Upper Blair Creek State of the Watershed

Final Report

CE787700-1 | 2

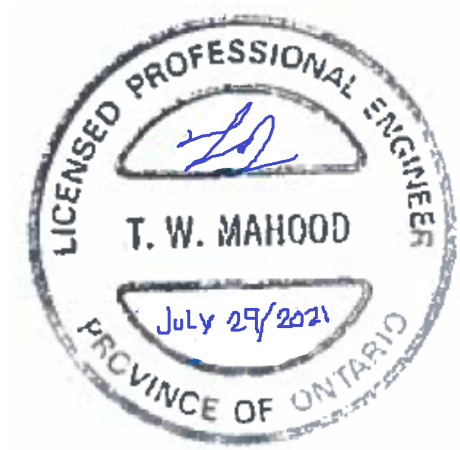
July 28, 2021

City of Kitchener

P20-005

Upper Blair Creek State of the Watershed

Project No: CE787700
Document Title: Final Report
Document No.: CE787700-1
Revision: 2
Document Status: Final
Date: July 28, 2021
Client Name: City of Kitchener
Client No: P20-005
Project Manager: Tom Mahood
Author: Jacobs
File Name: CE787700_UpperBlairSOW_Final.docx



Jacobs Canada Inc.

72 Victoria Street South, Third Floor
Kitchener, Ontario N2G 4Y9
Canada
T +1.519.579.3500

www.jacobs.com

Document history and status

Revision	Date	Description	Author(s)	Checked	Reviewed	Approved
1	Feb 8, 2021	Draft 2020 State of the Watershed	H. Bennet J. Schmitter M. Digaletos E. Henderson	J. Schmitter J. Kardos J. Seebeck	T. Mahood J. Schmitter	T. Mahood
2	July 28, 2021	Final 2020 State of the Watershed	M. Larocque J. Schmitter M. Digaletos	J. Schmitter J. Kardos	T. Mahood J. Schmitter	T. Mahood

Table of Contents

List of Figures

List of Tables

Executive Summary

Introduction

The 2020 State of the Watershed (SOW) report on the Upper Blair Creek Subwatershed has been prepared for the City of Kitchener (City). The 2020 Upper Blair SOW was prepared in cooperation with the Grand River Conservation Authority (GRCA), the Region of Waterloo, the City of Cambridge, and the Township of North Dumfries.

SOW Study Area

The Blair Creek subwatershed spans 18.4 square kilometers (km^2) in the southwest corner of the City of Kitchener, crossing the City's boundaries into the City of Cambridge and the Township of North Dumfries. Blair Creek is a groundwater fed, cold-water perennial watercourse that flows through predominantly agricultural and natural land and supports a Brook Trout population.

Upper Blair Creek is the headwaters of Blair Creek located at the South West boundary of the City and comprises the following two study areas:

1) East Study Area – Contains land located east of Reidel Drive which reflects the developed or developing land within the City's urban area boundary
2) West Study Area (Dundee North) – Contains land located west of Reidel Drive, outside the urban area boundary and is currently an approved agricultural resource area as per the Regional Official Plan (ROP).

Monitoring Program and SOW Goals

The goals of the Upper Blair Monitoring Program and State of the Watershed Study are:

1) To restore, protect, and enhance surface water quality, surface water quantity, and associated aquatic resources and water supplies;
3) To protect, restore and enhance groundwater quantity and quality;
4) To conserve, protect, and restore natural aquatic, wetland, woodland, and wildlife habitat.

The objective of the State of the Watershed (SOW) reporting is to compare the indicator thresholds established for the pre-development condition with the results of the monitoring program for the during-development period, and eventually, the post-development monitoring period.

Purpose of the 2020 SOW Study

The purpose of the 2020 Upper Blair Creek SOW study is to compare the current condition of the Upper Blair Creek to previously documented baseline conditions, assess the effectiveness of current monitoring programs, and make recommendations for improvements to future monitoring efforts. Specific areas of interest include flow regime impacts on stream stability, water quality, thermal impacts, sediment release, sediment loadings, erosion, and groundwater recharge. This is the first SOW to be completed for the during-development period and intends to apply a "weight of evidence" approach to conclusions and recommendations.

The objective of the 2020 Upper Blair Creek SOW report is to document and assess the effects of during-development activities, and compare these to the baseline conditions developed in the 2016 SOW (Aquafor Beech Limited 2016) and subsequent updates provided in the 2018 Cumulative Effects Assessment (GRCA 2018). management practices

Brief History of Upper Blair Creek Studies

To date, there have been four major evaluations of the Upper Blair Creek subwatershed:

1) Blair Bechtel, and Bauman Creeks Subwatershed Plan (CH2M Gore & Storrie Limited 1997)
2) Upper Blair Creek (Kitchener) Functional Drainage Study (Stantec 2009)
3) 2016 Upper Blair Creek State of the Watershed (Aquafor Beech Limited 2016)
4) Cumulative Effects Monitoring – Blair Creek Case Study (GRCA 2018)

The *Blair, Bechtel, and Bauman Creeks* study (BBB Study) provided a subwatershed management plan to balance development with preservation of natural resources. Management practices proposed in the BBB Study have been adapted in subsequent studies to achieve continued improvement. Monitoring plan recommendations, including streamflow, infiltration rates, stream temperature, and fisheries assessments provided the foundation for the current monitoring program.

The purpose of the *Functional Drainage Study* (FDS) was to determine if further development could be accomodated while successfully mitigating harmful impacts and achieving the preservation recommendations outlined in the BBB Study. Results from the FDS were used to develop a SWM Implementation Plan emphasizing an adaptive management approach (AMA) which provides guidance on changes to management approaches and involves revising monitoring protocols and targets over time based on monitoring results. The FDS recommended completing a SOW report on a 3 to 5-year cycle and outlined requirements for Rapid Assessment and Action Protocols (RAAPs).

The purpose of the *2016 Upper Blair Creek SOW* Report was to establish baseline conditions for surface water quality and quantity, groundwater, stream morphology and terrestrial and aquatic ecology to allow for continued application of an AMA to SWM and monitoring practices. The report included recommendations for future monitoring, sediment management during-development, and amendments to the RAAPs.

The Cumulative Effects Monitoring (CEA) study evaluated the pre-, and during- development monitoring data using a cumulative effects assessment framework. The framework analyses, which identify changes in key indicators and statistically differentiate the impact of climate and land use stressors, were recommended to be included in future SOWs and have been included in this 2020 SOW report. The 2016 SOW baseline conditions were adjusted for select parameters using more comprehensive statistical tools which were incorporated in this 2020 SOW report. No substantial development impacts were noted for the monitoring data from 2006-2016; however, potential indicators of change were found including changes in flow, and temperatures.

Study Approach for the 2020 SOW Report

For the first SOW report developed for the during-development period, there were a number of tasks required to establish the current SOW. The following tasks were completed to meet the project's objectives:

1) Review of relevant background reports, monitoring procedures and data
2) Evaluation of previous SOW goals, objectives, indicators, and targets
3) Management of monitoring data sets
4) Assessment of the 2013-2019 monitoring results using the 2016 SOW (Aquafor Beech Limited 2016) statistical methods
5) Assessment of the 2013-2019 monitoring results using R software to perform statistical analyses identified for pre- and during-development "early indicators of change" metrics (GRCA 2018)
6) Comparison of analyzed data to previously determined baseline conditions

7) Comprehensive evaluation of stormwater management (SWM) infrastructure performance and recommendations for future management. SWM infrastructure includes existing SWM facilities, contingency lots, annual monitoring program, and Rapid Assessment and Action Protocols (RAAP).
8) Identification of change to indicators and targets
9) Evaluation of existing conditions with respect to specific indicators and targets
10) Recommendations for the integrated monitoring program to support continued achievement of targets
11) Recommendation regarding the Rapid Assessment and Action Protocols (RAAPs) for temperature and sediment control adaptive management practices.

Specific indicators of change were used to evaluate progress towards achieving the three major SOW goals. These goals were sub-divided into individual objectives which were evaluated using at least one indicator. Indicators represent information describing an attribute or condition of an ecosystem or one of its components. At least one parameter was assigned to each indicator to measure the progress towards achieving that indicator. Parameters must be measurable, either quantitative or qualitative, and provide meaningful information about the health of the watershed. Specific targets were associated with each parameter and used to assess if the objectives were being achieved for each goal.

The “weight of evidence” approach uses these indicators to infer the overall stream health. This comprehensive approach considers the interconnections between disciplines and uses evidence from the entirety of the investigation to support individual conclusions.

Results & Conclusions

The key findings of the existing conditions evaluation for the 2020 SOW and key indicator analysis are summarized below.

Stream temperature has increased overall but currently remains within a range that supports the spawning and habitat of brook trout. If this increase in temperature is sustained, it may impact cold-water fish species and decrease the sustainability of the Brook Trout population. A definitive cause for this temperature increase cannot be identified at this time.

Changes in hydrological regime, including flow rates, flow peakiness, and an increase in hours of flow above critical erosive velocity, indicate increases in urban run-off and/or increases in impervious area. No observable impacts to stream morphology have been noted at this time.

Water quality impacts indicative of sediment releases have been observed at the Dodge Drive monitoring location. An increase in median TSS between pre- and during- development conditions was observed which the statistical analysis indicates is likely a direct result of development near Dodge Drive. Total phosphorus maximum concentrations were also increased in wet weather conditions. A similar increase in TSS and phosphorus was observed at New Dundee Road however effects due to high TSS or phosphorus levels associated with development were not observed downstream of these sites.

Terrestrial and aquatic ecosystems appear to be in fair to good condition despite small decreases in Index of Biological Integrity (IBI) metrics. Water quality remains fair to good throughout the watershed given small increases in pollution indices and changes to other metrics relative to baseline (pre-development) conditions. Brook Trout spawning was reliably supported in an area adjacent to the Doon South development area consistently throughout the during-development phase.

At this time, it is not possible to effectively evaluate the performance of the SWM Facilities within the watershed, therefore it is recommended that the contingency lots not be developed at this time. Review of SWM Facility performance should continue to be a priority in subsequent SOW reporting cycles.

Upper Blair Watershed Monitoring Plan Recommendations

Two key recommendations for the Upper Blair Watershed Monitoring Plan were identified which apply to all parameters and responsible parties:

1) Maintain program consistency

Collecting data in a consistent matter will ensure the same methods can be repeated and allow for reliable, scientifically relevant comparisons to be made with the baseline conditions. Long-term consistency in the monitoring program will reduce the level of effort required to consistently complete the SOW reporting requirements.

2) Develop and maintain consistent data collection procedures

It is recommended that all responsible parties continue to collect data in a consistent format while leveraging advancements in technology to accomplish the following:

- A consolidated database for the Upper Blair Watershed management program with automated scripting to reformat monitoring data collected by various parties
- A network of web enabled dataloggers at select monitoring locations to upload data at regular intervals
- Provide real-time alerts when monitoring data indicates potential impacts

This recommendation supports the objectives of the monitoring program, development of future SOW reports, and recommended improvements to the City's RAAP protocol.

Rapid Assessment and Action Protocols (RAAPs) Recommendations

The Rapid Assessment and Action Protocol (RAAP) is the developer monitoring program implemented in the during-development and post-construction phases. Two critical components of the stormwater management strategy include: 1) successful implementation of erosion and sediment controls (E&SC), and 2) temperature mitigation measures. The purpose of the During-Construction Monitoring program is to evaluate the effectiveness of erosion and sediment controls established for the development site during the construction process and to determine if the targets established in the monitoring program are being met.

The following key recommendations were identified to improve the efficacy of the RAAP:

1) Re-chartering of RAAP annually to ensure all relevant parties are familiar with the RAAP procedure and expectations
2) Refine RAAP Standard Operating Procedures (SOP) to define the following:
    a) Expectations of who is to be triggering erosion and sediment control RAAPs
    b) Responsible parties depending on who has triggered the RAAP. This should also define and track deadlines for actions
    c) Criteria for acceptable selection of monitoring sites for E&SC and temperature monitoring
    d) Requirements for data collection of grab samples, data formatting, and metadata standards to support a unified database
3) Real-time turbidity monitoring to rapidly detect sediment breeches
4) Real-time dashboard to expedite RAAP triggering and reporting while automating the process to facilitate a rapid response through the following:

a) A **Unified Database** using data from the City-wide monitoring program, GRCA, and developers can be generated through automated scripts as new data is uploaded.

b) **Internet Connected Dataloggers** in strategic locations for triggering temperature and E&SC RAAPs

c) Trigger **Alerts and Automated RAAPs** to the responsible parties identified in the RAAP SOP. The following alerts are recommended:

   i. **Temperature Triggers** on a monthly basis to automate monthly Temperature RAAPs currently issued by the developers

   ii. **Wet Weather Event Alert** to alert those responsible that wet weather sampling is required within the specified time frame

   iii. **Automated Action Item Tracking** to generate specific action items in response to the script. For example, identifying locations where TSS samples are required if a wet weather event is triggered.

Table of Abbreviations

Abbreviation	Explanation
AMA	Adaptive Management Approach
ANOVA	Analysis of Variance
BACI	Before-After-Control-Impact Study
BBB Study	1997 Blair, Bechtel, and Bauman Creeks Subwatershed Plan
BH	Borehole
CCME	Canadian Council of Ministers of the Environment
CEA	Cumulative Effects Assessment
CIF	Conveyance Infiltration Facility
City	City of Kitchener
Cl	Chloride
DI	Ditch Inlet
DO	Dissolved Oxygen
E&SC	Erosion and Sediment Control
EFC	Environmental Flow Components
ESPA	Environmentally Sensitive Protected Area
ET	Evapotranspiration
FDC	Flow Duration Curve
FDS	Functional Drainage Study
FFA	Flood Frequency Analysis
GRCA	Grand River Conservation Authority
GRFMP	Grand River Fisheries Management Plan
HW	Headwall
I	Infiltration
IBI	Index of Biological Integrity
IHA	Indicators of Hydrologic Alteration
IWM	Integrated Watershed Management

LVM	LVM Inc.
MAC	Maximum Acceptable Concentration
MAF	Mean Annual Flow
MECP	Ministry of Environment, Conservation, and Parks
MH	Manhole
MMM	Monitoring, Maintenance and Mitigation Program
MMP	Marsh Monitoring Program
MTE	More Than Engineering Consultants Inc.
NO_3	Nitrate
ODWS	Ontario Drinking Water Standard
P	Precipitation
PWQO	Provincial Water Quality Objective
R	Runoff
RAAPs	Rapid Assessment and Action Protocols
Region	Region of Waterloo
RFP	Request for Proposal
ROP	Regional Official Plan
RGA	Rapid Geomorphic Assessment
RVA	Range of Variability Analysis
SOP	Standard Operating Procedures
SOW	State of the Watershed
SWM	Stormwater Management
SWMF	Stormwater Management Facility
TP	Total Phosphorous
TSS	Total Suspended Solids
ZUM	Zone of Uniform Meteorology

1. Introduction

The 2020 State of the Watershed (SOW) report on the Upper Blair Creek Subwatershed has been prepared for the City of Kitchener (City). The 2020 Upper Blair SOW was prepared in cooperation with the Grand River Conservation Authority (GRCA), the Region of Waterloo, the City of Cambridge, and the Township of North Dumfries.

The purpose of the 2020 Upper Blair Creek SOW is to compare the current condition of Upper Blair Creek during-development to the baseline conditions put forward in the *2016 Upper Blair Creek SOW* and subsequent update from the *2018 Cumulative Effects Monitoring – Blair Creek Case Study* (CEA) (GRCA 2018). The 2020 Upper Blair Creek SOW incorporates the system wide monitoring undertaken by the City, developers, and the GRCA and maintains the Integrated Watershed Management (IWS) and Adaptive Management Approaches (AMA) recommended as part of the *1997 Blair, Bechtel, and Bauman Creeks Subwatershed Plan (BBB Study)* (CH2M Gore & Storrie Limited 1997). In addition, the recommendations and practices of previous reports including, the *2009 Upper Blair Creek Functional Drainage Study (FDS)* (Stantec 2009), *2016 Upper Blair Creek State of the Watershed (SOW) Report* (Aquafor Beech Limited 2016), and *2018 Cumulative Effects Monitoring (CEA) – Blair Creek Case Study* (GRCA 2018) have also been reviewed and incorporated into the SOW report where appropriate. The City intends to complete updates to the SOW report on a 5-year basis during- and post-development of the subwatershed in accordance with the recommendations of the FDS.

The goals, objectives and targets that are assessed through the efforts to develop the SOW reporting are the same as those developed for the management strategy of the Blair, Bechtel, Bauman subwatersheds overall. The Upper Blair Creek SOW effort is only a part of the overall management plan for the subwatershed areas in that the observation, review and documentation of the changes in the subwatershed support the overall management plan. The following information provides an overview of the management practices currently used for the Upper Blair Creek Subwatershed.

IWM as defined by Conservation Ontario (2012):

"the process of managing human activities and natural resources on a watershed basis, taking into account, social, economic and environmental issues, as well as community interests in order to manage water resources sustainably" (Conservation Ontario 2012).

The AMA as defined in the FDS:

"A systematic process for continually improving management policies and practices by learning from the outcomes of operational programs. Its most effective form - "active" adaptive management - employs management programs that are designed to experimentally compare selected policies or practices, by evaluating alternative hypotheses about the system being managed." (Stantec 2009).

The AMA, seen in Figure 1-1, supports a "revising-as-appropriate" approach, continually modifying the management of Upper Blair Creek based on the results of monitoring data. This allows Stormwater management (SWM), designs to be updated to better meet the needs of the subwatershed (Stantec 2009).

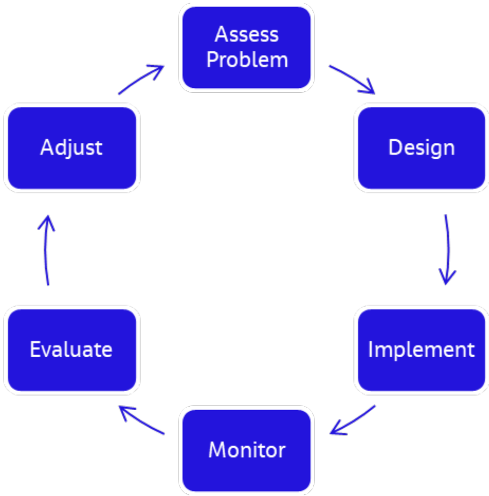


Figure 1-1 Integrative Watershed Management & Adaptive Management

The IWM and AMA approaches presented in the BBB study (CH2M Gore & Storrie Limited 1997) and FDS reports were updated for some indicators in the 2018 CEA report (GRCA 2018) to include a cumulative effects framework and weight-of-evidence approach. The CEA (GRCA 2018) identified early indicators, including flow regime, total suspended solids (TSS), total phosphorus (TP), nitrate, chloride (Cl), and stream temperature to prevent significant impact on Blair Creek itself. The weight-of-evidence approach uses statistical analyses to quantify effects from different stressors, including climate and development. This approach allows for earlier identification of impact to Upper Blair Creek and correspondingly a faster application of the AMA. Through these methodologies, Upper Blair Creek is managed, monitored, and maintained.

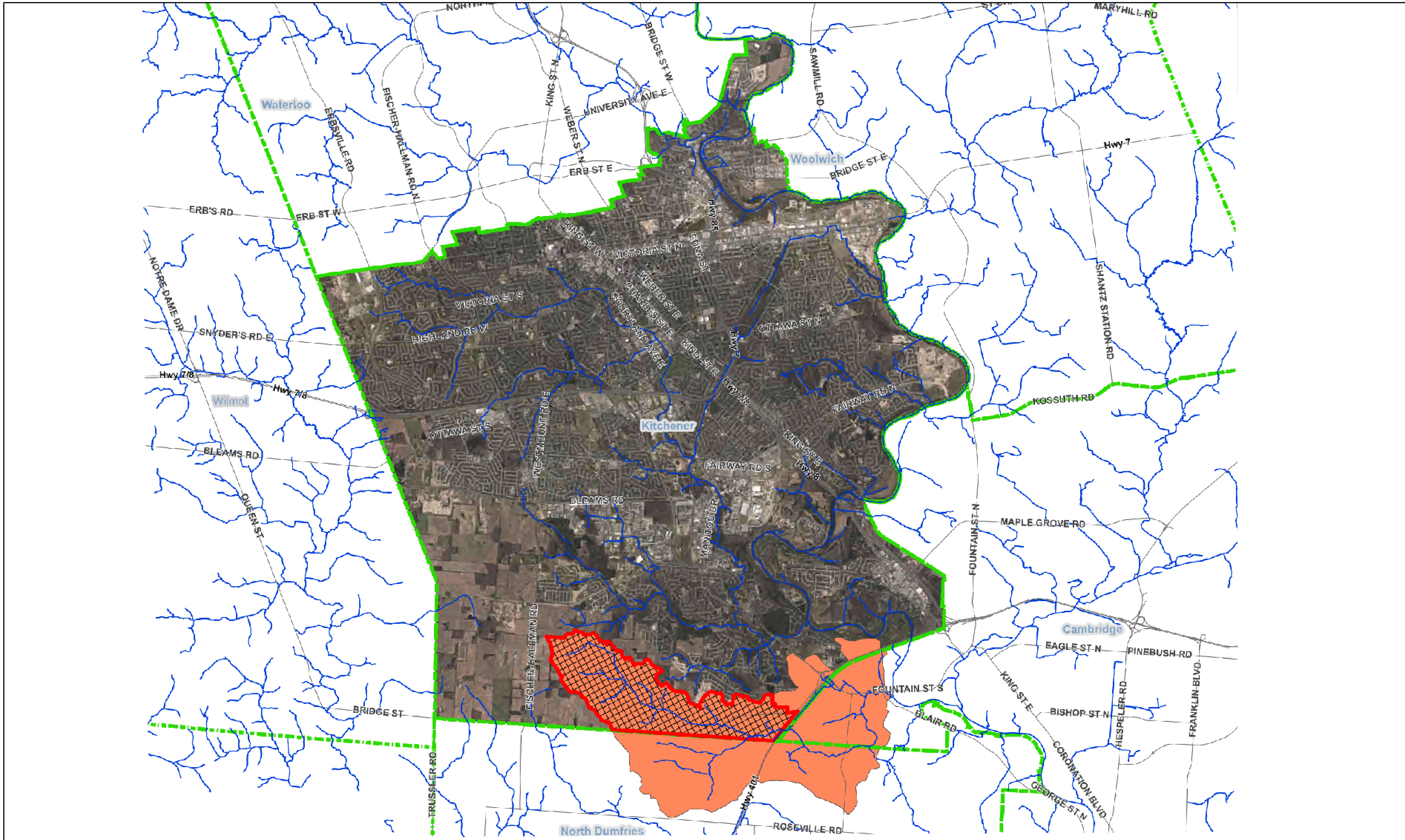
Previous technical reports including the BBB Study (CH2M Gore & Storrie Limited 1997), 2009 FDS, 2016 SOW (Aquafor Beech Limited 2016), and 2018 CEA (GRCA 2018), provide a comprehensive background on the physical, hydrologic, hydrogeological, and ecological systems as well as the baseline conditions of Upper Blair Creek. All four reports highlight the importance and sensitivity of Upper Blair Creek as a cold-water stream and fishery. Additionally, these reports provide recommendations for sustainable development and land use. These reports have provided stakeholders with the insight required to make sustainable decisions surrounding urban development and policy planning for upper Blair Creek and have been integral in developing the current monitoring and reporting procedures for Blair Creek. The monitoring procedures and practices monitor the integrity of Upper Blair Creek and the surrounding provincially significant wetland areas as the subwatershed area is developed.

In keeping with the recommendations of previous reports, monitoring practices and management strategies for Upper Blair Creek must be continually evaluated and, if necessary, updated. This evaluation and recommendation process is completed on a 3-5-year cycle through a SOW report. The following 2020 document is the second SOW report for the Upper Blair Creek Subwatershed. The 2020 Upper Blair Creek SOW provides an analysis and evaluation of the monitored conditions during-development between 2013 and 2019, as well as a comparison to the previously documented baseline (pre-development) conditions.

1.1 Project Context

The Blair Creek subwatershed is in the southwest corner of the City, as illustrated in Figure 1-1-1. The Blair Creek Subwatershed spans 18.4 square kilometres (km^2), crossing the City of Kitchener's boundaries into the City of Cambridge and the Township of North Dumfries. It is a cold-water perennial watercourse which flows through predominantly agricultural and natural land and supports a Brook Trout population. The fishery is highly dependent on groundwater recharge and discharge characteristics and is sensitive to changes in flow and thermal regime. The creek flows through the provincially significant Roseville Swamp Cedar Creek Wetland Complex and Blair Creek Wetland. The outlet of Blair Creek is the Grand River which is located approximately 9 kilometres (km) downstream of the City of Kitchener.

Upper Blair Creek is the headwaters of Blair Creek and is located at the South West boundary of the City. Upper Blair creek has been further divided into two study areas, East and West as shown in Figure 1-1-2. The East study area contains land located east of Reidel Drive which reflects the developed or developing land within the City of Kitchener's urban area boundary. Construction of residential development began in the East Study Area in 2011. The West Study Area encompasses land west of Reidel Drive, outside the urban area boundary, and is currently an approved Agricultural Resource Area as per the Regional Official Plan (ROP) approved by the Ontario Municipal Board, June 18, 2015. The West Study Area is referred to as Dundee North. The City is currently undertaking the development of a new Secondary Plan for the Dundee North area of the Blair Creek subwatershed.



N

0 1 2
Kilometers

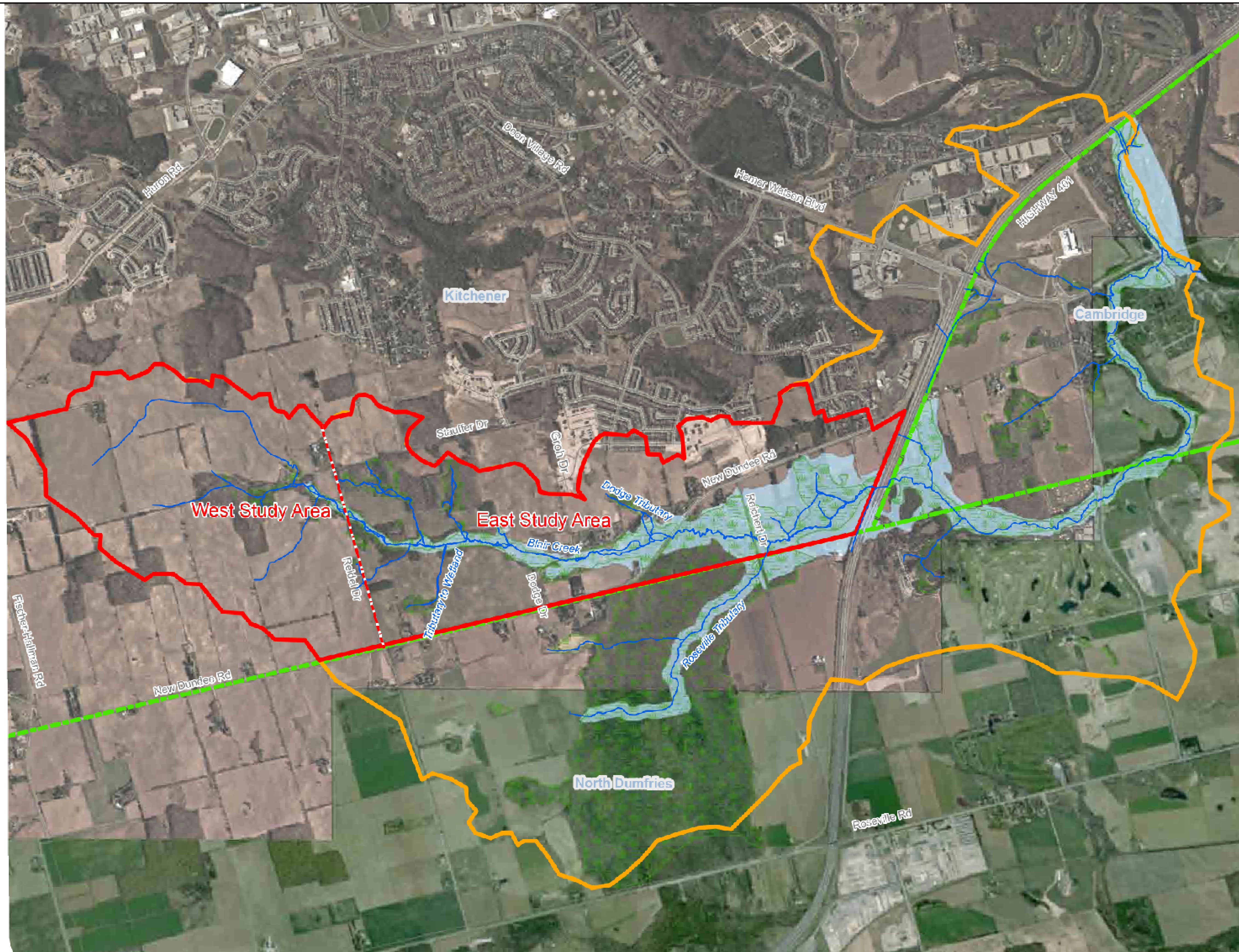
Roads
Watercourse
Municipal Boundaries
Upper Blair Creek Subwatershed Study Area
Blair Creek Watershed

Notes:
1. Image of figure 1.1 from page 4, Upper Blair Creek- State of the Watershed (SOW) Report, 2016.

Figure 1-1-1
Study Area
Upper Blair Creek State of the Watershed
City of Kitchener
Upper Blair Creek Subwatershed, Kitchener, Ontario

Jacobs

\\DC1VS01\GISPROJ\K\KITCHENERCITYOF\UPPERBLAIRCREEK_P20_005\MAPFILES\SOW\1_1_1_STUDYAREA.MXD SCYR 1/26/2021 4:24:12 PM



N

0 200 400 600
Meters

- Watercourse
- Municipal Boundaries
- Upper Blair Creek Subwatershed Study Area
- Blair Creek Watershed
- Wetland
- Floodplain

Notes:
1. Image of figure 1.2 from page 5, Upper Blair Creek- State of the Watershed (SOW) Report, 2016.

Figure 1-1-2
Blair Creek Watershed & Wetlands
Upper Blair Creek State of the Watershed
City of Kitchener
Upper Blair Creek Subwatershed, Kitchener, Ontario

Jacobs

\\DC1VS01\GISPROJ\K\KITCHENERCITYOF\UPPERBLAIRCREEK_P20_005\MAPFILES\SOW\1_1_2_WATERSHED_WETLANDS.MXD SCYR 1/26/2021 4:28:12 PM

1.2 Project Purpose and Objectives

1.2.1 Document Purpose

The purpose of the 2020 Upper Blair Creek SOW report is to compare the current condition of the Upper Blair Creek to previously documented baseline conditions, assess the effectiveness of the current monitoring programs and practices, and make recommendations for improvements to future monitoring efforts. The 2020 Upper Blair Creek SOW is the second SOW assessment for Upper Blair Creek. Subsequent SOW reports are scheduled to be completed every five years. Areas of interest for the City of Kitchener, Region of Waterloo, and GRCA include:

1) Changes to flow regime impacting stream stability;
2) Water quality, specifically the control of salts and chloride contamination;
3) Thermal impacts to Upper Blair Creek and the associated habitats;
4) Sediment release, loadings and construction erosion and sediment control issues; and
5) Groundwater recharge.

The evaluation of Upper Blair Creek is completed through monitoring quantitative and qualitative stream parameters throughout the subwatershed and with additional site-specific monitoring SWM facility effectiveness.

The evaluation and comparison of the Upper Blair Creek current condition, to previously reported baseline conditions, provides the Region, City, and GRCA with insight on the state of the subwatershed. Stream parameters with no change may be an indication of effective monitoring and successful application of adaptation measures. Negative changes in the creek condition, identified through monitoring, may indicate where adaptive measures can be improved. The information collected can provide stakeholders with the information necessary to make environmentally responsible development and policy decisions. The nature of the potential expansion of the City urban area boundary into the West Study Area, depends on maintaining the condition of Blair Creek through implementing appropriate SWM controls (Stantec 2009).

1.2.2 Study Objectives

The objective of the 2020 Upper Blair Creek SOW report is to document and assess the effects of during-development activities, and compare these to the baseline conditions developed in the 2016 SOW (Aquafor Beech Limited 2016) and subsequent updates provided in the 2018 CEA (GRCA 2018). This 2020 report continues the data analysis reported in the 2016 SOW (Aquafor Beech Limited 2016) with the subsequent GRCA and developer monitoring data. In meeting the project's objective, the following tasks were completed:

1) Review and summary of relevant background reports, monitoring procedures and data, and identification of data gaps;

2) Evaluation of previous SOW goals, objectives, indicators, and targets;

3) Management of monitoring data sets including organization and flagging of outliers;

4) Assessment of the 2013-2019 monitoring results using the 2016 SOW (Aquafor Beech Limited 2016) statistical methods;

5) Assessment of the 2013-2019 monitoring results using R software to perform statistical analyses identified for pre- and during-development "early indicators of change" metrics (GRCA 2018);

6) Comparison of analyzed data to previously determined pre-development/base line conditions and evaluation of trends;

7) Comprehensive evaluation of SWM infrastructure performance and recommendations for future management. SWM infrastructure includes existing SWM facilities, contingency lots, annual monitoring program, and Rapid Assessment and Action Protocols (RAAP);
8) Identification of change to indicators and targets;
9) Evaluation of existing conditions with respect to specific indicators and targets;
10) Recommendations for the integrated monitoring program to ensure continued achievement of targets. Recommendations include modifications, continuation, and change in flexibility of aspects of the current monitoring program; and
11) Review and recommendation regarding the Rapid Assessment and Action Protocols (RAAPs) for temperature and sediment control adaptive management practices.

1.3 Document Structure

The following list provides an overview of the sections included in the 2020 Upper Blair Creek Subwatershed SOW:

Section 1 - Includes the Upper Blair Creek SOW purpose and objectives. Provides an overview of the project context, previous reports, project history, stormwater management, and water balance and land development context.

Section 2 - Describes the existing conditions for each discipline including a summary and comparison to previous reports, updated data analysis, and results and conclusions.

Section 3 - Provides the projects goals, objectives, and targets.

Section 4 - Proposes a monitoring plan for each discipline outlined in Section 2. The monitoring plan includes monitoring locations, methodology, parameters, frequency, and the party responsible for monitoring.

Section 5 - Describes the RAAPs for temperature and erosion and sediment control, assess protocols and identifies recommendations.

Section 6 - Provides all reference documents.

1.4 Study Area Characterization

This section characterizes the geographical and environmental aspects of the Upper Clair Creek subwatershed area. This description is summarized from the 2016 SOW (Aquafor Beech Limited 2016) study area characterization which was completed using information provided by the BBB Study (CH2M Gore & Storrie Limited 1997) and the FDS (Stantec 2009). A more detailed description of site characterization, corresponding to each discipline, is provided in Section 2.

> *"The middle and lower reaches of Blair Creek system* [are] *characterized as a sensitive cold water fishery that is highly dependent upon the groundwater recharge and discharge characteristics and sensitive to changes in flow and thermal regime, such as those that generally result from an increase in impervious coverage (i.e., development) across the contributing drainage area"* (Stantec, 2009). Additionally, a significant portion of the Blair Creek Subwatershed is "*bounded by provincially significant wetlands and areas of natural scientific interest*" (CH2M Gore & Storrie Limited 1997).

The Blair Creek headwaters are in the Waterloo Moraine, which is characterized by ice-contact sand/gravels and intervening sand/silt till soils. The overlaying soil is sandy loam with medium permeability. Additionally, "*well records indicate that groundwater levels are below the streambed in the headwaters*" (Aquafor Beech Limited 2016). The physiography, hydrogeology, and soil combination, result in both measurable runoff and significant infiltration.

The headwaters of Blair Creek originate in wetlands west of Reidel Drive. The three small tributaries of Blair Creek flow at a 0.8 percent slope through fairly good riparian cover to meet upstream of Reidel Drive. "*A permanent tributary drains agricultural areas southwest of the headwater wetland and* [downstream] *joins the Blair Creek just west of Reidel Drive*" (Stantec 2009). This tributary and two others converge with Blair Creek upstream of Dodge Drive. "*Blair Creek is classified as an intermittent stream from its headwaters to west of Dodge Drive*" (Aquafor Beech Limited 2016).

"*South of Dodge Drive, Blair Creek enters a 5-hectare marsh before its confluence with the Roseville Swamp tributary east of King's Road*" (Stantec 2009). Increased baseflow South of New Dundee Road generates perennial flow. From the headwaters to Roseville Swamp Blair Creek is a locally gaining and losing stream. Minor groundwater input occurs through interflow and from the overburden aquifer during wet periods. "*The headwaters of Blair Creek convey little baseflow, but measurable amounts of runoff during wet conditions. The analysis completed as part of the BBB study shows that, during dry periods, the Roseville Swamp may convey 10 times the flow of the Blair Creek headwaters, while during wet periods the Roseville Swamp may convey 2 to 4 times the headwater flow*" (Aquafor Beech Limited 2016). Water infiltrated in the upland moraines does not contribute to the headwaters of Blair Creek.

1.5 Project History

To date there have been four major evaluations of the Upper Blair Creek subwatershed:

1) Blair Bechtel, and Bauman Creeks Subwatershed Plan (BBB Study)

   (CH2M Gore & Storrie Limited 1997)

2) Upper Blair Creek (Kitchener) Functional Drainage Study (FDS)

   (Stantec 2009)

3) 2016 Upper Blair Creek State of the Watershed (2016 SOW)

   (Aquafor Beech Limited 2016)

4) Cumulative Effects Monitoring – Blair Creek Case Study (CEA)

   (GRCA 2018)

In accordance with the objectives of the 2020 Upper Blair Creek SOW, the reports have been reviewed and summarized in detail, according to each discipline, within Section 2. The following provides an overview of the reports above as well as their relevance to the current SOW.

1.5.1 Blair, Bechtel, and Bauman Creeks Subwatershed Plan (BBB Study)

The BBB study was initiated in 1993 by the GRCA, Region of Waterloo, Cities of Kitchener and Cambridge, Township of Dumfries, and the Ontario Ministries of Natural Resources (now Ministry of Natural Resources and Forestry), Environment and Energy (now Ministry of Environment, Conservation and Parks [MECP]), and Transportation. The BBB Study (CH2M Gore & Storrie Limited 1997) was completed in 1997 and provided a subwatershed management plan for the Blair, Bechtel, and Bauman Creeks which balanced development and protection/preservation of natural resources. The BBB study identified Blair Creek as a cold-water stream with species sensitive to changes in flow regime and thermal conditions.

The BBB Study (CH2M Gore & Storrie Limited 1997) assessed the physical resources provided by Blair Creek, identified, and modelled the potential impacts of future development, analyzed the existing subwatershed issues, and provided a subwatershed management plan for Blair Creek. The management plan included goals and corresponding objectives with specific management practices to help facilitate their achievement. These management practices have been adapted and modified through subsequent reports to achieve continued improvement in the management plan. One of the highlighted practices implemented as part of the BBB recommendations were defined impervious cover limits for the subwatershed to ensure groundwater recharge levels were maintained. The BBB Study established preservation recommendations for Blair Creek which have been adapted with each subsequent assessment. Also, as part of the management plan, a monitoring plan was recommended by the BBB study. The monitoring plan included streamflow, infiltration rates, baseflow, stream temperature, erosion rates, groundwater levels, and fisheries assessments. These monitoring recommendations provided the foundation for the monitoring program which is currently used for Blair Creek.

1.5.2 Upper Blair Creek (Kitchener) Functional Drainage Study Final Report (FDS)

The Upper Blair Creek FDS (Stantec 2009) was commissioned to determine if further development could be accommodated in the Upper Blair subwatershed while successfully mitigating harmful impacts and achieving the protection/preservation recommendations outlined in the BBB Study. The FDS was intended to provide the Region, the City, and the GRCA with a technical basis for future development planning. Within the East Study Area, the focus was to develop a method, other than impervious cover limits, that could be used to identify if further development could occur within the boundaries defined by the objectives and recommendations of the BBB study. The FDS also investigated whether using enhanced SWM practices would allow for development to occur in the West Study Area of the Blair Creek Subwatershed.

One of the first determinations of the FDS (Stantec 2009) was that the East and West Study Areas could be treated independently of each other. The FDS also determined that using SWM practices on smaller sub-catchments within the watershed, could allow development to proceed more flexibly. In regard to the Impervious Cover Limits put forward in the BBB Study, it was determined that that the critical development design requirement is that a development meets the designated infiltration targets which may be achieved through design measures other than Infiltration Cover limits (ICLs).

The FDS (Stantec 2009) investigated existing geotechnical and hydrogeological conditions in the Blair Creek Subwatershed and reviewed and evaluated SWM technologies using modelled conditions. From this investigation, a SWM Implementation Plan was developed that put emphasis on an AMA which provides guidance on changes to management approaches and revises monitoring protocols and targets over time, and as conditions change, as appropriate. The revision of targets and monitoring protocols is based on the results from the extensive and ongoing monitoring of the subwatershed. This approach is currently used in the Upper Blair Creek SOW reports.

The FDS also recommended that a State of the Watershed Report for Upper Blair Creek be completed on a recurring 3-5-year cycle and outlined the requirements for RAAPs. The current monitoring practices used in the Upper Blair Creek subwatershed and the resulting database that has been compiled, as well as the AMA and reporting methods, have all been adopted from the FDS.

1.5.3 2016 Upper Blair Creek State of the Watershed (2016 SOW)

The 2016 SOW (Aquafor Beech Limited 2016) was prepared for the City, GRCA, Region, City of Cambridge, and the Township of North Dumfries. The purpose of this report was to establish baseline (pre-development) conditions for surface water quality and quantity, groundwater, stream morphology, and terrestrial and aquatic ecology. The baseline conditions in the 2016 SOW allowed for the continued application of the AMA to SWM and monitoring practices for Upper Blair Creek.

The 2016 SOW (Aquafor Beech Limited 2016) made recommendations for future monitoring activities, suggested sediment management during-development activities, and made amendments to the RAAPs. The 2016 SOW also recommended that future SOWs should be completed every five years.

Recommendations for future monitoring practices included a more holistic approach which would combine system-wide and site-specific monitoring. The 2016 SOW specified future monitoring locations, parameters to be measured, monitoring and measurement frequency, and responsible parties for each study discipline. Note that not all recommendations in the 2016 SOW were incorporated in this SOW report.

1.5.4 Cumulative Effects Monitoring – Blair Creek Case Study (CEA)

The CEA was created by the GRCA (2018) in partnership with the MECP, and the City to provide a case study of the Blair Creek Monitoring Program. The purpose of the CEA was to evaluate 2006-2016 monitoring data categorized as pre-, during-, and post-development using a cumulative effects assessment framework. The objectives included improved characterization of land-use and water quality, and increased awareness of cumulative effects monitoring.

The framework analyses identify changes in key indicators and statistically differentiates the impact of climate and land use stressors. This framework was recommended as an addition in future SOWs and has been added to this current 2020 SOW. The CEA highlighted the importance of monitoring site locations and recognizing early indicators. It recommended the use of a weight-of-evidence approach, drawing on climate, hydrology, water quality and stream temperature as indicators and as individual lines-of-evidence in the overall assessment of the Upper Blair Creek condition. The CEA also adjusted the 2016 SOW baseline conditions for select parameters using a more comprehensive data set and statistical tools (GRCA 2018). The updated baseline conditions have been incorporated into the 2020 SOW.

For the evaluated years, 2006-2016, the CEA identified that no substantial development impacts had been documented. However, potential indicators of change were found which include “flashiness” (rapid increase in flow) in the upstream confluence with the Roseville Tributary, increases in high TSS concentrations at sites immediately downstream of development, and slight temperature changes in various portions of the stream (GRCA 2018).

1.6 SWM and Water Balance Context

An overarching goal of the FDS and BBB studies (Stantec 2009; CH2M Gore & Storrie Limited 1997) was to implement a water balance approach to managing activity in the subwatershed which would limit changes to the hydrologic cycle.

Many factors affect the hydrologic cycle including natural features such as soil, topography, vegetation, geology and climate, and anthropogenic features such as climate change and development. The main mechanisms that maintain the hydrologic cycle are evaporation and transpiration (evapotranspiration), runoff, infiltration, and precipitation. These components are used in the water balance equation, normally expressed as:

$$\text{Precipitation (P)} = \text{Evapotranspiration (ET)} + \text{Runoff (R)} + \text{Infiltration (I)}$$

Changes to the hydrologic cycle result in impacts on water quantity and quality as well as stream morphology. Urbanization and the corresponding increase in impervious cover has a strong impact on the mechanisms that maintain the hydrologic cycle. Urbanization reduces evapotranspiration and infiltration which resulting increases runoff causing more frequent high flows in watercourses, correspondingly increasing flooding and erosion. Additionally, reduction in infiltration results in decreased groundwater recharge which can affect cool water streams and well access to aquifers.

The general goal of the water balance approach is to maintain the pre-development water balance condition within a developed area, hence avoiding the consequences of changes in evapotranspiration, runoff, and infiltration. Some of the objectives that correspond to this goal are maintaining groundwater recharge to aquifers, maintaining the continuity of flow paths between recharge and discharge areas, protecting natural features and ecological habitats, practicing water management practices which acknowledge the hydrologic interdependencies of the headwaters and downstream locations, reducing erosion, and improving water quality. These objectives help to maintain the integrity of natural areas as well as ensure continued access to water.

The FDS (Stantec 2009) established post-development water balance volume targets for runoff and infiltration to be used in the Upper Blair Creek Subwatershed. “All proposed development/SWM scenarios sufficiently mitigate potential impacts pertaining to the quantity of surface runoff, infiltrated water, and baseflows” (Stantec 2009). All future developments must also continue to achieve these water balance targets in order to maintain the condition of the Upper Blair Creek Subwatershed.

1.7 Land Development Context

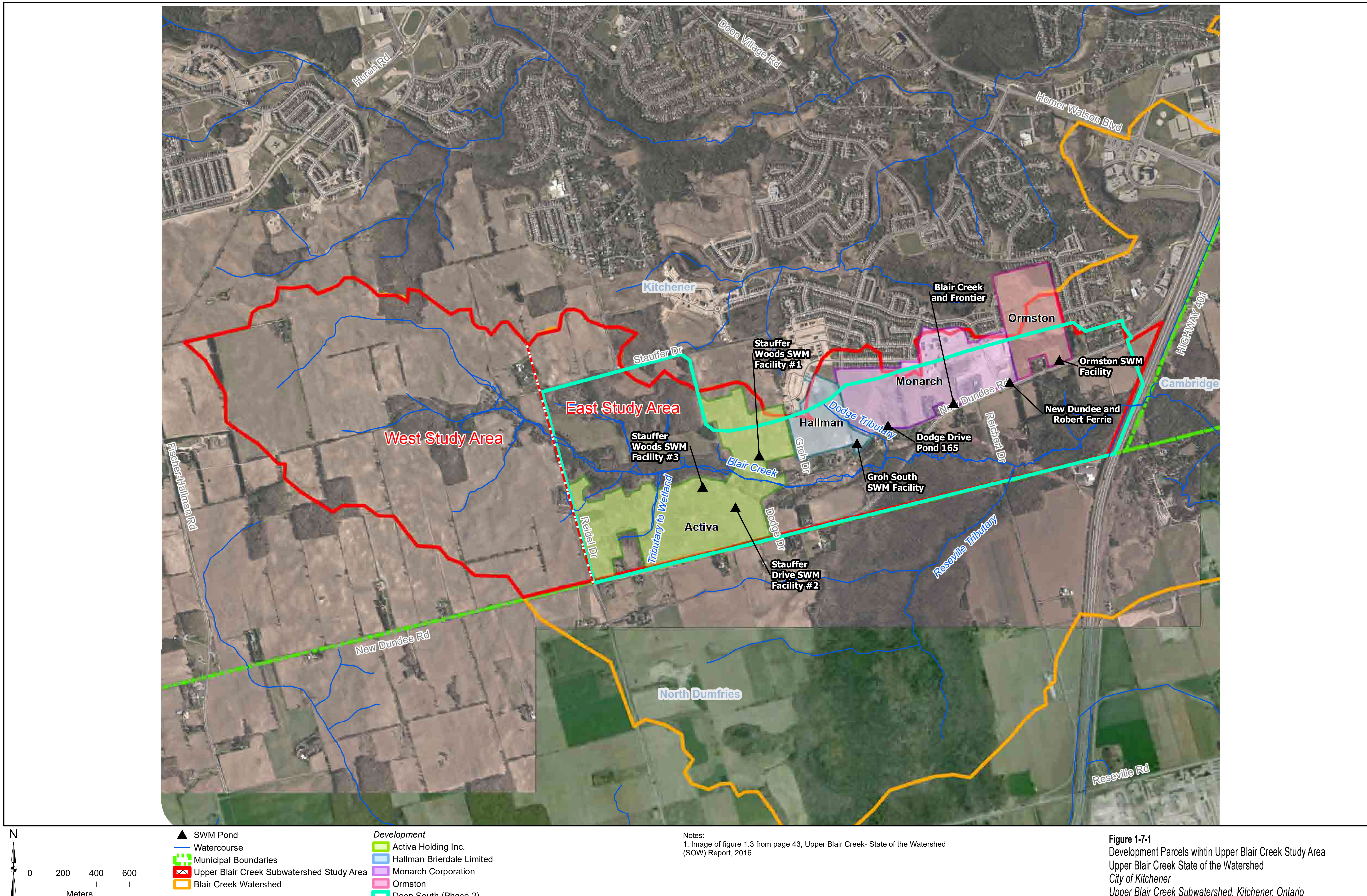
1.7.1 General

Land use in the Blair Creek subwatershed is predominantly agricultural. Approximately 9 percent of land is currently attributed to residential land use, however, this number is anticipated to increase in the future. There are two established development areas within the subwatershed; the East Study Area and the West Study Area, separated by Reidel Drive, as illustrated in Figure 1-7-1. The East Study Area represents the lands located to the east of Reidel Drive and generally reflects the extent of the City Urban Area and the Doon South Community Plan – Phase 2 Area (current Study Area). The West Study Area represents the lands located to the west of Reidel Drive, which are outside of the current urban area boundary as defined by the approved Regional Official Plan (Regional Municipality of Waterloo 2015) and the City of Kitchener Official Plan (City of Kitchener 2014). Land development parcels within the study area are shown on Figure 1-7-1.

Existing residential developments (i.e., complete or in construction) within the study area include:

- Dodge Drive Kelly Stage 1 by Mattamy Homes (formerly, Monarch Corporation)– in development
- Dodge Drive Kelly Stage 2 by Mattamy Homes– in development
- Groh South Subdivisions by Hallman Construction Limited – in development
- 508 New Dundee Road by Activa (formerly, Ormston) – in development
- Stauffer Woods Phase 2, Stages 1-10 by Activa – in development
- Topper Woods South Stage 1A by Mattamy Homes – completed in 2016
- Topper Woods South Stage 1B by Mattamy Homes – completed in 2013
- Topper Woods South Stage 2 and 3 by Mattamy Homes– in development

An additional, reasonably foreseeable development (i.e., in the planning or design phase), Urban Woods single family home development by Ridgeview Homes, was identified within the Monarch Corporation development area at Doonwoods Crescent.



SWM Pond
Watercourse
Municipal Boundaries
Upper Blair Creek Subwatershed Study Area
Blair Creek Watershed

Development
Activa Holding Inc.
Hallman Brierdale Limited
Monarch Corporation
Ormston
Doon South (Phase 2)

Notes:
1. Image of figure 1.3 from page 43, Upper Blair Creek- State of the Watershed (SOW) Report, 2016.

Figure 1-7-1
Development Parcels wihtin Upper Blair Creek Study Area
Upper Blair Creek State of the Watershed
City of Kitchener
Upper Blair Creek Subwatershed, Kitchener, Ontario

Jacobs

\\DC1VS01\GISPROJ\K\KITCHENERCITYOF\UPPERBLAIRCREEK_P20_005\MAPFILES\SOW\1_7_1_DEVELOPMENTPARCELS.MXD VM048279 7/13/2021 2:23:11 PM

1.7.2 Stormwater Management Facilities

Dodge Drive

Infiltration Measures

- Lot level infiltration: infiltration galleries retain 25 millimetres (mm) of runoff from all the residential rooftop areas. The infiltration galleries are located on the private side of the property line, within easements to facilitate maintenance by the municipality. Infiltration facilities include a 15 percent longevity factor. If infiltration trenches are at capacity, then the stormwater from the roof will overflow to the storm sewer. Lot level infiltration galleries consist of a modular underground stormwater storage chamber with a published void ration of 97 percent.
- Conveyance Infiltration: to achieve the water balance criteria, three conveyance infiltration facilities (CIFs) are located within the open space block (Block 146, hydro easement). The CIFs (CIF 1, 2 and 3) infiltrate runoff from the upstream area consisting of roof overflow, front and rear yards, road rights-of-way and driveways. The facilities are designed so that overflow from the first will spill into the second, and the second to the third, and the third to the mainline storm sewer. CIFs 2 and 3 will also accept drainage from the multiple residential Block 32. The CIFs will be shutoff in the winter.

SWM Pond

- Piped inlet to pond: minor systems (5 year) flows from development are captured via the proposed storm sewer network and discharge into the pond via a 900 mm diameter inlet and headwall.
- Overland flow routes into pond: flows in excess of the minor system are conveyed via overland flow (i.e., major system) along the rights-of-way. Major system runoff is conveyed to the SWM pond via two overland flow routes. A curb depression and reverse graded boulevard at the west side of the pond frontage, and additional overland flow route directs as much overland flow as possible around the forebay, prior to the ultimate low point. The major system peak flow rate to the pond block is approximately 2.5 cubic metres per second (m^3/s).
- Outlet configuration: the SWM pond outlet configuration consists of the components listed below. In the event the outlet becomes completely blocked, an emergency weir and spillway will convey the 100-year uncontrolled flow rate.
  - A 525 mm diameter outlet pipe from headwall to the control manhole
  - A 2,400 mm diameter control manhole
  - A 75 mm diameter orifice plate attached to a concrete wall within a control manhole with a perforated screen for protection from blockage
  - 300 mm diameter orifice plate attached to a concrete wall within the control manhole
  - An oil-grit separator located downstream of the control manhole
  - A valve chamber, diverting low flows to a cooling facility
  - A 525 mm diameter outlet pipe discharging via a headwall
  - An outlet channel conveying flow to the existing culvert under Dodge Drive
- The sediment forebay facilitates maintenance, improves pollutant removal, and prevents the conveyance of re-suspended material to the pond outlet. The forebay is limited to a 1 metre (m) depth as the bottom of the forebay is already below the composite high groundwater level, and the depth is limited to avoid excessive uplift pressure.

- Extended detention is provided in the pond via a 75 mm diameter orifice plate, located in the control manhole. The active storage fluctuations within the pond will outlet through a 525 mm diameter pipe to the control manhole. The orifice is sized to discharge the maximum extended detention ponding volume over a 49-hour period.
- Post-development flows are provided by a combination of the 75 mm diameter orifice and the 300 mm diameter orifice for quality control.

Maintenance

- A 4 m wide maintenance access road provides access to the pond bottom, and inlet and outlet structures.
- Sediment cleanout forebay requiring cleanout when the forebay volume has been reduced to 50 percent.
- Outlet structure maintenance includes the manual clearing of floating debris.

Hallman Groh South

SWM Facility Overview

- The SWM facility is a hybrid wet pond with a forebay, wet pond cell and sump outlet area providing the benefit of a deeper water wet pond component which is least impacted by winter/spring (frozen) conditions, and a wetland component that provides enhanced biological pollutant removal during the summer months. These facilities offer dilution and settling of sediment within the forebay, wet pond and wetland components combined with a reduced temperature impact when compared to a full wet pond design. The SWM facility is divided into three main cells, consisting of a sediment forebay that accepts minor storm event flows from a major/minor storm control (splitter) structure, with the second and third cells consisting of the wet pond and wetland control portions of the pond, respectively.
- The SWM area includes an approximate 13.4 hectare (ha) area of land comprised of 10.43 ha of residential development land draining to the SWM facility, approximately 0.3 ha of the Groh Drive right-of-way also draining to the SWM facility, 2.6 ha of open space/roof/rear yard area draining directly to the Dodge Drive wetland, and 0.09 ha of condominium block rear yard area that drains off-site towards Groh Drive.

Infiltration Measures

- Lot-level infiltration facilities are located within the front yard of the majority of residential lots with easements. Roof areas within the lots without infiltration systems are directed to the on-site wetland. Run-off enters the infiltration facilities and dedicated storm systems through the direct connection of roof leaders, and the systems will each contain surface overflows to the sites main minor/major storm sewer system. The lot-level facilities are designed to accept runoff resulting from a 25 mm storm event from the contributing roof area plus an additional 15 percent volume.
- Common element lot level systems are located within the condominium/multiple residential blocks consisting of independent infiltration galleries within appropriate areas of the site (e.g., pervious areas, road areas, under parking lots). Given the space constraints associated with the condominium blocks, the galleries are constructed with a manufactured subsurface storage system for efficiency. Runoff will enter the trenches through direct connection of roof leaders.

Conveyance Infiltration Measures

- The facility is located within the hydro corridor, servicing an area of 1.24 ha. The facility includes a pre-treatment device (oil-grit separator) and a valve so that the facility can be disconnected during winter months to prevent infiltration of chlorine-laden water. The conveyance facility was designed so that the contributing area does not produce any runoff during the 4-hour 25 mm storm event plus an additional 15 percent volume.

End-of-Pipe Infiltration Facility

- An end-of pipe infiltration chamber is located downstream of the outlet from the quality/quantity SWM facility and maintains pre-development runoff volumes for a 25 mm summer storm. The end-of pipe volumes use a manufactured subsurface stormwater management system. An arch chamber system was installed in a gravel trench that significantly increases the amount of storage that can be provided subsurface versus a conventional gravel trench. The chambers are installed in rows creating large connected cavities beneath the soil surface to facilitate maintenance and long-term operation with the inclusion of an isolator row designed to settle or trap sediment remaining within the SWM facility before contact with the bed of the main infiltration gallery.

Stormwater Quality Control

- The forebay was designed for the majority of annual rainfall occurring in storms less than or equal to a 25 mm event, therefore, the majority of water borne sediment is also transported to the SWM facilities in less intense events. The sediment forebays was designed to target smaller flows since larger storm events have a greater peak flow with potential for resuspension of accumulated sediment. Smaller flows into the forebay are separated from the larger flows that enter the main pond directly. An appropriately sized splitter structure upstream of the stormwater management pond was installed.

Water Quality (TSS)

- Quality control measures include a hybrid wet pond servicing a total drainage area of 10.73 ha. A permanent pool volume of 1,210 m cubic metres (m^3) is included including 1,070 m^3 of volume in the main pond area and the remaining pool volume in the forebay. Combined, the control measures exceed required volume by 20 percent.
- In May 2015, quality sampling and the turbidity meter were permanently moved to MH106 due to stagnant water conditions in the ditch inlet caused by lack of flow from the cooling trench. Groundwater seepage through the ditch inlet joints, small vertebrate animal decomposition and direct sunlight were causing artificially elevated turbidity readings.

Water Quantity (Temperature)

- Lot level infiltration ensures the roof areas associated with the development are effectively disconnected from the stream during all rain events up to a 25 mm depth through conveyance and end-of-infiltration measures. Approximately 12 percent of the site is designed to be completely disconnected from the stream during all rain events up to 4-hour 25 mm events. The end-of-pipe infiltration facility is sized with the volume required to maintain pre-development runoff volumes for a 25 mm summer storm. All site runoff above the pre-development summer runoff volume is infiltrated.
- The SWM facility includes rock filled cooling trenches that treat all flows from the extended detention portion of the facility that are released from or exceed the capacity of the infiltration facility. To achieve maximum cooling effects, the cooling trenches are located below the water table.
- The SWM facility contains emergency shut-off valves to prevent discharge of water from the facility should temperatures exceed targets. The valves are located in the diversion manhole located along the eastern edge of the facility.
- The primary outlet of surface water from the SWM facility is through the cooling trenches. Water out-letting from the cooling trench upwells through a ditch inlet structure (DI109) and flows into the Dodge Drive tributary located north of Dodge Drive. The outlet is closed in the winter months (December to March) so all stormwater is directed to a headwall (HW107) immediately west of the ditch inlet structure. SW7 was permanently added in MH106 in May 2015 to observe temperature of the surface water discharge from the SWM facility via HW107 while the cooling trenches are closed.

Stormwater Quantity Control

- Flows for all storm events are conveyed to the SWM facility by a combination of a minor (storm water system) and major (overland flow route) conveyance system. Discharge from the facility are controlled via a multi-stage outlet structure located within the control manhole at the southeast corner of the SWM facility. A reverse sloped bottom-draw outlet pipe conveys storm flows to the control manhole which contains a weir wall with multiple orifice plates to control a 25 mm 2-year storm event up to and including a 100-year storm event. For storms greater than the 100-year event, flows will be routed through the facility by an overflow spillway that directs flow to the Blair Creek floodplain located immediately south of Dodge Drive.

Ormston

SWM Facility Overview

- SWM facilities have been designed as either hybrid wet ponds or wetlands with a forebay, wet pond cell, wetland cell and sump pump outlet area offering benefits of dilution and settling of sediment within the forebay, wet pond and wetland components combined with a reduced temperature impact when compared to a full wet pond design.
- The SWM facility is divided into three main cells. The first cell consists of a sediment forebay that will accept minor (up to 5 year) storm event flows. The second and third cells consist of the wet pond and wetland quality control portions of the pond.

Infiltration Measures

- Lot level infiltration facilities are located within the front yards of all residential lots within easements for residences located within catchments 200 to 204. The facilities have been designed to accept runoff resulting from a 25 mm storm event from the contributing roof area with storage volume equivalent to 25 mm multiplied by the contributing roof area plus an additional 15 percent volume.

Conveyance Infiltration Measures

- One facility is located in the western portion of Park Block 12 with a 2.032 ha area serviced by the conveyance facility. The facility includes a pre-treatment device (oil-grit separator) and a valve that can be disconnected during winter months to prevent infiltration of chloride-laden water. The facility has been sized so that the contributing areas do not produce runoff during a 4-hour 25 mm storm event.

End-of Pipe Infiltration Facility

- An end-of-pipe filtration gallery is provided downstream of the outlet from the quality/quantity SWM facility, designed to maintain pre-development runoff volumes for a 25 mm summer storm. The end-of-pipe volume is provided within the SWM facility block using a manufactured subsurface stormwater management system that consists of an arch chamber system installed in a gravel trench to significantly increase the amount of storage provided subsurface, compared to a conventional gravel trench. Chambers are installed in rows to create large connected cavities beneath the soil surface. The isolator row that will settle or trap sediment remaining within the SWM facility discharge prior to contact with the bed of the main infiltration gallery. Regular maintenance (i.e., sediment removal) can be completed within the isolator row by using a water jet tool to scour sediment off of the floor of the isolator row for removal using a vacuum truck.

Stormwater Quality Control

- Forebay: since the majority of annual rainfall occurs in storms less than or equal to a 25 mm event, the majority of water borne sediment is transported to the SWM facilities. Therefore, the sediment forebays are intended to target smaller flows, since larger storm events will have greater peak flows.

- Water quality (TSS): a permanent pool volume of 1,568 m^3 was required with 1,043 m^3 for volume in the main pond area and the remaining volume for the forebay.
- Water quality (temperature): lot level infiltration for roof areas will be disconnected from the stream during all rain events up to a 25 mm depth through the proposed at-source infiltration. Approximately 15 percent of the site is designed to be completely disconnected from the stream during all rain events up to a 4-hour 25 mm storm event. The end-of-pipe infiltration facility is sized with the volume required to maintain pre-development runoff volumes for a 25 mm summer storm. Any pre-development summer runoff volume will be infiltrated. The SWM facility includes cooling trenches that treat all flows from the extended detention portion of the facility that are released from or exceed the capacity of the infiltration facility.

Stormwater Quality Control

- Flows for all storm events will be conveyed to the SWM facility by a combination of minor (storm sewer system) and major (overland flow route) conveyance system. Discharges from the facility will be controlled via orifice plates located within a multi-stage outlet structure within the control manhole at the southeast corner of the SWM facility. For storms larger than the 100-year event, flows will be routed through the facility via an overflow spillway that will direct flows to the Blair Creek floodplain located immediately south of New Dundee Road.

Stauffer Woods

SWM Facility Overview

- SWM facilities have been designed as either hybrid wet ponds or wetlands. The wet pond components are least impacted by winter/spring (frozen) conditions, and the wetland component provides enhanced biological pollutant removal during summer months. These facilities also offer the benefit of dilution and settling of sediment within the forebay, wet pond and wetland combined with a reduced temperature impact when compared to a full wet pond design.
- Flows from all storm events will be conveyed to the respective SWM facilities by a combination of storm sewers and overland flow routes (road rights-of-way).
- SWM facilities are divided into two cells, the first consisting of a sediment forebay that will accept minor storm event flows from a major/minor storm control structure (splitter), and the second consisting of a quality control portion (wet/pond, wetland, hybrid storage area) of the pond.

Infiltration Facilities

- Infiltration facilities are designed to accept 30 mm of runoff within the Pond Number (No.) 1(162) catchment area. Infiltration facilities within Pond No. 2 and 3 catchments will be sized to accept 20 mm of roof runoff.
- Infiltration galleries are located within the front yards of the majority of residential lots, regardless of soil conditions. Runoff enters the infiltration galleries through directly connected roof leaders. Overflow connections are provided to allow the galleries to perform relative to soil conditions. Designated roof area within the lots without infiltration systems will be directed to the on-site wetland. They are oversized by 15 percent to provide excess capacity to account for potential loss in performance over time.
- Common element lot-level systems are located within condominiums or other blocks and consist of a series of independent infiltration galleries located within appropriate areas of the site (e.g., pervious areas, roads, underground parking lots). In consideration of space constraints associated with condominium blocks, the galleries were constructed using a commercial subsurface storage system for efficiency. Runoff enters the galleries through direct connection roof leaders. The common element lot level facilities are to be designed

to infiltrate 20 mm or 30 mm runoff from the contributing roof area. The common element infiltration facilities will be oversized by 15 percent.

Conveyance/Block Measures

- SWM catchments 1 to 3 are serviced by conveyance or block infiltration facilities in 10.45 ha area consisting of 1.89 ha within the Pond 3 drainage area, 4.43 ha within the Pond 2 drainage area and 4.13 ha within the Pond 1 drainage area. The facilities include a pre-treatment device (oil-grit separator) and a sluice gate or valve such that it can be disconnected during winter months to prevent infiltration of chloride-laden water. These facilities have been designed so that the contributing area produces no runoff during the 4-hour 25 mm design storm event. The facilities use a flow-based design where the volume and contact area of the infiltration galleries is such that a single 4-hour 25 mm design storm event can be contained within the facility with no overtopping.

End-of-Pipe Measures

- An end-of-pipe filtration system will be provided downstream of each quality/quantity SWM facility. The infiltration storage area is sized based on the greater 10 mm runoff from front yard and road impervious areas, or the volume required to maintain pre-development runoff volumes to the creek from the site for a 25 mm summer storm, which was used to size the end-of-pipe facilities. For SWM Facilities 1 to 3, a manufactured subsurface SWM system will be used, and consists of a polypropylene arch chamber system installed in rows to create large connected cavities beneath the soil surface to facilitate long-term maintenance and operation within the header row. All infiltration header rows include an adjacent upstream manhole as well as two sumps where sediment will accumulate, to accommodate maintenance.

1.7.3 Stormwater Management Plans

Dodge Drive

A variety of infiltration measures were designed to provide at-source and conveyance infiltration and include roof leaders to soak-away pits and conveyance infiltration trenches. Lot level infiltration galleries with roof leaders draining into the galleries are included in the design of all houses. The lot level infiltration galleries overflow to the storm sewer.

External Drainage

Major system runoff from an approximate 1.1 ha are of low-density residential development from the subdivision located to the north (Doon Mills Stage 9B) drains into the development area via Doon South Drive. The existing lots on Thomas Slee Drive (Doon Mills Stage 9B) are split draining lots with the rear yards draining into the development lands. Major system runoff from an approximate 0.1 ha area of road right-of-way from the subdivision to the west (Groh South) drains into the development area via Blair Creek Drive. Runoff from an approximate 0.8 ha area of open space and 0.2 ha of rear yards from the subdivision to the west (Groh South) drains into the development area along the west boundary of the Groh South subdivision. There is a major/minor split drainage area (approximately 1.9 ha) from Topper Woods South Stages 2 and 3 subdivision where the major system runoff drains into the development lands.

Internal Drainage

The Dodge Drive Ltd. Stage 1 Subdivision accounts for a portion of Watermill Street to be serviced by the storm sewer system draining to the Dodge Drive Ltd. Stage 1 SWM Facility (“East SWM Facility 2”). As such, the minor system from this portion of Watermill Street drains out of the development lands. Road grading influenced the major system draining to SWM Pond No. 165.

Due to grading constraints, lots 6 to 15 and 22 to 29 on Blair Creek Drive are split draining lots where the back of the lots drain directly to the Dodge Drive roadside ditch and the Dodge Drive Wetland Pocket, respectively.

Three CIFs are located within the hydro corridor. The inlet to the CIFs is from the east side of Doon South Drive where Doon South Drive cuts through the hydro corridor. An approximate 3.0 ha area consisting of external open space to the west, external rear yards to the north, and the majority of the northern portion of Watermill Street and the lots on the north side of Watermill street, and Doon South Drive (north of the CIF inlet) will drain into the inlet to the CIFs. The multiple residential block (Block 140) will be split to drain to CIF No. 2 and to CIF No. 3. The CIFs can be shut off during the winter months. During overflow or winter shutoffs, runoff from the CIFs continue to the receiving storm sewer and ultimately to SWM Pond No. 165.

The remaining drainage areas drain minor and major system flows to SWM Pond No. 165 which discharges to the existing culvert under Dodge Drive immediately downstream of the Dodge Drive Wetland Pocket.

The minor system has been designed for the 5-year storm event, in accordance with City criteria. Quality control is provided through a series of SWM techniques including infiltration, oil-grit separators, and an extended detention dry pond complete with a sediment forebay.

Hallman Groh South

At the lot level, infiltration facilities connected to the majority of roof areas, and roof areas not directed to a lot-level infiltration gallery are collected by a second storm sewer system and brought to the wetland to assist in meeting the surface runoff volume requirements. Roof runoff from a number of the lots adjacent to the wetland provide surface water input to the wetland. All lot-level infiltration systems are located in the front yard within an easement. Front yard systems are preferred by the City, as they can be easily accessed to perform maintenance ensuring continuous operation over time. The condominium blocks contain common element infiltration facilities, located, and designed within the parameters of the individual block designs. Lot-level infiltration facilities are deigned to accept 25 mm of runoff.

A single infiltration facility located within the hydro corridor at the northeast limit of the development site provides infiltrate treated (via an oil-grit separator) non-roof (i.e., roads, yards) runoff. The facility was designed so that the contributing area produces no runoff during a 4-hour 25 mm storm event. The facility contains valves so that it can be disconnected during winter months to prevent infiltration of choline-laden water. This facility, in combination with passive infiltration in grassed/open space areas and lot level roof water infiltration galleries, will be used to provide an overall distributed infiltration volume for the site that is 120 percent of current conditions.

The end-of-pipe facility includes a hybrid wet pond/wetland design to provide quality and quantity control of runoff prior to discharge. An end-of-pipe infiltration facility located downstream of the SWM facility outlet will infiltrate the majority of the SWM facility discharge. The end-of-pipe infiltration facility is designed to have a small surface discharge component such that post-development summer runoff volumes for a 25 mm storm are equal to or less than pre-development summer runoff volumes.

Ormston

At the lot level, within Catchment 200, front yard infiltration facilities are connected to all roof areas and designed to accept 25 mm of runoff. All lot-level infiltration systems are located in the front yard within an easement. Front yard systems are preferred by the City, as they can be easily accessed to perform maintenance ensuring continuous operation over time. Within Catchments 201 to 204 (Doon South Creek watershed) will also be connected to front yard infiltration galleries, for consistency within the Ormston subdivision.

A conveyance infiltration gallery provides infiltrate treated (via an oil-grit separator) non-roof (i.e., roads, yards) runoff. The facility is designed so that no runoff is produced during the 4-hour 25 mm storm event. Valves allow for disconnection during the winter months to prevent infiltration of chlorine-laden water.

The SWM facility will utilize a hybrid wet pond/wetland design to provide quality and quantity control of runoff prior to discharge from the development area. An end-of-pipe infiltration facility located downstream of the SWM facility outlet will infiltrate the majority of the SWM facility discharge.

The end-of-pipe infiltration facility has been designed to include a small surface discharge component so that summer runoff volumes for the 25 mm storm are equal to or less than pre-development summer runoff volumes.

Stauffer Woods

The SWM plan incorporates a variety of SWM infrastructure under a treatment train approach. The site includes residential development (a mix of single family, street-fronting townhouses, and multiple family residential blocks) as well as municipal roadways, open space and park blocks, and commercial and institutional blocks.

Five SWM facilities are integrated into the Stauffer Woods (30T-08203) development, servicing five distinct drainage areas. Storm sewers convey minor flows to the SWM facilities, and major flows are contained within the rights-of-way and blocks and will also be directed to the SWM facilities.

At the lot level, infiltration facilities connect to the majority of roof areas within the development. The galleries are installed to include overflow connections to allow the galleries to perform relative to soil conditions. Roof runoff is directed to the wetland from a number of adjacent lots to maintain surface water input.

All lot-level infiltration systems will be located in the front yards or lots. Front yard systems are preferred by the City, as they can be easily accessed to perform maintenance ensuring continuous operation over time. The condominium lots contain common element infiltration facilities, and commercial, institutional, and other non-residential building are required to have onsite infiltration facilities for infiltration of roof runoff as well.

A number of conveyance infiltration facilities located within specified blocks or along the conveyance route infiltrate treated non-roof (i.e., roads, yards) runoff.

End-of-pipe facilities utilize either a hybrid wet pond or wetland design providing quality and quantity control of runoff prior to discharge from the development site. End-of pipe infiltration facilities are located downstream of SWM facility outlets and infiltrate the majority of the SWM facility discharge.

1.7.4 Functional Drainage Study

Section 6.0 of the FDS (Stantec 2009) recommends a comprehensive Monitoring, Maintenance and Mitigation (MMM) program to ensure that development and stormwater management strategies were implemented and function as designed.

1.7.4.1 Monitoring

Monitoring components were designed to provide the agencies with sufficient field data to observed watershed conditions under existing conditions, during the development period and over the long-term in order to identify alterations to hydrology and ecological conditions.

The goal of the Monitoring Program is to observe watershed conditions on a micro- and macro-scale in order to accomplish the following:

- Gain a comprehensive understanding of the natural systems under existing conditions and establish target criteria for the future
- Permit the continuing validity of the hydrologic modeling to be maintained
- Confirm assumptions/predictions incorporated within the proposed conditions design
- Ensure the measures developed and approved through the design process are implemented correctly

System monitoring includes the observation and assessment of watershed conditions on a macro-scale. Monitoring includes stations within and downstream of the Upper Blair watershed to monitor the overall health of the ecosystem and receiving environment downstream.

During-development monitoring is intended to observe detailed characteristics of each development and adjacent areas. This micro-scale observation is anticipated to provide sufficient information so potential offsite impacts during- or post-construction can be easily identified and traced to the source to the extent possible. During-development monitoring is divided into three phases: Pre-, During- and Post-Construction.

- Pre-Construction monitoring was done to determine baseline conditions within and adjacent to development areas. The information will be used to compare conditions during- and post-construction, and to facilitate and evaluation of the mitigation measures implemented. Pre-Construction monitoring is done seasonally, and includes surface water, groundwater, benthics and fisheries, and terrestrial parameters.
- During-Construction monitoring is intended to evaluate the effectiveness of erosion and sediment controls established at development sites during-development and determine if targets established in the monitoring program are being met. The During-Construction Monitoring should address the following activities and annual reports summarizing applicable information with mitigation implemented will be prepared.
  - Surface water: surface water monitoring should occur at the end-of-pipe facility outlet(s) (both temporary sediment basins and ultimate SWM facilities) and analyzed for TSS and temperature monthly and after significant rainfall events (i.e., equal to or greater than a 15 mm event).
  - Temperature: continuous monitoring of surface water and groundwater temperatures should be monitored to evaluate cooling measures with results interpreted in the context of climate conditions
  - Terrestrial: buffers should be inspected to ensure that construction activities did not influence the greenspace system
- Post-Construction monitoring will occur up to two years after 90 percent of the pond catchment area is stabilized, including the construction of buildings, sodding of lots and stabilization of undeveloped lots. This phase will evaluate how well the constructed stormwater management facilities performed to confirm design functionality and determine if the required control targets are met. This stage will also include monitoring of the completed SWM facilities. It is recommended that the following parameters are included. Terrestrial parameters are the same as the Pre-Construction and During-Construction monitoring.
  - Water quality and quantity: monitoring of temperature, TSS and flows at outlets from the SWM facilities and infiltration systems, specifically, following rainfall and runoff events. Outflow occurring from end-of-pipe facilities as a result of small rainfall events during non-winter periods may be evidence that the infiltration system is not functioning properly.
  - General inspection: including regular inspections of vegetation, any evidence of issues at the inlet and/or outlet structures, and general operational characteristics of the facilities (e.g., observed vs. designed drawdown characteristics). Seasonal inspections should occur.

Post-Development monitoring is intended to confirm that SWM facilities and maintenance requirements are operating as expected.

1.7.4.2 Maintenance

The Maintenance Program represents a series of required activities anticipated for each of the implemented SWM measures to minimize the potential for a decline in efficiency or functionality over time. A specific Maintenance Program should be prepared for each new development and provide to the future owner of the SWM facilities (e.g., City, corporation, private resident) so there is a complete understanding of the maintenance tasks required to ensure facilities function as designed.

1.7.4.3 Mitigation

Mitigation components provide guidance for appropriate responses should problems or deficiencies be identified. In the event the Monitoring Program indicated an issue with the SWM system, the following process should be started to determine the appropriate mitigative steps are taken.

- Complete analysis of the monitoring data and site visits by appropriate staff to determine the cause and extent of the problem.
- Identification of preliminary mitigation measures that will address the specific issue(s).
- Meeting or discussion with the appropriate review agencies to discuss the issue(s).
- Development of a proposed plan to resolve the issue(s) identified in consultation with the appropriate agency staff.
- Implementation of mitigation measures, and monitoring of results for an appropriate duration.

1.7.5 Summary of Recommended Monitoring Program

The MMM program is designed to be flexible, with modifications occurring over time to reflect observed changes in the systems (e.g., increases or decreases in work completed, shift in resources, focus to the most appropriate parameters). Table 1-7-1 summarizes the recommended monitoring program as outlined in the FDS (Stantec 2009). Since the publishing of the FDS, further consideration regarding available budgets and staffing has taken place. As a result, the City and Agencies have worked collectively to develop the ‘Minimum Requirements’ monitoring program which reflects the intent of the FDS while implementing more practical changes with available monitoring budgets and staffing resources considered. The 2016 State of the Watershed report (Aquafor Beech Limited 2016) outlines the Typical Monitoring Minimum Requirements which are summarized in Table 1-7-2.

Table 1-7-1 Original FDS Recommendation (Stantec 2009)

Monitoring Stage/Phase (Responsibility)	Parameter(s)	Location(s)	Frequency	Time Frame
System Monitoring (GRCA)	Surface flows (water quantity)	New Dundee Road (BBB 11) and Dickie Settlement Road (BBB 03)	Continuous	Ongoing – began immediately and is carried through development, continuing until such a time as it can reasonably be assumed that the potential for impacts is minimized to the satisfaction of the agencies. Data compiled and produced as "state-of-the-watershed" reports.
	Surface water quality		Seasonal/after large events (≥ 5-year) for TSS, CL Continuous for T (May-October) also at the mouth of Blair Creek at the Grand River (BBB 04) – Optional for DO, TP, NO_3, Bacteria, etc.	
	Environmental data (rainfall, temperature, snow, depression drawdown)	Within the upper watershed area	Continuous for rainfall, temperature, seasonal for snow and depressions	
	Groundwater levels and quality	BBB-1 and 2 / FDS No.s 4, 6, 8, 9, 10	Seasonal for levels, annual for quality	
	Benthics and fisheries	The mouth of Blair Creek at the Grand River (BBB 04), entrance to Doon Soccer Park (BBB F6), Dickie Settlement Road (BBB F5) and New Dundee Road	Seasonal	
	Fluvial geomorphology	Downstream of Old Mill Road, Dickie Settlement Road, New Dundee Road, Dodge Drive tributary	Annually, increasing to seasonally if warranted, and following large storm events	

Table 1-7-1 Original FDS Recommendation (Stantec 2009)

<table>
<tr><th colspan="2">Monitoring Stage/Phase (Responsibility)</th><th>Parameter(s)</th><th>Location(s)</th><th>Frequency</th><th>Time Frame</th></tr>
<tr><td rowspan="11">During-Development Monitoring (Developer)</td><td rowspan="5">Pre-Construction</td><td>Surface water quality</td><td rowspan="2">If watercourse exists, monitoring to be completed at upstream and downstream property limits.</td><td rowspan="2">Seasonal, continuous for temperature</td><td rowspan="5">To be proposed and approved in consultation with GRCA early in the planning stages for a proposed development, in order to compile as much background data as possible. A 2-year monitoring period is preferred. A summary report is to be submitted to the City and GRCA at the preliminary design stage.</td></tr>
<tr><td>Benthics and fisheries</td></tr>
<tr><td rowspan="2">Groundwater levels and quality</td><td rowspan="2">Levels – across entire site.
Quality – at upstream and downstream limits</td><td rowspan="2">Levels – seasonal
Quality – annual
Temperature – continuous</td></tr>
<tr></tr>
<tr><td>Vegetative units and buffers</td><td>Across site and adjacent natural features and/or perimeter lands</td><td>Annual</td></tr>
<tr><td rowspan="3">During-Construction
**we are here</td><td>All items from Pre-Construction Phase</td><td colspan="2">As outlined above</td><td rowspan="3">Strategy to be approved with the pre-grading or detailed design submission (erosion, sediment control plan and landscape plan). Annual reports are to be submitted to the City and GRCA during active construction from the start of grading until substantial completion (90 percent stabilization) of tributary areas</td></tr>
<tr><td>E&SC measures – TSS and T</td><td>At outlets from sedimentation facilities</td><td>Monthly, in conjunction with runoff events, continuous for temperature</td></tr>
<tr><td>Detailed buffer observations</td><td>Any vegetated area identified for protection</td><td>Seasonal</td></tr>
<tr><td rowspan="3">Post-Construction</td><td>All items from Pre-Construction Phase</td><td colspan="2">As outlined above</td><td rowspan="3">To be presented with the detailed design submission. Annual reports to be submitted to the City, GRCA and Municipality. Continues from the end of the During-Construction Phase to the end of the guaranteed period (i.e., 2-years from substantial completion [90 percent] stabilization] of areas tributary to the facility), provided performance is satisfactory.</td></tr>
<tr><td>Performance of SWM systems (t-source, conveyance, and end-of-pipe facilities)</td><td>End-of-pipe facility outlets, infiltration galleries, cooling systems</td><td>Monthly/Event-based, continuous for cooling systems</td></tr>
<tr><td>Detailed buffer observations</td><td>Any vegetated area identified for protection</td><td>Seasonal</td></tr>
</table>

Table 1-7-1 Original FDS Recommendation (Stantec 2009)

Monitoring Stage/Phase (Responsibility)	Parameter(s)	Location(s)	Frequency	Time Frame
Post-Development Monitoring (Municipality)	Performance of SWM systems (at-source, conveyance, and end-of-pipe facilities)	End-of-pipe facility outlets, infiltration galleries, cooling systems	Seasonal/Event-based, continuous for cooling systems	Initiated following assumption of SWM facilities by Municipality, continuing as required.

Notes:

DO = dissolved oxygen

NO_3 = nitrate

Table 1-7-2 Typical Monitoring Minimum Requirements Realized Since Functional Drainage Study Recommendations

Parameter	Location (Responsible)	Frequency	Timeframe			
			Monarch	Hallman	Activa	GRCA
Surface Water Quality	▪ Downstream Fountain Street – mouth (GRCA) ▪ Upstream Dickie Settlement Road – main branch (GRCA) ▪ Reichert Drive - Roseville tributary (GRCA) ▪ Reichert Drive – main branch (GRCA) ▪ Reichert Drive ditch (Monarch Stage 1) ▪ Upstream New Dundee Road – main branch (GRCA, Monarch) ▪ Upstream New Dundee Road – main branch - upstream of Dodge Drive tributary (GRCA) ▪ Dodge Drive - Dodge Drive Dr tributary (Monarch, Hallman) ▪ Dodge Drive - main branch (Activa) ▪ Reidel Drive – main branch (GRCA, Activa) ▪ Downstream New Dundee Road – culvert east of Robt. Ferrie Drive (Ormston) ▪ SWM facility outlets (Hallman, Monarch)	Monarch, Activa, Ormston ▪ 8 times per year: 1 high flow, 1 low flow event per season (winter, spring, summer, fall) Hallman, Monarch – during-development ▪ 12 times per year: monthly, including all rainfall events >15mm GRCA sites ▪ 22 times per year: 16x spring-summer-fall: minimum 5 times per season with at least 1 high flow, 1 low flow event per season ▪ Attempt to capture 3 high flow events in spring and 2 in summer ▪ 6 times in winter	▪ Stage 1: 2008 to present ▪ Stage 2: 2008 to September 2011 ▪ September. 2013 to present	▪ 2009 to 2012	▪ 2009 to 2013	▪ 2006 to 2008 – 2 sites (5 times per year) ▪ 2009 – 4 sites (12 times per year) ▪ 2010 to 2013 – 7 sites

Table 1-7-2 Typical Monitoring Minimum Requirements Realized Since Functional Drainage Study Recommendations

Parameter	Location (Responsible)	Frequency	Timeframe			
			Monarch	Hallman	Activa	GRCA
Surface Water Turbidity	▪ Upstream Dickie Settlement Road – main branch (spring, summer, fall only) ▪ Upstream New Dundee Road - main branch ▪ Downstream Reichert Drive – main branch ▪ Reichert Drive – Roseville tributary (spring, summer, fall only) ▪ Reidel Drive – main branch (winter only) ▪ SWM facility outlets (Hallman, Monarch)	Continuous – recorded every 15 minutes	▪ Stage 1 November 2011 to present	--	--	▪ 2009 to 2013 logger data ▪ Winter sampling began 2012
Surface Water – TSS	▪ Downstream Reichert Drive Dr – main branch	Grab samples – 60 samples/year	--	--	--	▪ Since 2011 60 samples was the goal, actual was less
Surface Water Temperature	▪ Upstream mouth – main branch (GRCA) ▪ Upstream Dickie Settlement Road – main branch (GRCA) ▪ Downstream Reichert Drive - main branch (GRCA) ▪ Downstream Reichert Drive - Roseville tributary (GRCA) ▪ New Dundee Road – main branch (GRCA, Monarch) ▪ Downstream Dodge Drive - Dodge Drive tributary upstream of confluence with main branch (GRCA, Hallman)	Continuous – record every 30 minutes	▪ Stage 1: 2011 to present	▪ 2008 to 2012 (MTE, 2012)	▪ 2008 to 2013 (MTE, 2015)	▪ 2006 - 2 sites ▪ 2007 – 3 sites ▪ 2008 – 8 sites ▪ 2009 – 7 sites ▪ 2010 to 2013 – 8 sites

Table 1-7-2 Typical Monitoring Minimum Requirements Realized Since Functional Drainage Study Recommendations

Parameter	Location (Responsible)	Frequency	Timeframe			
			Monarch	Hallman	Activa	GRCA
	▪ Upstream of Dodge Drive - Dodge Drive tributary (Hallman, Monarch) ▪ Upstream New Dundee Road – main branch upstream of Dodge Drive tributary (GRCA) ▪ Between Dodge Drive and Reidel Drive – main branch (Activa - 4 locations) ▪ Upstream Reidel Drive – main branch (GRCA) ▪ Wetland downstream of New Dundee Road (Ormston) ▪ SWM outlets (Hallman, Monarch)					
Fish – Spawning	▪ Between Dodge Drive and Reidel Drive – main branch (Activa) ▪ Between confluence with main branch to upstream of Dodge Drive – Dodge Drive tributary (Hallman/Monarch) ▪ Upstream of New Dundee Road – main branch (Hallman/Monarch) ▪ Downstream of New Dundee Road – main branch (Hallman/Monarch) ▪ Upstream of Reichert Drive – main branch (Hallman/Monarch) ▪ Downstream of Reichert Drive – main branch (Hallman/Monarch)	Annual – 3-4 visits/year in late Fall (Ecoplans)	▪ 2008 to 2013	▪ 2008-2013	--	--

Table 1-7-2 Typical Monitoring Minimum Requirements Realized Since Functional Drainage Study Recommendations

Parameter	Location (Responsible)	Frequency	Timeframe			
			Monarch	Hallman	Activa	GRCA
Fish - Electrofishing	Biomass survey ▪ Upstream Dickie Settlement Road – main branch ▪ Upstream Reichert Drive – Roseville tributary Presence/absence ▪ Upstream Dickie Settlement Road – main branch (if time allows) ▪ Upstream Highway 401 – main branch ▪ Upstream New Dundee Road – main branch	Biomass survey ▪ Summer – repeat every 2 years Presence/Absence ▪ Summer - annually	--	--	--	Since 2006
Benthics	▪ Dickie Settlement Road - main branch (GRCA) ▪ Upstream Hwy 401 – main branch (GRCA) ▪ Reichert Drive Road – main branch (GRCA) ▪ Reichert Drive Road – Roseville tributary (GRCA) ▪ Halfway between Reichert Drive Rd and New Dundee Road - main branch (Monarch/Hallman) ▪ Upstream New Dundee Road, upstream Dodge Drive Dr confluence – main branch (Monarch/Hallman) ▪ Downstream of Dodge Drive – Dodge Drive tributary (Monarch/Hallman)	▪ Spring only (Ecoplans) ▪ Spring and Fall (GRCA)	▪ 2008 to 2013	▪ 2008 to 2013	▪ 2008 to 2013	▪ Since 2006

Table 1-7-2 Typical Monitoring Minimum Requirements Realized Since Functional Drainage Study Recommendations

Parameter	Location (Responsible)	Frequency	Timeframe			
			Monarch	Hallman	Activa	GRCA
	▪ Upstream of Dodge Drive – Dodge Drive tributary (Monarch/Hallman) ▪ 3 sites upstream of Dodge Drive – main branch (Activa) ▪ Upstream of Reidel Drive (Activa)					
Groundwater Levels	▪ 5 locations (GRCA) ▪ 4 locations East of Reidel Drive (Activa) ▪ 4 locations west of Reidel Drive (Activa) ▪ 2 locations (Hallman) ▪ 5 locations (Ormston) ▪ 9 locations (Monarch Stage 1) ▪ 16 locations (Monarch Stage 2)	4 times per year: first week of March, June, September, and December (avoid sampling after storm event, coordinate sampling days)	▪ Stage 1: 2008 to present ▪ Stage 2: 2008 to September 2011 and June 2013 to present	▪ August 2008 to present (LVM)	▪ 2006 to 2013 (MTE, 2015)	▪ Four times per year ▪ 2006 to 2009 (6 wells) ▪ 2010 to 2013 (5 wells)
Groundwater Quality	▪ 5 locations (GRCA) ▪ 4 locations East of Reidel Drive ▪ 4 locations west of Reidel Drive (Activa) ▪ 2 locations (Hallman) ▪ 5 locations (Ormston) ▪ 9 locations (Monarch Stage 1) ▪ 4 locations (Monarch Stage 2)	Annually – first week of June (avoid sampling after storm event, coordinate sampling day)	▪ Stage 1: 2008 to present ▪ Stage 2: 2008 to September 2011 and June 2013 to present	▪ 2010 to present (LVM)	▪ 2006 to 2013 (MTE, 2015)	▪ Once per year ▪ 2006 to 2009 (6 wells) ▪ 2010 to 2013 (5 wells)

Table 1-7-2 Typical Monitoring Minimum Requirements Realized Since Functional Drainage Study Recommendations

Parameter	Location (Responsible)	Frequency	Timeframe			
			Monarch	Hallman	Activa	GRCA
Groundwater Temperature	▪ 6 locations (Activa) ▪ 2 locations downstream of Dodge Drive Dr (Hallman) ▪ 9 locations (Monarch Stage 1) ▪ 4 locations (Monarch Stage 2) ▪ 2 locations (Ormston)	Continuous	▪ Stage 1: 2008 to present ▪ Stage 2: June 2013 to present	▪ 2010 to 2012 (MTE, 2012) ▪ 2010 to Present (LVM)	▪ 2009 to 2013 (MTE, 2015)	--
Surface Water Quantity – Flow	▪ Dickie Settlement Road ▪ New Dundee Road	Continuous – hourly measurements	--	--	--	--
Fluvial Geomorphology	▪ Upstream Old Mill Road – main branch at 2 cross sections ▪ Halfway between Old Mill Road and Dickie Settlement Road – main branch at 1 cross section ▪ Upstream Dickie Settlement Road – main branch at 3 cross sections ▪ Upstream Reichert Drive Road – main branch at 3 cross sections ▪ Upstream Reichert Drive Road – Roseville tributary at 3 cross sections	Annually – spring and fall, contingency for high flow event	--	--	--	▪ Annual reports since 2003
Weather Station	▪ West of Reidel Drive	Continuous	--	--	--	--

Table 1-7-2 Typical Monitoring Minimum Requirements Realized Since Functional Drainage Study Recommendations

Parameter	Location (Responsible)	Frequency	Timeframe			
			Monarch	Hallman	Activa	GRCA
Vegetation	▪ 2 stations at the Dodge Drive Wetland north of Dodge Drive (Hallman/Monarch) ▪ 2 stations at the Roseville Swamp north of New Dundee Road (Hallman/Monarch) ▪ 10 stations (Activa) ▪ 2 stations proposed at the Roseville Swamp south of New Dundee Road (Ormston)	2 times per year (June and September)	▪ 2007 to 2013 (2007 to 2009 were only sampled once per year)	▪ 2007 to 2013 (2007 was only sampled once)		
Amphibian Calling	▪ 1 station at the Dodge Drive Wetland (Hallman/Monarch) ▪ 1 station at New Dundee Road (Activa) ▪ 3 stations at Environmentally Sensitive Policy Area No. 33 (Activa) ▪ 5 stations at Blair Creek Valley (Activa) ▪ 1 station west of Reidel Drive Road (Activa)	3 times per year (spring)	▪ 2009 to 2013	▪ 2008 to 2013		--

Table 1-7-2 Typical Monitoring Minimum Requirements Realized Since Functional Drainage Study Recommendations

Parameter	Location (Responsible)	Frequency	Timeframe			
			Monarch	Hallman	Activa	GRCA
Breeding Birds	▪ Five stations / areas – Dodge Drive roadside approximately 300 m east of Groh Drive – Dodge Drive Wetland – New Dundee Roadside at hydro corridor – Reichert Drive roadside – west side – Reichert Drive roadside – east side) (Hallman / Monarch) ▪ 3 areas – ESPA 33 – Blair Creek Valley – New Dundee Road ▪ 1 area proposed – Roseville Swamp (Ormston)	2 times per year (summer)	▪ 2009 to 2013	▪ 2009 to 2013		--
Road Mortality	▪ Reidel Drive, Stauffer Drive, Dodge Drive (Activa)	5 times per year during suitable wet/humid nights in spring/summer	--	--	▪ 2008 to 2013	--

Notes:

MTE = More Than Engineering Consultants Inc.

1.7.6 Existing Monitoring

In accordance with the recommendations of the FDS (Stantec 2009) , a development monitoring program was to be designed and implemented by the developer specific to each development property. Table 1-7-3 lists the sites monitored by GRCA and the City during the Pre-Construction and During-Construction phases of development. Table 1.7.4 outlines the developer led monitoring program.

Table 1-7-3 Aquatic Sites Monitored by the GRCA and the City of Kitchener

Monitoring sites (Sampling locations)	Development Status	
	Pre-Construction	During-Construction
Blair Creek upstream Reidel Drive. (2414061)	To present	
Blair Creek downstream Dodge Drive (2414049)	2006-July 2015	July 2015-present
Blair Creek upstream New Dundee Road above Dodge Drive Dr. tributary (2414058)	2006-July 2015	July 2015-present
Dodge Drive tributary upstream New Dundee Road (2414048)	2006-July 2014	August 2014-present
Blair Creek upstream New Dundee Road (2414002)	2006-July 2014	August 2014-present
Blair Creek downstream New Dundee Road (2414057)	2006-July 2014	August 2014-present
Blair Creek downstream New Dundee Road near fence (2414064)	2006-July 2014	August 2014-present
Blair Creek downstream Reichert Drive (2414044)	2006- Oct 2011	Nov 2011-present
Blair Creek upstream Highway #401 (2414047)	2006- Oct 2011	Nov 2011-present
Blair Creek upstream Dickie Settlement Road (2414059)	2006- Oct 2011	Nov 2011-present
Blair Creek downstream Dickie Settlement Road (2414001)	2006- Oct 2011	Nov 2011-present
Blair Creek downstream Dickie Settlement Road (2414060)	2006- Oct 2011	Nov 2011-present
Blair Creek Mouth (2414046)	2006- Oct 2011	Nov 2011-present
Roseville tributary upstream Kings Road (2414062)	To present	
Roseville tributary downstream Kings Road (2414045)	To present	

Table 1-7-4 Developer Monitoring

Development	Parameter	Monitoring Site	Start Date	Notes
Hallman-Groh	Surface Water Temperature Monitoring	Dodge Drive Tributary to Blair Creek downstream limit of development property (Dodge Drive culvert)	Spring 2007	Data was downloaded seasonally during the pre-construction phase. In the during-construction phase, surface water data is downloaded monthly and after each rain event >15 mm from June to September. Data is also downloaded in April, May, October, and November, since the increased frequency is intended to confirm that temperature mitigation measures in the SWM facility are operating as designed.
		Dodge Drive Tributary to Blair Creek	Spring 2008	
		Blair Creek (main) at New Dundee Road	2008	
		SWM Facility in forebay attached to cable concrete at HW102	Summer2014	
		SWM Facility installed in control MH105 upstream of end of pipe infiltration facility and cooling trench	Summer 2014	
		SWM Facility installed in DI109 (permanently in April 2015) – outlet from cooling trench	Summer 2014	
		SWM Facility installed in MH 106 (permanently in May 2015) – inlet to cooling trench	Spring 2015	
Groh (cont'd)	Water Quality Sampling – TSS and Turbidity	Dodge Drive tributary to Blair Creek downstream limit of the development site (Dodge Drive culvert)	Spring 2009	Grab samples are taken once per month following a storm event. As part of the during-construction monitoring program, a continuous turbidity monitor was installed at the SWM facility outlet at the same location where TSS grab samples were obtained. Locations of the grab samples and continuous turbidity meter were adjusted throughout the year depending on the status of the diversion manhole valve.
		Dodge Drive tributary to Blair Creek downstream of the development site (New Dundee Road culvert)	Spring 2009	

Development	Parameter	Monitoring Site	Start Date	Notes
		SWM Facility continuous turbidity meter at facility outlet	Summer 2014	
	Groundwater Temperature Monitoring	Dodge Drive tributary to Blair Creek north of Dodge Drive tributary and New Dundee Road wetland area	Summer 2010	Continuous monitoring will occur at these two sites as part of the during-construction monitoring program to determine whether surface water runoff directed to the end-of-pipe infiltration cells in the SWM facility will have an impact on groundwater temperature.
		Blair Creek between main creek and New Dundee Road	Summer 2010	
Groh (cont'd)	Erosion and Sediment Control Inspections	Entire development site	Weekly visual inspections starting during area grading; frequency has been reduced due to the stabilization of the ground vegetation	Inspections are also performed after large rainfall events now when there is a greater risk of erosion.
	Inspections	SWM facility	Regular basis and after rainfall events larger than 15 mm	--
Stauffer Woods	Surface Water SWM Facility Temperature Monitoring	Upper Blair Creek SWM Pond 1 at the forebay	Summer 2016	SWM facility 1 (162) construction not complete until end of 2015 (i.e., no data from 2015 is available). Data was downloaded seasonally during the pre-construction phase. When substantive area grading began in 2016, surface water data was downloaded monthly and after each rain event >15 mm from June to September to confirm that temperature mitigation measures in the SWM facility are operating as designed.
		Upper Blair Creek SWM Pond 1 at diversion manhole 106	Summer 2016	
		Upper Blair Creek SWM Pond 1 at the cooling trench outlet in DI109	Summer 2016	
	Stream Temperature Monitoring	Upper Blair Creek at SWM Pond 4	Spring 2008	Continuous temperature monitoring has been conducted along Blair Creek within the development site as well as within the southwest wetland.
		Upper Blair Creek at SWM Pond 1	Spring 2008	
		Upper Blair Creek upstream of Dodge Drive and downstream of Laneway	Spring 2009	
		Southern Wetland tributary to Blair Creek in Activa Stauffer	Summer 2009	

Development	Parameter	Monitoring Site	Start Date	Notes
		Southern Wetland tributary to Blair Creek tributary to Blair Creek from wetland in the culvert/tile	Summer 2009	
		Upper Blair Creek at Reidel Drive (81T SW)	Winter 2008	
		Upper Blair Creek at Reidel Drive (186T SW)	Spring 2014	
Stauffer Woods (cont'd)	Water Quality Sampling – TSS	Blair Creek at Dodge Drive	Winter 2009	Seasonal sampling was conducted upstream and downstream of the development site.
		Blair Creek at Reidel Drive	Winter 2009	
	Water Quality Sampling – Turbidity	SWM facility outlet in MH106	June 2016	Measurement frequency set to 15-minute intervals. Data collected once a month or after a storm event >15 mm
Stauffer Woods (cont'd)	Groundwater Temperature Monitoring	Blair Creek northern upstream control	Spring 2009	Completed on a continuous basis throughout the site, down-gradient of the SWM facility locations and in locations where is was expected that groundwater contributing to Blair Creek would not be impacted by SWM facility discharge.
		Blair Creek near SWM 5 in Blair Creek Valley	Spring 2009	
		Blair Creek near SWM 4 beside Blair Creek	Spring 2009	
		Blair Creek downstream of northern control[1]	Spring 2009	
		Blair Creek near SWM 1 beside Clair Creek 54T SW	Spring 2009	
		Blair Creek between Blair Creek Drive and Dodge Drive on north side of Blair Creek (most downgradient location)	Spring 2009	
	Groundwater Level Monitoring	Well IDs: BH5, BH7, BH8, BH1024, MW5-14 and MW18-14	2007	Manual water levels collected four times per year (March, May, August, October)

Development	Parameter	Monitoring Site	Start Date	Notes
	Groundwater Quality Monitoring	BH5	January 2004	Conducted annually. Modifications were made to the groundwater monitoring program in 2016 in accordance with the 2016 SOW meeting. Groundwater quality parameters were monitored quarterly.
		BH7	January 2004	
		BH8	January 2004	
		BH1024	October 2008	
		MW5-14	February 2014	
		MW18-14	February 2014	
Stauffer Woods (cont'd)	Erosion and Sediment Control Inspections	Entire site	Weekly visual inspections once area grading started	Inspections are also performed after large rainfall events now when there is a greater risk of erosion
Ormston	Surface Water Temperature Monitoring	Blair Creek at New Dundee Road	2008	Continuous temperature monitoring in 15-min intervals. Data was downloaded seasonally during the pre-construction phase. In the during-construction phase, data is downloaded monthly over the summer months and seasonally over the rest of the year.
		Blair Creek at Reichert Drive	2008	
		Blair Creek at the Confluence with Roseville Swamp	2008	
		Blair Creek at the 401 Culvert	2008	
		West side of pond at dock	April 2014	
		East of pond in tributary	April 2014	
		South east of pond at tributary inlet	April 2014	
	SWM Facility Temperature Monitoring	Forebay	July 2018	Continuous temperature monitoring in 15-min intervals. Data was downloaded seasonally during the pre-construction phase. In the during-construction phase, data is downloaded monthly over the summer months and seasonally over the rest of the year.
		Diversion manhole at SWM facility outlet	July 2018	
		Cooling trench inlet (in control manhole)	July 2018	
		Cooling trench outlet	July 2018	
		West side of pond at dock	Spring 2015	Grab samples collected seasonally after a storm event (4/yr)

Development	Parameter	Monitoring Site	Start Date	Notes
	Surface Water Quality Sampling - TSS	Blair Creek on CORE site driveway of New Dundee Road at culvert	Spring 2015	Grab samples collected seasonally after a storm event with an additional baseflow sample collected seasonally (8/yr)
	SWM Facility Quality Sampling - Turbidity	Diversion manhole upstream of cooling trench outlet pipe (SWM facility outlet)	Fall 2018	As part of the during-construction monitoring program, a continuous turbidity monitor was installed at the SWM facility outlet. Data will be collected once per month and/or after a summer storm event >15mm causing SWM facility outletting.
	Groundwater Temperature Monitoring (near surface)	North of pond	Spring 2014	Continuous monitoring in 60-min intervals.
		West of pond	Spring 2014	
	Groundwater Level & Quality Monitoring	Well BH04R-18 located South of SWM facility	Re-drilled August 2018	Groundwater level monitoring has been carried out since 2013 originally involving six monitoring wells. A number of the monitoring wells have been decommissioned during the development of the property. Water levels are manually collected at varying times throughout the year. Additionally, continuous data loggers have been installed to monitor data in 60-min intervals. Groundwater quality monitoring is conducted quarterly and historically included sampling five of the six original monitoring wells. assessed seasonally via grab sampling. Modifications to the groundwater quality monitoring program were made in 2016 in accordance with the 2017 SOW Meeting.
		Well BH06-13 located on South side of New Dundee Road	August 2014	

Notes:

1. relocated 70 m northwest in November 2015 due to bridge construction

> = greater than

2. Existing Conditions

2.1 Surface Water Quantity

2.1.1 Context

Monitoring of water quantity in Upper Blair Creek has been ongoing since 1994. The monitoring network covers the headwaters to the mouth of the creek. The BBB study characterizes the creek into three areas, Blair creek headwaters, Roseville swamp tributary, and Blair creek wetlands.

The Blair Creek headwaters drain into soils of medium permeability resulting in little baseflow and measurable runoff during wet periods as well as significant infiltration. Roseville swamp is the discharge for many local and regional overburden aquifer inputs. It is a poorly drained flat area with a high storage volume which attenuates runoff resulting in bog and swamp deposits. Roseville swamp is most often saturated from groundwater and tributary discharge; therefore, precipitation contributes significantly to runoff. Blair Creek flows perennially from its confluence at Roseville swamp through the Blair Creek wetlands to the Grand River. Blair Creek wetlands have high permeability soils resulting in little runoff except for in impervious areas. This area receives plentiful groundwater input and its corresponding temperature allows for brook trout spawning.

Succeeding the completion of the BBB Study (CH2M Gore & Storrie Limited 1997), the GRCA installed long term flow gauges. These have been used to complete continuous flow monitoring at New Dundee Road, upstream of Roseville swamp, and Dickie Settlement Road, downstream of Roseville swamp.

The FDS (Stantec 2009) developed a monitoring program and the AMA which were subsequently used to adapt the GRCA monitoring program, and to form recommendations in the 2016 SOW. The addition of the Blair Creek climate monitoring station in 2010 is attributed to the recommendations of the FDS. The 2016 SOW provided baseline conditions for surface water quantity and calculated four key indicators including watershed peakiness, annual water balance, groundwater functions, and in-channel high flows (Aquafor Beech Limited 2016).

The CEA Report (GRCA 2018) provided updated baseline conditions and methodology. The updated methodology included, in addition to peakiness factors, flood frequency analysis, indicators of hydrologic alteration (IHA), and range of variability analysis (RVA). Where possible this SOW will apply the same methods as those applied by the GRCA in the CEA report, comparisons with pre-development baselines will be made with those developed for the CEA report.

2.1.2 Summary of Past Monitoring

Figure 2-1-1 provides a map of the existing surface water quantity stations as well as the meteorological stations.

Surface water quantity monitoring for Upper Blair Creek Subwatershed is divided into two categories:

A. Monitoring for hydrologic modelling and drainage characterization purposes which included stream flow measurements for low, medium and high flow conditions between 1993 and 1994 for the BBB study (CH2M Gore & Storrie Limited 1997), and continuous meteorological and streamflow data for 1998-2005 for the FDS study (Stantec 2009).

B. Monitoring to assess the overall system which includes continuous meteorological data, 2010-2019 (GRCA) and Roseville Data (1973-2019), and continuous flow data, 1998-2019 (GRCA).

Table 2-1-1 contains a summary of the key findings for water quantity analyses provided by the past four major studies.

Table 2-1-1 Past Monitoring Key Findings

Study	Location of Observations Within Blair Creek	Key findings
BBB Study	Blair Headwaters	Supports high infiltration and offers little baseflow
	Roseville Swamp	Stores large volumes of groundwater for the subwatershed
	Blair Creek Wetlands	Perennial flow supported by high permeability soils Peak flow at outlet (1993-1994): 0.653 m^3/s
FDS	New Dundee Road	Peak Flows: ▪ 0.002 m^3/s (1998) ▪ 0.006 m^3/s (February 2000) ▪ 0.065 m^3/s (May 2000)
	Dickie Settlement Road	Peak Flows: ▪ 0.272 m^3/s (1998) ▪ 1.896 m^3/s (February 2000) ▪ 0.621 m^3/s (May 2000)
	Blair Creek	Annual Rainfall 2009: 880mm
2016 SOW	New Dundee Road	Developed flow duration curve. Generated Log Person III flood frequency analysis. Baseflow: 0.002 m^3/s Peakiness Factor: 213 Annual runoff (direct + baseflow): 126.1 mm/year Baseflow/mean annual flow: 0.08 25-Year Peak Flow/Baseflow: 450 Development at New Dundee Road resulted in more flashiness in the hydrographs. Roseville Swamp flow dynamics effects accuracy of infiltration-baseflow data.
	Dickie Settlement Road	Developed flow duration curve. Generated Log Person III flood frequency analysis. Baseflow: 0.14 m^3/s Peakiness Factor: 20.3 Annual runoff (direct + baseflow): 371 mm/year Baseflow/mean annual flow: 0.41 25-Year Peak Flow/Baseflow: 42.9 Many data gaps identified in streamflow measurements.
	Blair Creek	Annual Rainfall 2011: 926 mm

Table 2-1-1 Past Monitoring Key Findings

Study	Location of Observations Within Blair Creek	Key findings
CEA	New Dundee Road	Characterized and compared flow station data based on development phases: ▪ Pre-development: 2006-2013 ▪ During-development: 2014-present During-development Metrics: Baseflow: 0.002 m^3/s Peakiness Factor: 212.5
	Dickie Settlement Road	Characterized and compared flow station data based on development phases: ▪ Pre-development: 2006-2011 ▪ During-development: 2012-present During-development Metrics: Baseflow: 0.14 m^3/s Peakiness Factor: 19.21
	Blair Creek	Corrected precipitation data based on a combination of GRCA and Roseville station. 2011 annual precipitation (actual): 967.6 mm. Categorized precipitation data into season. No significant hydrological development changes observed. Increase in IHA factors observed, increasing peakiness factor observed.

Notes:

mm/year = millimetre(s) per year

N

0 200 400 600

Meters

— Watercourse

Municipal Boundaries

Upper Blair Creek Subwatershed Study Area

Flow Monitoring Sites

★ Dickie Settlement Road

★ New Dundee Road

Weather Station Sites

● GRCA Weather Station

Notes:
1. Image of figure 2.1 from page 49, Upper Blair Creek- State of the Watershed (SOW) Report, 2016.

Figure 2-1-1
Existing Surface Water Quanity Stations and Weather Stations
Upper Blair Creek State of the Watershed
City of Kitchener
Upper Blair Creek Subwatershed, Kitchener, Ontario

Jacobs

\\DC1VS01\GISPROJ\K\KITCHENERCITYOF\UPPERBLAIRCREEK_P20_005\MAPFILES\SOW\2_1_1_EXISITING_STATIONS.MXD SCYR 1/26/2021 4:30:12 PM

2.1.3 Data Analysis

Streamflow data was collected by the GRCA for 1998-2019. This was analyzed for key hydrologic parameters which are summarized in Table 2-1-2. Surface Water files can be found in Appendix A.

Table 2-1-2 Indicators and Parameters for Assessing Surface Water Quantity for Blair Creek

Indicators	Purpose of Indicator	Parameters
Watershed Peakiness (Flow rate)	Peakiness factor must be maintained at pre-development levels to avoid erosion.	1. Peakiness factor (2-year peak flow/baseflow)
Annual Water Balance (Hydrologic regime)	Water balance for pre-development conditions must be maintained to avoid excess runoff and sustain natural stream processes.	2. Annual runoff volume/area 3. Baseflow
Groundwater Functions (Surface and groundwater interactions)	Infiltration volumes must be maintained at pre-development levels to ensure runoff does not increase and groundwater storage is not depleted.	4. Ratio of baseflow to mean annual flow
In Channel High flows	Habitats located on floodplains must be maintained.	5. Peak flow frequency change beyond bankfull flow

The five parameters representing the four indicators were evaluated and compared to previously developed baseline conditions. In more detail the five parameters are as follows:

1) **Watershed Peakiness Factor (-):** Peakiness factor is an effective way at determining stream flashiness. The calculated peakiness factors from the CEA for pre-development values at New Dundee Road and Dickie Settlement Road were compared to the updated during-development peakiness factors using updated GRCA data. Two-year peak flow and baseflow were calculated using Flood Frequency Analysis (FFA) and the log Pearson distribution, and GRCA data from 2006-2019. These new values were used to calculate the peakiness factor. All values were compared to the CEA baseline/pre-development values to determine if hydrologic change occurred.

2) **Annual Runoff Volume/Area (mm)**: This parameter is used to monitor runoff and baseflow volume. Annual runoff volume is calculated from the flows observed at Dickie Settlement Road and New Dundee Road gauges. The annual average flows are divided by the drainage area upstream of the respective gauges. The following equations were used respectively to represent stream hydrology and the annual water balance:

$$\text{Median Flow} = \text{Direct Runoff} + \text{Baseflow} \quad (1)$$

$$\text{Precipitation} = \text{Median Flow} + \text{Evapotranspiration} + \text{Net Storage} \quad (2)$$

   The annual water balance is determined based on annual precipitation and median flow which are known, evapotranspiration which is calculated from air temperature, baseflow which is calculated by baseflow separation, and direct runoff and net storage which are estimated.

3) **Baseflow** (m^3/s)**:** This is calculated at each gauge by finding the median minimum flow for a period of time. Baseflow is important to stream hydrology as it is used in the annual water balance and changes in its quantity affect other stream process including aquatic habitat requirements.

4) **Ratio of Baseflow to Mean Annual Flow:** This parameter, also known as Baseflow Index, is important in understanding groundwater to surface water interactions. Higher Baseflow Indices normally correspond to greater baseflow contributions.

5) **Peak Flow Frequency Change Beyond Bankfull Flow:** This parameter gives insight into the frequency of larger floods. High values correspond to more frequent peak flows. This parameter is calculated by dividing the peak flow value for the 25-return year, Q_{25}, by the stream baseflow. When this parameter is high it corresponds to the inundation of riparian areas and the necessity of ecological maintenance.

For further information regarding the five parameters, please refer to the 2016 SOW Report (Aquafor Beech Limited 2016). Other parameters included are IHA parameters, as recommended by the CEA, low flow Index (Q90) corresponding to the flow which is exceeded 90 percent of the time, and Q95, the flow which is exceeded 95 percent of the time, a parameter used as an international minimum flow to protect rivers (Aquafor Beech Limited 2016).

Results and conclusions from the water quantity analysis are discussed in detail in Sections 2.2.5 and 2.2.6.

2.2 Stream Temperature

2.2.1 Context

Stream temperature is an important part of maintaining the integrity of Blair Creek. Brook trout which breed in the cold-water conditions of Blair Creek require temperature to remain below 9˚C during spawning months, October, and November, and to remain below 20 degrees Celsius (˚C) at all other times. Water is stratified into three regimes, warm, cool, and cold-water as per the Stoneman and Jones (1996) method, as was done in the 2016 SOW (Aquafor Beech Limited 2016) and the CEA (GRCA 2018).

2.2.2 Summary of Past Monitoring

Stream temperature has been monitored since 2006 by the GRCA, Table 2-2-1 provides the monitoring locations as well as the years monitored for Blair Creek. Stream temperature has been monitored continuously at the stations at thirty-minute and fifteen-minute intervals for older and more current data, respectively. For data from 2006-2011 a Vemco logger was used and from 2012 onward a HOBO logger. The locations of current monitoring stations can be seen on a map in Figure 2-2-1.

Some data is missing from parts of July and August for 2019 at the Mouth monitoring station due to a data logger malfunction. All other data collection years are true to Table 2-1-2 with minimal data gaps.

Table 2-2-1 Stream Water Monitoring Site Locations and Years Monitored

Station Location	Station ID	Easting	Northing	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Blair Creek upstream Reidel Drive Dr.	2414061	544106	4802158						X	X	X	X	X	X	X	X	X
Blair Creek upstream Dodge Drive Dr.	2414049	545517	4801853		X								X	X	X	X	X
Blair Creek upstream New Dundee Road Rd. Above Dodge Drive Dr. Tributary	2414058	546086	4801975			X	X	X	X	X	X	X					
Dodge Drive tributary upstream New Dundee Road Rd.	2414048	546156	4802030			X	X	X	X	X	X	X					
Blair Creek upstream New Dundee Road Rd.	2414002	546219	4802014			X	X	X	X	X	X	X	X	X	X	X	X
Blair Creek downstream New Dundee Road Rd.	2414057	546243	4801996	X	X	X	X	X	X	X	X	X					
Blair Creek downstream Reichert Drive Dr.	2414044	546774	4802010			X	X	X	X	X	X	X	X	X	X	X	X
Roseville tributary downstream Reichert Drive Dr.	2414045	546828	4801821			X	X	X	X	X	X	X	X	X	X	X	X
Blair Creek upstream Highway 401	2414047	547569	4802341							X	X	X					
Blair Creek upstream Dickie Settlement Road Rd.	2414001	549039	4802264			X	X	X	X	X	X	X					
Blair Creek downstream Dickie Settlement Road Rd.	2414060	549062	4802277	X	X	X	X										
Blair Creek upstream mouth	2414046	549663	4803774					X	X	X	X	X	X	X	X	X	X

Surface Water Temperature Monitoring Station
Upper Blair Creek Subwatershed Study Area
Municipal Boundary

Notes:
1. Imagery Source: City of Kitchener, 2019.
2. Monitoring Data Sources:
- Upper Blair Creek- State of the Watershed (SOW) Report, 2016.

Figure 2-2-1
Surface Water Temperature Monitoring Stations
Upper Blair Creek State of the Watershed
City of Kitchener
Upper Blair Creek Subwatershed, Kitchener, Ontario

Jacobs

\\DC1VS01\GISPROJ\K\KITCHENERCITYOF\UPPERBLAIRCREEK_P20_005\MAPFILES\SOW\SURFACEWATERTEMPLOCS.MXD VM048279 3/10/2021 11:55:02 AM

2.2.3 Analysis and Results

As per the 2016 SOW (Aquafor Beech Limited 2016) and CEA (GRCA 2018), the Stoneman and Jones method was used to classify the stream reaches of Blair Creek into cold-water, cool-water, and warm-water for both pre-development and during-development periods. The distribution of points was calculated to determine if the stream temperature regime at Blair Creek was shifting due to development activity.

The Stoneman and Jones (1996) method involves plotting the maximum air temperature against the maximum stream water temperature between the hours of 16:00 and 18:00. Data points were restricted to those that are found in a stable atmosphere, which requires the maximum air temperature to be greater than 24.5˚C for at least 3 consecutive days (GRCA 2018). Data analysis was limited to the months of July and August and also to years from 2010 onward as preceding this air temperature data is only available from the Roseville climate station.

"The proportion of data points falling within each of the thermal regime classifications from the pre-development plots was used to generate the expected value in the during- development plots" (GRCA 2018). Expected values for days in each thermal regime were compared to the actual or observed days in each thermal regime. Chi-square tests statistics were calculated for all three stream temperature regimes using the equation:

$$\frac{(observed - expected)^2}{expected}$$

The results of the chi-squares were summed and then the statistical significance was calculated. Results are shown in Table 2-2-2, where alpha less than 0.05 indicates change. Red highlighted values indicate worsening water quality and green squares indicate the betterment of water quality based on the Brook trout stream temperature requirements (GRCA 2018). Both New Dundee Road and the Mouth have improved stream water quality, regarding temperature, where the number of cold-water days has increased, improving conditions for Brook trout. Reidel Drive and Reichert Drive have significantly worse quality water for Brook trout, with more stream temperature days being warmer than expected. Reichert Drive had statistically significant worsening of water quality temperature in the CEA and has greater significance now than before.

Figure 2-2-2 through Figure 2-2-6 show the thermal regimes and plot stream temperature against maximum air temperature, with colour-coded points for individual years. Thermal regimes are represented as dark blue for cold-water, light blue for cool-water, and values above these highlighted areas are considered warmwater. It should be noted that the years 2018 and 2019 at Reichert Drive have increased stream and air temperatures compared to previous years, and this trend should be monitored closely to ensure that temperatures do not continue to increases and become harmful to the brook trout population. At New Dundee Road and the Mouth there are very few days falling in the cold-water regime, but as the trends for both these locations are positive regarding stream health and decreasing temperature it should not be considered a concern.

Table 2-2-3 contains the percent of days that fall in each thermal regime for both pre- and during-development time periods. At Reidel Drive and Reichert Drive the number of days falling into the cool-water regime has increased and that the percent of cold-water days has decreased, this agrees with previously stated trends. At New Dundee Road warmwater days decreased and at the Mouth cool-water days increased therefore, increasing the stream water quality at both locations which agrees with the trends seen in Table 2-2-2.

For brook trout temperatures must remain below 9˚C during spawning season, October, and November. Table 2-2-4 through Table 2-2-8 contain the 9˚C stream temperature exceedances for each year following that which was reported in the CEA (GRCA 2018). All pre-development years and years preceding 2015 can be found in the CEA. 2015 was previously recorded to be the year with the most exceedances, both 2016 and 2017 had very similar exceedance values to 2015. As hypothesized in the CEA the increase in exceedances is most likely to do with the air temperature, 2016 and 2017 had warmer Octobers than usual leading to the increase in stream temperature exceedances (GRCA 2018).

Table 2-2-2 Sum of chi-square values using the above equation for each of the three thermal regime categories for each site with associated p-values (α = 0.05)

Site	Chi-Square	p-value
Reidel Drive	21.04	0.00003
New Dundee Road	14.21	0.00082
Reichert Drive	151.70	0.00000
Roseville	3.19	0.20313
Mouth	7.95	0.01875

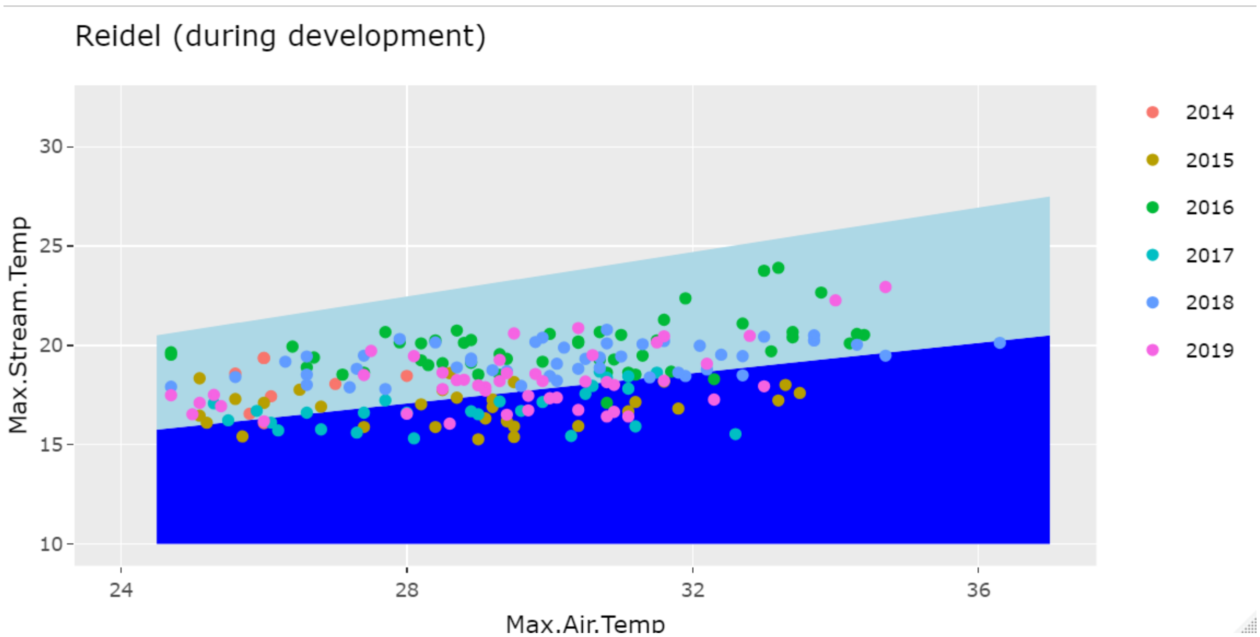


Figure 2-2-2 Reidel Drive during-development thermal regime

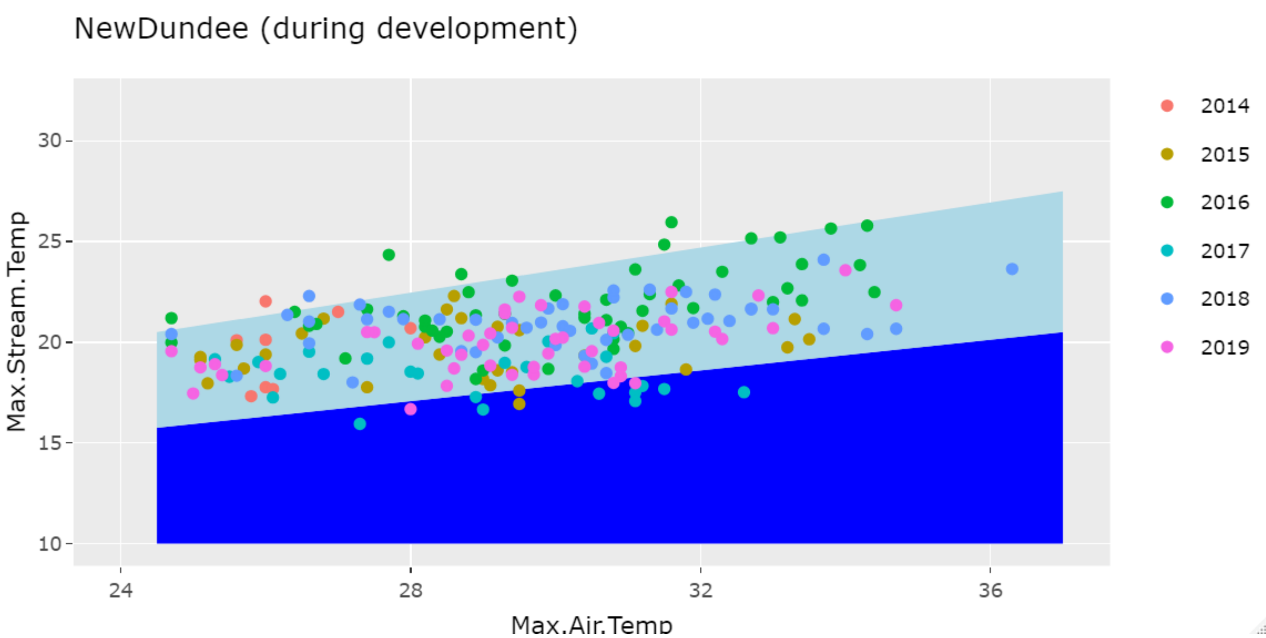


Figure 2-2-3 New Dundee Road during-development thermal regime

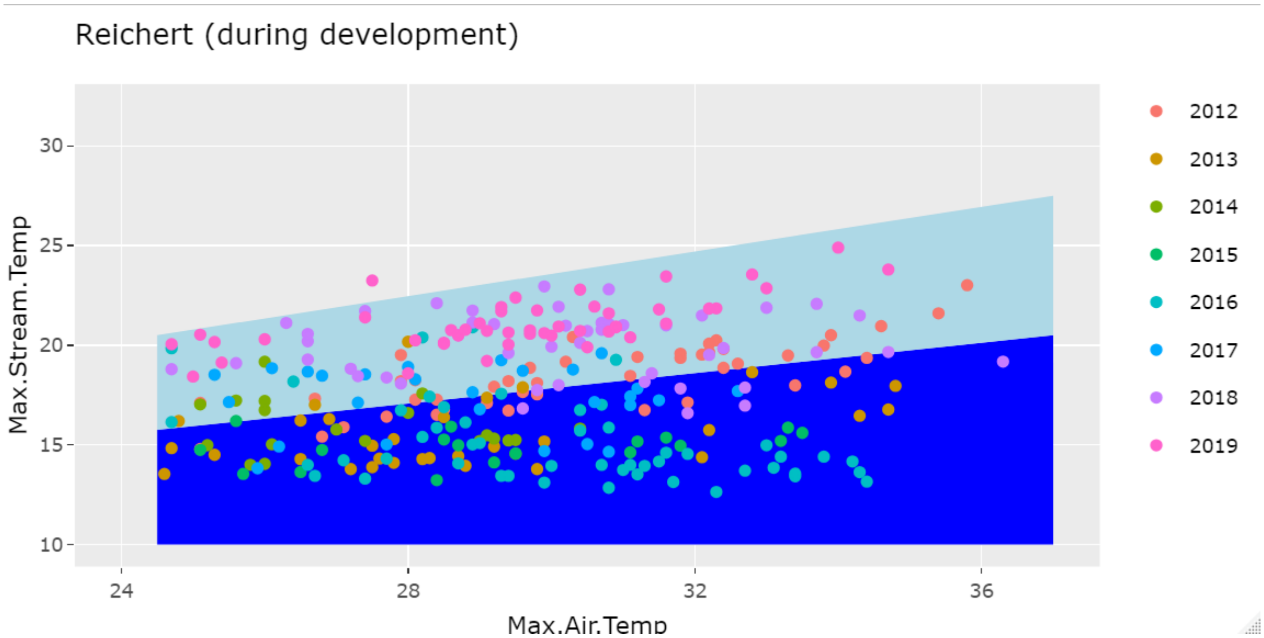


Figure 2-2-4 Reichert Drive during-development thermal regime

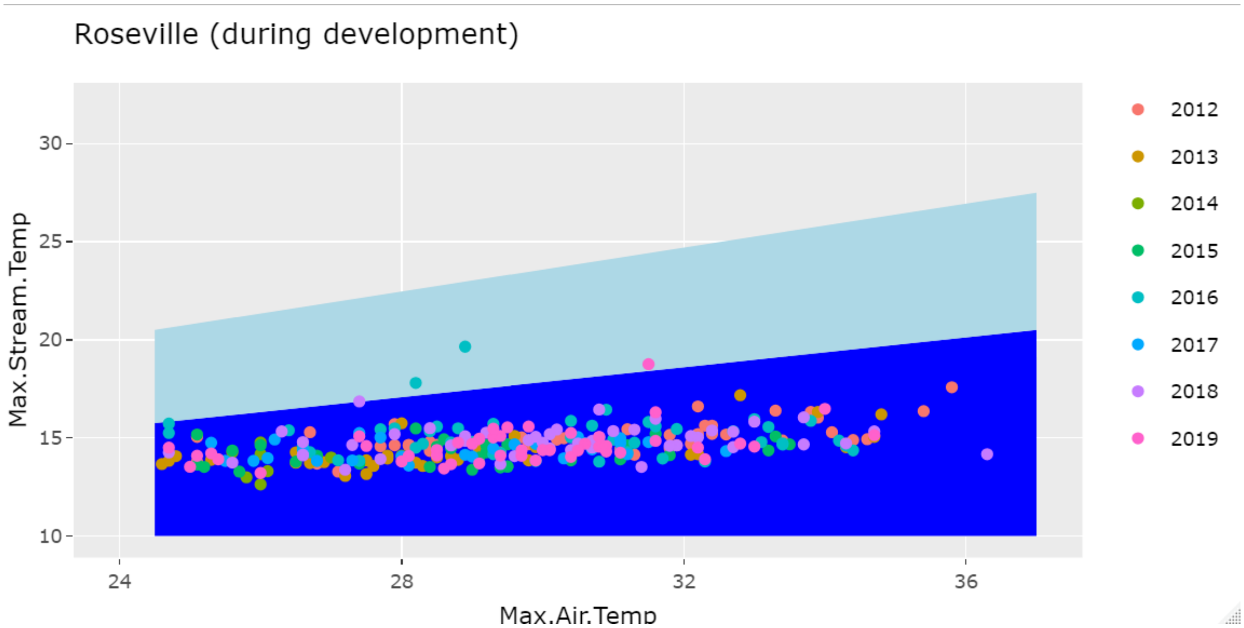


Figure 2-2-5 Roseville during-development thermal regime

Figure 2-2-6 the Mouth during-development thermal regime

Table 2-2-3 Proportion of observations within each thermal category for Pre- and During-development data at all sites

Site	% Cold-water Pre-Development	% Cold-water During-Development	% Cool-water Pre-Development	% Cool-water During-Development	% Warm-water Pre-Development	% Warm-water During-Development
Blair Creek at Reidel Drive	43	28	57	72	0	0
Blair Creek at New Dundee Road	8	7	80	89	12	4
Blair Creek at Reichert Drive	77	46.2	23	53.5	0	0.3
Blair Creek at Roseville Tributary	97	99	3	1	0	0
Blair Creek at the Mouth	0	17	96	80	4	3

Table 2-2-4 2015 Stream temperature exceedances during brook trout spawning period (October 1 - November 30) N/A = No Data

2015	**Stream Site**								
Number of days exceeding 9°C	**New Dundee Road**	**Dodge Drive**	**Dodge**	**Reidel**	**Reichert**	**Roseville**	**Dickie**	**Mouth**	**Dodge Drive New**
October	23	N/A	23	16	20	17	N/A	25	23
November	8	N/A	4	3	5	2	N/A	8	7
Total	31	N/A	27	19	25	19	N/A	33	30

Table 2-2-5 2016 Stream temperature exceedances during brook trout spawning period (October 1 - November 30) N/A = No Data

2016	**Stream Site**								
Number of days exceeding 9°C	**New Dundee Road**	**Dodge Drive Tributary**	**Dodge Drive**	**Reidel Drive**	**Reichert Drive**	**Roseville Tributary**	**Dickie**	**Mouth**	**Dodge Drive New**
October	27	N/A	N/A	26	26	26	N/A	27	3
November	10	N/A	N/A	9	5	10	N/A	8	6
Total	37	N/A	N/A	35	31	36	N/A	35	9

Table 2-2-6 2017 Stream temperature exceedances during brook trout spawning period (October 1 - November 30) N/A = No Data

2017	Stream Site								
Number of days exceeding 9°C	**New Dundee Road**	**Dodge Drive Tributary**	**Dodge Drive**	**Reidel Drive**	**Reichert Drive**	**Roseville Tributary**	**Dickie**	**Mouth**	**Dodge Drive New**
October	28	N/A	N/A	24	26	27	N/A	29	26
November	4	N/A	N/A	4	4	4	N/A	4	4
Total	32	N/A	N/A	28	30	31	N/A	33	30

Table 2-2-7 2018 Stream temperature exceedances during brook trout spawning period (October 1 - November 30) N/A = No Data

2018	Stream Site								
Number of days exceeding 9°C	**New Dundee Road**	**Dodge Drive Tributary**	**Dodge Drive**	**Reidel Drive**	**Reichert Drive**	**Roseville Tributary**	**Dickie**	**Mouth**	**Dodge Drive New**
October	19	N/A	N/A	15	15	17	N/A	21	17
November	1	N/A	N/A	1	1	0	N/A	0	1
Total	20	N/A	N/A	16	16	17	N/A	21	18

Table 2-2-8 2019 Stream temperature exceedances during brook trout spawning period (October 1 - November 30) N/A = No Data

2019	Stream Site								
Number of days exceeding 9°C	**New Dundee Road**	**Dodge Drive Tributary**	**Dodge Drive**	**Reidel Drive**	**Reichert Drive**	**Roseville Tributary**	**Dickie**	**Mouth**	**Dodge Drive New**
October	26	N/A	N/A	25	3	29	N/A	28	27
November	0	N/A	N/A	0	0	0	N/A	0	0
Total	26	N/A	N/A	25	3	29	N/A	28	27

2.2.4 Stream Temperature Conclusion

Overall stream temperature remains in a range which supports the spawning and habitat of brook trout. The number of days at Reidel Drive and Reichert Drive monitoring stations in the cool-water regime are higher than expected (compared to the pre-development number of days) and therefore, this should be monitored carefully to ensure that temperature does not continue to increase and negatively impact the surrounding habitat.

Temperatures at Reichert Drive may be impacted by beaver activity between New Dundee Road and Reichert Drive. This is discussed further in Section 2.5.

2.2.5 Water Quantity Results

This section presents hydrologic monitoring data collected between 1998 and 2019. The discussion includes a comparison of the pre-development parameters to during-development parameters.

2.2.5.1 Climate Monitoring and Analysis

The climate data was developed from a blended dataset of the Environment and Climate Change Canada Roseville station and GRCA Blair weather station. The two stations are separated by 2.2 km and are both located within the same Zone of Uniform Meteorology (ZUM). The ZUM are boundaries produced by the GRCA in which all areas within that boundary experience similar climatic conditions (Aquafor Beech Limited 2016).

Roseville station is equipped to monitor snow and rainfall and reports total precipitation. The GRCA Blair station provides rainfall data. To provide an accurate account of precipitation the Blair weather station data was supplemented with snow fall data from Roseville station.

In previous years there have been significant data gaps in the Roseville station record. The QA/QC review performed by the GRCA for the CEA report acknowledges the following regarding Roseville station data:

> *"it was found that since the year 2006, there have been between 11 – 53 days per year of missing data. From 1973 to 2005, there were only two years that had > 10 days of missing data and the majority of years had no missing data. This suggests that for the years 2006 – 2009 when climate data were taken from Roseville Climate Station only, the total annual precipitation values may be slightly underestimated."*

The quality assurance and quality control (QA/QC) review for the years 2017, 2018 and 2019 observed a similar trend; with each year missing respectively 43, 27, and 14 data points. To accommodate for this, GRCA weather data was used in place of missing Roseville station data. This approach may have underestimated total precipitation as no snow data points where available for the days Roseville station data was missing.

The monitoring period, using the blended dataset, is 2010-2019. Preceding 2010 continuous monitoring data was not available from the Blair weather station. An asterisk has been used to denote years that use only Roseville station data. The data for Roseville station, downloaded from the Environment Canada online historical data collection, and the Blair Weather station data, was used to update the CEA 2006-2016 data set with new climate data from 2017, 2018, and 2019. The annual summary for the cumulative data set for years 2006-2019 is represented graphically in Figure 2-2-7. Additionally, a scatter plot of annual precipitation and air temperature can be seen in Figure 2-2-8 and has been used to group years into climatic conditions. Figure 2-2-8 shows that 50 percent of the years between 2006 and 2019 can be considered cool wet years.

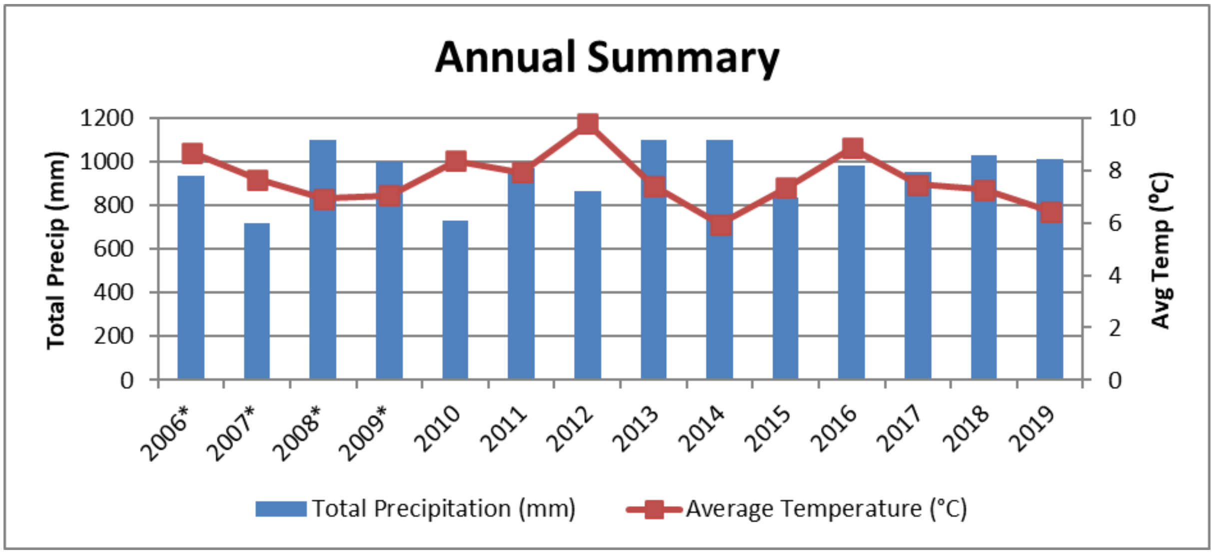
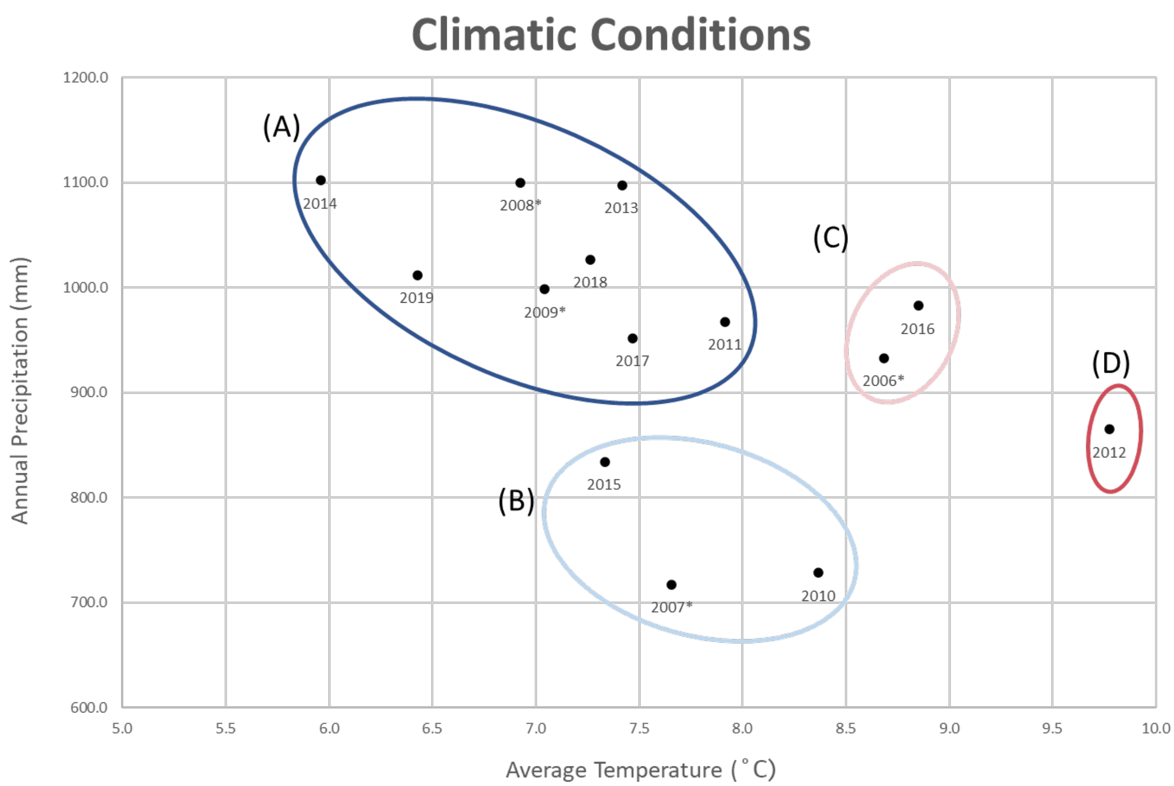


Figure 2-2-7 Annual Summary of Total Precipitation and Temperature, Blended data 2010-2019, Roseville Station Data 2006-2009



(A) Dark blue circle = cool, wet years; (B) light blue circle = cool, dry years; (C) light red circle = warm, wet years; (D) dark read circle = hot, dry year.

Figure 2-2-8 Scatter plot of annual average precipitation and air temperatures, showing clusters of climatic conditions

As per the specifications in the CEA report (GRCA 2018) data is further broken down and analyzed by season. The seasonal average temperature and total precipitation values for 2006-2019 can be seen in Figure 2-2-9.

Seasonal definitions are as follows:

- Fall: October – November
- Winter: December – March
- Spring: April – May
- Summer: June – September

Historic annual precipitation and mean temperature have been reported as 880 mm and 8.7˚C (Stantec 2009), and 899 mm and 7.3 ˚C (GRCA 2018). The average annual values for pre- and during-development temperatures and total precipitation values can be seen in Table 2-2-9. Average annual precipitation was slightly elevated over the during-development period compared to the long-term averages. Average temperatures were comparable between the during-development and long-term study periods (Stantec 2009; GRCA 2018).

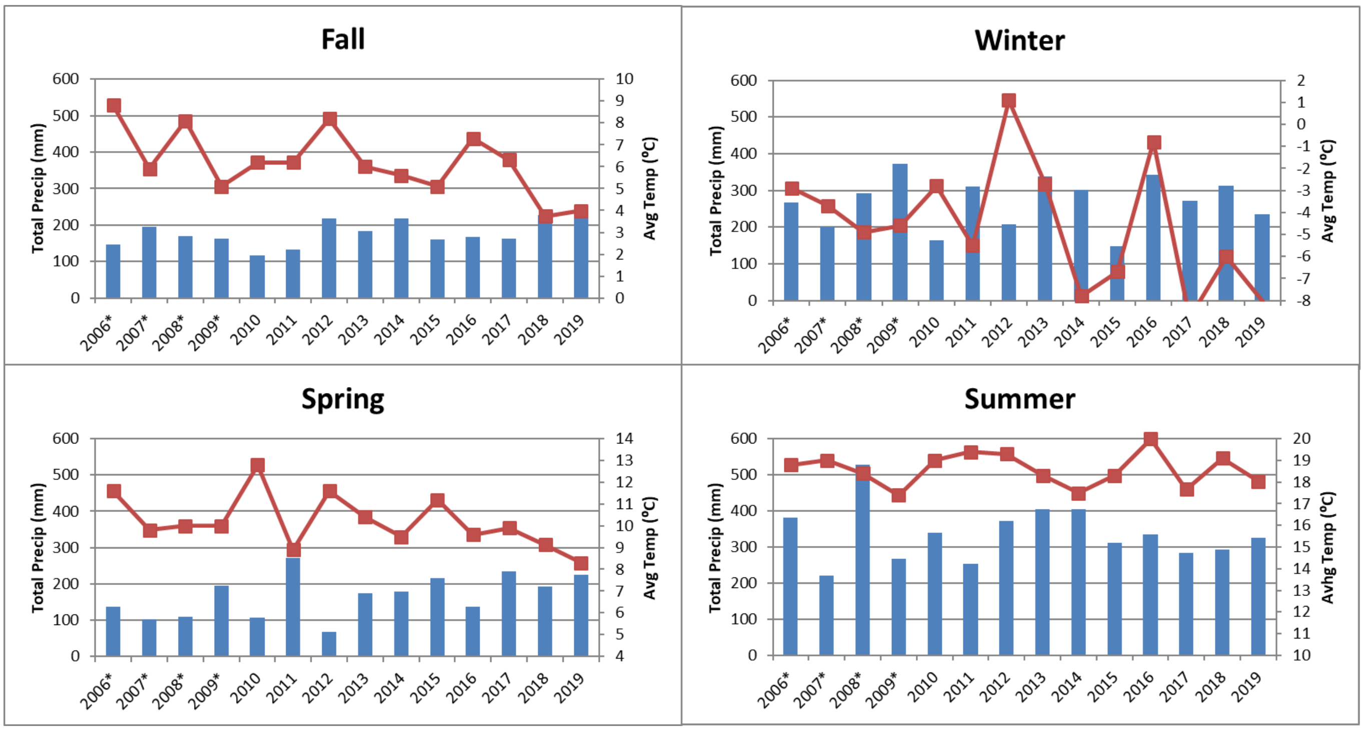


Figure 2-2-9 Seasonal Precipitation and Temperature, Blended data 2010-2019, Roseville Station Data 2006-2009

Table 2-2-9 Pre- and During- Development Annual Precipitation and Average Temperatures

Pre-Development Climate Conditions		
Year	**Total Precipitation (mm)**	**Average Temperature (˚C)**
2006*	932.9	8.7
2007*	717.2	7.7
2008*	1100.3	6.9
2009*	998.3	7.0
2010	728.4	8.4
2011	967.6	7.9

Average Pre-Development	907.5	7.8
During-Development Climate Conditions		
Year	**Total Precipitation (mm)**	**Average Temperature (˚C)**
2012	865.2	9.8
2013	1097.8	7.4
2014	1102.3	6.0
2015	834.1	7.3
2016	982.6	8.9
2017	952.0	7.5
2018	1026.8	7.3
2019	1012.0	6.4
Average During-Development	984.1	7.6
Long-term Average Values (Stantec 2009)	**882.1**	**8.7**
Long-term Average Values (GRCA 2018)	**899**	**7.3**

Notes: * indicates only Roseville station data reported

2.2.5.2 Streamflow Monitoring and Analysis

Flow monitoring data for the years 1998-2019 was collected from New Dundee Road and Dickie Settlement Road stations. There were a variety of different temporal patterns used throughout the years including 1-hour, 30-min, 15-min, and 10-minute (min) intervals. The entirety of Blair Creek subwatershed is 18.5 km^2, approximately 6 km^2 is upstream of New Dundee Road station, approximately 17 km^2 is upstream of Dickie Settlement Road station. To estimate surface water quantity parameters an FFA, using log Pearson III, and a flood duration curve (FDC) were completed. Pre-development GRCA flow data for New Dundee Road and Dickie Settlement Road was considered respectively, to be for the periods 2006-2013 and 2006-2012. Cumulative data from each station for 2006 to 2019 was used for the during-development FFA. The during-development data set included pre-development water years "to increase sample size and accuracy for determination of return periods" (GRCA,2018). Years preceding 2006 were excluded from the analyses, as was done in the CEA and 2016 SOW, "due incomplete data sets during higher flow events as predicted through rainfall records" (Aquafor Beech Limited 2016). Difference between flow metrics between this SOW and the 2016 SOW can be attributed to the inclusion of the CEA defined pre- and during-development periods as well as the exclusion of the incomplete datasets preceding 2006. Figure 2-2-10 contains the FFA for pre- and during-development for both New Dundee Road and Dickie Settlement Road. Figure 2-2-11 displays flow duration curves (FDC) for the pre- and during-development flows at New Dundee Road and Dickie Settlement Road. For the New Dundee Road FDC zero flow has been left out of the curve to maintain consistency with the 2016 SOW. These curves were used to find low flow and high flow metrics including Q50 (median flow), Q90 and Q95. Low flow and high flow metrics are presented in the following subsections. Baseflow was identified using the IHA software.

At New Dundee Road, the FFA resulted in increased peak flows for all return periods as seen in Figure 2-2-10 (A). The pre-development 2-year flow is 0.368 m^3/s and the during-development 2-year flow is now 0.502 m^3/s. In comparison to the CEA report (GRCA 2018) the during-development 2-year flow has also increased as previously is was 0.425 m^3/s. The baseflow at New Dundee Road decreased from 0.002318 m^3/s to 0.000552 m^3/s between development periods leading to a large increase in peakiness factor with pre-development being 167 and during-development being 909. In comparing Figure 2-2-11 (A) and (B) for New Dundee Road, the max hourly flow is more than five times greater in the during-development curve, this increase supports the evidence seen in Figure 2-2-10 (A) that flood frequency at New Dundee Road is increasing.

At Dickie Settlement Road, the FFA resulted in increased flows for shorter return periods and decreased flows for return periods of 10 years or greater, as can be seen in Figure 2-2-10 (B). The pre-development 2-year flow is 2.40 m^3/s and the during-development 2-year flow is now 2.88 m^3/s. In comparison to the CEA report, the during-development 2-year flow has also increased as previously is was 2.69 m^3/s. The baseflow decreased slightly between pre- and during-development periods from 0.139 m^3/s to 0.121 m^3/s and corresponding to this peakiness factor increased slightly from 17.3 to 23.8.

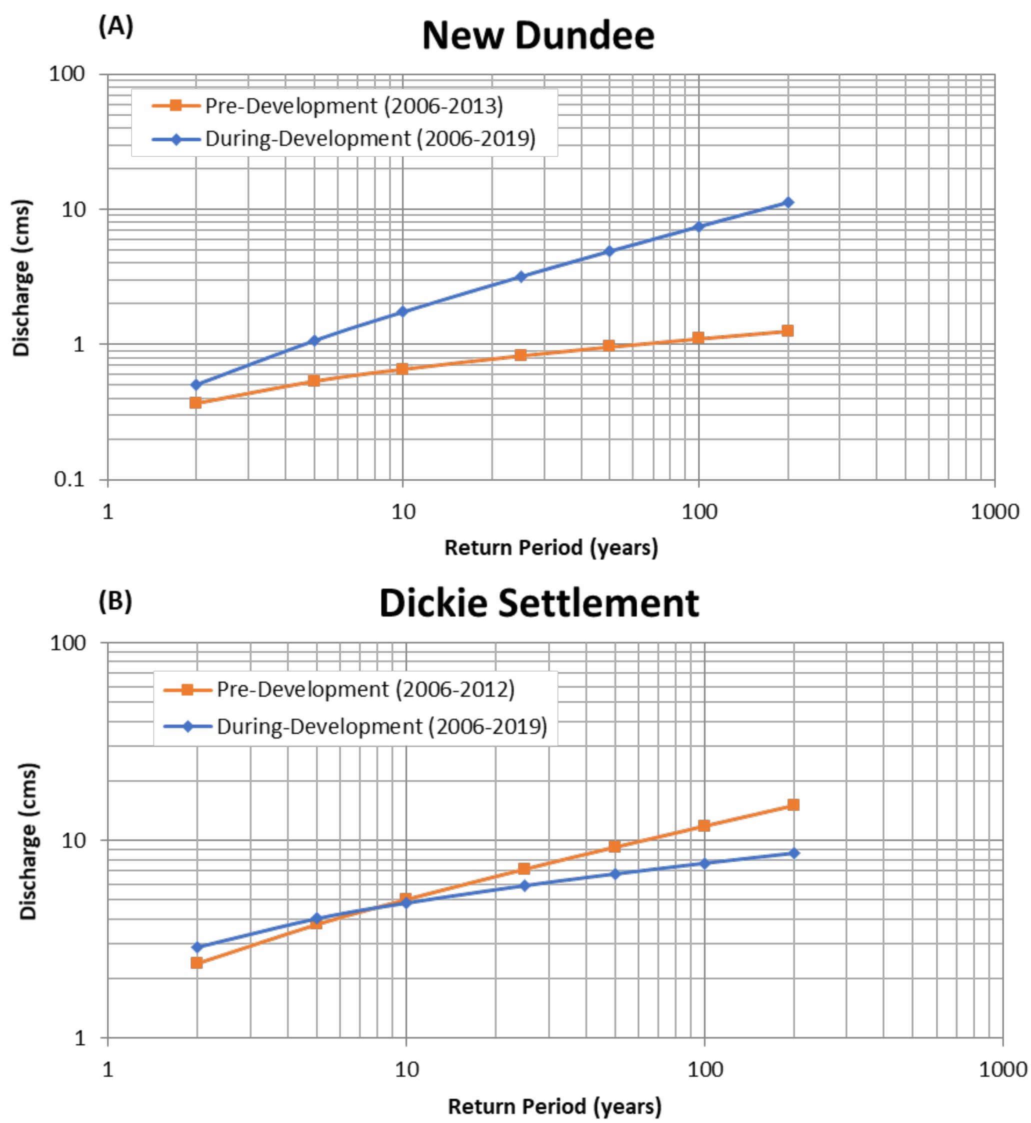


Figure 2-2-10 Comparison of pre- and during-development FFA using log Pearson III for (A) New Dundee Road and (B) Dickie Settlement Road

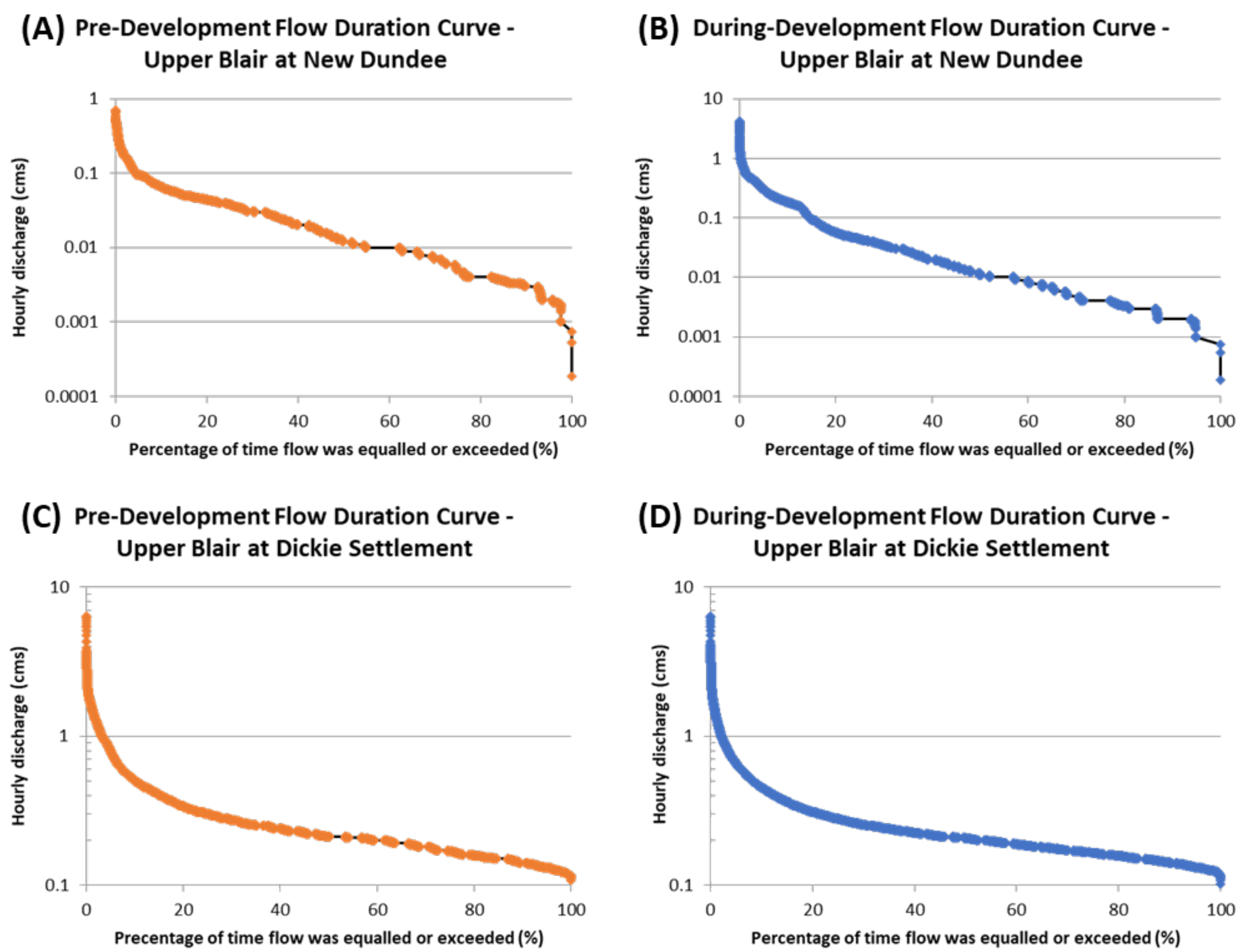


Figure 2-2-11 Flow duration curves for pre-development curves for (A) New Dundee Road and (C) Dickie Settlement Road and during-development (B) New Dundee Road and (D) Dickie Settlement Road

2.2.5.2.1 Low Flow Metrics

Table 2-2-10 contains the low flow metric for both New Dundee Road and Dickie Settlement Road for pre- and during-development. For New Dundee Road station mean annual flow increased and all other low flow metrics had slight decreases. For Dickie Settlement Road baseflow, mean annual flow, and median flow had small decreases and the Q90 and Q95 stayed stable from pre-development conditions. The flows at Dickie Settlement Road station are consistently higher than the flows seen at the New Dundee Road station. This is evident in the FDC curves in Figure 2-2-11. The gap between median flow and baseflow is a higher order of magnitude at New Dundee Road than at Dickie Settlement Road. As suggested by the 2016 SOW (Aquafor Beech Limited 2016), this indicated that the hydrology at Dickie Settlement Road, which is located further downstream than New Dundee Road, is influenced more by baseflow. It should also be noted that the median flow for New Dundee Road was around five times greater than baseflow for pre-development and is now almost twenty times greater in during-development conditions.

Table 2-2-10 Low flow metrics

Station	Hydrologic Metric	Pre-Development	During-Development
New Dundee Road	Q50 (m^3/s) (Median Flow)	0.012	0.011
	Q90 (m^3/s)	0.003	0.002
	Q95 (m^3/s)	0.002	0.001
	Mean Annual Flow (m^3/s)	0.023	0.049
	Baseflow (m^3/s)	0.002318	0.000552
Dickie Settlement Road	Q50 (m^3/s) (Median Flow)	0.210	0.206
	Q90 (m^3/s)	0.140	0.141
	Q95 (m^3/s)	0.130	0.132
	Mean Annual Flow (m^3/s)	0.283	0.277
	Baseflow (m^3/s)	0.139	0.121

2.2.5.2.2 High Flow Metrics

The peak flows calculated using FFA are seen in Figure 2-2-10 for their respective return periods. Table 2-2-11 displays the 2-year and 25-year (riparian flow) peak flows for both pre- and during-development periods for New Dundee Road and Dickie Settlement Road monitoring stations.

Table 2-2-11 High Flow Metrics

Station	Hydrologic Metric	Pre-Development	During-Development
New Dundee Road	2 Year Peak Flow (m^3/s)	0.368	0.502
	Riparian Flow 25 Year Peak Flow (m^3/s)	0.825	3.180
Dickie Settlement Road	2 Year Flow (m^3/s)	2.40	2.88
	Riparian Flow 25 Year Peak Flow (m^3/s)	7.16	5.91

Table 2-2-12 provides a comparison of the 2020 SOW FFA, the modelled flows from this current SOW, the 2018 CEA (GRCA 2018), the 2016 SOW (Aquafor Beech Limited 2016) and the FDS (Stantec 2009). Both monitoring stations during-development flows have trended towards the larger modeled flows of the FDS. The 2016 SOW FFA 2-year flow values can be considered an underestimate as they are less than both the 2020 SOW and FDS analysis. The 2018 CEA 2-year flow at New Dundee Road is less than the current value and greater than the 2016 SOW indicating an upward trend in the 2-year peak flow value as development has continued. The Dickie Settlement Road 2-year peak flow values are similar across all the models.

Table 2-2-12 Comparison between the modeled and observed 2-Year Stream Flows 2020 SOW, 2016 SOW, and FDS

2-Year Flow	FFA Log Pearson III 2020 SOW (m^3/s)	FFA Log Pearson III 2018 CEA (m^3/s)	FFA Log Pearson III 2016 SOW (m^3/s)	Modeled (Stantec, 2009) (m^3/s)
At New Dundee Road	0.502	0.452	0.426	0.78
At Dickie Settlement Road	2.88	2.69	2.84	2.91

2.2.5.2.3 Surface Water Quantity Parameters

The five parameters described in Section 2.1.3 were calculated based on the low and high flow metrics seen in the previous two sections. The resulting metrics for the parameters are displayed for New Dundee Road and Dickie Settlement Road respectively in Table 2-2-13 and Table 2-2-14.

As the baseflow input at New Dundee Road is very small the peakiness factor is correspondingly much higher than that which is found at Dickie Settlement Road. Previously in the 2016 SOW, it was noted that "any development upstream of New Dundee Road would add to the flashiness of the existing hydrograph" (Aquafor Beech Limited 2016) therefore it is important to note that the peakiness factor has increased by over a factor of five.

At New Dundee Road, baseflow contribution to stream flow has decreased from approximately ten to one percent between pre- and during-development periods. Baseflow contribution at Dickie Settlement Road has remained fairly constant between development periods and makes up almost fifty percent of stream flow.

Overall, Dickie Settlement Road saw small changes in flow parameters whereas at New Dundee Road some very large differences occurred between pre- and during-development. In addition to the increase in peakiness factor, peak flow frequency change beyond bankfull flow increased by more than a factor of sixteen. At New Dundee Road significant decrease in baseflow, of 76 percent, was seen which has led to large changes in these other related parameters.

Table 2-2-13 New Dundee Road Parameters Pre- and During-Development Conditions Summary

Station	Parameters	Pre-Development	During-development
New Dundee Road	1. Peakiness factor (2-year peak flow/baseflow)	2-Year Peak Flow = 0.386 m^3/s Baseflow = 0.002318 m^3/s Peakiness Factor = 167	2-Year Peak Flow = 0.502 m^3/s Baseflow = 0.000552 m^3/s Peakiness Factor = 909
	2. Annual runoff volume/area 3. Baseflow	Median flow (direct + baseflow) = 63.1 mm/year Baseflow = 12.2 mm/year (Assumption drainage area = 6 km^2)	Median flow (direct + baseflow) = 57.8 mm/year Baseflow = 2.9 mm/year (Assumption drainage area = 6 km^2)
	4. Ratio of baseflow to mean annual flow	Baseflow/mean annual flow = 0.101	Baseflow/mean annual flow = 0.011
	5. Peak flow frequency change beyond bankfull flow	25-Year Peak Flow = 0.825 m^3/s Baseflow = 0.002318 m^3/s 25-Year Peak Flow/Baseflow = 355.9	25-Year Peak Flow = 3.180 m^3/s Baseflow = 0.000552 m^3/s 25-Year Peak Flow/Baseflow = 5760.9

Table 2-2-14 Dickie Settlement Road Parameters Pre- and During-Development Conditions Summary

Station	Parameters	Pre-Development	During-development
Dickie Settlement Road	1. Peakiness factor (2-year peak flow/baseflow)	2-Year Peak Flow = 2.40 m^3/s Baseflow = 0.139 m^3/s Peakiness Factor = 17.3	2-Year Peak Flow = 2.88 m^3/s Baseflow = 0.121 m^3/s Peakiness Factor = 23.8
	2. Annual runoff volume/area 3. Baseflow	Median flow (direct + baseflow) = 389.6 mm/year Baseflow = 257.9 mm/year (Assumed drainage area = 17 km^2)	Median flow (direct + baseflow) = 382.1 mm/year Baseflow = 224.4 mm/year (Assumed drainage area = 17 km^2)
	4. Ratio of baseflow to mean annual flow	Baseflow/mean annual flow = 0.491	Baseflow/mean annual flow = 0.437
	5. Peak flow frequency change beyond bankfull flow	25-Year Peak Flow = 7.16 m^3/s Baseflow = 0.139 m^3/s 25-Year Peak Flow/Baseflow = 51.5	25-Year Peak Flow = 5.91 m^3/s Baseflow = 0.121 m^3/s 25-Year Peak Flow/Baseflow = 48.8

Water balance estimates for both pre- and during-development are provided for New Dundee Road and Dickie Settlement Road respectively in Table 2-2-15 and Table 2-2-16. The ET values were cited from the modeling results in the BBB study (CH2M Gore & Storrie Limited 1997). The use of the BBB ET values may be a source of inaccuracy as the annual average precipitation was calculated as the average of all annual precipitations for the designated time periods. Further assessment of the approach to ET calculation is warranted in the next SOW.

As indicated int the BBB Study (CH2M Gore & Storrie Limited 1997), FDS (Stantec 2009), and summarized in the 2016 SOW, “Further investigation of the interconnectedness between the swamp system and the creek is warranted to accurately assess water balance at the New Dundee Road gauge and provide a better idea about the net storage in the swamp system, and reasonable estimates for the baseflow and net storage at that location” (Aquafor Beech Limited 2016).

Table 2-2-15 Annual water Balance Estimates for New Dundee Road Pre- and During-Development

Period	Annual Precipitation (mm)	Evapotranspiration (mm)	Direct Runoff (mm)	Baseflow (mm)	Net Storage (mm)
Pre-development New Dundee Road (2006-2013)	926.0	455	50.9	12.2	407.9
During-development New Dundee Road (2006-2019)	951.3	455	54.9	2.9	438.5

Table 2-2-16 Annual water Balance Estimates for Dickie Settlement Road Pre- and During-Development

Period	Annual Precipitation (mm)	Evapotranspiration (mm)	Direct Runoff (mm)	Baseflow (mm)	Net Storage (mm)
Pre-development Dickie Settlement Road (2006-2012)	901.4	455	131.7	257.9	56.8
During-development Dickie Settlement Road (2006-2019)	951.3	455	157.7	224.4	114.2

2.2.5.3 Indicators of Hydrologic Alteration (IHA)

The IHA software was developed by the Nature Conservancy “to calculate hydrologic regime characteristics of natural and altered streams” (GRCA 2018). The software is used to calculate 33 hydrologic flow parameters categorized into five groups and an additional 34 Environmental Flow Components (EFCs). The IHA parameter groups can be seen in Table 2-2-17, these parameters provide “useful information for those trying to understand the hydrologic impacts of human activities or trying to develop environmental flow recommendations for water managers” (The Nature Conservancy 2018).

Date and daily mean streamflow were input into the IHA software (version 7.1) and flows were calculated based on the defined years. The water year was defined to start on October 1st and run until September 30th of the following year. Data was divided into pre- and post- impact periods using a defined impact date. The impact dates for both New Dundee Road and Dickie Settlement Road respectively, October 1, 2015 and October 1, 2012, are the beginning of the water year closest to the start of development in the respective sub-catchments. The impact date for Dickie Settlement Road is the same as the CEA but the New Dundee Road date was shifted forward to the 2015 water year as development started in the summer of 2014.

An RVA was applied to statistically compare the pre- and post-impact periods, or in terms of this report, the pre- and during-development periods for both monitoring sites. The changes in IHA parameters were quantified using RVA analysis. RVA analysis is only available for IHA parameters, and not for EFC parameters (GRCA 2018).

> “The RVA uses as its starting point either measured or synthesized daily streamflow values from a period during which human perturbations to the hydrological regime were negligible. This streamflow record is then characterized using [thirty-three] different hydrological [flow] parameters … Using the RVA, a range of variation in each of the [thirty-three] parameters, e.g. the values at ±1 standard deviation from the mean or the twenty-fifth to seventy-fifth percentile range, are selected as initial flow targets. … targets are intended to guide the design of river management strategies” (Richter et al. 1997).

The boundaries for the RVA categories:

- Low = 0-33 percentile
- Middle = 34-66 percentile
- High = 67-100 percentile

The Hydrologic Alteration Factor is then calculated using the equation:

$$\frac{(observed\ frequency - expected\ frequency)}{expected\ frequency}$$

The user manual for the IHA software recommends at least 20 years of daily flow data be used for both pre- and post-impact periods to accurately capture the climatic variability (GRCA 2018). Therefore, results should be interpreted with caution and the weight-of-evidence should be used, drawing on other lines of evidence in support of the IHA parameters.

Table 2-2-17 Description of IHA parameter groups; Adapted from (GRCA, 2005) (GRCA, 2018)

Group	Description	Number of Parameters
1	Magnitude of monthly water conditions	12
2	Magnitude and duration of annual extremes	12
3	Timing of annual extremes	2
4	Frequency and duration of high and low pulses	4
5	Rate and frequency of change in conditions	3

Included below is a discussion focused on leveraging the updated during-development dataset and revisiting the relevant parameters of the 33 IHA and 34 EFC parameters that were highlighted in the CEA (GRCA 2018).

Figure 2-2-12 includes the maximum flow indices for pre- and post-impact at New Dundee Road monitoring station. The 1-day, 3-day, 7-day, and 30-day maximum flows are the moving averages for each time span over an entire water year. For all cases the post- impact median was a greater flow rate than the pre-impact 75th percentile. This agrees with the CEA and suggests increased maximum flows at New Dundee Road in the developed or post-impact time period.

Figure 2-2-13 compares the minimum flow indices for pre- and post-impact at New Dundee Road for 1-day, 3-day, 7-day, and 30-day moving averages. It can be noted that the year 2019 had a much higher minimum flow for 3-day, 7-day and 30-day cases than previous years.

In Figure 2-2-14 low and high pulse counts are displayed. Low and high pulse counts are the number of days that the flow is above the 75th percentile (high pulse) and below the 25th percentile (low pulse). The median for low and high pulse counts has increased for post-impact which is in agreement with the CEA (GRCA 2018) and continues to suggest that the stream at New Dundee Road is having a flashier response to events. This is also supported by the increased during-development peakiness value seen in Table 2-2-13.

RVA was performed on the 33 IHA parameters for New Dundee Road and the resulting categories for each parameter are displayed in Figure 2-2-15. A positive value represents where post-impact parameters were greater than pre-impact, a negative value is the opposite where pre-impact parameters were greater than post-impact. The red category represents a high range of parameter variability, with RVA between 67-100 percent. The green category represents a middle range of parameter variability with RVA between 34-66 percent, and the yellow category represents a low range of parameter variability with RVA between 0-33 percent.

Figure 2-2-16 displays the 33 hydrologic alteration factors and their greatest RVA category. Minimum flows have decreased for all moving averages which indicates a decrease in baseflow. Maximum flows, excluding the 90-day moving average, have all increased and are in the red RVA category. The combination of increasing peak flows and decreasing minimum flows leads to an increased peakiness factor and correspondingly, a flashier stream. For monthly median flows in the highest variability, i.e., red RVA, category, the largest change occurred with increased flows during November and August, and decreased flow in May.

Figure 2-1-11 displays key low and high flow metrics at Dickie Settlement Road station that were reported in the CEA (GRCA 2018). There is no significant change in maximum flow for the 1-Day or 30-Day moving average. Additionally, for minimum flows, the 1-day moving average minimum appears to be decreasing as the median flow is lower than the 25th percentile from the pre-impact. This trend does not hold for the 30-day minimum, as the 2019 water year 30-day minimum flow is much greater than all previous years, therefore, trends here are inconclusive.

The same RVA was applied to Dickie Settlement Road, Figure 2-2-17 contains the RVA categories for all 33 IHA parameters. For monthly median flows in the highest variability, i.e., red RVA, category, there was increased median flow in April and decreased median flow in August. An increase for minimum flow occurred for all moving-averages, excluding 90-days, suggesting increased baseflow. Change in maximum flow varied by averaging periods, and high and low pulse counts both increased.

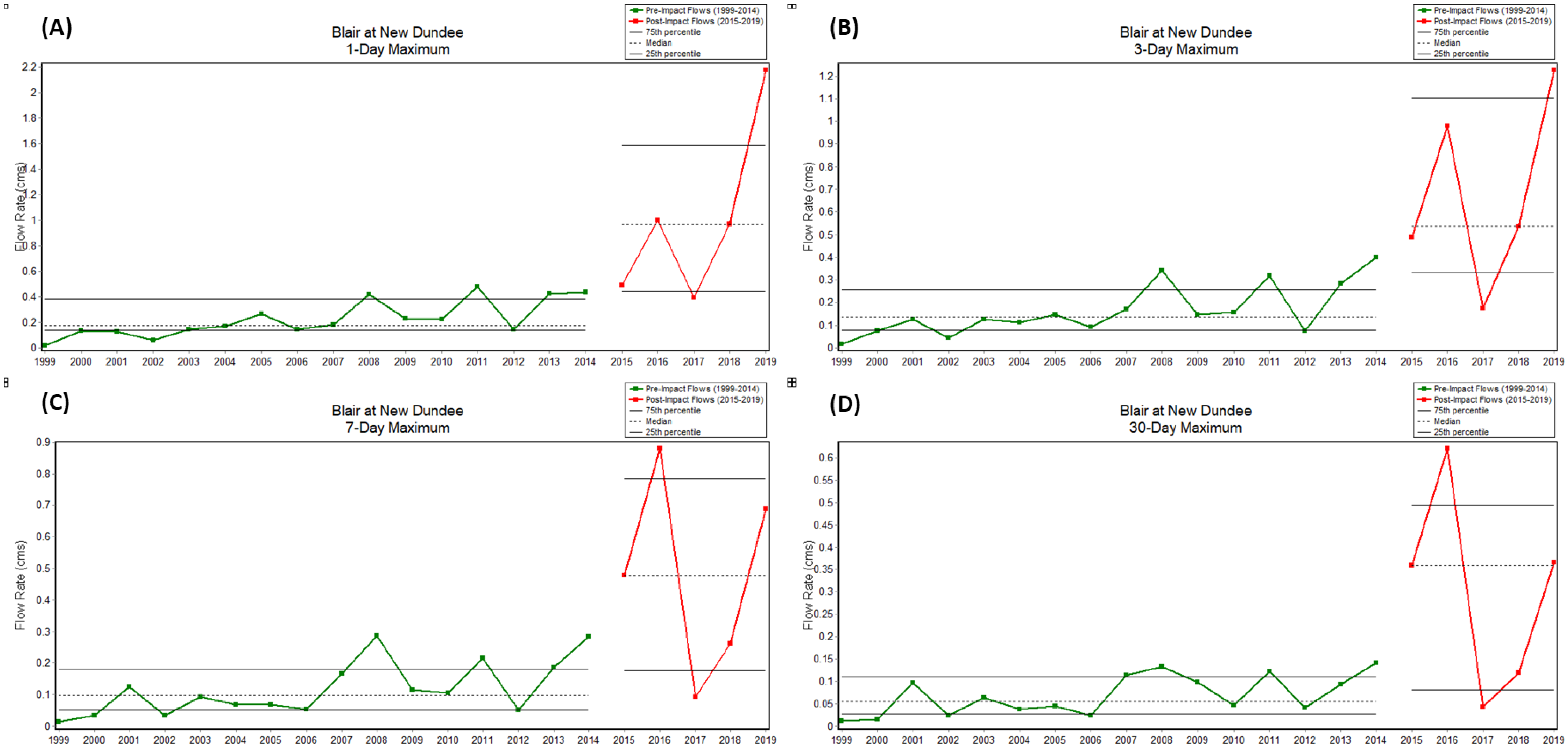


Figure 2-2-12 Indicator of Hydrologic Alteration Group 2 high flow metrics for Blair Creek at New Dundee Road Station A) 1-day maximum B) 3-day maximum C) 7-day maximum and D) 30-day maximum

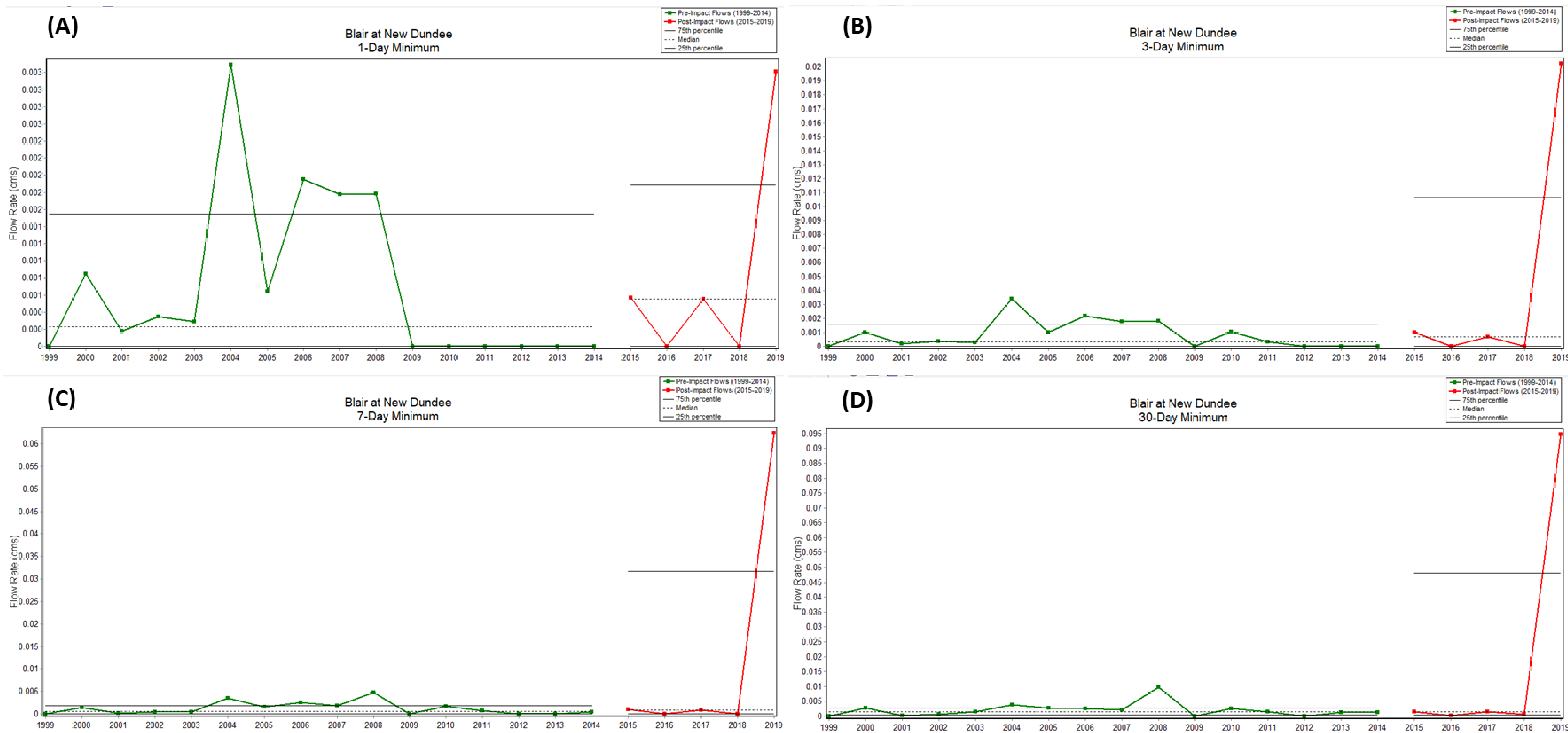


Figure 2-2-13 Indicator of Hydrologic Alteration Group 2 low flow metrics for Blair Creek at New Dundee Road Station A) 1-day minimum B) 3-day minimum C) 7-day minimum and D) 30-day minimum

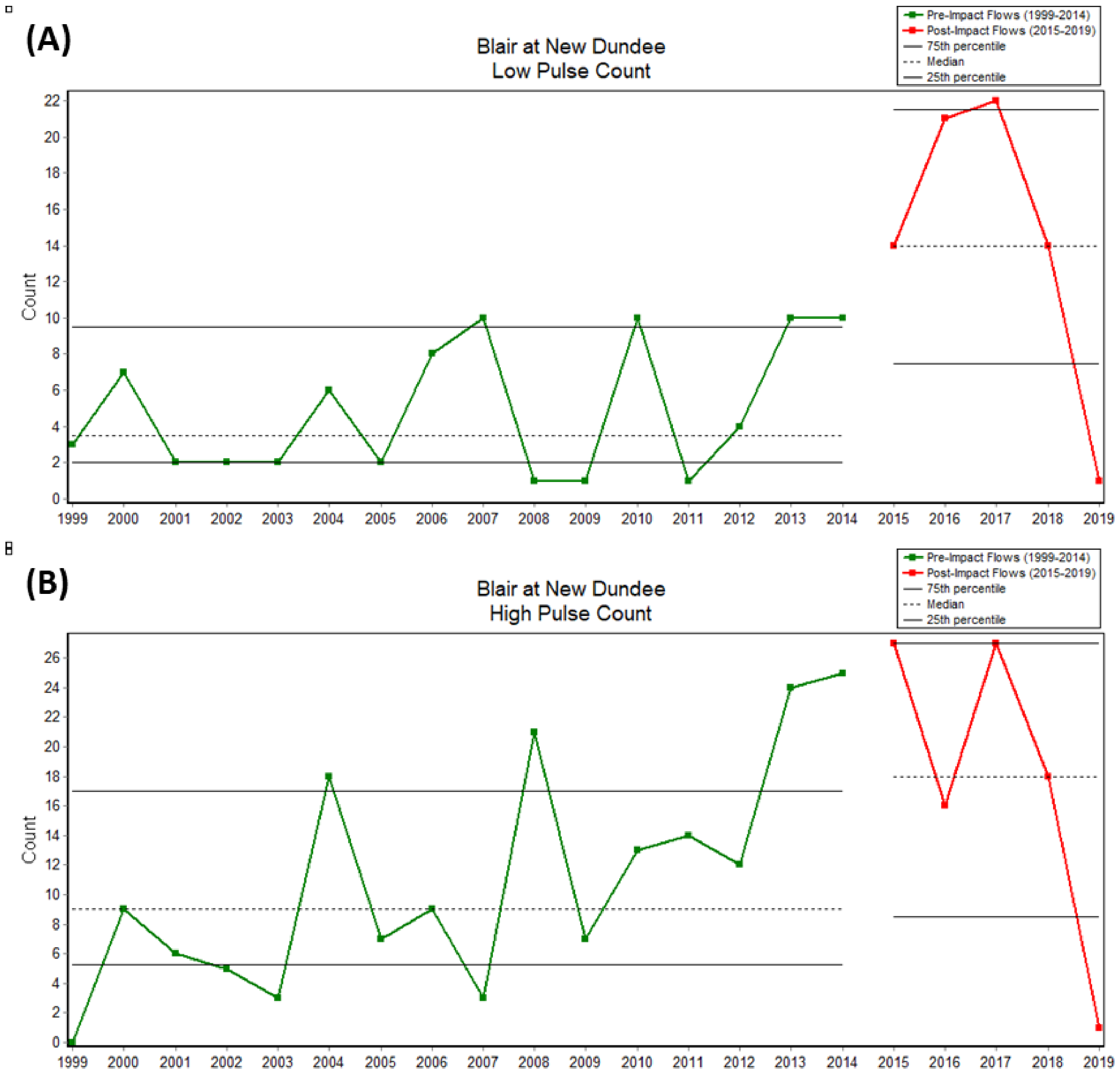


Figure 2-2-14 Group 4 metrics at New Dundee Road A) low pulse count B) high pulse count

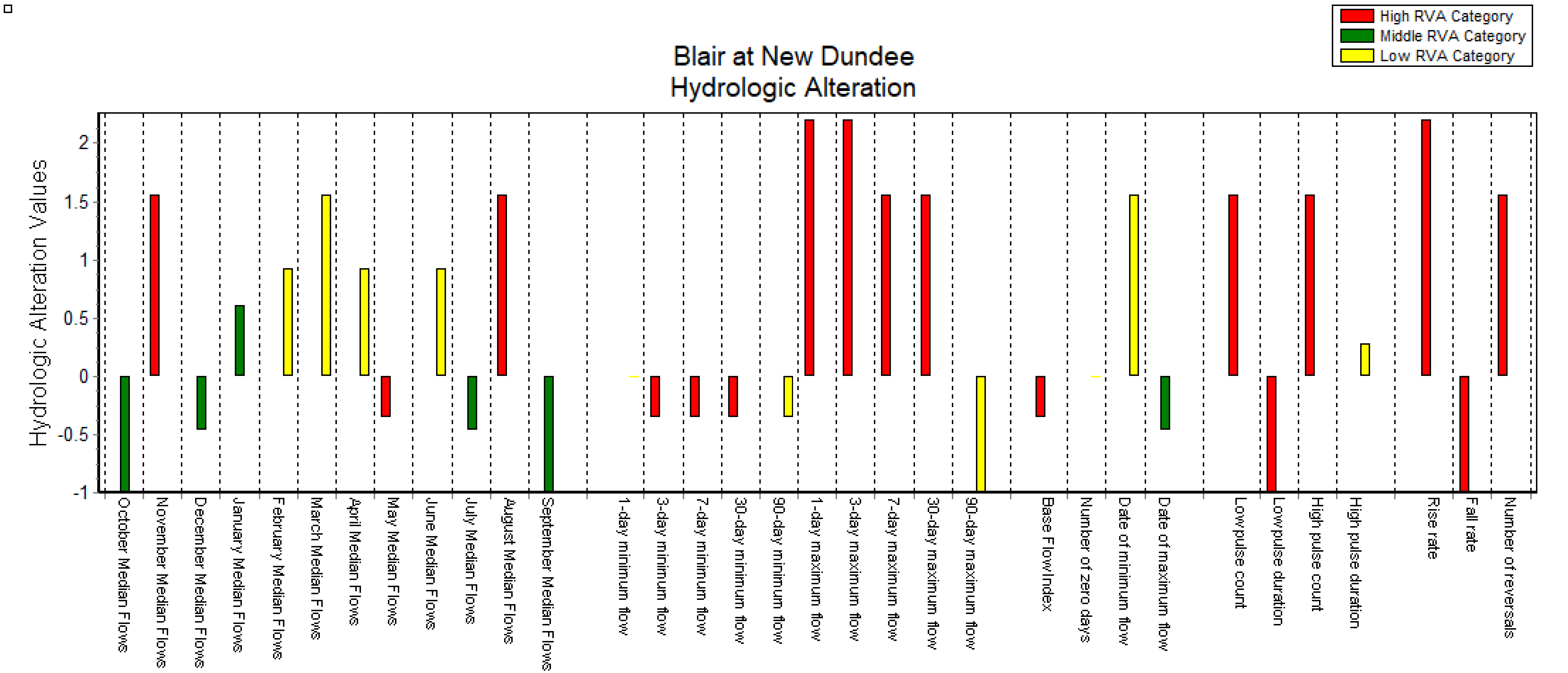


Figure 2-2-15 Range of Variability Analysis summary for New Dundee Road indication the highest Hydrologic Alteration Factor for each of the 33 IHA flow parameters.

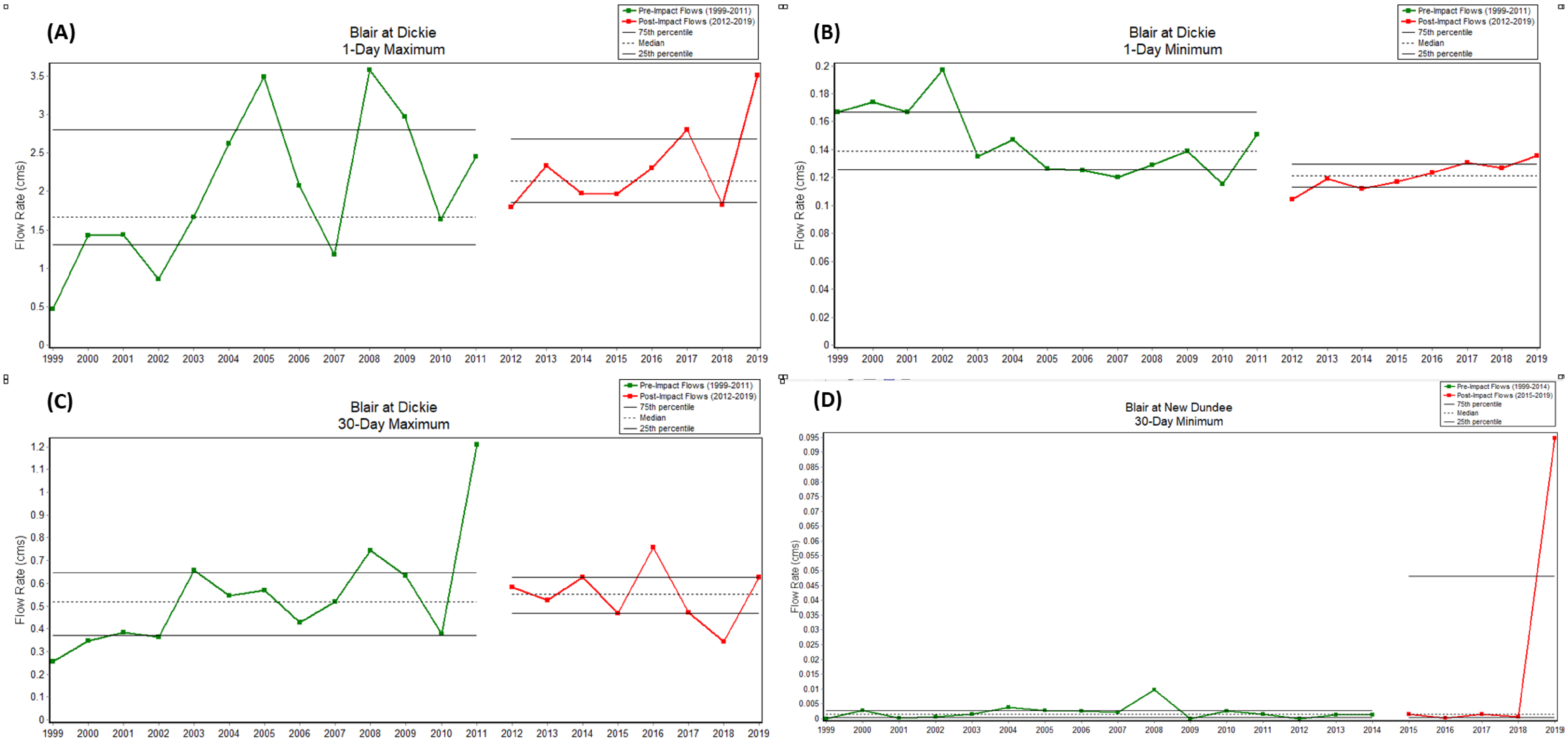


Figure 2-2-16 Group 2 low and high flow metrics for Dickie Settlement Road A) 1-day maximum B) 1-day minimum C) 30-day maximum and D) 30-day minimum

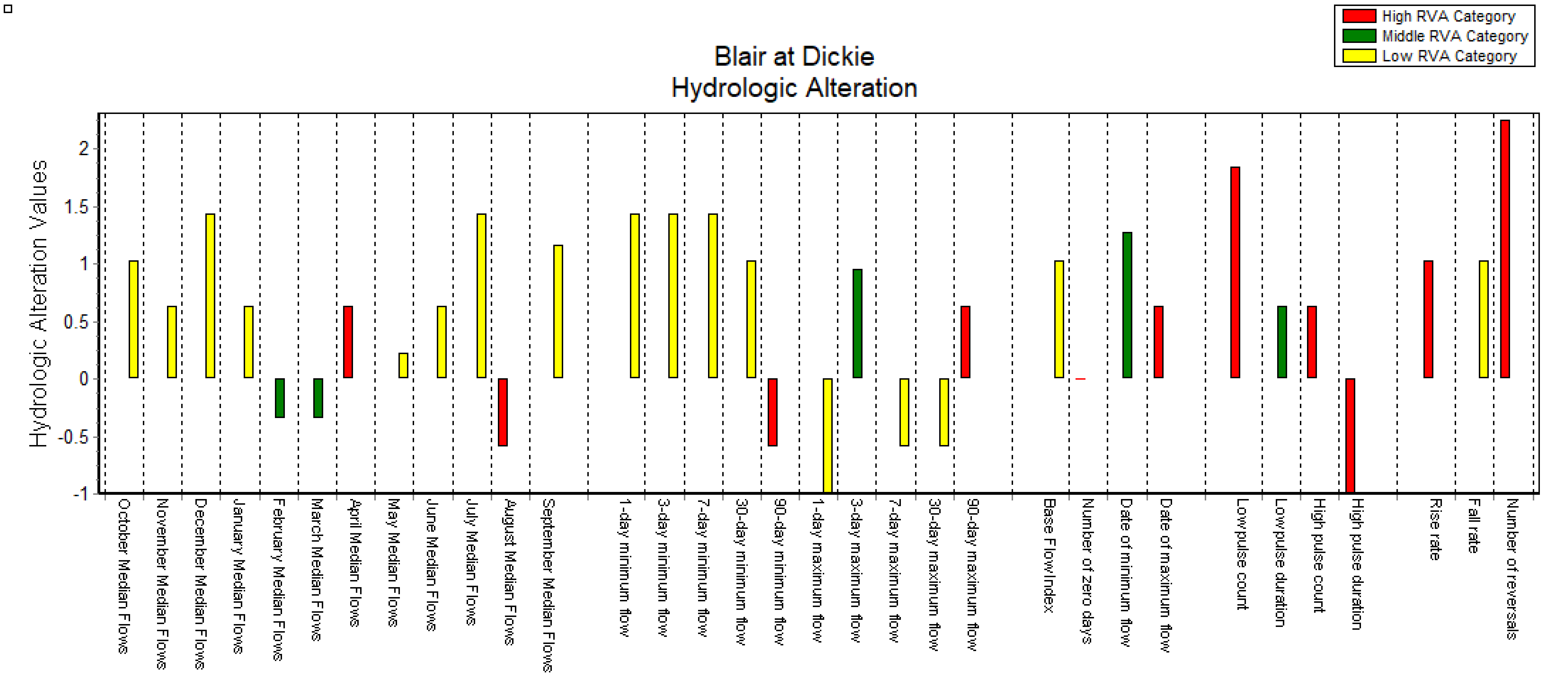


Figure 2-2-17 Range of Variability Analysis summary for Dickie Settlement Road indication the highest Hydrologic Alteration Factor for each of the 33 IHA flow parameters.

2.2.5.4 Overall System Hydrology

Previous reports, including the BBB study (CH2M Gore & Storrie Limited 1997), FDS (Stantec 2009), 2016 SOW (Aquafor Beech Limited 2016), and CEA (GRCA 2018) have noted that the headwaters of Blair Creek convey little baseflow but do convey significant runoff in wet conditions. Additionally, a large portion of water which infiltrates into the ground, flows into the Roseville Swamp. Monitoring results from New Dundee Road station, located upstream of Roseville swamp, and Dickie Settlement Road, located downstream of the swamp, agree with the previous hydrologic observations. The following findings confirm the conclusions of previous studies:

1) Peakiness factor: As baseflow is low at New Dundee Road, peak flows have a more dominant role in shaping hydrographs.
2) Annual runoff volume/area: Baseflow is a small portion of the water balance in the headwaters of Blair Creek.
3) Baseflow: Baseflow at New Dundee Road is now 2.9 mm/year and at Dickie Settlement Road it is 224.4 mm/year.
4) Ratio of baseflow to mean annual flow: Baseflow at New Dundee Road only accounts for one percent of mean annual flow, at Dickie Settlement Road baseflow accounts for approximately 44 percent.
5) Change in frequency of peak flows beyond bankfull flow: The data shows that peak flow beyond bankfull flow has a very high frequency at New Dundee Road station.

The IHA trends for Dickie Settlement Road suggest increased baseflow, consistent with the CEA (GRCA 2018). The IHA parameters should be continually updated to monitor for the occurrence of significant trends. For New Dundee Road, the IHA show a flashier response at New Dundee Road than previously observed.

2.2.6 Water Quantity Conclusions

Water quantity data was analyzed for the years 2006-2019. The results provide insight into the existing condition at Blair Creek for the five parameters and four key indicators, watershed peakiness (flow rate), annual water balance (hydrologic regime), groundwater functions (surface-groundwater interactions), and in-channel high flows (eco-hydrology). Section 3 incorporates the parameters and indicators into goals, objectives, and targets, and section 4 discusses monitoring plan recommendations based on the existing conditions and current practices.

The key findings of the surface water quantity analyses are as follows:

1) Precipitation may be slightly underestimated due to data gaps from Roseville station.
2) Through the FFA and FDC, increased peak flows and decreased baseflow at New Dundee Road station has been observed. These changes have led to a flashier stream response as well as risk of higher frequency flooding.
3) Due to the impact of Roseville swamp, observed data at New Dundee Road station may not be able to accurately describe surface-groundwater interactions.
4) IHA parameters indicate a flashier response at New Dundee Road station. The range of available data for the IHA parameters is not large enough to draw significant conclusions and a weight of evidence approach was used in conjunction with the resulting observations to draw conclusions.

2.3 Surface Water Quality

2.3.1 Context

As per the recommendations of the FDS (Stantec 2009), the GRCA has been monitoring the water quality of Blair Creek from 2006 through to the current day. Prior to this, the monitoring parameter recommendations from the BBB Study (CH2M Gore & Storrie Limited 1997) were used. The analyzed water quality parameters have remained relatively constant throughout the life span of the current monitoring program. The water quality parameters are stratified into wet and dry conditions to compare samples with similar flow and precipitation threshold values.

2.3.2 Summary of Past Monitoring

This section provides a summary of surface water quality monitoring from 1997 to 2019. Locations of current monitoring locations can be seen in Figure 2-3-1.

The BBB study (CH2M Gore & Storrie Limited 1997) monitored water quality from 1993 and 1994. Continuous temperature and DO measurements were taken at five different monitoring stations in Blair Creek on hourly timesteps. The interval of time which the measurements were taken over was inconsistent and ranged from five days to over a month. Discrete chemical analyses were also completed approximately biannually for grab samples from the five monitoring stations, detailed in Table 2-3-1. Additionally, temperature, dissolved oxygen, conductivity, and pH were also monitored bimonthly at these same stations.

Table 2-3-1 Summary of BBB Study Past Monitoring of Blair Creek Subwatershed Water Quality

Station	Station Description	Sample Dates
BBB01	Blair Creek and Reichert Drive	06/24/1994, 08/24/1994
BBB02	Roseville tributary and Reichert Drive	06/24/1994, 08/24/1994
BBB04	Upstream of the mouth of Blair Creek	02/17/1994, 06/24/1994, 08/24/1994
BBB13	Tributary upstream of Highway 401	02/17/1994, 08/24/1994
BBB14	Blair creek downstream of the confluence with the Roseville tributary	02/17/1994

The monitoring program of the GRCA was established in 2006, and then expanded upon following the completion of the FDS.

> "The system-wide monitoring program was based on a BACI (before, after, control, impact) study design. BACI study designs compare impacted and control sites both before and after a large-scale change to the system, which in the case of Blair Creek, is residential land development." (GRCA 2017)

From 2006 until 2016, water quality monitoring was completed with grab samples. From 2016 onward, in addition to grab samples, autosamplers were installed to collect flow proportionate samples. Autosampler data generally exists for high flow events. The composite samples from autosampling have been incorporated into the water quality data set for the 2020 SOW. Sampling frequency has also increased since 2009 from approximately quarterly to monthly and includes sampling in winter and after significant rainfall events. A summary of the surface water quality monitoring dates and monitoring stations is provided in Table 2-3-2.

N

0 200 400 600

Meters

Watercourse

Municipal Boundaries

Upper Blair Creek Subwatershed Study Area

Notes:
1. Image of figure 2.2.1 from page 62, Upper Blair Creek- State of the Watershed (SOW) Report, 2016.

Figure 2-3-1
Existing Surface Water Quality Monitoring Locations
Upper Blair Creek State of the Watershed
City of Kitchener
Upper Blair Creek Subwatershed, Kitchener, Ontario

Jacobs

\\DC1VS01\GISPROJ\K\KITCHENERCITYOF\UPPERBLAIRCREEK_P20_005\MAPFILES\SOW\2_3_1_EXISITING_SW_STATIONS.MXD SCYR 1/26/2021 5:00:40 PM

Table 2-3-2 Surface Water Quality Monitoring Summary

Station Location	Station ID	Easting	Northing	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Blair Creek upstream Reidel Drive	2414061	544106	4802158						X	X	X	X	X	X	X	X	X
Blair Creek downstream Reidel Drive	2414069	544109	4802153					X									
Blair Creek upstream of Dodge Drive (New)	2414049	545517	4801853										X	X	X	X	X
Blair Creek upstream of Dodge Drive Tributary	2414058	546086	4801975					X	X	X	X	X					
Blair Creek upstream of New Dundee Road	2414002	546219	4802014	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Blair Creek upstream of Reichert Drive	2414068	546760	4802010						X	X	X	X	X				
Blair Creek downstream of Reichert Drive	2414044	546774	4802010				X	X						X	X	X	X
Roseville Tributary upstream of Reichert Drive	2414062	546767	4801734						X	X	X	X	X				
Roseville Tributary downstream of Reichert Drive	2414045	546828	4801821				X	X						X	X	X	X
Blair Creek upstream of Dickie Settlement Road	2414001	549039	4802264			X	X	X	X	X	X	X		X	X	X	X
Blair Creek downstream of Dickie Settlement Road	2414060	549062	4802277	X	X												
Blair Creek upstream of the mouth	2414046	549663	4803774					X	X	X	X	X	X	X	X	X	X

Turbidity has been monitored at six separate stations for the dates listed in Table 2-3-3. The GRCA collected data continuously on intervals of 15 minutes using a YSI sonde instrument at the stations seen in Figure 2-3-2.

Table 2-3-3 Summary of GRCA Monitoring of Turbidity in Blair Creek Subwatershed

Station ID	Station Description	Years of Data Collection
2414001	Upstream Dickie Settlement Road	2013, 2014
2414002	Upstream New Dundee Road	2013-2019
2414044	Downstream Reichert Drive	2009-2019
2414045	Roseville Tributary Downstream Reichert Drive	2009-2019
2414049	Upstream Dodge Drive	2015-2019
2414061	Upstream of Reidel Drive	2013, 2015-2019
2414057	Downstream New Dundee Road	2009-2012

Watercourse
Municipal Boundaries
Upper Blair Creek Subwatershed Study Area

Existing Turbidity Monitoring Sites

- Blair Creek Downstream of Reichert Drive (2414044)
- Blair Creek Upstream of Dickie Settlement Road (2414001)
- Blair Creek Upstream of New Dundee Road (2414002)
- Blair Creek Upstream of Reidel Drive (2414061)
- Roseville Tributary Downstream of Reichert Drive (2414045)

Notes:
1. Image of figure 2.2.2 from page 64, Upper Blair Creek- State of the Watershed (SOW) Report, 2016.

Figure 2-3-2
Existing Turbidity Monitoring Locations
Upper Blair Creek State of the Watershed
City of Kitchener
Upper Blair Creek Subwatershed, Kitchener, Ontario

Jacobs

\\DC1VS01\GISPROJ\K\KITCHENERCITYOF\UPPERBLAIRCREEK_P20_005\MAPFILES\SOW\2_3_2_EXISITING_TURBIDITY_STATIONS.MXD SCYR 1/26/2021 5:01:28 PM

2.3.3 Data Analysis Water Chemistry

The data analysis for 2020 SOW focused on six chemical parameters, DO, TP, NO_3, dissolved Cl, total copper (Cu), total zinc (Zn) as well as TSS. Note that TP, Cl, and TSS were the three primary water quality indicators in the CEA (GRCA 2018); the larger set of six parameters was the subject of Objective 1d in the 2016 SOW (Aquafor Beech Limited 2016).

To analyze surface water quality, the samples were divided into wet and dry events using two methods. The 2016 SOW (Aquafor Beech Limited 2016) method characterizes samples taken when 10 mm or less rainfall occurs as dry and all other samples as wet. The CEA (GRCA 2018) method characterizes samples taken during events when the flow at Dickie Settlement Road is less than 0.4 m^3/s as dry and all other events as wet.

Table 2-3-4 through Table 2-3-10 represent wet weather, and Table 2-3-11 through Table 2-3-17 represent dry weather. These tables present data and statistics for the parameters DO, TP, NO_3, dissolved Cl, total Cu, total Zn, and TSS. Wet and dry periods were defined using the 2016 SOW method. The data in the tables is for the years 2014 – 2019, which is compared in the following text to the existing conditions (2008-2013) cited from the 2016 SOW (Aquafor Beech Limited 2016). Yellow highlighted cells represent occurrences where the new minimum or maximum was respectively below or above the previously defined range in the 2016 SOW, which underpinned the 'maintain status quo' targets in Objective 1d of the 2016 SOW. Cells highlighted in red are the 2014-2019 averages which exceed the objectives from the Provincial Water Quality Objectives (PWQO; Province of Ontario, 1994), Grand River Management Plan (GRCA, 2014), or Canadian Council of Ministers of the Environment (CCME, 1999), defined in the second column of each table.

DO must be maintained as it is integral in the growth and reproduction of aerobic aquatic life. The average DO value at Dodge Drive in dry weather did not meet the PWQO (Province of Ontario, 1994); all other monitoring stations had an average value above 7 milligrams per litre (mg/L). The minimum DO dropped below the 2016 SOW recorded minimums at Reidel Drive during wet conditions, Dickie Settlement Road during dry conditions, and at Reichert Drive during both wet and dry conditions. The upper reach of Blair Creek is more susceptible to oxygen depletion as the area upstream of New Dundee Road does not have perennial flow.

Excess phosphorus, beyond that needed for plant growth, can contribute to levels of eutrophication detrimental to the ecology of a stream, and therefore it is important to maintain phosphorus levels at or below the PWQO. Wet weather average phosphorus concentrations exceeded the PWQO of 0.03 mg/L at all stations. Phosphorus levels are expected to be higher at the upstream stations as these are closer to agricultural land. Results at upstream stations Reidel Drive, Dodge Drive and New Dundee Road all have dry weather average phosphorus concentrations exceeding PWQO which supports this expectation (Province of Ontario, 1994). The maximum phosphorus concentration increased from the 2016 SOW conditions at Reidel Drive, New Dundee Road, Roseville tributary and Dickie Settlement Road for both wet and dry weather, at the Mouth for only dry weather, and at Dodge Drive for only wet weather.

Nitrate has a similar effect in ecosystems as phosphorus and therefore must also be maintained at pre-development levels. Nitrate averages between 2014 and 2019 did not exceed the Grand River Management Plan (GRCA, 2014) objectives for any stations in either dry or wet weather. The maximum value for nitrate increased from the 2016 SOW conditions at Dodge Drive during wet weather and at New Dundee Road during both wet and dry weather. The minimum value for nitrate decreased from the 2016 SOW conditions at Roseville tributary and Dickie Settlement Road Drive during both wet and dry weather, and at Reidel Drive, Reichert Drive, and Mouth during only dry weather.

Chloride is produced from runoff containing road salt. Chloride is toxic to aquatic life and should be kept below 120 mg/L as per the CCME guideline (CCME, 1999). The average value for chloride did not exceed the CCME guideline for any station in dry or wet weather. The maximum values of chloride increased from the 2016 SOW for wet and dry conditions at Reidel Drive, Reichert Drive, and Dickie Settlement Road, for wet weather alone at the Mouth and Roseville tributary, and for dry weather at Dodge Drive and New Dundee Road.

Copper in quantities greater than 5 micrograms per litre (µg/L), as per the PWQO, is toxic to aquatic life Province of Ontario, 1994). Average wet weather values of copper exceeded the PWQO guidelines at Reidel Drive and Dodge Drive. The maximum concentration of copper increased from the 2016 SOW value for dry weather at New Dundee Road and the Mouth, and for wet weather at all stations except Dickie Settlement Road and the Mouth.

Zinc is toxic to microscopic organisms at quantities greater than 20 µg/L as per the PWQO (Province of Ontario, 1994). Average wet weather values of zinc exceeded the PWQO at Reidel Drive and Dodge Drive. Wet weather maximum values increased from the 2016 SOW reported values at Reidel Drive, Dodge Drive, New Dundee Road, Roseville Tributary and Reichert Drive.

High quantities of TSS causes many problems for stream health, therefore, pre-development conditions must be maintained. TSS maximum concentrations have increased from 2016 SOW reported values for dry weather at all stations except Dodge Drive, and for wet weather at all stations except Dickie Settlement Road and the Mouth. It is important to note that at four stations (Reidel Drive, Dodge Drive, New Dundee Road, and Roseville), the maximum wet weather TSS value is now greater than 120 mg/L, which was the maximum TSS concentration amongst all stations and weather conditions for the years 2006-2013.

Table 2-3-4 Wet Weather Surface Water Quality Data Summary at Reidel Drive

Wet Weather – Reidel Drive (2014-2019)							
Parameter	**Objective**	**# samples**	**min**	**max**	**average**	**standard deviation**	**median**
DO (mg/L)	7*	24	3.09	12.78	8.01	2.61	7.74
TP (mg/L)	0.03*	43	0.0400	1.9000	0.2651	0.3970	0.1100
NO_3, N (mg/L)	3.0**	43	0.005	2.010	0.494	0.389	0.430
Dissolved Cl (mg/L)	120***	43	1.33	120.00	26.62	20.94	22.00
Total Cu (µg/L)	5*	29	**ND**	44.0	5.9	9.7	2.3
Total Zn (µg/L)	20*	29	**ND**	302.0	31.8	70.1	6.8
TSS (mg/L)	N/A	43	1.1	830.0	70.9	170.0	10.3

* PWQO (Province of Ontario, 1994)

** Grand River Management Plan (GRCA, 2014)

*** CCME (CCME, 1999)

N/A = not applicable

ND = non-detect

Table 2-3-5 Wet Weather Surface Water Quality Data Summary at Dodge Drive Tributary

Wet Weather – Dodge Drive Tributary (2014-2019)							
Parameter	**Objective**	**# samples**	**min**	**max**	**average**	**standard deviation**	**median**
DO (mg/L)	7*	6	3.85	10.69	7.40	2.64	6.88
TP (mg/L)	0.03*	31	0.0210	1.9000	0.3191	0.4019	0.1600
NO_3, N (mg/L)	3.0**	31	**ND**	1.840	0.457	0.380	0.418
Dissolved Cl (mg/L)	120***	31	5.85	58.00	35.20	8.44	35.00
Total Cu (µg/L)	5*	31	**ND**	42.0	7.6	9.2	4.4
Total Zn (µg/L)	20*	31	**ND**	210.0	32.9	42.6	18.0
TSS (mg/L)	N/A	31	**ND**	2200.0	195.5	400.8	79.0

* PWQO (Province of Ontario, 1994)

** Grand River Management Plan (GRCA, 2014)

*** CCME (CCME, 1999)

Table 2-3-6 Wet Weather Surface Water Quality Data Summary at Upstream New Dundee Road

Wet Weather - Upstream New Dundee Road (2014-2019)							
Parameter	**Objective**	**# samples**	**min**	**max**	**average**	**standard deviation**	**median**
DO (mg/L)	7*	29	2.31	13.02	7.75	2.73	6.93
TP (mg/L)	0.03*	46	0.0178	0.6280	0.1047	0.1197	0.0576
NO_3, N (mg/L)	3.0**	46	0.010	2.260	0.186	0.341	0.065
Dissolved Cl (mg/L)	120***	46	12.4	66.00	42.52	11.36	41.30
Total Cu (µg/L)	5*	31	**ND**	10.0	2.2	2.3	1.5
Total Zn (µg/L)	20*	31	**ND**	25.6	7.5	6.8	4.3
TSS (mg/L)	N/A	46	**ND**	136.0	18.3	28.1	5.0

* PWQO (Province of Ontario, 1994)

** Grand River Management Plan (GRCA, 2014)

*** CCME (CCME, 1999)

Table 2-3-7 Wet Weather Surface Water Quality Data Summary at Roseville Tributary at Reichert Drive

Wet Weather – Roseville Tributary at Reichert Drive (2014-2019)							
Parameter	**Objective**	**# samples**	**min**	**max**	**average**	**standard deviation**	**median**
DO (mg/L)	7*	10	7.72	13.02	9.54	1.58	9.22
TP (mg/L)	0.03*	34	0.0040	0.1700	0.0572	0.0483	0.0400
NO_3, N (mg/L)	3.0**	34	0.590	4.540	2.474	0.904	2.320
Dissolved Cl (mg/L)	120***	34	19.0	36.00	27.86	4.46	28.15
Total Cu (µg/L)	5*	34	ND	6.6	1.5	1.3	1.3
Total Zn (µg/L)	20*	34	ND	32.0	11.0	7.4	9.6
TSS (mg/L)	N/A	34	ND	130.0	34.6	32.9	27.3

* PWQO (Province of Ontario, 1994)

** Grand River Management Plan (GRCA, 2014)

*** CCME (CCME, 1999)

Table 2-3-8 Wet Weather Surface Water Quality Data Summary at Reichert Drive

Wet Weather – Reichert Drive (2014-2019)							
Parameter	**Objective**	**# samples**	**min**	**max**	**average**	**standard deviation**	**median**
DO (mg/L)	7*	25	2.00	12.99	8.25	2.85	7.51
TP (mg/L)	0.03*	44	0.0110	0.1270	0.0455	0.0247	0.0383
NO_3, N (mg/L)	3.0**	44	**ND**	2.240	0.452	0.525	0.261
Dissolved Cl (mg/L)	120***	44	16.6	72.00	44.17	8.66	44.00
Total Cu (µg/L)	5*	29	**ND**	8.8	1.5	1.7	**ND**
Total Zn (µg/L)	20*	29	**ND**	26.0	6.5	5.5	5.2
TSS (mg/L)	N/A	44	0.8	75.0	10.2	12.6	7.0

* PWQO (Province of Ontario, 1994)

** Grand River Management Plan (GRCA, 2014)

*** CCME (CCME, 1999)

Table 2-3-9 Wet Weather Surface Water Quality Data Summary at Dickie Settlement Road

Wet Weather – Dickie Settlement Road (2014-2019)							
Parameter	**Objective**	**# samples**	**min**	**max**	**average**	**standard deviation**	**median**
DO (mg/L)	7*	25	7.89	14.74	10.45	1.65	10.02
TP (mg/L)	0.03*	25	**ND**	0.1540	0.0315	0.0334	0.0181
NO_3, N (mg/L)	3.0**	25	0.664	3.640	2.001	0.735	2.040
Dissolved Cl (mg/L)	120***	25	21.3	50.80	39.63	6.09	40.00
Total Cu (μg/L)	5*	10	**ND**	1.8	0.8	0.5	**ND**
Total Zn (μg/L)	20*	10	**ND**	9.5	3.8	2.8	**ND**
TSS (mg/L)	N/A	25	**ND**	38.0	13.3	11.0	10.0

* PWQO (Province of Ontario, 1994)

** Grand River Management Plan (GRCA, 2014)

*** CCME (CCME, 1999)

Table 2-3-10 Wet Weather Surface Water Quality Data Summary at Upstream of the Mouth

Wet Weather – Upstream of the Mouth (2014-2019)							
Parameter	**Objective**	**# samples**	**min**	**max**	**average**	**standard deviation**	**median**
DO (mg/L)	7*	24	8.95	16.52	10.94	1.66	10.66
TP (mg/L)	0.03*	24	0.0090	0.0980	0.0357	0.0249	0.0284
NO_3, N (mg/L)	3.0**	21	1.280	3.280	1.929	0.513	1.940
Dissolved Cl (mg/L)	120***	25	44.5	99.00	58.70	13.32	55.70
Total Cu (μg/L)	5*	6	1.3	2.1	1.7	0.3	1.7
Total Zn (μg/L)	20*	7	6.1	10.0	8.4	1.5	8.3
TSS (mg/L)	N/A	24	2.0	63.0	20.3	16.3	15.4

* PWQO (Province of Ontario, 1994)

** Grand River Management Plan (GRCA, 2014)

*** CCME (CCME, 1999)

Table 2-3-11 Dry Weather Surface Water Quality Data Summary at Reidel Drive

Dry Weather – Reidel Drive (2014-2019)							
Parameter	**Objective**	**# samples**	**min**	**max**	**average**	**standard deviation**	**median**
DO (mg/L)	7*	36	2.28	16.36	9.53	3.10	9.32
TP (mg/L)	0.03*	27	0.0370	0.4500	0.0912	0.0932	0.0660
NO_3, N (mg/L)	3.0**	27	0.005	2.690	1.237	0.804	1.060
Dissolved Cl (mg/L)	120***	37	7.10	30.00	13.00	3.90	12.20
Total Cu (µg/L)	5*	15	**ND**	2.7	0.9	0.8	**ND**
Total Zn (µg/L)	20*	15	**ND**	13.0	4.4	3.5	**ND**
TSS (mg/L)	N/A	37	**ND**	110.0	10.8	18.9	4.2

* PWQO (Province of Ontario, 1994)

** Grand River Management Plan (GRCA, 2014)

*** CCME (CCME, 1999)

Table 2-3-12 Dry Weather Surface Water Quality Data Summary at Dodge Drive Tributary

Dry Weather – Dodge Drive Tributary (2014-2019)							
Parameter	**Objective**	**# samples**	**min**	**max**	**average**	**standard deviation**	**median**
DO (mg/L)	7*	13	3.67	8.75	6.06	1.72	5.33
TP (mg/L)	0.03*	9	0.0170	0.0620	0.0367	0.0171	0.0300
NO_3, N (mg/L)	3.0**	9	**ND**	0.620	0.124	0.189	0.050
Dissolved Cl (mg/L)	120***	14	32.00	66.00	50.07	10.68	46.00
Total Cu (µg/L)	5*	9	**ND**	2.4	0.7	0.6	**ND**
Total Zn (µg/L)	20*	9	**ND**	2.5	2.5	0.0	**ND**
TSS (mg/L)	N/A	14	**ND**	5.0	1.9	1.4	1.5

* PWQO (Province of Ontario, 1994)

** Grand River Management Plan (GRCA, 2014)

*** CCME (CCME, 1999)

Table 2-3-13 Dry Weather Surface Water Quality Data Summary at Upstream New Dundee Road

Dry Weather - Upstream New Dundee Road (2014-2019)							
Parameter	**Objective**	**# samples**	**min**	**max**	**average**	**standard deviation**	**median**
DO (mg/L)	7*	59	2.57	16.96	7.22	2.82	6.64
TP (mg/L)	0.03*	47	0.0160	0.4400	0.0556	0.0632	0.0440
NO_3, N (mg/L)	3.0**	32	**ND**	3.650	0.679	0.814	0.410
Dissolved Cl (mg/L)	120***	59	13.50	72.00	44.29	10.50	43.00
Total Cu (µg/L)	5*	18	**ND**	1.8	0.6	0.4	**ND**
Total Zn (µg/L)	20*	18	**ND**	7.7	3.0	1.5	**ND**
TSS (mg/L)	N/A	59	0.025	220.0	6.7	28.6	2.0

* PWQO (Province of Ontario, 1994)

** Grand River Management Plan (GRCA, 2014)

*** CCME (CCME, 1999)

Table 2-3-14 Dry Weather Surface Water Quality Data Summary at Roseville Tributary at Reichert Drive

Dry Weather – Roseville tributary at Reichert Drive (2014-2019)							
Parameter	**Objective**	**# samples**	**min**	**max**	**average**	**standard deviation**	**median**
DO (mg/L)	7*	30	8.07	17.16	11.41	2.13	11.21
TP (mg/L)	0.03*	18	**ND**	0.3100	0.0244	0.0715	0.0065
NO_3, N (mg/L)	3.0**	18	2.380	5.270	4.356	0.892	4.440
Dissolved Cl (mg/L)	120***	30	23.00	34.00	31.70	2.97	33.00
Total Cu (µg/L)	5*	18	**ND**	4.0	0.8	0.8	**ND**
Total Zn (µg/L)	20*	18	**ND**	11.0	4.7	2.8	**ND**
TSS (mg/L)	N/A	30	**ND**	35.0	4.3	8.5	1.0

* PWQO (Province of Ontario, 1994)

** Grand River Management Plan (GRCA, 2014)

*** CCME (CCME, 1999)

Table 2-3-15 Dry Weather Surface Water Quality Data Summary at Reichert Drive

Dry Weather – Reichert Drive (2014-2019)							
Parameter	**Objective**	**# samples**	**min**	**max**	**average**	**standard deviation**	**median**
DO (mg/L)	7*	26	0.51	16.68	9.11	2.68	8.77
TP (mg/L)	0.03*	26	0.0070	0.1100	0.0254	0.0255	0.0150
NO_3, N (mg/L)	3.0**	26	0.050	4.120	1.769	1.323	1.345
Dissolved Cl (mg/L)	120***	26	33.00	55.10	42.74	4.75	42.00
Total Cu (µg/L)	5*	18	**ND**	1.7	0.6	0.3	**ND**
Total Zn (µg/L)	20*	18	**ND**	13.0	5.3	3.9	**ND**
TSS (mg/L)	N/A	26	**ND**	23.0	2.8	4.8	1.0

* PWQO (Province of Ontario, 1994)

** Grand River Management Plan (GRCA, 2014)

*** CCME (CCME, 1999)

Table 2-3-16 Dry Weather Surface Water Quality Data Summary at Dickie Settlement Road

Dry Weather – Dickie Settlement Road (2014-2019)							
Parameter	**Objective**	**# samples**	**min**	**max**	**average**	**standard deviation**	**median**
DO (mg/L)	7*	56	8.82	17.67	12.03	1.99	11.29
TP (mg/L)	0.03*	44	**ND**	0.1610	0.0177	0.0294	0.0080
NO_3, N (mg/L)	3.0**	29	0.079	4.240	3.127	0.780	3.200
Dissolved Cl (mg/L)	120***	56	0.66	56.70	43.02	8.03	43.50
Total Cu (µg/L)	5*	14	**ND**	1.8	0.7	0.4	**ND**
Total Zn (µg/L)	20*	14	**ND**	7.8	3.2	1.8	**ND**
TSS (mg/L)	N/A	56	**ND**	48.0	6.2	9.3	3.0

* PWQO (Province of Ontario, 1994)

** Grand River Management Plan (GRCA, 2014)

*** CCME (CCME, 1999)

Table 2-3-17 Dry Weather Surface Water Quality Data Summary at Upstream of the Mouth

Dry Weather – Upstream of the Mouth (2014-2019)							
Parameter	**Objective**	**# samples**	**min**	**max**	**average**	**standard deviation**	**median**
DO (mg/L)	7*	64	9.15	18.47	11.98	2.06	11.40
TP (mg/L)	0.03*	57	**ND**	0.1500	0.0162	0.0233	0.0097
NO_3, N (mg/L)	3.0**	32	0.010	3.900	2.865	0.714	2.945
Dissolved Cl (mg/L)	120***	67	0.25	85.00	56.16	12.64	58.00
Total Cu (µg/L)	5*	17	**ND**	3.5	0.8	0.7	**ND**
Total Zn (µg/L)	20*	17	**ND**	18.0	6.5	5.7	**ND**
TSS (mg/L)	N/A	67	**ND**	51.0	9.9	12.4	4.0

* PWQO (Province of Ontario, 1994)

** Grand River Management Plan (GRCA, 2014)

*** CCME (CCME, 1999)

ND: Nondetectable. Half the detection limit was used for ND samples in calculating average, and standard deviation.

Minimum detection limits for ND samples are:
Dissolved oxygen: 0.2 mg/L
Total phosphorus: 0.004 mg/L
Nitrate: 0.10 mg/L
Dissolved chloride: 1.0 mg/L
Total copper: 1.0 µg/L
Total zinc: 5.0 µg/L
Total suspended solids: 1.0 mg/L

2.3.4 Results Based on CEA Methodology

The data for all CEA primary water quality indicators (TSS, TP, nitrate, chloride) was stratified using the CEA method by flow conditions into wet and dry weather categories. Wet weather samples are most strongly impacted by construction activities as hydrologic connectivity is greater during wet weather events. Development status, including pre- and during-development dates for each water quality monitoring station, are listed in Table 2-3-18. Roseville Tributary and Reidel Drive serve as control sites that were not subject to development.

Table 2-3-18 Water quality monitoring stations development status

Monitoring Station	Pre-Development	During-Development
Roseville Tributary	To present	N/A
Reidel Drive	To present	N/A
Dodge Drive	2006 - July 2015	July 2015 - Present
New Dundee Road	2006 - July 2014	August 2014 - Present
Reichert Drive	2006 - October 2011	November 2011 - Present
Dickie Settlement Road	2006 - October 2011	November 2011 - Present
Mouth	2006 - October 2011	November 2011 - Present

Table 2-3-19 through Table 2-3-26 present flow stratified Wilcoxon rank-sum tests performed on TSS, TP, nitrate, and chloride data for each monitoring site on Blair Creek. P-values equal to or lower than 0.05 give evidence to parameter change due to development impact. Statistically significant change is reflected in the highlighted cells.

Changes in water quality parameters for wet weather conditions can be seen in Table 2-3-19 through Table 2-3-22. For wet weather conditions, statistically significant increases between pre-development and during-development median levels were seen for TSS, TP and chloride respectively for four, one, and four monitoring stations. This differs from the CEA report (GRCA 2018) as previously statistically significant change for wet weather conditions was only seen at one monitoring station for increasing chloride. Statistically significant decreases in median nitrate values were seen for the three downstream stations during wet weather conditions. Statistically significant increases in TSS occurred at both control sites and Dodge Drive and New Dundee Road; in TP at Dodge Drive; and in chloride at Reidel Drive (control site), New Dundee Road, Dickie Settlement Road and Mouth.

Changes in water quality parameters for dry weather conditions can be seen in Table 2-3-23 through Table 2-3-26. For dry weather conditions statistically significant decreases between pre-development and during-development median levels were seen for all parameters. For TSS, TP, nitrate, and chloride respectively one, four, four, and two monitoring stations were observed to have significantly decreased median values. A significantly increased median level for dry weather was observed at the Mouth for chloride. The CEA had only one occurrence of statistical significance for dry weather, in comparison to this analysis where there are twelve total significant changes in dry weather median, of which eleven of the changes are decreases (GRCA 2018).

All stations experienced significant change in at least one parameter for both wet weather and dry weather conditions. Some of the most significant change can be seen in Table 2-3-19 with TSS median values during wet weather conditions increasing for all seven stations and by more than double for four stations, where the latter includes both control sites. Furthermore, at Dodge Drive an increase of 60 mg/L for the wet weather median value of TSS was observed between pre- and during-development conditions. The CCME recommends, in the Canadian Water Quality Guidelines for the Protection of Aquatic Life, for freshwater not to exceed an "increase of 25 mg/L [for TSS] from background levels for any short-term exposure (e.g., 24-h period)" (CCME, 1999). This guideline was exceeded at Dodge Drive.

The median levels for phosphorus during wet weather, seen in Table 2-3-20, increased by a small amount for most stations and statistically significantly at Dodge Drive by more than a factor of five. It should be noted that all wet weather during-median concentrations, except Dickie Settlement Road monitoring station, exceed the PWQO of 0.03 mg/L for phosphorus (Province of Ontario, 1994). Both nitrate and chloride wet weather median levels had no exceedances of guidelines or objectives.

For dry weather parameters, statistical significance was discussed above. It should be noted that during-development median values for phosphorus and nitrate both exceeded the respective guidelines of 0.03 mg/L and 3.0 mg/L respectively at three stations (including at least one control site) for each parameter. These exceedances are the same as those recorded for during-development in the CEA (GRCA 2018).

Trends were in median TSS and TP concentrations were higher in the wet weather samples compared to the dry weather samples. This could be anticipated as both of these indicators are commonly correlated with flow. Additionally, nitrate and chloride have high solubility and tend to be diluted in higher flows" (GRCA 2018).

Table 2-3-19 Comparison of pre- and during-development wet weather TSS (mg/L) concentrations. Highlighted cells are significant (α=0.05)

Wet Weather Total Suspended Solids				
Site	**pre-median**	**during-median**	**W test**	**p-value**
Roseville	10.0	25.0	202.0	0.0410
Reidel Drive	4.0	10.7	181.0	0.0010
Dodge Drive	0.5	60.5	51.5	0.0001
New Dundee Road	1.5	5.0	313.5	0.0005
Reichert Drive	4.0	7.0	309.0	0.1787
Dickie Settlement Road	9.0	11.0	350.5	0.3733
Mouth	13.5	17.0	247.0	0.3033

Table 2-3-20 Comparison of pre- and during-development wet weather TP (mg/L) concentrations. Highlighted cells are significant (α=0.05)

Wet Weather Total Phosphorus				
Site	**pre-median**	**during-median**	**W test**	**p-value**
Roseville	0.032	0.041	240.5	0.1599
Reidel Drive	0.087	0.096	239.0	0.1614
Dodge Drive	0.029	0.150	97.0	0.0058
New Dundee Road	0.039	0.053	423.5	0.2377
Reichert Drive	0.037	0.038	373.5	0.4653
Dickie Settlement Road	0.029	0.018	342.5	0.0956
Mouth	0.031	0.033	309.5	0.2338

Table 2-3-21 Comparison of pre- and during-development wet weather Nitrates (mg/L) concentrations. Highlighted cells are significant (α=0.05)

Wet Weather Nitrate				
Site	**pre-median**	**during-median**	**W test**	**p-value**
Roseville	2.9	2.3	374.5	0.0577
Reidel Drive	0.4	0.4	317.0	0.3415
Dodge Drive	0.1	0.4	136.0	0.0602
New Dundee Road	0.2	0.1	522.0	0.1050
Reichert Drive	0.9	0.3	517.0	0.0035
Dickie Settlement Road	2.6	2.0	416.0	0.0037
Mouth	2.2	2.0	241.0	0.0483

Table 2-3-22 Comparison of pre- and during-development wet weather chloride (mg/L) concentrations. Highlighted cells are significant (α=0.05)

Wet Weather Chloride				
Site	**pre-median**	**during-median**	**W test**	**p-value**
Roseville	29.0	26.5	281	0.4158
Reidel Drive	13.0	21.0	186	0.0255
Dodge Drive	31.0	34.5	178	0.3119
New Dundee Road	33.0	39.0	364.5	0.0374
Reichert Drive	42.0	43.0	314.5	0.2025
Dickie Settlement Road	36.0	39.3	214	0.0403
Mouth	42.0	58.0	100.5	0.0003

Table 2-3-23 Comparison of pre- and during-development dry weather TSS (mg/L) concentrations. Highlighted cells are significant (α=0.05)

Dry Weather Total Suspended Solids				
Site	**pre-median**	**during-median**	**W test**	**p-value**
Roseville	1.0	1.0	457.0	0.2837
Reidel Drive	3.0	3.0	140.5	0.3680
Dodge Drive	2.0	1.0	128.5	0.0719
New Dundee Road	2.0	1.7	1014.5	0.0704
Reichert Drive	3.0	2.0	684.0	0.0124
Dickie Settlement Road	3.0	3.0	894.0	0.4095
Mouth	2.0	3.8	251.0	0.1619

Table 2-3-24 Comparison of pre- and during-development dry weather TP (mg/L) concentrations. Highlighted cells are significant (α=0.05)

Dry Weather Total Phosphorus				
Site	**pre-median**	**during-median**	**W test**	**p-value**
Roseville	0.010	0.006	536.0	0.0405
Reidel Drive	0.063	0.062	140.0	0.3744
Dodge Drive	0.051	0.036	134.0	0.0483
New Dundee Road	0.072	0.045	1039.0	0.0248
Reichert Drive	0.029	0.015	729.0	0.0026
Dickie Settlement Road	0.010	0.008	963.0	0.1329
Mouth	0.010	0.009	320.0	0.4723

Table 2-3-25 Comparison of pre- and during-development dry weather nitrate (mg/L) concentrations. Highlighted cells are significant (α=0.05)

Dry Weather Nitrate				
Site	**pre-median**	**during-median**	**W test**	**p-value**
Roseville	5.20	4.41	584.5	0.0067
Reidel Drive	1.90	1.00	201.0	0.0146
Dodge Drive	0.05	0.05	81.0	0.2283
New Dundee Road	0.50	0.36	921.0	0.0558
Reichert Drive	3.00	1.70	658.5	0.0292
Dickie Settlement Road	4.30	3.36	1254.5	1.60E-06
Mouth	3.30	3.02	285.0	0.1789

Table 2-3-26 Comparison of pre- and during-development dry weather chloride (mg/L) concentrations. Highlighted cells are significant (α=0.05)

Dry Weather Chloride				
Site	**pre-median**	**during-median**	**W test**	**p-value**
Roseville	32	32	419.0	0.4970
Reidel Drive	12	12	110.5	0.2905
Dodge Drive	41	41	96.0	0.4830
New Dundee Road	48	44	1125.0	0.0176
Reichert Drive	46	40	767.5	0.0005
Dickie Settlement Road	43	43	883.5	0.4470
Mouth	44	49	109.5	0.0008

Table 2-3-27 contains the differences between wet and dry weather concentrations for each of the parameters in pre-development conditions. Negative differences represent where dry concentrations were higher and positive differences represent occurrences where wet concentrations were higher than dry. Highlighted cells are statistically significant using the Wilcoxon rank-sum non-parametric test with α =0.05. TSS and TP were significantly higher for wet weather samples at Roseville, Dickie Settlement Road and the Mouth monitoring stations. Due to the high solubility and dilution of nitrate and chloride all statistically significant differences were for dry concentrations being higher than wet concentrations. Statistical significance for the differences between wet and dry concentrations for nitrate and chloride occurred at respectively six and three stations.

Table 2-3-27 Magnitude of change in [wet] - [dry] in mg/L for pre-development grab samples at all sites. Statistical significance indicated by colour

Dry vs Wet Weather Samples Pre-Construction							
Parameter	**Reidel Drive**	**Roseville**	**Dodge Drive**	**New Dundee Road**	**Reichert Drive**	**Dickie Settlement Road**	**Mouth**
TSS	1	9	-1.5	-0.5	1	6	11.5
TP	0.024	0.0225	-0.022	-0.0325	0.008	0.019	0.0205
NO_3	-1.50	-2.30	0.05	-0.30	-2.10	-1.70	-1.10
Cl	1.00	-3.00	-10.00	-15.00	-4.00	-7.00	-2.00

(green)	[wet] significantly less than [dry]
(red)	[wet] significantly higher than [dry]

Table 2-3-28 was created in an identical fashion to Table 2-3-27 except during-development data was used. It can be observed that now all stations have statistical significance for TSS and TP with wet concentrations being significantly higher than dry. The stations which had statistically significant higher dry concentrations for nitrate and chloride for pre-development are the same for during-development. Dodge Drive and Reidel Drive station now have significantly higher wet concentrations of chloride and nitrate, respectively. In comparing the results of Table 2-3-28 to the during-development table created in the CEA, there are now nine more occurrences with statistically significant differences at various stations between wet and dry concentrations.

Table 2-3-28 Magnitude of change in [wet] - [dry] in mg/L for during-development grab samples at all sites. Statistical significance indicated by colour

Dry vs Wet Weather Samples During-Construction							
Parameter	**Reidel Drive**	**Roseville**	**Dodge Drive**	**New Dundee Road**	**Reichert Drive**	**Dickie Settlement Road**	**Mouth**
TSS	7.65	24	59.5	3.3	5	8	13.21
TP	0.0335	0.035	0.114	0.0075	0.0232	0.0106	0.024
NO_3	-0.56	-2.08	0.35	-0.26	-1.39	-1.31	-1.07
Cl	9	-5.5	-6.5	-5	3	-3.7	9

(green)	[wet] significantly less than [dry]
(red)	[wet] significantly higher than [dry]

In addition to the observations of dry weather and wet weather mean, median, and Wilcoxon rank-sum statistics for TSS, TP, nitrate, and chloride, the high end of the data distribution range was also examined for the combined all-weather datasets. It is important, from an ecosystem health perspective, to observe more than central statistics. Therefore, box plots were created displaying ranges of concentrations between the 5^{th} and 95^{th} percentile, which can be seen in Figure 2-3-3 through Figure 2-3-6. A side by side comparison is provided for the pre- and during-development periods for all four parameters, with dry and wet weather data combined.

Figure 2-3-3 contains the TSS percentiles for the 75^{th}, 90^{th}, and 95^{th} percentiles which are represented respectively by the top of the box, the top whisker, and the dot above the whisker. For Roseville tributary, Reidel Drive, Dodge Drive, and New Dundee Road monitoring stations, increases were seen in the all the upper percentiles. Changes in Roseville and Reidel Drive station TSS upper percentiles are likely attributed to upstream agricultural activities. Reichert Drive, Dickie Settlement Road, and the Mouth monitoring stations remained relatively unchanged in the observed distributions of TSS concentrations. Dodge Drive, New Dundee Road, and Reichert Drive monitoring stations are all closest to development activity as well as downstream of stormwater outfalls. Though Reichert Drive experienced little change between pre- and during-development TSS, Dodge Drive and New Dundee Road are consistent with the observations of the CEA and suggest that the result of increasing TSS concentrations in the 75th, 90th, and 95th percentiles is a result of development. It should be noted that some of the 90th and 95th percentile concentrations at New Dundee Road and Dodge Drive more than tripled. Downstream sites, including Dickie Settlement Road and the Mouth, remained relatively unchanged in agreement with the CEA.

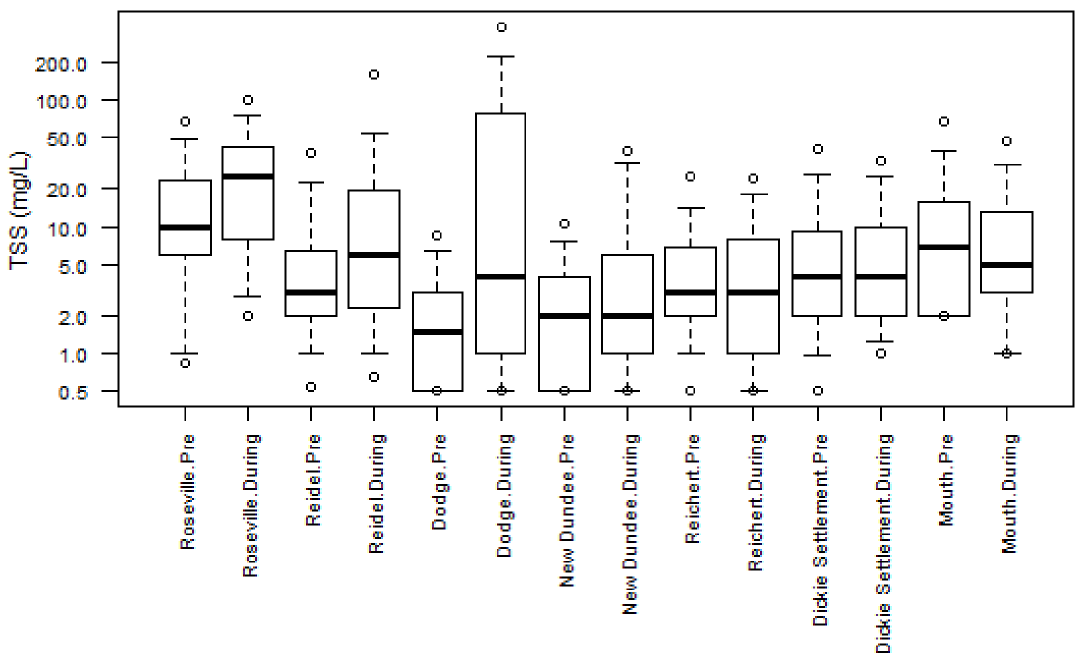


Figure 2-3-3 Boxplots of TSS concentrations on log-scale with dry and wet weather data combined and grouped by pre- and during-development. Top and bottom of the boxes are respectively the 75th and 25th percentiles, the line is the median, the whiskers represent the 10th and 90th percentiles, and the dots are the 5th and 95th percentiles.

Figure 2-3-4 contains total phosphorus box plots for pre- and during-development at all water quality monitoring stations, with dry and wet weather data combined. The increase in the 75th, 90th, and 95th percentiles at Roseville and Reidel Drive stations is likely due to upstream agricultural activities. A similar trend for all stations occurred as to what was observed for TSS, which is likely because of the sorptive capacity of TP to sediment. Again, large increases in the 75th, 90th, and 95th percentiles were seen for Dodge Drive, and to a lesser extent at New Dundee Road. Little change was seen for downstream stations suggesting the same localized impact for TP as was seen for TSS.

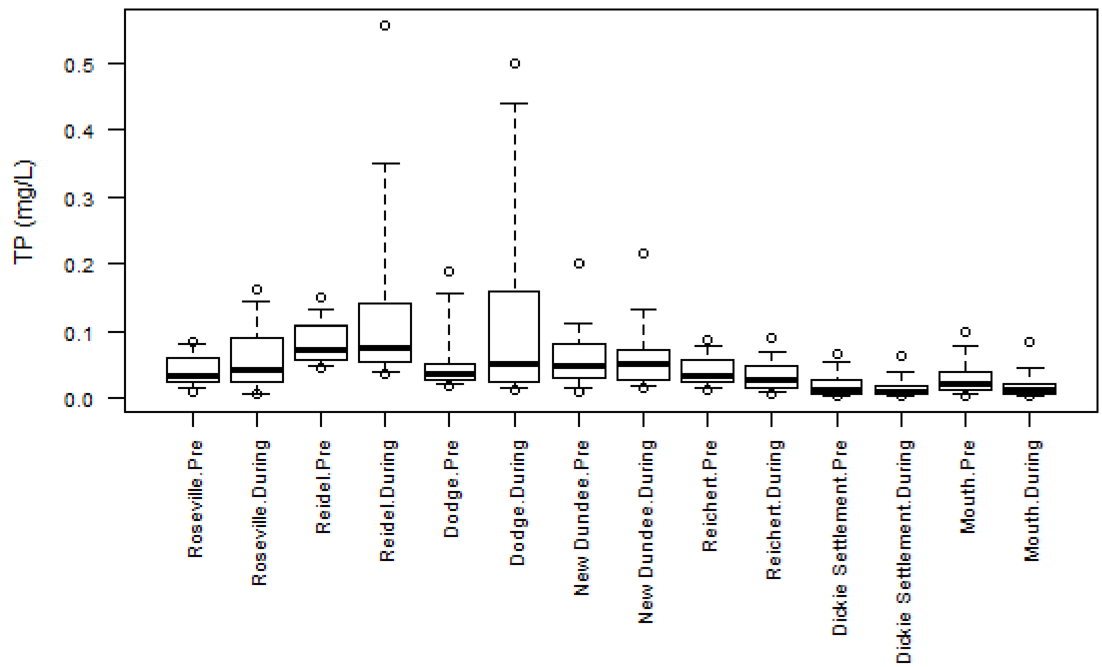


Figure 2-3-4 Boxplots of TP concentrations with dry and wet weather data combined and grouped by pre- and during-development. Top and bottom of the boxes are respectively the 75th and 25th percentiles, the line is the median, the whiskers represent the 10th and 90th percentiles, and the dots are the 5th and 95th percentiles.

Figure 2-3-5 contains the boxplots for nitrate for pre- and during-development for all water quality monitoring stations, with dry and wet weather data combined. Median and high percentile nitrate concentrations generally decreased for all stations except Dodge Drive and the Mouth. As suggested by the CEA (GRCA 2018) this could be due to changes in agricultural practices at the headwaters.

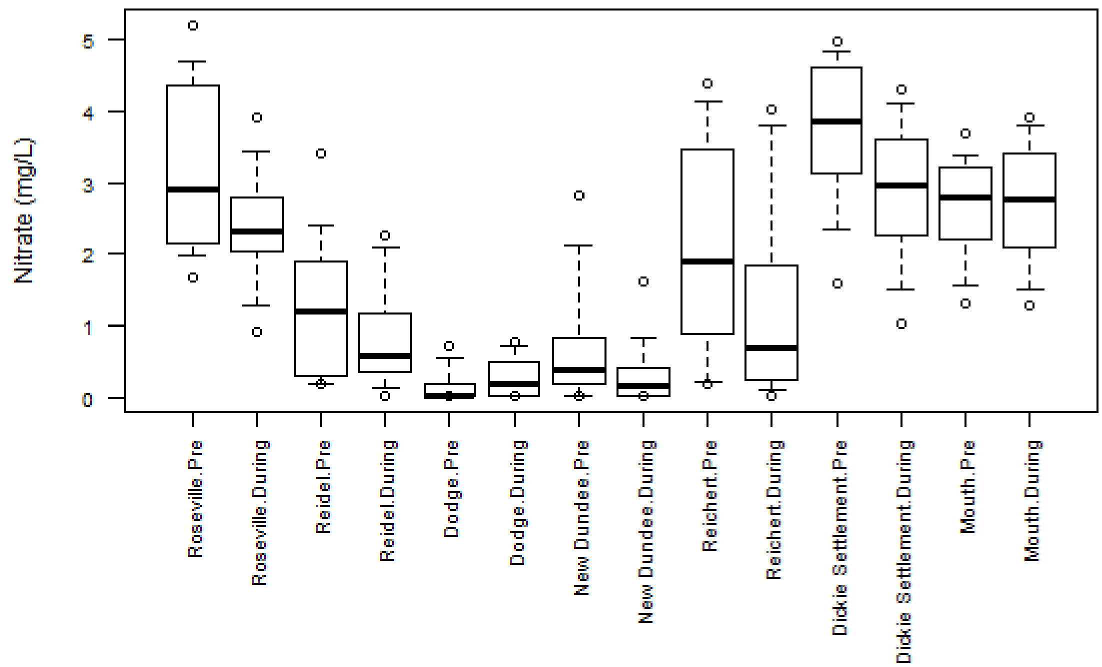


Figure 2-3-5 Boxplots of Nitrate concentrations with dry and wet weather data combined and grouped by pre- and during-development. Top and bottom of the boxes are respectively the 75th and 25th percentiles, the line is the median, the whiskers represent the 10th and 90th percentiles, and the dots are the 5th and 95th percentiles.

Figure 2-3-6 contains the boxplots for chloride for pre- and during-development for all water quality monitoring stations, with dry and wet weather data combined. Roseville tributary, Dodge Drive, Reichert Drive and Dickie Settlement Road saw very little change in chloride concentrations. Reidel Drive and the Mouth both had chloride concentration increases in the 75th, 90th, and 95th percentile. New Dundee Road had a large decrease in the 95th percentile. The median for all stations, excluding the Mouth, was similar between pre- and during-development. It should be noted that chloride is typically higher in the winter due to road salt and therefore seasonal distribution of samples may skew results.

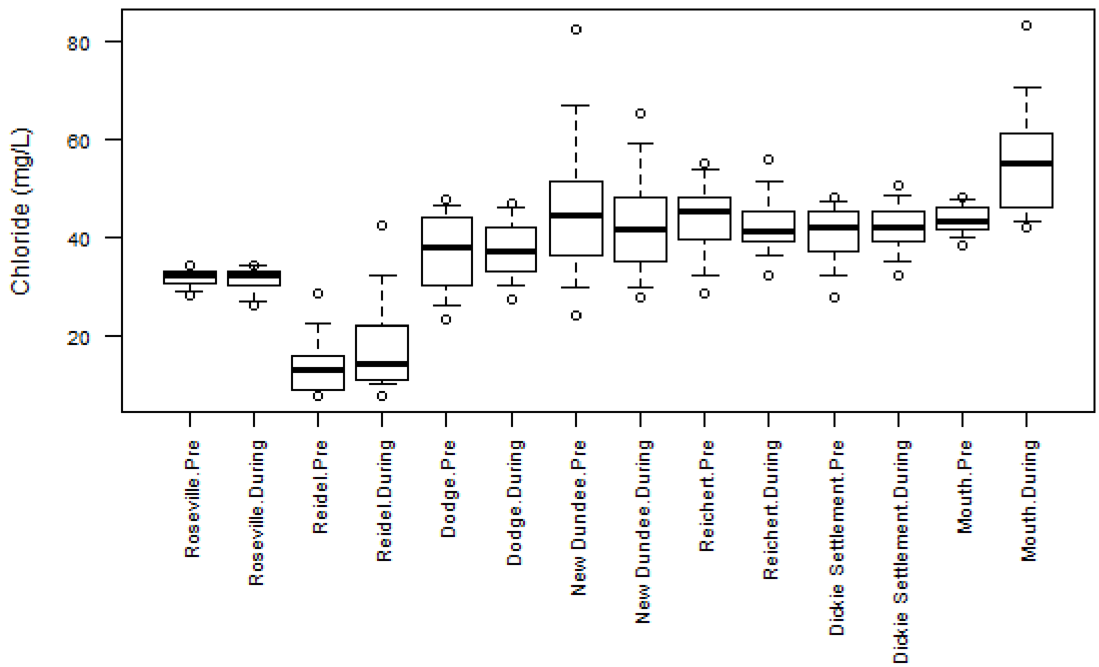


Figure 2-3-6 Boxplots of chloride concentrations with dry and wet weather data combined and grouped by pre- and during-development. Top and bottom of the boxes are respectively the 75th and 25th percentiles, the line is the median, the whiskers represent the 10th and 90th percentiles, and the dots are the 5th and 95th percentiles.

2.3.4.1 Before-After-Control-Impact (BACI) Analysis

The BACI analysis explores wet weather TSS data by comparing both a) the change in pre- to during-development data and b) impacted sites to a control site, using the same methodology as the CEA (GRCA 2020). If the impacted sites are unaffected by development activities, then the impacted sites should have a similar slope and direction of change as the control site. Observing Figure 2-3-7, Dickie Settlement Road, the Mouth, and Reichert Drive monitoring stations all follow similar trends with the control increasing between pre- and during-development and the impact site TSS concentration staying the same or decreasing slightly between development periods. At New Dundee Road the TSS concentration increased at a lesser rate than the control. Dodge Drive was the only station to have a higher rate of increase and a final value of TSS concentration for during-development than the control station.

Table 2-3-29 provides the results of a two factor ANOVA test, which agree with the conclusions of Figure 2-3-7. Dodge Drive is the only site which had a statistically significant result for the product of the p values of time and impact. There is evidence supporting that TSS increased due to the development at Dodge Drive (as shown in Figure 2-3-7). All other sites had no statistically significant change which agrees with Figure 2-3-7.

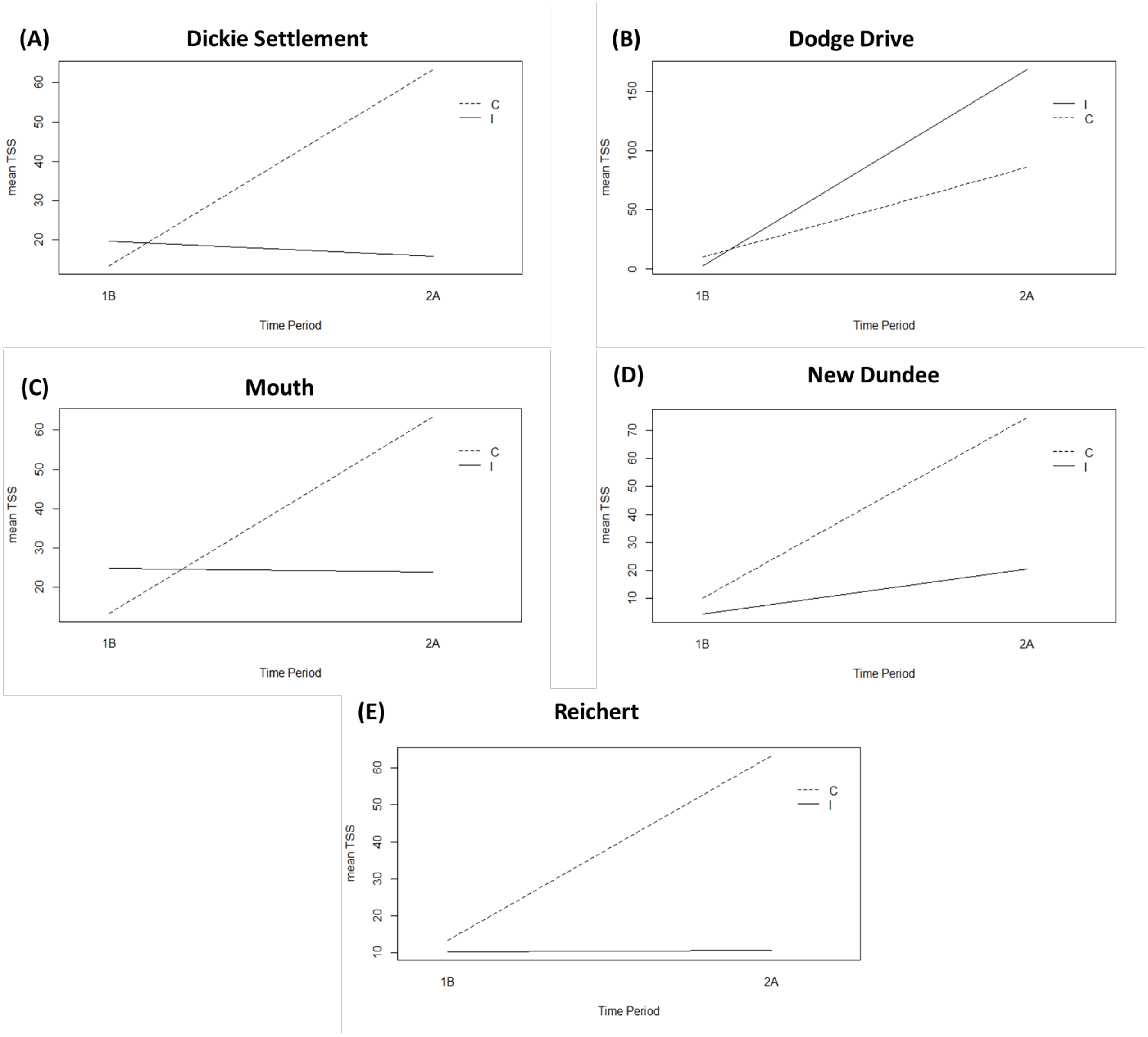


Figure 2-3-7 BACI Interaction plots of mean TSS concentration (I = impact, C = control_ which shows the change in concentration between before and after construction for both control and impacted sites A) Dickie Settlement Road B) Dodge Drive C) Mouth D) New Dundee Road E) Reichert Drive

Table 2-3-29 Results from two-factor ANOVA. All sites failed normality test and had to be log-transformed to run parametric statistics.

Site	Normality Test (pre; post)	log Transformed (pre; post)	ANOVA	Time	Impact	Time*Impact
Dodge Drive	(<0.0001; <0.0001)	(0.0003; 0.014)		<0.0001	0.4466	0.0277
New Dundee Road	(<0.0001; <0.0001)	(0.009; 0.05)		<0.0001	0.000165	0.702181
Reichert Drive	(0.0002;< 0.0001)	(0.36 ; 0.58)		0.0347	0.0061	0.24469
Dickie Settlement Road	(<0.0001; 0.0004)	(0.89 ; 0.32)		0.103	0.974	0.103
Mouth	(0.0003 ; 0.004)	(0.70 ; 0.095)		0.107	0.369	0.156

2.3.4.2 Trend Analysis

Mann-Kendall trend tests were performed to assess temporal trends in flow-adjusted TSS at each of the monitoring sites potentially impacted by development activities using the same methodology as the CEA with the updated during-development data (GRCA 2018). Figure 2-3-8 displays the results of the trend tests graphically for all stations. No significant trends can be observed for Dickie Settlement Road, the Mouth, New Dundee Road, or Reichert Drive. At Dodge Drive the slope is positive for all seasons and there is a recognizable upward trend of flow-adjusted TSS corresponding to passing time. This agrees with what was seen in the previous section for BACI analysis. Additionally, as can be seen in Table 2-3-30, fall, winter, and summer seasons for Dodge Drive all have statistical significance for an increasing trend in flow adjusted TSS concentration.

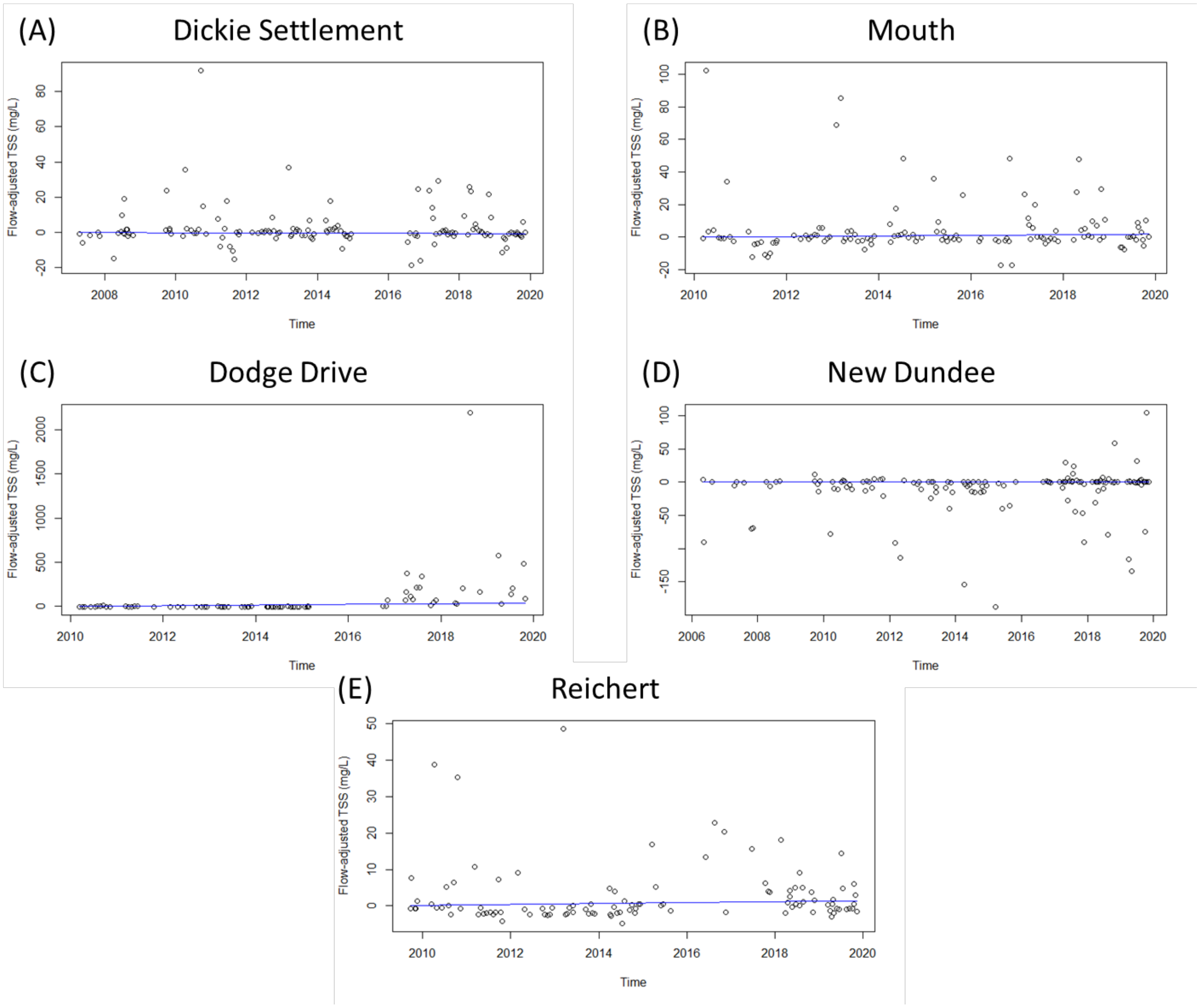


Figure 2-3-8 Trend tests of flow adjusted TSS concentrations over time at the five sites impacted by development activities A) Dickie Settlement Road B) Mouth C) Dodge Drive D) New Dundee Road E) Reichert Drive

Table 2-3-30 Seasonal Kendall trend test results, significance indicated by highlighted cells (α = 0.05)

	Dodge Drive			New Dundee Road			Reichert Drive			Dickie Settlement Road			Mouth		
	n	slope	p-value	n	slope	p-value	n	slope	p-value	n	slope	p-value	n	slope	p-value
Fall	22	+	0.0002	37	+	0.0619	31	+	0.0803	35	0	1	29	+	0.1829
Winter	15	+	0.0064	13	0	0.7528	11	-	0.7555	12	-	0.837	14	-	0.6614
Spring	21	+	0.0907	40	0	0.0949	26	+	0.5085	30	+	0.5207	28	+	0.3333
Summer	20	+	0.0086	50	0	0.8603	37	+	0.0915	61	-	0.0917	55	+	0.1913

2.3.5 Water Quality Conclusions

The following conclusions have been made regarding the surface water chemistry of Blair Creek. It is important to note that most samples are discrete grab samples; autosampled wet weather data collected since 2016 is flow-composited at one result per event.

Numbered items 1, 2 and 3 are general conclusions for the entirety of Upper Blair Creek.

1) Using the 2016 SOW wet weather and dry weather stratification method (Aquafor Beech Limited 2016) and observing the corresponding general statistics tables the conclusions were:
   a) Chloride maximum concentrations have increased at every station at either wet and/or dry weather conditions.
   b) Total phosphorus maximum concentrations increased at 6 stations at either wet and/or dry weather, and wet weather average phosphorus concentrations exceeded the PWQO of 0.03 mg/L at all stations (Province of Ontario, 1994). Average nitrate concentration at either dry or wet weather conditions did not exceed the Grand River Management Plan target of 3.0 mg/L at any stations between 2014 and 2019 (GRCA, 2014).
   c) Total copper maximum concentrations have increased at either wet and/or dry weather at six monitoring stations.
   d) Total zinc maximum concentrations increased during wet weather at all stations upstream of Dickie Settlement Road.
   e) TSS maximum concentrations increased at 5 stations for wet weather and at 6 stations for dry weather. The maximum values at five stations exceeded the previous overall maximum TSS in the 2016 SOW.
2) Using the 2018 CEA wet and dry stratification method (GRCA 2018) and observing the Wilcoxon rank-sum non-parametric test results the conclusions were:
   a) All stations had a statistically significant change in median values for at least one parameter (TSS, TP, NO_3 or Cl).
   b) For the 12 cases of dry weather median values with statistically significant change, all but one case decreased for during-development. The opposite trend was observed for wet weather where all statistically significant median changes were increases, except those for nitrate which decreased.
   c) In wet weather conditions, median TSS values increased for all seven stations, and by more than double for four stations where the latter includes both control sites. Furthermore, at Dodge Drive an increase of 60 mg/L for the wet weather median value of TSS was observed between pre- and during-development conditions.
   d) Median wet weather concentrations of TSS and TP are observed to be statistically significantly higher than dry concentrations for all stations during-development.
   e) For during-development data, there are ten more occurrences of statistical significance between wet and dry weather samples then there are for pre-development. This further highlights the importance of stratifying chemistry grab samples into wet and dry.
   3) From the box plots produced for the 5^{th} to 95^{th} percentiles for pre and during-development conditions the following conclusions were made:

Increases in the upper percentiles of TSS and phosphorus at New Dundee Road and Dodge Drive is a potential product of development (which was further analyzed through BACI and Mann-Kendall tests). The effects of high concentrations of TSS or phosphorus associated with development is not seen downstream of these monitoring sites.

Nitrate concentration values for high percentiles generally decreased for the during-development period, which suggests changes in agricultural practices upstream.

The following are more specific conclusions for each station which include some key findings.

1) At Reidel Drive, the average values for copper and zinc exceeded their respective PWQO thresholds (Province of Ontario, 1994). The increase in the upper percentiles of the box plot for phosphorus at Reidel Drive station is most likely due to agricultural activities upstream.
2) At Dodge Drive, the average DO value was found to be below the PWQO and the average values for copper and zinc were found to exceed their respective PWQO thresholds (Province of Ontario, 1994). The TSS average in wet weather for Dodge Drive was 195.5 mg/L which is higher than all maximum and average values for all stations and weather types prior to 2014. Additionally, an increase of 60 mg/L for the median value of TSS was observed between pre- and during-development conditions. Phosphorus at Dodge Drive increased by more than a factor of five in wet weather conditions. The TSS 90th and 95th percentiles more than tripled and BACI analysis, ANOVA test, and Mann-Kendall trend tests all support that TSS increased due to development near Dodge Drive.
3) TSS 90th and 95th percentiles more than tripled at New Dundee Road.
4) There are no site-specific conclusions for Reichert Drive. The general conclusions apply.
5) Roseville Tributary saw increases in upper percentiles for phosphorus, most likely due to agricultural activities upstream.
6) There are no site-specific conclusions for Dickie Settlement Road. The general conclusions apply.
7) At the Mouth, the upper percentiles and median value for chloride increased between pre and during-development.

2.4 Groundwater

2.4.1 Physiographic and Geologic Setting

The physiographic and geologic setting of the Blair Creek subwatershed was previously described in the BBB (CH2M Gore & Storrie Limited 1997) and summarized in the 2016 SOW report (Aquafor Beech Limited 2016).

2.4.1.1 Physiography

The physiography of the area is presented in Figure 2-4-1 after Chapman and Putnam (1984). The study area is located within the Waterloo Moraine, which is comprised of sand and gravel. The thickness of the deposits associated with the moraine vary between 30 and 100 m. These sand and gravel deposits are underlain by regional till sheets. Valleys to the east and south of the moraine are occupied by outwash deposits. Additional physiographic features in the study area include till outcrops, kettles, outwash plains/terraces, and bog/swamp deposits.

2.4.1.2 Regional Geology

The regional geology consists of Paleozoic bedrock of Silurian age that dips gently to the southwest. The Salina Group (formerly the Salina Formation) subcrops beneath the subwatershed and consists of buff to brown dolostone and limestones interbedded with grey and green shales. The Guelph Formation, consisting of brown to grey dolostone, underlies the Salina Group and subcrops locally and to the east. The Guelph Formation is a proven producer of good quality groundwater.

Overlying the bedrock in the Blair Creek subwatershed is a series of glacial deposits of the Late Wisconsinan sub-stage of the Pleistocene epoch (23,000 to 10,000 before present). The quaternary geology and surficial deposits have been mapped by the Ontario Geological Survey (OGS) (2006). Surficial geology for the study area is reproduced in Figure 2-4-2. Due to the erratic nature of glacial deposition, it is to be expected that soil characteristics will vary both areally and with depth.

Glacial ice lobes advanced from several directions, eventually converging the Waterloo region. These glacial advances deposited thick glacial tills in the subsurface, notably the Catfish Creek and Maryhill Tills, outwash sands and gravels, kame deposits (i.e., the aforementioned Waterloo Moraine) and glaciolacustrine deposits.

2.4.1.3 Site Geology

The Upper Blair Creek FDS by Stantec (2009) included additional subsurface investigation information and provided a detailed interpretation. The study reported that surficial deposits are more heterogenous than the Quaternary mapping suggests. A map of borehole and test pit locations is provided in the previous SOW report on pg. 89 (Aquafor Beech Limited 2016) and cross sections are included here in Appendix B - Groundwater. The following is a summary of the local shallow materials encountered within the Upper Blair Creek subwatershed:

- In the northwestern portion of the study area (northwest of Reidel Drive and Stauffer Drive), test pits typically encountered subsurface deposits of sand or silt, with occasional occurrences of silt till and sand and gravel. Two boreholes (BH1 and BH2) encountered sand with a thickness of approximately 3.5 to 6 m of sand overlying silt/silt till. The silt/silt till was observed up to approximately 5 m or more in thickness.
- In the southwestern portion of the study area (west of Reidel Drive), test pits encountered a variety of soil types: sand/silt and sand deposits were common further away from New Dundee Road, and silty deposits were more common near the road. In addition, one borehole (BH1024) in this area encountered thick sand/sand and gravel deposits over silt till.
- In the central portion of the study area (between Reidel Drive and Groh Drive), test pits typically encountered silt, with some isolated pockets of coarser material such as sandy soil. Borehole logs within this area also show interlayered sands, silts, and tills. Overall, the geology is dominated by silty soils, with pockets of predominantly sandy material.
- Just east of the central portion of the study area (north of Dodge Drive and east of Groh Drive), sandy deposits were observed in boreholes and shallow test pits near Dodge Drive. Sandy soils overlaying silt deposits were observed to the north (distal to Dodge Drive).
- In the northeastern portion of the study area (north-east of Groh Drive and further north of Dodge Drive), boreholes typically encountered thick sand sequences, occasionally interlayered with silts and tills.
- In the eastern portion of the study area (east of Dodge Drive), test pits generally encountered sandy soils with occasional occurrences of silt and silt till. Boreholes in the far eastern portion of the area encountered thick sequences of sand and/or silt with occasional till deposits. Silty deposits were typically encountered in proximity to Dodge Drive, eventually grading to interlayered sands and silts, and then to sands further north.

2.4.2 Hydrogeological Setting

Although there are several regional till units found within the region, there are only two continuous till units within the Blair Creek subwatershed: the Catfish Creek Till and Maryhill Till (Karrow 1993). These low permeable till units are considered the main aquitards within the study area. Overburden aquifers within the subwatershed are associated with reworked till material consisting of sand and gravel, associated with moraine and outwash deposits.

A simplified interpretation of the regional hydrostratigraphic units was discussed in the BBB study (CH2M Gore & Storrie Limited 1997). According to the study, there are two overburden aquifers (shallow and deep) comprised of sand and gravel, separated by the Maryhill Till aquitard. The shallow aquifer within the western portion of the subwatershed is associated with the Waterloo Moraine deposits lying on the regional till, which thin out to the east. The shallow aquifer in the eastern portion of the study area is associated with the outwash deposits. The deeper accumulation of sand and gravel deposits within the western portion are associated with the bedrock valley and is connected to the Grand River in the east. The deeper aquifer is separated from the underlying bedrock aquifers by the Catfish Creek Till. In addition to contributing flow to Blair Creek, Roseville Swamp, and the Grand River, the shallow and deep overburden aquifers provide water for residential and municipal wells.

A FEFLOW model developed as part of the *Tier 2 Water Budget Study* for the Grand River watershed by AquaResource (2009) was previously used to define the hydrogeologic setting within the subwatershed. The model consists of six overburden units and eight bedrock layers; however, not all are present in the study area. The top of the bedrock unit (Unit 7) in the FEFLOW model is presented in Figure 2-4-3. The bedrock surface elevation decreases westward from approximately 260 metres above sea level [masl] to 245 masl at the eastern portion of the site. The overburden thickness was estimated by subtracting the bedrock surface top (Unit 7) from the land surface topography (Unit 1). The estimated overburden thickness ranges from 40 m in the east to 105 m in the west (Figure 2-4-4).

2.4.3 Groundwater Flow

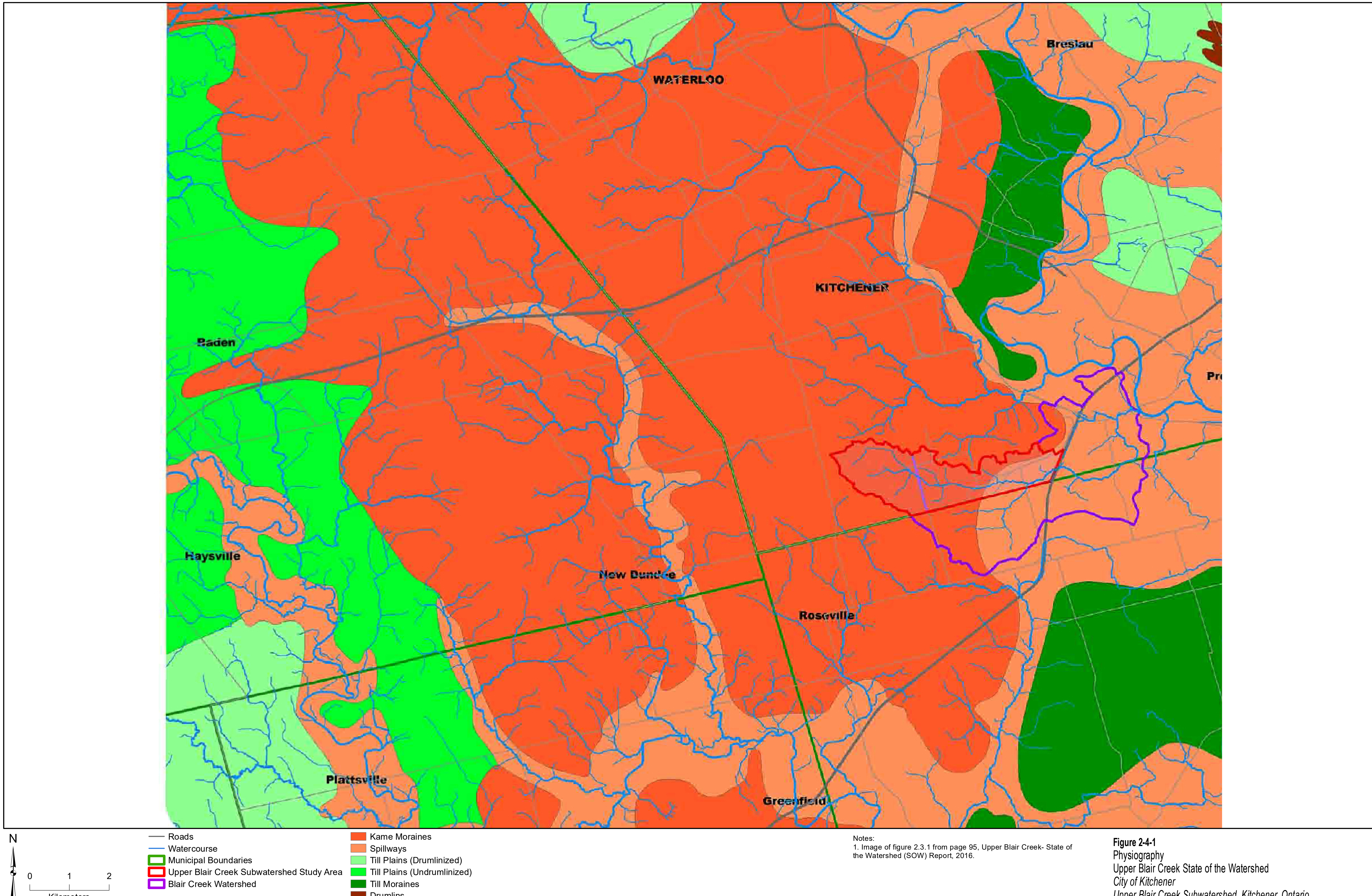
Local flow patterns were assessed in the BBB (CH2M Gore & Storrie Limited 1997) and FDS (Stantec 2009) studies using historical groundwater levels observed in shallow and deep wells within the study area. According to the BBB study, regional groundwater flow is generally radially outward from the Waterloo Moraine (high recharge area), discharging to the Grand River in the east. The groundwater flow was reassessed in the 2016 SOW (Aquafor Beech Limited 2016).

As part of the scope of the 2016 SOW, the Region Water Resources Analysis System (WRAS+) database was accessed to extract static groundwater levels from 186 wells in the subwatershed, and from 83 private wells located within the study area. According to the RMOW database, 49 wells were screened in the shallow overburden aquifer, and 28 wells were screened within the deeper overburden aquifer. Two wells were identified as being screened within the bedrock.

It was noted that the dataset exhibited a high level of variation. This variation may be related to the limitations in the dataset, including that measurements were collected on different dates and during varying seasons. In addition, there may be well location and elevation transcription errors within the database. Outliers were removed and the data were interpolated to infer general flow direction patterns. The interpolated groundwater levels for shallow and deeper wells are shown on Figure 2-4-5 and 2-4-6.

The inferred local groundwater flow is generally from west to east within both the shallow and deeper overburden aquifers (Figures 2-4-5 and 2-4-6). This observation is within agreement with flow direction described in the BBB (CH2M Gore & Storrie Limited 1997) and FDS (Stantec 2009). West of Reidel Drive, the shallow aquifer contributes to flow in the Upper Blair Creek and its tributaries. Flow to the creek within this area is intermittent and depends on whether the water table intersects the creek.

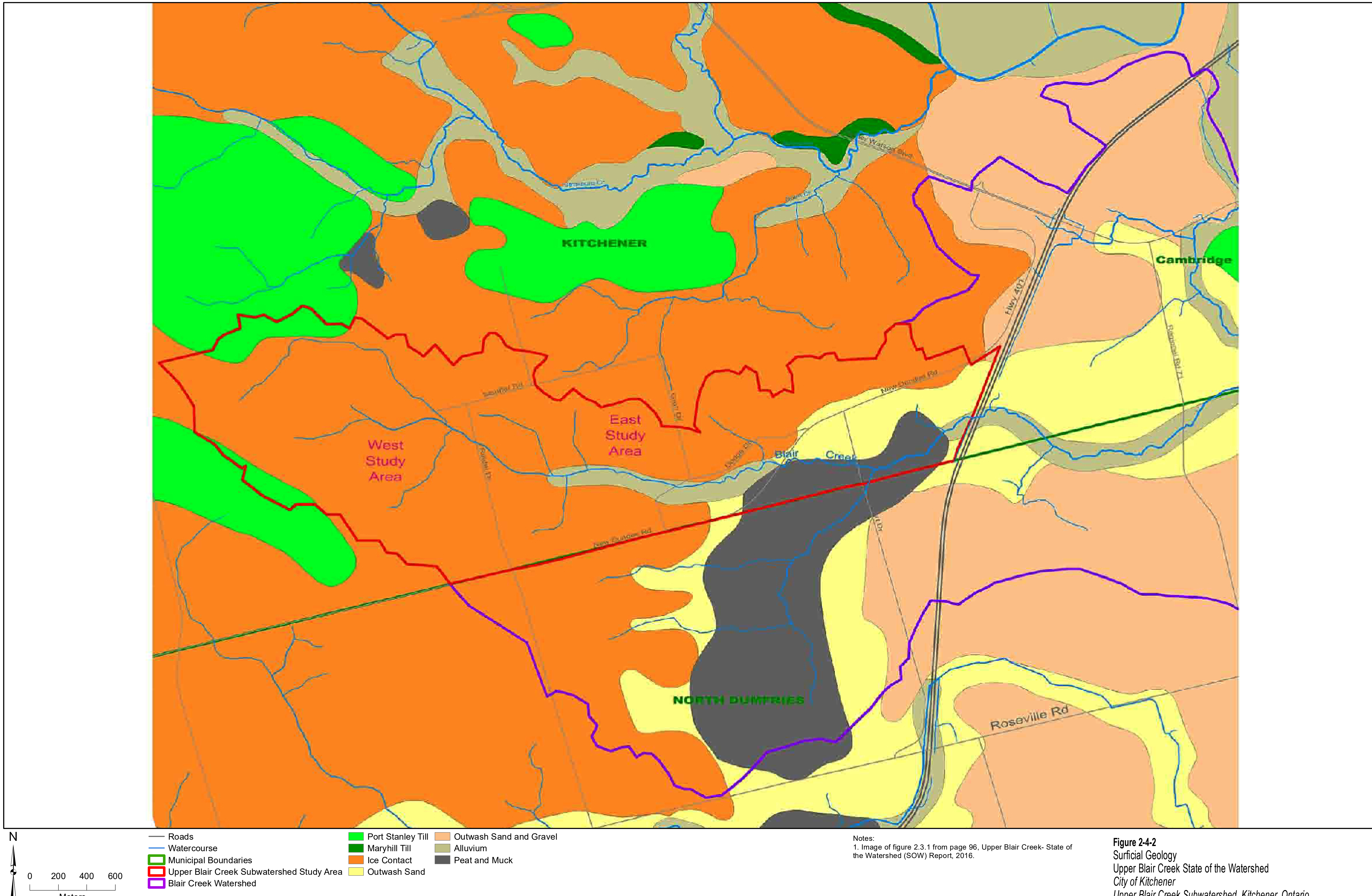
Hydraulic gradients were also assessed in the 2016 SOW using the interpolated data and were observed to be generally downward within the study area between the shallow and deeper wells. At Roseville Swamp, hydraulic gradients were observed to be locally upward, indicating groundwater discharge into the swamp (Aquafor Beech Limited 2016).



Notes:
1. Image of figure 2.3.1 from page 95, Upper Blair Creek- State of the Watershed (SOW) Report, 2016.

Figure 2-4-1
Physiography
Upper Blair Creek State of the Watershed
City of Kitchener
Upper Blair Creek Subwatershed, Kitchener, Ontario

Jacobs

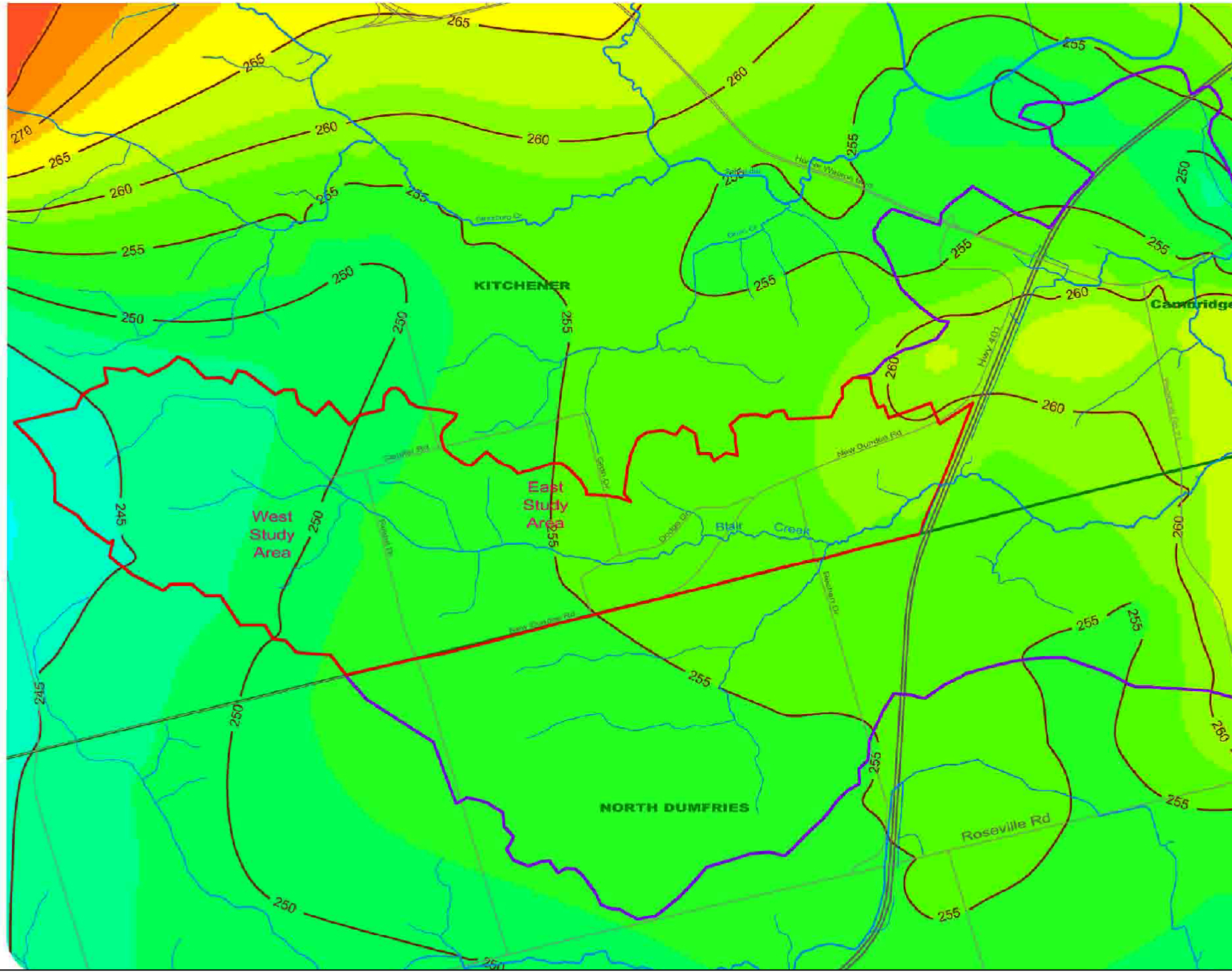


Notes:
1. Image of figure 2.3.1 from page 96, Upper Blair Creek- State of the Watershed (SOW) Report, 2016.

Figure 2-4-2
Surficial Geology
Upper Blair Creek State of the Watershed
City of Kitchener
Upper Blair Creek Subwatershed, Kitchener, Ontario

Jacobs

\\DC1VS01\GISPROJ\K\KITCHENERCITYOF\UPPERBLAIRCREEK_P20_005\MAPFILES\SOW\2_4_2_SURFICIALGEOLOGY.MXD SCYR 1/26/2021 4:54:46 PM



N

0 200 400 600

Meters

- Roads
- Watercourse
- Municipal Boundaries
- Upper Blair Creek Subwatershed Study Area
- Blair Creek Watershed

Top of Bedrock (masl)

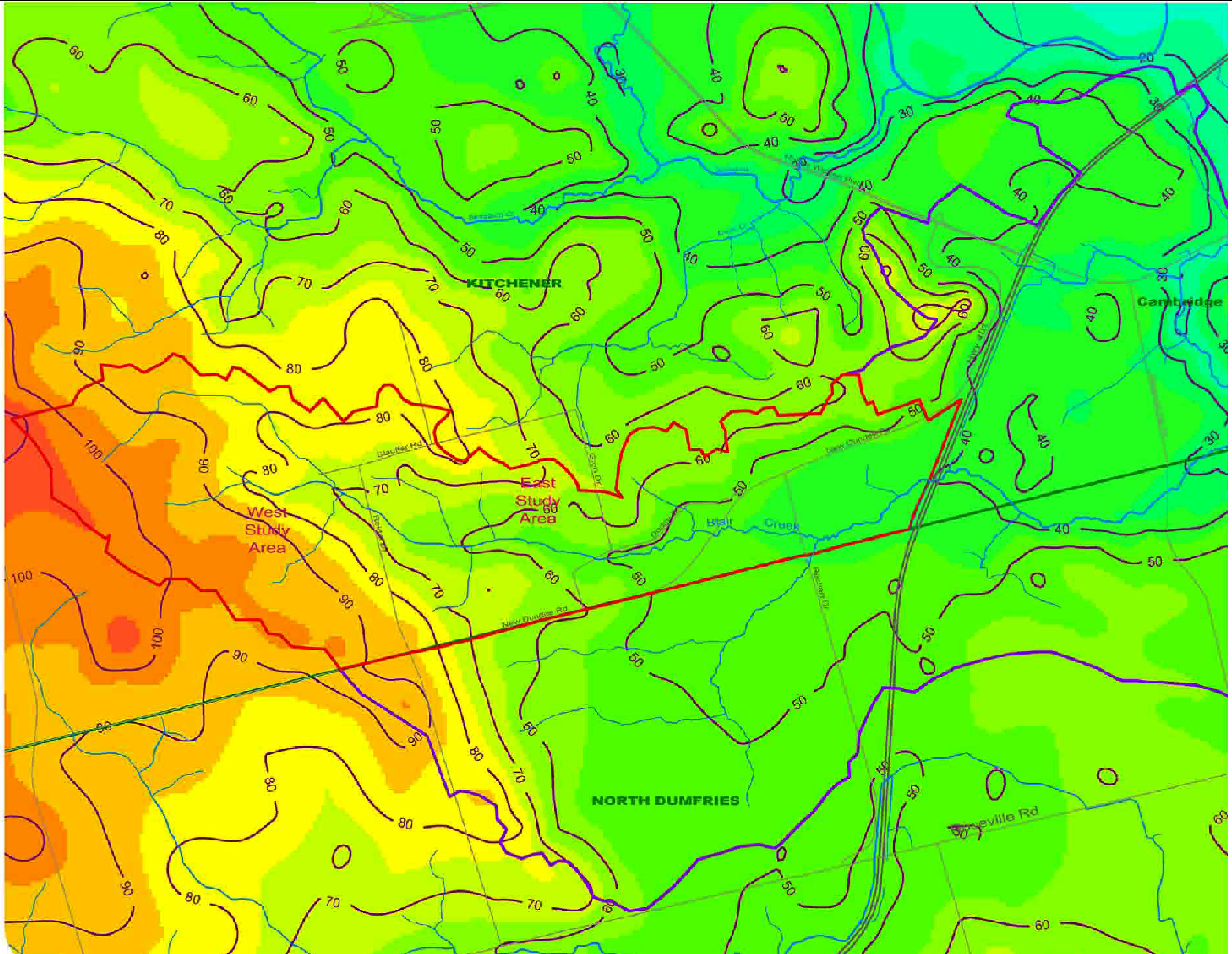
- Contour (5m Interval)
- High : 290
- Low : 240

Notes:
1. Image of figure 2.3.1 from page 97, Upper Blair Creek- State of the Watershed (SOW) Report, 2016.

Figure 2-4-3
Bedrock Topography
Upper Blair Creek State of the Watershed
City of Kitchener
Upper Blair Creek Subwatershed, Kitchener, Ontario

Jacobs

\\DC1VS01\GISPROJ\K\KITCHENERCITYOF\UPPERBLAIRCREEK_P20_005\MAPFILES\SOW\2_4_3_BEDROCKTOPOGRAPHY.MXD SCYR 1/26/2021 4:44:39 PM



N

0 200 400 600
Meters

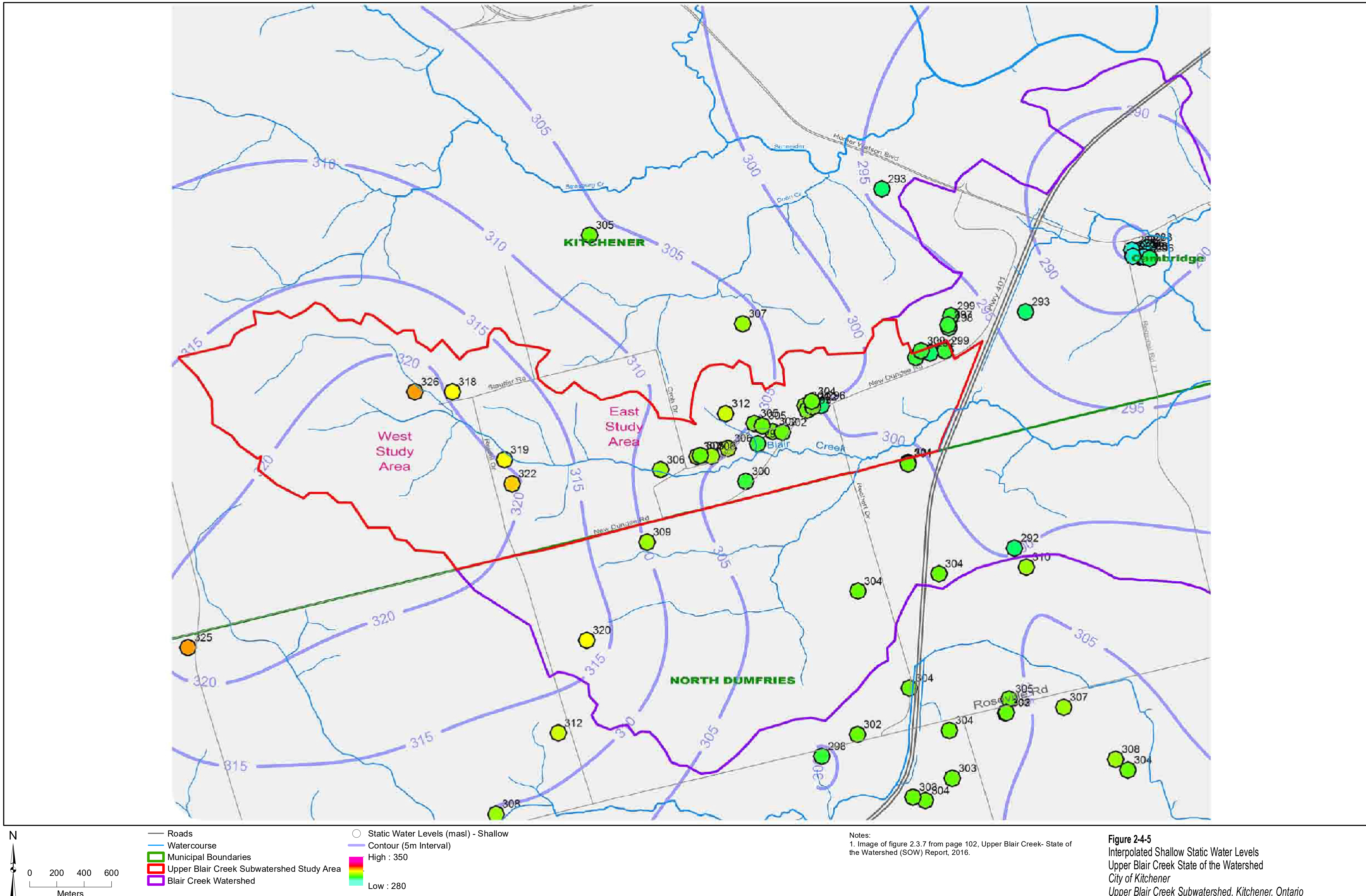
Roads
Watercourse
Municipal Boundaries
Upper Blair Creek Subwatershed Study Area
Blair Creek Watershed

Overburden Thickness (m)
Contour (10m Interval)
High : 150
Low : 0

Notes:
1. Image of figure 2.3.4 from page 98, Upper Blair Creek- State of the Watershed (SOW) Report, 2016.

Figure 2-4-4
Overburden Thickness
Upper Blair Creek State of the Watershed
City of Kitchener
Upper Blair Creek Subwatershed, Kitchener, Ontario

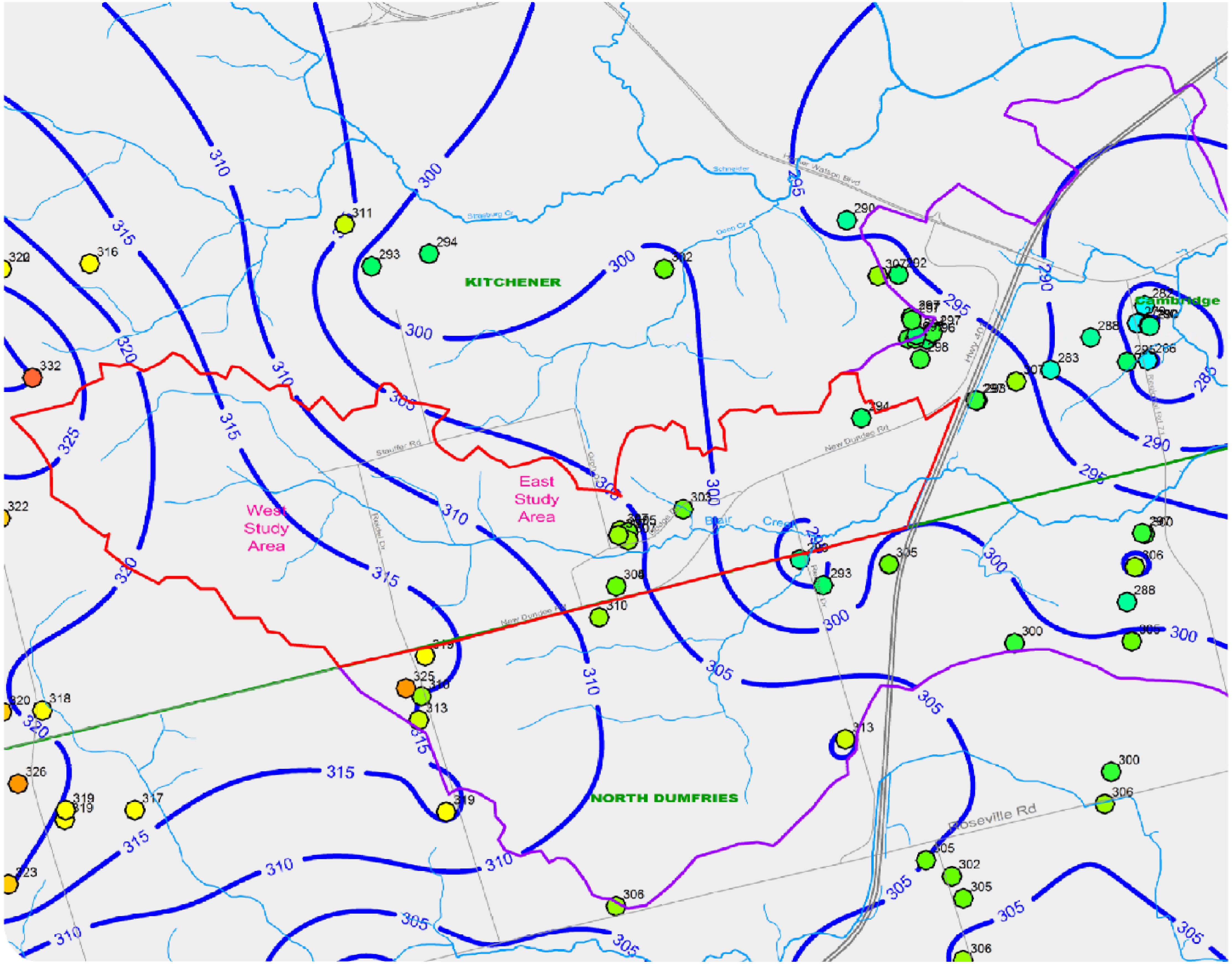
Jacobs



Notes:
1. Image of figure 2.3.7 from page 102, Upper Blair Creek- State of the Watershed (SOW) Report, 2016.

Figure 2-4-5
Interpolated Shallow Static Water Levels
Upper Blair Creek State of the Watershed
City of Kitchener
Upper Blair Creek Subwatershed, Kitchener, Ontario

Jacobs



N

0 200 400 600
Meters

Roads
Watercourse
Municipal Boundaries
Upper Blair Creek Subwatershed Study Area
Blair Creek Watershed

Static Water Levels (masl) - Deep
Contour (5m Interval)
High : 350
Low : 280

Notes:
1. Image of figure 2.3.8 from page 103, Upper Blair Creek- State of the Watershed (SOW) Report, 2016.

Figure 2-4-6
Interpolated Deep Static Water Levels
Upper Blair Creek State of the Watershed
City of Kitchener
Upper Blair Creek Subwatershed, Kitchener, Ontario

Jacobs

\\DC1VS01\GISPROJ\K\KITCHENERCITYOF\UPPERBLAIRCREEK_P20_005\MAPFILES\SOW\2_4_6_DEEP_GW_CONTOURS.MXD SCYR 1/26/2021 4:45:16 PM

2.4.3.1 Connectivity between Surface Water, Shallow Groundwater & Deep Groundwater

According to the FDS (Stantec 2009), shallow groundwater across the study area generally occurs at depths of less than 7 metres below ground surface (mbgs). Variation in groundwater depth is thought to be influenced by topographic features such as kettle depressions, hummocky topography, and the Blair Creek valley, and by soil permeability. In addition, local discontinuities within the till aquitards may allow greater infiltration of groundwater from the shallow to deeper overburden aquifers.

Discharge from the shallow aquifer contributes to hydrogeological features, including portions of Blair Creek, and to wetlands and marshes, including Roseville Swamp. All overburden aquifers are expected to ultimately discharge to the Grand River southeast of the study area.

2.4.3.2 Geotechnical/Hydrogeological Input to Surface Hydrology Model

Geotechnical and hydrogeological conditions collected through 2008 were incorporated into an existing surface water hydrologic model (GAWSER) provided by the GRCA as a deliverable for the FDS. The GAWSER model was developed using information collected through 2008 from Naylor Engineering Associates Ltd. The model was used to estimate the percent flow split of water to the creek and to deeper groundwater. As reported in the FDS, values ranged from 25 percent infiltration to the creek in the western portion of the subwatershed to 100 percent infiltration along the creek valley towards the east. For a more detailed methodology, including assumptions and limitations, refer to the FDS (Stantec 2009). The GAWSER model was not updated with new information for the purpose of this report.

2.4.3.3 Existing Groundwater Usage and Source Protection

Existing groundwater usage within the Upper Blair Creek drainage system was assessed in the FDS and reiterated in the 2016 SOW. The following is a summary of groundwater usage and protection as of 2009 and may not be representative of current conditions (Stantec 2009):

- There are private wells completed primarily within the overburden aquifers. Nearby municipal supply wells include two Strasburg wells (K34 and K36) to the north, two Roseville wells (R5 and R6) to the southwest, and three Ayr wells (A1, A2, and A3) to the south.
- Wellhead Protection Sensitivity Areas 2, 3, and 4 for the Strasburg wells extend into the northwestern corner of the subwatershed. The steady state capture area for the Ayr wells extends into the southwestern corner. The Wellhead Protection Sensitivity Area 4 areas correspond to the ultimate capture zones of these wells, thereby incorporating the contributing areas.
- Lands west of Reidel Drive were identified as providing high rates of recharge to the Strasburg and Ayr wells in addition to contributing base flow to Blair Creek. This observation is in accordance with the BBB report.
- A target area for potential future groundwater supply was identified in the eastern part of the subwatershed as part of the Region's *Long-Term Water Strategy* (Region 2003). The BBB report also indicated that there was a high potential for additional municipal-scale groundwater production within the lower aquifer sequence in the Upper Blair Creek area, and in the bedrock aquifer system further to the east where the overburden is thinner (CH2M Gore & Storrie Limited 1997). This information, from should be reviewed and updated in future SOW reports.

The Province introduced the *Clean Water Act* in 2006 (*Clean Water Act*, 2006) which laid the framework for protecting sources of drinking water in Ontario. Technical rules were established for delineating and assessing vulnerable groundwater areas, identifying threats in those areas, and assessing the risks of those threats to municipal water supplies in terms of water quantity and quality. Areas of the Upper Blair Creek Subwatershed have already been identified by the Region as vulnerable groundwater areas. It is recommended that the existing groundwater usage and source protection areas be reassessed to incorporate any changes or updates made since 2009.

2.4.3.4 Potential Groundwater Threats

In 1994, the Region adopted a comprehensive water resource protection strategy. As part of the implementation of this strategy, Regional Council adopted an amendment to the ROP in 2000 that delineated vulnerable groundwater areas and restricted the establishment of new non-residential land uses which pose a potential threat to municipal water supplies.

The BBB and FDS studies (CH2M Gore & Storrie Limited 1997 and Stantec 2009, respectively) proposed a significant portion of the Upper Blair Creek drainage system be developed as municipally serviced residential development. These developments generally pose the least risk to water quantity and quality due to the elimination of potential threats commonly associated with commercial or industrial development, and even agricultural practices.

However, the following potential threats to groundwater quantity and quality were identified:

1) Development may potentially restrict recharge to the underlying aquifer systems. This may result in a reduction of groundwater contribution to municipal water supply wells, to local baseflow to Blair Creek, and to other downgradient receivers such as Roseville Swamp and the Grand River.
2) The long-term cumulative loading of road salt may negatively impact water quality in the underlying aquifers. This may impact existing groundwater users, the surface water quality of the Blair Creek drainage system and may negate a future potential water supply option for the Region.

Since 2000, as a result of winter road salting, the Region has witnessed a marked increase in chloride levels in the groundwater supplies. The Region's mitigation approach is to ensure that chloride levels in the groundwater from proposed development meet the MECP's Reasonable Use Concept (RUC) water quality guidelines (MECP 1994).

In addition to meeting the RUC guidelines, development planners and engineers are encouraged to investigate ways to reduce chloride impacts while balancing infiltration quantities such as:

- Minimizing impervious areas, reducing road densities, and changing road grades and orientations.
- Promoting at-source infiltration where feasible to infiltrate only clean stormwater.
- Bypassing end-of-pipe infiltration facilities during the winter months and spring thaw.
- Emplacing clay liners beneath boulevards to redirect road splash back onto roads.

2.4.4 General Summary of Existing Monitoring

Monitoring well locations for groundwater elevation and temperature are presented on Figure 2-4-7 and Figure 2-4-8, respectively.

2.4.4.1 Long-Term Regional Monitors

Two monitoring wells located upgradient of Blair Creek represent a baseline condition with which to compare changes during the post-construction period.

Monitoring location BBB1-94 consists of two multilevel boreholes screened at seven intervals installed on behalf of the GRCA in 1994 that has been continuously monitored by the Region since 1999. The screened interval and hydrologic setting of each monitoring location is provided on Table 2.3.1 in the 2016 SOW. Water level data obtained from Region's WRAS+ database was compiled as part of the 2016 SOW (Aquafor Beech Limited 2016).

A second regional monitoring location, BBB2, was part of the Provincial Groundwater Monitoring Network (identification: PGMN 0000430-1). This well is screened between 284.12 and 287.15 masl. It is assumed to be completed in the upper overburden aquifer.

The groundwater elevations observed at these monitoring points can be found on Figure 2.3.9 in the 2016 SOW (Aquafor Beech Limited 2016). The compilation of additional groundwater elevations recorded since 2014 should be considered for future comparison of groundwater quantity pre-, during-, and post-construction.

2.4.4.2 During-Construction Monitors

The background monitoring summary was included in the 2016 SOW. Refer to Table 2.3.2 in the 2016 SOW for a complete summary of groundwater monitoring and water level ranges (Aquafor Beech Limited 2016). The following section describes the current monitoring program carried out between 2014 and 2019.

Monitoring locations associated with the GRCA and each developer is tabulated in Table 2-4-1 and includes updated groundwater elevation ranges for the recording period. The groundwater monitoring program consists of continuous water levels, quarterly (seasonal) manual water levels and water quality sampling, continuous temperature monitoring, and annual groundwater quality sampling. Underlined monitoring locations were also subject to continuous groundwater monitoring with the use of transducers. Monitoring locations marked by an "*" were sampled as part of the groundwater quality monitoring program.

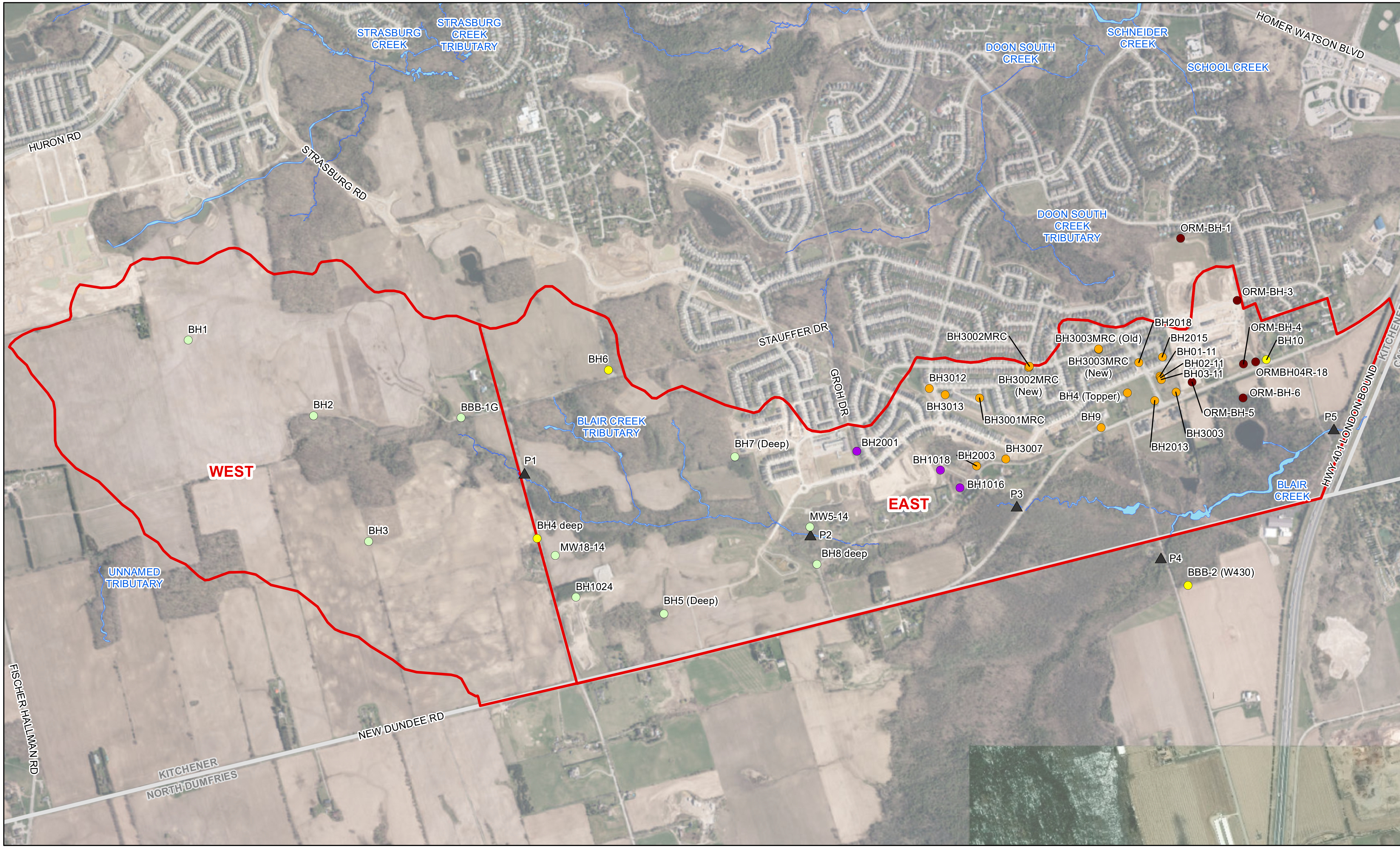
The GRCA undertook the following four monitoring wells: BBB-2 (W430), BH4 (Deep), BH6, and BH10. The GRCA's system-wide monitoring is complemented by site-scale during development monitoring which is undertaken by the developers and their consulting teams. Site-scale monitoring was carried out by the following developers:

- Mattamy (formerly Monarch) retained MMM Group Limited (formerly MRC) to undertake the groundwater monitoring for the following sixteen wells: BH01-11, BH02-11, BH03-11, BH-2003, BH-2013, BH-2015, BH-2018, BH-3001MRC, BH-3002MRC, BH-3003, BH-3003MRC, BH-3007, BH3012, BH-3013, and BH-4 Topper, and BH9.
- Activa Holdings Inc. retained MTE Consultants to undertake the groundwater monitoring for the following six wells: BH-5 (Deep), BH-7 (Deep), BH-8 (Deep), BH1024-16, MW5-14, and MW18-14. In addition, Activa Holdings Inc retained MTW Consultants to undertake groundwater monitoring for the following five wells: BH01-13, BH03-13, BH04-13(-18), BH05-13, and BH06-13.
- Hallman retained EnGlobe Corp. (formerly LVM) to undertake the groundwater monitoring for the following two wells: BH2001 and BH1016.

Note that groundwater elevation monitoring data from Activa Holdings Inc. was not provided during preparation of this report. However, the groundwater elevation data is presented in the 2017 annual report (MTE, 2018). In addition, the during-construction Ormston monitoring data from Activa Holdings Inc. can be found in the 2018 annual report (MTE, 2019). Similarly, Hallman datasets (groundwater elevation and quality) were not provided at the time of this report and were therefore not presented within this report. However, the during-construction groundwater quantity is included as part of a 2017 annual report (MTE, 2018). It is recommended that these datasets be incorporated for the post-construction assessment.

Continuous conductivity monitoring programs were implemented at wells BH4, BBB-2 (W430), BH1016, BH2018, and BH3003 to help determine the impacts of road salt applications on groundwater chloride concentrations using conductivity as a surrogate (GRCA, 2017). These data were not analyzed as part of the SOW. It is recommended that these data be used if an in-depth assessment of chloride impacts is necessary following construction activities. These data are included in Appendix B of the report.

In addition to the monitoring locations described above, five in-stream piezometers were installed in June 2016. Details of the piezometer installations can be found in the CEA (GRCA 2018). The water level data collected at these locations was not assessed as part of the SOW. It is recommended that the data be used to assess the groundwater-surface water interactions along Blair Creek, to help identify sections which are gaining or losing, and to confirm any seasonal influences. These data are attached in Appendix B of the report.



N

0 200 400
Meters

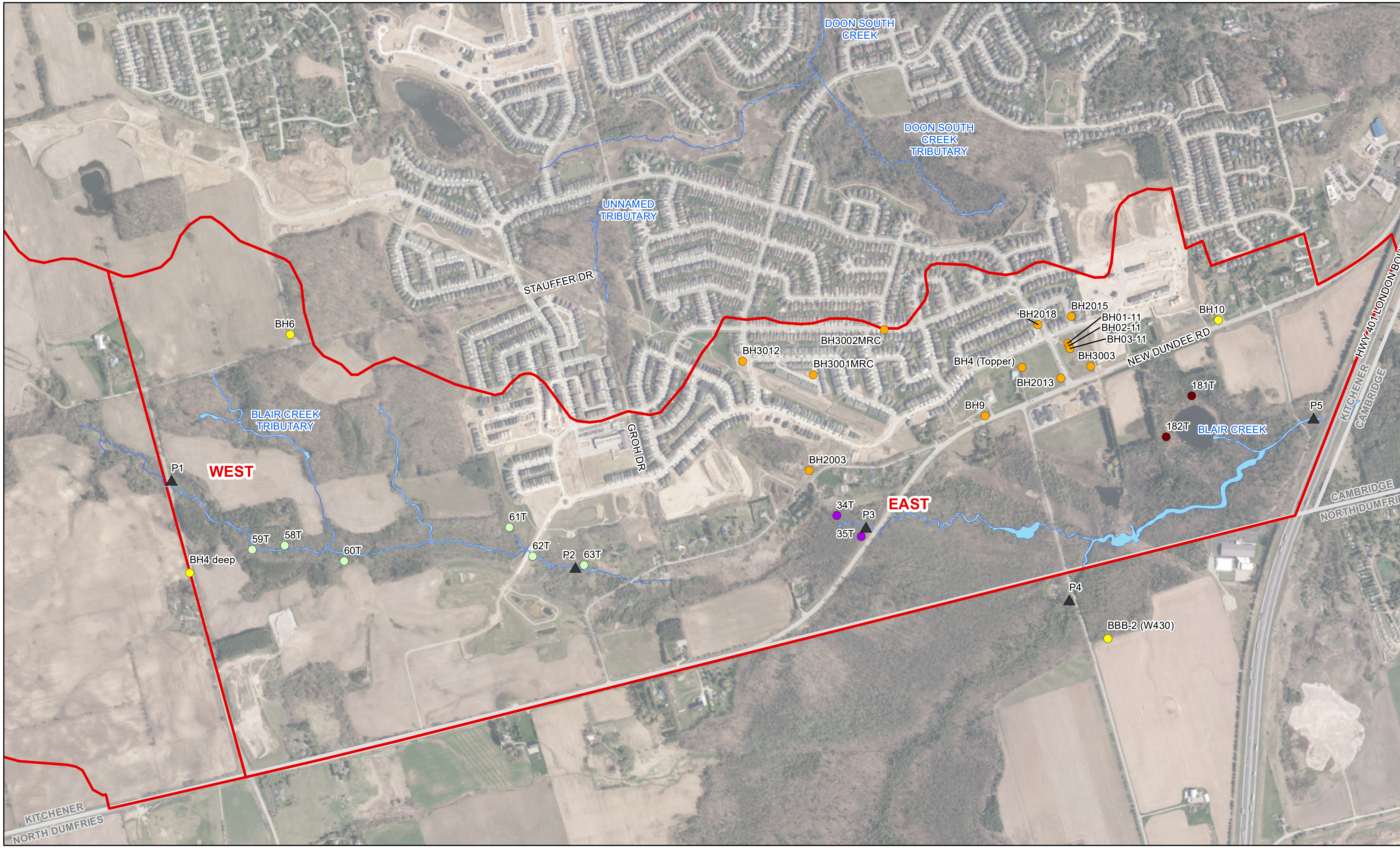
Monitoring Location
- Activa
- GRCA Monitoring Network
- Hallman
- Monarch (now Mattamy)
- Ormston (now Activa)
- GRCA Stream Piezometer Location
- Waterbody
- Upper Blair Creek Subwatershed Study Area
- Municipal Boundary

Notes:
1. Imagery Source: City of Kitchener, 2019.

Figure 2-4-7
Groundwater Level and Quality Monitoring Network
Upper Blair Creek State of the Watershed
City of Kitchener
Upper Blair Creek Subwatershed, Kitchener, Ontario

Jacobs

\\DC1VS01\GISPROJ\K\KITCHENERCITYOF\UPPERBLAIRCREEK_P20_005\MAPFILES\SOW\2_4_7_GWLEVEL_QUALITYMONITORINGNETWORK.MXD SCYR 1/26/2021 4:47:16 PM



N

0 200 400
Meters

Monitoring Location
- Activa
- GRCA Monitoring Network
- Hallman
- Monarch (now Mattamy)
- Ormston (now Activa)
- GRCA Stream Piezometer Location
- Waterbody
- Upper Blair Creek Subwatershed Study Area
- Municipal Boundary

Notes:
1. Imagery Source: City of Kitchener, 2019.

Figure 2-4-8
Groundwater Temperature Monitoring Network
Upper Blair Creek State of the Watershed
City of Kitchener
Upper Blair Creek Subwatershed, Kitchener, Ontario

Jacobs

\\DC1VS01\GISPROJ\K\KITCHENERCITYOF\UPPERBLAIRCREEK_P20_005\MAPFILES\SOW\2_4_8_GWTEMPMONITORINGNETWORK.MXD SCYR 1/26/2021 4:46:15 PM

Table 2-4-1 – Groundwater Level Range (2014-2019) and Monitoring Summary

Monitoring Location ID	Min (masl)	Max (masl)	2014	2015	2016	2017	2018	2019
Topper Woods South Stage 1A, Stage 1B, Dodge Drive Kelly (DK) Stage 1 / Topper Woods South Stage 2/3, Dodge Drive Kelly Stage 2 (formerly Dodge Drive Kelly Stage 2/3) (Monarch, now Mattamy)								
BH01-11*	300.83	304.21	X	X	X	X	X	NM
BH02-11*	300.22	303.96	X	X	X	X	X	NM
BH03-11*	301.27	303.17	X	X	X	X	X	NM
BH09-13*	NM	NM	NM	NM	NM	NM	NM	NM
BH2003*	301.73	302.52	X	X	X	X	X	NM
BH2013*	298.54	300.16	X	X	X	X	X	NM
BH2015*	300.36	302.20	X	X	X	X	X	NM
BH2018*	301.50	303.01	X	X	X	X	X	NM
BH3001MRC*	309.72	312.24	X	X	X	X	X	NM
BH3002MRC*	308.20	309.50	NM	X	X	X	X	NM
BH3003*	297.34	298.61	X	X	X	X	X	NM
BH3003MRC*	296.56	298.61	X	X	X	X	X	NM
BH3007*	300.34	303.21	X	X	X	X	X	NM
BH3011*	NM	NM	NM	NM	NM	NM	NM	NM
BH3012*	311.28	312.30	X	X	X	X	X	NM
BH3013*	310.68	312.41	X	X	X	X	NM	NM
BH4 (Topper)*	300.25	301.86	X	X	X	X	X	NM
BH9*	299.06	300.26	X	X	X	X	X	NM
GRCA								
BBB-2 (W430)*	300.18	300.79	X	X	X	X	X	X
BH4 (Deep)*	320.22	321.45	X	X	X	X	X	X
BH6*	330.78	332.89	NM	NM	X	X	X	X
BH10*	298.21	298.97	NM	NM	X	X	X	X
Stauffer Woods, Phase 2, Stages 1-10 (Activa)								
BH5 (Deep)*	-	-	-	-	-	-	-	-
BH7 (Deep)*	-	-	-	-	-	-	-	-
BH8 (Deep)*	-	-	-	-	-	-	-	-
BH1024-16*	-	-	-	-	-	-	-	-
MW5-14*	-	-	-	-	-	-	-	-
MW18-14*	-	-	-	-	-	-	-	-
508 New Dundee Road Rd (Ormston, now Activa)								
BH01-13*	-	-	-	-	-	-	-	-
BH03-13*	-	-	-	-	-	-	-	-
BH04-13*	-	-	-	-	-	-	-	-
BH04R-18 (replacement)*	-	-	-	-	-	-	-	-

Monitoring Location ID	Min (masl)	Max (masl)	2014	2015	2016	2017	2018	2019
BH05-13*	-	-	-	-	-	-	-	-
BH06-13*	-	-	-	-	-	-	-	-
Groh South (Hallman)								
BH2001*	-	-	-	-	-	-	-	-
BH1016*	-	-	-	-	-	-	-	-

Notes:

NM = not measured

"-" = no dataset provided

X = data collected for this year

*Water Quality Sample

Underlined Monitoring Locations include continuous water elevation data

2.4.5 Well Location Validation

Groundwater levels and water quality are monitored at numerous wells in the study area. In 2016, discrepancies were identified related to the well locations according to well logs provided by the GRCA. Additional well locations were pulled from the MECP Water Well Information System and from the Region database. These locations were generally found to be inaccurate, as noted in the 2016 SOW requiring coordinates to be georeferenced in the preparation of figures (Aquafor Beech Limited 2016). In addition to issues with coordinates, many of the installed boreholes have similar designations (e.g. BH-1 and BH01) and many of the well locations could not be verified with certainty in the 2016 SOW. Refer to Table 2.3.3 in the 2016 SOW for a complete list of monitoring wells with suggested corrections. It is recommended that field verification of well locations and elevations be carried out as part of the ongoing field program.

2.4.6 Groundwater Level and Temperature Analysis

The current record period (2014-2019) collected since the 2016 SOW are presented herein. The groundwater elevation monitoring network is presented on Figure 2-4-7 and temperature monitors are presented on Figure 2-4-8. Groundwater level monitoring at each well was conducted on either a manual or continuous basis, as indicated in Table 2-4-1. Individual analysis of manual and continuous measurements is provided in the following sections to be consistent with analysis in the 2016 SOW (Aquafor Beech Limited 2016).

2.4.6.1 Existing Manual Groundwater Level Summary

The City of Kitchener provided a record of groundwater levels for the following 14 stations within the study area:

- BBB-2 (W430)
- BH4 (Deep)
- BH6
- BH10
- BH2013
- BH2018
- BH2015
- BH4 (Topper)
- BH3003
- BH3002MRC
- BH01-11
- BH02-11
- BH03-11
- BH9

Additional water level data not included in the 2016 SOW were provided for six additional stations within the study area (Aquafor Beech Limited 2016):

- BH2003
- BH3001MRC
- BH3003MRC
- BH3007
- BH3012
- BH3013

The following eight monitoring locations were included in the 2016 SOW, but datasets were not provided for this update (Aquafor Beech Limited 2016):

- BH2001
- BH1016
- BBB-1G
- BH1
- BH2
- BH8 (Deep)
- BH5 (Deep)
- BH7 (Deep)

Hydrographs for the manual water levels collected at 14 stations are shown from west to east in Figure 2-4-9 (central portion) and Figure 2-4-10 (eastern portion). Most water levels were generally measured on a quarterly basis. The spatial variation in water levels may be reflective of differences in land surface topography.

The groundwater elevations observed within the central portion of the site ranged from approximately 299 masl to 333 masl and were generally consistent between the pre- and during-development periods (Figure 2-4-9). The groundwater elevations observed within the eastern portion of the site ranged from 297 to 307 masl (Figure 2-4-10). The decreasing water level trend observed across the site from west to east matches the inferred groundwater flow across the site. Fluctuations in groundwater elevation in the eastern portion of the site are more pronounced compared to the central portion; however, this is observed in the baseline (pre-2014) and existing conditions elevation trends.

In general, the manual groundwater elevations from 2014-2019 exhibited relatively small fluctuations, typically less than 2 m, which is consistent with the pre-development fluctuations. The water levels generally exhibited seasonal patterns with elevated levels observed in the spring and lower elevations in the winter. Continuous data are expected to better capture these fluctuations. The difference between the maximum and minimum elevations observed at each location generally ranged from 0.6 to 3 m over the course of the 5-year period. However, groundwater elevations at BH01-11 and BH02-11 had elevated observed changes between 3.38 and 3.74 m respectively. This observation is consistent with the 2016 SOW (Aquafor Beech Limited 2016).

The groundwater levels observed in the western portion of the study area was not reassessed in this report as there was insufficient data provided at this time. Refer to Figure 2.3.12 in the 2016 SOW for observed groundwater levels (non-continuous measurements) in the western part of the study area (2006-2014) (Aquafor Beech Limited 2016). It is recommended that the dataset be updated, and groundwater elevation ranges re-evaluated prior to establishing post-construction conditions.

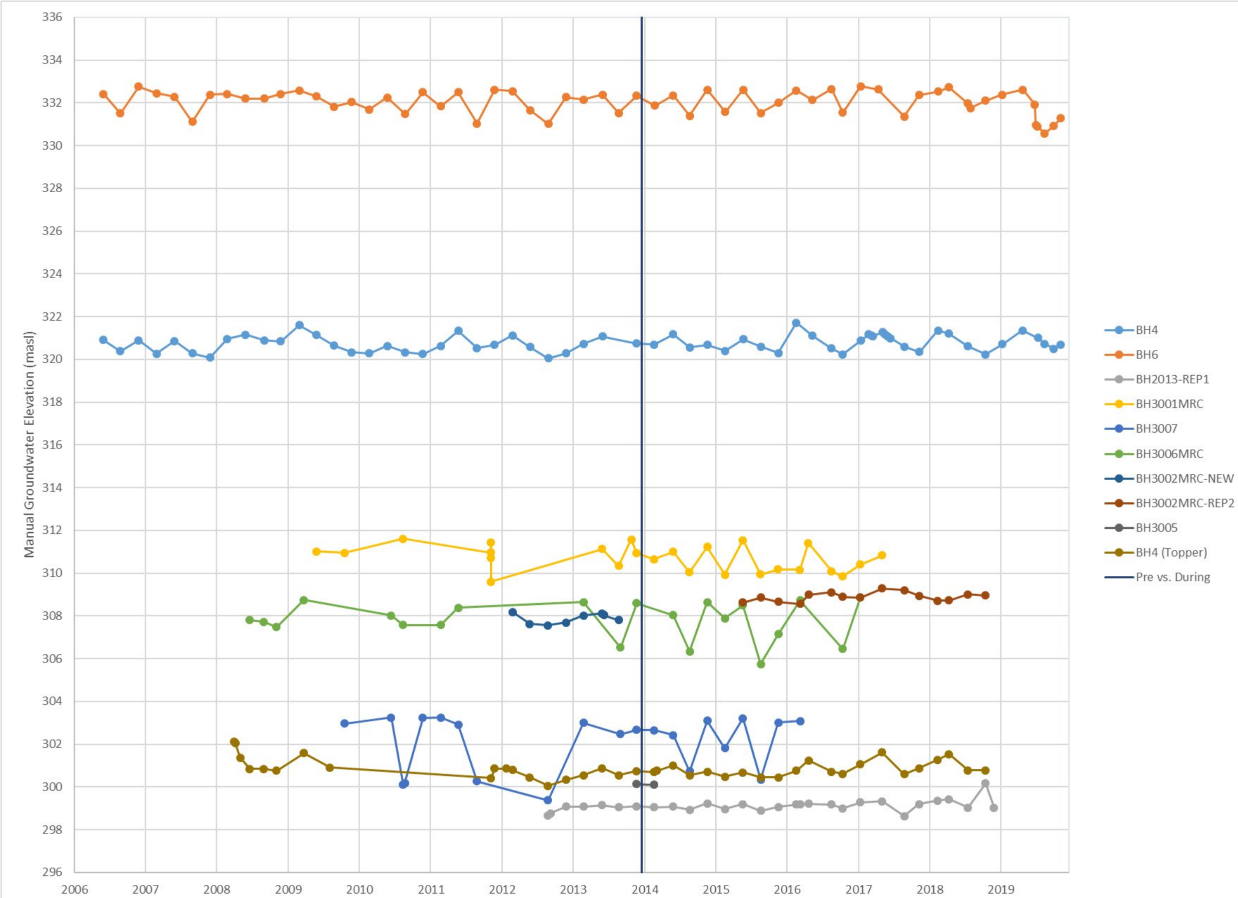


Figure 2-4-9 – Manual Groundwater Elevations across the Central Study Area

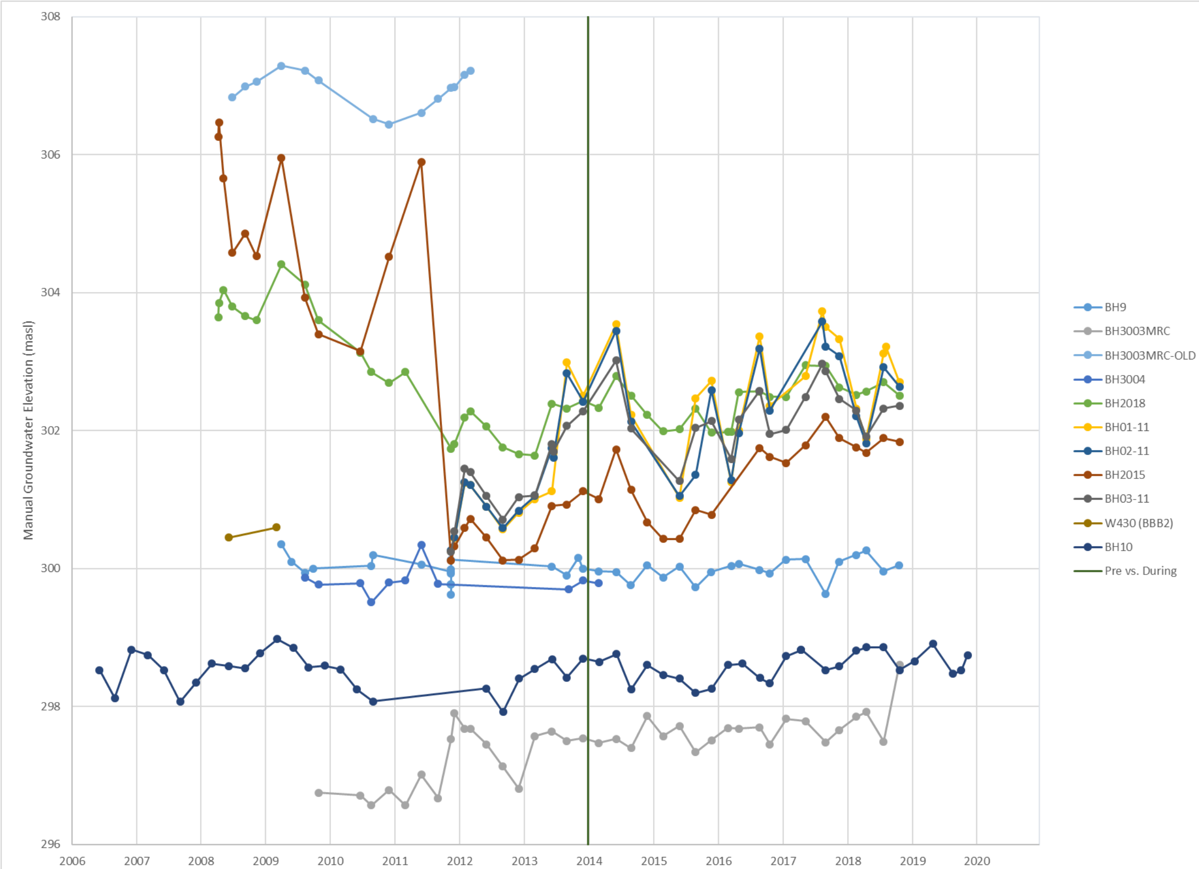


Figure 2-4-10 – Manual Groundwater Elevations across the Eastern Study Area

2.4.6.2 Existing Continuous Groundwater Level Summary

Continuous groundwater elevation data produced by MMM were provided for the preparation of this report and is presented in Figures 2-4-11a (Stage 2/3) and 2-4-11b (Stage 1a). Data gaps can be attributed to logger maintenance, repair, and changes to location (e.g. BH3002MRC).

Based on these hydrographs, the wells are showing seasonal fluctuations <0.5 to approximately 2.5 m, with elevated water levels associated with spring melt, which is consistent with observations made in the 2016 SOW. In general, groundwater elevations were relatively consistent in wells monitored pre and during-construction in Stage 2/3 (Figure 2-4-11a). Monitors BH01-11, BH02-11, and BH03-11 exhibited the most pronounced changes in water elevation during- and post-construction in Stage 1a (Figure 2-4-11b). However, the remaining monitors are all within 1 m from 2011 to 2019.

In addition to the continuous water level data presented, the GRCA collected continuous groundwater elevation data at the following wells: BBB-2 (W430), BH4 (Deep), BH6, and BH10, and are included in Appendix B. Activa Holdings Inc. has collected continuous groundwater elevations at BH5 (Deep), BH7 (Deep), BH8 (Deep), MW5-14, and MW18-14, and Hallman Construction Limited deployed transducers in the following wells: BH1016 and BH2001. These datasets should be included in future assessments to increase the understanding of the groundwater level regime across the site.

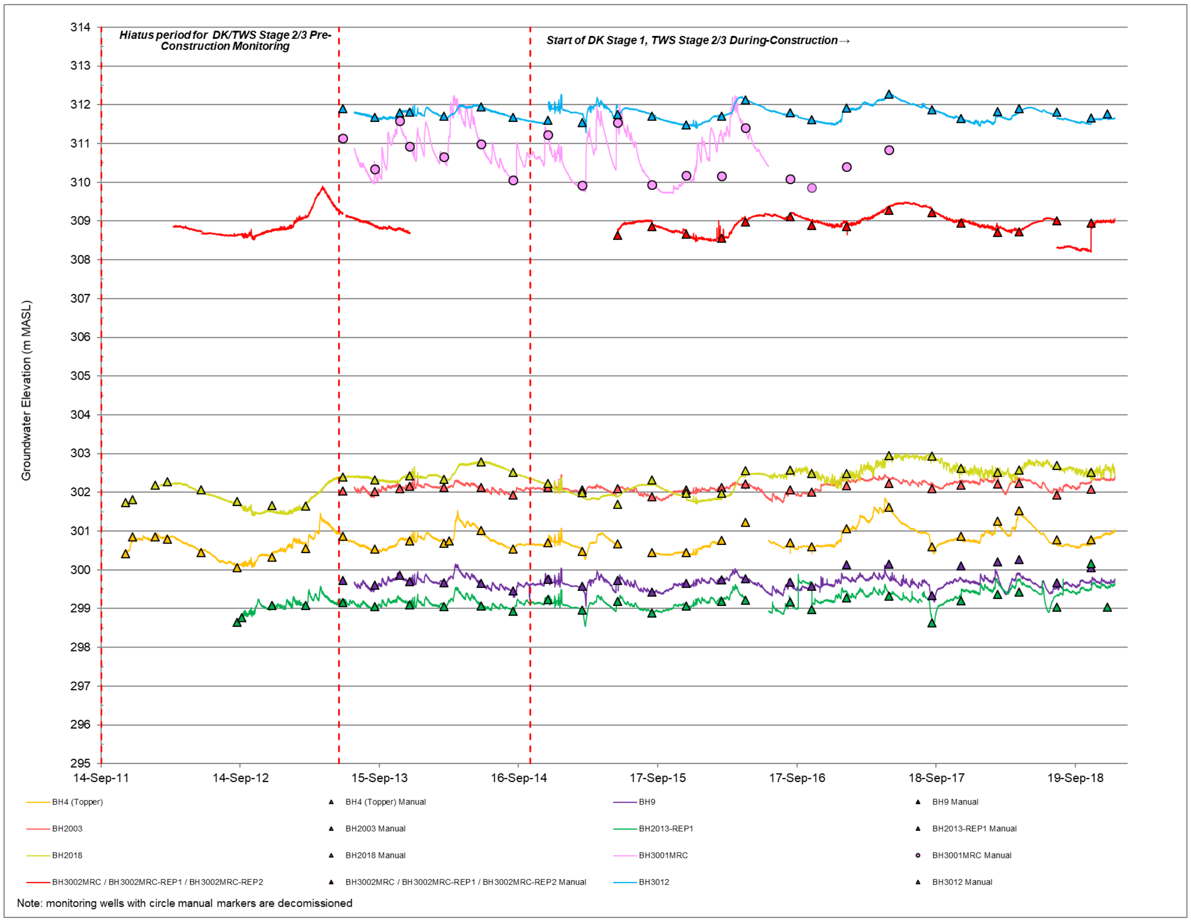


Figure 2-4-11a - Continuous Groundwater Levels for TWS/DK Stage 2/3

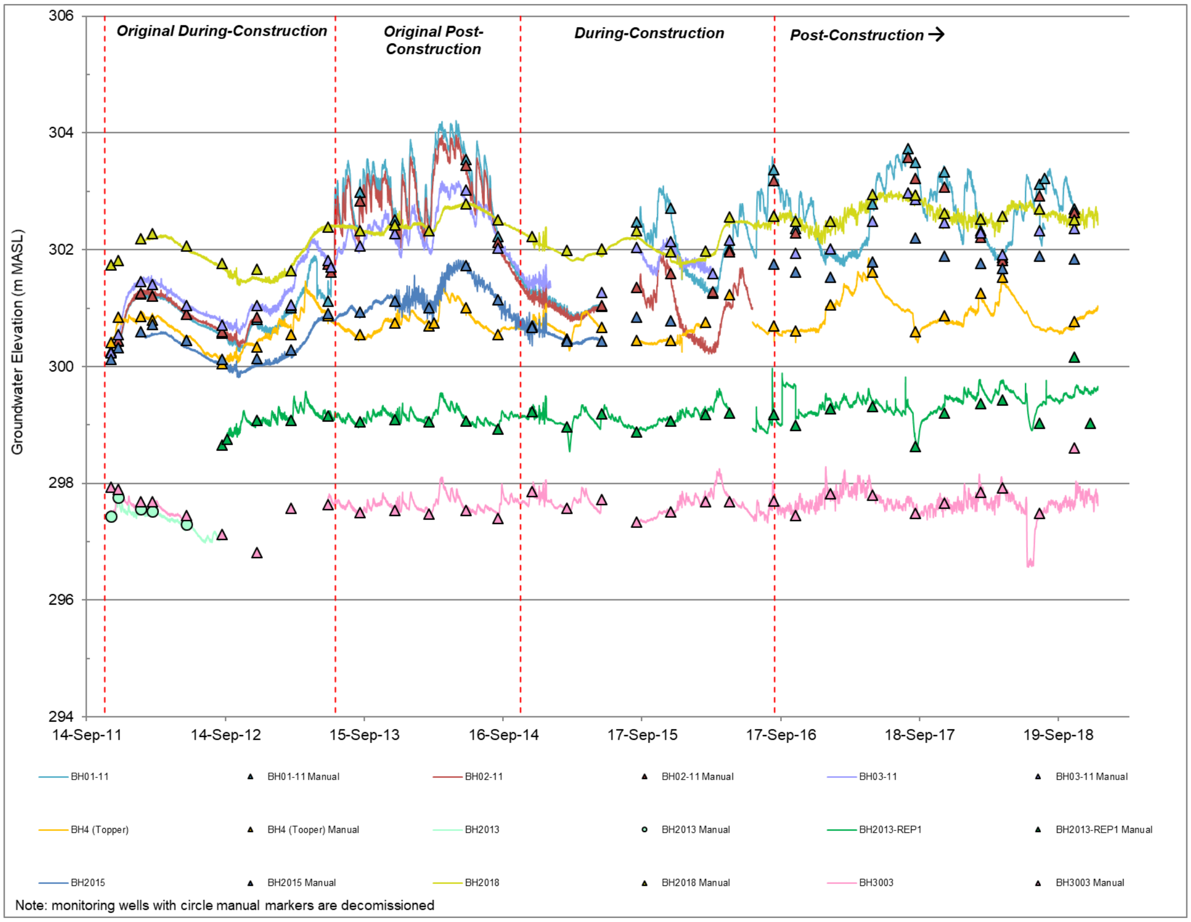


Figure 2-4-11b - Continuous Groundwater Levels for TWS Stage 1a

2.4.6.3 Cross-Sections

Cross-sections running west-east in the study area were presented in the 2016 SOW with minimum and maximum groundwater elevations observed for that period of record posted on the figures. These cross-sections were not updated with this period of record. However, the groundwater level ranges along each cross section are tabulated below in Table 2-4-2a and 2.4.2b below. Refer to Figures 2.3.16 and 2.3.17 in the 2016 SOW for the placement of the stations within these cross-sections (Aquafor Beech Limited 2016).

Groundwater elevations tabulated from west to east in Tables 2-4-2a-b indicate a decreasing trend along each cross section, decreasing from ~320-330 to ~300 masl. These trends are observed in both the baseline (2016 SOW) and current (2014-2019) record periods. These decreasing trends from west-east agree with the inferred groundwater flow direction at the site.

Note that missing well log information was flagged in the 2016 SOW, along with a recommendation to confirm locations and construction details as part of the ongoing monitoring program.

Table 2-4-2a – Minimum and maximum groundwater elevations from West – East (see Figure 2.3.16 in 2016 SOW [Aquafor Beech Limited 2016])

Station ID	2016 SOW Min (masl)	2016 SOW Max (masl)	2014-2019 Min (masl)	2014-2019 Max (masl)
BH1	328.05	329.4	NM	NM
BH6	331.01	332.76	330.78	332.89
BH7 (Deep)	312.98	315.94	-	-
BH2001	306.01	306.94	-	-
BH3001MRC	309.58	311.60	309.72	312.24
BH3002MRC	307.56	308.19	308.20	309.50
BH3003MRC	305.97	306.07	296.56	298.61
BH2018	301.64	304.41	301.50	303.01
BH2015	300.12	306.47	300.36	302.20

Table 2-4-2b – Minimum and maximum groundwater elevations from West – East (see Figure 2.3.17 in 2016 SOW [Aquafor Beech Limited 2016])

Station ID	2016 SOW Min (masl)	2016 SOW Max (masl)	2014-2019 Min (masl)	2014-2019 Max (masl)
BH4 (Deep)	320.06	321.60	320.22	321.45
BH2003	301.85	302.35	301.73	302.52
BH3007	299.38	303.25	300.34	303.21
BH9	299.57	300.39	299.06	300.26
BH4 (Topper)	300.05	302.10	300.25	301.86
BH01-11	300.81	304.35	300.83	304.21
BH02-11	300.53	304.08	300.22	303.96
BH03-11	299.56	303.06	301.27	303.17
BH10	297.92	298.98	298.21	298.97

2.4.6.4 Existing Groundwater Temperature Summary

The continuous groundwater monitoring network is shown on Figure 2-4-8. Note that the monitoring locations ending in "T" (e.g.181T) represent near-surface groundwater temperatures, which have been found to be heavily influenced by climatic conditions and not truly representative of groundwater. These locations were not included in the 2016 SOW to characterize groundwater temperature and therefore not included in the groundwater temperature assessment of existing conditions. The dataset is included in Appendix B.

Continuous groundwater temperature was measured in the following 16 monitoring wells:

- BH4 (Deep)
- BH6
- BH10
- BBB2 (W430)
- BH01-11
- BH02-11
- BH03-11
- BH4 (Topper)
- BH9
- BH2003
- BH2013
- BH2015
- BH2018
- BH3001MRC
- BH3002MRC
- BH3012

The continuous groundwater temperature from these stations are plotted on Figure 2-4-12 which illustrates the sinusoidal nature of the groundwater temperature regime. The temperature data indicate a seasonally variable groundwater temperature regime, with lows generally occurring in March-April, and highs in September-October. Groundwater temperatures are lagged due to travel time. Groundwater temperatures are at their maximum in the fall before frost penetrates the soil. The temperature data from BH2003 was not measured consistently and was omitted from the plot.

Data reported prior to 2014 (baseline) are shown to the left of the grey vertical line, and data recorded to represent existing conditions are observed on the right. Groundwater temperature fluctuations are generally consistent at each well and vary in intensity between wells.

Continuous groundwater temperature was also measured in the five streambed piezometers. These data are not analyzed as part of the updated SOW; these data may be useful to include in the post-construction assessment to characterize the groundwater-surface water relationship along Blair Creek. The dataset is included in Appendix B.

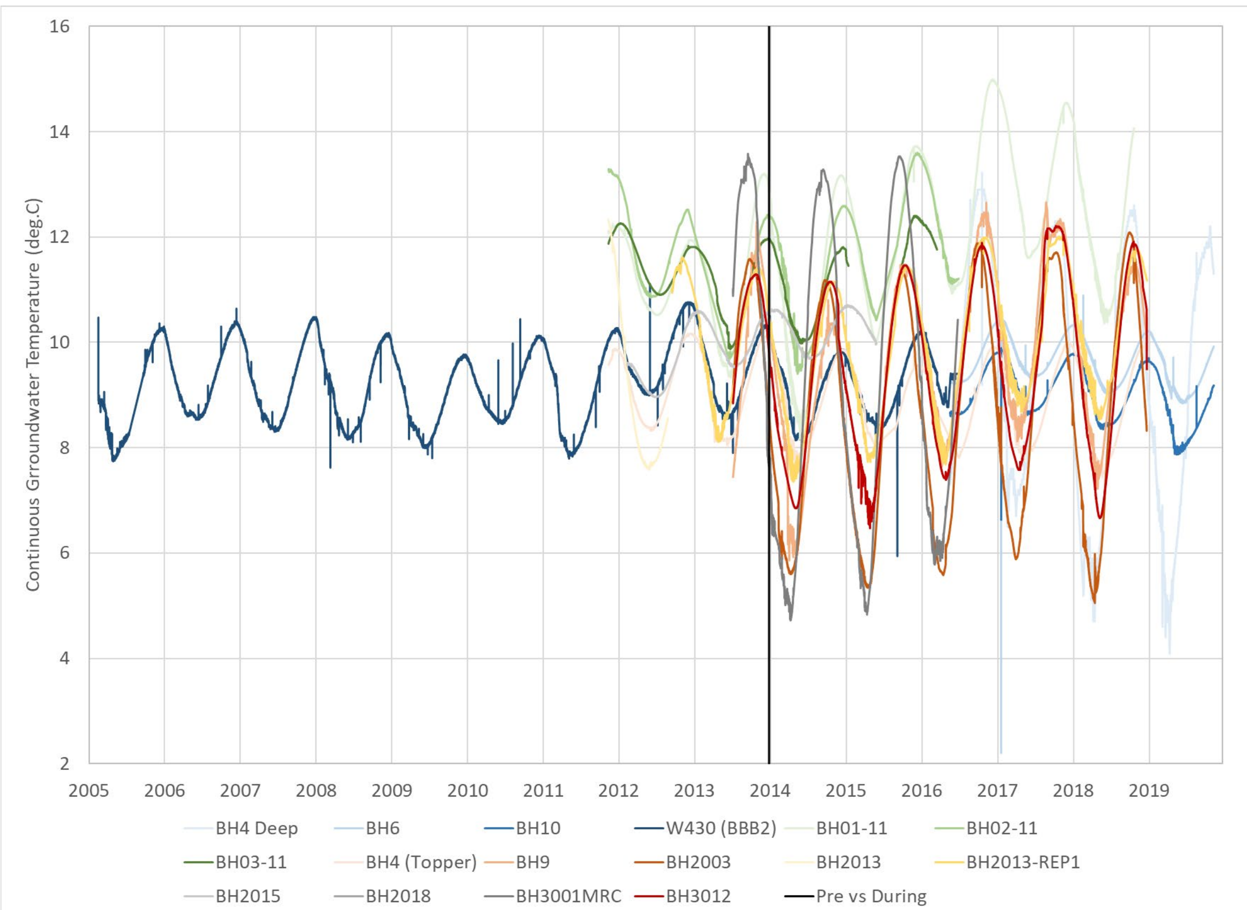


Figure 2-4-12 – Continuous Groundwater Temperature Monitoring

2.4.7 Groundwater Quality Monitoring

Groundwater quality samples were collected at 37 monitoring locations between 2014 and 2019 to represent existing conditions for groundwater quality. Monitors are listed in Tables 2.4.3 to 2.4.6.

2.4.7.1 Data Analysis

The target parameters selected to analyze groundwater quality are the same as those listed in the 2016 SOW with one amendment:

1) Nutrients:
   a) Nitrate + Nitrite
   b) Nitrate
   c) Nitrite – added parameter
   d) Ammonia
2) Inorganic compounds:
   a) Calcium
   b) Copper
   c) Lead
   d) Magnesium
   e) Zinc
3) pH
4) Chloride

The maximum, minimum, mean, median, and standard deviation was determined for each parameter at each location, following the method used in the 2016 report (Aquafor Beech Limited 2016).

The results were compared to the Ontario Drinking Water Standards (ODWS), and exceedances are shown in red bold font. Chloride was also compared to the RUC, which is 133 mg/L.

Note that nitrate + nitrite was reported in 2016, but the ODWS has since amended the guidelines, and removed this parameter, recommending the assessment of nitrate and nitrite separately. Both nitrate + nitrite, nitrate, and nitrite are presented in this report for convenience.

2.4.7.2 Results

Nutrients: Nutrient concentrations (Table 2-4-3a-b) were generally below the ODWS for nitrate + nitrite, nitrate, and nitrite for most monitoring locations. Concentrations exceeding the ODWS for nitrate + nitrite (10 mg/L) were observed at two monitoring locations, BH1 and BH1024-16. In nitrate samples, concentrations exceeding the ODWS (10 mg/L) were observed at four additional monitoring locations (BH2015, BH2018, BH3001MRC, and BH9).

Three monitoring locations with exceedances in this record period (BH1, BH2015, and BH2018) did not have exceedances reported in the 2016 SOW. In comparison, nitrate concentrations in baseline reporting (2006-2013) exceeded the ODWS at eleven monitoring locations. Overall, nutrient concentrations are generally within the same range as the baseline conditions report in 2016. For example, nitrate concentrations in 2016 ranged from <MDL to 18.5 mg/L compared to a maximum concentration of 15.2 mg/L in this record period ((Aquafor Beech Limited 2016).

There were no groundwater quality samples with nitrite concentrations exceeding the ODWS of 1 mg/L. There currently isn't an ODWS for ammonia.

Inorganic Compounds: Inorganic compound concentrations are reported in Table 2-4-4a-c. There was an exceedance of the lead ODWS (10 ug/L) observed at one monitoring location (BH6) in this period. In the baseline record period, lead exceedances were observed at three monitoring locations which did not report any exceedances in this period (BH2013, BH3003MRC, and BH9). There were no ODWS exceedances observed for copper, lead, or zinc. There are currently no guidelines for calcium or magnesium.

pH: The pH results from 2014-2019 are tabulated in Table 2-4-5. Fifteen monitoring locations had pH results which fell outside the range of 6.5-8.5. There were no instances of pH measurements outside this range in the baseline report. It is recommended that the entirety of the pH dataset be subject to further QA/QC to identify any differences between field and laboratory measurement methods.

Chloride: Chloride concentrations from the current record period (2014-2019) are presented in Table 2-4-6. Additionally, chloride concentrations vs time is illustrated on Figure 2-4-13. Two monitoring locations (BH4 (Deep) and BH01-11) had concentrations which exceeded the ODWS of 250 mg/L. The pre-development assessment in 2016 identified one monitoring location with exceedances (BH2018).

The FDS included a recommendation that chloride concentrations should not exceed 133 mg/L based on the RUC. This was determined using the method provided by the *MECP Groundwater Management Activities* (MECP 1994). Mean chloride concentrations exceeded this guideline (133 mg/L) at three monitoring locations: BH4 (Deep), BH01-11, and BH2013. In addition, maximum chloride concentrations exceeded 133 mg/L at five additional locations: BH02-11, BH03-11, BH2018, MW18-14, and BH04R-18.

The RUC exceedances observed at BH04R-18 and MW18-14 are isolated to one measurement each. The exceedances at BH4 (Deep) and BH3003 are more consistent and occur during the baseline and existing conditions results. The discrete chloride concentrations in Figure 2-4-13 indicate potential seasonality, with maximum concentrations observed in April-June. These potential fluctuations may indicate that road salt application may be impacting groundwater quality following snowmelt. However, these results are discrete samples, and more consistent measuring may verify seasonal variations. It is recommended that chloride concentrations be assessed in conjunction with continuous conductivity measurements to assess any potential road salt impacts to groundwater quality.

Table 2-4-3a – Existing Monitoring Summary, Nutrient Concentrations

Monitoring Location	Nitrate + Nitrite (mg/L)[1]						Nitrate (mg/L)					
	# Samples	Min	Max	Mean	Median	Std. Dev	# Samples	Min	Max	Mean	Median	Std. Dev
GRCA												
BB-2 (W430)	0	-	-	-	-	-	16	0.01	0.28	0.06	0.05	0.06
BH4 (Deep)	0	-	-	-	-	-	17	0.05	5.99	1.68	1.47	1.65
BH6	0	-	-	-	-	-	17	0.22	5.68	4.06	4.32	1.48
BH10	0	-	-	-	-	-	17	0.29	6.68	1.62	1.00	1.52
Topper Woods South Stage 1A, Stage 1B, Dodge Drive Kelly (DK) Stage 1 / Topper Woods South Stage 2/3, Dodge Drive Kelly Stage 2 (formerly Dodge Drive Kelly Stage 2/3) (Monarch, now Mattamy)												
BH4 (Topper)	0	-	-	-	-	-	13	0.17	7.27	2.25	1.60	2.05
BH9	0	-	-	-	-	-	15	1.46	**11.0**	4.88	3.70	3.04
BH01-11	0	-	-	-	-	-	12	0.10	2.21	0.40	0.13	0.61
BH02-11	0	-	-	-	-	-	11	0.10	1.69	0.32	0.10	0.48
BH03-11	0	-	-	-	-	-	13	0.10	0.24	0.11	0.10	0.04
BH09-13	0	-	-	-	-	-	0	-	-	-	-	-
BH2003	0	-	-	-	-	-	16	0.05	0.10	0.10	0.10	0.01
BH2013	0	-	-	-	-	-	14	2.63	5.00	3.54	3.47	0.74
BH2015	0	-	-	-	-	-	12	1.76	**12.7**	7.50	8.02	4.09
BH2018	0	-	-	-	-	-	14	4.65	**15.2**	8.45	8.44	2.67
BH3001MRC	0	-	-	-	-	-	9	7.53	**11.4**	9.31	9.40	1.16
BH3002MRC	12	4.82	8.05	6.16	6.04	1.04	12	4.82	8.05	6.16	6.04	1.04
BH3003MRC	0	-	-	-	-	-	0	-	-	-	-	-
BH3007	0	-	-	-	-	-	0	-	-	-	-	-
BH3011	1	6.63	6.63	6.63	6.63	-	1	6.63	6.63	6.63	6.63	-
BH3012	0	-	-	-	-	-	16	1.17	9.73	5.51	6.72	2.93
BH3013	0	-	-	-	-	-	0	-	-	-	-	-
Stauffer Woods, Phase 2, Stages 1-10 (Activa)												
BH1	4	**10.3**	**11.4**	**10.85**	**10.85**	0.45	4	**10.3**	**11.4**	**10.9**	**10.9**	0.45
BH2	4	4.56	8.42	5.88	5.27	1.75	4	4.56	8.42	5.88	5.27	1.75
BH5 (Deep)	12	0.1	0.1	0.1	0.1	0.0	12	0.10	0.10	0.10	0.10	0.00
BH7 (Deep)	12	0.63	6.78	1.97	1.42	1.68	12	0.63	6.78	1.97	1.42	1.68
BH8 (Deep)	12	3.15	6.96	5.34	5.64	1.24	12	3.15	6.96	5.34	5.64	1.24
BH1024-16	8	6.64	**12.7**	9.13	9.12	2.00	8	6.64	**12.7**	9.13	9.12	2.00
MW5-14	11	0.1	0.1	0.1	0.1	0.0	11	0.10	0.12	0.10	0.10	0.01
MW18-14	12	4.47	9.29	6.37	6.31	1.38	12	4.47	9.29	6.37	6.31	1.38
508 New Dundee Road Rd (Ormston, now Activa)												
ORMBH01-13	8	0.011	5.54	3.13	4.20	2.05	8	0.011	5.54	3.13	4.20	2.05
ORMBH03-13	4	3.91	6.05	4.82	4.66	0.98	4	3.91	6.05	4.82	4.66	0.98
ORMBH04-13	3	0.62	1.48	1.00	0.89	0.44	3	0.62	1.48	1.00	0.89	0.44
ORMBH04R-18	4	0.29	1.76	0.99	0.96	0.72	4	0.29	1.76	0.99	0.96	0.72
ORMBH-5-13	6	0.55	2.81	1.42	1.23	0.80	6	0.55	2.81	1.42	1.23	0.80
ORMBH06-13	17	0.28	2.79	1.67	1.83	0.78	17	0.28	2.79	1.67	1.83	0.78
Groh South (Hallman)												
BH2001	-	-	-	-	-	-	-	-	-	-	-	-
BH1016	-	-	-	-	-	-	-	-	-	-	-	-
ODWS	10						10					

Notes

[1]Nitrate + Nitrite was removed from the ODWS and separated into Nitrate and Nitrite.

The ODWS are reported in O. Reg. 169/03: Ontario Drinking Water Quality Standards under Safe Drinking Water Act, 2002, S.O. 2002, c.32.

Concentrations are reported as nitrogen (N)

Concentrations exceeding the ODWS are **bolded in red**

Bolded Monitoring Locations were reported in the 2016 State of the Watershed Report.

O. Reg. = Ontario Regulation

Table 2-4-3b – Existing Monitoring Summary, Nutrient Concentrations

Monitoring Location	Nitrite (mg/L)						Ammonia (mg/L)					
	# Samples	Min	Max	Mean	Median	Std. Dev	# Samples	Min	Max	Mean	Median	Std. Dev
GRCA												
BB-2 (W430)	16	0.005	0.043	0.008	0.005	0.009	0	-	-	-	-	-
BH4 (Deep)	17	0.005	0.010	0.005	0.005	0.001	0	-	-	-	-	-
BH6	17	0.005	0.217	0.065	0.038	0.067	0	-	-	-	-	-
BH10	17	0.005	0.015	0.006	0.005	0.002	0	-	-	-	-	-
Topper Woods South Stage 1A, Stage 1B, Dodge Drive Kelly (DK) Stage 1 / Topper Woods South Stage 2/3, Dodge Drive Kelly Stage 2 (formerly Dodge Drive Kelly Stage 2/3) (Monarch, now Mattamy)												
BH4 (Topper)	13	0.01	0.02	0.01	0.01	0.00	12	0.05	0.25	0.08	0.05	0.06
BH9	15	0.01	0.03	0.01	0.01	0.00	13	0.05	0.05	0.05	0.05	0
BH01-11	12	0.01	0.01	0.01	0.01	0.00	11	0.05	0.10	0.06	0.05	0.02
BH02-11	11	0.01	0.03	0.01	0.01	0.01	10	0.07	0.25	0.14	0.13	0.06
BH03-11	13	0.01	0.12	0.04	0.03	0.03	12	0.05	0.47	0.26	0.25	0.10
BH09-13	2	0.01	0.01	0.01	0.01	0.00	2	0.05	0.06	0.05	0.05	0.00
BH2003	16	0.01	0.05	0.02	0.01	0.01	14	0.05	0.25	0.14	0.13	0.05
BH2013	14	0.01	0.02	0.01	0.01	0.00	13	0.05	0.21	0.06	0.05	0.04
BH2015	12	0.01	0.02	0.01	0.01	0.00	11	0.05	0.31	0.09	0.07	0.08
BH2018	14	0.01	0.30	0.03	0.01	0.08	13	0.05	0.27	0.09	0.06	0.07
BH3001MRC	9	0.01	0.01	0.01	0.01	0.00	7	0.05	0.10	0.06	0.05	0.02
BH3002MRC	12	0.01	0.02	0.01	0.01	0.00	11	0.05	0.05	0.05	0.05	0.00
BH3003MRC	0	-	-	-	-	-	0	-	-	-	-	-
BH3007	0	-	-	-	-	-	0	-	-	-	-	-
BH3011	1	0.01	0.01	0.01	0.01	-	1	0.05	0.05	0.05	0.05	-
BH3012	16	0.01	0.01	0.01	0.01	0.00	14	0.05	0.06	0.05	0.05	0.00
BH3013	0	-	-	-	-	-	0	-	-	-	-	-
Stauffer Woods, Phase 2, Stages 1-10 (Activa)												
BH1	4	0.01	0.01	0.01	0.01	0.00	0	-	-	-	-	-
BH2	4	0.01	0.01	0.01	0.01	0.00	0	-	-	-	-	-
BH5 (Deep)	12	0.01	0.03	0.01	0.01	0.01	0	-	-	-	-	-
BH7 (Deep)	12	0.01	0.02	0.01	0.01	0.00	0	-	-	-	-	-
BH8 (Deep)	12	0.01	0.06	0.02	0.01	0.01	0	-	-	-	-	-
BH1024-16	8	0.01	0.01	0.01	0.01	0.00	0	-	-	-	-	-
MW5-14	11	0.01	0.02	0.01	0.01	0.00	0	-	-	-	-	-
MW18-14	12	0.01	0.01	0.01	0.01	0.00	0	-	-	-	-	-
508 New Dundee Road Rd (Ormston, now Activa)												
ORMBH01-13	8	0.01	0.01	0.01	0.01	0	0	-	-	-	-	-
ORMBH03-13	4	0.01	0.01	0.01	0.01	0	0	-	-	-	-	-
ORMBH04-13	3	0.01	0.01	0.01	0.01	0	0	-	-	-	-	-
ORMBH04R-18	4	0.01	0.01	0.01	0.01	0	0	-	-	-	-	-
ORMBH-5-13	6	0.01	0.01	0.01	0.01	0	0	-	-	-	-	-
ORMBH06-13	17	0.01	0.01	0.01	0.01	0	0	-	-	-	-	-
Groh South (Hallman)												
BH2001	-	-	-	-	-	-	-	-	-	-	-	-
BH1016	-	-	-	-	-	-	-	-	-	-	-	-
ODWS	1						No standard					

Notes

[1]Nitrate + Nitrite was removed from the ODWS and separated into Nitrate and Nitrite.

The ODWS are reported in O. Reg. 169/03: Ontario Drinking Water Quality Standards under Safe Drinking Water Act, 2002, S.O. 2002, c.32.

Concentrations are reported as nitrogen (N)

Concentrations exceeding the ODWS are **bolded in red**

Bolded Monitoring Locations were reported in the 2016 State of the Watershed Report.

Table 2-4-4a – Existing Monitoring Summary, Inorganic Concentrations

Monitoring Location	Calcium (mg/L)						Copper (ug/L)					
	# Samples	Min	Max	Mean	Median	Std. Dev	# Samples	Min	Max	Mean	Median	Std. Dev
GRCA												
BB-2 (W430)	16	140	180	165.0	160.0	12.6	16	0.50	2.80	0.71	0.50	0.59
BH4 (Deep)	17	46	160	75.4	70.0	27.4	16	0.00	0.00	0.00	0.00	0.00
BH6	17	58	340	78.4	61.0	67.5	17	0.00	0.50	0.30	0.50	0.25
BH10	17	73	98	79.1	77.0	6.4	17	0.00	0.50	0.41	0.50	0.20
Topper Woods South Stage 1A, Stage 1B, Dodge Drive Kelly (DK) Stage 1 / Topper Woods South Stage 2/3, Dodge Drive Kelly Stage 2 (formerly Dodge Drive Kelly Stage 2/3) (Monarch, now Mattamy)												
BH4 (Topper)	10	89	130	110.9	110.0	11.2	13	1.00	2.20	1.12	1.00	0.34
BH9	12	85	170	117.8	115.0	27.6	15	1.00	4.10	1.32	1.00	0.81
BH01-11	10	41	420	134.4	62.5	142.4	12	1.00	2.10	1.23	1.00	0.35
BH02-11	8	64	130	98.8	103.0	29.1	11	1.00	2.30	1.66	1.70	0.43
BH03-11	10	90	180	124.2	130.0	26.5	13	1.60	3.30	2.49	2.60	0.51
BH09-13	0	-	-	-	-	-	2	1.10	1.90	1.50	1.50	0.57
BH2003	13	60	77	72.6	73.0	4.6	16	1.00	1.00	1.00	1.00	0.00
BH2013	**11**	98	140	122.5	130.0	17.1	14	1.00	4.10	1.22	1.00	0.83
BH2015	9	110	170	146.7	150.0	18.0	12	1.00	1.10	1.01	1.00	0.03
BH2018	11	72	140	94.7	93.0	21.9	14	1.00	2.90	1.25	1.00	0.54
BH3001MRC	9	65	140	87.0	85.0	21.1	9	1.00	2.70	1.19	1.00	0.57
BH3002MRC	9	82	97	91.9	94.0	4.7	12	1.00	3.20	1.42	1.00	0.67
BH3003MRC	0	-	-	-	-	-	0	-	-	-	-	-
BH3007	0	-	-	-	-	-	0	-	-	-	-	-
BH3011	0	-	-	-	-	-	1	1.00	1.00	1.00	1.00	-
BH3012	13	47	97	73.9	74.0	15.6	16	1.00	5.80	1.33	1.00	1.20
BH3013	0	-	-	-	-	-	0	-	-	-	-	-
Stauffer Woods, Phase 2, Stages 1-10 (Activa)												
BH1	4	75	80	78.0	78.5	2.2	4	1.90	31.00	10.70	4.95	13.61
BH2	4	110	150	122.5	115.0	18.9	4	1.00	1.50	1.13	1.00	0.25
BH5 (Deep)	12	97	110	102.9	100.0	5.3	12	1.00	1.00	1.00	1.00	0.00
BH7 (Deep)	12	67	110	85.9	80.5	15.9	12	1.00	1.50	1.04	1.00	0.14
BH8 (Deep)	12	89	120	104.2	105.0	10.7	12	1.00	7.10	2.72	2.10	1.81
BH1024-16	8	70	100	90.5	96.0	11.3	16	1.00	1.00	1.00	1.00	0.00
MW5-14	11	52	60	54.5	54.0	2.7	11	1.00	5.10	2.85	2.90	1.57
MW18-14	12	75	110	86.3	84.0	9.1	12	1.00	2.90	1.67	1.50	0.68
508 New Dundee Road Rd (Ormston, now Activa)												
ORMBH01-13	8	53	89	79.9	82.5	11.3	8	1.00	1.60	1.10	1.00	0.21
ORMBH03-13	4	53	60	57.0	57.5	3.2	4	1.00	24.00	8.28	4.05	10.67
ORMBH04-13	3	64	74	67.7	65.0	5.5	3	1.00	1.40	1.13	1.00	0.23
ORMBH04R-18	4	45	120	87.5	92.5	31.8	4	1.00	9.30	4.98	4.80	4.49
ORMBH-5-13	6	41	57	49.3	50.5	6.0	6	1.00	1.80	1.25	1.10	0.33
ORMBH06-13	17	57	90	76.0	76.0	8.6	17	1.00	63.00	5.04	1.20	14.95
Groh South (Hallman)												
BH2001	-	-	-	-	-	-	-	-	-	-	-	-
BH1016	-	-	-	-	-	-	-	-	-	-	-	-
ODWS	no standard						1000					

Notes

The ODWS are reported in O. Reg. 169/03: Ontario Drinking Water Quality Standards under Safe Drinking Water Act, 2002, S.O. 2002, c.32.

Concentrations exceeding the ODWS are **bolded in red**

Bolded Monitoring Locations were reported in the 2016 State of the Watershed Report.

Table 2-4-4b – Existing Monitoring Summary, Inorganic Concentrations

Monitoring Location	Lead (ug/L)						Magnesium (mg/L)					
	# Samples	Min	Max	Mean	Median	Std. Dev	# Samples	Min	Max	Mean	Median	Std. Dev
GRCA												
BB-2 (W430)	16	0.25	2.8	0.41	0.25	0.64	16	33	43	38.3	38.5	2.89
BH4 (Deep)	17	0.25	0.61	0.27	0.25	0.09	17	11	38	16.8	15	6.67
BH6	17	0.25	**22**	1.69	0.25	5.28	17	20	48	22.5	21	6.66
BH10	17	0.25	0.25	0.25	0.25	0.00	17	16	20	17.5	17	1.23
Topper Woods South Stage 1A, Stage 1B, Dodge Drive Kelly (DK) Stage 1 / Topper Woods South Stage 2/3, Dodge Drive Kelly Stage 2 (formerly Dodge Drive Kelly Stage 2/3) (Monarch, now Mattamy)												
BH4 (Topper)	12	0.5	0.5	0.5	0.5	0.0	13	21	27	23.9	24	1.98
BH9	14	0.5	0.5	0.5	0.5	0.0	15	16	43	28.13	28	7.89
BH01-11	11	0.5	0.5	0.5	0.5	0.0	13	7.8	71	20.9	12	20.76
BH02-11	10	0.5	0.5	0.5	0.5	0.0	11	13	33	21.1	18	7.19
BH03-11	12	0.5	0.5	0.5	0.5	0.0	13	19	40	26.8	28	5.63
BH09-13	2	0.5	0.5	0.5	0.5	0.0	2	15	15	15.0	15	0.00
BH2003	15	0.5	0.5	0.5	0.5	0.0	16	21	28	25.7	26	1.58
BH2013	13	0.5	0.5	0.5	0.5	0.0	14	24	39	31.5	32.5	4.55
BH2015	11	0.5	0.5	0.5	0.5	0.0	12	26	41	36.3	37	3.87
BH2018	13	0.5	3.4	0.72	0.5	0.80	14	17	31	20.8	19	4.49
BH3001MRC	9	0.5	3.3	0.81	0.5	0.93	9	15	31	20.2	20	4.55
BH3002MRC	11	0.5	0.5	0.5	0.5	0.0	12	25	34	30.6	31	2.19
BH3003MRC	0	-	-	-	-	-	0	-	-	-	-	-
BH3007	0	-	-	-	-	-	0	-	-	-	-	-
BH3011	1	0.5	0.5	0.5	0.5	-	1	17	17	17.0	17	-
BH3012	15	0.5	0.5	0.5	0.5	0.0	16	9.8	23	16.9	16.5	3.90
BH3013	0	-	-	-	-	-	0	-	-	-	-	-
Stauffer Woods, Phase 2, Stages 1-10 (Activa)												
BH1	4	0.5	0.5	0.5	0.5	0.0	4	17	18	17.5	17.5	0.58
BH2	4	0.5	1.6	0.775	0.5	0.55	4	20	27	22.8	22	2.99
BH5 (Deep)	12	0.5	0.5	0.5	0.5	0.0	12	31	38	33.2	33	1.70
BH7 (Deep)	12	0.5	0.5	0.5	0.5	0.0	12	14	31	18.2	17	4.88
BH8 (Deep)	12	0.5	0.5	0.5	0.5	0.0	12	23	33	28.4	29	2.94
BH1024-16	15	0.5	0.5	0.5	0.5	0.0	16	21	28	25.7	26	1.58
MW5-14	11	0.5	0.5	0.5	0.5	0.0	11	21	24	22.2	22	1.08
MW18-14	12	0.5	0.5	0.5	0.5	0.0	12	15	25	18.8	18	2.52
508 New Dundee Road Rd (Ormston, now Activa)												
ORMBH01-13	8	0.5	0.5	0.5	0.5	0.0	8	16	30	27.0	28.5	4.60
ORMBH03-13	4	0.5	0.5	0.5	0.5	0.0	4	16	18	17.0	17	1.15
ORMBH04-13	3	0.5	0.5	0.5	0.5	0.0	3	15	18	16.7	17	1.53
ORMBH04R-18	4	0.5	0.5	0.5	0.5	0.0	4	6.5	19	14.1	15.5	5.48
ORMBH-5-13	6	0.5	0.5	0.5	0.5	0.0	6	14	21	16.3	15.5	2.73
ORMBH06-13	17	0.5	1.4	0.55	0.5	0.22	17	11	18	15.5	15	1.66
Groh South (Hallman)												
BH2001	-	-	-	-	-	-	-	-	-	-	-	-
BH1016	-	-	-	-	-	-	-	-	-	-	-	-
ODWS	10						no standard					

Notes

The ODWS are reported in O. Reg. 169/03: Ontario Drinking Water Quality Standards under Safe Drinking Water Act, 2002, S.O. 2002, c.32.

Concentrations exceeding the ODWS are **bolded in red**

Bolded Monitoring Locations were reported in the 2016 State of the Watershed Report.

Table 2-4-4c – Existing Monitoring Summary, Inorganic Concentrations

Monitoring Location	Zinc (ug/L)					
	# Samples	Min	Max	Mean	Median	Std. Dev
GRCA						
BB-2 (W430)	16	2.5	5.7	3.48	2.5	3.17
BH4 (Deep)	17	2.5	14	3.68	2.5	3.36
BH6	17	2.5	99	16.68	10.0	23.80
BH10	17	2.5	19	5.44	2.5	5.56
Topper Woods South Stage 1A, Stage 1B, Dodge Drive Kelly (DK) Stage 1 / Topper Woods South Stage 2/3, Dodge Drive Kelly Stage 2 (formerly Dodge Drive Kelly Stage 2/3) (Monarch, now Mattamy)						
BH4 (Topper)	13	7.5	210	39.25	14.0	59.37
BH9	15	5	12	5.47	5.0	1.81
BH01-11	13	5	54	11.52	7.6	13.48
BH02-11	11	5	190	34.33	5.0	58.53
BH03-11	13	5	20	6.22	5.0	4.15
BH09-13	2	5	5	5.00	5.0	0.00
BH2003	8	5	8.4	5.64	5.0	1.18
BH2013	14	5	16	6.26	5.0	3.02
BH2015	12	5	6.5	5.13	5.0	0.43
BH2018	14	5	16	6.50	5.0	3.82
BH3001MRC	9	5	36	13.74	8.9	11.01
BH3002MRC	12	5	13	6.45	5.3	2.45
BH3003MRC						
BH3007	-	-	-	-	-	-
BH3011	1	5	5	5	5	-
BH3012	16	22	250	81.56	66.5	61.03
BH3013	-	-	-	-	-	-
Stauffer Woods, Phase 2, Stages 1-10 (Activa)						
BH1	4	5	6.6	5.40	5.0	0.80
BH2	4	5	5.4	5.10	5.0	0.20
BH5 (Deep)	12	5	14	5.75	5.0	2.60
BH7 (Deep)	12	5	15	5.83	5.0	2.89
BH8 (Deep)	12	5	5	5.00	5.0	0.00
BH1024-16	16	5	370	36.96	5.3	92.12
MW5-14	11	5	6.2	5.11	5.0	0.36
MW18-14	12	5	9.1	5.63	5.0	1.28
508 New Dundee Road Rd (Ormston, now Activa)						
ORMBH01-13	8	5	5	5.00	5.0	0.00
ORMBH03-13	4	5	5	5.00	5.0	0.00
ORMBH04-13	3	5	23	11.00	5.0	10.39
ORMBH04R-18	4	5	9.6	6.73	6.2	2.20
ORMBH-5-13	6	5	5	5.00	5.0	0.00
ORMBH06-13	17	5	38	7.09	5.0	8.24
Groh South (Hallman)						
BH2001	-	-	-	-	-	-
BH1016	-	-	-	-	-	-
ODWS	5000					

Notes

The ODWS are reported in O. Reg. 169/03: Ontario Drinking Water Quality Standards under Safe Drinking Water Act, 2002, S.O. 2002, c.32.

Concentrations exceeding the ODWS are **bolded in red**

Bolded Monitoring Locations were reported in the 2016 State of the Watershed Report.

Table 2-4-5 – Existing Monitoring Summary, pH

Monitoring Location	pH (units)					
	# Samples	Min	Max	Mean	Median	Std. Dev
GRCA						
BB-2 (W430)	-	-	-	-	-	-
BH4 (Deep)	-	-	-	-	-	-
BH6	-	-	-	-	-	-
BH10	-	-	-	-	-	-
Topper Woods South Stage 1A, Stage 1B, Dodge Drive Kelly (DK) Stage 1 / Topper Woods South Stage 2/3, Dodge Drive Kelly Stage 2 (formerly Dodge Drive Kelly Stage 2/3) (Monarch, now Mattamy)						
BH4 (Topper)	15	6.73	**8.54**	7.47	7.35	0.45
BH9	30	6.63	**8.65**	7.58	7.52	0.50
BH01-11	15	7.23	**8.59**	7.66	7.63	0.40
BH02-11	13	7.11	7.94	7.50	7.44	0.29
BH03-11	15	6.58	7.82	7.71	7.26	0.35
BH09-13	2	7.52	7.83	7.68	7.68	0.22
BH2003	21	**6.01**	**8.84**	7.77	7.89	0.58
BH2013	17	7.00	8.46	7.58	7.49	0.37
BH2015	14	**5.69**	8.42	7.13	7.04	0.64
BH2018	17	6.95	**8.53**	7.61	7.59	0.35
BH3001MRC	13	7.23	**8.70**	7.84	7.94	0.36
BH3002MRC	10	7.24	8.10	7.61	7.60	0.24
BH3003MRC	-	-	-	-	-	-
BH3007	-	-	-	-	-	-
BH3011	1	7.74	7.74	7.74	7.74	-
BH3012	21	**6.04**	**8.73**	7.78	7.76	0.51
BH3013	-	-	-	-	-	-
Stauffer Woods, Phase 2, Stages 1-10 (Activa)						
BH1	3	7.90	**10.98**	**8.99**	8.09	1.73
BH2	3	7.48	7.72	7.59	7.57	0.12
BH5 (Deep)	4	**5.88**	8.07	7.30	7.63	1.00
BH7 (Deep)	5	7.67	**9.08**	8.10	7.93	0.57
BH8 (Deep)	5	7.10	**9.09**	7.89	7.74	0.74
BH1024-16	4	7.61	**9.44**	7.84	7.82	0.25
MW5-14	4	8.18	**9.44**	**8.68**	**8.56**	0.57
MW18-14	5	7.54	**8.96**	8.23	7.99	0.58
508 New Dundee Road Rd (Ormston, now Activa)						
ORMBH01-13	2	7.76	8.30	8.03	8.03	0.38
ORMBH03-13	-	-	-	-	-	-
ORMBH04-13	-	-	-	-	-	-
ORMBH04R-18	4	7.99	8.50	8.19	8.14	0.23
ORMBH-5-13	-	-	-	-	-	-
ORMBH06-13	4	7.43	8.26	7.90	7.95	0.38
Groh South (Hallman)						
BH2001	-	-	-	-	-	-
BH1016	-	-	-	-	-	-
ODWS	6.5-8.5					

Notes

The ODWS are reported in O. Reg. 169/03: Ontario Drinking Water Quality Standards under Safe Drinking Water Act, 2002, S.O. 2002, c.32.

Concentrations exceeding the ODWS are **bolded in red**

Bolded Monitoring Locations were reported in the 2016 State of the Watershed Report.

Table 2-4-6 – Existing Monitoring Summary, Chloride

Monitoring Location	Chloride (mg/L)					
	# Samples	Min	Max	Mean	Median	Std. Dev
GRCA						
BB-2 (W430)	16	87	120	104.3	105	10.84
BH4 (Deep)	17	75	***<u>340</u>***	*<u>184.4</u>*	*<u>160</u>*	74.62
BH6	17	6.8	15	9.0	9.1	1.95
BH10	17	5.8	79	19.8	18	17.90
Topper Woods South Stage 1A, Stage 1B, Dodge Drive Kelly (DK) Stage 1 / Topper Woods South Stage 2/3, Dodge Drive Kelly Stage 2 (formerly Dodge Drive Kelly Stage 2/3) (Monarch, now Mattamy)						
BH4 (Topper)	13	4.1	16	8.3	7.1	3.59
BH9	15	16	43.0	26.5	26.0	9.4
BH01-11	13	8.8	***<u>1400</u>***	***<u>255.8</u>***	31	481.19
BH02-11	11	9	*<u>170</u>*	51.6	21	57.24
BH03-11	13	5	*<u>170</u>*	52.5	34	44.55
BH09-13	2	6.9	11	9.0	8.95	2.90
BH2003	16	5	6.4	6.0	6	0.36
BH2013	14	45	*<u>210</u>*	*<u>144.4</u>*	*<u>160</u>*	55.04
BH2015	12	3	14	7.2	6.75	3.99
BH2018	14	22	*<u>250</u>*	108.4	100	58.84
BH3001MRC	9	2.4	18	9.6	7.3	5.94
BH3002MRC	12	10	37	25.2	29	9.32
BH3003MRC	0	-	-	-	-	-
BH3007	0	-	-	-	-	-
BH3011	1	37	37	37.0	37	-
BH3012	16	1	11	4.6	3.55	3.14
BH3013	0	-	-	-	-	-
Stauffer Woods, Phase 2, Stages 1-10 (Activa)						
BH1	4	6.6	7.3	6.9	6.85	0.29
BH2	4	6.8	12	8.3	7.15	2.49
BH5 (Deep)	12	14	19	17.0	17	1.41
BH7 (Deep)	12	1.4	26	3.9	2.05	6.95
BH8 (Deep)	12	14	26	20.7	20.5	3.45
BH1024-16	8	2.7	18	5.7	3.45	5.09
MW5-14	11	1.4	2.5	1.9	1.9	0.34
MW18-14	12	8.8	*<u>140</u>*	40.8	22.5	45.46
508 New Dundee Road Rd (Ormston, now Activa)						
ORMBH01-13	2	5.3	5.4	5.4	5.35	0.07
ORMBH03-13	0	-	-	-	-	-
ORMBH04-13	0	-	-	-	-	-
ORMBH04R-18	4	77	*<u>160</u>*	110.8	103	35.51
ORMBH-5-13	0	-	-	-	-	-
ORMBH06-13	4	24	47	38.5	41.5	10.21
Groh South (Hallman)						
BH2001	-	-	-	-	-	-
BH1016	-	-	-	-	-	-
ODWS	250					

Notes
The ODWS are reported in O. Reg. 169/03: Ontario Drinking Water Quality Standards under Safe Drinking Water Act, 2002, S.O. 2002, c.32.
Concentrations exceeding the ODWS are **bolded in red**
Concentrations exceeding the RUC (133 mg/L) are *<u>underlined and italicized</u>*.
Bolded Monitoring Locations were reported in the 2016 State of the Watershed Report.

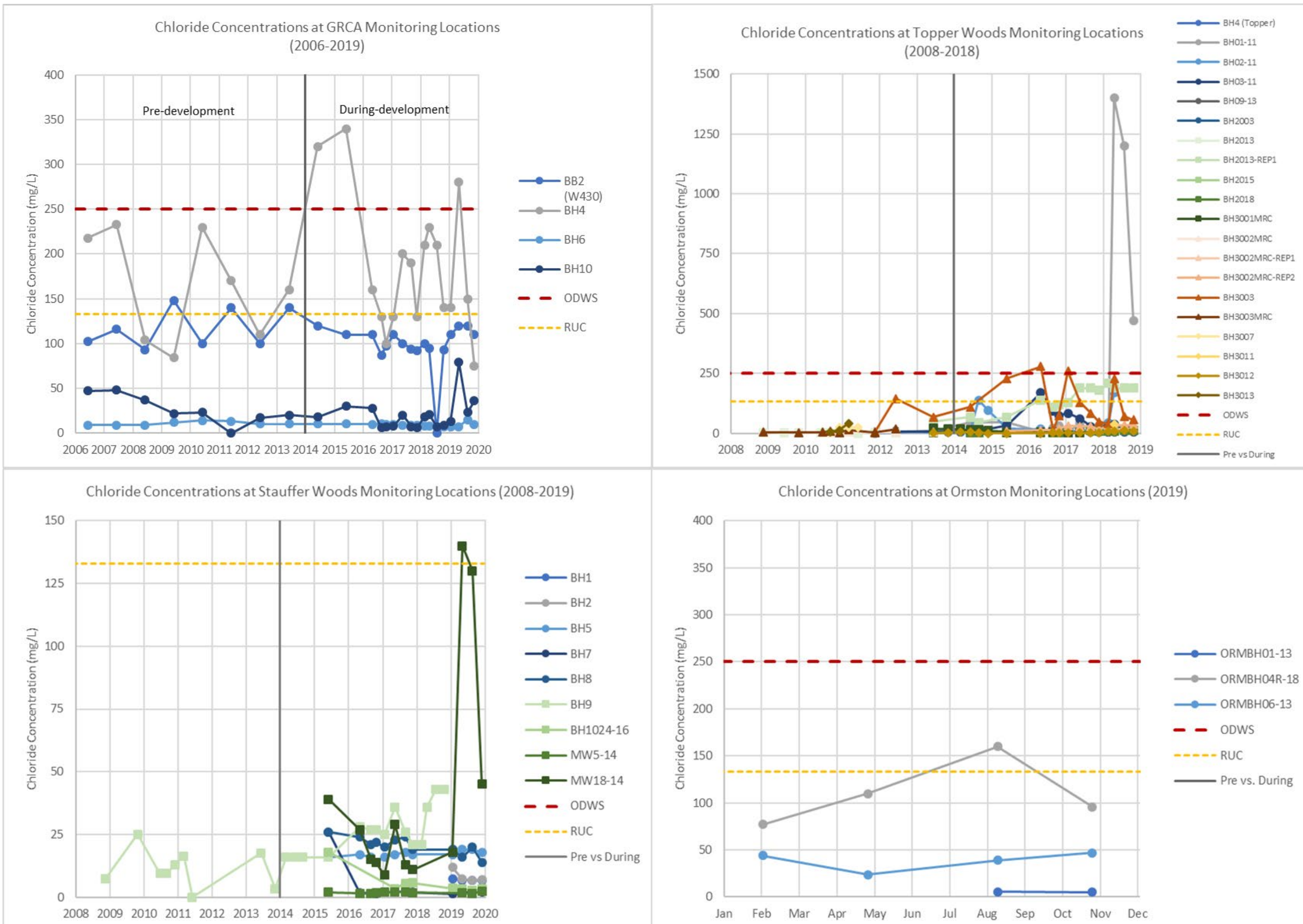


Figure 2-4-13 – Chloride Concentrations Vs. Time

2.4.8 Conclusions

Based on the analysis of groundwater levels and temperature, the following conclusions have been made.

1) Manual and continuous groundwater measurements were consistent. Manual groundwater elevations for this study period exhibited relatively small fluctuations, typically less than 2 m, which is consistent with the pre-development fluctuations. The water levels generally exhibited seasonal patterns with elevated levels observed in the spring and lower elevations in the winter. Continuous groundwater elevations exhibit seasonal fluctuations <0.5 m to approximately 2.5 m, with elevated water levels associated with spring melt events.
2) Groundwater elevations generally decrease from west to east from ~320 masl to ~300 masl which indicates an inferred eastern flow direction, which is consistent with groundwater flow directions described in previous studies.
3) The temperature data indicate a seasonally variable groundwater temperature regime, with lows generally occurring in March-April, and highs in September-October, and temperature fluctuations are generally consistent at each well and vary in intensity between wells.

Based on the analysis of key groundwater quality parameters, the following conclusions have been made.

1) The results of the groundwater quality monitoring continue to indicate typical impacts from adjacent agricultural land use activities. Specifically, the concentration of nutrients (nitrate) exceeds the ODWS (10 mg/L) in six of the 31 boreholes with groundwater quality results reported within the study area.
2) The results continue to show no issues related to heavy metals including zinc, lead, and copper, except for lead where one sample had observed concentrations greater than the ODWS (10 ug/L).
3) Most of the monitoring locations had pH results which fell outside the ODWS range (6.5-8.5). There were no instances of pH measurements outside this range in the baseline report. This could be related to discrepancies between pH measurements in field compared to pH observed in laboratory samples.
4) The chloride exceedance identified in the 2016 SOW at BH2018 was observed at concentrations less than the ODWS during this study period. Overall, concentrations of chloride were below the ODWS limit (250 mg/L) in all cases except BH4 (Deep) and BH01-11 which had maximum concentrations exceeding the ODWS; however, only BH01-11 had a mean chloride concentration value (256 mg/L) exceeding the ODWS.
5) Mean concentrations of chloride exceeded the recommended maximum concentration of chloride in groundwater of 133 mg/L per the Reasonable Use Concept (RUC) at three locations: BH4 (Deep), BH01-11, and BH2013. Maximum sampled chloride concentrations exceeded 133 mg/L at five additional locations: BH02-11, BH03-11, BH2018, MW18-14, and BH04R-18.
6) There is no apparent trend in the concentrations of nutrients or heavy metals over the monitoring period. Potential seasonal fluctuations related to chloride concentrations may indicate that road salt application may be impacting groundwater quality following snowmelt. However, these groundwater quality results are from discrete samples, and more consistent observations may verify seasonal variations.

Based on the groundwater analysis, the following recommendations have been made.

1) Confirm locations and construction details of each monitoring location as part of the ongoing monitoring program.
2) Incorporate groundwater elevations observed in the western portion of the study area to increase understanding of flow across the subwatershed and to produce updated flow contours and hydraulic gradients.
3) Incorporate datasets of water elevation and temperature from five streambed piezometers to characterize groundwater-surface water relationships along Bair Creek.
4) Review the pH dataset to identify any differences between field and laboratory measurement methods.
5) Assess chloride concentrations in conjunction with continuous conductivity measurements to assess any potential road salt impacts to groundwater quality. In addition, it is recommended that the continuous conductivity data be utilized as a surrogate to identify any potential seasonal trends.
6) Continue to monitor chloride concentrations, which exceeded the ODWS (250 mtg/L) at two locations. Further investigations may be required to determine the source.

2.5 Stream Morphology

2.5.1 Context

The pre- and during-development geomorphic conditions within the Blair Creek Watershed are described through several key studies and monitoring reports. Geomorphology files can be found in Appendix C. These include the following:

Pre-Development

- **Blair, Bechtel, and Bauman Creeks Subwatershed Plan** (CH2M Gore and Storrie 1997): This study established the pre-development geomorphic conditions within the Blair Creek watershed. The BBB Study established the Blair Creek as a C4 stream and established the reaches of Blair Creek discussed in subsequent studies and field monitoring studies.
- **Functional Drainage Study (Stantec, 2009)**. This study established the expectations for the Upper Blair Creek monitoring program including the annual geomorphic monitoring activities.
- **2016 Upper Blair Creek State of the Watershed Report (Aquafor Beech Limited, 2016)**. This was the first state of the watershed report and established the pre-development baseline condition and identified indicators of change.

During-Development

- Ongoing geomorphic monitoring reports (2015 to 2019) by Water's Edge.

The field investigations completed through the BBB Study established two reaches of Blair Creek (CH2M Gore and Storrie 1997):

- Between Highway 401 and Dickie Settlement Road (reaches 1 and 2), and
- Between Dickie Settlement Road and Old Mill Road (reaches 3 and 4).

Two representative riffles were selected for measurements within each reach. These include monitoring sites XS-1 to XS-3 for reaches 1 and 2 and XS-4 to XS-6 for reaches 3 and 4 respectively. Measurements included cross-sectional surveys and bulk sampling of bed sediment material.

These reaches are maintained throughout the Upper Blair Creek monitoring program with some additional cross-sections added early in the during-development period.

2.5.2 Summary of Past Monitoring

Stream morphology monitoring was undertaken by Parish Geomorphic limited from 2003 to 2014. Water's Edge Environmental Solutions (Water's Edge) undertook the stream morphology monitoring for 2015 to 2019. Cross-sections are monitored at least once a year with some locations monitored twice a year. Figure 2-5-1 shows the locations of the geomorphic cross sections. Table 2-5-1 illustrates annual geomorphic monitoring by cross-section.

Notes:
1. Image of map No. 1, Blair Creek Geomorphic Monitoring, by Grand River Conservtion Authority, June 4 2020.

Figure 2-5-1
Existing Geomorphic Cross-section Monitoring Locations
Upper Blair Creek State of the Watershed
City of Kitchener
Upper Blair Creek Subwatershed, Kitchener, Ontario

Jacobs

\\DC1VS01\GISPROJ\K\KITCHENERCITYOF\UPPERBLAIRCREEK_P20_005\MAPFILES\SOW\2_5_1_EXISTING_XSECT_MWLOCATIONS.MXD SCYR 1/26/2021 4:43:00 PM

Table 2-5-1 - Geomorphic Monitoring by Cross Section

Reach	**Cross Section**	**Year**																
		2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Reach 4	XS-1A													✓	✓	✓	✓	✓
	XS-1	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
	XS-2	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Reach 3	XS-3A													✓	✓	✓	✓	✓
	XS-3				✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
	XS-3B													✓	✓	✓	✓	✓
Reach 2	XS-4			✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
	XS-5						✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
	XS-6						✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Reach 1 Main Tributary	XS-6A													✓	✓	✓	✓	✓
	XS-6B													✓	✓	✓	✓	✓
	XS-6C													✓	✓	✓	✓	✓
	XS-6D													✓	✓	✓	✓	✓
	XS-6E													✓	✓	✓	✓	✓
	XS-6F													✓	✓	✓	✓	✓
	XS-7						✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
	XS-8						✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
	XS-9						✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Roseville Tributary	XS-10						✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
	XS-11						✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
	XS-12						✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓

In 2008, sediment traps were added to the monitoring program at XS-2, XS-3, and XS-4.

In 2009, the monitoring program was expanded to include:

- Eight additional cross-sections were added to the monitoring program (XS-5 to XS-12),
- 21 erosion pins, at various cross sections
- 12 depth disturbance rods (one per cross section), and
- 6 longitudinal profile measurements.

These changes were the result of an Ontario Municipal Board recommendation.

Based on recommendations in the 2016 SOW additional cross sections were added to the monitoring program in 2016 (Aquafor Beech Limited 2016). These include XS-1A, XS-3A, XS-3B, XS-6A, XS-6B, XS-6C, XS-6D, XS-6E, and XS-6F.

2.5.3 Data Analysis

Monitoring data from between 2003 and 2019 were collected by Parish Geomorphic Limited (Parish) and Water's Edge. These time periods can be divided into the pre-development conditions, which were used to establish the baseline documented in the 2016 SOW, and the during-development conditions. The monitoring data collected for the during-development period is compared to the thresholds identified and defined in the 2016 SOW (Aquafor Beech Limited 2016). To confirm that the same methods were used for the review of the during-development data as those to establish the baseline, a review of the pre-development monitoring data was performed. In some cases where the established baseline was not replicated, a review of previous methods was conducted to determine if the pre-development (existing condition) baseline needed to be re-defined.

2.5.3.1 Monitoring

Parish conducted monitoring between 2003-2014. The data collected was analyzed in the 2016 SOW to establish the existing stream geomorphology conditions and to recommend during-development monitoring targets. The 2016 SOW reviewed four parameters to establish the baseline predevelopment condition of Blair Creek (Aquafor Beech Limited 2016). Water's Edge conducted monitoring between 2015 and 2019 for the during-development period and will be reviewed as part of this SOW and compared with the baseline.

These included:

- **Stream Flow Volume and Hours of Erosion Discharge:** this parameter is an indicator for levels of erosion and sediment transport. The 2016 SOW notes that there are large amounts of sand within the Upper Blair Creek watershed and therefore it is anticipated that any change in runoff volumes will impact sediment transport rates (Aquafor Beech Limited 2016).
- **Bankfull Cross-sectional area (square metres [m^2])**: is an effective way to monitor changes in stream morphological conditions and can detect channel enlargement or sediment deposition. Rate of change in bankfull cross sectional area is a key indicator for the during-development period.
- **Bankfull Channel Depth (m):** average bankfull depth is an indicator of changes in morphological conditions and can detect channel deepening.
- **Substrate size (D_{50} and D_{90}):** can be an indicator of urban runoff carrying sediment from areas under construction. This parameter can be subject to limitations for monitoring development related impacts but should be considered as part of a weight of evidence approach.

- **Bank Migration:** rates defined in the pre-development period in the 2016 SOW are the natural channel migration rates for comparison with the during-development data or, eventually, the post development periods (Aquafor Beech Limited 2016).

2.5.3.2 Definition of Geomorphic Indicators

Table 2-5-2 outlines the quantitative indicators of change for the geomorphology parameters.

Table 2-5-2 Quantitative indicators of change for geomorphology parameters

<table>
<tr><th>Monitoring Parameter</th><th colspan="3">Existing Conditions</th><th>Indicator Monitoring Target</th></tr>
<tr><td>Stream flow volume and hours of erosion discharge</td><td colspan="3">XS-4 (Dickie Settlement Road Gauge)
2yr Discharge: 2.84 m^3/s
Bankfull Discharge: 2.62 m^3/s [a]
Critical Discharge: 0.4 m^3/s
Average Annual Exceedances over 5-year Periods
Volume of Exceedance: 2 x 10^6 m^3
Time of Exceedance: 700 hours</td><td>Maintain annual flow volume and hours of exceedance above critical discharge within 15% of existing conditions assessed over 5-year period.</td></tr>
<tr><td>Bankfull cross-sectional area (m^2) [b]</td><td colspan="3">Reaches 3-4 (XS-1 to 3): 3.0 ± 0.2 m^2
Reach 2 (XS-4 to 6): 2.40 ± 0.3 m^2
Main tributary Reach (X-7 to 9): 0.8 ± 0.1 m^2
Roseville Tributary Reach (XS-10 to 12): 2.7 ± 0.3 m^2</td><td>Maintain bankfull cross-sectional area (m^2) within 30% of existing conditions.</td></tr>
<tr><td>Average bankfull channel depth (m)</td><td colspan="3">Reaches 3-4 (XS-1 to 3): 0.05 ± 0.05 m^2
Reach 2 (XS-4 to 6): 0.40 ± 0.05 m^2
Main tributary Reach (X-7 to 9): 0.35 ± 0.05 m^2
Roseville Tributary Reach (XS-10 to 12): 0.55 ± 0.05 m^2</td><td>Maintain bankfull depth (m) within 30% of existing conditions.</td></tr>
<tr><td>Bank Migration Rates (cm/yr)</td><td colspan="3">At locations where bank migration is expected (e.g. EP 4,5,10,12,19) Migration Rates are 5-10 cm/yr (or 1-2% of bankfull width per year)</td><td>Normal migration rates ≈ 10% bankfull width over 5 years at locations where bankfull migration is expected</td></tr>
<tr><td rowspan="4">Substrate Particle Size, D_{50} and D_{90} (mm)</td><td colspan="3">Gravel Bed</td><td rowspan="4">Maintain D50 and D90 particle sizes within plus or minus one order of magnitude compared to existing conditions, assess at 5-year intervals</td></tr>
<tr><td>Reaches 3-4 (XS-2 & 3)</td><td>D_{50} (mm)
6 ± 5
7 ± 6</td><td>D_{90} (mm)
6 ± 5
7 ± 6</td></tr>
<tr><td colspan="3">Sand Bed [c]</td></tr>
<tr><td>Tributary Reaches (XS-7 to 12)</td><td>Fine sand
(0.1 to 1)</td><td>Coarse sand
(1-3)</td></tr>
</table>

Note:

[a] Parish, 2009

[b] Existing conditions here are based on the 2016 SOW reinterpreted cross sectional areas from Parish's measurements.

[c] "Assessment of target threshold exceedances requires interpretation of site conditions and monitoring trends by a qualified geomorphologist. Further data and interpretation are required to refine the existing grain size values for sand bed channels" (ABL, 2016 pg. 253).

cm/yr = centimetre(s) per year

2.5.3.3 Cross-Section Impacts

Water's Edge reported activities in the watershed that will impact the ability of this SOW to determine if changes observed are connected to development activities or due to other factors (Water's Edge 2020). These limitations are as follows:

- **XS-1A**: Cross-section XS-1A was added to the monitoring program to monitor construction impacts from changes at the Blair Creek crossing with the Fountain Street Bridge. Due to this known upstream impact at this cross section during the during-development period, for the purposes of this SOW, impacts noted at XS-1A cannot be correlated to development within the Study Area.
- **XS-2:** A beaver dam was constructed upstream of XS-2. This beaver dam has resulted in overland flow which re-enters the channel upstream of XS-2 which has resulted in bank erosion and has impacted sediment deposition at this cross section. Therefore, this SOW will not be able to determine if changes to the Creek at this cross section are due to beaver activity or development within the Study Area.
- **XS-7, 8, and 9**: Beginning in 2017 beaver activity was observed in the area and subsequent flooding was observed. The channel could be located, however, increased water depth meant erosion pins were submerged and sediment samples could not be collected. The channel is fully dammed at XS-7 and overland flow has resulted in a side channel forming. This channel re-enters along the left bank at XS-7. Note that these cross sections are immediately downstream from development areas and are the cross sections that would have been most likely to show impacts due to development.

As a result of these impacts, the evaluation of during-development conditions with the pre-development conditions will focus on the non-impacted cross sections. Where data is available during the development period, this SOW will make recommendations on future monitoring activities.

2.5.3.4 Methodology

A review of the assessment/analysis methodology in the 2016 SOW was performed to ensure a consistent approach is applied between SOW reports. The findings of this review, by indicating parameter, is summarized below.

Stream Flow Volume and Hours of Erosion Discharge: Section 2.4.3 of the SOW (Aquafor Beech Limited 2016) used the average annual volume and time of exceedance above the 0.4 m^3/s critical discharge, put forward in the FDS (Stantec 2009), as measured at the Dickie Settlement Road flow gauge. The Water's Edge 2020 Final report applies the same methods and gauging location. Therefore, this SOW presents the analysis performed by Water's Edge with interpretation of what these results indicate with respect to the SOW.

Bankfull Cross Sectional Area: Section 2.4.3 of the 2016 SOW states that the cross-sectional area reported by Parish is a simplification of true bankfull cross sectional area (Aquafor Beech Limited 2016). The data reported by Parish is the cross-sectional area for the cross section below the elevation of the tape and survey pins (Parish, 2014). This type of cross-section data may not reveal variability in the cross section within the active bankfull channel. The 2016 SOW review of the Parish data indicated potential variability in the sag in the tape during depth and width measurements (Aquafor Beech Limited 2016). Therefore, the 2016 SOW reinterpreted the Parish monitoring data using a bankfull width and depth to compute bankfull cross sectional area. The source for the bankfull widths and depths used for the computation of the reinterpreted bankfull cross sectional areas presented in the 2016 SOW is unclear (Aquafor Beech Limited 2016).

Bankfull Depth: Section 2.4.3 of the 2016 SOW identifies average bankfull depth as the depth of disturbance rods (Aquafor Beech Limited 2016). Changes in average bankfull depths is an efficient parameter to evaluate short-term (recent) changes to the channel. Combined with other factors like sedimentation and scour on floodplains, bankfull depth can be considered an indication of a long-term trend. This methodology is consistent with the analysis completed by Water's Edge in the 2020 Final report. This report will present their findings with interpretation on application of findings to the current SOW.

Substrate Particle Size Distribution: Section 2.4.3 notes that the 2016 SOW focused on comparison of the D_{50} and D_{90} substrates as hand-texture grain sizing for particles under 5 mm is less reliable. The 2016 SOW rounded the reported substrate values to be consistent with significant digits with one significant figure considered reasonable for finer grain sizes (e.g. <5 mm and <0.2 mm for fine sand). The analysis of particle size distribution in this SOW will maintain this approach. For the during-development period, the interpretation of data will focus on increases in sand and silt in reaches downstream of Blair Creek (that are not impacted by beaver or other known construction activities).

Bank Migration: The 2016 SOW established bank migration rates based on where migration is anticipated to occur (Aquafor Beech Limited 2016). The work by Water's Edge, summarized in the 2020 Final Report, is consistent with this approach. The results and comparison with the existing conditions will be presented with interpretation on how this impacts the current SOW.

2.5.4 Results

This section presents the results of the analysis of the during-development period and compares the results with the baseline established in the 2016 SOW (Aquafor Beech Limited 2016).

2.5.4.1 Stream Flow Volume and Hours of Erosive Discharge

The long-term intention of monitoring stream flow volume and hours of erosive discharge at XS-4 (Dickie Settlement Road gauging station) is to monitor the effectiveness of the stormwater management facilities. However, at this time, many of the stormwater management facility (SWMF) performance (are not yet online and therefore this parameter cannot currently provide information on SWMF performance.

Table 2-5-3 presents the indicating parameter, baseline condition established in the 2016 SOW (Aquafor Beech Limited 2016), and the results for the during-development period.

Table 2-5-3 Assessment of Stream Flow Volume and Hours of Erosion Discharge (Aquafor Beech Limited 2016)

Parameter	During-Development Value [b]	Baseline Condition [a]	Change from Baseline
Erosion Threshold / Critical Discharge (m^3/s) [A]		0.4	N/A
Total Time Exceeding Erosion Threshold (hours)	5,502	700	**786%**
Total Volume Exceeding (gigalitres)	7.4	2.0	**368%**

Notes:

[a] Used as evaluation for Exceedance Time, Source: 2016 SOW (Aquafor Beech Limited 2016), derived from the 2009 FDS (Stantec 2009)

[b] Source: Water's Edge 2020

These findings show that total time exceeding the erosion threshold and total volume are significantly greater than the threshold target outlined in the 2016 SOW of changes within 15 percent (Aquafor Beech Limited 2016). This evaluation has not, however, been corrected to account for differences in precipitation between the baseline condition and existing conditions. The monitoring location for this parameter is at XS-4, which is downstream of the beaver impacted areas along XS-7 to 9. It is unclear if this has a mitigating effect on the results or exacerbates them. These results are consistent with the Hydrology findings in section 2.2.5 of this SOW, which found increasing trends in flood frequency and flow volumes.

2.5.4.2 Bankfull Cross Sectional Area Results

The monitoring carried out by Water's Edge from 2015 to 2019 completed a quantitative assessment of bankfull cross-sectional area. The 2020 Final Report (Water's Edge 2020) also provided a qualitative assessment that bankfull cross-sectional areas were within the threshold indicators set out in the 2016 SOW (Aquafor Beech Limited 2016).

Review of the existing conditions baseline established in the 2016 SOW, included a review of the reported Parish values and percent adjustments reported in their 2014 Final monitoring report (Parish 2014). This review identified some inconsistencies in the computation of percent adjustment; therefore, this current SOW re-establishes the rate of change by cross section for the baseline (existing) condition. The 2016 SOW established the existing (pre-development) conditions for bankfull cross-sectional area based on the adjusted cross-sectional areas. Due to inconsistencies between the basis of comparison between the Parish monitoring (Parish 2014), 2016 SOW (Aquafor Beech Limited 2016), and the 2020 Water's Edge monitoring, the baseline established in 2016 was reviewed and determined appropriate as the basis of comparison for this current SOW report.

This review determined that it was not appropriate to use the adjusted bankfull cross sectional areas, established as the baseline condition in the 2016 SOW (Aquafor Beech Limited 2016), to determine if changes occurring over the during-development period are due to development activities. Water's Edge reported the mean bankfull cross-sectional area for each cross-section. Water's Edge compared these cross-sectional areas to the 2014 mean cross-sectional area. Review of this analysis indicated that for many cross-sectional areas, the 2014 mean cross-sectional area reported (and used as the basis of comparison) was not consistent with the baseline reported in the 2016 SOW (Water's Edge 2020). Therefore, few conclusions can be made from the direct comparison of cross-sectional areas. Rather, a comparison of annual percent change between the pre- and during-development periods was completed qualitatively to evaluate cross sectional area with respect to the indicators, (in Table 2-5-2).

Table 2-5-4 presents the average pre-development cross-sectional area by cross section as reported by Parish in their 2014 final monitoring report, compared with the average during-development cross sectional areas reported by Water's Edge in 2020. This table also presents the percent of change in bankfull cross-sectional area over the pre-development and during-development monitoring periods. The defined threshold indicator is based on a reach basis rather than a cross sectional basis as shown above.

The cross-sections which fail this preliminary comparison of average bankfull cross sectional area does not allow for meaningful conclusions beyond the possibility that there are impacts within the watershed. The cross sections which failed cannot provide meaningful indications of change related to the development impacts within the study area due to their location. The Roseville Tributary locations are intended to be used for reference purposes. Cross sections 1 and 3 are far downstream from the study area and may be subject to any number of potential impacts upstream.

Table 2-5-4 Pre- and During- Development Bankfull Cross-sectional Area Rate of Change by Cross Section

Reach	Cross Section	During-Development Average Bankfull Cross-Sectional Area (m^2) [1]	Existing Condition Average Bankfull Cross-Sectional Area (m^2) [2]	During-Development Rate of Change (%) [3]	Existing Condition Rate of Change (%) [4]	Threshold indicator of change (30% from Existing Conditions)		Individual Cross Section Performance to Indicator of Change (Pass/Fail)
						Maximum Area (m^2)	Minimum Area (m^2)	
Reach 4	XS-1A [5]	4.1	-	-1.4%	-	-	-	-
	XS-1	7.4	4.8	29.7%	15.0%	6.2	3.3	Fail
	XS-2 [6]	*6.7*	5.0	43.4%	15.3%	-	-	-
Reach 3	XS-3A	5.4	-	2.2%	-	-	-	-
	XS-3	5.7	4.1	16.9%	0.2%	5.4	2.9	Fail
	XS-3B	4.6	-	0.0%	-	-	-	-
Reach 2	XS-4	3.6	3.2	3.4%	-4.1%	4.1	2.2	Pass
	XS-5	4.4	3.6	22.1%	3.1%	4.7	2.5	Pass
	XS-6	3.1	2.5	-3.7%	-0.6%	3.3	1.8	Pass
Reach 1 Main Tributary	XS-6A	4.6	-	25.4%	-	-	-	-
	XS-6B	6.0	-	6.2%	-	-	-	-
	XS-6C	6.1	-	8.1%	-	-	-	-
	XS-6D	7.6	-	1.5%	-	-	-	-
	XS-6E	3.0	-	-4.7%	-	-	-	-
	XS-6F	4.8	-	5.4%	-	-	-	-
	XS-7 [6]	*2.2*	1.4	39.4%	12.9%	-	-	-
	XS-8 [6]	*1.8*	1.2	17.6%	-8.5%	-	-	-
	XS-9 [6]	*2.6*	1.3	39.3%	-3.2%	-	-	-
Roseville Tributary	XS-10	6.3	4.1	-4.5%	4.3%	5.3	2.9	Fail
	XS-11	5.0	3.7	0.6%	-10.9%	4.8	2.6	Fail
	XS-12	6.0	-	-5.6%	-	-	-	-

Notes:

1. Average is for data collected 2016 to 2020. Except for XS1A, and XS-6A to 6F where measurements are available for 2017 to 2020. (Water's Edge 2020)
2. Based on values reported by Parish for Bankfull Cross-sectional Area (Parish 2014)
3. As reported by Water's Edge (Water's Edge 2020). Computed for 2016 to 2020, except for XS-1A, and XS-6A to 6F where measurements are available for 2017 to 2020.
4. As reported by Computed for first pre-development measurement (varies by cross-section, refer to Table 2-5-1) through 2014.
5. Cross section location is intended to monitor construction impacts from activities at the Fountain Street bridge, adjustments seen at this cross section cannot be correlated to development activities within the Study Area.
6. Cross section is impacted by Beaver activity, adjustments seen at this cross section cannot be correlated to development activities within the Study Area.

The 2020 Final Report by Water's Edge identifies XS-7 and XS-9 as having exceeded the 2016 SOW threshold for change in bankfull area. However, both cross sections have also been identified as being beaver dam impacted with a significant upstream flooded area and an emerging wetland area. Therefore, this SOW cannot determine if there are changes occurring at these locations related to development activities within the study area. (Water's Edge 2020)

Table 2-5-5 compares the change in cross-sectional area by reach to the threshold indicator of change identified in the 2016 SOW (Aquafor Beech Limited 2016). This comparison identifies that only Reach 1 has exceeded the defined threshold. As identified in the 2020 Water's Edge report, the primary driver for this is beaver activity. All three of the cross-sections within this reach, which form the basis of the pre-development condition, are significantly impacted by beaver activity. Therefore, impacts within these reach areas cannot be directly related to development activities. Water's Edge makes recommendations for changes to the monitoring program with respect to these cross sections due to the beaver activity.

Table 2-5-5 Pre- and During- Development Bankfull Cross-sectional Area Rate of Change by Reach

Reach	During-Development Reach Average Bankfull Cross-Sectional Area (m^2) [1]	Existing Condition Reach Average Bankfull Cross-Sectional Area (m^2) [2]	Threshold Indicator of Change (30% from Existing Conditions) [3]		Performance to Indicator of Change (Pass/Fail)
			Maximum	Minimum	
Reach 4	5.8	4.9	6.3	3.4	Pass
Reach 3	5.2	4.1	5.4	2.9	Pass
Reach 2	3.7	3.1	4.0	2.2	Pass
Reach 1 Main Tributary	5.3	1.3	1.7	0.9	Fail [4]
Roseville Tributary	5.8	3.9	5.1	2.7	Pass

Notes:

1. Excludes Beaver impacted Cross-Sections
2. Based on Bankfull Cross-sectional Area reported by Parish (Parish, 2014)
3. Threshold as defined and put forward in the 2016 SOW (Aquafor Beech, 2016)
4. Failure is due to beaver impacted cross sections, and addition of XS-6A to XS-6F to monitoring program in 2017.

2.5.4.3 Substrate Particle Size Results

Table 2-5-6 presents the comparison of the substrate particle size reported by Water's Edge for the during-development period with existing conditions and an evaluation of the results with respect to the indicator threshold established in the 2016 SOW (Aquafor Beech Limited 2016).

Table 2-5-6 Particle Size Adjustment to Existing Conditions

Reach	Cross Section	During-Development Average Substrate Particle Size (mm) [1,2]		Existing Condition Average Substrate Particle Size (mm) [2]		Order of Magnitude Adjustment from Existing Condition		Performance to Indicator Threshold (Pass/Fail) [3]	
		D_{50}	D_{90}	D_{50}	D_{90}	D_{50}	D_{90}	D_{50}	D_{90}
Reach 4	*XS-1A* [4]	*15*	*35*	-	-	-	-	-	-
	XS-1	0.4	3	0.2	3	0	0	Pass	Pass
	XS-2 [5]	*1*	*41*	*4*	*103*	*0*	*+ 1*	*Pass*	*Pass*

Reach	Cross Section	During-Development Average Substrate Particle Size (mm) [1,2]		Existing Condition Average Substrate Particle Size (mm) [2]		Order of Magnitude Adjustment from Existing Condition		Performance to Indicator Threshold (Pass/Fail) [3]	
		D_{50}	D_{90}	D_{50}	D_{90}	D_{50}	D_{90}	D_{50}	D_{90}
Reach 3	XS-3A	2	12	-	-	-	-	-	-
	XS-3	15	55	9	90	+ 1	0	Pass	Pass
	XS-3B	3	16	-	-	-	-	-	-
Reach 2	XS-4	12	50	6	51	+ 1	0	Pass	Pass
	XS-5	1	5	0.6	10	+ 1	+ 1	Pass	Pass
	XS-6	11	53	8	58	+ 1	0	Pass	Pass
Reach 1 Main Tributary	XS-6A	1	3	-	-	-	-	-	-
	XS-6B	3	21	-	-	-	-	-	-
	XS-6C	23	48	-	-	-	-	-	-
	XS-6D	7	40	-	-	-	-	-	-
	XS-6E	12	29	-	-	-	-	-	-
	XS-6F	10	29	-	-	-	-	-	-
	XS-7 [5]	*< 0.2*	*1*	*< 0.2*	*< 0.2*	*0*	*- 1*	*Pass*	*Pass*
	XS-8 [5]	*< 0.2*	*1*	*0.2*	*2*	*0*	*0*	*Pass*	*Pass*
	XS-9 [5]	*< 0.2*	*1*	*< 0.2*	*1*	*0*	*0*	*Pass*	*Pass*
Roseville Tributary	XS-10	< 0.2	1	0.2	3	0	0	Pass	Pass
	XS-11	< 0.2	1	< 0.2	1	0	0	Pass	Pass
	XS-12	< 0.2	< 0.2	< 0.2	1	0	+ 1	Pass	Pass

Notes:

1. Source: Water's Edge (2020)
2. Rounded to the nearest mm or tenth of a mm (consistent with 2016 SOW approach)
3. Defined as *"Maintain D50 and D90 particle sizes within plus or minus one order of magnitude compared with existing conditions."* (Aquafor Beech Limited 2016)
4. Cross section location is intended to monitor construction impacts from activities at the Fountain Street bridge, adjustments seen at this cross section cannot be correlated to development activities within the Study Area.
5. Cross section is impacted by Beaver activity, adjustments seen at this cross section cannot be correlated to development activities within the Study Area.

This evaluation shows substrate particle size is within the threshold for all sample cross sections. A confirmation of the existing conditions substrate particle size was completed to verify the approach to this comparison is consistent with the 2016 SOW methods.

In addition, a review of trends related to decreasing particle size for D_{50} or D_{90} was completed and found no identifiable trends. Typically, increases in sand and silt would be indicative of impacts due to increased urban runoff, however, the Blair Creek subwatershed is dominated by sandy soils and as a result, changes in particle size alone is not a good indicator of development related impacts.

2.5.4.4 Bank Migration Rate Results

Table 2-5-7 presents the comparison of the bank migration rates, reported by Water's Edge (2020) for the during-development period, with existing conditions and an evaluation of the results with respect to the indicator threshold established in the 2016 SOW (Table 2-5-7).

Table 2-5-7 Bank Migration to Existing Conditions

Reach	Bank	Cross Section	Bankfull Width at Cross Section (m) [1,2]	Measurements (cm) [1]		During-development Migration Rate (cm/yr) [1]	Existing Conditions Migration Rate (cm/yr) [3]	% of Bankfull Width	Performance to Indicator Threshold (Pass/Fail) [5]
				Initial [4]	Final [2]				
Reach 4		XS-1A [6]	-	-	-	-	-	-	-
		XS-1 [7]	-	-	-	-	0	-	-
	RB	XS-2 [8]	8.09	13.5	26	1.1	9	0.14%	Pass
	RB			14.5	24	0.9	4	0.11%	Pass
Reach 3		XS-3A	-	-	-	-	-	-	-
		XS-3	7.65	16	37	1.9	4	0.25%	Pass
		XS-3B	-	-	-	-	-	-	-
Reach 4	LB	XS-4	6.61	15	13	-0.2	0	-0.03%	Pass
	RB	XS-5	6.35	12	34	2.0	0	0.31%	Pass
	RB	XS-6	5.55	15	26	1.0	8	0.18%	Pass
Reach 1 Main Tributary		XS-6A	-	-	-	-	-	-	-
		XS-6B	-	-	-	-	-	-	-
		XS-6C	-	-	-	-	-	-	-
		XS-6D	-	-	-	-	-	-	-
		XS-6E	-	-	-	-	-	-	-
		XS-6F	-	-	-	-	-	-	-
	RB	XS-7 [9]	-	-	-	-	4	-	-
		XS-8 [9]	-	-	-	-	0	-	-
	RB	XS-9 [9]	-	-	-	-	1	-	-
Roseville Tributary	LB	XS-10	4.9	14.5	42	2.5	2	0.51%	Pass
	LB	XS-11	4.8	15	30	1.4	-	0.28%	Pass
	RB			12	49	3.4	4	0.70%	Pass
	RB	XS-12 [10]	2.77	15	27	1.1	2	0.39%	Pass

Notes:

1. Source: Water's Edge (2020)
2. As measured in 2020 from top of bank
3. Source: 2016 SOW (Aquafor Beech Limited 2016)
4. Source: 2009 FDS (Stantec 2009)
5. Defined as *"Normal migration rates are approximately equal to 10 percent of bankfull width over 5 years at locations where migration is expected."* (Aquafor Beech Limited 2016)
6. XS-1A LB (20 m US) pin fell out of bank and could not be reset due to soft bank not being stable enough to support the pin.
7. XS-1 no pins were installed due to soft banks. (Water's Edge 2020)

Reach	Bank	Cross Section	Bankfull Width at Cross Section (m) [1,2]	Measurements (cm) [1]		During-development Migration Rate (cm/yr) [1]	Existing Conditions Migration Rate (cm/yr) [3]	% of Bankfull Width	Performance to Indicator Threshold (Pass/Fail) [5]
				Initial [4]	Final [2]				

8. Cross section impacted by beaver activity (Water's Edge 2020)
9. Pins are no longer accessible due to flooding from beaver activity. (Water's Edge 2020)
10. XS-12 pin is buried under loose sediment, bank was not stable enough to allow for pin to be reset. (Water's Edge 2020)

cm = centimetre(s)

Monitoring of bank erosion is targeted to where migration is expected to occur and is therefore not monitored for at all cross sections. A number of monitoring locations have been impacted by beaver activity since 2016 and could not be compared with existing conditions. Those where a comparison is possible are shown to be within the target threshold. The Water's Edge interpretation of the bank migration over the 5-year period is that while annual fluctuations were observed that exceeded the thresholds, these changes balanced out over time and no long-term trends were identified that indicated a change in rate of migration from the pre-development conditions (Water's Edge 2020).

2.5.4.5 Average Bankfull Depth Results

Table 2-5-8 presents the comparison of the average bankfull depth, reported by Water's Edge (2020) for the during-development period, with existing conditions and an evaluation of the results with respect to the indicator threshold established in the 2016 SOW (Aquafor Beech Limited 2016).

Table 2-5-8 Average Bankfull Depth to Existing Conditions

Reach	Cross Section	During-development Average Bankfull Depth (m) [1]	Existing Condition Average Bankfull Depth (m) [2]	Existing Condition for Threshold Evaluation (m) [2]	Performance to Indicator Threshold (Pass/Fail) [3]
Reach 4	XS-1A	0.43	-	0.50 ± 0.05 m	-
	XS-1	0.56	0.43		Pass
	XS-2 [4]	0.56	0.53		Pass
Reach 3	XS-3A	0.39	-		-
	XS-3	0.58	0.45		Pass
	XS-3B	0.33	-		-
Reach 2	XS-4	0.42	0.39	0.40 ± 0.05 m	Pass
	XS-5	0.53	0.41		Pass
	XS-6	0.45	0.41		Pass
Reach 1 Main Tributary	XS-6A [5]	0.39	-	0.35 ± 0.05 m	-
	XS-6B [5]	0.45	-		-
	XS-6C [5]	0.46	-		-
	XS-6D [5]	0.82	-		-
	XS-6E [5]	0.47	-		-
	XS-6F [5]	0.51	-		-
	XS-7 [4]	0.49	0.35		-
	XS-8 [4]	0.40	0.34		-

Reach	Cross Section	During-development Average Bankfull Depth (m) [1]	Existing Condition Average Bankfull Depth (m) [2]	Existing Condition for Threshold Evaluation (m) [2]	Performance to Indicator Threshold (Pass/Fail) [3]
	XS-9 [4]	0.55	0.37		-
Roseville Tributary	XS-10	0.57	0.59	0.55 ± 0.05 m	Pass
	XS-11	0.52	0.57		Pass
	XS-12	0.50	0.52		Pass

Notes:

1. Based on mean depth reported by Water's Edge (2020)
2. Source: 2016 SOW (Aquafor Beech Limited 2016)
3. Defined as "*Maintain bankfull depth (m) within 30% of existing conditions*". (Water's Edge 2020)
4. Cross sectional measurements impacted by beaver activities
5. Existing conditions not established for cross section.

Average bankfull depths were found to be within the thresholds put forward in the 2016 SOW (Aquafor Beech Limited 2016).

2.5.5 Conclusions

In conclusion, the indicators of change for monitoring impacts within the study area are within thresholds as defined in the 2016 SOW (Aquafor Beech Limited 2016). Exceedances in the thresholds are in areas which have other known impacts causing geomorphological changes, primarily due to beaver activity. The first during-development monitoring report completed by Water's Edge did not identify any changes that were identified as related to development activities. However, the three cross sections immediately downstream of the developments (XS-7, 8 and 9) are significantly impacted by beaver activity. As noted by Water's Edge, the beaver pond has submerged the bank and erosion pins at these cross sections. They concluded that the ponded area is likely functioning as a stormwater management pond (Water's Edge 2020) and may be mitigating any potential development impacts downstream.

2.5.6 Monitoring Plan Recommendations

The review of the geomorphic monitoring data with respect to the existing conditions put forward in the 2016 SOW (Aquafor Beech Limited 2016) identified the following recommendations with respect to the monitoring program.

- **Bankfull cross sectional areas** are a key indicator. It is recommended that subsequent efforts review and define the pre-development bankfull area. Reporting should clearly report on bankfull cross sectional area and provide a direct comparison with respect to the established existing conditions. This is a key indicator and measuring this qualitatively should be prioritized in the ongoing SOW reporting intervals.
- . It is recommended that the scope included in the issue of the RFP for the next monitoring period include a task that focuses on integrating the upcoming program with the previous SOW to allow the data collected between monitoring periods to be compared. Specifically allowing the comparison of bankfull cross sectional area's between monitoring periods.
- Water's Edge's 2020 Final Report recommends moving "Site 6" (XS-7 to XS-9) due to local beaver activity and suggested moving these cross sections upstream of Reichert Drive. This SOW affirms this recommendation for the subsequent monitoring period.

2.6 Terrestrial Ecology

2.6.1 Context

The pre- and during-development terrestrial ecology conditions within the Blair Creek Watershed are described through several key studies and monitoring reports. These include the following:

Pre-Development

- **Blair, Bechtel, and Bauman Creeks Subwatershed Plan (CH2M Gore and Storrie 1997):** This study established the pre-development natural heritage conditions within the Blair Creek watershed. The BBB Study identified existing vegetation communities, wetlands, rare species, and significant wildlife habitat.
- **Stauffer Woods Subdivision and Ormston Environmental Implementation Reports (Ecoplans 2008 and 2013, respectively):** These studies document the results of pre-development monitoring and existing natural heritage resources from 2003 to 3007 and in 2013, respectively.
- **2016 Upper Blair Creek State of the Watershed Report (Aquafor Beech Limited 2016)**. This was the first SOW report and established the pre-development baseline conditions, established the Index of Biological Integrity (IBI) framework, and identified indicators of change.

During-Development

- Ongoing annual ecological monitoring reports (WSP 2015, 2016, 2017, and 2018)

The field investigations completed through the first state of the watershed report established the terrestrial monitoring locations. These monitoring locations are maintained throughout the Upper Blair Creek monitoring program with some additional locations added early in the during-development period following the initial state of the watershed reports.

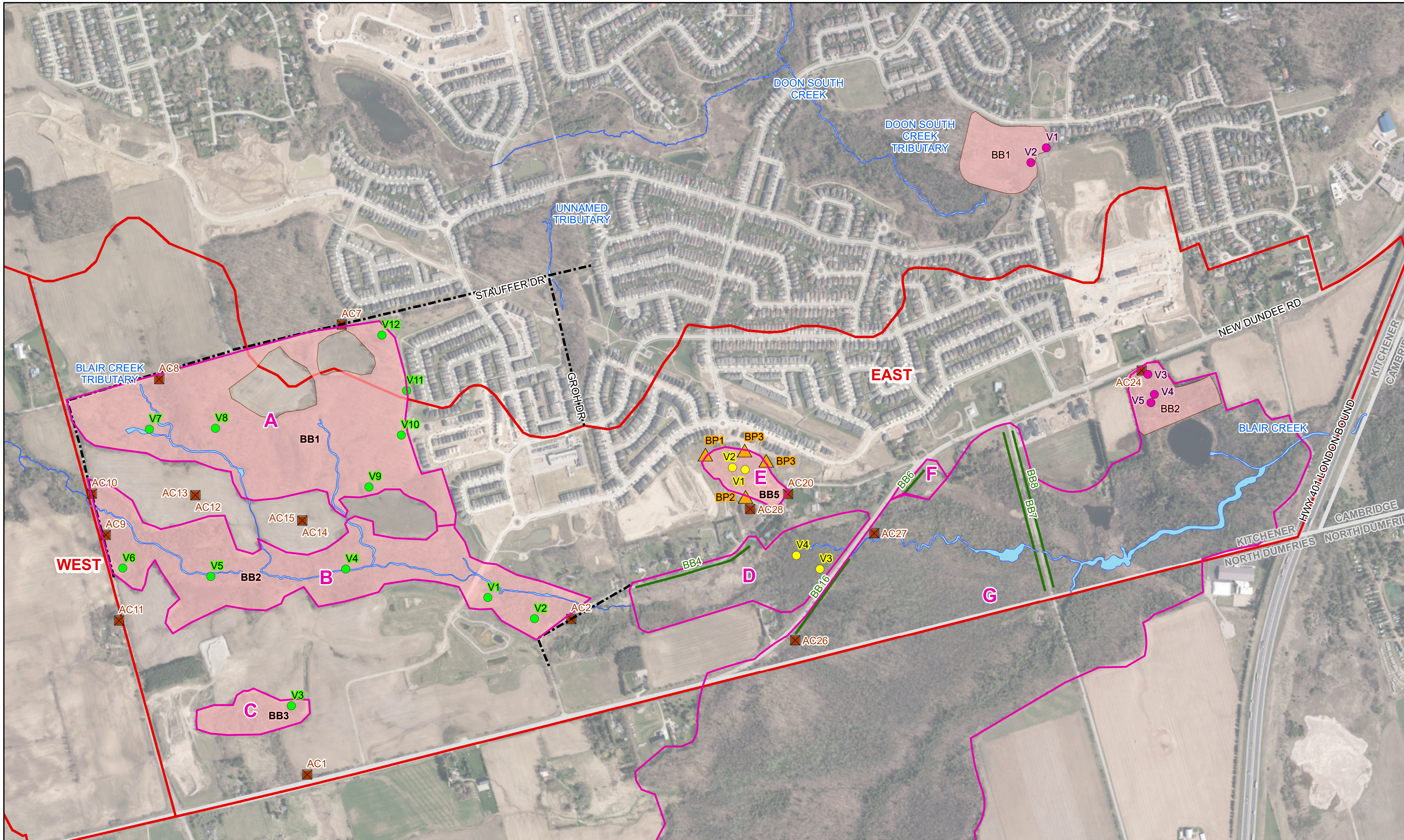
The Upper Blair watershed study area is largely agricultural communities with pockets of upland, and lowland forest, as well as thicket swamp. Sugar Maple dominates the upland forest with American Beech, White Ash, Bitternut Hickory and Red Oak occurring as well. Lowland forests are dominated by Yellow Birch, Black Ash, and White Elm with stands of Eastern White Cedar and Balsam Poplar. *Salix* species dominate the thicket swamps. In addition to the above communities, the Roseville Swamp Complex, a Provincially Significant Wetland occurs throughout the study area. The Roseville Swamp is primarily a forested swamp with Silver Maple, Red Maple, Black Ash, and Yellow birch as the dominant species. Eastern Hemlock and Eastern White Cedar are secondary species (CH2M Gore and Storrie 1997; Aquafor Beech Limited 2016).

2.6.2 Summary of Past Monitoring

The biological monitoring program commenced in 2007 during the pre-development phase. Vegetation, avifauna, and herpetofauna surveys have been completed to 2018 in the form of plot surveys, breeding bird surveys, amphibian call surveys and road mortality surveys (See 2016 SOW Report [Aquafor Beech Limited 2016] for details). Table 2-6-2 below summarize the terrestrial ecology surveys. Figure 2-6-1 below illustrates terrestrial biological monitoring locations.

Table 2-6-2 Summary of Past Monitoring Across Study Area

	Location	Phase	
		Pre-Construction	**During-development**
Vegetation Plots	Stauffer Woods	2007-2014	2015-2018
	Doon South	2007-2014	2015-2018
	Ormston	2014-2015	2016-2018
Vegetation Buffers	Stauffer Woods	--	2015-2018
	Doon South	--	2015-2018
Breeding Bird	Stauffer Woods	2009-2014	2015-2018
	Doon South	2009-2014	2015-2018
	Ormston	2014-2015	2016-2018
Amphibian Call	Stauffer Woods	2008-2014	2015-2018
	Doon South	2009-2014	2015-2018
	Ormston	2014-2015	2016-2018
Road Mortality	Stauffer Woods	2008-2014	2015-2018
	Doon South	-	-
	Ormston	-	-



Vegetation Monitoring

- Stauffer Vegetation Monitoring Plots
- Doon South Vegetation Plots
- Ormston Vegetation Plots (V1-V5)
- Vegetation Buffer Plots (BP1 – BP4)
- Fauna Monitoring – Frogs
- Road Mortality

Bird Monitoring

- Breeding Bird Survey Polylines
- Breeding Bird Survey Polygon
- Habitat Blocks (A-G)
- Waterbody
- Upper Blair Creek Subwatershed Study Area
- Municipal Boundary

Notes:
1. Imagery Source: City of Kitchener, 2019.
2. Monitoring Data Sources:
- Upper Blair Creek- State of the Watershed (SOW) Report, 2016.
- 2018 During Construction Biological Monitoring Report
- 2017 During- Construction Biological Monitoring Report

Figure 2-6-1
Existing Terrestrial Biological Monitoring Locations
Upper Blair Creek State of the Watershed
City of Kitchener
Upper Blair Creek Subwatershed, Kitchener, Ontario

Jacobs

\\DC1VS01\GISPROJ\K\KITCHENERCITYOF\UPPERBLAIRCREEK_P20_005\MAPFILES\SOW\2_6_1_EXISTING_TERRESTRIAL_BIOMONITORINGLOCATIONS.MXD VM048279 7/13/2021 12:15:42 PM

2.6.3 Data Analysis

The following data analysis examines the terrestrial monitoring data collected over the entire pre-development and during-development periods. Data collection methods are outlined in the first state of the watershed report.

2.6.3.1 Index of Biological Integrity

The first state of the watershed report established the IBI framework for pre-development monitoring data. An IBI combines a series of biological indicators into a single summary index. Each indicator is a measurable component of the ecological function of an area with an anticipated change in response to disturbance. The IBI can therefore be used to examine ecological function of an area during different phases of development or disturbance,

The first state of the watershed report established a total of 25 metrics across three taxonomic guilds of Flora, Avifauna, and Amphibians. This report followed the methods established in the first state of the watershed report to calculate the metric for each year of monitoring data (Table 2-6-3 to Table 2-6-5). Metric B8 was removed from analysis because it only applied to one breeding bird survey site. Metrics were calculated and scores were then averaged across the pre- and during-development phases. One an average for each phase was determined, an IBI score ranging from 1 (very poor) to 10 (very good) was assigned according to the criteria outlined in the first state of the watershed report (Table 2-6-6 to Table 2-6-8). Finally, IBI scores from all metrics during a phase are averaged to yield an overall IBI score for each taxonomic guild allowing for direct comparison of ecological function across phases. Amphibian calling data is highly variable and few species are present in the Upper Blair Study Area. Therefore, due to a lack of variance, IBI scores were not assigned to amphibian data, rather metrics were averaged over phases and qualitatively assessed.

Table 2-6-3 Methods for calculating floristic index of biological integrity metrics

Metric		Calculation
F1	Modified Floristic Quality Index of Herbaceous Layer	$FQI = \bar{C}(\sqrt{N})$ Where: $\bar{C}$ = the mean Coefficient of Conservatism N = the total number of native and non-native species recorded
F2	Mean Coefficient of Wetness	$\bar{C} = \frac{\sum C}{N}$ Where: C = Coefficient of Wetness
F3	Mean Coefficient of Conservatism	$\overline{CC} = \frac{\sum CC}{N}$ Where: CC = Coefficient of Conservatism
F4	% Widely Tolerant Plant Species	$\frac{CC_0 + CC_1 + CC_2}{N} * 100$ Where: C_n = Number of species with Coefficient of Conservatism value of n
F5	% Narrowly Tolerant Plant Species	$\frac{CC_7 + CC_8 + CC_9 + CC_{10}}{N} * 100$ Where: C_n = Number of species with Coefficient of Conservatism value of n
F6	Cumulative Number of Rare Species	Total number of rare species recoded in a habitat over a phase

Metric		Calculation
F7	% Native Trees	$$\frac{NT}{N} * 100$$ Where: NT = Number of native tree species
F8	% Vascular Cryptograms	$$\frac{VC}{N} * 100$$ Where: VC = Number of vascular cryptogram species excluding *Equisetum arvense*
F9	% Annual and Biennial Species	$$\frac{A + B}{N} * 100$$ Where: A = Number of annual Species B = Number of biennial species
F10	% Non-native Species	$$\frac{E}{N} * 100$$ Where: E = Number of exotic species
F11	% Invasive Species	$$\frac{I}{N} * 100$$ Where: I = Number of invasive species

Table 2-6-4 Methods for calculating avifaunal index of biological metrics

Metric		Calculation
B1	Total Species Richness	Number of Species Recorded
B2	Highest Breeding Evidence Recorded	Confirmed = 4 Probably = 3 Possible = 2 Probably = 1
B3	% of Disturbance Tolerant Species	Metrics B3 to B8 were calculated using weighted values for the guild of interest and total number of species recorded as follows. $$\sum \frac{X_i \times b_i}{X \times b} \times 100$$ Where: X= Highest abundance of a species observed X_i= Highest abundance of a species in bird guild i b_i= Highest breeding evidence for species X_i b = Highest breeding evidence for species X
B4	% of Disturbance Intolerant Species	
B5	% Non-native Species	
B6	% Dependent on Wetlands	
B7	% Ground Nesters	
B9	Cumulative Total of Rare Species	$$\sum X_R \times b_R$$ Where: X_R= Highest abundance of a rare species b_R= Highest breeding evidence for species X_R

Table 2-6-5 Amphibian index of biological integrity metrics

Metric		Calculation
A1	Total Species Richness	Number of species recorded
A2	Maximum Calling Code	Maximum calling code recorded
A3	Number of Disturbance Tolerant Species	Number of disturbance tolerant species
A4	Number of Disturbance Sensitive Species	Number of disturbance sensitive species
A5	Number of Rare Species	Cumulative number of rare species recorded

Table 2-6-6 Scores for floristic index of biological integrity metrics

Metric	IBI Score									
	1	2	3	4	5	6	7	8	9	10
F1 Modified Floristic Quality Index of Herbaceous Layer	<5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	>45
F2 Mean Coefficient of Wetness	N/A									
F3 Mean Coefficient of Conservatism	N/A									
F4 % Widely Tolerant Plant Species	90-100	80-90	60-80	50-60	45-50	20-45	15-20	12.5-15	10-12.5	<10
F5 % Narrowly Tolerant Plant Species	0				0.1-0.5	0.5-1.0	1.0-2.5	2.5-5.0	5.0-7.5	>7.5
F6 Cumulative Number of Rare Species	0				1-2	3-4	5-7	8-12	13-19	>20
F7 % Native Trees	<0.1	0.1-1.0	1-5	5-10	10-12	12-15	15-20	20-25	25-30	>30
F8 %Vascular Cryptograms	<0.1			0.1-1.0	1.0-2.5	2.5-5	5-10	10-15	15-20	>20
F9 % Annual and Biennial Species	90-100	75-90	50-75	45-50	30-45	5-30	1-5	0.5-1.0	0.1-0.5	<0.1
F10 %Non-native Species	90-100	65-90	50-65	45-50	20-45	10-20	5-10	2.5-5	1.0-25	<1
F11 % Invasive Species	90-100	65-90	50-65	45-50	20-46	10-20	5-10	1-5	0.1-1.0	<0.1

Table 2-6-7 Scores for avifaunal of biological integrity metrics

Metric	IBI Score									
	1	2	3	4	5	6	7	8	9	10
B1 Total Species Richness	0	1-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	>45
B2 Highest Breeding Status Recorded	0-0.5	0.5-1	1-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-3.75	3.75-4.0	4.0
B3 % Disturbance Tolerant Species	95-100	90-95	85-90	80-85	75-80	70-75	65-70	60-65	55-60	<55

Metric	IBI Score									
	1	2	3	4	5	6	7	8	9	10
B4 % Disturbance Intolerant Species	<0.1				0.1-2	2-3	3-5	5-10	10-15	>15
B5 % Non-native Species	>70	50-70	30-50	15-30	10-15	7-10	5-7	2-5	0.1-2	<0.1
B6 % Species Dependent on Wetlands	<0.1				0.1-2	2-3	3-5	5-10	10-15	>15
B7 % Ground Nesters	<0.1	0.1-1	1-2	2-3	3-5	5-10	10-15	15-20	20-25	>25
B9 Cumulative Total of Rare Species	0		1-5	5-10	10-50	50-70	70-100	100-120	120-130	>130

Table 2-6-8 Biological Scoring System

IBI Score	Rating
1-2	Very Poor
3-4	Poor
5-6	Fair
7-8	Good
9-10	Very Good

2.6.3.2 Data limitations

The majority of data limitations relate to survey methodology and timing. Deviations in survey methodology did not create outlies and as such these deviations do not appear to affect data analysis, however, may introduce some biases. A brief summary of limitations is included below.

2.6.3.2.1 Flora

Flora data did not include abundance data or cover data. Therefore, results may be skewed as data cannot be used to determine dominant cover in plot surveys. Further, data from 2008-2013 was not provided for Doon South plots. Therefore, an average over the entire pre-development period could not be established. Additionally, surveys from 2007-2009 were only completed in late summer/early Autumn. As such data from early season flora is excluded and may create bias in the pre-development phase results.

2.6.3.2.2 Avifauna

Inconsistencies with breeding bird surveys primarily consisted of surveys not completed greater than 15 days apart. Furthermore, some surveys were completed beyond the breeding bird period for the Upper Blair Study Area.

2.6.3.2.3 Amphibians

Inconsistencies with amphibian monitoring protocols of the Marsh Monitoring Program primarily consist of completing surveys outside of the specified timing windows and surveying during temperatures that were lower than those specified by the Marsh Monitoring Program.

2.6.3.2.4 Road Mortality

Road mortality data was collected as cumulative totals for the entire survey area. Road mortality by survey transect would allow for more spatially detailed analysis. Further, road mortality survey effort varied from year to year, where effort for the pre-development phase was nearly half that of the during-development phase.

2.6.4 Results

The results of the terrestrial biological monitoring program are presented in the subsections below according to location

- Stauffer Woods – Activa
- Doon South – Hallman and Monarch
- Ormston
- Upper Blair – All combined

Data from 2014 were added to data from Stauffer Woods and Doon South as presented in the first state of the watershed report and re analyzed below to encapsulate the full pre-development period. However, vegetation data from Doon South was not provided from the period of 2007 to 2013, so vegetation data from 2014 is analyzed separately.

2.6.4.1 Stauffer Woods

The following subsections present the results of the terrestrial biological monitoring including vegetation, avifauna, calling amphibian and road mortality for the pre-development (2007-2014) and during-development (2015-2018) phases.

2.6.4.1.1 Vegetation

Vegetation data is presented for all years during pre-development (2007-2014) and during-development (2015-2018). Analysis was restricted to species observed within the established quadrats to ensure consistency. An overall IBI was assigned by averaging all years for the pre-development and during-development phases (Table 2-6-9 and Table 2-6-10). Below is a summary of each metric by site.

V1

The modified FQI score for the vegetation in monitoring plot V1 was 18.2 during-development which was a small increase from the pre-development phase. Plot V1 consisted of facultative wetland species (F2; -2.9) during-development, which was a negligible decrease from the pre-development phase. Metric F3 indicated the species in plot V1 were moderately conservative in habitat requirements (4.0). Similarly, the majority of species were neither widely tolerant (F4; 11.9 percent) or narrowly tolerant (F5; 1.1 percent) species. Non - native species accounted for 5.2 percent of species during-development, with 5.2 percent annual or biennial species and 2.1 percent of species considered invasive. Native trees accounted for 0 percent of inventoried species. One rare species was recorded during-development. The overall IBI score for V1 was 6.1 during-development which is considered fair. In comparison, the overall IBI score for V1 during the pre-construction phase was 6.3 (fair). Differences between the phases were negligible for all metrics and a result of small fluctuations.

V2

The modified FQI score for the vegetation in monitoring plot V2 was 13.7 during-development indicating a small increase from the pre-development phase. Metric F2 indicates plot V2 consisted of facultative wetland species (-3.4) during-development, which was an increase over the pre-development phase. Metric F3 indicated the species in plot V2 were moderately conservative in habitat requirements (3.6). Similarly, the majority of species were neither widely tolerant (F4; 20 percent) or narrowly tolerant (F5; 1.7 percent) species. Non-native species accounted for 9.2 percent of species during-development, with 4.6% annual or biennial species and 7.7 percent of species considered invasive. Native trees accounted for 11 percent of inventoried species. Three rare species were recorded during-development, an increase from pre-development. The overall IBI score for V2 was 6.0 during-development which is considered fair. The pre-development IBI score was 6.4 (fair) which was a small decrease across phases.

V3

The modified FQI score for the vegetation in monitoring plot V3 was 9.7 during-development indicating an increase from the pre-development phase. Metric F2 indicated plot V3 consisted of obligate wetland species (-4.7) during-development, which was an increase from the pre-development phase. Metric F3 indicated the species in plot V3 had tolerant habitat requirements (3.3). Twenty-five percent of species were widely tolerant (F4) and no species were narrowly tolerant. No non-native or invasive species were present, but 5.6 percent of species were annual of biennial. No native trees were present. Six rare species were recorded during-development, an increase from pre-development. The overall IBI score for V3 was 5.9 during-development which was considered fair. Overall differences between phases was negligible for all metrics indicated little change as a result of development.

V4

The modified FQI score for the vegetation in monitoring plot V4 was 19.1 during-development indicating an increase from the pre-development phase. Metric F2 indicated plot V4 consists of both wetland and upland species (0.0) during-development, which was a large increase in upland species from the pre-development phase. Metric F3 indicated the species in plot V4 have moderately conservative habitat requirements (4.1), an increase from the pre-development phase which largely consisted of more tolerant species. Twelve percent of species were widely tolerant (F4) and 3 precent of species were narrowly tolerant. Non-native and invasive species were present, accounting for 9.1 percent of species recorded. Annual of biennial species were 1.4 percent of species in the during-development phase. Twelve percent of species inventoried were native trees. Three rare species were recorded during-development, an increase from pre-development. The overall IBI score for V4 was 7.2 during-development which is considered fair and was an increase over the pre-development phase.

V5

The modified FQI score for the vegetation in monitoring plot V5 was 20.0 during-development indicating a small decrease from the pre-development phase. Metric F2 indicated plot V5 consisted of facultative wetland species (-2.7) during-development, which represents increase in wetland species from the pre-development phase. Metric F3 indicated the species in plot V5 had moderately conservative habitat requirements (4.5), similar to pre-development. Widely tolerant (F4) species accounted for 7.2 percent and narrowly tolerant (F5) species accounted for 10.9 percent of species. Relatively few non-native (2.4 percent) and invasive (1.0 percent) were present. However, 8.6% of species were annual of biennial. Twelve percent of species inventoried were native trees. Three rare species were recorded during-development, an increase from pre-development. The overall IBI score for V5 was 7.2 during-development which is considered fair but was a decrease from the pre-development phase.

V6

The modified FQI score for the vegetation in monitoring plot V6 was 11.9 during-development indicating a small decrease from the pre-development phase. Metric F2 indicated plot V6 consisted of facultative wetland species (-2.9) during-development, which represents small increase in wetland species from the pre-development phase.

Metric F3 indicates the species in plot V6 had moderately conservative habitat requirements (3.5), which was more tolerant than the pre-development phase. Widely tolerant (F4) species accounted for 19.9 percent and narrowly tolerant (F5) species accounted for 4.6 percent of species. Non-native and invasive species accounted for 10.9% of species present. However, no species were annual or biennial. No native trees or rare species were recorded during-development. The overall IBI score for V6 was 5.7 during-development which is considered fair but was a decrease from the pre-development phase.

V7

The modified FQI score for the vegetation in monitoring plot V7 was 16.7 during-development indicating an increase from the pre-development phase. Plot V7 consisted of both upland and wetland species (F2; -0.8) during-development, which was an increase in upland species compared to the pre-development phase. Metric F3 indicated the species in plot V7 had moderately conservative habitat requirements (4.3), which was more conservative than the pre-development phase. Widely tolerant (F4) species accounted for 12.7 percent and narrowly tolerant (F5) species accounted for 13.4 percent of species. Non-native species accounted for 8.2 percent of species present, however only 1.6 percent of species were invasive. Further 8.9 percent of species were annual or biennial species. Of the species inventoried, 10.4% were native trees. The overall IBI score for V7 is 6.7 during-development which is considered fair and was an increase over the pre-development phase.

V8

The modified FQI score for the vegetation in monitoring plot V8 was 13.6 during-development and was small increase from the pre-development phase. During-development, plot V8 consisted of upland species (F2; 2.0) which was a shift from wetland species during the pre-development phase. Metric F3 indicated the species in plot V8 had moderately conservative habitat requirements (4.9), which was more conservative than the pre-development phase. Widely tolerant (F4) species accounted for 2.8 percent of species and narrowly tolerant species were not present (F5). No non-native and invasive species were not present. However, 6.8 percent of species were annual or biennial species. Of the species inventoried, 29.3 percent were native trees representing a large increase over the pre-development phase. The overall IBI score for V8 was 5.7 during-development which was considered fair and was a small decrease over the pre-development phase.

V9

The modified FQI score for the vegetation in monitoring plot V9 was 15.3 during-development indicating an increase from the pre-development phase. During-development, plot V9 consisted of upland species (F2; 2.0), similar to the pre-development phase. Metric F3 indicated the species in plot V9 had moderately conservative habitat requirements (4.6), which was slightly less conservative than the pre-development phase. Widely tolerant (F4) species accounted for 9.3 percent of species and narrowly tolerant (F5) species accounted for 5.0 percent of species (F5). Non-native and invasive species were not present. However, 2.3 percent of species were annual or biennial species. Of the species inventoried, 39.5 percent were native trees representing an increase over the pre-development phase. The overall IBI score for V9 was 6.9 during-development which is considered fair and was a small increase over the pre-development phase.

V10

The modified FQI score for the vegetation in monitoring plot V10 was 14.7 during-development indicating a small decrease from the pre-development phase. During-development, plot V10 consisted of upland species (F2; 2.7), consistent with the pre-development phase. All species present were moderately tolerant (i.e. F4 and F5 are 0 percent). A large portion of species present were non-native and invasive (20.7 percent), and 12.8 percent of species were annual or biennial. Of the species inventoried, 20.2 percent were native trees representing decrease over the pre-development phase. The overall IBI score for V10 was 5.2 during-development which is considered fair and was a decrease over the pre-development phase.

Table 2-6-9 Pre-development Flora Monitoring Results – Stauffer

	SV1		SV2		SV3		SV4		SV5		SV6		SV7		SV8		SV9		SV10	
	Metric	**IBI**	**Metric**	**IBI**	**Metric**	**IBI**	**Metric**	**IBI**	**Metric**	**IBI**	**Metric**	**IBI**	**Metric**	**IBI**	**Metric**	**IBI**	**Metric**	**IBI**	**Metric**	**IBI**
F1	17.3	4.0	16.1	4.0	14.2	3.0	5.4	2.0	20.3	5.0	17.5	4.0	12.5	3.0	13.3	3.0	12.6	3.0	15.2	4.0
F2	-3.0	N/A	2.5	N/A	-2.6	N/A	-4.3	N/A	0.0	N/A	-2.3	N/A	-2.7	N/A	-1.8	N/A	2.2	N/A	2.5	N/A
F3	3.8	N/A	4.8	N/A	3.4	N/A	2.3	N/A	4.4	N/A	4.3	N/A	3.7	N/A	4.2	N/A	5.0	N/A	4.9	N/A
F4	13.3	8.0	4.2	10.0	23.5	6.0	52.1	4.0	9.1	10.0	10.9	9.0	21.0	6.0	11.7	9.0	0.0	10.0	1.0	10.0
F5	2.2	7.0	0.0	1.0	1.1	7.0	1.3	7.0	13.1	10.0	3.4	8.0	6.2	9.0	9.1	10.0	3.1	8.0	0.0	1.0
F6	2.0	5.0	0.0	1.0	5.0	7.0	2.0	5.0	7.0	7.0	1.0	5.0	0.0	1.0	0.0	1.0	0.0	1.0	2.0	5.0
F7	0.0	1.0	22.7	8.0	5.2	4.0	0.0	1.0	14.5	6.0	0.7	2.0	0.0	1.0	8.7	4.0	23.8	8.0	31.7	10.0
F8	18.6	9.0	12.6	8.0	10.8	8.0	5.0	7.0	21.7	10.0	10.0	8.0	18.6	9.0	2.5	6.0	0.0	1.0	4.3	6.0
F9	5.0	7.0	0.0	10.0	6.3	6.0	0.0	10.0	0.0	10.0	8.9	6.0	0.0	10.0	13.5	6.0	1.6	7.0	1.1	7.0
F10	5.0	8.0	3.1	8.0	10.4	6.0	0.0	10.0	10.6	6.0	12.0	6.0	10.4	6.0	8.3	7.0	0.0	10.0	10.8	6.0
F11	2.1	8.0	3.1	8.0	7.4	7.0	0.0	10.0	9.6	7.0	4.4	8.0	10.4	6.0	4.6	8.0	0.0	10.0	8.5	7.0
Average		6.3		6.4		6.0		6.2		7.9		6.2		5.7		6.0		6.4		6.2

Table 2-6-10 During-development Flora Monitoring Results – Stauffer

	V1		V2		V3		V4		V5		V6		V7		SV8		SV9		SV10	
	Metric	**IBI**	**Metric**	**IBI**	**Metric**	**IBI**	**Metric**	**IBI**	**Metric**	**IBI**	**Metric**	**IBI**	**Metric**	**IBI**	**Metric**	**IBI**	**Metric**	**IBI**	**Metric**	**IBI**
F1	18.2	4	13.7	3	9.7	2	19.1	4	20.0	4	11.9	3	16.7	4	13.6	3	15.3	4	14.7	3
F2	-2.9	N/A	-3.4	N/A	-4.7	N/A	0.0	N/A	-2.7	N/A	-2.9	N/A	-0.8	N/A	2.0	N/A	2.5	N/A	2.7	N/A
F3	4.0	N/A	3.6	N/A	3.3	N/A	4.1	N/A	4.5	N/A	3.5	N/A	4.3	N/A	4.9	N/A	4.6	N/A	4.6	N/A
F4	11.9	9	20.0	6	25.3	6	12.0	9	7.2	10	19.9	7	12.7	8	2.8	10	9.3	10	0.0	10
F5	1.1	7	1.7	7	0.0	1	9.9	10	10.9	10	4.6	8	13.4	10	0.0	1	5.0	9	0.0	1
F6	1.0	5	3.0	6	6.0	7	3.0	6	2.0	5	0.0	1	2.0	5	0.0	1	0.0	1	0.0	1
F7	0.0	1	11.0	5	0.0	1	12.0	5	1.0	3	0.0	1	10.4	5	29.3	9	39.5	10	20.2	8
F8	11.6	8	3.1	6	14.2	8	20.9	10	14.1	8	15.2	9	8.2	7	0.0	1	0.0	1	10.3	8
F9	5.0	6	4.6	7	5.6	6	1.4	7	8.6	6	0.0	10	8.9	6	6.7	6	2.3	7	12.8	6
F10	5.2	7	9.2	7	0.0	10	9.1	7	2.4	9	10.9	6	8.2	7	0.0	10	0.0	10	20.7	5
F11	2.4	8	7.7	7	0.0	10	9.1	7	1.0	8	10.9	6	1.6	8	0.0	10	0.0	10	20.7	5
Average		6.1		6.0		5.7		7.2		7.0		5.7		6.7		5.7		6.9		5.2

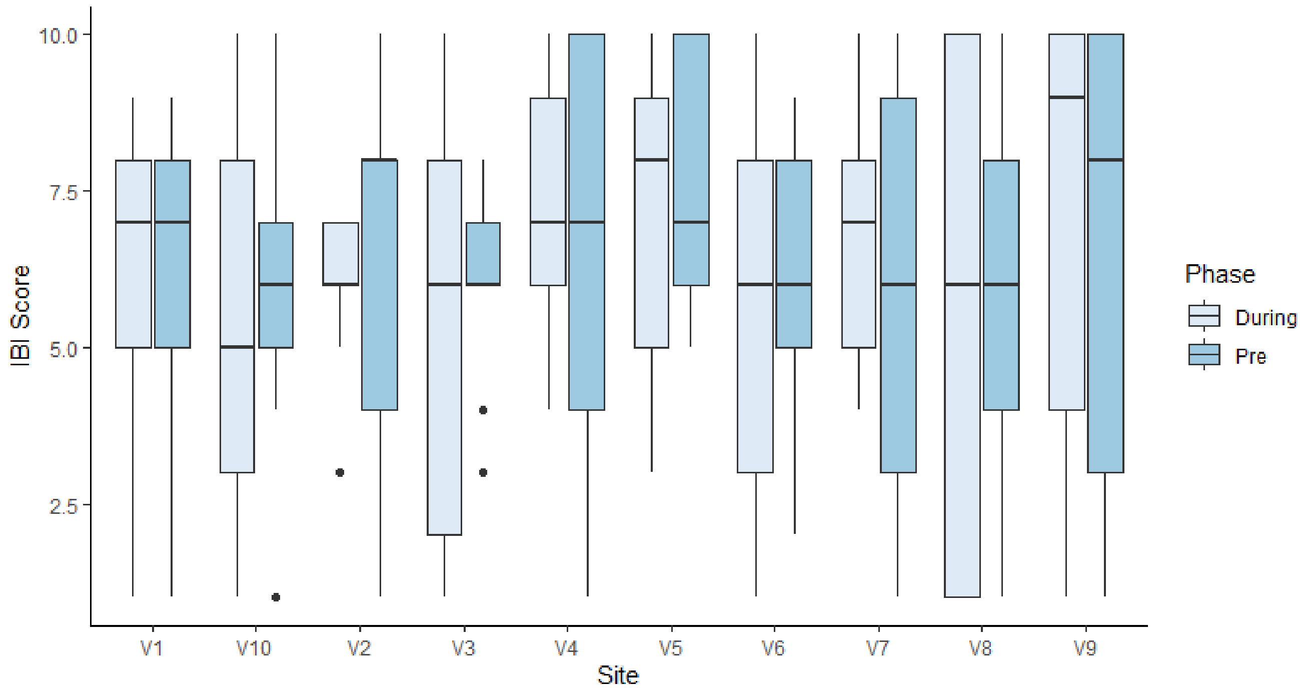


Figure 2-6-2 Boxplots of Stauffer Flora IBI scores by site and phase. Top and bottom of the boxes are respectively the 75th and 25th percentiles, the line is the median, the whiskers represent the maximum and minimum, and the dots represent outliers.

2.6.4.1.2 Avifauna

Tables 2-6-11 and 2-6-12 present the results of data analysis of the pre-development (2009-2014) and during-development (2015 – 2018) phases of the avifauna monitoring program for Stauffer Woods (Activa). The results for each metric presented are expressed as an average across all monitoring years for each phase, with the exception of B9 which is a cumulative tally weighted by abundance. An overall IBI score is presented below the table.

BB1

Site BB1 is primarily forest with deciduous and coniferous treed swamp and vernal pools. Adjacent lands are agricultural and residential (WSP 2018).

An average of 30 species (B1) were recorded at BB1 during the development phase. Breeding was confirmed on site the majority of years during-development (B2; 3.8). The majority of species are disturbance tolerant (B3; 60.4 percent) with relatively few disturbance intolerant species (B4; 3.8 percent). 9.2 percent of species are non-native, a considerable increase from the pre-development phase. While ground nesting species (1.8 percent) decreased from the pre-development phase, the abundance of interior forest species remained nearly the same (3.8 percent). A total of 10 rare species (weighted value: 107) were recorded during-development. The average avifaunal IBI score across all metrics is 6.8 (fair) and is a decrease from the pre-development phase.

BB2

Site BB2 contains deciduous and coniferous woodlands, treed swamps, and upland forest as well as riparian and thicket swamp proximal to Upper Blair Creek. Adjacent lands are agricultural and residential (WSP 2018).

An average of 35.8 species (B1) were recorded at BB2 during the development phase. Breeding was confirmed on site for all years during-development (B2; 4.0). The majority of species are disturbance tolerant (B3; 71.2 percent) with relatively few disturbance intolerant species (B4; 2.1 percent). 2.1% of species are non-native. The abundance of ground nesting species was 11.9 percent of species recorded, which is a large increase over the pre-development phase. While ground nesting species (1.8 percent) decreased from the pre-development phase, the abundance of interior forest species remained nearly the same (3.8 percent). A total of 14 rare species (weighted value: 328) were recorded during-development. The average avifaunal IBI score across all metrics is 7.9 (good) and is an increase from the pre-development phase.

BB3

Site BB3 is primarily treed swamp with meadow marsh and open water ponds. Adjacent habitat is meadow and thicket with agricultural and residential properties (WSP 2018). An average of 24.8 species (B1) were recorded at BB3 during the development phase. Breeding was confirmed on site the majority of years during-development (B2; 3.5). A large portion of species are disturbance tolerant (B3; 41.4 percent) with relatively few disturbance intolerant species (B4; 0.7 percent). Non-native species account for 3.9 percent of species recorded. The abundance of wetland species (B6; 4.1 percent) and ground nesting species (B7; 3.3 percent) faced a large decrease compared to the pre-development phase. A total of 6 rare species (weighted value: 28) were recorded during-development. The average avifaunal IBI score across all metrics is 6.8 (fair) and is a decrease from the pre-development phase.

Table 2-6-11 Pre-development Avifauna Monitoring Results - Stauffer Woods Sites

	BB1		BB2		BB3	
	Metric	IBI	Metric	IBI	Metric	IBI
B1	31.7	7.0	34.0	7.0	25.5	6.0
B2	3.8	9.0	3.7	9.0	3.7	9.0
B3	45.9	10.0	65.6	7.0	42.4	10.0
B4	3.6	7.0	3.1	7.0	5.0	8.0
B5	0.3	9.0	2.6	8.0	0.0	10.0
B6	3.7	7.0	4.9	7.0	17.1	10.0
B7	5.4	6.0	2.4	4.0	16.4	8.0
B9	202.0	10.0	155.0	10.0	115.0	8.0
Average		8.1		7.4		8.6

Table 2-6-12 During-development Avifauna Monitoring Results – Stauffer Woods Sites

	BB1		BB2		BB3	
	Metric	IBI	Metric	IBI	Metric	IBI
B1	30.0	7.0	35.8	8.0	24.8	5.0
B2	3.8	9.0	4.0	10.0	3.5	9.0
B3	60.4	8.0	71.2	6.0	41.4	10.0
B4	3.8	7.0	2.9	6.0	0.7	5.0
B5	9.2	6.0	2.1	8.0	3.9	8.0
B6	3.2	-	6.7	8.0	4.1	7.0
B7	1.8	3.0	11.9	7.0	3.3	5.0
B9	107.0	8.0	328.0	10.0	28.0	5.0
Average		6.9		7.9		6.8

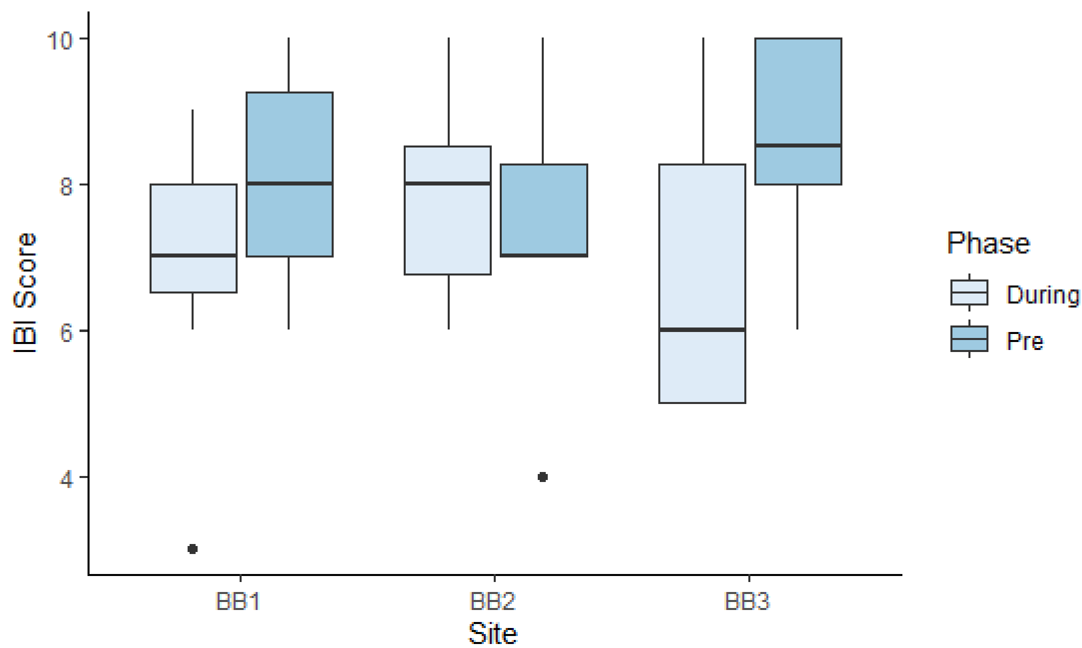


Figure 2-6-3 Boxplots of Stauffer Avifauna IBI scores by site and phase. Top and bottom of the boxes are respectively the 75th and 25th percentiles, the line is the median, the whiskers represent the maximum and minimum, and the dots represent outliers.

2.6.4.1.3 Amphibians

Tables 2-6-13 and 2-6-14 present the results of the pre-development and during-development amphibian calling monitoring program for years 2008-2014 and 2015-2018, respectively. The results are averaged across all metrics except A5, which is a cumulative tally of rare species. As discussed in detail within the first SOW report (Aquafor Beech Limited, 2016), results from amphibian calling monitoring can be highly variable owing to the extreme seasonality of each species. As such, it is difficult to ascertain trends from short-term data.

The results of the amphibian calling monitoring program are highly variable for both the pre- and during-development phases. However, while sites AC1, AC2, AC7, AC8, AC11, AC13, and AC15 appear to fluctuate around pre-development values, there is a discernable decrease in all metrics at sites AC9, AC10, AC12, and AC14 indicating these sites may be affected by development. Additionally, while there are several records of Western Chorus Frog (*Pseudacris triseriata*) in the pre-development phase, this species-at-risk was not recorded at any site during-development.

Table 2-6-13 Pre-development Amphibian Monitoring Results – Stauffer Woods Sites

	AC1	AC2	AC7	AC8	AC9	AC10	AC11	AC12	AC13	AC14	AC15
A1	2.3	3.0	3.4	2.6	1.4	0.9	2.9	1.9	2.7	2.1	2.6
A2	3.0	2.4	3.0	2.4	1.6	1.0	2.1	2.3	3.0	2.1	2.6
A3	1.7	1.9	2.9	1.7	2.0	0.6	1.9	1.7	2.0	2.4	1.9
A4	0.6	1.1	0.6	0.9	0.4.	0.3	1.0	0.1	0.7	0.7	0.7
A5	0.0	0.0	1.0	1.0	1.0	0.0	0.0	1.0	0.0	1.0	1.0

Table 2-6-14 During-development Amphibian Monitoring Results - Stauffer Woods Sites

	AC1	AC2	AC7	AC8	AC9	AC10	AC11	AC12	AC13	AC14	AC15
A1	2.3	4.3	4.0	2.5	0.3	0.3	4.3	0.3	2.5	0.3	3.5
A2	3.0	3.0	3.0	2.0	0.3	0.3	3.0	0.5	1.8	0.3	3.0
A3	1.8	2.8	3.0	2.0	0.3	0.3	3.0	0.3	2.0	0.3	2.5
A4	0.3	1.5	1.0	0.5	0.0	0.0	1.3	0.0	0.5	0.0	1.0
A5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

2.6.4.1.4 Road Mortality

Tables 2-6-15 and 2-6-17 present the results of the road mortality surveys during the pre-development (2008-2014) and during-development phases. The number of individuals dead increased by 170 percent from the pre-development phase. Similarly, the percent of individuals dead increased from the pre-development phase. The proportion of taxa in road mortalities is similar in both pre- and during-development phases with amphibians accounting for the majority of road mortalities in both pre- and during-development phases (85.6 percent and 90.4 percent, respectively). The species recorded are common, widespread and expected for the study area. Given the large increase in road mortalities, development may increase road mortalities. However, given the limitations of the data, the direct cause, whether through habitat pressures or increased traffic, is unknown.

Table 2-6-15 Summary of Road Mortality Results – Stauffer Woods

Phase	No. Individuals Dead	% of Individuals Dead
Pre-Development	281	44.6
During-development	476	52.5

Table 2-6-16 Summary of Road Mortality by Taxa – Stauffer Woods

Phase	Taxa	No. Individuals Dead	% of Total Dead
Pre-Development	Amphibians	107	85.6
	Reptiles	0	0
	Mammals	1	0.8
	Unknown	17	13.6
During-development	Amphibians	226	90.4
	Reptiles	2	0.9
	Mammals	0	0
	Unknown	23	9.7

2.6.4.2 Doon South

The following subsections present the results of the terrestrial biological monitoring including vegetation, avifauna, calling amphibian and road mortality for the pre-development (2007-2014) and during-development (2015-2018) phases.

2.6.4.2.1 Vegetation

Vegetation data prior to 2014 was not included as part of the data package. As such, data is presented for 2014 during pre-development and all during-development years (2015-2018). Analysis was restricted to species observed within the established quadrats to ensure consistency. An overall IBI was assigned by averaging all years for the pre-development and during-development phases (Table 2-6-17 and Table 2-6-18). Below is a summary of each metric by site.

Table 2-6-17 Pre-development Flora Monitoring Results – Doon South Sites

	V1		V2		V3		V4	
	Metric	**IBI**	**Metric**	**IBI**	**Metric**	**IBI**	**Metric**	**IBI**
F1	18.3	4.0	17.8	4.0	18.4	4.0	17.7	4
F2	-0.9	N/A	-0.1	N/A	-1.7	N/A	-1.6	N/A
F3	4.2	N/A	3.9	N/A	5.1	N/A	4.4	N/A
F4	5.6	10.0	16.7	7.0	0.0	10.0	7.1	10.0
F5	5.6	9.0	5.6	9.0	10.0	10.0	7.1	9.0
F6	0.0	1.0	1.0	5.0	0.0	1.0	0.0	1.0
F7	0.0	1.0	5.6	4.0	0.0	1.0	14.3	6.0
F8	11.1	8.0	22.2	10.0	10.0	8.0	21.4	10.0
F9	11.1	6.0	5.6	6.0	10.0	6.0	7.1	6.0
F10	11.1	6.0	5.6	7.0	0.0	10.0	0.0	10.0
F11	11.1	6.0	5.6	7.0	0.0	10.0	0.0	10.0
Average	5.7		6.6			6.7	7.3	

Table 2-6-18 During-development Flora Monitoring Results – Doon South Sites

	V1		V2		V3		V4	
	Metric	**IBI**	**Metric**	**IBI**	**Metric**	**IBI**	**Metric**	**IBI**
F1	17.2	4.0	13.4	3.0	16.0	4.0	16.8	4.0
F2	-1.0	N/A	0.2	N/A	-1.8	N/A	-1.6	N/A
F3	4.0	N/A	3.4	N/A	5.0	N/A	4.3	N/A
F4	11.1	9.0	16.6	7.0	0.0	10.0	6.9	10.0
F5	9.7	10.0	1.5	7.0	12.4	10.0	8.5	10.0
F6	3.0	6.0	3.0	6.0	1.0	5.0	3.0	6.0
F7	4.1	3.0	4.8	3.0	12.4	6.0	22.3	8.0
F8	11.1	8.0	14.9	8.0	10.2	8.0	17.4	9.0
F9	5.6	6.0	10.1	6.0	10.2	6.0	6.9	6.0
F10	11.1	6.0	18.8	6.0	2.3	9.0	0.0	10.0
F11	11.1	6.0	18.8	6.0	0.0	10.0	0.0	10.0
Average	6.4		5.8		7.6		8.1	

V1

The modified FQI score for the vegetation in monitoring plot V1 is 17.2 during-development indicating a small increase from the pre-development phase. Metric F2 indicates plot V1 consists of both upland and lowland species (-1.0) during-development, which represents a negligible decrease from the pre-development phase. Metric F3 indicates the species in plot V1 are moderately conservative in habitat requirements (4.0). Similarly, the majority of species are neither widely tolerant (F4; 11.1 percent) or narrowly tolerant (F5; 9.7 percent) species. Non - native and invasive species account for 11.1 percent of species during-development, with 5.6 percent of species being annual or biennial. Native trees accounted for 4.1 percent of inventoried species. Three rare species were recorded during-development, an increase from no recorded rare species in the pre-development phase. The overall IBI score for V1 is 6.4 during-development which is considered fair and an increase over the pre-development phase.

V2

The modified FQI score for the vegetation in monitoring plot V2 is 13.4 during-development indicating a small increase from the pre-development phase. Metric F2 indicates plot V2 consists of both upland and lowland species (0.2) during-development, which represents a negligible increase from the pre-development phase. Metric F3 indicates the species in plot V2 are tolerant in habitat requirements (3.4). Similarly, the majority of species are neither widely tolerant (F4; 16.6 percent) or narrowly tolerant (F5; 1.5 percent) species. Non - native and invasive species account for 18.8 percent of species during-development, with 10.1 percent of species being annual or biennial. Native trees accounted for 4.8 percent of inventoried species. Three rare species were recorded during-development, an increase from no recorded rare species in the pre-development phase. The overall IBI score for V2 is 5.8 during-development which is considered fair and a small decrease over the pre-development phase.

V3

The modified FQI score for the vegetation in monitoring plot V3 is 16.0 during-development indicating a small increase from the pre-development phase. Metric F2 indicates plot V3 consists of predominantly wetland species (-1.8) during-development, which represents a negligible decrease from the pre-development phase. Metric F3 indicates the species in plot V3 are moderately conservative in habitat requirements (5.0). The majority of species are moderately tolerant, with no tolerant species (F4; 0 percent) and 12.4 percent of species being narrowly tolerant (F5; 1.5 percent) species. Non - native species account for 2.3% of species during-development, however no invasive species are present. 10.2 percent of species are annual or biennial. Native trees accounted for 12.4 percent of inventoried species. One rare species was recorded during-development, an increase from no recorded rare species in the pre-development phase. The overall IBI score for V3 is 7.6 during-development which is considered good and an increase over the pre-development phase.

V4

The modified FQI score for the vegetation in monitoring plot V4 is 16.8 during-development indicating a small increase from the pre-development phase. Metric F2 indicates plot V4 consists of predominantly wetland species (-1.6) which is the same as the pre-development phase. Metric F3 indicates the species in plot V4 are moderately conservative in habitat requirements (4.3)). Similarly, the majority of species are neither widely tolerant (F4; 6.9 percent) or narrowly tolerant (F5; 8.5 percent) species. No non - native or invasive species were recorded during-development. 6.9 percent of species are annual or biennial. Native trees accounted for 22.3 percent of inventoried species. Three rare species were recorded during-development, an increase from no recorded rare species in the pre-development phase. The overall IBI score for V4 is 8.1 during-development which is considered good and an increase over the pre-development phase.

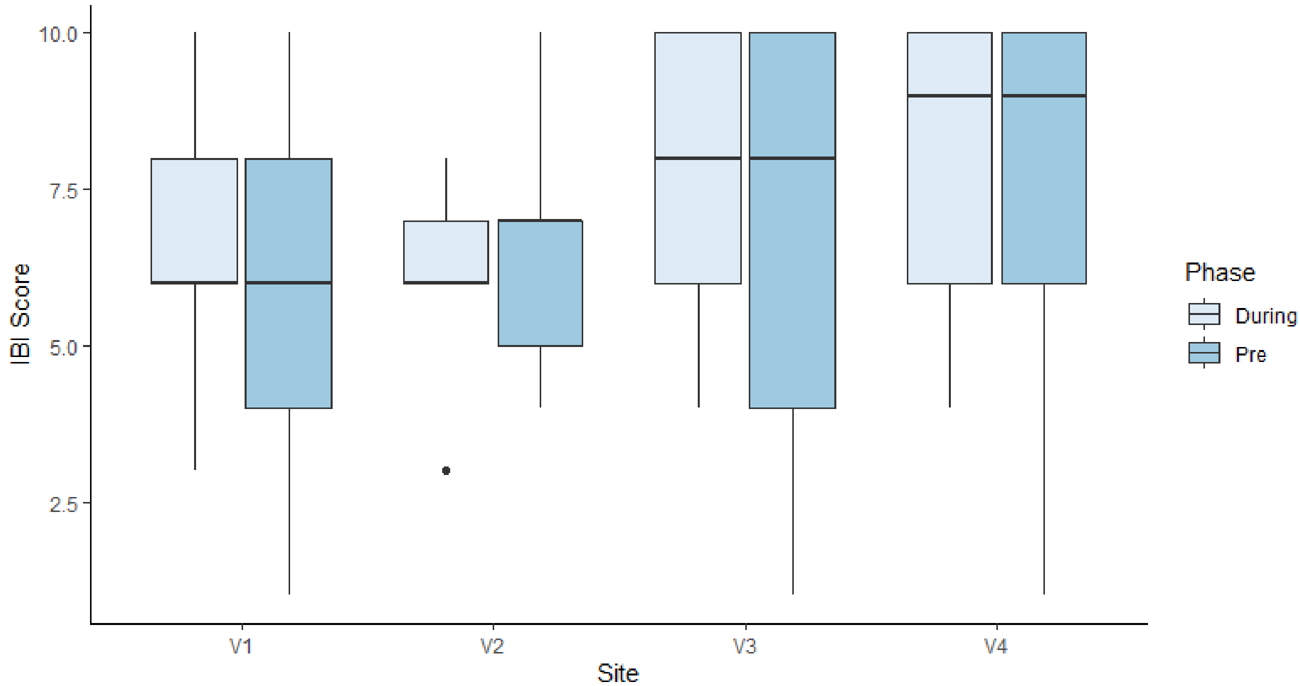


Figure 2-6-4 Boxplots of Doon South Flora IBI scores by site and phase. Top and bottom of the boxes are respectively the 75th and 25th percentiles, the line is the median, the whiskers represent the maximum and minimum, and the dots represent outliers.

2.6.4.2.2 Vegetation Buffers

Buffer plots were analyzed in a similar manner to vegetation plots, however as quadrats were not included for buffers, all species observations were included. Buffers were established during-development, so pre-development data does not exist. Buffers are expected to have lower IBI than vegetation plots, as they mediate between developed and non-developed areas and are newly planted. Table 2-6-19 below summarizes the results of IBI analysis for the buffers.

In general, buffer plots have low modified FQI (F1), feature both facultative species (F2) and have tolerant species (F3). The plots feature a high percentage of native tree species which have been planted. The plots also feature high numbers of non-native and invasive species, which is expected of recently disturbed sites. Overall IBI scores range from poor (BP1; 3.8) to fair (BP2, 5.1). As these sites become more established, the IBI scores are expected to increase. Data from these sites are limited, and these conclusions drawn from them should be taken with caution, however, can be used as a baseline as succession proceeds.

Table 2-6-19 During-development Buffer Monitoring – Doon South Sites

	BP1		BP2		BP3		BP4	
	Metric	Score	Metric	Score	Metric	Score	Metric	Score
F1	8.2	2.0	14.5	3.0	8.0	2.0	8.1	2.0
F2	1.5	N/A	1.3	N/A	0.8	N/A	-0.7	N/A
F3	2.0	N/A	3.2	N/A	2.2	N/A	1.8	N/A
F4	23.5	6.0	9.5	10.0	30.5	6.0	24.5	6.0

	BP1		BP2		BP3		BP4	
	Metric	Score	Metric	Score	Metric	Score	Metric	Score
F5	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
F6	0.0	1.0	1.0	5.0	3.0	6.0	0.0	1.0
F7	23.5	8.0	19.0	7.0	32.8	10.0	9.3	4.0
F8	0.0	1.0	4.8	6.0	0.0	1.0	17.5	9.0
F9	11.8	6.0	9.5	6.0	4.6	7.0	0.0	10.0
F10	47.1	4.0	57.1	3.0	32.1	5.0	27.9	5.0
F11	23.5	5.0	23.8	5.0	16.8	6.0	23.2	5.0
Average	3.8		5.1		4.9		4.8	

2.6.4.2.3 Avifauna

Tables 2-6-20 and 2-6-21 present the results of data analysis of the pre-development (2009-2014) and during-development (2015 – 2018) phases of the avifauna monitoring program for Doon South The results for each metric presented are expressed as an average across all monitoring years for each phase, with the exception of B9 which is a cumulative tally weighted by abundance. BB6 was discontinued in 2016 following recommendations from GRCA; therefore, the results for the during-development phase are for years 2015-2016. Site BB16 was added in 2016 and does not have pre-development monitoring data.

Table 2-6-20 Pre-development Avifauna Monitoring Results - Doon South Sites

	BB4		BB5		BB6		BB7		BB8	
	Metric	IBI	Metric	IBI	Metric	IBI	Metric	IBI	Metric	IBI
B1	25.2	6.0	25.5	6.0	11.5	3.0	20.3	5.0	20.5	5.0
B2	3.2	7.0	3.5	9.0	3.0	7.0	2.8	6.0	3.0	7.0
B3	45.8	10.0	32.3	10.0	13.7	10.0	21.4	10.0	22.1	10.0
B4	1.4	5.0	0.7	5.0	0.0	1.0	2.0	6.0	0.8	5.0
B5	7.5	6.0	7.6	6.0	9.6	6.0	2.6	8.0	7.7	6.0
B6	7.0	8.0	5.5	8.0	5.2	8.0	7.4	8.0	8.5	8.0
B7	0.9	2.0	4.0	5.0	0.0	1.0	0.5	2.0	4.3	5.0
B9	67.0	6.0	116.0	8.0	14.0	5.0	38.0	5.0	68.0	6.0
Average	6.3		7.1		5.1		6.3		6.5	

Table 2-6-21 During-development Avifauna Monitoring Results - Doon South Sites

	BB4		BB5		BB6		BB7		BB8		BB16	
	Metric	IBI	Metric	IBI	Metric	IBI	Metric	IBI	Metric	IBI	Metric	IBI
B1	28.0	6.0	26.8	6.0	19.0	4.0	23.7	5.0	25.3	6.0	18.0	4.0
B2	3.3	8.0	3.8	9.0	3.0	7.0	3.3	8.0	3.5	9.0	3.0	7.0
B3	39.5	10.0	29.3	10.0	14.6	10.0	20.6	10.0	21.9	10.0	7.9	10.0

	BB4		BB5		BB6		BB7		BB8		BB16	
	Metric	IBI	Metric	IBI	Metric	IBI	Metric	IBI	Metric	IBI	Metric	IBI
B4	1.5	5.0	0.4	5.0	0.0	1.0	1.7	5.0	3.7	7.0	6.7	8.0
B5	3.1	8.0	6.9	7.0	0.0	10.0	0.6	9.0	3.8	8.0	0.0	10.0
B6	6.2	8.0	8.0	8.0	4.2	7.0	10.8	9.0	9.7	8.0	11.5	9.0
B7	0.8	2.0	13.1	7.0	0.0	1.0	1.0	2.0	2.9	4.0	7.3	6.0
B9	18.0	5.0	38.0	5.0	1.0	3.0	29.0	5.0	38.0	5.0	19.0	5.0
Average	6.5		7.1		5.4		6.6		7.1		7.1	

BB4

Site BB4 is adjacent to Groh Drive and consists of floodplain meadow, thicket, and swamp habitats. Adjacent lands also include residential properties (WSP 2018).

An average of 28 species (B1) were recorded at BB4 during the development phase. Breeding was probable on site the majority of years during-development (B2; 3.3). 29 percent of species are disturbance tolerant (B3) with few disturbance intolerant species (B4; 0.4 percent). Non-native species account for 3.1 percent of species recorded (B5). The abundance of wetland species (B6; 6.2 percent) and ground nesting species (B7; 0.8 percent). A total of 6 rare species (weighted value: 18) were recorded during-development. Overall, the values for all pre-development metrics are very similar to those during-development. The average avifaunal IBI score across all metrics is 6.5 (fair) and is a slight increase from the pre-development phase.

BB5

Site BB5 consist of meadow, thicket, and swamp communities. Adjacent areas are active subdivision development and existing residential properties (WSP 2018).

An average of 26.8 species (B1) were recorded at BB5 during the development phase. Breeding was confirmed on site the majority of years during-development (B2; 3.8). 29 percent of species are disturbance tolerant (B3) with few disturbance intolerant species (B4; 0.4 percent). Non-native species account for 6.8 percent of species recorded (B5). The abundance of wetland species (B6; 8.0 percent) and ground nesting species (B7; 13.1 percent). A total of 9 rare species (weighted value: 38) were recorded during-development. Overall, the values for all pre-development metrics are similar to those during-development. The average avifaunal IBI score across all metrics is 7.1 (fair) and is the same as pre-development.

BB6

Site BB6 is adjacent to New Dundee Road and a hydro corridor and consists of meadow, thicket, and swamp habitats. Adjacent lands also include residential properties (WSP 2018).

An average of 19 species (B1) were recorded at BB6 during the development phase which is an increase from the pre-development phase. Breeding was probable on site the majority of years during-development (B2; 3.0). 14 percent of species are disturbance tolerant (B3) with no disturbance intolerant species (B4). No non-native species were recorded during-development (B5) which is a decrease from the pre-development phase. The abundance of wetland species (B6; 4.1 percent) decreased slightly from pre-development, while no ground nesting species were recorded during either phase (B7). One rare species (weighted value: 3) was recorded during-development, a decrease from the pre-development phase. Overall, the values for all pre-development metrics are similar to those during-development. The average avifaunal IBI score across all metrics is 5.4 (fair) and a slight increase from the pre-development phase.

BB7

Site BB7 is adjacent to Reichert Drive and consists of meadow, thicket, deciduous and coniferous swamp, and forest. Adjacent lands include residential properties (WSP 2018).

An average of 23.7 species (B1) were recorded at BB7 during the development phase which is an increase from the pre-development phase. Breeding was probable on site the majority of years during-development (B2; 3.3). 20.6 percent of species are disturbance tolerant (B3) with 1.6 percent of species disturbance intolerant (B4). Relatively few species are non-native (B5; 0.6 percent) is a slight increase from the pre-development phase. The abundance of wetland species (B6; 10.8 percent) increased from pre-development, and 0.97% of species are ground nesters (B7). Seven rare species (weighted value: 29) were recorded during-development, a decrease from the pre-development phase. The average avifaunal IBI score across all metrics is 6.6 (fair) and a slight increase from the pre-development phase.

BB8

Site BB8 is adjacent to Reichert Drive and consists of agricultural (row crops), meadow, thicket, deciduous and coniferous swamp forest habitat (WSP 2018).

An average of 25.2 species (B1) were recorded at BB8 during the development phase which is an increase from the pre-development phase. Breeding was probable on site the majority of years during-development (B2; 3.5). 21.9 percent of species are disturbance tolerant (B3) with 3.7 percent of species disturbance intolerant (B4). 3.8 percent of species are non-native (B5), which is a decrease from the pre-development phase. The abundance of wetland species (B6; 9.7 percent) increased from pre-development, and 2.9 percent of species are ground nesters (B7). Eight rare species (weighted value: 38) were recorded during-development, a decrease from the pre-development phase. The average avifaunal IBI score across all metrics is 7.1 (fair) and an increase from the pre-development phase.

BB16

Site BB16 is adjacent to New Dundee Road and consists of deciduous and coniferous swamp habitat (WSP 2018).

An average of 18 species (B1) were recorded at BB8 during the development phase. Breeding was probable on site the majority of years during-development (B2; 3.0). 7.9 percent of species are disturbance tolerant (B3) with 6.7 percent of species disturbance intolerant (B4). No non-native species were recorded (B5). Wetland species accounted for 11.4 percent of species (B6), while 7.3 percent of species were ground nesters (B7). Eight rare species (weighted value: 19) were recorded during-development. The average avifaunal IBI score across all metrics is 7.3 (fair).

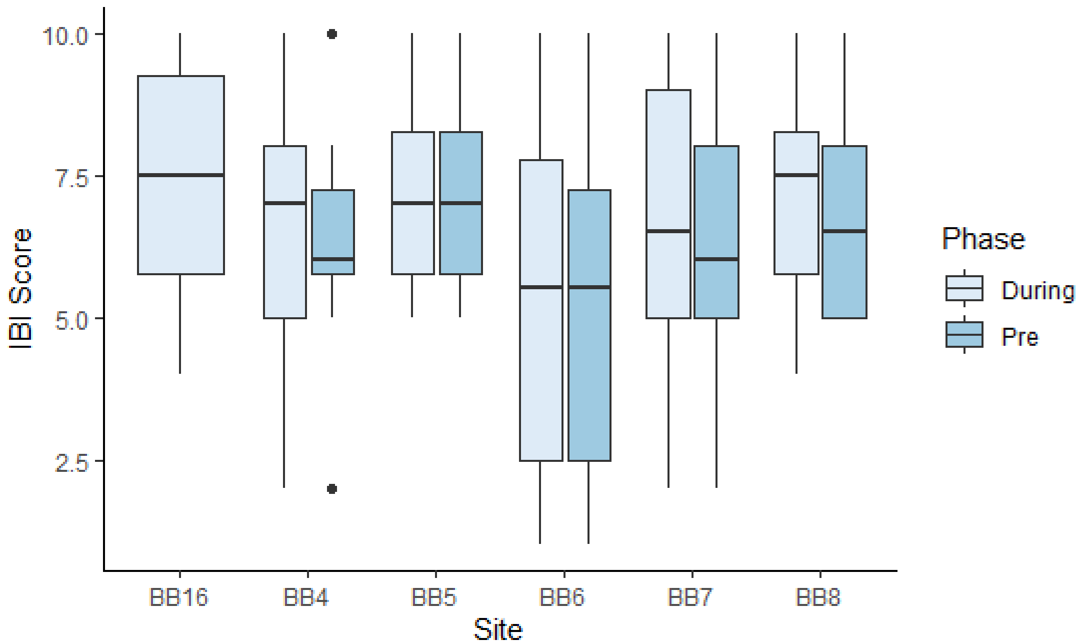


Figure 2-6-5 Boxplots of Doon South Avian IBI scores by site and phase. Top and bottom of the boxes are respectively the 75th and 25th percentiles, the line is the median, the whiskers represent the maximum and minimum, and the dots represent outliers.

2.6.4.2.4 Amphibians

Tables 2-6-22 and 2-6-23 present the results of the pre-development (2008 – 2014) and during-development amphibian calling monitoring program (2015-2018). Sites AC26 and AC27 were added in 2016, and site AC28 was added in 2018. Therefore, pre-development data do not exist for these sites. The results are averaged across all metrics except A5, which is a cumulative tally of rare species. As discussed in detail within the first state of the watershed report (Aquafor Beech Limited 2016), results from amphibian calling monitoring can be highly variable owing to the extreme seasonality of each species. As such, it is difficult to ascertain trends from short-term data.

The results of the amphibian calling monitoring program are highly variable for both the pre- and during-development phases. Site AC20 appears to decrease in all metrics indicating the site may be affected by development. American Bullfrog (*Lithobates catesbeianus*), considered regionally rare, was recorded during the monitoring in 2018 at AC28.

Table 2-6-22 Pre-development Amphibian Monitoring Results – Doon South Sites

	AC20
A1	1.9
A2	1.4
A3	2.0
A4	0.0
A5	0.0

Table 2-6-23 During-development Amphibian Monitoring Results – Doon South

	AC20	AC26	AC27	AC28
A1	1.3	0.3	0.3	5.0
A2	1.3	0.7	0.3	3.0
A3	1.3	0.0	0.3	4.0
A4	0.0	0.3	0.0	2.0
A5	0.0	0.0	0.0	1.0

2.6.4.3 Ormston

The following subsections present the results of the terrestrial biological monitoring including vegetation, avifauna, and calling amphibian for the pre-development (2014-205) and during-development (2015-2018) phases.

2.6.4.3.1 Vegetation Plots

Vegetation data is presented for all years during pre-development (2014-2015) and during-development (2016-2018). Site V4 was added in 2017, so pre-development data for V4 does not exist. Analysis was restricted to species observed within the established quadrats to ensure consistency. An overall IBI was assigned by averaging all years for the pre-development and during-development phases (Table 2-6-24 and Table 2-6-25). Below is a summary of each metric by site.

Table 2-6-24 Pre-development Flora Monitoring Results – Ormston Sites

	V1		V2		V3		V4	
	Metric	IBI	Metric	IBI	Metric	IBI	Metric	IBI
F1	15.2	4.0	19.7	4.0	13.1	3.0	13.0	3.0
F2	3.0	N/A	2.7	N/A	-1.1	N/A	-3.0	N/A
F3	4.4	N/A	4.9	N/A	3.3	N/A	4.1	N/A
F4	0.0	10.0	6.3	10.0	10.0	9.0	0.0	10.0
F5	0.0	1.0	12.5	10.0	0.0	1.0	0.0	1.0
F6	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
F7	33.3	10.0	18.8	7.0	10.0	5.0	0.0	1.0
F8	0.0	1.0	0.0	1.0	20.0	10.0	11.1	8.0
F9	25.0	6.0	12.5	6.0	10.0	6.0	22.2	6.0
F10	16.7	6.0	18.8	6.0	20.0	5.0	11.1	6.0
F11	16.7	6.0	12.5	6.0	0.0	10.0	11.1	6.0
Average	5.0		5.7		5.6		4.7	

Table 2-6-25 During-development Flora Monitoring Results – Ormston Sites

	V1		V2		V3		V4		V5	
	Metric	IBI	Metric	IBI	Metric	IBI	Metric	IBI	Metric	IBI
F1	14.9	3.0	19.6	4.0	13.1	3.0	14.4	3.0	21.8	5.0
F2	2.9	N/A	2.7	N/A	-1.7	N/A	-2.3	N/A	-1.7	N/A
F3	4.5	N/A	5.1	N/A	3.1	N/A	4.0	N/A	4.7	N/A
F4	0.0	10.0	2.1	10.0	14.7	8.0	7.6	10.0	2.5	10.0
F5	2.6	8.0	15.8	10.0	0.0	1.0	11.7	10.0	18.8	10.0
F6	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.0	5.0
F7	19.2	7.0	18.5	7.0	8.0	4.0	10.2	5.0	18.8	7.0
F8	0.0	1.0	0.0	1.0	14.3	8.0	16.3	9.0	21.8	10.0
F9	38.4	5.0	15.8	6.0	7.6	6.0	10.2	6.0	7.9	6.0
F10	31.4	5.0	13.3	6.0	20.6	5.0	4.5	8.0	10.9	6.0
F11	25.5	5.0	11.0	6.0	5.9	7.0	4.5	8.0	10.9	6.0
Average	5.0		5.7		4.8		6.7		7.2	

V1

The modified FQI score for the vegetation in monitoring plot V1 is 14.9 during-development indicating a small decrease from the pre-development phase. Metric F2 indicates plot V1 consists of predominantly upland species (2.9) which is nearly equal to the pre-development phase. Metric F3 indicates the species in plot V1 are moderately conservative in habitat requirements (4.5). Similarly, the majority of species are neither widely tolerant (F4; 0 percent) or narrowly tolerant (F5; 2.6 percent) species. Non - native (F10) and invasive species (F11) account for 31.5 percent and 25.5 percent, respectively. Additionally, 38.4 percent of species are annual or biennial (F9). Native trees (F7) accounted for 19.2 percent of inventoried species. No rare species were recorded during-development. The overall IBI score for V1 is 5.0 during-development which is considered fair and is the same as the pre-development phase.

V2

The modified FQI score for the vegetation in monitoring plot V2 is 19.6 during-development indicating a negligible decrease from the pre-development phase. Metric F2 indicates plot V2 consists of predominantly upland species (2.7) which is equal to the pre-development phase. Metric F3 indicates the species in plot V2 are moderately conservative in habitat requirements (5.1). Similarly, the majority of species are neither widely tolerant (F4; 10.0 percent) or narrowly tolerant (F5; 10.0 percent) species. Non - native (F10) and invasive species (F11) account for 13.3 percent and 11.0 percent, respectively. Additionally, 15.8% of species are annual or biennial (F9). Native trees (F7) accounted for 18.5 percent of inventoried species. No rare species were recorded during-development. The overall IBI score for V2 is 5.7 during-development which is considered fair and is the same as the pre-development phase.

V3

The modified FQI score for the vegetation in monitoring plot V3 is 13.1 during-development indicating a negligible decrease from the pre-development phase. Metric F2 indicates plot V3 consists of facultative wetland species (-1.7) and consists of more wetland species than the pre-development phase. Metric F3 indicates the species in plot V3 are tolerant in habitat requirements (3.1). The majority of species are neither widely tolerant

(F4; 14.7 percent) or narrowly tolerant (F5; 0.0 percent%) species. Non - native (F10) and invasive species (F11) account for 20.6 percent and 5.9 percent, respectively. Additionally, 7.6 percent of species are annual or biennial (F9). Native trees (F7) accounted for 8.0 percent of inventoried species. No rare species were recorded during-development. The overall IBI score for V3 is 4.8 during-development which is considered fair and is a decrease from the pre-development phase.

V4

The modified FQI score for the vegetation in monitoring plot V4 is 14.4 during-development which is an increase from the pre-development phase. Metric F2 indicates plot V4 consists of facultative wetland species (-2.3) and consists of less wetland species than the pre-development phase. Metric F3 indicates the species in plot V4 are moderately conservative in habitat requirements (4.0). The majority of species are neither widely tolerant (F4; 7.6 percent) or narrowly tolerant (F5; 11.7 percent) species. Non - native (F10) and invasive species (F11) account for 4.5 percent of species. Additionally, 10.2 percent of species are annual or biennial (F9). Native trees (F7) accounted for 10.2 percent of inventoried species. No rare species were recorded during-development. The overall IBI score for V4 is 6.7 during-development which is considered good and is an increase from the pre-development phase.

V5

The modified FQI score for the vegetation in monitoring plot V5 is 21.8 during-development which is an increase from the pre-development phase. Metric F2 indicates plot V5 consists of facultative wetland species (-1.7). Metric F3 indicates the species in plot V5 are moderately conservative in habitat requirements (4.7). The majority of species are neither widely tolerant (F4; 2.5 percent) or narrowly tolerant (F5; 18.8 percent) species. Non - native (F10) and invasive species (F11) account for 10.9 percent of species. Additionally, 7.9 percent of species are annual or biennial (F9). Native trees (F7) accounted for 18.8 percent of inventoried species. One rare species were recorded during-development. The overall IBI score for V5 is 7.2 during-development which is considered good and is an increase from the pre-development phase.

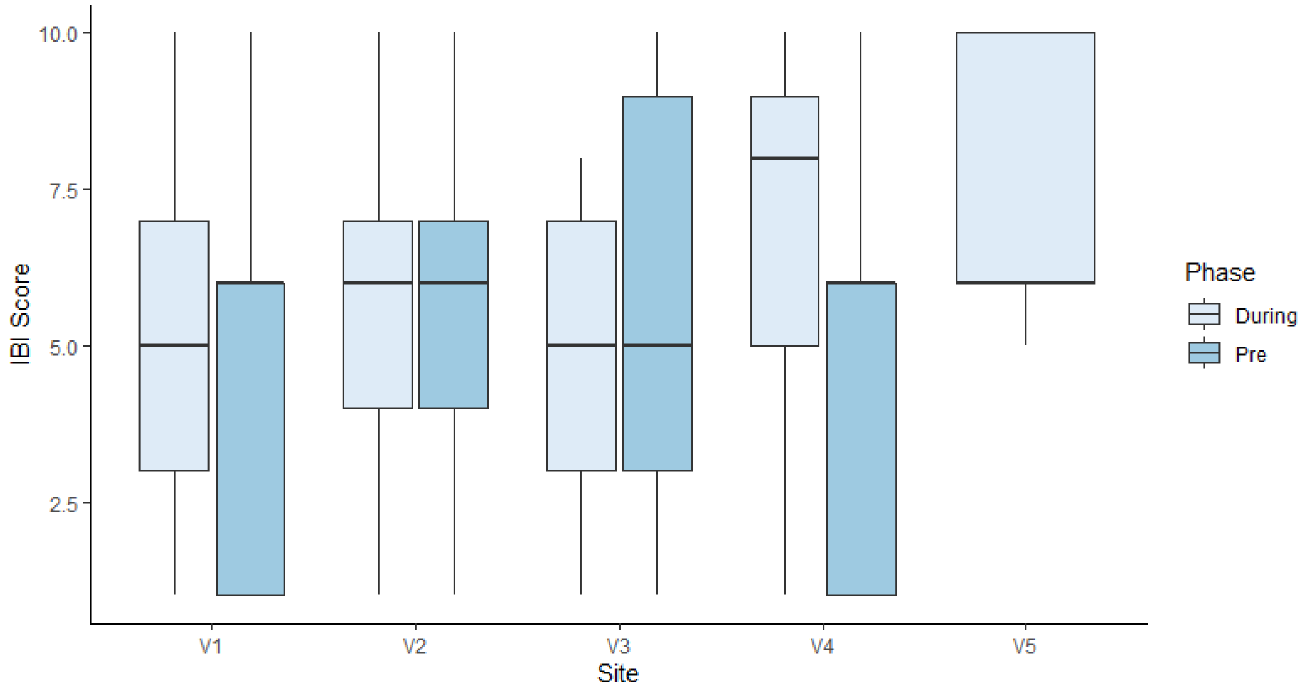


Figure 2-6-6 Boxplots of Ormston Flora IBI scores by site and phase. Top and bottom of the boxes are respectively the 75th and 25th percentiles, the line is the median and the whiskers represent the maximum and minimum.

2.6.4.3.2 Avifauna

Tables 2-6-26 and 2-6-27 present the results of data analysis of the pre-development (2014-2015) and during-development (2015 – 2018) phases of the avifauna monitoring program for Ormston. The results for each metric presented are expressed as an average across all monitoring years for each phase, with the exception of B9 which is a cumulative tally weighted by abundance.

OBB1

Site OBB1 consists of mature deciduous forest. Adjacent lands include active development and residential lands.

An average of 23.7 species (B1) were recorded at OBB1 during the development phase which is a decrease from the pre-development phase. Breeding was probable on site the majority of years during-development (B2; 3.3). 21.8 percent of species are disturbance tolerant (B3) and is an increase over the pre-development phase 5.4 percent of species disturbance intolerant (B4), a decrease from the pre-development phase. 2.1 percent of species are non-native (B5) which is an increase over the pre-development phase. No wetland species (B6) were recorded during the development phase. 0.7 percent of species are ground nesters (B7). Ten rare species (weighted value: 49) were recorded during-development, an increase from the pre-development phase. The average avifaunal IBI score across all metrics is 5.1 (fair) and a decrease from the pre-development phase.

OBB2

Site OBB2 primarily consists of mature deciduous swamp and coniferous plantation habitat as well as a large open water pond. Adjacent lands are agriculture (cropland) and residential properties.

An average of 23.3 species (B1) were recorded at OBB2 during the development phase which is an increase from the pre-development phase. Breeding was confirmed on site every year during-development (B2; 4.0). 19.0 percent of species are disturbance tolerant (B3) and is an increase over the pre-development phase. 2.4 percent of species disturbance intolerant (B4), a decrease from the pre-development phase. 5.4 percent of species are non-native (B5) which is an increase over the pre-development phase. No wetland species (B6) were recorded during the development phase. 3.7 percent of species are ground nesters (B7). Seven rare species (weighted value: 28) were recorded during-development, an increase from the pre-development phase. The average avifaunal IBI score across all metrics is 7.0 (fair) and is the same as the pre-development phase.

Table 2-6-26 Pre-development Avifauna Monitoring Results - Ormston Sites

	OBB1		OBB2	
	Metric	IBI	Metric	IBI
B1	25.5	6.0	20.0	5.0
B2	3.5	9.0	3.5	9.0
B3	14.7	10.0	15.3	10.0
B4	7.3	8.0	4.1	7.0
B5	0.9	9.0	3.1	8.0
B6	2.2	6.0	5.0	7.0
B7	0.4	2.0	3.8	5.0
B9	31.0	5.0	18.0	5.0
Average	6.9		7.0	

Table 2-6-27 During-development Avifauna Monitoring Results - Ormston Sites

	OBB1		OBB2	
	Metric	IBI	Metric	IBI
B1	23.7	5.0	23.3	5.0
B2	3.3	8.0	4.0	10.0
B3	21.8	10.0	19.0	10.0
B4	5.4	8.0	2.4	6.0
B5	2.1	8.0	5.4	7.0
B6	0.0	1.0	6.1	8.0
B7	0.7	2.0	3.7	5.0
B9	49.0	5.0	28.0	5.0
Average	5.9		7.0	

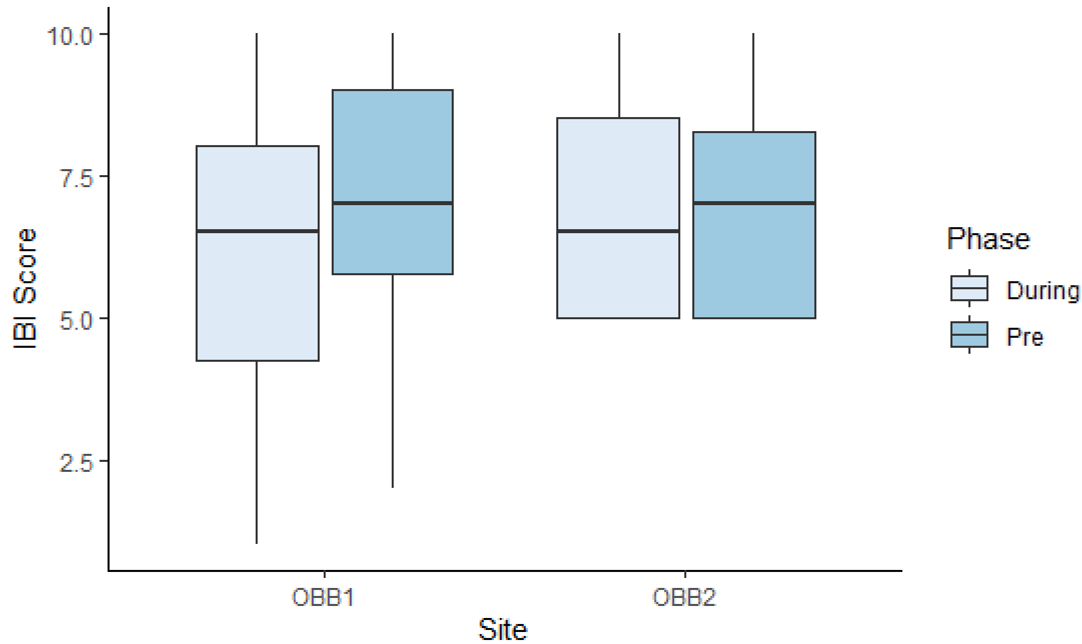


Figure 2-6-7 Boxplots of Ormston Avifauna IBI scores by site and phase. Top and bottom of the boxes are respectively the 75th and 25th percentiles, the line is the median and the whiskers represent the maximum and minimum.

2.6.4.3.3 Amphibians

Tables 2-6-28 and 2-6-29 present the results of the pre-development (2014 – 2015) and during-development amphibian calling monitoring program (2016-2018). The results are averaged across all metrics except A5, which is a cumulative tally of rare species. As discussed in detail within the first state of the watershed report (Aquafor Beech Limited 2016), results from amphibian calling monitoring can be highly variable owing to the extreme seasonality of each species. As such, it is difficult to ascertain trends from short-term data.

The results of the amphibian calling monitoring program are highly variable for both the pre- and during-development phases. Notably, calling was not observed at the site in 2016 and 2017. Site AC20 appears to decrease in all metrics, however little data is available.

Table 2-6-28 Pre-construction Amphibian Monitoring Results – Ormston Sites

	AC24
A1	3.5
A2	2.0
A3	2.5
A4	1.0
A5	0

Table 2-6-29. During-development Amphibian Monitoring Results – Ormston Sites

	AC24
A1	2.3
A2	0.7
A3	2.0
A4	0.3
A5	0.0

2.6.4.4 Upper Blair

The following sections provide the overall IBI scores for the 2007-2014 and 2015-2018 periods. Development over the study areas commenced on different schedules. Stauffer and Doon South commenced development in 2015, whereas Ormston commenced development in 2016. Therefore, the 2007-2014 period encompasses the entire pre-development period, but the 2015-2018 time period encompasses the during-development phases for Stauffer Woods and Doon South, and both phases of Ormston.

2.6.4.4.1 Vegetation

The overall Vegetation IBI score for Upper Blair is 6.8 (Fair) for both pre-development and during-development phases (Table 2-6-30). While the overall score itself did not change, there is slight variation amongst the metrics. Stauffer Woods plots V4 and V5, Doon South plots V3 and V4, and Ormston plot V5 had the highest IBI scores with considerable variation from the pre-development phases. In general Stauffer Woods plots faced a decrease in IBI scores, while Doon South and Ormston plots increased or remained equal.

Table 2-6-30 Scores for floristic index of biological integrity metrics – Upper Blair Study Area

	2007-2014		2015-2018	
	Metric	IBI	Metric	IBI
F1	14.6	3.0	15.0	3.0
F2	-1.0	N/A	-0.6	N/A
F3	4.1	N/A	4.0	N/A
F4	14.3	8.0	11.2	9.0
F5	4.1	8.0	5.6	9.0
F6	6.0	7.0	7.0	7.0
F7	10.4	5.0	13.5	6.0
F8	10.7	8.0	10.1	8.0
F9	3.9	7.0	8.4	6.0
F10	6.9	7.0	11.9	6.0
F11	5.0	8.0	8.6	7.0
Average	6.8		6.8	

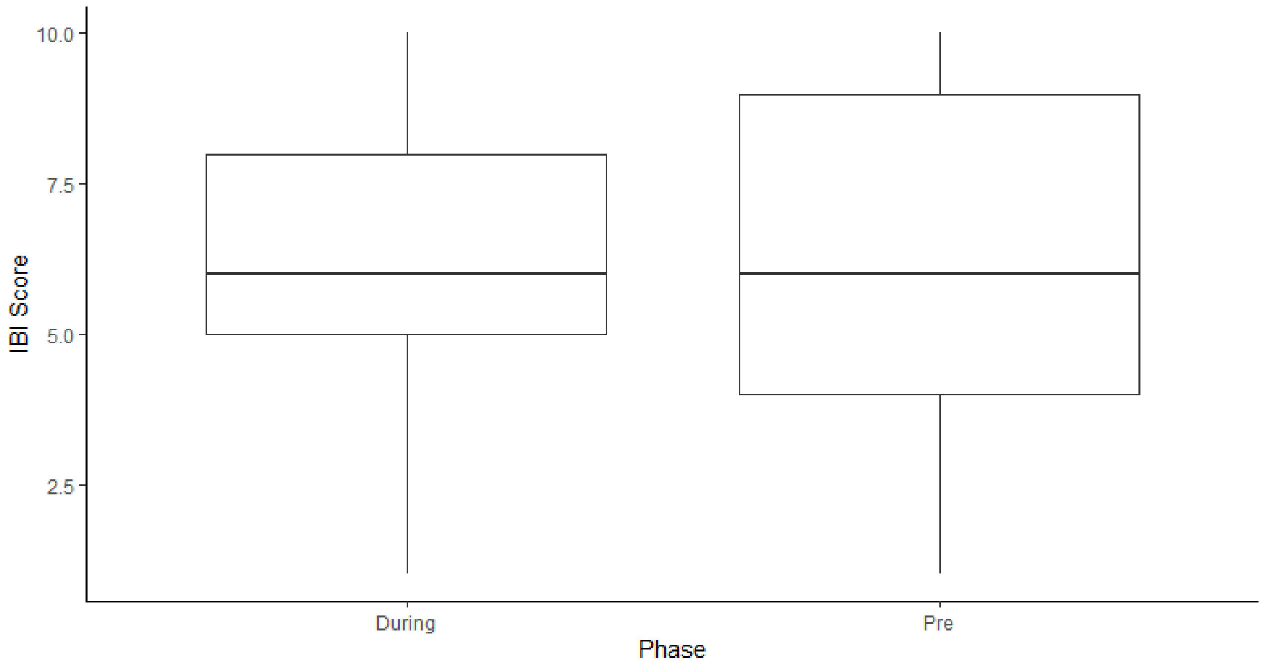


Figure 2-6-8 Boxplots of Upper Blair Flora IBI scores by site and phase. Top and bottom of the boxes are respectively the 75th and 25th percentiles, the line is the median and the whiskers represent the maximum and minimum.

2.6.4.4.2 Avifauna

The overall Vegetation IBI score for Upper Blair is 7.3 (Good) which was a slight increase over the pre-development phase (7.1) (Table 2-6-31). Stauffer Woods BB2, Doon South BB5 and BB8 had the highest IBI scores with considerable variation from the pre-development phases. In general Stauffer Woods and Ormston sites faced a decrease in IBI scores, while Doon South and Ormston sites increased or remained equal.

Table 2-6-31 Scores for avifaunal index of biological integrity metrics – Upper Blair Study Area

	2007-2014		2015-2018	
	Metric	IBI	Metric	IBI
B1	24.1	5.0	25.9	6.0
B2	3.3	8.0	3.5	9.0
B3	35.2	10.0	32.1	10.0
B4	2.3	6.0	3.0	6.0
B5	4.6	8.0	3.5	8.0
B6	7.2	8.0	6.3	8.0
B7	4.1	5.0	4.2	5.0
B9	96.9	7.0	63.5	6.0
Average	7.1		7.3	

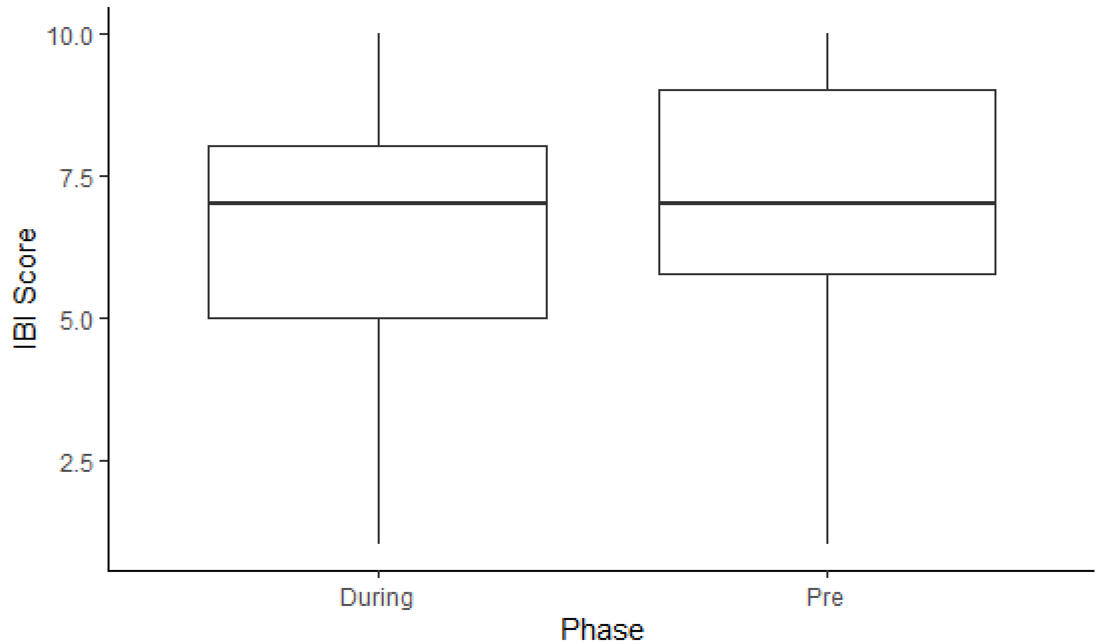


Figure 2-6-9 Boxplots of Upper Blair Avifauna IBI scores by site and phase. Top and bottom of the boxes are respectively the 75th and 25th percentiles, the line is the median, the whiskers represent the maximum and minimum.

2.6.4.4.3 Amphibians

In general, the temporal variability and limited dataset of the amphibian call surveys makes interpretation of the data difficult. In total 8 species or anuran were identified over the Upper Blair Study Area. All species were typical and expected for the area. One species at risk was recorded over the study area, Western Chorus Frog during 2008-2014. In general, the number of species and amount of calling decreased over the study period, indicating a potential decrease in amphibian habitat quality and populations (Table 2-6-32).

Table 2-6-32 Scores for amphibian index of biological integrity metrics – Upper Blair Area

	2008-2014	2015-2018
A1	2.3	2.0
A2	2.3	1.3
A3	1.9	1.5
A4	0.6	0.6
A5	1	0

2.6.5 Conclusions

In general, terrestrial communities within the Upper Blair Study Area score in the mid-range indicating the terrestrial ecosystems are in fair to good condition. Individual sites face considerable variation, as is expected in a heterogenous and fragmented landscape. Tables 2-6-33 and 2-6-34 summarize the pre-development and during-development (2015-2018) IBI scores for each habitat block as illustrated in Figure 2-6-1. General trends for amphibians are presented qualitatively. The average IBI scores for the majority of the habitat blocks decreased, except for blocks D and G which increased. However, data during the development period is more limited than the pre-development period. As such monitoring should continue to determine whether the changes are pervasive and as a result of development or due to natural variation. Habitat blocks from the 2016 SOW Report, **(Aquafor Beech Limited 2016)** are shown in Figure 2-6-1**.**

Table 2-6-33 Pre-development (2007-2014) IBI scores by Habitat Block

Habitat Block	Average IBI Score by taxon		Amphibians
	Flora	Avifauna	
A	Stauffer V7 5.7 (fair) Stauffer V8 6.0 (fair) Stauffer V9 6.4 (fair) Stauffer V10 6.2 (fair) Average 6.1 (fair)	BB1 8.1 (good)	AC8, AC12, AC14 Amphibian Community is dominated by disturbance tolerant species with relatively consistent and full chorus.
B	Stauffer V1 6.3 (fair) Stauffer V2 6.4 (fair) Stauffer V4 6.2 (fair) Stauffer V5 7.9 (fair) Stauffer V6 6.2 (fair) Average 6.6 (fair)	BB2 7.4 (good)	AC2, AC9, AC10, AC13, AC15 Species Richness is variable across years and dominated by tolerant species. A full chorus is present at most sites during most years
C	Stauffer V3 6.0 (fair)	BB3 8.6 (good)	AC1 Species Richness is variable across years and dominated by tolerant species. A full chorus is present during all years.
D	Doon V3* 6.7 (fair) Doon V4* 7.3 (good) Average 7.0 (good)	BB4 6.3 (fair)	N/A
E	Doon V1* 5.7 (fair) Doon V2* 6.6 (fair) Average 6.2 (fair)	BB5 7.1 (good)	AC20 Species Richness is variable and appears to be declining. Disturbance tolerant species dominate.
F	N/A	BB6 5.1 (fair)	N/A
G	Ormston V3 5.6 (fair) Ormston V4 4.7 (poor) Average 5.2 (fair)	BB7 6.3 (fair) BB8 6.5 (fair) OBB2 7.0 (good) Average 6.6 (fair)	AC24 Species Richness is variable while calling remains consistent. Disturbance tolerant species dominate.
H	Ormston V1 5.0 (fair) Ormston V2 5.7 (fair) Average 5.4 (fair)	OBB1 6.9 (fair)	N/A

Table 2-6-34 2015-2018 During-development IBI scores by Habitat Block

Habitat Block	Average IBI Score by taxon		Amphibians
	Flora	Avifauna	
A	Stauffer V7 6.7 (fair) Stauffer V8 5.7 (fair) Stauffer V9 6.9 (fair) Stauffer V10 5.2 (fair) Average 6.1 (fair)	BB1 6.8 (fair)	AC8, AC12, AC14 Amphibian community is less stable with declining species richness and chorus calling. Disturbance tolerant species continue to dominate.
B	Stauffer V1 6.1 (fair) Stauffer V2 6.0 (fair) Stauffer V4 7.2 (fair) Stauffer V5 7.0 (fair) Stauffer V6 5.7 (fair) Average 6.4 (fair)	BB2 7.8 (good)	AC2, AC9, AC10, AC13, AC15 Species Richness is variable across years and dominated by tolerant species. The presence of a full chorus appears to be declining at sites AC9, AC10, and AC13.
C	Stauffer V3 5.7 (fair)	BB3 6.8 (fair)	AC1 Species Richness is variable across years and dominated by tolerant species. A full chorus is present during all years.
D	Doon V3 7.6 (fair) Doon V4 8.1 (good) Average 7.8 (good)	BB4 6.5 (fair)	N/A
E	Doon V1 6.4 (fair) Doon V2 5.8 (fair) Average 6.1 (good)	BB5 7.1 (good)	AC20, AC28 Species Richness and calling is variable and appears to be declining at AC20, while AC28 remains high. Calling Disturbance tolerant species dominate.
F	N/A	BB6 5.3 (fair)	N/A
G	Ormston V3 4.8 (poor) Ormston V4 6.7 (fair) Ormston V5 7.2 (good) Average 6.2 (fair)	BB7 6.6 (fair) BB8 7.1 (good) BB16 7.4 (good) OBB2 7.0 (good) Average 7.0 (good)	AC24, AC26, AC27 Species Richness and calling is variable. Species richness and calling is particularly low at AC 26 and 27, Disturbance tolerant species dominate.
H	Ormston V1 5.0 (fair) Ormston V2 5.7 (fair) Average 5.4	OBB1 5.9 (fair)	N/A

* data for 2014 only

2.7 Aquatic Ecology

2.7.1 Context

The pre- and during-development aquatic ecology conditions within the Blair Creek Watershed are described through several key studies and monitoring reports. These include the following:

Pre-Development

- **Blair, Bechtel, and Bauman Creeks Subwatershed Plan** (CH2M Gore and Storrie 1997): This study established the pre-development natural heritage conditions within the Blair Creek watershed. The BBB Study identified key Brook Trout spawning areas, characterized stream benthic communities, linked ecosystem functions to sensitive aquatic habitat, and identified limiting factors to coldwater fish production
- **Stauffer Woods Subdivision and Ormston Environmental Implementation Reports (Ecoplans 2008 and 2013, respectively):** These studies document the results of pre-development monitoring and existing natural heritage resources from 2003 to 2007 and in 2013, respectively.
- **2016 Upper Blair Creek State of the Watershed Report (Aquafor Beech Limited 2016)**. This was the first SOW report and established the pre-development baseline conditions, established the IBI framework, and identified indicators of change.

During-Development

- Ongoing annual ecological monitoring reports (WSP 2015, 2016, 2017, and 2018)

Continuous temperature monitoring conducted by GRCA (2018) and as part of the BBB study (CH2M Gore & Storrie 1997) identified water temperature was highest at the mouth of Blair Creek and lowest downstream of the Roseville Swamp. Temperatures are marginal for Brook Trout near New Dundee Road due to the lack of forest canopy and intermittent baseflows which relates to a rise in stream temperature. Groundwater discharge has the highest influence on surface water temperatures downstream of the Roseville Swamp (CH2M Gore & Storrie 1997; Aquafor Beech Limited 2016). Further, these studies found Upper Blair Creek supports a self-sustaining Brook Trout population throughout the watershed, but that the area upstream of New Dundee Road may be limiting to the population due to a lack of perennial baseflow. The BBB study also conducted analysis of benthic macroinvertebrate data collected by GRCA and determined the presence of sensitive species indicate higher quality habitat (CH2M Gore & Storrie 1997).

2.7.2 Summary of Past Monitoring

The aquatic ecology monitoring program commenced as a result of residential development and commenced prior to the development. The monitoring program is based on direction provided in the Upper Blair Creek FDS (Stantec 2009) and initiated by the developers. GRCA data (2018) supplements the aquatic monitoring program.

The Upper Blair Aquatic Monitoring program consists of four components:

- Benthic Macroinvertebrate surveys;
- Fish community surveys;
- Spawning surveys; and
- Continuous Temperature monitoring

Tables 2-7-1 and 2-7-2 summarize the aquatic monitoring program effort. Spawning Surveys were completed by MMM Group from 2008-2018. Figure 2-7-1, 2-7-2, and 2-7-3 below illustrate the aquatic monitoring locations for the Upper Blair Study Area. Additional aquatic monitoring did not occur for the Ormston development area.

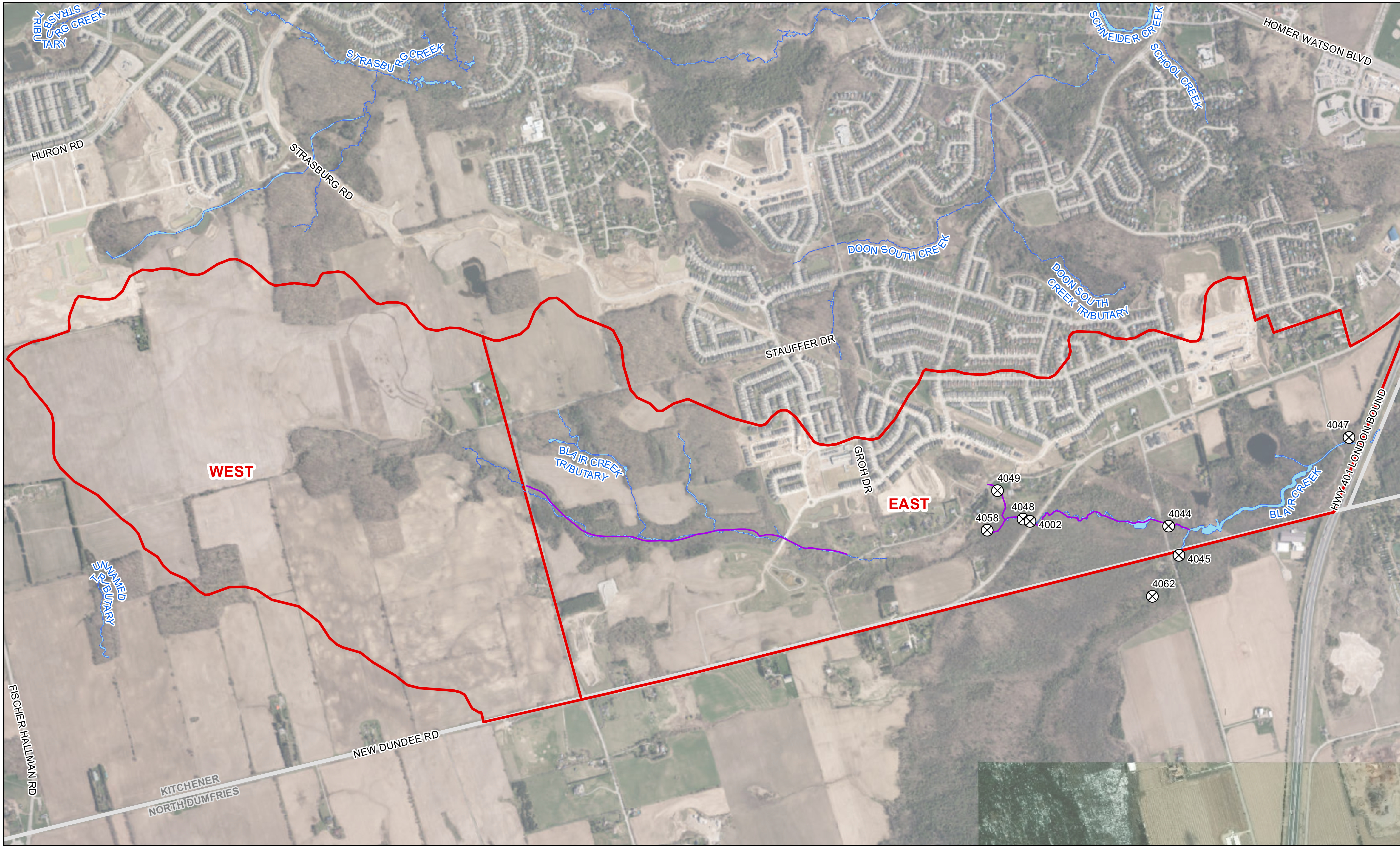
Table 2-7-1 Location and date of fish community surveys conducted by GRCA

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
2414001 - Dickie Settlement Road	X		X		X	X	X	X	X	X	X	X	X	X
2414002 - Upstream New Dundee Road												X	X	X
2414044 - Downstream Reichert Drive			X											
2414045 - Roseville Tributary Downstream of Reichert Drive					X									
2414046 - Mouth of Blair Creek		X		X	X									
2414047 - Upstream Highway 401	X	X		X	X	X	X	X	X	X	X	X	X	X
2414048 - Dodge Drive Tributary			X											
2414049 – Downstream Dodge Drive		X												
2414058 - Upstream New Dundee Road			X											
2414062 - Roseville Tributary Upstream Reichert Drive					X		X		X	X	X	X	X	X

Table 2-7-2 Location and dates of benthic macroinvertebrate surveys conducted by GRCA and developers

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
2414001 - Dickie Settlement Road	X		X	X	X	X	X	X	X					
2414044 - Downstream Reichert Drive			X		X	X	X	X	X	X	X			X
2414045 - Roseville Tributary Downstream of Reichert Drive			X		X	X	X	X	X	X	X			X
2414046 - Mouth of Blair Creek		X		X	X									
2414047 - Upstream of Highway 401	X	X		X	X	X	X	X	X	X	X	X	X	X
2414048 - Dodge Drive Tributary			X											
B1			X*	X	X	X	X	X	X	X	X	X	X	
B2a			X*	X	X	X	X	X	X	X	X	X	X	
B2b			X*	X	X	X	X	X	X	X	X	X	X	
B3			X*	X	X	X	X	X	X	X	X	X	X	
B4			X*	X	X	X	X	X	X	X	X	X	X	
B5			X*	X	X	X	X	X	X	X	X	X	X	
B6			X*	X	X	X	X	X	X	X	X	X	X	
B7			X*	X	X	X	X	X	X	X	X	X	X	

* Fall Sampling only



N

0 200 400
Meters

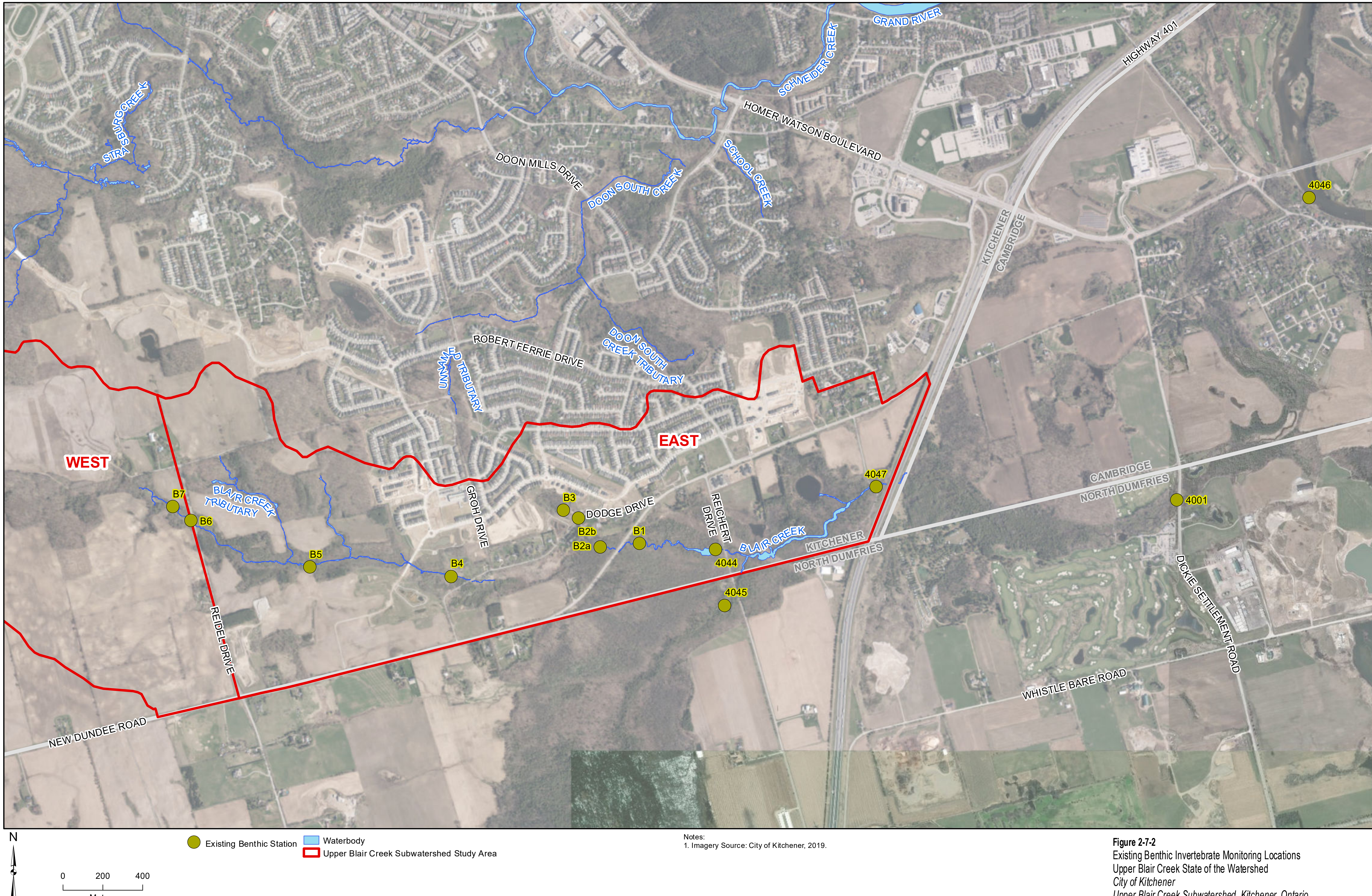
Existing Fish Sampling Location
Existing Fish Spawning
Waterbody
Upper Blair Creek Subwatershed Study Area

Notes:
1. Imagery Source: City of Kitchener, 2019.

Figure 2-7-1
Existing Fish Community Sampling Locations
Upper Blair Creek State of the Watershed
City of Kitchener
Upper Blair Creek Subwatershed, Kitchener, Ontario

Jacobs

\\DC1VS01\GISPROJ\K\KITCHENERCITYOF\UPPERBLAIRCREEK_P20_005\MAPFILES\SOW\2_7_1_EXISTING_FISHCOMMUNITY_SAMPLINGLOCATIONS.MXD SCYR 1/26/2021 4:37:28 PM



Notes:
1. Imagery Source: City of Kitchener, 2019.

Figure 2-7-2
Existing Benthic Invertebrate Monitoring Locations
Upper Blair Creek State of the Watershed
City of Kitchener
Upper Blair Creek Subwatershed, Kitchener, Ontario

Jacobs

N

0 200 400

Meters

Sampling Locations

- Activa Site
- GRCA Site
- Monarch/Hallman Site
- Ormston Subdivion

- Waterbody
- Upper Blair Creek Subwatershed Study Area
- Municipal Boundary

Notes:
1. Imagery Source: City of Kitchener, 2019.
2. Monitoring Data Sources:
- Upper Blair Creek- State of the Watershed (SOW) Report, 2016.
- During & Post Construction Surface and Groundwater Monitoring, Figure 2.2, 2016.

Figure 2-7-3
Existing Surface Water Temperature Sampling Locations
Upper Blair Creek State of the Watershed
City of Kitchener
Upper Blair Creek Subwatershed, Kitchener, Ontario

Jacobs

\\DC1VS01\GISPROJ\K\KITCHENERCITYOF\UPPERBLAIRCREEK_P20_005\MAPFILES\SOW\2_7_3_EXISTING_SW_TEMP_SAMPLINGLOCATIONS.MXD VM048279 3/10/2021 11:32:23 AM

2.7.3 Data Analysis

The following data analysis examines the aquatic monitoring data collected over the entire pre-development and during-development periods. Data collection methods are outlined in the first SOW report (Aquafor Beech Limited 2016).

2.7.3.1 Index of Biological Integrity

The first SOW report (Aquafor Beech Limited 2016) established the IBI framework for pre-development monitoring data. An IBI combines a series of biological indicators into a single summary index. Each indicator is a measurable component of the ecological function of an area with an anticipated change in response to disturbance. The IBI can therefore be used to examine ecological function of an area during different phases of development or disturbance.

The first SOW report established a series of metrics for benthic macroinvertebrates and the fish community. However, alteration of metrics to yield an IBI score for benthic macroinvertebrates is not advised (Aquafor Beech Limited 2016), and these IBI scores were not assigned to the benthic macroinvertebrate metrics. This report followed the methods established in the first state of the watershed report to calculate the metric for each year of monitoring data (Tables 2-7-3 and 2-7-4). Metrics were calculated and scores were then averaged across the pre- and during-development phases. Once an average for each phase was determined for the fish community, an IBI score ranging from 1 (very poor) to 10 (very good) was assigned according to the criteria outlined in the first state of the watershed report (Table 2-7-5). Finally, IBI scores from all metrics during a phase are averaged to yield an overall IBI score for the fish community. The IBI method is not applicable to fish spawning surveys or continuous temperature analysis, and so these results are examined qualitatively.

Table 2-7-3 Method for calculating Benthic Macroinvertebrate Metrics

<table>
<tr><th colspan="2">Metric</th><th></th></tr>
<tr><td>M1</td><td>Hilsenhoff Biotic Index (HBI)</td><td>$$HBI = \sum \frac{(x_i)(t_i)}{n}$$
Where:
x_i= number of organisms in ith taxon
t_i= tolerance value of ith taxon
n = total number of organisms in the sample
HBI interpretation is as follows:
<table>
<tr><th>HBI</th><th>Water Quality</th><th>Degree of Organic Pollution</th></tr>
<tr><td>0.00-3.50</td><td>Excellent</td><td>No apparent organic pollution</td></tr>
<tr><td>3.50-4.50</td><td>Very Good</td><td>Possible slight organic pollution</td></tr>
<tr><td>4.50-5.50</td><td>Good</td><td>Some organic pollution</td></tr>
<tr><td>5.50-6.50</td><td>Fair</td><td>Fairly significant organic pollution</td></tr>
<tr><td>6.50-7.50</td><td>Fairly Poor</td><td>Significant organic pollution</td></tr>
<tr><td>7.50-8.50</td><td>Poor</td><td>Very significant organic pollution</td></tr>
<tr><td>8.50-10.00</td><td>Very Poor</td><td>Severe organic pollution</td></tr>
</table></td></tr>
<tr><td>M2</td><td>Shannon Wiener Index</td><td>$$H' = \sum (p_i)(Lnp_i)$$
Where:
p_i= the proportion of individuals in i^{th} taxon</td></tr>
</table>

Metric		
M3	Taxa Richness	Number of species recorded
M4	% Oligochaeta	$\frac{O}{n} \times 100$ Where: O= Number of Oligochaetes organisms
M5	% Chironomidae	$\frac{C}{n} \times 100$ Where: C= Number of Chironomids
M6	% Ephemeroptera, Plecoptera and Trichoptera (EPT)	$\frac{E+P+T}{n} \times 100$ Where: E= Number of Ephemeroptera P= Number of Plecoptera T= Number of Trichoptera
M7	Number EPT Taxa	Number of EPT
M8	% Shredders	$\frac{Sh}{n} \times 100$ Where: Sh= Number of Shredders
M9	%Scrapers	$\frac{Sc}{n} \times 100$ Where: Sc= Number of Scrapers
M10	% Predators	$\frac{P}{n} \times 100$ Where: P= Number of Predators
M11	% Collector-filterer (c-f)	$\frac{CF}{n} \times 100$ Where: CF= Number of collector-filterers
M12	Collector-gatherer (c-g)	$\frac{CG}{n} \times 100$ Where: CG= Number of collector-gatherers

Table 2-7-4 Methods for calculating fish community IBI metrics

Metric		**Calculation**
FC1	Total species richness	Number of species recorded
FC2	Number of Disturbance Tolerant Species	Number of disturbance tolerant species recorded
FC3	Number of Disturbance Intolerant Species	Number of disturbance intolerant species recorded

Metric		Calculation
FC4	% Non-native Species	$$\frac{E}{N} \times 100$$ Where: E= Number of non-native fish captured N= Total number of fish captured
FC5	% Coldwater species	$$\frac{W}{N} \times 100$$ Where: W= Number of coldwater fish captured
FC6	% Insectivores	$$\frac{I}{N} \times 100$$ Where: W= Number of insectivores captured
FC7	% Carnivores	$$\frac{C}{N} \times 100$$ Where: W= Number of carnivores captured
FC8	% Omnivores/Detrivores	$$\frac{O + D}{N} \times 100$$ Where: O= Number of omnivores captured D= Number of detrivores captured
FC9	% Specialist Species	$$\frac{S}{N} \times 100$$ Where: S= Number of specialists captured
FC10	% Darter and Sculpin Species	$$\frac{F}{N} \times 100$$ Where: F= Number of darter and sculpin fish
FC11	% Brook Trout	$$\frac{B}{N} \times 100$$ Where: B= Number of brook trout
FC12	Number of fish per 100 electrofish seconds	$$\frac{N}{e}$$ Where: e= Number of electrofish seconds/100
FC13	Number of Brook Trout per100 electrofish seconds	$$\frac{B}{e}$$

Table 2-7-5 Scores for fish community IBI

Metric		IBI Score									
		1	2	3	4	5	6	7	8	9	10
FC1	Total species richness	<1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	>9
FC2	Number of Disturbance Tolerant Species	>5	4-5	3.5-4	3-3.5	2-3	1.5-2	1-1.5	0.5-1	0.1-0.5	<0.1
FC3	Number of Disturbance Intolerant Species	0	0-0.3	0.3-0.5	0.5-0.6	0.6-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	>3.0
FC4	% Non-native Species	>20	15-20	10-15	7-10	5-7	1.5-5	1.0-1.5	0.1-1.0	0-0.5	0
FC5	% Coldwater species	<20	20-40	40-45	45-50	50-55	55-60	60-70	70-80	80-95	>95
FC6	% Insectivores	<20	20-30	30-40	40-50	50-60	60-65	65-75	75-85	85-95	>95
FC7	% Carnivores	<0.3	0.3-0.5	0.5-5.0	5-15	15-25	25-40	40-50	50-65	65-80	>80
FC8	% Omnivores/ Detrivores	>30	25-30	20-25	15-20	12-15	9-12	6-9	3-6	0.1-3	0
FC9	% Specialist Species	<50	50-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	>95
FC10	% Darter and Sculpin Species	<5	5-7	7-10	10-15	15-20	20-25	25-36	35-45	45-55	>55
FC11	% Brook Trout	<5	5-10	10-15	15-20	20-35	35-50	50-60	60-70	70-95	>95
FC12	Number of Fish Per 100 electrofish seconds	<0.2	0.2-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-3.0	3.0-4.0	4.0-6.5	6.5-8.0	>8.0
FC13	Number of Brook Trout per 100 electrofish seconds	<0.1	0.1-0.3	0.3-0.4	0.4-0.5	0.5-0.6	0.6-0.7	0.7-0.9	0.9-1.5	1.5-2.0	>2.0

2.7.4 Results

The following sections discuss the results of the aquatic ecology monitoring program over the pre-development and during-development monitoring program.

2.7.4.1 Benthic Macroinvertebrates

Tables 2-7-6 and 2-7-7 present the results of the pre-development (2006-2014) and during-development (2015-2018) phases. The results for each metric are presented as an average over each phase.

Table 2-7-6 Pre-development Benthic Macroinvertebrates

	2414045	2414046	2414047	2414001	2414044	B1	B2a	B2b	B3	B4	B5	B6	B7
M1	6.0	5.8	3.9	4.6	5.9	5.4	6.2	7.1	4.5	5.7	5.3	5.0	6.2
M2	2.5	2.1	3.1	3.4	2.5	3.2	2.3	1.9	2.3	2.9	3.1	3.0	2.6
M3	45.0	79.0	96.8	127.6	57.8	52.5	35.7	31.0	31.7	43.2	48.3	44.7	39.3
M4	0.0	0.0	0.0	0.0	0.0	2.0	3.0	0.4	0.1	0.8	0.3	0.1	0.1
M5	84.4	61.7	21.4	33.8	79.1	57.2	52.6	65.4	59.8	71.4	63.3	50.0	60.9
M6	4.3	14.7	46.5	38.4	7.0	14.1	15.4	4.8	17.8	13.5	19.1	21.5	19.6
M7	11.7	26.3	44.3	58.3	11.5	8.3	3.0	2.0	3.3	6.2	7.5	8.7	4.2
M8	2.2	0.8	18.2	10.0	1.5	12.4	1.8	1.3	22.4	13.4	17.4	15.5	14.6
M9	0.3	3.8	19.3	10.7	1.0	2.7	2.5	0.8	0.4	2.5	0.5	1.3	1.1
M10	16.9	8.8	6.0	13.9	17.6	24.8	17.3	11.6	16.4	20.9	32.9	35.7	43.6
M11	5.0	4.0	20.6	7.0	1.2	13.0	19.9	19.1	2.0	7.4	7.7	9.2	2.3
M12	73.4	81.2	27.5	50.1	77.4	41.8	51.1	61.2	56.2	50.2	38.0	34.3	34.6

Table 2-7-7 During-development Benthic Macroinvertebrates

	2414045	2414047	2414044	B1	B2a	B2b	B3	B4	B5	B6	B7
M1	6.0	5.3	6.3	5.7	6.9	7.3	4.7	5.9	5.5	5.3	5.8
M2	1.3	2.9	2.0	3.0	2.3	1.7	2.8	2.8	3.0	3.0	2.9
M3	12.0	46.0	22.0	47.8	32.5	24.0	36.5	45.0	45.5	43.8	41.5
M4	0.0	0.0	0.0	0.7	3.2	0.2	0.2	0.2	0.1	0.2	2.2
M5	96.5	46.7	70.8	62.7	78.4	70.6	45.5	70.7	76.8	67.0	72.4
M6	0.9	21.2	0.9	5.3	0.9	0.5	15.0	2.5	5.3	4.3	3.8
M7	3.0	17.5	3.0	6.5	2.0	0.8	3.0	3.5	6.8	5.0	3.3
M8	0.0	12.9	0.0	6.1	0.8	0.8	22.2	8.2	15.5	7.2	4.2
M9	0.3	16.2	0.0	5.4	7.1	0.5	0.4	0.4	0.6	0.6	0.6
M10	0.9	8.0	1.2	20.3	13.1	9.9	28.1	21.9	24.3	35.5	34.6
M11	0.0	2.6	0.0	14.4	12.4	21.3	4.0	4.3	5.3	7.1	3.3
M12	98.0	58.4	91.0	52.5	65.0	67.1	44.4	55.6	50.7	44.2	55.9

B7 – Upstream Reidel Drive

Station B7 is located upstream of the study area and is used as a control site. The average taxa richness during-development was 41.5, which was an increase from the pre-development phase. An average of 2.2 percent of Oligochaeta were sampled at this site during-development and was a small decrease from the pre-development stage. The average percent Chironomidae during-development was 72.4 percent, which is an increase from the pre-development phase. An average of 3.3 EPT taxa, representing 3.8 percent of the sample were recorded during the development phase. The average SW value during-development was 2.9, a small increase from the pre-development phase. The average Hilsenhoff biotic index scored 5.8 (Fair), indicating fairly significant organic pollution and is a slight decrease in pollution over the pre-development phase. On average, this station is comprised of mostly collector-gatherers (55.9 percent) followed by predators (35.6 percent), shredders (4.2 percent), collector-filters (3.3 percent), and scrapers (0.6 percent), which is a proportional shift from the pre-development phase.

B6 – Downstream Reidel Drive

Station B6 is located downstream of Reidel Drive Road. The average taxa richness during-development was 43.8, which was an increase from the pre-development phase. An average of 0.2 percent of Oligochaeta were sampled at this site during-development and was a small decrease from the pre-development stage. The average percent Chironomidae during-development was 67.0 percent, which was a decrease from the pre-development phase. An average of 5.0 EPT taxa, representing 4.3 percent of the sample were recorded during the development phase. The average SW value during-development was 3.0, a negligible decrease from the pre-development phase. The average Hilsenhoff biotic index scored 5.3 (Good), indicating some organic pollution and is a slight increase in pollution over the pre-development phase. On average, this station is comprised of mostly collector-gatherers (44.24 percent) followed by predators (35.5 percent), shredders (7.2 percent), collector-filters (7.1 percent), and scrapers (0.6 percent).

B5 – Mid-Site

Station B5 is located midway between Reidel Drive Road and Groh Drive. The average taxa richness during-development was 45.5, which was an increase from the pre-development phase. An average of 0.01 percent of Oligochaeta were sampled at this site during-development and was a small decrease from the pre-development stage. The average percent Chironomidae during-development was 76.8 percent, which was a decrease from the pre-development phase. An average of 6.8 EPT taxa, representing 5.3 percent of the sample were recorded during the development phase. The average SW value during-development was 3.0, a negligible decrease from the pre-development phase. The average Hilsenhoff biotic index scored 5.5 (Fair), indicating fairly significant organic pollution and is a slight increase in pollution over the pre-development phase. On average, this station is comprised of mostly collector-gatherers (50.7 percent) followed by predators (24.3 percent), shredders (15.5 percent), collector-filters (2.3 percent), and scrapers (0.6 percent).

B4 – Upstream Groh Drive

Station 4 is located midway upstream of Groh Drive. The average taxa richness during-development was 45, which was an increase from the pre-development phase. An average of 0.2 percent of Oligochaeta were sampled at this site during-development and was a small decrease from the pre-development stage. The average percent Chironomidae during-development was 70.7 percent, which was a decrease from the pre-development phase. An average of 3.5 EPT taxa, representing 2.5 percent of the sample were recorded during the development phase. The average SW value during-development was 2.8, a negligible decrease from the pre-development phase. The average Hilsenhoff biotic index scored 5.9 (Fair), indicating fairly significant organic pollution and is a slight increase in pollution over the pre-development phase. On average, this station is comprised of mostly collector-gatherers (55.6 percent) followed by predators (21.8 percent), shredders (8.17 percent), collector-filters (4.3 percent), and scrapers (0.4 percent).

B3 – Dodge Drive Tributary, Upstream Dodge Drive

Station B3 is located on the Dodge Drive Tributary, approximately 185 m upstream of Dodge Drive. The average taxa richness during-development was 36.5, which was an increase from the pre-development phase. An average of 0.2 percent of Oligochaeta were sampled at this site during-development and was a small increase from the pre-development stage. The average percent Chironomidae during-development was 45.5 percent, which was a decrease from the pre-development phase. An average of 3 EPT taxa, representing 15 percent of the sample were recorded during the development phase. The average SW value during-development was 2.8, an increase from the pre-development phase. The average Hilsenhoff biotic index scored 4.6 (Good), indicating some organic pollution and is a slight increase in pollution over the pre-development phase. On average, this station is comprised of mostly collector-gatherers (44.4 percent) followed by predators (21.9 percent), shredders (22.2 percent), collector-filters (4.0 percent), and scrapers (0.4 percent).

B2b – Dodge Drive Tributary Near Confluence

Station B2b is located within the Dodge Drive wetland tributary, immediately upstream of the confluence with Blair Creek. The average taxa richness during-development was 24, which was a small decrease from the pre-development phase. An average of 0.2 percent of Oligochaeta were sampled at this site during-development and was a small decrease from the pre-development stage. The average percent Chironomidae during-development was 70.6 percent, which was an increase from the pre-development phase. An average of 0.8 EPT taxa, representing 0.5 percent of the sample were recorded during the development phase. The average SW value during-development was 1.7, a decrease from the pre-development phase. The average Hilsenhoff biotic index scored 7.3 (Fairly Poor), indicating significant organic pollution and is a slight increase in pollution over the pre-development phase. On average, this station is comprised of mostly collector-gatherers (67.1 percent) followed by collector-filterers (21.3 percent), predators (9.9 percent), shredders (0.8 percent), and scrapers (0.5 percent).

B2a – Downstream Dodge Drive Tributary

Station B2a is located upstream of New Dundee Road, just downstream of the undefined channel of Blair Creek. The average taxa richness during-development was 32.5, which represents a small decrease from the pre-development phase. An average of 3.2 percent of Oligochaeta were sampled at this site during-development which is a small decrease from the pre-development stage. The average percent Chironomidae during-development was 78.4 percent%, which is a large increase from the pre-development phase. An average of 2.0 EPT taxa, representing 0.9 percent of the sample were recorded during the development phase. The average SW value during-development was 2.3 and is equal to the pre-development phase. The average Hilsenhoff biotic index scored 6.9 (Fairly Poor), indicating significant organic pollution and is an increase in pollution over the pre-development phase. On average, this station is comprised of mostly collector-gatherers (65.0 percent) followed by predators (13.1 percent), collector-filterers (12.4 percent), scrapers (7.1 percent) and shredders (0.8 percent).

B1 – Downstream New Dundee Road

Station B1 is located approximately 360 m downstream of New Dundee Road. The average taxa richness during-development was 47.5, which represents a small decrease from the pre-development phase. An average of 0.7 percent of Oligochaeta were sampled at this site during-development which is a small decrease from the pre-development stage. The average percent Chironomidae during-development was 62.7 percent, which is a small increase from the pre-development phase. An average of 6.5 EPT taxa, representing 5.3 percent of the sample were recorded during the development phase. The average SW value during-development was 3.0 and a small decrease from pre-development. The average Hilsenhoff biotic index scored 5.7 (Fair), indicating fairly significant organic pollution and is a small increase in pollution over the pre-development phase. On average, this station is comprised of mostly collector-gatherers (52.5 percent) followed by predators (20.3 percent), collector-filterers (14.4 percent), shredders (6.1 percent) and scrapers (5.4 percent).

2414044 – Downstream Reichert Drive

Station 4044 is located on the main branch of Blair Creek at King Road. The average taxa richness during-development was 22.0, which represents a large decrease from the pre-development phase. No Oligochaeta were sampled at this site during-development or pre-development phases. The average percent Chironomidae during-development was 70.81 percent, which is a large increase from the pre-development phase. An average of 3.0 EPT taxa, representing 0.93 percent of the sample were recorded during the development phase. The average SW value during-development was 1.97 and a decrease from pre-development. The average Hilsenhoff biotic index scored 6.28 (Fair), indicating fairly significant organic pollution and is a large increase in pollution over the pre-development phase. On average, this station is comprised of mostly collector-gatherers (91.0 percent) and predators (1.2 percent).

2414045 – Roseville Tributary Downstream Reichert Drive

Station 4045 is located on Roseville Tributary to Blair Creek, upstream of King Road. The Roseville tributary was selected as a control site as it is the only area deemed not to be affected by development in the foreseeable future. The average taxa richness during-development was 12, which represents a large decrease from the pre-development phase. No Oligochaeta were sampled at this site during-development or pre-development phases. The average percent Chironomidae during-development was 96.5 percent, is an increase from the pre-development phase. An average of 3 EPT taxa, representing 0.87 percent of the sample were recorded during the development phase which is a decrease from the pre-development phase. The average SW value during-development was 1.3 and a decrease from pre-development. The average Hilsenhoff biotic index scored 6.0 (Fair), indicating fairly significant organic pollution. On average, this station is comprised of mostly collector-gatherers (98.0 percent), with very few predators (0.9 percent) and scrapers (0.3 percent).

2414047 – Upstream Highway 401

Station 2414047 is located upstream of Highway 401, the downstream limit of the study area. The average taxa richness during-development was 46.0, which represents a large decrease from the pre-development phase. No Oligochaeta were sampled at this site during-development or pre-development phases. The average percent Chironomidae during-development was 46.7 percent, which is a decrease from the pre-development phase. An average of 17.5 EPT taxa, representing 21.2 percent of the sample were recorded during the development phase. The average SW value during-development was 2.9 and a decrease from pre-development. The average Hilsenhoff biotic index scored 6.3 (Fair), indicating fairly significant organic pollution and is a large increase in pollution over the pre-development phase. On average, this station is comprised of mostly collector-gatherers (58.4 percent), followed by scrapers (16.2 percent), shredders (12.9 percent), predators (8.0 percent) and collector-filters (2.6 percent).

2414001 – Dickie Settlement Road

Station 4001 is located just upstream of Dickie Settlement Road, downstream of the study area. The site was only sampled during the pre-development phase. Average taxa richness was 127.6. No Oligochaeata were captured at this site. The average percent of Chironomidae in the sample was 33.8 percent. An average of 58.3 EPT taxa, accounting for 38.4 percent of organisms were recorded. The average Shannon Wiener (SW) value for the pre-development phase at 2414001 is 3.4. The average Hilsenhoff biotic index scored 4.6 (Good), indicating some organic pollution. On average, collector-gatherers dominated the sample (50.1 percent), followed by predators (13.9 percent) and a nearly equal distribution of shredders (10.0 percent), scrapers (10.7 percent) and collector-filterers (7.0 percent).

2414046 – Mouth of Blair Creek

Station 2414046 is located at the mouth of Blair Creek, downstream of the study area. The site was only sampled during the pre-development phase. The average taxa richness sampled throughout the monitoring program was 79. No Oligochaeata were captured at this site. The average percent of Chironomidae in the sample was 61.7 percent. An average of 26.3 EPT taxa, accounting for 14.7 percent of organisms were recorded. The average SW value for the pre-development phase was is 2.1. The average Hilsenhoff biotic index scored 5.8 (Fair), indicating fairly significant organic pollution. Collector-gatherers dominated the sample (81.2 percent), followed by predators (8.8 percent), collector-filterers (4.0 percent), scrapers (3.8 percent), and shredders (0.8 percent).

2.7.4.2 Fish Community

Few stations have been continuously monitored in both the pre-development and during-development stages. Stations 2414001, 2414002, 2414047, and 2414062 were monitored during the development stage and are discussed below. Tables 2-7-8 and 2-7-9 summarize metrics for all sites.

Table 2-7-8 Pre-development Fish IBI Scores - Upper Blair

	2414001		2414044		2414045		2414046		2414047		2414048		2414058		2414062	
	Metric	IBI	Metric	IBI	Metric	IBI	Metric	IBI	Metric	IBI	Metric	IBI	Metric	IBI	Metric	IBI
FC1	5.7	6.0	9.0	10.0	3.0	4.0	9.0	10.0	5.0	6.0	1.0	2.0	3.0	4.0	2.5	3.0
FC2	1.3	7.0	3.0	4.0	0.0	10.0	3.0	4.0	0.7	8.0	3.0	4.0	1.0	7.0	1.0	7.0
FC3	1.7	7.0	1.0	5.0	1.0	5.0	2.0	7.0	1.7	7.0	1.0	5.0	1.0	5.0	1.0	5.0
FC4	0.0	10.0	0.0	10.0	0.0	10.0	0.6	8.0	0.0	10.0	0.0	10.0	0.0	10.0	0.0	10.0
FC5	70.2	8.0	20.0	2.0	98.9	10.0	64.0	7.0	63.9	7.0	100.0	10.0	29.3	2.0	61.7	7.0
FC6	39.4	3.0	77.1	8.0	56.8	5.0	76.8	8.0	69.6	7.0	0.0	1.0	43.1	4.0	38.3	3.0
FC7	50.7	8.0	2.9	3.0	43.2	7.0	0.5	2.0	30.4	6.0	100.0	10.0	29.3	6.0	61.7	8.0
FC8	9.9	6.0	20.0	3.0	0.0	10.0	22.8	3.0	0.0	10.0	0.0	10.0	27.6	2.0	0.0	10.0
FC9	82.9	7.0	62.9	3.0	100.0	10.0	92.2	9.0	65.8	4.0	100.0	10.0	56.9	2.0	98.9	10.0
FC10	19.5	5.0	17.1	5.0	55.8	10.0	66.6	10.0	34.1	7.0	0.0	1.0	0.0	1.0	37.2	8.0
FC11	49.2	6.0	2.9	1.0	43.2	6.0	0.0	1.0	29.4	5.0	100.0	10.0	29.3	5.0	61.7	8.0
FC12	4.7	8.0	4.3	8.0	2.1	6.0	4.6	8.0	4.3	8.0	0.1	1.0	1.7	5.0	1.4	4.0
FC13	2.1	10.0	0.1	2.0	0.9	8.0	0.0	1.0	1.1	8.0	0.1	2.0	0.5	5.0	0.8	7.0
Average		7.0		4.9		7.8		6.0		7.2		5.8		4.5		6.9

Table 2-7-9 During-development Fish IBI Scores - Upper Blair

	2414001		2414002		2414047		2414062	
	Metric	IBI	Metric	IBI	Metric	IBI	Metric	IBI
FC1	5.3	6.0	4.0	5.0	6.0	7.0	3.4	4.0
FC2	1.0	7.0	1.0	7.0	1.0	7.0	1.2	7.0
FC3	1.9	7.0	1.0	5.0	1.9	7.0	1.4	6.0
FC4	0.0	10.0	27.0	1.0	0.0	10.0	0.0	10.0
FC5	58.4	6.0	48.5	4.0	61.4	7.0	67.9	7.0
FC6	63.5	6.0	51.0	5.0	68.7	7.0	46.7	4.0
FC7	25.7	6.0	48.5	7.0	29.6	6.0	50.2	8.0
FC8	10.7	6.0	1.2	9.0	1.6	9.0	3.1	8.0
FC9	69.3	4.0	61.4	3.0	64.0	3.0	100.0	10.0
FC10	32.7	7.0	0.0	1.0	31.8	7.0	42.5	8.0
FC11	23.6	5.0	48.5	6.0	23.6	5.0	47.9	6.0
FC12	5.0	8.0	4.2	8.0	2.3	6.0	1.7	5.0
FC13	1.1	8.0	1.0	8.0	0.5	5.0	0.8	7.0
Average		6.6		5.3		6.6		6.9

2414062 – Roseville Tributary Upstream Reichert Drive

Station 2414062 is located on the Roseville Tributary, upstream of the confluence. The average number of species captured at this site during-development was 3.4, which was an increase from the pre-development phase. An average of 1.2 species was disturbance tolerant and 1.4 species were disturbance intolerant during the development period, an increase from the similar to the pre-development phase. Non-native species were not recorded during either the pre-development or during-development phases. On average, 67.9 percent of species were coldwater species, an increase from the pre-development phase. Carnivores accounted for an average of

50.2 percent, followed by 46.7 percent insectivores and 3.1 percent omnivores and detrivores, compared to the pre-development phase where carnivores accounted for a higher proportion of species. 100 percent of fish captured were specialist species which was an increase from the pre-development phase. Darters and sculpins accounted for 42.5 percent of species captured, a decrease from the pre-development phase. Meanwhile, Brook Trout accounted for 47.9 percent of fish captured which was an increase from the pre-development phase. 1.7 fish and 0.9 Brook trout were captured per 100 seconds of effort. The overall during-development IBI score was 6.9 (Fair) and was the same as the pre-development phase.

2414047 – Upstream Highway 401

Station 2414047 is located upstream of Highway 401. The average number of species captured at this site during-development was 6.0, which was an increase from the pre-development phase. Most species were moderately tolerant; an average of 1.0 species was disturbance tolerant and 1.9 species were disturbance intolerant during the development period, similar to the pre-development phase. Non-native species were not recorded during either the pre-development or during-development phases. On average, 61.4 percent of species were coldwater species, a small decrease from the pre-development phase. Insectivores accounted for an average of 68.7 percent, followed by 29.6 percent carnivores and 1.6 percent omnivores and detrivores which is similar to the pre-development phase. 64.0 percent of fish captured were specialist species which was a decrease from the pre-development phase. Darters and sculpins accounted for 31.8 percent of species captured, a decrease from the pre-development phase. Meanwhile, brook trout accounted for 23.6 percent of fish captured which was a decrease from the pre-development phase. 2.3 fish and 0.5 Brook trout were captured per 100 seconds of effort. The overall during-development IBI score was 6.6 (Fair) and was a decrease from the pre-development phase.

2414001 Dickie Settlement Road

Station 2414001 is located at Dickie Settlement Road. The average number of species captured at this site during-development was 5.3, which was a slight decrease from the pre-development phase. Most species were moderately tolerant; an average of 1.0 species were disturbance tolerant and 1.9 species were disturbance intolerant during the development period, similar to the pre-development phase. Non-native species were not recorded during either the pre-development or during-development phases. On average, 58.4 percent of species were coldwater species, a decrease from the pre-development phase. Insectivores accounted for an average of 63.5 percent, followed by 25.7 percent carnivores and 10.7 percent omnivores and detrivores compared to the pre-development phase where carnivores dominated. 69.3 percent of fish captured were specialist species which was a decrease from the pre-development phase. Darters and sculpins accounted for 32.7 percent of species captured, an increase from the pre-development phase. Meanwhile, brook trout accounted for 23.6 percent of fish captured which was a decrease from the pre-development phase. 5.0 fish and 1.1 Brook trout were captured per 100 seconds of effort. The overall during-development IBI score was 6.6 (Fair) and was a decrease from the pre-development phase.

2414002 – Upstream New Dundee Road

Station 2414002 is located upstream of New Dundee Road and was not sampled during the pre-development phase. The average number of species captured at this site during-development was 4.0. Most species were moderately tolerant; an average of 1.0 species were disturbance tolerant and 1.0 species were disturbance intolerant during the development period. An average of 27 percent of fish captured were non-native species. On average, 48.5 percent of species were coldwater species. Insectivores accounted for an average of 51.0 percent, followed by 48.5 percent carnivores and 1.2 percent omnivores and detrivores. 61.4 percent of fish captured were specialist species. No darters or sculpins were captured at this site during the development phase. Brook Trout accounted for 48.5 percent of fish captured. 2.3 fish and 0.5 Brook trout were captured per 100 seconds of effort. The overall during-development IBI score was 5.3 (Fair).

Figure 2-7-4 shows the boxplots of the Fish Community IBI scores by site and phase for Blair Creek.

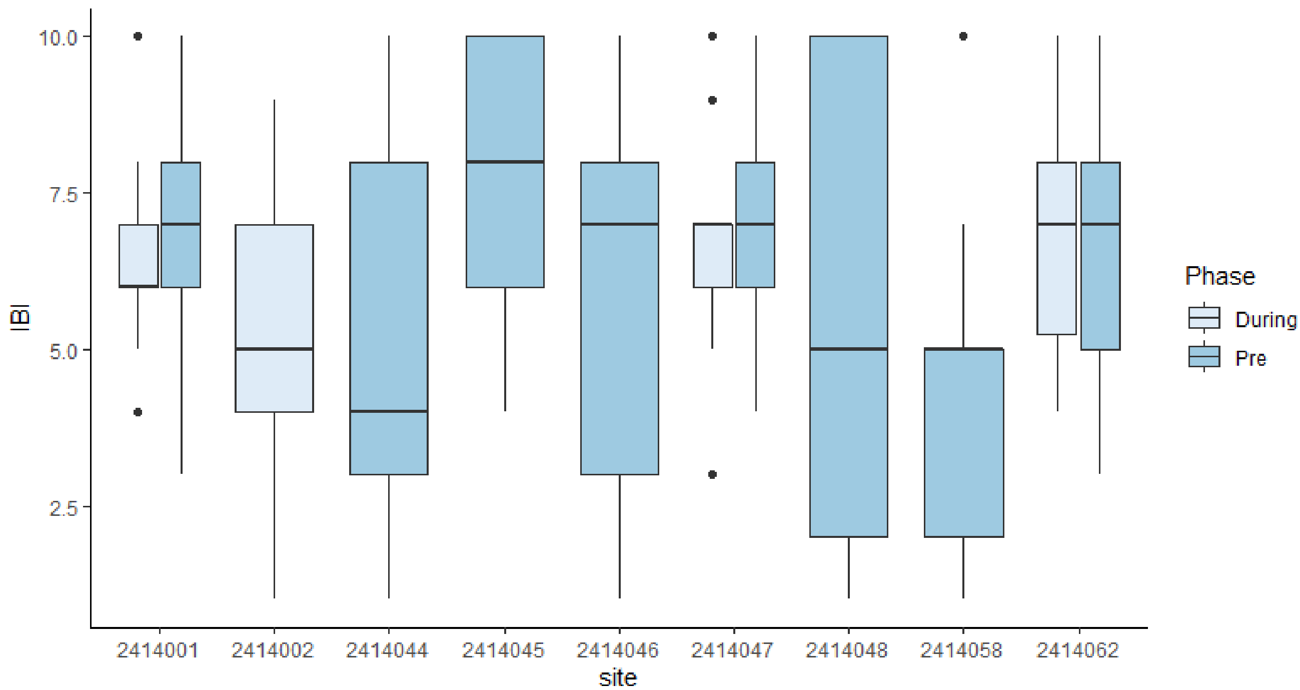


Figure 2-7-4 Boxplots of Fish Community IBI scores by site and phase. Top and bottom of the boxes are respectively the 75th and 25th percentiles, the line is the median, the whiskers represent the maximum and minimum, and the dots represent outliers.

2.7.4.3 Spawning Surveys

Table 2-7-10 below summarizes the results of the spawning surveys over the entire survey period. In summary, no evidence of spawning was observed adjacent to the Stauffer Woods Development during the entire survey period. However, there is evidence that Brook Trout spawn proximal to the Doon South development area as spawning activity has been consistently observed since 2011.

Table 2-7-10 Spawning Survey Results at Stauffer Woods and Doon South across entire study period.

	Stauffer				Doon South			
	Total Redds	Adults on Redds	Adults in Vicinity of Redds	Adults Holding in Pools	Total Redds	Adults on Redds	Adults in Vicinity of Redds	Adults Holding in Pools
2008	1	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0
2010	0	0	0	0	0	0	0	0
2011	0	0	0	0	2	6	0	0
2012	0	0	0	0	3	3	8	0
2013	0	0	0	0	3	0	8	4
2014	0	0	0	0	3	0	16	0

	Stauffer				Doon South			
	Total Redds	Adults on Redds	Adults in Vicinity of Redds	Adults Holding in Pools	Total Redds	Adults on Redds	Adults in Vicinity of Redds	Adults Holding in Pools
2015	0	0	0	0	3	0	22	25
2016	0	0	0	0	5	0	19	19
2017	0	0	0	0	6	0	14	11
2018	0	0	0	0	5	0	13	16

2.7.4.4 Continuous Temperature Monitoring

Figures 2-7-5 through 2-7-12 show the results of continuous temperature monitoring. Results for each site cover the entire study period, however data gaps exist due to logger errors and malfunctions. Brook Trout face heat stress above 20°C during the non-spawning period and above 9°C during spawning (October-November) (Eakins 2012). These thresholds are indicated on each graph during the relevant time of year.

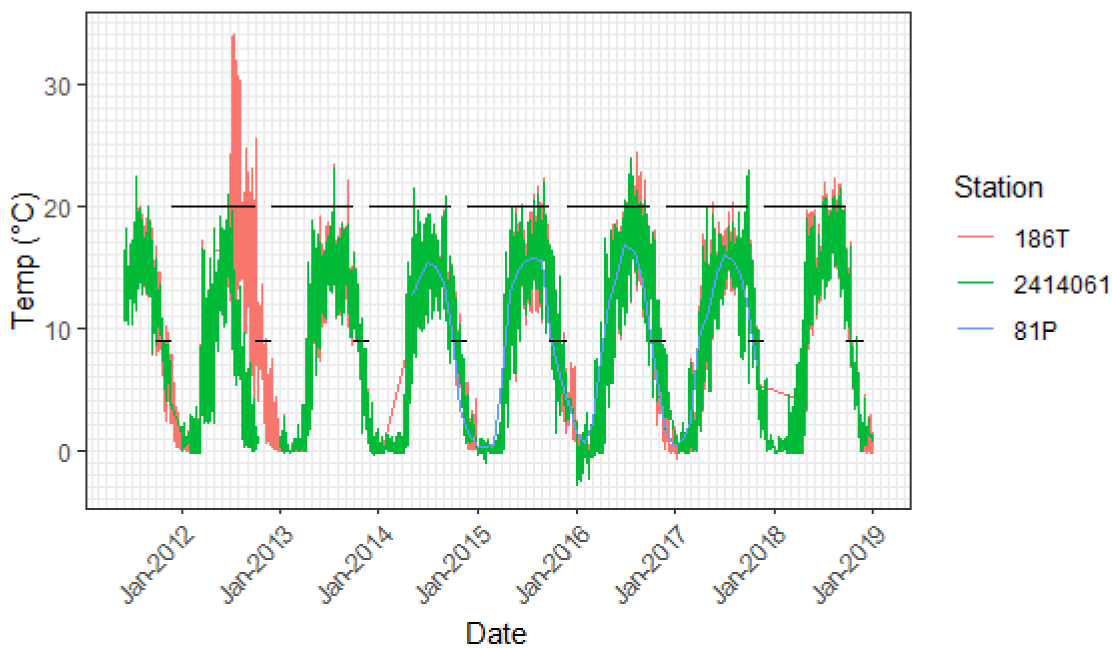


Figure 2-7-5 Continuous temperature monitoring – Reidel Drive

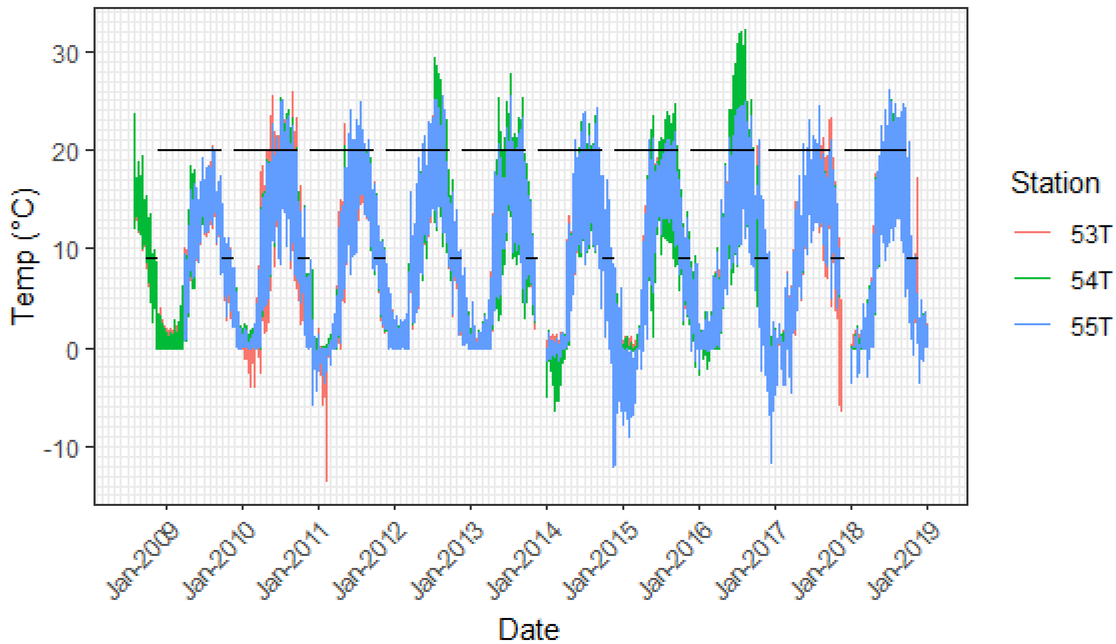


Figure 2-7-6 Continuous temperature monitoring: Mid-site to U/S Doge Drive

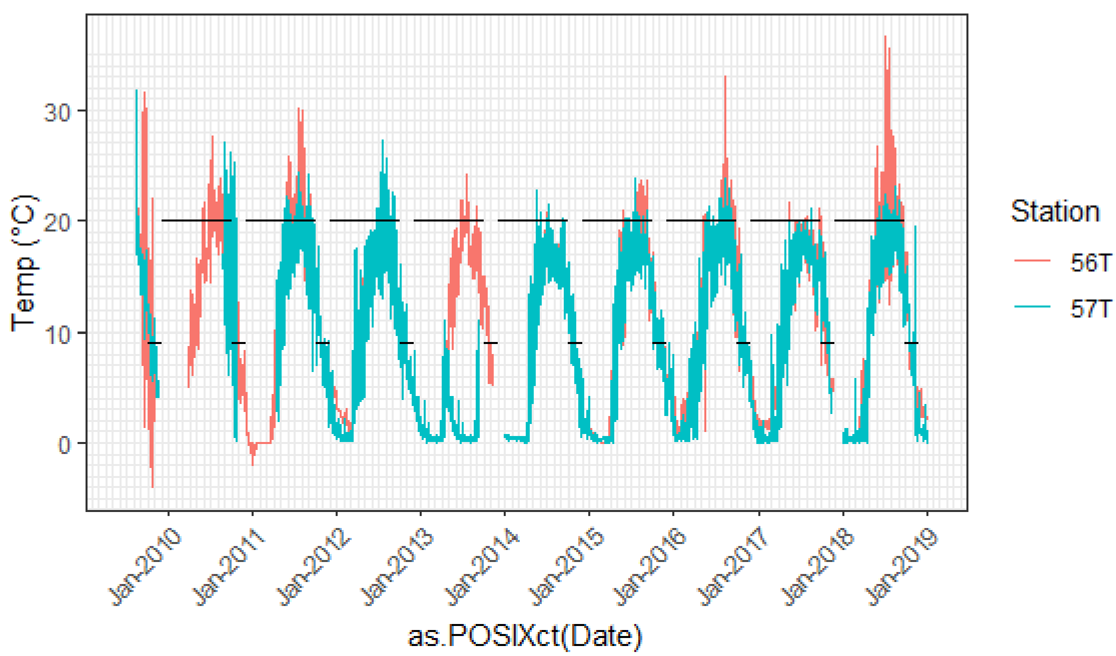


Figure 2-7-7 Continuous temperature monitoring: Tributary to wetland and wetland

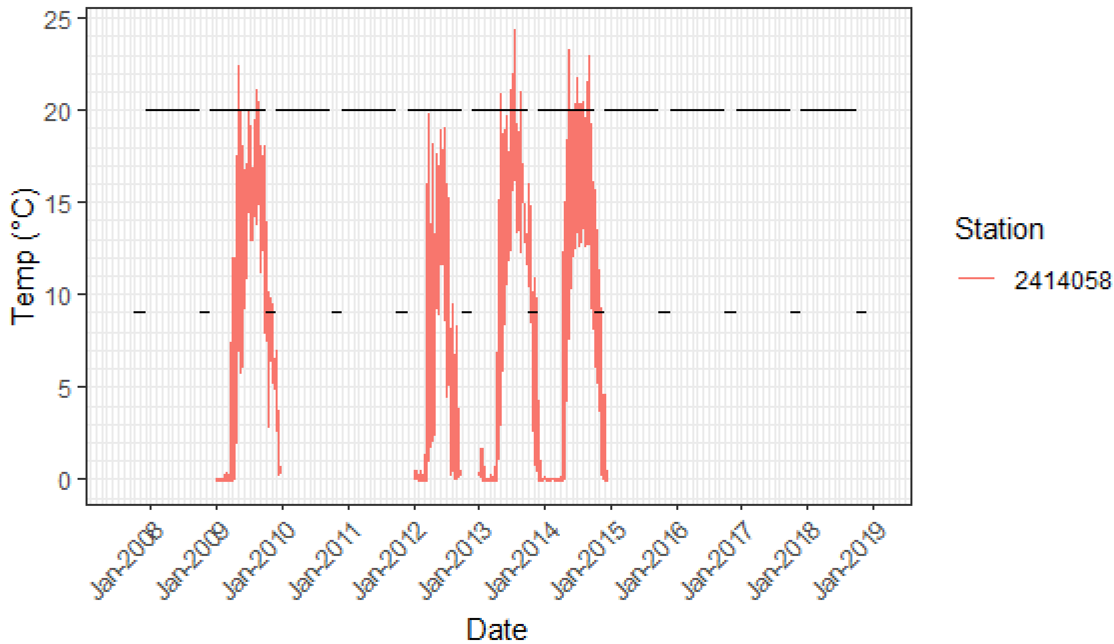


Figure 2-7-8 Continuous temperature monitoring: U/S Dodge Drive tributary

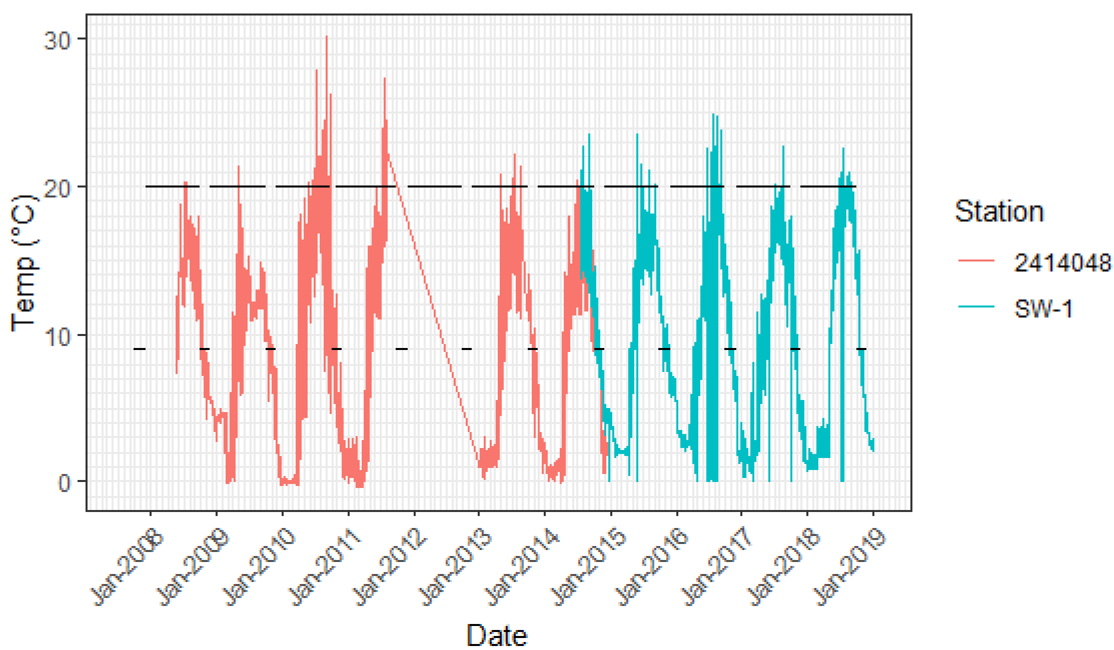


Figure 2-7-9 Continuous temperature monitoring: Dodge Drive Tributary

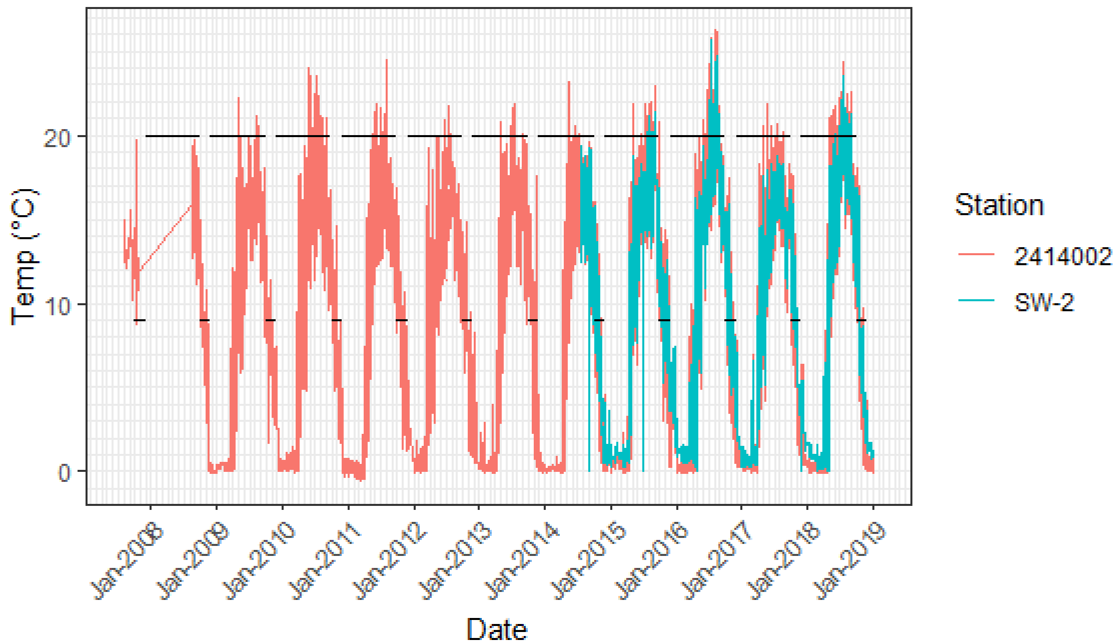


Figure 2-7-10 Continuous temperature monitoring: U/S of New Dundee Road

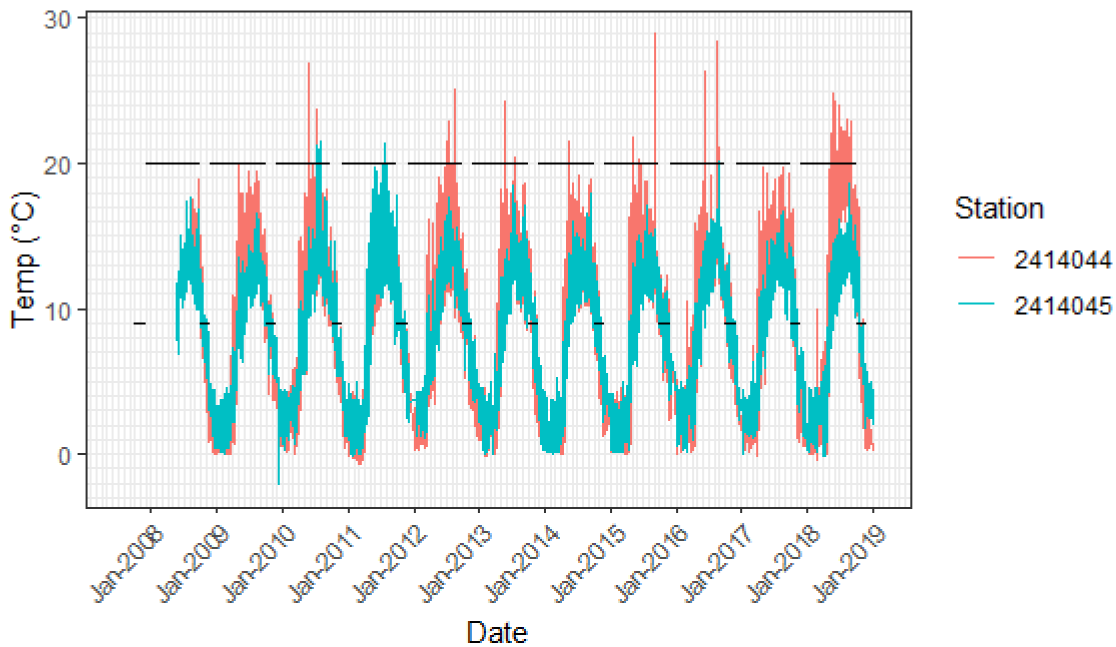


Figure 2-7-11 Continuous temperature monitoring: D/S of Reichert Drive

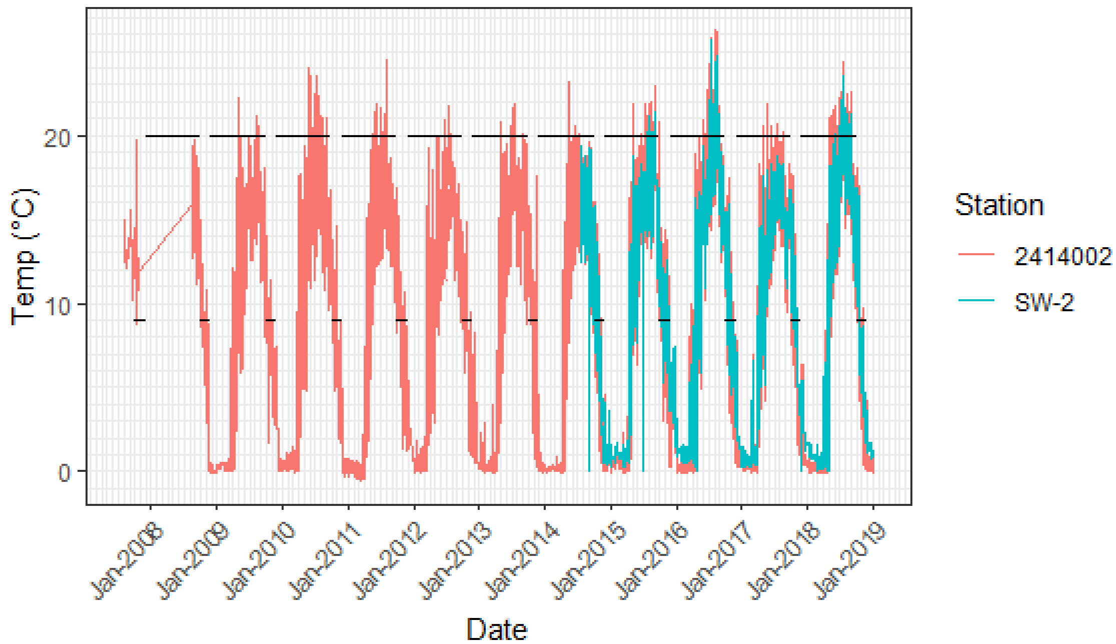


Figure 2-7-12 Continuous temperature monitoring: Highway 401 to mouth of Blair Creek

Table 2-7-11 Average days per year exceeded during the pre- and during- construction period

	Days Over 9°C		Days Over 20°C	
	Pre-development	During-development	Pre-development	During-development
2414001	25.7	--	2.9	--
2414002	23.9	31.8	10.0	40.5
2414044	26.0	27.8	2.4	18.3
2414045	25.7	29.3	0.9	0.3
2414046	27.2	29.5	30.6	33.0
2414047	23.3	--	3.4	--
2414048	19.3	--	19.5	--
2414058	16.5	--	11.0	--
2414061	18.3	28.3	2.3	15.3
186T	25.5	28.5	18.5	22.8
53T	23.7	27.5	17.6	21.8
54T	26.7	25.3	35.3	48.8
55T	22.7	28.0	25.9	46.5
56T	14.4	27.8	28.0	51.8
57T	17.6	32.0	19.0	22.8
SW-1	28.0	32.5	10.0	15.5
SW-2	27.0	29.3	0.0	24.5
Average	23.0	29.0	14.0	27.8

2.7.5 Conclusions

The conclusions of the aquatic ecology monitoring are presented below.

2.7.5.1 Benthic Macroinvertebrates

Comparison of pre-development and during-development results indicate that water quality has slightly decreased across the watershed. Pollution indices increased at all sites with the exception of site B7 which is upstream of the development areas. In general, EPT taxa decreased, and Chironomids increased across all sites while the relative proportions of the feeding groups changed from pre-development to during-development phases. However, changes in metrics are relatively small, and water quality remains fair to good throughout the watershed.

2.7.5.2 Fish Community

Results of the fish community sampling indicate small decreases in the IBI metrics; however, all sites are rated as fair and sustains a fairly healthy coldwater fish community. In total 17 species were captured within the Upper Blair watershed. The majority of species identified are moderately tolerant species. Brook Trout was found at all sites sampled in both the pre- and during-development phases.

2.7.5.3 Spawning Surveys

Few instances of spawning were observed adjacent to Stauffer Woods and Doon South development areas during the pre-construction period. With the exception of a single redd in 2008, there has been no evidence of spawning in the Stauffer Woods development area (i.e. Blair Creek between Reidel Drive and Dodge Drive). However, spawning activities were observed adjacent to the Doon South development consistently throughout the during-development phase and appears to be a reliable area for Brook Trout spawning.

2.7.5.4 Continuous Temperature Monitoring

Results of the continuous temperature monitoring indicate that surface water temperatures are increasing across the watershed. The average number of days during the spawning period exceeding 9C increased from 23 days pre-development to 29 days during-development. Similarly, the number of days exceeding 20C during the non-spawning period increased from 14 days pre-development to 27.8 days during-development. A sustained increase in surface water temperatures may impact the coldwater fish species and decrease the sustainability of the Brook Trout population.

2.7.6 Monitoring Plan Recommendations

Recommendations for future monitoring of aquatic ecology are to continue with the same methods. Few sites have been consistently monitored throughout the entire study period, so future recommendations including reinstating previous monitoring locations, or at minimum ensuring existing monitoring stations remain.

2.8 Stormwater Management Facilities

2.8.1 Context

Pre-construction monitoring for the Hallman Groh South, Stauffer Woods, and Ormston SWM facilities was conducted from 2008 to 2016 to establish existing water temperatures and quality prior to development. These monitoring protocols have been supplemented in the during-construction monitoring programs to better assess SWM facility performance as development proceeds in these subdivisions.

Current SWM facility monitoring practices and results were reviewed in the following reports prepared by MTE Consultants Inc.:

- Hallman Groh South: during-construction monitoring program annual reports from 2015 to 2018
- Stauffer Woods: during-construction monitoring program annual reports from 2015 to 2017
- Ormston: during-construction monitoring program annual reports from 2017 to 2018

Further assessment of facility design appropriateness was based on the stormwater management reports identified below:

- Dodge Drive Ltd. (Plan 30T-07204) Stages 2 and 3 (SCS Consultants, 2016)
- Ormston Residential Subdivision (30T-13203) (MTE, 2016)
- Stauffer Woods Subdivision Phase 2 Stage 1-8 (30T-08203) (MTE, 2014)
- Hallman Groh South Subdivision (MTE, 2013)

2.8.2 Summary of Monitoring

Existing monitoring sites and start dates are summarized in Section 1.7.6. The timeline for temperature monitoring was contingent on construction of the SWMF and installation of monitoring equipment and varied between SWMFs with Hallman Groh South beginning in 2015, Stauffer Woods in 2016, and Ormston in 2018. Temperature monitoring locations include the following:

- Hallman Groh South: forebay, wetland outlet, cooling trench inlet and outlet
- Stauffer Woods: forebay, diversion manhole, cooling trench outlet
- Ormston: forebay, SWM facility outlet, cooling trench inlet and outlet

Water quality was assessed in terms of TSS grab sampling and continuous turbidity monitoring at Hallman Groh South and Stauffer Woods. As of the 2018 during-construction monitoring report, turbidity monitoring had not yet started at Ormston.

Key findings from the during-development monitoring reports are summarized in Table 2-8-1 below.

Table 2-8-1 During-development monitoring report summary

	Metric	Key Findings
Hallman Groh South	Temperature	▪ Forebay ~3-4°C warmer than ambient temperatures ▪ Wetland outlet temperature profile followed forebay trends but was 1-3°C cooler in summer months ▪ Temperatures before and after cooling trench substantially lower than forebay ▪ Cooling trench exhibits good cooling performance thus far
	TSS	▪ Minimal flow from SWM facility produced stagnant flow conditions resulting in artificially high downstream TSS results
	Turbidity	▪ Lack of outflow and improper logger installation produced artificially high turbidity results in 2015 and 2016 ▪ More monitoring data is required to establish turbidity baseline

	Metric	Key Findings
Stauffer Woods	Temperature	▪ Maximum average temperatures at the SWM facility in summer 2017: 20.6°C at the forebay, 22.1°C at the diversion manhole, and 14.4°C at the cooling trench outlet ▪ Decrease in temperature after the cooling trench confirms that it is functioning as designed to cool outlet water from the SWM facility
	TSS	▪ During-construction TSS samples (2015-2017) were consistent with pre-construction values
	Turbidity	▪ High turbidity readings (~1000 NTU) during and after rainfall events
Ormston	Temperature	▪ Forebay temperature decreased after rainfall events in summer 2018 ▪ No SWM facility outlet due to rain events
	TSS	▪ Baseflow and storm TSS sampling in 2018 for the pond south of SWM facility were similar to pre-construction values
	Turbidity	▪ Continuous turbidity monitor was installed at SWM facility outlet (immediately upstream of cooling trench inlet) in 2018. Monitoring to begin 2019.

Notes:

~ = approximately

NTU = nepthelometric turbidity unit

2.8.3 Review of Facility Design

In the design criteria stipulated by the functional drainage study, the maximum average surface water discharge temperature is 20.4°C (for the summer) and the maximum surface water discharge temperature is 21.2°C. These target temperature values have not yet been exceeded at the cooling trench outlets of the SWMFs; however, these results are based on limited drainage and flows through the SWMFs and performance may change as development proceeds further.

Proposed final SWMF storage volumes are summarized in Table 2-8-2 below along with the water quality storage requirements from the MECP. The MECP determines required storage volumes based on the SWMF type to capture differences in removal efficiencies

SWMF design storage volume capacities agree with the requirements of the MECP at the targeted TSS removals and impervious levels. Wet facilities (Hallman Groh South, Ormston, and Stauffer Woods) also meet the 40 cubic metres per hectare (m^3/ha) recommendation for extended detention, with the permanent pool making up the remainder of the storage volume.

Table 2-8-2 SWM facility storage volumes and MECP requirements

SWM Facility	Type	Protection Level	Impervious Level (%)	MECP Required Storage Volume (m^3/ha)[1]	Design Storage Volume (m^3/ha)
Dodge Drive	Dry Pond	Basic (60% TSS Removal)	49.7	134.1	134
Hallman Groh South	Hybrid Wet Pond/ Wetland	Enhanced (80% TSS Removal)	56.4	152.3	152.5
Ormston	Hybrid Wet Pond/ Wetland	Enhanced (80% TSS Removal)	55	150	147.5

SWM Facility	Type	Protection Level	Impervious Level (%)	MECP Required Storage Volume (m^3/ha)[1]	Design Storage Volume (m^3/ha)
Stauffer Woods SWMF1	Wetland	Enhanced (80% TSS Removal)	57.5	107.5	107.5
Stauffer Woods SWMF 2	Wetland	Enhanced (80% TSS Removal)	63.5	113.5	113.5
Stauffer Woods SWMF 3[2]	Hybrid Wet Pond/ Wetland	Enhanced (80% TSS Removal)	54.6	149.2	149

1. Interpolated based on Table 3.2 in MECP guidelines
2. To be constructed in future

Note that the design protection level achieved at Dodge Drive is enhanced (80 percent TSS removal) with the use of an oil/grit separator.

The MECP recommends that post-development peak flows not exceed pre-development values for storms with return periods from 2 to 100 years. Unit release rates for the Hallman Groh South, Ormston, and Stauffer Woods facilities were determined using existing catchment peak flows over a unit area basis. This method is recommended by the MECP as the more accurate approach for determining peak flows. The designed SWM facility peak flow does not exceed calculated peak flows for each catchment area, therefore post-development peak flows are expected to meet the MECP design requirement.

2.8.4 Results

Hallman Groh South SWMF Monitoring

Temperatures in the forebay have been consistently 3-4°C higher than ambient temperatures throughout the during-construction monitoring program (2015 to 2018) due to the low water levels in the forebay and full exposure to sun at this monitoring location. The logger located at the wetland outlet generally followed the forebay trends but was often 1-3°C cooler in the summer months due to its shaded location.

Temperatures logged immediately prior to and after the cooling trench were substantially cooler than surface water measurements in the forebay. Thus far, the cooling trench has performed well during rainfall events. During a 66 mm rainfall event on August 25, 2016, an outlet temperature of 21.2°C from the SWM pond was reached, meeting the criteria for maximum designed surface discharge for a 25 mm storm.

Water quality sampling accuracy has been limited due to the limited flow from the SWMF throughout the during-construction monitoring program. Stagnant flow conditions at the downstream TSS sampling locations has produced artificially high measurements that are not representative of true conditions under flow. In both 2015 and 2016, downstream baseflow and storm TSS samples were comparable during the spring, but stagnant water conditions during the summer and fall produced artificially high TSS measurements. In 2017, significant rainfall from April to May resulted in sediment heavy runoff from the development east of the SWMF preventing the collection of representative samples.

The lack of outflow from the SWMF and improper installation of the logger produced artificially high turbidity readings in 2015 and 2016. Turbidity readings were more stable in 2017, with average monthly readings from 4-13 NTU and spikes during rain events from 110-425 NTU. More monitoring data is required to establish a reliable baseline for turbidity levels and produce more reliable results.

Stauffer Woods SWMF Monitoring

Temperature data from 2016 was not representative of SWMF functionality due to logger malfunction and the lack of drainage from the catchment area into the pond. In 2017, the first SWMF was now receiving run-off but there were no rainfall events that resulted in outlet to Blair Creek from the SWMF.

Maximum average temperatures in 2017 were higher at the diversion manhole (22.1°C) than the forebay (20.6°C) due to the low water flow through the SWMF as the manhole logger was in a smaller volume of water. The decrease in temperature after the cooling trench (14.4°C) confirms that it is functioning as designed to cool outlet water from the SWMF.

During-construction TSS samples (2015-2017) were consistent with pre-construction values, with baseflow TSS lower than 10 mg/L and storm samples ranging from 20-60 mg/L. Turbidity readings were high (~1000 NTU) during and after rainfall events, however this is not an accurate estimate of SWMF outlet quality as flows from the SWMF were not high enough for visible out-letting into Blair Creek.

Ormston SWMF Monitoring

Forebay temperatures decreased after rainfall events throughout the summer of 2018. These effects were likely more pronounced due to a low water volume in the forebay. The SWMF did not outlet water from rain events in 2018 thus cooling trench performance cannot be assessed at this time.

TSS sampling was completed in the pond south of the SWMF and on the main branch of Blair Creek. Baseflow and storm TSS sampling in 2018 were similar to pre-construction values.

2.8.5 Conclusions

Overall, SWMF outlet temperatures are below the specified limits thus far based on the limited flows and rainfall events monitored to date. Further water quality and temperature monitoring is required to establish reliable baselines to accurately assess SWMF performance. Based on the limited information available, it is recommended not allowing the development of contingency lots at this time.

3. Goals, Objectives and Targets

3.1 Process Overview

The City of Kitchener, Region, GRCA, City of Cambridge, and Township of New Dumfries worked collaboratively to develop goals, objective, and targets for Upper Blair Creek. These goals, objectives and targets were first outlined in the 2016 SOW (Aquafor Beech Limited 2016) and have been added to this SOW to compare the current conditions to the pre-development conditions at Upper Blair Creek. Furthermore, this SOW accounts for the methodology of the CEA (GRCA 2009) and therefore, the updated baseline conditions have been incorporated into targets.

The goals, objectives and targets have been drafted and refined since 2006, when the GRCA monitoring program was instated. These goals reflect the maintenance of the status quo of Upper Blair Creek based on data from the years 2006-2013. This has been updated as aforementioned, to include true baseline or pre-development conditions as development started prior to 2013 in some areas of the creek.

The proposed goals, objectives, and targets for the future of Upper Blair Creek can be seen in Section 3.5. The minimum target for all indicators is maintenance of existing conditions.

3.2 Goals

As defined in the 2016 SOW "Environmental goals are broad aims associated with the conservation or restoration of natural features and processes within Upper Blair" (Aquafor Beech Limited 2016). Goals are less specific than objectives and reflect the overall areas of priority and issuess within Upper Blair Creek.

The goals for Upper Blair Creek as per the BBB Study (CH2M Gore & Storrie 1997) are as follows:

1) **"To restore, protect and enhance surface water quality, surface water quantity, and associated aquatic resources and water supplies."**
2) **"To conserve, protect and restore natural land, water, forest, and wildlife resources."**
3) **"To protect, restore and enhance groundwater quantity and quality."**
4) "To minimize the threat to life and the destruction of property and natural resources from flooding and erosion, and preserve natural flood plain hydrologic functions."

As was done in the 2016 SOW (Aquafor Beech Limited 2016) the fourth goal of the BBB study was removed for the pupose of this report. The fourth goal relates to modelling, not monitoring, and hence, is not applicble to the moniotring program of Upper blair Creek. Therefore the goals for the Upper Blair Monitoring program and 2020 SOW are goal one, two and three, which have been bolded above.

3.3 Objectives

"Environmental objectives are qualitative components necessary to meet environmental goals" (Aquafor Beech Limited 2016). Objectives can apply to sub regions in a watershed and or the entirety of the watershed and can be related to technical principles. Objectives were created based on issues and important components of pre-development conditions of Upper Blair Creek.

Thirteen environmental objectives were listed in the 2016 SOW (Aquafor Beech Limited 2016), these all relate to a specific goal and have been listed below underneath their corresponding goals:

1) Restore, protect, and enhance surface water quality, surface water quantity, and associated aquatic resources and water supplies.
   a) Control sediment discharges and provide erosion control during-development.
   b) Maintain, enhance, or restore natural stream processes to achieve a balance of flow and sediment transport, and to maintain/reduce erosion rates post-development.
   c) Maintain, enhance, or restore coldwater fisheries potential in the watercourses.
   d) Maintain existing water quality and contribute to achieving federal, provincial, and municipal water and sediment quality objectives and guidelines within the watercourses.
   e) Preserve and re-establish the natural hydrologic cycle.
   f) Manage wet weather flows to maintain ecohydrology (e.g. stream, riparian, wetland).
2) Protect, restore, and enhance groundwater quantity and quality.
   a) Maintain infiltration, baseflow, and discharge to natural features.
   b) Maintain groundwater levels and baseflows (GW discharge to streams) to sustain watershed functions, human uses, and mitigate climate change.
   c) Maintain groundwater quality to support watershed functions.
3) Conserve, protect and restore natural land, water, forest, and wildlife resources.
   a) Protect, restore, or enhance the integrity of the watershed ecosystem through an integrated approach involving natural areas, habitats, and connected links.
   b) Design and operate stormwater management facilities to maintain a healthy aquatic ecosystem, that supports the existing coldwater fisheries.
   c) Maintain or improve the ecohydrology of wetlands, especially the Roseville Swamp and wetlands within the Endangered Species habitat.
   d) Protect, restore, or enhance native terrestrial and aquatic plant and animal species, community diversity, and productivity.

3.4 Indicators, Parameters and Targets

An indicator is information that describes an attribute or condition of an ecosystem or one of its components. Several indicators have been selected for each environmental objective for Upper Blair Creek.

A parameter must be measurable and either quantitative or qualitative. A parameter is *"a way to measure progress towards achieving the indicator" and multiple may be used for an individual indicator (Aquafor Beech Limited 2016). All parameters must "individually result in meaningful information about the watershed, … collectively provide enough information to assess watershed health, … be available, retrievable and cost effective to collect and, … be able to track changing environmental trends"* (Aquafor Beech Limited 2016).

"Targets are specific aims that will be achieved in the future" (Aquafor Beech Limited 2016). All targets are associated with parameters and are used to evaluate if objectives are being achieved. Targets can be for varying periods of time depending on the response rate of the environment or the level of effort required to achieve them. All targets reflect the baseline conditions of Upper Blair Creek.

In analyzing the individual indicators, the significance in terms of overall stream health can be understood using the weight of evidence approach from the CEA (GRCA 2018). This approach draws on all the monitoring diciplines as lines of evidence to determine if change between pre- and during-developement has occurred. This is a comprehensive understanding of stream health because it takes into account the interconnections between different disciplines and uses evidence from the entirety of the investigation to support individual conclusions.

The tables in Section 3.5 contain the goals, objectives, indicators, parameters, and targets.

3.5 Goals, Objectives and Targets

Tables 3-5-1 through 3-5-13 are cited from the 2016 SOW (Aquafor Beech Limited 2016) with the addition of the existing conditions column, which is used to refer to the sections of this SOW that display the current conditions of Upper Blair relating to a respective indicator.

Goal 1: Restore, protect, and enhance surface water quality, surface water quantity, and associated aquatic resources and water supplies.

Table 3-5-1 Objective 1a: Control sediment discharges and provide erosion control during-development

Indicators	Rationale for Target Setting	Parameters	2016 SOW Conditions (2006-2013) Min-max (mean ± standard deviation)	Existing Conditions (2014-2019)	Maintain Status Quo
Sediment	High levels of suspended solids negatively impact aquatic habitat. Blair Creek at New Dundee Road accepts runoff from a significant portion of developing and proposed development areas.	TSS (mg/L)	Blair Creek at Reidel Drive **Wet:** 1-85 (4.2 ± 19.4) **Dry:** 3-6 (4.6 ± 1.4) Blair Creek upstream of Dodge Drive Tributary **Wet:** ND-18 (2.1 ± 4.0) **Dry:** 2-6 (2.9 ± 3.2) Blair Creek upstream of New Dundee Road **Wet:** 13-35 (4.7 ± 8.3) **Dry:** 3-6 (2.1 ± 2.1) Roseville tributary at Reichert Drive **Wet:** ND-97 (19.2 ± 15.2) **Dry:** 3-10 (3.8 ± 2.5) Blair Creek at Reichert Drive **Wet:** 10-35 (10.1 ± 15.2) **Dry:** 3-10 (2.3 ± 2.5) Blair Creek at Dickie Settlement Road **Wet:** 2-100 (20.8 ± 23.1) **Dry:** 3-10 (3.3 ± 3.8) Blair Creek upstream of the mouth **Wet:** 2-120 (25.8 ± 33.8) **Dry:** 3-10 (3.5 ± 2.8)	See Table 2-3-4 through Table 2-3-10 for the changes in TSS concentrations in Upper Blair Creek between 2014 and 2019	Maintain to pre-construction (2016 SOW) concentrations range for Wet and Dry at all locations

Table 3-5-2 Objective 1b: Maintain, enhance, or restore natural stream processes to achieve a balance of flow and sediment transport, and to maintain/reduce erosion rates post-development (stream stability)

Indicators	Rationale for Target Setting	Parameters	2016 SOW Conditions (2006-2013) (Baseline conditions corrected with CEA methods)	Existing Conditions (During-development)	Maintain Status Quo
Change in stream flow exceedance volume and hours above critical discharge	Stream flows, volumes, and hours above the critical discharge need to be maintained at existing levels to preserve natural levels of erosion and sediment transport.	Flow volume and hours of exceedance above the critical discharge.	Dickie Settlement Road gauge 2-Year Discharge: 2.40 m^3/s Bankfull Discharge: 2.62 m^3/s (Parish, 2009) Critical Discharge: 0.4 m^3/s (Parish, 2009) Average Annual Exceedances over 5 Year Periods Volume of Exceedance: 2.0 gigalitres Time of Exceedance: 700 hours	See Table 2-2-10 for the 2-Year flow See Section 2.5.4.5 for existing conditions	Maintain annual flow volume and hours of exceedance above critical discharge within 15% of existing conditions, assessed over 5-year periods.
Change in bankfull cross sectional area	Cross-section enlargement generally results from an urbanized flow regime.	Bankfull cross sectional area.	Reaches 3 – 4 (XS 1 – 3): 3.0 ± 0.2 m^2 Reach 2 (XS 4 – 6): 2.4 ± 0.3 m^2 North Tributary Reach (XS 7 – 9): 0.8 ± 0.1 m^2 Roseville Trib. Reach (XS 10 – 12): 2.7 ± 0.3 m^2	See Section 2.5.4.1	Maintain bankfull cross-sectional area (m^2) within 30% of existing conditions.

Indicators	Rationale for Target Setting	Parameters	2016 SOW Conditions (2006-2013) (Baseline conditions corrected with CEA methods)	Existing Conditions (During-development)	Maintain Status Quo
Change in bankfull channel depth	Aggradation or degradation can result from an urbanized flow regime.	Average bankfull channel depth.	Reaches 3–4 (XS 1–3): 0.50 ± 0.05 m^2 Reach 2 (XS 4–6): 0.40 ± 0.05 m^2 North Tributary Reach (XS 7–9): 0.35 ± 0.05 m^2 Roseville Trib. Reach (XS 10–12): 0.55 ± 0.05 m^2	See Section 2.5.4.5	Maintain bankfull depth (m) within 30% of existing conditions.
Change in bank migration rate	Accelerated planform adjustment can occur from an urbanized flow regime.	Bank migration rate.	At locations where bank migration is expected (e.g., EP 4, 5, 10, 12, 19) Migration rates are 5–10 cm/year (or 1–2% of bankfull width per year)	See Section 2.5.4.4	Normal migration rates = 10% of bankfull width assessed over a 5-year period at locations where bank migration is expected. (Bank migration is not to be assessed annually, but only every 5 years i.e., 2% x 5 years = 10%).
Change in substrate particle size distribution	Maintaining particle size distribution helps provide stable channels and suitable habitats for different aquatic life stages.	Substrate particle size distribution (D50 and D90).	<u>Gravel Bed</u> — D_{50} (mm) — D_{90} (mm) Reaches 3-4 (XS 2&3): 6 ± 5 — 100 ± 90 Reach 2 (XS 4 and 6): 7 ± 6 — 55 ± 25 <u>Sand Bed*</u> Trib. Reaches (XS 7-12): (0.1-1) — (1-3)	See Section 2.5.4.3 Substrate Particle Size Results	Maintain D50 and D90 particle sizes within plus or minus one order of magnitude compared to existing conditions, assessed at 5-year intervals.
Riparian vegetation communities	Vegetation communities will respond to significant changes in watercourse erosion and bank migration. Riparian areas provide habitat for wildlife.	All Flora metrics for sites V4, V5, Doon V3, and Doon V4.	See tables 2.5.13 and Table 2.5.19 in the 2016 SOW	Refer to Section 2.5.4.2	No significant change in vegetation structure or quality.

* Assessment of target threshold exceedances requires interpretation of site conditions and monitoring trends by a qualified professional geomorphologist. Further data and interpretation are required to refine the existing grain size values for sand bed channels.

Table 3-5-3 Objective 1c Maintain, enhance, or restore coldwater fisheries potential of the watercourses

Indicators	Rationale for Target Setting	Parameters	2016 SOW Conditions (2006-2013)			Existing Conditions (During-development)	Maintain Status Quo
Temperature	Maximum instream temperatures need to be low in order to support cold-water fisheries. Brook Trout are very sensitive to thermal gradients and tend to seek water temperatures below 20˚C. During spawning season (October 1 to November 31) water temperatures below 9˚C are preferred.	Temperature (continuous)	Existing Conditions Water Temperature Exceedances Summary			Refer to Table 2-2-3 (low flow metrics) through Table 2-2-8 for percent of days in each thermal regime and 9˚C exceedances	<u>Previous Approach:</u> Station 4061: Exceed 20° C no more than 5 days per year and exceed 9°C during spawning period no more than 30 days per year. Maintain a cool to coldwater thermal regime. Station 4002: Exceed 20°C no more than 15 days per year and exceed 9°C during spawning period no more than 25 days per year. Maintain a coolwater thermal regime. Station 4044: Exceed 20°C no more than 5 days per year and exceed 9°C during spawning period no more than 25 days per year. Maintain a cool to coldwater thermal regime. <u>Current Approach:</u> For comparison the CEA approach should be used as this accounts for the effect of air temperature on stream temperature. Refer to section 4.5 of the CEA document for the baseline/pre-development conditions for stream temperature. These conditions should be maintained and continually compared to the existing conditions.
			Site	Average Days per year Over 20 ˚C	Average Days Over 9˚C During Spawning Season (Oct 1 to Nov 30)		
			Reidel Drive 2414061	2.7	25.0		
			New Dundee Road 2414002	13.7	23.5		
			Reichert Drive 2414044	1.0	24.8		

Site 55T has been removed from 2016 SOW conditions as this site is no longer monitored

Table 3-5-4 Objective 1d Maintain existing water quality and contribute to achieving federal, provincial, and municipal water and sediment quality objectives and guidelines in watercourse.

Indicators	Rationale for Target Setting	Parameters	2016 SOW Conditions (2006-2013) Min-max (average)	Existing Conditions (During-development)	Maintain Status Quo
Dissolved Oxygen	Dissolved oxygen (DO) saturation levels need to be maintained or increased to support respiration and decomposition in aquatic ecosystems.	DO (mg/L)	<u>Blair Creek at Dickie Settlement Road</u> **Wet:** 7.79-14.01 (10.54) **Dry:** 8.96-13.40 (10.81) <u>Blair Creek at New Dundee Road</u> **Wet:** 1.87-13.17 (7.94) **Dry:** 2.69-11.91 (6.90) <u>Blair Creek at Reichert Drive</u> **Wet:** 5.88-13.95 (8.82) **Dry:** 6.50-11.96 (9.15) <u>Roseville Tributary at Reichert Drive</u> **Wet:** 6.99-13.32 (9.54) **Dry:** 5.04-11.88 (9.67) <u>Blair Creek Downstream of Reidel Drive</u> **Wet:** 5.5-13.33 (8.59) **Dry:** 0.29-13.13 (8.01) <u>Blair Creek Upstream of Dodge Drive Tributary</u> **Wet:** 5.50-13.22 (8.77) **Dry:** 2.54-13.13 (7.61) <u>Mouth of Blair Creek</u> **Wet:** 6.60-15.65 (11.32) **Dry:** 9.13 -14.40 (11.26)	See Table 2-3-4 through Table 2-3-17 for the changes in DO concentrations in Upper Blair Creek between 2014 and 2019.	Maintain to pre-construction concentrations range for Wet and Dry. Note: PWQO recommends DO, for the stream temperature conditions of Upper Blair Creek, not fall below 7.0 mg/L (Province of Ontario, 1994).
Nutrients	Nutrient loading often results in eutrophication of water bodies, which leads to decreased aquatic habitat quality.	Total phosphorus (TP) (mg/L) Nitrate (N) (mg/L)	<u>Blair Creek at Dickie Settlement Road</u> Total Phosphorus: **Wet:** 0.002-0.140 (0.038) **Dry:** 0.004-0.028 (0.009) Nitrate(N): **Wet:** 1.0-4.2 (2.6) **Dry:** 2.5-5.1 (4.1) <u>Blair Creek at New Dundee Road</u> Total Phosphorus: **Wet:** 0.010-0.280 (0.072) **Dry:** 0.007-0.100 (0.046) Nitrate(N): **Wet:** ND-1.1 (0.3) **Dry:** ND-2.7 (0.7) <u>Blair Creek at Reichert Drive</u> Total Phosphorus: **Wet:** 0.009-0.150 (0.049) **Dry:** 0.002-0.042(0.019) Nitrate(N): **Wet:** ND-4.2 (1.1) **Dry:** 0.9 -5.3 (2.3) <u>Roseville Tributary at Reichert Drive</u> Total Phosphorus: **Wet:** ND-0.090 (0.037) **Dry:** 0.003-0.033 (0.008) Nitrate(N): **Wet:** 0.9-5.5 (3.0) **Dry:** 3.0-6.3 (4.9) <u>Blair Creek Downstream of Reidel Drive</u> Total Phosphorus: **Wet:** 0.018-0.200 (0.083) **Dry:** 0.018-0.150 (0.054) Nitrate(N): **Wet:** ND-2.0 (0.7) **Dry:** 0.8-4.0 (1.7) <u>Blair Creek Upstream of Dodge Drive Tributary</u> Total Phosphorus: **Wet:** 0.003-0.300 (0.060) **Dry:** 0.006-0.170 (0.054) Nitrate(N): **Wet:** ND-0.8 (0.2) **Dry:** ND-2.2 (0.2) <u>Mouth of Blair Creek</u> Total Phosphorus: **Wet:** ND-0.160 (0.046) **Dry:** 0.003-0.033 (0.009) Nitrate(N): **Wet:** 1.1-3.7 (2.2) **Dry:** 2.1-4.3 (3.4)	See Table 2-3-4 through Table 2-3-17 for the changes in TP and N concentrations in Upper Blair Creek between 2014 and 2019.	Total Phosphorus & Nitrate(N): Maintain to pre-construction concentration range for Wet and Dry Note: PWQO recommends TP concentrations below 0.03 mg/L (Province of Ontario, 1994), and Grand River management Plan recommends N concentrations below 3.0 mg/L (GRCA, 2014).

Indicators	Rationale for Target Setting	Parameters	2016 SOW Conditions (2006-2013) Min-max (average)	Existing Conditions (During-development)	Maintain Status Quo
Chlorides	Chlorides are surrogate indicators of urbanization (e.g. sewage, road salt), and can negatively affect aquatic and terrestrial wildlife.	Chloride (mg/L)	Blair Creek at Dickie Settlement Road **Wet:** 25-46 (35.8) **Dry:** 33-46 (40.9) Blair Creek at New Dundee Road **Wet:** 19 -95 (38.2) **Dry:** 28-65 (41.7) Blair Creek at Reichert Drive **Wet:** 22-61 (40.3) **Dry:** 32-54 (41.3) Roseville Tributary at Reichert Drive **Wet:** 17-33 (25.9) **Dry:** 23-45 (32.4) Blair Creek Downstream of Reidel Drive **Wet:** 4 -31 (15.5) **Dry:** 4-16 (11.0) Blair Creek Upstream of Dodge Drive Tributary **Wet:** 19-95 (37.2) **Dry:** 28-47 (38.9) Mouth of Blair Creek **Wet:** 32-86 (47.0) **Dry:** 40-110 (47.0)	See Table 2-3-4 through Table 2-3-17 for the changes in chloride concentrations in Upper Blair Creek between 2014 and 2019.	Chlorides: Maintain to pre-construction concentration range for Wet and Dry. Note: PWQO for chloride is 120 mg/L long-term exposure limit for freshwater species (Province of Ontario, 1994).
Inorganic Compounds	The presence and accumulation of metals can lead to acute and lethal toxicity in aquatic organisms.	Copper (mg/L) Zinc (mg/L)	Blair Creek at Dickie Settlement Road Total Copper: **Wet:** ND-3 (1.1) **Dry:** ND-3.3 (0.6) Total Zinc: **Wet:** ND-27 (7.2) **Dry:** ND-14 (2.7) Blair Creek at New Dundee Road Total Copper: **Wet:** ND-3.4 (1.0) **Dry:** ND-1 (0.5) Total Zinc: **Wet:** ND-12 (4.8) **Dry:** ND-12 (3.6) Blair Creek at Reichert Drive Total Copper: **Wet:** ND-2 (0.9) **Dry:** ND-2.5 (1.2) Total Zinc: **Wet:** ND-16 (5.9) **Dry:** ND-34 (4.1) Roseville Tributary at Reichert Drive Total Copper: **Wet:** ND-3 (1.0) **Dry:** ND-22 (1.2) Total Zinc: **Wet:** ND-19 (6.5) **Dry:** ND-69 (7.3) Blair Creek Downstream of Reidel Drive Total Copper: **Wet:** ND-6.2 (1.6) **Dry:** ND-4.8 (1.0) Total Zinc: **Wet:** ND-22 (5.5) **Dry:** ND-15 (3.8) Blair Creek Upstream of Dodge Drive Tributary Total Copper: **Wet:** ND-3.6 (0.9) **Dry:** ND-4.8 (0.9) Total Zinc: **Wet:** ND-9 (3.0) **Dry:** ND-9 (2.7) Mouth of Blair Creek Total Copper: **Wet:** ND-4.4 (1.6) **Dry:** ND-2.5 (0.6) Total Zinc: **Wet:** ND-30 (8.4) **Dry:** ND-75 (6.7)	See Table 2-3-4 through Table 2-3-17 for the changes in copper and zinc concentrations in Upper Blair Creek between 2014 and 2019.	Copper and Zinc: Maintain to pre-construction concentration range for Wet and Dry For copper 5 ug/L is the long-term exposure limit for freshwater species and zinc is 20 ug/L. Both limits are PWQO (Province of Ontario, 1994).

Table 3-5-5 Objective 1e: Preserve and re-establish the natural hydrologic cycle

Indicators	Rationale for Target Setting	Parameters	Pre-development Conditions (Baseline conditions corrected with CEA methods) Dickie Settlement Road	Pre-development Conditions (Baseline conditions corrected with CEA methods) New Dundee Road	Existing Conditions (During-development)	Maintain Status Quo
Watershed peakiness (Flow rate)	Peakiness factor needs to be maintained to more natural (historic) levels to reduce erosive stresses on aquatic habitats.	Peakiness factor (Q2/Qbaseflow)	Q2 = 2.40 m^3/s Qbaseflow = 0.139 m^3/s Peakiness Factor = 17.3	Q2 = 0.386 m^3/s Qbaseflow = 0.002318 m^3/s Peakiness Factor = 167	See Table 2-2-13 and Table 2-2-14	Maintain pre-construction levels (existing conditions) at Dickie Settlement Road and New Dundee Road
Annual Water Balance (Hydrologic regime)	Pre-development unit area runoff volumes need to be maintained to sustain natural processes, including streamflow continuity, habitat requirements, and channel processes.	Annual runoff volume/area Baseflow	Median flow (direct + baseflow) = 389.6 mm/year Baseflow = 257.9 mm/year (Assumption drainage area = 17 km2)	Median flow (direct + baseflow) = 63.1 mm/year Baseflow = 12.2 mm/year (Assumption drainage area = 6 km2)	See Table 2-2-13 and Table 2-2-14	Maintain pre-construction levels (existing conditions) at Dickie Settlement Road and New Dundee Road
Groundwater functions (surface-groundwater interaction)	Groundwater infiltration needed to maintain runoff volume at current level and increase stream baseflows.	Ratio of baseflow to mean annual flow	Qbaseflow / MAF = 0.491	Qbaseflow / MAF = 0.101	See Table 2-2-13 and Table 2-2-14	Maintain pre-construction Qbaseflow / MAF ratio Per Objective 2b Groundwater Discharge and Recharge - Maintain existing Net Storage of 407 mm/year at New Dundee Road and 57 mm/year at Dickie Settlement Road

Table 3-5-6 Objective 1f: Manage wet weather flows to maintain ecohydrology (e.g. stream, riparian, wetland)

Indicators	Rationale for Target Setting	Parameters	Pre-development Conditions (Baseline conditions corrected with CEA methods) Dickie Settlement Road	Pre-development Conditions (Baseline conditions corrected with CEA methods) New Dundee Road	Existing Conditions (During-development)	Maintain Status Quo
In-channel high flows	Maintenance of habitat in floodplains.	Change in frequency of peak flows beyond bankfull flow (Q25/Qbaseflow)	Q25 = 7.16 m^3/s Qbaseflow = 0.139 m^3/s Q25/Qbaseflow = 51.5	Q25 = 0.825 m^3/s Qbaseflow = 0.002318 m^3/s Q25/Qbaseflow = 355.9	See Table 2-2-13 and Table 2-2-14	Maintain pre-construction levels (existing conditions) at Dickie Settlement Road and New Dundee Road
In-channel flushing flows	Maintenance of habitat in channel.	See all under Objective 1b.	2-year flow (generally cited as channel maintenance flow) = 2.40 m^3/s	2-year flow (generally cited as channel maintenance flow) = 0.386 m^3/s	See Table 2-2-13 and Table 2-2-14	Maintain pre-construction levels (existing conditions) at Dickie Settlement Road and New Dundee Road

Goal 2: Protect, restore, and enhance groundwater quantity and quality

Table 3-5-7 Objective 2a: Maintain infiltration, baseflow, and discharge to natural features

Indicators	Rationale for Target Setting	Parameters	2016 SOW Conditions (2006-2013)	Existing Conditions (During-development)	Maintain Status Quo
Groundwater levels	Groundwater levels are critical to maintaining wetland hydrology (hydroperiod).	Groundwater levels in portions of Roseville Swamp within the study area vs. downstream of study area	Insufficient groundwater discharge data to establish existing conditions for discharge into wetlands. Insufficient groundwater level data to establish existing conditions for average water table elevation.	See Figures 2-4-9 to 2-4-11 and Table 2-4-2	No target proposed Utilize proposed monitoring program to establish groundwater discharge regime into wetland. Utilize proposed monitoring program to establish long-term groundwater level regime.

Table 3-5-8 Objective 2b: Maintain groundwater levels and baseflows (GW discharge to streams) to sustain watershed functions, human uses, and mitigate climate change

Indicators	Rationale for Target Setting	Parameters	2016 SOW Conditions (2006-2013) (Baseline conditions corrected with CEA methods)	Existing Conditions (During-development)	Maintain Status Quo
Baseflows in streams	Baseflow sustains flow in streams in the low flow season and provides habitat for fisheries and the benthic zone.	Baseflow (mm/yr) Ratio of baseflow (mm/yr) to Mean Annual Flow (existing groundwater discharge) See Objective 1e	Baseflow = 12.2 mm/year at New Dundee Road and 260 mm/year at Dickie Settlement Road.	See Table 2-2-15 and Table 2-2-16	Maintain existing annual baseflow at New Dundee Road and Dickie Settlement Road
Groundwater Discharge and Recharge	Surface groundwater interaction. Hydrological connection with wetlands. Sustaining wetland habitat and biodiversity. Replenishing groundwater.	Existing groundwater discharge into wetlands Net Storage (deep groundwater recharge + depression storage)	Insufficient groundwater discharge data to establish existing conditions for discharge into wetlands Net Storage = 407.9 mm/year at New Dundee Road and 56.8 mm/year at Dickie Settlement Road	See Table 2-2-15 and Table 2-2-16	Net Storage = 407.9 mm/year at New Dundee Road and 56.8 mm/year at Dickie Settlement Road
Water Table Elevation	Access to groundwater sources	Average Water Table Elevation	Insufficient groundwater level data to establish existing conditions for average water table elevation.		No target proposed Utilize proposed monitoring program to establish long-term groundwater level regime

Table 3-5-9 Objective 2c: Maintain groundwater quality to support watershed functions

Indicators	Rationale for Target Setting	Parameters	2016 SOW Conditions (2006-2013)	Existing Conditions (During-development)	Maintain Status Quo
Nutrients	Nutrient loading often results in eutrophication of water bodies, which in turn leads to decreased aquatic habitat quality. Nutrient inputs can originate from both surface runoff and contaminated groundwater discharge.	Total Ammonia-N Nitrate Nitrate + Nitrite.	Most of the inorganic compound concentrations are below the Maximum Acceptable Concentration (MAC) according to the ODWS requirements. There are nine (9) boreholes where concentrations exceed the MAC for Nitrate-Nitrite (mg/L) and ten (10) boreholes where concentrations exceed the MAC for Nitrate (mg/L). Regarding Ammonia concentrations, there are no ODWS requirements that can be cited. Refer to Table 2.3.4.1 in the 2016 SOW	Refer to Section 2.4.7	Maintain to pre-construction concentrations.
Chlorides	Chlorides from infiltrating runoff can negatively impact groundwater.	Dissolved chlorides	All the samples collected are below the Maximum Acceptable Concentration (MAC) according to the ODWS requirements, which is 250 mg/L. One borehole (BH2018) located to the east of the study area has high Chloride concentrations (mean concentration = 419 mg/L). Refer to Table 2.3.4.4 in the 2016 SOW	Refer to Section 2.4.7	Maintain to pre-construction concentrations.
Inorganic Compounds	Metals in groundwater have impacts on receiving waters through groundwater discharge. Significant metals are in listed in the parameters column. Other metals are generally not significant for overall water quality.	Dissolved Calcium (Ca) Dissolved Copper (Cu) Dissolved Lead (Pb) Dissolved Magnesium (Mg) Dissolved Zinc (Zn)	Most of the nutrients concentrations are below the Maximum Acceptable Concentration (MAC) according to the ODWS requirements. Specifically, Lead, Copper, and Zinc (μg/L), where there are certain ODWS requirements, are below he Maximum Acceptable Concentration (MAC), except for Lead concentrations at three (3) of the investigated boreholes. Refer to Table 2.3.4.2 in the 2016 SOW	Refer to Section 2.4.7	Maintain to pre-construction concentrations.
pH	Deviations outside accepted range (6.5- 8.5) may negatively affect aquatic vegetation and can mobilize retained metals in the soil matrix.	pH	All the samples collected are within the ODWS range (6.5-8.5). Refer to Table 2.3.4.3. in the 2016 SOW	Refer to Section 2.4.7	Maintain pre-development levels (No exceedances in pre-construction conditions)

Goal 3: Conserve, protect, and restore natural land, water, forest, and wildlife resources.

Table 3-5-10 Objective 3a: Protect, restore, or enhance the integrity of the watershed ecosystem through an integrated approach of natural areas, habitats, and connected links

<table>
<tr><th>Indicators</th><th>Rationale for Target Setting</th><th>Parameters</th><th>2016 SOW Conditions (2006-2013)</th><th>Existing Conditions (During-development)</th><th>Maintain Status Quo</th></tr>
<tr><td>Riparian corridors</td><td>Increasing the proportion of riparian corridors covered by wetlands and forests helps restore the natural hydrologic cycle (water quantity) and improves quality of ground and surface waters. Aquatic microhabitat is an important component of the habitat of fish and benthic zone and is usually the first morphological component of a watercourse to respond to change. Terrestrial species also use riparian corridors for movement and habitat needs.</td><td>Structural quality of riparian vegetation
Aquatic microhabitat</td><td>Vegetation monitoring sites in riparian areas include sites V4, V5, Doon V2, Doon V3, and Doon V4. Metrics F7, F10 and F11
are indicators for, among other things, structural integrity. Corresponding average values are as follows:
<u>V4</u>
F7: 26.28%; F10: 6.82%; F11: 4.55%
<u>V5</u>
F7: 17.61%; F10: 12.82%; F11: 2.56%
<u>Doon V2</u>
F7: 17.74%; F10: 10.20%; F11: 8.16%
<u>Doon V3</u>
F7: 25.06%; F10: 9.52%; F11: 4.76%
<u>Doon 4</u>
F7: 21.88%; F10: 33.33%; F11: 13.33%
Benthic indices relating to functional feeding groups can indicate changes in aquatic microhabitat:
<table>
<tr><th></th><th>B3</th><th>B2b</th><th>B2a</th><th>B1</th><th>4044</th><th>4045</th><th>4047</th></tr>
<tr><td>% Shr</td><td>27</td><td>2</td><td>3</td><td>10</td><td>2</td><td>1</td><td>19</td></tr>
<tr><td>% Scr</td><td>0</td><td>1</td><td>2</td><td>2</td><td>0</td><td>2</td><td>16</td></tr>
<tr><td>% Prd</td><td>10</td><td>21</td><td>30</td><td>14</td><td>47</td><td>10</td><td>13</td></tr>
<tr><td>% C-f</td><td>4</td><td>24</td><td>29</td><td>10</td><td>4</td><td>18</td><td>10</td></tr>
<tr><td>% C-g</td><td>60</td><td>53</td><td>37</td><td>41</td><td>46</td><td>67</td><td>35</td></tr>
</table>
Fish community IBIs relating to trophic level, specialist species, and individual species habitat preferences can indicate changes in aquatic microhabitat:
<table>
<tr><th></th><th>4044</th><th>4062</th><th>4047</th><th>4001</th></tr>
<tr><td>% Insectivores</td><td>8</td><td>3</td><td>7</td><td>4</td></tr>
<tr><td>% Carnivores</td><td>3</td><td>8</td><td>6</td><td>7</td></tr>
<tr><td>% Omnivores/Detrivores</td><td>1</td><td>10</td><td>8</td><td>6</td></tr>
<tr><td>% Specialist species</td><td>3</td><td>10</td><td>4</td><td>7</td></tr>
<tr><td>% Darter and Sculpin species</td><td>5</td><td>8</td><td>8</td><td>6</td></tr>
<tr><td>% Brook Trout</td><td>6</td><td>8</td><td>5</td><td>6</td></tr>
</table></td><td>Refer to Section 2.6.2</td><td>No significant change in floral metrics F7, F10 & F11.
No significant change benthic indices or fish IBI scores</td></tr>
<tr><td>Aquatic In-stream corridors</td><td>Removal of in-stream barriers increases access to streams by fish</td><td>Qualitative & quantitative assessment of instream barriers</td><td>Two instream barriers exist along Blair Creek (Perched culvert under driveway upstream of Dodge Drive and on New Dundee Road). Brook Trout are found upstream of New Dundee Road, but no spawning evidence has been found upstream of New Dundee Road.</td><td></td><td>Perched culvert under driveway upstream of Dodge Drive and on New Dundee Road.</td></tr>
</table>

Table 3-5-11 Objective 3b: Design and operate stormwater management facilities to maintain a healthy aquatic ecosystem, including the existing cold-water fisheries

<table>
<tr><th>Indicators</th><th>Rationale for Target Setting</th><th>Parameters</th><th>2016 SOW Conditions (2006-2013)</th><th>Existing Conditions (During-development)</th><th>Maintain Status Quo</th></tr>
<tr><td>Rep. Aquatic Communities</td><td>Fish and aquatic invertebrates are barometers of healthy water bodies.
Specific habitat requirements for Coldwater fish communities must be present on a subwatershed basis to ensure survival.
Brook trout are sensitive to water quality (temperature and pollutants).</td><td>Presence of target coldwater fish community
Presence of redds and scrapes
Presence/absence of benthic species</td><td>Dominant fish community in cold water during pre-construction monitoring include target species: Brook trout, Brown trout and Mottled sculpin;
One confirmed active spawning location was recorded in 2011 within a pool just downstream of New Dundee Road.
Additionally, the BBB Study has shown most spawning activity is downstream of the confluence with Roseville Tributary. As such, the spawning survey limit has been extended downstream.
Existing conditions should reflect the BBB Study for these locations.
Benthic indices
<table>
<tr><th></th><th>B3</th><th>B2b</th><th>B2a</th><th>B1</th><th>4044</th><th>4045</th><th>4047</th></tr>
<tr><td>HBI</td><td>4.42</td><td>7.19</td><td>6.47</td><td>4.18</td><td>4.49</td><td>6.12</td><td>4.86</td></tr>
<tr><td>Taxa Richness</td><td>25</td><td>26</td><td>33</td><td>34</td><td>31</td><td>25</td><td>55</td></tr>
<tr><td>% Oligochaeta</td><td>0</td><td>3</td><td>3</td><td>2</td><td>2</td><td>0</td><td>0</td></tr>
<tr><td>% Chironomidae</td><td>62</td><td>64</td><td>59</td><td>41</td><td>52</td><td>77</td><td>27</td></tr>
<tr><td>% EPT</td><td>21</td><td>4</td><td>5</td><td>21</td><td>7</td><td>13</td><td>25</td></tr>
<tr><td>EPT Taxa</td><td>3</td><td>2</td><td>3</td><td>5</td><td>2</td><td>4</td><td>14</td></tr>
</table></td><td>Refer to Section 2.7.4</td><td>Coldwater fish community
Indicator species: brook trout, brown trout & mottled sculpin
No significant reduction in presence of redds and scrapes at New Dundee Road and downstream of the Roseville Tributary.
No significant change in benthic indices</td></tr>
<tr><td>Aquatic Community Diversity</td><td>Higher values of fish and benthic indices (e.g. IBI, BioMap, EPT) indicate improved water quality, quantity, and aquatic habitats.</td><td>Benthic metrics (Taxa richness, % Oligochaeta, % Chironomidae, % EPT, # EPT Taxa)
Fish metrics (Species richness, Number of Intolerant species, % Non-native species, % Coldwater species, % Darter and sculpin species, % Brook Trout)
Species targets per the Grand River Fisheries Management Plan (GRFMP, Brook Trout and other coldwater species)</td><td>Fish IBI Scores
<table>
<tr><th>Metrics</th><th>4044</th><th>4062</th><th>4047</th><th>4001</th></tr>
<tr><td>Total species richness</td><td>9</td><td>3</td><td>6</td><td>7</td></tr>
<tr><td>Number of Disturbance Intolerant Species</td><td>5</td><td>7</td><td>9</td><td>9</td></tr>
<tr><td>% Non-native species</td><td>10</td><td>10</td><td>10</td><td>10</td></tr>
<tr><td>% Cold water species</td><td>2</td><td>10</td><td>5</td><td>8</td></tr>
<tr><td>% Darter and Sculpin species</td><td>5</td><td>8</td><td>8</td><td>6</td></tr>
<tr><td>% Brook Trout</td><td>6</td><td>8</td><td>5</td><td>6</td></tr>
<tr><td># fish/100 efish seconds</td><td>8</td><td>4</td><td>7</td><td>8</td></tr>
<tr><td># Brook Trout/100 efish seconds</td><td>2</td><td>7</td><td>7</td><td>9</td></tr>
</table></td><td>Refer to Section 2.7.4</td><td>No significant change benthic indices or fish IBI scores</td></tr>
<tr><td>Aquatic Community Abundance</td><td>Greater densities of fish indicate improved water quality and aquatic habitats.</td><td>Density (fish/100 sqm)
Biomass</td><td>Station 4062 (Control)
Average biomass: 0.202 Brook Trout/m^2
Average density: 4.467 Brook Trout/m^2
Station 4047
Average biomass: 0.203 Brook Trout/m^2
Average density: 4.454 Brook Trout/m^2</td><td>Refer to Section 2.7.4</td><td>No loss in density or biomass of Brook Trout.</td></tr>
<tr><td>Aquatic Community Health</td><td>DO saturation levels to be maintained or increased to support respiration & decomposition
Max. in-stream temp. to be maintained or reduced to maintain/support sensitive coldwater fish communities;
TSS levels to be maintained to min. siltation of aquatic habitats &clogging of fish gills;
Nutrients to be lowered to avoid excessive algae growth & decrease in DO;</td><td>Changes in thermal regime
Chemical concentrations
Trace metal concentrations
DO
maximum temperatures
TSS
nutrient levels</td><td>Refer to Objective 1c: Maintain/enhance coldwater fisheries potential of watercourses.
Refer to Objective 1d: Contribute to achieving federal, provincial, and municipal water quality objectives and guidelines in watercourses.</td><td>Refer to Section 2.7.4</td><td>Refer to Objective 1c: Maintain/enhance coldwater fisheries potential of watercourses.
Refer to Objective 1d: Contribute to achieving federal, provincial, and municipal water quality objectives and guidelines in watercourses.</td></tr>
</table>

Indicators	Rationale for Target Setting	Parameters	2016 SOW Conditions (2006-2013)	Existing Conditions (During-development)	Maintain Status Quo
	Trace metal conc. to be reduced to min. the potential for chronic toxic levels during periodic wet conditions.				
Aquatic Habitat Integrity	Support target coldwater fish community; Water quantity conditions, physical instream & streamside habitats to be improved to support sensitive aquatic life; Peakiness factor to be at a natural level to reduce erosive stresses on natural habitat; Groundwater contributions to total annual flow required to maintain stream flow; Time of flow exceedance and excess stream power to be at natural (historic) levels to restore stable streams and habitats; Woody riparian vegetation & instream woody debris increases stream shading and instream cover; Pool and riffle habitat in streams provide spawning, nursery, and refuge habitat for fish; Increasing depths of flow over riffles improves spawning/nursery habitat for fish, increases oxygenation of water and increases food supplies; Minimizing the RGA factor (a measure of stream stability) provides refuge habitats for fish and decreases limiting habitats.	Channel morphology Peakiness factor Water temperature Dissolved Oxygen (DO) Vegetation community abundance and quality RGA factor	Channel Morphology and RGA – Section 2.5.4 Peakiness Factor – See Table 2-2-13 and Table 2-2-14 and refer to Objective 1e Water temperature – see Aquatic Community Health (above) Dissolved Oxygen - See Objective 2c Vegetative Community Abundance and Quality – See Section 2.6.4 and Objective 3d	Refer to Section 2.7.4	Maintain pre-development existing conditions. Refer to relevant section (s).

Table 3-5-12 objective 3c: Maintain or Improve the ecohydrology of wetlands, especially the Roseville Swamp and wetlands within the Endangered Species habitat

Indicators	Rationale for Target Setting	Parameters	2016 SOW Conditions (2006-2013)	Existing Conditions (During-development)	Maintain Status Quo
Refer to Objective 1e for hydrological indicators related to the following indicators:					
Annual Water Balance (Hydrologic regime)	Vegetation monitoring sites in wetland areas include all sites except for V8-V10. These sites may be used as indicators for changes in water balance. Vascular cryptograms found at these are wetland-dependent and sensitive to hydrologic change. Accordingly, a change in the amount of these species at a site may be indicative of hydrologic change.	Average CW (metric F2) for all sites except V8-V10. Use plants with low CW values (-5 to -3) as wetland indicators % vascular cryptograms (metric F8) for all sites except V8-V10.	Average CW values for these sites V1 to V7 and Doon V1 – Doon V4 are -2.28, -2.25, -2.56, -0.28, -1.78, -2.12, -0.77, -1.73, -0.92, -1.63, and -0.74, respectively. % vascular cryptograms for sites V1 to V7 and Doon V1 – Doon V4 are 4.23%, 0%, 1.02%, 16.07%, 10.50%, 6.05%, 5.68%, 13.00%, 15.96%, 18.47%, and 19.88% respectively.	Refer to Section 2.6.4	No significant change in CW values No significant change in vascular cryptograms
Groundwater functions (surface-groundwater interaction)	Groundwater is the primary factor in hydrology of the Roseville Swamp. Vegetation monitoring sites in areas of known groundwater upwelling include sites V1, V2, and V3. These sites may be used as indicators for changes in groundwater elevation. Vascular cryptograms found at sites V1, V2, & V3 are wetland-dependent and sensitive to hydrologic change. Accordingly, a change in the amount of these	CW (metric F2) for sites V1-V3. % vascular cryptograms (metric F8) for sites V1-V3.	Average CW values for these sites V1, V2, and V3 are -2.28, -2.25, and -2.56, respectively. % vascular cryptograms for sites V1, V2, and V3 are 4.23%, 0%, and 1.02%, respectively.	Refer to Section 2.6.4	No significant change in CW values No significant change in vascular cryptograms

	species at a site may be indicative of hydrologic change.				

Table 3-5-13 Objective 3d: Protect, restore, or enhance native terrestrial and aquatic plant and animal species, community diversity, and productivity

Indicators	Rationale for Target Setting	Parameters	2016 SOW Conditions (2006-2013)	Existing Conditions (During-development)	Maintain Status Quo
Vegetation	Extant vegetation communities comprise habitats for wildlife in Upper Blair. Increasing development pressure has the potential to impact vegetation communities and the wildlife that are dependent on them. Vegetation communities are also important factors and contribute to maintaining the quality & quantity of ground & surface water.	Quantitative and qualitative measurements of vegetation Nutrient and chloride levels pH Water quantity (groundwater and surface water)	Results of taxonomic metrics for flora, F1 to F11 are too numerous to list here. See details in the 2016 SOW sections 2.5.4.1. and 2.5.4.3. Water quality and water quantity as described under objectives 1d, 1e, 2a, and 2b.	Refer to Section 2.6.4	No net loss of vegetation communities No significant negative change to IBI metrics No change in pH No change in water quantity and quality
Representative Terrestrial Communities	Sensitive communities and/or species recorded at the preconstruction phase often haven arrow requirements for existence within a given landscape Significant changes in the indicator communities and/or species may provide clues to the presence of negative (abiotic) changes in the environment. An increase in sensitive communities and/or indicator species may indicate a shift towards an increase in specific habitat type(s), abundance, and/or quality.	Indicator communities (high-level, e.g. amphibians); Indicator species (specific-level, e.g. Scarlet Tanager); Species of conservation concern; Average CC value Average CW value Representative community health (vegetation, avifauna, amphibians). IBI metrics Species which satisfy multiple indicator categories (e.g. a species of conservation concern that is also area-sensitive) may be better indicators than species which only fall into one indicator category.	Overall, floristic quality in Upper Blair is split with 50% of sites considered ‘good’ and 50% considered ‘fair’. 37.5% of avifaunal monitoring sites are considered ‘good’; 50% are considered ‘fair’; and 12.5% are considered ‘poor’. Taxonomic indicator communities include those described under metrics F5 to F8, B4, B6 to B7, and metrics A1 to A5. Floral indicator species: Skunk Cabbage, Crested Wood Fern, Rough Goldenrod, Large-leaved Avens, Meadow Horsetail. Avifaunal indicator species: Scarlet Tanager, Ovenbird, Wood Thrush, Northern Waterthrush, Eastern Wood-pewee. Amphibian indicator species: Chorus Frog, Wood Frog. Amphibian communities have not currently been assessed due to survey methodology. Recommendations for improvement are contained in Section 5.1.1 of the 2016 SOW. For the purpose of assessing potential targets, changes in amphibian metrics A1 to A5 should be considered. CC and CW values for each monitoring site are shown in Table 2.5.13 and Table 2.5.19 of the 2016 SOW. Yearly average CC and CW values should be compared against both the pre-development average CC/CW for a site and the average CC/CW of the previous monitoring year. Representative community health scores are detailed in Tables 2.5.22 to 2.5.24 and Figure 2.5.9 in the 2016 SOW.	Refer to Section 2.6.4	No significant net loss (allow for typical yearly fluctuations while monitoring long-term trends); Indicator communities: amphibians, forest interior birds, & area-sensitive avifauna; Species of Conservation Concern remain on site; No significant change in avg. CC and CW values.
Community Diversity	Diverse communities are generally more robust over the short- and long-term. Diverse communities indicate improved habitat(s). Exotic species are generally ubiquitous, but high numbers of exotic species may indicate disturbance. Developers are currently required to note incidences of Garlic Mustard and prevent its proliferation.	Native species richness by taxa. Exotic species.	Species richness is included under metrics for Flora (F1), Avifauna (B1), and Amphibians (A1). Summary of the percentage of exotic species in Upper Blair is as follows: Flora - Range: 3.57% to 33.33%; Average: 10.32% Avifauna - Range: 0% to 9.30%; Average: 2.63% Amphibians - None. Detailed information by site is contained within Tables 2.5.13, 2.5.14, 2.5.19, and 2.5.20 in the 2016 SOW.	Refer to Section 2.6.4	No significant negative change in species richness; No net loss of vegetation communities; No significant increase in the presence of exotic species.
Community Abundance	Greater densities of native species indicate improved terrestrial habitat(s).	Species counts, overall and by taxa.	Total native species counts are as follows: Flora: 237 (33 non-native) Avifauna: 75 (3 non-native) Amphibians: 8 Reptiles: 1 (data deficient) Mammals: 2 (data deficient)	Refer to Section 2.6.4	No significant change in native species abundance.
Buffers	Buffers aid in mitigating the potential negative effects of development on the natural heritage system. In this way, they aid in the conservation and protection natural heritage resources. Buffer monitoring is a requirement of developer-led monitoring in Upper Blair.	Quantitative and qualitative measurements of vegetation Presence of exotic and invasive species Planting survival	Buffer monitoring has not yet been initiated.	See Table 2-6-19	n/a

4. Monitoring Plan Recommendations

The purpose of this section of the report is to document recommendations for the ongoing monitoring program within the Blair Creek subwatershed. The previous reports and sections have documented the existing conditions and provided a comparison and context with respect to the previously established baseline condition (Section 2).

Recommendations and conclusions were discussed in Section 2, this section collects these recommendations and provides additional context for how the indicators of change are interrelated using a weight of evidence approach.

Section 5 will document recommendations with respect to the City's RAAP protocol for developers.

4.1 Summary of Conclusions

The following section summarizes the key findings put forward in Section 2 of this report and identifies relationships between key indicators.

4.1.1 Water Quantity

The water quantity analysis looks at five key indicators of change. These include watershed peakiness (flow rate), annual water balance (hydrologic regime), groundwater functions (surface-groundwater interactions), and in-channel high flows (eco-hydrology).

The key findings of the analysis found:

1) Precipitation may be slightly underestimated due to data gaps from Roseville station.
2) Through the FFA and FDC, increased peak flows and decreased baseflow at New Dundee Road station has been observed. These changes have led to a flashier stream response as well as risk of higher frequency flooding. (Refer to Table 2-2-13)
    a) Baseflow has decreased from 10 to 1 percent between pre- to during-development periods at the New Dundee Road Station.
    b) Peakiness factor at New Dundee Road has increased significantly from the pre- to during-development conditions.
3) Due to the impact of Roseville swamp, observed data at New Dundee Road station may not be able to accurately describe surface-groundwater interactions.
4) IHA parameters indicate a flashier response at New Dundee Road station. The range of available data for the IHA parameters is not large enough to draw significant conclusions and a weight of evidence approach must be used in conjunction with the resulting observations.

The New Dundee Road monitoring location is immediately downstream from portions of the study area currently under development. The changes in the hydrology regime observed at this station indicate an increase in impervious area upstream. As noted in the review of the stream morphology monitoring, there has been significant beaver activity downstream of this monitoring locations (upstream of the Reichert Drive Road and Dickie Settlement Road monitoring locations). The field observations noted by Water's Edge indicate that the beaver dam constructed in this area is functioning similar to a stormwater management facility, which may be why similar changes in the hydrologic regime are not observed downstream. A further source of inaccuracy may include the use of ET values from the modelling results in the BBB study as the annual average precipitation was calculated as the average of all annual precipitations for the designated time periods. Further assessment of the approach to ET calculation is warranted in the next SOW.

4.1.2 Water Quality

4.1.2.1 Water Temperature

Overall stream temperature remains in a range which supports the spawning and habitat of brook trout. The number of days at Reidel Drive and Reichert Drive monitoring stations in the cool-water regime are higher than expected (compared to the pre-development number of days) and therefore, this should be monitored carefully to ensure that temperature does not continue to increase and negatively impact the surrounding habitat. Temperatures at Reichert Drive may be impacted by beaver activity between New Dundee Road and Reichert Drive.

4.1.2.2 Water Chemistry

The following conclusions have been made regarding the surface water chemistry of Blair Creek. It is important to note that most samples are discrete grab samples; autosampled wet weather data collected since 2016 is flow-composited at one result per event.

The following conclusions for each station which include some key findings.

1) At Reidel Drive, the average values for copper and zinc exceeded their respective PWQO thresholds (Province of Ontario, 1994). The increase in the upper percentiles of the box plot for phosphorus at Reidel Drive station is most likely due to agricultural activities upstream.
2) At Dodge Drive, the average DO value was found to be below the PWQO and the average values for copper and zinc were found to exceed their respective PWQO thresholds (Province of Ontario, 1994). The TSS average in wet weather for Dodge Drive was 195.5 mg/L which is higher than all maximum and average values for all stations and weather types prior to 2014. Additionally, an increase of 60 mg/L for the median value of TSS was observed between pre- and during-development conditions. Phosphorus at Dodge Drive increased by more than a factor of five in wet weather conditions. The TSS 90th and 95th percentiles more than tripled and BACI analysis, ANOVA test, and Mann-Kendall trend tests all support that TSS increased due to development near Dodge Drive.
3) TSS 90th and 95th percentiles more than tripled at New Dundee Road.
4) There are no site-specific conclusions for Reichert Drive. The general conclusions apply.
5) Roseville Tributary saw increases in upper percentiles for phosphorus, most likely due to agricultural activities upstream.
6) There are no site-specific conclusions for Dickie Settlement Road. The general conclusions apply.
7) At the Mouth, the upper percentiles and median value for chloride increased between pre and during-development.

These station specific findings, specifically those at Dodge Drive (in item 2 above), indicate there are impacts related to construction activities in the during-development monitoring period. It is understood that while the stormwater management facilities are constructed it is likely that connectivity of impervious area has changed over the course of the during-development period of concern in this SOW.

Numbered items 1, 2 and 3 are general conclusions for the entirety of Upper Blair Creek.

1) Using the 2016 SOW wet weather and dry weather stratification method (Aquafor Beech Limited 2016) and observing the corresponding general statistics tables the conclusions were:
   a) Chloride maximum concentrations have increased at every station at either wet and/or dry weather conditions.

   b) Total phosphorus maximum concentrations increased at 6 stations at either wet and/or dry weather, and wet weather average phosphorus concentrations exceeded the PWQO of 0.03 mg/L at all stations (Province of Ontario, 1994). Average nitrate concentration at either dry or wet weather conditions did not exceed PWQO at any stations between 2014 and 2019.
   c) Total copper maximum concentrations have increased at either wet and/or dry weather at six monitoring stations.
   d) Total zinc maximum concentrations increased during wet weather at all stations upstream of Dickie Settlement Road.
   e) TSS maximum concentrations increased at 5 stations for wet weather and at 6 stations for dry weather. The maximum values at five stations exceeded the previous overall maximum TSS in the 2016 SOW.
2) Using the 2018 CEA wet and dry stratification method (GRCA 2018) and observing the Wilcoxon rank-sum non-parametric test results the conclusions were:
   a) All stations had a statistically significant change in median values for at least one parameter (TSS, TP, NO_3 or Cl).
   b) For the 12 cases of dry weather median values with statistically significant change, all but one case decreased for during-development. The opposite trend was observed for wet weather where all statistically significant median changes were increases, except those for nitrate which decreased.
   c) In wet weather conditions, median TSS values increased for all seven stations, and by more than double for four stations where the latter includes both control sites. Furthermore, at Dodge Drive an increase of 60 mg/L for the wet weather median value of TSS was observed between pre- and during-development conditions.
   d) Median wet weather concentrations of TSS and TP are observed to be statistically significantly higher than dry concentrations for all stations during-development.
   e) For during-development data, there are ten more occurrences of statistical significance between wet and dry weather samples then there are for pre-development. This further highlights the importance of stratifying chemistry grab samples into wet and dry.
3) From the box plots produced for the 5^{th} to 95^{th} percentiles for pre and during-development conditions the following conclusions were made:
   a) Increases in the upper percentiles of TSS and phosphorus at New Dundee Road and Dodge Drive is a potential product of development (which was further analyzed through BACI and Mann-Kendall tests). The effects of high concentrations of TSS or phosphorus associated with development is not seen downstream of these monitoring sites.
   b) Nitrate concentration values for high percentiles generally decreased for the during-development period, which suggests changes in agricultural practices upstream.

4.1.3 Stream Morphology

The indicators of change for monitoring impacts within the study area are within thresholds as defined in the 2016 SOW (Aquafor Beech Limited 2016). Exceedances of thresholds have occurred; however, they are in areas which have other known impacts causing geomorphological changes, primarily due to beaver activity.

The first during-development monitoring report completed by Water's Edge did not identify any changes that were identified as related to development activities. However, the three cross sections immediately downstream of the developments (XS-7, 8 and 9) are significantly impacted by beaver activity. As noted by Water's Edge, the beaver pond has submerged the bank and erosion pins at these cross sections. They concluded that the ponded area is likely functioning as a stormwater management pond (Water's Edge 2020) and may be mitigating any potential development impacts downstream.

Other water quality and quantity indicators may be impacted by the observed beaver activity in the study area. The stream morphology monitoring concurs with the water quantity finding with respect to an observed significant increase in hours during which flows exceed the critical flow erosive threshold. At this time this exceedance of thresholds (increase of hours of erosive flows) has not resulted in observable impacts on stream morphology, however, this may change over the next monitoring period.

4.1.4 Terrestrial Ecology

Terrestrial communities within the Upper Blair Study Area score in the mid-range indicating the terrestrial ecosystems are in fair to good condition. Individual sites face considerable variation, as is expected in a heterogenous and fragmented landscape. Tables 2-6-33 and 2-6-34 summarize the pre-development and during-development (2015-2018) IBI scores for each habitat block as illustrated in Figure 2-6-1. General trends for amphibians are presented qualitatively. The average IBI scores for the majority of the habitat blocks decreased, except for blocks D and G which increased.

4.1.5 Aquatic Ecology

Table 4-1-1 summarized the conclusions for the aquatic ecology by indicator.

Table 4-1-1: Aquatic Ecology Conclusion Summary

Item	Conclusion
Benthic Macroinvertebrates	Comparison of pre-development and during-development results indicate that water quality has slightly decreased across the watershed. Pollution indices increased at all sites with the exception of site B7 which is upstream of the development areas. In general, EPT taxa decreased, and Chironomids increased across all sites while the relative proportions of the feeding groups changed from pre-development to during-development phases. However, changes in metrics are relatively small, and water quality remains fair to good throughout the watershed.
Fish Community	Results of the fish community sampling indicate small decreases in the IBI metrics; however, all sites are rated as fair and sustains a fairly healthy coldwater fish community. In total 17 species were captured within the Upper Blair watershed. The majority of species identified are moderately tolerant species. Brook Trout was found at all sites sampled in both the pre- and during-development phases.
Spawning Surveys	Few instances of spawning were observed adjacent to Stauffer Woods and Doon South development areas during the pre-construction period. However, spawning activities were observed adjacent to the Doon South development consistently throughout the during-development phase and appears to be a reliable area for Brook Trout spawning.
Continuous Temperature Monitoring	Results of the continuous temperature monitoring indicate that surface water temperatures are increasing across the watershed. The average number of days during the spawning period exceeding 9°C increased from 23 days pre-development to 29 days during-development. Similarly, the number of days exceeding 20°C during the non-spawning period increased from 14 days pre-development to 27.8 days during-development. A sustained increase in surface water temperatures may impact the coldwater fish species and decrease the sustainability of the Brook Trout population.

4.1.6 Overall Conclusions

In conclusion the following common conclusions have emerged from the analysis conducted for the 2020 SOW:

- Stream temperature has increased. A sustained increase in water temperature will result in impacts within this coldwater fishery. At this time, definitive causes of increasing temperatures cannot be identified. The related observed changes in hydrological regime indicates that increased urban runoff is a potential factor.
- There have been observed changes in the hydrologic regime across the watershed – including changes in flow rates, flow peakiness, and increases in hours of flow above critical erosive velocity. These changes are indicative of increases in urban runoff and/or increases in impervious area. At this time these changes in the flow regime have not resulted in observable impacts to the stream morphology.
- Water Quality impacts indicative of sediment releases have been observed at the Dodge Drive monitoring location. At this time, it is not possible to effectively evaluate the performance of the SWMFs within the watershed, therefore, it is recommended that the contingency lots not be developed. Review of SWMF performance should continue to be a priority in subsequent SOW reporting cycles.

4.2 Monitoring Plan Recommendations

This report has identified two key recommendations and overarching themes of the monitoring plan recommendations which apply to all parameters and responsible parties, these include:

1) **Maintain program consistency**. The objective of the SOW cycle is to compare during- and post- development conditions to the baseline (pre-development) condition. Imperative to this objective is the collection of data in a consistent manner such that the same analysis methods can be repeated, and results can be compared to the baseline pre-development conditions reliably and with a high degree of confidence and scientific merit. Long term consistency in the monitoring program will also reduce the level of effort required to consistently complete the SOW reporting requirements.
2) **Develop and maintain consistent data collection procedures.** Related to the above recommendation, it is recommended that all responsible parties continue to collect data in a consistent format. It is recommended that the City and GRCA leverage advancements in technology to:
   a) Develop a consolidated database of monitoring data for the Upper Blair Watershed Monitoring Program. Automated scripting can be used to reformat data collected by the various parties responsible for collection of monitoring data such that data is formatted into a consolidated database.
   b) Update select monitoring locations with network or web enabled dataloggers to upload data at regular intervals.
   c) Maintain the database and leverage technological tools to provide real-time alerts to relevant team members when monitoring data indicates potential impacts.

   This recommendation supports both the objectives of the monitoring program, development of future SOW reports, and recommended improvements to the City's RAAP protocol. Additional details on how technological tools can be used to reduce City staff effort while improving responsiveness of the RAAP is detailed in Section 5 of this report.

Table 4-2-1 details the recommendations for the monitoring plan by indicator. Unless a change to the monitoring location or sampling method is noted in Table 4-2-1, the recommendation is that the City, GRCA, and/or property owner (developer) should maintain the existing monitoring plan.

Table 4-2-1: Monitoring Plan Recommendations

Indicator	Monitoring Plan Recommendation	Responsibility
Surface Water Quantity	Add network or web enabled dataloggers to: ▪ New Dundee Road (Flow rate) ▪ Dickie Settlement Road (Flow rate) ▪ Weather Station Maintain sampling frequency (15-minute time intervals).	GRCA
Surface Water Quality	Add network or web enabled dataloggers to report continuous stream temperature at: ▪ Reidel Drive ▪ New Dundee Road ▪ Roseville Tributary ▪ Reichert Drive ▪ Mouth Maintain reporting frequency for stream temperature (15-minute intervals). Maintain existing monitoring plan.	GRCA
Groundwater	Maintain existing monitoring plan. The next during-development SOW (2025) scope should include establishing threshold indicators of change for groundwater parameters.	All City
Stream Morphology	Relocate beaver impacted cross sections (XS-7, 8 and 9) upstream of New Dundee Road. Continue to monitor beaver dams at these cross sections to determine if actively maintained (active or abandoned). Exact cross section location selection should be conducted in consultation with a Fluvial Geomorphologist familiar with the study area. The scope of work for subsequent monitoring should include consideration for how monitoring data collected will add to previous monitoring periods. Consistent reporting of bankfull cross sectional area is a key indicator that requires consistent measurement and clear reporting in order to achieve the SOW objectives for geomorphological monitoring.	GRCA
Terrestrial Ecology	Maintain monitoring methods and sites.	Developer
Aquatic Ecology	Maintain monitoring methods and sites. Consistency in monitoring sites (revisiting of previously monitoring sites and/or reinstating previously monitored sites) would value to future SOW.	All
Stormwater Management Facilities	Maintain monitoring methods, locations, and frequency. Refer to Section 5 for RAAP recommendations. Implementation of a web-hosted database of climate and flow monitoring and automated alerts for wet-weather events should be used to improve the collection of downstream TSS grab sampling.	Developer City & GRCA

5. Rapid Assessment & Action Protocols Temperature and ESC

Table 5-1 Erosions and sediment control rapid assessment and action protocols (RAAP) components and action, recommendations or outcome resulting from monitoring

Component of Existing RAAP	Action, Recommendation or Outcome resulting from Monitoring
a) The process for immediate notification to the GRCA, City of Kitchener, and other applicable agencies	The inspector to notify developer and or developer representative and the developer and or developer representative to notify the City of Kitchener and GRCA. All sediment releases and spills outside the designated control area (development limits) be recorded and reported to the City and GRCA within 24 hours.
b) Identify the options for immediate action(s) required to address performance issues and assign the responsible party to implement the mitigation measure(s)	Implement additional erosion control BMPs and sediment control BMPs listed in Table 5.1. ESC plans are dynamic and require application of the Adaptive Management Approach (AMA) whereby the ESC plan is continually updated as a result of site inspections.
c) Identify the sequence and timing of mitigation actions to be implemented by the proponent to address any short term, immediate impacts	Weekly ESC reports to be prepared by inspector for submission to the contractor/ developer and City. Report to identify: 1) Rationale for inspection (see inspection frequency i.e. weekly, following precipitation, etc.) 2) Observations/ findings relating to the inspection (both positive and negative) 3) Person(s) informed/ notified of findings and or observations 4) Actions required All deficiencies to be corrected by the developer immediately upon notification by inspectors.
d) Establish a methodology to determine an exceedance that may have occurred due to climate normal conditions	Analysis of climate normal to be completed as part of data tracking (review and analysis) by the consultant. It has been recommended that the GRCA and City of Kitchener review the results as provided by the consultant every 6 months during the 'During Development' and 'Post Development" phases. ▪ For TSS, the consultant shall look at whether the storm even falls within the design storm and design parameters of the SWM facility. ▪ For temperature, the consultant shall use a 24-hour rolling average temperature and compare to historical averages.
e) Identify the Subdivider as the responsible party to implement the protocol to the satisfaction of the GRCA and City of Kitchener and that failure to implement this protocol may result in the City of Kitchener implementing the mitigation measures identified in the protocol, at the Subdivider's expense	Responsible party is identified in the sub - division agreements and site plan approvals. Accordingly, the City requires the following in regard to erosion and sediment control (ESC): 1) ESC Report and Plan to the satisfaction of the City, RMOW and GRCA in accordance with the *Erosion and Sediment Control Guidelines for Urban Development* 2) Construction of sedimentation basins be located outside of the SWM facility. 3) Prior to area grading, a Letter of Credit (LoC) based on 60% of the estimated cost of the approved ESC Plan (or $100,000 whichever is greater) to ensure implementation of the approved Rapid Assessment and Action Protocol (RAAP) as detailed in the approved ESC Report and Plan. The LoC shall be reduced to 15% (or $50,000 whichever is greater), upon completion of area grading, inspection, and approvals of the ESC controls by the City.
f) Identify the primary contact(s) responsible for the monitoring and maintenance of these works for each phase of development, such as	Responsible Party ▪ Inspector (monitoring) ▪ Developer and or developer representative (maintenance)

Component of Existing RAAP	Action, Recommendation or Outcome resulting from Monitoring
grading, servicing, and construction on the site	Enforcement of sub - division agreements (contacts should include): ▪ GRCA ▪ City – Development Engineering Project Manager
g) Inspector qualifications	It is recommended that all inspectors be CISEC certified.

Table 5-2 Temperature rapid assessment and action protocols (RAAP) components and action, recommendations or outcomes resulting from monitoring

Component of Existing RAAP	Action, Recommendation or Outcome resulting from Monitoring
a) Identify the process for immediate notification to the GRCA, City of Kitchener, and other applicable agencies	Surface water quality (including temperature) results as presented in formal report format by the developers is recommended to be reviewed twice annually, spring and late summer by the GRCA and City of Kitchener as part of data tracking (review and analysis) during the 'During Development' and 'Post Development" phases. The developers shall identify persistent temperature deviations outside Existing Conditions Temperature Exceedances (per Objective 1c), with special attention to spawning Seasons. Persistent temperature deviations would require the developer to notify the City, GRCA and other applicable agencies.
b) Identify immediate alternative implementation strategies for stormwater runoff and infiltration as a 'temperature contingency plan' that will be implemented to address surface and/or groundwater discharge that fall outside of the temperature and thermal regime impacts documented in the Upper Blair SOW report and assign the responsible party to implement the mitigation measure(s) c) Identify the sequence and timing of mitigation actions to be implemented by the proponent to address any short term, immediate impacts	Process should include upon notification of the GRCA, City of Kitchener by the developer of persistent temperature deviations, the developer shall prior to the subsequent spawning season: ▪ Immediately identify the location of the failed SWM infiltration infrastructure and cause of the failure. ▪ Remediate or re-construct the failed infrastructure ▪ Re-monitor If remediation or re-constructions of failed SWM infiltration infrastructure does not reduce or eliminate the persistent temperature deviations outside Existing Conditions Temperature Exceedances (per Objective 1c) or cause of persistent temperature deviations cannot be identified, implementation of the contingency infiltration facilities may be considered.
d) Establish a methodology to determine an exceedance that may have occurred due to climate normal conditions	Analysis of climate normal to be completed as part of data tracking (review and analysis) which has been recommended to be undertaken as part of Surface water quality review - twice annually, spring and late summer by the GRCA and City of Kitchener during the 'During Development' and 'Post Development" phases.
e) Identify the Subdivider as the responsible party to implement the protocol to the satisfaction of the GRCA and City of Kitchener and that failure to implement this protocol may result in the City of Kitchener implementing the mitigation measures identified in the protocol, at the Subdivider's expense.	The sub-division agreements and site plan approvals include: ▪ The required amount of contingency SWM facilities as specified in the FDS, is identified within the sub-division agreements and site plan approvals. The developer shall implement the contingency SWM facilities if during-construction and or postconstruction monitoring (until 90% of the pond catchment area is stabilized meaning buildings are constructed and lots/blocks are sodded or vegetated) identifies the need. This need may include impacts to groundwater quantity or impacts to stream temperatures relating to groundwater discharges to Blair Creek. ▪ Requires a letter of credit based on 60% of the estimated cost of the approved "end of pipe" SWM facilities (including ponds, infiltration galleries, cooling trenches and other related appurtenances,) and 100% of the estimated cost of contingency end of pipe infiltration facilities. The letter of credit will be reduced after the "post construction" monitoring program has expired.

Component of Existing RAAP	Action, Recommendation or Outcome resulting from Monitoring
	▪ During-Construction Monitoring – Requires the implementation of any remedial action deemed necessary as a result of the aforementioned monitoring program at their sole expense to the satisfaction of the City and relevant agencies.
f) Identify the primary contact(s) responsible for the monitoring and maintenance of these works for each phase of development.	Responsible Party ▪ Developer (monitoring) ▪ GRCA/ City of Kitchener (data tracking – review and analysis) ▪ GRCA/ City of Kitchener (notification of developer) ▪ Developer (Remediate or re-construct the failed infrastructure) ▪ Developer (Implementation of the contingency infiltration facilities) Enforcement of sub-division agreements (contacts should include): ▪ GRCA ▪ City – Development Engineer Project Manager

The RAAP is the developer monitoring program implemented in the during-development and post-construction phases of development. RAAP must be documented and implemented by the development proponent. Two critical components of the stormwater management strategy associated with the study area are the successful implementation of erosion and sediment controls, and temperature mitigation measures. The components of the RAAP to be used 'During-development' and 'Post Construction' will be completed to the satisfaction of the GRCA and City of Kitchener and will include but is not limited to:

- Identify the primary contact(s) responsible for the monitoring and maintenance
- The process for immediate notification to the GRCA, City of Kitchener, and other applicable agencies
- Identify the options for immediate action(s) required to address performance issues and assign the responsible party to implement the mitigation measure(s)
- Identify immediate alternative implementation strategies for stormwater runoff and infiltration as a 'temperature contingency plan' that will be implemented to address surface and/or groundwater discharge that fall outside of the temperature and thermal regime impacts documented in this report and assign the responsible party to implement the mitigation measure(s)
- Identify the sequence and timing of mitigation actions to be implemented by the proponent to address any short term, immediate impacts
- Establish a methodology to determine an exceedance that may have occurred due to climate normal conditions Surface water and groundwater temperatures should be monitored on a continuous basis for use in evaluating cooling measures. The results will be interpreted in the context of observed climate conditions.
- Identify the options for immediate action(s) required to address performance issues and assign the responsible party to implement the mitigation measure(s)

The purpose of the During-Construction Monitoring Program is to evaluate the effectiveness of the erosion and sediment controls established for the development site during the construction process, and to determine if the targets established in the monitoring program are being met. During-construction monitoring does not capture stormwater management performance.

5.1 Mitigation Steps

If the Monitoring Program indicates a problem with the stormwater management system, then the following process should be undertaken to determine appropriate mitigative measures:

- Thorough analysis of the monitoring data and field visits by all relevant staff, as required, to determine the cause of the problem.
- Development of a preliminary mitigation plan to address the issue.
- Convene a meeting with the appropriate review agencies to discuss the problem.
- Development of a consensus on a proposed plan of action to resolve the problem in consultation with agency staff.
- Mitigation measures should be implemented, and the results monitored by the proponent for a mutually agreed upon duration.

5.2 Issues with RAAP

The following issues were identified with respect to the existing implementation of the RAAP for Upper Blair Creek:

a) The monitoring program has a number of field issues

b) The monitoring program has a number of equipment issues

c) Temperature analysis and reporting or response time may lag

d) TSS monitoring may not capture the full picture of what is occurring

e) Sampling locations may not capture rainfall response

f) Erosion and sediment control inspections may be more reactive than proactive

g) Immediate response direction from the Functional Drainage Study may not be met

h) RAAP may not be effectively linked to an overall Surface Water Management Plan

i) Reporting may be more aligned with long-term trend analysis

j) There are no specific groundwater targets

k) The majority of erosion and sediment control RAAP have been triggered by the GRCA, with some triggered by the developer inspectors, and none triggered by City Inspectors

5.3 Recommendations

The following recommendations have been identified to improve the efficacy of RAAP.

1) Re-chartering of RAAP: an annual chartering meeting with the GRCA, Developers and City staff (including inspectors) is recommended to ensure these parties are familiar with the Upper Blair Creek RAAP procedure and expectations.
2) Refine RAAP Standard Operating Procedures (SOP) to determine the responsibilities of reporting, including:
    a) Expectations of who is to be triggering erosion and sediment control RAAPs
    b) The SOP should outline responsible parties depending on who has triggered the RAAP. This should also define and track deadlines for actions.

   c) The SOP should outline criteria for acceptable selection of monitoring sites for E&SC and temperature monitoring.

   d) The SOP should outline the requirements for data collection of grab samples and for data formatting and metadata standards in order to support a unified database.

3) Addition of turbidity meters: it is recommended that real-time turbidity monitoring is implemented to detect sediment breeches in a rapid manner.

4) Real-time dashboard to increase the timeline of RAAP triggering and reporting while automating as much of the process as possible to facilitate a rapid response. This will be possible through the following.

   a) **Unified Database:** Data is collected by three groups in order to monitor Blair Creek. These include the City through the City-wide monitoring program, through the GRCA, and through the developers. A unified data based from all three sources can be generated through automated scripts as new data is uploaded. Webhosting this database will allow for automatic data processing and analysis.

   b) **Internet Connected Dataloggers:** It is recommended that internet connectivity be added to strategic locations for triggering temperature and E&SC RAAPs. The recommended locations for connected dataloggers are identified in Table 4-2-1 in Section 4.2 of this SOW Report.

   c) **Alerts and Automated RAAPs:** With a unified database generated on an ongoing basis through the manual upload and automatic upload from strategic locations, it is recommended that scripts be executed to trigger alerts to the responsible parties identified in the RAAP SOP. At a minimum is it recommended that the following alerts be implemented:

      i. **Temperature Triggers.** Currently, monthly Temperature RAAPs are issued by the developers. The analysis in these reports of the temperature data can be automated. Automating portions of this report and emailing this report to the responsible parties can facilitate the timely receipt and review of these RAAP reports.

      ii. **Wet Weather Event Alert.** The script can be used to identify the threshold rainfall or stream flow to be considered a wet weather event and alert those responsible that wet weather sampling is required within the specified time frame. Review indicated that TSS sampling to monitor E&SC impact in the creek are frequently delayed.

      In addition, the following could be implemented to further add value:

      iii. **Automated Action Item Tracking.** When combined with a tool such as ESRI WebAPP action items can be generated for users based on the results of the script. For example, if a wet weather event is triggered, the tool can identify the locations where TSS samples are required and provide the responsible party driving directions to those locations. The responsible person can also mark the action as complete when the activity is completed. Similarly, this could be used to assign actions with a location where an E&SC measure requires repair and prompt those responsible to provide a photo of the completed repair.

6. References

Aquafor Beech Limited. 2016. *2016 Final Report State of the Watershed (SOW) Report Upper Blair Creek.* Guelph: Aquafor Beech Limited.

AquaResource. 2009. *Integrated water budget report: Grand River watershed.* Final Report, Prepared for the Grand River Conservation Authority.

Canadian Council of Ministers of the Environment (CCME). 1999. "Water Quality for the Protection of Aquatic Life." *Canadian Environmental Quality Guidelines.*

CH2M Gore & Storrie Limited. 1997. *Blair, Bechtel, and Bauman Creeks Subwatershed Plan.* Kitchener: CH2M Gore & Storrie Limited.

City of Kitchener. 2014. *City of Kitchener Official Plan.* Kitchener: Approved by the Region of Waterloo.

Clean Water Act. 2006. (Province of Ontario).

Conservation Ontario. 2012. "Integrated Watershed Management." *Conservation Ontario.*

Ecoplans Limited. 2013. *Ormston Property Environmental Impact Study.* Kitchener: Ecoplans Limited.

Ecoplans Limited. 2008. *Stauffer Woods Subdivision Environmental Implementation Report.* Kitchener: Ecoplans Limited.

Grand River Conservation Authority (GRCA). 2017. *Blair Creek Monitoring Program Summary.* Kitchener: Grand River Conservation Authority (GRCA).

Grand River Conservation Authority (GRCA). 2018. *Cumulative Effects Monitoring - Blair Creek Case Study.* Kitchener: Grand River Conservation Authority (GRCA).

Grand River Conservation Authority (GRCA). 2005. *Evaluation of Ecological Flow Assessment Techniques*. Cambridge, ON.

Grand River Conservation Authority (GRCA). 2014. *Grand River Watershed Water Management Plan.* Cambridge: Grand River Conservation Authority (GRCA). https://www.grandriver.ca/en/our-watershed/resources/Documents/WMP/Water_WMP_Plan_Complete.pdf.

Karrow, P. F. 1993. "Quarternary geology, Stratford-Conestogo area, Ontario Geological Survery, Report 283." 104.

More Than Engineering (MTE) Consultants Inc. 2018. *Hallman Groh South Subdivision 2017 Annual During-Construction Monitoring Report.* Kitchener: More Than Engineering (MTE) Consultants Inc.

More Than Engineering (MTE) Consultants Inc. 2012. *Hallman Groh South Subdivision Final Stormwater Management Report.* Kitchener: More Than Engineering (MTE) Consultants Inc.

More Than Engineering (MTE) Consultants Inc. 2015. *Ormston residential Subdivision 30T-13203 Final Stormwater Management Report.* Kitchener: More Than Engineering (MTE) Consultants Inc.

More Than Engineering (MTE) Consultants Inc. 2018. *Ormston Residential Subdivision Draft Plan 30T-13203 During Development Monitoring Program: 2017 Annual During-Construction Monitoring Report.* Kitchener: More Than Engineering (MTE) Consultants Inc.

More Than Engineering (MTE) Consultants Inc. 2019. *Ormston Residential Subdivision Draft Plan 30T-13203 During Development Monitoring Program: 2018 Annual During-Construction Monitoring Report.* Kitchener: More Than Engineering (MTE) Consultants Inc.

More Than Engineering (MTE) Consultants Inc. 2016. *Stauffer Woods Subdivision Phase 2, Stages 1-10 (Draft Plan 30T-08203) During Development Monitoring Program: 2015 Annual During-Construction Monitoring Report.* Kitchener: More Than Engineering (MTE) Consultants Inc.

More Than Engineering (MTE) Consultants Inc. 2017. *Stauffer Woods Subdivision Phase 2, Stages 1-10 (Draft Plan 30T-08203) During Development Monitoring Program: 2016 Annual During-Construction Monitoring Report.* Kitchener: More Than Engineering (MTE) Consultants Inc.

More Than Engineering (MTE) Consultants Inc. 2018. *Stauffer Woods Subdivision Phase 2, Stages 1-10 (Draft Plan 30T-08203) During Development Monitoring Program: 2017 Annual During-Construction Monitoring Program.* Kitchener: More Than Engineering (MTE) Consultants, Inc.

More Than Engineering (MTE) Consultants Inc. 2014. *Stauffer Woods Subdivision Phase 2, Stages 1-8 (30T-08203) Final Stormwater Management Report (SWM Facilities 1,2 and 3).* Kitchener: More Than Engineering (MTE) Consultants Inc.

Parish Aquatic Services. 2014. *Blair Creek Geomorphic Monitoring Study.* Monitoring Results, Mississauga: Parish Aquatic Services.

Province of Ontario. 1994. "Water management: policies, guidelines, provincial water quality objectives." https://www.ontario.ca/page/water-management-policies-guidelines-provincial-water-quality-objectives.

Region of Waterloo. 2015. *Regional Official Plan (to 2031).* Waterloo: Approved by Ontario Municipal Board. https://www.regionofwaterloo.ca/en/regional-government/land-use-planning.aspx.

Region of Waterloo. 2003. *Long Term Water Strategy - Phase III Report.* Volume 1, August 2003.

Richter, Brian D., Jefferey V. Baumgartner, Robert Wigington, and David P. Braun. 1997. "How much water does a river need?" *Freshwater Biology* 231-249.

SCS Consulting Group Ltd. 2016. *Dodge Drive Ltd. (Plan 30T-07204) Stages 2 and 3.* Kitchener: SCS Consulting Group Ltd.

Stantec Consulting Ltd. 2009. *Upper Blair Creek (Kitchener) Functional Drainage Study Final Report.* Kitchener: Stantec.

Stoneman, C. L., and M. L. Jones. 1996. "A Simple Method to Classify Stream Thermal Stability with Single Observations of Daily Maximum Water and Air Temperatures." *North American Journal of Fisheries Management* 16 (4): 728-737.

The Nature Conservancy. 2018. *Indications of Hydrologic Alteration (IHA).* https://www.conservationgateway.org/ConservationPractices/Freshwater/EnvironmentalFlows/MethodsandTools/IndicatorsofHydrologicAlteration/Pages/indicators-hydrologic-alt.aspx#:~:text=Indicators%20of%20Hydrologic%20Alteration%20(IHA)%20is%20a%20software%20p.

Water's Edge Environmental Solutions Team. 2020. *Blair Creek Stream Morphology Monitoring Program.* 5-Year Monitoring Report, Cambridge: Water's Edge Environmental Solutions Team.

(WSP 2015, 2016, 2017, and 2018) – ecological monitoring reports

Appendix A. Surface Water

See companion files.

Appendix B. Groundwater

See companion files.

Appendix C. Geomorphology

See companion files.