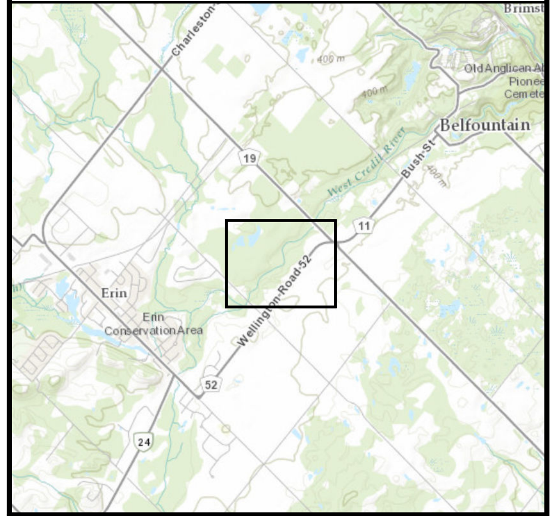

**Figure 9**:
West Credit River Study Area Characterization

Intake Pipe
Man-made Dam
Culvert
Tributary Input
Stream
Road
Large Woody Debris
Reach



N

0 25 50 100 150 200 m

**Prepared by**: Eric Dilligeard
**Data Source**: LIO, HESL, Esri Imagery.
**Coordinate System**: NAD 1983 UTM Zone 17N

**Project Lead**: Tara Roumeliotis and Deborah Sinclair
**Project**: Town of Erin Class EA Wastewater Servicing. Assimilative Capacity Study
**Project#**: 160005

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Hutchinson
Environmental Sciences Ltd.

Three small tributary inputs to the study area were observed on the north bank of the river, in Reach 4 and 5 (Photograph 10). Flows were observed to be low and their influence was captured in the measured increase in flow between 10th Line and Winston Churchill Blvd. (Table 11) The flow contribution from these small tributaries did not have a notable impact on the total flow in the river.

An intake pipe located on the north bank and a culvert located on the south bank were observed, both in Reach 5 in the vicinity of the residential properties. At the time of the reconnaissance, the intake pipe was not drawing water and there was no discharge from the culvert.

The bridge crossings at 10th Line (Photograph 11) and Winston Churchill Blvd. (Photograph 12) represent the only potential human contact points in the West Credit River study area, with the exception of the residences located along the north and south banks in the latter half of the study area. The area near the West Credit River at Winston Churchill Blvd. appears to be a well-visited location and groundwater was flowing from riverbank seeps and drainage pipes to the river (Photograph 13).

**Photograph 4. River substrate is mostly fine sediments with few cobbles near 10th Line**

**Photograph 5. River substrate is fines with cobbles near Winston Churchill Blvd. Note the periphyton on the cobbles**

**Photograph 6. Riffle section within the West Credit River study area, looking upstream**

**Photograph 7. Woody debris within the West Credit River study area**

**Photograph 8. The beaver dam located approximately 40 m downstream of 10th Line, looking upstream**

**Photograph 9. Breached man made dam within West Credit River study area, looking upstream**

**Photograph 10. Small tributary entering north bank of West Credit River**

**Photograph 11. Bridge located at 10th Line, looking downstream**

**Photograph 12. East side of culvert located at Winston Churchill Blvd., looking upstream**

**Photograph 13. Groundwater seep at Winston Churchill Blvd**

## 4.4 Dye Tracer Study

Tracer testing was conducted in the West Credit River between 10$^{th}$ Line and Shaws Creek Road (downstream of Winston Churchill Blvd.) on August 25, 2016. The volume of Rhodamine WT 20% dye added to the 10 L bucket of West Credit River water was determined to be 455 mL based on Equation 1.

Figure 10 presents the Rhodamine WT concentration over time, as recorded at each of the fluorometer stations during the slug injection tracer test.

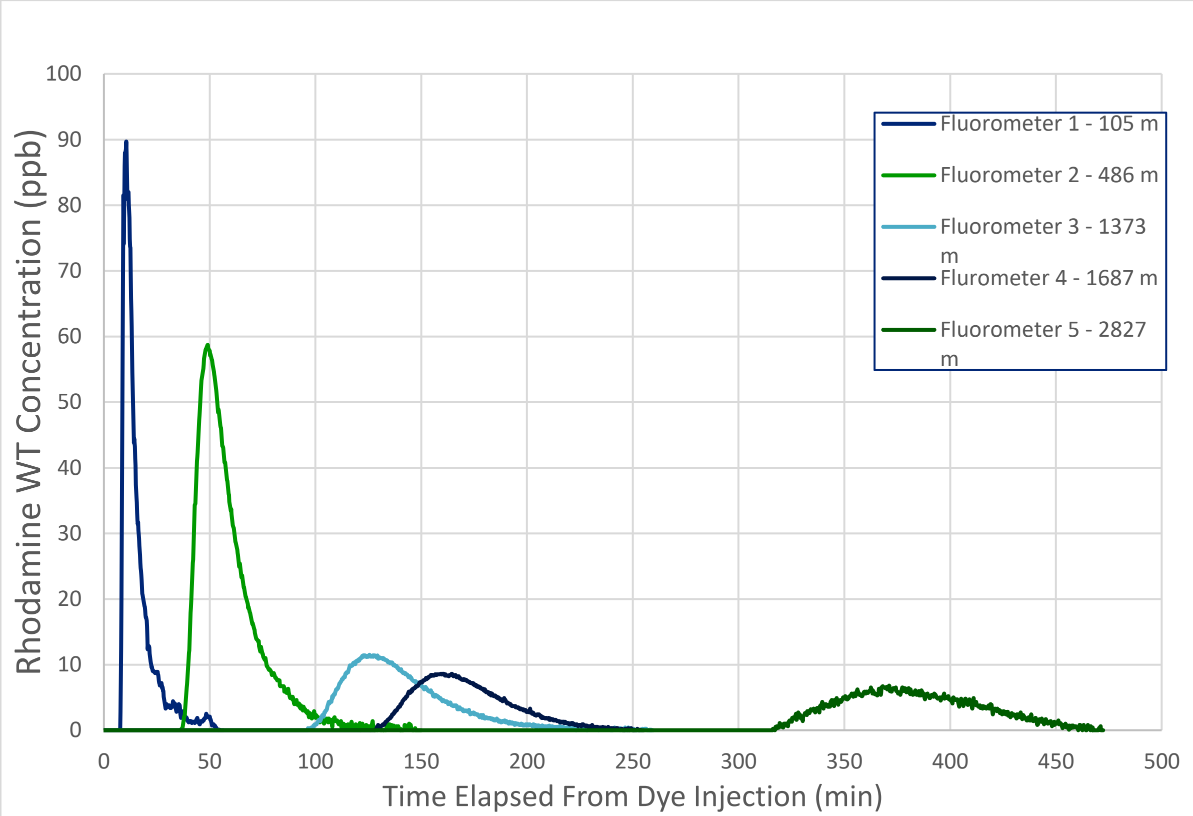


**Figure 10 Slug Injection Test Results**

The data obtained from the slug injection tests showed that dye dispersion in West Credit River behaved in the expected manner (as per Figure 10) and could therefore be used to determine the time of travel between the dye injection point and each fluorometer station. Data are presented as total travel time (in minutes, Table 12), average velocity (in m/s) between each fluorometer station (Table 13), and longitudinal dispersion (in $m^2$/min) between each fluorometer station (Table 14).

**Table 12. Travel Time Between Fluorometer Stations**

| Fluorometer | Time of Travel (min) |
|---|---|
| 1 (105 m) | 16 |
| 2 (486 m) | 59 |
| 3 (1,373 m) | 140 |
| 4 (1,687 m) | 171 |
| 5 (2,827 m) | 382 |

**Table 13. West Credit River Velocity (m/s) between Fluorometer Stations**

| Upstream Fluorometer | Downstream Fluorometer | | | | |
|---|---|---|---|---|---|
| | Fluorometer 1 | Fluorometer 2 | Fluorometer 3 | Fluorometer 4 | Fluorometer 5 |
| **Fluorometer 1** | x | 0.15 | 0.17 | 0.17 | 0.12 |
| **Fluorometer 2** | x | x | 0.18 | 0.18 | 0.12 |
| **Fluorometer 3** | x | x | x | 0.17 | 0.10 |
| **Fluorometer 4** | x | x | x | x | 0.09 |
| **Fluorometer 5** | x | x | x | x | x |

*Table should be read as the dispersion between the upstream fluorometer (list in 1st column) and the next flurometer of interest, by reading along the appropriate row.

**Table 14. West Credit River Longitudinal Dispersion ($m^2$/min) between Fluorometer Stations**

| Upstream Fluorometer | Downstream Fluorometer | | | | |
|---|---|---|---|---|---|
| | Fluorometer 1 | Fluorometer 2 | Fluorometer 3 | Fluorometer 4 | Fluorometer 5 |
| **Fluorometer 1** | x | 51 | 139 | 164 | 184 |
| **Fluorometer 2** | x | x | 203 | 222 | 194 |
| **Fluorometer 3** | x | x | x | 264 | 158 |
| **Fluorometer 4** | x | x | x | x | 135 |
| **Fluorometer 5** | x | x | x | x | x |

*Table should be read as the velocity between the upstream fluorometer (list in 1st column) and the next flurometer of interest, by reading along the appropriate row.

The average West Credit River velocity for the August 25, 2016 slug injection test was calculated as 0.17 m/s between 10th Line and Winston Churchill Blvd. (Table 13). The data also show that the river moves more slowly downstream of Winston Churchill Blvd., toward Shaws Creek Road.

## 4.5 Mass Balance Modelling

The treated effluent flows from the proposed Erin WWTP are limited by total phosphorus concentrations with respect to both treatment technology limits for TP removal in wastewater and the need to maintain fully mixed TP concentrations in the West Credit River within their site-specific water quality objective of 0.024 mg/L (Appendix D). A mass balance model was used to back-calculate maximum effluent flows based on varying effluent TP concentrations, 7Q20 low flows in the West Credit River, and a fully mixed downstream TP concentrations of 0.024 mg/L in the river (Table 15).

**Table 15. Maximum WWTP Effluent Flows Corresponding to Effluent TP Concentrations and a Downstream TP Concentration of 0.024 mg/L**

| Effluent Total Phosphorus Concentration (mg/L) | Maximum WWTP Effluent Flow ($m^3/d$) |
|---|---|
| 0.15 | 1,234 |
| 0.1 | 2,046 |
| 0.07 | 3,380 |
| 0.05 | 5,982 |
| 0.045 | 7,406 |

Based on the results of the TP mass balance modelling, HESL was directed by Ainley Group to carry forward a Phase 1 WWTP effluent flow of 3,380 $m^3/s$ and a Full Build Out flow of 7,172 $m^3/s$ corresponding to effluent total phosphorus concentrations of 0.07 and 0.046 mg/L respectively.

Using these Phase 1 and Full Build Out effluent flows, mass balance modelling of TAN and nitrate were carried out to determine appropriate WWTP effluent limits for these parameters. The resulting effluent limits were then confirmed using the far-field QUAL2K model, and in the case of TAN, the near-field (mixing zone) CORMIX model.

The TAN mass balance results are presented in Table 16. The corresponding un-ionized ammonia concentrations were computed using the fully mixed downstream pH and temperature (see Table 6 for particulars on downstream mass balance of pH and temperature), and compared against the PWQO of 0.02 mg/L un-ionized ammonia (Table 17).

**Table 16. Fully Mixed Downstream Total Ammonia Nitrogen Concentration (mg/L) for Varying Effluent Concentrations, at Phase 1 and Full Build Out Effluent Flows**

| Effluent Flow (m3/d) | Effluent Concentration | | | |
|---|---|---|---|---|
| | TAN=1.3 mg/L | TAN=1.0 mg/L | TAN=0.8 mg/L | TAN=0.7 mg/L |
| Phase 1 – 3,381 | 0.24 | 0.20 | 0.17 | 0.15 |
| Full Build Out – 7,172 | 0.39 | 0.31 | 0.26 | 0.23 |

**Table 17. Fully Mixed Downstream Un-ionized Ammonia Concentration (mg/L) for Varying Effluent TAN Concentrations, at Phase 1 and Full Build Out Effluent Flows**

| Effluent Flow ($m^3$/d) | Effluent Concentration | | | |
|---|---|---|---|---|
| | TAN=1.3 mg/L | TAN=1.0 mg/L | TAN=0.8 mg/L | TAN=0.7 mg/L |
| Phase 1 – 3,381 | 0.017 | 0.014 | 0.012 | 0.011 |
| Full Build Out – 7,172 | ***0.030*** | ***0.024*** | ***0.020*** | 0.018 |

Note: Bold and italicized concentrations represent an exceedance of the PWQO for un-ionized ammonia

As shown in Tables 16 and 17, effluent TAN concentrations were varied from 1.3 mg/L to 0.7 mg/L. At a summer TAN concentration of 1.3 mg/L, which was based on email correspondence dated October 3, 2016 from the MOECC providing guidance on effluent limits (Appendix E), un-ionized ammonia concentrations were below the PWQO at fully mixed Phase 1 effluent flows; however, at Full Build Out flows, the PWQO was exceeded. The effluent TAN concentration was decreased until, at a concentration of 0.7 mg/L, the downstream, fully mixed un-ionized ammonia concentration at Full Build Out effluent flows was met.

As such, summer TAN effluent concentrations of 1.3 mg/L (Phase 1) and 0.7 mg/L (Full Build Out) were carried forward for further examination in the QUAL2K and CORMIX models.

Of note, winter effluent TAN concentrations (of 2 mg/L at both Phase 1 and Full Build Out flows) were also checked to determine the corresponding concentration of un-ionized ammonia. Since speciation of ammonia to its un-ionized state is driven by increasing temperature and pH, un-ionized ammonia at winter temperatures is rarely of concern. In this case, the Phase 1 and Full Build Out flows corresponded with winter un-ionized ammonia concentrations of 0.003 mg/L and 0.006 mg/L, respectively, assuming a water temperature of 4°C. Therefore, the winter effluent TAN concentrations are acceptable.

The nitrate mass balance results are presented in Table 18.

**Table 18. Fully Mixed Downstream Nitrate-N Concentration (mg/L) for Varying Effluent Concentrations, at Phase 1 and Full Build Out Effluent Flows**

| Effluent Flow ($m^3$/d) | Effluent Concentration | |
|---|---|---|
| | Nitrate=6 mg/L | Nitrate=5 mg/L |
| Phase 1 – 3,381 | 2.51 | 2.36 |
| Full Build Out – 7,172 | 3.00 | 2.74 |

At effluent nitrate-N concentrations of 5 and 6 mg/L (which were the effluent objective and limit concentrations proposed in the B.M. Ross, 2014, *West Credit River Assimilative Capacity Study*), the fully mixed downstream nitrate-N concentrations were at or below the CWQG of 3 mg/L nitrate-N for both the Phase 1 and Full Build Out effluent flows. However, nitrification (which would increase the nitrate concentrations in the river) is expected in the West Credit River which is not accounted for in the mass balance model. Given that the effluent nitrate concentration of 6 mg/L results in a fully mixed downstream concentration that is right at the CWQG of 3 mg/L, this does not leave any room for the generation of additional nitrate through nitrification. As such, the lower effluent nitrate-N concentration of 5 mg/L was carried forward for further examination in QUAL2K. QUAL2K modelling confirmed that a nitrate concentration of 5 mg/L at Full Build Out flows would maintain the downstream mixed nitrate concentration below the CWQG of 3 mg/L.

## 4.6 Far-Field Water Quality Modelling (QUAL2K)

Downstream, far-field concentrations of dissolved oxygen, nitrate and un-ionized ammonia, as predicted by the QUAL2K model, were of particular interest. The far-field model results for these parameters are presented in the following sub-sections. All QUAL2K water quality output data can be found in Appendix F. The actual WWTP discharge location has not yet been determined; however, for the purposes of the running the QUAL2K model, the discharge was simulated as entering the West Credit River at 10th Line. This is considered a conservative location since it has been established that water quality in the West Credit River study area improves moving downstream to Winston Churchill Blvd. The choice of the preferred location will also consider the specific ecological sensitivities within this reach of river and factors such as access or cost.

### 4.6.1 Dissolved Oxygen Far-Field Modelling Results

For the Phase 1 summer low flow scenario, dissolved oxygen concentrations were predicted to decrease by approximately 1 mg/L to a minimum concentration of 6.73 mg/L at a distance approximately 700 m to 1 km downstream of the simulated WWTP discharge location and then begin recovering (Figure 11). As such, dissolved oxygen concentrations were predicted to remain well above the PWQO of 5 mg/L for cold water biota at river temperatures of 20°C and 25°C.

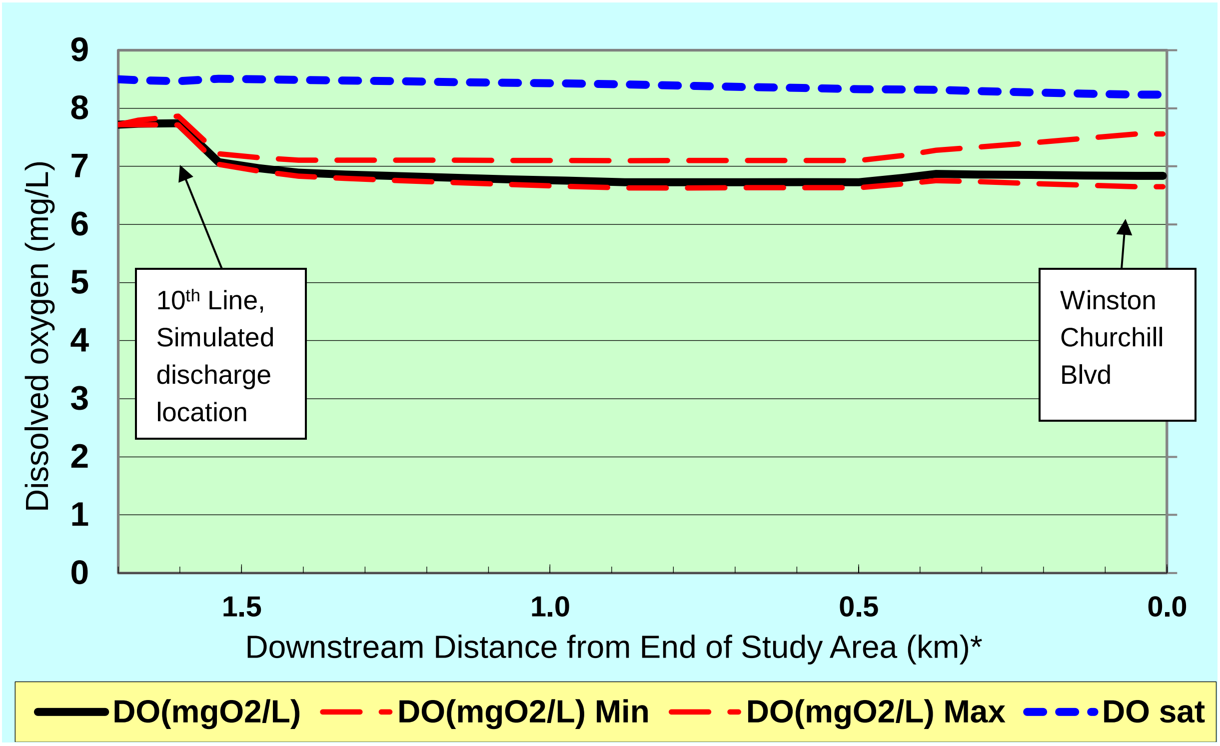


**Figure 11. Phase 1: Dissolved Oxygen in the West Credit River Predicted by QUAL2K for Low Summer flow and 5 mg/L Effluent cBOD**

*Note: *QUAL2K model calculates using a descending distance from the upstream-most point in the study area. In this case, the model begins at 1.7 km (which corresponds to 100 m upstream of 10th Line) and ends at 0 km (which corresponds to 40 m downstream of Winston Churchill Blvd.).*

For the Full Build Out summer low flow scenario, dissolved oxygen concentrations were predicted to decrease by 1.33 mg/L to a minimum concentration of 6.39 mg/L at a distance approximately 700 m downstream of the simulated WWTP discharge location and then begin recovering (Figure 12). As such, dissolved oxygen concentrations were predicted to remain well above the PWQO of 5 mg/L for cold water biota at river temperatures of 20°C and 25°C.

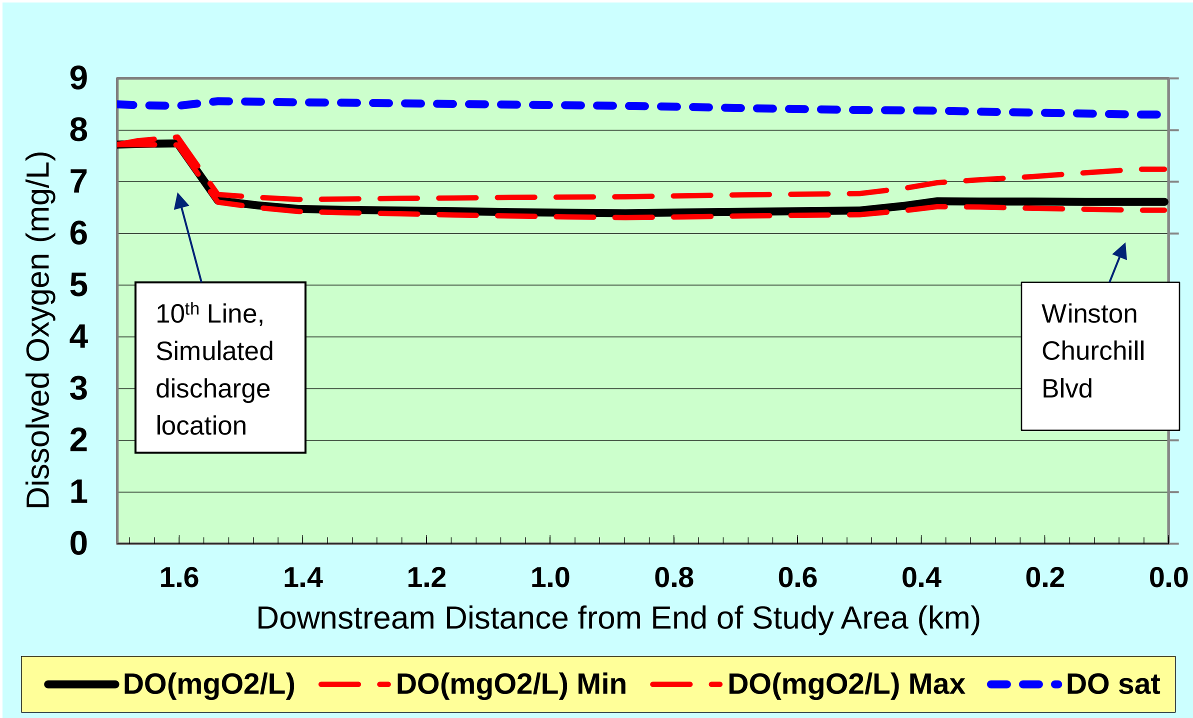


**Figure 12. Full Build Out: Dissolved Oxygen in the West Credit River Predicted by QUAL2K for Low Summer flow and 5 mg/L Effluent cBOD**

### 4.6.2 Un-ionized Ammonia Far-Field Modelling Results

For the Phase 1 summer low flow scenario, the maximum un-ionized ammonia concentration beyond the point of complete mixing was predicted at 17 µg/L for 1.3 mg/L effluent ammonia (Figure 13), which is below the PWQO of 20 µg/L. Un-ionized ammonia concentrations declined to 9.8 µg/L at the downstream edge of the study area.

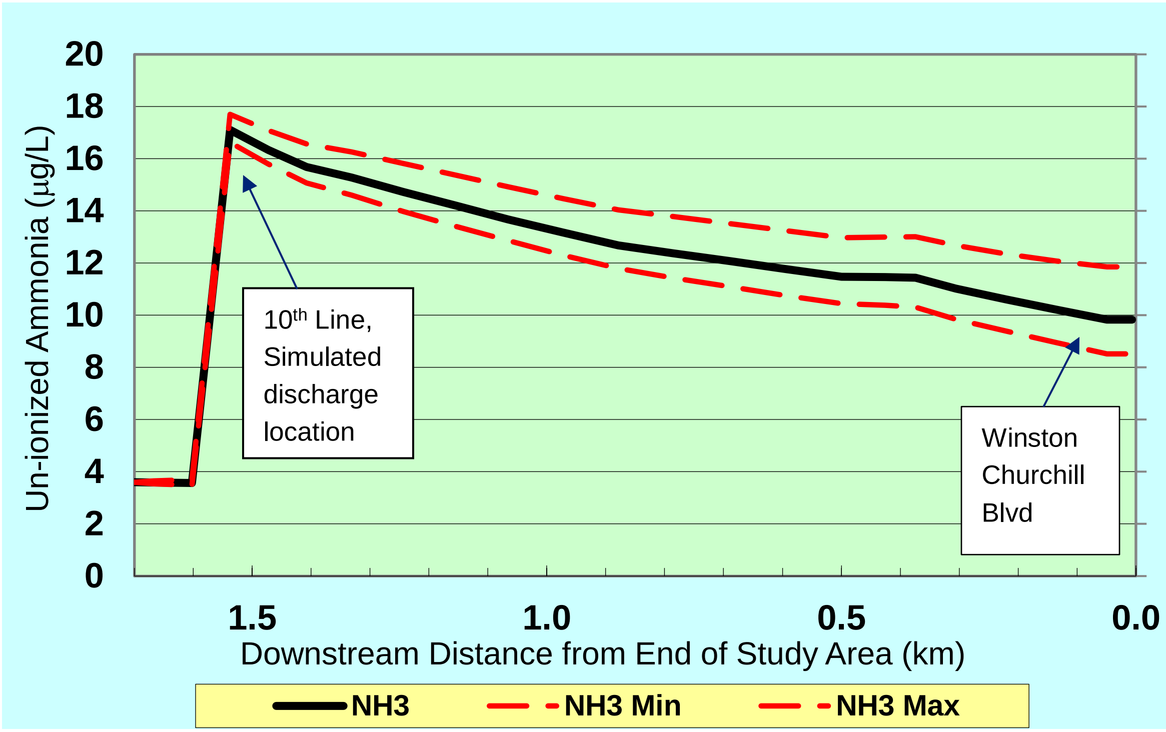


**Figure 13. Phase 1: Un-ionized Ammonia in the West Credit River Predicted by QUAL2K for Low Summer flow and 1.3 mg/L Effluent TAN**

For the Full Build Out summer low flow scenario, the maximum un-ionized ammonia concentration beyond the point of complete mixing was predicted at 18 µg/L for 0.7 mg/L effluent ammonia (Figure 14), which is below the PWQO of 20 µg/L. Un-ionized ammonia concentrations declined to 11 µg/L at the downstream edge of the study area.

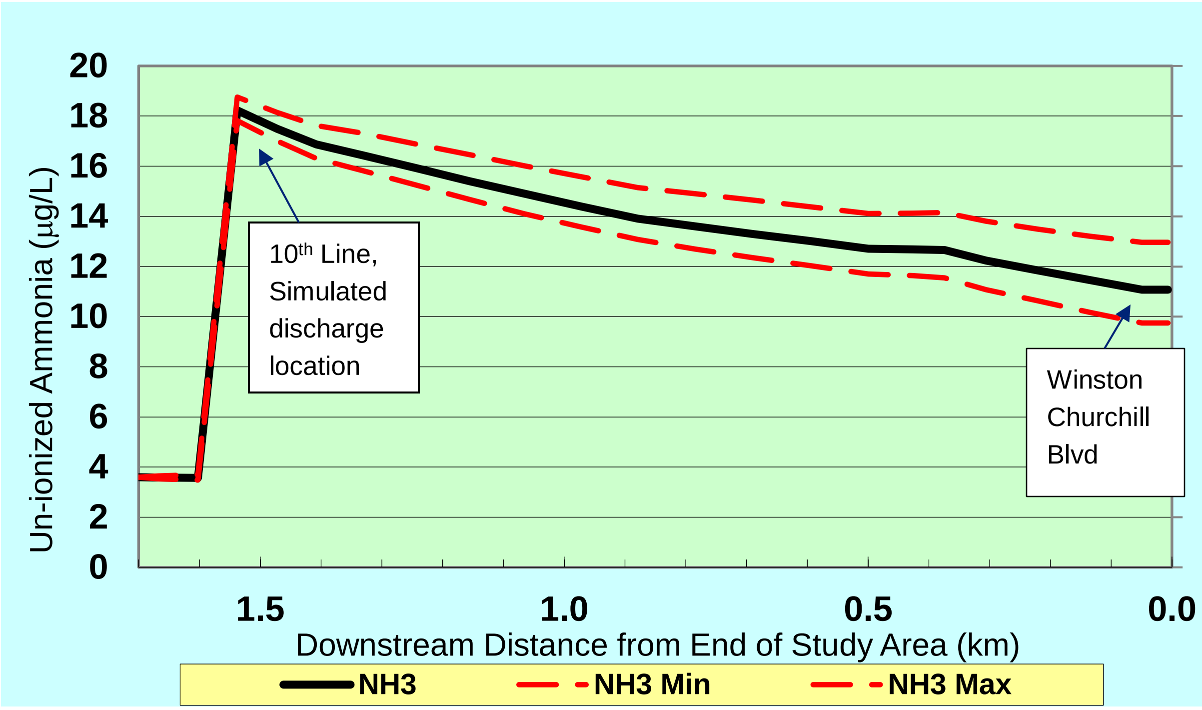


**Figure 14. Full Build Out: Un-ionized Ammonia in the West Credit River Predicted by QUAL2K for Low Summer flow and 0.7 mg/L Effluent TAN**

### 4.6.1 Nitrate Far-Field Modelling Results

For the Phase 1 summer low flow scenario, the maximum nitrate concentration beyond the point of complete mixing was predicted to remain below the CWQG of 3 mg/L, with a maximum concentration of approximately 2.4 mg/L (Figure 15).

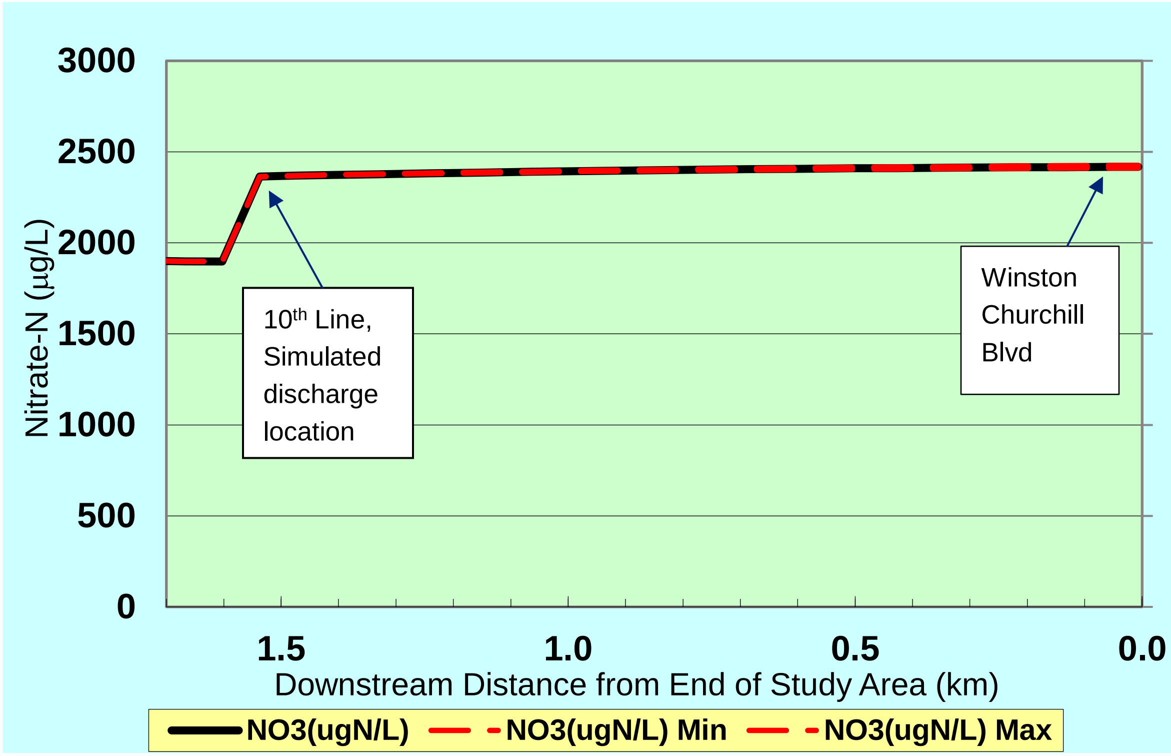


**Figure 15. Phase 1: Nitrate-N in the West Credit River Predicted by QUAL2K for Low Summer flow and 5 mg/L Effluent Nitrate-N**

For the Full Build Out summer low flow scenario, the maximum nitrate concentration beyond the point of complete mixing was predicted to remain below the CWQG of 3 mg/L, with a maximum concentration of approximately 2.8 mg/L (Figure 16).

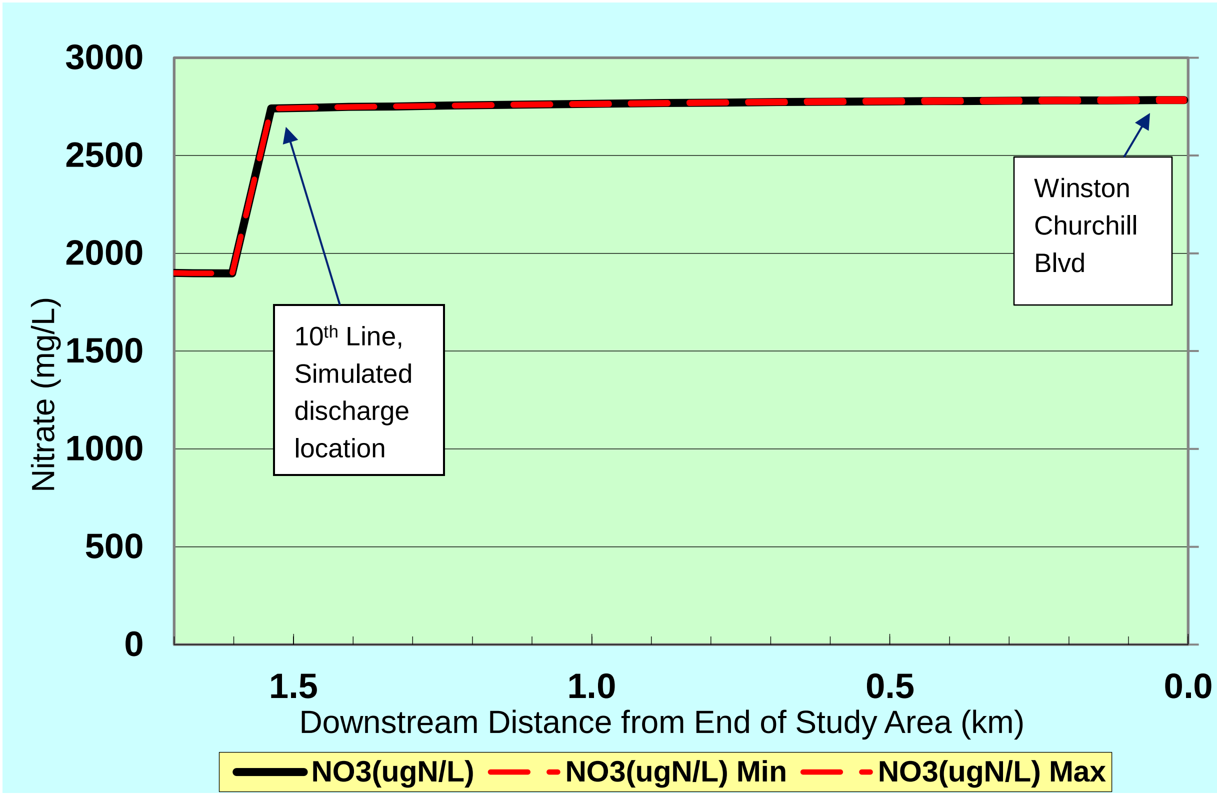


**Figure 16. Full Build Out: Nitrate-N in the West Credit River Predicted by QUAL2K for Low Summer flow and 5 mg/L Effluent Nitrate-N**

### 4.6.2 Summary of Far-Field Modelling

The summer low flow Phase 1 and Full Build Out scenarios resulted in dissolved oxygen concentrations above the PWQO at all locations in the West Credit River downstream of the point of complete mixing (Table 19).

**Table 19. Overview of QUAL2K Modelling Results for Dissolved Oxygen**

| Development Phase (Effluent Flow) | CBOD Concentration (mg/L) | Minimum West Credit River Dissolved Oxygen Concentration and Location |
|---|---|---|
| Phase 1 (3,380 $m^3/d$) | 5 | 6.73 mg/L at 0.7 to 1 km |
| Full Build Out (7,172 $m^3/d$) | | 6.39 mg/L at 0.7 km |

The summer low flow Phase 1 and Full Build Out scenarios resulted in un-ionized ammonia concentrations below the PWQO at all locations in the West Credit River (Table 13), downstream of the point of complete mixing.

The un-ionized ammonia concentrations declined with distance from the outfall and reached concentrations between 9.8 and 11 µg/L at the downstream end of the study area (i.e., Winston Churchill Blvd.), 1.5 km from the point of discharge (Table 20). These concentrations are well below the PWQO.

**Table 20. Overview of QUAL2K Modelling Results for Un-ionized Ammonia**

| Development Phase (Effluent Flow) | Effluent Total Ammonia Concentration (mg/L) | West Credit River $NH_3$ Concentration: | |
|---|---|---|---|
| | | Maximum after discharge (assuming complete mixing, µg/L) | At 1.5 km downstream of outfall (µg/L) |
| Phase 1 (3,380 $m^3$/d) | 1.3 | 17 | 9.8 |
| Full Build Out (7,172 $m^3$/d) | 0.7 | 18 | 11 |

For nitrate-N in both the Phase 1 and Full Build Out summer low flow scenario, the maximum nitrate concentration beyond the point of complete mixing was predicted to remain below the CWQG of 3 mg/L throughout the study area.

Given that the maximum summer water temperature for the WWTP effluent of 19°C is below the 75th percentile West Credit River water temperature of 21.18°C, the input from the WWTP effluent will slightly cool the river temperatures downstream of the outfall.

## 4.7 Mixing Zone Modelling (CORMIX)

The mixing zone modelling focussed on ammonia as the potentially toxic component of the effluent that is assimilated by a) dilution in the near field area through initial mixing with the creek and b) nitrification, the biological conversion of ammonia to nitrate. There were two aspects to the assessment of ammonia:

- The requirement that undiluted effluent be non-acutely lethal at the point of discharge; and
- The determination of the size and characteristics of the mixing zone for ammonia in the West Credit River.

These two assessment aspects are detailed below.

### 4.7.1 Effluent characteristics - Non-lethal Effluent Requirement

The MOECC requires that all effluent discharging to surface waters be non-acutely lethal at the end of the pipe. This requires an effluent concentration of 0.27 mg/L or less of un-ionized ammonia ($NH_3$) as a conservative estimate of the lethal threshold[3]. An effluent pH of 8.6 and temperature of 19°C, were used to estimate un-ionized ammonia concentrations based on recommendations made by B.M Ross (2014). The maximum effluent total ammonia concentration (corresponding to 0.27 mg/L of un-ionized ammonia) was calculated to be 2.1 mg/L. Thus, a total ammonia effluent limit of 2.1 mg/L or less would meet the requirement for non-lethality during the summer discharge period.

### 4.7.2 Near-Field (Mixing Zone) Model Results – Phase 1

At a Phase 1 effluent flow of 0.039 $m^3/s$, with the outfall modelled as a pipe discharge at the level of the water surface, pointing perpendicular to the water surface, CORMIX predicted that the plume would immediately attach to the near bank. Mixing was dominated by the initial momentum of the effluent discharge, causing spreading towards the far bank of the river. Following this initial momentum, the cross flow of the West Credit River began to dominate, bending the plume toward the downstream bank. The plume then began to spread laterally (buoyant spreading) while being advected downstream. In the final mixing region, ambient was the predominant mixing process and the plume grew in the vertical and horizontal directions.

The CORMIX model predicted that the plume will encounter the opposite bank at a distance 24 m downstream of the outfall, meet the PWQO of 0.02 mg/L at 28 m downstream, and become fully mixed at 39 m downstream. Note that although the plume contacts the opposite bank prior to meeting the PWQO, the plume is not homogenously mixed at this point and therefore there is width available for safe passage of aquatic species. Ammonia concentrations laterally across the river at 24 m were computed using Equation 8 to determine the width of the plume that met PWQO at this point. The centreline concentration presented in the CORMIX prediction file was located along the nearest river bank.

[3] *The MOECC does not provide formal documented guidance on what levels of un-ionized ammonia are considered acutely toxic. We therefore consulted EPA (2009) which recommends 5 mg/L ammonia nitrogen as a criterion for acute toxicity at pH 8 and 25ºC or, that the average not exceed 4.5 mg/L over any 4 day period. Total ammonia concentrations of 5 and 4.5 mg/L correspond to un-ionized concentrations of 0.27 and 0.24 mg/L respectively at pH 8 and 25ºC. USEPA. 2009. DRAFT 2009 UPDATE AQUATIC LIFE AMBIENT WATER QUALITY CRITERIA FOR AMMONIA – FRESHWATER EPA 822-D-09-001. December 2009. Environment Canada (2009) provide a median LC50 of 0.481 mg/L unionized ammonia ($NH_3$) for rainbow trout and 1.16 mg/L for the most sensitive daphnid (water flea) species tested. An effluent concentration of 0.27 mg/L or less (as derived using EPA (2009) is therefore a conservative estimate of a concentration that would assure no acute toxicity to test organisms. Environment Canada/Health Canada (2001) Canadian Environmental Protection Act. Ammonia in the Aquatic Environment – Priority Substances List Assessment Report. February 2001. TD195.A44P74 2000.*

**Table 21. Total Ammonia Nitrogen Concentrations Laterally Across River at 24 m Downstream (Location where Plume Encounters Opposite Bank) for Phase 1 Pipe Design**

| Lateral Distance from Centerline Concentration (m) | Total Ammonia Nitrogen Concentration (mg/L) |
|---|---|
| 1 | 0.288 |
| 2 | 0.282 |
| 2.8 | 0.275 |
| 3 | 0.273 |
| 4 | 0.261 |
| 5 | 0.246 |
| 6 | 0.238 |
| 7 | 0.230 |
| 8 | 0.212 |
| 9 | 0.193 |
| 10 | 0.175 |
| 11 | 0.158 |

From Table 6, the PWQO for un-ionized ammonia at Phase 1 flows was met at a TAN concentration of 0.275 mg/L. Thus, from Table 21, the PWQO was met at a distance of 2.8 m from the closest bank (i.e., the location of the centerline concentration). Therefore, there is about 75% of the width of the river available for fish passage.

The Phase 1 flows were also modelled as discharged from a 5 m long diffuser located parallel to the south bank of the river, with 10 ports opening vertically upward. (The Full Build Out flows were modelled as a diffuser discharge, which is discussed further below. Therefore, for consistency, the Phase 1 flows were also modelled as a diffuser discharge).

With the diffuser design, the CORMIX model predicted that the plume will encounter the opposite bank at a distance 72 m downstream of the outfall, meet the PWQO of 0.02 mg/L at 104 m downstream, and become fully mixed at 121 m downstream. The low velocities from the individual diffuser ports result in less jet momentum spreading the plume across the width of the river. Therefore, there is less initial mixing with river water and the plume requires a larger downstream distance to meet PWQO.

Ammonia concentrations laterally across the river at 72 m downstream were computed using Equation 8 to determine the width of the plume that met PWQO at this point. The centreline concentration presented in the CORMIX prediction file was located along the nearest river bank.

**Table 22. Total Ammonia Nitrogen Concentrations Laterally Across River at 72 m Downstream (Location where Plume Encounters Opposite Bank) for Phase 1 Diffuser Design**

| Lateral Distance from Centerline Concentration (m) | Total Ammonia Nitrogen Concentration (mg/L) |
|---|---|
| 1 | 0.346 |
| 2 | 0.338 |
| 3 | 0.327 |
| 4 | 0.312 |
| 5 | 0.293 |
| 6 | 0.283 |
| 7 | 0.273 |
| 8 | 0.250 |
| 9 | 0.228 |
| 10 | 0.205 |
| 11 | 0.183 |

For the Phase 1 diffuser scenario at 72 m downstream, the PWQO was met at a distance of 7 m from the closest bank (i.e., the location of the centerline concentration). Therefore, there is about 36% of the width of the river available for fish passage.

### 4.7.3 Near-Field (Mixing Zone) Model Results – Full Build Out

At a Full Build Out effluent flow of 0.083 $m^3/s$, and the outfall modelled as a pipe discharge at the level of the water surface, pointing perpendicular to the water surface, CORMIX could not predict the downstream mixing with any degree of certainty because the momentum of the Full Build Out effluent flow in comparison to the 7Q20 West Credit River flow resulted in numerous hydraulic jumps in the vicinity of the outfall. Further, the momentum of the discharge caused the plume to spread very quickly across the width of the river (i.e., within a few meters downstream), thus blocking any means of fish passage around the outfall. For these reasons, a multi-port diffuser was designed and modelled. The diffuser was identical in design to the one described above for the Phase 1 discharge, with the exception that there were 5 additional ports (for 15 ports total).

The CORMIX model predicted that the plume will encounter the opposite bank at a distance 42 m downstream of the outfall, meet the PWQO of 0.02 mg/L at 185 m downstream, and become fully mixed at 187 m downstream. Since the exit velocity of the discharge from the multi-port diffusers is higher for Full Build Out flows than Phase 1 flows, the additional momentum causes the opposite bank to be encountered more quickly than for the Phase 1 scenario (42 m versus 72 m downstream). However, this opposite bank interaction limits the amount of mixing that can occur, resulting in a longer downstream distance to meet the PWQO.

Ammonia concentrations laterally across the river at 42 m downstream were computed using Equation 8 to determine the width of the plume that met PWQO at this point. The centreline concentration presented in the CORMIX prediction file was located along the nearest river bank.

**Table 23. Total Ammonia Nitrogen Concentrations Laterally Across River at 42 m Downstream (Location where Plume Encounters Opposite Bank) for Full Build Out Diffuser Design**

| Lateral Distance from Centerline Concentration (m) | Total Ammonia Nitrogen Concentration (mg/L) |
|---|---|
| 1 | 0.377 |
| 2 | 0.365 |
| 3 | 0.347 |
| 4 | 0.323 |
| 5 | 0.294 |
| 6 | 0.264 |
| 6.2 | 0.258 |
| 7 | 0.233 |
| 8 | 0.203 |
| 9 | 0.175 |
| 10 | 0.150 |
| 11 | 0.128 |

For the Full Build Out diffuser scenario at 42 m downstream, the PWQO is met at a distance of 6.2 m from the closest bank (i.e., the location of the centerline concentration). Therefore, there is about 44% of the width of the river available for fish passage.

A 2-d figure showing a top view (i.e., "bird's eye view") of the plume created by the multi-port diffuser at Full Build Out effluent flows is presented in Figure 17. The red-shaded regions (which hug the southern bank) represent areas with the highest TAN concentrations.

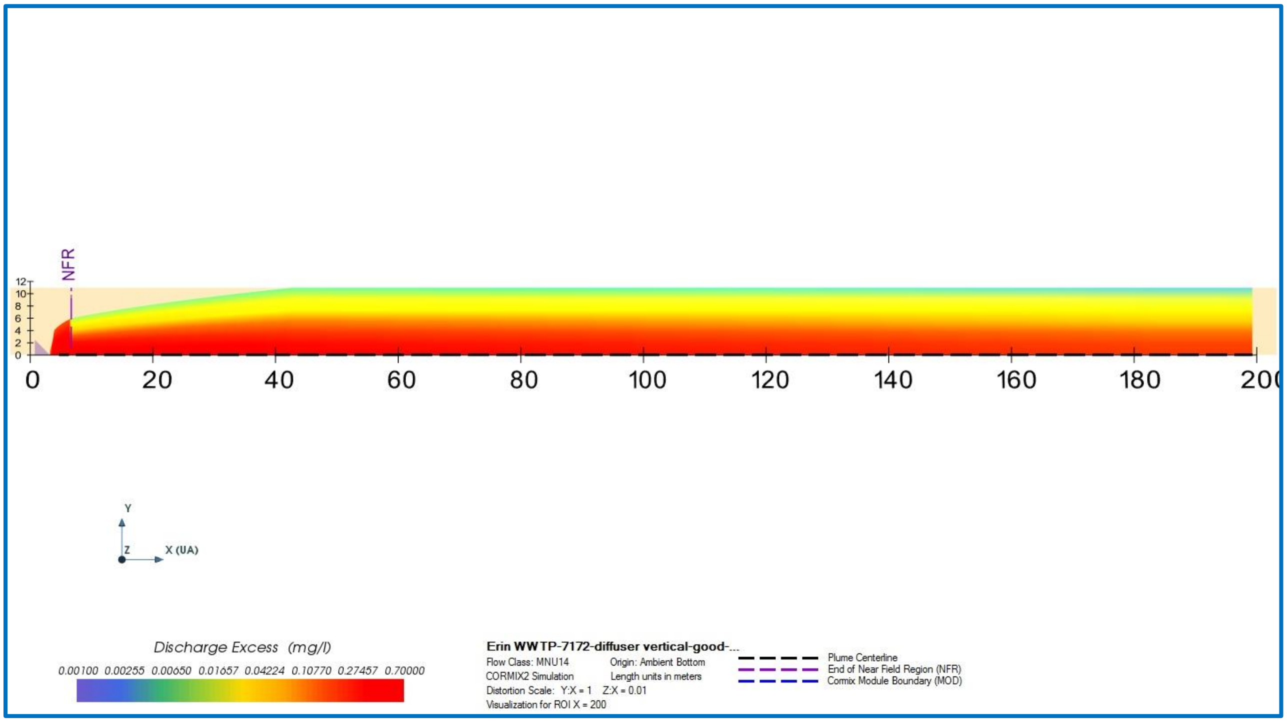


**Figure 17. Top View of Full Build Out Discharge Plume for Summer Low River Flow and 0.7 mg/L Effluent Ammonia**

### 4.7.4 Summary of Near-Field CORMIX Modelling

The Phase 1 effluent flow of 0.039 $m^3/s$ was modelled as a pipe discharge at the level of the water surface, pointing perpendicular to the water surface, and also as a multi-port diffuser from a 5 m long diffuser located parallel to the south bank of the river, with 10 ports opening vertically upward. The Full Build Out effluent flow of 0.083 $m^3/s$ was modelled as a multi-port diffuser only, with 15 ports.

The mixing zone results are presented below. CORMIX output results are presented in Appendix G.

**Table 24. Summary of CORMIX Mixing Zone Modelling Results**

| Parameter | Phase 1 Pipe Discharge | Phase 1 Multiport Diffuser | Full Build Out Multiport Diffuser |
|---|---|---|---|
| Distance to Meet PWQO (m downstream of outfall) | 28 m | 104 m | 185 m |
| Plume Width (% of channel) below PWQO at distance in which plume encounters the opposite bank (representing the narrowest place for safe fish passage) | 75% | 36% | 44% |

It is recommended that a detailed design of the outfall pipe or diffuser be carried out prior to construction activities. For example, a staged outfall, with a pipe at bank for Phase 1 and the multiport diffuser for Phase 2 would provide for optimum effluent dispersion, based on results to date.

# 5. Summary and Recommended Erin WWTP Effluent Limits

This ACS report provides an update to the preliminary ACS completed as part of Class Environmental Assessment (Class EA) for a communal wastewater and collection system for the Villages of Erin and Hillsburgh. It includes:

- Recent (2016) water quality data collected for the West Credit River at 10th Line;
- An updated 7Q20 low flow statistic for the West Credit River at 10th Line;
- Mixing zone modelling (using CORMIX) to predict the size and shape of the mixing zone; and
- Hydrodynamic, far-field modelling (using QUAL2K) to predict downstream concentrations of oxygen, temperature, nitrate, and ammonia; and
- Effluent limit recommendations to meet PWQOs in the West Credit River;

<u>Water Quality</u>

In 2016 water quality at 10th Line was very good with low concentrations of suspended sediments and nutrients (e.g. nitrate, TKN, TP, and ammonia). Total phosphorus, and un-ionized ammonia concentrations were well below their PWQO values of 0.03 and 0.02 mg/L respectively; indicating Policy 1 status for these parameters. Dissolved oxygen concentrations were above the PWQO (temperature dependant), indicting a well oxygenated system. Water quality data collected from the West Credit River at Winston Churchill Blvd. was compared to data collected at 10th Line. The 75th percentile concentrations computed for Winston Churchill Blvd., are for the most part, similar or lower than the 75th percentile concentrations calculated for 10th Line, due to the likely input of groundwater between to two stations.

<u>Low Flow Analysis</u>

CVC recalculated the 7Q20 low flow statistic for 10th Line, using water level and flow data from 8th and 10th Line for July 2013 to December 2015 (Appendix B). The new 7Q20 flow statistic for 10th Line of 225 L/s includes a 10% reduction to account for effects on climate change. Spot flows were measured monthly by HESL from May to September 2016. The lowest flow of 305 L/s was measured during the August sampling event (downstream of the beaver dam) and was 80 L/s greater than the calculated 7Q20 flow.

<u>Site characterization</u>

The study area of the West Credit River, between 10th Line and Winston Churchill Blvd. exhibits an irregular meander pattern. The river is easily wadeable with gentle to steep banks and a bankfull width between approximately 8 m and 12 m within the study area. The water clarity is good, with the river bottom visible. The substrate of the West Credit River in the study area is characterized by fine sediment with some cobbles and rocks. The ratio of fines to rocks/cobbles changed back and forth moving downstream from 10th Line toward Winston Churchill Blvd. The banks are lined with vegetation including tall grasses, shrubs and coniferous trees. Emergent macrophytes were noted along some banks. Bank erosion (under-cutting) was also visible along some bank sections. Fallen woody debris altered the river flow in several sections of the West Credit River study area.

Dye tracer testing

Tracer testing was conducted on August 25, 2016 under a low flow of 0.37 $m^3/s$. Based on the dye tracer results, the average velocity in the West Credit River in the study area was calculated to be 0.17 m/s on the day of the tracer test, which was used to hydraulically calibrate the far-field QUAL2K model.

Mass balance modelling

The treated effluent flows from the proposed Erin WWTP are limited by total phosphorus concentrations with respect to both treatment technology limits for TP removal in wastewater and fully mixed TP concentrations in the West Credit River. A mass balance model was used to back-calculate maximum effluent flows based on varying effluent TP concentrations, 7Q20 low flows in the West Credit River, and a fully mixed downstream TP concentrations of 0.024 mg/L in the river. Based on the results of the TP mass balance modelling, HESL was directed by Ainley Group to carry forward a Phase 1 WWTP effluent flow of 3,380 $m^3/s$ and a Full Build Out flow of 7,172 $m^3/s$, based on an effluent TP concentration of 0.07 mg/L (Phase 1) and 0.046 mg/L (Full Build Out).

Mass balance modelling of total ammonia nitrogen (TAN) and nitrate were also completed as a "starting point" in determining effluent limits for these parameters using the Phase 1 and Full Build Out effluent flows which were derived from the TP mass balance modelling. The mass balance modelling found that at summer temperatures, a TAN concentration of 1.3 mg/L (Phase 1) and 0.7 mg/L (Full Build Out) resulted in fully mixed downstream TAN concentrations that equated to un-ionized ammonia concentrations that were below the PWQO for un-ionized ammonia.

Winter effluent TAN concentrations (of 2 mg/L at both Phase 1 and Full Build Out flows) were also checked to determine the corresponding concentration of un-ionized ammonia. Since speciation of ammonia to its un-ionized state is driven by increasing temperature and pH, un-ionized ammonia at winter temperatures is rarely of concern. In this case, the Phase 1 and Full Build Out flows corresponded with winter un-ionized ammonia concentrations of 0.003 mg/L and 0.006 mg/L, respectively, assuming a water temperature of 4°C. Therefore, the winter effluent TAN concentrations are acceptable.

Far-field (QUAL2K) Modelling

QUAL2K is a one-dimensional (1-D) river and stream water quality model, supported by the United States Environmental Protection Agency (US EPA), which is typically used to assess the environmental impact of pollution discharges along rivers. A wide range of water quality parameters and chemical and biological pollutants within the river can be modelled, including temperature, pH, dissolved oxygen (DO), carbonaceous biochemical oxygen demand (CBOD), nitrogen species, phosphorus species, and suspended solids. The QUAL2K model is known as a far-field model since its water quality predictions apply beyond the point in which the effluent is fully mixed with the river, also known as the far-field.

We limited the far-field modelling to the summer scenario since it is the most critical season due to increased water temperatures which result in increased speciation of ammonia to its un-ionized form.

The summer low flow Phase 1 and Full Build Out scenarios resulted in un-ionized ammonia concentrations below the PWQO at all locations in the West Credit River, downstream of the point of complete mixing.

The un-ionized ammonia concentrations declined with distance from the outfall and reached concentrations between 9.8 and 11 µg/L at the downstream end of the study area (i.e., Winston Churchill Blvd.), 1.5 km from the point of discharge (Table 20). These concentrations are well below the PWQO.

For nitrate-N in both the Phase 1 and Full Build Out summer low flow scenario, the maximum nitrate concentration beyond the point of complete mixing was predicted to remain below the CWQG of 3 mg/L throughout the study area.

Mixing Zone (CORMIX) Modelling

The mixing zone modelling focussed on ammonia as the potentially toxic component of the effluent. There were two aspects to the assessment of ammonia:

- The requirement that undiluted effluent be non-acutely lethal at the point of discharge. This was calculated without the need for an assimilation model and is based solely on the toxicity of ammonia in the effluent; and
- The determination of the size and characteristics of the mixing zone for ammonia in the West Credit River since this is the volume of water in which concentrations will exceed the PWQO of 0.02 mg/L of un-ionized ammonia (MOE, 1994). The mixing zone is allowed under MOECC surface water quality Policy 5 (MOE, 1994). The size of the mixing zone is determined by modelling the physical mixing of effluent with the river and then setting an ammonia limit for the effluent which will maintain the un-ionized ammonia concentration below the PWQO outside of the mixing zone. For a smaller receiver such as West Credit River, this limit will be lower than that required to maintain non-lethal effluent.

At an effluent pH of 8.6 and temperature of 19°C, [based on recommendations made by B M Ross [2014]), the maximum effluent total ammonia concentration (corresponding to 0.27 mg/L of un-ionized ammonia) was calculated to be 2.1 mg/L. Thus, a total ammonia effluent limit of 2.1 mg/L or less would meet the requirement for non-lethality during the summer discharge period.

The near-field mixing of the proposed Erin WWTP discharge with the West Credit River was hydrodynamically modeled using CORMIX Version 10.0. The Erin WWTP discharge to the West Credit River for Phase 1 flows was modeled using CORMIX3, a subsystem which is used for buoyant surface discharges, and schematized as a round pipe located at the water surface level. The Phase 1 flows were also modelled using the CORMIX2 subsystem for multi-port discharges, schematized as a buried 5 m long multi-port diffuser running parallel to the south bank of the West Credit River, with vertical ports located along the river bed. The Full Build Out flows were modelled using the same CORMIX2 system for multi-port discharges.

The mixing zone results are presented below.

**Table 25. Summary of CORMIX Mixing Zone Modelling Results**

| Parameter | Phase 1 Pipe Discharge | Phase 1 Multiport Diffuser | Full Build Out Multiport Diffuser |
|---|---|---|---|
| Distance to Meet PWQO (m downstream of outfall) | 28 m | 104 m | 185 m |
| Plume Width (% of channel) below PWQO at distance in which plume encounters the opposite bank (representing the narrowest place for safe fish passage) | 75% | 36% | 44% |

It is recommended that a detailed design of the outfall pipe or diffuser be carried out prior to construction activities.

Recommended Erin WWTP Effluent Limits

Based on the results of the ACS, including mass balance modelling, mixing zone modelling, and far-field modelling, the following effluent limits are recommended for adoption at the proposed Erin WWTP (Table 26). The ACS shows that a discharge at these concentrations, will maintain West Credit River water quality downstream of the proposed outfall the PWQO/CWQG requirements.

**Table 26. Proposed Erin WWTP Effluent Limits**

| Parameter | Stage 1 (Effluent flow of 3,380 $m^3$/d) | Full Build Out (Effluent flow of 7,172 $m^3$/d) |
|---|---|---|
| pH | Within range of 7 – 8.6 | |
| Total suspended solids | 5 mg/L | |
| Total phosphorus | 0.07 mg/L | 0.045 mg/L |
| Total ammonia nitrogen | 1.3 mg/L summer;<br>2 mg/L winter | 0.7 mg/L summer;<br>2 mg/L winter |
| Nitrate nitrogen | 5 mg/L | |
| E.coli | 100 cfu/100 mL | |
| Dissolved oxygen | 4 mg/L | |
| 5-day carbonaceous biochemical oxygen demand (CBOD5) | 5 mg/L | |

# 6. References

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