Existing Concentration - No Discharge (mg/L)	1.98	1.97	2.00	1.96	1.98
Future Concentration - Discharge at L1 (m/L)	2.00	1.99	2.02	1.99	2.00
Future Concentration - Discharge at L2 (mg/L)	2.00	1.99	2.02	1.99	2.00
Future Concentration - Discharge at L3 (mg/L)	2.00	1.99	2.02	1.99	2.00
Future Concentration - Discharge at L4 (mg/L)	1.98	1.97	2.00	1.96	1.98
A3 - Chippewa Creek at Triangle Island					
Existing Concentration - No Discharge (mg/L)	2.00	2.00	2.00	2.00	2.00
Future Concentration - Discharge at L1 (m/L)	2.00	2.00	2.00	2.00	2.00
Future Concentration - Discharge at L2 (mg/L)	2.00	2.00	2.00	2.00	2.00
Future Concentration - Discharge at L3 (mg/L)	2.02	2.02	2.02	2.02	2.02
Future Concentration - Discharge at L4 (mg/L)	2.00	2.00	2.00	2.00	2.00
A4 - Niagara River at Falls (Canadian Shore)					
Existing Concentration - No Discharge (mg/L)	2.00	2.00	2.00	2.00	2.00
Future Concentration - Discharge at L1 (m/L)	2.00	2.00	2.00	2.00	2.00
Future Concentration - Discharge at L2 (mg/L)	2.00	2.00	2.00	2.00	2.00
Future Concentration - Discharge at L3 (mg/L)	2.00	2.00	2.00	2.00	2.00
Future Concentration - Discharge at L4 (mg/L)	2.14	2.13	2.14	2.14	2.13
A5 - HEPC at Sir Adam Beck					
Existing Concentration - No Discharge (mg/L)	2.03	2.02	2.05	2.01	2.03
Future Concentration - Discharge at L1 (m/L)	2.05	2.04	2.07	2.04	2.05
Future Concentration - Discharge at L2 (mg/L)	2.05	2.04	2.07	2.04	2.05
Future Concentration - Discharge at L3 (mg/L)	2.05	2.04	2.07	2.04	2.05
Future Concentration - Discharge at L4 (mg/L)	2.03	2.02	2.05	2.01	2.03
A6 - Niagara River Below Sir Adam Beck					
Existing Concentration - No Discharge (mg/L)	2.00	2.00	2.01	2.00	2.00
Future Concentration - Discharge at L1 (m/L)	2.01	2.00	2.01	2.00	2.01
Future Concentration - Discharge at L2 (mg/L)	2.01	2.00	2.01	2.00	2.01
Future Concentration - Discharge at L3 (mg/L)	2.01	2.00	2.01	2.00	2.01
Future Concentration - Discharge at L4 (mg/L)	2.01	2.00	2.01	2.00	2.01

6.0 CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Based on the analysis in this report, the following conclusions are provided:

- Elevated total phosphorus concentrations in the Niagara River leads to effluent constraints during the winter for discharges to the HEPC, Chippewa Creek, and the Niagara River.
- Degraded water quality in the Welland River East leads to effluent constraints related to total phosphorus and unionized ammonia for the option to discharge to the Welland River East.
- In most cases, the recommended effluent limits and limits for total and unionized ammonia are defined by the end-of-pipe acute toxicity criteria for unionized ammonia (0.1 mg/L).
- Based on seasonal water temperatures and pH in the receiving water, summer is the most restrictive season for total ammonia. Maximum allowable total ammonia concentrations range from 0.19 mg/L for the Welland River East discharge to 1.0 mg/L for the Chippewa Creek and Niagara River discharges. A value of 0.50 mg/L has been recommended for the Welland River East based on the limits reliably achievable in a nitrifying facility.
- For all other parameters (nitrate, *E. coli*, $CBOD_5$, dissolved oxygen, and TSS) the maximum allowable effluent concentrations at the local and system compliance points are greater than the expected effluent concentrations from a conventional activated sludge treatment plant.
- At most locations and discharge options, the expected water quality concentrations are not expected to be measurably different from the existing conditions. Only the discharge at Location 1 – Welland River East is expected to cause measurable differences in water quality in the immediate area of the discharge.
- Since the modelling presented in this study assumes complete and instant mixing of the effluent after release into the environment, a mixing zone study is required to assess and identify any limitations on assimilative capacity near the outfall.
- Since the information regarding the expected effluent quality from various treatment technologies is not site specific, more detailed assessments should be completed prior to the final selection of the required technology for each discharge location.

Recommendations

Based on the analysis in this report, the recommended effluent objectives and limits for each discharge location are provided in Table 64 through Table 67. Limits and objectives have not been included for nitrate and dissolved oxygen since the effluent quality from any typical plant is expected to be better than the allowable maximum effluent concentrations.

These recommended limits and limits should be re-evaluated upon the completion of a mixing zone study and an assessment of the expected effluent quality from various treatment technologies based in site specific conditions.

Table 64: Proposed Effluent Objectives and Limits for Discharge at Location 1 – Welland River East

Parameter		Proposed Effluent Objectives	Proposed Effluent Limits
Total Phosphorus (mg/L)		0.075	0.100
Total Ammonia (mg/L)	Summer	0.50	0.50
	Winter/Spring/Fall	1.40	1.40
E. coli (cfu/100 mL)		100	200
CBOD$_5$ (mg/L)		15	25
Total Suspended Solids (mg/L)		5	10

Table 65: Proposed Effluent Objectives and Limits for Discharge at Location 2 – Hydro Electric Power Canal

Parameter		Proposed Effluent Objectives	Proposed Effluent Limits
Total Phosphorus (mg/L)		0.5	0.75
Total Ammonia (mg/L)	Summer	1.3	1.3
	Winter/Spring/Fall	2.0	2.0
E. coli (cfu/100 mL)		100	200
CBOD$_5$ (mg/L)		15	25
Total Suspended Solids (mg/L)		15	25

Table 66: Proposed Effluent Objectives and Limits for Discharge at Location 3 – Chippewa Creek

Parameter		Proposed Effluent Objectives	Proposed Effluent Limits
Total Phosphorus (mg/L)		0.5	0.75
Total Ammonia (mg/L)	Summer	1.0	1.0
	Winter/Spring/Fall	1.7	1.7
E. coli (cfu/100 mL)		100	200
CBOD$_5$ (mg/L)		15	25
Total Suspended Solids (mg/L)		15	25

Table 67: Proposed Effluent Objectives and Limits for Discharge at Location 4 – Niagara River

Parameter		Proposed Effluent Objectives	Proposed Effluent Limits
Total Phosphorus (mg/L)		0.5	0.75
Total Ammonia (mg/L)	Summer	1.0	1.0
	Winter/Spring/Fall	1.7	1.7
E. coli (cfu/100 mL)		100	200
CBOD$_5$ (mg/L)		15	25
Total Suspended Solids (mg/L)		15	25

7.0 LIMITATIONS

Golder has prepared this report for the exclusive use by the Niagara Region and other members of the project team for the South Niagara Falls Wastewater Solutions Schedule C Class EA Project. The results presented in this report are for a proposed wastewater treatment plant with a specific design capacity of 30 MLD discharging to four potential locations in the study area. The results presented in this report should not be used to assess other design capacities or discharge locations in any way.

Information, analysis, and commentary presented in this report regarding wastewater treatment technologies and the associated typical effluent quality have been provided by CIMA+.

The assessment has been completed using data and information collected and provided by others. Golder does not assume any responsibility related to the accuracy or reliability of the data or information.

Water quality modelling requires the use of many assumptions due to the uncertainty related to determining the physical and chemical characteristics of a complex system. The prediction of water quality is based on several inputs (flows and chemistry), all of which have inherent variability and uncertainty.

GoldSim derives a maximum allowable concentration distribution for each parameter and location by combining randomly sampled flows over numerous (1,000s) of cycles using a Monte Carlo approach. While this approach is valuable because it considers numerous combinations, it may be inaccurate if certain environmental conditions are less represented in historic data than others.

The conventional mass balance ACS approach calculates the maximum allowable effluent concentration for a specific case where the low-flow condition (e.g., 7Q20) occurs for all the inflows at the same time. This is the approach that is typically requested by the MECP and is assumed to represent a worst-case scenario. However, because of the range of the inflow watershed sizes (e.g., Niagara River compared to Lyons Creek), it is highly unlikely that low-flow conditions will occur in all the inflows at the same time.

In natural systems and complex man-made systems, observed conditions will almost certainly vary with respect to estimated conditions. Water quality and flow data has shown a vast range of variability across seasons and locations. This variability may not be captured by the flow and water quality statistics (e.g., 75th percentile concentrations) used as inputs to the models. This is especially true for data sets with small sample sizes.

The modelling presented in this study assumes complete and instant mixing of the effluent after release into the environment. As such, this assessment does not consider any potential water quality effects in the immediate area of the outfall. A mixing zone study is required to assess these issues and identify any related limitations on assimilative capacity near the outfall.

Since the information regarding the expected effluent quality from various treatment technologies is not site specific, more detailed assessments should be completed prior to the final selection of the required technology for each discharge location.

This assessment is one part of a larger project to select the location and effluent criteria for the proposed wastewater treatment plant. The results of this assessment should be used in conjunction with the other components of the Project to support any decisions. Given all the inherent uncertainties provided, the results should be used as a tool to aid in the design and planning of the proposed wastewater treatment plant rather than to provide absolute water quality predictions.

Signature Page

We trust that this report meets your needs at this time. If you have any questions, please do not hesitate to contact the undersigned.

Yours truly,

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https://golderassociates.sharepoint.com/sites/29902g/deliverables/03_assimilative_capacity_study/screening_acs/final_rev0_may2020/18104462-r-rev0-21may2020-screening level_acs.docx

REFERENCES

AquaResource. 2009. Water Availability Study for the Central Welland River, Big Forks Creek, and Beaverdams Shriners Creeks Watershed Plan Areas, Niagara Peninsula Source Protection Area. A report prepared for Niagara Peninsula Conservation Authority. January 23, 2009.

CCME. 2014. Canadian Environmental Quality Guidelines. Canadian Council of Ministers of the Environment. Available at www.ccme.ca/en/resources/canadian_environmental_quality_guidelines.

Environment and Climate Change Canada and the U.S. Environmental Protection Agency. 2018. Lake Ontario Lakewide Action and Management Plan, 2018-2022. https://binational.net/wp-content/uploads/2019/04/2018-Lake-Ontario-For-Public-Comment-APRIL-2019.pdf

Fischer, H. B., List, J. E., Koh, C. R., Imberger, J., & Brooks, N. H. 1979. Mixing in inland and coastal waters. New York, Academic Press

Hutchinson. 2019. Hutchinson Environmental Sciences Ltd. Peer Review Comments: South Niagara Falls Wastewater Solutions Schedule C Class Environmental Assessment – Screening Level Assimilative Capacity Study of Discharge Location Alternatives. December 2, 2019

Manning, R. 1891. "On the flow of water in open channels and pipes". Transactions of the Institution of Civil Engineers of Ireland. 20: 161–207.

MOEE. 1994. Water Management Policies Guidelines Provincial Water Quality Objectives of The Ministry of Environment and Energy. Reprinted 1999.

MOEE. 1994a. B-1-5 Deriving Receiving Water Based Point Source Effluent Requirements for Ontario Water.

Ministry of the Environment (MOE). 2010. Amended Certificate of Approval for Niagara Falls Wastewater Treatment Plant (Stanley Avenue). Number 7962-7ZLK6. Issues February 3, 2010.

Ministry of Environment, Conservation, and Parks (MECP). 2019. Design Guidelines for Sewage Works. ISBN 978-1-4249-8438-1. (https://www.ontario.ca/document/design-guidelines-sewage-works-0).

Ministry of Transportation (MTO). 1997. Drainage Management Manual. Part 3. Drainage and Hydrology Section. Transportation Engineering Branch. Quality and Standards Division.

Niagara Parks. 2018. http://www.niagaraparks.com/visit-niagara-parks/plan-your-visit/niagara-falls-geology-facts-figures/.

NPCA. 2011. The Welland River Eutrophication Study in the Niagara River Area of Concern in Support of the Beneficial Use Impairment: Eutrophication and Undesirable Algae. A report written by Niagara Peninsula Conservation Authority on behalf of the Welland River Eutrophication Technical Working Group. March 2011.

NOAA. 2019. Tides & Currents Database (http://tidesandcurrents.noaa.gov/stationhome.html?id=9063020/).

NWQMC. 2019. Water Quality Portal of the National Water Quality Monitoring Council (http://www.waterqualitydata.us/).

NYPA. 2005. Surface Water Quality of the Niagara River and its U.S. Tributaries. A report prepared for the Niagara Power Project FERC No. 2216 and the New York Power Authority. August 2005.

SLSMA. 2019. Water Diversion Report Production Guide. The St. Lawrence Seaway Management Corporation. September 2019.

USGS. 2019. National Water Information System (http://nwis.waterdata.usgs.gov/usa/nwis/qwdata/?site_no=04216070/)

XCG. 2007. Assimilative Capacity Assessment of the Welland River, Ontario. A technical memorandum prepared for Niagara Region. November 1, 2007

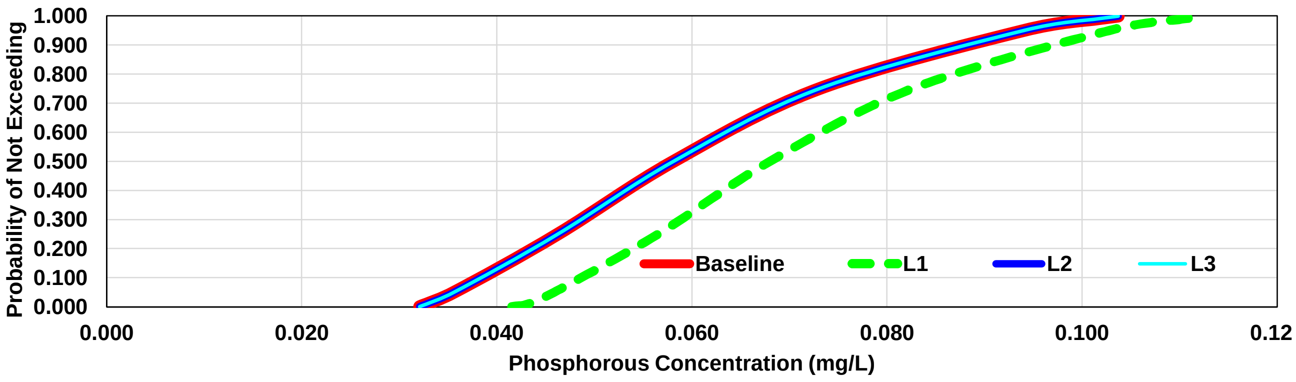
APPENDIX A

Predicted Phosphorus Concentration Distributions in Welland River East, Chippewa Creek, and HEPC

Prediction of Phosphorous for Summer

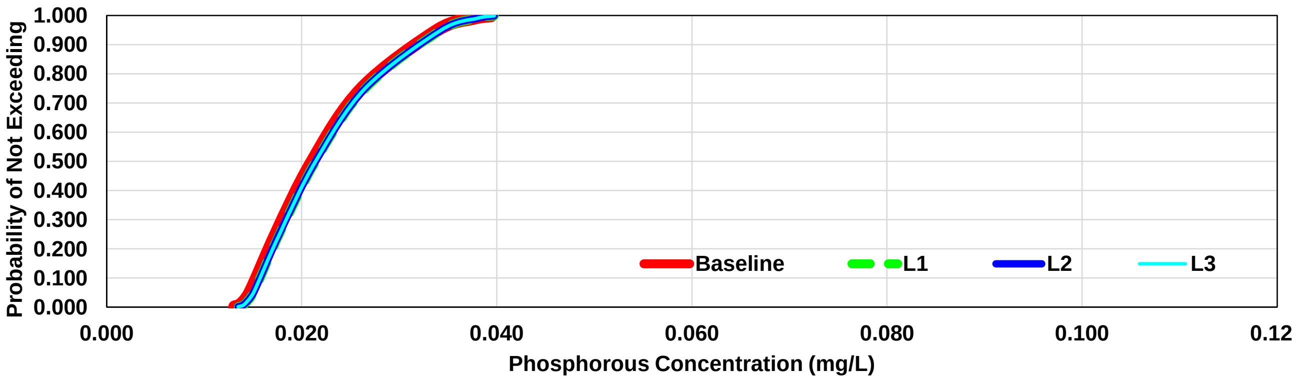
Predictions at L1

Cumulative Probability	Baseline	L1	L2	L3
0.001	0.032	0.042	0.032	0.032
0.010	0.033	0.043	0.033	0.033
0.050	0.036	0.046	0.036	0.036
0.250	0.046	0.057	0.046	0.046
0.500	0.058	0.068	0.058	0.058
0.750	0.073	0.083	0.073	0.073
0.950	0.094	0.103	0.094	0.094
0.990	0.102	0.111	0.102	0.102
0.999	0.104	0.113	0.104	0.104



Predictions at L2

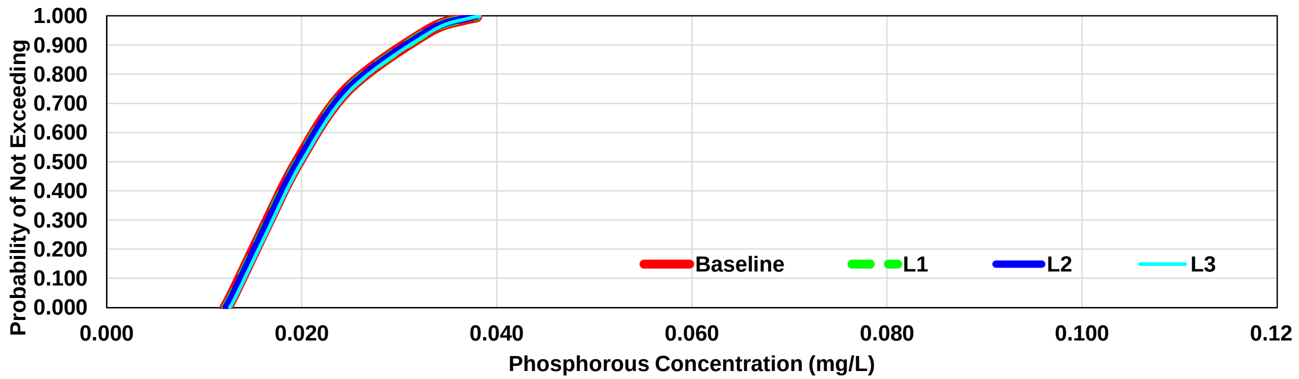
Cumulative Probability	Baseline	L1	L2	L3
0.001	0.013	0.014	0.014	0.014
0.010	0.014	0.014	0.014	0.014
0.050	0.015	0.015	0.015	0.015
0.250	0.017	0.018	0.018	0.018
0.500	0.021	0.021	0.021	0.021
0.750	0.026	0.027	0.027	0.027
0.950	0.034	0.034	0.034	0.034
0.990	0.038	0.038	0.038	0.038
0.999	0.039	0.040	0.040	0.040



Prediction of Phosphorous for Summer

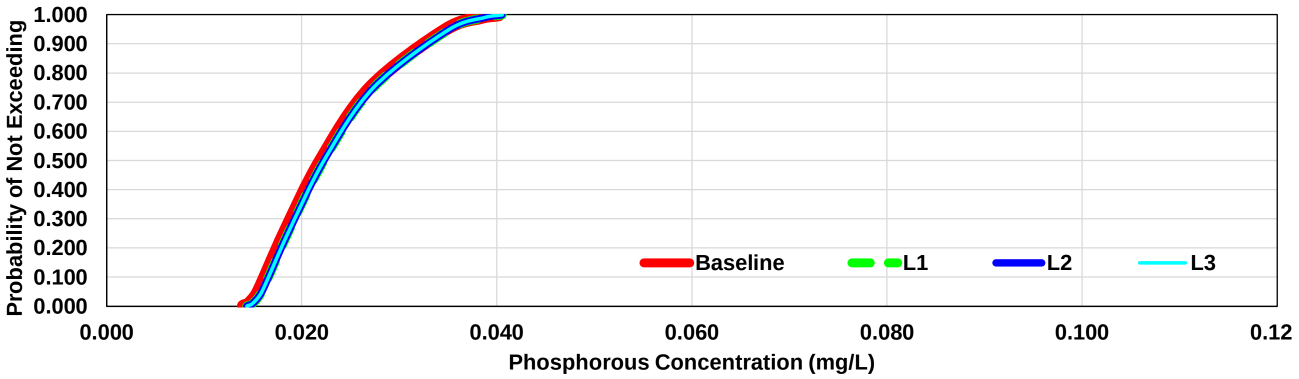
Predictions at L3

Cumulative Probability	Baseline	L1	L2	L3
0.001	0.012	0.012	0.012	0.013
0.010	0.012	0.012	0.012	0.013
0.050	0.013	0.013	0.013	0.013
0.250	0.016	0.016	0.016	0.016
0.500	0.020	0.020	0.020	0.020
0.750	0.025	0.025	0.025	0.025
0.950	0.033	0.033	0.033	0.033
0.990	0.037	0.037	0.037	0.037
0.999	0.038	0.038	0.038	0.038



Predictions at System Compliance Point

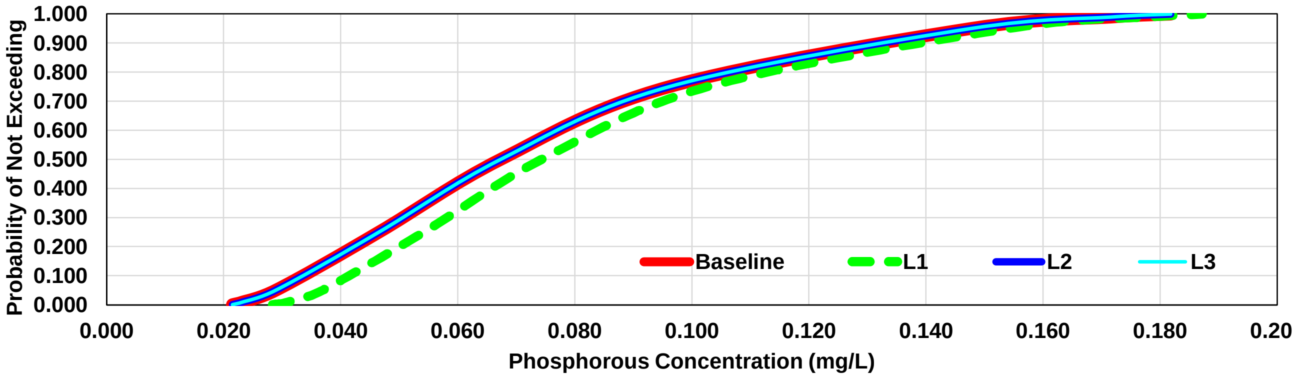
Cumulative Probability	Baseline	L1	L2	L3
0.001	0.014	0.014	0.014	0.014
0.010	0.015	0.015	0.015	0.015
0.050	0.016	0.016	0.016	0.016
0.250	0.018	0.019	0.019	0.019
0.500	0.022	0.022	0.022	0.022
0.750	0.027	0.027	0.027	0.027
0.950	0.035	0.035	0.035	0.035
0.990	0.038	0.039	0.039	0.039
0.999	0.040	0.041	0.041	0.041



Prediction of Phosphorous for Fall

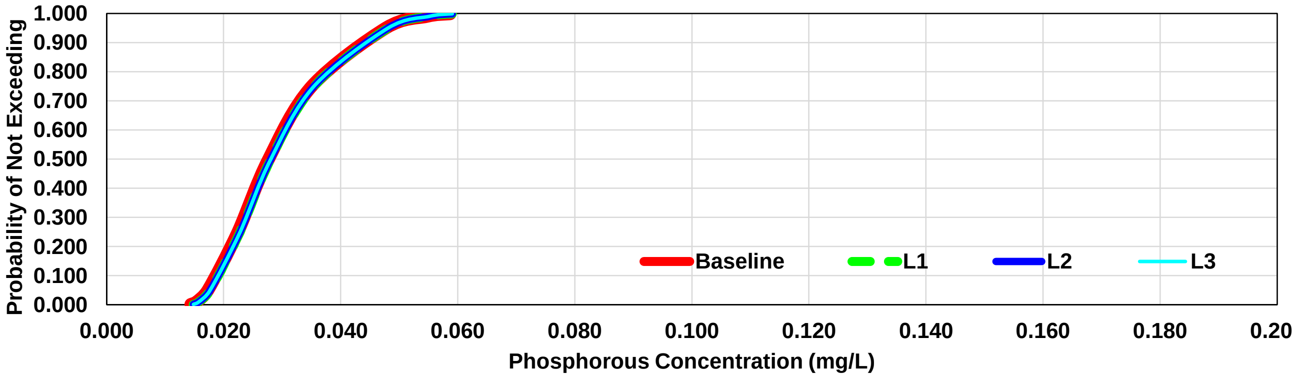
Predictions at L1

Cumulative Probability	Baseline	L1	L2	L3
0.001	0.021	0.028	0.021	0.021
0.010	0.023	0.031	0.023	0.023
0.050	0.029	0.037	0.029	0.029
0.250	0.047	0.054	0.047	0.047
0.500	0.067	0.074	0.067	0.067
0.750	0.096	0.103	0.096	0.096
0.950	0.148	0.154	0.148	0.148
0.990	0.173	0.179	0.173	0.173
0.999	0.182	0.187	0.182	0.182



Predictions at L2

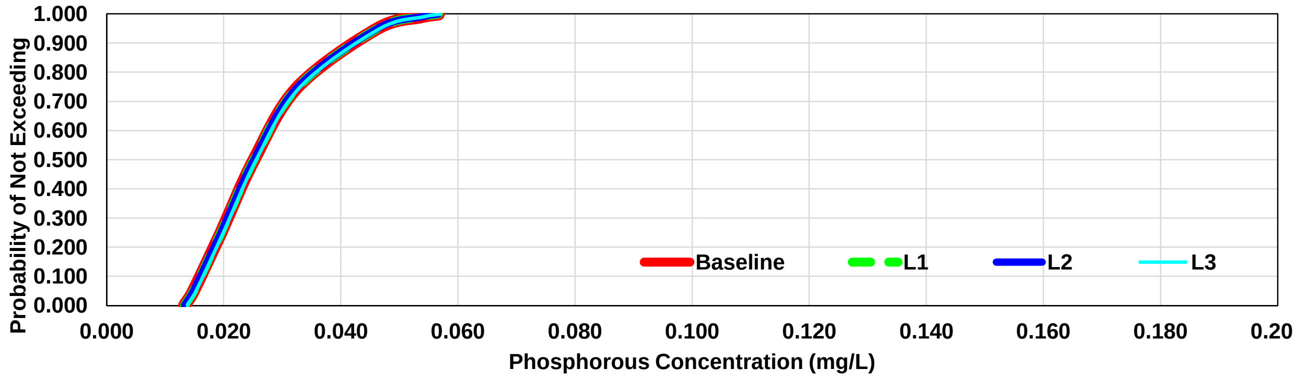
Cumulative Probability	Baseline	L1	L2	L3
0.001	0.014	0.015	0.015	0.015
0.010	0.015	0.016	0.016	0.016
0.050	0.017	0.018	0.018	0.018
0.250	0.022	0.023	0.023	0.023
0.500	0.028	0.028	0.028	0.028
0.750	0.035	0.035	0.035	0.035
0.950	0.048	0.048	0.048	0.048
0.990	0.055	0.055	0.055	0.055
0.999	0.059	0.059	0.059	0.059



Prediction of Phosphorous for Fall

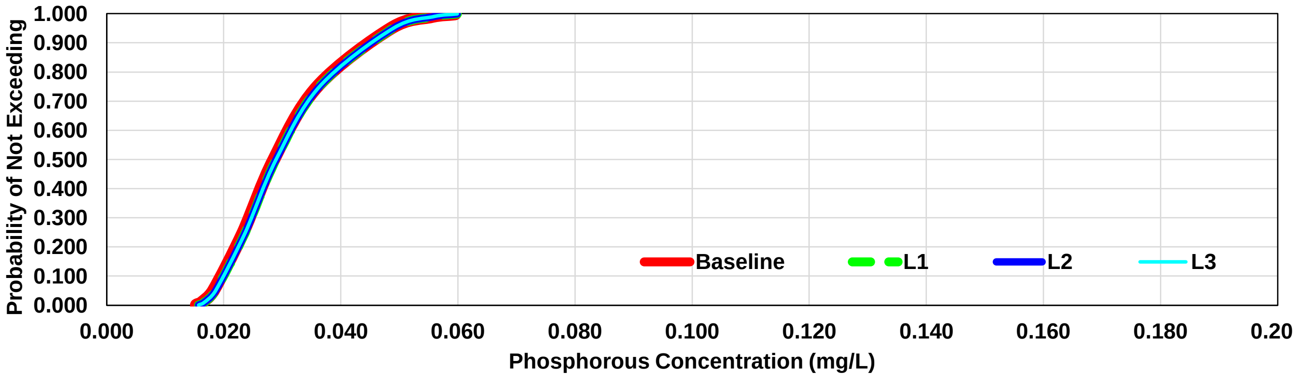
Predictions at L3

Cumulative Probability	Baseline	L1	L2	L3
0.001	0.013	0.013	0.013	0.014
0.010	0.014	0.014	0.014	0.014
0.050	0.015	0.015	0.015	0.015
0.250	0.020	0.020	0.020	0.020
0.500	0.025	0.025	0.025	0.026
0.750	0.033	0.033	0.033	0.033
0.950	0.046	0.046	0.046	0.047
0.990	0.054	0.054	0.054	0.054
0.999	0.057	0.057	0.057	0.057



Predictions at System Compliance Point

Cumulative Probability	Baseline	L1	L2	L3
0.001	0.015	0.016	0.016	0.016
0.010	0.016	0.017	0.017	0.017
0.050	0.018	0.019	0.019	0.019
0.250	0.023	0.024	0.024	0.024
0.500	0.029	0.029	0.029	0.029
0.750	0.036	0.036	0.036	0.036
0.950	0.049	0.049	0.049	0.049
0.990	0.056	0.056	0.056	0.056
0.999	0.060	0.060	0.060	0.060

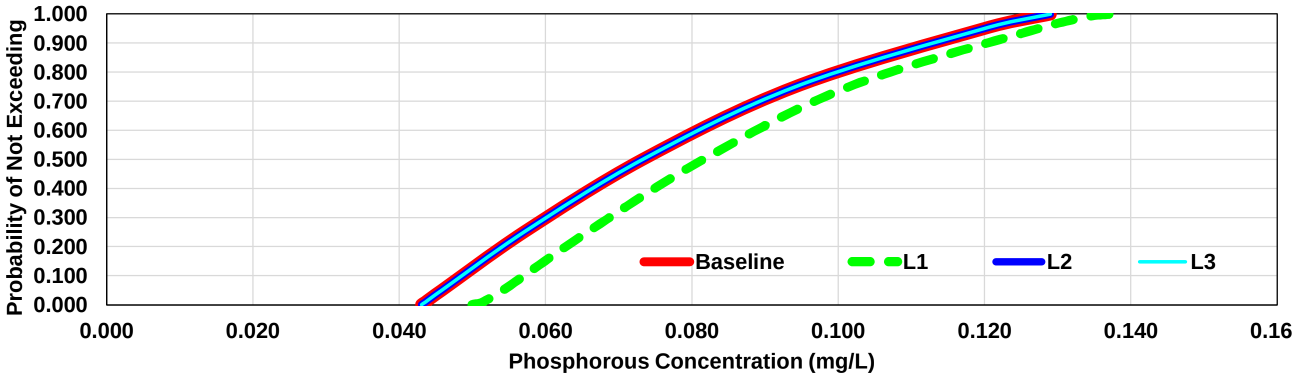


Appendix A
Winter

Prediction of Phosphorous for Winter

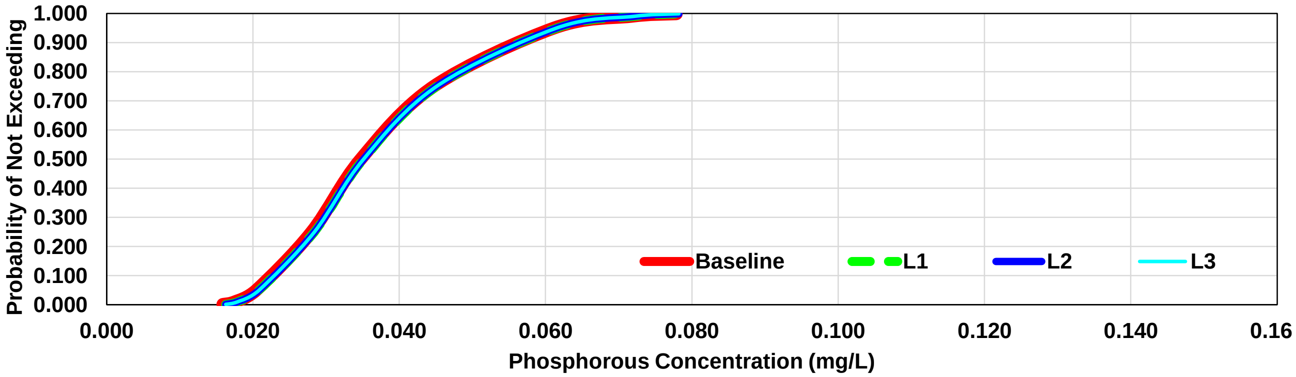
Predictions at L1

Cumulative Probability	Baseline	L1	L2	L3
0.001	0.043	0.050	0.043	0.043
0.010	0.044	0.051	0.044	0.044
0.050	0.046	0.054	0.046	0.046
0.250	0.057	0.066	0.057	0.057
0.500	0.073	0.082	0.073	0.073
0.750	0.094	0.102	0.094	0.094
0.950	0.120	0.127	0.120	0.120
0.990	0.127	0.134	0.127	0.127
0.999	0.129	0.137	0.129	0.129



Predictions at L2

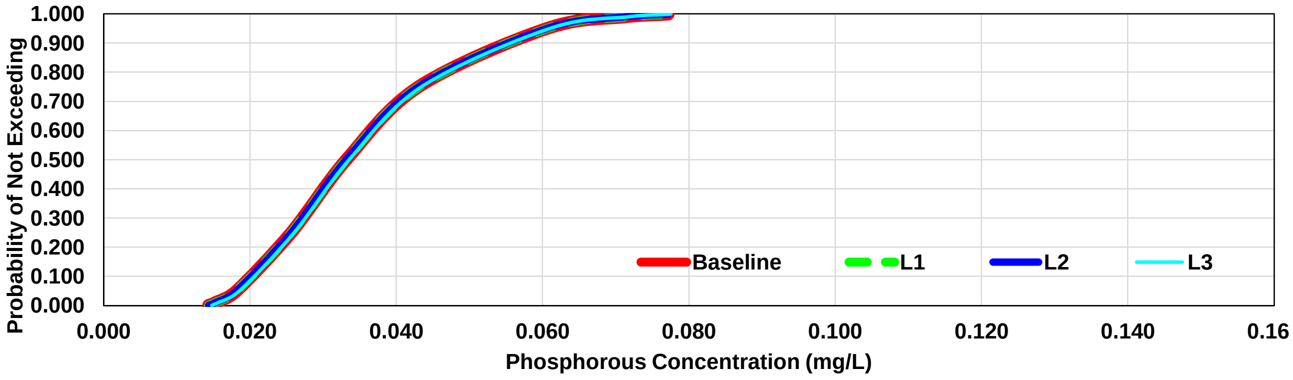
Cumulative Probability	Baseline	L1	L2	L3
0.001	0.016	0.016	0.016	0.016
0.010	0.018	0.018	0.018	0.018
0.050	0.020	0.021	0.021	0.021
0.250	0.028	0.028	0.028	0.028
0.500	0.035	0.035	0.035	0.035
0.750	0.045	0.045	0.045	0.045
0.950	0.061	0.062	0.062	0.062
0.990	0.072	0.072	0.072	0.072
0.999	0.078	0.078	0.078	0.078



Prediction of Phosphorous for Winter

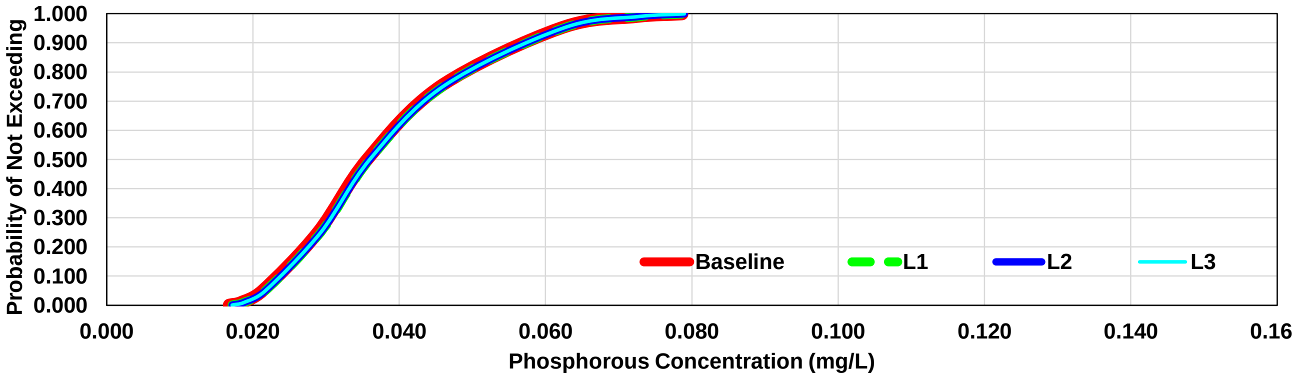
Predictions at L3

Cumulative Probability	Baseline	L1	L2	L3
0.001	0.014	0.014	0.014	0.015
0.010	0.015	0.015	0.015	0.016
0.050	0.018	0.018	0.018	0.019
0.250	0.026	0.026	0.026	0.026
0.500	0.033	0.033	0.033	0.034
0.750	0.043	0.043	0.043	0.043
0.950	0.061	0.061	0.061	0.061
0.990	0.071	0.071	0.071	0.072
0.999	0.077	0.077	0.077	0.078



Predictions at System Compliance Point

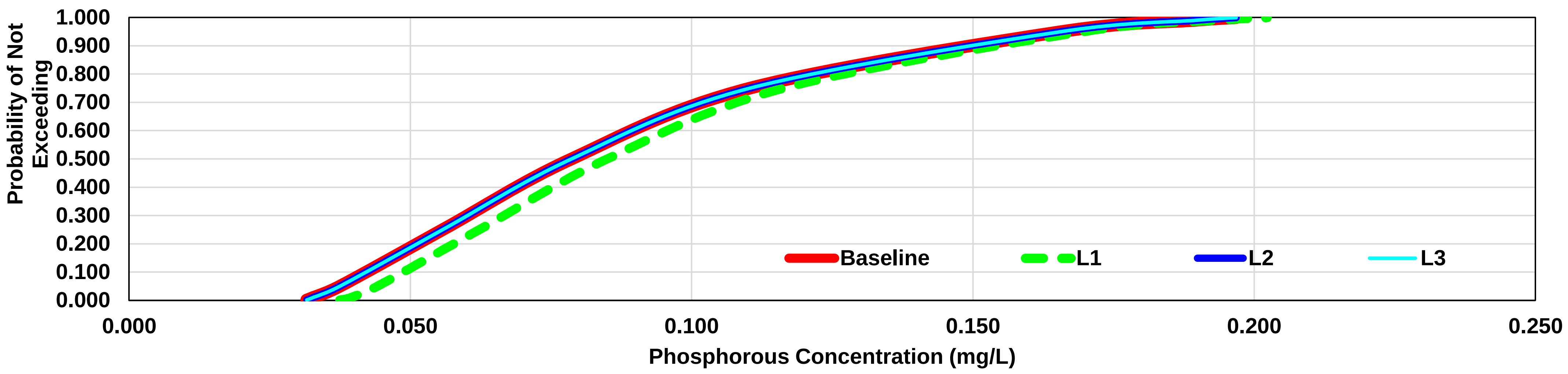
Cumulative Probability	Baseline	L1	L2	L3
0.001	0.017	0.017	0.017	0.017
0.010	0.018	0.019	0.019	0.019
0.050	0.021	0.022	0.022	0.022
0.250	0.029	0.029	0.029	0.029
0.500	0.036	0.036	0.036	0.036
0.750	0.046	0.046	0.046	0.046
0.950	0.062	0.062	0.062	0.062
0.990	0.073	0.073	0.073	0.073
0.999	0.079	0.079	0.079	0.079



Prediction of Phosphorous for Spring

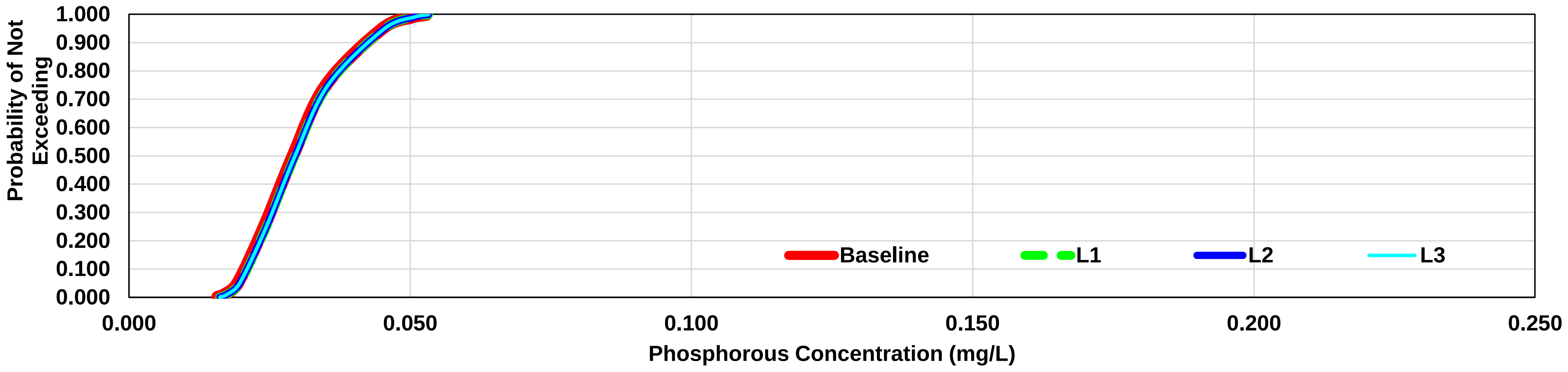
Predictions at L1

Cumulative Probability	Baseline	L1	L2	L3
0.001	0.032	0.037	0.032	0.032
0.010	0.033	0.039	0.033	0.033
0.050	0.038	0.044	0.038	0.038
0.250	0.056	0.062	0.056	0.056
0.500	0.079	0.085	0.079	0.079
0.750	0.110	0.116	0.110	0.110
0.950	0.166	0.170	0.166	0.166
0.990	0.190	0.194	0.190	0.190
0.999	0.197	0.202	0.197	0.197



Predictions at L2

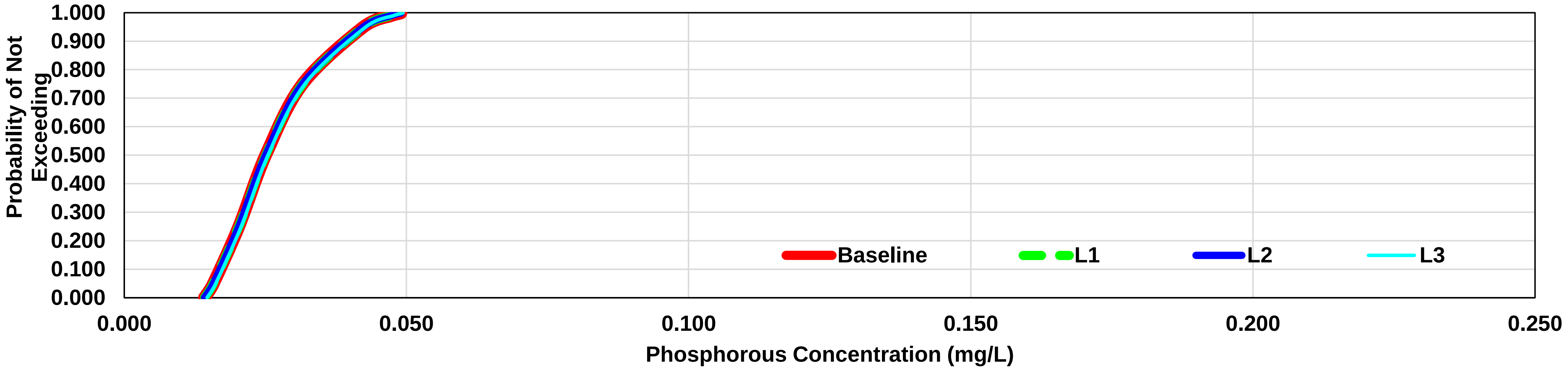
Cumulative Probability	Baseline	L1	L2	L3
0.001	0.016	0.016	0.016	0.016
0.010	0.017	0.017	0.017	0.017
0.050	0.019	0.020	0.020	0.020
0.250	0.024	0.024	0.024	0.024
0.500	0.029	0.030	0.030	0.030
0.750	0.035	0.035	0.035	0.035
0.950	0.045	0.045	0.045	0.045
0.990	0.050	0.051	0.051	0.051
0.999	0.053	0.053	0.053	0.053



Prediction of Phosphorous for Spring

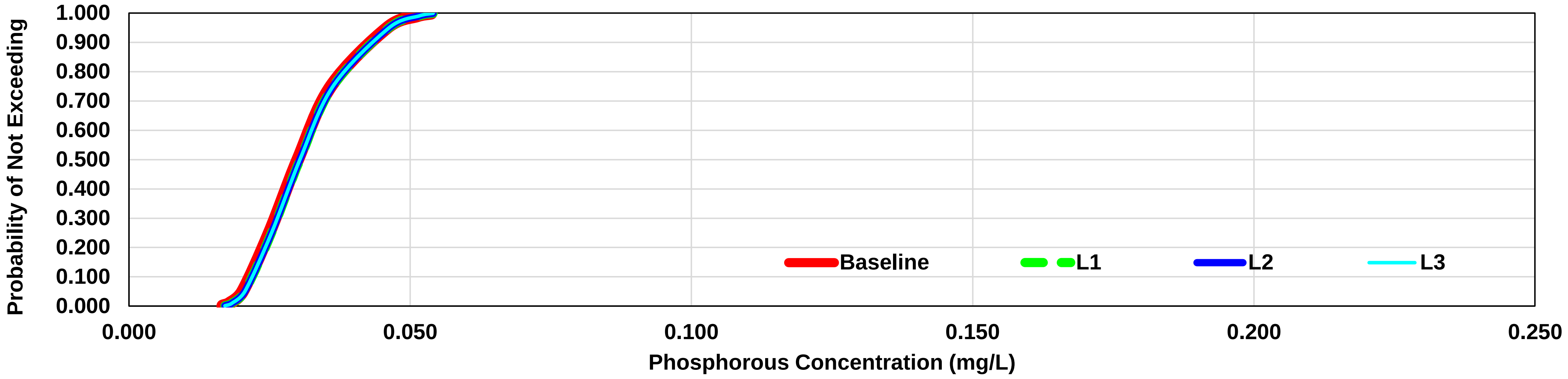
Predictions at L3

Cumulative Probability	Baseline	L1	L2	L3
0.001	0.014	0.014	0.014	0.015
0.010	0.015	0.015	0.015	0.015
0.050	0.016	0.016	0.016	0.016
0.250	0.020	0.020	0.020	0.021
0.500	0.025	0.025	0.025	0.025
0.750	0.032	0.032	0.032	0.032
0.950	0.042	0.042	0.042	0.043
0.990	0.047	0.047	0.047	0.048
0.999	0.049	0.049	0.049	0.049



Predictions at System Compliance Point

Cumulative Probability	Baseline	L1	L2	L3
0.001	0.017	0.017	0.017	0.017
0.010	0.018	0.018	0.018	0.018
0.050	0.020	0.021	0.021	0.021
0.250	0.025	0.025	0.025	0.025
0.500	0.030	0.030	0.030	0.030
0.750	0.036	0.036	0.036	0.036
0.950	0.046	0.046	0.046	0.046
0.990	0.051	0.052	0.052	0.052
0.999	0.054	0.054	0.054	0.054



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REGIONAL MUNICIPALITY OF NIAGARA
SOUTH NIAGARA FALLS WASTEWATER SOLUTIONS

Assimilative Capacity Studies

ACS Detailed Assessment

GOLDER
MEMBER OF WSP

February 2, 2022 Project No. 18104462

SOUTH NIAGARA WWPT EA – ASSIMILATIVE CAPACITY STUDY: IMPLICATIONS OF MOVING PROPOSED OUTFALL ON EFFLUENT PLUME MODELLING

To whom it may concern,

Golder completed a detailed assimilative capacity study (ACS) in August 2020 in support of the South Niagara Falls Wastewater Solutions Project (Project) Municipal Class EA. Since the completion of the ACS, existing environmental conditions at the proposed waste water treatment plant (WWTP) site have put additional constraints on the location of the proposed outfall for the WWTP. As a result of these constraints, the location of the outfall is expected to be approximately 260 m east (upstream) of the location indicated on Figures 17 and 18 in the ACS. This letter addresses concerns regarding the implications of moving the proposed outfall location on the plume modelling results presented in the ACS.

The section of Chippewa Creek where the proposed outfall is located is effectively a constructed channel with a uniform depth and width. As such the expected conditions at the new location will be very similar to the conditions at the location used in the ACS. As a result, the predictions provided by CORMIX for nearfield mixing and plume dilution would not measurably change between the two locations. As a result, the predicted performance of proposed the diffuser would not change as a result of moving the outfall to the new location.

Similarly, as CORMIX assumes a uniform channel downstream of the outfall, the shape of the plume downstream of the outfall would be similar for the two locations. The differences in the plumes shown on Figures 17 and 18 would be limited to shifting the plumes such that the start of the plume aligns with the new location of the outfall.

As there are no material changes to the predicted diffuser performance and downstream plume concentrations, there would be no expected changes to the proposed effluent limits presented in the ACS as a result of moving the proposed outfall to a location approximately 250 m to the east of the location used in the ACS.

We hope that this letter meets your requirements at this time. Should you have any questions or need additional information, please feel free to contact the undersigned.

Golder Associates Ltd.

Greg Rose, BSc (Hons) MSc
Associate, Senior Water Resources Specialist

Gerard J Van Arkel, MEng, PEng
Principal, Water Resources Engineer

GVA/GR/mp

https://golderassociates.sharepoint.com/sites/29902g/deliverables/03_assimilative_capacity_study/detailed_acs/18104462-letter moved outfall-02feb2022.docx

REPORT

South Niagara Falls Wastewater Solutions Schedule C Class Environmental Assessment

Detailed Assimilative Capacity Study

Submitted to:

Niagara Region
1815 Sir Isaac Brock Way
Thorold ON L2V 4T7

Submitted by:

Golder Associates Ltd.
6925 Century Avenue, Suite #100, Mississauga, Ontario,
L5N 7K2, Canada

+1 905 567 4444

18104462/3000/3002

Rev1; February 2, 2022

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1 electronic copy – CIMA+

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APPENDICES

APPENDIX A
Screening Level Assimilative Capacity Study

ACRONYMS AND ABBREVIATIONS

Acronym or Abbreviation	Description
ACS	Assimilative Capacity Study
BOD_5	Biochemical Oxygen Demand
$CBOD_5$	Carbonaceous Biochemical Oxygen Demand
CCME	Canadian Council of Ministers of the Environment
CSO	Combined Sewer Overflow
E. coli	*Escherichia coli*
EA	Environmental Assessment
ECA	Environmental Compliance Approval
GS	Generating Station
HEPC	Hydro Electric Power Canal
ICD	International Control Dam
INCW	International Niagara Control Works
MECP	Ministry of the Environment, Conservation and Parks
MOEE	Ministry of Energy and Environment
NOAA	National Oceanic and Atmospheric Administration
NPCA	Niagara Peninsula Conservation Authority
NYPA	New York Power Authority
OPG	Ontario Power Generation
the Project	South Niagara Falls Wastewater Solutions Schedule C Class EA
PWQMN	Provincial Water Quality Monitoring Network
PWQO	Provincial Water Quality Objectives
SAB	Sir Adam Beck GS
SLSMC	St. Lawrence Seaway Management Corporation
TSS	Total Suspended Solids
USGS	United States Geological Survey
WSC	Water Survey of Canada
WWTP	Wastewater Treatment Plant

UNITS OF MEASURE

Symbol or Unit	Description
cfs	Cubic feet per second
cfu	Colony-forming unit
kg/d	kilograms per day
km	kilometre
km^2	Square kilometres
m	metre
µg/L	Microgram per litre
mg/L	Milligrams per litre
MLD	Megalitres per day
m^3/s	Cubic metres per second
mL	Millilitre
ºC	Degrees Celsius
%	Percent

1.0 INTRODUCTION

The Regional Municipality of Niagara (Niagara Region) is currently conducting a Schedule "C" Municipal Class Environmental Assessment (EA) for a proposed Wastewater Treatment Plant (WWTP) in the southern area of the City of Niagara Falls. As well as providing other ancillary services, Golder Associates Ltd. (Golder) has been retained to conduct an Assimilative Capacity Study (ACS) in support of the South Niagara Falls Wastewater Solutions Schedule C Class EA Project (the Project), which is the subject of this technical report.

1.1 Study Background

With significant future regional growth and urban intensification forecast for the area, the 2017 Niagara Region Master Servicing Plan provided a long-term wastewater solutions strategy to improve the existing collection system and add a new, second wastewater treatment facility in South Niagara Falls that can accommodate phased growth, provide wastewater service to currently subserviced areas, reduce pressure on existing wastewater infrastructure, decrease the magnitude and frequency of untreated combined sewer overflows and WWTP bypasses and, in doing so, enhance overall environmental performance.

Wastewater collection within Niagara Falls is currently facilitated through a number of collection systems and pumping stations. These systems convey the wastewater to the existing Niagara Falls WWTP (sometimes referred to as the Stanley Avenue WWTP). Many of the components of the collection system are nearing their design capacity.

The 2017 Master Servicing Plan identified several candidate discharge locations for a new WWTP in South Niagara Falls that could potentially accept an effluent discharge rate of up to 30 Megalitres per day (30 MLD). The preferred location was discharge from the south bank into Chippewa Creek approximately 350 m east of Triangle Island and chosen based on available property for the new WWTP, existing and required infrastructure to convey raw sewage to the new plant and a screening level assimilative capacity assessment (see Appendix A). The preferred discharge location is identified as Location 3 on Figure 1. Details of the selection process were presented at several Public Information Centres (PICs) and will be fully documented in the Environmental Study Report.

1.1.1 Study Area Overview and Nomenclature

The hydrology of the study area has been highly modified and regulated from the natural predevelopment conditions that existed prior to the 1950s. During the 1950s, the Hydro Electric Power Canal (HEPC) was constructed from the Welland River (upstream of Horseshoe Falls) to the Sir Adam Beck Generating Station (GS) which discharges to Niagara Gorge. As a result, the flow within last 6.5 km of the Welland River was reversed to direct a portion of Niagara River flows towards the HEPC. The section from the Niagara River to Triangle Island is referred as Chippewa Creek. The amount of flow that is diverted is primarily determined by the following factors:

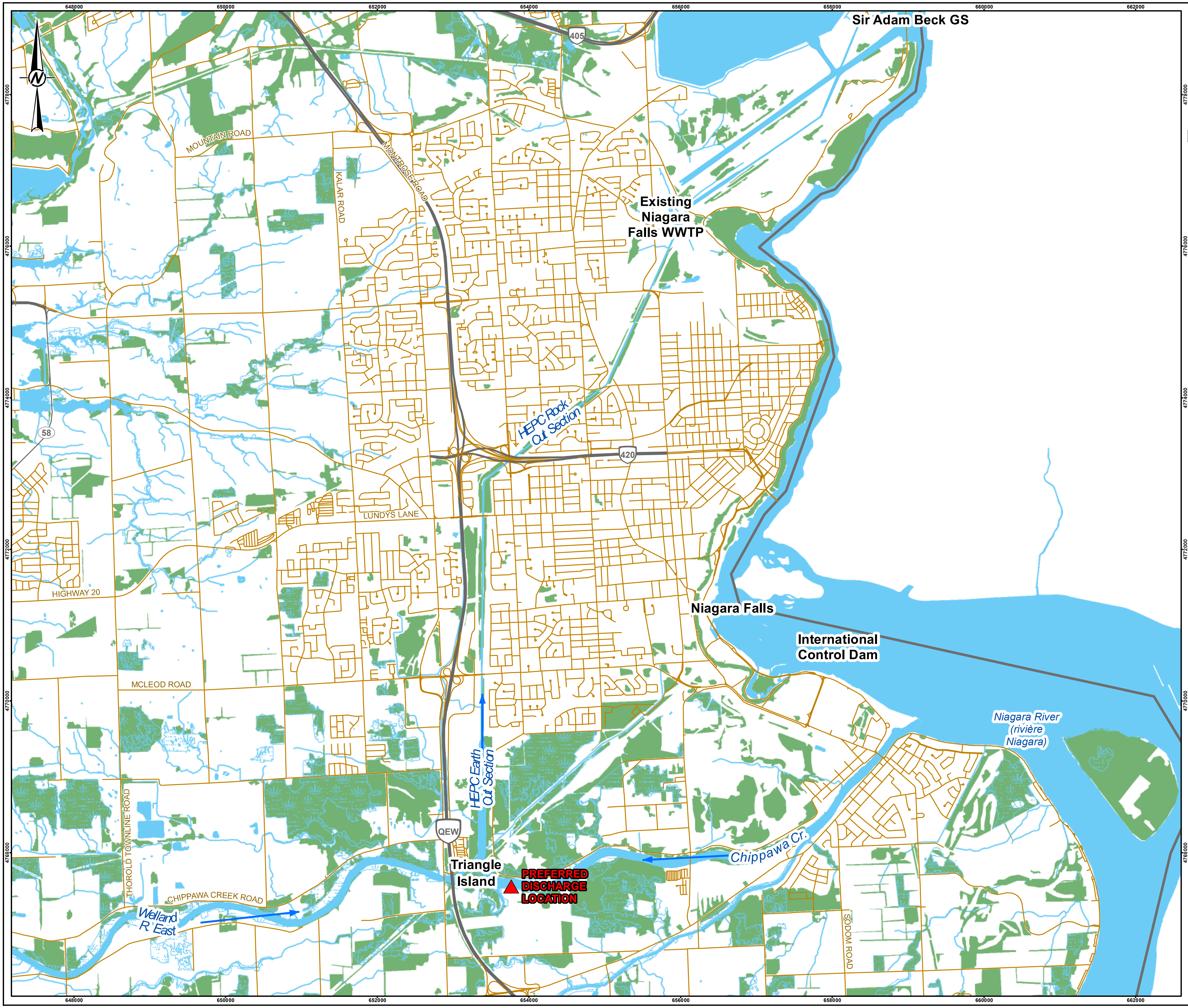
- the operation of the International Control Dam (ICD) in the Niagara River; which can alternatively increase or decrease the water level in the Niagara River at the mouth of Chippewa Creek; and
- upstream flows in the Niagara River which are determined by water levels at the outlet of Lake Erie, that are influenced by both long-term weather patterns and short-term meteorological events (such as seiching).

The daily operation of the ICD is influenced by the electrical demands and markets in both Ontario and New York State as well as maintaining minimum flow over the falls during tourist periods.

In addition, construction of the Welland Canal to the west of the study area has modified the hydrology and drainage area of the Welland River and several small contributing tributaries. The Welland River passes under the Welland Canal at two locations via siphons that may alter the flow in the river. The Lyons Creek watershed area was also decreased by the Welland Canal to the extent that water must now be pumped from the Welland Canal into Lyons Creek to maintain a minimum flow requirement.

For the purposes of maintaining consistent terminology, key surface water features referred to in this ACS use a naming convention adopted by the Ministry of the Environment, Conservation and Parks (MECP), the Niagara Peninsula Conservation Authority (NPCA), and Ontario Power Generation (OPG). Specifically, these key surface water features include:

- **International Control Dam (ICD):** This multi-gated dam in the Niagara River built in 1954 is located approximately 800 m above the Horseshoe Falls and is used to control flows to the Sir Adam Beck GS operated by OPG, the Robert Moses GS operated by the New York Power Authority (NYPA) and the American Falls operated according to Niagara River Treaty (1950). In other literature and documentation, the ICD has sometimes also been referred to as the International Niagara Control Works (INCW).
- **Chippewa–Grass Island Pool:** This is the area of the Niagara River upstream of the ICD where water levels vary with upstream flow and the operation of the ICD.
- **Hydro Electric Power Canal (HEPC):** This is a canal that conveys diverted flow from the Niagara River (via Chippewa Creek) to the Sir Adam Beck GS.
- **Chippewa Creek:** This is a former portion of the Welland River that flows from the Niagara River to the HEPC when the HEPC is in operation (e.g., reverse flow to natural conditions). During the construction of the HEPC, the width and depth of this section of river were increased to accommodate the increased flow.
- **Triangle Island:** this is a small, constructed island at the junction of the Welland River East, Chippewa Creek, and the HEPC. During normal operation of the HEPC, the diverted flow from the Niagara River flows past the northeast side of Triangle Island from Chippewa Creek into the HEPC while flow from the Welland River East flows past the northwest side of Triangle Island into the HEPC. The channel to the south of Triangle Island is narrower and shallower than the other channels and does not typically have significant flows. Triangle Island is also the location of the safety booms (northeast and northwest sides) used to prevent boat traffic from entering the HEPC.
- **Earth Cut Section:** This is the wide portion of the HEPC dug into soil between Triangle Island and the Rock Cut Section of the HEPC and is approximately 1.5 km long.
- **Rock Cut Section:** This is the narrower and deeper section of the HEPC cut into bedrock below the Earth Cut Section. The rock cut section of the HEPC is approximately 12 km long and ends at the Sir Adam Beck GS.
- **Welland River East:** This is the portion of the Welland River upstream of triangle island. MECP / NPCA use this convention to distinguish the sections of the Welland River east or west of the Welland Canal.



LEGEND

- ▲ PREFERRED DISCHARGE LOCATION
- → FLOW DIRECTION
- ― LOCAL ROAD
- ― PRIMARY HIGHWAY
- ― SECONDARY HIGHWAY
- ― WATERCOURSE
- ▭ INTERNATIONAL BORDER
- ▨ WETLAND
- 🟩 WOODED AREA
- 🟦 WATERBODY

0 1 2

1:50,000 KILOMETRES

NOTE(S)

1. ALL LOCATIONS ARE APPROXIMATE.

REFERENCE(S)

BASE DATA COURTESY OF MNRF LIO. PRODUCED BY GOLDER ASSOCIATES UNDER LICENSE FROM ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY
PROJECTION: UTM ZONE 17N DATUM: NAD 83

CLIENT
REGIONAL MUNICIPALITY OF NIAGARA

PROJECT
SOUTH NIAGARA FALLS WASTEWATER SOLUTIONS
SCHEDULE C CLASS ENVIRONMENTAL ASSESSMENT

TITLE
LOCATION OF PROJECT AREA

CONSULTANT

GOLDER

YYYY-MM-DD	2020-05-19
DESIGNED	PR
PREPARED	PR
REVIEWED	GVA
APPROVED	GVA

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1.1.2 Selected Discharge Location

The preferred discharge location is located on the south bank of Chippewa Creek approximately 350 m east of Triangle Island. The effluent from the new WWTP would mix with flow that is composed mainly by water from the Niagara River diverted into the HEPC and minimal flow from Lyons Creek.

The creek channel in the area of the outfall is effectively a constructed channel with a uniform width, depth and side slopes that follows the original path of the Welland River prior to the construction of the HEPC. The channel is approximately 100 m wide and 12 m deep with approximately 1:2 (horizontal:vertical) side slopes. During typical operation of the ICD, the flow in the creek is from east to west and the current speeds range from approximately 0.35 to 0.5 m/s with an average of approximately 0.42 m/s.

1.2 Study Purpose

The purpose of this ACS is to provide an assessment of the preferred discharge location (Chippewa Creek) in support of the Municipal Class EA by:

1) Evaluating the assimilative capacity of the discharge location, considering the monthly characteristics of key water quality parameters that could be affected by treated effluent discharge.

2) Determining the environmental constraints of the discharge location with respect to assimilating a treated wastewater discharge of 30 MLD.

3) Identifying the discharge concentration limits of key water quality parameters to meet Provincial Water Quality Objectives (PWQOs), to meet Canadian Council for Ministers of the Environment (CCME) criteria (where PWQOs are not available), or to maintain water quality in accordance with MECP Policy 2 requirements at the discharge location.

4) Developing a conceptual outfall design and evaluating the performance of the outfall in terms of effluent mixing with the receiving water.

1.3 General Study Approach and Report Outline

The characterisation of the discharge location considered in this study is based on available sources discussed in Appendix A. The structure of this detailed ACS report for Chippewa Creek is presented in the following order:

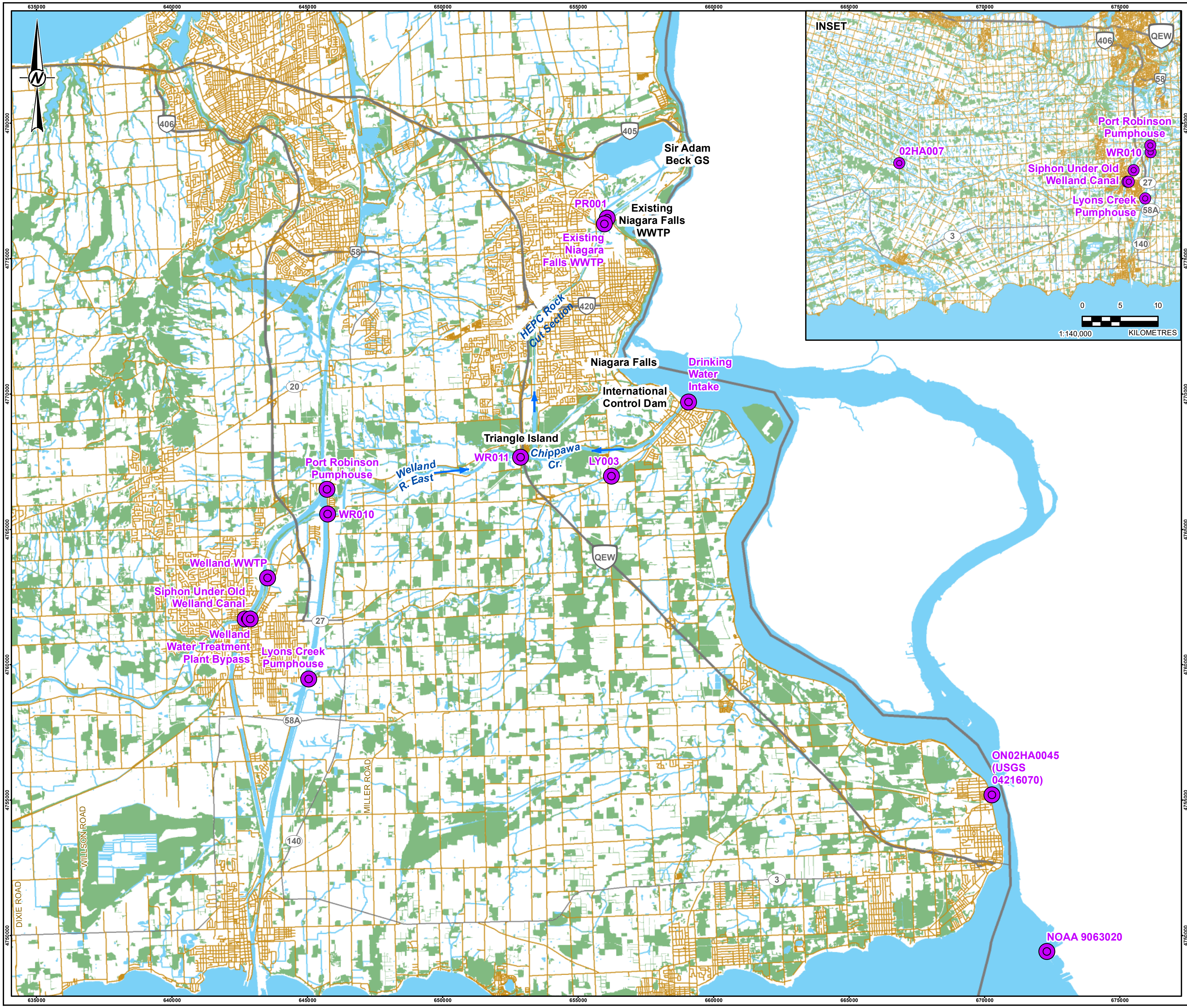
- Section 2 details the background information obtained and used to characterise monthly water quality and flow conditions in the study area.
- The hydrological nature of the selected location required a slightly modified approach compared to conventional Assimilative Capacity Studies. Namely, the flow in Chippewa Creek and the HEPC is heavily regulated, which meant that the conventional 7Q20 approach to flow derivation was replaced with a stochastic approach. Section 3 introduces the modelling approach adopted and identifies relevant monthly and/or environmental constraints, as well as identifying the maximum allowable effluent concentrations at each discharge location to achieve regulatory compliance. Section 3 also includes the mixing zone assessment and the evaluation of the expected performance of the proposed outfall conceptual design.
- Based on the constraints identified in Section 3, Section 4 recommends effluent limits for each parameter as well as the predicted parameters in the effluent plume immediately downstream of the outfall and the expected effect of the Project on water quality at selected downstream locations.

- Section 5 summarises the key conclusions and recommendations of the detailed ACS for the preferred discharge location into Chippewa Creek.

This study assesses the assimilative capacity and water quality effects at two compliance points for each discharge option. The local compliance point is located immediately downstream of the discharge. In order to consider the cumulative effects of existing discharges to the HEPC, the system compliance point is located in the HEPC immediately downstream of the existing Niagara Falls WWTP and upstream of the confluence with the power tunnels.

2.0 BACKGROUND INFORMATION AND DATA REVIEW

This section provides details and summaries of the data used in the ACS. The location of the monitoring locations where the data were collected are shown on Figure 2.



LEGEND

- ◎ REGIONAL SAMPLING STATION LOCATION
- → FLOW DIRECTION
- LOCAL ROAD
- PRIMARY HIGHWAY
- SECONDARY HIGHWAY
- WATERCOURSE
- ▭ INTERNATIONAL BORDER
- 🟩 WOODED AREA
- 🟦 WATERBODY

0 5 10
1:140,000 KILOMETRES

NOTE(S)

1. ALL LOCATIONS ARE APPROXIMATE.

REFERENCE(S)

BASE DATA COURTESY OF MNRF LIO. PRODUCED BY GOLDER ASSOCIATES UNDER LICENSE FROM ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY
PROJECTION: UTM ZONE 17N DATUM: NAD 83

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PROJECT
SOUTH NIAGARA FALLS WASTEWATER SOLUTIONS
SCHEDULE C CLASS ENVIRONMENTAL ASSESSMENT

TITLE
DATA COLLECTION AND MONITORING LOCATIONS

CONSULTANT
GOLDER

YYYY-MM-DD	2020-05-19
DESIGNED	MM/PR
PREPARED	PR
REVIEWED	GVA
APPROVED	GVA

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IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B
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2.1 Flow Data

2.1.1 Water Management in Study Area

The flow in Chippewa Creek and the HEPC has been controlled since 1921. The ICD has been in operation since 1954 and is jointly funded and controlled by OPG and NYPA in accordance with the 1950 Niagara Treaty (Canada, 1950) and a Memorandum of Understanding between the two power companies which are intended to maximize the beneficial use of the hydro electric potential of the Niagara River, while maintaining the scenic value of Niagara Falls for tourism and other uses of water in the Niagara River. The treaty stipulates that:

- Scenic flow is allocated first, domestic use second, navigational requirements third, and power generation fourth.
- Any river flow diverted for hydro electric power is to be split equally between both countries.
- During tourist times, the flow over the falls must be at least 2,832 m^3/s (100,000 cfs). Tourist times are defined as 8 AM to 10 PM from April 1 to September 15 and 8 AM to 8 PM from September 16 to October 31.
- The specified minimum flow over the falls is at least 1,416 m^3/s (50,000 cfs) at all other times.
- If the upstream flow in the Niagara River is less than the specified minimum flows, no river flow is to be diverted to the power canals.

Water levels in the Chippewa-Grassy Island Pool are regulated in accordance with the 1993 Directive of the International Niagara Board of Control.

In addition, OPG is required to maintain a minimum flow of 240 m^3/s to the HEPC via Chippewa Creek to ensure that water from the Niagara River reaches the existing drinking water intake of the City of Niagara Falls Water supply plant located near the junction of Chippewa Creek and the Niagara River (Kowalski 2019). Niagara Region is currently in the process of relocating the water supply intake to the Niagara River upstream of Chippewa Creek.

2.1.2 Welland River East

In general, low flow frequency analysis of natural flows is used to generate the low-flow conditions (7Q20) to assess the assimilative capacity of the receiving water body (MOE 1994a). The Welland River East, however, is a complex hydrologic system characterized by natural flows and supplemental flows and the low-flow conditions are dominated by the supplemental flows. As a result, the 7Q20 would not be applicable for this specific assessment. Previous Assimilative Capacity Studies in the Welland River East have successfully applied an approach where the low flows conditions are based on combination of natural and supplemental flows rather than an approach based solely on the 7Q20, as shown in the ACS completed for the Welland Wastewater Treatment Plant (XCG 2007).

2.1.2.1 Natural Flows in the Welland River East

Regional station data was used to estimate natural flow for the Welland River East. Flow data for the Welland River below Caistor Corners (station 02HA007) from the WSC are available from 1957 to 2017. Flows at the site are calculated based on the prorated watershed area of the site (906 km^2) and the total watershed area of the gauged station (223 km^2). Natural flows in the system are generally low with punctual peak flows recorded during storm events and snowmelt.

Since supplemental flows are significantly higher than average natural flows in the system (i.e., approximately double the annual average flows), natural flows in the Welland River East become relevant only under peak flow conditions. Therefore, flows were prorated between the gauging station (223 km^2) and the area at the site (906 km^2) according to the Transposition of Flood Discharges Method (MTO 1997) applying a coefficient of 0.75 to represent peak flows (the coefficient used for average and low flows is 1.0).

The estimated natural flows yield an average annual flow of 6.50 m^3/s with estimated maximum and minimum flows in the range of 132.41 m^3/s and 0.046 m^3/s. The 7Q20 for the natural flows based on the Log Pearson Type III distribution would yield 0.004 m^3/s.

2.1.2.2 Supplemental Flow from Welland Canal into Welland River East

Supplemental flows enter the Welland River East from the Welland Canal (St. Lawrence Seaway Management Corporation [SLSMC] 2019) as follows:

- A series of ports in the roof of the old syphon provide flow from the canal into the river. Depending on the season and water levels in the canal, the total flow ranges from 5 to 7 m^3/s.
- The bypass of the Welland Water Treatment Plant provides a flow between the canal and the river that ranges from 4 m^3/s to 6 m^3/s.
- A pump at Port Robinson provides a flow of 0.97 m^3/s to a side channel of the Welland River East, which was cut-off from the main branch of the river during the straightening of the canal in the 1950s.
- The effluent from the Welland Wastewater Treatment Plant provides a flow of 0.8 m^3/s (XCG 2007).

In general, the supplemental flows from the Welland Canal are from Lake Erie and have better water quality than that of the upstream areas of the Welland River.

Monthly estimates of the supplemental flows for the siphon ports, Port Robinson Pump, the Welland Water Treatment Plant, and the Welland WWTP were provided by the SLSMC (SLSMC 2019) for the period 2014 to 2019 and are summarized in Table 1.

Table 1: Summary of Supplemental Flows from Welland Canal into the Welland River East

Source	Old Welland Canal at Old Siphon[1]		Welland Water Treatment Plant[1]		Port Robinson Pump[1]	Welland WWTP[2]
	Minimum (m^3/s)	Average (m^3/s)	Minimum (m^3/s)	Average (m^3/s)	Average (m^3/s)	Average (m^3/s)
January	5.58	5.94	4.80	5.17	0.97	0.80
February	5.17	5.61	4.45	4.87		
March	5.85	6.35	5.03	5.48		
April	6.54	6.88	5.62	5.94		
May	6.03	6.60	5.19	5.77		
June	6.69	6.86	5.75	5.88		
July	6.82	6.90	5.87	5.90		
August	6.68	6.85	5.75	5.89		
September	6.62	6.81	5.69	5.86		
October	6.56	6.79	5.64	5.84		
November	6.87	7.04	5.90	6.06		
December	7.03	7.09	6.04	6.10		

Notes:

[1] SLSMC 2019.

[2] XCG 2007.

2.1.3 Lyons Creek

During the construction of the Welland Canal, the watershed of Lyons Creek (originally draining to Chippewa Creek) was split between the western section which now drains into the Welland Canal, and the eastern section which still drains into Chippewa Creek. As a result of this reduction in drainage area, the natural flows in Lyons Creek are supplemented by the pumping of water from the Welland Canal at the location where the main channel of Lyons Creek was interrupted to the eastern section of Lyons Creek, which is of interest for this study.

- Flow data for Lyons Creek is not available. Natural flows were estimated using Regional station data for the Welland River Below Castor Corners (station 02HA007) from the WSC, by prorating the watershed area for the site (88 km²) and the total watershed area of the gauged station (223 km²).
- Supplemental flows vary seasonally ranging from 0.142 m³/s between December to March (when Welland Canal is drained) to 0.283 m³/s during the rest of the year (SLSMC 2019).

2.1.4 Hydro Electric Power Canal (HEPC)

Flow from the Niagara River is diverted to the Sir Adam Beck GS from the Chippewa-Grass Island Pool via three tunnels and the HEPC. Under normal operating conditions, each of these conveyances carries approximately one quarter of the total diverted flow. The flow in the HEPC and tunnels can vary hourly and seasonally due to flow variations in the Niagara River, minimum flow requirements over the falls (see Section 2.4.1), electrical demand, and the market price for electricity.

The flow data provided by OPG (Kowalski 2019) represents the total flow diverted by OPG from the Niagara River to the HEPC and the three tunnels. Typically, the flow in the HEPC represents 27% of the total diverted flow.

Hourly flow data provided by OPG for a three-year period (2016 to 2018) was used as a basis for the following observations regarding the flow in the HEPC:

- The hourly flow rate ranged from 292 m³/s to 624 m³/s with an average of 429 m³/s.
- Flow rates are typically highest during the summer months (446 m³/s) and lowest in the fall (411 m³/s).

Typically, the flows are lowest at 4:00 AM (402 m³/s) and highest at 6:00 PM (456 m³/s).

2.1.5 Chippewa Creek

Water from the Niagara River is diverted into Chippewa Creek based on the water levels in the Chippewa-Grass Island Pool. Chippewa Creek extends approximately 6.5 km from the Niagara River to Triangle Island. Lyons Creek drains to the south shore of Chippewa Creek approximately 2 km west of the Niagara River.

Given the highly regulated system, flow in Chippewa Creek was estimated in the model based on the flow demand in the HEPC and the estimated flows contributing to the system from the Welland River East and Lyons Creek. The estimated flow (diverted from Niagara River) was calculated in the modelling exercise.

2.1.6 Existing Niagara Falls Wastewater Treatment Plant

The existing Niagara Falls WWTP operates at an average flow of approximately 0.472 m³/s (40,810 m³/day). For the ACS modelling, the effluent flow was maintained at the existing rated capacity of 0.79 m³/s (68,300 m³/d). The effluent from the plant to the HEPC and immediately upstream from the system compliance point (upstream of Sir Adam Beck GS).

2.1.7 Combined Sewer Overflows (CSOs) and Wastewater Treatment Plan Bypass

Niagara Region has a total of five Regional CSOs discharging into the HEPC from regional pumping stations. Discharges from the CSOs into the HEPC are primarily triggered by storm events. Since the ACS focuses on dry events, CSOs were excluded from the detailed analysis for the proposed discharge location to Chippewa Creek.

2.2 Water Quality Data

For the ACS, the parameters of concern include total ammonia, unionized ammonia, nitrate, phosphorus, *Escherichia coli* (*E. coli*), dissolved oxygen, Carbonaceous Biochemical Oxygen Demand ($CBOD_5$), and total suspended solids (TSS). The assessment used pH and water temperature in the Niagara River to estimate unionized ammonia concentration using the equations provided by the MECP (Ministry of Energy and Environment [MOEE] 1994).

The monthly data summary (for each flow source) includes the geometric mean and 75th percentile values (or 25th percentile for dissolved oxygen) for all parameters and available water quality monitoring associated with each individual flow source. These percentiles are used in subsequent analysis as follows:

- The 75th percentile values for total ammonia, nitrate, total phosphorus, E. coli, CBOD5 (when sufficient data was available), and TSS were used as the background concentrations when estimating the maximum allowable effluent concentrations.
- The 75th percentile values of pH and water temperature from the Niagara River and HEPC were used to estimate the maximum allowable concentration of total ammonia in the effluent, based on the estimated maximum allowable effluent concentration for unionized ammonia. The most restrictive value was used to estimate the maximum allowable concentration of total ammonia in the effluent.
- If more than one water quality monitoring station was available for any given flow source, the maximum reported 75th percentile value was used for conservatism in the modelling exercise.
- The 25th percentile values for dissolved oxygen were used as the background concentrations when estimating the maximum allowable effluent concentrations for CBOD5.

2.2.1 Applicable Water Quality Guidelines

Applicable PWQOs for the parameters discussed in this memorandum are presented in Table 2 and are discussed in the following points.

- Since the study area is effectively a river, the PWQO for phosphorus for the avoidance of excessive plant growth in rivers and streams (0.03 mg/L) was used.
- Since there is no PWQO for nitrate, the Canadian Council of Ministers of the Environment (CCME) guideline was selected.
- Seasonal temperature and pH values were used to determine the limits for total ammonia based on the PWQO for unionized ammonia.
- Since the Niagara River, Lyons Creek, and Welland River East are all considered warm water aquatic habitat (NPCA 2011), the dissolved oxygen guideline for warm water fisheries was used.
- The PWQO for fecal coliforms (*E. coli*) is for recreational use (e.g., beaches).

- Since the new WWTP is not expected to release a thermal discharge or alter the pH in the receiving waters, water temperature and pH were excluded from the modelling exercise.
- Since there is no PWQO for total suspended solids, the CCME guideline for clear flow (low flow) was selected

Table 2: Summary of Applicable Water Quality Objectives

Parameter	PWQO or CCME Guideline
Unionized Ammonia	0.0164 mg/L as N[1]
Total Ammonia	Estimated from unionized ammonia criteria based on ambient water temperature and pH using equations in the Provincial Water Quality Objectives (MOEE 1994)
Nitrate	3 mg/L as N[2,3]
pH	6.5 to 8.5[1,4]
E. coli	100 cfu/100 mL[1,3]
Total Phosphorus	0.03 mg/L to avoid excessive plant growth in rivers and streams[1]
Dissolved Oxygen	47% of saturation or 4 mg/L above 20ºC for warm water fisheries[1,5]
Total Suspended Solids	During clear flow (low flow): Maximum average increase of 5 mg/L from background levels for longer term exposures (24 hours to 30 days).[2]
Water Temperature	10ºC above background or 30ºC for thermal discharges[1,4]

Notes:

1. Provincial Water Quality Objectives (MOEE 1994).
2. Guideline for freshwater aquatic life in CCME Guidelines (CCME 2014).
3. PWQO for *E. coli* is for recreational use (e.g., swimming beaches).
4. Since the new WWTP is not expected to release a thermal discharge or alter the pH in the receiving waters, water temperature and pH were excluded from the modelling exercise (explicitly) but used to assess capacity in the system for unionized ammonia.
5. Since the Niagara River, Lyons Creek, and Welland River East are all considered warm water aquatic habitat (NPCA 2011), the dissolved oxygen guideline for warm water fisheries was used.

2.2.2 Welland River East

For the water quality assessment of the Welland River East, data from two monitoring stations were used:

- immediately west (upstream) of Triangle Island at Montrose Road (WR011) with available data from 2011 to 2018; and
- further west (upstream), where the Welland River crosses at the Welland Canal (WR010) with available data from 2003 to 2018.

Water quality data for the Welland River East was provided by NPCA. A summary of the monthly water quality geo-mean and 75th percentile values for WR010 and WR011 are presented in Table 3.

The flows in the Welland River East are a combination of supplemental flows from the Welland Canal (which is effectively water from Lake Erie) and natural drainage from the upper sections of the Welland River Watershed. The water from the Welland Canal is typically of better quality than that of the upper Welland River (e.g., lower phosphorus concentrations). The screening level ACS (Appendix A) demonstrated that during high natural flows, total phosphorus concentrations are elevated.

Water quality in the Welland River East consistently exceeds the PWQO guidelines for phosphorus and *E. coli.* Comparing the 75th percentile concentrations for both stations showed that, overall, water quality parameters do not show distinctive trends between upstream (WR010) and downstream (WR011), with maximum monthly values generally alternating between the stations. The highest 75th percentile concentrations are observed, respectively on: March, January, and February, for total ammonia; January, February, and December for Nitrate; January, December, and November for *E. coli*; March, June, and November to January for total phosphorus.

The GoldSim model uses the monthly 75th percentile of ammonia, *E. coli*, nitrate, and total phosphorus. For each parameter, the highest 75th percentile value from WR011 and WR010 was selected. The decision to use this approach is based on the uncertainty of WR011 (as it would be influenced by flow from Niagara River) and the additional sources which could affect water quality in the reach between WR010 and WR011. Using the highest value of the two stations yields a conservative approach for prediction of assimilative capacity of the system. The assimilative capacity of the system for ammonia is based on the regulatory limit of unionized ammonia, ammonia in the system (based on 75th percentile), and 75th percentile values of pH and temperature.

Table 3: Summary of Monthly Water Quality Concentrations for Welland River East

Month	Station	Number of Samples[1]	Total Ammonia (mg/L)		Nitrate (mg/L)		*E. coli* (cfu/100 mL)		Total Phosphorus (mg/L)		Dissolved Oxygen (mg/L)		Total Suspended Solids (mg/L)		Water Temperature (°C)		pH	
			Geo-mean	75th	Geo-mean	75th	Geo-mean	75th	Geo-mean	75th	Geo-mean	25th	Geo-mean	75th	Geo-mean	75th	Geo-mean	75th
January	WR010	1	0.11	0.11[3]	2.29	2.29[3]	--[5]	--[5]	**0.133**	**0.133[3]**	17.3	17.3[3]	--[5]	--[5]	0.97	0.97[3]	7.82	7.82[3]
	WR011	1	0.68	0.68[3]	2.44	2.44[3]	**9000**	**9000[3]**	**0.130**	**0.130[3]**	16.0	16.0[3]	22.0	22[3]	1.16	1.16[3]	7.88	7.88[3]
February	WR010	4	0.24	0.52	1.67	2.36	--[5]	--[5]	**0.079**	**0.079[3]**	12.9	13.1[4]	--[5]	--[5]	2.07	2.10	7.82	8.09
	WR011	1	0.32	0.32[3]	2.21	2.21[3]	**680**	**680[3]**	**0.110**	**0.110[3]**	13.1	13.1[3]	31.0	31[3]	2.26	2.26[3]	7.58	7.58[3]
March	WR010	7	0.13	0.48	1.25	1.42	--[5]	--[5]	**0.109**	**0.200**	13.3	15.2	--[5]	--[5]	1.42	4.82	8.02	8.17
	WR011	3	0.46	0.97	1.22	1.41	**1173**	**2700**	**0.073**	**0.100**	13.2	13.6[4]	7.5	8.9[4]	3.80	5.16[4]	8.02	8.12
April	WR010	13	0.18	0.22	0.76	1.21	--[5]	--[5]	**0.078**	**0.143**	11.9	12.7	--[5]	--[5]	9.13	10.92	8.15	8.23
	WR011	7	0.12	0.27	0.51	0.89	23	**293**	**0.044**	**0.110**	12.2	13.7	7.1	24.0	7.42	11.34	8.08	8.17
May	WR010	14	0.16	0.22	0.61	0.91	--[5]	--[5]	**0.059**	**0.103**	11.3	12.6	--[5]	--[5]	14.74	16.42	8.06	8.28
	WR011	7	0.13	0.29	0.56	0.71	36	**118**	**0.054**	**0.080**	11.3	13.8	24.3	42.5	15.51	17.50	7.86	8.18
June	WR010	13	0.21	0.32	0.48	0.74	--[5]	--[5]	**0.063**	**0.128**	9.73	10.8	--[5]	--[5]	20.81	22.02	8.17	8.28
	WR011	6	0.09	0.18	0.65	1.72	32	**215**	**0.071**	**0.168**	9.66	10.7	13.1	25.5	21.89	24.00	8.00	8.20
July	WR010	12	0.10	0.17	0.33	0.48	--[5]	--[5]	**0.056**	**0.072**	8.93	10.5	--[5]	--[5]	23.34	24.52	8.17	8.27
	WR011	5	0.08	0.10	0.38	0.50	37	**130**	**0.058**	**0.073**	10.7	12.1	7.9	25.1	25.30	26.56	8.17	8.25
August	WR010	13	0.12	0.20	0.21	0.33	--[5]	--[5]	**0.047**	**0.056**	9.19	10.1	--[5]	--[5]	23.72	24.68	8.18	8.26
	WR011	5	0.04	0.07	0.13	0.23	15	**140**	0.018	**0.047**	8.74	9.28	1.7	5.0	24.58	26.65	8.08	8.17
September	WR010	15	0.10	0.20	0.34	0.46	--[5]	--[5]	**0.049**	**0.062**	8.63	9.90	--[5]	--[5]	20.55	22.35	8.18	8.27
	WR011	7	0.08	0.21	0.38	0.48	55	**1673**	0.032	**0.050**	9.54	10.9	3.7	7.0	22.72	25.63	7.95	8.15
October	WR010	14	0.10	0.20	0.48	1.14	--[5]	--[5]	**0.065**	**0.119**	9.91	11.2	--[5]	--[5]	13.62	15.59	8.16	8.20
	WR011	6	0.09	0.15	0.45	1.55	27	**604**	**0.041**	**0.115**	8.99	10.7	6.5	26.8	19.28	23.48	8.04	8.22
November	WR010	12	0.11	0.30	0.91	1.79	--[5]	--[5]	**0.076**	**0.129**	12.5	14.6	--[5]	--[5]	7.94	9.66	8.21	8.30
	WR011	7	0.12	0.23	0.67	0.91	**153**	**2228**	**0.049**	**0.090**	10.0	13.3	9.5	26.5	13.78	14.52	8.08	8.09
December	WR010	0	0.11[2]	0.20[2]	1.60[2]	0.04[2]	--[5]	--[5]	**0.104[2]**	**0.131[2]**	14.9[2]	15.9[2]	--[5]	--[5]	4.46[2]	5.32[2]	8.02[2]	8.06[2]
	WR011	0	0.40[2]	0.46[2]	1.56[2]	1.68[2]	**4577[2]**	**5614[2]**	**0.089[2]**	**0.110[2]**	11.04	14.24	15.7[2]	24.2[2]	10.35	15.31	7.98[2]	7.99[2]

Notes:

[1] Total number of samples collected for the period of record for Welland River WR010 (2003 to 2018) and Welland River WR011 (2011 to 2018) per the month of interest

[2] Value calculated as average of previous and next month

[3] Insufficient samples to develop a distribution. Value corresponds to geo-mean.

[4] Insufficient samples to develop a distribution. Value corresponds to maximum monthly value.

[5] No data available

[6] Highlighted values correspond with input to the GoldSim model.

[7] Bold values indicate exceedances of applicable PWQO.

2.2.3 Niagara River

The water quality in the Niagara River was quantified by compiling data from three sources since no one location offered a full complement of data for all required parameters. The data sources were:

- the Niagara River at Fort Erie (ON02HA0045) from 1981 to 1999 (total phosphorus, total ammonia, nitrate, dissolved oxygen, water temperature, and pH);
- the raw water intake data for the Niagara Falls drinking water supply plant from 2016 to 2018 (*E. coli*); and
- TSS concentrations were obtained from the USGS for station 04216070 (Niagara River at Fort Erie) for the period 2014 to 2019.

Water quality data for the Niagara River at Fort Erie were obtained from the Environment Canada website while the water intake data was provided by Niagara Region.

The total phosphorus concentrations in the upper section of the Niagara River at Fort Erie (ON02HA0045) are compared to those on the lower section on Niagara-on-the-Lake (ON02HA0019) in Part I of the ACS concluding that current direct phosphorus loads to the Niagara River (e.g., not from Lake Erie) are not measurable. As a result, phosphorus was characterized using only the Niagara River at Fort Erie (ON02HA0045) dataset.

Measured data regarding TSS and $CBOD_5$ were not available in sufficient quantity to provide monthly characterization. However, since the water in the Niagara River is typically clear (NYPA 2005), it is expected that concentrations of TSS and $CBOD_5$ are low. Sixteen samples collected by the USGS provide annual estimates for the geometric mean and 75th percentile TSS values of 5.2 mg/L and 11.3 mg/L, respectively.

A summary of the monthly water quality geo-mean and 75th percentile values for Niagara River (ON02HA0045) and the raw water intake are presented in Table 4.

In general, water quality in the Niagara River meets all of the applicable objectives. Exceedances for the 75th percentile were identified for total phosphorus for the period November to December, and *E. coli* for January and June to November. The highest monthly total phosphorus concentration typically occurs in December and January.

Measured data regarding TSS and $CBOD_5$ were not available in sufficient quantity to provide seasonal statistical summaries. However, since the water in the Niagara River is typically clear (NYPA, 2005), it is expected that concentrations of TSS and $CBOD_5$ are low. Sixteen samples collected by the USGS provide annual estimates for the geometric mean and 75th percentile TSS values of 5.2 mg/L and 11.3 mg/L, respectively.

The GoldSim model uses the monthly 75th percentile of ammonia, *E. coli*, nitrate, and total phosphorus. For nitrate, the highest value from the Niagara River or the Raw Water Intake was applied yielding a conservative approach for prediction of assimilative capacity of the system. The assimilative capacity of the system for ammonia is based on the regulatory limit of unionized ammonia, ammonia in the system (based on 75th percentile), and 75th percentile values of pH and temperature.

Table 4: Summary of Monthly Water Quality Concentrations for Niagara River

Month	Station	Number of Samples [1]	Total Ammonia (mg/L)		Nitrate		*E. coli*		Phosphorus (mg/L)		Temperature (ºC)		pH	
			Geo-mean	75th	Geo-mean	75th	Geo-mean	75th	Geo-mean	75th	Geo-mean	75th	Geo-mean	75th
January	Niagara River	247-78	0.01	0.01	0.26	0.32	--[2]	--[2]	**0.030**	**0.046**	0.07	0.67	7.95	8.10
	Raw Water Intake	41	--[2]	--[2]	0.20	0.28	6	11	--[2]	--[2]	--[2]	--[2]	--[2]	--[2]
February	Niagara River	226-69	0.01	0.01	0.26	0.31	--[2]	--[2]	0.021	**0.031**	0.06	0.25	8.06	8.18
	Raw Water Intake	36	--[2]	--[2]	0.40	0.54	6	10	--[2]	--[2]	--[2]	--[2]	--[2]	--[2]
March	Niagara River	297-75	0.01	0.02	0.26	0.29	--[2]	--[2]	0.019	0.025	0.74	2.49	7.93	8.10
	Raw Water Intake	38	--[2]	--[2]	0.24	0.26	3	4	--[2]	--[2]	--[2]	--[2]	--[2]	--[2]
April	Niagara River	298-47	0.03	0.06	0.26	0.30	--[2]	--[2]	0.020	0.026	4.40	7.82	8.06	8.10
	Raw Water Intake	38	--[2]	--[2]	0.15	0.19	4	6	--[2]	--[2]	--[2]	--[2]	--[2]	--[2]
May	Niagara River	292-54	0.03	0.05	0.26	0.32	--[2]	--[2]	0.018	0.026	11.68	14.07	8.12	8.20
	Raw Water Intake	39	--[2]	--[2]	0.24	0.30	2	3	--[2]	--[2]	--[2]	--[2]	--[2]	--[2]
June	Niagara River	276-53	0.03	0.05	0.28	0.32	--[2]	--[2]	0.016	0.023	18.52	20.29	8.18	8.30
	Raw Water Intake	37	--[2]	--[2]	0.17	0.23	3	4	--[2]	--[2]	--[2]	--[2]	--[2]	--[2]
July	Niagara River	285-56	0.02	0.04	0.19	0.23	--[2]	--[2]	0.015	0.021	23.16	24.45	8.31	8.40
	Raw Water Intake	41	--[2]	--[2]	0.14	0.18	3	4	--[2]	--[2]	--[2]	--[2]	--[2]	--[2]
August	Niagara River	309-56	0.02	0.04	0.13	0.17	--[2]	--[2]	0.015	0.022	23.59	24.41	8.27	8.40
	Raw Water Intake	39	--[2]	--[2]	0.12	0.13	4	5	--[2]	--[2]	--[2]	--[2]	--[2]	--[2]
September	Niagara River	299-58	0.03	0.04	0.12	0.16	--[2]	--[2]	0.016	0.021	21.19	22.51	8.23	8.30
	Raw Water Intake	39	--[2]	--[2]	0.11	0.12	4	9	--[2]	--[2]	--[2]	--[2]	--[2]	--[2]
October	Niagara River	309-58	0.01	0.04	0.14	0.18	--[2]	--[2]	0.017	0.025	15.07	17.49	8.22	8.30
	Raw Water Intake	40	--[2]	--[2]	0.11	0.11	6	10	--[2]	--[2]	--[2]	--[2]	--[2]	--[2]
November	Niagara River	271-73	0.01	0.02	0.17	0.22	--[2]	7.000	0.023	**0.033**	7.82	10.08	8.06	8.20
	Raw Water Intake	37	--[2]	--[2]	0.11	0.12	6	7	--[2]	--[2]	--[2]	--[2]	--[2]	--[2]
December	Niagara River	274-76	0.01	0.02	0.23	0.30	--[2]	--[2]	**0.032**	**0.049**	1.91	5.18	7.99	8.10
	Raw Water Intake	38	--[2]	--[2]	0.15	0.19	4	8	--[2]	--[2]	--[2]	--[2]	--[2]	--[2]

Notes:

1. Range of number of samples collected for the period of record for Niagara River at ON02HA0045 (1981 to 1991) and Niagara Falls Watertrax (2016 to 2018) per the month of interest
2. No data available
3. Highlighted values correspond with input to the GoldSim model.
4. Bold values indicate exceedances of applicable PWQO.

2.2.4 Lyons Creek

A summary of measured water quality in Lyons Creek is provided in Table 5, containing the monthly water quality geo-mean and 75th percentile values for monitoring station LY003. Data were provided by NPCA for station LY003 between 2003 and 2018.

The flows in Lyons Creek are a combination of supplemental flows from the Welland Canal (which is effectively water from Lake Erie) and natural drainage from the lower section of the Lyon Creek Watershed. Water quality in Lyons Creek consistently exceeds the PWQO guidelines for phosphorus as expected for a small watershed that drains agricultural areas, and occasionally exceeds *E. coli*. CBOD data was available only for the 2009 to 2014 period, while DO and TSS were not available in the dataset provided for this study.

The GoldSim model uses the monthly 75th percentiles of ammonia, *E. coli*, nitrate, and total phosphorus. The assimilative capacity of the system for ammonia is based on the regulatory limit of unionized ammonia, ammonia in the system (based on 75th percentile), and 75th percentile values of pH and temperature.

Table 5: Summary of Monthly Water Quality Concentrations for Lyons Creek

Month	Station	Number of Samples [1]	Total Ammonia (mg/L)		Nitrate		*E. coli*		Total Phosphorus (mg/L)		$CBOD_5$		Water Temperature (°C)		pH	
			Geo-mean	75th	Geo-mean	75th	Geo-mean	75th	Geo-mean	75th	Geo-mean	75th	Geo-mean	75th	Geo-mean	75th
January	LC003	3	0.06	0.06[3]	0.90	0.90[3]	**630**	**630[3]**	**0.280**	**0.280[3]**	1.32[4]	2.00[4]	0.30[5]	0.30[3]	7.38	7.38[3]
February	LC003	1	0.09[2]	0.20[2]	0.84	0.84[3]	**410**	**410[3]**	**0.230**	**0.230[3]**	1.74[4]	2.00[4]	3.38[5]	3.38[3]	7.03	7.03[3]
March	LC003	5	0.12	0.34	0.22	0.65	41	**110**	**0.123**	**0.150**	1.74[4]	2.00[4]	3.38	14.3[5]	7.70	7.89
April	LC003	15	0.06	0.12	0.09	0.20	56	**200**	**0.140**	**0.185**	1.74	2.00	6.42	14.7[5]	7.79	7.95
May	LC003	16	0.04	0.11	0.06	0.20	37	56	**0.112**	**0.130**	1.52	2.00	9.67	18.70	7.90	8.16
June	LC003	16	0.04	0.09	0.06	0.20	51	94	**0.153**	**0.208**	1.26	2.00	7.88	25.70	7.88	8.04
July	LC003	16	0.05	0.10	0.06	0.09	21	40	**0.151**	**0.168**	0.76	1.50	23.97	26.40	7.86	8.03
August	LC003	13	0.03	0.08	0.09	0.20	27	40	**0.116**	**0.145**	0.84	1.75	27.00	27.0[3]	7.87	8.00
September	LC003	16	0.03	0.07	0.09	0.20	28	66	**0.086**	**0.115**	0.76	1.00	23.76	25.10	7.75	7.96
October	LC003	14	0.04	0.09	0.11	0.21	58	**153**	**0.113**	**0.193**	1.43	2.50	21.92	25.30	7.82	8.02
November	LC003	14	0.04	0.10	0.12	0.24	56	90	**0.117**	**0.200**	1.32	2.00	12.65	23.40[5]	7.78	7.90
December	LC003	1	0.05[2]	0.08[2]	0.55	0.55[3]	10	10[3]	**0.049**	**0.050[3]**	1.32[4]	2.00[4]	0.30	0.30[3]	7.91	7.91[3]

Notes:

[1] Total number of samples collected for the period of record (2003 to 2018) and month of interest for all parameters except CBOD5 and water temperature

[2] Value calculated as average of previous and next month

[3] Insufficient samples to develop a distribution. Value corresponds to geo-mean.

[4] Insufficient samples to develop a distribution. Value corresponds to maximum monthly value.

[5] No data for the month. Value corresponds to closer month with available data

[6] Highlighted values correspond with input to the GoldSim model.

[7] Bold values indicate exceedances of applicable PWQO.

2.2.5 Existing Niagara Falls Wastewater Treatment Plant, Primary Bypass, and Secondary Bypass

Water quality data and laboratory analysis were provided for the existing Niagara Falls WWTP final effluent from 2015 to 2018 by the Niagara Region.

The assimilative capacity of the system was estimated by excluding all CSOs, and assuming that the water quality from the effluent at the existing Niagara Falls WWTP corresponds with the regulatory limits outlined in the Amended Environmental Compliance Approval (ECA) number 7962-7ZLKR6, issued on February 3, 2010. The regulated parameters which are outlined in the aforementioned ECA are total phosphorus and *E. coli*, with effluent limits specified as at 0.75 mg/L and 200 counts/100 ml, respectively.

The historic monthly final effluent quality is summarized in Table 6.

Table 6: Summary of Monthly Final Effluent Quality Concentrations for Existing Niagara Falls WWTP

Month	Number of Samples[1]	Total Ammonia (mg/L)		Nitrate		*E. coli*		Total Phosphorus (mg/L)		CBOD$_5$		Water Temperature (ºC)		pH	
		Geo-mean	75th	Geo-mean	75th	Geo-mean	75th	Geo-mean	75th	Geo-mean	75th	Geo-mean	75th	Geo-mean	75th
January	124	4.35	10.13	6.12	9.68	7.4	11.5	0.298	0.355	4.12	5.65	9.22	10.88	7.27	7.38
February	113	3.62	9.60	6.93	9.29	4.6	10.0	0.310	0.410	4.82	6.23	9.25	10.87	7.25	7.33
March	124	3.96	8.78	5.67	8.46	9.1	9.5	0.267	0.350	4.72	6.48	9.47	10.97	7.26	7.38
April	120	2.32	6.28	5.60	8.20	10.7	22.0	0.237	0.300	4.46	6.00	11.69	12.84	7.32	7.47
May	124	2.66	7.10	6.46	9.69	7.4	11.0	0.346	0.410	4.97	6.80	15.20	16.64	7.29	7.40
June	120	3.07	8.43	4.49	7.43	5.5	8.0	0.396	0.483	5.20	6.90	18.30	19.50	7.26	7.40
July	124	4.01	9.26	5.86	7.52	7.8	13.0	0.389	0.528	4.38	6.38	20.88	22.01	7.27	7.40
August	124	3.99	7.43	5.85	8.02	6.0	9.0	0.417	0.570	6.08	10.65	21.65	22.66	7.20	7.30
September	120	3.53	7.81	6.23	8.20	7.1	10.0	0.444	0.598	6.84	11.45	20.88	22.35	7.25	7.34
October	124	3.63	8.58	4.96	7.49	7.3	10.0	0.349	0.420	6.02	9.63	17.53	19.24	7.25	7.30
November	120	3.93	7.78	6.10	8.12	13.4	34.0	0.263	0.333	4.19	6.00	14.28	15.48	7.22	7.32
December	124	4.16	8.79	6.64	9.76	11.3	17.0	0.285	0.360	4.29	5.40	11.99	13.70	7.25	7.35

Notes:

[1] Total number of samples collected for the period of record (2015 to 2018)

2.3 Data Conclusions and Generalizations

Based on the preceding characterisation of available flow and water quality data, the following conclusions are provided with respect to the detailed assessment discharge of the effluent into Chippewa Creek:

- Flows in the HEPC and Chippewa Creek are controlled by the operation of the ICD and should not be represented as a natural flow regime in the ACS.
- The background concentrations of two parameters, phosphorus, and *E. coli* are shown to exceed their respective water quality criteria within two or more watercourses discharging to the HEPC.
- While the Niagara River generally has lower concentrations of phosphorus when compared to the Welland River and Lyons Creek, it represents a far more significant loading source of this parameter due to the considerable difference in flows directed through the HEPC from all sources:
  - Niagara River approximates 95.1% of background HEPC flows;
  - Welland River (natural and supplemental flows) approximates 4.5% of background HEPC flows;
  - Lyons Creek contributes less than 0.3% of background HEPC flows; and
  - Existing Niagara Falls WWTP approximates 0.1% of background HEPC flows.
- Total phosphorus concentrations within the Niagara River tend to increase substantially outside the growing season. During the winter months, the 75th percentile phosphorus concentration in the Niagara River are almost twice that of other months.
- Notably, it has recently been estimated that 57% of all phosphorus loads to Lake Ontario come from the Niagara River from upstream sources in Lake Erie (ECCC & USEPA 2018).
- The Welland River East and Lyons Creek also have some local influence, particularly in spring when background phosphorus loading to the HEPC from these two watercourses alone can exceed 20%.
- Water quality in Welland River East, particularly total phosphorus, deteriorates as the natural flows increase. This correlation is likely attributed to the increased influence of poor land management practices during rainfall runoff compared to the beneficial dilution effects of consistent, supplemental inflows from the Welland Canal via the Port Robinson Pumping Station, ports in the old siphon, and the Welland WWTP bypass under low flow conditions.
- Relative to the Niagara River, bacteriological concentrations in the Welland River and Lyons Creek are so high that the Welland River and Lyons Creek are the dominant sources of *E. coli* throughout the winter and spring to the HEPC, despite order of magnitude differences in flow volume.
- As such, much of the water quality issues in the system are currently being influenced by background contributions from Lake Erie and smaller watersheds located upstream of the HEPC.

3.0 MODELLING APPROACH AND RESULTS

The modelling approach was designed with the following objectives:

- Estimate the remaining capacity of the receiving waters to accept the proposed WWTP effluent flows without exceeding applicable guidelines on a monthly basis;
- Estimate the recommended effluent limits for the preferred discharge location to Chippewa Creek and compare those limits to feasible limits based on the available treatment technology; and
- Estimate the existing and future concentrations in the receiving waters for effluent discharge to Chippewa Creek based on the recommended effluent limits.

The modelling approach was consistent with the Screening Level ACS completed to evaluate the original four discharge location options (Appendix A). The following points summarize the approach:

- Given the complex and regulated hydrodynamic conditions in the system, a stochastic model (GoldSim) was used to complete the ACS for total phosphorus, total ammonia, nitrate, and fecal coliforms (*E. coli*). Estimates for unionized ammonia were calculated based on modelled ammonia and measured 75th percentile values for temperature and pH.
- To provide an alternate estimate of the assimilative capacity, a mass balance model was developed to estimate the maximum allowable effluent concentrations for total ammonia, unionized ammonia, nitrate, fecal coliforms (*E. coli*), and total phosphorus for conditions where all the flows in the study area were assumed to be representative of low-flow conditions (e.g., 7Q20 or minimum regulated flow).
- The assimilative capacity was assessed at two compliance points; a local compliance point that is immediately downstream of the proposed discharge in Chippewa Creek and a system compliance point in the HEPC downstream of the existing Niagara Falls WWTP to consider cumulative effects in the study area.
- For parameters associated with oxygen in the water (dissolved oxygen and $CBOD_5$), the maximum allowable effluent concentrations were estimated using a simplified and conservative dissolved oxygen mass balance model that included $CBOD_5$ decay at the local compliance point. The assessment of dissolved oxygen also considered oxygen consumption due to the nitrification of ammonia. The system compliance point was not evaluated as reaeration is expected in the HEPC due to current speeds.
- A simple mass balance model was used to estimate the maximum allowable effluent concentrations for TSS based on the CCME recommended maximum increase of 5 mg/L over the background conditions.

In addition to the assimilative capacity modelling, this document also includes a mixing zone assessment that provides a conceptual outfall design, predictions of the performance of the outfall under various seasonal and flow conditions, and predicted plume concentration profiles immediately downstream of the proposed outfall.

A schematic of the study area showing the location of the local and system compliance points is provided in Figure 3.

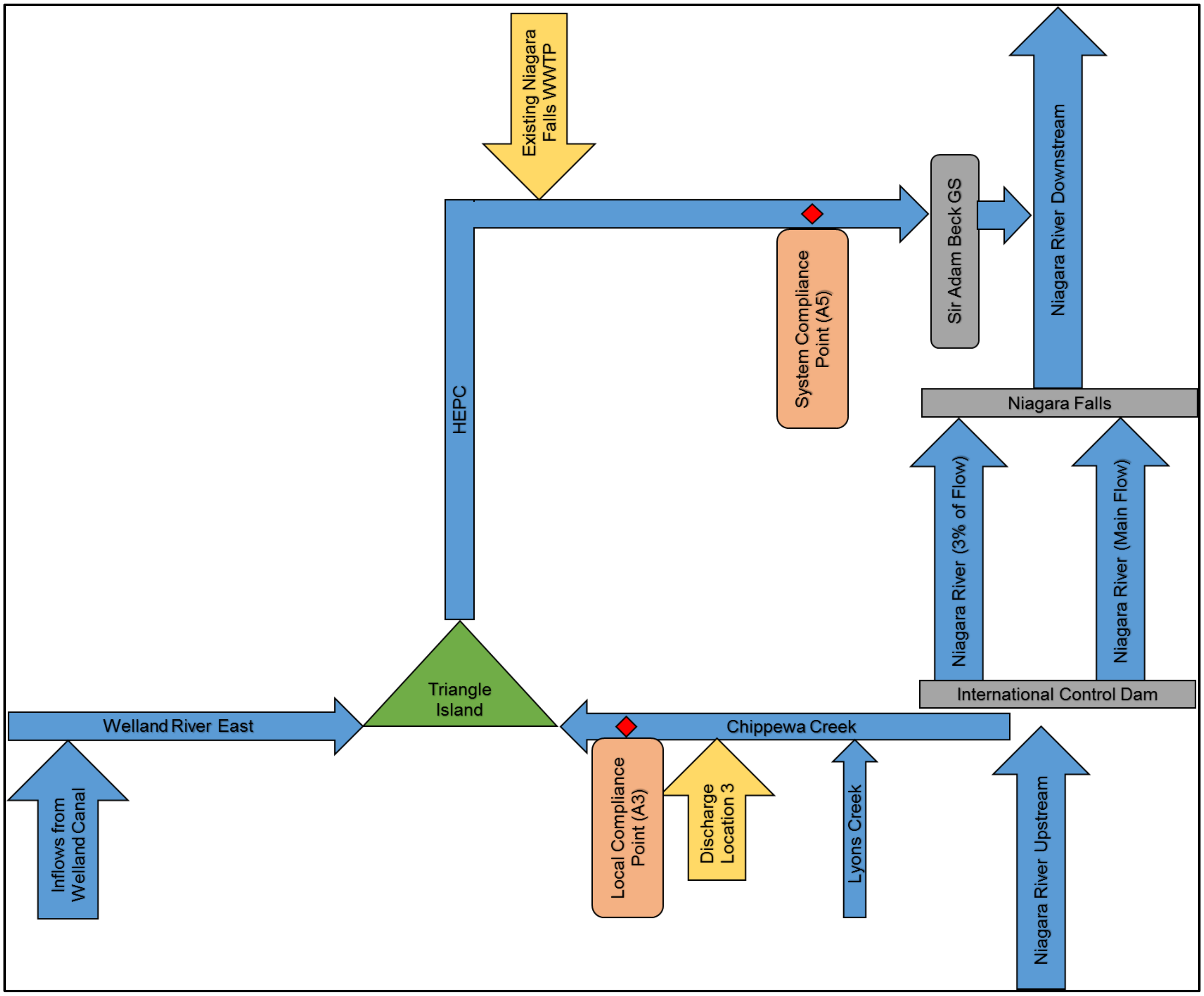


Figure 3: Local and System Compliance Points for Discharge at Location to Chippewa Creek

3.1 GoldSim Modelling

The stochastic water balance and water quality model developed for the Screening ACS using GoldSim was modified to use monthly input data (monthly flow distributions and monthly water quality data) instead of seasonal values. Technical details of the GoldSim software and model development are presented in detail in Appendix A. In GoldSim, conditional formatting was applied to the model compartments representing each month to become active only during the days corresponding to the specific month. The model was run stochastically using 1,000 iterations, for the modelling period which extended to a full year.

Flow and water quality data observed within the first and last day of each month were used to characterize flow and water quality for each specific month. Average, standard deviation, maximum and minimum flows were used to characterize monthly flow distributions for the Welland River East, Lyons Creek, and HEPC. Flows at the existing Niagara Falls WWTP were assumed as a constant value throughout the year. Water quality concentrations for inflows were based on the 75th percentile monthly concentrations from measured water quality data for total phosphorus, nitrate, total ammonia, and *E. coli*.

GoldSim was applied with the following objectives:

- Estimate the remaining capacity of the receiving waters to accept the proposed WWTP effluent flows without exceeding applicable guidelines on a monthly basis.
- To estimate the allowable effluent limits that will result in exceedances of the criteria no more than 5% of the time. The applicable water quality limits for phosphorus, nitrate, *E. coli*, and unionized ammonia were used by the model to calculate, for each constituent, the monthly mass allowed in the system based on input mass load from all sources and the regulatory limits. The model was run stochastically for 1,000 iterations which allowed the expression of the assimilative capacity results in terms of probability of exceedance. The capacity in the system was assessed for the local and system compliance points and included phosphorus, nitrate, *E. coli* and total ammonia. Allowable mass was then converted to the allowable concentration according to the flow in the new WWTP.
- To predict future phosphorus, nitrate, *E. coli*, and total ammonia concentrations at the local and system compliance points based on proposed effluent limits at the new WWTP. Future concentrations are expressed in probabilistic form on a monthly basis.

3.1.1 Flow Implementation

Flow was implemented in the model based on the available data and the stochastic modelling using the GoldSim model for Welland River East, Lyons Creek, and the HEPC. Flow in Chippewa Creek was estimated using the HEPC flow as well as the flows coming from the Welland River East and Lyons Creek (Sections 2.1.3 and 2.1.4).

3.1.1.1 Welland River East

Table 7 shows the parameters associated with the log-normal distributions developed to characterize the monthly flow in Welland River East in GoldSim. These distributions include all supplemental inflows from the Welland Canal into the Welland River East. Figure 4 and Figure 5 show the probability distribution of monthly flows.

Table 7: Summary of Monthly Flow Statistics for Welland River East Including Supplemental Flows

Parameter	Mean Flow (m^3/s)	Standard Deviation (m^3/s)	Maximum Flow (m^3/s)	Minimum Flow (m^3/s)
January	20.58	16.68	177.90	12.83
February	22.37	23.18	244.81	12.21
March	32.53	26.98	289.10	13.59
April	27.33	21.65	240.58	14.77
May	18.88	13.15	137.07	14.04
June	16.39	7.04	136.11	14.52
July	15.60	3.57	70.11	14.61
August	15.47	3.14	64.00	14.51
September	16.14	6.08	130.31	14.44
October	17.43	8.78	176.05	14.40
November	21.30	14.78	166.79	14.87
December	24.55	19.81	250.99	14.96

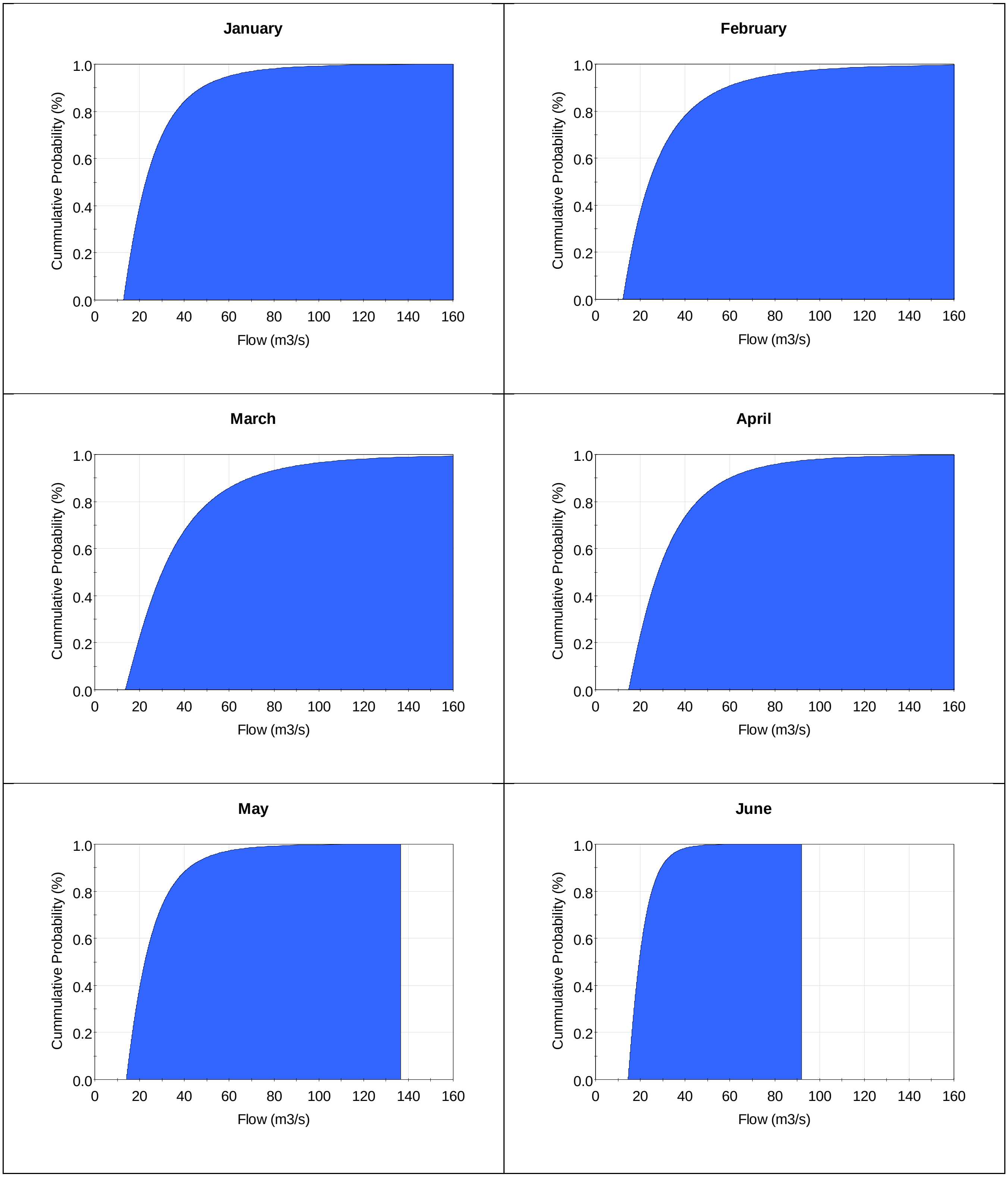
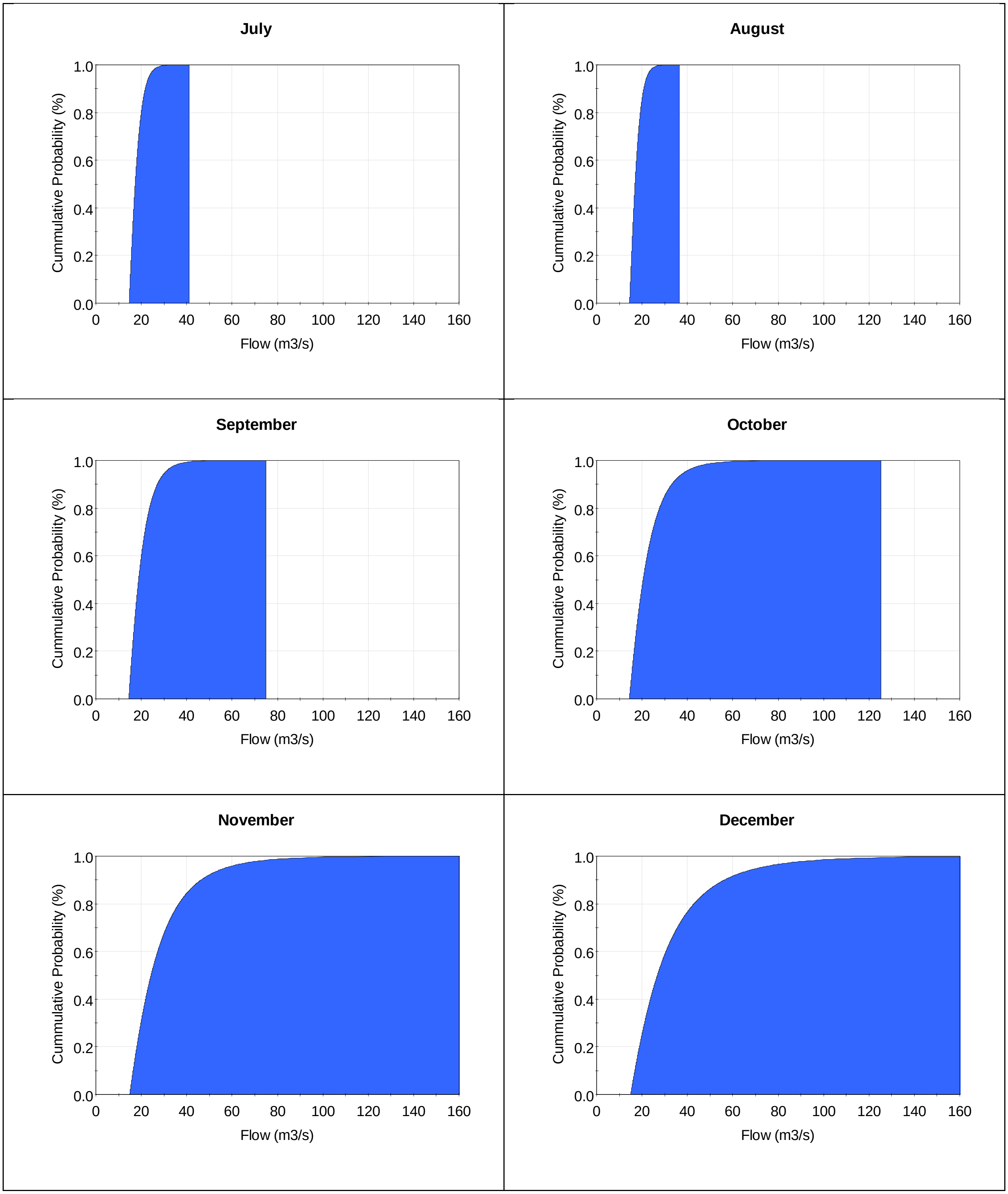


Figure 4: Monthly Log-Normal Distribution of Flows in the Welland River East Including Supplemental Inflows (January to June)



July

August

September

October

November

December

Figure 5: Monthly Log-Normal Distribution of Flows in the Welland River East Including Supplemental Inflows (July to December)

3.1.1.2 Lyons Creek

Table 8 shows the parameters associated with the monthly log-normal distributions developed to characterize the flow in Lyons Creek in GoldSim. Figure 6 and Figure 7 show the probability distribution of monthly flows.

Table 8: Summary of Monthly Flow Statistics for Lyons Creek

Parameter	Mean Flow (m^3/s)	Standard deviation (m^3/s)	Maximum Flow (m^3/s)	Minimum Flow (m^3/s)
January	1.21	2.30	22.95	0.14
February	1.55	3.20	32.27	0.14
March	2.76	3.73	38.20	0.14
April	2.05	2.99	31.51	0.31
May	0.95	1.82	17.28	0.28
June	0.54	0.97	17.08	0.28
July	0.42	0.49	7.95	0.28
August	0.42	0.43	7.12	0.28
September	0.52	0.84	16.29	0.28
October	0.70	1.21	22.61	0.28
November	1.17	2.04	21.27	0.28
December	1.47	2.74	32.75	0.14

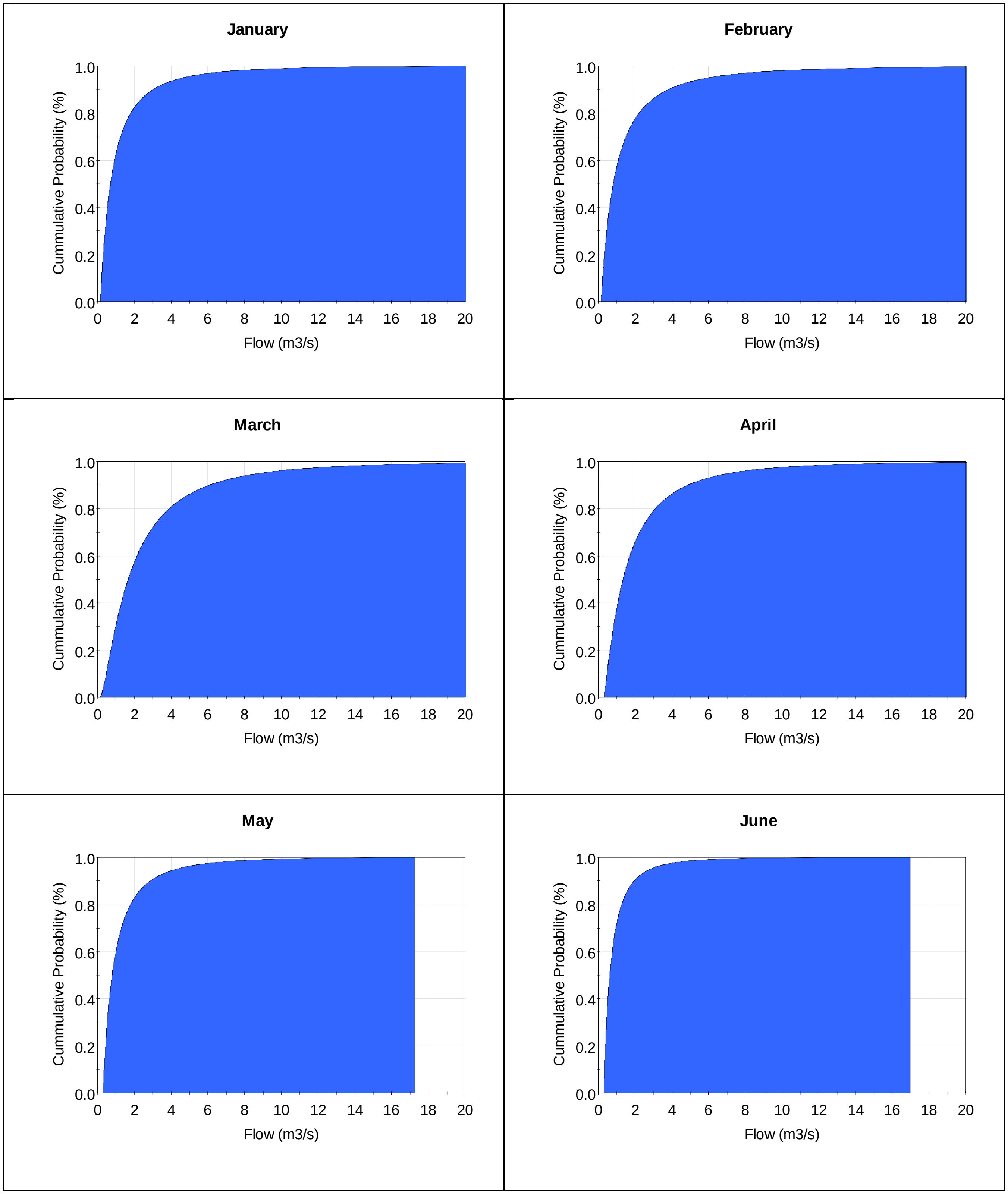


Figure 6: **Monthly Log-Normal Distribution of Flows in Lyons Creek Including Supplemental Inflows (January to June)**

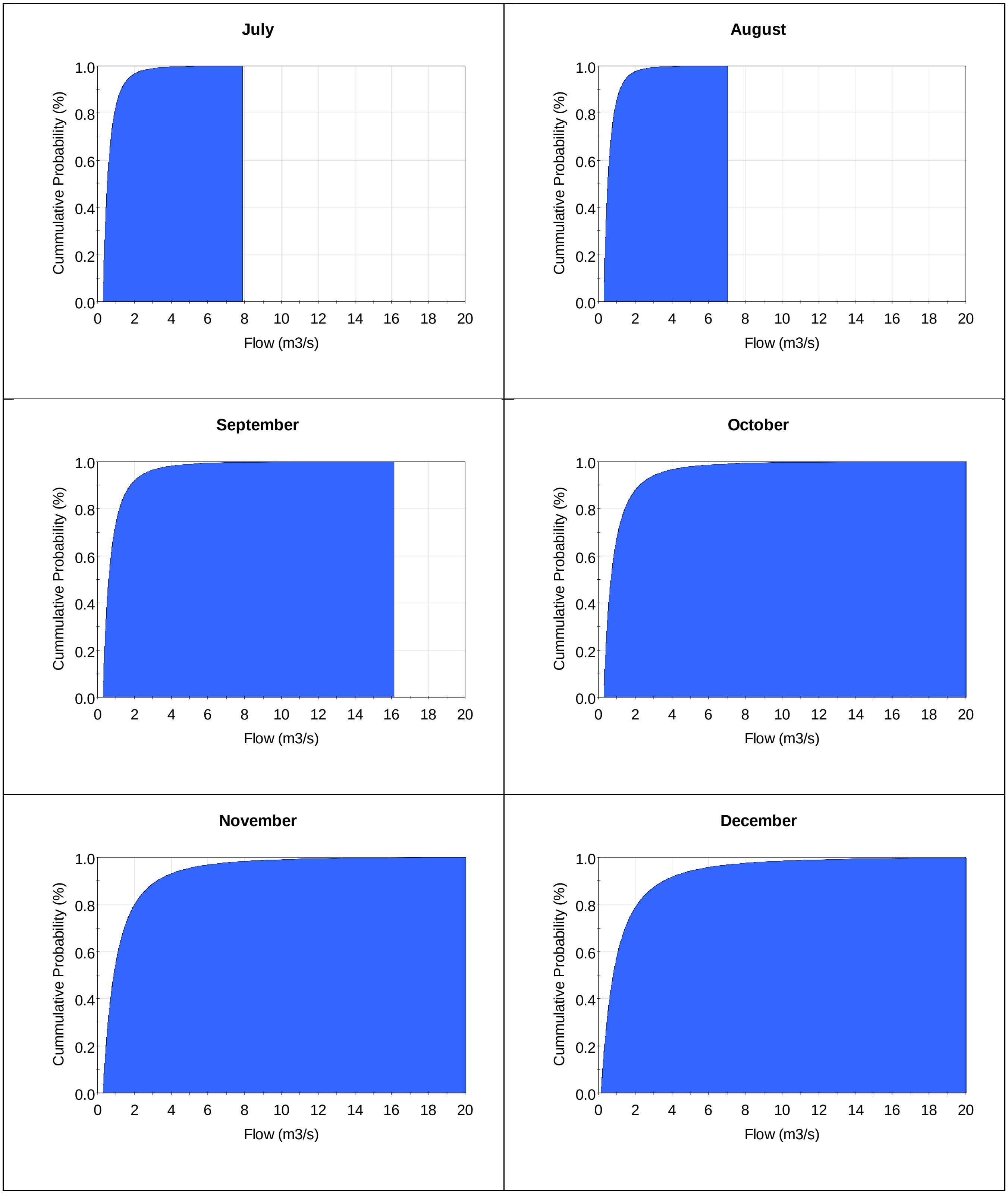


Figure 7: Monthly Log-Normal Distribution of Flows in Lyons Creek Including Supplemental Inflows (July to December)

3.1.1.3 Hydro Electric Power Canal (HEPC)

Table 9 shows the parameters associated with the log-normal distributions followed to characterize the monthly flow in HEPC in GoldSim. Figure 8 and Figure 9 show the probability distribution of monthly flow. In GoldSim, the flow through Chippewa Creek was calculated based on the difference between the flow in the HEPC and the corresponding flow in Welland River East and Lyons Creek.

Table 9: Summary of Monthly Flow Statistics for the Hydro Electric Power Canal

Parameter	Mean Flow (m^3/s)	Standard Deviation (m^3/s)	Maximum Flow (m^3/s)	Minimum Flow (m^3/s)
January	435	46.7	546	343
February	429	46.5	555	351
March	407	38.1	539	351
April	416	45.9	557	350
May	412	29.0	506	361
June	425	35.4	510	363
July	456	42.7	558	374
August	458	41.6	551	371
September	438	43.5	541	364
October	407	23.8	476	358
November	417	37.3	501	347
December	444	59.3	562	329

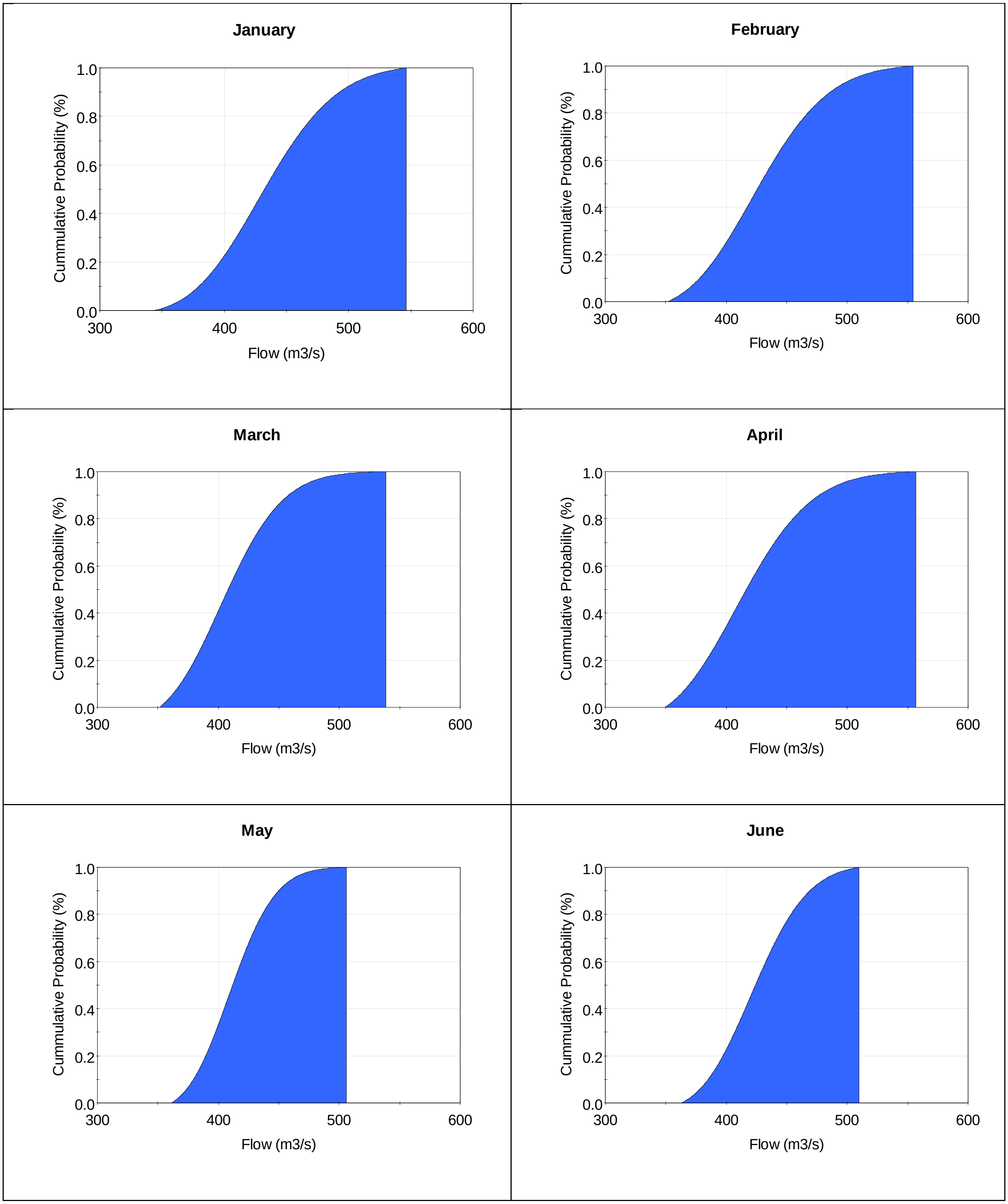


Figure 8: **Monthly Log-Normal Distribution of Flows in HEPC (January to June)**

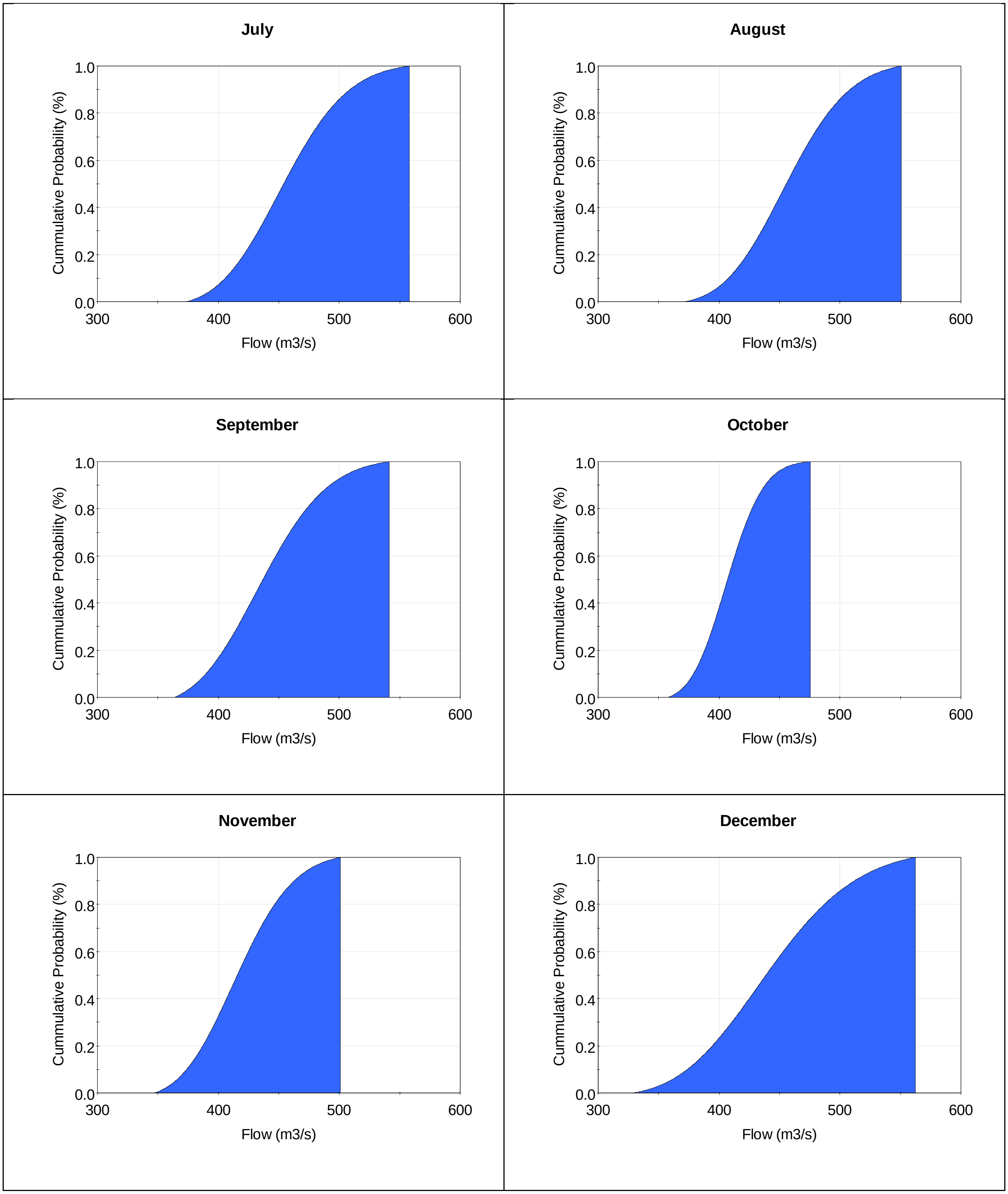


Figure 9: **Monthly Log-Normal Distribution of Flows in HEPC (July to December)**

3.1.1.4 Existing Niagara Falls Wastewater Treatment Plant

The effluent flow rate from the existing Niagara Falls WWTP was assumed to be equal to the rated capacity listed in the ECA of 68.3 MLD (0.79 m^3/s).

3.1.1.5 New South Niagara Wastewater Treatment Plant

Flow from proposed WWTP was assumed to be constant at 0.347 m^3/s (30,000 m^3/d).

3.1.2 Water Quality Implementation

The available data for water quality included ammonia, *E. coli*, nitrate, and total phosphorus. Water quality data associated with the 75th percentile was used for all inputs to the model, with the exception of the effluent from the existing Niagara Falls WWTP, which considered water quality as per the ECA regulatory limits for total phosphorus and *E. coli*.

3.1.3 Water Quality Objectives

The allowable effluent concentration for the proposed WWTP were estimated by calculating the mass allowed in the system until reaching applicable water qualitive objectives. The threshold for *E. coli*, total phosphorus, and nitrate were based on the guidelines provided in Table 2.

GoldSim does not incorporate accurate modelling of pH and water temperature. The fraction of the total ammonia that is unionized is a function of pH and temperature. The monthly target values for total ammonia were back calculated from the PWQO limit of 0.0164 mg/L as nitrogen for unionized ammonia based on the monthly 75th percentile water temperature and pH in Chippewa Creek and the HEPC.

The monthly thresholds for total ammonia, *E. coli*, nitrate, and total phosphorus in the receiver used to estimate recommended effluent limits are summarized in Table 10.

Table 10: Summary of Monthly Water Quality Objectives used in GoldSim

Month	Water Temperature (°C)[1]	pH[1]	Total Ammonia (mg/L)[2]	*E. coli* (cfu/100ml)	Nitrate (mg/L)	Total Phosphorus (mg/L)
January	0.7	8.10	1.51	100	3	0.03
February	0.3	8.10	1.57	100	3	0.03
March	3.2	8.20	0.98	100	3	0.03
April	7.9	8.18	0.71	100	3	0.03
May	14.1	8.20	0.42	100	3	0.03
June	20.3	8.30	0.22	100	3	0.03
July	24.5	8.40	0.14	100	3	0.03
August	24.4	8.40	0.14	100	3	0.03
September	22.5	8.30	0.19	100	3	0.03
October	17.5	8.30	0.27	100	3	0.03
November	10.1	8.20	0.57	100	3	0.03
December	5.2	8.10	1.05	100	3	0.03

Note:

[1] Measured 75th percentile value for either Niagara River or HEPC. Values used represented the conditions that resulted in the highest fraction of unionized ammonia.

[2] Total ammonia criteria based on target unionized ammonia concentration of 0.0164 mg/L as N and seasonal average water temperature and pH in receiving water.

3.1.4 Maximum Allowable Effluent Concentrations

The allowable mass modelled in the system was extracted for the local compliance point (immediately downstream of the preferred discharge location) and at the system compliance point (downstream of the existing Niagara Falls WWTP). The recommended effluent concentrations were calculated by dividing the allowable mass by the flow from new WWTP. Large values in the table can be explained by the small flow rate in the proposed WWTP compared to the other flows in the system.

Table 11 shows the recommended effluent limits based on assimilative capacity at the local and system compliance points. These concentrations were calculated based on the GoldSim predictions for the 5% probability of exceedance.

These modelling results show that the system is currently at capacity for *E. coli* at the system compliance point from November to March and in September primarily due to contributions from the Welland River East. Elevated total phosphorus concentrations in the Niagara River from November and February result in no additional capacity for phosphorus at the local and system compliance points in those months. There are additional constraints on capacity to receive phosphorus at the system compliance point from March to June due to contributions from the Welland River East and the existing Niagara Falls WWTP.

Table 11: Summary of Maximum Allowable Effluent Concentrations from GoldSim Modelling

Month	Total Ammonia (mg/L)		*E. coli* (cfu/100ml)[1]		Nitrate (mg/L)		Total Phosphorus (mg/L)[1]	
	Local	System	Local	System	Local	System	Local	System
January	1,467	1,554	79,518	nc	2,530	2,594	nc	nc
February	855	919	75,315	nc	2,186	2,302	nc	nc
March	617	546	86,722	nc	2,457	2,687	2.7	nc
April	361	361	92,226	67,543	2,670	2,816	2.2	nc
May	174	154	98,596	97,296	2,725	2,851	3.2	nc
June	95	66	103,967	97,529	2,910	2,965	7.6	nc
July	102	80	104,734	102,999	3,025	3,139	9.9	6.5
August	151	135	98,330	95,695	2,933	3,077	8.2	5.4
September	225	213	90,825	nc	2,837	3,010	8.1	3.9
October	512	529	85,688	10,447	2,702	2,840	3.3	nc
November	940	1,016	85,288	nc	2,553	2,704	nc	nc
December	947	1,002	84,521	nc	2,484	2,602	nc	nc

Note:

1. “nc” denotes no capacity since existing background water quality exceeds (PWQO or CCME).

3.2 Mass Balance Modelling

A secondary verification to the GoldSim model results, mass balance modelling was completed using 75th percentile background water quality concentrations and minimum supplemental flows. Mass balance modelling estimated the maximum allowable effluent concentrations for total phosphorus, *E. coli*, nitrate, total ammonia, $CBOD_5$, and TSS, and the minimum dissolved oxygen concentration. The mass balance models generally followed the same structure as the GoldSim model as shown on Figure 3 and provided monthly estimates. One mass balance model was developed to assess total phosphorus, ammonia, nitrate, and *E. coli* such that both the local and system compliance points could be considered. Because dissolved oxygen and $CBOD_5$ are not independent, a specific mass balance model was developed for these two parameters simultaneously. A third mass balance model was developed for TSS since the water quality guideline for that parameter is based on an increase over ambient.

These models are intended to provide a secondary verification of the results provided by GoldSim by estimating the maximum allowable effluent concentrations for the worst-case conditions. The worst-case conditions were assumed to be the monthly cases where the low-flow conditions in each of the waterbodies occurred simultaneously.

The following points outline the inputs into the mass balance modelling:

- Total phosphorus, nitrate*,* *E. coli*, total ammonia, unionized ammonia, and TSS were modelled as conservative parameters and used the water quality limits provided in Table 2.
- The monthly maximum allowable effluent concentrations for total ammonia were estimated based on the maximum allowable unionized ammonia concentration and 75th percentile values for water temperature and pH.
- The discharge of effluent from the existing Niagara Falls WWTP was assumed to be the rated capacity (68.3 MLD).
- The effluent discharge rate from the proposed WWTP was 30 MLD.
- Inflow concentrations from the Niagara River, Lyons Creek, and Welland River East were assumed to be equal to the 75th percentile of the monthly concentrations.
- Where applicable, the existing effluent limits for the existing Niagara Falls WWTP were used (total phosphorus and *E. coli*).
- Since there are no effluent limits for the existing Niagara Falls WWTP for nitrate or ammonia, monthly 75th percentile values based on measured data were used (Section 2.2.5).
- The effluent from both the existing Niagara Falls WWTP and the proposed plant was assumed to mix completely in the receiving water immediately after release.
- Natural flows in the Welland River East were assumed to be negligible. The low-flow conditions in the Welland River East were assumed to be equal to the minimum supplemental flows from the Welland Canal as provided in Table 1.
- Inflows from Lyons Creek were assumed to be equal to the pumping rates from the Welland Canal since naturally occurring low-flow conditions (e.g., 7Q20) are negligible (Section 2.1.3).
- Flows in the HEPC were assumed to be equal to the 5th percentile of the monthly daily average flows in the HEPC based on data provided by OPG between 2016 and 2018.
- Flow into Chippewa Creek from the Niagara River was assumed be the same as the flow in the HEPC less the contributions from the Welland River East and Lyons Creek.

The assumed low-flow conditions used in the mass balance modelling are provided in Table 12.

Table 12: Summary of Low-Flow Conditions Used in Mass Balance Modelling

Month	HEPC[1] (m³/s)	Welland River			Lyons Creek			Chippewa Creek	
		Natural[2] (m³/s)	Pumped[3] (m³/s)	Total (m³/s)	Natural[2] (m³/s)	Pumped[4] (m³/s)	Total (m³/s)	Mouth[5] (m³/s)	Discharge[6] (m³/s)
January	370.6	0.022	12.2	12.2	0.003	0.140	0.143	358.3	358.4
February	364.5	0.018	11.4	11.4	0.003	0.140	0.143	353.0	353.1
March	360.4	0.015	12.7	12.7	0.002	0.140	0.142	347.6	347.7
April	376.8	0.332	13.9	14.3	0.046	0.280	0.326	362.2	362.5
May	375.8	0.041	13.0	13.0	0.006	0.280	0.286	362.5	362.8
June	375.1	0.000	14.2	14.2	0.000	0.280	0.280	360.6	360.9
July	389.7	0.000	14.5	14.5	0.000	0.280	0.280	375.0	375.3
August	384.6	0.000	14.2	14.2	0.000	0.280	0.280	370.1	370.4
September	377.8	0.000	14.1	14.1	0.000	0.280	0.280	363.4	363.7
October	369.3	0.000	14.0	14.0	0.000	0.280	0.280	355.0	355.3
November	358.0	0.000	14.5	14.5	0.000	0.280	0.280	343.2	343.5
December	356.2	0.038	14.8	14.9	0.005	0.140	0.145	341.2	341.3

Notes:

[1] Estimate of low-flow condition in HEPC equal to 5th percentile of average daily flows

[2] Estimated monthly 7Q20 flow from runoff.

[3] Sum of all supplemental flows into Welland River East from Welland Canal (SLSMA 2019).

[4] Estimated supplemental pumping rate from Welland Canal into Lyons Creek.

[5] Estimated flow into Chippewa Creek from Niagara River (HEPC flow less flow from Welland River East and Lyons Creek).

[6] Estimated flow in Chippewa Creek at preferred discharge location (HEPC flow less flow from Welland River East).

3.2.1 Mass Balance Modelling for Total Phosphorus, Ammonia, Nitrate, and *E. coli*

Monthly maximum allowable effluent concentrations were estimated at the local compliance point (Chippewa Creek east of Triangle Island) as well as at the system compliance point below the existing Niagara Falls WWTP. The resulting estimates of the maximum allowable effluent concentrations are provided in Table 13.
The modelling results were generally similar to those form the GoldSim modelling and suggest that:

- Poor water quality from the Welland River East may limit the available capacity for *E. coli* at the system compliance point in January, March, and December.
- Elevated total phosphorus concentrations in the Niagara River from November to February may limit capacity in Chippewa Creek.
- High phosphorus loads from the Welland River East may also limit the available capacity at the system compliance point during the spring (March through June).
- Contributions from the existing Niagara Falls WWTP may limit the available capacity at the system compliance point (A5) during October.

Table 13: Summary of Maximum Allowable Effluent Concentrations from Mass Balance Modelling of Low-Flow Conditions

Month	Total Ammonia (mg/L)[1]		*E. coli* (cfu/100ml)		Nitrate (mg/L)		Total Phosphorus (mg/L)	
	Local	System	Local	System	Local	System	Local	System
January	1,510	1,518	91,711	nc	2,772	2,777	nc	nc
February	1,542	1,564	91,467	72,188	2,744	2,751	nc	nc
March	931	913	95,937	822	2,716	2,762	4.9	nc
April	658	663	97,791	89,654	2,825	2,887	3.8	nc
May	381	370	101,149	100,264	2,799	2,863	3.8	nc
June	172	155	99,801	94,869	2,785	2,828	7.7	0.4
July	98	78	103,824	102,346	2,997	3,091	9.9	6.5
August	95	81	101,943	100,079	3,024	3,122	8.9	6.2
September	151	133	95,634	31,610	2,974	3,064	8.9	6.0
October	230	216	92,334	71,848	2,890	2,939	5.3	0.1
November	528	525	92,034	2,717	2,752	2,791	nc	nc
December	990	997	90,788	nc	2,661	2,687	nc	nc

Note:

[1] "nc" denotes no capacity since existing water quality exceeds applicable criteria.

3.2.2 Mass Balance Modelling for Dissolved Oxygen and $CBOD_5$

Since dissolved oxygen, the nitrification of ammonia, and $CBOD_5$ of the effluent and background water all affect the downstream dissolved oxygen concentrations, these two parameters must be assessed together and could not be represented in GoldSim. The downstream dissolved oxygen at any downstream location is determined by the mixed (effluent and river) concentration of dissolved oxygen and the amount of oxygen consumed by the $CBOD_5$ in the time taken to reach that location. Other factors that affect the downstream dissolved oxygen include surface reaeration and algal growth/decay.

The nitrification of ammonia was considered in this assessment as it is expected to consume oxygen downstream of the outfall. However, the following points outline the rationale as to why the effects of nitrification on dissolved oxygen were considered negligible:

- The conversion of ammonia to nitrate consumes oxygen at a rate of 4.572 mg of oxygen per mg of ammonia (as N).
- The maximum increase in total ammonia concentration in Chippewa Creek as a result of the proposed discharge is predicted to be 0.003 mg/L based on the recommended effluent limits (Section 4.9) .
- If all the ammonia is instantly converted to nitrate, the total dissolved oxygen downstream of the outfall would decrease by approximately 0.014 mg/L.

The assessment of dissolved oxygen and $CBOD_5$ provides a conservative estimate of allowable effluent concentrations based on the following assumptions:

- Although measurements of dissolved oxygen in the Niagara River and HEPC are frequently at or above saturation due to turbulent flow conditions that provide a high degree of surface reaeration, surface reaeration is not included in this assessment.
- Given the typical clarity of the water in Niagara River and HEPC, the effects of algae are assumed to be negligible and are not included in the assessment.
- Given the short retention time in the system (e.g., less than a few hours), it is expected that only a fraction of the $CBOD_5$ will be consumed before leaving the study area. This assessment assumes that 50% of the $CBOD_5$ from upstream sources and the effluent will be consumed before leaving the system.
- $CBOD_5$ data was not available for the Niagara River. As such a background $CBOD_5$ concentration of 2 mg/L was assumed based on the highest seasonal 75th percentile $CBOD_5$ concentration found for the Welland River East (Table 3). These upstream conditions were applicable to the discharges into Chippewa Creek and the Niagara River.
- Upstream $CBOD_5$ concentrations in the Welland River East were based on the 75th percentile of the measured data (2 mg/L) since insufficient data was available to estimate monthly values.
- Upstream dissolved oxygen concentrations in the Niagara River were based on the monthly 25th percentile of the measured data.
- Water temperatures (required to estimate dissolved oxygen saturation concentrations) were based on the monthly 75th percentile temperature values for the Niagara River.
- Given the high degree of surface reaeration in the HEPC, dissolved oxygen, and $CBOD_5$ were not assessed at the system compliance point (below existing Niagara Falls WWTP).
- The assessment was based on the dissolved oxygen criteria for warm water fisheries (47% of saturation below 20ºC and 4 mg/L above 20ºC).

The allowable effluent $CBOD_5$ concentration was estimated by re-arranging the following equation:

$$Q_d D_d = Q_r D_r - f Q_r B_r + Q_e D_e - f Q_e B_e$$

Where: Q_d downstream flow (m^3/s) equal to sum of upstream and effluent flows,
Q_r upstream flow (m^3/s),
Q_e effluent flow (m^3/s),
D_d downstream dissolved oxygen concentration (mg/L) equal to guideline,
D_r upstream dissolved oxygen concentration (mg/L),
D_e effluent dissolved oxygen concentration (mg/L),
B_r upstream $CBOD_5$ concentration (mg/L),
B_e effluent $CBOD_5$ concentration (mg/L), and
f fraction of CBOD5 consumed in study area (assumed to be 0.5).

Estimates of the allowable monthly effluent $CBOD_5$ concentrations are provided in Table 14 for three levels of effluent dissolved oxygen saturation (10%, 50%, and 90%). Allowable concentrations for $CBOD_5$ are all greater than the minimum standard limit for secondary treated effluent of 15 mg/L.

The results indicate that allowable $CBOD_5$ concentrations are not sensitive to the dissolved oxygen levels in the effluent. Therefore, effluent dissolved oxygen concentration equal to 50% of the saturation concentration is recommended. The corresponding allowable monthly effluent $CBOD_5$ concentrations will be carried forward in this assessment.

Table 14: Estimated Allowable Monthly $CBOD_5$ Concentrations Based on Effluent Dissolved Oxygen

Month	Allowable Effluent $CBOD_5$ Concentration		
	Eff DO = 10% Sat[1]	Eff DO = 50% Sat[1]	Eff DO = 90% Sat[1]
January	12,241	12,253	12,264
February	12,852	12,863	12,874
March	13,824	13,835	13,846
April	14,349	14,359	14,368
May	12,946	12,954	12,962
June	9,297	9,304	9,311
July	7,091	7,098	7,104
August	**5,869**	**5,876**	**5,882**
September	5,876	5,883	5,890
October	7,022	7,030	7,037
November	7,951	7,960	7,969
December	8,959	8,969	8,979

Note:

1. Dissolved oxygen concentration in effluent expressed as percent of saturation.
2. **Bold** values indicate maximum allowable effluent concentrations carried forward in assessment.

3.2.3 Mass Balance Modelling for Total Suspended Solids

The assessment of TSS was based on the annual 75th percentile of the measured data in the Niagara River (11.3 mg/L) because there was insufficient data to establish monthly or seasonal values. The assessment was based on an allowable increase of TSS of 5 mg/L over the background conditions.

The allowable effluent TSS concentration was estimated by re-arranging the following equation:

$$(Q_r + Q_e)(C_r + \Delta C) = Q_r C_r + Q_e C_e$$

Where: Q_r upstream flow (m³/s),
Q_e effluent flow (m³/s),
C_r upstream TSS (mg/L),
C_e effluent TSS (mg/L), and
ΔC allowable TSS concentration increase (5 mg/L).

The estimated allowable monthly effluent concentrations for TSS are provided in Table 15 and indicate that the allowable effluent TSS concentration show little variation through the year.

Table 15: Estimated Allowable Monthly Effluent Total Suspended Solids Concentrations

Month	Allowable Total Suspended Solids (mg/L)
January	5,178
February	5,102
March	5,023
April	5,241
May	5,241
June	5,213
July	5,420
August	5,350
September	5,254
October	5,133
November	4,963
December	**4,932**

Note:

1. **Bold** values indicate maximum allowable effluent concentrations carried forward in assessment.

3.3 Mixing Zone Assessment (CORMIX Modelling)

This section provides the modelling and analysis included in the mixing zone assessment for the preferred outfall location into Chippewa Creek and includes the following:

- Estimates of the required effluent dilution required to meet PWQOs in the effluent plume based on the recommended effluent limits and background water quality.
- Development of a conceptual design for the outfall that will provide adequate performance under a range of environmental conditions and effluent flow rates.

- Prediction of the performance of the outfall design in terms of downstream mixing and dilution of the effluent plume under design flow conditions.
- Completion of a sensitivity analysis of outfall performance for variations in effluent flow rate and creek flows.

The mixing zone assessment assumes that the effluent will be discharging at a design flow of 0.35 m^3/s (30 MLD). The effluent discharge rate is expected to range from 0.23 m^3/s (20 MLD) during low flow periods to 1.39 m^3/s (120 MLD) during rainfall events.

3.3.1 Modelling Approach for Mixing Zone

The Cornell Mixing Zone Expert System (CORMIX) model, recognized by US EPA for mixing zone analysis, was used to conduct the assessment of effluent discharge and mixing processes and to quantify the dilution and mixing characteristics in the immediate vicinity of the discharge.

3.3.2 Required Effluent Dilution

The required dilution to either meet the applicable criteria (PWQO or CCME) was estimated on a monthly basis using background water quality in Chippewa Creek (Section 2.2.3) and recommended effluent limits (Section 4.7). Because there is no criterion for $CBOD_5$, the corresponding required dilution to meet criteria could not be estimated. The results of this analysis are summarized in Table 16.

Table 16: Summary of Estimated Effluent Dilution to Meet Water Quality Criteria

Parameter	Criteria or PWQO (mg/L)	Required Dilution to Meet Criteria	
		Minimum	Maximum
Total Ammonia[1]	0.14 to 1.51	2.26:1	8.18:1
Nitrate[2]	3.00	6.99:1	7.35:1
E. coli[1]	100	2.03:1	2.12:1
Total Phosphorus[1]	0.03	na[5]	**196:1**
$CBOD_5$	na[6]	na[6]	na[6]
TSS[1,4]	12.43	3.27:1	

Notes

[1] Criteria based on PWQO

[2] Criteria based on CCME Guidelines

[3] PWQO for total ammonia is based in monthly water temperature and pH using unionized criteria of 0.0164 mg/L as N for unionized ammonia.

[4] PWQO for TSS based on 10% increase over background concentration

[5] Not available for several months when background concentrations of total phosphorus exceed PWQO (0.03 mg/L)

[6] Not available – no criteria for $CBOD_5$

With the exception of total phosphorus, all the parameters with an applicable criterion require an effluent dilution of less than 10:1 to meet the criterion. The required dilution for total phosphorus can be as high as 196:1. Based on the required dilution for total phosphorus, a required dilution of 200:1 was used in subsequent assessments to compare the outfall performance for various conditions. Additionally, a dilution of 20:1 was also used for comparison as it represents 10% of the maximum required dilution.

3.3.3 Conceptual Outfall Design

The preferred discharge location is from the south bank of Chippewa Creek. Based on surveyed transects (Golder 2019), the creek channel in the area of the outfall is effectively a constructed channel with a uniform width, depth and side slopes that follows the original path of the Welland River prior to the construction of the HEPC. The channel is approximately 100 m wide at the surface and has a maximum depth of 12.6 m. The side slopes are approximately 2:1 (horizontal:vertical). The depth averaged width of the channel is approximately 76 m and the cross-sectional are was estimated to be 959 m².

The following points provide details of the conceptual outfall design that is also shown on Figure 10:

- Multiport diffuser with three duckbill valve ports angled 45° above horizontal (θ).
- The diffuser length (L_D) is 24 m with 12 m spacings between the ports.
- The distance from riverbank for the first port is 20 m and the distance to the centre of the diffuser is 32 m (DISTB).
- The ports are located 0.5 m above the creek bed (h_0).
- The ports are oriented in a downstream direction (e.g., pointed in same direction as flow during normal operation of the ICD).
- The diffuser is oriented perpendicular to the shoreline and current direction.

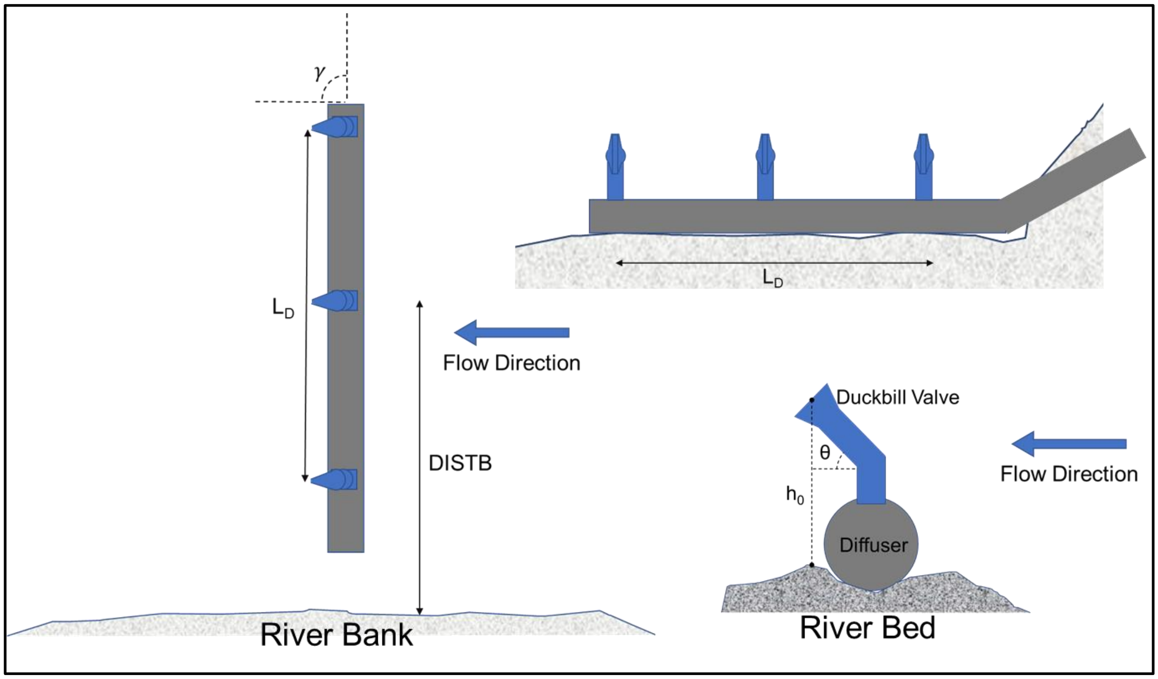


Figure 10: Schematic Views of The Multiport Diffuser

A TideFlex 250 duckbill valve outfall was selected for the conceptual design and is shown on Figure 11. Duckbill valves are made of flexible material that will generate variable effective cross section as a function of pressure and flow inside the duckbill valves, which provide higher jet exit velocities in low design flows and lower jet exit velocities in high design flows when compared to a conventional port. Duckbill valves also provide lower head losses than typical round ports that may be beneficial to the design of the treatment plant itself.

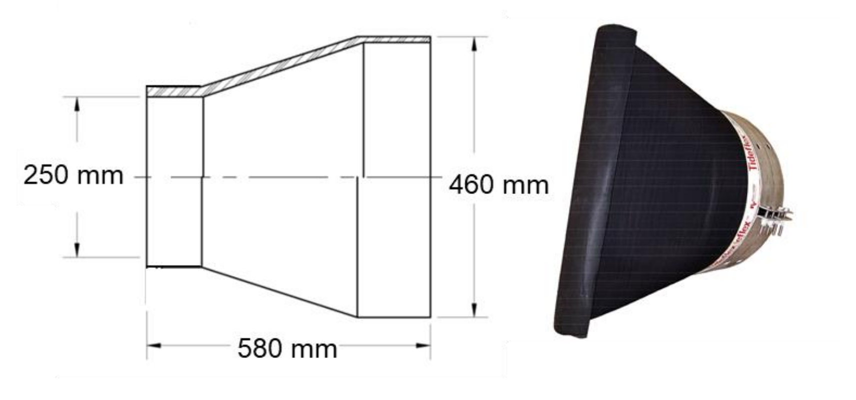


Figure 11: TideFlex 250 Duckbill Valve Dimensions

Wide bill TideFlex diffuser 250 characteristics such as jet exit velocity and total headloss are provided by TideFlex Technologies and shown on Figure 12.

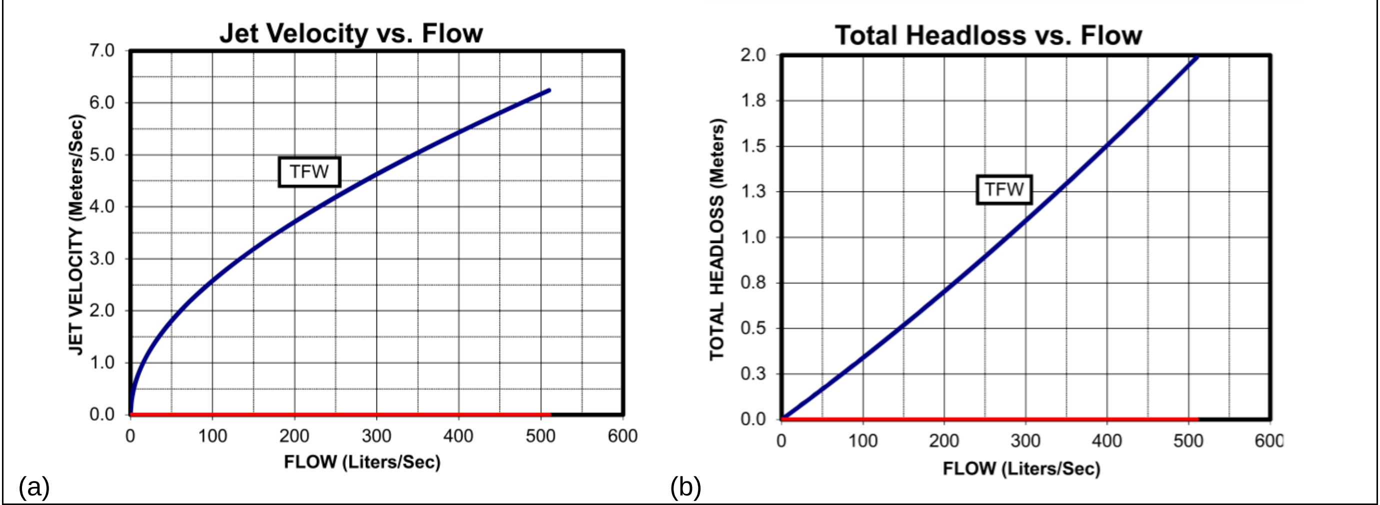


Figure 12: (a) Jet velocity and (b) Headloss for TideFlex 250 Duckbill Valve

While the design flow for the effluent is 30 MLD, the effluent flow rate is expected to vary from a low flow of 20 MLD up to 120 MLD for peak hourly flows. The operational parameters of the duckbill valve for the expected range of effluent flow rates are presented in Table 17.

Table 17: Jet Initial Flow Characteristics for TideFlex 250

Total flow		For Each TideFlex Port			
MLD	(m^3/s)	Flow (m^3/s)	Jet Velocity (m/s)	Total Headloss at Diffuser (m)	Effective Area (cm^2)
20	0.23	0.077	2.2	0.3	340
30	0.35	0.117	2.8	0.4	417
120	1.39	0.463	5.9	1.8	783

3.3.4 Selected Scenarios

This section outlines the selection of the scenarios used in the mixing zone assessment and considered the following factors:

- Expected flows from the proposed WWTP,
- Effluent buoyancy related effects based on water temperature and dissolved solids, and
- Expected range of flows in Chippewa Creek.

As stated earlier, the mixing zone assessment assumes that the effluent will be discharging at a design flow of 0.35 m³/s (30 MLD) but the effluent discharge rate is expected to range from 0.23 m³/s (20 MLD) during low flow periods to 1.39 m³/s (120 MLD) during rainfall events.

Monthly water temperatures for Chippewa Creek were estimated from data collected in the Niagara River (NOAA 9063020, 2007 to 2019) while the effluent temperatures for the new WWTP were based on recorded water temperatures from the existing Niagara Falls WWTP (2015 to 2018). The water temperatures used represent the average monthly value of the measured data. Monthly ambient water temperature varies from 0.4°C to 23.7C° from February to August and monthly effluent temperature changes from 9.5ºC to 21.7ºC from January to August as shown on Figure 13.

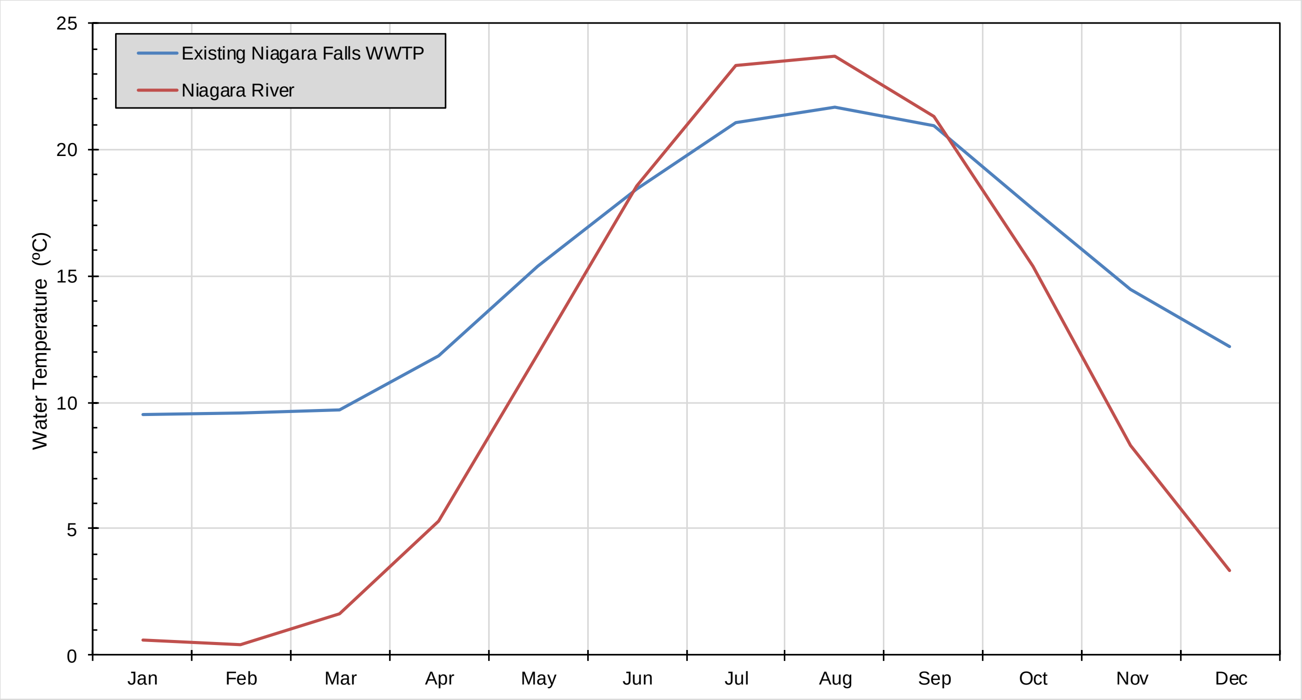


Figure 13: Monthly Temperatures for Effluent and Ambient Water

The dissolved solids concentrations in Chippewa Creek were based on conductivity measurements in the Niagara River (NOAA 9063020, 2007 to 2019). In general, the monthly average conductivities are consistent year-round and ranged from 277 to 295 µmhos/cm which correspond to dissolved solids concentrations that range from 154 to 164 mg/L. Neither dissolved solids nor conductivity data was available for the existing Niagara Falls WWTP. However, because the drinking water source for Niagara Falls is also the Niagara River, it was assumed that the dissolved solids in the effluent were the same as those in the Niagara River.

The densities of the effluent and Chippewa Creek were estimated based on the water temperatures and dissolved solids concentrations. Figure 14 shows the estimated monthly values for the ambient density (ρ_a) and effluent density (ρ_0). Density differences between the creek and effluent ($\rho_a - \rho_0$) show that from June to September the effluent is denser than the ambient water (negative value on Figure 15) which would result in an effluent plume that may have a tendency to sink to the bottom. However, the design of the outfall (e.g., upward orientation of ports and exit velocities) may be able to counteract some of the sinking tendencies.

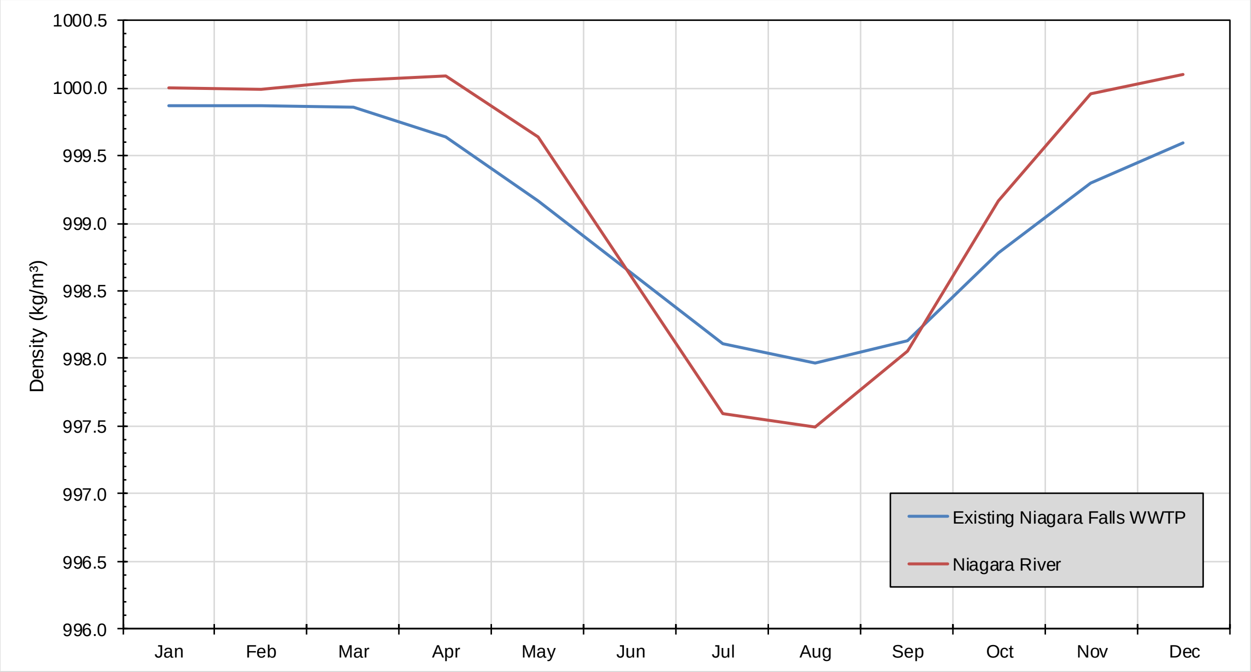


Figure 14: Monthly Density for Effluent and Ambient Water

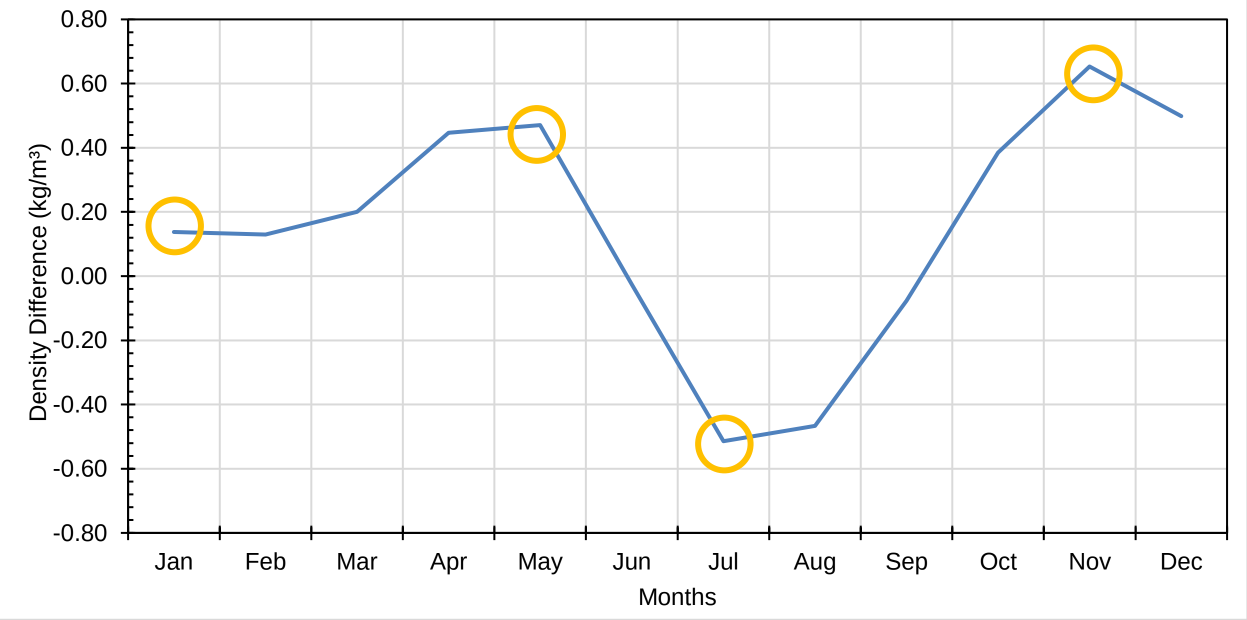


Figure 15: Ambient Water Density Difference with Respect to Effluent Density ($\rho_a - \rho_0$)

Flows in Chippewa Creek for the mixing zone assessment were estimated based on daily flows in the HEPC (2016 to 2018) less estimated inflows from the Welland River East and are summarized in Table 18.

Table 18: Estimated Monthly Flow Statistics for Chippewa Creek at Preferred Discharge Location

Parameter	Minimum Flow (m^3/s)	Average Flow (m^3/s)	Maximum Flow (m^3/s)
January	404	416	443
February	412	407	421
March	375	376	408
April	378	391	449
May	394	395	409
June	378	409	429
July	413	441	472
August	426	443	469
September	413	422	439
October	378	390	402
November	369	397	426
December	407	423	468

The primary scenarios for the assessment of the outfall design were selected to include a range of conditions that can be expected. Maximum absolute density difference in each season was selected (orange circles on Figure 15) to ensure that the selected scenarios included the critical conditions with respect to effluent buoyancy. January, May, and November were selected to represent the month where the effluent was most buoyant (e.g., effluent tends to float) while July was selected as the least buoyant month (e.g., effluent tends to sink). In all the primary scenarios, the minimum monthly flow and design effluent flows (30 MLD) were used. The monthly ambient and discharged effluent characteristics are summarized in Table 19.

Table 19: Summary of Ambient and Effluent Characteristics Used in Mixing Zone Assessment

Flow Information		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ambient Conditions	Low Flow (m^3/s)	404	412	375	378	394	378	413	426	413	378	369	407
	Current Speed (m/s)	0.42	0.43	0.39	0.39	0.41	0.39	0.43	0.44	0.43	0.39	0.38	0.42
	Water Temperature (ºC)	0.6	0.4	1.6	5.3	11.9	18.6	23.3	23.7	21.3	15.4	8.3	3.4
	Conductivity (µS/cm@25C)	294.9	294.2	289.5	283.2	276.9	276.5	278.1	283.5	282.0	282.6	280.2	283.4
	Total Dissolved Solids (mg/L)	164.5	164.1	161.5	158.0	154.4	154.2	155.1	158.1	157.3	157.6	156.3	158.1
	Density (ρ_a) (kg/m^3)	1,000.01	999.99	1,000.05	1,000.08	999.63	998.61	997.59	997.50	998.05	999.17	999.96	1,000.09
Effluent Conditions	Water Temperature (ºC)	9.5	9.6	9.7	11.9	15.4	18.4	21.1	21.7	21.0	17.7	14.5	12.2
	Total Dissolved Solids (mg/L)	164.5	164.1	161.5	158.0	154.4	154.2	155.1	158.1	157.3	157.6	156.3	158.1
	Density (ρ_0) (kg/m^3)	999.87	999.87	999.85	999.64	999.16	998.64	998.10	997.96	998.13	998.78	999.30	999.60
Effluent Buoyancy	Density Difference ($\rho_a - \rho_0$) (kg/m^3)	0.14	0.13	0.20	0.45	0.47	-0.02	-0.51	-0.47	-0.08	0.39	0.65	0.50
	Buoyancy	Float	Float	Float	Float	Float	Sink	Sink	Sink	Sink	Float	Float	Float

3.3.5 Expected Outfall Performance

The performance and predicted downstream mixing of the plume for the primary scenarios was completed using CORMIX for a maximum downstream distance of 1,000 m. The results of the modelling are summarized in Table 20 and are presented graphically on Figures 16 to 18, respectively. The spatial extents of the January and July plumes are shown on spatial extent maps but were not prepared for May and November since they were similar to January. The following points summarize key results of the modelling:

- Scenarios with a floating plume (January, May, and November) had consistent results with a 200:1 dilution being reached in less than 5 m from the outfall.
- For the July scenario, CORMIX predictions in the turbulent mixing zone are for plumes from individual ports. The individual plumes become joined at the end of the turbulent mixing zone approximately 130 m downstream of the diffuser.
- For January, May, and November scenarios, the turbulent mixing zone is predicted to be 12 m in length and provide a dilution of greater than 340:1.
- For July, the turbulent mixing zone is predicted to be 133 m in length and provide a dilution of approximately 92:1. In July, a dilution of 200:1 is predicted to occur at a distance of just over 300 m.
- Beyond the turbulent mixing zone, mixing of the effluent is slower and is determined by the ambient conditions (passive mixing) in all the scenarios.
- For January, May, and November scenarios, the plume is expected to become vertically mixed with the ambient water at distances between 111 and 150 m.
- In July, the negative buoyancy of the plume (e.g., tendency to sink) is expected to cause the plume to remain vertically stratified in the bottom 2 m of the channel and travel along the channel bottom beyond a distance of 1,000 m.
- CORMIX does not predict the plume to become laterally well mixed within the modelled area.

Table 20: Summary of Mixing Zone Modelling for a Conceptual Outfall Design

Scenario	Turbulent Mixing Zone[1]			20:1 Dilution Plume		200:1 Dilution Plume		Distance to Vertically Mixed (m)
	Length (m)	Width (m)	Dilution	Length (m)	Width (m)	Length (m)	Width (m)	
Design Flow in January	12.0	24	350:1	0.1	24	4.0	24	111
Design Flow in May	12.0	24	342:1	0.1	24	4.1	24	130
Design Flow in July	133	4.2[2]	91.7:1	12.8	1.9[2]	328	47	-
Design Flow in November	12.0	24	342:1	0.1	24	4.1	24	150

Notes:

1. Turbulent mixing zone assumed to be the first output module from CORMIX and represents the mixing that is mostly influenced by the design of the outfall.
2. For the July scenario, CORMIX predictions in the turbulent mixing zone are for plumes from individual ports. The individual plumes become joined at the end of the turbulent mixing zone.

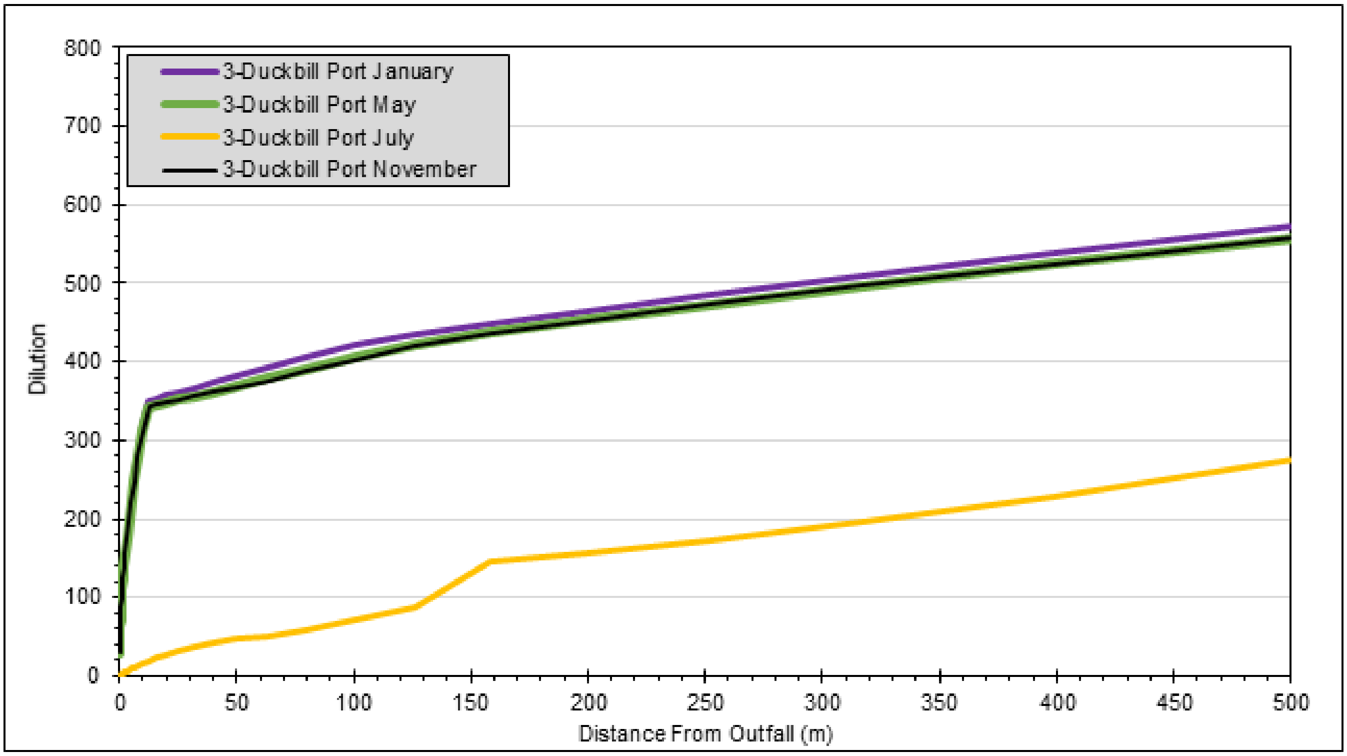
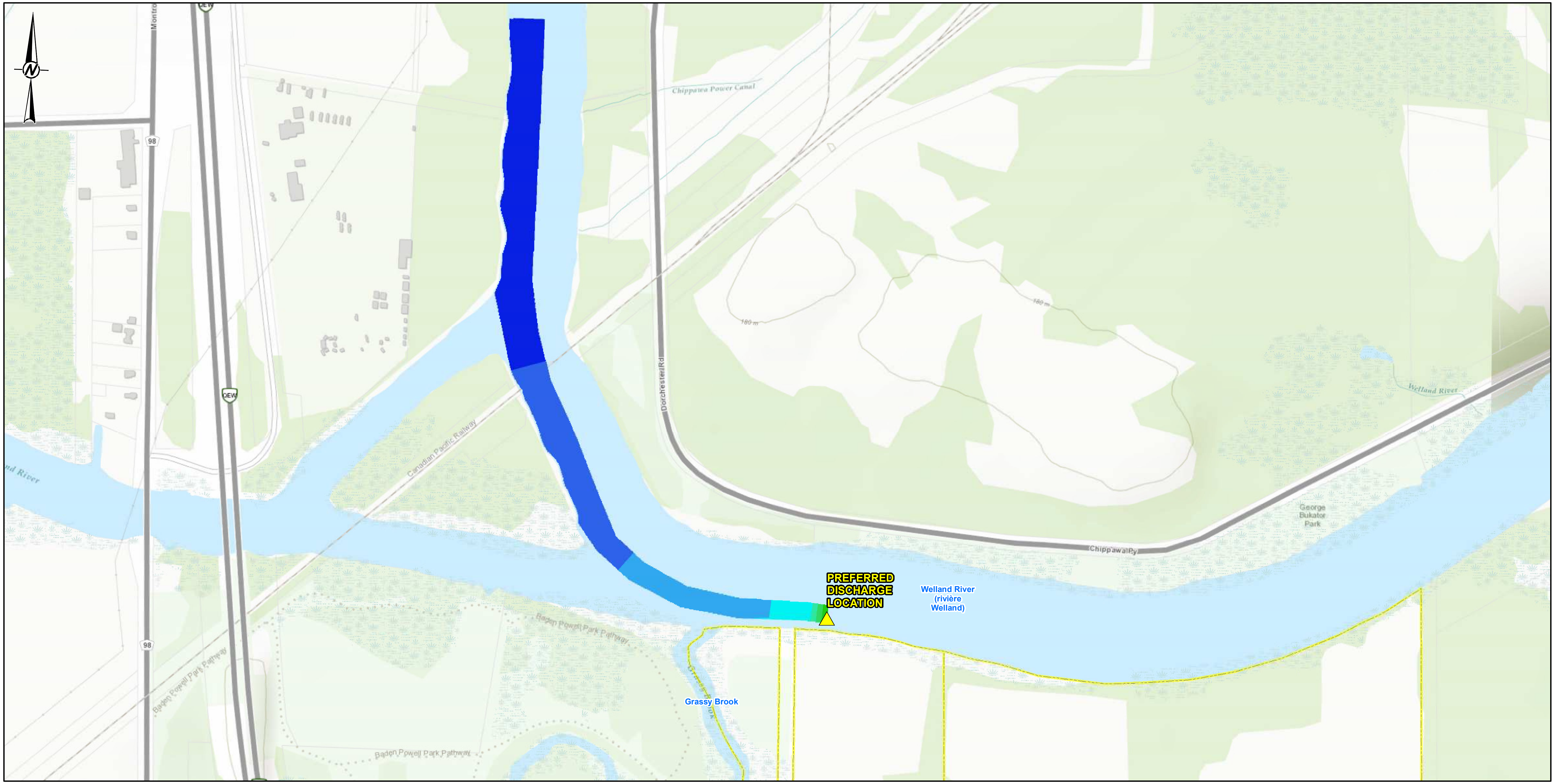


Figure 16: Distance-Dilution Plots for Primary Scenarios at 30 MLD



LEGEND

△	PREFERRED DISCHARGE LOCATION
🟦	WATERBODY
☐	PREFERRED SITE LOCATION 8

PLUME DILUTION

🟩	0 - 100
🟩	100 - 200
🟩	200 - 300
🟦	300 - 400
🟦	400 - 500
🟦	500 - 600
🟦	600- 700

0 100 200

1:5,000 METRES

REFERENCE(S)

1. BASE DATA - MNRF LIO, OBTAINED 2019
2. PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY, © QUEENS PRINTER 2019
3. SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

CLIENT
REGIONAL MUNICIPALITY OF NIAGARA

PROJECT
SOUTH NIAGARA FALLS WASTEWATER SOLUTIONS
SCHEDULE C CLASS ENVIRONMENTAL ASSESSMENT

CONSULTANT
GOLDER

YYYY-MM-DD	2020-05-19
DESIGNED	PR
PREPARED	PR
REVIEWED	GVA
APPROVED	GVA

TITLE
PREDICTED EFFLUENT PLUME IN JANUARY

PROJECT NO.	CONTROL	REV.	FIGURE
18104462	0010	0.0	17

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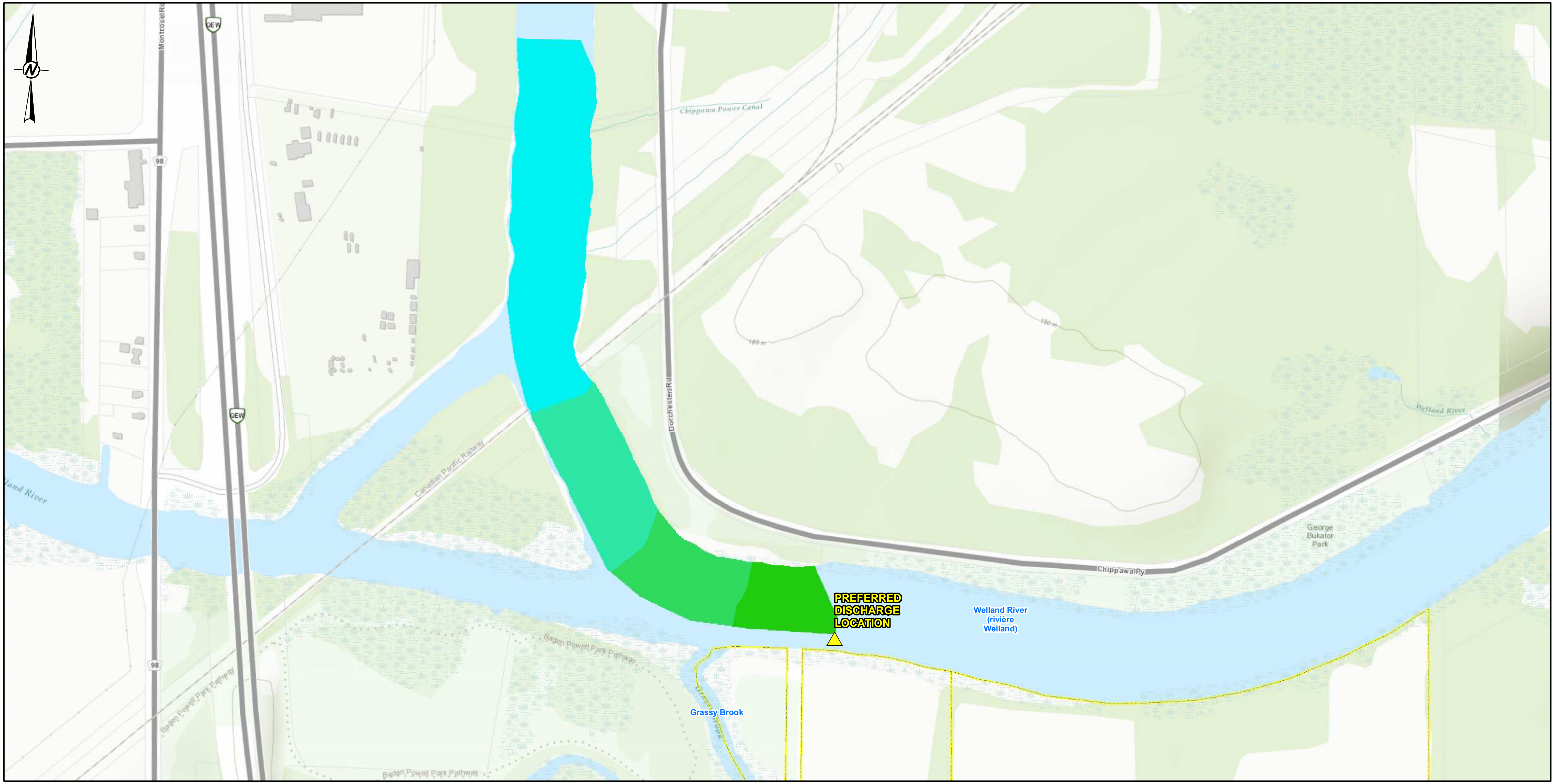
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25mm

0



LEGEND

- △ PREFERRED DISCHARGE LOCATION
- 🟦 WATERBODY
- ▭ PREFERRED SITE LOCATION 8

PLUME DILUTION

- 🟩 0 - 100
- 🟩 100 - 200
- 🟩 200 - 300
- 🟦 300 - 400
- 🟦 400 - 500
- 🟦 500 - 600
- 🟦 600- 700

0 100 200
1:5,000 METRES

REFERENCE(S)

1. BASE DATA - MNRF LIO, OBTAINED 2019
2. PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY, © QUEENS PRINTER 2019
3. SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

CLIENT
REGIONAL MUNICIPALITY OF NIAGARA

PROJECT
SOUTH NIAGARA FALLS WASTEWATER SOLUTIONS
SCHEDULE C CLASS ENVIRONMENTAL ASSESSMENT

CONSULTANT
GOLDER

YYYY-MM-DD	2020-05-19
DESIGNED	PR
PREPARED	PR
REVIEWED	GVA
APPROVED	GVA

TITLE
PREDICTED EFFLUENT PLUME IN JULY

PROJECT NO.	CONTROL	REV.	FIGURE
18104462	0010	0.0	18

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25mm

3.3.6 Sensitivity Analysis

This section provides a sensitivity analysis of the modelling results to effluent flow rate and flow in Chippewa Creek.

Effluent Flow Rate Variations

A sensitivity analysis was performed for the effluent flow rate for the months of January and July by considering effluent flow rates of 20 MLD and 120 MLD. The effects of variations in effluent flow rate are shown on Figure 19.

In January (plume tends to float), the dilution increased for the reduced effluent flow rate and decreased for the elevated effluent flow rate. This suggests that the increased exit velocity at higher flow rates produced a longer and thinner plume when compared to the design flow.

In July (plume tends to sink) there was a small increase in the far-field dilution when the effluent flow rate decreased. However, when the effluent flow rate increased, the near-field dilution increases. This suggests that the increased exit velocity counteracts some of the negative buoyancy of the effluent in July.

In all cases except the high flow January scenario, the plume dilution reaches 200:1 in a distance of less than 350 m. However, because the high flow cases are expected to have a duration of a few hours at most, there are no adverse affects expected from the low effluent dilution expected.

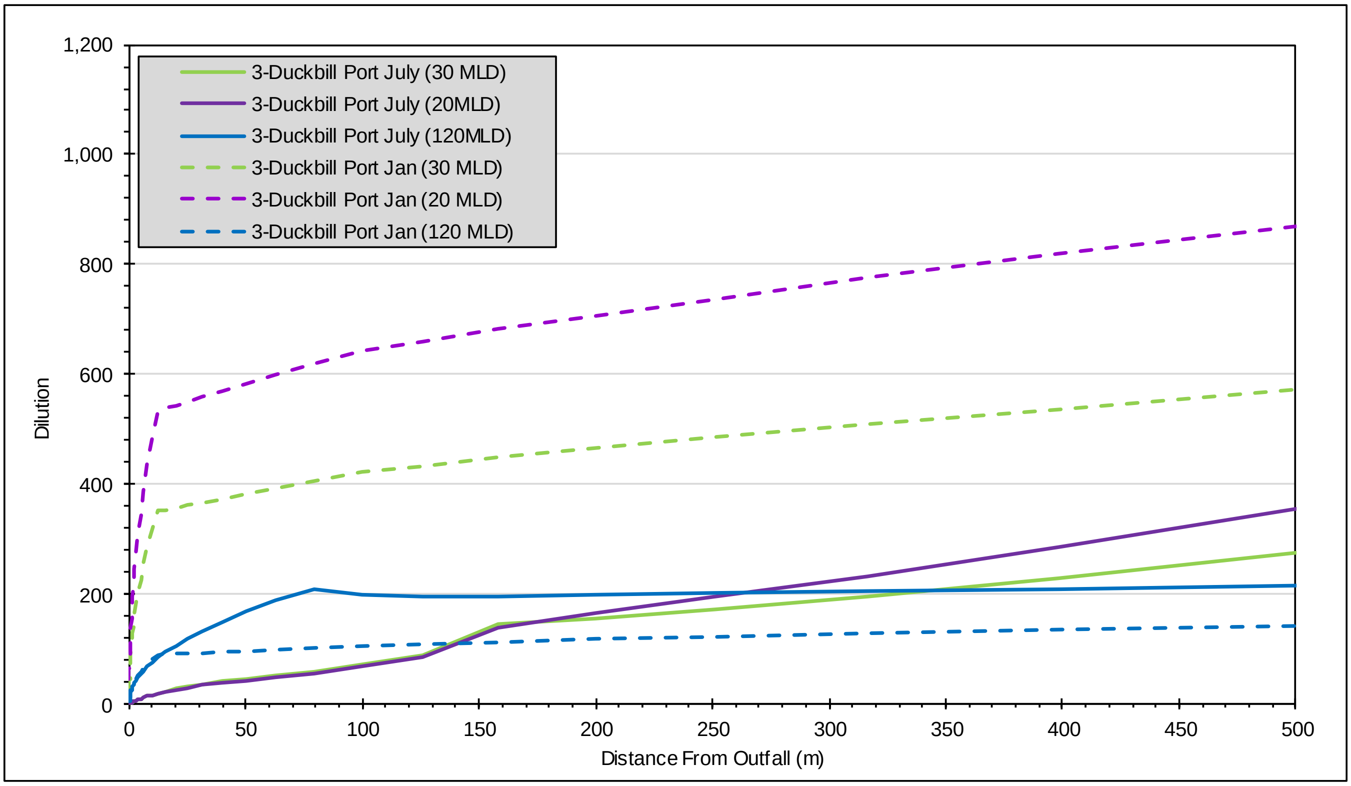


Figure 19: Distance-Dilution Plots for Effluent Flow Rate Variation Sensitivity Analysis

Ambient Flow Rate Variations

Changes in the flow in Chippewa Creek will change the current speed in the area of the outfall and can potentially affect the performance of the outfall. A sensitivity analysis was performed that compared the outfall performance for selected maximum flows from Table 18. July was selected as the highest Chippewa Creek flow (472 m^3/s) when the effluent plume is expected to have a tendency to sink and December was selected as the highest Chippewa Creek flow (468 m^3/s) when the effluent plume is expected to have a tendency to float.

In July and November, the ambient current speeds are expected to increase to 0.49 m/s when the high flow conditions in Chippewa Creek are considered.

The sensitivity analysis for the ambient flow rate variation showed that an increase in the ambient current velocity enhanced the mixing of the effluent, increasing by approximately 30% for December (plume tends to float) in both the near-filed and far-field as shown on Figure 20. However, in July (plume tends to sink) the increased current speeds had no effect in the near field and only a small decrease (10%) of the effluent dilution in the far-field.

The sensitivity analysis suggests that there are no concerns related to outfall performance during high flow conditions in Chippewa Creek. In both cases, the effluent dilution reaches 200:1 at distances similar to the corresponding primary scenarios.

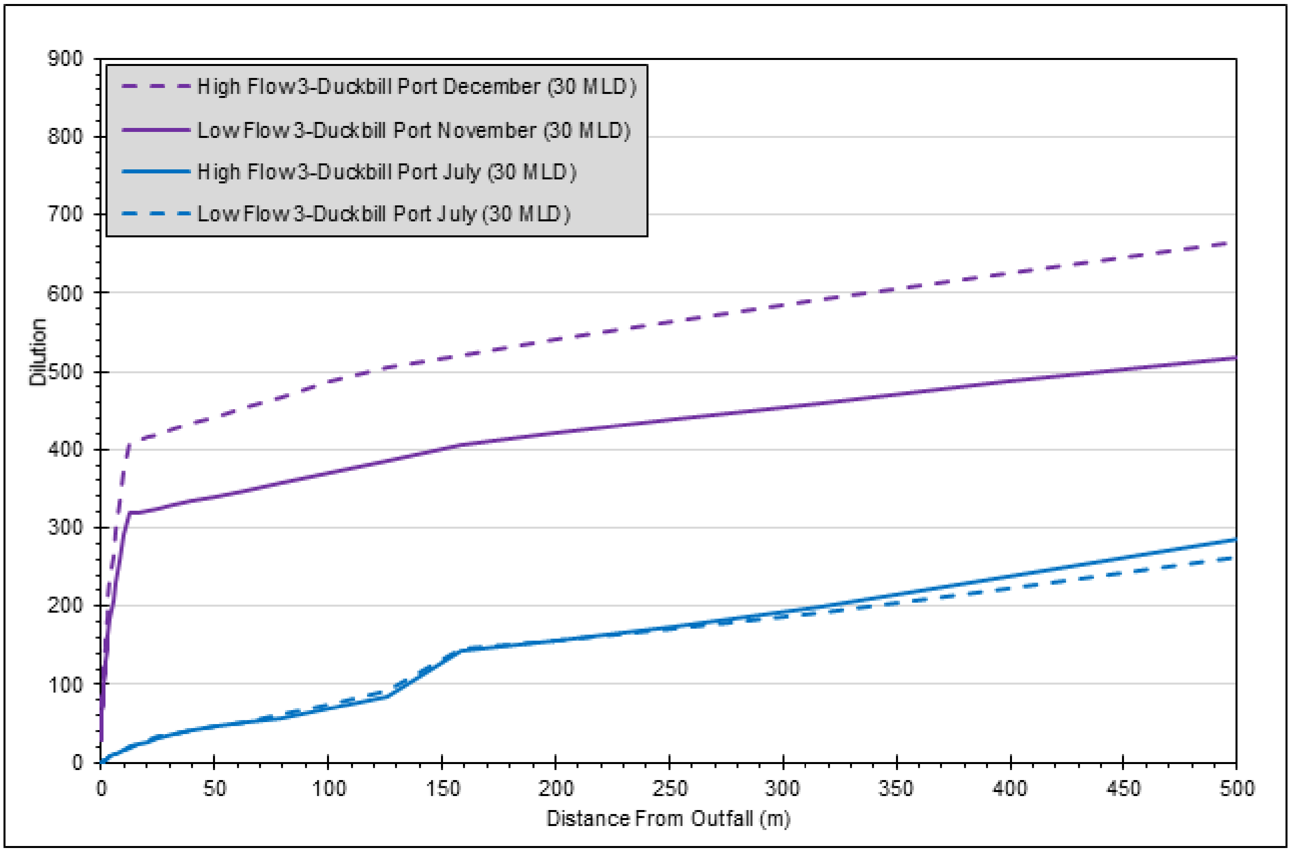


Figure 20: Distance-Dilution Plots for Ambient Flow Rate Variation Sensitivity Analysis

3.3.7 Mixing Zone Assessment Summary

The results of the mixing zone assessment are summarized in the following points;

- The conceptual outfall design that includes duckbill valves provides reasonable performance for most of the scenarios modelled. The only exception is during high effluent flow rates (120 MLD) during the summer when plume dilution does not reach 200:1 within 1,000 m. However, high effluent flow rates are expected to occur infrequently and have a duration of a few hours or less.
- In periods when the plume has a tendency to float (October to May), a 20:1 dilution is expected within 1 m of the outfall.
- In periods when the plume has a tendency to sink (June to September), the sinking jets produce lower dilution factors closer to outfall and the distance to a 20:1 dilution is approximately 13 m
- In periods when the plume has a tendency to sink (June to September), the sinking jets produce lower dilution factors closer to outfall and the distance to a 200:1 dilution is approximately 350 m
- In periods when the plume has a tendency to float (October to May), a 200:1 dilution is expected within 5 m of the outfall.
- Variations in the Chippewa Creek flow are not expected to noticeably affect the performance of the outfall design.
- In general, variations in the effluent flow rate are not expected to adversely affect the performance of the outfall design.

4.0 DERIVATION OF RECOMMENDED EFFLUENT LIMITS

The following sections outline the development of the recommended effluent objectives and limits based on the ACS and include the following details:

- the applicable water quality assessment points;
- if specific parameters meet or exceed relevant criteria and whether a Policy 2 Condition applies;
- the critical months for each parameter; and
- an appropriate treatment technology.

The available assimilative capacity is first considered without the effluent inputs from the new WWTP to determine if there is any capacity in the system for each of the parameters at the local compliance point. In cases where there was assimilative capacity to assimilate effluent, a treatment technology was selected that could meet the maximum allowable effluent concentrations for each parameter. In cases were there was no available assimilative capacity (e.g., Policy 2), the effluent quality was selected such that the effluent concentration would be equal or less than the existing background conditions.

The typical effluent quality for the available treatment technologies considered in this study, based on information available from the MECP (MECP 2019), are summarized in Table 21.

Table 21: Typical Effluent Quality for Various Treatment Processes

Process	Effluent Parameter[1,2]			
	$CBOD_5$ (mg/L)	Total Suspended Solids (mg/L)	Total Phosphorus (mg/L)	Total Ammonia (mg/L as N)[3]
Conventional Activated Sludge System				
Without Phosphorus Removal	25	25	3.5	15 to 20
With Phosphorus Removal	25	25	<1.0	15 to 20
With Phosphorus Removal and Filtration	10	10	0.3	15 to 20
With Nitrification and Phosphorus Removal	25	25	<1.0	<3
Membrane Bioreactor				
Without Phosphorus Removal	2	1	3.0	15 – 20
With Phosphorus Removal	2	1	0.1	15 – 20
With Phosphorus Removal and Filtration	2	1	0.1	0.3

Notes:

[1] Taken from “Design Considerations for Sewage Treatment Plants” (MECP 2019)

[2] The above values are based on raw sewage with $CBOD_5$ = 150-200 mg/L, Soluble $CBOD_5$ = 50% of $CBOD_5$, TSS = 150-200 mg/L, TP = 6-8 mg/L, TKN = 30-40 mg/L, TAN = 20-25 mg/L.

[3] TAN (total ammonia nitrogen) concentrations may be lower during warm weather conditions if nitrification occurs.

With regard to parameters not listed in Table 21, the following assumptions have been used:

- any treatment plant with disinfection can expect to have an *E. coli* concentration objective of less than 200 cfu/100 mL;

- if needed, aeration of the dissolved oxygen concentration in the final effluent can be provided to at least 80% of the saturation concentration; and
- The expected effluent nitrate concentration from an activated sludge system without denitrification was assumed to be 20 mg/L.

Other Considerations

In addition, the development on the effluent limits and objectives also considered the following;

- Section 6(1) of Wastewater Systems Effluent Regulations states that to be in accordance with the Fisheries Act (Canada, 2020);
  - a) the average CBOD demand due to the organic matter in the effluent does not exceed 25 mg/L;
  - b) the average concentration of suspended solids in the effluent does not exceed 25 mg/L;
  - c) the average concentration of total residual chlorine in the effluent does not exceed 0.02 mg/L, if chlorine, or one of its compounds, was used in the treatment of wastewater; and
  - d) the maximum concentration of unionized ammonia in the effluent is less than 1.25 mg/L, expressed as nitrogen (N), at 15ºC ± 1ºC.
- The common pH effluent objective and limit ranges specified in ECAs are 6.5 to 8.5 (PWQO) and 6.0 to 9.0, respectively.
- Where chlorination is used for disinfection, the common effluent objective for total residual chlorine is non-detectable while the common effluent limit is 0.02 mg/L as specified in the Fisheries Act.

The preferred discharge location will release effluent to the Chippewa Creek between Lyons Creek and Triangle Island. The existing water quality in Chippewa Creek is dominated by the water quality in the Niagara River. Under normal conditions, the effluent will travel downstream into the HEPC and eventually enter the Niagara River at the Sir Adam Beck GS. The local compliance point (A3) is in Chippewa Creek just upstream of Triangle Island and the system compliance point (A5) is in the HEPC below the existing Niagara Falls WWTP, so that the combined effects of both plants are considered in the ACS. The preferred discharge location is not expected to affect water quality in Welland River East or in the Niagara River upstream of the Sir Adam Beck GS.

In typical assimilative capacity assessments, it is expected that the low-flow conditions (e.g., worst case conditions) will result in the most restrictive conditions and the results from GoldSim and the mass balance modelling should be similar. In this assessment there are many cases where GoldSim predicts maximum allowable effluent concentrations that are lower than those predicted by the mass balance modelling. The differences occur because the flow conditions in the various inflows are independent and low-flow conditions do not necessarily occur at the same time for the different inflows (e.g., a high flow event after a rainfall event in the Welland River East at the same time as a low flow occurs in the HEPC due to the operation of the ICD). A review of the modelling results suggests that high flow events in the Welland River East occurring at the same time as low HEPC flows can alter the maximum allowable effluent concentrations in two ways:

1) Because the water quality in the Welland River East is degraded, the higher relative contribution of water into the from the river reduces the assimilative capacity at the system compliance point (below existing Niagara Falls WWTP).

2) Because the flow in Chippewa Creek is assumed to be the difference between the flow in the HEPC and the flow entering from the Welland River East, a high flow event in the river will cause a decrease in the Chippewa Creek flow and reduce the amount of water available for dilution.

The following sections outline the rationales for developing the proposed effluent limits based on existing conditions, results from all the modelling, specific MECP end-of-pipe toxicity limits, and the typical effluent quality from the available treatment technologies.

4.1 Total Phosphorus

The measured monthly 75th percentile total phosphorus concentrations in Chippewa Creek range from 0.021 mg/L (July and September) to 0.49 mg/L (December) and are effectively the same as the measured conditions in the Niagara River. There are additional constraints at the system compliance point caused by the discharge of effluent into the HEPC from the existing Niagara Falls WWTP and by the mass contribution from the Welland River East which exceeds objectives year-round.

The calculated maximum allowable effluent concentration for total phosphorus at the local and system compliance points and regulatory objectives are presented in Table 22.

Table 22: Maximum Allowable Monthly Total Phosphorus Concentrations for Discharge to Chippewa Creek

Month	GoldSim Modelling[1]		Mass-Balance Modelling[2]	
	Local Compliance Point (mg/L)	System Compliance Point (mg/L)	Local Compliance Point (mg/L)	System Compliance Point (mg/L)
January	nc	nc	nc	nc
February	nc	nc	nc	nc
March	2.7	nc	4.9	nc
April	2.2	nc	3.8	nc
May	3.2	nc	3.8	nc
June	7.6	nc	7.7	0.4
July	9.9	6.5	9.9	6.5
August	8.2	5.4	8.9	6.2
September	8.1	3.9	8.9	6.0
October	3.3	nc	5.3	0.1
November	nc	nc	nc	nc
December	nc	nc	nc	nc

Notes:

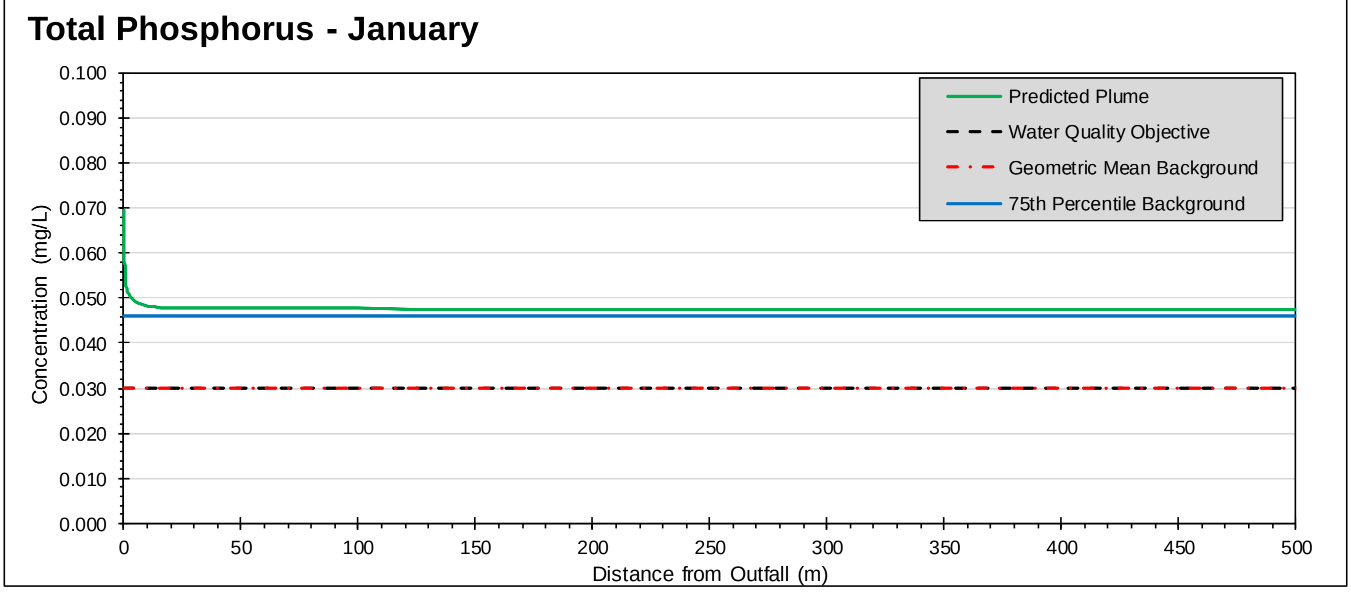
1. Calculated concentrations based on allowable mass capacity based on 5% probability of no exceedance.
2. Calculated based on low flow conditions occurring for all inflows simultaneously.
3. ‘nc’ denotes no assimilative capacity at compliance point.
4. Modelled results exclude effects of CSOs and WWTP bypasses.

The elevated total phosphorus concentrations under baseline conditions result in Policy 2 conditions at the local compliance point in the November to February. At the local compliance point, Chippewa Creek can accept total phosphorus concentration of 2.2 mg/L or greater in the effluent in all months except for November to February. At the system compliance point, elevated phosphorus concentrations under baseline conditions are experienced from October to June due to inputs from the Welland River East and existing Niagara Falls WWTP.

An effluent limit for total phosphorus of 0.75 mg/L is recommended based in the following rationale:

- On an annual basis, there is sufficient capacity to accept an effluent concentration greater than 0.5 mg/L.
- The effluent flow rate represents less than 0.1% of the total flow in Chippewa Creek and as such the contributions of the proposed discharge will cause negligible increase in the total phosphorus concentrations within Chippewa Creek and the HEPC.
- The elevated phosphorus concentration in Chippewa Creek are only experienced during October to February, which is outside the algae growing season. Furthermore, the elevated background phosphorus concentrations are the result of factors outside the study area (e.g., inflow from the Niagara River and Lyons Creek).
- Similarly, the effluent flow rate is insignificant when compared to the flow in the Niagara River below the Sir Adam Beck GS.

The predicted plume centreline concentration for January and July are provided on Figure 21 for an effluent discharge rate of 30 MLD. In January, while the plume is never expected to meet the PWQO for total phosphorus (0.03 mg/L) due to elevated background conditions, the plume is expected to be within 0.003 mg/L of the ambient within 10 m of the outfall. In July, the plume is expected to meet the PWQO at a downstream distance of approximately 125 m.



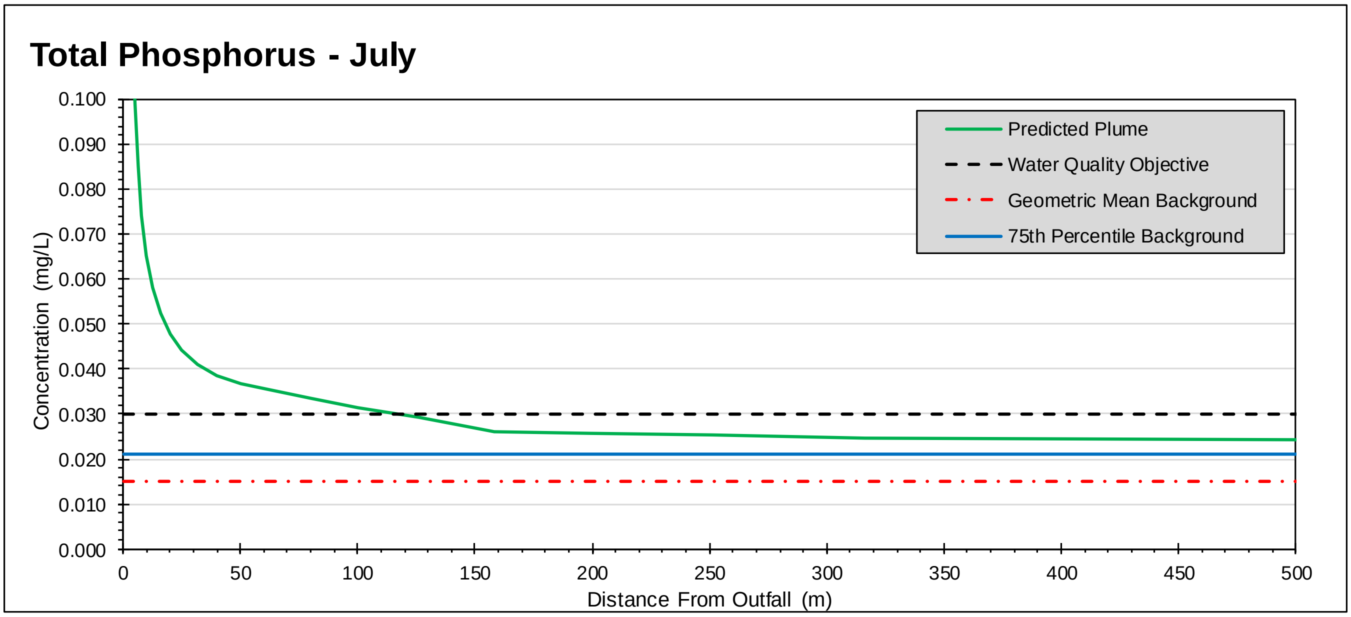


Figure 21: Predicted Total Phosphorus Concentrations Downstream of Outfall

The predicted effects of the proposed WWTP on the monthly total phosphorus concentrations in the receiving waters are summarized and compared to the predicted worst–case existing conditions in Table 23. The existing conditions are predicted using the mass balance model for low-flow conditions and assume that the existing Niagara Falls WWTP is operating at the rated capacity (68.3 MLD) and discharging effluent with a total phosphorus concentration equal to the ECA limits (0.75 mg/L).

The total phosphorus concentrations are expected to increase by approximately 0.0007 mg/L (0.7 µg/L) in Chippewa Creek and the HEPC, an increase of 3.2% or less. In the Niagara River, the increase in total phosphorous are predicted to be approximately 0.0001 mg/L (0.1 µg/L) which represents an increase of 0.3% or less.

Table 23: Summary of Predicted Effects of Project on Total Phosphorus Concentrations

Month	Chippewa Creek at Triangle Island (A3)			HEPC at Montrose Gate (A2)			HEPC Above SAB[1] (A5)			Niagara River Below SAB[1] (A6)		
	Existing (mg/L)	Future (mg/L)	Difference (mg/L)	Existing (mg/L)	Future (mg/L)	Difference (mg/L)	Existing (mg/L)	Future (mg/L)	Difference (mg/L)	Existing (mg/L)	Future (mg/L)	Difference (mg/L)
January	0.0461	0.0468	0.0007 (1.5%)	0.0489	0.0496	0.0007 (1.3%)	0.0504	0.0511	0.0007 (1.3%)	0.0464	0.0465	0.0001 (0.1%)
February	0.0311	0.0318	0.0007 (2.3%)	0.0335	0.0342	0.0007 (2.0%)	0.0351	0.0358	0.0007 (1.9%)	0.0314	0.0314	0.0001 (0.2%)
March	0.0252	0.0259	0.0007 (2.9%)	0.0313	0.0320	0.0007 (2.2%)	0.0329	0.0336	0.0007 (2.1%)	0.0258	0.0259	0.0001 (0.2%)
April	0.0264	0.0270	0.0007 (2.6%)	0.0308	0.0314	0.0007 (2.2%)	0.0323	0.0329	0.0007 (2.0%)	0.0267	0.0268	0.0001 (0.2%)
May	0.0264	0.0271	0.0007 (2.6%)	0.0290	0.0297	0.0007 (2.3%)	0.0305	0.0312	0.0007 (2.2%)	0.0266	0.0267	0.0001 (0.2%)
June	0.0226	0.0233	0.0007 (3.1%)	0.0281	0.0288	0.0007 (2.4%)	0.0296	0.0303	0.0007 (2.2%)	0.0231	0.0231	0.0001 (0.2%)
July	0.0208	0.0215	0.0007 (3.2%)	0.0228	0.0234	0.0006 (2.8%)	0.0243	0.0249	0.0006 (2.7%)	0.0210	0.0211	0.0001 (0.3%)
August	0.0217	0.0224	0.0007 (3.1%)	0.0230	0.0236	0.0007 (2.9%)	0.0245	0.0251	0.0007 (2.7%)	0.0219	0.0219	0.0001 (0.2%)
September	0.0215	0.0222	0.0007 (3.2%)	0.0230	0.0237	0.0007 (2.9%)	0.0246	0.0252	0.0007 (2.7%)	0.0217	0.0218	0.0001 (0.3%)
October	0.0249	0.0256	0.0007 (2.8%)	0.0284	0.0291	0.0007 (2.4%)	0.0300	0.0307	0.0007 (2.3%)	0.0252	0.0253	0.0001 (0.2%)
November	0.0333	0.0340	0.0007 (2.2%)	0.0372	0.0378	0.0007 (1.9%)	0.0387	0.0394	0.0007 (1.8%)	0.0337	0.0337	0.0001 (0.2%)
December	0.0492	0.0499	0.0007 (1.4%)	0.0526	0.0533	0.0007 (1.3%)	0.0542	0.0548	0.0007 (1.2%)	0.0496	0.0497	0.0001 (0.1%)
Annual	0.0290	0.0297	0.0007 (2.4%)	0.0322	0.0329	0.0007 (2.1%)	0.0338	0.0344	0.0007 (2.0%)	0.0291	0.0292	0.0001 (0.2%)

Notes:

[1] SAB – Sir Adam Beck GS

4.2 Nitrate

The measured 75th percentile nitrate concentrations in Chippewa Creek range from 0.16 mg/L (September) to 0.54 mg/L (February) and are effectively the same as the measured conditions in the Niagara River. The modelled baseline concentrations and calculated maximum allowable effluent concentration for nitrate at the local and system compliance points and regulatory objectives are presented in Table 24.

At the local and system compliance points, nitrate concentrations are below the regulatory objectives for each month. In general, the local compliance point provides the most restrictive conditions. Based on the modelling results, both the local and system compliance points can accept effluent nitrate concentrations in excess of 2,500 mg/L.

Based on the assumptions in Section 4.0, a conventional activated sludge system without denitrification is expected to provide effluent nitrate concentrations of 20 mg/L. As a result, nitrate limits would not be required for the proposed discharge location to Chippewa Creek.

Table 24: Maximum Allowable Monthly Nitrate Concentrations for Discharge to Chippewa Creek

Month	GoldSim Modelling[1]		Mass-Balance Modelling[2]	
	Local Compliance Point (mg/L)	System Compliance Point (mg/L)	Local Compliance Point (mg/L)	System Compliance Point (mg/L)
January	2,530	2,594	2,772	2,777
February	2,186	2,302	2,744	2,751
March	2,457	2,687	2,716	2,762
April	2,670	2,816	2,825	2,887
May	2,725	2,851	2,799	2,863
June	2,910	2,965	2,785	2,828
July	3,025	3,139	2,997	3,091
August	2,933	3,077	3,024	3,122
September	2,837	3,010	2,974	3,064
October	2,702	2,840	2,890	2,939
November	**2,553**	2,704	2,752	2,791
December	2,484	2,602	2,661	2,687

Notes:

1. Calculated concentrations based on allowable mass capacity based on 5% probability of no exceedance.
2. Calculated based on low flow conditions occurring for all inflows simultaneously.
3. Modelled results exclude effects of CSOs and WWTP bypasses.

The predicted plume centreline concentration for January and July are provided on Figure 22 for an effluent discharge rate of 30 MLD. In January and July, the plume is expected to meet the CCME guideline (3 mg/L) within a downstream distance of approximately 10 m.

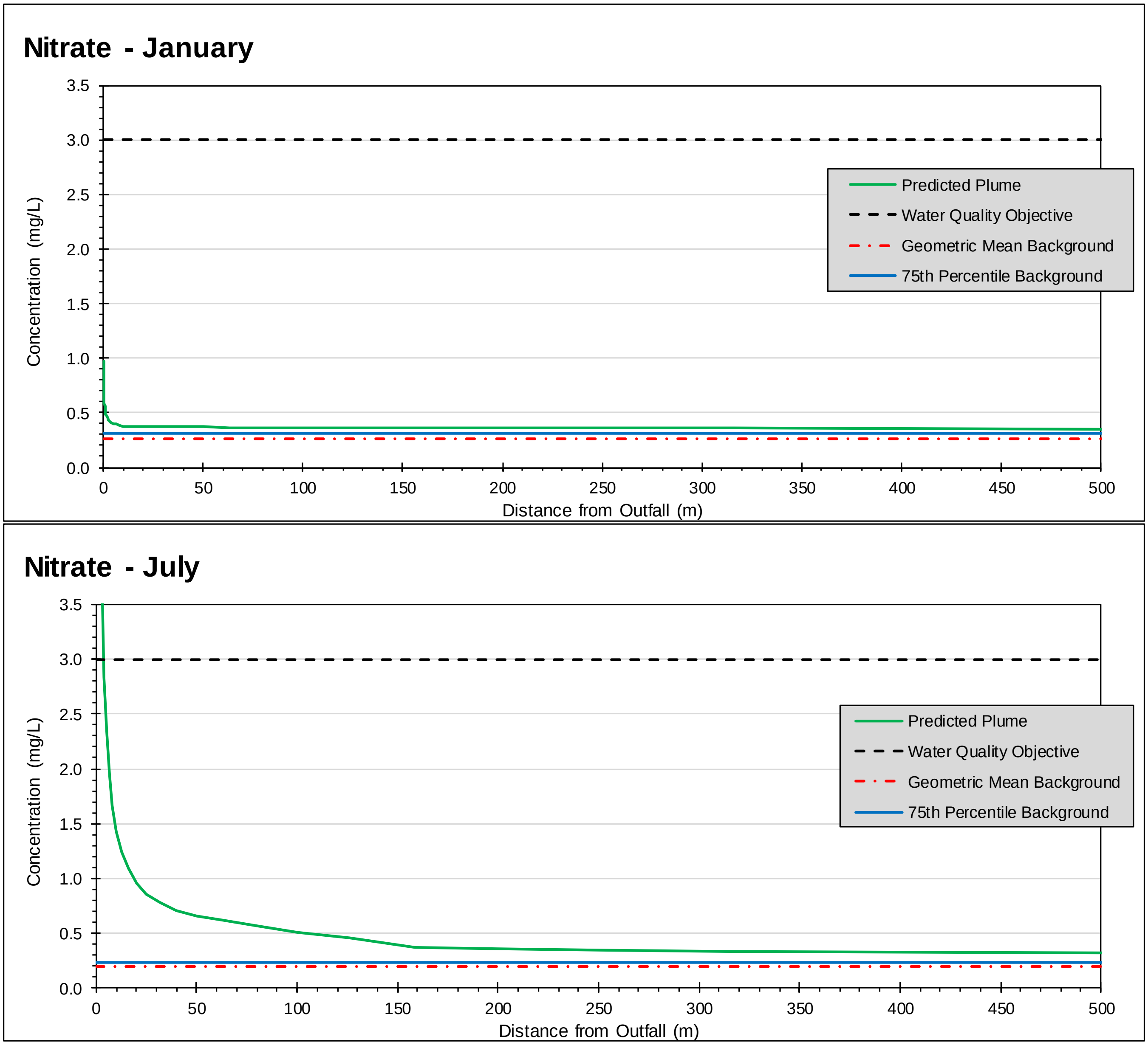


Figure 22: Predicted Nitrate Concentrations Downstream of Outfall

The predicted effects of the Project on the monthly nitrate concentrations in the study are summarized and compared to the predicted worst-case existing conditions in Table 25. The existing conditions are predicted using the mass balance model for low-flow conditions and assume that the existing Niagara Falls WWTP is operating at the rated capacity (68.3 MLD) and discharging effluent with a nitrate concentration equal to the monthly 75th percentile of the measured effluent data (8.41 to 9.71 mg/L).

The nitrate concentrations are expected to increase by approximately 0.02 mg/L in Chippewa Creek and the HEPC, an increase of 11.5% or less. In the Niagara River, the increases in nitrate concentrations are predicted to be less than 0.002 mg/L which represents an increase of 0.9% or less.

Table 25: Summary of Predicted Effects of Project on Nitrate Concentrations

Month	Chippewa Creek at Triangle Island (A3)			HEPC at Montrose Gate (A2)			HEPC Above SAB (A5)			Niagara River Below SAB (A6)		
	Existing (mg/L)	Future (mg/L)	Difference (mg/L)	Existing (mg/L)	Future (mg/L)	Difference (mg/L)	Existing (mg/L)	Future (mg/L)	Difference (mg/L)	Existing (mg/L)	Future (mg/L)	Difference (mg/L)
January	0.317	0.336	0.019 (6.0%)	0.387	0.405	0.018 (4.7%)	0.407	0.425	0.018 (4.5%)	0.325	0.327	0.002 (0.5%)
February	0.305	0.325	0.019 (6.3%)	0.370	0.388	0.019 (5.1%)	0.388	0.407	0.019 (4.8%)	0.313	0.315	0.002 (0.6%)
March	0.290	0.310	0.020 (6.8%)	0.330	0.349	0.019 (5.7%)	0.348	0.367	0.019 (5.4%)	0.295	0.297	0.002 (0.6%)
April	0.297	0.316	0.019 (6.4%)	0.331	0.349	0.018 (5.5%)	0.348	0.366	0.018 (5.2%)	0.301	0.302	0.001 (0.5%)
May	0.324	0.343	0.019 (5.8%)	0.344	0.362	0.018 (5.3%)	0.363	0.381	0.018 (5.0%)	0.327	0.329	0.001 (0.4%)
June	0.323	0.342	0.019 (5.9%)	0.376	0.394	0.018 (4.8%)	0.390	0.409	0.018 (4.6%)	0.328	0.329	0.001 (0.4%)
July	0.229	0.248	0.018 (8.0%)	0.239	0.257	0.018 (7.4%)	0.254	0.271	0.018 (6.9%)	0.231	0.233	0.001 (0.6%)
August	0.168	0.186	0.019 (11.1%)	0.174	0.191	0.018 (10.3%)	0.189	0.207	0.018 (9.4%)	0.169	0.171	0.001 (0.9%)
September	0.164	0.183	0.019 (11.5%)	0.176	0.194	0.018 (10.4%)	0.192	0.211	0.018 (9.4%)	0.166	0.168	0.002 (0.9%)
October	0.179	0.198	0.019 (10.8%)	0.230	0.249	0.019 (8.1%)	0.246	0.264	0.019 (7.5%)	0.184	0.186	0.002 (0.8%)
November	0.221	0.241	0.020 (9.0%)	0.285	0.304	0.019 (6.7%)	0.302	0.321	0.019 (6.3%)	0.228	0.229	0.002 (0.7%)
December	0.296	0.316	0.020 (6.8%)	0.369	0.388	0.019 (5.2%)	0.390	0.409	0.019 (4.9%)	0.304	0.305	0.002 (0.5%)
Annual	0.259	0.278	0.019 (7.4%)	0.299	0.318	0.018 (6.1%)	0.317	0.335	0.018 (5.8%)	0.263	0.265	0.002 (0.6%)

Notes:

1. SAB – Sir Adam Beck GS

4.3 Ammonia

The effluent limits are typically expressed as total ammonia but are based on the regulatory limit for un-ionized ammonia (chronic toxicity limit of 0.0164 mg/L as N). The fraction of the total ammonia that is unionized is directly related to the water temperature and pH. As such, water temperature and pH for the Niagara River are also described in this section.

The measured 75th percentile ammonia concentrations in Chippewa Creek ranged from 0.012 mg/L (February) to 0.058 mg/L (April) and are effectively the same as the measured conditions in the Niagara River. In the Niagara River, the measured 75th percentile water temperatures ranged from 0.3ºC (February) to 24.5ºC (July) and the measured pH 75th percentile values ranged from 8.10 to 8.40 (no pattern observed). The observed ammonia concentrations and calculated unionized ammonia for the Niagara River are summarized in Table 26.

Table 26: Monthly Observed 75th Percentile Values for Water Temperature, pH, Total Ammonia, and Calculated Unionized Ammonia for Niagara River

Month	Water Temperature[1] (ºC)	pH[1]	Unionized Ammonia Fraction	Total Ammonia[1] (mg/L)	Unionized Ammonia[2] (mg/L)
January	0.7	8.1	1.1%	0.014	0.00015
February	0.3	8.1	1.0%	0.012	0.00013
March	2.5	8.1	1.3%	0.023	0.00029
April	7.8	8.1	1.9%	0.058	0.00112
May	14.1	8.2	3.9%	0.049	0.00190
June	20.3	8.3	7.5%	0.049	0.00366
July	24.5	8.4	12.0%	0.043	0.00512
August	24.4	8.4	12.0%	0.044	0.00529
September	22.5	8.3	8.7%	0.041	0.00355
October	17.5	8.3	6.2%	0.035	0.00216
November	10.1	8.2	2.9%	0.023	0.00067
December	5.2	8.1	1.6%	0.016	0.00025

Notes:

[1] values presented represent 75th percentile value of measured data.

[2] estimated using equations presented in MOEE (1994).

The monthly maximum allowable effluent concentrations for total ammonia were calculated from the monthly allowable concentrations of unionized ammonia using the monthly measured 75th percentiles of water temperature and pH. The modelled baseline concentrations and calculated maximum allowable effluent concentration for ammonia at the local and system compliance points and estimated monthly regulatory limits are presented in Table 27.

In addition to the maximum allowable effluent concentrations for total ammonia based on assimilative capacity, Table 28 provides the estimated monthly effluent limit based on the end-of-pipe acute toxicity limit of 0.1 mg/L for unionized ammonia and the measured 75th percentile effluent temperatures and pH from the existing Niagara Falls WWTP.

Table 27: Maximum Allowable Monthly Total Ammonia Concentrations for Discharge to Chippewa Creek Based on Water Quality Modelling

Month	GoldSim Modelling[1]		Mass-Balance Modelling[2]	
	Local Compliance Point (mg/L)	System Compliance Point (mg/L)	Local Compliance Point (mg/L)	System Compliance Point (mg/L)
January	1,467	1,554	1,510	1,518
February	855	919	1,542	1,564
March	617	546	931	913
April	361	361	658	663
May	174	154	381	370
June	95	66	172	155
July	102	80	98	78
August	151	135	95	81
September	225	213	151	133
October	512	529	230	216
November	940	1,016	528	525
December	947	1,002	990	997

Notes:

[1] Calculated concentrations based on allowable mass capacity based on 5% probability of no exceedance.
[2] Calculated based on low flow conditions occurring for all inflows simultaneously.
[3] Modelled results exclude effects of CSOs and WWTP bypasses.

Table 28: Maximum Allowable Monthly Total Ammonia Concentrations for Discharge to Chippewa Creek Based on Acute Toxicity of Unionized Ammonia

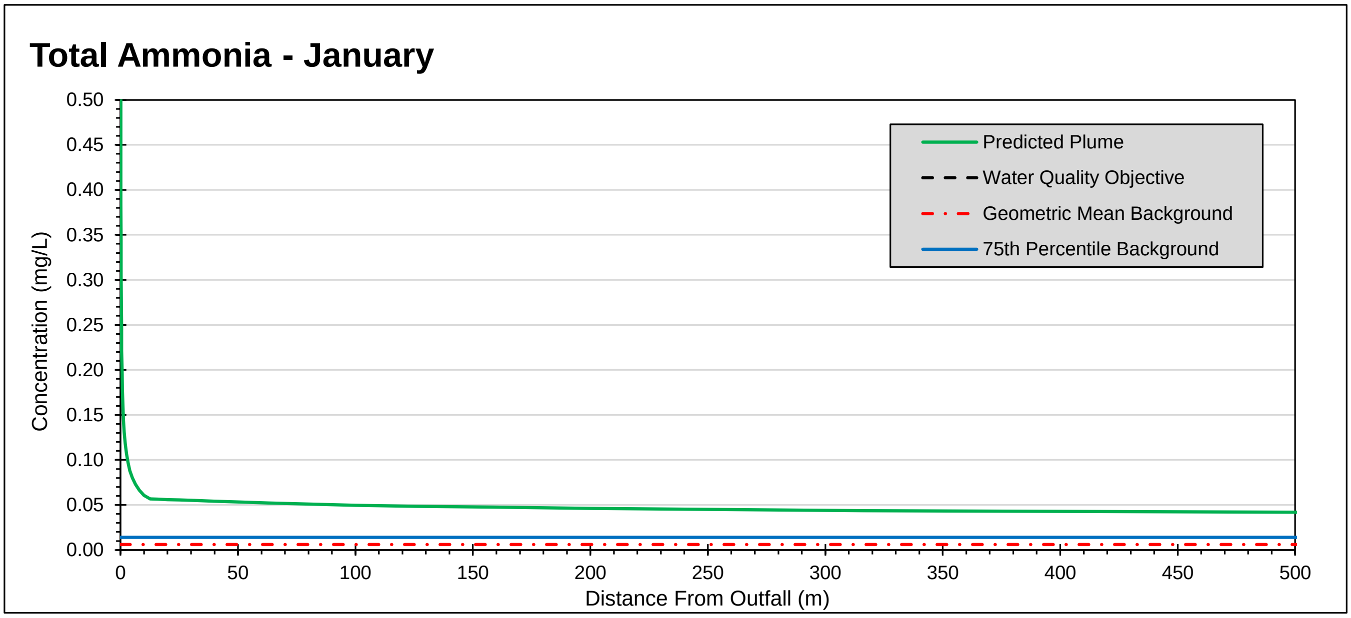
Month	75th Percentile Effluent Temperature[1] (ºC)	75th Percentile Effluent pH[1]	Maximum Allowable Effluent Concentration[2] (mg/L)
January	10.9	7.38	21.1
February	10.9	7.33	23.6
March	11.0	7.38	20.8
April	12.8	7.47	14.9
May	16.6	7.40	13.0
June	19.5	7.40	10.5
July	22.0	7.40	8.80
August	22.7	7.30	10.5
September	22.3	7.34	9.95
October	19.2	7.30	13.5
November	15.5	7.32	16.9
December	13.7	7.35	18.2

Notes:

[1] Based on measured effluent temperatures and pH from the existing Niagara Falls WWTP (2015 to 2018).
[2] Estimated using equations presented in MOEE (1994).

The predicted maximum allowable total ammonia concentrations based on the assimilative capacity are consistently greater than the values based on the acute toxicity guideline for unionized ammonia. As such, it is recommended that the effluent objectives for total ammonia be based on meeting the acute toxicity limit for unionized ammonia at end-of-pipe and monthly water temperature and pH. Based on the resulting values presented in Table 28, the recommended total ammonia objectives are recommended to be 8.8 mg/L from May to October and 15.0 mg/L from November to April.

The predicted plume centreline concentrations for January and July are provided on Figure 23 for an effluent discharge rate of 30 MLD. The total ammonia guidelines for January and July are 1.51 mg/L and 0.14 mg/L respectively based on monthly water temperatures and pH. The guideline for total ammonia for January is not shown on Figure 23 since it is greater than the predicted and measured concentrations shown on the figure. In January and July, the plume is expected to meet the monthly PWQO guideline within a downstream distance of approximately 130 m.



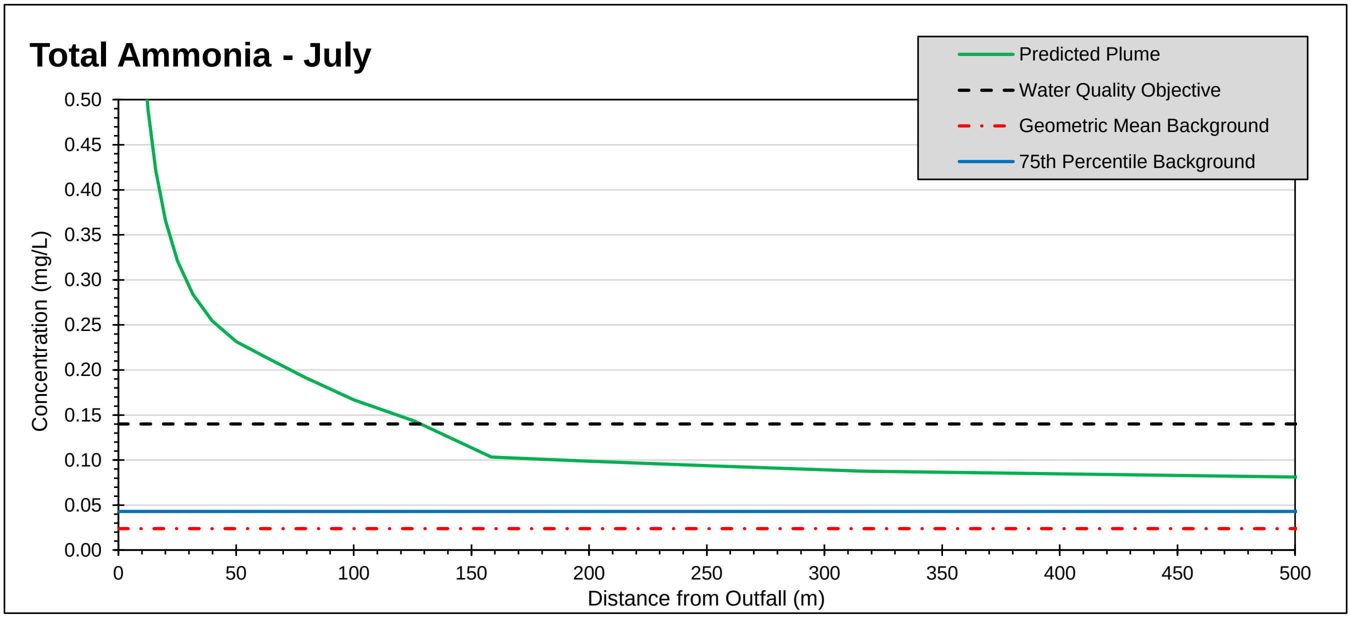


Figure 23: Predicted Total Ammonia Concentrations Downstream of Outfall

The predicted effects of the Project on the monthly total ammonia concentrations in the study are summarized and compared to the predicted worst-case existing conditions in Table 29. The existing conditions are predicted using the mass balance model for low-flow conditions and assume that the existing Niagara Falls WWTP is operating at the rated capacity (68.3 MLD) and discharging effluent with a total ammonia concentration equal to the monthly 75th percentile of the measured effluent data (6.23 to 10.0 mg/L).

The total ammonia concentrations are expected to increase by approximately 0.05 mg/L in Chippewa Creek and the HEPC. In the Niagara River, the increases in total ammonia concentrations are predicted to be approximately 0.001 mg/L which represents an increase of 9% or less.

Table 29: Summary of Predicted Effects of Project on Total Ammonia Concentrations

Month	Chippewa Creek at Triangle Island (A3)			HEPC at Montrose Gate (A2)			HEPC Above SAB (A5)			Niagara River Below SAB (A6)		
	Existing (mg/L)	Future (mg/L)	Difference (mg/L)	Existing (mg/L)	Future (mg/L)	Difference (mg/L)	Existing (mg/L)	Future (mg/L)	Difference (mg/L)	Existing (mg/L)	Future (mg/L)	Difference (mg/L)
January	0.014	0.029	0.015 (103.5%)	0.036	0.050	0.014 (39.0%)	0.057	0.071	0.014 (24.4%)	0.018	0.019	0.001 (7.2%)
February	0.012	0.027	0.015 (119.4%)	0.022	0.036	0.014 (64.9%)	0.043	0.057	0.014 (33.3%)	0.015	0.016	0.001 (8.8%)
March	0.023	0.038	0.015 (63.9%)	0.056	0.071	0.014 (25.5%)	0.075	0.090	0.014 (19.0%)	0.028	0.029	0.001 (4.5%)
April	0.058	0.072	0.014 (24.6%)	0.066	0.080	0.014 (20.8%)	0.079	0.093	0.014 (17.3%)	0.060	0.061	0.001 (1.9%)
May	0.049	0.057	0.008 (17.1%)	0.057	0.065	0.008 (14.1%)	0.072	0.080	0.008 (11.1%)	0.051	0.051	0.001 (1.3%)
June	0.049	0.057	0.008 (17.2%)	0.054	0.062	0.008 (15.0%)	0.071	0.079	0.008 (11.3%)	0.051	0.051	0.001 (1.2%)
July	0.043	0.051	0.008 (19.0%)	0.044	0.052	0.008 (17.5%)	0.063	0.071	0.008 (12.3%)	0.044	0.045	0.001 (1.4%)
August	0.044	0.052	0.008 (18.6%)	0.045	0.053	0.008 (17.6%)	0.060	0.068	0.008 (13.1%)	0.045	0.046	0.001 (1.4%)
September	0.041	0.049	0.008 (20.4%)	0.047	0.055	0.008 (17.1%)	0.063	0.071	0.008 (12.6%)	0.043	0.044	0.001 (1.6%)
October	0.035	0.044	0.009 (24.4%)	0.039	0.048	0.008 (20.9%)	0.058	0.066	0.008 (14.2%)	0.037	0.038	0.001 (1.8%)
November	0.023	0.038	0.015 (64.9%)	0.032	0.046	0.015 (45.7%)	0.049	0.063	0.014 (29.6%)	0.025	0.027	0.001 (4.7%)
December	0.016	0.031	0.015 (95.0%)	0.034	0.049	0.015 (42.4%)	0.053	0.068	0.015 (27.3%)	0.019	0.020	0.001 (6.2%)
Annual	0.034	0.046	0.011 (33.4%)	0.045	0.056	0.011 (24.7%)	0.062	0.073	0.011 (17.7%)	0.037	0.038	0.001 (2.5%)

Notes:

1. SAB – Sir Adam Beck GS

4.4 *E. coli*

The measured 75th percentile *E. coli* concentrations in the Niagara River at the drinking water intake range from 3 cfu/100ml (May) to 11 cfu/100ml (January). There are constraints at the system compliance point caused by the discharge of effluent into the HEPC from the existing Niagara Falls WWTP and by the contribution from the Welland River East which exceeds objectives year-round. The calculated maximum allowable effluent concentration for total phosphorus at the local and system compliance points and regulatory objectives are presented in Table 30.

There are limitations on the discharge at the system compliance point from November to March and in September due to contributions from Welland River East. As such, the effluent concentration is not to exceed background conditions in the HEPC. The measured *E. coli* concentrations in the HEPC range from 5 to over 16,000 cfu/100 mL with an average of over 1,600 cfu/100 mL.

An effluent limit for *E. coli* of 200 cfu/100 mL is recommended and is consistent with other treatment plants in the area and recognizes that the HEPC is not used for body-contact recreation. This value is also well below the measured *E. coli* concentrations in the HEPC.

Table 30: Maximum Allowable Monthly *E. coli* Concentrations for Discharge to Chippewa Creek

Month	GoldSim Modelling[1]		Mass-Balance Modelling[2]	
	Local Compliance Point (cfu/100 mL)	System Compliance Point (cfu/100 mL)	Local Compliance Point (cfu/100 mL)	System Compliance Point (cfu/100 mL)
January	79,518	nc	91,711	nc
February	75,315	nc	91,467	72,188
March	86,722	nc	95,937	822
April	92,226	67,543	97,791	89,654
May	98,596	97,296	101,149	100,264
June	103,967	97,529	99,801	94,869
July	104,734	102,999	103,824	102,346
August	98,330	95,695	101,943	100,079
September	90,825	nc	95,634	31,610
October	85,688	10,447	92,334	71,848
November	85,288	nc	92,034	2,717
December	84,521	nc	90,788	nc

Notes:

1. Calculated concentrations based on allowable mass capacity based on 5% probability of no exceedance.
2. Calculated based on low flow conditions occurring for all inflows simultaneously.
3. Modelled results exclude effects of CSOs and WWTP bypasses.

The predicted plume centreline concentrations for January and July are provided on Figure 24 for an effluent discharge rate of 30 MLD. In January and July, the plume is expected to meet the PWQO (100 cfu/100 mL) within a downstream distance of approximately 10 m. The PWQO is not shown on Figure 24 since the measured and predicted concentrations near the outfall are well below the PWQO.

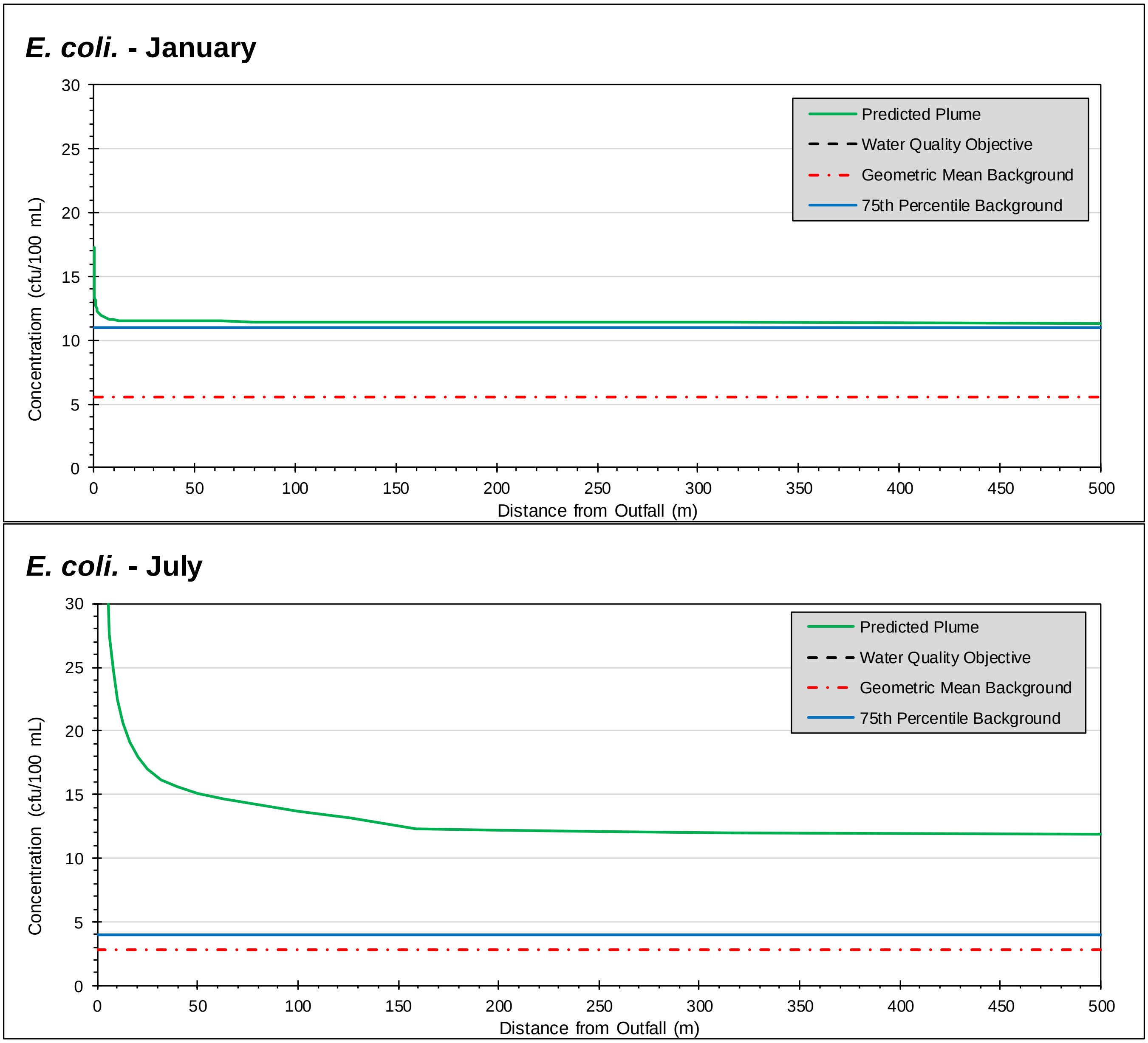


Figure 24: Predicted *E. coli* Concentrations Downstream of Outfall

The predicted effects of the Project on the monthly *E coli* concentrations in the study are summarized and compared to the predicted worst-case existing conditions in Table 30. The existing conditions are predicted using the mass balance model for low-flow conditions and assume that the existing Niagara Falls WWTP is operating at the rated capacity (68.3 MLD) and discharging effluent with an *E. coli* concentration equal to the ECA limits (200 cfu/100 mL).

The *E. coli* concentrations are expected to increase by approximately 0.2 cfu/100 mL in Chippewa Creek and the HEPC, an increase of 6% or less. In the Niagara River, the increases in *E. coli* concentrations are predicted to be less than 0.01 cfu/100 mL which represents an increase of 0.4% or less.

Table 31: Summary of Predicted Effects of Project on *E. coli* Concentrations

Month	Chippewa Creek at Triangle Island (A3) (cfu/100 mL)			HEPC at Montrose Gate (A2) (cfu/100 mL)			HEPC Above SAB (A5) (cfu/100 mL)			Niagara River Below SAB (A6) (cfu/100 mL)		
	Existing	Future	Difference	Existing	Future	Difference	Existing	Future	Difference	Existing	Future	Difference
January	11.2	11.4	0.18 (1.6%)	306.5	306.4	-0.10 (0.0%)	306.3	306.2	-0.10 (0.0%)	38.2	38.2	0.01 (0.0%)
February	10.2	10.3	0.19 (1.8%)	31.1	31.3	0.16 (0.5%)	31.5	31.6	0.16 (0.5%)	12.0	12.0	0.02 (0.1%)
March	4.3	4.5	0.20 (4.5%)	99.1	99.2	0.10 (0.1%)	99.3	99.4	0.10 (0.1%)	12.5	12.6	0.02 (0.1%)
April	6.4	6.6	0.19 (2.9%)	17.3	17.4	0.17 (1.0%)	17.6	17.8	0.17 (0.9%)	7.2	7.2	0.01 (0.2%)
May	3.3	3.5	0.19 (5.7%)	7.3	7.4	0.18 (2.5%)	7.7	7.8	0.18 (2.3%)	3.6	3.6	0.01 (0.4%)
June	4.1	4.3	0.19 (4.6%)	12.1	12.2	0.17 (1.4%)	12.5	12.6	0.17 (1.4%)	4.6	4.6	0.01 (0.3%)
July	4.0	4.2	0.18 (4.5%)	8.7	8.9	0.17 (2.0%)	9.1	9.3	0.17 (1.9%)	4.4	4.4	0.01 (0.3%)
August	4.5	4.7	0.18 (4.0%)	9.5	9.7	0.17 (1.8%)	9.9	10.1	0.17 (1.7%)	4.9	5.0	0.01 (0.3%)
September	8.8	9.0	0.18 (2.1%)	70.8	70.9	0.12 (0.2%)	71.1	71.2	0.12 (0.2%)	14.0	14.0	0.01 (0.1%)
October	9.9	10.0	0.19 (1.9%)	32.3	32.5	0.16 (0.5%)	32.7	32.8	0.16 (0.5%)	11.6	11.7	0.01 (0.1%)
November	7.1	7.3	0.19 (2.8%)	97.2	97.3	0.10 (0.1%)	97.5	97.6	0.10 (0.1%)	14.4	14.4	0.01 (0.1%)
December	7.8	7.9	0.20 (2.5%)	241.8	241.8	-0.04 (0.0%)	241.7	241.7	-0.04 (0.0%)	26.8	26.8	0.01 (0.1%)
Annual	6.7	6.9	0.19 (2.8%)	77.2	77.3	0.11 (0.1%)	77.4	77.5	0.11 (0.1%)	12.4	12.5	0.01 (0.1%)

4.5 Biochemical Oxygen Demand ($CBOD_5$) and Dissolved Oxygen

The mass balance modelling suggests that the dissolved oxygen concentrations downstream of the discharge are not sensitive to the effluent dissolved oxygen concentrations. As such, effluent dissolved oxygen concentrations equal to 50% of the saturation concentration are recommended as the effluent limit

The recommended annual maximum allowable $CBOD_5$ concentration for effluent is based on the minimum value of 5,876 mg/L (fall) from Table 32. This value is well above the minimum secondary effluent standard compliance limit of 25 mg/L (Table 21). As such, the recommended effluent compliance limit for $CBOD_5$ is 25 mg/L.

Table 32: Maximum Allowable Monthly $CBOD_5$ Concentrations for Discharge to Chippewa Creek

Season	Maximum Allowable Effluent Concentration (mg/L)[1]
January	12,253
February	12,863
March	13,835
April	14,359
May	12,954
June	9,304
July	7,098
August	**5,876**
September	5,883
October	7,030
November	7,960
December	8,969

Notes:

[1] Based on effluent dissolved oxygen concentration equal to 50% of saturation.

The predicted effects of the Project on the monthly $CBOD_5$ concentrations in the study are summarized and compared to the predicted worst-case existing conditions in Table 33. The existing conditions are predicted using the mass balance model for low-flow conditions and assume that the existing Niagara Falls WWTP is operating at the rated capacity (68.3 MLD) and discharging effluent with an $CBOD_5$ concentration equal to the monthly 75th percentile of the measured effluent data (5.3 to 11.4 mg/L).

The $CBOD_5$ concentrations are expected to increase by approximately 0.02 mg/L in Chippewa Creek and the HEPC, an increase of 1.2% or less. In the Niagara River, the increases in $CBOD_5$ concentrations are predicted to be less than 0.02 mg/L which represents an increase of 0.1% or less.

Table 33: Summary of Predicted Effects of Project on $CBOD_5$ Concentrations

Month	Chippewa Creek at Triangle Island (A3)			HEPC at Montrose Gate (A2)			HEPC Above SAB (A5)			Niagara River Below SAB (A6)		
	Existing (mg/L)	Future (mg/L)	Difference (mg/L)	Existing (mg/L)	Future (mg/L)	Difference (mg/L)	Existing (mg/L)	Future (mg/L)	Difference (mg/L)	Existing (mg/L)	Future (mg/L)	Difference (mg/L)
January	2.000	2.022	0.022 (1.1%)	2.000	2.022	0.022 (1.1%)	2.008	2.029	0.021 (1.1%)	2.001	2.003	0.002 (0.1%)
February	2.000	2.023	0.023 (1.1%)	2.000	2.022	0.022 (1.1%)	2.009	2.031	0.022 (1.1%)	2.001	2.003	0.002 (0.1%)
March	2.000	2.023	0.023 (1.1%)	2.000	2.022	0.022 (1.1%)	2.010	2.032	0.022 (1.1%)	2.001	2.003	0.002 (0.1%)
April	2.000	2.022	0.022 (1.1%)	2.000	2.021	0.021 (1.1%)	2.008	2.029	0.021 (1.1%)	2.001	2.002	0.002 (0.1%)
May	2.000	2.022	0.022 (1.1%)	2.000	2.021	0.021 (1.1%)	2.010	2.031	0.021 (1.1%)	2.001	2.003	0.002 (0.1%)
June	2.000	2.022	0.022 (1.1%)	2.000	2.021	0.021 (1.1%)	2.010	2.031	0.021 (1.1%)	2.001	2.002	0.002 (0.1%)
July	2.000	2.021	0.021 (1.1%)	2.000	2.020	0.020 (1.0%)	2.008	2.028	0.020 (1.0%)	2.001	2.002	0.002 (0.1%)
August	2.000	2.021	0.022 (1.1%)	2.000	2.021	0.021 (1.0%)	2.017	2.038	0.021 (1.0%)	2.001	2.003	0.002 (0.1%)
September	1.999	2.021	0.022 (1.1%)	1.999	2.020	0.021 (1.1%)	2.019	2.040	0.021 (1.0%)	2.002	2.003	0.002 (0.1%)
October	2.000	2.023	0.022 (1.1%)	2.000	2.022	0.022 (1.1%)	2.016	2.038	0.022 (1.1%)	2.001	2.003	0.002 (0.1%)
November	2.000	2.023	0.023 (1.2%)	2.000	2.022	0.022 (1.1%)	2.009	2.031	0.022 (1.1%)	2.001	2.003	0.002 (0.1%)
December	2.000	2.023	0.023 (1.2%)	2.000	2.022	0.022 (1.1%)	2.007	2.030	0.022 (1.1%)	2.001	2.002	0.002 (0.1%)
Annual	2.000	2.022	0.022 (1.1%)	2.000	2.021	0.021 (1.1%)	2.011	2.032	0.021 (1.1%)	2.001	2.003	0.002 (0.1%)

Notes:

1. SAB – Sir Adam Beck GS

4.6 Total Suspended Solids (TSS)

The annual 75th percentile upstream TSS is 11.3 mg/L suggesting that Chippewa Creek does not typically have high concentration of suspended solids. The mass balance modelling results provided in Table 34 show that, the recommended annual maximum allowable TSS concentration for effluent is the December minimum value of 4,932. This value is well above the minimum secondary effluent standard compliance limit of 25 mg/L. As such, the recommended effluent compliance limit for TSS is 25 mg/L.

Table 34: Maximum Allowable Monthly TSS Concentrations for Discharge to Chippewa Creek

Season	Maximum Allowable Effluent Concentration (mg/L)[1]
January	5,178
February	5,102
March	5,023
April	5,241
May	5,241
June	5,213
July	5,420
August	5,350
September	5,254
October	5,133
November	4,963
December	**4,932**

4.7 Total Residual Chlorine

The effluent limit for total residual chlorine is recommended to be 0.02 mg/L as specified in the Fisheries Act (Canada, 2020). This approach is consistent with effluent limits for total residual chlorine specified in existing ECAs for wastewater treatment plants throughout Ontario.

4.8 pH

the recommended effluent limit range for pH is 6.0 to 9.0 and is consistent with effluent limit ranges for pH specified in existing ECAs for wastewater treatment plants throughout Ontario.

4.9 Recommended Effluent Objectives

Based on the preceding discussions, a summary of the recommended effluent concentrations for the Chippewa Creek discharge is presented in Table 35.

- While background phosphorus concentrations can exceed PWQO during some months, effluent TP compliance limits for the new plant are recommended based on a well operated secondary treatment facility with phosphorus removal based on the following rationale:
- On an annual basis, there is sufficient capacity to accept an effluent concentration greater than 0.75 mg/L.
- The effluent flow rate represents less than 0.1% of the total flow in Chippewa Creek and as such the contributions of the proposed discharge will cause negligible increase in the total phosphorus concentrations within Chippewa Creek and the HEPC.
- The elevated phosphorus concentration in Chippewa Creek are only experienced during October to February, which is outside the algae growing season. Furthermore, the elevated background phosphorus concentrations are the result of factors outside the study area (e.g., inflow from the Niagara River and Lyons Creek).
- Similarly, the effluent flow rate is insignificant when compared to the flow in the Niagara River below the Sir Adam Beck GS.

Table 35: Summary of Development of Effluent Compliance Limits for Preferred Discharge Location into Chippewa Creek

Parameter		Limiting Assimilative Capacity Concentration[1]	Typical Treatment Plant Effluent[2]	Proposed Effluent Compliance Limits
Total Phosphorus (mg/L)		0 to 9.9[3]	0.5	0.75
Unionized Ammonia (mg/L)		0.1	--	0.10
Total Ammonia (mg/L)	May to October	8.8[4]	<1	8.8
	November to April	14.9[4]	<3	15.0
E. coli (cfu/100 mL)		75,315[5]	200	200
Dissolved Oxygen (% of Saturation)		50%	>80%	N/A[6]
$CBOD_5$ (mg/L)		5,876	25	25
Total Suspended Solids (mg/L)		4,932	25	25
pH		Not Estimated[7]	--	6.0 to 8.5
Total Residual Chlorine (mg/L)		Not Estimated[7]	--	0.02

Notes:

[1] Lowest seasonal value from local and system compliance points.

[2] Typical effluent for a conventional activated sludge without filtration.

[3] Limiting concentration at local compliance point varies seasonally. Policy 2 receiver conditions only occur during winter months. Downstream concentrations of total phosphorus are expected to increase by 0.0007 mg/L (0.7 µg/L) or as a result of the project.

[4] Limits based on acute end-of-pipe toxicity limit of 0.1 mg/L unionized ammonia adjusted for monthly effluent water temperature and pH.

[5] Minimum allowable effluent concentration for *E. coli* based on assimilative capacity in Chippewa Creek

[6] Not applicable – typical effluent is expected to be better than the limiting assimilative capacity concentration.

[7] Not estimated – proposed effluent compliance limits based on typical values used for similar facilities

5.0 CONCLUSIONS

Based on the analysis in this report, the following conclusions are provided:

- Elevated total phosphorus concentrations in the Niagara River lead to effluent constraints during the winter.
- Degraded water quality in the Welland River East leads to periodic effluent constraints related to total phosphorus and *E. coli* at the system compliance point.
- The recommended effluent objectives and limits for total and unionized ammonia are defined by the end-of-pipe acute toxicity criteria for unionized ammonia (0.1 mg/L) and not by receiving water limitations.
- As expected, summer is the most restrictive season for total ammonia.
- For all other parameters (nitrate, *E. coli*, $CBOD_5$, dissolved oxygen, and TSS) the maximum allowable effluent concentrations at the local and system compliance points are greater than the expected effluent concentrations from a conventional activated sludge treatment plant and so treatment-based limits are recommended.
- The expected water quality concentrations in the receiving waters are not expected to be measurably different from the existing conditions throughout the study area.
- The conceptual outfall design that includes duckbill valves provides reasonable performance for most of the scenarios modelled. The only exception is during high effluent flow rates (120 MLD) during the summer when plume dilution does not reach 200:1 within 1,000 m. However, high effluent flow rates are expected to occur infrequently and have a duration of a few hours or less.
- In periods when the plume has a tendency to sink (June to September), sinking jets produces less dilution factors closer to outfall and the distance to a 200:1 dilution is approximately 350 m
- In periods when the plume has a tendency to float (October to May), a 200:1 dilution is expected within 5 m of the outfall.
- In general variations in the Chippewa Creek flow and effluent flow rate are not expected to noticeably affect the performance of the outfall design.

Table 36 summarizes the proposed effluent objectives and compliance limits for the new 30 ML/d South Niagara Falls WWTP discharging to Chippewa Creek.

Table 36: Recommended Effluent Objectives and Limits for Preferred Discharge Location into Chippewa Creek

Parameter		Effluent Objectives	Effluent Limits
Total Phosphorus (mg/L)		0.5	0.75
Total Ammonia (mg/L)[1]	May to October	6.5	8.8
	November to April	12.0	15.0
E. coli (cfu/100 mL)		100	200
$CBOD_5$ (mg/L)		15	25
Total Suspended Solids (mg/L)		15	25
pH		6.5 to 8.5	6.0 to 9.5
Total Residual Chlorine (mg/L)		Non-detectable	0.02

Notes:

[1] Limits based on acute end-of-pipe toxicity limit of 0.1 mg/L unionized ammonia adjusted for monthly water temperature and pH.

6.0 LIMITATIONS

Golder has prepared this report for the exclusive use by the Niagara Region and other members of the Project team for the South Niagara Falls Wastewater Solutions Schedule C Class EA Project. The results presented in this report are for a proposed wastewater treatment plant with a specific design capacity of 30 MLD discharging to the Chippewa Creek location identified Screening Level ACS (Appendix A 2019). The results presented in this report should not be used to assess other design capacities or discharge locations in any way.

Information, analysis, and commentary presented in this report regarding wastewater treatment technologies and the associated typical effluent quality have been provided by CIMA+.

The assessment has been completed using data and information collected and provided by others. Golder does not assume any responsibility related to the accuracy or reliability of the data or information.

Water quality modelling requires the use of many assumptions due to the uncertainty related to determining the physical and chemical characteristics of a complex system. The prediction of water quality is based on several inputs (flows and chemistry), all of which have inherent variability and uncertainty.

GoldSim derives a maximum allowable concentration distribution for each parameter and location by combining randomly sampled flows over numerous (1,000s) of cycles using a Monte Carlo approach. While this approach is valuable because it considers numerous combinations, it may be inaccurate if certain environmental conditions are less represented in historic data than others.

The conventional mass balance ACS approach calculates the maximum allowable effluent concentration for a specific case where the low-flow condition (e.g., 7Q20) occurs for all the inflows at the same time. This is the approach that is typically requested by the MECP and is assumed to represent a worst-case scenario. However, because of the range of the inflow watershed sizes (e.g., Niagara River compared to Lyons Creek), it is highly unlikely that low-flow conditions will occur in all the inflows at the same time.

In natural systems and complex man-made systems, observed conditions will almost certainly vary with respect to estimated conditions. Water quality and flow data has shown a vast range of variability across seasons and locations. This variability may not be captured by the flow and water quality statistics (e.g., 75th percentile concentrations) used as inputs to the models. This is especially true for data sets with small sample sizes.

The mixing zone assessment was completed using a commercially available software package (CORMIX). CORMIX is an expert system that uses the results of a series of laboratory measured plumes (referred to as modules in CORMIX documentation) to represent the release of effluent into a receiving water. Depending on the conditions for individual scenarios (e.g., differences to plume buoyancy), CORMIX can toggle between modules and predict different plume behaviour for these conditions. While CORMIX is regarded as one of the best software packages available for modelling effluent outfall, the results should be interpreted with caution. Golder assumes no responsibility related to the accuracy and reliability of CORMIX.

Since the information regarding the expected effluent quality from various treatment technologies is not site specific, more detailed assessments should be completed prior to the final selection of the required technology.

This assessment is one part of a larger project to select the location and effluent criteria for the proposed WWTP. The results of this assessment should be used in conjunction with the other components of the Project to support any decisions. Given all the inherent uncertainties provided, the results should be used as a tool to aid in the design and planning of the proposed wastewater treatment plant rather than to provide absolute water quality predictions.

Signature Page

We trust that this report meets your needs at this time. If you have any questions, please do not hesitate to contact the undersigned.

Yours truly,

CIMA+

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REFERENCES

AquaResource. 2009. Water Availability Study for the Central Welland River, Big Forks Creek, and Beaverdams Shriners Creeks Watershed Plan Areas, Niagara Peninsula Source Protection Area. A report prepared for Niagara Peninsula Conservation Authority. January 23, 2009.

Canada. 1950. Treaty Between Canada and the United States of America Concerning the Diversion of the Niagara River (E100418). Signed October 10, 1950.

Canada. 2020. Wastewater Systems Effluent Regulations of the Fisheries Act, SOR/2012-139, Government of Canada. https://laws-lois.justice.gc.ca/eng/regulations/sor-2012-139/fulltext.html.

CCME. 2014. Canadian Environmental Quality Guidelines. Canadian Council of Ministers of the Environment. Available at www.ccme.ca/en/resources/canadian_environmental_quality_guidelines.

Environment and Climate Change Canada (ECCC) and the U.S. Environmental Protection Agency (USEPA). 2018. Lake Ontario Lakewide Action and Management Plan, 2018-2022. https://binational.net/wp-content/uploads/2019/04/2018-Lake-Ontario-For-Public-Comment-APRIL-2019.pdf

GMBP. 2017. City of Niagara Falls Pollution Prevention & Control Plan Study Update. GM BluePlan Engineering Limited. November 2017.

Golder Associates Ltd. (Golder). 2019. Welland River Survey, Sir Adam Beck 1 Canal Rehabilitation Project, H353744-00000-200-230-000X. A report prepared for Ontario Power Generation. June 2018.

Kowalski, P. 2019. Personal communication with Peter Kowalski (Peter Kowalski Consulting Inc.) on February 11, 2019.

MOEE. 1994. Water Management Policies Guidelines Provincial Water Quality Objectives of The Ministry of Environment and Energy. Reprinted 1999.

MOEE. 1994a. B-1-5 Deriving Receiving Water Based Point Source Effluent Requirements for Ontario Water.

Ministry of the Environment (MOE). 2010. Amended Certificate of Approval for Niagara Falls Wastewater Treatment Plant (Stanley Avenue). Number 7962-7ZLK6. Issues February 3, 2010.

Ministry of Environment, Conservation, and Parks (MECP). 2019. Design Guidelines for Sewage Works. ISBN 978-1-4249-8438-1. (https://www.ontario.ca/document/design-guidelines-sewage-works-0).

Ministry of Transportation (MTO). 1997. Drainage Management Manual. Part 3. Drainage and Hydrology Section. Transportation Engineering Branch. Quality and Standards Division.

NOAA. 2019. Tides & Currents Database (http://tidesandcurrents.noaa.gov/stationhome.html?id=9063020/).

NPCA. 2011. The Welland River Eutrophication Study in the Niagara River Area of Concern in Support of the Beneficial Use Impairment: Eutrophication and Undesirable Algae. A report written by Niagara Peninsula Conservation Authority on behalf of the Welland River Eutrophication Technical Working Group. March 2011.

NWQMC. 2019. Water Quality Portal of the National Water Quality Monitoring Council (http://www.waterqualitydata.us/).

NYPA. 2005. Surface Water Quality of the Niagara River and its U.S. Tributaries. A report prepared for the Niagara Power Project FERC No. 2216 and the New York Power Authority. August 2005.

SLSMA. 2019. Water Diversion Report Production Guide. The St. Lawrence Seaway Management Corporation. September 2019.

USGS. 2019. National Water Information System (http://nwis.waterdata.usgs.gov/usa/nwis/qwdata/?site_no=04216070/)

XCG. 2007. Assimilative Capacity Assessment of the Welland River, Ontario. A technical memorandum prepared for Niagara Region. November 1, 2007

APPENDIX A

Screening Level Assimilative Capacity Study

REPORT

South Niagara Falls Wastewater Solutions Schedule C Class Environmental Assessment

Screening Level Assimilative Capacity Study of Discharge Location Alternatives

Submitted to:

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APPENDIX A

ACRONYMS AND ABBREVIATIONS

Acronym or Abbreviation	Description
ACS	Assimilative Capacity Study
BOD_5	Biochemical Oxygen Demand
$CBOD_5$	Carbonaceous Biochemical Oxygen Demand
CCME	Canadian Council of Ministers of the Environment
CSO	Combined Sewer Overflow
E. coli	*Escherichia coli*
EA	Environmental Assessment
ECA	Environmental Compliance Approval
GS	Generating Station
HEPC	Hydro Electric Power Canal
ICD	International Control Dam
INCW	International Niagara Control Works
MECP	Ministry of the Environment, Conservation and Parks
MOEE	Ministry of Energy and Environment
NOAA	National Oceanic and Atmospheric Administration
NPCA	Niagara Peninsula Conservation Authority
NYPA	New York Power Authority
OPG	Ontario Power Generation
the Project	South Niagara Falls Wastewater Solutions Schedule C Class EA
PWQMN	Provincial Water Quality Monitoring Network
PWQO	Provincial Water Quality Objectives
SLSMC	St. Lawrence Seaway Management Corporation
TSS	Total Suspended Solids
USGS	United States Geological Survey
WSC	Water Survey of Canada
WWTP	Wastewater Treatment Plant

UNITS OF MEASURE

Symbol or Unit	Description
cfs	Cubic feet per second
cfu	Colony-forming unit
kg/d	kilograms per day
km	kilometre
km^2	Square kilometres
m	metre
µg/L	Microgram per litre
mg/L	Milligrams per litre
MLD	Megalitres per day
m^3/s	Cubic metres per second
mL	Millilitre
ºC	Degrees Celsius
%	Percent

1.0 INTRODUCTION

The Regional Municipality of Niagara (Niagara Region) is currently conducting a Schedule “C” Municipal Class Environmental Assessment (EA) for a proposed Wastewater Treatment Plant (WWTP) in the vicinity of Chippewa Creek, Niagara. As well as providing other ancillary services, Golder Associates Ltd. (Golder) has been retained to conduct an Assimilative Capacity Study (ACS) in support of the South Niagara Falls Wastewater Solutions Schedule C Class EA Project (the Project), which is the subject of this technical report.

1.1 Study Background

With significant future regional growth and urban intensification forecast for the area, the 2017 Niagara Region Master Servicing Plan provided a long-term wastewater solutions strategy to improve the existing collection system and add a new, second wastewater treatment facility in South Niagara Falls that can accommodate phased growth, provide wastewater service to currently subserviced areas, reduce pressure on existing wastewater infrastructure, decrease the magnitude and frequency of untreated combined sewer overflows and WWTP bypasses and, in doing so, enhance overall environmental performance.

Wastewater collection within Niagara Falls is currently facilitated through a number of collection systems and pumping stations. These systems convey the wastewater to the existing Niagara Falls WWTP (sometimes referred to as the Stanley Avenue WWTP). Many of the components of the collection system are nearing their design capacity.

The 2017 Master Servicing Plan identified a number of candidate discharge location for a new WWTP in South Niagara Falls that could potentially accept an effluent discharge rate of up to 30 Megalitres per day (30 MLD).

1.1.1 Study Area Overview and Nomenclature

The extent of this study area was identified as the preferred geographical context for siting the new WWTP for the City of Niagara Falls (GMBP, 2019). As depicted on Figure 1, the study area features a number of potential discharge receivers for assimilating the new WWTP discharge, including:

- the Hydro Electric Power Canal (HEPC);
- the eastern portion of the Welland River East;
- Chippewa Creek; and
- The Canadian shoreline of the Niagara River upstream of the International Control Dam (ICD).

The hydrology of the study area has been highly modified and regulated from the natural predevelopment conditions that existed prior to the 1950s. During the 1950s, the HEPC was constructed from the Welland River (upstream of Horseshoe Falls) to the Sir Adam Beck Generating Station (GS) which discharges to Niagara Gorge. As a result, the flow within last 6.5 km of the Welland River was reversed to direct a small portion of Niagara River flows towards the HEPC. The section from the Niagara River to Triangle Island is referred as Chippewa Creek. The amount of flow that is diverted is primarily determined by the following factors:

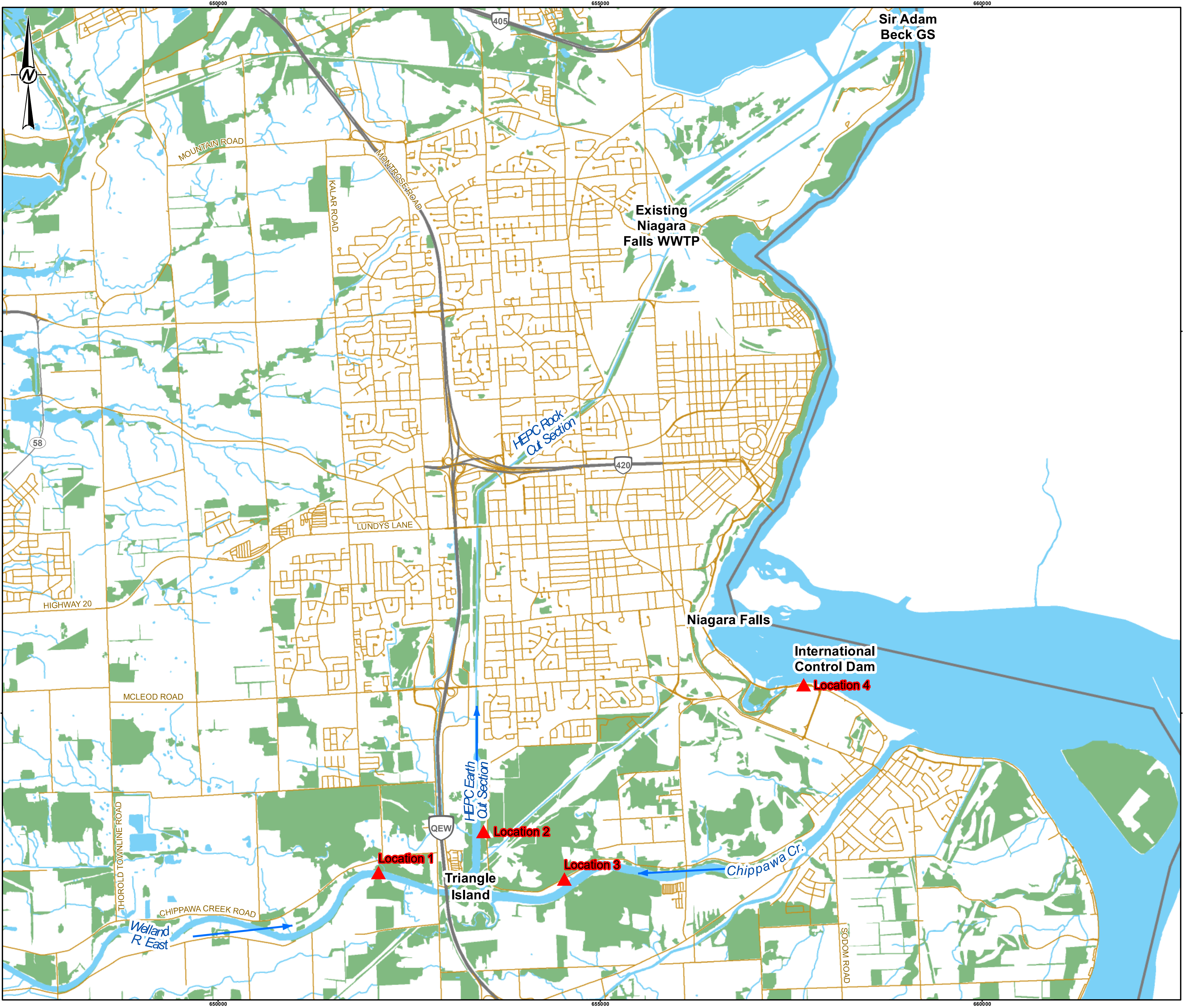
- the operation of the ICD in the Niagara River; which can alternatively increase or decrease the water level in the Niagara River at the mouth of Chippewa Creek; and
- upstream flows in the Niagara River which are determined by water levels at the outlet of Lake Erie, that are influenced by both long-term weather patterns and short-term meteorological events (such as seiching).

The daily operation of the ICD is influenced by the electrical demands and markets in both Ontario and New York State as well as maintaining minimum flow over the falls during tourist periods.

In addition, construction of the Welland Canal to the west of the study area has modified the hydrology and drainage area of the Welland River and several small contributing tributaries. The Welland River passes under the Welland Canal at two locations via siphons that may alter the flow in the river during high flow events. The Lyons Creek watershed area was also decreased by the Welland Canal to the extent that water must now be pumped from the Welland Canal into Lyons Creek to maintain a minimum flow requirement.

For the purposes of maintaining consistent terminology, key surface water features referred to in this ACS use a naming convention adopted by the Ministry of the Environment, Conservation and Parks (MECP), the Niagara Peninsula Conservation Authority (NPCA), and Ontario Power Generation (OPG). Specifically, these key surface water features include:

- **International Control Dam (ICD):** This multi-gated dam in the Niagara River built in 1954 is located approximately 800 m above the Horseshoe Falls and is used to control flows to the Sir Adam Beck GS operated by OPG, the Robert Moses GS operated by the New York Power Authority (NYPA) and the American Falls operated according to Niagara River Treaty (1950). In other literature and documentation, the ICD has sometimes also been referred to as the International Niagara Control Works (INCW).
- **Chippewa–Grass Island Pool (GIP):** This is the area of the Niagara River upstream of the ICD where water levels vary with upstream flow and the operation of the ICD.
- **Hydro Electric Power Canal (HEPC):** This is a canal that conveys diverted flow from the Niagara River (via Chippewa Creek) to the Sir Adam Beck Generating Station.
- **Chippewa Creek:** This is a former portion of the Welland River that flows from the Niagara River to the HEPC when the HEPC is in operation (e.g., reverse flow to natural conditions). During the construction of the HEPC, the width and depth of this section of river were increased to accommodate the increased flow.
- **Triangle Island:** this is a small, constructed island at the junction of the Welland River East, Chippewa Creek, and the HEPC. During normal operation of the HEPC, the diverted flow from the Niagara River flows past the northeast side of Triangle Island from Chippewa Creek into the HEPC while flow from the Welland River East flows past the northwest side of Triangle Island into the HEPC. The channel to the south of Triangle Island is narrower and shallower than the other channels and does not typically have significant flows. Triangle Island is also the location of the safety booms (northeast and northwest sides) used to prevent boat traffic from entering the HEPC.
- **Earth Cut Section:** This is the wide portion of the HECP dug into soil between Triangle Island and the Rock Cut Section of the HEPC and is approximately 1.5 km long.
- **Rock Cut Section:** This is the narrower and deeper section of the HECP cut into bedrock below the Earth Cut Section. The rock cut section of the HEPC is approximately 12 km long and ends at the Sir Adam Beck GS.
- **Welland River East:** This is the portion of the Welland River upstream of triangle island. MECP / NPCA use this convention to distinguish the sections of the Welland River east or west of the Welland Canal.



LEGEND

▲	APPROXIMATE DISCHARGE LOCATON
→	FLOW DIRECTION
—	LOCAL ROAD
—	PRIMARY HIGHWAY
—	SECONDARY HIGHWAY
—	WATERCOURSE
☐	INTERNATIONAL BORDER
🟩	WOODED AREA
🟦	WATERBODY

0 1 2

1:50,000 KILOMETRES

NOTE(S)

1. ALL LOCATIONS ARE APPROXIMATE.

REFERENCE(S)

BASE DATA COURTESY OF MNRF LIO. PRODUCED BY GOLDER ASSOCIATES UNDER LICENSE FROM ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY
PROJECTION: UTM ZONE 17N DATUM: NAD 83

CLIENT

REGIONAL MUNICIPALITY OF NIAGARA

PROJECT

SOUTH NIAGARA FALLS WASTEWATER SOLUTIONS
SCHEDULE C CLASS ENVIRONMENTAL ASSESSMENT

TITLE

LOCATION OF PROJECT AREA

CONSULTANT

GOLDER

YYYY-MM-DD	2020-05-19
DESIGNED	MM/PR
PREPARED	PR
REVIEWED	GVA
APPROVED	GVA

PROJECT NO.	CONTROL	REV.	MAP
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1.1.2 Potential Discharge Locations

With reference to Figure 1, the ACS considered four different effluent discharge location alternatives for the purpose of receiving treated wastewater effluent discharges from the new WWTP, as follows:

- **Location 1 – Welland River East:** Located immediately west of Triangle Island, the discharge from the new WWTP would mix with flow from Welland River East.
- **Location 2 – Earth Cut Section of HEPC:** Located immediately north of Triangle Island, the discharge from the new WWTP would mix with flow from Chippewa Creek and Welland River East.
- **Location 3 – Chippewa Creek:** Located immediately east of Triangle Island, the discharge from the new WWTP would mix with flow from Chippewa Creek (composed mainly by water from the Niagara River diverted into the HEPC based on flow demand and flow from Lyons Creek) and occasionally with water from Welland River East when the HEPC is not operational.
- **Location 4 – Niagara River:** Located immediately downstream of the ICD and below Chippewa, the WWTP would discharge directly into the Niagara River via a shoreline discharge.

1.2 Study Purpose

The purpose of this ACS is to provide alternatives assessment input in support of the Municipal Class EA by:

1) Evaluating the assimilative capacity of each considered discharge location, considering the seasonal characteristics of key water quality parameters that could be affected by treated effluent discharges at local and system compliance points.
2) Determining the environmental constraints of each discharge location with respect to assimilating a treated wastewater discharge of 30 MLD.
3) Identifying the discharge concentration limits of key water quality parameters to meet Provincial Water Quality Objectives (PWQOs), to meet Canadian Council for Ministers of the Environment criteria (where PWQOs are not available), or to maintain water quality in accordance with MECP Policy 2 requirements conditions at the discharge location.

This study assesses the assimilative capacity and water quality effects at two compliance points for each discharge option. The local compliance point is located immediately downstream of the discharge. In order to consider the cumulative effects of existing discharges to the HEPC, the system compliance point is located in the HEPC immediately downstream of the existing Niagara Falls WWTP and upstream of the confluence with the power tunnels.

1.3 General Study Approach and Report Outline

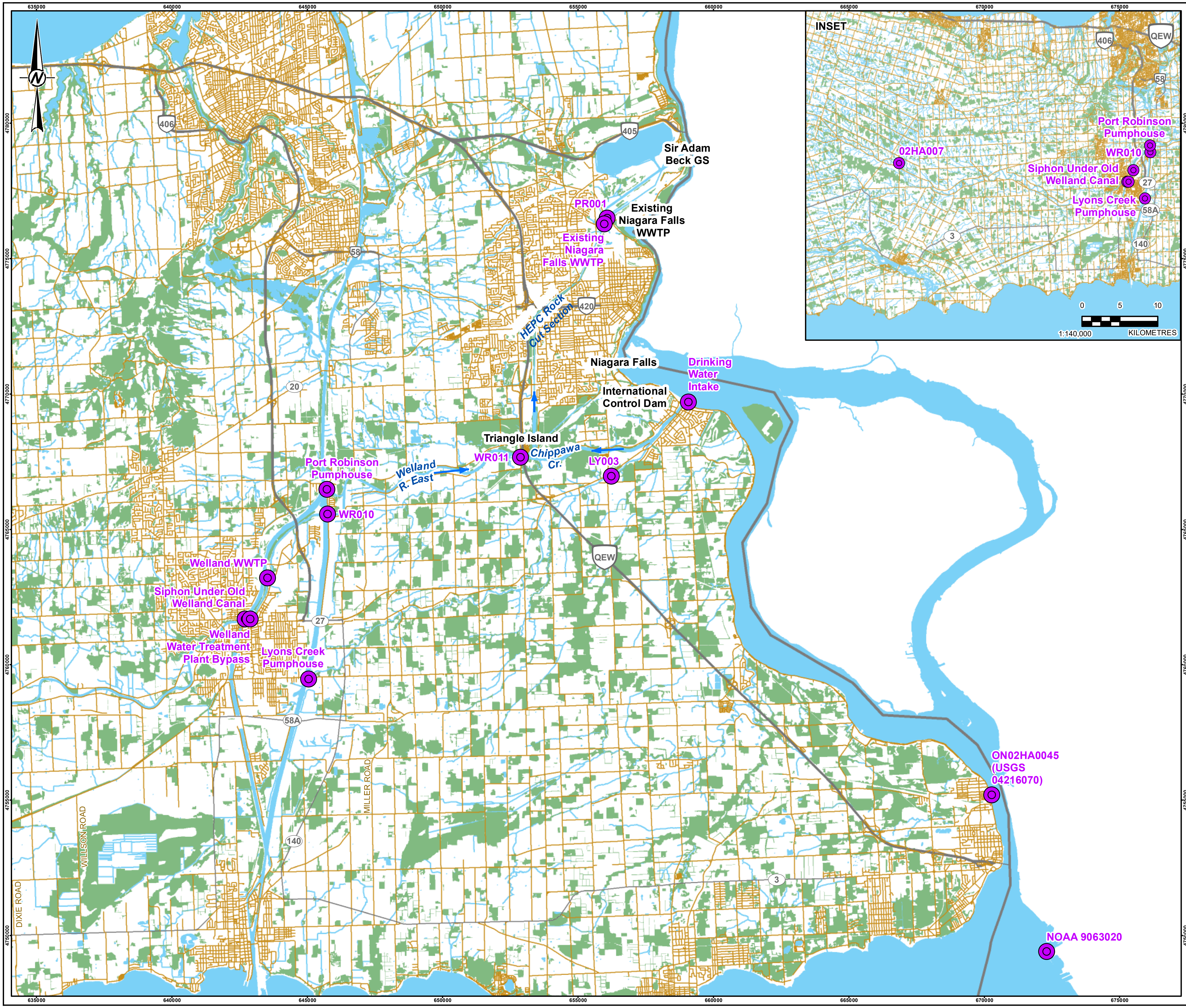
The characterisation of discharge locations considered in this study were based on a number of corporate and publicly available sources including water quality obtained from the MECP Provincial Water Quality Monitoring Network (PWQMN), the US Geological Survey (USGS), The National Oceanic and Atmospheric Administration (NOAA), and the NPCA. Flow data for the Welland River was obtained from the Water Survey of Canada (WSC), flow data for the Niagara River were obtained from the USGS, and flow data for the HEPC were provided by OPG. The structure of this ACS report is presented in the following order:

- Section 2 details the background information obtained and used to characterise seasonal water quality and flow conditions for each of the four discharge locations.

- The hydrological nature of the four locations considered in this study required a slightly modified approach compared to conventional Assimilative Capacity Studies. Namely, system flows at three of the locations (Welland River East, Chippewa Creek and HEPC) are heavily regulated, which meant that the conventional 7Q20 approach to flow derivation was replaced with a stochastic approach. Secondly, the fact that effluent discharges to the Niagara River would only mix with a limited portion of river flow prior to reaching Niagara Falls meant that the mixing potential of effluent discharges at this location were assumed to be limited to only 3% of the Niagara River flows. Section 3 introduces the modelling approach adopted for each discharge location and identifies relevant seasonal and/or environmental constraints, as well as identifying the maximum allowable effluent concentrations at each discharge location to achieve regulatory compliance.
- Based on the constraints identified in Section 3, Section 4 identifies the appropriate treatment technology for each discharge location, presents the ensuing water quality results at each location and provides a high-level discussion of the overall implications on the Project. Section 4 also recommends effluent limits and limits for each location and parameter.
- Section 5 estimates the effects of the Project on the receiving water at selected locations in terms of total phosphorus, nitrate, fecal coliforms (*E. coli*), Carbonaceous Biochemical Oxygen Demand (CBOD$_5$)), and ammonia (total and unionized).
- Section 6 summarises the key conclusions and recommendations of the ACS.

2.0 BACKGROUND INFORMATION AND DATA REVIEW

This section provides details and summaries of the data used in the ACS. The locations of the monitoring locations where the data were collected are shown in Figure 2.



LEGEND

- ◎ REGIONAL SAMPLING STATION LOCATION
- → FLOW DIRECTION
- — LOCAL ROAD
- — PRIMARY HIGHWAY
- — SECONDARY HIGHWAY
- — WATERCOURSE
- ▭ INTERNATIONAL BORDER
- 🟩 WOODED AREA
- 🟦 WATERBODY

0 5 10
1:140,000 KILOMETRES

NOTE(S)

1. ALL LOCATIONS ARE APPROXIMATE.

REFERENCE(S)

BASE DATA COURTESY OF MNRF LIO. PRODUCED BY GOLDER ASSOCIATES UNDER LICENSE FROM ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY
PROJECTION: UTM ZONE 17N DATUM: NAD 83

CLIENT
REGIONAL MUNICIPALITY OF NIAGARA

PROJECT
SOUTH NIAGARA FALLS WASTEWATER SOLUTIONS
SCHEDULE C CLASS ENVIRONMENTAL ASSESSMENT

TITLE
DATA COLLECTION AND MONITORING LOCATIONS

CONSULTANT
GOLDER

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2.1 Hydrology and Flow Data

2.1.1 Water Management in Study Area

The flow in Chippewa Creek and the HEPC has been controlled since 1921. The ICD has been in operation since 1954 and is jointly funded and controlled by OPG and NYPA in accordance with the 1950 Niagara Treaty (Canada, 1950) and a Memorandum of Understanding between the two power companies which are intended to maximize the beneficial use of the hydro electric potential of the Niagara River, while maintaining the scenic value of Niagara Falls for tourism and other uses of water in the Niagara River. The treaty stipulates that:

- Scenic flow is allocated first, domestic use second, navigational requirements third, and power generation fourth.
- Any river flow diverted for hydro electric power is to split equally between both countries.
- During tourist times, the flow over the falls must be at least 2,832 m³/s (100,000 cfs). Tourist times are defined as 8 AM to 10 PM from April 1 to September 15 and 8 AM to 8 PM from September 16 to October 31.
- The specified minimum flow over the falls is at least 1,416 m³/s (50,000 cfs) at all other times.
- If the upstream flow in the Niagara River is less than the specified minimum flows, no river flow is to be diverted to the power canals.

Water levels in the Chippewa-Grass Island Pool are regulated in accordance with the 1993 Directive of the International Niagara Board of Control.

In addition, OPG is required to maintain a minimum flow of 240 m³/s to the HEPC via Chippewa Creek to ensure that water from the Niagara River reaches the existing drinking water intake of the City of Niagara Falls Water supply plant located near the junction of Chippewa Creek and the Niagara River (Kowalski 2019). Niagara Region is currently in the process of relocating the water supply intake to the Niagara River upstream of Chippewa Creek.

2.1.2 Welland River East

In general, low flow frequency analysis of natural flows is used to generate the low-flow conditions (7Q20) to assess the assimilative capacity of the receiving water body (MOE 1994a). The Welland River East, however, is a complex hydrologic system characterized by natural flows and supplemental flows and the low-flow conditions are dominated by the supplemental flows. As a result, the 7Q20 would not be applicable for this specific assessment. Previous Assimilative Capacity Studies in the Welland River East have successfully applied an approach where the low flows conditions are based on combination of natural and supplemental flows as shown in the ACS completed for the Welland Wastewater Treatment Plant (XCG 2007).

2.1.2.1 Natural Flows in the Welland River East

Regional station data was used to estimate natural flow for the Welland River East. Flow data for the Welland River below Caistor Corners (station 02HA007) from the WSC are available from 1957 to 2017. Flows at the site are calculated based on the prorated watershed area of the site (906 km²) and the total watershed area of the gauged station (223 km^2). Natural flows in the system are generally low with punctual peak flows recorded during storm events and snowmelt.

Since supplemental flows are significantly higher than average natural flows in the system (i.e., approximately double the annual average flows), natural flows in the Welland River East become relevant only under peak flow conditions. Therefore, flows were prorated between the gauging station (223 km^2) and the area at the site

(906 km^2) according to the Transposition of Flood Discharges Method (MTO, 1997) applying a coefficient of 0.75 to represent peak flows (the coefficient used for average and low flows is 1.0).

The estimated natural flows yield an average annual flow of 6.50 m^3/s with estimated maximum and minimum flows in the range of 132.41 m^3/s and 0.046 m^3/s. The 7Q20 for the natural flows based on the Log Pearson Type III distribution would yield 0.004 m^3/s.

2.1.2.2 Supplemental Flow from Welland Canal into Welland River East

Supplemental flows enter the Welland River East from the Welland Canal (St. Lawrence Seaway Management Corporation [SLSMC] 2019) as follows:

- A series of ports in the roof of the old syphon provide flow from the canal into the river. Depending on the season and water levels in the canal, the total flow ranges from 5 to 7 m^3/s.
- A pump at Port Robinson provides a flow of 0.97 m^3/s to a side channel of the Welland River East, which was cut-off from the main branch of the river during the straightening of the canal in the 1950s.
- The bypass of the Welland Water Treatment Plant provides a flow between the canal and the river that ranges from 4 m^3/s to 6 m^3/s.
- The effluent from the Welland Wastewater Treatment Plant provides a flow of 0.8 m^3/s (XCG 2007).

In general, the supplemental flows from the Welland Canal are from Lake Erie and have better water quality than that of the upstream areas of the Welland River.

Monthly estimates of the supplemental flows for the siphon ports, Port Robinson Pump, the Welland Water Treatment Plant and the Welland WWTP were provided by the SLSMC (SLSMC 2019) for the period 2014 to 2019 and are summarized in Table 1.

Table 1: Summary of Supplemental Flows from Welland Canal into the Welland River East

Source	Winter		Spring		Summer		Fall	
	Min	Avg	Min	Avg	Min	Avg	Min	Avg
Old Welland Canal at Old Siphon[1]	5.17	5.82	5.85	6.61	6.68	6.88	5.56	6.88
Welland Water Treatment Plant[1]	4.45	5.05	4.61	5.65	5.19	5.87	5.64	5.92
Port Robinson Pump[1]	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Welland WWTP[2]	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Total[3]	**11.39**	**12.64**	**12.23**	**14.03**	**13.64**	**14.52**	**12.97**	**14.57**

Notes:
1. SLSMC 2019.
2. XCG 2007.
3. All flow values in Table 1 are presented in m^3/s.

2.1.3 Niagara River

Daily flow data for Niagara River at Buffalo, New York (opposite Fort Erie, Ontario) were obtained from the USGS for Station 04216000 located in the Niagara River at Buffalo, New York for the years 1926 to 2018 (93 years).

As shown in Table 2, the monthly average flows for the Niagara River at Buffalo range from 5,501 m^3/s (February) to 6,139 m^3/s (May) with an average flow is 5,808 m^3/s. The peak daily flow over the period of record for fall, winter, summer, and spring are 8,466 m^3/s, 9,825 m^3/s, 7,957 m^3/s, and 8,410 m^3/s, respectively. In general, the flows are seasonally consistent year-round with only a slight increase during the spring.

The average daily flow in the Niagara River at Fort Erie did not fall below the tourist time minimum daytime (tourist hours) flow requirements of 2,832 m^3/s (see Section 2.1.1) over the 93-year data period suggesting that there is consistently excess flow available for power generation (e.g., excess flow above treaty requirements).

2.1.3.1 Flow Diversions

Flow diversions from the Niagara River into Chippewa Creek are controlled by OPG based on the requirements in the Treaty for equitable streamflow apportioning between OPG and NYPA. NYPA flows are adjusted upwards to reduce the benefit to OPG at Niagara for the Ogoki-Long Lac diversion south into Great Lakes watershed since mid-1940's

Total diversion flow (HEPC plus three tunnels) data was obtained from OPG for the period 2016 to 2018. As shown in Table 2, the monthly average total flow diversions by OPG range from 1,461 m^3/s (March) to 1,645 m^3/s (August) with an average flow of 1,540 m^3/s. As mentioned previously, the diverted flows by NYPA would be equal to the OPG diverted flows. Instantaneous (hourly) flows ranged from 1,014 m^3/s to 2,272 m^3/s.

Table 2: Average Flow Data for Niagara River at Fort Erie, Diverted Flow by OPG, and Flow Over Niagara Falls

Month	Season	Niagara River at Fort Erie[1] (m^3/s)		Total OPG Diverted Flow[2,3] (m^3/s)		Estimated Flow over Niagara Falls[4] (m^3/s)			
		Monthly Average	Season Average	Monthly Average	Season Average	Monthly Average	Season Average	Monthly Min	Season Min
Jan	Winter	5,573	5,583	1,562	1,521	2,627	2,687	2,124	2,124
Feb		5,501		1,541		2,598		2,124	
Mar		5,667		1,461		2,828		2,124	
Apr	Spring	5,908	6,055	1,493	1,499	2,993	3,101	2,242	2,242
May		6,139		1,479		3,210		2,242	
Jun		6,115		1,526		3,095		2,242	
Jul	Summer	6,023	5,899	1,637	1,619	2,836	2,762	2,242	2,124
Aug		5,909		1,645		2,735		2,242	
Sep		5,760		1,573		2,712		2,124	
Oct	Fall	5,672	5,690	1,464	1,519	2,799	2,738	2,124	2,124
Nov		5,685		1,498		2,763		2,124	
Dec		5,715		1,595		2,654		2,124	
Annual		**5,808**		**1,540**		**2,822**		**2,124**	

Notes:

1. Measured daily flows for Niagara River at Buffalo, New York (USGS Station 04216000) from 1926 to 2018.
2. Total diverted flow diverted by OPG for 2016 to 2018 (Kowolski, 2019).
3. As per the 1950 Niagara Treaty, diverted flows by NYPA would be equal to the OPG diverted flows.
4. Estimated flow over Niagara Falls based on Niagara River flow, diverted flows by OPG and NYPA, and 1950 Niagara Treaty requirements.

2.1.3.2 Estimated Flow Over Falls

For an evaluation of Location 4, the flow over Niagara Falls (e.g., below the ICD) was based on the following assumptions and methods:

- As per the Niagara Treaty, on any day the flow diverted by NYPA was assumed to be equal to that diverted by OPG.

- While the operation of the ICD may disproportionately affect the flow at Location 4 depending on which gates are closed, it was assumed that the flow downstream of the ICD is distributed equally across the width of the Niagara River.
- Monthly average total diverted flows were estimated based on the data provided by OPG (2016 to 2018).
- The minimum flow requirements of the Niagara Treaty were converted to a time-weighted daily average minimum flow requirement (2,242 m³/s from April 1st to September 15th and 2,124 m³/s from September 16th to March 31st).
- Daily average flows over the falls were estimated for the long-term flow record at Buffalo (1926 to 2018) by subtracting the average monthly total diverted flows. If the resulting flow was less than the appropriate daily average minimum flow requirement, then the minimum flow requirement was used (e.g., assumed reduction in diverted flow).

The estimated seasonal and monthly flows over Niagara Falls are also provided in Table 2. The monthly average flows over Niagara Falls range from 2,598 m³/s (February) to 3,210 m³/s (May) with an average flow is 2,822 m³/s.

Restrictions in the total diverted flow by OPG and NYPA occurred approximately 22% of the time between 1926 and 2018 in order to meet the required minimum daily average flow over the falls. These restrictions occurred most frequently during January and February (approximately 33% of the time) and least frequently in May (approximately 8% of the time).

Since the flow over the falls is regulated, a statistical analysis of the flows to determine the 7Q20 low-flow condition is not appropriate. As such, the low-flow condition over the falls was assumed to be the minimum regulated daily average flow over the falls as outlined in the Niagara Treaty (2,242 m³/s during the tourist season and 2,124 m³/s during the non-tourist season) that occurs in each assessment season.

2.1.4 Lyons Creek

Historically, the drainage area of Lyons Creek extended into the City of Welland. However, during the construction of the Welland Canal, the watershed was split with the western section draining into the Welland Canal. While the eastern section of Lyons Creek still drains into Chippewa Creek, the drainage area was reduced to approximately 88 km². As a result of this reduction in drainage area, the natural flows in Lyons Creek are supplemented by the pumping of water from the Welland Canal at the location where the main channel of Lyons Creek was interrupted by the construction of the canal. From April to November, during the shipping season when the Welland Canal is full, the pumping rate is approximately 0.283 m³/s (SLSMC 2019). From December to March, when sections of the canal are drained, the flow is reduced to approximately 0.142 m³/s.

Regional station data was used to estimate the natural flows for the Lyons Creek. Flow data for the Welland River Below Castor Corners (station 02HA007) from the WSC are available from 1957 to 2017. Flows at site are calculated based on the prorated watershed area of the site (88 km²) and the total watershed area of the gauged station (223 km²).

2.1.5 Hydro Electric Power Canal (HEPC)

Flow from the Niagara River is diverted to the Sir Adam Beck GS from the Chippewa-Grass Island Pool via three tunnels and the HEPC. Under normal operating conditions, each of these conveyances carries approximately one quarter of the total diverted flow. The flow in the HEPC and tunnels can vary hourly and seasonally due to flow variations in the Niagara River, minimum flow requirements over the falls (see Section 2.4.1), electrical demand, and the market price for electricity.

The flow data provided by OPG (Kowalski 2019) represents the total flow diverted by OPG from the Niagara River to the HEPC and the three tunnels. Typically, the flow in the HEPC represents 27% of the total diverted flow.

Hourly flow data provided by OPG for a three-year period (2016 to 2018) was used as a basis for the following observations regarding the flow in the HEPC:

- The hourly flow rate ranged from 292 m^3/s to 624 m^3/s with an average of 429 m^3/s.
- Flow rates are typically highest during the summer months (446 m^3/s) and lowest in the fall (411 m^3/s).
- Typically, the flows are lowest at 4:00 AM (402 m^3/s) and highest at 6:00 PM (456 m^3/s).

2.1.6 Chippewa Creek

Water from the Niagara River is diverted into Chippewa Creek based on the water levels in the Chippewa-Grass Island Pool. Chippewa Creek extends approximately 6.5 km from the Niagara River to Triangle Island. Lyons Creek drains to the south shore of Chippewa Creek approximately 2km west of the Niagara River.

Given the highly regulated system, flow in Chippewa Creek was estimated in the model based on the flow demand in the HEPC and the estimated flows contributing to the system from the Welland River East and Lyons Creek. The estimated flow (diverted from Niagara River) was calculated in the modelling exercise.

2.1.7 Existing Niagara Falls Wastewater Treatment Plant

The daily volume of the water from the existing Niagara Falls WWTP was provided by Niagara Region for the period 2015 to 2018.

The measured daily flow over the period of record for fall, winter, summer, and spring are 0.55 m^3/s, 0.45 m^3/s, 0.49 m^3/s, and 0.53 m^3/s, respectively. For comparison, the existing Niagara Falls WWTP is rated for an average daily flow of 0.79 m^3/s (68,300 m^3/day), a peak flow rate of 1.58 m^3/s (136,400 m^3/day) during dry weather, and 2.37 m^3/s (205,000 m^3/day) during wet weather (MOE, 2010). These rates are well above the average and peak flows observed for the period 2015 to 2018, meaning that the plant was operating under capacity for the period of record.

The existing Niagara Falls WWTP operates at an average flow of approximately 0.472 m^3/s (40,810 $m^{3/}$day). For the ACS modelling, the effluent flow was maintained at the existing rated capacity of 0.79 m^3/s (68,300 m^3/d). The effluent from the plant to the HEPC and immediately upstream from the system compliance point (upstream of Sir Adam Beck GS).

2.1.8 Combined Sewer Overflows (CSOs) and Wastewater Treatment Plan Bypass

Niagara Region has a total of five Regional CSOs discharging into the HEPC from regional pumping stations. Discharges from the CSOs into the HEPC are primary triggered by storm events. The pumping stations associated with these Regional CSOs are Dorchester Road, Drummond Road, Royal Manor, High Lift and existing Niagara Falls WWTP. The existing Niagara Falls WWTP is further differentiated in terms of water quality as direct overflow (i.e., no treatment) and secondary bypass (i.e., primary treatment).

The City of Niagara Falls has a total of three municipal CSOs discharging to the HPEC from their sanitary and storm sewer collection systems. The locations associated with these municipal CSOs are Sinnicks Avenue, Bellevue Street, and McLeod Road. Volume and frequency of CSOs from the City of Niagara Falls has not been made available and therefore, are excluded from this analysis.

Measured CSO flows were provided by Niagara Region for 2015 through 2018. The measured seasonal frequency and magnitude of overflows from these regional CSOs was analyzed for the period of record. The average seasonal overflow volumes per overflow event (and volume% calculated over average CSO flow discharge over the season) and number of events are summarized on Table 3.

In general, the majority of CSO events occur in spring and summer, coinciding with the largest overflow magnitudes. The secondary bypass from the existing Niagara Falls WWTP yields the largest volume and frequency of CSO flows into the system, followed, by the overflow from the existing Niagara Falls WWTP. These two items yield approximately 94.0% (summer) to 99.6% (fall) of the total CSO flows in the system.

Table 3: Summary of Average Seasonal Flow per Event and Average Number of Events per Season

Season	Dorchester Road	Drummond Road	Royal Manor	High Lift	Existing Niagara Falls WWTP Primary Bypass	Existing Niagara Falls WWTP Secondary Bypass
Average Overflow Volume (m³/event)						
Winter	720(0.3%)	0(0%)	0(0%)	1,820(0.5%)	7,100(2.5%)	9,200(96.7%)
Spring	4,740(0.5%)	140(0%)	970(0%)	6,810(0.7%)	15,700(2.8%)	17,900(95.9%)
Summer	970(3.9%)	220(0.6%)	0(0%)	3,880(1.5%)	4,300(11.4%)	3,200(82.6%)
Fall	1,360(0.4%)	80(0%)	0(0%)	5,020(0.6%)	8,000(2.3%)	14,500(96.7%)
Annual	1,840(0.2%)	160(0%)	970(0.1%)	4,530(0.2%)	9,500(0.9%)	11,200(98.6%)
Average Number of Overflow Events (events/month)						
Winter	1.75	0	0	1.5	1.75	5.25
Spring	3	1.67	1	2.75	4.75	9
Summer	5.25	3.5	1	0.5	3.5	8
Fall	2	1	0	1	2.25	5.5
Annual	3	1.64	2	1.44	3.06	6.94

Notes:

1. Values in brackets indicate the approximate percentage of the total seasonal volume contributed by each source.

2.2 Water Quality Data

Water quality data for the existing Niagara Falls WWTP and receivers were available for several locations. Most of these locations included parameters suitable to the ACS (e.g., basic chemistry, nutrients, metals, temperature, etc.).

For the initial phases of the ACS, the parameters of concern include total ammonia, unionized ammonia, nitrate, phosphorus, *Escherichia coli* (*E. coli*), dissolved oxygen, Carbonaceous Biochemical Oxygen Demand (CBOD$_5$), and Total Suspended Solids (TSS). The assessment also used pH and water temperature estimate unionized ammonia concentration of the reported water quality data using the equations provided by the MECP (Ministry of Energy and Environment [MOEE], 1994).

The data summaries for the locations in the following sections present the 75th percentile values for all the parameters. These percentiles are used in subsequent analysis as follows:

- The 75th percentile values for total ammonia, nitrate, total phosphorus, *E. coli*, dissolved oxygen, CBOD$_5$, and TSS were used as the background concentrations when estimating the maximum allowable effluent concentrations.
- The 75th percentile values of pH and water temperature were used to estimate the maximum allowable concentration of total ammonia in the effluent based on the estimated maximum allowable effluent concentration for unionized ammonia.
- If more than one water quality monitoring station was available for any given flow source, the maximum reported 75th percentile value was used for conservatism in the modelling exercise.

2.2.1 Applicable Water Quality Guidelines

Applicable PWQOs for the parameters discussed in this memorandum are presented in the Table 4 and are discussed in the following points.

- Since the study area is effectively a river, the PWQO for phosphorus for the avoidance of excessive plant growth in rivers and streams (0.03 mg/L) was used.
- Since there is no PWQO for nitrate, the Canadian Council of Ministers of the Environment (CCME) guideline was selected.
- Seasonal temperature and pH values were used to determine the limits for total ammonia based on the PWQO for unionized ammonia.
- Since the Niagara River, Lyons Creek, and Welland River East are all considered warm water aquatic habitat (NPCA 2011), the dissolved oxygen guideline for warm water fisheries was used.
- The PWQO for fecal coliforms (*E. coli*) is for recreational use (e.g., beaches).
- Since the new WWTP is not expected to release a thermal discharge or alter the pH in the receiving waters, water temperature and pH were excluded from the modelling exercise.
- Since there is no PWQO for total suspended solids, the CCME guideline for clear flow (low flow) was selected.

Table 4: Summary of Applicable Water Quality Objectives

Parameter	PWQO or CCME Guideline
Unionized Ammonia	0.0164 mg/L as N[1]
Total Ammonia	Estimated from unionized ammonia criteria based on ambient water temperature and pH using equations in the Provincial Water Quality Objectives (MOEE 1994)
Nitrate	3 mg/L as N[2]
pH	6.5 to 8.5[1]
E. coli.	100 cfu/100mL[1,3]
Total Phosphorus	0.03 mg/L to avoid excessive plant growth in rivers and streams[1]
Dissolved Oxygen	47% of saturation or 4 mg/L above 20ºC for warm water fisheries[1,5]
Total Suspended Solids	During clear flow (low flow): Maximum average increase of 5 mg/L from background levels for longer term exposures (24 hours to 30 days).[2]
Water Temperature	10ºC above background or 30ºC for thermal discharges[1]

Notes:

1. Provincial Water Quality Objectives (MOEE, 1994).
2. Guideline for freshwater aquatic life in CCME Guidelines (CCME, 2014).
3. PWQO for *E. coli* is for recreational use (e.g., swimming beaches).
4. Since the new WWTP is not expected to release a thermal discharge or alter the pH in the receiving waters, water temperature and pH were excluded from the modelling exercise (explicitly) but used to assess capacity in the system for unionized ammonia.
5. Since the Niagara River, Lyons Creek, and Welland River East are all considered warm water aquatic habitat (NPCA 2011), the dissolved oxygen guideline for warm water fisheries was used.

2.2.2 Welland River East

For the water quality assessment of the Welland River East, data from two monitoring stations were used:

- immediately west (upstream) of Triangle Island at Montrose Road (WR011) with available data from 2011 to 2018; and
- further west (upstream), where the Welland River crosses at the Welland Canal (WR010) with data from 2003 to 2018.

Water quality data for the Welland River East was provided by NPCA. A summary of the seasonal water quality values for WR010 and WR011 are presented in Table 5. Water quality in the Welland River East consistently exceeds the PWQO guidelines for phosphorus and *E. coli*.

As mentioned in Section 0, the flows in the Welland River East are supplemented by flows from the Welland Canal. As a result, the water quality in the Welland River East is a combination of water from the Welland Canal which is effectively water from Lake Erie) and natural drainage from the upper sections of the Welland River Watershed. The water from the canal is typically of better quality than that of the upper Welland River (e.g., lower phosphorus concentrations). The contributions of the Welland Canal flows on the water quality in the Welland River East are demonstrated on Figure 3 when the natural flows are low and diluted by Welland Canal flows, the total phosphorus concentrations are low (e.g., less than 0.05 mg/L). During higher natural flows, the dilution by the canal flows are less pronounced and the total phosphorus concentration are elevated (e.g., up to 0.45 mg/L).

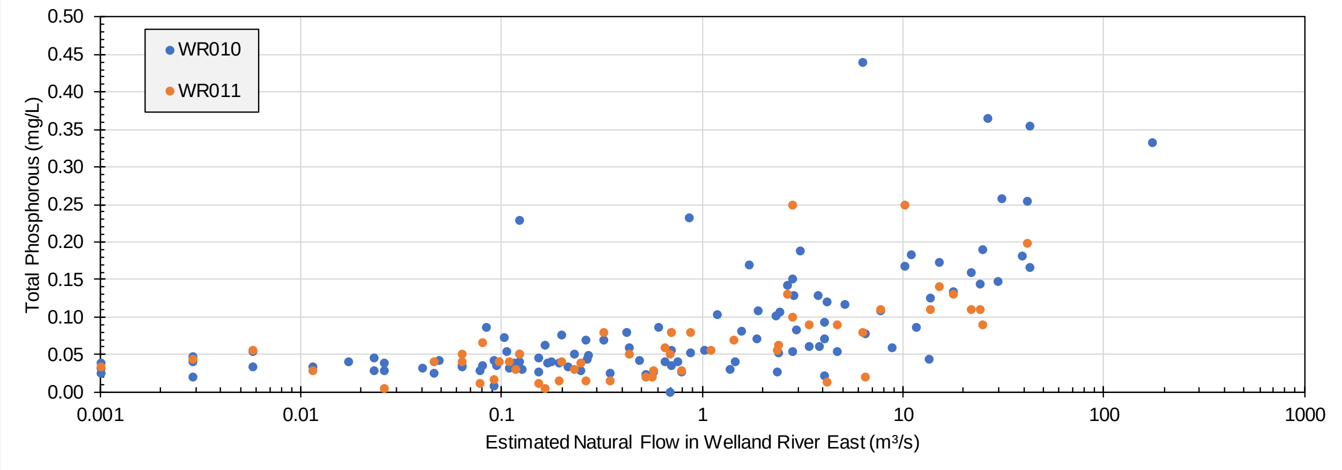

Figure 3: Total Phosphorus Concentration Against Estimated Natural Flow in Welland River East

Comparing the 75th percentile concentrations for both stations showed that ammonia concentrations are higher at WR011 during winter/spring and that overall, the concentration of phosphorus is higher upstream in the Welland River (WR010). The remaining parameters do not show significant differences between upstream (WR010) and downstream (WR011) monitoring stations. Based on the data, there are frequent exceedances of the PWQOs for phosphorus and *E. coli.* in the Welland River East.

The GoldSim model uses the monthly 75th percentile of ammonia, *E. coli*, nitrate, and total phosphorus. For each parameter, the highest 75th percentile value from WR011 and WR010 was selected. The decision to use this approach is based on the uncertainty of WR011 (as it would be influenced by flow from Niagara River) and the additional sources which could affect water quality in the reach between WR010 and WR011. Using the highest value of the two stations yields a conservative approach for prediction of assimilative capacity of the system. The assimilative capacity of the system for ammonia is based on the regulatory limit of unionized ammonia, ammonia in the system (based on 75th percentile), and 75th percentile values of pH and temperature.

The seasonal values selected to characterize the water quality in the Welland River East are presented in Table 5.

Table 5: Summary of Seasonal Water Quality Concentrations for Welland River East

Parameter		Winter		Spring		Summer		Fall	
		WR010	WR011	WR010	WR011	WR010	WR011	WR010	WR011
Number of Samples		**5**	**2**	**34**	**17**	**38**	**16**	**41**	**20**
Total Ammonia (mg/L)	Geo-mean	0.21	0.47	0.16	0.16	0.14	0.07	0.10	0.10
	75th	0.23	0.59	0.21	0.28	0.22	0.09	0.20	0.16
Unionized Ammonia (mg/L)	Geo-mean	0.001	0.003	0.003	0.004	0.009	0.003	0.004	0.004
	75th	0.001	0.007	0.006	0.007	0.018	0.004	0.009	0.007
Nitrate (mg/L)	Geo-mean	1.78	2.32	0.76	0.62	0.32	0.33	0.50	0.50
	75th	2.29	2.38	1.11	0.91	0.49	0.48	1.05	0.82
E. coli. (cfu/100 mL)	Geo-mean	-	**2474**	-	66	-	25	-	64
	75th	-	**6920**	-	**308**	-	**105**	-	**170**
Total Phosphorus (mg/L)	Geo-mean	**0.09**	**0.12**	**0.07**	**0.05**	**0.06**	**0.04**	**0.06**	**0.04**
	75th	**0.14**	**0.13**	**0.16**	**0.09**	**0.08**	**0.06**	**0.10**	**0.08**
Dissolved Oxygen (mg/L)	Geo-mean	13.73	14.48	11.64	12.04	9.17	9.78	9.84	9.85
	25th	12.68	13.81	10.66	11.48	8.12	8.66	8.51	8.97
CBOD$_5$ (mg/L)	Geo-mean	-	-	-	0.16	-	0.31	-	0.16
	75th	-	-	-	1.03	-	2.00	-	1.00
Total Suspended Solids (mg/L)	Geo-mean	20.2	26.1	12.6	7.4	8.9	5.6	6.6	4.7
	75th	34.9	28.8	20.9	21.0	11.4	11.8	9.7	6.0
Water Temperature (ºC)	Geo-mean	1.78	1.62	7.54	8.77	22.57	23.64	13.52	13.40
	75th	2.10	1.99	14.39	13.46	24.06	25.27	19.69	20.45
pH	Geo-mean	7.82	7.73	8.08	7.98	8.17	8.08	8.18	8.02
	75th	7.82	7.81	8.23	8.16	8.26	8.23	8.27	8.15

Notes:

1. **Bold** values indicate exceedances of applicable PWQO.
2. Data provided by NPCA.
3. Highlighted values correspond with input to the GoldSim model.

2.2.3 Niagara River

The water quality in the Niagara River was quantified by compiling data from three sources since no one location offered a full complement of data for all required parameters. The data sources were:

- The Niagara River at Fort Erie (ON02HA0045) from 1981 to 1999 (total phosphorus, total ammonia, unionized ammonia, nitrate, and pH).
- The Niagara River at Niagara-on-the-Lake (ON02HA0019) from 1975 to 1999 (total phosphorus only, not used as modelling input).
- The raw water intake data for the Niagara Falls Drinking Water Supply Plant from 2016 to 2018 (*E. coli*).
- Water temperatures in the Niagara River were based on hourly measurements taken at Buffalo, NY (Station 9063020) by NOAA between 2007 and 2018.
- Dissolved oxygen and TSS concentrations were obtained from the USGS for station 04216070 (Niagara River at Fort Erie) for the period 2014 to 2019.

Water quality data for the eastern basin of Lake Erie and the Niagara River at Fort Erie were obtained from the Environment Canada website while the water intake data was provided by Niagara Region. Data from NOAA and the USGS were obtained from their respective websites.

Although older than the Lake Erie data, the Niagara River data was selected since the Lake Erie data was collected sporadically and could not adequately define seasonal variations.

In general, the water quality in the Niagara River meets all of the applicable objectives. The only exception was total phosphorus where the 75th percentile concentration of 0.043 mg/L during winter months exceeds the PWQO (0.03 mg/L). This is a consistent annual pattern that occurs throughout the entire data record, with phosphorus below PWQO during all seasons with the exception of winter. The highest monthly total phosphorus concentrations typically occur in December and January.

Measured data regarding TSS and Carbonaceous Biochemical Oxygen Demand ($CBOD_5$) were not available in sufficient quantity to provide seasonal statistical summaries. However, since the water in the Niagara River is typically clear (NYPA, 2005), it is expected that concentrations of TSS and $CBOD_5$ are low. Sixteen samples collected by the USGS provide annual estimates for the geometric mean and 75th percentile TSS values of 5.2 mg/L and 11.3 mg/L, respectively.

The 75th percentile of seasonal values of different parameters for Niagara River and Lake Erie are presented in Table 6.

This study model uses the seasonal 75th percentile values for the Niagara River station for all parameters except dissolved oxygen. The seasonal 75th percentile values for pH and temperature were used to estimate unionized ammonia concentrations. The seasonal 25th percentile values for dissolved oxygen were used.

Table 6: Summary of Seasonal Water Quality Concentrations for Niagara River

Parameter		Winter		Spring		Summer		Fall	
		Niagara River[2]	Raw Water Intake[2]	Niagara River[2]	Raw Water Intake[2]	Niagara River[2]	Raw Water Intake[2]	Niagara River[2]	Raw Water Intake[2]
Number of Samples		596	39	361	39	346	39	375	39
Total Ammonia (mg/L)	Geo-mean	0.007	-	0.029	-	0.022	-	0.012	-
	75th	0.014	-	0.046	-	0.044	-	0.032	-
Unionized Ammonia (mg/L)	Geo-mean	<0.001	-	<0.001	-	0.001	-	<0.001	-
	75th	<0.001		0.001	-	0.002	-	<0.001	-
Nitrate (mg/L)	Geo-mean	0.25	0.20	0.26	0.19	0.19	0.10	0.14	0.07
	75th	0.31	0.36	0.31	0.30	0.26	0.20	0.18	0.12
E. coli. (cfu/100 mL)	Geo-mean	-	5	-	3	-	3	-	5
	75th	-	50	-	12	-	8	-	26
Total Phosphorus (mg/L)	Geo-mean	0.027	-	0.019	-	0.015	-	0.019	-
	75th	**0.043**	-	0.026	-	0.022	-	0.027	-
Dissolved Oxygen[3] (mg/L)	Geo-mean	11.1	-	9.81	-	10.5	-	10.4	-
	25th	10.4	-	8.60	-	8.98	-	8.75	-
Water Temperature (°C)[4]	Geo-mean	1.5	-	6.4	-	21.7	-	13.8	-
	75th	2.5	-	10.1	-	23.9	-	20.1	-
pH	Geo-mean	7.98	-	8.12	-	8.27	-	8.08	-
	75th	8.12	-	8.20	-	8.33	-	8.20	-

Notes:

1. **Bold** values indicate exceedances of applicable PWQO.
2. Data provided by Niagara Region.
3. Dissolved oxygen data obtained from USGS.
4. Data downloaded from NOAA (NOAA, 2019).
5. Average value – geometric mean could not be calculated due to water temperatures below zero.
6. Shaded cells correspond with input to the GoldSim and Mass Balance models.

The total phosphorus concentrations in the upper section of the Niagara River (Fort Erie) are compared to those on the lower section (Niagara-on-the-Lake) in Table 7 for the period 1981 to 1999. Apart from summer, the mean total phosphorus concentrations in the lower sections are lower than the concentrations in the upper section. In all seasons except winter, the difference in mean and 75th percentile concentrations are less than 0.03 mg/L (3 µg/L) suggesting that the effects of current direct phosphorus loads to the Niagara River (e.g., not from Lake Erie) are not measurable.

Table *7*: Comparison of Total Phosphorus in Niagara River Between Fort Erie and Niagara-on-the-Lake

Statistic	Location	Winter	Spring	Summer	Fall
Number of Samples	Fort Erie[1]	597	626	605	618
	Niagara-on-the-Lake[2]	819	865	846	839
Geometric Mean (mg/L)	Fort Erie	0.0346	0.0238	0.0196	0.0241
	Niagara-on-the-Lake	0.0249	0.0206	0.0200	0.0228
75th Percentile (mg/L)	Fort Erie	0.0427	0.0259	0.0215	0.0265
	Niagara-on-the-Lake	0.0345	0.0264	0.0204	0.0257

Notes:

1. Data for Fort Erie collected at Station ON02HA0045 (1981 to 1999).
2. Data for Niagara-on-the-Lake collected at Station ON02HA0019 (1981 to 1999).

2.2.4 Lyons Creek

A summary of measured water quality in Lyons Creek is provided in Table 8. Data were provided by NPCA for station LY003 between 2003 and 2018. $CBOD_5$ data was available only for the 2009 to 2014 period, while dissolved oxygen was not available in the dataset provided for this study.

As expected for a small watershed that drains agricultural areas, the total phosphorus concentrations in Lyons Creek are elevated well above the PWQO.

Table 8: Summary of Seasonal Water Quality Concentrations for Lyons Creek

Parameter		Winter	Spring	Summer	Fall
	Number of Samples	3	35	44	44
Total Ammonia (mg/L)	Geo-mean	0.059	0.051	0.041	0.035
	75th	0.059	0.120	0.080	0.060
Unionized Ammonia (mg/L)	Geo-mean	-	0.002	0.002	0.004
	75th	-	0.005	0.004	0.008
Nitrate (mg/L)	Geo-mean	0.75	0.08	0.07	0.10
	75th	0.87	0.20	0.20	0.20
E. coli. (counts/100 mL)	Geo-mean	**137**	45	32	44
	75th	**520**	95	57	88
Total Phosphorus (mg/L)	Geo-mean	0.147	0.124	0.141	0.103
	75th	**0.255**	**0.160**	**0.160**	**0.140**
CBOD$_5$ (mg/L)	Geo-mean	-	1.16	0.95	1.13
	75th	-	2.00	1.00	1.00
Water Temperature (ºC)	Geo-mean	0.30	6.4	15.1	18.4
	75th	0.30	14.9	26.1	24.7
pH	Geo-mean	7.43	7.83	7.87	7.78
	75th	7.65	7.99	8.02	7.95

Note:

1. **Bold** values indicate exceedances of applicable PWQO.
2. Data provided by NPCA.
3. Shaded correspond with input to the GoldSim and Mass Balance models.

2.2.5 Hydro Electric Power Canal (HEPC)

A summary of the measured water quality in the HEPC near the existing Niagara Falls WWTP is provided in Table 9. Data were provided by NPCA for station PR001 (HEPC at Whirlpool Road) between 2012 and 2018. Based on these data, there are exceedances of the PWQOs for phosphorus during fall and winter months and *E. coli.* in the HEPC.

The GoldSim model does not use this data as input, but these measurements are used to validate the model performance downstream of the existing Niagara Falls WWTP.

Table 9: Summary of Seasonal Water Quality Concentrations in the Hydro Electric Power Canal

Parameter		Winter	Spring	Summer	Fall
	Number of Samples	3	17	17	15
Total Ammonia (mg/L)	Geo-mean	0.078	0.264	0.186	0.209
	75th	0.180	0.375	0.250	0.280
Unionized Ammonia (mg/L)	Geo-mean	0.001	0.004	0.008	0.008
	75th	0.001	0.006	0.015	0.012
Nitrate (mg/L)	Geo-mean	0.37	0.21	0.14	0.12
	75th	0.51	0.27	0.22	0.16
E. coli. (cfu/100 mL)	Geo-mean	**5,780**	**283**	**116**	**570**
	75th	**7,550**	**440**	**220**	**4,200**
Total Phosphorus (mg/L)	Geo-mean	**0.042**	0.013	0.015	0.022
	75th	**0.059**	0.018	0.020	**0.040**
Dissolved Oxygen (mg/L)	Geo-mean	16.37	12.46	10.00	9.07
	25th	13.56	9.88	8.26	6.62
$CBOD_5$ (mg/L)	Geo-mean	-	0.24	0.07	0.57
	75th	-	2.00	0.05	2.00
Total Suspended Solids (mg/L)	Geo-mean	15.4	2.6	2.5	4.7
	75th	19.5	2.8	2.2	14.8
Water Temperature (ºC)	Geo-mean	2.1	11.5	22.4	9.8
	75th	3.5	18.6	23.6	13.5
pH	Geo-mean	7.86	8.00	8.12	8.03
	75th	7.99	8.16	8.22	8.14

Note:

1. **Bold** values indicate exceedances of applicable PWQO.
2. Data provided by NPCA.

2.2.6 Existing Niagara Falls Wastewater Treatment Plant, Primary Bypass, and Secondary Bypass

Water quality data and laboratory analysis were provided for the existing Niagara Falls WWTP Final Effluent from 2015 to 2018 by the Niagara Region. Water quality data for the Plant Bypass (Sewage receives no treatment prior to release) and the Secondary Bypass (Sewage receives primary treatment prior to release) were also provided. The water quality data are summarized in Table 10.

For validation, the GoldSim model uses the largest between the geometric mean and the 75th percentile value to characterize the effluent to the existing Niagara Falls WWTP and the primary and secondary bypass data. The effects of CSOs were included and the water quality was assumed to correspond to values reported for the Plant Bypass. The assimilative capacity of the system was estimated by excluding all CSOs, and assuming that the water quality from the effluent at existing Niagara Falls WWTP correspond with the regulatory limits outlined in the Amended Environmental Compliance Approval (ECA) number 7962-7ZLKR6, issued on February 3, 2010. The regulated parameters which are outlined in the aforementioned ECA are total phosphorus and *E. coli*, with effluent limits specified as at 0.75 mg/L and 200 counts/100 ml, respectively.

The data presented in Table 10 indicates that the 75th percentile of total phosphorus during summer would be exceeding the regulatory requirement outlined in the ECA.

Table 10: Summary of Seasonal Water Quality Concentrations for the Existing Niagara Falls Wastewater Treatment Plant Effluent, Primary Bypass, and Secondary Bypass

Parameter		Winter			Spring			Summer			Fall		
		Effluent	Primary Bypass	Secondary Bypass	Effluent	Primary Bypass	Secondary Bypass	Effluent	Primary Bypass	Secondary Bypass	Effluent	Primary Bypass	Secondary Bypass
Number of Samples		361	7	18	368	18	34	368	14	31	364	9	20
Total Ammonia (mg/L)	Geo-mean	4.04	17.09	18.79	2.91	10.20	15.87	3.66	10.45	20.17	3.69	5.66	14.59
	75th	9.61	33.28	22.83	7.37	19.60	23.50	8.42	19.78	27.80	8.01	18.35	19.65
Unionized Ammonia (mg/L)	Geo-mean	**0.014**	-	-	**0.013**	-	-	**0.026**	-	-	**0.021**	-	-
	75th	**0.032**	-	-	**0.032**	-	-	**0.058**	-	-	**0.046**	-	-
Nitrate (mg/L)	Geo-mean	**6.53**	0.46	0.22	**5.91**	0.44	0.32	**5.38**	0.24	0.22	**5.71**	0.29	0.24
	75th	**9.64**	2.03	0.20	**8.61**	1.70	0.21	**7.65**	0.20	0.21	**7.82**	0.47	0.20
E. coli. (cfu/100 mL)	Geo-mean	7	-	**4,102,000**	9	**1,395,500**	**1,972,600**	6	**4,177,700**	**4,447,900**	8	**2,800,600**	**5,047,200**
	75th	13	-	-	13	**2,550,000**	**3,650,000**	10	**5,802,500**	**8,160,000**	11	**6,995,000**	**8,422,500**
Total Phosphorus (mg/L)	Geo-mean	**0.30**	**3.60**	**5.12**	**0.28**	**2.26**	**3.05**	**0.40**	**3.21**	**3.50**	**0.35**	**2.53**	**3.39**
	75th	**0.38**	**5.87**	**8.08**	**0.36**	**2.98**	**5.18**	**0.52**	**4.35**	**4.40**	**0.47**	**4.60**	**4.53**
$CBOD_5$ (mg/L)	Geo-mean	4.39	68.12	175.41	4.72	71.21	100.42	5.23	105.87	128.56	5.61	90.31	126.15
	75th	5.80	142.75	279.75	6.50	122.50	143.00	7.73	136.25	177.00	8.40	167.00	166.25
Water Temperature (ºC)	Geo-mean	10	-	-	11.9	-	-	20.2	-	-	17.3	-	-
	75th	11.7	-	-	14.5	-	-	21.9	-	-	20.2	-	-
pH	Geo-mean	7.25	-	-	7.29	-	-	7.25	-	-	7.24	-	-
	75th	7.35	-	-	7.4	-	-	7.36	-	-	7.31	-	-

Note:

1. **Bold** values indicate exceedances of applicable PWQO.
2. Data provided by Niagara Region.
3. Shaded cells correspond with input to the GoldSim for verification only

2.3 Total Phosphorus Loads in Study Area

The existing total phosphorus loads in the study area provided in Table 11 were estimated based on seasonal average flows and geometric mean concentrations for background. The estimates show that:

- Over 98% of the total phosphorus in the Niagara River comes from Lake Erie.
- The contributions from the Welland River East represent about 1% of the total phosphorus loads.
- Based on the rated capacity and effluent discharge limits, the existing Niagara Falls WWTP contributes approximately 19 tonnes/year (0.3% of the total).
- Total annual contributions from the primary secondary bypasses at the existing Niagara Falls WWTP and the CSOs are estimated to be less than 2 tonnes/year (less than 0.05% of the total loads in the Niagara River).

Table 11: Estimated Seasonal and Annual Total Phosphorus Loads in Study Area

Season	Winter (kg/d)	Spring (kg/d)	Summer (kg/d)	Fall (kg/d)	Annual (tonnes/year)
Niagara River at Fort Erie	15,066.2	11,036.0	8,952.9	10,748.6	4,173.1 (98.3%)
Niagara River into Chippewa Creek	960.4	622.2	554.9	654.1	254.3 (6.0%)
Lyons Creek	35.1	40.0	10.6	16.8	9.3 (0.2%)
Welland River East	114.7	173.0	88.0	106.3	44.0 (1.0%)
Existing Niagara Falls WWTP Effluent[2]	51.2	51.2	51.2	51.2	18.7 (0.3%)
Existing Niagara Falls WWTP Primary Bypass	0.5	1.6	0.5	0.5	0.3 (0.01%)
Existing Niagara Falls WWTP Secondary Bypass	3.0	4.8	1.3	1.9	1.0 (0.02%)
Combined Sewer Overflows	0.3	1.2	0.3	0.5	0.2 (<0.01%)
HEPC at Sir Adam Beck	1,165.2	893.9	706.9	831.3	327.8 (7.7%)
Total[3]	15,271.0	11,307.7	9,104.8	10,925.8	4,246.6 (100%)

Note:

1. Values in brackets represent percentage of total annual loads to Niagara River not including other inflows.
2. Based on ECA effluent limits (0.75 mg/L) and rated capacity of plant (68.3 MLD).
3. Total does not include contributions from other sources (e.g., other tributaries, discharges to Niagara River, etc.)

2.4 Data Conclusions and Generalizations

Based on the preceding characterisation of available flow and water quality data, the following conclusions are provided:

- There are no major seasonal variations in Niagara River flow. Variations in Niagara River flow are likely related to changes in the water level in Lake Erie. These variations can either be long-term due to seasonal or interannual changes in the regional hydrology and precipitation (e.g., over entire Great Lakes basin) or short-term due to wind related events (e.g. longitudinal seiching) along Lake Erie.
- Flows in the HEPC and Chippewa Creek are controlled by the operation of the ICD and should not be represented as a natural flow regime in the ACS.
- The background concentrations of two parameters, phosphorus and *E. coli*, are shown to exceed their respective water quality criteria within two or more watercourses discharging to the HEPC:
- While the Niagara River generally has lower concentrations of phosphorus when compared to the Welland River and Lyons Creek, it represents a far more significant loading source of this parameter due to the considerable difference in flows directed through the HEPC from all sources:
  - Niagara River approximates 95.1% of background HEPC flows;
  - Welland River (natural and supplemental flows) approximates 4.5% of background HEPC flows;
  - Lyons Creek contributes less than 0.3% of background HEPC flows; and
  - Existing Niagara Falls WWTP approximates 0.1% of background HEPC flows.
- Total phosphorus concentrations within the Niagara River tend to increase substantially outside the growing season; the winter 75th percentile phosphorus concentration in the Niagara River is almost twice that of other seasons (22 to 27 µg/L).
- A comparison of the total phosphorus concentrations in the upper and lower sections of the Niagara River suggest that the current direct phosphorus loads to the Niagara River (e.g., not from Lake Erie) are not measurable.
- Notably, it has recently been estimated that 57% of all phosphorus loads to Lake Ontario come from the Niagara River from upstream sources in Lake Erie (ECCC & USEPA, 2018).
- The Welland River East and Lyons Creek also have some local influence, particularly in spring when background phosphorus loading to the HEPC from these two watercourses alone can exceed 20%.
- Water quality in Welland River East, particularly total phosphorus, deteriorates as the natural flows increase. This correlation is likely attributed to the increased influence of poor land management practices during rainfall runoff compared to the beneficial dilution effects of consistent, supplemental inflows from the Welland Canal via the Port Robinson Pumping Station, ports in the old siphon, and the Welland WWTP bypass under low flow conditions.
- Relative to the Niagara River, bacteriological concentrations in the Welland River and Lyons Creek are so high that the Welland River and Lyons Creek are the dominant sources of *E. coli* throughout the winter and spring, despite order of magnitude differences in flow volume.
- As such, much of the water quality issues in the system are currently being influenced by background contributions from Lake Erie and smaller watersheds located upstream of the HEPC.

3.0 MODELLING APPROACH AND RESULTS

The modelling approach was designed with the following objectives:

- Estimate the remaining capacity of the receiving waters to accept the proposed WWTP effluent flows without exceeding applicable guidelines,
- Estimate the recommended effluent limits for each of the discharge locations and compare those limits to feasible limits based on the available treatment technology, and
- Estimate the existing and future concentrations in the receiving waters at selected locations based on the recommended effluent limit.

Given the complexity of the hydrodynamic conditions in the study area, the first three discharge locations (Location 1 – Welland River East, Location 2 – HEPC and Location 3 – Chippewa Creek) will be modelled using a stochastic approach. The fourth location, evaluating a discharge to the Niagara River, is relatively simple by comparison and was modelled using a mass balance approach.

The following points outline the methods used to complete the ACS at the four locations and for various parameters:

- Given the complex and regulated hydrodynamic conditions in Location 1 – Welland River East, Location 2 – HECP and Location 3 – Chippewa Creek, a stochastic model (GoldSim) was used to complete the ACS for total phosphorus, total ammonia, nitrate, and fecal coliforms (*E. coli*). Estimates for unionized ammonia were calculated based on modelled ammonia and measured 75th percentile temperature and pH.
- To provide an alternate estimate of the assimilative capacity, a mass balance model was developed to estimate the maximum allowable effluent concentrations for total ammonia, unionized ammonia, nitrate, fecal coliforms (*E. coli*), and total phosphorus for conditions where all the flows in the study area were assumed to be representative of low-flow conditions (e.g., 7Q20 or minimum regulated flow).
- The assimilative capacity was assessed at two compliance points; a local compliance point that is immediately downstream of the proposed discharge and a system compliance point in the HEPC downstream of the existing Niagara Falls WWTP to consider cumulative effects in the study area.
- For Location 4 – Niagara River, the effluent is not expected to mix with the entire width if the Niagara River before reaching Niagara Falls. As such a 2-Dimensional Gaussian Plume model was used to predict the lateral mixing of the proposed effluent in the Niagara River. This model was used to assess for total phosphorus, total ammonia, unionized ammonia, nitrate, and fecal coliforms (*E. coli*).
- For parameters associated with oxygen in the water (dissolved oxygen and $CBOD_5$), the maximum allowable effluent concentrations were estimated using a simplified and conservative dissolved oxygen mass balance model that included $CBOD_5$ decay for all the locations. Since a high rate of reaeration is expected in the Niagara River and HEPC due to current speeds, this assessment was only completed for a local compliance point.
- The assimilative capacity did not consider the depletion of dissolved oxygen associated with the nitrification of ammonia.
- A simple mass balance model was used to estimate the maximum allowable effluent concentrations for TSS based on the CCME recommended maximum increase of 5 mg/L over the background conditions (Table 4).

3.1 GoldSim Modelling for Locations 1 Through 3

A stochastic water balance and water quality model was developed using GoldSim version 12.1. GoldSim is a graphical, object-oriented mathematical model where all input flows, constituents and functions are defined by the user and are built as individual objects or elements linked together by mathematical expressions. The object-based nature of the model is designed to facilitate understanding of the various factors, which control an engineered or natural system and predict the future performance of the system.

In GoldSim, each flow that could influence water quality predictions for the Project was itemized and assigned a source term chemistry, for the constituents of interest, based on measured water quality in the system. The model was developed to allow the user to run specific scenarios, including baseline or future conditions (by specifying the desired location of the new WWTP).

3.1.1 Model Conceptualization

The water balance and water quality model were designed to estimate the assimilative capacity and future concentrations in the system. GoldSim runs calculations on a daily timestep for the season of interest.

In GoldSim, each flow (e.g., river flows, discharges, etc.) entering the area of interest and with potential to affect water quantity and/or quality of the system was itemized and assigned a source term chemical profile for selected constituents, based on measured water quality data. Inflow volumes and concentrations were included as inputs to the system to account for loadings from major watersheds, CSOs, and WWTPs draining into the study area.

The stochastic approach was selected to account for the variability and/or uncertainty of the input parameters controlling the model associated with flow. Stochastic modelling in GoldSim was achieved using a Monte Carlo simulation approach. This approach consists of running the model for a selected number of iterations (i.e., realizations). For each realization, the stochastic inputs are randomly sampled based on their statistical distributions. It was assumed that 1,000 realizations would be sufficient to reach a representative and convergent distribution of results. The probability distribution assumed a log-normal distribution for the flows, defined seasonally. By running the model stochastically, each flow will present a range rather than a single value, which accounts for the observed variability in the available dataset.

For the purpose of analysing the flows on a seasonal manner, the months were grouped as follows: March to May to represent spring, June to August to represent summer, September to November to represent fall; and December to February to represent winter. For the purpose of analysing the flows on a seasonal manner, the months were grouped as follows: March 1st to May 31st to represent spring, June 1st to August 31st to represent summer, September 1st to November 30th to represent fall; and December 1st to February 28th to represent winter. While the seasonal patterns varied between flows assessed, the seasonal definition remained unchanged between flow inputs. Average, standard deviation, maximum and minimum flows were used to characterize flow distribution. Flows which did not show seasonal variability were input as a constant value throughout the year.

Water quality concentrations for inflows were based on the 75th percentile seasonal concentrations from measured water quality data for total phosphorus, nitrate, and total ammonia.

Following the model run, the probability of exceedance was calculated based on the 1,000 values calculated at each timestep to assess the range of conditions that could occur in the local and system compliance point for each scenario and season. In a typical ACS, the recommended effluent limits are estimated for a low flow condition that occurs for one week every 20 years (i.e., 7Q20). GoldSim was used to estimate the allowable effluent limits that will result in exceedances of the criteria no more than 5.0% of the time.

Recommended effluent limits were estimated by iteratively running the model to identify a mass flow that results in the water quality in the HEPC meeting PWQO criterion for each of the water quality parameters at the discharge location of the HEPC into the Niagara River. Allowable mass was then converted to the allowable concentration according to the flow in the new WWTP.

3.1.2 Flow Implementation

Flow was implemented in the model based on the available data and the stochastic modelling using the GoldSim model for Welland River East, Lyons Creek, and the HEPC. Flow in Chippewa Creek was estimated using the HEPC flow as well as the flows coming from the Welland River East and Lyons Creek (Sections 2.1.4 and 2.1.5).

3.1.2.1 Welland River East

Table 12 shows the parameters associated with the log-normal distributions followed to characterize the seasonal flow in Welland River East in GoldSim. These distributions include all supplemental inflows from the Welland Canal into the Welland River East. Figure 4 shows the probability distribution of seasonal flows.

Table 12: Summary of Seasonal Flow Statistics for Welland River East Including Supplemental Flows

Parameter	Winter	Spring	Summer	Fall
Mean flow (m^3/s)	17.7	24.4	14.9	20.6
Maximum flow (m^3/s)	29.0	40.2	19.9	32.8
Minimum flow (m^3/s)	14.0	14.7	13.6	12.7
Standard deviation (m^3/s)	3.8	5.4	1.3	4.8

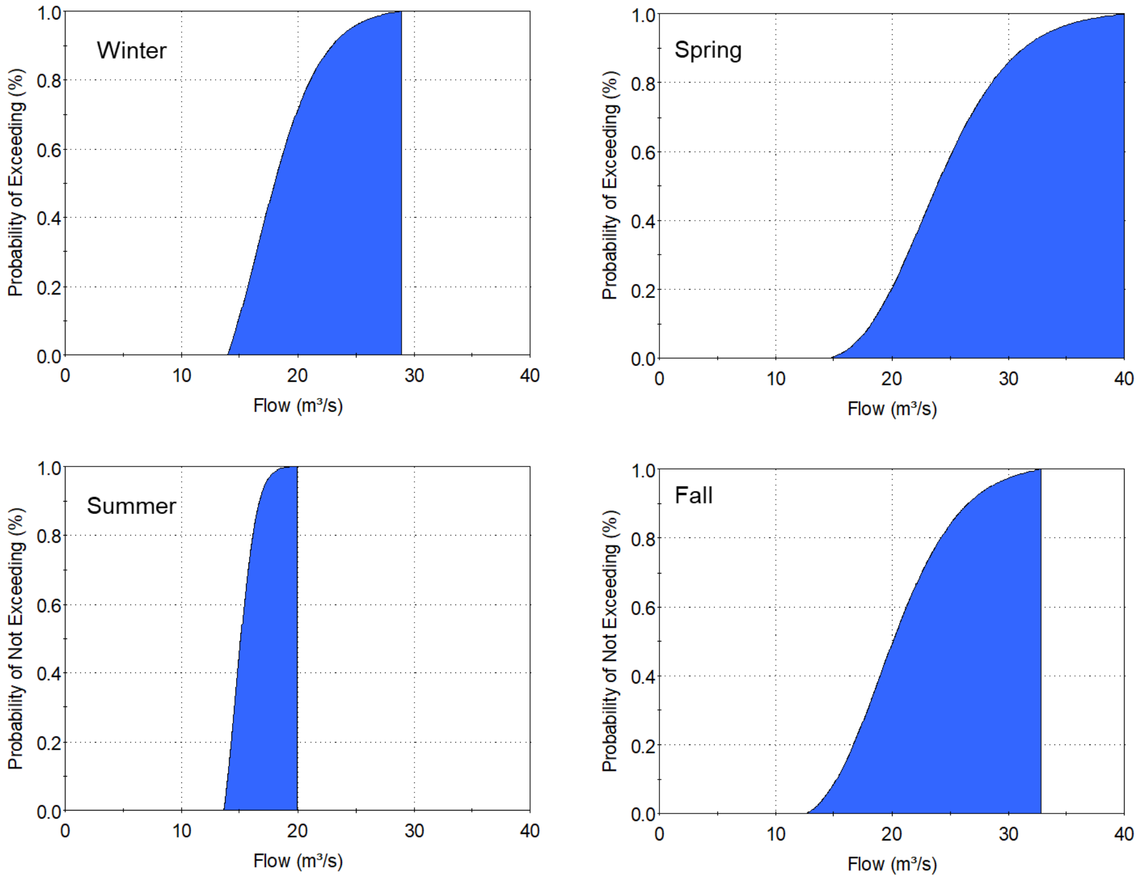

Figure 4: **Seasonal Log-Normal Distribution of Flows in the Welland River East Including Supplemental Inflows**

3.1.2.2 Lyons Creek

Table 13 shows the parameters associated with the seasonal log-normal distributions followed to characterize the flow in Lyons Creek in GoldSim. Figure 5 shows the probability distribution of seasonal flow.

Table 13: **Summary of Seasonal Flow Statistics for Lyons Creek**

Parameter	Winter	Spring	Summer	Fall
Mean flow (m^3/s)	1.4	2.0	0.5	0.7
Maximum flow (m^3/s)	3.1	4.0	1.2	2.2
Minimum flow (m^3/s)	0.2	0.6	0.3	0.3
Standard deviation (m^3/s)	0.7	0.7	0.2	0.5

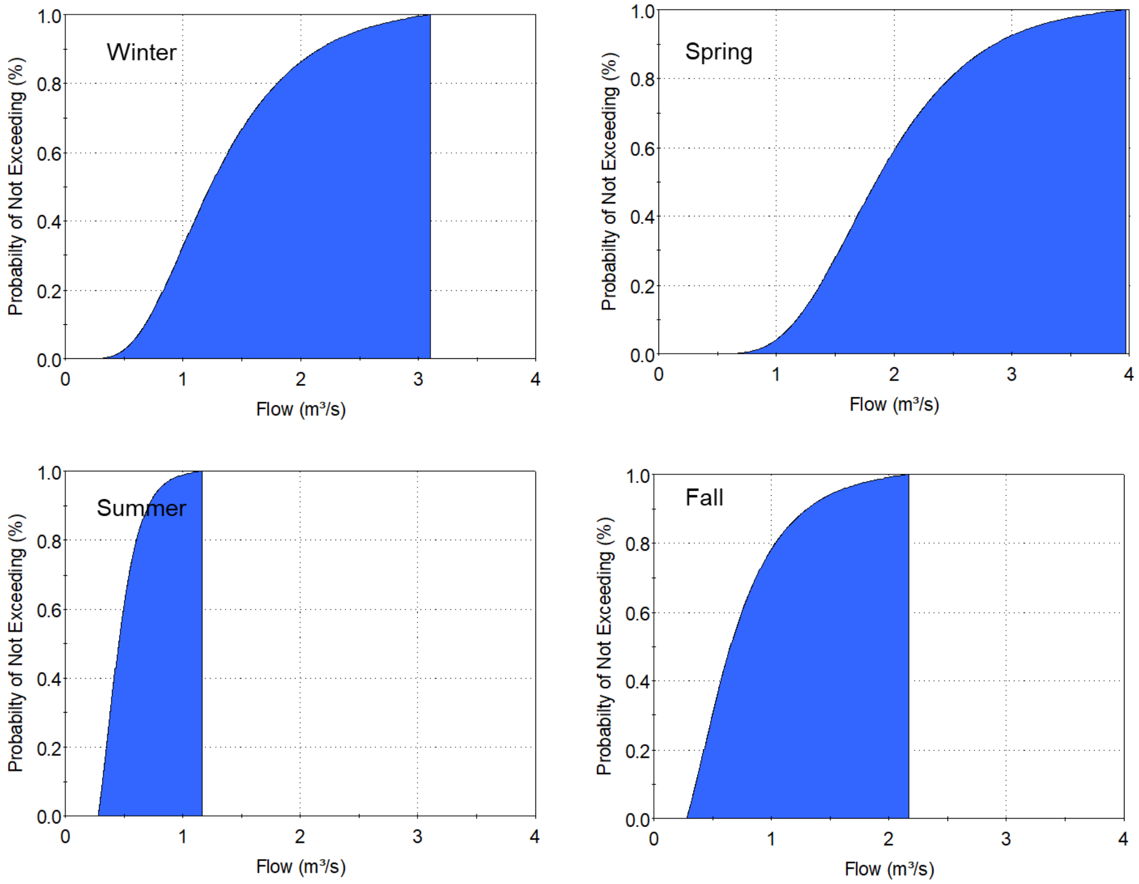

Figure 5: **Seasonal Log-Normal Distribution of Flows in the Lyons Creek**

3.1.2.3 Hydro Electric Power Canal (HEPC)

Table 14 shows the parameters associated with the log-normal distributions followed to characterize the flow in HEPC in GoldSim. Figure 6 shows the probability distribution of seasonal flow. The flow through Chippewa Creek was calculated based on the difference between the flow in the HEPC (input in GoldSim as per the distribution below) and the corresponding flow in Welland River East.

Table 14: Summary of Seasonal Flow Statistics for the Hydro Electric Power Canal

Parameter	Winter	Spring	Summer	Fall
Mean flow (m³/s)	429	411	446	421
Maximum flow (m³/s)	435	431	469	436
Minimum flow (m³/s)	420	401	419	403
Standard deviation (m³/s)	8.4	16.7	25.3	16.7

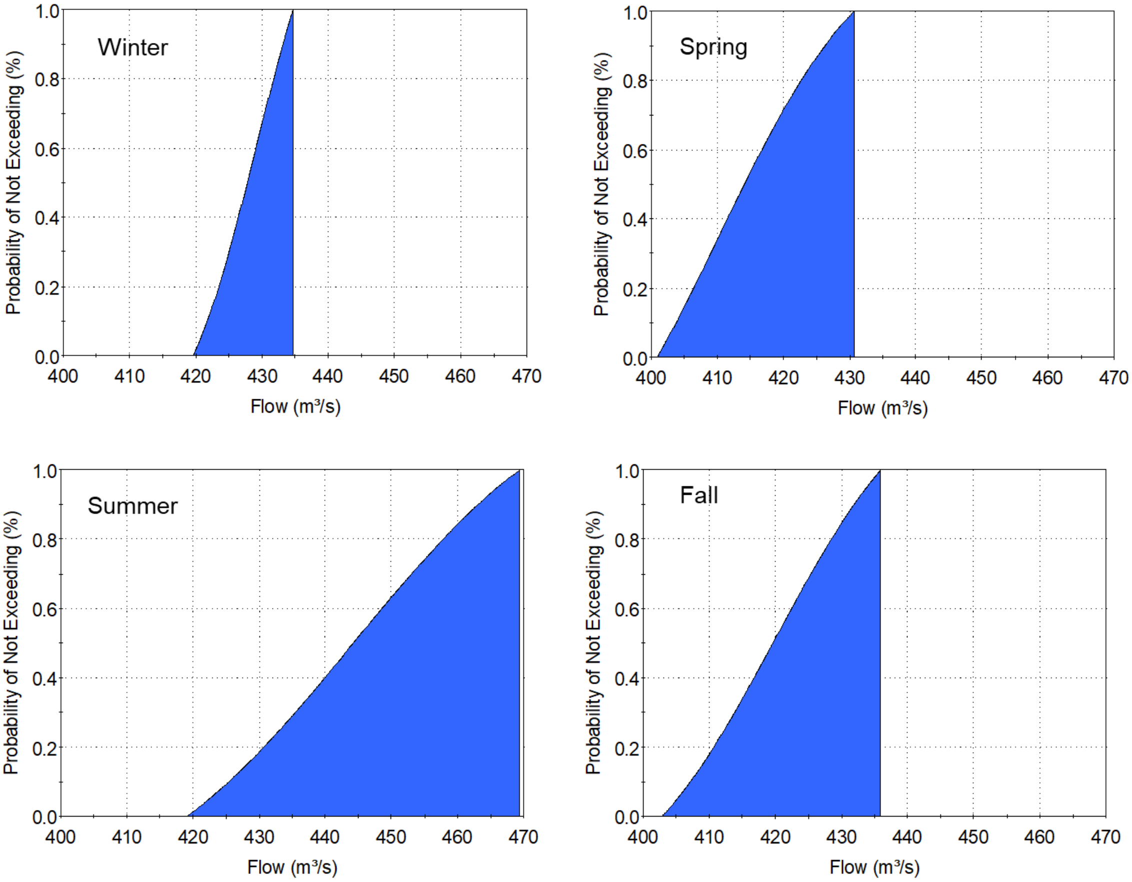

Figure 6: Seasonal Log-Normal Distribution of flows in the Hydro Electric Power Canal

3.1.2.4 *Existing Niagara Falls Wastewater Treatment Plant*

A statistical analysis of the flow data from the existing Niagara Falls WWTP showed little variation throughout the year. Table 15 shows the statistical flow distribution of existing Niagara Falls WWTP (based on data provided by Niagara Region), the flow limit based on existing ECA, and the assumed yearly mean flow used for modelling purposes in the GoldSim model.

Table 15: Summary of Seasonal Flow Statistics for Existing Niagara Falls Wastewater Treatment Plant, Environmental Compliance Approval Limit, and Assumed Mean Flow

Parameter	Winter	Spring	Summer	Fall	ECA Flow Limit	Assumed Mean Flow
Mean flow (m^3/s)	0.23	0.27	0.24	0.22	0.79[2]	0.47[3]
Minimum flow (m^3/s)	0.02	0.02	0.01	0.01	na[1]	na[1]
Maximum flow (m^3/s)	0.25	0.30	0.25	0.23	na[1]	na[1]
Standard deviation (m^3/s)	0.19	0.25	0.23	0.2	na[1]	na[1]

Notes

1. Mean flow which is assumed constant throughout the year (i.e., no probability distribution required).
2. Mean flow based on the ECA limit of 68,300 m$^{3/}$day.
3. Information provided by CIMA+.
4. Highlighted value corresponds with input to GoldSim model.

Given the above noted little variation throughout each season and between seasons, the mean value of 0.47 m^3/s was used to define the flow associated with the existing Niagara Falls WWTP. This fixed value was used instead of defining a probability distribution to characterize this input.

3.1.3 Model Validation

Model validation was done using the measured water quality data at the HEPC. The 75th percentile measurements at station PR001 was used for this purpose. Comparison were done considering two scenarios:

- excluding the CSOs from the model (No-CSO); and
- including the CSOs in the model (CSO).

The scenario that included the CSOs in the model also included, the overflow and secondary bypass from the existing Niagara Falls WWTP. As presented in Table 3, these flows represent approximately 94.0 to 99.6% of the total CSO flows. Water quality for each CSO (either overflow or secondary bypass) was allocated to each corresponding flow.

Table 16 compares the measured 75th percentile at PR001 with modelled (either CSO or No-CSO) 75th percentile concentration for the key parameters. These results show the effect of modelling CSO or No-CSOs does not affect the 75th percentile, which is to be expected given the low probability of occurrence of CSO events triggering high-load events...

Figure 7 though Figure 9 shows the box plots for comparing the measured and predicted concentration in the two scenarios as No-CSO and CSO for *E. coli*, total ammonia and phosphorus. These figures show how the consideration of CSOs in the model affects significantly the maximum modelled concentrations, specifically for *E. coli.*

When comparing the modelled results against the measured values, it is observed that total ammonia and *E. coli* are underpredicted by GoldSim. Generally, nitrate concentrations are well captured by GoldSim, with the later underpredicting winter concentrations by approximately 20%, and overpredicting nitrate concentrations for the rest of the year, with a maximum overestimation of 44% observed in fall. Phosphorus concentrations are also well captured in GoldSim, with general underprediction of phosphorus concentrations in winter and fall and overpredictions the rest of the year. The largest disagreement between measured and modelled concentration is observed in fall (23% underestimation) and spring (50% overprediction).

The differences between model predicted and measured concentrations are attributed to the following factors: exclusion of the variability of water quality in the model inputs, limited measured water quality data to better characterize chemistry in the system and exclusion of any other potential high-load sources which could affect water quality between the monitoring stations used to develop model inputs and monitoring station used to validate model output.

Table 16: Summary of GoldSim Model Verification

Parameter	Winter			Spring			Summer			Fall		
	PR001 Measured	Model without CSOs	Model with CSOs	PR001 Measured	Model without CSOs	Model with CSOs	PR001 Measured	Model without CSOs	Model with CSOs	PR001 Measured	Model without CSOs	Model with CSOs
Total Ammonia (mg/L)	0.18	0.05	0.05	0.38	0.07	0.07	0.25	0.05	0.05	0.28	0.05	0.05
E. coli (mg/L)	7,550	379	400	440	32	33	220	12	12	4,200	34	34
Nitrate (mg/L)	0.51	0.41	0.41	0.27	0.37	0.37	0.22	0.27	0.27	0.16	0.23	0.23
Total Phosphorus (mg/L)	0.059	0.049	0.049	0.018	0.036	0.036	0.020	0.024	0.025	0.040	0.031	0.032

Notes

1. All values in table are either measured or modelled 75th percentile concentrations.

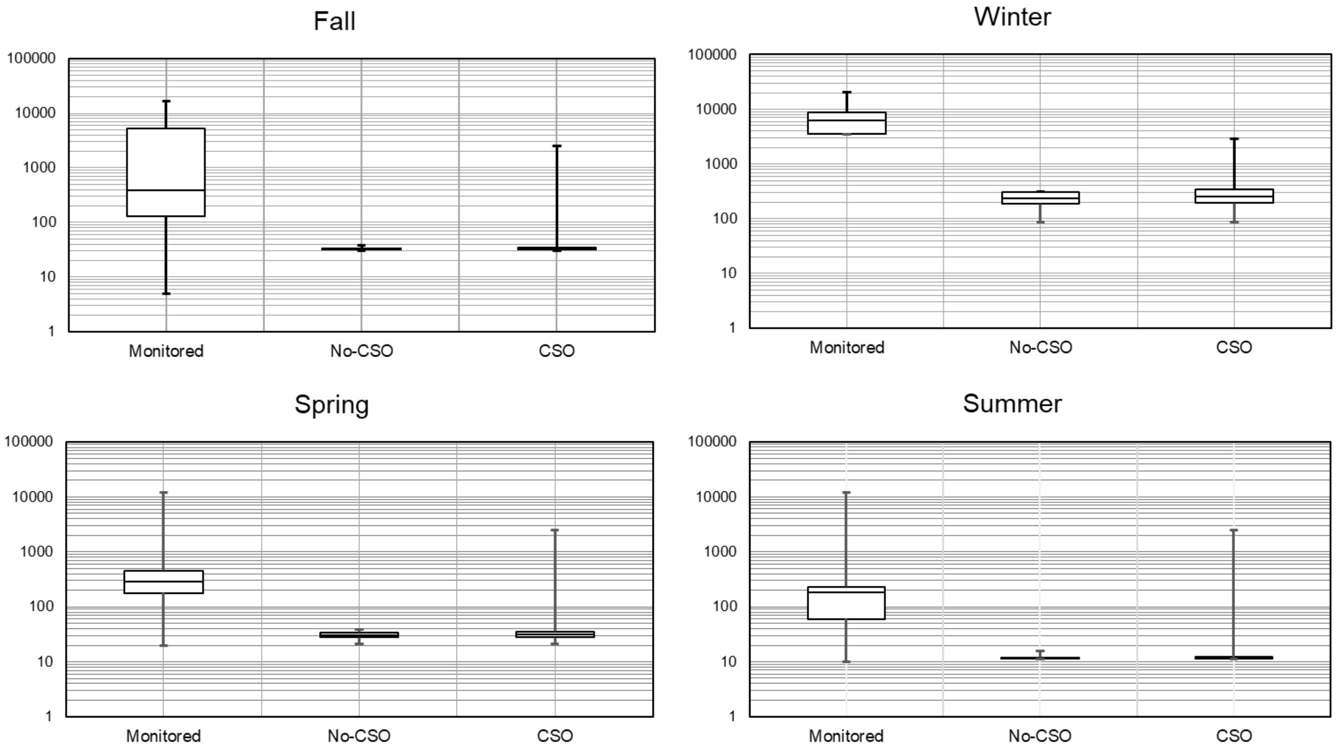

Figure 7: Box Plots Comparing Seasonal Measured and Modeled (No-CSO, CSO) *E. coli* Concentrations

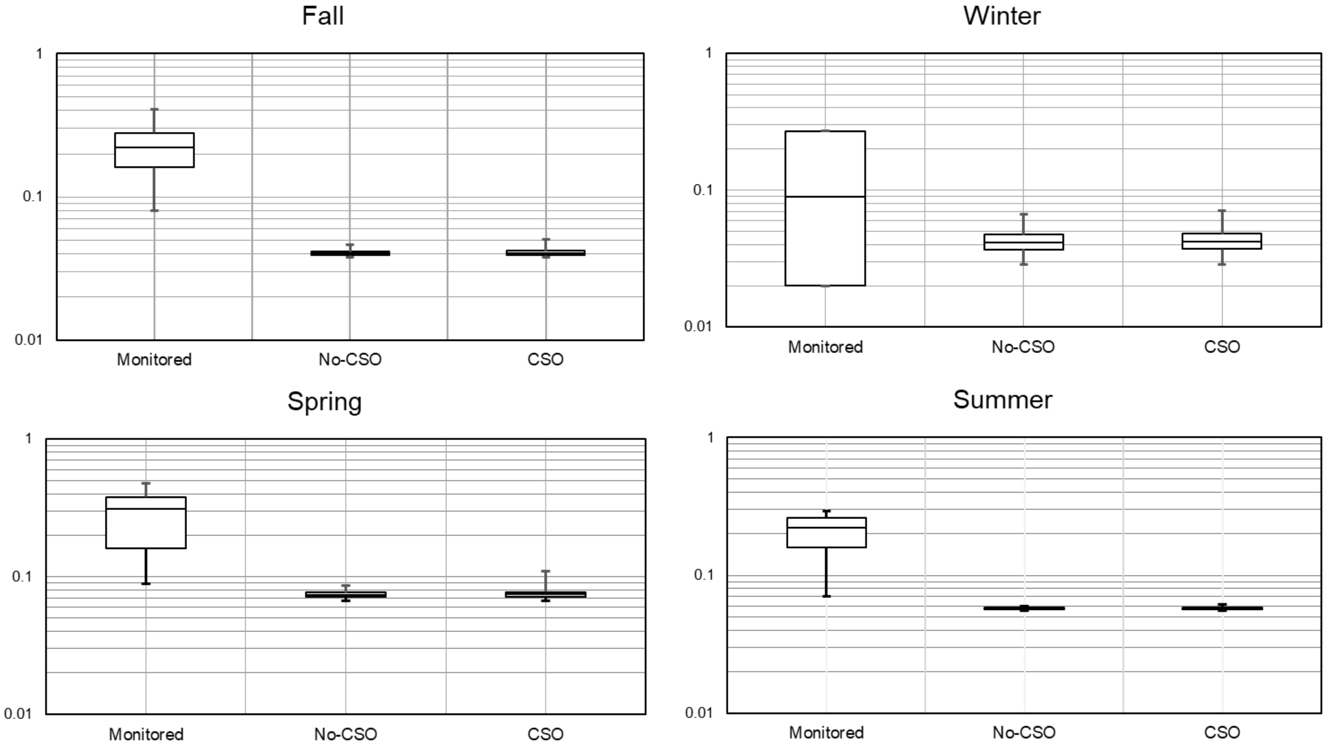

Figure 8: Box Plots Comparing Seasonal Measured and Modeled (No-CSO, CSO) Total Ammonia Concentrations

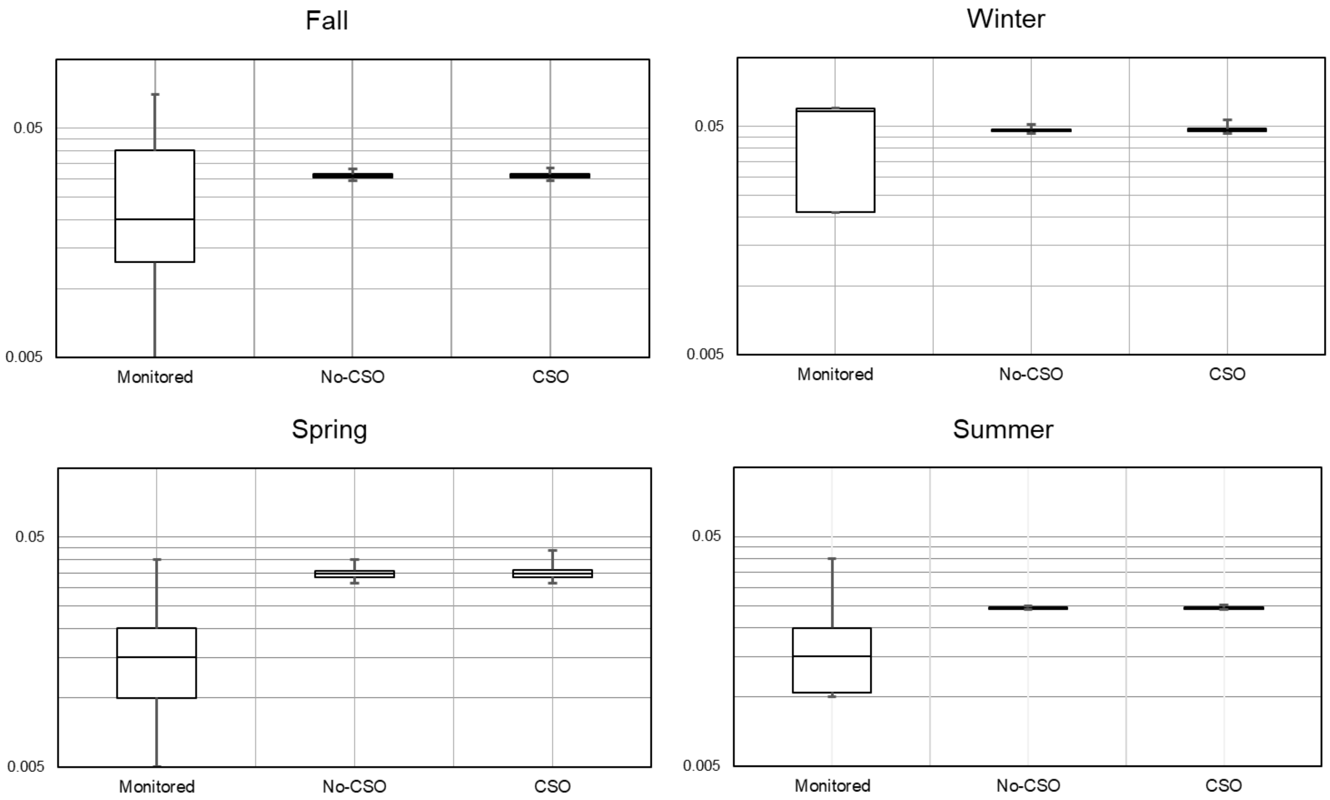

Figure 9: Box Plots Comparing Seasonal Measured and Modeled (No-CSO, CSO) Total Phosphorus Concentrations

3.1.4 Modelling Scenarios

Four different modelling scenarios were considered to assess assimilative capacity of the system under existing conditions, and under three potential locations of the new WWTP (Location 1 to Location 3). Each scenario was run independently for each season using a stochastic approach. These scenarios are described as follows:

- Baseline Scenario: To represent existing conditions, which includes the existing Niagara Falls WWTP but does not include the new WWTP.
- Scenario L1: Assumed the new WWTP discharges to the Welland River East, immediately upstream from Triangle Island.
- Scenario L2: Assumed the new WWTP discharges to the HEPC, downstream from Triangle Island and upstream from the existing Niagara Falls WWTP.
- Scenario L3: Assumed the new WWTP discharges to Chippewa Creek, immediately upstream from Triangle Island and downstream from the confluence with Lyons Creek.

3.1.5 Flow Implementation

As previously mentioned, the flow was implemented in the model based on the available data and the stochastic modelling using the GoldSim model for Welland River East, Lyons Creek and the HEPC. Flow in Chippewa Creek was estimated using the HEPC flow demand. The HEPC demand is provided by the flow coming from triangle west (Welland River East and the flow from new existing plant in case of Scenario L1) and flow coming from triangle east (Chippewa Creek, Lyons Creek and flow from new WWTP in case of scenario L2).
Therefore, flow in Chippewa Creek implemented in the model as the HEPC demand subtracted by flow coming from triangle west, Lyons Creek and L2. Flow from new WWTP was considered to be 0.347 m^3/s (30,000 m^3/d).

Effluent from the existing Niagara Falls WWTP was considered as per the average daily flow outlined in the ECA (i.e., 0.79 m^3/s equivalent to 68,300 m^3/day). CSOs associated with overflow and secondary bypass from the existing Niagara Falls WWTP were considered in this analysis.

3.1.6 Water Quality Implementation

The available data for water quality included ammonia, *E. coli*, nitrate, and total phosphorus. Water quality data associated with the 75th percentile was used for all inputs to the model with the exception of the effluent from the existing Niagara Falls WWTP, which considered water quality as per the ECA regulatory limits for total phosphorus and *E. coli*.

3.1.7 Water Quality Objectives

The allowable effluent concentration for the proposed WWTP were estimated by calculating the mass allowed in the system until reaching applicable water qualitive objectives. The threshold for *E. coli*, total phosphorus and nitrate were based on the guidelines provided in Table 4.

The GoldSim model does not incorporate accurate modelling of pH and water temperature. The fraction of the total ammonia that is unionized is a function of pH and temperature. The seasonal target values for total ammonia were back calculated from the PWQO limit of 0.0164 mg/L as nitrogen for unionized ammonia based on the monthly 75th percentile water temperature and pH in Chippewa Creek and the HEPC.

The seasonal thresholds for total ammonia, *E. coli*, nitrate and total phosphorus in the receiver used to estimate recommended effluent limits are summarized in Table 17.

Table 17: Summary of Water Quality Criteria used in GoldSim

Parameter	Winter	Spring	Summer	Fall
Total Ammonia (mg/L)[1]	1.150	0.288	0.142	0.176
E. coli. (cfu/100 mL)	100	100	100	100
Nitrate (mg/L)	3	3	3	3
Total Phosphorus (mg/L)	0.03	0.03	0.03	0.03

Note:

1. Total ammonia criteria based on target unionized ammonia concentration of 0.0164 mg/L as N and seasonal average water temperature and pH in receiving water.

3.1.8 Maximum Allowable Effluent Concentrations

The allowable mass modelled in the system was extracted for the local compliance point (immediate receiver where effluent from the new WWTP plant would enter the system) and at the system compliance point (downstream of the existing Niagara Falls WWTP). The recommended effluent concentrations were calculated by dividing the allowable mass by the flow from new WWTP. Large values in the table can be explained by the small flow rate in the proposed WWTP compared to the other flows in the system.

Table 18 shows the recommended effluent limits based on assimilative capacity at the local and system compliance points. These concentrations were calculated based on the GoldSim predictions for the 5% probability of exceedance.

These results show that the system is currently at capacity for *E. coli* in the summer and total phosphorus in the winter, spring, and fall.

The required effluent concentrations for total ammonia and total nitrate for the discharge into the Welland River East yielded the most restrictive treatment capacity, given the lower assimilative capacity of the immediate receiver. The differences between the discharges to the HEPC and Chippewa Creek are negligible in term required treatment.

Table 18: Summary of Maximum Allowable Effluent Concentrations from GoldSim Modelling

Parameter	Compliance Point	Winter			Spring			Summer			Fall		
		Location 1	Location 2	Location 3	Location 1	Location 2	Location 3	Location 1	Location 2	Location 3	Location 1	Location 2	Location 3
Total Ammonia (mg/L)	Local	24.5	1,347	1,312	0.7	262	261	nc	112	115	nc	157	159
	System	1,342			258			107			152		
E. coli (cfu/100 mL)	Local	nc	nc	55,235	nc	75,615	94,761	nc	107,736	107,869	nc	76,549	81,586
	System	nc			75,382			107,502			76,349		
Nitrate (mg/L)	Local	29	3,149	3,108	96	3,069	2,910	103	3,334	3,219	83	3,245	3,133
	System	3,142			3,062			3,328			3,238		
Total Phosphorus (mg/L)	Local	nc	nc	nc	nc	nc	3.28	nc	6.93	9.20	nc	nc	2.97
	System	nc			nc			6.28			nc		

Note:

1. “nc” denotes no capacity since existing background water quality exceeds applicable criteria (PWQO or CCME).

3.2 Mass Balance Modelling for Total Phosphorus, Ammonia, Nitrate, and *E. coli*

A secondary verification to the GoldSim model results, mass balance modelling was completed using 75th percentile background water quality concentrations and minimum supplemental flows. Mass balance modelling estimated the maximum allowable effluent concentrations for total phosphorus, E. coli, nitrate, total ammonia, CBOD5, and TSS and the minimum dissolved oxygen concentration. The mass balance models generally followed the same structure as the GoldSim model as shown on Figure 10 and provided seasonal estimates. One mass balance model was developed to assess total phosphorus, ammonia, nitrate, and *E. coli* such that both the local and system compliance points could be considered. Because dissolved oxygen and $CBOD_5$ are not independent, a specific mass balance model was developed for these two parameters simultaneously. A third mass balance model was developed for TSS since the water quality guideline for that parameter is based on an increase over ambient.

These models are intended to provide a secondary verification of the results provided by GoldSim by estimating the maximum allowable effluent concentrations for the worst-case conditions. The worst-case conditions were assumed to be the monthly cases where the low-flow conditions in each of the waterbodies occurred simultaneously.

The following points outline the inputs into the mass balance modelling:

- Total phosphorus, nitrate*, E. coli*, unionized ammonia, and TSS were modelled as conservative parameters and used the water quality limits provided in Table 4.
- The seasonal maximum allowable effluent concentrations for total ammonia were estimated based on the seasonal maximum allowable unionized ammonia concentration and 75th percentile values for water temperature and pH.
- The discharge of effluent from the existing Niagara Falls WWTP was assumed to be the rated capacity (68.3 MLD).
- The effluent discharge rate from the proposed WWTP was 30 MLD.
- Inflow concentrations from the Niagara River, Lyons Creek, and Welland River East were assumed to be equal to the 75th percentile of the measured seasonal concentrations.
- Where applicable, the existing effluent limits for the existing Niagara Falls WWTP were used (total phosphorus and *E. coli*).
- Since there are no effluent limits for the existing Niagara Falls WWTP for nitrate or ammonia, seasonal 75th percentile values based on measured data were used (Table 10).
- The effluent from both the existing Niagara Falls WWTP and the proposed plant was assumed to mix completely in the receiving water immediately after release.

Natural flows in the Welland River East were assumed to be negligible. The low-flow conditions in the Welland River East were assumed to be equal to the minimum supplemental flows from the Welland Canal as provided in Supplemental flows enter the Welland River East from the Welland Canal (St. Lawrence Seaway Management Corporation [SLSMC] 2019) as follows:

- A series of ports in the roof of the old syphon provide flow from the canal into the river. Depending on the season and water levels in the canal, the total flow ranges from 5 to 7 m^3/s.

- A pump at Port Robinson provides a flow of 0.97 m³/s to a side channel of the Welland River East, which was cut-off from the main branch of the river during the straightening of the canal in the 1950s.
- The bypass of the Welland Water Treatment Plant provides a flow between the canal and the river that ranges from 4 m³/s to 6 m³/s.
- The effluent from the Welland Wastewater Treatment Plant provides a flow of 0.8 m³/s (XCG 2007).

In general, the supplemental flows from the Welland Canal are from Lake Erie and have better water quality than that of the upstream areas of the Welland River.

Monthly estimates of the supplemental flows for the siphon ports, Port Robinson Pump, the Welland Water Treatment Plant and the Welland WWTP were provided by the SLSMC (SLSMC 2019) for the period 2014 to 2019 and are summarized in Table 1.

- Table 1Inflows from Lyons Creek were assumed to be equal to the pumping rates from the Welland Canal since naturally occurring low-flow conditions (e.g., 7Q20) are negligible (Section 2.1.4).
- Flows in the HEPC were assumed to be equal to the minimum daily average flow in the HEPC based on data provided by OPG between 2016 and 2018 (349 m³/s).
- Flow in Chippewa Creek was assumed be the same as the flow in the HEPC less the contributions from the Welland River East and Lyons Creek.
- Seasonal maximum allowable effluent concentrations were estimated at local compliance point specific to each discharge location as well as at the system compliance point below the existing Niagara Falls WWTP.

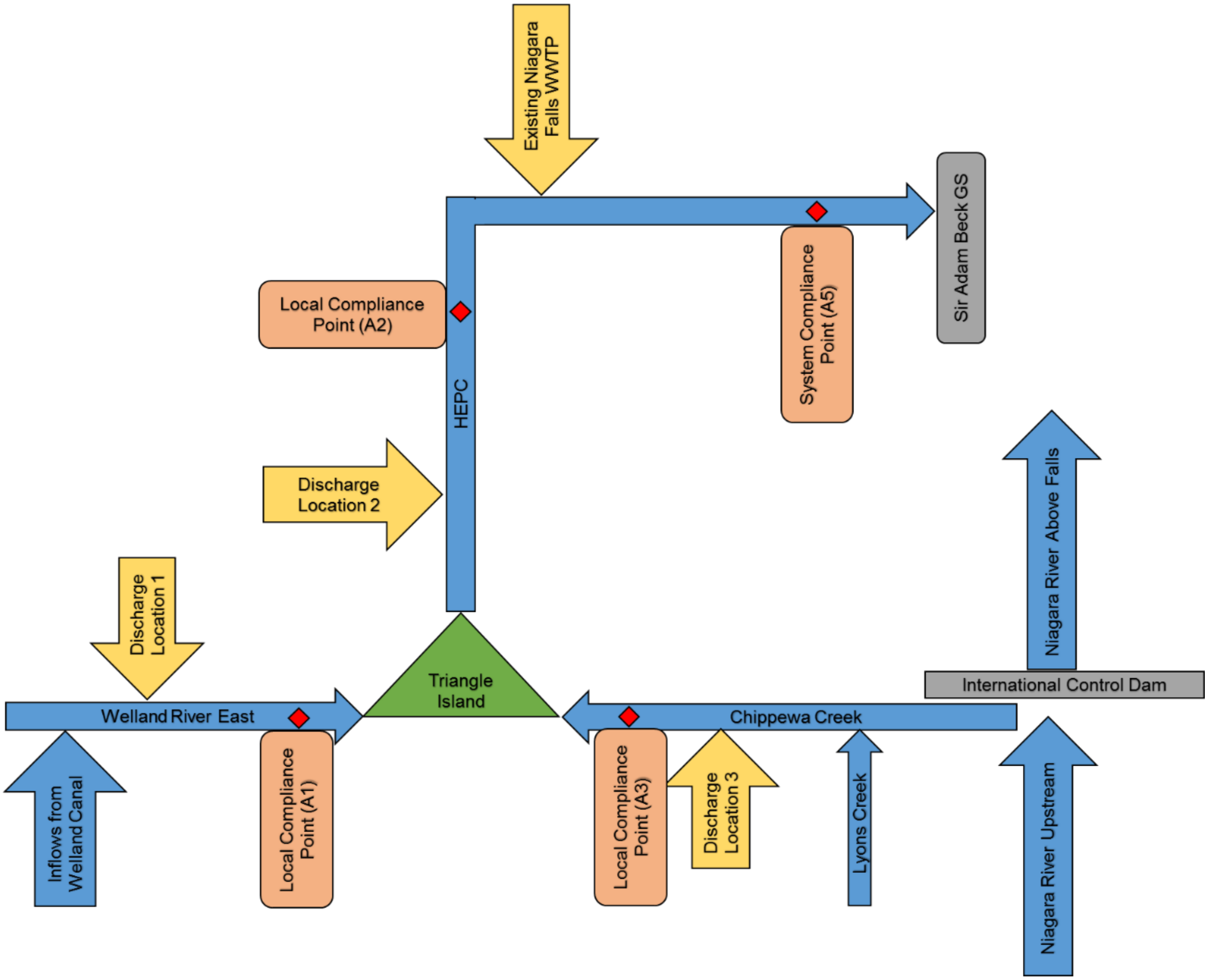

Figure 10: Schematic of Mass Balance Modelling for Total Phosphorus, Ammonia, Nitrate, and *E. coli*

The resulting estimates of the maximum allowable effluent concentrations are provided in Table 19. The modelling results suggest that:

- Poor water quality in the Welland River East provide no additional capacity for effluent in terms of total phosphorus and *E. coli* year-round and unionized ammonia during the summer.
- Elevated total phosphorus concentrations in the Niagara River during the winter are above the guideline and will limit capacity in Chippewa Creek and the HEPC.
- High *E. coli* contributions from the Welland River East limit the available capacity in the HEPC during the winter.
- High phosphorus loads from the Welland River East also limit the available capacity in the HEPC during the spring.
- Contributions from the existing Niagara Falls WWTP limit the available capacity at the system compliance point (A5) during the fall.

Table 19: Summary of Maximum Allowable Effluent Concentrations from Mass Balance Modelling of Worst Case Low-Flow Conditions

Parameter	Compliance Point	Winter			Spring			Summer			Fall		
		Location 1	Location 2	Location 3	Location 1	Location 2	Location 3	Location 1	Location 2	Location 3	Location 1	Location 2	Location 3
Unionized Ammonia (mg/L)	Local	0.5	15.5	15.0	0.4	15.3	15.0	nc	13.9	13.9	0.3	14.2	14.0
	System	15.5			15.3			13.8			14.2		
Total Ammonia (mg/L)	Local	33	1,227	1,194	4.4	284	280	nc	113	115	2.8	254	251
	System	1,216			610			101			243		
E. coli (cfu/100 mL)	Local	nc	nc	48,567	nc	78,132	85,459	nc	88,800	88,996	nc	69,113	71,728
	System	nc			78,132			88,800			69,113		
Nitrate (mg/L)	Local	23	2,644	2,621	67	2,681	2,614	99	2,750	2,652	73	2,807	2,735
	System	2,629			2,668			2,740			2,796		
Total Phosphorus (mg/L)	Local	nc	nc	nc	nc	nc	3.80	nc	5.69	7.65	nc	0.23	2.84
	System	nc			nc			5.02			nc		

Note:

1. “nc” denotes no capacity since existing water quality exceeds applicable criteria.

3.2.1 Comparison of Mass Balance Model Results to GoldSim Results

The following observations were made while comparing the results of the mass balance modelling to those of GoldSim:

- In cases where both models predicted assimilative capacity, the results from the mass balance model were lower than the results of GoldSim. This was expected since the mass balance model assumed the worst-case conditions (e.g., all low flows occur at once), which is expected to occur less than 5% of the time in the GoldSim model.
- With only one exception, both models predicted no assimilative capacity for the same cases.
- In the case for a discharge into the HEPC during the fall, GoldSim predicts no capacity for total phosphorus, while the mass balance model estimates a maximum allowable effluent concentration of 0.23 mg/L. Further investigation indicates that the difference is attributed to phosphorus loads from Welland River East. The mass balance model assumes that natural flows in Welland River East are negligible, while GoldSim uses a distribution of flows that include some natural flows. This results in a lower total phosphorus load in the mass balance model compared to that in GoldSim. Sensitivity analysis using the mass balance model suggest that natural flows from Welland River East were as low as 2 m^3/s increase the total phosphorus loads to the HEPC enough to eliminate any assimilative capacity in the fall.

3.3 Modelling for Niagara River Discharge (Location 4)

The following points summarize the approach used to assess the discharge to the Niagara River (Location 4):

- This discharge was assessed as a single port outfall (e.g., pipe) into a wide shallow river.
- The compliance point was assumed to be at the top of Niagara Falls along the Canadian shore approximately 1.6 km downstream of the ICD.
- The low-flow condition over the falls was assumed to be the minimum regulated daily average flow over the falls as outlined in the Niagara Treaty (2,242 m^3/s during the tourist season and 2,124 m^3/s during the non-tourist season). These flow conditions are the result of the operation of the ICD.
- The discharge location was assumed to be below the ICD and as such, water level fluctuations in the Grass Island Pool due to the operation of the ICD are not expected to affect the mixing of the effluent in the Niagara River.
- Since neither bathymetric data or current measurements are available for the Niagara River below the ICD, hydraulic modelling was completed to estimate the depth and current speed in that section of the Niagara River (see Section 3.3.1).
- Given that the Niagara River below the ICD is fast moving and wide, complete mixing with the effluent into the Niagara River flow cannot be expected before the compliance point. A Gaussian Plume model was used to estimate the width if the effluent plume at the compliance point to approximate the amount of river flow available for effluent dilution before passing the compliance point (See Section 3.3.2).
- Maximum allowable effluent concentrations were estimated for each season based on the available flow for dilution, upstream water quality, and ambient water temperature and pH.

3.3.1 Estimation of Hydraulic Conditions

Manning equation (Manning 1891) was iteratively solved to estimate the flow depth and current speed:

$$Q = UBH = \frac{1}{n}\left(\frac{BH}{B+2H}\right)^{2/3} S^{1/2}$$

Where: Q total flow in river (m³/s),
U current speed (m/s),
B river width (m),
H depth (m),
n Manning's roughness coefficient, and
S slope of river (m/m).

For this assessment, the average river width was assumed to be 887 m based on four width measurements (Google Earth) and the Manning's Roughness Coefficient was assumed to be 0.03.

The slope of the Niagara River was based on a downstream distance of 1,600 m and a reported river drop of 15 m between the ICD and the falls (Niagara Parks 2018). The slope for this section of the Niagara River was estimated to be 0.009 (0.9%).

The estimated low-flow hydraulic conditions in the Niagara River below the ICD for tourist and non-tourist periods are summarized in Table 20. For both periods, the estimated water depths are less than 1 m and the current speeds are greater than 2.8 m/s. Under these conditions, the effluent is expected to travel from the discharge location to the compliance point in less than 10 minutes.

Table 20: Summary of Estimated Low-Flow Hydraulic Conditions in Niagara River below the ICD

	Non-Tourist Season Winter Regulated Minimum Flow Over Falls	Tourist Season Spring/Summer/Fall Regulated Minimum Flow Over Falls
Flow over Falls (m^3/s)	2,124	2,242
Average Width (m)	887	
Depth (m)[1]	0.87	0.85
Current Speed (m/s)[1]	2.89	2.83
Lateral Dispersion Coefficient (m^2/s)[2]	0.146	0.139

Note:

1. Estimated using Manning's Equation.
2. Estimated using equations from Fischer (1979).

3.3.2 Gaussian Plume Modelling

A 2-dimensional Gaussian plume model is used to estimate the spread of the effluent in the Niagara River for the conditions provided in Table 20. The general form of a Gaussian plume for a continuous release from a shoreline discharge is:

$$C(x,y) = \frac{2W}{H\sqrt{4\pi D_y U x}} e^{\left(-Uy^2 / 4D_y x\right)}$$

Where:	$C(x,y)$	predicted concentration at specified location (g/m³),
	x	downstream distance (m),
	y	distance from shoreline (m),
	W	effluent mass loading rate (flow x concentration) (g/s),
	U	current speed (m/s),
	H	depth (m), and
	D_y	lateral dispersion coefficient (m²/s).

The lateral dispersion coefficient was estimated as follows (Fischer et al. 1979):

$$D_y = 0.6HU^*$$

$$U^* = \sqrt{gHS}$$

Where:	U^*	shear velocity (m/s),
	g	acceleration due to gravity (m/s²), and
	S	river slope (m/m)

Based on the Gaussian plume modelling, at a distance of 1,600 m the width of plume that contains 95% of the effluent is predicted to be approximately 25 m or approximately 3% of the average river width. This suggests that the effluent will only mix with 3% of the total flow in the Niagara River below the ICD. This translates to available river flows for dilution of 72.7 m³/s during the tourist season and 63.7 m³/s during the non-tourist season.

3.3.3 Maximum Allowable Effluent Concentrations

A mass balance model was used to estimate the seasonal maximum allowable effluent concentrations for the Niagara River discharge option based on seasonal upstream water quality. For parameters listed in the ECA, the 75th percentile was used for the upstream water quality while for water temperature and pH seasonal averages were used.

Seasonal low-flow conditions were based on the minimum daily average flow requirements from the Niagara Treaty that occur in each of the assessment seasons. The mass balance assumed an effluent flow rate of 30 MLD (0.35 m³/s).

The maximum allowable effluent concentration was estimated for each parameter (except total ammonia) and season using:

$$C_e = \frac{(Q_e + Q_r)C_g - Q_r C_r}{Q_e}$$

Where:		
	C_e	allowable effluent concentration (mg/L),
	C_r	river/background concentration (mg/L),
	C_g	water quality guideline/target (mg/L),
	Q_r	upstream river flow (m³/s), and
	Q_e	effluent flow rate (m³/s)

The maximum allowable total ammonia concentrations were based on the maximum allowable unionized ammonia concentrations, average seasonal water temperature, and average seasonal pH.

A summary of the mass balance modelling and the resulting maximum allowable effluent concentrations are provided in Table 21.

Table 21: Detailed Summary of Allowable Effluent Concentrations for Discharge to Niagara River

	Winter	Spring	Summer	Fall
Flow Conditions				
Total Flow Over Falls (m^3/s)	2,124	2,124	2,424	2,124
Flow Available for Dilution (m^3/s)	63.7	63.7	72.7	63.7
Effluent Flow	0.347	0.347	0.347	0.347
Ultimate Dilution	185:1	185:1	210:1	185:1
Total Phosphorus				
Background / Upstream Concentration (mg/L)	0.043	0.026	0.022	0.027
PWQO / Target at Flow over Falls (mg/L)	0.030	0.030	0.030	0.030
Allowable Effluent Concentration (mg/L)	No Capacity	0.764	1.705	0.581
Nitrate				
Background / Upstream Concentration (mg/L)	0.310	0.310	0.260	0.180
PWQO / Target at Flow over Falls (mg/L)	3.0	3.0	3.0	3.0
Allowable Effluent Concentration (mg/L)	497	497	577	521
E. coli				
Background / Upstream Concentration (cfu/100 mL)	50	12	8	26
PWQO / Target at Flow over Falls (cfu/100 mL)	100	100	100	100
Allowable Effluent Concentration (cfu/100 mL)	9,276	16,249	19,368	13,680
Unionized and Total Ammonia				
75th Percentile Water Temperature (ºC)	2.5	10.1	23.9	20.1
75th Percentile pH	8.1	8.2	8.3	8.2
Fraction Unionized Ammonia (%)	1.32%	2.88%	10.09%	5.95%
Upstream Total Ammonia Concentration (mg/L)	0.014	0.046	0.044	0.032
Upstream Unionized Ammonia Concentration (mg/L)	0.00018	0.00133	0.00444	0.00190
PWQO / Target at Flow over Falls (mg/L)	0.0164	0.0164	0.0164	0.0164
Allowable Effluent Unionized Ammonia Concentration (mg/L)	2.99	2.78	2.52	2.68
Allowable Effluent Total Ammonia Concentration (mg/L)	227	97	25.0	45

3.4 Mass Balance Modelling for Dissolved Oxygen, CBOD$_5$, and Total Suspended Solids

Allowable effluent concentrations were estimated for dissolved oxygen, CBOD5, and TSS using a spreadsheet-based mass-balance model. These parameters could not be modelled in GoldSim for the following reasons:

- dissolved oxygen and CBOD$_5$ are interconnected such that they could not be represented in GoldSim and,
- the criteria for TSS (see Section 2.2.1) is based on an increase over background.

The mass balance modelling was based on low flow conditions that represent the minimum regulated flows over the falls (Section 2.1.3.2), supplemental inflows in the Welland River (Section 0), and estimated 7Q20 flows in the HEPC (Section 2.1.5). For the discharge to the Niagara River, the available flow for dilution was assumed to be 3% of the total flow over the falls (Section 3.3.2). A summary of the flows used in the mass balance modelling for dissolved oxygen, CBOD$_5$, and TSS is provided in Table 22.

Table 22: Summary of Flows Used in Mass Balance Modelling

Season	Niagara River Below ICD		Chippewa Creek[3] (m³/s)	Welland River East[4] (m³/s)	HEPC[5] (m³/s)
	Total[1] (m³/s)	Available for Dilution[2] (m³/s)			
Winter	2,124	63.7	338	11.4	349
Spring	2,142	63.7	337	12.2	349
Summer	2,224	67.3	335	13.6	349
Fall	2,124	63.7	336	13.0	349

Notes:

1. Minimum flows as defined in Niagara Treaty of 1950.
2. Only 3% of flow available for dilution before reaching falls (Section 3.3.2).
3. Flow in HEPC less flow from Welland River East.
4. Sum of all supplemental flows into Welland River East from Welland Canal.
5. Low flow condition (7Q20) for flow in HEPC.

3.4.1 Dissolved Oxygen and CBOD$_5$

Since dissolved oxygen and CBOD$_5$ of the effluent and background water all affect the downstream dissolved oxygen concentrations, these two parameters must me assessed together. The downstream dissolved oxygen at any downstream location is determined by the mixed (effluent and river) concentration of dissolved oxygen and the amount of oxygen consumed by the CBOD$_5$ in the time taken to reach that location. Other factors that affect the downstream dissolved oxygen include surface reaeration and algal growth/decay.

The assessment of dissolved oxygen and CBOD$_5$ provides a conservative estimate of allowable effluent concentrations based on the following assumptions:

- Although measurements of dissolved oxygen in the Niagara River and HEPC are frequently at or above saturation due to turbulent flow conditions that provide a high degree of surface reaeration, surface reaeration is not included in this assessment.
- Given the typical clarity of the water in the study area, the effects of algae are assumed to be negligible and are not included in the assessment.

- Given the short retention time in the system (e.g., less than a few hours), it is expected that only a fraction of the $CBOD_5$ will be consumed before leaving the study area. This assessment assumes that 50% of the $CBOD_5$ from upstream sources and the effluent will be consumed before leaving the system.
- $CBOD_5$ data was not available for the Niagara River. As such a background $CBOD_5$ concentration of 2 mg/L was assumed based on the highest seasonal 75th percentile $CBOD_5$ concentration found for the Welland River East (Table 5). These upstream conditions were applicable to the discharges into Chippewa Creek and the Niagara River.
- Upstream $CBOD_5$ concentrations in the Welland River East were based on the seasonal 75th percentile of the measured data.
- Upstream dissolved oxygen concentrations were based on the seasonal 25th percentile of the measured data.
- Upstream $CBOD_5$ and dissolved oxygen for the HEPC discharge were based on flow weighted values for Chippewa Creek and Welland River East.
- Water temperatures (required to estimate dissolved oxygen saturation concentrations) were based on the seasonal 75th percentile temperature values for Chippewa Creek, the HEPC, and Welland River East.
- Given the high degree of surface reaeration in the HEPC, dissolved oxygen and $CBOD_5$ were not assessed at the system compliance point (Sir Adam Beck GS).
- The assessment was based on the dissolved oxygen criteria for warm water fisheries (47% of saturation below 20ºC and 4 mg/L above 20ºC).

The allowable effluent $CBOD_5$ concentration was estimated by re-arranging the following equation:

$$Q_d D_d = Q_r D_r - f Q_r B_r + Q_e D_e - f Q_e B_e$$

Where:	Q_d	downstream flow (m³/s) equal to sum of upstream and effluent flows,
	Q_r	upstream flow (m³/s),
	Q_e	effluent flow (m³/s),
	D_d	downstream dissolved oxygen concentration (mg/L) equal to guideline,
	D_r	upstream dissolved oxygen concentration (mg/L),
	D_e	effluent dissolved oxygen concentration (mg/L),
	B_r	upstream $CBOD_5$ concentration (mg/L),
	B_e	effluent $CBOD_5$ concentration (mg/L), and
	f	fraction of $CBOD_5$ consumed in study area (assumed to be 0.5).

Estimates of the allowable seasonal effluent $CBOD_5$ concentrations are provided in Table 23 for three levels of effluent dissolved oxygen saturation (10%, 50%, and 90%). Allowable concentrations for $CBOD_5$ are all greater than the minimum standard limit for secondary treated effluent of 15 mg/L.

The results indicate that allowable $CBOD_5$ concentrations are not sensitive to the dissolved oxygen levels in the effluent. Therefore, effluent dissolved oxygen concentration equal to 50% of the saturation concentration is recommended. The corresponding allowable seasonal effluent $CBOD_5$ concentrations will be carried forward in this assessment.

Table 23: Estimated Allowable CBOD₅ Concentrations Based on Effluent Dissolved Oxygen

Discharge Location	Season	Allowable Effluent $CBOD_5$ Concentration		
		Eff DO = 10% Sat[1]	Eff DO = 50% Sat[1]	Eff DO = 90% Sat[1]
Welland River East (Location 1)	Winter	360	371	382
	Spring	376	384	392
	Summer	239	**245**	252
	Fall	282	289	296
HEPC (Location 2)	Winter	6,758	6,768	6,779
	Spring	6,793	6,800	6,808
	Summer	7,934	7,940	7,947
	Fall	5,943	**5,952**	5,960
Chippewa Creek (Location 3)	Winter	6,370	6,380	6,391
	Spring	6,376	6,384	6,391
	Summer	7,682	7,689	7,695
	Fall	5,699	**5,707**	5,715
Niagara River (Location 4)	Winter	1,194	1,204	1,215
	Spring	1,201	1,275	1,283
	Summer	1,536	1,461	1,468
	Fall	1,074	**1,083**	1,091

Note:

1. Dissolved oxygen concentration in effluent expressed as percent of saturation.
2. **Bold** values indicate maximum allowable effluent concentrations carried forward in assessment.

3.4.2 Total Suspended Solids

The assessment of TSS was based on the following assumptions:

- Upstream TSS concentrations in the Welland River East were based on the seasonal 75th percentile of the measured data.
- Upstream TSS concentrations in the Niagara River, Chippewa Creek, and the HEPC were based on an annual 75th percentile of the measured data in the Niagara River (11.3 mg/L).

The allowable effluent TSS concentration was estimated by re-arranging the following equation:

$$(Q_r + Q_e)(C_r + \Delta C) = Q_r C_r + Q_e C_e$$

Where: Q_r upstream flow (m^3/s),
Q_e effluent flow (m^3/s),
C_r upstream TSS (mg/L),
C_e effluent TSS (mg/L), and
ΔC allowable TSS concentration increase (5 mg/L).

The estimated allowable seasonal effluent concentrations for TSS are provided in Table 24 and indicate that the allowable effluent TSS concentration show little seasonal variation. Allowable concentrations for TSS are all greater than the minimum standard limit for secondary treated effluent of 15 mg/L.

Table 24: Estimated Allowable Seasonal Effluent TSS Concentrations

Discharge Location	Season	Allowable Total Suspended Solids (mg/L)
Welland River East (Location 1)	Winter	204
	Spring	202
	Summer	213
	Fall	**201**
HEPC (Location 2)	Winter	5,047
	Spring	5,047
	Summer	**5,046**
	Fall	**5,046**
Chippewa Creek (Location 3)	Winter	4,880
	Spring	4,866
	Summer	**4,846**
	Fall	4,855
Niagara River (Location 4)	Winter	934
	Spring	985
	Summer	**934**
	Fall	**934**

Note:

1. **Bold** values indicate maximum allowable effluent concentrations carried forward in assessment.

4.0 DERIVATION OF RECOMMENDED EFFLUENT LIMITS

The following sections outline the development of the recommended effluent limits and limits based on the ACS and include the following details for each discharge location:

- the applicable water quality assessment points for each discharge location alternative,
- if specific parameters meet or exceed relevant criteria and whether a Policy 2 Condition applies,
- the critical season for each parameter and location, and
- an appropriate treatment technology for the location.

A quick summary of the adopted approach is provided below. Using this approach, the detailed evaluation of assimilative capacity and selection of treatment technologies is documented for each discharge location alternative in Section 4.1 through 4.4.

Water Quality Assessment Points

The water quality effects of introducing the new WWTP at each of four discharge location alternatives is evaluated at selected downstream assessment points. Referring to Section 0, the new WWTP effluent at each discharge location alternative is specifically evaluated at local assessment points (A1, A2, A3 or A4), located immediately downstream of each discharge location alternative, and at a system assessment point (A5) in the HEPC below the existing Niagara Falls WWTP (Locations 1, 2, and 3 only).

Available Assimilative Capacity

The available assimilative capacity for each assessment point is first considered without the effluent inputs from the new WWTP to determine if there is any for each of the parameters at the local compliance point. Where locations are shown to have capacity to assimilate effluent, a treatment technology was selected that could meet the maximum allowable effluent concentrations for each parameter. In cases were there was no available assimilative capacity (e.g., Policy 2), the effluent quality was selected such that the effluent concentration would be equal or less than the existing background conditions.

The typical effluent quality for the available treatment technologies considered in this study, based on information available from the MECP (MECP 2019), are summarized in Table 25.

Table 25: Typical Effluent Quality for Various Treatment Processes

Process	Effluent Parameter[1,2]			
	$CBOD_5$ (mg/L)	Total Suspended Solids (mg/L)	Total Phosphorus (mg/L)	Total Ammonia (mg/L as N)[3]
Conventional Activated Sludge System				
Without Phosphorus Removal	25	25	3.5	15 to 20
With Phosphorus Removal	25	25	<1.0	15 to 20
With Phosphorus Removal and Filtration	10	10	0.3	15 to 20
With Nitrification and Phosphorus Removal	25	25	<1.0	<3
Membrane Bioreactor				
Without Phosphorus Removal	2	1	3.0	15 – 20
With Phosphorus Removal	2	1	0.1	15 – 20
With Phosphorus Removal and Filtration	2	1	0.1	0.3

Notes:

1. Taken from “Design Considerations for Sewage Treatment Plants” (MECP 2019)
2. The above values are based on raw sewage with CBOD5 = 150-200 mg/L, Soluble CBOD5 = 50% of CBOD5, TSS = 150-200 mg/L, TP = 6-8 mg/L, TKN = 30-40 mg/L, TAN = 20-25 mg/L.
3. TAN (total ammonia nitrogen) concentrations may be lower during warm weather conditions if nitrification occurs.

With regard to parameters not listed in Table 25, the following assumptions have been used:

- Any treatment plant with disinfection can expect to have an *E. coli* concentration objective of less than 200 cfu/100 mL,
- If needed, aeration of the dissolved oxygen concentration in the final effluent can be provided to at least 80% of the saturation concentration.
- The expected effluent nitrate concentration from an activated sludge system without denitrification was assumed to be 20 mg/L.

4.1 Location 1 – Welland River East

4.1.1 Overview of Existing Conditions

The Welland East discharge would release effluent to Welland River East between Montrose Road and Triangle Island. Under normal conditions, the effluent is expected to travel downstream into the HEPC and eventually enter the Niagara River at the Sir Adam Beck GS. The local compliance point (A1), in the Welland River East just upstream of Triangle Island, and the system compliance point (A5), in the HEPC below the existing Niagara Falls WWTP (both shown on Figure 11).

The Welland River East discharge is not expected to affect water quality in Chippewa Creek or in the Niagara River upstream of the Sir Adam Beck GS.

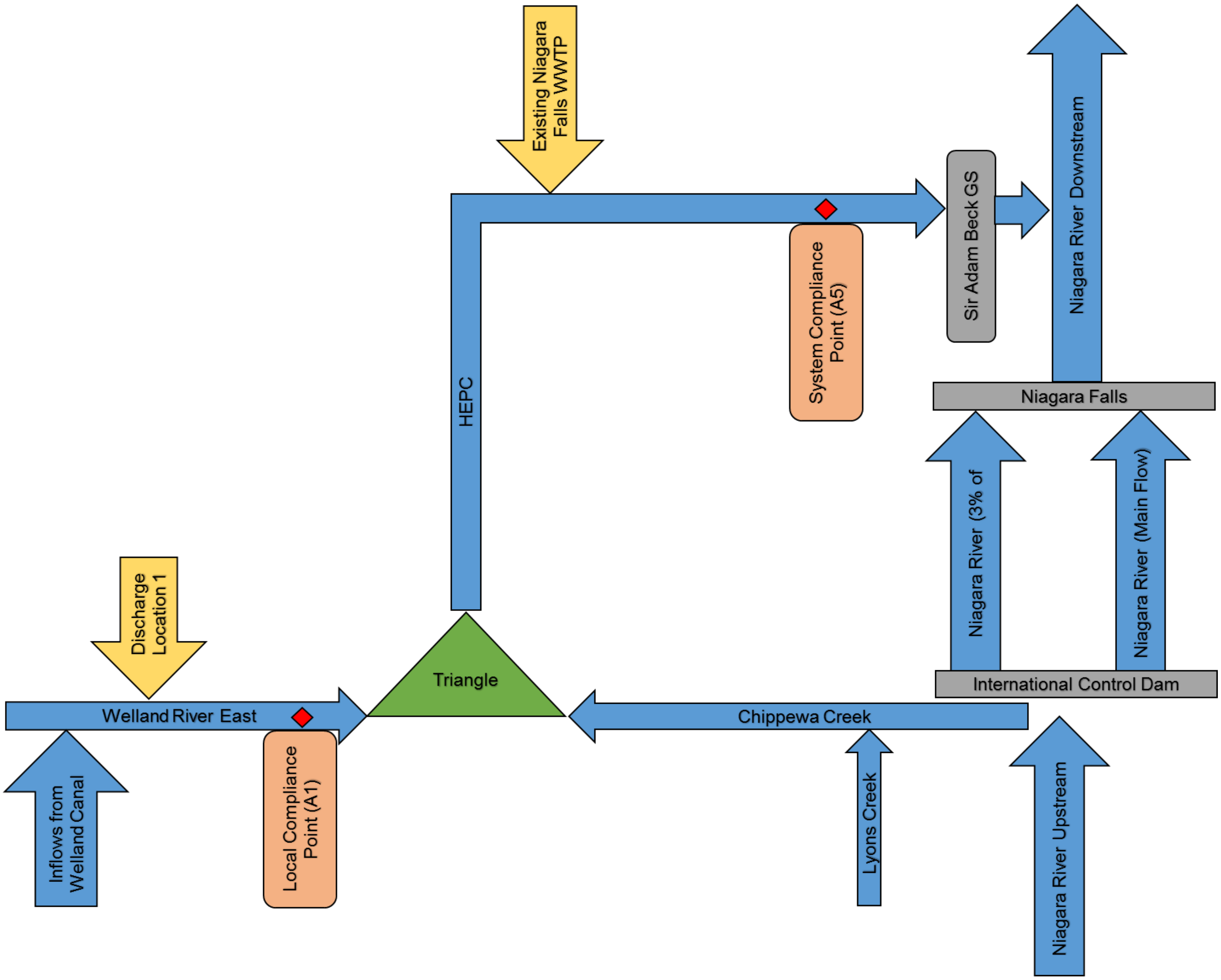

Figure 11: Local and System Compliance Points for Discharge at Location 1 – Welland River East

4.1.2 Phosphorus

The total phosphorus concentrations in the Welland River East are elevated and consistently exceed the applicable PWQO (0.03 mg/L). The seasonal geometric mean concentration ranges from 0.04 mg/L to 0.12 mg/L while the 75th percentile concentrations range from 0.06 mg/L to 0.14 mg/L. Total phosphorus concentrations are typically higher at Welland (WR010) than at Montrose Road (WR011). It is suspected that the water quality at Montrose Road is periodically affected flow reversals that occur due to the operation of the ICD (e.g., water from the Niagara River with better water quality is periodically samples at WR011).

The predicted maximum allowable effluent concentrations for phosphorus are presented in Table 26.
The elevated upstream total phosphorus concentrations result in Policy 2 conditions year-round at the local and system compliance points. Discharge from the existing Niagara Falls WWTP results in no additional capacity to receive phosphorus at the system compliance point in all seasons except summer.

Table 26: Maximum Allowable Seasonal Total Phosphorus Concentrations for Discharge at Location 1 – Welland River East

Season	Upstream[1] (mg/L)	Maximum Allowable Effluent Concentration (mg/L)	
		Local Compliance Point	System Compliance Point
Winter	0.140	No Capacity[2]	No Capacity[2]
Spring	0.160		
Summer	0.080		
Fall	0.100		

Notes:

1. 75th percentile of seasonal upstream concentrations.

2. No capacity due to elevated concentrations at the compliance point.

Since the upstream phosphorus concentration in Welland River East exceed the PWQO (0.03 mg/L), it is considered a Policy 2 receiver with respect to total phosphorus. As such, the effluent concentration is not to exceed background conditions. The seasonal 75th percentile phosphorus concentration varies from 0.075 mg/L to 0.125 mg/L. It is recommended that the annual average 75th percentile value be used (0.10 mg/L) as the effluent limit for phosphorus.

Based on the information provided in Table 25, in terms of total phosphorus discharge the recommended treatment technology at Location 1 is equivalent to a membrane bioreactor with phosphorus removal.

4.1.3 Nitrate

The seasonal geometric mean nitrate concentration ranges from 0.33 mg/L to 2.32 mg/L while the 75th percentile concentrations range from 0.48 mg/L to 2.38 mg/L. The highest nitrate concentrations, which typically occur during the winter, are approaching the CCME guideline (3 mg/L). This suggests that there may be seasonal limitations on the maximum allowable effluent concentration of nitrate.

The predicted maximum allowable effluent concentrations for nitrate are presented in Table 27. In general, the local compliance point provides the most restrictive conditions. Based on the modelling results, the most restrictive value is 29 mg/L.

Based on the assumptions in Section 4.0, a conventional activated sludge system without denitrification is expected to provide effluent nitrate concentrations of 20 mg/L. As a result, nitrate limits would not be required for Location 1.

Table 27: Maximum Allowable Seasonal Nitrate Concentrations for Discharge at Location 1 – Welland River East

Season	Upstream[1] (mg/L)	Maximum Allowable Effluent Concentration (mg/L)	
		Local Compliance Point	System Compliance Point
Winter	2.38	**29 (23)**	3,142 (2,629)
Spring	1.11	96 (67)	3,062 (2,668)
Summer	0.49	103 (99)	3,328 (2,740)
Fall	1.05	83 (73)	3,238 (2,796)

Notes:

1. 75th percentile of seasonal upstream concentrations.
2. Values in brackets refer to predictions from the mass balance modelling approach, if different from the GoldSim modelling approach.

4.1.4 Ammonia

The seasonal geometric mean total ammonia concentration ranges from 0.07 mg/L to 0.47 mg/L while the 75th percentile concentrations range from 0.09 mg/L to 0.59 mg/L. The corresponding unionized ammonia concentrations are below the applicable PWQO (0.0164 mg/L as N) for all the seasons except summer.

The maximum allowable effluent concentrations for total and unionized ammonia are presented in Table 28. In general, the local compliance point provides the most restrictive conditions. The elevated upstream unionized ammonia concentrations result in Policy 2 conditions in the summer.

Table 28: Maximum Allowable Seasonal Total and Unionized Ammonia Concentrations for Discharge at Location 1 – Welland River East

Season	Total Ammonia			Unionized Ammonia		
	Upstream	Maximum Allowable Concentration (mg/L)		Upstream	Maximum Allowable Concentration (mg/L)	
		Local Compliance Point	System Compliance Point		Local Compliance Point	System Compliance Point
Winter	0.59	25 (33)	1,342 (1,216)	0.001	0.3 (0.5)	12.5 (15.5)
Spring	0.28	0.7 (4.4)	258 (284)	0.007	0.4 (0.4)	14.0 (15.3)
Summer	0.22	No Capacity	107 (101)	0.018	No Capacity[2]	11.8 (13.8)
Fall	0.20	No Capacity (2.8)	152 (243)	0.009	0.2 (0.3)	11.6 (14.2)

Notes:
1. 75th percentile of seasonal upstream concentrations.
2. No capacity due to elevated concentrations at the compliance point.
3. Values in brackets refer to predictions from the mass balance modelling approach, if different from the GoldSim modelling approach.
4. Unionized ammonia concentrations predicted in GoldSim based on modelled ammonia and average seasonal pH and temperature.
5. Unionized ammonia concentrations predicted using the mass balance approach based on measured concentrations and modelled as a conservative constituent.

According to Policy 2, during the summer, the effluent unionized ammonia concentration cannot exceed the upstream concentration of 0.018 mg/L. As such, the recommend effluent limits during the summer for unionized and total ammonia are 0.018 mg/L and 0.20 mg/L, respectively. Reliably achieving 0.20 mg/L total ammonia will be difficult for any nitrifying wastewater facility. Accordingly, 0.50 mg/L total ammonia concentration limits that are demonstrated in a nitrifying activated sludge system are recommended for summer conditions.

The predicted maximum allowable unionized ammonia concentrations listed in Table 28 for winter, spring, and fall exceed the acute toxicity guideline for unionized ammonia (0.10 mg/L as N). As such, it is recommended that the effluent limits for total ammonia be based on meeting the acute toxicity limit for unionized at end-of-pipe and 75th percentile water temperature and pH. Based on the resulting values presented in Table 29, the recommended total ammonia limit is recommended to be 1.4 mg/L for winter, spring, and fall. Accordingly, the recommended effluent limits for unionized and total ammonia in the summer are 0.50 mg/L and 1.4 mg/L, respectively.

Based on the information provided in Table 25, in terms of total ammonia discharge the required treatment level is equivalent to a membrane bioreactor at Location 1 is a membrane bioreactor with phosphorus removal and filtration.

Table 29: Maximum Allowable Seasonal Total Ammonia Concentrations for Discharge at Location 1 – Welland River East Based on Acute Toxicity Limits for Unionized Ammonia

Season	Ambient Conditions		Maximum Allowable Effluent Concentration (mg/L)	
	Water Temperature (ºC)	PH	Unionized Ammonia	Total Ammonia
Winter	2.1	7.82	0.1	15.2
Spring	14.4	8.23	0.1	2.36
Summer	25.3	8.26	0.018	**0.19**
Fall	20.5	8.27	0.1	**1.41**

Notes:
1. Lowest concentration reliably achievable in a nitrifying secondary treatment plant.

4.1.5 *E. coli*

The seasonal upstream geometric mean *E. coli* concentration ranges from 25 cfu/100 mL to 2,474 cfu/100 mL while the 75th percentile concentrations range from 105 cfu/100 mL to 6,920 cfu/100 mL. Since the upstream *E. coli* concentrations in the Welland River East consistently exceed the PWQO (100 cfu/100 mL), it is considered a Policy 2 receiver with respect to *E. coli*. As such, the effluent concentration is not to exceed background conditions. It is recommended that an effluent limit of 200 cfu/100 mL, consistent with other treatment plants in the area.

Table 30: Maximum Allowable Seasonal *E. coli* Concentrations for Discharge at Location 1 – Welland River East

Season	Upstream (mg/L)	Maximum Allowable Effluent Concentration (mg/L)	
		Local Compliance Point	System Compliance Point
Winter	6,920	No Capacity[2]	No Capacity
Spring	308		75,382 (78,132)
Summer	105		107,502 (88,800)
Fall	170		76,349 (69,113)

Notes:

1. 75th percentile of seasonal upstream concentrations.
2. No capacity due to elevated concentrations at the compliance point.
3. Values in brackets refer to predictions from the mass balance modelling approach, if different from the GoldSim modelling approach.

4.1.6 $CBOD_5$ and Dissolved Oxygen

The seasonal 25th percentile upstream dissolved oxygen concentrations range from 8.1 mg/L to 13.8 mg/L, which correspond to approximately levels in excess of 90% of the dissolved oxygen saturation concentration at the seasonal water temperatures. The upstream $CBOD_5$ values are typically less than 2 mg/L. This combination of conditions indicates that dissolved oxygen is not likely to restrict the discharge of oxygen consuming organic material.

The mass balance modelling suggests that the dissolved oxygen concentrations downstream of the discharge are not sensitive to the effluent dissolved oxygen concentrations.

The recommended annual maximum allowable $CBOD_5$ concentrations for effluent is based on the minimum value of 245 mg/L (fall) from Table 31. This value is well above the minimum secondary effluent standard limit of 25 mg/L (Table 25). As such, the recommended effluent limit for $CBOD_5$ is 25 mg/L. However, it should be noted that the treatment level required to achieve the phosphorus limits will result in an effluent $CBOD_5$ concentration of <5 mg/L.

Table 31: Maximum Allowable Seasonal $CBOD_5$ Concentrations for Discharge at Location 1 – Welland River East

Season	Upstream $CBOD_5$ (mg/L)[1]	Maximum Allowable Effluent Concentration (mg/L)[2]
Winter	1.3	371
Spring	1.0	384
Summer	2.0	**245**
Fall	1.0	289

Notes:

1. Upstream 75th percentile concentration.
2. Based on effluent dissolved oxygen concentration equal to 50% of saturation.

4.1.7 Total Suspended Solids (TSS)

The seasonal 75th percentile upstream TSS concentrations range from 9.7 mg/L to 34.9 mg/L suggesting that the receiving water is not heavily impacted by suspended sediment. Based on the mass balance modelling results provided in Table 33, the recommended annual maximum allowable TSS concentration for effluent is 202 based on the minimum value (fall) from the table below.

This value is well above the minimum secondary effluent limit of 15 mg/L (Table 25). As such, the recommended effluent limit for TSS is 15 mg/L.

Table 32: Maximum Allowable Seasonal TSS Concentrations for Discharge at Location 1 – Welland River East

Season	Upstream TSS (mg/L)[1]	Maximum Allowable Effluent Concentration (mg/L)[2]
Winter	34.9	204
Spring	20.9	202
Summer	11.4	213
Fall	9.7	**202**

Notes:

1. Upstream 75th percentile concentration.

4.1.8 Recommended Effluent Limits

Based on the preceding discussions, a summary of the recommended effluent limits for the Welland River East discharge is presented in Table 33.

Table 33: Summary of Development of Effluent Limits for Discharge at Location 1 – Welland River East

Parameter		Limiting Assimilative Capacity Concentration[1]	Typical Treatment Plant Effluent[2]	Proposed Effluent Limits
Total Phosphorus (mg/L)		0.10[3]	0.10	0.100
Nitrate (mg/L)		29	20	N/A[4]
Unionized Ammonia (mg/L)	Summer	0.018[3]	--	0.018
	Winter/Spring/Fall	0.1	--	0.10
Total Ammonia (mg/L)	Summer	0.2[3]	0.3	0.5
	Winter/Spring/Fall	1.4	0.3	1.4
E. coli (cfu/100 mL)		no capacity[3]	<100	200
Dissolved Oxygen (% of Saturation)		50%	>80%	N/A[4]
$CBOD_5$ (mg/L)		239	10	25
Total Suspended Solids (mg/L)		202	5	15

Notes:

1. lowest seasonal value from local and system compliance points.
2. typical effluent for a membrane bioreactor with phosphorus removal and filtration.
3. No capacity – Policy 2 receiver.
4. 4.Not applicable – typical effluent is expected to be better than the limiting assimilative capacity concentration.

4.2 Location 2 – Hydro Electric Power Canal (HECP)

4.2.1 Overview of Existing Conditions

The HEPC discharge would release effluent to the earth-cut section of the HECP between Triangle Island and the Montrose Gate (start of rock-cut section). The existing water in the HEPC is a combination of inflows from the Niagara River (Chippewa Creek), Lyons Creek, and Welland River East. Under normal conditions, the effluent is expected to travel downstream in the HEPC and eventually enter the Niagara River at the Sir Adam Beck GS. The local compliance point (A2) is in the HEPC just upstream of the Montrose Gate and the system compliance point (A5) is in the HECP below the existing Niagara Falls WWTP so that the combined effects of both plants are considered in the ACS. The HEPC discharge is not expected to affect water quality in Chippewa Creek, Welland River East, or in the Niagara River upstream of the Sir Adam Beck GS.

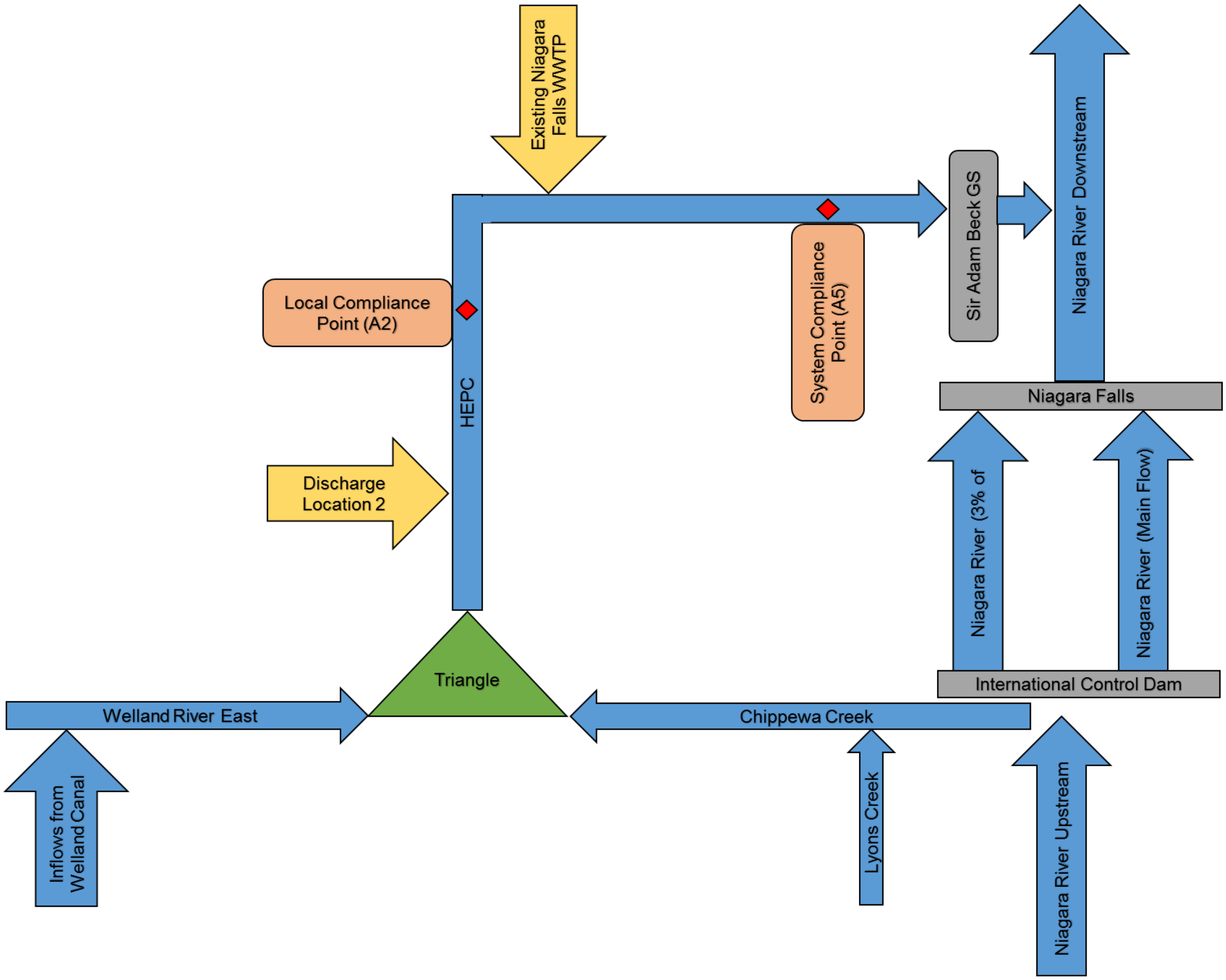

Figure 12: Local and System Compliance Points for Discharge at Location 2 – Hydro Electric Power Canal

4.2.2 Total Phosphorus

The total phosphorus concentrations in the HEPC are elevated in the winter, spring, and fall and consistently exceed the applicable PWQO (0.03 mg/L) in those seasons. The predicted seasonal 75th percentile concentrations range from 0.022 mg/L to 0.46 mg/L. Elevated total phosphorus concentrations in the HEPC are a result of elevated concentrations in the Niagara River during the winter and large phosphorus loads from Welland River East during the spring and fall. There are additional constraints at the system compliance point caused by the discharge of effluent into the HEPC from the existing Niagara Falls WWTP.

The predicted maximum allowable effluent concentrations for phosphorus are presented in Table 34. The elevated upstream total phosphorus concentrations result in Policy 2 conditions at the local and system compliance point in winter, spring, and fall. During summer, both the GoldSim and mass balance models show that effluent concentrations of 4.5 mg/L or more can be discharged to the HEPC without exceeding the total phosphorus target in the HEPC.

An effluent limit for total phosphorus of 0.75 mg/L is recommended based in the following rationale:

- The elevated phosphorus concentrations in the HEPC are the result of factors outside the study area (e.g., inflow from the Niagara River and Welland River East).
- The effluent flow rate represents less than 0.1% of the total flow in the HEPC and as such the contributions of the proposed discharge will cause negligible increases in the total phosphorus concentrations within the HEPC.
- Similarly, the effluent flow rate is insignificant when compared to the flow in the Niagara River below the Sir Adam beck GS.

Based on the information provided in Table 25, in terms of total phosphorus discharge the recommended treatment technology at Location 2 is a conventional activated sludge system with phosphorus removal and filtration.

Table 34: Maximum Allowable Seasonal Total Phosphorus Concentrations for Discharge at Location 2 – Hydro Electric Power Canal

Season	Upstream[1,2] (mg/L)	Maximum Allowable Effluent Concentration (mg/L)	
		Local Compliance Point	System Compliance Point
Winter	0.046 **(0.047)**	No Capacity	No Capacity
Spring	0.031 **(0.032)**	No Capacity	No Capacity
Summer	0.024 **(0.020)**	6.9 (5.7)	6.3 (5.0)
Fall	0.030 **(0.034)**	No Capacity	No Capacity

Notes:

1. Estimated value based on flow weighted average of inputs from Niagara River, Lyons Creek, and Welland River East at local compliance point during low flow conditions.
2. Values in bold indicate estimated value based on flow weighted average of inputs from Niagara River, Lyons Creek, and Welland River East at local compliance point during average conditions.
3. Values in brackets refer to predictions from the mass balance modelling approach, if different from the GoldSim modelling approach.

4.2.3 Nitrate

The predicted 75th percentile concentrations in the HEPC range from 0.18 mg/L to 0.37 mg/L. The highest nitrate concentrations typically occur during the winter. The predicted maximum allowable effluent concentrations for nitrate are presented in Table 35. In general, the local compliance point provides the most restrictive conditions. Based on the modelling results, the both the local and system compliance points can accept effluent nitrate concentrations in excess of 2,000 mg/L.

Based on the assumptions in Section 4.0, a conventional activated sludge system without denitrification is expected to provide effluent nitrate concentrations of 20 mg/L. As a result, nitrate limits would not be required for Location 2.

Table 35: Maximum Allowable Seasonal Nitrate Concentrations for Discharge at Location 2 – Hydro Electric Power Canal

Season	Upstream[1,2] (mg/L)	Maximum Allowable Effluent Concentration (mg/L)	
		Local Compliance Point	System Compliance Point
Winter	0.37 **0.31**	3,149 (2,644)	3,142 (2,629)
Spring	0.34 **0.31**	3,069 (2,681)	3,062(2,668)
Summer	0.27 **0.26**	3,334(2,750)	3,328 (2,740)
Fall	0.21 **0.18**	3,245(2,807)	3,238 (2,796)

Notes:

1. Estimated value based on flow weighted average of inputs from Niagara River, Lyons Creek, and Welland River East at local compliance point.
2. Values in bold indicate estimated value based on flow weighted average of inputs from Niagara River, Lyons Creek, and Welland River East at local compliance point during average conditions.
3. Values in brackets refer to predictions from the mass balance modelling approach, if different from the GoldSim modelling approach

4.2.4 Ammonia

The predicted 75th percentile concentrations for total ammonia in the HEPC range from 0.033 mg/L to 0.064 mg/L. The corresponding unionized ammonia concentrations are consistently below the applicable PWQO (0.0164 mg/L as N) for all the seasons. The maximum allowable effluent concentrations for total and unionized ammonia are presented in Table 36.

The predicted maximum allowable unionized ammonia concentrations listed in Table 36 exceed the acute toxicity guideline for unionized ammonia (0.10 mg/L as N). As such, it is recommended that the effluent limits for total ammonia be based on meeting the acute toxicity limit for unionized at end-of-pipe and seasonal water temperature and pH. The recommended effluent limit for unionized is 0.10 mg/L.

Based on the resulting values presented in Table 37, the recommended total ammonia limits are recommended to be 1.3 mg/L during the summer and 2.0 mg/L for the remainder if the year based on seasonal 75th percentile water temperature and pH in the HEPC.

Table 36: Maximum Allowable Seasonal Total and Unionized Ammonia Concentrations for Discharge at Location 2 – Hydro Electric Power Canal

Season	Total Ammonia			Unionized Ammonia		
	Upstream^{1,2}	Maximum Allowable Concentration (mg/L)		Upstream^{1,2}	Maximum Allowable Concentration (mg/L)	
		Local Compliance Point	System Compliance Point		Local Compliance Point	System Compliance Point
Winter	0.033 (**0.037)**	1.347 (1,227)	1,342 (1,216)	0.0011 **0.0010**	12.6 (15.5)	12.5 (15.5)
Spring	0.054 (**0.064)**	262 (284)	258 (275)	0.0013 **0.0012**	14.1 (15.3)	14.0 (15.3)
Summer	0.051 (**0.063)**	112 (113)	107 (101)	0.0028 **0.0014**	12.2 (13.9)	11.8 (13.8)
Fall	0.038 (**0.050)**	157 (254)	152 (243)	0.0024 **0.0012**	11.8 (14.2)	11.6 (14.2)

Notes:

1. Estimated value based on flow weighted average of inputs from Niagara River, Lyons Creek, and Welland River East at local compliance point.
2. Values in **bold** indicate estimated value based on flow weighted average of inputs from Niagara River, Lyons Creek, and Welland River East at local compliance point during average conditions.
3. Values in brackets refer to predictions from the mass balance modelling approach, if different from the GoldSim modelling approach.
4. Unionized ammonia concentrations predicted in GoldSim based on modelled ammonia and average seasonal pH and temperature.
5. Unionized ammonia concentrations predicted using the mass balance approach based on measured concentrations and modelled as a conservative constituent.

Table 37: Maximum Allowable Seasonal Total Ammonia Concentrations for Discharge at Location 2 – Hydro Electric Power Canal Based on Acute Toxicity Limits for Unionized Ammonia

Season	Ambient Conditions		Maximum Allowable Effluent Concentration (mg/L)	
	Water Temperature (ºC)	pH	Unionized Ammonia	Total Ammonia
Winter	3.5	7.99	0.1	9.39
Spring	18.6	8.16	0.1	**2.04**
Summer	23.6	8.22	0.1	**1.27**
Fall	13.5	8.14	0.1	3.08

4.2.5 *E. coli*

The predicted 75th percentile *E. coli* concentration in the HEPC ranges from 12 cfu/100 mL to 319 cfu/100 mL. The predicted *E. coli* concentration exceed the PWQO (100 cfu/100 mL) during the winter due to contributions from Welland River East at both the local and system compliance points. As such, the effluent concentration is not to exceed background conditions during the winter. As shown in Table 38, during the remaining seasons, there is capacity at both compliance points to accept effluent *E. coli* concentrations that exceed 60,000 cfu/100 mL. These allowable concentrations greatly exceed the expected effluent quality from a treatment plant.

It is recommended that an effluent limit of 200 cfu/100 mL be applied, consistent with other treatment plants in the area. With disinfection of the final effluent, any of the treatment plant can expect to meet these criteria.

Table 38: Maximum Allowable Seasonal *E. coli* Concentrations for Discharge at Location 2 – Hydro Electric Power Canal

Season	Upstream[1,2] (mg/L)	Maximum Allowable Effluent Concentration (mg/L)	
		Local Compliance Point	System Compliance Point
Winter	274 **319**	No Capacity	No Capacity
Spring	22 **36**	75,615 (78,132)	75,382 (78,132)
Summer	12 **13**	107,736 (88,800)	107,502 (88,800)
Fall	31 **34**	76,549 (69,113)	76,349 (69,113)

Notes:

1. Estimated value based on flow weighted average of inputs from Niagara River, Lyons Creek, and Welland River East at local compliance point.
2. Values in **bold** indicate estimated value based on flow weighted average of inputs from Niagara River, Lyons Creek, and Welland River East at local compliance point during average conditions.
3. Values in brackets refer to predictions from the mass balance modelling approach, if different from the GoldSim modelling approach

4.2.6 Biochemical Oxygen Demand (CBOD$_5$) and Dissolved Oxygen

The mass balance modelling suggests that the dissolved oxygen concentrations downstream of the discharge are not sensitive to the effluent dissolved oxygen concentrations.

The recommended annual maximum allowable CBOD$_5$ concentrations for effluent is based on the minimum value of 5,952 mg/L (fall) from Table 39. This value is well above the minimum secondary effluent standard limit of 25 mg/L (Table 25). As such, the recommended effluent limit for CBOD$_5$ is 25 mg/L.

Table 39: Maximum Allowable Seasonal CBOD$_5$ Concentrations for Discharge at Location 2 – Hydro Electric Power Canal

Season	Upstream CBOD$_5$ (mg/L)[1]	Maximum Allowable Effluent Concentration (mg/L)[2]
Winter	2.0	6,768
Spring		6,800
Summer		7,940
Fall		**5,952**

Notes:

1. Highest seasonal 75th percentile concentration in HEPC.
2. Based on effluent dissolved oxygen concentration equal to 50% of saturation.

4.2.7 Total Suspended Solids (TSS)

The annual 75th percentile upstream TSS is estimated to be 11.3 mg/L suggesting that the HEPC does not typically have high concentration od suspended solids. The mass balance modelling results provided in Table 40, the recommended annual maximum allowable TSS concentration for effluent is 5,046 based on the minimum value (summer and fall).

This value is well above the expected effluent from a conventional activated sludge system of 15 mg/L (Table 25). This value is well above the minimum secondary effluent standard limit of 25 mg/L (Table 25). As such, the recommended effluent limit TSS is 25 mg/L.

Table 40: Maximum Allowable Seasonal TSS Concentrations for Discharge at Location 2 – Hydro Electric Power Canal

Season	Upstream TSS (mg/L)[1]	Maximum Allowable Effluent Concentration (mg/L)[2]
Winter	11.3	5,047
Spring		5,047
Summer		**5,046**
Fall		**5,046**

Notes:

1. Annual 75th percentile concentration from Niagara River.

4.2.8 Recommended Effluent Limits

Based on the preceding discussions, a summary of the recommended effluent limits for the HEPC discharge is presented in Table 41.

Table 41: Summary of Development of Effluent Limits and Limits for Discharge at Location 2 – Hydro Electric Power Canal

Parameter		Limiting Assimilative Capacity Concentration[1]	Typical Treatment Plant Effluent[2]	Proposed Effluent Limits
Total Phosphorus (mg/L)		No capacity[3]	0.5	0.75
Nitrate (mg/L)		2,620	20	N/A[4]
Unionized Ammonia (mg/L)		0.1	--	0.1
Total Ammonia (mg/L)	Summer	1.3	<1	1.3
	Winter/Spring/Fall	2.0	<3	2.0
E. coli (cfu/100 mL)			<100	200
Dissolved Oxygen (% of Saturation)		50%	>80%	N/A[4]
CBOD_5 (mg/L)		5,097	25	25
Total Suspended Solids (mg/L)		5,046	25	25

Notes:

1. Lowest seasonal value from local and system compliance points.
2. Typical effluent for secondary effluent without filtration
3. No capacity – Policy 2 receiver.
4. 4.Not applicable – typical effluent is expected to be better than the limiting assimilative capacity concentration.

4.3 Location 3 – Chippewa Creek

4.3.1 Overview of Existing Conditions

The Chippewa Creek discharge would release effluent to the Chippewa Creek between Lyons Creek and Triangle Island. The existing water quality in Chippewa Creek is dominated by the water quality in the Niagara River. Under normal conditions, the effluent will travel downstream into the HEPC and eventually enter the Niagara River at the Sir Adam Beck GS. The local compliance point (A3) is in Chippewa Creek just upstream of Triangle Island and the system compliance point (A5) is in the HEPC below the existing Niagara Falls WWTP, so that the combined effects of both plants are considered in the ACS. The Chippewa Creek discharge is not expected to affect water quality in Welland River East or in the Niagara River upstream of the Sir Adam Beck GS.

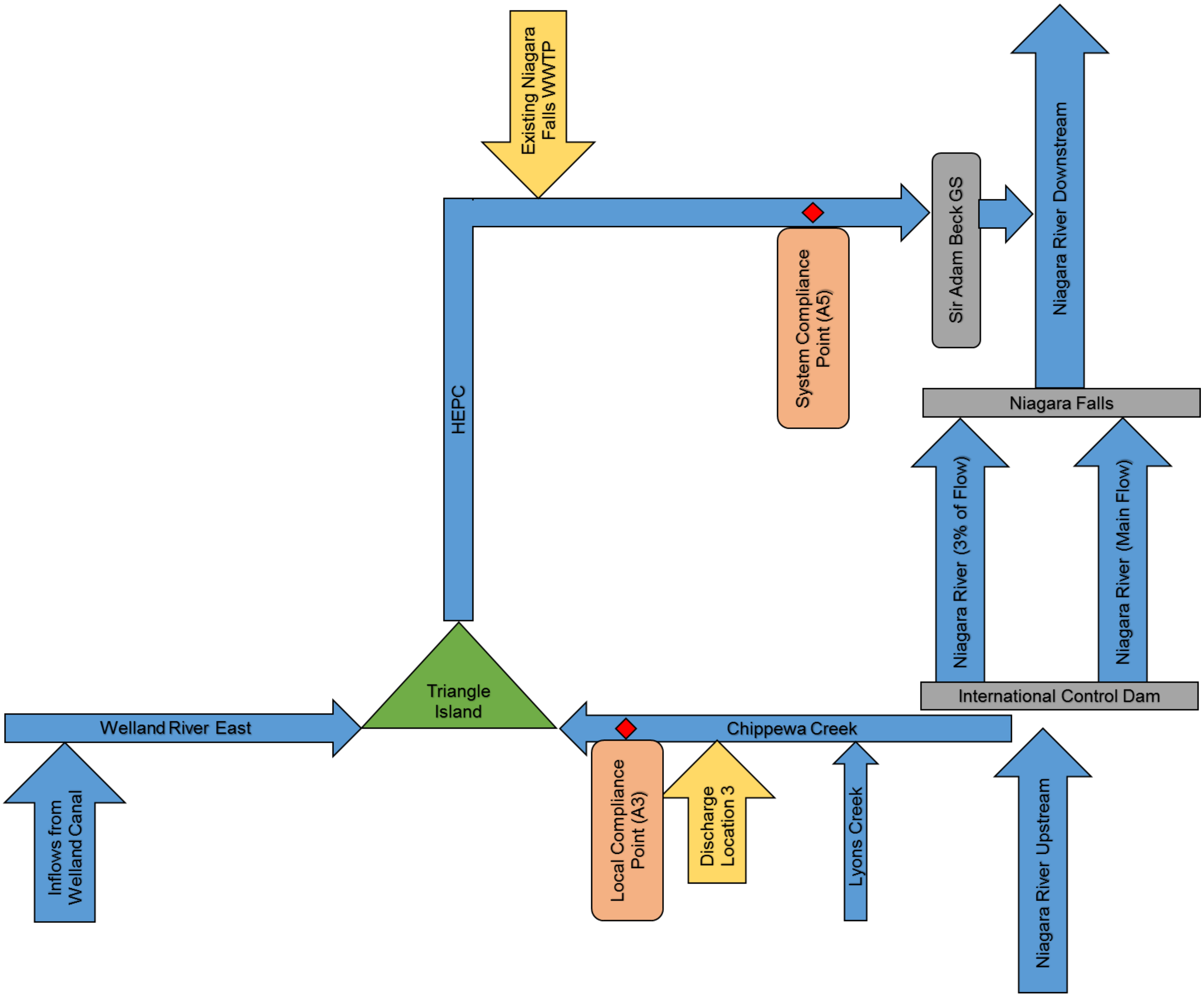

Figure 13: Local and System Compliance Points for Discharge at Location 3 – Chippewa Creek

4.3.2 Total Phosphorus

The measured seasonal 75th percentile concentrations of total phosphorus in Chippewa Creek range from 0.022 mg/L to 0.43 mg/L and are effectively the same as the measured conditions in the Niagara River.
The total phosphorus concentrations in Chippewa are elevated in the winter as a result of elevated concentrations in the Niagara River during the winter. There are additional constraints at the system compliance point caused by the discharge of effluent into the HEPC from the existing Niagara Falls WWTP.

The predicted maximum allowable effluent concentrations for phosphorus are presented in Table 42.
The elevated upstream total phosphorus concentrations result in Policy 2 conditions at the local compliance point in the winter months. At the local compliance point, Chippewa Creek can accept total phosphorus concentration of 2.8 mg/L or greater in the effluent in all the seasons except winter. At the system compliance point, elevated phosphorus concentrations are experienced in winter, spring and fall months due to inputs from the Welland River East and existing Niagara Falls WWTP.

An effluent limit for total phosphorus of 0.75 mg/L is recommended based in the following rationale:

- On an annual basis, there is sufficient capacity to accept an effluent concentration greater than 0.75 mg/L.
- The effluent flow rate represents less than 0.1% of the total flow in Chippewa Creek and as such the contributions of the proposed discharge will cause negligible increases in the total phosphorus concentrations within Chippewa Creek and the HEPC.
- The elevated phosphorus concentrations in Chippewa Creek are only experienced during the winter months, which is outside the algae growing season. The elevated winter background concentrations are the result of factors outside the study area (e.g., inflow from the Niagara River).
- Similarly, the effluent flow rate is insignificant when compared to the flow in the Niagara River below the Sir Adam beck GS.

Table 42: Maximum Allowable Seasonal Total Phosphorus Concentrations for Discharge at Location 3 – Chippewa Creek

Season	Upstream[1] (mg/L)	Maximum Allowable Effluent Concentration (mg/L)	
		Local Compliance Point	System Compliance Point
Winter	0.043	No Capacity	No Capacity
Spring	0.026	3.3 (3.8)	No Capacity
Summer	0.022	9.2 (7.7)	6.3 (5.0)
Fall	0.027	3.0 (2.8)	No Capacity

Notes:

1. Estimated value based on flow weighted average of inputs from Niagara River and Lyons Creek
2. Values in brackets refer to predictions from the mass balance modelling approach, if different from the GoldSim modelling approach

4.3.3 Nitrate

The measured 75th percentile nitrate concentrations in Chippewa Creek range from 0.18 mg/L to 0.31 mg/L. The highest nitrate concentrations typically occur during the winter. The predicted maximum allowable effluent concentrations for nitrate are presented in Table 43. In general, the local compliance point provides the most restrictive conditions. Based on the modelling results, the both the local and system compliance points can accept effluent nitrate concentrations in excess of 2,000 mg/L.

Based on the assumptions in Section 4.0, a conventional activated sludge system without denitrification is expected to provide effluent nitrate concentrations of 20 mg/L. As a result, nitrate limits would not be required for Location 3.

Table 43: Maximum Allowable Seasonal Nitrate Concentrations for Discharge at Location 3 – Chippewa Creek

Season	Upstream[1] (mg/L)	Maximum Allowable Effluent Concentration (mg/L)	
		Local Compliance Point	System Compliance Point
Winter	0.31	3,108 (2,621)	3,142 (2,629)
Spring	0.31	2,910 (2,614)	3,062 (2,668)
Summer	0.26	3,219 (2,652)	3,328 (2,740)
Fall	0.18	3,133 (2,735)	3,238 (2,796)

Notes:

1. Estimated value based on flow weighted average of inputs from Niagara River and Lyons Creek
2. Values in brackets refer to predictions from the mass balance modelling approach, if different from the GoldSim modelling approach

4.3.4 Ammonia

The measured 75th percentile concentrations for total ammonia in Chippewa Creek range from 0.014 mg/L to 0.032 mg/L. The corresponding unionized ammonia concentrations are consistently below the applicable PWQO (0.0164 mg/L as N) for all the seasons. The maximum allowable effluent concentrations for total and unionized ammonia are presented in Table 44.

The predicted maximum allowable unionized ammonia concentrations listed in Table 44: exceed the acute toxicity guideline for unionized ammonia (0.10 mg/L as N). As such, it is recommended that the effluent limits for total ammonia be based on meeting the acute toxicity limit for unionized at end-of-pipe and seasonal water temperature and pH.

Based on the resulting values presented in Table 45, the recommended total ammonia limits are recommended to be 1.0 mg/L during the summer and 1.7 mg/L for the remainder if the year based on seasonal average water temperature and pH in the HEPC.

Table 44: Maximum Allowable Seasonal Total and Unionized Ammonia Concentrations for Discharge at Location 3 – Chippewa Creek

Season	Total Ammonia			Unionized Ammonia		
	Upstream[1]	Maximum Allowable Concentration (mg/L)		Upstream[1]	Maximum Allowable Concentration (mg/L)	
		Local Compliance Point	System Compliance Point		Local Compliance Point	System Compliance Point
Winter	0.014	1,312 (1,294)	1,342 (1,216)	0.00012	12.12 (15.0)	12.52 (15.5)
Spring	0.046	261 (280)	258 (275)	0.00083	13.40 (15.0)	13.98 (15.3)
Summer	0.044	115 (115)	107 (101)	0.00339	12.24 (13.9)	11.82 (13.8)
Fall	0.032	159 (251)	152 (243)	0.00093	11.85 (14.0)	11.65 (14.2)

Notes:

1. Estimated value based on flow weighted average of inputs from Niagara River and Lyons Creek.
2. Values in brackets refer to predictions from the mass balance modelling approach, if different from the GoldSim modelling approach.
3. Unionized ammonia concentrations predicted in GoldSim based on modelled ammonia and average seasonal pH and temperature.
4. Unionized ammonia concentrations predicted using the mass balance approach based on measured concentrations and modelled as a conservative constituent.

Table 45: Maximum Allowable Seasonal Total Ammonia Concentrations for Discharge at Location 3 – Chippewa Creek Based on Acute Toxicity Limits for Unionized Ammonia

Season	Ambient Conditions		Maximum Allowable Effluent Concentration (mg/L)	
	Water Temperature (ºC)	pH	Unionized Ammonia	Total Ammonia
Winter	2.5	8.12	0.100	7.58
Spring	10.1	8.20	0.100	3.47
Summer	23.9	8.33	0.100	**0.99**
Fall	20.1	8.20	0.100	**1.68**

4.3.5 *E. coli*

The measured 75th percentile *E. coli* concentration in Chippewa Creek ranges from 8 cfu/100 mL to 50 cfu/100 mL and are consistently below the PWQO (100 cfu/100 mL). There are limitations on the discharge at the system compliance point during the winter due to contributions from Welland River East. As such, the effluent concentration is not to exceed background conditions during the winter. As shown in Table 46, during the remaining seasons, there is capacity at both compliance points to accept effluent *E. coli* concentrations that exceed 55,000 cfu/100 mL. These allowable concentrations greatly exceed the expected effluent quality from a treatment plant.

It is recommended that an effluent limit of 200 cfu/100 mL be used, consistent with other treatment plants in the area.

Table 46: Maximum Allowable Seasonal *E. coli* Concentrations for Discharge at Location 3 – Chippewa Creek

Season	Upstream[1] (mg/L)	Maximum Allowable Effluent Concentration (mg/L)	
		Local Compliance Point	System Compliance Point
Winter	50	55,235	No Capacity
Spring	12	94,761	75,382
Summer	8	107,502	107,502
Fall	26	81,586	76,349

Notes:

1. Estimated value based on flow weighted average of inputs from Niagara River and Lyons Creek
2. Values in brackets refer to predictions from the mass balance modelling approach, if different from the GoldSim modelling approach

4.3.6 Biochemical Oxygen Demand ($CBOD_5$) and Dissolved Oxygen

The mass balance modelling suggests that the dissolved oxygen concentrations downstream of the discharge are not sensitive to the effluent dissolved oxygen concentrations. As such, effluent dissolved oxygen concentrations equal to 50% of the saturation concentration are recommended as the effluent limit

The recommended annual maximum allowable $CBOD_5$ concentrations for effluent is based on the minimum value of 5,707 mg/L (fall) from Table 47. This value is well above the minimum secondary effluent standard limit of 25 mg/L (Table 25). As such, the recommended effluent limit for $CBOD_5$ is 25 mg/L.

Table 47: Maximum Allowable Seasonal $CBOD_5$ Concentrations for Discharge at Location 3 – Chippewa Creek

Season	Upstream $CBOD_5$ (mg/L)[1]	Maximum Allowable Effluent Concentration (mg/L)[2]
Winter	2.0	6,380
Spring		6,384
Summer		7,689
Fall		**5,707**

Notes:

1. Highest seasonal 75th percentile concentration in Welland River East.
2. Based on effluent dissolved oxygen concentration equal to 50% of saturation.

4.3.7 Total Suspended Solids (TSS)

The annual 75th percentile upstream TSS is estimated to be 11.3 mg/L suggesting that Chippewa Creek does not typically have high concentration od suspended solids. The mass balance modelling results provided in Table 48, the recommended annual maximum allowable TSS concentration for effluent is 4,846 based on the minimum value (summer and fall). This value is well above the minimum secondary effluent standard limit of 25 mg/L (Table 25). As such, the recommended effluent limit TSS is 25 mg/L.

Table 48: Maximum Allowable Seasonal TSS Concentrations for Discharge at Location 3 – Chippewa Creek

Season	Upstream TSS (mg/L)[1]	Maximum Allowable Effluent Concentration (mg/L)[2]
Winter	11.3	4,880
Spring		4,866
Summer		**4,846**
Fall		4,855

Notes:

2. Annual 75th percentile concentration from Niagara River.

4.3.8 Recommended Effluent Limits

Based on the preceding discussions, a summary of the recommended effluent concentrations for the Chippewa Creek discharge is presented in Table 49. In order to meet the limits and limits for each parameter, if the new WWTP discharges to Chippewa Creek the new plant would be designed as a membrane bioreactor with phosphorus removal and filtration. This advanced level of treatment is required in order to meet the end-of-pipe acute toxicity criteria during the summer.

Table 49: Summary of Development of Effluent Limits for Discharge at Location 3 – Chippewa Creek

Parameter		Limiting Assimilative Capacity Concentration[1]	Typical Treatment Plant Effluent[2]	Proposed Effluent Limits
Total Phosphorus (mg/L)		No capacity[3]	0.5	0.75
Nitrate (mg/L)		2,614	20	N/A[4]
Unionized Ammonia (mg/L)		0.1	--	0.10
Total Ammonia (mg/L)	Summer	1.0	<1	1.1
	Winter/Spring/Fall	1.7	<3	1.7
E. coli (cfu/100 mL)		55,235	100	200
Dissolved Oxygen (% of Saturation)		50%	>80%	N/A[4]
$CBOD_5$ (mg/L)		4,885	25	25
Total Suspended Solids (mg/L)		4,846	25	25

Notes:

1. Lowest seasonal value from local and system compliance points.
2. Typical effluent for a conventional activated sludge without filtration.
3. No capacity – Policy 2 receiver during winter months only.
4. Not applicable – typical effluent is expected to be better than the limiting assimilative capacity concentration.

4.4 Location 4 – Niagara River

4.4.1 Overview of Existing Conditions

The Niagara River discharge would release effluent to the Niagara River just downstream of the ICD approximately 1.8 km upstream of Niagara Falls. The effluent is expected to form a shoreline plume as it travels downstream to the falls. The effluent is expected to mix with approximately 3% of the total flow in the Niagara River in the 10-minute travel time. Below the falls, the effluent is expected to mix completely with the Niagara River flow. The local compliance point (A4) is located on the Canadian shoreline at the crest of the falls. There is no system compliance point for this location since the Niagara River discharge not expected to affect water quality in Welland River East, Chippewa Creek, in the HEPC where the existing Niagara Falls WWTP discharges into. There is no system compliance point for this location since the Niagara River discharge not expected to affect water quality in Welland River East, Chippewa Creek, in the HEPC where the existing Niagara Falls WWTP discharges into.

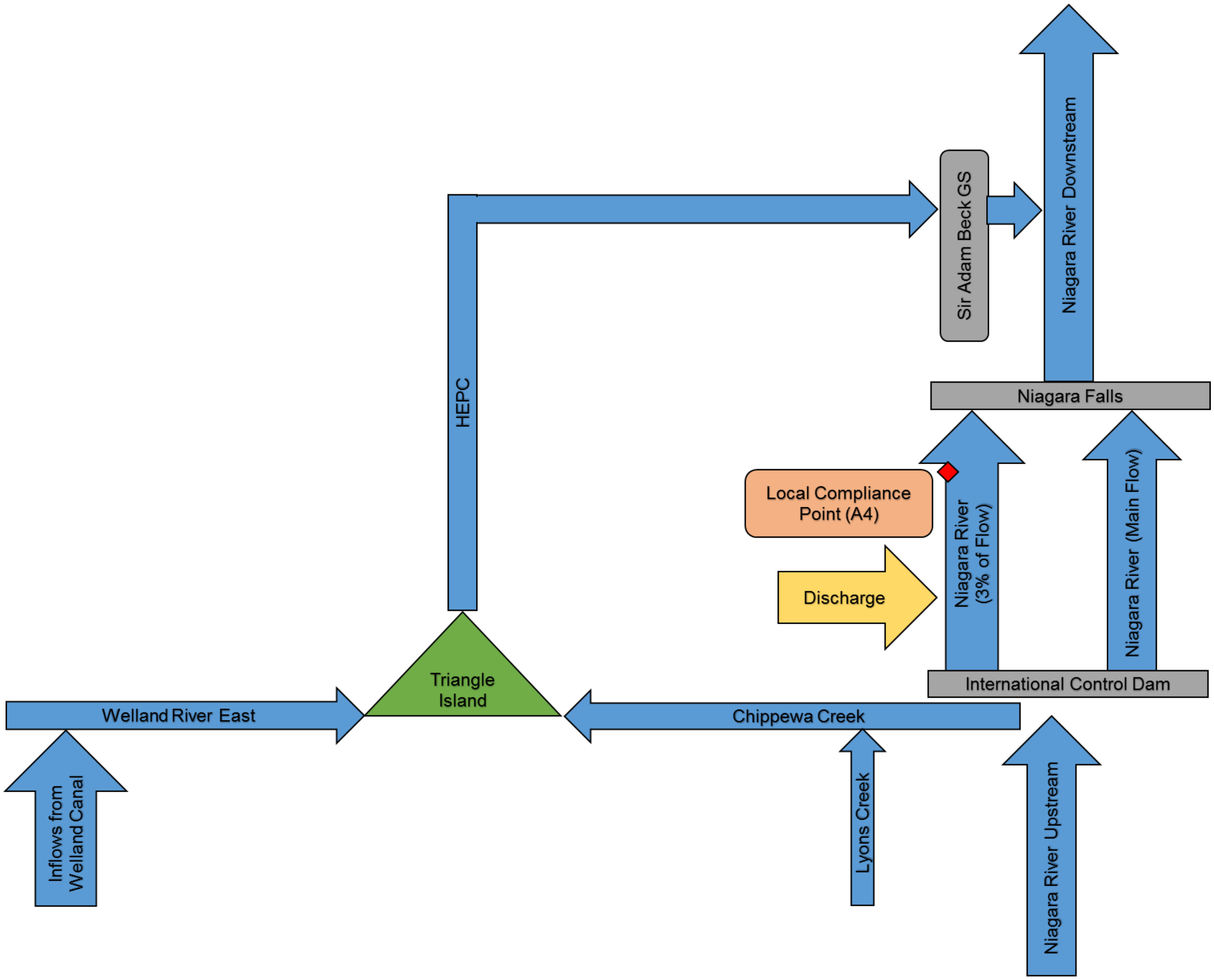

Figure 14: Local and System Compliance Points for Discharge at Location 4 – Niagara River

4.4.2 Total Phosphorus

The measured seasonal 75th percentile concentrations of total phosphorus in Niagara River range from 0.022 mg/L to 0.43 mg/L. The total phosphorus concentrations in Niagara River are elevated in the winter and result in discharge constraints in the winter.

The predicted maximum allowable effluent concentrations for phosphorus are presented in Table 50. The elevated upstream total phosphorus concentrations result in Policy 2 conditions at the local compliance during winter months. At the local compliance point, the Niagara River can accept total phosphorus concentration of 0.58 mg/L or greater in the effluent in all the seasons except winter.

An effluent limit for total phosphorus of 0.75 mg/L is recommended based in the following rationale:

- On an annual basis, there is sufficient capacity to accept an effluent concentration greater than 0.75 mg/L.
- The elevated phosphorus concentrations in the Niagara River are only during winter months and are the result of factors outside the study area (e.g., upstream in the Niagara River and Lake Erie).
- The effluent flow rate represents less than 0.01% of the total flow in Niagara River and as such the contributions of the proposed discharge will cause negligible increases in the total phosphorus concentrations downstream.

Table 50: Maximum Allowable Seasonal Total Phosphorus Concentrations for Discharge at Location 4 – Niagara River

Season	Upstream (mg/L)	Maximum Allowable Effluent Concentration (mg/L)
Winter	0.043	No Capacity
Spring	0.026	0.764
Summer	0.022	1.498
Fall	0.027	0.581

4.4.3 Nitrate

The measured 75th percentile nitrate concentrations in the Niagara River range from 0.18 mg/L to 0.31 mg/L. The highest nitrate concentrations typically occur during the winter. The predicted maximum allowable effluent concentrations for nitrate are presented in Table 53:. Based on the modelling results, the Niagara River can accept effluent nitrate concentrations in of 497 mg/L or greater.

Based on the assumptions in Section 4.0, a conventional activated sludge system without denitrification is expected to provide effluent nitrate concentrations of 20 mg/L. As a result, nitrate limits would not be required for Location 3.

Table 51: Maximum Allowable Seasonal Nitrate Concentrations for Discharge at Location 4 – Niagara River

Season	Upstream (mg/L)	Maximum Allowable Effluent Concentration (mg/L)
Winter	0.31	**497**
Spring	0.31	497
Summer	0.26	577
Fall	0.18	521

4.4.4 Ammonia

The measured 75th percentile concentrations for total ammonia in Niagara River range from 0.014 mg/L to 0.032 mg/L. The corresponding unionized ammonia concentrations are consistently below the applicable PWQO (0.0164 mg/L as N) for all the seasons. The maximum allowable effluent concentrations for total and unionized ammonia are presented in Table 52.

The predicted maximum allowable unionized ammonia concentrations listed in Table 52 exceed the acute toxicity guideline for unionized ammonia (0.10 mg/L as N). As such, it is recommended that the effluent limit for total ammonia be based on meeting the acute toxicity limit for unionized at end-of-pipe and seasonal water temperature and pH.

Based on the resulting values presented in Table 53:, the recommended total ammonia limits are recommended to be 1.0 mg/L during the summer and 1.7 mg/L for the remainder if the year based on seasonal average water temperature and pH in the HEPC.

Table 52: Maximum Allowable Seasonal Total and Unionized Ammonia Concentrations for Discharge at Location 4 – Niagara River

Season	Upstream (mg/L))		Maximum Allowable Effluent Concentration (mg/L)	
	Total	Unionized	Total	Unionized
Winter	0.014	0.00012	227	3.0
Spring	0.046	0.00083	97	2.8
Summer	0.044	0.00339	25	2.5
Fall	0.032	0.00093	45	2.7

Table 53: Maximum Allowable Seasonal Total Ammonia Concentrations for Discharge at Location 4 – Niagara River Based on Acute Toxicity Limits for Unionized Ammonia

Season	Ambient Conditions		Maximum Allowable Effluent Concentration (mg/L)	
	Water Temperature (ºC)	pH	Unionized Ammonia	Total Ammonia
Winter	2.5	8.12	0.100	7.58
Spring	10.1	8.20	0.100	3.47
Summer	23.9	8.33	0.100	**0.99**
Fall	20.1	8.20	0.100	**1.68**

4.4.5 *E. coli*

The measured 75th percentile *E. coli* concentration in the Niagara River ranges from 8 cfu/100 mL to 50 cfu/100 mL and are consistently below the PWQO (100 cfu/100 mL). There are no seasonal limitations on the discharge identified. As shown in Table 54, there is capacity in all seasons to accept effluent *E. coli* concentrations that exceed 9,000 cfu/100 mL. These allowable concentrations greatly exceed the expected effluent quality from a treatment plant.

It is recommended that an effluent limit of 200 cfu/100 mL be used, consistent with other treatment plants in the area.

Table 54: Maximum Allowable Seasonal Nitrate Concentrations for Discharge at Location 4 – Niagara River

Season	Upstream (cfu/100 mL)	Maximum Allowable Effluent Concentration (cfu/100 mL)
Winter	50	**9,276**
Spring	12	16,249
Summer	8	19,368
Fall	26	13,680

4.4.6 Biochemical Oxygen Demand ($CBOD_5$) and Dissolved Oxygen

The mass balance modelling suggests that the dissolved oxygen concentrations downstream of the discharge are not sensitive to the effluent dissolved oxygen concentrations.

The recommended annual maximum allowable $CBOD_5$ concentrations for effluent is based on the minimum value of 1,083 mg/L (fall) from Table 55. This value is well above the minimum secondary effluent standard limit of 25 mg/L (Table 25). As such, the recommended effluent limit for $CBOD_5$ is 25 mg/L.

Table 55: Maximum Allowable Seasonal $CBOD_5$ Concentrations for Discharge at Location 4 – Niagara River

Season	Upstream $CBOD_5$ (mg/L)[1]	Maximum Allowable Effluent Concentration (mg/L)[2]
Winter	2.0	1,204
Spring		1,275
Summer		1,461
Fall		**1,083**

Notes:

1. Highest seasonal 75th percentile concentration in Welland River East.
2. Based on effluent dissolved oxygen concentration equal to 50% of saturation.

4.4.7 Total Suspended Solids (TSS)

The annual 75th percentile upstream TSS is estimated to be 11.3 mg/L suggesting that the Niagara River does not typically have high concentration od suspended solids. The mass balance modelling results provided in

Table 56, the recommended annual maximum allowable TSS concentration for effluent is 934 based on the minimum value. This value is well above the minimum secondary effluent standard limit of 25 mg/L (Table 25). As such, the recommended effluent limit TSS is 25 mg/L.

Table 56: Maximum Allowable Seasonal TSS Concentrations for Discharge at Location 4 – Niagara River

Season	Upstream TSS (mg/L)[1]	Maximum Allowable Effluent Concentration (mg/L)[2]
Winter	11.3	**934**
Spring		985
Summer		**934**
Fall		**934**

Notes:

1. Annual 75th percentile concentration from Niagara River.

4.4.8 Recommended Effluent Limits

Based on the preceding discussions, a summary of the recommended effluent concentrations for the Niagara River discharge is presented in Table 57.

Table 57: Summary of Development of Effluent Limits for Discharge at Location 4 – Niagara River

Parameter		Limiting Assimilative Capacity Concentration[1]	Typical Treatment Plant Effluent[2]	Proposed Effluent Limits
Total Phosphorus (mg/L)		No capacity[3]	0.5	0.5
Nitrate (mg/L)		497	20	N/A[4]
Unionized Ammonia (mg/L)		0.10	0.1	0.1
Total Ammonia (mg/L)	Summer	1.0	<1	1.0
	Winter/Spring/Fall	1.7	<3	1.7
E. coli (cfu/100 mL)		9,276	<100	200
Dissolved Oxygen (% of Saturation)		50%	>80%	N/A[4]
$CBOD_5$ (mg/L)		927	25	25
Total Suspended Solids (mg/L)		934	25	25

Notes:

1. Lowest seasonal value.
2. Typical effluent for a conventional activated sludge without filtration.
3. No capacity – Policy 2 receiver during winter months only.
4. 4.Not applicable – typical effluent is expected to be better than the limiting assimilative capacity concentration.

5.0 CUMULATIVE EFFECTS OF THE PROJECT ON WATER QUALITY

The following subsections of this report present the projected cumulative effect of different discharge location alternatives on receiving water quality within the system at downstream assessment points with accompanying discussion of seasonal sensitivities, where relevant. It should be noted that presented results specifically consider the effects of the proposed effluent discharge under the 7Q20 flow and 75th percentile condition, meaning that water quality conditions would typically be better than presented. A schematic of the mass balance model including the assessment points used in the cumulative effects assessment is provided in Figure 10.

5.1 Total Phosphorus

Table 58 compares the water quality effects of proposed discharge location alternatives at each of six assessment points recognising that the phosphorus effluent limit for discharge location 1 is limited to 0.1 mg/L due to Policy 2 conditions while the phosphorus effluent limit for discharge locations 2, 3 and 4 is 0.75 mg/L which are achievable in conventional activated sludge system with phosphorus removal.

As observed in the tables below, the WWTP at discharge location 1 results in the smallest cumulative change in downstream phosphorus concentrations. Total phosphorus concentrations at Assessment Point A1 generally decrease due to the intensified level of treatment and poor background water quality in Welland River East. Marginal increases in phosphorus concentrations are observed further downstream at Assessment Point A2 during the winter and fall and, on average, over the course of the year.

Owing to the higher phosphorus effluent limit at discharge locations 2, 3 and 4, the effect of the new WWTP at each of these locations at downstream assessment points (A2, A5 and A6 for discharge location 2; A3, A2, A5 and A6 for discharge location 3; A4 and A6 for discharge location 4) is slightly higher than for discharge location 1. However, that these increases are typically less than 0.1 µg/L (approximately 1.5%) and do not result in exceedances of the PWQO for phosphorus during the summer when the risk of algal growth is elevated.

To further demonstrate the effect of the Project on the total phosphorus concentrations, GoldSim was used to predict the expected distribution of total phosphorus concentrations at each of the assessment locations. This was accomplished completing a Monte Carlo simulation for each season and discharge location using statistical distributions of inflows (same as used in to estimate maximum allowable effluent concentrations) and statistical distributions of the total phosphorus concentration in the Niagara River, Lyons Creek, and Welland River East. In all cases, a log-normal distribution was used.

The results of this analysis are provided in Appendix A. For the discharge options into the HEPC and Chippewa Creek, the predicted distributions at all the affected assessment points are nearly identical to the baseline condition. For the discharge option to Welland River East, there is a predicted change to the distribution at Assessment Point A1 (a shift of the distribution to the right) suggesting an increase in total phosphorus concentrations.

Based on these two assessments, it is expected that the change in phosphorus concentrations in the receiving waters as a result of the Project will not be measurable for all cases except for the discharge into the Welland River East.

Table 58: Predicted Total Phosphorus Concentrations at Assessment Points by Season and Discharge Location

	Winter	Spring	Summer	Fall	Annual
New WWTP Flow (m^3/s)	0.35				
New WWTP Total Phosphorus Limit	0.1 mg/L at L1; 0.75 mg/L at L2, L3, L4				
A1 – Welland River East at Triangle Island					
Existing Concentration (µg/L) – No Discharge	140.0	160.0	80.0	100.0	118.2
Future Concentration (µg/L) – Discharge at L1	138.8	158.3	80.5	100.0	117.7
Future Concentration (µg/L) – Discharge at L2	140.0	160.0	80.0	100.0	118.2
Future Concentration (µg/L) – Discharge at L3	140.0	160.0	80.0	100.0	118.2
Future Concentration (µg/L) – Discharge at L4	140.0	160.0	80.0	100.0	118.2
A2 – HEPC at Montrose Gate					
Existing Concentration (µg/L) – No Discharge	46.2	30.8	24.4	29.8	32.7
Future Concentration (µg/L) – Discharge at L1	46.3	30.9	24.5	29.9	32.8
Future Concentration (µg/L) – Discharge at L2	46.9	31.5	25.1	30.5	33.5
Future Concentration (µg/L) – Discharge at L3	46.9	31.5	25.1	30.5	33.5
Future Concentration (µg/L) – Discharge at L4	46.2	30.8	24.4	29.8	32.7
A3 – Chippewa Creek at Triangle Island					
Existing Concentration (µg/L) – No Discharge	43.1	26.1	22.1	27.1	29.6
Future Concentration (µg/L) – Discharge at L1	43.1	26.1	22.1	27.1	29.6
Future Concentration (µg/L) – Discharge at L2	43.1	26.1	22.1	27.1	29.6
Future Concentration (µg/L) – Discharge at L3	43.8	26.9	22.9	27.8	30.3
Future Concentration (µg/L) – Discharge at L4	43.1	26.1	22.1	27.1	29.6
A4 – Niagara River at Falls (Canadian Shore)					
Existing Concentration (µg/L) – No Discharge	43.0	26.0	22.0	27.0	29.4
Future Concentration (µg/L) – Discharge at L1	43.0	26.0	22.0	27.0	29.4
Future Concentration (µg/L) – Discharge at L2	43.0	26.0	22.0	27.0	29.4
Future Concentration (µg/L) – Discharge at L3	43.0	26.0	22.0	27.0	29.4
Future Concentration (µg/L) – Discharge at L4	47.1	29.9	26.1	31.1	33.4
A5 – HEPC at Sir Adam Beck GS					
Existing Concentration (µg/L) – No Discharge	47.8	32.4	26.0	31.4	34.4
Future Concentration (µg/L) – Discharge at L1	47.9	32.5	26.1	31.5	34.4
Future Concentration (µg/L) – Discharge at L2	48.5	33.1	26.7	32.1	35.1
Future Concentration (µg/L) – Discharge at L3	48.5	33.1	26.7	32.1	35.1
Future Concentration (µg/L) – Discharge at L4	47.8	32.4	26.0	31.4	34.4
A6 – Niagara River below Sir Adam Beck GS					
Existing Concentration (µg/L) – No Discharge	43.6	26.8	22.5	27.5	30.0
Future Concentration (µg/L) – Discharge at L1	43.6	26.8	22.5	27.6	30.0
Future Concentration (µg/L) – Discharge at L2	43.7	26.9	22.6	27.6	30.1
Future Concentration (µg/L) – Discharge at L3	43.7	26.9	22.6	27.6	30.1
Future Concentration (µg/L) – Discharge at L4	43.7	26.9	22.6	27.6	30.1

5.2 Unionized Ammonia

Table 59 compares the water quality effects of proposed discharge location alternatives at each of six assessment points recognising that the unionized ammonia effluent limit for discharge location 1 is limited to 0.018 mg/L during the summer (membrane bioreactor with phosphorus removal and filtration) because existing background water quality in this watercourse is close to the PWQO of 0.0164 mg/L as N. The unionized ammonia effluent limit that has been applied during all other seasons and at all other discharge locations is 0.1 mg/L.

The effect of introducing the new WWTP at discharge locations 1 and 4 on local assessment points is conspicuous when compared to siting the new WWTP at discharge locations 2 and 3. Only minor differences in water quality effects between the four discharge locations are in evidence by the time the mixed effluent stream reaches the system assessment point (A5) and final assessment point (A6) indicating that water quality effects for unionized ammonia are relatively localized.

Table 59: Predicted Unionized Ammonia Concentrations at Assessment Points by Season and Discharge Location

	Winter	Spring	Summer	Fall	Annual
New WWTP Flow (m^3/s)	0.35				
New WWTP Unionized Ammonia Limit	18 µg/L at L1 (summer); otherwise 100 µg/L				
A1 – Welland River East at Triangle Island					
Existing Concentration (µg/L) – No Discharge	1.00	6.00	18.00	9.00	8.94
Future Concentration (µg/L) – Discharge at L1	3.93	8.59	18.00	11.37	10.83
Future Concentration (µg/L) – Discharge at L2	1.00	6.00	18.00	9.00	8.94
Future Concentration (µg/L) – Discharge at L3	1.00	6.00	18.00	9.00	8.94
Future Concentration (µg/L) – Discharge at L4	1.00	6.00	18.00	9.00	8.94
A2 – HEPC at Montrose Gate					
Existing Concentration (µg/L) – No Discharge	1.00	1.18	2.63	2.26	1.77
Future Concentration (µg/L) – Discharge at L1	1.10	1.28	2.64	2.36	1.85
Future Concentration (µg/L) – Discharge at L2	1.10	1.28	2.72	2.36	1.87
Future Concentration (µg/L) – Discharge at L3	1.10	1.28	2.72	2.36	1.87
Future Concentration (µg/L) – Discharge at L4	1.00	1.18	2.63	2.26	1.77
A3 – Chippewa Creek at Triangle Island					
Existing Concentration (µg/L) – No Discharge	1.00	1.00	2.00	2.01	1.50
Future Concentration (µg/L) – Discharge at L1	1.00	1.00	2.00	2.01	1.50
Future Concentration (µg/L) – Discharge at L2	1.00	1.00	2.00	2.01	1.50
Future Concentration (µg/L) – Discharge at L3	1.10	1.11	2.10	2.11	1.60
Future Concentration (µg/L) – Discharge at L4	1.00	1.00	2.00	2.01	1.50
A4 – Niagara River at Falls (Canadian Shore)					
Existing Concentration (µg/L) – No Discharge	1.00	1.00	2.00	2.00	1.49
Future Concentration (µg/L) – Discharge at L1	1.00	1.00	2.00	2.00	1.49
Future Concentration (µg/L) – Discharge at L2	1.00	1.00	2.00	2.00	1.49
Future Concentration (µg/L) – Discharge at L3	1.00	1.00	2.00	2.00	1.49
Future Concentration (µg/L) – Discharge at L4	1.54	1.52	2.54	2.54	2.03
A5 – HEPC as Sir Adam Beck GS					
Existing Concentration (µg/L) – No Discharge	1.07	1.25	2.75	2.36	1.86
Future Concentration (µg/L) – Discharge at L1	1.17	1.35	2.77	2.46	1.94
Future Concentration (µg/L) – Discharge at L2	1.17	1.35	2.85	2.46	1.96
Future Concentration (µg/L) – Discharge at L3	1.17	1.35	2.85	2.46	1.96
Future Concentration (µg/L) – Discharge at L4	1.07	1.25	2.75	2.36	1.86
A6 – Niagara River below Sir Adam Beck GS					
Existing Concentration (µg/L) – No Discharge	1.01	1.03	2.09	2.05	1.54
Future Concentration (µg/L) – Discharge at L1	1.02	1.04	2.10	2.06	1.55
Future Concentration (µg/L) – Discharge at L2	1.02	1.04	2.11	2.06	1.55
Future Concentration (µg/L) – Discharge at L3	1.02	1.04	2.11	2.06	1.55
Future Concentration (µg/L) – Discharge at L4	1.02	1.04	2.11	2.06	1.55

5.3 Total Ammonia

Table 60 compares the water quality effects of proposed discharge location alternatives at each of six assessment points for total ammonia. In each case the total ammonia was estimated using the unionized ammonia effluent limits (discussed in Section 5.2), the average seasonal water temperature and pH within each receiver. The below water quality results for total ammonia thus reflect a variety of seasonal and location-based water quality and temperature characteristics.

The tabulated results indicate that water quality at local assessment points, particularly at A1, can be substantially influenced by introducing the new WWTP upstream. As would be expected, the magnitude of these influences decreases considerably with distance downstream as the influence of other loadings sources and flows becomes more dominant.

As no provincial water quality limit is tied directly to total ammonia, the significance of water quality effects of discharge location alternatives at each assessment is best evaluated for unionized ammonia (Section 5.2).

Table 60: Predicted Total Ammonia Concentrations at Assessment Points by Season and Discharge Location

	Winter	Spring	Summer	Fall	Annual
New WWTP Flow (m^3/s)	0.35				
New WWTP Total Ammonia Limit	1.4 mg/L (winter, spring, fall) & 0.5 mg/L (summer) at L1; 1.3 mg/L (winter, spring, fall) & 2.0 mg/L (summer) at L2; 1.0 mg/L (winter, spring, fall) & 1.7 mg/L (summer) at L3 & L4				
A1 - Welland River East at Triangle Island					
Existing Concentration - No Discharge (mg/L)	0.2300	0.2100	0.2200	0.2000	0.2146
Future Concentration - Discharge at L1 (mg/L)	0.2646	0.2428	0.2270	0.2313	0.2404
Future Concentration - Discharge at L2 (mg/L)	0.2300	0.2100	0.2200	0.2000	0.2146
Future Concentration - Discharge at L3 (mg/L)	0.2300	0.2100	0.2200	0.2000	0.2146
Future Concentration - Discharge at L4 (mg/L)	0.2300	0.2100	0.2200	0.2000	0.2146
A2 - HEPC at Montrose Gate					
Existing Concentration - No Discharge (mg/L)	0.0240	0.0518	0.0509	0.0238	0.0377
Future Concentration - Discharge at L1 (mg/L)	0.0253	0.0531	0.0513	0.0252	0.0389
Future Concentration - Discharge at L2 (mg/L)	0.0253	0.0531	0.0511	0.0252	0.0388
Future Concentration - Discharge at L3 (mg/L)	0.0256	0.0534	0.0518	0.0255	0.0392
Future Concentration - Discharge at L4 (mg/L)	0.0240	0.0518	0.0509	0.0238	0.0377
A3 - Chippewa Creek at Triangle Island					
Existing Concentration - No Discharge (mg/L)	0.0170	0.0461	0.0440	0.0170	0.0311
Future Concentration - Discharge at L1 (mg/L)	0.0170	0.0461	0.0440	0.0170	0.0311
Future Concentration - Discharge at L2 (mg/L)	0.0170	0.0461	0.0440	0.0170	0.0311
Future Concentration - Discharge at L3 (mg/L)	0.0187	0.0478	0.0450	0.0188	0.0327
Future Concentration - Discharge at L4 (mg/L)	0.0170	0.0461	0.0440	0.0170	0.0311
A4 - Niagara River at Falls (Canadian Shore)					
Existing Concentration - No Discharge (mg/L)	0.0170	0.0460	0.0440	0.0170	0.0313
Future Concentration - Discharge at L1 (mg/L)	0.0170	0.0460	0.0440	0.0170	0.0313
Future Concentration - Discharge at L2 (mg/L)	0.0170	0.0460	0.0440	0.0170	0.0313
Future Concentration - Discharge at L3 (mg/L)	0.0170	0.0460	0.0440	0.0170	0.0313
Future Concentration - Discharge at L4 (mg/L)	0.0263	0.0548	0.0494	0.0263	0.0395
A5 - HEPC at Sir Adam Beck GS					
Existing Concentration - No Discharge (mg/L)	0.0456	0.0683	0.0698	0.0419	0.0565
Future Concentration - Discharge at L1 (mg/L)	0.0470	0.0696	0.0702	0.0432	0.0576
Future Concentration - Discharge at L2 (mg/L)	0.0470	0.0696	0.0699	0.0432	0.0575
Future Concentration - Discharge at L3 (mg/L)	0.0472	0.0699	0.0707	0.0435	0.0580
Future Concentration - Discharge at L4 (mg/L)	0.0456	0.0683	0.0698	0.0419	0.0565
A6 - Niagara River Below Sir Adam Beck					
Existing Concentration - No Discharge (mg/L)	0.0205	0.0487	0.0472	0.0201	0.0344
Future Concentration - Discharge at L1 (mg/L)	0.0207	0.0488	0.0473	0.0203	0.0345
Future Concentration - Discharge at L2 (mg/L)	0.0207	0.0488	0.0472	0.0203	0.0345
Future Concentration - Discharge at L3 (mg/L)	0.0208	0.0489	0.0473	0.0203	0.0346
Future Concentration - Discharge at L4 (mg/L)	0.0208	0.0489	0.0473	0.0203	0.0346

5.4 Nitrate

Table 61 compares the water quality effects of proposed discharge location alternatives at each of six assessment points with the conventional secondary treatment effluent nitrate concentrations of 20 mg/L being applied consistently across seasons and locations. This concentration is consistent with a fully nitrifying facility without denitrification.

Notable from the results is that the new WWTP has a negligible effect on nitrate concentrations within receiving waters in all cases except at assessment point A1 when discharge location 1 is considered. In this case increases in nitrate concentrations of between 25% and 100% are observed, depending on season. Even so, these changes are not considered significant from a water quality perspective because instream nitrate concentrations remain below the Canadian Water Quality Guideline of 3 mg/L.

Table 61: Predicted Nitrate Concentrations at Assessment Points by Season and Discharge Location

A1 – Welland River East at Triangle Island	Winter	Spring	Summer	Fall	Annual
New WWTP Flow (m^3/s)	0.35				
New WWTP Nitrate Limit	20 mg/L				
A1 – Welland River East at Triangle Island					
Existing Concentration (mg/L) – No Discharge	2.29	1.11	0.49	1.05	1.19
Future Concentration (mg/L) – Discharge at L1	2.81	1.63	0.97	1.54	1.69
Future Concentration (mg/L) – Discharge at L2	2.29	1.11	0.49	1.05	1.19
Future Concentration (mg/L) – Discharge at L3	2.29	1.11	0.49	1.05	1.19
Future Concentration (mg/L) – Discharge at L4	2.29	1.11	0.49	1.05	1.19
A2 – HEPC at Montrose Gate					
Existing Concentration (mg/L) – No Discharge	0.37	0.34	0.27	0.21	0.30
Future Concentration (mg/L) – Discharge at L1	0.39	0.36	0.29	0.23	0.32
Future Concentration (mg/L) – Discharge at L2	0.39	0.36	0.29	0.23	0.32
Future Concentration (mg/L) – Discharge at L3	0.39	0.36	0.29	0.23	0.32
Future Concentration (mg/L) – Discharge at L4	0.37	0.34	0.27	0.21	0.30
A3 – Chippewa Creek at Triangle Island					
Existing Concentration (mg/L) – No Discharge	0.31	0.31	0.26	0.18	0.27
Future Concentration (mg/L) – Discharge at L1	0.31	0.31	0.26	0.18	0.27
Future Concentration (mg/L) – Discharge at L2	0.31	0.31	0.26	0.18	0.27
Future Concentration (mg/L) – Discharge at L3	0.33	0.33	0.28	0.20	0.29
Future Concentration (mg/L) – Discharge at L4	0.31	0.31	0.26	0.18	0.27
A4 – Niagara River at Falls (Canadian Shore)					
Existing Concentration (mg/L) – No Discharge	0.31	0.31	0.26	0.18	0.27
Future Concentration (mg/L) – Discharge at L1	0.31	0.31	0.26	0.18	0.27
Future Concentration (mg/L) – Discharge at L2	0.31	0.31	0.26	0.18	0.27
Future Concentration (mg/L) – Discharge at L3	0.31	0.31	0.26	0.18	0.27
Future Concentration (mg/L) – Discharge at L4	0.42	0.41	0.37	0.29	0.37
A5 – Niagara River below Sir Adam Beck GS					
Existing Concentration (mg/L) – No Discharge	0.40	0.36	0.29	0.23	0.32
Future Concentration (mg/L) – Discharge at L1	0.42	0.38	0.31	0.25	0.34
Future Concentration (mg/L) – Discharge at L2	0.42	0.38	0.31	0.25	0.34
Future Concentration (mg/L) – Discharge at L3	0.42	0.38	0.31	0.25	0.34
Future Concentration (mg/L) – Discharge at L4	0.40	0.36	0.29	0.23	0.32
A6 – Niagara River below Sir Adam Beck GS					
Existing Concentration (mg/L) – No Discharge	0.32	0.32	0.26	0.19	0.27
Future Concentration (mg/L) – Discharge at L1	0.32	0.32	0.27	0.19	0.27
Future Concentration (mg/L) – Discharge at L2	0.32	0.32	0.27	0.19	0.27
Future Concentration (mg/L) – Discharge at L3	0.32	0.32	0.27	0.19	0.27
Future Concentration (mg/L) – Discharge at L4	0.32	0.32	0.27	0.19	0.27

5.5 *E. coli*

Table 62 compares the water quality effects of proposed discharge location alternatives at each of six assessment points with the conventional secondary treatment with disinfection effluent limit for *E. coli* (200 cfu/100ml) being applied consistently across seasons and locations.

While the tabulated provide some insight into potential changes in *E. coli* concentrations it should be noted that there are no water quality concerns as the effluent objectives meet provincial guidelines for receiving water quality.

Table 62: Predicted *E. coli* Concentrations at Assessment Points by Season and Discharge Location

A1 – Welland River East at Triangle Island	Winter	Spring	Summer	Fall	Annual
New WWTP Flow (m³/s)	0.35				
New WWTP *E. coli* Limit	200 cfu/100 mL				
A1 – Welland River East at Triangle Island					
Existing Concentration (cfu/100 mL) – No Discharge	6920.0	308.0	105.0	170.0	1695.1
Future Concentration (cfu/100 mL) – Discharge at L1	6721.2	305.0	107.4	170.8	1654.9
Future Concentration (cfu/100 mL) – Discharge at L2	6920.0	308.0	105.0	170.0	1695.1
Future Concentration (cfu/100 mL) – Discharge at L3	6920.0	308.0	105.0	170.0	1695.1
Future Concentration (cfu/100 mL) – Discharge at L4	6920.0	308.0	105.0	170.0	1695.1
A2 – HEPC at Montrose Gate					
Existing Concentration (cfu/100 mL) – No Discharge	274.2	22.4	11.8	31.4	84.1
Future Concentration (cfu/100 mL) – Discharge at L1	274.2	22.6	12.0	31.6	84.2
Future Concentration (cfu/100 mL) – Discharge at L2	274.2	22.6	12.0	31.6	84.2
Future Concentration (cfu/100 mL) – Discharge at L3	274.2	22.6	12.0	31.6	84.2
Future Concentration (cfu/100 mL) – Discharge at L4	274.2	22.4	11.8	31.4	84.1
A3 – Chippewa Creek at Triangle Island					
Existing Concentration (cfu/100 mL) – No Discharge	50.2	12.1	8.0	26.1	24.0
Future Concentration (cfu/100 mL) – Discharge at L1	50.2	12.1	8.0	26.1	24.0
Future Concentration (cfu/100 mL) – Discharge at L2	50.2	12.1	8.0	26.1	24.0
Future Concentration (cfu/100 mL) – Discharge at L3	50.4	12.3	8.2	26.2	24.2
Future Concentration (cfu/100 mL) – Discharge at L4	50.2	12.1	8.0	26.1	24.0
A4 – Niagara River at Falls (Canadian Shore)					
Existing Concentration (cfu/100 mL) – No Discharge	50.0	12.0	8.0	26.0	23.7
Future Concentration (cfu/100 mL) – Discharge at L1	50.0	12.0	8.0	26.0	23.7
Future Concentration (cfu/100 mL) – Discharge at L2	50.0	12.0	8.0	26.0	23.7
Future Concentration (cfu/100 mL) – Discharge at L3	50.0	12.0	8.0	26.0	23.7
Future Concentration (cfu/100 mL) – Discharge at L4	51.1	13.0	9.1	27.1	24.8
A5 – Niagara River below Sir Adam Beck GS					
Existing Concentration (cfu/100 mL) – No Discharge	274.1	22.8	12.3	31.8	84.3
Future Concentration (cfu/100 mL) – Discharge at L1	274.0	23.0	12.4	31.9	84.5
Future Concentration (cfu/100 mL) – Discharge at L2	274.0	23.0	12.4	31.9	84.5
Future Concentration (cfu/100 mL) – Discharge at L3	274.0	23.0	12.4	31.9	84.5
Future Concentration (cfu/100 mL) – Discharge at L4	274.1	22.8	12.3	31.8	84.3
A6 – Niagara River below Sir Adam Beck GS					
Existing Concentration (cfu/100 mL) – No Discharge	77.8	13.3	8.5	26.7	31.2
Future Concentration (cfu/100 mL) – Discharge at L1	77.8	13.3	8.6	26.7	31.2
Future Concentration (cfu/100 mL) – Discharge at L2	77.8	13.3	8.6	26.7	31.2
Future Concentration (cfu/100 mL) – Discharge at L3	77.8	13.3	8.6	26.7	31.2
Future Concentration (cfu/100 mL) – Discharge at L4	77.8	13.3	8.6	26.7	31.2

5.6 Biological Oxygen Demand ($CBOD_5$)

Table 63 compares the water quality effects of proposed discharge location alternatives at each of six assessment points with the conventional secondary treatment effluent limit for $CBOD_5$ (25 mg/L) being applied consistently across seasons and locations.

While the tabulated provide some insight into potential changes $CBOD_5$ concentrations it should be noted that there are no water quality concerns as the effluent objectives meet provincial guidelines for receiving water quality.

Table 63: Predicted CBOD_5 Concentrations at Assessment Points by Season and Discharge Location

A1 – Welland River East at Triangle Island	Winter	Spring	Summer	Fall	Annual
New WWTP Flow (m^3/s)	0.35				
New WWTP CBOD_5 Limit	25 mg/L				
A1 – Welland River East at Triangle Island					
Existing Concentration - No Discharge (mg/L)	1.34	1.03	2.00	1.00	1.36
Future Concentration - Discharge at L1 (m/L)	2.04	1.69	2.57	1.63	1.99
Future Concentration - Discharge at L2 (mg/L)	1.34	1.03	2.00	1.00	1.36
Future Concentration - Discharge at L3 (mg/L)	1.34	1.03	2.00	1.00	1.36
Future Concentration - Discharge at L4 (mg/L)	1.34	1.03	2.00	1.00	1.36
A2 - HEPC at Montrose Gate					
Existing Concentration - No Discharge (mg/L)	1.98	1.97	2.00	1.96	1.98
Future Concentration - Discharge at L1 (m/L)	2.00	1.99	2.02	1.99	2.00
Future Concentration - Discharge at L2 (mg/L)	2.00	1.99	2.02	1.99	2.00
Future Concentration - Discharge at L3 (mg/L)	2.00	1.99	2.02	1.99	2.00
Future Concentration - Discharge at L4 (mg/L)	1.98	1.97	2.00	1.96	1.98
A3 - Chippewa Creek at Triangle Island					
Existing Concentration - No Discharge (mg/L)	2.00	2.00	2.00	2.00	2.00
Future Concentration - Discharge at L1 (m/L)	2.00	2.00	2.00	2.00	2.00
Future Concentration - Discharge at L2 (mg/L)	2.00	2.00	2.00	2.00	2.00
Future Concentration - Discharge at L3 (mg/L)	2.02	2.02	2.02	2.02	2.02
Future Concentration - Discharge at L4 (mg/L)	2.00	2.00	2.00	2.00	2.00
A4 - Niagara River at Falls (Canadian Shore)					
Existing Concentration - No Discharge (mg/L)	2.00	2.00	2.00	2.00	2.00
Future Concentration - Discharge at L1 (m/L)	2.00	2.00	2.00	2.00	2.00
Future Concentration - Discharge at L2 (mg/L)	2.00	2.00	2.00	2.00	2.00
Future Concentration - Discharge at L3 (mg/L)	2.00	2.00	2.00	2.00	2.00
Future Concentration - Discharge at L4 (mg/L)	2.14	2.13	2.14	2.14	2.13
A5 - HEPC at Sir Adam Beck					
Existing Concentration - No Discharge (mg/L)	2.03	2.02	2.05	2.01	2.03
Future Concentration - Discharge at L1 (m/L)	2.05	2.04	2.07	2.04	2.05
Future Concentration - Discharge at L2 (mg/L)	2.05	2.04	2.07	2.04	2.05
Future Concentration - Discharge at L3 (mg/L)	2.05	2.04	2.07	2.04	2.05
Future Concentration - Discharge at L4 (mg/L)	2.03	2.02	2.05	2.01	2.03
A6 - Niagara River Below Sir Adam Beck					
Existing Concentration - No Discharge (mg/L)	2.00	2.00	2.01	2.00	2.00
Future Concentration - Discharge at L1 (m/L)	2.01	2.00	2.01	2.00	2.01
Future Concentration - Discharge at L2 (mg/L)	2.01	2.00	2.01	2.00	2.01
Future Concentration - Discharge at L3 (mg/L)	2.01	2.00	2.01	2.00	2.01
Future Concentration - Discharge at L4 (mg/L)	2.01	2.00	2.01	2.00	2.01

6.0 CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Based on the analysis in this report, the following conclusions are provided:

- Elevated total phosphorus concentrations in the Niagara River leads to effluent constraints during the winter for discharges to the HEPC, Chippewa Creek, and the Niagara River.
- Degraded water quality in the Welland River East leads to effluent constraints related to total phosphorus and unionized ammonia for the option to discharge to the Welland River East.
- In most cases, the recommended effluent limits and limits for total and unionized ammonia are defined by the end-of-pipe acute toxicity criteria for unionized ammonia (0.1 mg/L).
- Based on seasonal water temperatures and pH in the receiving water, summer is the most restrictive season for total ammonia. Maximum allowable total ammonia concentrations range from 0.19 mg/L for the Welland River East discharge to 1.0 mg/L for the Chippewa Creek and Niagara River discharges. A value of 0.50 mg/L has been recommended for the Welland River East based on the limits reliably achievable in a nitrifying facility.
- For all other parameters (nitrate, *E. coli*, $CBOD_5$, dissolved oxygen, and TSS) the maximum allowable effluent concentrations at the local and system compliance points are greater than the expected effluent concentrations from a conventional activated sludge treatment plant.
- At most locations and discharge options, the expected water quality concentrations are not expected to be measurably different from the existing conditions. Only the discharge at Location 1 – Welland River East is expected to cause measurable differences in water quality in the immediate area of the discharge.
- Since the modelling presented in this study assumes complete and instant mixing of the effluent after release into the environment, a mixing zone study is required to assess and identify any limitations on assimilative capacity near the outfall.
- Since the information regarding the expected effluent quality from various treatment technologies is not site specific, more detailed assessments should be completed prior to the final selection of the required technology for each discharge location.

Recommendations

Based on the analysis in this report, the recommended effluent objectives and limits for each discharge location are provided in Table 64 through Table 67. Limits and objectives have not been included for nitrate and dissolved oxygen since the effluent quality from any typical plant is expected to be better than the allowable maximum effluent concentrations.

These recommended limits and limits should be re-evaluated upon the completion of a mixing zone study and an assessment of the expected effluent quality from various treatment technologies based in site specific conditions.

Table 64: Proposed Effluent Objectives and Limits for Discharge at Location 1 – Welland River East

Parameter		Proposed Effluent Objectives	Proposed Effluent Limits
Total Phosphorus (mg/L)		0.075	0.100
Total Ammonia (mg/L)	Summer	0.50	0.50
	Winter/Spring/Fall	1.40	1.40
E. coli (cfu/100 mL)		100	200
$CBOD_5$ (mg/L)		15	25
Total Suspended Solids (mg/L)		5	10

Table 65: Proposed Effluent Objectives and Limits for Discharge at Location 2 – Hydro Electric Power Canal

Parameter		Proposed Effluent Objectives	Proposed Effluent Limits
Total Phosphorus (mg/L)		0.5	0.75
Total Ammonia (mg/L)	Summer	1.3	1.3
	Winter/Spring/Fall	2.0	2.0
E. coli (cfu/100 mL)		100	200
$CBOD_5$ (mg/L)		15	25
Total Suspended Solids (mg/L)		15	25

Table 66: Proposed Effluent Objectives and Limits for Discharge at Location 3 – Chippewa Creek

Parameter		Proposed Effluent Objectives	Proposed Effluent Limits
Total Phosphorus (mg/L)		0.5	0.75
Total Ammonia (mg/L)	Summer	1.0	1.0
	Winter/Spring/Fall	1.7	1.7
E. coli (cfu/100 mL)		100	200
$CBOD_5$ (mg/L)		15	25
Total Suspended Solids (mg/L)		15	25

Table 67: Proposed Effluent Objectives and Limits for Discharge at Location 4 – Niagara River

Parameter		Proposed Effluent Objectives	Proposed Effluent Limits
Total Phosphorus (mg/L)		0.5	0.75
Total Ammonia (mg/L)	Summer	1.0	1.0
	Winter/Spring/Fall	1.7	1.7
E. coli (cfu/100 mL)		100	200
$CBOD_5$ (mg/L)		15	25
Total Suspended Solids (mg/L)		15	25

7.0 LIMITATIONS

Golder has prepared this report for the exclusive use by the Niagara Region and other members of the project team for the South Niagara Falls Wastewater Solutions Schedule C Class EA Project. The results presented in this report are for a proposed wastewater treatment plant with a specific design capacity of 30 MLD discharging to four potential locations in the study area. The results presented in this report should not be used to assess other design capacities or discharge locations in any way.

Information, analysis, and commentary presented in this report regarding wastewater treatment technologies and the associated typical effluent quality have been provided by CIMA+.

The assessment has been completed using data and information collected and provided by others. Golder does not assume any responsibility related to the accuracy or reliability of the data or information.

Water quality modelling requires the use of many assumptions due to the uncertainty related to determining the physical and chemical characteristics of a complex system. The prediction of water quality is based on several inputs (flows and chemistry), all of which have inherent variability and uncertainty.

GoldSim derives a maximum allowable concentration distribution for each parameter and location by combining randomly sampled flows over numerous (1,000s) of cycles using a Monte Carlo approach. While this approach is valuable because it considers numerous combinations, it may be inaccurate if certain environmental conditions are less represented in historic data than others.

The conventional mass balance ACS approach calculates the maximum allowable effluent concentration for a specific case where the low-flow condition (e.g., 7Q20) occurs for all the inflows at the same time. This is the approach that is typically requested by the MECP and is assumed to represent a worst-case scenario. However, because of the range of the inflow watershed sizes (e.g., Niagara River compared to Lyons Creek), it is highly unlikely that low-flow conditions will occur in all the inflows at the same time.

In natural systems and complex man-made systems, observed conditions will almost certainly vary with respect to estimated conditions. Water quality and flow data has shown a vast range of variability across seasons and locations. This variability may not be captured by the flow and water quality statistics (e.g., 75th percentile concentrations) used as inputs to the models. This is especially true for data sets with small sample sizes.

The modelling presented in this study assumes complete and instant mixing of the effluent after release into the environment. As such, this assessment does not consider any potential water quality effects in the immediate area of the outfall. A mixing zone study is required to assess these issues and identify any related limitations on assimilative capacity near the outfall.

Since the information regarding the expected effluent quality from various treatment technologies is not site specific, more detailed assessments should be completed prior to the final selection of the required technology for each discharge location.

This assessment is one part of a larger project to select the location and effluent criteria for the proposed wastewater treatment plant. The results of this assessment should be used in conjunction with the other components of the Project to support any decisions. Given all the inherent uncertainties provided, the results should be used as a tool to aid in the design and planning of the proposed wastewater treatment plant rather than to provide absolute water quality predictions.

Signature Page

We trust that this report meets your needs at this time. If you have any questions, please do not hesitate to contact the undersigned.

Yours truly,

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REFERENCES

AquaResource. 2009. Water Availability Study for the Central Welland River, Big Forks Creek, and Beaverdams Shriners Creeks Watershed Plan Areas, Niagara Peninsula Source Protection Area. A report prepared for Niagara Peninsula Conservation Authority. January 23, 2009.

CCME. 2014. Canadian Environmental Quality Guidelines. Canadian Council of Ministers of the Environment. Available at www.ccme.ca/en/resources/canadian_environmental_quality_guidelines.

Environment and Climate Change Canada and the U.S. Environmental Protection Agency. 2018. Lake Ontario Lakewide Action and Management Plan, 2018-2022. https://binational.net/wp-content/uploads/2019/04/2018-Lake-Ontario-For-Public-Comment-APRIL-2019.pdf

Fischer, H. B., List, J. E., Koh, C. R., Imberger, J., & Brooks, N. H. 1979. Mixing in inland and coastal waters. New York, Academic Press

Hutchinson. 2019. Hutchinson Environmental Sciences Ltd. Peer Review Comments: South Niagara Falls Wastewater Solutions Schedule C Class Environmental Assessment – Screening Level Assimilative Capacity Study of Discharge Location Alternatives. December 2, 2019

Manning, R. 1891. "On the flow of water in open channels and pipes". Transactions of the Institution of Civil Engineers of Ireland. 20: 161–207.

MOEE. 1994. Water Management Policies Guidelines Provincial Water Quality Objectives of The Ministry of Environment and Energy. Reprinted 1999.

MOEE. 1994a. B-1-5 Deriving Receiving Water Based Point Source Effluent Requirements for Ontario Water.

Ministry of the Environment (MOE). 2010. Amended Certificate of Approval for Niagara Falls Wastewater Treatment Plant (Stanley Avenue). Number 7962-7ZLK6. Issues February 3, 2010.

Ministry of Environment, Conservation, and Parks (MECP). 2019. Design Guidelines for Sewage Works. ISBN 978-1-4249-8438-1. (https://www.ontario.ca/document/design-guidelines-sewage-works-0).

Ministry of Transportation (MTO). 1997. Drainage Management Manual. Part 3. Drainage and Hydrology Section. Transportation Engineering Branch. Quality and Standards Division.

Niagara Parks. 2018. http://www.niagaraparks.com/visit-niagara-parks/plan-your-visit/niagara-falls-geology-facts-figures/.

NPCA. 2011. The Welland River Eutrophication Study in the Niagara River Area of Concern in Support of the Beneficial Use Impairment: Eutrophication and Undesirable Algae. A report written by Niagara Peninsula Conservation Authority on behalf of the Welland River Eutrophication Technical Working Group. March 2011.

NOAA. 2019. Tides & Currents Database (http://tidesandcurrents.noaa.gov/stationhome.html?id=9063020/).

NWQMC. 2019. Water Quality Portal of the National Water Quality Monitoring Council (http://www.waterqualitydata.us/).

NYPA. 2005. Surface Water Quality of the Niagara River and its U.S. Tributaries. A report prepared for the Niagara Power Project FERC No. 2216 and the New York Power Authority. August 2005.

SLSMA. 2019. Water Diversion Report Production Guide. The St. Lawrence Seaway Management Corporation. September 2019.

USGS. 2019. National Water Information System (http://nwis.waterdata.usgs.gov/usa/nwis/qwdata/?site_no=04216070/)

XCG. 2007. Assimilative Capacity Assessment of the Welland River, Ontario. A technical memorandum prepared for Niagara Region. November 1, 2007

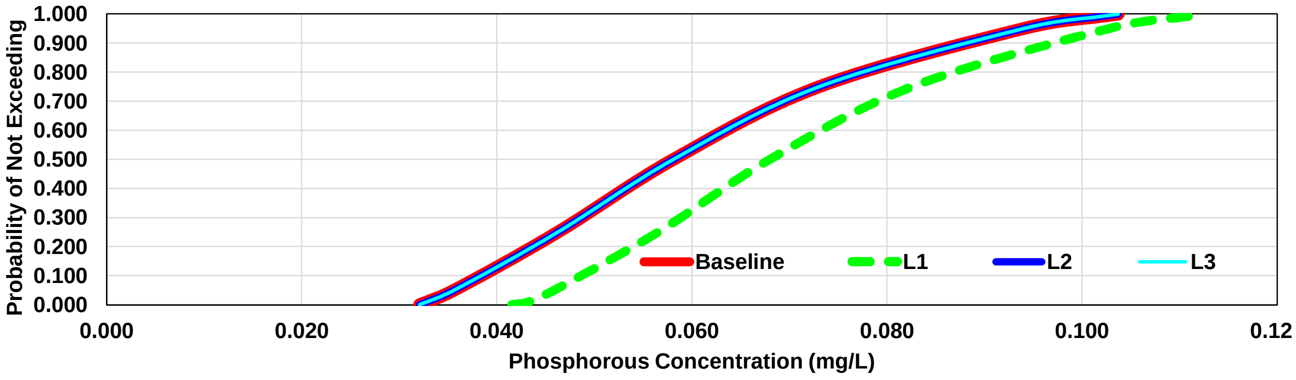
APPENDIX A

Predicted Phosphorus Concentration Distributions in Welland River East, Chippewa Creek, and HEPC

Prediction of Phosphorous for Summer

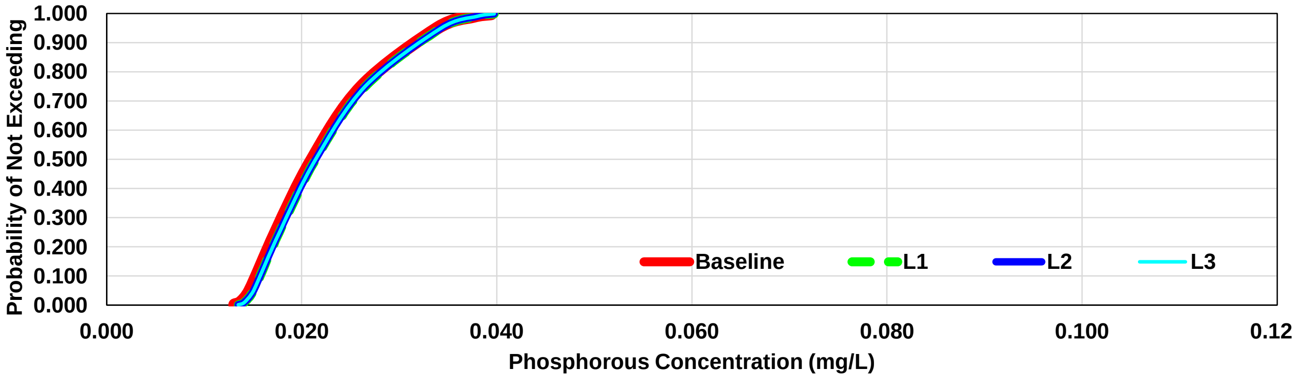
Predictions at L1

Cumulative Probability	Baseline	L1	L2	L3
0.001	0.032	0.042	0.032	0.032
0.010	0.033	0.043	0.033	0.033
0.050	0.036	0.046	0.036	0.036
0.250	0.046	0.057	0.046	0.046
0.500	0.058	0.068	0.058	0.058
0.750	0.073	0.083	0.073	0.073
0.950	0.094	0.103	0.094	0.094
0.990	0.102	0.111	0.102	0.102
0.999	0.104	0.113	0.104	0.104



Predictions at L2

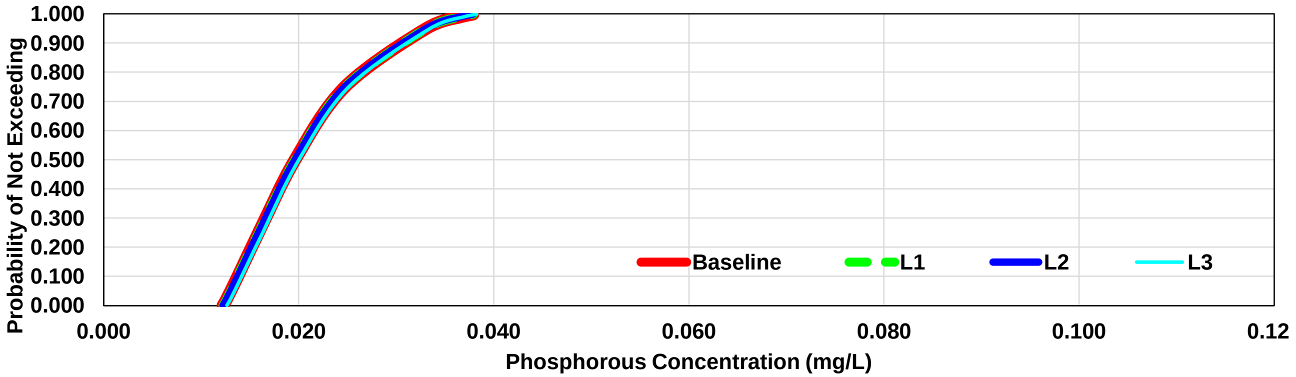
Cumulative Probability	Baseline	L1	L2	L3
0.001	0.013	0.014	0.014	0.014
0.010	0.014	0.014	0.014	0.014
0.050	0.015	0.015	0.015	0.015
0.250	0.017	0.018	0.018	0.018
0.500	0.021	0.021	0.021	0.021
0.750	0.026	0.027	0.027	0.027
0.950	0.034	0.034	0.034	0.034
0.990	0.038	0.038	0.038	0.038
0.999	0.039	0.040	0.040	0.040



Prediction of Phosphorous for Summer

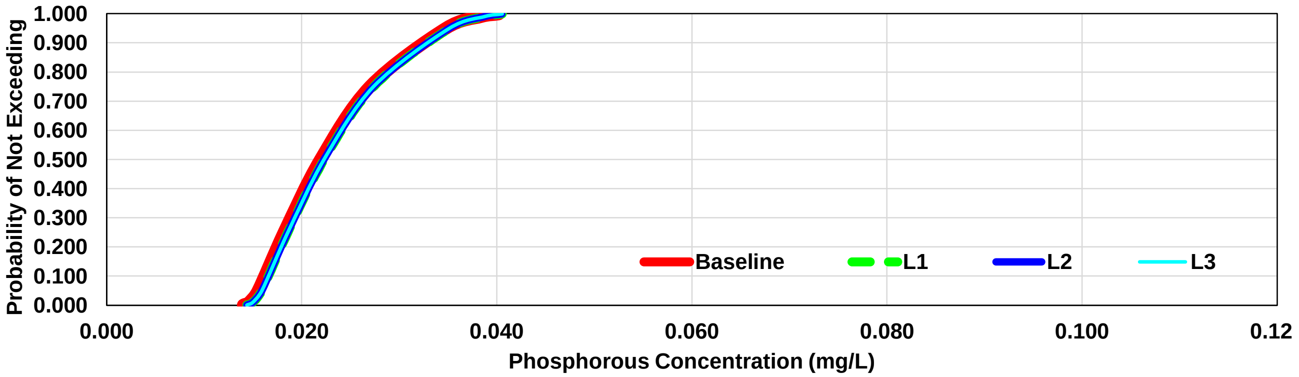
Predictions at L3

Cumulative Probability	Baseline	L1	L2	L3
0.001	0.012	0.012	0.012	0.013
0.010	0.012	0.012	0.012	0.013
0.050	0.013	0.013	0.013	0.013
0.250	0.016	0.016	0.016	0.016
0.500	0.020	0.020	0.020	0.020
0.750	0.025	0.025	0.025	0.025
0.950	0.033	0.033	0.033	0.033
0.990	0.037	0.037	0.037	0.037
0.999	0.038	0.038	0.038	0.038



Predictions at System Compliance Point

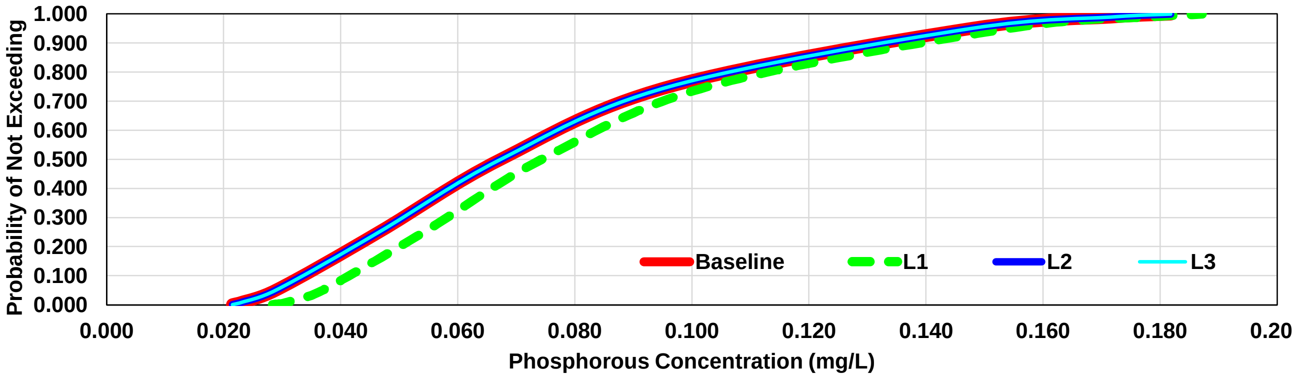
Cumulative Probability	Baseline	L1	L2	L3
0.001	0.014	0.014	0.014	0.014
0.010	0.015	0.015	0.015	0.015
0.050	0.016	0.016	0.016	0.016
0.250	0.018	0.019	0.019	0.019
0.500	0.022	0.022	0.022	0.022
0.750	0.027	0.027	0.027	0.027
0.950	0.035	0.035	0.035	0.035
0.990	0.038	0.039	0.039	0.039
0.999	0.040	0.041	0.041	0.041



Prediction of Phosphorous for Fall

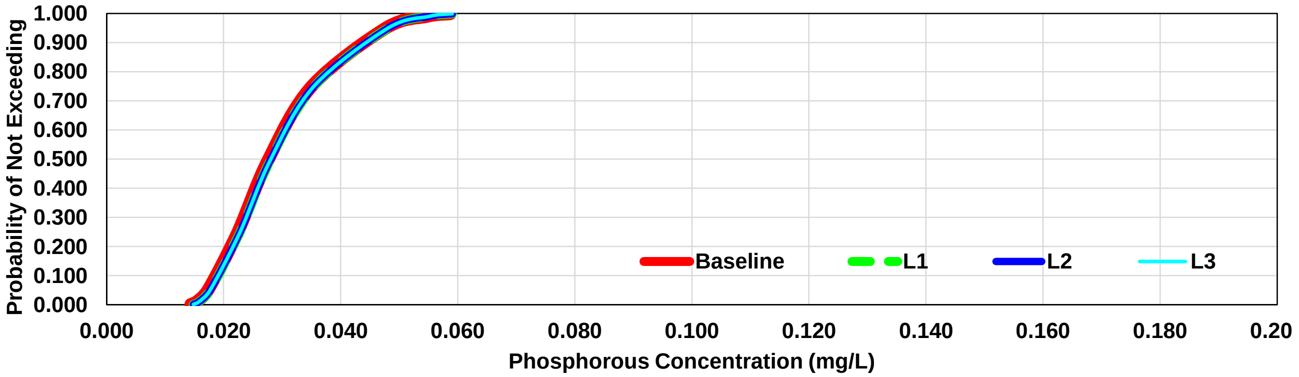
Predictions at L1

Cumulative Probability	Baseline	L1	L2	L3
0.001	0.021	0.028	0.021	0.021
0.010	0.023	0.031	0.023	0.023
0.050	0.029	0.037	0.029	0.029
0.250	0.047	0.054	0.047	0.047
0.500	0.067	0.074	0.067	0.067
0.750	0.096	0.103	0.096	0.096
0.950	0.148	0.154	0.148	0.148
0.990	0.173	0.179	0.173	0.173
0.999	0.182	0.187	0.182	0.182



Predictions at L2

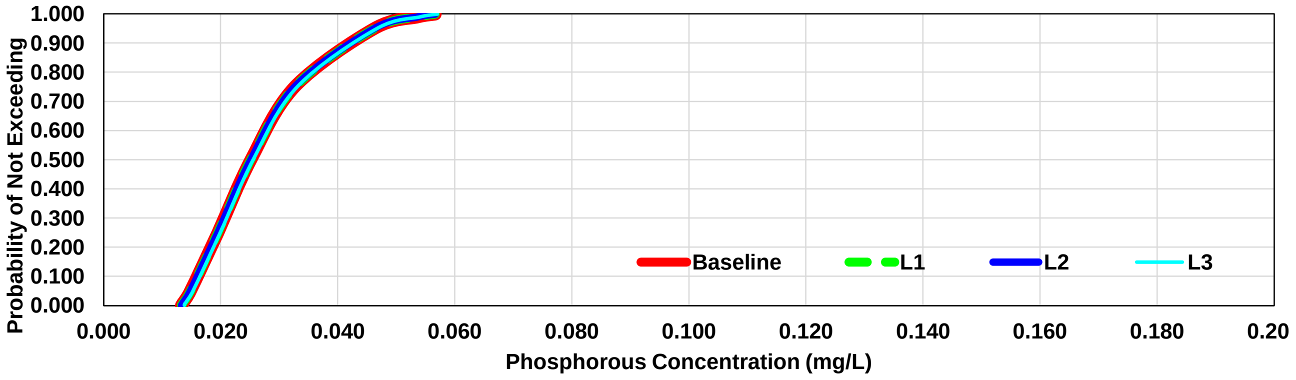
Cumulative Probability	Baseline	L1	L2	L3
0.001	0.014	0.015	0.015	0.015
0.010	0.015	0.016	0.016	0.016
0.050	0.017	0.018	0.018	0.018
0.250	0.022	0.023	0.023	0.023
0.500	0.028	0.028	0.028	0.028
0.750	0.035	0.035	0.035	0.035
0.950	0.048	0.048	0.048	0.048
0.990	0.055	0.055	0.055	0.055
0.999	0.059	0.059	0.059	0.059



Prediction of Phosphorous for Fall

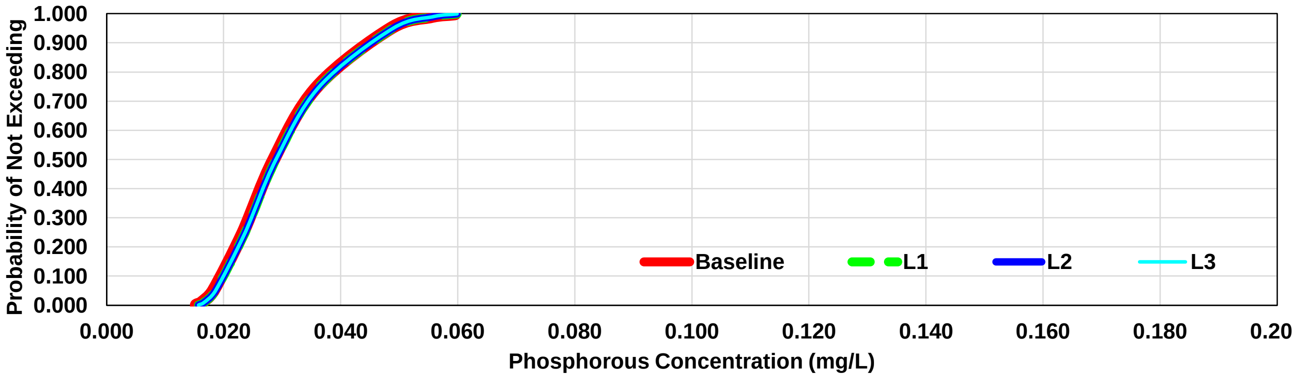
Predictions at L3

Cumulative Probability	Baseline	L1	L2	L3
0.001	0.013	0.013	0.013	0.014
0.010	0.014	0.014	0.014	0.014
0.050	0.015	0.015	0.015	0.015
0.250	0.020	0.020	0.020	0.020
0.500	0.025	0.025	0.025	0.026
0.750	0.033	0.033	0.033	0.033
0.950	0.046	0.046	0.046	0.047
0.990	0.054	0.054	0.054	0.054
0.999	0.057	0.057	0.057	0.057



Predictions at System Compliance Point

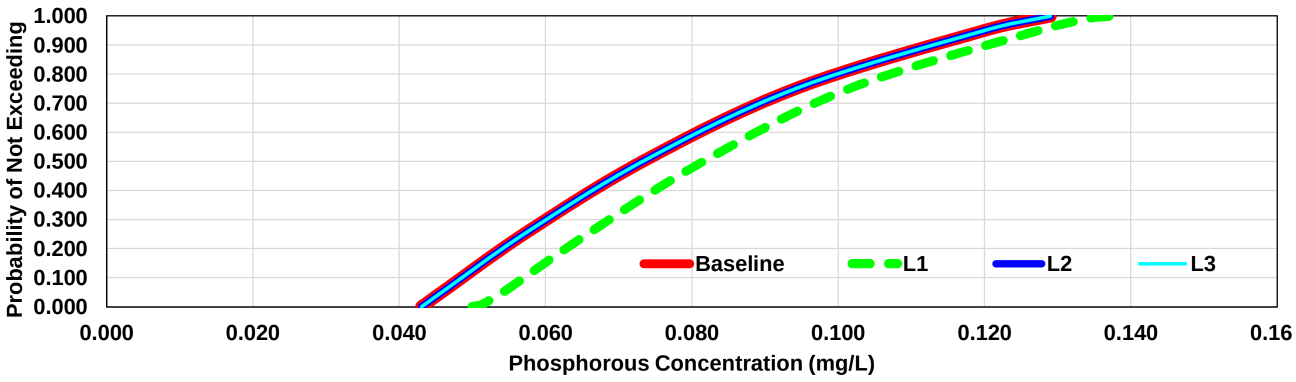
Cumulative Probability	Baseline	L1	L2	L3
0.001	0.015	0.016	0.016	0.016
0.010	0.016	0.017	0.017	0.017
0.050	0.018	0.019	0.019	0.019
0.250	0.023	0.024	0.024	0.024
0.500	0.029	0.029	0.029	0.029
0.750	0.036	0.036	0.036	0.036
0.950	0.049	0.049	0.049	0.049
0.990	0.056	0.056	0.056	0.056
0.999	0.060	0.060	0.060	0.060



Prediction of Phosphorous for Winter

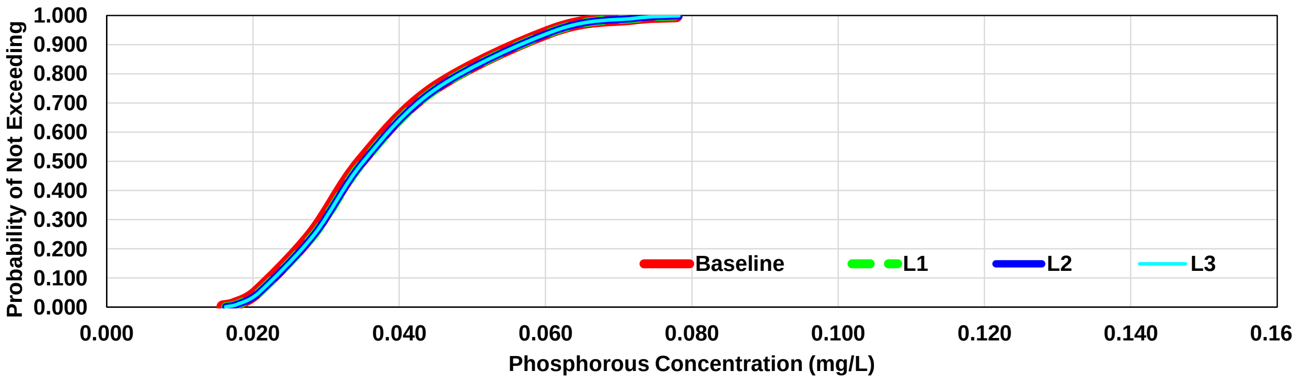
Predictions at L1

Cumulative Probability	Baseline	L1	L2	L3
0.001	0.043	0.050	0.043	0.043
0.010	0.044	0.051	0.044	0.044
0.050	0.046	0.054	0.046	0.046
0.250	0.057	0.066	0.057	0.057
0.500	0.073	0.082	0.073	0.073
0.750	0.094	0.102	0.094	0.094
0.950	0.120	0.127	0.120	0.120
0.990	0.127	0.134	0.127	0.127
0.999	0.129	0.137	0.129	0.129



Predictions at L2

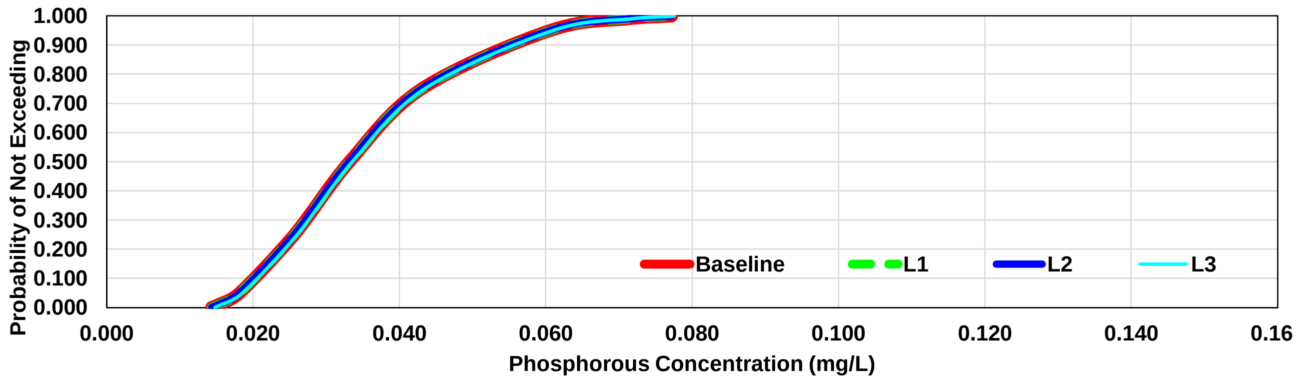
Cumulative Probability	Baseline	L1	L2	L3
0.001	0.016	0.016	0.016	0.016
0.010	0.018	0.018	0.018	0.018
0.050	0.020	0.021	0.021	0.021
0.250	0.028	0.028	0.028	0.028
0.500	0.035	0.035	0.035	0.035
0.750	0.045	0.045	0.045	0.045
0.950	0.061	0.062	0.062	0.062
0.990	0.072	0.072	0.072	0.072
0.999	0.078	0.078	0.078	0.078



Prediction of Phosphorous for Winter

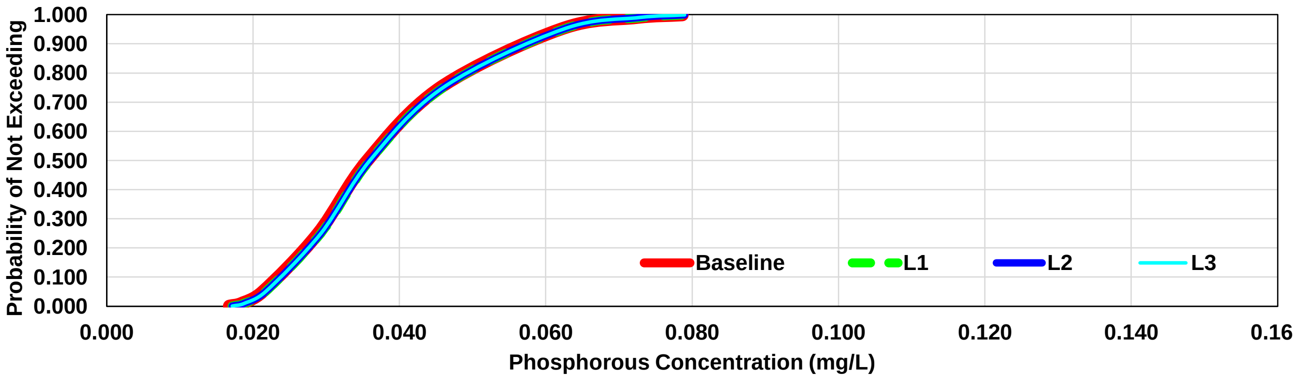
Predictions at L3

Cumulative Probability	Baseline	L1	L2	L3
0.001	0.014	0.014	0.014	0.015
0.010	0.015	0.015	0.015	0.016
0.050	0.018	0.018	0.018	0.019
0.250	0.026	0.026	0.026	0.026
0.500	0.033	0.033	0.033	0.034
0.750	0.043	0.043	0.043	0.043
0.950	0.061	0.061	0.061	0.061
0.990	0.071	0.071	0.071	0.072
0.999	0.077	0.077	0.077	0.078



Predictions at System Compliance Point

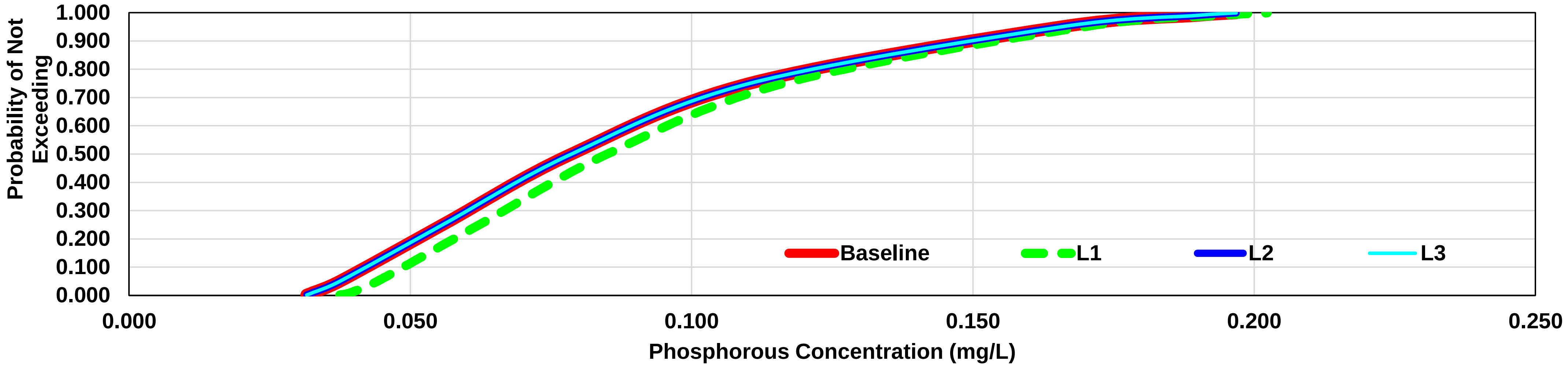
Cumulative Probability	Baseline	L1	L2	L3
0.001	0.017	0.017	0.017	0.017
0.010	0.018	0.019	0.019	0.019
0.050	0.021	0.022	0.022	0.022
0.250	0.029	0.029	0.029	0.029
0.500	0.036	0.036	0.036	0.036
0.750	0.046	0.046	0.046	0.046
0.950	0.062	0.062	0.062	0.062
0.990	0.073	0.073	0.073	0.073
0.999	0.079	0.079	0.079	0.079



Prediction of Phosphorous for Spring

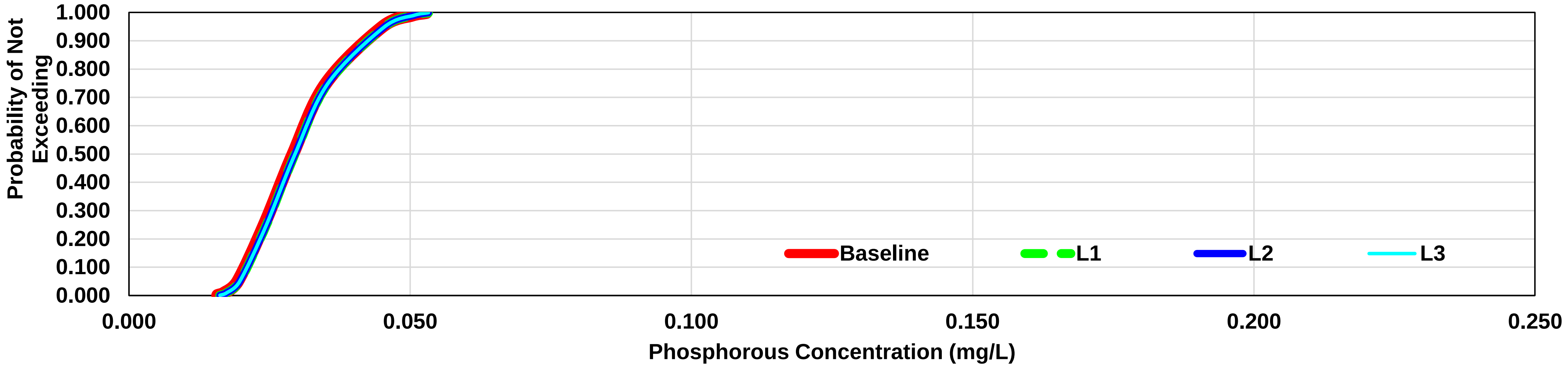
Predictions at L1

Cumulative Probability	Baseline	L1	L2	L3
0.001	0.032	0.037	0.032	0.032
0.010	0.033	0.039	0.033	0.033
0.050	0.038	0.044	0.038	0.038
0.250	0.056	0.062	0.056	0.056
0.500	0.079	0.085	0.079	0.079
0.750	0.110	0.116	0.110	0.110
0.950	0.166	0.170	0.166	0.166
0.990	0.190	0.194	0.190	0.190
0.999	0.197	0.202	0.197	0.197



Predictions at L2

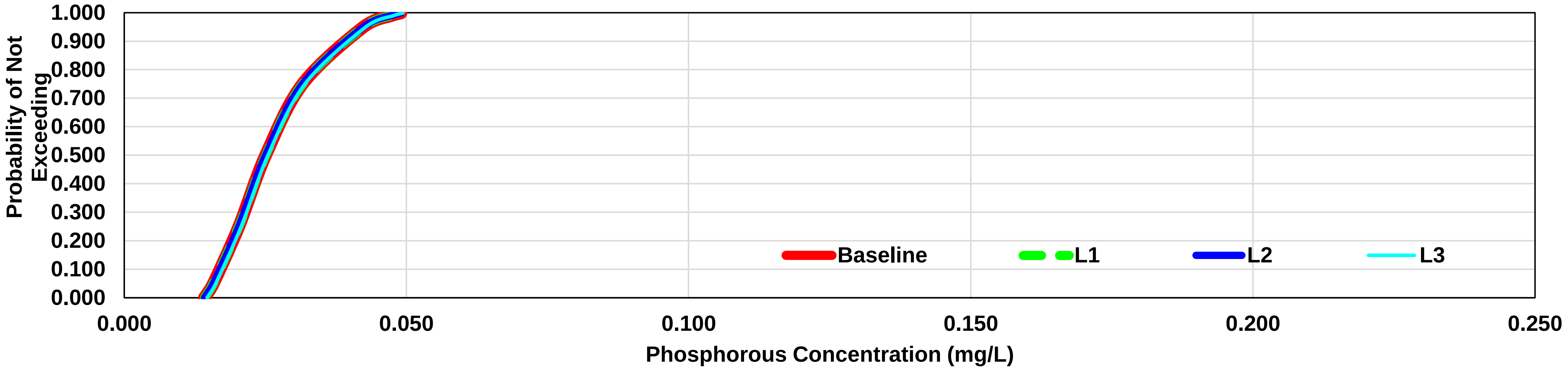
Cumulative Probability	Baseline	L1	L2	L3
0.001	0.016	0.016	0.016	0.016
0.010	0.017	0.017	0.017	0.017
0.050	0.019	0.020	0.020	0.020
0.250	0.024	0.024	0.024	0.024
0.500	0.029	0.030	0.030	0.030
0.750	0.035	0.035	0.035	0.035
0.950	0.045	0.045	0.045	0.045
0.990	0.050	0.051	0.051	0.051
0.999	0.053	0.053	0.053	0.053



Prediction of Phosphorous for Spring

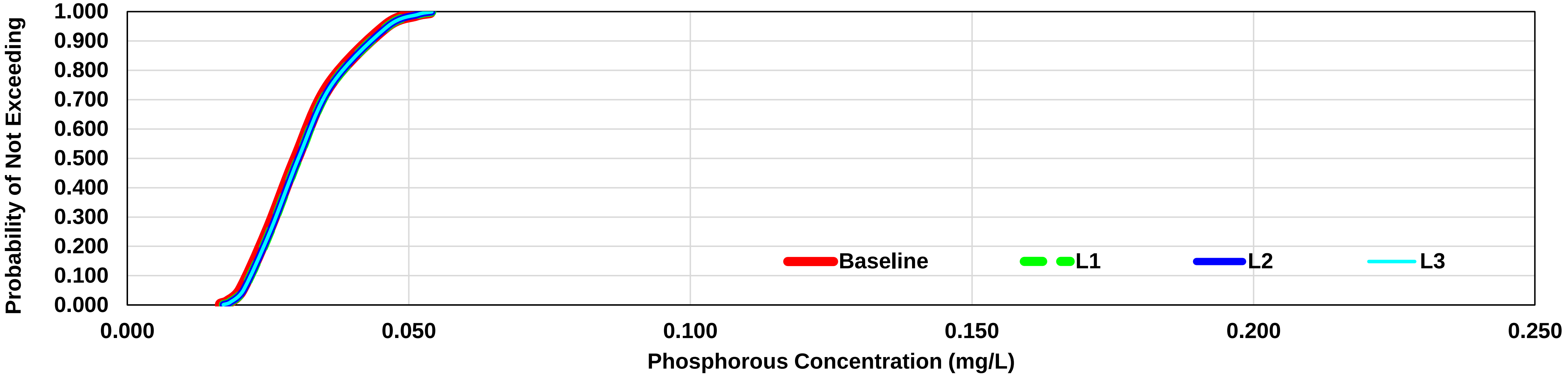
Predictions at L3

Cumulative Probability	Baseline	L1	L2	L3
0.001	0.014	0.014	0.014	0.015
0.010	0.015	0.015	0.015	0.015
0.050	0.016	0.016	0.016	0.016
0.250	0.020	0.020	0.020	0.021
0.500	0.025	0.025	0.025	0.025
0.750	0.032	0.032	0.032	0.032
0.950	0.042	0.042	0.042	0.043
0.990	0.047	0.047	0.047	0.048
0.999	0.049	0.049	0.049	0.049



Predictions at System Compliance Point

Cumulative Probability	Baseline	L1	L2	L3
0.001	0.017	0.017	0.017	0.017
0.010	0.018	0.018	0.018	0.018
0.050	0.020	0.021	0.021	0.021
0.250	0.025	0.025	0.025	0.025
0.500	0.030	0.030	0.030	0.030
0.750	0.036	0.036	0.036	0.036
0.950	0.046	0.046	0.046	0.046
0.990	0.051	0.052	0.052	0.052
0.999	0.054	0.054	0.054	0.054



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