City of Guelph

Clythe Creek Subwatershed Study Update

Draft Phase 1 Characterization Report

July 25, 2025

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WSP E&I Canada Limited
3450 Harvester Road
Burlington, ON
Canada L7N 3W5

wsp.com

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Prepared By	Reviewed by	Approved By
Abhi Patel and Amin Azarkhish, Project Engineers, Water Resources Eeshan Kumar, Senior Project Engineer, Water Resources Subconsultant Team Listed	Steve Chipps, (former) Project Manager, Water Resources	Matt Senior, Senior Manager, Water Resources

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Prepared By	Reviewed by	Approved By
Abhi Patel and Amin Azarkhish, Project Engineers, Water Resources Eeshan Kumar, Senior Project Engineer, Water Resources Subconsultant Team Listed	Matt Senior, Senior Manager, Water Resources	Matt Senior, Senior Manager, Water Resources

Revision 2: <Date>, <Remarks>

Prepared By	Reviewed by	Approved By
<name, title>	<name, title>	<name, title>

Final: <Date>, <Remarks>

Prepared By	Reviewed by	Approved By
<name, title>	<name, title>	<name, title>

Signatures

Prepared by (WSP Contributors)

DRAFT

Amin Azarkhish, M.A.Sc., P.Eng. — Date
Water Resources Engineer

DRAFT

Abhijeet Patel, M.Eng., P.Eng. — Date
Water Resources Engineer

DRAFT

Eeshan Kumar, P.Eng., PMP — Date
Senior Water Resources Engineer

Approved[1] by

DRAFT

Matt Senior, M.A.Sc., P.Eng. — Date
Senior Manager, Water Resources

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Lead Contributors

City of Guelph Reviewers

Project Manager	Leah Lefler
Project Advisor	Jane Gurney
Water Resources Modelling Advisor	Anindita Datta
Water Resources Modelling Advisor	Tara Roumeliotis
Infrastructure Planning Advisor	Colleen Gammie
Groundwater Resources Advisor	Emily Stahl
Groundwater Resources Advisor	Albanie Douglas
Ecology Advisor	Ryan Hamelin
Ecology Advisor	Karen Reis
Development Engineering Advisor	Michelle Thalen

Lead Consulting Team: WSP

Manager, Water Resources	Matt Senior
Senior Project Engineer, Water Resources	Eeshan Kumar
Project Engineer, Water Resources	Amin Azarkhish
Project Engineer, Water Resource	Abhijeet Patel
Senior Technologist, Water Resources	Richard Bartolo
Report Formatting and Accessibility	Melinda Nowak

Lead Contributors

Subconsultants

Project Advisor, Scheckenberger & Associates Ltd.	Ron Scheckenberger
Natural Systems and Engagement Lead, Grounded Solutions	Margot Ursic
Aquatic Ecology Lead, C. Portt and Associates	Cam Portt
Groundwater Advisor, Blackport and Associates	Bill Blackport
Groundwater, Montrose Environmental	Daron Abbey
	Christian Gabriel
	Simon Martin
Fluvial Geomorphology, Montrose Environmental	John McDonald
	Roger Phillips
Aquatic Ecology, Montrose Environmental	Kierian Keele
	Shari Muscat
Natural Systems, Dougan and Associates	Steve Hill
	Christina Olar
	Janel Sauder

City of Guelph's Territorial Acknowledgement

As we gather, let us take time to reflect on our privilege to live and work in Guelph; a city built over rich Indigenous histories. We are guests here, and we should reflect upon the responsibility to care for this land, the people who live here today, and the generations to come. If our actions today can move us towards reconciliation, we should take pause and make those decisions with intention and gratitude.

This place we call Guelph has served as traditional lands and a place of refuge for many peoples over time, but more specifically the Attiwonderonk, and the Haudenosaunee. This land is held as the treaty lands and territory with the Mississaugas of the Credit First Nation. Guelph lies directly adjacent to the Haldimand Tract and is part of a long-established traditional hunting ground for the Six Nations of the Grand River. Many First Nations, Inuit, and Métis peoples who have come from across Turtle Island call Guelph home today.

Study Acknowledgements

This study has involved extensive support and guidance from the City of Guelph, as well as input and guidance from the Grand River Conservation Authority (GRCA), County of Wellington, Guelph-Eramosa Township and the Technical Advisory Group (TAG) established for this Subwatershed Study Update. Indigenous Nations and Peoples, and diverse local organizations and community members have also been engaged and provided feedback at key points in the study process. Special thanks are extended to the following TAG members who volunteered many hours to provide valuable technical review and input throughout the study process:

Amanjot Singh, Senior Engineer, Credit Valley Conservation (CVC)

Charles Cecile, retired Naturalist

Chris Denich, Consultant, Aquafor Beech Limited

Dr. Hugh Whiteley, Adjunct Professor

Phil James, Senior Manager, Integrated Water Management, CVC

Mike White, Senior Scientist, Ecoreg Solutions

Colin Oaks, Aquatic Ecologist at Hamilton Conservation Authority

Hugh Handy, Planner and Vice President, GSP Group

Imran Khan, Senior Geomorphologist, Momentum Earth Sciences

Tony Elias, Senior Engineer and Project Manager, Crozier Consulting Engineers

Yvette Roy, Program Manager, Ecosystem and Climate Change Strategies, CVC

Acronyms

ANSI	areas of natural and scientific interest
BMP	best management practices
CLI-ECA	consolidated linear infrastructure - environmental compliance approval
DEM	digital elevation modelling
EIS	environmental impact study
ELC	ecological land classification
HBI	Hilsenhoff biotic index
GID	Guelph Innovation District
GIS	geographic information systems
GPS	geographic positioning system
GRCA	Grand River Conservation Authority
HDF	headwater drainage feature
HVA	high vulnerability aquifers
IDF	intensity-duration-frequency
IPZ	intake protection zone
LID	low impact development
MBW	meander belt width
MMAH	Ministry of Municipal Affairs and Housing (Ontario)
MNR	Ministry of Natural Resources (Ontario)
MTO	Ministry of Transportation (Ontario)
NAD	North American datum
NHS	natural heritage system
OBBN	Ontario Benthos Biomonitoring Network
OMAFRA	Ontario Ministry of Agriculture, Food and Rural Affairs
OWES	Ontario Wetland Evaluation System

PPS	Provincial Planning Statement
PSA	Primary Study Area
PSW	provincially significant wetland
PTTW	permit to take water
SAR	species at risk
SGRA	significant groundwater recharge area
SSA	Secondary Study Area
SWH	significant wildlife habitat
SWM	stormwater management
SWMF	stormwater management facility
SWS	subwatershed study
SWSU	subwatershed study update
TAG	Technical Advisory Group (for this study)
UTM	universal transverse mercator
WaPUG	wastewater planning users group
WRS	water resource system

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1 Introduction

In 2022 the City of Guelph (the City) engaged a multi-disciplinary team led by WSP to undertake the Clythe Creek Subwatershed Study Update (SWSU).

A subwatershed study (SWS) involves a characterization of subwatershed conditions and includes groundwater, surface water, fluvial geomorphology, aquatic ecology and terrestrial ecology as explained in subsequent sub-sections.

The purpose of this study is to provide integrated management recommendations to support the protection, enhancement and restoration of the natural heritage system (NHS) and water resource system (WRS) in the study area.

You can find a concise and plain-language overview of this report under separate cover.

The study objectives[2] are to:

1. refine and confirm the Clythe Creek subwatershed boundary (i.e., the study area);
2. update regulatory floodplain mapping for Clythe Creek, Hadati Creek and Watson Creek in Guelph;
3. update the NHS mapping, including updates based on field studies in the PSA;
4. generate the WRS mapping for the study area, including WRS mapping in the PSA to inform implementation of the York-Elizabeth Land Use Study and Guelph Innovation District Secondary Plan in the City of Guelph;
5. inform and support the return to service of the Clythe Well as part of the City of Guelph's potable water infrastructure; and
6. identify management measures (including monitoring) intended to support the protection, enhancement and restoration of the NHS and WRS in the context of historic impacts, planned development and climate change, particularly within the PSA (i.e., the portion of the subwatershed within the City of Guelph);

With respect to Objective 1, refinements to and confirmation of, the Clythe Creek subwatershed boundary was completed as part of the background review and assessments, with the outcome presented in this Characterization Report. The updated subwatershed boundary is illustrated in Figure 1.1 and the difference between the updated and the original (i.e., 1998) boundary is illustrated in Figure 3.1.

[2] These objectives have been adapted from the original project Terms of Reference (2021) and refined to reflect the updated study Work Plan which was finalized in the summer of 2023.

The work to address Objectives 2 through 5 and the outcomes of this work are presented and summarized in this Characterization Report, with the supporting technical details available in a separate appendix (available from the City on request).

Objective 6 will be addressed as part of Phase 2 Impact Assessment and Management, which will be the subsequent and final deliverable for this study.

1.1 Why undertake a subwatershed study?

Watershed and subwatershed studies are critical foundational studies that are used to inform sustainable land use planning and, in the City of Guelph, to inform city-wide master plans. They take a technical and science-based approach to identifying management strategies to protect and enhance land and water-based resources within a given watershed or subwatershed over time. These studies are prepared using a multi-disciplinary approach involving the technical disciplines of groundwater, surface water, fluvial geomorphology, aquatic and terrestrial ecology and integrate engineering, land use planning and municipal resource management.

In addition to the technical and environmental justification for assessments at a watershed / subwatershed scale, the Province of Ontario's Provincial Planning Statement states that (MMAH, 2024):

- "Planning authorities shall protect, improve or restore the quality and quantity of water by: (a) using the watershed as the ecologically meaningful scale for integrated and long-term planning ..."
- "[L]arge and fast-growing municipalities [which include Guelph] shall undertake watershed planning to inform planning for sewage and water services and stormwater management, including low impact development, and the protection, improvement or restoration of the quality and quantity of water".

The City's Official Plan (February 2024, Consolidation) and Natural Heritage Action Plan (City of Guelph, 2018) also direct the use of subwatershed studies to inform land use planning.

1.2 What is the study area for the Clythe Creek subwatershed?

The Clythe Creek subwatershed of the Eramosa River and Blue Springs Creek watershed covers an area of 2,450 hectares (ha) and is located partially in the City of Guelph and partially in the adjacent County of Wellington (Figure 1.1).

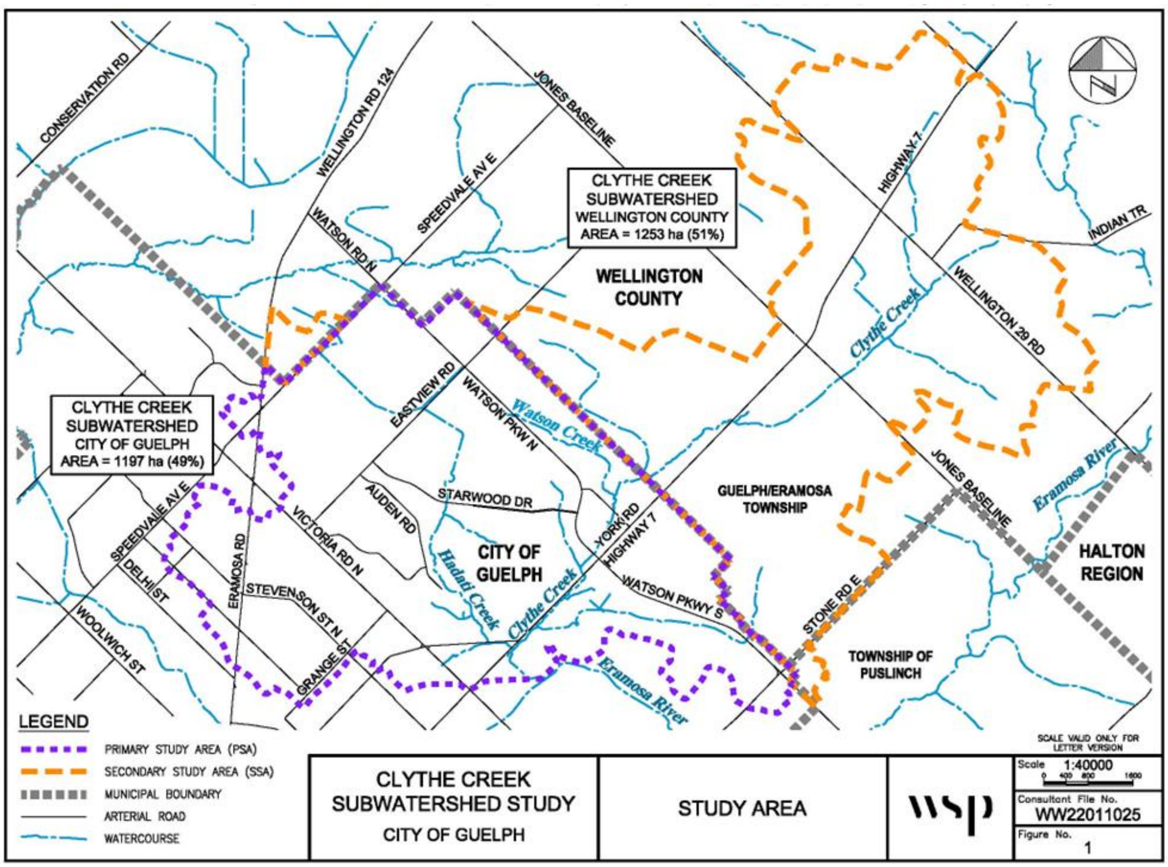
The study area for the SWSU includes the subwatershed plus lands within 100 metres of the subwatershed boundary. The study area is broken down into the Primary Study Area (PSA) and Secondary Study Area (SSA).

- The PSA corresponds to 49 per cent of the subwatershed (1,197 ha) located in Guelph.

- The SSA corresponds to 51 per cent of the subwatershed (1,253 ha) located in the County of Wellington in Guelph/Eramosa Township and Puslinch Township.

The subwatershed includes the drainage areas of Clythe Creek, Watson Creek and Hadati Creek, which drain to the Eramosa River, the Speed River, the Grand River and Lake Erie.

Figure 1.1: The Clythe Creek Primary Study Area (PSA) Secondary Study Area (SSA) and overall subwatershed boundary (i.e., the study area)



1.3 What is the approach and who is involved in the study?

The SWSU is being completed by a multi-disciplinary team including professionals from WSP, Montrose Environmental, Blackport and Associates, C. Portt and Associates, Dougan and Associates, Grounded Solutions and Scheckenberger & Associates. This multi-disciplinary team has collaborated to provide assessments of groundwater, surface water, fluvial geomorphology, aquatic ecology and terrestrial ecology. While the desktop and field-based work has been undertaken on a discipline-specific basis, the study approach has been integrative, with the various disciplines coordinating their assessments and findings. This approach provides a sound basis for understanding how the NHS and WRS) function, how they interrelate, and their sensitivity to land use changes and other stressors.

This study has taken an integrated, multi-disciplinary approach to the assessment of existing conditions and will take an equally integrative approach to the analytical modelling of water systems (ground and surface) to assess anticipated conditions to inform the impact assessment and identify mitigation and management measures (to be described in the Impact Assessment and Management Report).

Outside the consulting study team, this SWSU for Clythe Creek has also been guided and informed by input received from the Project Team (including City staff from various divisions, representatives from the Grand River Conservation Authority (GRCA), and representatives from the County of Wellington, Guelph/Eramosa Township and the Township of Puslinch, the Technical Advisory Group (TAG), high-level input from local Indigenous Nations and feedback from other local stakeholders and community members (Figure 1.2).

Figure 1.2: Clythe Creek Subwatershed Study Update (SWSU) governance structure

A summary of the input received through the Phase 1 Engagement for the SWSU is available under separate cover (City of Guelph, 2024b).

1.4 What are the study phases?

The SWSU consists of the following three phases:

Phase 1 – Characterization of Existing Conditions (this study report)

- Develop an updated characterization of the subwatershed area based on available background reports and data supplemented by desktop assessments and targeted field studies for groundwater, surface water, fluvial geomorphology, aquatic and terrestrial ecology to 2024.
- Complete a high-level comparison of conditions documented in the 1998 Clythe Creek Subwatershed Study (1998 SWS) and subwatershed conditions in 2024.
- Complete an integrated multi-disciplinary characterization of the subwatershed, including groundwater and surface water modelling, to identify a preliminary WRS and preliminary updated NHS based on the available data and information.

Phase 2 – Impact Assessment and Management

- Undertake groundwater and surface water modelling based on anticipated land use changes in the context of climate change.
- Based on the updated understanding of the subwatershed and the modelling outcomes, identify anticipated impacts to the WRS and NHS.
- Provide management recommendations to mitigate impacts and improve the conditions and function of the NHS and WRS.
- Provide guidance to the City and its stakeholders as how best to implement the study recommendations including future studies.
- Provide input to monitoring potential impacts related to land use change in accordance with existing and future monitoring programs including for the CLI ECA.

This Characterization Report includes the current planning context (Section 2), an overview of the Clythe Creek SWS conditions at the time of the first assessment in 1998 (Section 3), a comprehensive overview of current biophysical conditions in the subwatershed (Section 4), an integrated assessment of these conditions (Section 5), and a high-level comparison of the subwatershed status in 1998 and 2024 (Section 6).

This Characterization Report provides the planning context and technical basis for the Phase 2 Impact Assessment and Management report for the SWSU to follow.

2 Policy and planning context

Subwatershed goals, objectives, and targets must be developed in the context of applicable legislation, policy and guidelines, which provide the framework for assessing and managing environmental impacts associated with development and climate change.

The following sub-sections and tables provide an overview of the federal, provincial and municipal legislation, policy and guidelines that apply and their relevance to the Clythe Creek SWSU.

2.1 Federal legislation and guidelines

Table 2.1 provides a summary of federal legislation and guidelines applicable to the SWSU.

Table 2.1: Relevant federal legislation and guidelines

Federal document	General application	Relevance to the Clythe Creek Subwatershed Study Update
Fisheries Act (R.S.C. 1995)	The fish and fish habitat protection provisions of the Fisheries Act apply to all fish and fish habitat throughout Canada and include: • a prohibition against causing the death of fish, by means other than fishing (section 34.4) • a prohibition against causing the harmful alteration, disruption or destruction of fish habitat (section 35) • a framework of considerations to guide the Minister's decision-making functions (section 34.1) • ministerial powers to ensure the free passage of fish or the protection of fish or fish habitat with respect to existing obstructions (section 34.3) In addition, Section 36 of the Fisheries Act prohibits the deposit of a deleterious substance in water frequented by fish or in any place under any conditions where the deleterious substance or any other deleterious substance that results from the deposit of the deleterious substance may enter such water. The Fisheries Act defines fish habitat and regulates activities that may impact fish or their habitat.	The Clythe Creek subwatershed is known to support cold, cool and warm water fish habitat. Any potential changes to these habitats as a result of proposed infrastructure or land use changes need to be assessed in the context of the Fisheries Act and may only be permitted if they are in accordance with the requirements of this Act.
Migratory Birds Convention Act (S.C. 1994, c. 22)	Most species of birds in Canada are protected under this Act. It is to ensure the protection of listed migratory bird species, their nests, eggs and offspring. In its application, it requires best management practices to detect and avoid disturbance to active nests during development activities on public and private lands.	Many bird species protected under this Act occur within the Clythe Creek SWSU. Any potential impacts to these species as a result of proposed infrastructure or land use changes need to comply with the requirements of this Act.

Federal document	General application	Relevance to the Clythe Creek Subwatershed Study Update
Species at Risk Act (S.C. 2002, c. 29)	This Act is to prevent wildlife species in Canada from disappearing, to provide for the recovery of wildlife species that are extirpated (i.e., no longer exist in the wild in Canada), endangered or threatened, and to manage species of special concern to prevent them from becoming endangered or threatened. Listed aquatic species are protected in all waterways, while listed terrestrial species are only fully protected on federal lands. However, many of the federally listed species are also protected more broadly under the Province's Endangered Species Act (Table 3.2 below) and under the Provincial Planning Statement (PPS).	Several species regulated under this Act may or do have habitat within the Clythe Creek SWSU. However, the application of this Act is limited to aquatic Species at Risk (SAR) and terrestrial SAR on federal lands.
Canadian Water Quality Guidelines - Aquatic Life (updated periodically, see the Canadian Council of Ministers of the Environment website)	These guidelines (also referred to as the "CCME" guidelines) provide a set of recommended "safe limits" for various polluting substances in raw (untreated) drinking water, recreational water, water used for agricultural and industrial purposes, and water supporting aquatic life. They include 90 substance-specific guidelines for aquatic life that provide what are considered generally safe thresholds for aquatic species. These guidelines apply only to inland surface waters and groundwater (not to estuarine and marine waters).	These guidelines provide pan-Canadian scientifically-based thresholds that can be used to assess and monitor surface and groundwater quality from an aquatic health perspective in the study area.
Guidelines for Canadian Drinking Water Quality (updated periodically, see the Government of Canada website)	A series of guidelines based on current, published scientific research related to health effects, aesthetic effects and operational considerations. These guidelines provide maximum acceptable concentrations or treatment goals based on a comprehensive review of the known health effects associated with each contaminant, exposure levels, and the availability of treatment and analytical technologies. Aesthetic objectives are provided when they play a role in determining whether consumers will consider the water drinkable.	These guidelines provide pan-Canadian scientifically-based thresholds that can be used to assess and monitor surface and groundwater quality from a human use perspective in the study area.

2.2 Provincial policy and planning context

Table 2.2 provides a summary of provincial legislation and guidelines applicable to water resources.

Table 2.2: Relevant provincial legislation and guidelines pertaining to water resources

Provincial water resource document	General application	Relevance to the Clythe Creek Subwatershed Study Update
Environmental Protection Act (R.S.O.1990, c.E.19, s.3)	This Act is the primary pollution control legislation in Ontario and can be used interchangeably with the Water Resources Act. It prohibits discharge of any contaminants into the environment that cause or are likely to cause adverse effects to the natural environment or any person.	This Act regulates activities and substances that may be discharged into the water, land or air. As such it limits the types of activities that may affect the environment in the watershed and the types of changes that can be considered.
Lakes and Rivers Improvement Act (R.S.O. 1990, c.L.3)	This Act regulates the public and private use of Ontario's lakes and rivers, including the construction, repair and use of dams. The Act requires Water Management Plans from waterpower facilities to ensure environmental, social and economic concerns are addressed. The Act also prohibits the deposit of refuse, matter or substances into lakes and rivers that may impair water quality and/or quantity.	This Act regulates the types of changes that can be made to waterbodies. As such, it limits the types of changes that may be permitted to rivers and creeks in the watershed (e.g., introductions or removals of dams) and may influence management options and/or recommended monitoring.
Ontario Water Resources Act (R.S.O. 1990, c.O.40)	This Act focuses on both groundwater and surface water throughout the province. It regulates sewage disposal and sewage works and prohibits the discharge of polluting materials that may impair water quality. Permits to take more than 50,000 litres of water per day from ground or surface water sources are regulated under this Act. This Act also regulates well construction, operation and abandonment in addition to the approval, construction and operation of water works.	This Act regulates activities including water taking and potential pollution of surface and groundwater. As such, it regulates activities that may impact the quantity and/or quality of surface or groundwater resources and may influence management options and/or recommended monitoring.
Nutrient Management Act (S.O. 2002, c.4)	As part of the Ontario government's Clean Water Strategy, this Act provides Province-wide standards to address the effects of agricultural practices on the environment, especially as they relate to land-applied materials containing nutrients. This Act enhances protection of the natural environment and provide a sustainable future for agricultural operations and rural development.	This Act regulates activities and substances that may be discharged into the water, land or air as a result of agricultural practices. As such, it has more bearing on any recommendations for the Secondary Study Area where the land uses have been and are expected to continue to be largely rural and agricultural.
Clean Water Act (S.O.2006, c. 22)	This Act was established to protect Ontario's existing and future drinking water sources as part of an overall commitment to safeguard human health and the environment. A key focus of the legislation is the preparation of local Source Protection Plans.	The City of Guelph is one of the few communities in Ontario that relies exclusively on its groundwater resources for all potable water. One objective of this study is to inform and support the return to service of the Clythe Well as

Provincial water resource document	General application	Relevance to the Clythe Creek Subwatershed Study Update
	The goal of these plans is to eliminate and/or manage existing significant water quantity and quality threats and to ensure no future drinking water threats become significant. According to the Act, Source Protection Plans must include policies and programs to (a) eliminate and/or manage existing significant threats and (b) ensure no future activities become significant drinking water threats. These can apply to activities in Wellhead Protection Areas (WHPAs) and Intake Protection Zones (IPZ). This Act includes specific regulations such as Ontario Regulation 287/07 which identifies 22 drinking water quantity and quality threat activities.	part of the City of Guelph's potable water infrastructure. This Act is a key consideration in framing and guiding the technical work and the related management guidance to achieve this objective.
Safe Drinking Water Act (S. O. 2002, c. 32)	Under this Act, all municipal drinking water systems must obtain approval from the Director of the Ministry of the Environment to operate, and operators must be trained and certified to provincial standards. The Act also provides a framework for testing with legally binding standards for contaminants in drinking water and the mandatory use of licensed and accredited laboratories for drinking water testing. It includes specific regulations such as Ontario Regulation 169/03 which prescribes Ontario Drinking Water Quality Standards.	As noted above, the City of Guelph is one of the few communities in Ontario that relies exclusively on its groundwater resources for all potable water and one objective of this study is to inform and support the return to service of the Clythe Well as part of the City of Guelph's potable water infrastructure. This Act is another key consideration in framing and guiding the technical work and the related management guidance to achieve this objective.
Provincial Water Quality Objectives (MOEE, 1994)	This document contains provincial guidelines for the management of Ontario's water resources, including direction on how to manage the quality and quantity of both surface and ground waters for the protection of aquatic life.	These guidelines provide scientifically-based thresholds for Ontario that can be used to assess and monitor surface and groundwater quality from an aquatic health perspective in the study area.
Stormwater Management Planning and Design Manual (MOE, 2003)	This technical manual provides guidance on sizing, designing, implementing, and monitoring stormwater management measures.	These guidelines are an important consideration in framing management guidance related to stormwater management in the study area, and particularly the Primary Study Area.

The Planning Act and Provincial Planning Statement (PPS) (MMAH, 2024) are two primary drivers of environmental planning policy direction in Ontario, with the PPS including specific direction related to the requirement for watershed planning, as well as protection of WRSs and NHSs.

The PPS direction is intended to be supported by guidance documents including the Watershed Planning in Ontario Guidance for land-use planning authorities (GOO, 2018, Draft) and the Subwatershed Planning Guide (MECP, 2022, Draft). However, these guides remain in draft hence their use is conditional, and practitioners need to apply overall industry best practices when conducting subwatershed planning studies.

GRCA is the local conservation authority for the City of Guelph. GRCA provides mapping of regulated areas and makes this information publicly available on their website. GRCA policies were updated and approved by the GRCA Board of Directors on May 24, 2024 to align with the updated provincial regulations (i.e., O. Reg. 41/24)114. GRCA remains an important partner in watershed planning and management, including being a key partner for this project, and consultation with GRCA is required on all matters within the regulated areas including potential or confirmed wetlands, areas of interference or hazardous lands.

Table 2.3 provides a summary of provincial legislation and guidelines applicable to land use planning, subwatershed planning and the protection of natural heritage and water resources.

Table 2.3: Relevant provincial legislation and guidelines pertaining to environmental planning

Provincial environmental planning document	General application	Relevance to the Clythe Creek Subwatershed Study Update
Planning Act (R.S.O. 1990, c. P. 13)	This Act governs land use planning in Ontario. It describes how land uses may be controlled and who may control them. The purpose of this act is to promote sustainable economic development in a healthy natural environment, as well as to provide a land use planning system led by provincial policy. The Act is intended to be implemented through application of the Provincial Planning Statement (MMAH, 2024). The Ontario Planning Act provides the framework for land use planning in the province, and watershed planning, a key component of land use planning, is guided by this Act.	Municipalities, as planning authorities, are responsible for incorporating watershed planning into their land use planning processes, often with the assistance of Conservation Authorities. This Act is a key driver of the primary purpose for this SWSU – to provide integrated management recommendations to support the protection, enhancement and restoration of the NHS and WRS in the study area. This Act also strongly supports the collaborative approach to this work.
Provincial Planning Statement (MMAH, 2024)	The PPS is issued under the authority of the Planning Act, which requires decisions affecting planning matters to be consistent with policy statements under the Act. The 2024 PPS includes policies and definitions related to watersheds, water resources, natural heritage and natural	The policies in the 2024 PPS provide the overarching policy framework for the identification of the WRS and NHS in the City and the County, which they implement through their Official Plans. Policies particularly relevant to this study specifically related to watershed planning including the following:

Provincial environmental planning document	General application	Relevance to the Clythe Creek Subwatershed Study Update
	hazards, as well as stormwater management. As stated in the 2024 PPS: "The policies of the Provincial Planning Statement represent minimum standards. Within the framework of the provincial policy-led planning system, planning authorities and decision-makers may go beyond these minimum standards to address matters of importance to a specific community, unless doing so would conflict with any policy of the Provincial Planning Statement."	• 4.2.1 "Planning authorities shall protect, improve or restore the quality and quantity of water by: (a) using the watershed as the ecologically meaningful scale for integrated and long-term planning, which can be a foundation for considering cumulative impacts of development;" • 4.2.3 "Municipalities are encouraged to undertake, and large and fast-growing municipalities shall undertake watershed planning to inform planning for sewage and water services and stormwater management, including low impact development, and the protection, improvement or restoration of the quality and quantity of water." • 4.2.5 "All municipalities undertaking watershed planning are encouraged to collaborate with applicable conservation authorities."
Endangered Species Act (S.O. 2007, c. 6) Note: With Bill 5 passing royal assent, changes to the Endangered Species Act are forthcoming.	This Act controls the protection of species identified and listed as endangered, threatened or special concern at the provincial level. Significant habitats of provincially endangered and threatened species are protected through this legislation, while the habitats of provincial species of special concern are afforded protection through the significant wildlife habitat policies in the PPS, and the supporting ecoregional criteria schedules.	Several species regulated under this Act may or do have habitats within the Clythe Creek SWSU. Any potential impacts to these species or their critical habitats as a result of proposed infrastructure or land use changes may only be permitted if they are in accordance with the requirements of this Act. Although there are exemptions and further changes being proposed, this Act remains the primary legislative tool for protecting endangered and threatened species identified in the Clythe Creek subwatershed.
Watershed Planning in Ontario Guidance, Draft (GOO, 2018) Note: Still under review ERO website number 013-1817	This guideline is intended to support municipalities in watershed planning throughout Ontario, and to support the implementation of the applicable provincial land use plans. The guideline includes: the context of watershed planning, engagement approaches including consideration of Indigenous perspectives, approaches	This is a guidance document that remains in draft form. It includes some valuable guidance that has informed the engagement planning and continues to inform the framework for this study.

Provincial environmental planning document	General application	Relevance to the Clythe Creek Subwatershed Study Update
	and best practices for watershed characterization, approaches for setting a direction (i.e., vision, objectives, goals, targets), and guidance on how to develop a plan including monitoring and adaptive management.	
Subwatershed Planning Guide, Draft (MECP, 2022) Note: this document is still under review https://ero.ontario.ca/notice/019-4978	This draft guide supersedes the 1993 provincial guidance and promotes a more consistent subwatershed planning approach across Ontario, leading to better coordinated and more efficient planning processes. It includes a general framework for subwatershed planning and provides information related to roles and responsibilities amongst agencies; the purpose and principles of subwatershed planning; recommended steps, approach, and best practices for undertaking subwatershed planning; best practices for stakeholder and Indigenous community engagement in the subwatershed planning process; and some key technical tools and considerations to support subwatershed planning.	This is also a guidance document that remains in draft form. Nonetheless, like the document above it includes some valuable guidance that has informed the engagement planning and continues to inform the framework for this study.
Municipal Act (S.O. 2001, c. 25)	The Municipal Act provides municipalities in Ontario with a range of powers related to public utilities such as water supply and the natural environment, specifically related to tree by-laws and site alteration.	In the Clythe Creek SWS, the County of Wellington is an upper-tier municipality while the City of Guelph is a single-tier municipality, so both are afforded comparable municipal powers under this Act. This underscores the need for a collaborative and consultative approach to planning in this subwatershed.
Conservation Authorities Act (R.S.O. 1990, c. C.27)	This act was recently amended (with Ontario Regulations 596/22, 474/24 and 41/24). The amended Act maintains the advisory role of conservation authorities as it pertains to natural hazards on Planning Act applications. It also reaffirms their regulatory role related to activities within wetlands, the areas of interference associated with wetlands, hazardous lands, river or stream valleys and other areas determined by the regulations.	In Guelph, the City and GRCA have entered into a Memorandum of Understanding to document the terms and conditions for the programs and services to be performed by the GRCA on behalf of the City, as required by the Act for non-mandatory programs and services.

Provincial environmental planning document	General application	Relevance to the Clythe Creek Subwatershed Study Update
Policies for the Administration of the Prohibited Activities, Exemptions and Permits Regulation Ontario: Regulation 41/24 (GRCA, 2024)	This provincial regulation allows the conservation authorities, including the GRCA, to prohibit or regulate development in or adjacent to shorelines, wetlands, floodplains, watercourses, valleys, dynamic beaches and hazard lands.	In the Clythe Creek SWSU, GRCA is an active Project Team member and has a special technical role in reviewing and commenting on updated floodplain mapping, wetland mapping, surface and groundwater modelling, and overall watershed management recommendations coming out of this work. Further, the results of the Clythe Creek SWSU will be used to update GRCA's Regulation Mapping (e.g., wetlands and floodplain limits).
Natural Heritage Reference Manual (MNR, 2010)	Although the guidance document was originally developed to help implement the 2005 PPS, it remains the most current and applicable provincial guidance for the implementation of the natural heritage policies of the PPS by planning authorities. This manual includes guidance for how to identify and evaluate the various components of natural heritage systems as listed in the PPS (e.g., significant wetlands, significant woodlands, significant valleylands, significant wildlife habitat, etc.) as well as how to consider linkages between these components as well as linkages to water resources.	Although both the County and the City have identified and defined the various components of their respective natural heritage systems, the Natural Heritage Reference Manual provides guidance that can help them defend and, if needed, update their natural heritage system components.
Significant Wildlife Habitat Technical Guide (MNR, 2000) and Criteria Schedule for Ecoregion 6E (MNR, 2015)	The Significant Wildlife Habitat Technical Guide supports the Natural Heritage Reference Manual by providing supplemental Province-wide guidance on the identification of the various types of significant wildlife habitat (SWH). The ecoregional criteria then supplement the SWH Technical Guide with specific species and/or thresholds for identifying candidate versus confirmed SWH types for different ecoregions in Ontario.	The SWH Technical Guide and the supporting Criteria Schedule for Ecoregion 6E are directly applicable to this study as Clythe Creek subwatershed falls within Ecoregion 6E. The technical guidance in both these documents, in conjunction with the relevant policies in the County's and City's Official Plans, have been used to identify candidate and confirmed SWH.
Ontario Wetland Evaluation System Southern Manual, 4th edition (MNR, 2022)	This technical manual defines wetlands and provides detailed technical guidance for their boundary delineation and evaluation to confirm their significance (i.e., provincially significant or non-provincially significant).	Despite substantial changes in 2022, this system remains the standard for identifying, confirming or updating mapping of provincially significant wetlands (PSW) in this watershed and throughout southern Ontario.

2.3 Municipal policy and planning context

The portion of the Clythe Creek subwatershed outside the City of Guelph, is mainly in Guelph/Eramosa Township with a small portion in Puslinch Township (Figure 1.1). The County of Wellington is the applicable authority for setting water resource and natural heritage system policies in both townships. Wellington County is currently completing an Official Plan Review to update its Official Plan policies to prepare for planned growth and to ensure the Official Plan supports healthy, compact and complete communities. Based on discussions with County Planners, at this time, policy modifications made through the Official Plan Review are not expected to impact the lands within the SSA significantly. The County has indicated that the current and in effect policies and mapping related to natural heritage and water remain the most current and applicable policy framework.

Table 2.4 provides a summary of the key documents that provide environmental planning direction at the municipal level, and the relevance of these documents.

Table 2.4: Applicable environmental planning direction at the municipal level

Regional or municipal document	General application	Relevance to the Clythe Creek Subwatershed Study Update
Wellington County Official Plan (1999, July 2024 Consolidation)	An Official Plan is a statutory document under the Ontario Planning Act that sets out land use policy to guide future development and to manage growth. It provides a policy framework for the Council of Wellington County to make decisions regarding the use of land, the provision of municipal services required to support growth, and the phasing of development.	Half of the subwatershed is located in the County of Wellington. The natural heritage and water resource system policies of the County's Official Plan provide direction for the SSA.
City of Guelph Official Plan (1994, February 2024 Consolidation)	Guelph's Official Plan is a statutory document under the Ontario Planning Act that sets out land use policy to guide future development and to manage growth. It provides a policy framework for the Council of Guelph to make decisions regarding the use of land, the provision of municipal services required to support growth, and the phasing of development. Guelph's Official Plan includes policies and definitions related to identification and protection of both its WRS – Section 4.2 - and NHS – Section 4.1. Section 4.1.6 of the Official Plan provides policies for trees in the urban forest outside the NHS (e.g., to ensure that where tree removals are permitted, tree canopy cover is replaced). Section 4.1.7 of the Official Plan provides policies that support monitoring of both the NHS and the	Policies and definitions related to the City's WRS and NHS have been primary drivers in how these systems are being identified in this study, particularly within the PSA (see Table 2.5 below). The Clythe Creek SWSU has also assessed and will address both impact assessment and management recommendations related to the WRS, NHS and trees outside the NHS, including recommendations related to monitoring and stewardship.

Regional or municipal document	General application	Relevance to the Clythe Creek Subwatershed Study Update
	urban forest in the City through stewardship and partnerships.	
Guelph-Guelph/Eramosa Water Quantity Policy Development Study: Threats Management Strategy (Matrix, 2018)	The Threats Management Strategy consists of a recommended set of risk management measures designed to achieve the overall goal of maintaining the supply of drinking water for the City of Guelph and Guelph/Eramosa Township. The strategy identifies the risk management measures that were identified to be most likely effective at reducing water quantity impacts to municipal wells in the WHPA-Q. The Threats Management Strategy expands on each of these recommended measures and describes what could be done to maximize the benefits of each.	This Strategy includes information that is directly relevant to some of the technical considerations and recommendations related to drinking water in the Clythe Creek study area.
City of Guelph Stormwater Management (SWM) Master Plan Update (Aquafor Beech, 2023)	The City of Guelph's SWM Master Plan is a comprehensive strategy for managing stormwater within the city's boundaries. It guides the City's SWM infrastructure and policies for the next 20 to 30 years, ensuring that stormwater management practices align with the city's growth and development. The plan addresses infrastructure needs, prioritizes recommended works, and establishes policies and guidelines to meet future challenges.	The SWM Master Plan has assessed the drainage and stormwater management for the existing developed areas within the PSA. Modelling from the SWM Master Plan has been built upon within the PSA.
City of Guelph Final Water Supply Master Plan (AECOM, 2022)	The 2022 WSMP provides an update to the 2014 WSMP and covers a 30-year period from 2021 to 2051 to align with the Provincial Growth Plan, A Place to Grow: Growth Plan for the Greater Golden Horseshoe (amended in August 2020), and the update to the City's Official Plan.	Groundwater modelling, which is the basis of water quantity assessments, has been used in developing the conceptual and integrated models for the Clythe Creek SWSU.
City of Guelph Development Engineering Manual (2023)	This Manual includes water balance requirements and use of LID BMPs, and maintenance of water balance components including recharge for all new developments as well as other SWM water quality and quantity control criteria.	This Manual includes requirements that will inform some of the management recommendations related to stormwater made through this study, particularly within the PSA.
Erosion and Sediment Control Guideline for Urban Construction (GGHCA, 2006)	This document was prepared by the Greater Golden Horseshoe Conservation Authorities for common usage to coordinate the response of various municipalities and agencies involved in land development, construction and water management. It focuses on erosion and sediment control plan requirements, as well as related considerations, inspections and performance monitoring.	This Guidelines includes technical guidance that will inform some of the management recommendations related to erosion control made through this study, particularly within the PSA.
City of Guelph Urban Forest Study (2019), Urban	These City-wide plans and documents provide guidance including a vision, objectives, targets and a suite of actions to achieve the established	These Plans includes technical information and guidance that will inform some of the

Regional or municipal document	General application	Relevance to the Clythe Creek Subwatershed Study Update
Forest Management Plan (2012) and Urban Forest Management Plan Update (2020)	objectives and targets related to the City's urban forest. These documents consider all treed areas in the City on public and private lands, both within and outside of wooded natural areas.	management recommendations related to the City's urban forest made through this study (i.e., within the PSA).
Natural Heritage Action Plan (City of Guelph, 2018)	This plan has been developed to support the implementation of Official Plan policy through actions that include watershed and subwatershed-based planning informed by scientific and technical information. Objective 6 of the plan is: "to use an ecosystem-based watershed planning approach to inform the identification, evaluation and management of the natural environment".	This Plan provides support for the use of the subwatershed as a meaningful and technically appropriate scale for informing sustainable land use planning.

** The GRCA currently has a Memorandum of Understanding (MOU) with the City of Guelph to provide non-mandatory programs and services under Section 21.1.1 of the Conservation Authorities Act, including providing technical review and support in watershed and subwatershed studies.

City of Guelph Official Plan: Water Resource System and Natural Heritage System

While all the municipal documents listed in Table 2.4 above are relevant to the Clythe Creek SWSU, the policies and definitions in the City's current and in effect Official Plan are particularly relevant and therefore are described in more detail below.

The protection, conservation and enhancement of the City's water resources, both surface water and groundwater, are integral to sustaining the environmental, social and economic well-being of the community. The City has used a subwatershed-based planning approach to inform broader scale natural heritage, land use and infrastructure planning policy, and as part of this requires identification of a WRS.

The City emphasizes water resource protection and conservation, ensuring long term safety and security through the identification of potential quality and quantity threats to surface water and groundwater resources. Additional measures to protect the City's existing and future sources of water supply are provided in the Source Protection Plan, as required by the Clean Water Act (see Table 2.3).

Natural and human-made hazards pose threats to human health, safety and well-being. Natural hazards are naturally occurring processes that create unsafe conditions for development generally identified as flooding, erosion and unstable soils. Development or redevelopment is not permitted within the Regulatory Floodplain because of inherent dangers, such as loss of life, property damage and social disruption, should flooding occur, except in special circumstances where the general prohibition of new development or redevelopment in floodplain areas of historic communities is not practical.

The City's NHS, as also outlined in Guelph's Official Plan, consists of Significant Natural Areas and Natural Areas. Minimum or established buffers, where they exist, are also designated as part of the NHS (Schedule 2 and Schedule 4 of the Official Plan). Designation criteria and minimum buffer width requirements prescribed by Section 4.1 of the City's Official Plan are set out in Table 2.5 of the Official Plan.

The NHS and WRS policies in the City's Official Plan are a primary source of guidance and direction for the identification of and refinements to these systems in the Clythe Creek study area, as outlined in detail in this report.

Note: Key definitions and specific criteria for identifying the water resource system (WRS) and natural heritage system (NHS) in Guelph from the City's Official Plan are included in Section 8 (Glossary of key technical terms).

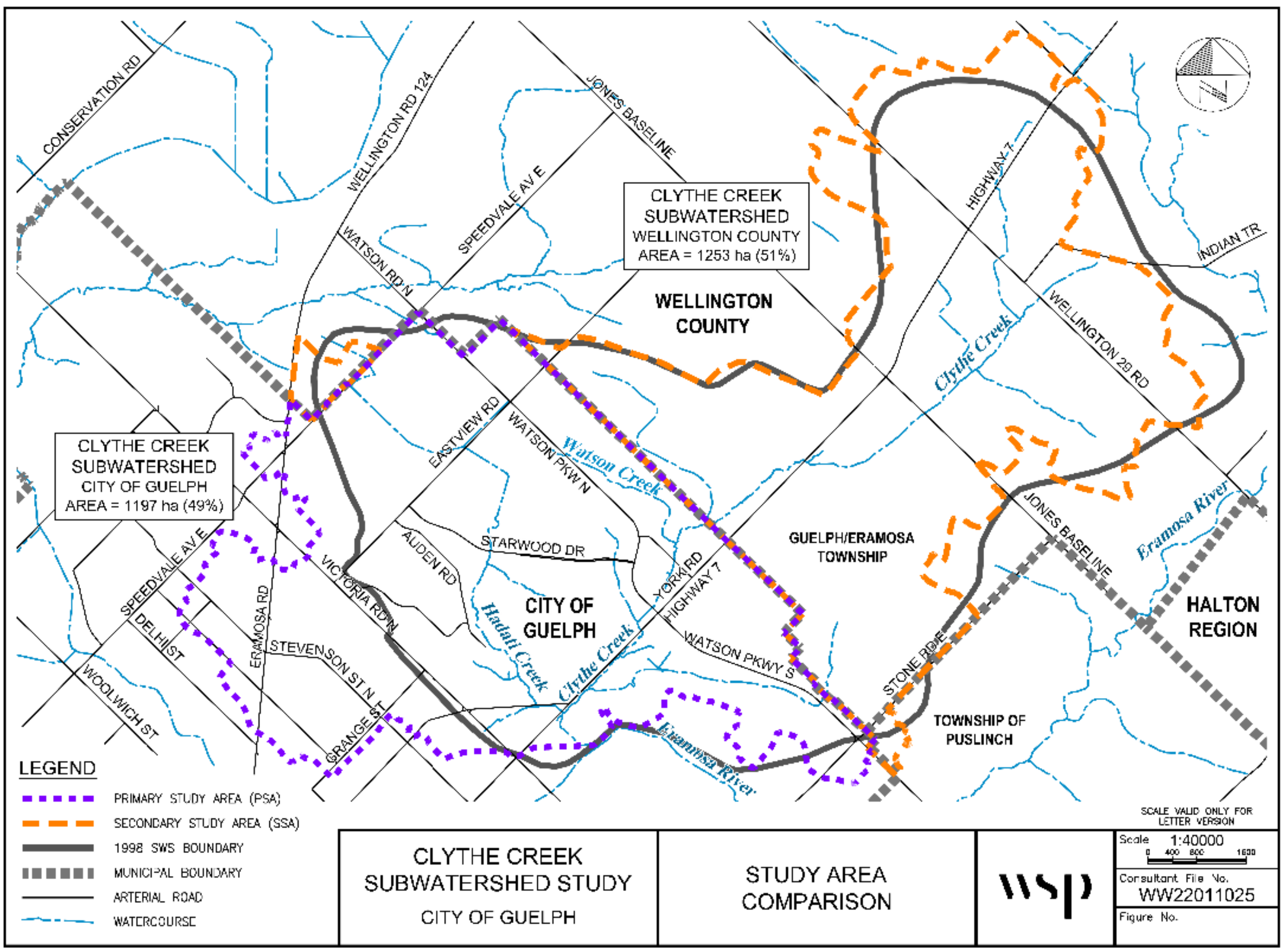
3 Historical subwatershed conditions: 1998

This section provides an overview of the conditions in the Clythe Creek subwatershed as they existed in 1998.

Section 6 provides a comparison and audit of the recommendations from the 1998 SWS to illustrate where progress has been made to present and where some work and perhaps adaptive management remains to be done.

The subwatershed boundary used for the 1998 SWS and the refined subwatershed boundary used in the SWSU are shown in Figure 3.1. The overall subwatershed boundary has been updated as part of the current study using current topographic data, which would generally be expected to be more resolute than the data available in 1998.

Figure 3.1: Clythe Creek subwatershed boundary in 1998 and 2024



3.1 Groundwater

The 1998 SWS was a desktop study based on available information at the time. The regional groundwater flow system was identified in a conceptual model (CM) however there was minimal discussion provided on recharge to this system and the importance and function of recharge in maintaining the municipal groundwater supply at existing wells (e.g. Helmar, Park, Emma and Clythe). The Clythe well had been active in 1997 and 1998 but was not discussed within the report.

The 1998 groundwater characterization identified both local and regional flow systems throughout the subwatershed and provided supporting recharge and discharge functions within the subwatershed.

In 1998, existing City Official Plan policy provided guidance for new developments to address issues related to recharge and stormwater management to encourage recharge to local and regional aquifers. As part of the policy, there was a requirement through development applications to characterize existing local and regional recharge conditions, the influence of municipal groundwater sources, and receiving water baseflow, temperature and fisheries potential, as well as potential impacts to these features, areas and systems from proposed development. The 1998 SWS was undertaken to provide subwatershed level characterization and provide guidelines to protect all resources, including local and regional groundwater systems, for site scale development proposals.

The 1998 SWS groundwater characterization was a desktop study informed by regional geological mapping, and groundwater resource studies examining potential bedrock water supplies throughout the City of Guelph (Jagger Hims 1995), which also included spot stream flow measurements taken in 1995 to estimate recharge and assess groundwater discharge contributions.

The groundwater characterization included the following:

- Classification of surficial and bedrock geology into hydrostratigraphic units:
    - Overburden: Port Stanley Till Aquitard and Outwash Sand Aquifer, and
    - Bedrock: Guelph Formation and Amabel Formation: Main aquifers.
- Identification and mapping of recharge-discharge areas based on material type (e.g. outwash sand), thickness and topography, and bedrock topography to identify linkages to stream reaches and other catchments.
- Identification of potentially sensitive recharge/discharge areas based on the recharge-discharge mapping (conceptual model) and findings from baseflow and aquatic habitat surveys.
- Aquifer contaminant susceptibility assessed based on overlying material thickness and hydraulic conductivity of the overlying materials.

As part of the 1998 SWS, the Jagger Hims (1995) spot baseflow data were analyzed to estimate average subwatershed recharge which was approximately 120 mm/year to 200 mm/year. Sand recharge was estimated to range from 250 to 300 mm/year while tills were closer to 120 mm/year on average.

The 1995 report notes that there were several human-made ditches flowing into Clythe Creek which modified the natural channels assumed to be located on the east side of the subwatershed, both within and outside the City, based on mapping in the report.

The 1998 SWS identified the following characteristics of the subwatershed groundwater flow system:

Clythe Creek - headwaters to ponds at the Correction Centre (1998 Catchments S1 to S6, S8, S10)

- primarily outwash with some fractured rock outcrops in the headwater areas, high potential for recharge and discharge to the stream
- recharge in areas supports discharge to Clythe Creek and associated riparian wetlands

  most groundwater flow towards Clythe Creek, but there is some southerly flow out of subwatershed to surrounding areas near boundaries of the subwatershed
- groundwater flow in upper bedrock expected to follow topography
- largest baseflow and potential to support coldwater fisheries

Clythe Creek - Correction Centre to Eramosa River (1998 Catchment S20)

- primarily outwash and shallow water table with high recharge and discharge
- groundwater flow toward Clythe and Eramosa
- developed area with some channel modifications
- no discussion of observed or measured groundwater discharge

Unnamed Tributary (1998 Catchment S7)

- land uses include the Former Reformatory Lands, airport, and agriculture
- thin permeable outwash in general, locally some thicker deposits
- groundwater flow likely directed to main Clythe tributary in west and Eramosa River in the east

Watson Creek Tributary (1998 Catchments S9, S11, S12)

- mostly agricultural in 1998
- primarily till and generally low recharge
- localized esker, sand deposits provide some recharge
- groundwater contributions to headwater wetland unknown

- Watson Creek had been piped to Hadati Creek previously to manage flows around the Former Eastview Landfill

Hadati Creek Tributary (1998 Catchments S13 through S19)

- undergoing development in 1998
- primarily till and lower recharge
- Watson Creek flow re-routed to Hadati Creek in 1998
- middle reaches potential small groundwater discharge
- recharge to bedrock aquifers expected with flow towards Clythe Creek

High priority groundwater areas associated with main tributary Clythe Creek outside the City and from Townline to York Road were identified where significant groundwater discharge was evident. The report acknowledged the need for detailed studies to better evaluate conditions and assess impacts from proposed developments.

As an outcome of the 1998 SWS, these high priority areas were mapped as Potentially Sensitive Recharge/Discharge Areas (Figure 4 in the 1998 SWS). Any proposed development in these areas would trigger detailed studies of these groundwater functions and potential impacts for a proposed development.

The key hydrologic function of groundwater based on the 1998 SWS was recharge supporting discharge areas mapped in "high priority" areas in the Clythe Creek. Together they are identified as Potentially Sensitive/Significant Recharge/Discharge Areas (i.e., key hydrologic areas and features).

3.2 Surface water

The 1998 SWS provided high level characterization of intermittent and permanent watercourses, with a focus on characterization of groundwater and aquatic and terrestrial ecological features. Characterization of watercourse reaches is provided on a reach-by-reach basis indicating what reaches were modified through lining and/or straightening.

The Clythe Creek subwatershed, including Hadati Creek and Watson Creek, was in various stages of development, with the Hadati Creek catchments being the most developed (Figure 4.2). Most of the existing development within the Clythe Creek subwatershed did not have stormwater management controls (i.e., quality and/or quantity) apart from the residential area under development on Hadati Creek contributing to SWMF #127 located at the rail corridor and the industrial area under development at Watson Parkway South that contributes to SWMF #38 (Map SW-4).

Flood hazards along part of Clythe Creek had been determined using the US Army Corps of Engineers HEC-2 which originated in 1986 as part of the Guelph Eastview Planning District Assessment. Regulatory flows were prorated from the 1988 Speed and Eramosa Study (based on calibrated GAWSER Hydrology). The Regional Storm floodplain, as determined from the HEC-2 modelling, was not available to represent the flood hazards along Clythe Creek for the 1998 SWS.

3.3 Fluvial geomorphology

The 1998 SWS completed fluvial geomorphological desktop and field assessments with a reach delineation and characterization extending through the PSA and SSA. The characterization captured observations including cross-section geometry, channel sinuosity, erosion sensitivity (method unknown), substrate type (general), vegetative cover, riparian width, and other observations detailed within reach descriptions. The reach delineation numbered reaches from upstream to downstream along Clythe Creek, Hadati Creek, Watson Creek, and an Unnamed Tributary. The following summarizes some key observations made through the 1998 SWS.

Erosion hazards were not delineated, nor were detailed field assessments (surveys) in support of erosion thresholds. The following provides an overview of the findings related to creek conditions and characteristics from the 1998 SWS.

Clythe Creek

The upper reaches of Clythe Creek are narrow, well vegetated and natural, with the headwaters located in a lowland cedar swamp surrounded by agricultural land whose runoff enters the creek through seasonal tributaries. However, the creek becomes impacted by ponds, open (unvegetated) sections, constructed weirs, and dams as it flows through Watson Road North, toward the confluence with Eramosa River approximately 6.0 kilometres (km) from the headwaters. At the downstream end of the creek, significant channel straightening has occurred, facilitating flow through numerous culverts and dams with cobble substrate before widening and ponding near the confluence.

From a cursory level survey of ten reaches in Clythe Creek, extending through the PSA and SSA, the range for bankfull width was found to be 1 metre (m) to approximately 11 m, channel depth from 0 m to 0.5 m, and sinuosity from 1.08 to 1.43. The 30.0 m bankfull width measurement was isolated to the reach immediately upstream of Jones Baseline, where it appears to be undefined through organic materials and a wide, wet area dominated by cattails. Substrate type included organic, silt, and gravel predominantly with rubble noted in one reach within the City. All reaches were deemed to have a stable channel state, though channel processes were noted with observations such as undercuts progressing along banks. Seventeen crossings were identified through the characterization, with 13 occurring within one reach (south side of York Road to about Reach CC-3 in the current study), which included culverts, weirs, and trickle-downs.

Hadati Creek

As a tributary of Clythe Creek, Hadati Creek drains an area of 390 ha (about 20 per cent) of the Clythe Creek subwatershed and has been divided into seven reaches along its approximately

3.3 km length. With its headwaters originating as a roadside ditch north of the Former Eastview Landfill, Hadati Creek flows through ditches and piping to accommodate crossings such as that at Eastview Road before ponding and displaying minimal flow due to beaver activity. It then travels through a developing area with dry conditions and evidence of construction (e.g., bare soil banks) before becoming concrete lined and straightened with little to no vegetation.

Modelled flows for the 5-year event showed an increase in the downstream direction from 0.9 m^3/s at the upper limits near the Former Eastview Landfill to 7.0 m^3/s downstream of Elizabeth Street. This reflects the impact of development and impervious surfaces in the lower reaches (Cosburn Patterson Wardman Ltd., 1991).

Reaches were numbered from upstream to downstream, while the current study has delineated reaches in the upstream direction, starting at the confluence (Section 4.3.2.1).

Seven reaches in Hadati Creek were surveyed, displaying a range for bankfull width of 1.0 to 3.0 m, channel depth from 0.02 to 0.15 m, and sinuosity of 1.0 to 1.38. Substrate type included organic, concrete, silt, and sand with noted algae growth. All reaches were deemed stable, with the exception of two, whose stability was unknown, and a riparian zone width range of 0.0 to 40.0 m. Finally, all but three reaches had no bridge or culvert crossings with two displaying one each and one displaying three.

Watson Creek

As a tributary to Clythe Creek, Watson Creek drains an area of about 103 ha (5 per cent) of the Clythe Creek subwatershed and was divided into four reaches along its 2.0 km length. Despite once originating from the Guelph Northeast Wetland complex, the headwaters of Watson Creek were diverted toward Hadati Creek through a disturbed gravel extraction area adjacent to the swamp, southeast under Watson Road, and through agricultural land with an approximately 40.0 m wide buffer strip of deciduous secondary growth. Headwaters now originate south of Eastview Road. The creek then joins Clythe Creek through an open marsh and old field area, where it exhibits some flow split due to low gradients and control from wetland vegetation.

A survey of the four reaches in Watson Creek revealed no range for bankfull width as the channel was noted as dry or inaccessible due to their intermittent nature, though the five-year flow in this area was calculated as 0.20 m^3/s. Channel depth, substrate, and stability were also not noted. Sinuosity ranged from 1.05 to 1.32, and one bridge or culvert crossing was observed. The width of the riparian zone was noted as 30.0 to 40.0 m.

Unnamed Tributary T3

Surface water features though the Former Reformatory Lands were identified as the Unnamed Tributary, T3 in the 1998 SWS. Upstream of the wet ponds, the feature width ranged from 1.0 to 5.0 m, with a depth of 0.3 m. The remainder of the Unnamed Tributary T3 was impacted with observed dams, pipes, and concrete lined segments. Stream bed definition disappears near the upper limit at Watson Road, and the channel was described as primarily intermittent and stable.

The SWSU has designated these reaches as Headwater Drainage Features (HDFs), with some portions to be confirmed as watercourses or HDFs (Section 5.3).

3.4 Aquatic ecology

In 1998, the Clythe Creek system was affected by on-line and off-line ponds that increased the water temperature and by other culverts, weirs, and dams. The creeks were also impacted by runoff from agricultural lands, roads, and stormwater from residential areas and industries. The lack of adequate buffers allowed for potentially polluted waters to enter the main creek. The habitat conditions in Clythe Creek and its tributaries (Watson Creek, Hadati Creek, Unnamed Tributary) from 1998 are presented below.

In the 1998 SWS, no fish sampling was conducted, no specifics regarding sampling by others were identified within Clythe Creek, and no fish community information was provided for the Clythe Creek tributaries. Another limitation is that no benthic invertebrate sampling was completed within Clythe Creek, Hadati Creek, Watson Creek, or the Unnamed Tributary in the 1998 SWS.

Aquatic habitat assessments were however completed for the 1998 SWS, as outlined below.

- Clythe Creek substrate type included organic material, silt, gravel, and rubble in 1998, as opposed to substrate observed in 2024 which ranged from soft sediment, sandy clay, sand (fine and medium), gravel, and cobble. Gravel, boulders, stone walls, and gabion baskets were also observed along the banks of the channel.
- Substrates were not recorded for the four reaches of Watson Creek that were investigated.
- Substrate within Hadati Creek included organic material, silt, sand, and concrete. In the 2024 study, substrate ranged from exposed bedrock/shale, sand, cobble, and boulders. Concrete stacked stone/pillow/sack walls and retaining walls were also observed along Hadati Creek. At the time of the 1998 SWS, agricultural lands were present north and south of Hadati Creek; however, residential areas and parks fell within the vicinity of the creek in 2024. New roadways such as Severn Drive, Fleming Road, and Creekside Drive, for example, were constructed since the 1998 SWS. Development in the vicinity of Hadati Creek has therefore increased since 1998.

Clythe Creek

The upper reaches of the creek were moderately well vegetated and the creek channel morphology was relatively natural. Dense cedar woods, swamp and marsh communities were found along the upstream portions of the creek. Towards Watson Road, the creek was altered in several ways, with ponds, open sections of creek, weirs and dams.

Downstream of the first CNR crossing, the creek flowed through some open areas. Watson Creek joined Clythe Creek upstream of Watson Road. Herbaceous meadow vegetation dominated this portion of the creek and it was open with little cover. The channel was quite meandering with small dimensions and the substrate was organic material.

Immediately downstream of Watson Road, the creek appeared to have been straightened and ran through an abandoned agricultural field with little cover. The substrate through this reach consisted of gravel and organic material. A dense cedar stand, which provided good cover and cooled the stream, was present farther downstream from Watson Road. Water temperature in this area ranged from 14.5°C to 20°C in the months of July and August (GRCA, 1995). Evidence of groundwater seepage was found which supplemented the baseflow and moderated water temperature. The MNR had identified this area as an important invertebrate production area.

South of Highway 7/York Road, the creek had been altered significantly, and it followed a fairly straight path on the south side of Highway 7. Several culverts and dams were present in this portion of the creek. Cobbles lined the bottom of the creek and the grass was mowed along the banks. Landscape trees provided occasional shady patches, but otherwise the creek was completely open in a park-like setting. Two large ponds and stormwater drains discharged into the creek.

Hadati Creek joined Clythe Creek just west of the intersection of Elizabeth Street and Highway 7. Downstream of the confluence with Hadati Creek the creek became wider and deeper with some ponded areas. It flowed through a shrubby area with silver maple and willow trees alongside playing fields.

Watson Creek

Historically, Watson Creek originated from the Guelph Northeast Wetland Complex, however, the construction of the Former Eastview Landfill resulted in flow from that area being permanently diverted to Hadati Creek.

Residential development was pending in the Watson Creek drainage area when the 1998 SWS was prepared. The upper reaches of the creek flowed through a disturbed gravel extraction area and then southeast under Watson Road and through agricultural fields. Clumps of willow provided patches of cover.

Further downstream the creek ran through active agricultural land with a buffer strip of deciduous secondary growth approximately 40 m wide. It then split and flowed through an open marsh and old field area before joining Clythe Creek.

The upper reaches of Watson Creek were dry during a field survey in August 1997.

Hadati Creek

Hadati Creek was channelized along most of its length and ran through a developing residential area. Hadati Creek originated as a roadside ditch north of the Former Eastview Landfill, was piped through the former landfill, and continued as a ditch along Eastview Road. The ditch was dry during 1997 field investigations completed as part of the 1998 SWS.

The ditch crossed under Eastview Road and flowed south to an area that was ponded due to beaver activity. Downstream of the pond, the creek flowed through a developing residential area. Most of this section was dry and there was sparse vegetation cover. The creek continued to Grange Road as a straightened concrete-lined channel, with mowed grass along the banks. Very little water was observed in the creek at the time of the field survey.

Downstream of Grange Road, the channel was undergoing construction. This reach of creek had been excavated and the banks were bare soil. A small tributary joined the creek from the west at the culvert under the CNR and it also had been cleared of vegetation.

Downstream of the rail line, the creek flowed through an existing urbanized area. The channel was fairly straight with some natural vegetation such as jewelweed, grasses and shrubs. The riparian strip was very narrow and the creek received flows from roadside ditches and from an urban area to the west. Hadati Creek joined Clythe Creek south of Highway 7.

Unnamed Tributary

An unnamed intermittent tributary originated in a woodlot south of the Guelph Transfer Station and flowed from the south through the two large Reformatory Ponds into Clythe Creek. This tributary varied in width from 1 m to 5 m and was approximately 0.3 m deep. Flow was intermittent and the substrate was organic material and silt. No natural riparian vegetation was observed and piped and/or concrete lined sections were present.

Fish communities and thermal regimes

As noted, no fish sampling was conducted as part of the 1998 SWS and no specifics regarding sampling by others were provided. The 1998 SWS reported that the MNR managed Clythe Creek as a coldwater stream that provided habitat for a range of species including brook stickleback (*Culaea inconstans*), creek chub (*Semotilus atromaculatus*), blacknose dace (*Rhinichthys a*tratulus), minnows (*Leuciscidae*), shiners (*Notropis* spp.), and brook trout (*Salvelinus fontinalis*). No fish community information was provided for the Clythe Creek tributaries.

The 1998 SWS stated that Clythe Creek was regarded as having coldwater fisheries potential. It was stated that ultimately it could provide habitat for coldwater species such as brook trout and brown trout (*Salmo trutta*), which were found in the Eramosa River. It was stated that the creek once supported a coldwater fish community and could once again support such a community if riparian corridors and groundwater inputs were maintained and rehabilitated.

Thermal regimes for Watson Creek, Hadati Creek, and the Unnamed Tributary were not outlined in the 1998 SWS.

3.5 Terrestrial ecology

The 1998 SWS included vegetation community mapping (but not using the ELC system which had not yet been published), species lists of flora and fauna, and subwatershed level recommendations related to natural heritage.

Approximately 10 per cent (218 ha) of the subwatershed area was naturally vegetated upland classified as: Old Field (109 ha), Upland Scrub (18.8 ha), Cedar Dominated Woods (12.8 ha), Mixed Deciduous Woods (28.7 ha), and Conifer Plantation (48.7 ha). Comparably, 7.5 per cent (156 ha) of the subwatershed area was identified as wetland consisting of 121 ha of swamp and 35 ha of marsh. Wetland communities largely consisted of: Deciduous Swamp (44.4 ha) and Cedar Dominated Swamp (60.2 ha). Other communities included: Tall Shrub Swamp, Alder/Aspen Swamp, Cattail Dominated Marsh, Narrow Emergent Marsh, Wet Meadow, Dead Tree Swamp, Submergent Marsh, and Seasonal Wetland. A total of 170 species of plants were identified of which 71 per cent were native.

The 1998 SWS wildlife studies documented a total of 57 bird species (most of which were assumed to be breeding in the area), nine mammals, three reptiles and amphibians. A total of 11 significant species were field verified through the 1998 SWS including three Species at Risk (SAR) and nine locally significant species (Table 3.1).

Table 3.1: Summary of significant wildlife species field-verified in the 1998 SWS based on 2024 status designations

Common Name	Scientific Name	SARA Status (2024)	SARO Status (2024)	S Rank	Wellington County (2009)**
Snapping Turtle	*Chelydra serpentina*	SC	SC	S3	
American Black Duck	*Anas rubripes*	---	---	S4	X
Pied-billed Grebe	*Podilymbus podiceps*	---	---	S4B,S4N	X
Ring-billed Gull	*Larus delawarensis*	---	---	S5B,S4N	X
Herring Gull	*Larus argentatus*	---	---	S5B,S5N	X
American Bittern	*Botaurus lentiginosus*	---	---	S4B	X
Least Bittern	*Ixobrychus exilis*	THR	THR	S4B	X
Great Blue Heron	*Ardea herodias*	---	---	S4	X
Turkey Vulture	*Cathartes aura*	---	---	S5B	X
Barn Swallow	*Hirundo rustica*	THR	SC	S4B	
Western Meadowlark	*Sturnella neglecta*	---	---	S3B	X

SARA = Species at Risk Act (federal), SARO = Species at Risk in Ontario, SC = Special Concern, THR = threatened
** Wellington County (Dougan & Associates, 2009); x = locally significant

3.6 Overview of land use changes: 1998 to 2024

The 1998 land cover within the subwatershed was dominated by agricultural lands in the County, built-up and undeveloped lands in the City, and approximately 10 per cent (218 ha) being naturally vegetated. Natural vegetation was concentrated in narrow lowland corridors along Clythe Creek and its tributaries as well as small, isolated pockets of upland woods and hedgerows found on farms and private properties.

The 1998 SWS pre-dated the Ecological Land Classification (ELC) system for southern Ontario (Lee *et al.,* 1998), so community descriptions noted in the study were converted to current ELC Community Series for comparison to 2024 conditions. The assessment and comparison of land covers between 1998 and 2024 has several caveats:

- Although the 1998 SWS and SWSU areas are slightly different sizes and extents, the current subwatershed boundary has been applied to allow the changes to be more comparable.
- Land cover mapping from GRCA from 1999, which spans the entire subwatershed and was the closest date available, and was used to compare the land cover conditions between 1999 and 2024.
- The 1999 GRCA dataset is coarse as it was based on more dated remote sensing techniques applied to 25 m resolution imagery.
- The classification approach was different in 1999 as no wetlands were mapped, with some assumed to have been captured in the forest areas and some appear to have been captured in the agricultural land class.

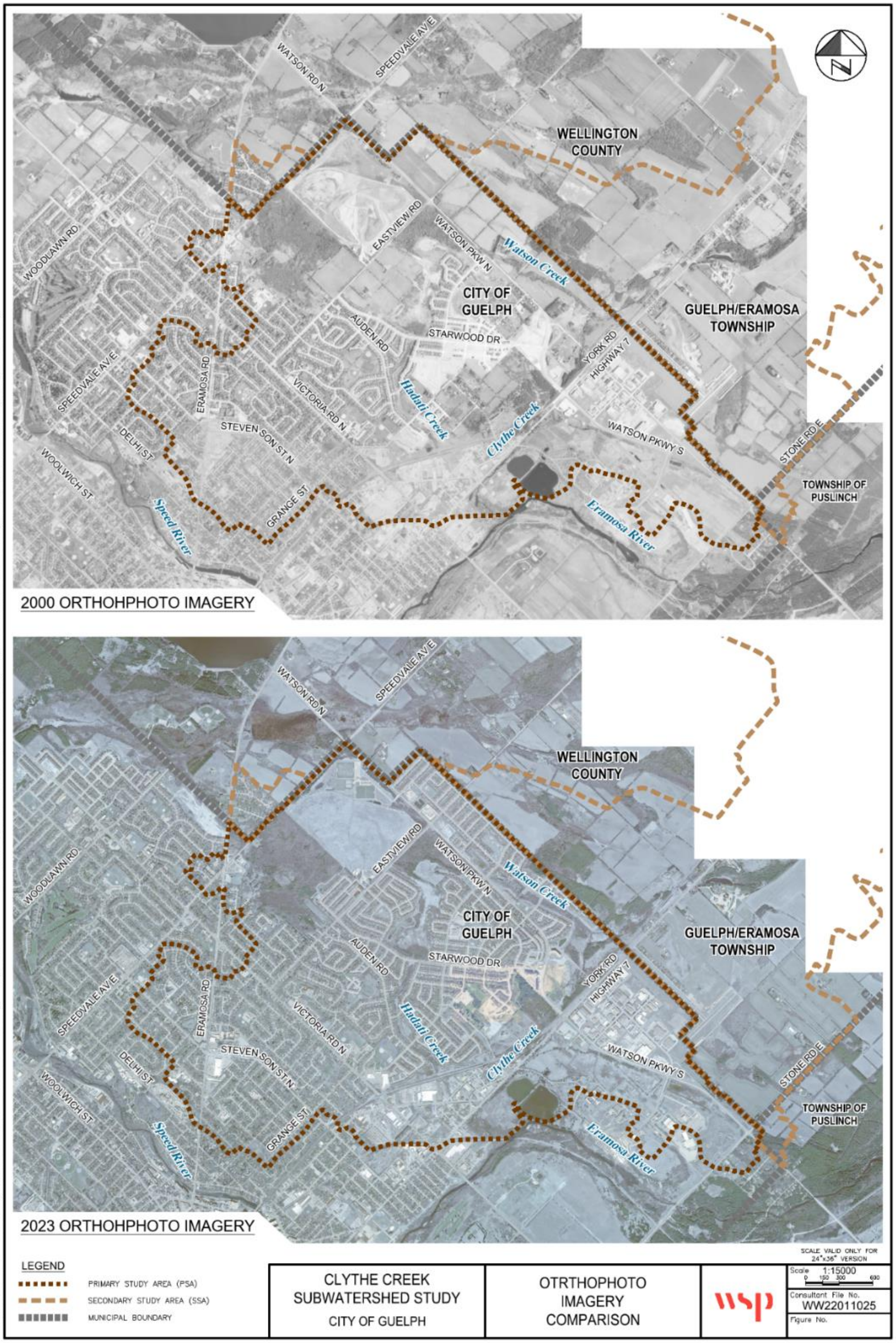
The results of this high-level comparison are provided in Table 3.2 and illustrated in Map TE-7.

Table 3.2: Summary of land cover change from 1998 to 2024**

Landcover Description	GRCA 1999 (in hectares)	2024 (in hectares)	Change from 1998 to 2024 (in hectares)
Anthropogenic	627.76	1012.9	385.1
Agriculture	1415.9	849.76	-566.1
Cultural Woodland/Cultural Savannah/Cultural Plantation	16.28	100.39	84.11
Cultural Meadow/Cultural Thicket	143.96	194.66	50.7
Aquatic	17.93	19.3	1.37
Forest/Wetland	228.5	273.38	44.88
Total	**2450.33**	**2450.33**	

** Note: The current subwatershed boundary was used for the purposes of this comparison.

Figure 3.2: Imagery of the portion of the subwatershed in the City 2000 and 2023



As shown in Table 3.2, it appears that natural, cultural, and anthropogenic land cover has increased in the subwatershed since 1999 (by about 100 ha) while aquatic cover has remained approximately the same. Agricultural lands have declined significantly, largely as a result of the transition to urban land uses, but in some cases due to lands being left fallow and naturalizing.

Similar trends are also apparent when looking at the historical and current air photos within the PSA, as shown in Figure 3.2 which shows imagery from 2000 (note 1998 orthophotography was not available) and 2023. As can be seen, the land use changes have occurred primarily within the east end of the PSA, with the conversion of mainly cultural meadows and agricultural areas to residential land uses north of Highway 7 and industrial land uses south of Highway 7 along Watson Parkway South.

The current conditions, described in detail in Section 5, are set within a largely, but not entirely, urbanized PSA and an SSA that has remained largely rural, as shown in Map TE-7.

4 Current subwatershed conditions: 2024

This section provides a comprehensive assessment of the current environmental conditions in the Clythe Creek subwatershed based on background reviews, desktop assessments and field studies completed between 2022 and 2024.

4.1 Groundwater characterization

Groundwater is a precious resource for the City of Guelph, as it both supplies the City's residential and industrial needs and supports the area's natural heritage systems and the overall health of the community. Increased groundwater demand, due to land use change, and climate change have the potential to stress the supply capacity and ecosystem functions and as a result, these stressors are some of the key drivers of the City's overall groundwater management efforts. The City's Water Supply Master Plan (WSMP) 2022c is updated every five to seven years to evaluate existing and potential new drinking water sources to align with the Provincial Growth Plan, A Places to Grow: Growth Plan for the Greater Golden Horseshoe (amended in August 2020, no longer in force and effect), and the updates to the City's Official Plan. The City has also developed source water protection policies that are part of the Grand River Source Protection Plan, which in turn is part of the Lake Erie Source Protection Region. The source water protection policies are developed to manage significant drinking water threats for water quantity and quality as defined in the Clean Water Act. Areas of interest for the City to add additional water supply to the existing drinking water system within the Clythe Creek SWS include the Clythe Well (currently permitted) and the Logan Test Well (WSMP, 2022c).

Existing Source Water Protection mapping (LERSPC, 2022a), analyses and policy protect groundwater quality and ecological functions of groundwater, based on the citywide understanding of these systems. The northeast quadrant of the City, including the Clythe Creek subwatershed, is one of the fastest growing parts of the City. The SWMMP (2022c) emphasizes the importance of existing municipal wells in the northeast quadrant, including the Clythe Well (currently offline) and Logan Test Well, to meet the current and future water demand to achieve provincial growth targets.

Based on background reports and existing data, the key hydrologic functions of groundwater in the Clythe Creek subwatershed are:

- Groundwater discharge through the shallow groundwater flow system at seeps, wetlands and stream features that support Significant Wildlife Habitat (SWH) and cool/cold-water habitat.
- Recharge to deep bedrock aquifers through local and regional groundwater flow systems which supplies drinking water to active municipal well features (Park, Emma and Helmar) to meet existing City-water supply demands.

- Recharge to overburden and shallow bedrock aquifers that provide water for existing domestic and agricultural well features, the majority of which are located in the SSA and in adjacent subwatersheds.

The objective of the groundwater characterization component of the SWSU is to:

1. Refine and quantify the understanding from the 1998 SWS of existing spatial and temporal (e.g. seasonal) conditions and dynamics of the local and regional groundwater flow system.
2. Update the 1998 conceptual model (CM) by refining key hydrologic areas (groundwater recharge and discharge areas, and WHPAs), and key hydrologic features (seeps, wetlands, cool/cold water stream reaches, municipal wells, and domestic and agricultural wells).

4.1.1 Groundwater assessment methods

The groundwater characterization included the following:

- Reviewing background information, historical and current mapping, modelling, and reports.
- Monitoring groundwater levels, stream flows and groundwater surface water interactions linked to key hydrologic functions.
- Developing an integrated surface water-groundwater flow model using MIKE SHE (DHI 2023) simulation software to integrate field data and represent spatial and temporal dynamics.
- Characterizing the influence of the existing municipal wells (within the PSA and SSA) on the groundwater levels in the Clythe Creek subwatershed and the function of recharge in the PSA in sustaining current groundwater demand at these active municipal wells.

4.1.1.1 Background Information Reviewed

The following reports and data sources were reviewed to obtain background hydrogeologic data and interpretations:

- Ontario Correctional Centre Water Supply (International Water Supply, 1975)
- City of Guelph Northeast Quadrant Study (Jagger Hims Ltd., 1995)
- Clythe Creek Subwatershed Study (Ecologistics and Blackport, 1998)
- Eramosa River - Blue Springs Creek Watershed Study Hydrogeology report (Stantec, 1999)
- Groundwater-Surface Water Interactions and Thermal Regime in Clythe Creek (Ashworth, 2012)
- Final Report of Stream Daylighting - Yorklands Green Hub (Trout Unlimited, 2014)
- City of Guelph Tier Three Risk Assessment (Matrix, 2017)

- Closed Eastview Road Landfill Site Annual Report (AECOM, 2024)
- Guelph Operations Campus Preliminary Subsurface Investigation (AECOM, 2021)
- Clythe Environmental Monitoring Program (Stantec, 2021)
- Watson Creek Development Area Monitoring Program (GM BluePlan, 2022)
- Waste Resource Innovation Centre Annual Report (AECOM, 2022a)
- Guelph Stormwater Management Monitoring Program (AECOM, 2022b)
- Hydrogeological Study to Support a Category 3 Permit to Take Water Renewal Clythe Well, Guelph Ontario. Version 1.0. (Matrix, 2023a)
- Assessment of Vulnerability to Contamination by Protozoa Stage 1 Hydrogeological Study for the Clythe Well, Guelph Ontario. Version 1.0.(Matrix, 2023b)
- Logan Well Reconstruction and Water Supply Feasibility Assessment Report (Stantec, 2023)
- Guelph Water Supply Master Plan (AECOM, 2022c)
- Assessment report for the Grand River Source Protection Area (LERSPC, 2022a)
- The Ministry of Environment, Conservation, and Parks (MECP) Water Well Information System (WWIS) and Permits to Take Water (PTTW)
- Ontario Geological Survey surficial geology and bedrock geology mapping
- Site-level Hydrogeologic or Geotechnical Reports Supporting Local-Scale Development Projects:
    - 55 and 75 Cityview Drive N. (NRSI, 2014; AGL, 2013, 2014; CVD, 2014)
    - 20 and 37 Cityview Drive. N. (GM BluePlan, 2021)
    - 300 Grange Road. (MTE, 2022; 2021a)
    - 105 Victoria Road. N. (MTE, 2021b)
    - 46, 47, and 87 Hyland Road. (Englobe, 2018)
    - 5063 Jones Baseline (CVD, 2021)
- Environment Canada and GRCA Climate Data (Precipitation, Temperature)
- City of Guelph Groundwater Level and Pumping Monitoring Data

4.1.1.2 Overview of field work completed

The groundwater field program was completed between November 2022 and December 2024 and was designed based on the SWSU team's understanding of the study area and insights from the 1998 SWS, existing monitoring data and Tier 3 / Water Quantity Master Plan conceptual model of the groundwater flow system and groundwater modelling tools / simulations (AECOM, 2022c). The program (as outlined in the Technical Work Plan provided in Appendix A) leveraged existing surface water and groundwater monitoring stations that, together with new field data collection, updated the conceptual site model (understanding of the groundwater system) and developed an integrated surface water – groundwater model to simulate existing and future conditions. In addition, the field program supports the understanding of ecological function and linkage of groundwater and surface water and the groundwater flow systems that support existing municipal pumping wells.

The methods and results of the groundwater field program are detailed in Appendix B-1 and include the following components. Groundwater and surface water monitoring stations are shown in Map GW-1. The subsequent subsections summarize the field program.

Groundwater Monitoring

- Nine monitoring wells were installed at three groundwater monitoring locations between August and September 2022. Screened internals at each location include the overburden, and/or Guelph, and/or Gasport Formation at MW22-01, MW22-02, and MW22-03:
    - MW22-01A, -01B, -01C were installed within the Gasport Formation, Guelph Member and overburden, respectively
    - MW22-02A, -02B, -02C, -02D were installed within the Gasport Formation, Guelph Member, deep and shallow overburden, respectively
    - MW22-03A and -03B were installed within the Gasport Formation and Reformatory Member, respectively
- Groundwater levels were measured and recorded manually and with a pressure transducer at each newly installed monitoring well.
- Slug tests were conducted at each newly installed monitoring well to estimate the hydraulic properties such as conductivity of the surrounding formations and hydrostratigraphic units (overburden, upper and deep bedrock) in the vicinity of the well screen.

Pumping Test at Clythe Well

As part of the SWSU and in support of the development of Clythe Water Treatment Plant design, a constant rate pumping test was completed on November 21, 2022 for a total duration of 94 hours, as described in Matrix 2023a, 2023b. The total drawdown at the Clythe Well after 94 hours of pumping was 19.4 m (92 per cent of available head).

Based on the pumping test (Matrix 2023a and 2023b), the following was determined:

- The pumping test demonstrated that the well can sustain 45 L/s with the maximum available head of 21 m based on current pump installation.
- Distance-drawdown plots estimate the area of influence at 45 L/s to extend as far as 3 km to the west from the pumping well in the lower bedrock aquifer.
- Vertical leakage to the lower bedrock was observed during the pumping test and is interpreted to be primarily transmitted through the contact zone where the Vinemount aquitard is absent from the overlying bedrock and overburden units, but the vertical flux is much less than that derived from the lower bedrock aquifer.

- It is not expected that pumping at the Clythe Well would have an impact on the available head at the nearest municipal production wells.
- Changes in groundwater discharge at surface water stations CC1 and CC2 (Map GW-1) may occur because of long-term pumping at the Clythe Well. However, the significance of these changes to the health of the aquatic and hydrologic system will be further evaluated through the City's Environmental Monitoring Program (EMP) and a 30-day pumping test once appropriate treatment and/or discharge location is available to avoid discharge water interference with surface water monitoring locations CC1 through CC4.
- The influence of Clythe pumping well in the long-term will be further assessed with the integrated surface water-groundwater flow model being used to characterize existing conditions (Appendix B-2) and complete the impact assessment as part of Phase 2 of the study.

Surface Water Flow Monitoring

- Twelve monitoring events occurred between March 2023 and December 2024, at surface water stations along downstream portions of Clythe Creek (CC5 and CC6) and Hadati Creek (HC2) to help in developing rating curves and as part of stream level monitoring.
- Groundwater level data were collected manually and automatically by a pressure transducer from shallow and deep mini piezometers at each surface water station, with the exception of HC2 where the mini piezometers were missing. The water level data were also plotted on a hydrograph.
- Surface water flow (discharge) at each surface water station were measured manually using an Acoustic Doppler Velocimeter (ADV), and water levels (stage) measured automatically with a pressure transducer to develop rating curves. A rating curve was developed to determine a relationship between the manual discharge measurements and the automatic river stage measurements.
- Surface water spot flow measurements were collected over a two-year period, September 2022 to August 2024, to observe the seasonal and spatial variability of baseflow along watercourses.
- Seven spot flow monitoring events (September 2022, October 2022, May 2023, August 2023, October 2023, May 2024, August 2024 and September 2024) were completed to capture seasonal flow levels at 14 baseflow monitoring locations along the main channels of Clythe Creek, as well as the supporting tributaries of Hadati Creek and Watson Creek.

Surface Water Quality Monitoring

- Surface water quality samples were collected during six sampling events on March 24, 2023; August 21, 2023; November 9, 2024; May 8, 2024; August 22, 2024, and October 21, 2024.

- Sample analytical results were compared to Ontario Drinking Water Quality Standards (DWSQ) and Ontario Provincial Water Quality Objective (PWQO) Guidelines criteria.

Bathymetric Surveying

- Bathymetric surveying of the two Reformatory ponds along York Road and Clythe Creek was conducted on October 17, 2022 using sonar and GPS survey equipment.
- A relatively flat and uniform depth in the center with more significant variations in depth closer to the pond shore was observed at the large south pond. Similar variations along the pond shore were also observed at the north pond, likely due to vegetation.
- The maximum depths of the south and north pond are 4 m and 3 m, respectively.
- The measured bathymetry has been used to inform the mapping and the modelling.

The data, mapping and analysis from the background review and new field work completed for the SWSU were used to update the characterization of the current groundwater flow system. The physical information and mapping provide snapshots of the spatial and temporal processes and features driving, or being support by, groundwater flow interpreted at available monitoring locations.

The reader is directed to Groundwater Maps section of the Report (Maps with the GW- prefix) for maps referenced in the following sections. Tables and charts referenced in the text can be found in Appendix B-1 Groundwater Field Work and Appendix B-2 Integrated Modelling.

4.1.1.3 Overview of integrated modelling

A three-dimensional integrated surface water-groundwater flow was developed to further integrate the available data and interpret spatial and temporal characteristics of the CM. The integrated model was developed with MIKE SHE simulation software (DHI 2023), which represents, in three-dimensions, the subsurface (e.g., aquifers and wells) and surface (e.g., topography and vegetation) features and processes using a 40 x 40 m finite grid and detailed stream network, with hourly precipitation inputs. The model domain includes the entire subwatershed (PSA and SSA) and 500 m buffer beyond the subwatershed boundary.

Model inputs such as hourly precipitation, hourly temperature, topography, and vegetation are used to simulate the surface processes which generate runoff, infiltration and evapotranspiration and groundwater flow within aquifers and through aquitard to wells, streams or wetlands. A 10-year simulation period (2012 - 2023) based on current conditions (e.g., land use vegetation, SWM) was completed and simulated groundwater levels, stream flow and well responses were compared to field observations. A 10-year period was selected to be consistent with the land use and to incorporate multiple years of variable climate (wet and dry years). The interaction with adjacent subwatersheds was represented using specified head boundary conditions informed from the WSMP model (AECOM, 2022c). Adjustments were made to the input parameters informed by the range of field measurements of input parameters to improve the fit to observed field observations. The model development and calibration to represent existing conditions are presented in Appendix B-2.Overall, the integrated model calibration, as described in Appendix B-2, provides a good representation of spatial and temporal variations in observed groundwater flow levels and directions, and stream flow including baseflow and is a suitable tool for understanding the dynamics and linkages of regional and local groundwater flow systems with key hydrologic features and mapping of key hydrologic areas. The tool will be further refined in Phase 2 to better represent baseflow on Hadati Creek before completing the impact assessment and to increase confidence in magnitude of groundwater discharge. The current model is representative of the discharge locations and capable of being modified to assess future conditions, including the impacts due to changes in land use, SWM practices for new developments and changes in municipal pumping.

The integrated model simulation of existing conditions extends characterization of the groundwater flow conditions by integrating the spatial and temporal observations and mapping into a three-dimensional representation of the hourly, daily, seasonal dynamics in groundwater flow conditions. The simulated conditions provide a water balance for each grid cell in the model based on the input parameters of the CM. The simulation also provides insights and quantifies the temporal changes in runoff to streams and evapotranspiration, as well as groundwater-surface water interactions including groundwater discharge to ponds, wetlands and stream segments for grid cells representing these features. Flow analysis techniques available with the model (e.g. particle tracking) enable mapping and analysis of recharge area linkages to discharge areas and variability of the groundwater levels and discharge conditions at well, stream, wetland and seep features under existing conditions.

Appendix B-2 Figure 1, Table M and Groundwater Maps GW-11 through GW-26 show the simulated output which is used to characterize the spatial locations and temporal variation in:

- depth to the water table, and groundwater levels in key hydrostratigraphic units
- groundwater recharge
- groundwater seepage and discharge (surface water, wetlands, ponds)
- ponded water depth
- stream flow including gaining and losing reaches
- water balances for catchments in the PSA and SSA

Additionally, Maps GW-24, 25, 26 show the simulated groundwater recharge area linkages to specific discharge areas and wetland, stream and seepage features, and capture zones for municipal wells, including those that are considered key hydrologic features (Section 4.1.3).

In Phase 2 of the SWSU, the insights from the subwatershed-specific integrated groundwater-surface water (MIKE SHE) model simulation of existing conditions will be used to inform the development of initial future land use and stormwater management approaches. Future conditions will be simulated using the integrated model and will demonstrate the effectiveness of various management alternatives to maintain and enhance the current groundwater related key hydrologic functions by comparing simulated changes under future conditions with existing conditions.

4.1.2 Groundwater findings

The following sections describe the groundwater data and mapping that were collected and analyzed from available background information and field work. These maps, data and interpretation form the basis for the CM presented in Section 4.1.2.6.

The detailed results of the groundwater field program and integrated surface water and groundwater model are detailed in Appendix B-1 and Appendix B-2, respectively. Groundwater and surface water monitoring stations are shown in Map GW-1.

4.1.2.1 Climate

The Environment Canada Guelph Turfgrass Station and GRCA Guelph Lake Climate Station collectively provide multiple decades of climate data in the PSA, including hourly precipitation and daily temperature data. Climate data for the SWSU were primarily obtained from these two stations, but where data are missing, gaps have been infilled with high-quality data from neighbouring GRCA climate stations in consultation with the GRCA. Details of the climate data are presented in Appendix B-2 Section 2.2. The following summarizes key information on precipitation and temperature.

The climate stations used to derive the precipitation dataset and the reference stations used to evaluate these data are presented in Appendix B-2 Section 2.2. The infilled climate dataset was evaluated in terms of the average annual precipitation rate and average monthly precipitation rate. On an annual basis, an average precipitation rate of 990 mm/year is estimated for the period of 2006 to 2022, the complete years of observation in the dataset for the Guelph Lake Climate Station. The climate normal precipitation rates published for the five closest stations in the period of 1981 to 2010 average 941 mm/year with a range of 877 to 1,014 mm/year from all the stations. Therefore, the infilled climate station is aligned with published climate normals in the area; however, some variation from these normals is expected given the differing period of record, 1981 to 2010 vs. 2006 to 2022, and spatial variability inherent to climate data.

The observed daily temperature dataset for the period of 2006 to 2022 was evaluated against published long-term climate 1981 to 2010 normals at nearby Environment Canada stations (Appendix B-2). In general, mean monthly temperature values are within 1 degree Celsius of the historic climate normal values for the 2006 to 2022 period. Average annual temperature is slightly elevated on average, by approximately 0.4 degrees Celsius, relative to the historic annual average temperature from 1981 to 2010 for the climate normal stations.

The climate dataset including hourly precipitation and daily temperature values were extended to the end of 2023. These additional data were taken primarily from the GRCA Guelph Lake Climate Station using the approach described in Appendix B-2 Section 4 for infilling. This climate data extension facilitated calibration of the MIKE SHE model against observed data through to the end of 2023.

4.1.2.2 Surficial geology and hydrostratigraphy

The regional surficial geology mapping and data provided by the Ontario Geological Survey (OGS; OGS 2010) are presented in Map GW-2. The major hydrostratigraphic units within the overburden are presented in Table 4.1. The surficial geology of the Clythe Creek subwatershed largely consists of the silty Port Stanley Till and outwash deposits along Clythe Creek.

Table 4.1: Major hydrostratigraphic units

	Stratigraphic Unit	Hydrostratigraphy
Overburden	Recent Glaciofluvial Outwash	Aquifer
Overburden	Port Stanley Till	Aquitard
Overburden	Maryhill Till	Aquitard
Overburden	Catfish Till	Aquitard
Overburden	Pre-Catfish Glaciofluvial Outwash	Aquifer
	Contact Zone	Aquifer
Bedrock	Guelph Fm	Aquifer
Bedrock	Eramosa Fm - Reformatory Quarry Member	Aquifer/Aquitard
Bedrock	Eramosa Fm - Vinemount Member	Aquitard
Bedrock	Goat Island Fm	Aquifer/Aquitard
Bedrock	Gasport Fm - Upper	Aquifer
Bedrock	Gasport Fm - Middle	Aquifer – Municipal Supply
Bedrock	Gasport Fm - Lower	Aquifer
Bedrock	Irondequoit / Rockway/Merritton Fm	Aquifer/Aquitard
Bedrock	Cabot Head Fm	Aquitard

Sands and gravel occur within glaciofluvial outwash deposits found along Clythe Creek (Map GW-2) and occur locally within kames and eskers (OGS, 2010). These coarser sediments are often underlain by finer grained, lower permeability tills and, as a result, infiltrating water is more likely to flow laterally through the shallow, localized groundwater flow system and discharge locally to adjacent areas. In these areas, groundwater recharge to deeper overburden and bedrock is expected to be lower than the recharge to the water table. Conversely, where overburden is thin and surficial sediments consist of sands and gravels, there is a higher potential for a hydraulic connection between these coarser sediments and the underlying fractured bedrock and higher potential for recharge to the bedrock. Areas of coarse sands and gravels and/or thin overburden are also areas where there is the greatest potential for groundwater discharge to streams and wetlands.

A well log and slug test from the nested MW22-02 well are presented Appendix B-1.3. This well is located within the buried valley within the SSA where the overburden is quite thick and the deeper overburden is variable including silty sand to silty clay intervals (Map GW-7). Map GW-2 displays the location of three geologic cross-sections, which are presented in Maps GW-3 through GW-5. Each cross-section is aligned from northwest to southeast, and intersects the three boreholes (MW22-01, -02 and -03) drilled as part of this study. The overburden is thickest on topographic highs or where buried valleys are present (20 to 40 m; Map GW-3 and GW-4) and is thinnest within valleys (0 to 5 m; Map GW-3) and near the headwaters of Clythe Creek (0 to 10 m; Map GW-5).

The hydraulic conductivity of the Quaternary geology units from all sources is presented in Appendix B-2, Table K. The ranges of hydraulic conductivity for outwash sands and gravels are $1x10^{-6}$ to $1x10^{-3}$ m/s and for the tills is $1x10^{-8}$ to $1x10^{-6}$ m/s.

4.1.2.3 Bedrock geology and hydrostratigraphy

The regional bedrock geology mapping and topography (with interpreted buried valleys) are provided by the OGS (OGS 2010) and are presented in Map GW-6 and GW-7. The major hydrostratigraphic units within the bedrock are presented in Table 4.1. Underlying the overburden deposits, the Paleozoic bedrock stratigraphy of this area consists of sedimentary Silurian aged dolostones, shales, and limestones.

The bedrock stratigraphy consists of (from youngest to oldest): Guelph Formation, the Reformatory Quarry and Vinemount Members of the Eramosa Formation, Goat Island Formation, and the Gasport Formation. The stratigraphic sequences are presented on Maps GW-3 through GW-5, as well a brief description of each of these bedrock units is excerpted below as originally described in the City's Tier Three Assessment Characterization Report (Golder 2011; from youngest to oldest):

- Guelph Formation: The Guelph Formation consists of medium to thickly bedded crinoidal grainstones and wackestones and reefal complexes (Brunton, 2008). The Guelph Formation is cream coloured and fossiliferous and where present in the Cambridge and Guelph area it is most often the uppermost bedrock unit.
- Eramosa Formation - Stone Road Member: This cream coloured coarsely crystalline Upper Eramosa unit is not present in most of the cores and outcrops and can be difficult to distinguish from the Guelph Formation.
- Eramosa Formation - Reformatory Quarry Member: The Eramosa Formation above the Vinemount Member is described by Brunton (2008) as light brown to cream coloured, pseudonodular, thickly bedded and coarsely crystalline dolostone. This unit is susceptible to karstification due to its uniform fine dolomite crystallinity (Brunton, 2008). This unit often contains mud rich and microbial mat bearing lithofacies that may act as aquitard materials, reducing the vertical permeability across this unit. This unit was logged as either the Guelph Formation or Eramosa Member in previous studies within the City.
- Eramosa Formation - Vinemount Member: The Vinemount Member comprises thinly bedded, fine crystalline dolostone with shaley beds that give off a distinctive petroliferous odour when broken (Brunton 2008). This dark grey to black dolostone unit was commonly identified in water well records as "black shale" and mapped in previous City studies as the Eramosa Member. The shaley beds of this formation significantly reduce the vertical permeability across this unit relative to the other formations.

- Goat Island Formation - Ancaster Member: The Ancaster Member is a chert rich, finely crystalline dolostone that is medium to ash grey in colour. This unit generally overlies the Niagara Falls Member, although in some cases these units are interfingered.
- Goat Island Formation - Niagara Falls Member: The Niagara Falls Member is a finely crystalline and cross laminated crinoidal grainstone with small reef mounds. This unit is typically less than 10 m thick in the City.
- Gasport Formation: The Gasport Formation is a cross bedded crinoidal grainstone packstone with sequences of reef mound and coquina (shell bed) lithofacies. This unit was referred to as the Amabel Formation in previous studies in the area. In the City, the formation generally varies in thickness from about 25 to over 70 m, and the upper sections of the reef mounds, the crinoidal grainstones and the coquina shell beds make this formation highly transmissive, where they are present.

The main bedrock units that subcrop within the subwatershed include the Guelph Formation and Reformatory Quarry Member of the Eramosa Formation (Map GW-6). The top of bedrock surface is interpreted to be weathered, resulting in relatively higher permeability and this, along with the bedrock topography, will control shallow horizontal groundwater flow and the potential for groundwater discharge (Contact Zone; Table 4.1).

Multiple buried bedrock valleys are interpreted in the PSA and extend in from the SSA, including an especially deep valley trending from the northeast to the southwest through the subwatershed (as shown in Map GW-4). In the buried valleys, both shallow and deep bedrock units have been fully to partially eroded including the deeper Vinemount Member of the Eramosa Formation (a regional bedrock aquitard), the Goat Island Formation, and the Gasport Formation (an important bedrock aquifer where many of the City's wells draw water). Valleys such as these can provide a more direct hydraulic connection between the shallow and deeper groundwater flow systems where the protective Vinemount Member aquitard has been eroded away, especially where the overburden infill contains coarser sediments. This vertical connection has implications with respect to water quantity (e.g., more direct recharge) and water quality (e.g., potential faster travel times of contaminants from ground surface to the bedrock aquifer). The extent and orientation of these valleys are interpreted to influence groundwater flow in both the overburden and bedrock units in this area. A bedrock valley was encountered during drilling of monitoring wells for this project (MW22-02; Map GW-4).

The Guelph Formation has a relatively high permeability and is regionally considered an aquifer and is locally used by domestic groundwater users. Hydraulic conductivity (K) of the Guelph Formation ranges from 1.0×10^{-6} to 1.0×10^{-4} m/s. Within the City, the Goat Island Formation (K ranges from 1.0×10^{-6} to 8.0×10^{-5} m/s) and Gasport Formation (K ranges from 1.0×10^{-6} to 3.6×10^{-3} m/s) are collectively considered the lower bedrock aquifer, and are targeted as a municipal drinking water supply due to the highly transmissive grain texture, reef mounds and fracture network, especially in the middle portion of the Gasport Formation.

4.1.2.4 Groundwater use

Within the PSA and SSA, groundwater users include both municipal water supply and non-municipal groundwater users where more than 50,000 litres per day are being pumped that have a permit to take water (PTTW) (Map GW-8). The permitted municipal wells Park, Emma and Helmar are located on the western and northwestern boundary of the subwatershed.

The PSA and SSA lie within the City of Guelph Wellhead Protection Areas (WHPAs) (LERSPC, 2022a) which define the capture area and area of influence of the active production wells (Emma and Park). Permitted (both active and inactive) municipal production wells near the Clythe Creek Subwatershed in the northeast quadrant of the City include Emma, Park and Helmar as shown on Map GW-8. The Helmar Well is not currently active. The areas contributing groundwater to most municipal wells in the City overlap and cumulatively lower groundwater levels within the lower and upper bedrock aquifers compared to the areas where permitted City municipal water supply wells are non-pumping.

The Clythe Well is currently permitted under PTTW No. 1568-D7ASGU to pump 60.6 L/s with a workplan, per PTTW condition 3.4. The Clythe Well is not currently active. A groundwater treatment plant will be constructed to address aesthetic water quality. Table 4.2 provides additional details for each of the permitted production wells.

Table 4.2: Table of Permitted Municipal Production Wells in the Northeast Quadrant of City of Guelph

Municipal Well	PTTW Rate[1] (m^3/d)	Estimated Capacity[2] (m^3/d)	Average 2021 Pumping (m^3/d)
Clythe[3]	5,237	3,888	0
Emma	3,100	2,800	2,110
Helmar	3,273	800	83
Park Wells	10,300	8,000	1916
Total	21,910	11,600	4,109

[1]Effective as of 2024.

[2]Estimated Sustainable Rates from the City of Guelph Water Supply Master Plan (AECOM, 2022), up to the most recent permitted rate.

[3] Not operating during the Study Period

When the groundwater taking is less than 50,000 litres per day no PTTW is required. Wells that do not have PTTWs are shown on Map GW-8 and include monitoring wells, temporary dewatering, and industrial and agricultural supply wells. No information is available about which wells with PTTWs are active.

Local groundwater users can influence the local groundwater flow conditions and may represent threats to the Clythe Creek Well source water quality if they are not properly constructed or maintained and are completed in the lower aquifer (Gasport Formation).

The WHPA-Q is a policy area defined under the Source Water Directors Rules (MECP, 2021) and corresponds to the zone of influence (e.g. results in drawdown of groundwater levels) of the municipal wells delineated using the Tier 3 groundwater flow model (LERSPC, 2022a). Both the PSA and SSA are fully within the WHPA-Q that extends outside the City. Within this WHPA-Q, Source Protection policies require the identification of any threats to the sustainability of the water supply. Any activities within, or adjacent to, the WHPA-Q that might reduce recharge and increase drawdown of a municipal production well, must be assessed and mitigated to protect the well sustainability.

4.1.2.5 Aquifer Vulnerability

As described in Section 4.1.2.4, the PSA and SSA lie within City of Guelph WHPA. Time of Travel WHPAs are areas that contribute groundwater to each municipal production well (capture zones) in the City and provide an estimate of travel time from each area to the well (e.g. 2 years). The water quality WHPA-Qs are mapped as WHPA-A, B, C, and D with A having the shortest travel time to the well and D being the up to 25 years time of travel (Map GW-8).

- WHPA A – 100 m fixed radius
- WHPA B – 0 to 2 year travel time
- WHPA C – 2 to 5 year travel time
- WHPA D – 5 to 25 year travel time

The WHPAs are delineated using the City's Tier 3 groundwater flow model using methods described in the Source Protection Director Rules (MECP 2021). Policies to identify and manage existing threats to water quality were identified within these areas. Specific policies apply to areas mapped as Highly Vulnerable Aquifers (HVA) from the Source Water Protection program (LERSPC, 2022a).

The water quality WHPAs for municipal wells and the associated HVAs are shown on Map GW-8 (i.e., scores of 10; LERSPC, 2022a). The entire Clythe Creek subwatershed lies within the WHPA-Q indicating that groundwater within the lower bedrock aquifer, recharged primarily outside the subwatershed and portions of the shallow bedrock (recharge in the subwatershed), contributes recharge to the municipal wells. The WHPA-Q estimates the typical travel time in the groundwater in the deep bedrock aquifer to active municipal wells (Emma, Park, Helmar and Clythe) located primarily in adjacent subwatersheds, is approximately 2 to 5 years.

Within the WHPA-Q, most areas are defined as high and, to a lesser extent, medium aquifer vulnerability. The vulnerability scores within these areas are high (as shown on Map GW-8), which means that there is a greater chance that activities within these areas may be considered significant threats to municipal groundwater supplies' water quality, and the Sourcewater Protection Plan policies would apply to help manage the risk associated with those activities (Map GW-8).

4.1.2.6 Surface Water and Groundwater Quality

In August 2022, baseline water quality characterization samples were collected from select surface water monitoring stations in Clythe Creek and Watson Creek, as well as the groundwater monitoring wells OW11 06 S/I/D and the Clythe Well (Matrix 2023a; Map GW-1). The samples were submitted for laboratory analysis of inorganic parameters and, at select locations, total and dissolved metals. Tables in Appendix B-1.2 shows the results of the water quality analysis for groundwater and surface water collected during the study.

Baseline groundwater quality results met the applicable Ontario DWQS for all analyzed parameters except for the aesthetic objectives for the following parameters and locations (Matrix, 2023a):

- Clythe Well: sulphide, hardness, and total dissolved solids (TDS)
- OW11-06 D: sulphate, hardness, TDS, and turbidity
- OW11-06I: hardness and TDS
- OW11-06 S: hardness, TDS, and turbidity

The major constituents of the Clythe Well water quality samples were plotted in a piper diagram and are presented in the PTTW report (Figure 14, Matrix 2023a) and can be found in Appendix B-1.7 of this report. The groundwater from the lower bedrock units (Goat Island and Gasport formations), as collected from the Clythe Well, are characterized as a mixed water type between a calcium bicarbonate to calcium sulphate water. The most dominant anions in the Clythe Well samples are bicarbonate followed by sulphate and then chloride. The elevated sodium and chloride values are indicative of road salt impacts.

Water quality samples were also collected during the 24-hour pilot test from Clythe Creek and the SWM Pond 52 outlet riser (Appendix B-1). A sample of the produced groundwater from the Clythe Well was also collected. Samples were submitted for laboratory analysis of inorganic parameters including sulphide.

The results for the Clythe Well samples collected during the pilot test met the applicable Ontario DWQS for all analyzed parameters except for the aesthetic objectives for hydrogen sulphide, manganese, iron, hardness, and turbidity. The results met PWQO for surface water for all parameters analyzed except for hydrogen sulphide with a concentration of 0.73 mg/L compared to the PWQO of 0.002 mg/L and total iron with a result of 0.37 mg/L compared to the PWQO of 0.3 mg/L. However, the background concentration of iron in Clythe Creek was 1.5 to 3 times higher than those observed at the Clythe Well.

Design and construction of the Clythe Water Treatment Plant is ongoing with an estimated completion of 2027. The Clythe Water Treatment Plant is designed to remove hydrogen sulphide, manganese, and iron from groundwater to improve aesthetic objectives. The Clythe Well was identified in the WSMP (2022) as an option for additional water supply to support future population growth in Guelph.

For surface water quality sampling at stations CC-5, CC-6, and HC-2, manual field measured electrical conductivity (EC) and grab sampling were completed for five sampling events between March 2023 and August 2024. The lowest EC was measured in November 2023 with values of

560 µS/cm at CC-5 SW, 461 µS/cm at CC-6 SW and 416 µS/cm at HC-2 SW (Table B-1.2.3 - Appendix B-1.2). Intermediate EC values were measured in the summer (both August 2023 and August 2024). The highest conductivity values were noted in the spring (both May 2023 and May 2024). In May 2023 the measured conductivity values were 1,006 µS/cm at CC-5 SW, 880 µS/cm at CC-6 SW and 1,025 µS/cm at HC-2 SW. These values are only slightly higher than the typical values measured noted during the summer sampling events in August 2023 and August 2024. However, in May 2024 the conductivity increased by approximately ten-fold to 9,662 µS/cm at CC-5 SW, 9,576 µS/cm at CC-6 SW and 9,970 µS/cm at HC-2 SW.

All surface water samples met the Ontario PWQOs except for Total Iron, Manganese and DOC (MOEE, 1999). Turbidity ranged from 1 to 9 NTU and Dissolved Oxygen (DO) ranged from 4.5 to 18.1 ug/L. These exceedances reflect natural conditions and agricultural and urban land use. The iron and manganese exceedances are associated with groundwater discharge from aquifers with naturally occurring iron (Grand River Management Plan 2014). Turbidity, TDS and DOC exceedances result from runoff from natural sources (e.g. decaying plant matter) and agricultural runoff (Hutchins 2011). Ammonium-N exceedances likely reflect the runoff from agricultural fields located primarily in the SSA. The observed range of dissolved oxygen is consistent with other areas of the Grand River Watershed (GRCA 2025).

The chloride concentrations consistently exceeded 100 mg/L in surface water and were as high as 230 mg/L which is just below drinking water guidelines. Similarly, the sodium concentrations consistently exceed 100 mg/L. These values are indicative of historical road salt impacts in runoff and groundwater discharge.

The guideline and objective exceedances for each surface water station are described in Appendix B-1.

4.1.2.7 Conceptual model for groundwater flow systems

During precipitation or snowmelt events a portion of precipitation percolates or infiltrates into the ground based on the intensity of rainfall or snow melt and the infiltration capacity, slope of the surface, and existing soil moisture. The portion of precipitation that does not infiltrate runs off to downslope areas where it may infiltrate or flow into a surface water feature (e.g. wetlands, creeks).

Water which reaches the water table may provide recharge to the overall groundwater flow system. Areas where water moves downward to the water table are known as recharge areas. These areas are commonly in areas of topographically higher relief. Areas where groundwater moves upward to the water table are known as discharge areas and these generally occur in areas of topographically low relief, such as creek valleys. Groundwater that discharges to creeks or streams maintains the baseflow of the creek. Wetlands may also be fed by groundwater discharge.

There are different types and rates of recharge and discharge. Water percolating into the ground at a specific location may discharge to a small pond or wetland a short distance away.

This is local recharge and local discharge. Some water may recharge in a certain area and discharge to a creek or stream basin more distant from the source of recharge; this is known as regional recharge and regional discharge, or regional groundwater flow system.

Permeable geologic materials that can transmit locally or regionally significant quantities of water are known as aquifers. Aquifers are "water bearing" formations meaning that water can be relatively easily extracted from these units. The less permeable units are known as aquitards, and although water can move through these units, it moves slowly and it is difficult to extract water from these units. How these aquifers are connected within a hydrogeologic setting is what controls much of the movement of groundwater.

Mapping of the regional and local aquifer-aquitard systems (Maps GW-2 through GW-7) provides a framework to characterize where groundwater originates, where it discharges, and the most prominent paths it travels between these points (e.g., the aquifer pathways or more permeable hydrostratigraphic units). The framework enables an assessment of the relative sensitivity of the linkage of the groundwater system to the aquatic, terrestrial or water supply systems or the function of groundwater in supporting these systems. Knowing the level of sensitivity of the receptor, facilitates the estimation of the impacts of particular types and scales of land uses or land use changes on the groundwater flow system and other linked ecosystem components. Best management practices can then be developed to minimize unacceptable impacts associated with future development.

Clythe Creek groundwater flow system

The Conceptual Model is depicted on Map GW-9 and is based on the interpretation of background information and field work. The groundwater flow system consists of a shallow/local groundwater flow system and a regional/deeper groundwater flow system that interact with each other across the regional aquitard (Vinemount Member) and provide seepage and groundwater discharge to the surface water systems. The combined water resource system (surface water and groundwater) in the PSA and SSA provides key hydrologic functions by sustaining healthy aquatic and terrestrial ecosystems and providing drinking water (groundwater) to meet current and future demands due primarily to population growth.

The shallow/local groundwater flow system (water table) is recharged by infiltration of precipitation at surface within the subwatershed and more strongly influenced by topography which reflects the depositional environment and hydraulic conductivity of overburden sediments that overlie bedrock. The shallow/local groundwater flow systems transmit water to streams (areas and features) through the overburden and shallow bedrock (Contact Zone, Guelph Formation, Reformatory Quarry Member) supplying baseflow to the streams and supporting aquatic habitat. A comparison of groundwater levels in mini piezometers with surface water levels at the stream flow station helped to characterize the seasonality of discharge conditions to streams at those locations (Appendix B-1 and Map GW-10).

The portion of the shallow groundwater that does not discharge to surface or streams in the subwatershed moves vertically downward to recharge the lower bedrock aquifer units (Goat

Island and Gasport Formations) which are part of the regional groundwater flow system and the primary municipal aquifers supplying municipal wells in the City. The regional groundwater flow system transmits groundwater into the subwatershed primarily through groundwater recharge to the bedrock aquifer units in areas outside the subwatershed to the north and northeast and flows south in the SSA to Eramosa River. In the eastern portion of the PSA, regional flow is also to the south but on the western portion of the PSA, deep groundwater is captured by municipal groundwater pumping from the bedrock aquifers at the Park, Emma, Helmar and Clythe municipal wells on the border of, and just outside the subwatershed. Future additional demand for groundwater for human consumption is planned to use the Clythe Well which is currently not active, and a North East Water Supply (NEWS) well which may include the Logan Well. A Municipal Class EA is currently underway to select the preferred municipal water supply source in the NEWS. The Clythe Well, Logan and/or future NEWS wells derive water from the Gasport and Goat Island aquifers.

The buried bedrock valley shown on Maps GW-7 and GW-9 is not a significant aquifer based on the tested hydraulic conductivity but does represent areas where the bedrock flow system may be better connected to the shallow system due to the erosion of bedrock aquitard units. In this area, recharge to the lower bedrock can be enhanced compared to areas where bedrock aquitards are more continuous.

The updated CM reaffirms and extends the findings of the 1998 SWS that the key hydrologic functions of groundwater in the Clythe Creek as described in the introduction to section 4.1.2. These key functions are described further in section 5.3.

The following sections introduce the integrated model outputs related to the spatial (3D) and temporal characteristics of groundwater flow, water balance, recharge, and discharge conditions in the PSA and SSA. The maps, charts and analysis extend the spatial resolution and temporal understanding of groundwater flow conditions and the interaction with surface water and provide insights on the sensitivity of the key hydrologic functions to existing climate variability. Section 4.1.1.3 and Appendix B-2 provide additional details on the model development, calibration and overall representation of existing conditions in the PSA and SSA.

4.1.2.8 Depth to the water table and groundwater levels and flow

Depth to the water table

A map of the simulated average depth to the water table is presented in Map GW-12. This map represents the average depth from the ground surface to the water table as simulated by the model on average from 2012 through 2023.

The average simulated depth to the water table is at ground surface or within 10 cm of ground surface in areas below headwater drainage features and upper segments of Watson, Hadati and Clythe Creek, the north and south ponds in the southern portion of the PSA and in the undeveloped land near and along the Unnamed Tributary. All of these areas occupy local or regional topographic lows (topography shown on Map FG-1), and many align with simulated seepage or discharge (Section 4.1.2.9) for all or part of the year (e.g. spring) and many of these reaches include riparian wetland features supported in part by groundwater seepage/discharge.

Development in areas of shallow water table has the potential to interfere with infrastructure and buildings. On the Former Reformatory Lands along the Unnamed Tributary and associated wetlands, the water table is at groundwater surface and may be a constraint to development in this area.

The depth to water increases away from headwater drainage features, wetlands, and streams in the regional and topographic highs especially near the subwatershed boundaries. The largest estimated depth to water table exceeds 10 m beneath the Former Eastview Landfill, where mitigation measures reduce recharge to this topographic high area. Depth to the water table exceeds 5 m or more along boundaries of the PSA and SSA where the thickest accumulations of sediments are in areas that are primarily till.

Groundwater levels and flow

As depicted on the observed groundwater level hydrographs presented in Appendix B-1.4, groundwater levels associated with local flow systems will vary by 1 to 2 m annually due to variations in precipitation and evapotranspiration. Wells and groundwater levels in the regional flow system (bedrock aquifers) are less influenced by short-term recharge in response to precipitation but show clear responses due to changes in pumping at municipal wells. In addition, muted seasonal variations in lower bedrock aquifer groundwater levels are observed that may be in response to changes in Guelph Lake water levels (Appendix B-1.4 MW22-01 A, B).

As depicted in the CM (Map GW-9), the groundwater level maps for Overburden (Map GW-12) and Guelph Formation (Map GW-13) exhibit characteristics of the local groundwater flow system with horizontal flow directions from topographic highs to local topographic lows (topography shown on GW-1) toward streams and headwater features. Horizontal flow gradients are highest (smaller contour spacing) at breaks in topography around streams and lowest in flatter areas of the till outside the stream valleys and in flatter areas along Clythe Creek associated with outwash deposits. A steeper gradient is simulated for the Guelph Formation along the buried valley that trends north to south from the northern model boundary near the Logan Test Well to the Clythe Well and towards the Former Reformatory Lands in the south (Map GW-13).

The simulated groundwater levels and flow directions in the lower bedrock, Gasport Formation (Map GW-14), reflect the characteristics of the regional groundwater system. Gasport Formation shows groundwater flowing from north to south through the subwatershed and much smoother contours than other units due to the continuity of the Gasport Formation. The lower bedrock including the Gasport is overlain and confined by the Vinemount aquitard so there is minimal influence from the local flow system except where the Vinemount aquitard is locally eroded (e.g. Map GW-4, MW22-02). On the western side of the PSA, the influence of municipal pumping from Park and Emma Wells causes north-south flow to bend to the west to converge on the active wells.

A comparison of water levels between the maps shows a decrease in groundwater levels at common locations with depth between overburden and the Guelph Formation (downward gradients) on each map in recharge areas and increase in groundwater level discharge areas (upward gradients) in areas adjacent and below the creeks.

Map GW-15 shows vertical gradient between the Guelph and Gasport Formations with the thickness of the Vinemount show for context. The largest vertical gradients are simulated in the discharge areas where hydrostratigraphic units are thin and cause a convergence of flow and increased gradient.

A comparison of the Guelph Formation groundwater levels with the Gasport Formation at common locations shows some of the highest downward gradients in the subwatershed and highlights the recharge of the regional system (Gasport Formation) by vertical flow from the upper bedrock and overburden. Upward flow from the lower bedrock to shallow bedrock was not observed in any of the observation wells' hydrographs (Appendix B-1.4) or predicted in the model simulation results (Appendix B-2.2).

4.1.2.9 Groundwater recharge

A map depicting the spatial distribution of simulated average annual groundwater recharge is presented in Map GW-16 and simulated evapotranspiration in Map GW-17.

The normalized recharge rate across the PSA and SSA is 252 mm/yr for the 2012 to 2023 period. Average Monthly recharge for the simulated time period of 2012 through 2023 varied from 2 mm to 71 mm. The highest monthly recharge (71 mm) occurs in April following the spring melt events (see details in Appendix B-2.1, Figure 1).

In developed areas in the PSA, recharge rates are the lowest due to the impervious surfaces associated with the existing development. Recharge is higher in the SSA which is primarily rural agricultural land use with less impervious surfaces and predominately outwash sands and gravels.

In the SSA, the simulated mean annual recharge rate is 306 mm/yr for the 2012 to 2023 period. Recharge is zero in areas of shallow water table (< 10 cm below ground surface, bgs) along the stream valleys and headwater drainage features. In the higher elevation areas away from the streams, recharge is approximately 300 to 350 mm/yr. The highest recharge (400+ mm/yr) rates occur at the base of slopes away from the stream valley in the outwash deposits where the water table is greater than 10 cm bgs (see Map GW-16).

In the PSA, the Hadati and Watson Creek catchments are mostly urbanized and the simulated average annual recharge is 143 and 212 mm/yr respectively, due to the large amount of impervious surfaces within the areas which are underlain primarily by till. Development density is slightly lower in Watson Creek than Hadati Creek and there are some outwash deposits in the lower part of the catchment that result in the higher recharge rate compared to Hadati Creek (Appendix B2.1, Table B-14).

The portion of Clythe Creek catchment in the PSA that extends from the mouth of Watson Creek to the Eramosa River (excluding Hadati Creek) has a simulated mean annual recharge rate of approximately 291 mm/yr. The recharge in this area is lower than the SSA but still moderate due to the predominance of permeable outwash deposits that supports a high infiltration capacity. However, a shallow depth to the water table along Clythe Creek and the Unnamed Tributary on the Former Reformatory Lands, limits the recharge (see details in Appendix B2.1, Table B-14).

4.1.2.10 Evapotranspiration

Simulated mean evapotranspiration rates across the PSA are presented in Map GW-17. The simulated results indicate that evapotranspiration rates generally range between 540 mm/year to 700 mm/year in the east and from 390 mm/year to 600 mm/year in the west. Increased evapotranspiration rates ranging between 600 mm/year and 800 mm/yr are found along the creeks in wetlands and in ponded areas. Peak evapotranspiration upwards of 800 mm/year is specifically observed in the north and south ponds, in the southern portion of the PSA, and adjacent to Clythe Creek. An elevated water table, which corresponds to the presence of ponds and wetlands in the PSA, limits groundwater recharge promoting the water near, or at, the ground surface. The available water at the surface likely results in increased evapotranspiration rates in wetlands and ponds.

In contrast, low evapotranspiration rates are observed throughout the developed portion of the PSA ranging from less than 390 mm/year to 650 mm/year. The lowest rates are observed in the developed areas along York Road, west of the City boundary, as well as north of Clythe Creek near the confluence of Hadati Creek and Clythe Creek. Developed areas have a large proportion of impervious land surface which impacts the ability for water to infiltrate into the groundwater. Unlike in wetlands and ponded areas, evapotranspiration rates are interpreted to be lower, due to drainage and other stormwater management features which direct overland flow away from impervious areas and into either surrounding pervious land or storm sewers.

4.1.2.11 Groundwater seepage and discharge

Groundwater discharge areas were identified in the field by observing seeps in stream valleys and by comparison of stream flow measurements and stream temperatures during baseflow periods between measurement locations (Map GW-1 and GW-10 and Figure 4.1.). An increase in baseflow between stations is indicative of groundwater discharge along that reach. A comparison of groundwater levels in mini piezometers with surface water levels at the stream flow station helped to characterize the seasonality of discharge conditions to streams at those locations.

The continuous stream flow hydrographs (CC-5,6 and HC-2) helped to understand variation in stream flow, with additional snapshots of stream flow provided by spot baseflow measurements.

(Appendix B-1). Existing monitoring of stream stage was available for stations CC-1 through CC-4 as well as WC-1 and WC-2 but a rating curve was not available to convert these to flows.

Stream flow stations for HC-2, CC-5 and CC-6 were commissioned in this study to address the streamflow data gap in the lower reaches of Clythe Creek. However, significant backwater and pond influences at CC-5 and CC-6 resulted in higher uncertainty in stream flows compared to other stations in the subwatershed. Spot baseflows on the lower Clythe were also affected by backwater effects and are less reliable than stations upstream on Clythe (Figure 4.1). Continuous flow data available for locations at Watson Parkway (GSC-C053(03 and 05) were found to be the most reliable for understanding variability in flows and to support model calibration (Appendix B-2).

The integrated model simulates depth to water table (Map GW-11), seepage flux to ground surface (Map GW-18, 19, 20), discharge from the water table to the stream channels (Map GW-21), and ponded water elevations and stream thermal regimes (Map GW-22, 23). All these model outputs relate to identifying and characterizing groundwater discharge areas and features.

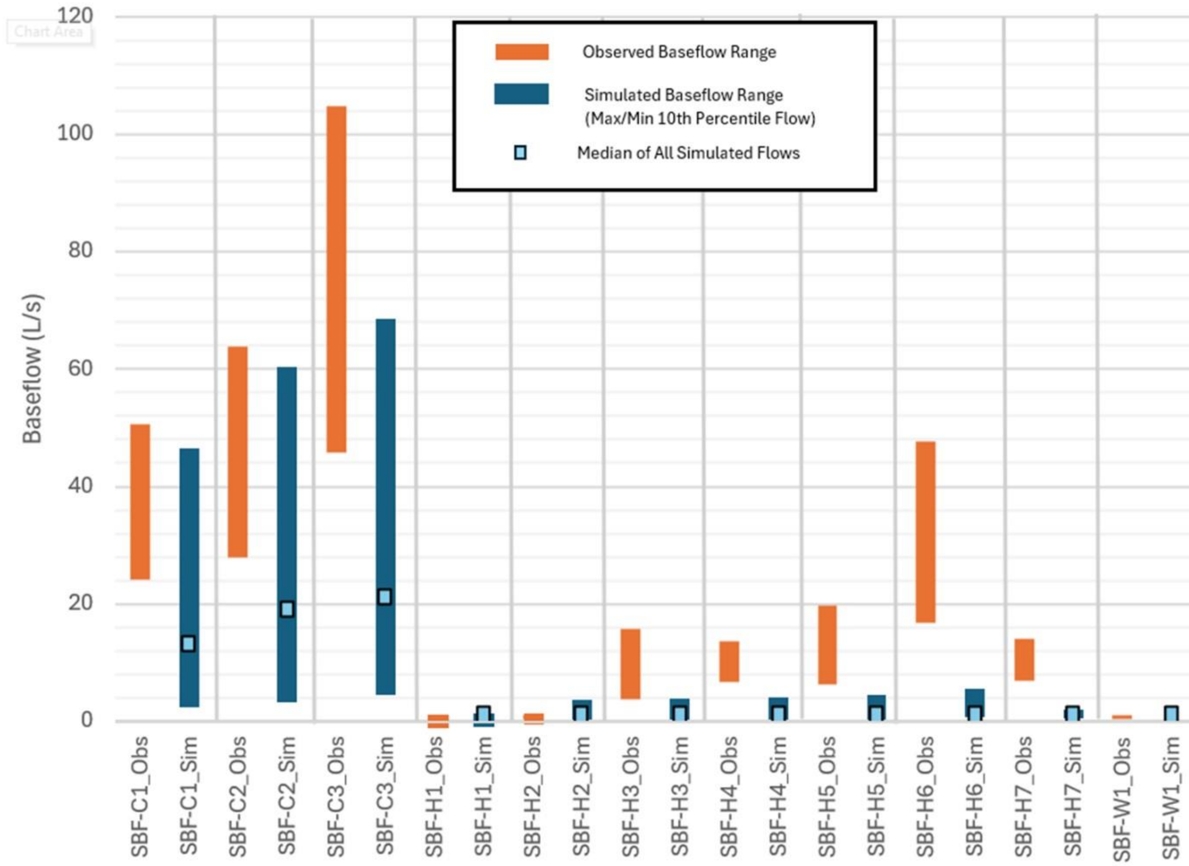
Average annual seepage rates within the PSA are displayed on Map GW-18. Seepage is associated with stream valleys and steep breaks in topography, headwater drainage features, wetlands, and streams. Seepage up to 10 mm/day is observed in the southern portion of the PSA at the north and south ponds in the low-lying areas where the depth to water table is at, or near, the ground surface. At other locations, such as the eastern portion of the PSA at the headwaters of Clythe Creek as well as adjacent to the City boundary, south of Clythe Creek, seepage rates range between approximately 0.1 mm/day and 1 mm/day.

The simulated seepage in the drier summer season (August 2021) is illustrated on Map GW-19, which is significantly less extensive than the average annual map of seepage locations (Map GW-18). Due to drier conditions, groundwater levels fluctuate towards a minimum during the summer months, hence seepage rates are observed to significantly drop across the PSA compared to the annual average. In August 2021, simulated seepage rates of 10 mm/day continued to be observed in the north and south ponds, in the southern portion of the PSA. Although the water table fluctuates, the pond's seepage rates are impacted less due to the low-lying topography. The SSA has an elevated topography which in combination with a deeper groundwater table in the summer, limits the opportunity for seepage to occur. Map GW-20 provides additional context for the seasonality of the seepage locations by depicting the simulated frequency as the percentage of the year that the area is simulated to have seepage. Most areas seep for less than 50% of the year meaning they flow primarily in the spring but typically are dry in summer and fall.

The simulated average annual discharge to streams within the PSA is displayed in Map GW-21. Groundwater discharge is simulated in areas consistent with observed groundwater discharge, namely between station CC-1 and CC-4 on Clythe Creek. Discharge in the SSA occurs at a higher rate and longer stretch of the Clythe Creek than within the PSA. Downstream of CC-4 at Watson Parkway to CC-6, there is less discharge than in the reaches upstream of this location.

The Unnamed Tributary located on the Former Reformatory Lands has a poorly defined channel in many locations, so groundwater discharge is primarily by seepage to surface and is shown on Maps GW-19-21.

Figure 4-1: Simulated and observed (spot flows) baseflow - summer



Watson Creek

The simulated results show discharge/baseflow along Watson Creek in the lower reaches. Monitoring at surface water stations along Watson Creek (WC-1 and WC-2; Map GW-1, Appendix B-1) are consistent with the simulated results which also low groundwater discharge to the creek. Monitoring suggests neutral to slightly varying upward and downward hydraulic gradients at WC-1 and WC-2 from 2019 to the end of 2022; however, the creek was observed to go dry at WC-2 in the summer and/or early fall in 2019, 2020, and 2021. The only observation of potential groundwater discharge along Watson Creek during the February 2023 winter watercourse walk, included open water observations and possible watercress approximately 150 m upstream of WC-1. A wetland was also identified along Watson Creek south-east of Grange Road in proximity to monitoring well nest MW22-02 on June 28, 2024, however downstream and upstream of this location, Watson Creek was observed to be intermittently dry.

Hadati Creek

Along the upper reaches of Hadati Creek, simulated results show minimal discharge/baseflow, however towards the point of confluence with Clythe Creek, Hadati Creek sees discharge ranging between 0.0 L/s and 0.01 L/s. The simulated results show lower flows than the observed at HC-2 and observed spotflows in the lower reaches and this is attributed to the model not accounting for groundwater intersecting existing subsurface infrastructure and conducting flow to the stream and potentially the effect of the SWM pond upstream of the railway bridge. Additional calibration will be completed at the start of Phase 2 to improve the fit based on findings or most recent updates to the hydrologic model to improve this representation, accounting for potential leaky infrastructure and stormwater storage more explicitly on Hadati.

A downstream vertical hydraulic gradient was observed at MW22-01 near Auden Road, in proximity to the reach of Hadati Creek that is simulated to not have discharge to the creek. In contrast, near Clythe Creek, along the lower reaches of Hadati Creek watercress was identified at spot base flow locations SBF-H5 and SBF-H6 (SBF-H5 and SBF-H6; Map GW-10, Appendix B-1) during spot base flow monitoring events on October 3, 2023, and May 7, 2024, respectively. The presence of watercress is often an indicator of groundwater discharge and where it was observed in the field generally corresponds to the simulated results.

Clythe Creek

The simulated discharge/baseflow rates along Clythe Creek vary from 0.0 L/s to 0.13 L/s at the headwaters and upper reaches, 0.13 L/s to over 0.25 L/s near the City boundary, and at the point of confluence with Watson Creek, as well as 0.0 L/s to 0.13 L/s at the lower reaches near the ponds and at the point of confluence with Hadati Creek. Monitoring results and field observations support the findings of the simulated results.

From the field findings, surface water stations CC-1 and CC-2 (CC-1 and CC-2; Map GW-10, Appendix B-1) displayed clear and relatively continuous upward vertical hydraulic gradients during 2021 and the first 5 months of 2020, as well as from 2019 through the end 2021, respectively. In February 2024, groundwater discharge was observed in the field along the bank of Clythe Creek and possible watercress in the water, between CC-1 and CC-2, just upstream of the confluence with Watson Creek.

In addition to the field findings at the surface water stations, seepage was identified along Clythe Creek upstream of SBF-C1 (Map GW-10, Appendix B-1) during spot baseflow monitoring on June 28, 2024. These findings demonstrate consistent observations of discharge along the portion of Clythe Creek near Watson Creek and the City boundary. Downstream, the simulation indicates lower rates of discharge to the creek. Dry conditions, downward gradients and losing stream condition were observed near surface water station CC-3 (Map GW-10, Appendix B-1) between 2019 and 2022. Both surface water stations, CC-5 and CC-6 (CC-5 and CC-6; Map GW-10, Appendix B-1), were observed to have slight downward vertical gradients during the winter and early spring in 2023, as well as the winter through to summer in 2024. At these locations, neutral gradients were observed from spring 2023 to early winter 2024. In contrast, both watercress and seepage were identified along the north side of Clythe Creek upstream of SBF-C1 (Map GW-10, Appendix B-1) on October 3, 2023, and June 28, 2024, respectively. These observations indicate the presence of both discharge and limited discharge to the lower reaches of Clythe Creek, as seen in the simulated results.

The MNR thermal regime mapping classifies Watson and Clythe creeks as cool water streams; however, Ashworth (2012) suggests that Clythe Creek may be better characterized as a cool warmwater stream. An aquatic survey, completed by Trout Unlimited in 2011, concluded that the only aquatic species inhabiting Clythe Creek are cool to warm water species (Ashworth 2012). Ashworth (2012) reported that Brook Trout have been absent from Clythe Creek since 1953 and Brook Stickleback and Sculpin have been absent since 1994.

Additional fish surveys were completed as part of the SWSU and are detailed in Section 4.4. The characterization of Clythe Creek, upstream of the confluence with Hadati Creek as a coolwater stream, is more consistent with monitoring data and winter field reconnaissance observations along parts of Clythe Creek. Watson and Hadati Creeks do not show continuous and widespread groundwater discharge along these watercourses. Watson Creek and Hadati Creek below the railway line are classified as cool water. Hadati Creek upstream of the rail line is classified as warm water. Clythe Creek below the confluence of Hadati Creek is classified as warmwater. Clythe Creek upstream of the City boundary (in the SSA) is classified by the MNR as coldwater but was not evaluated for this project.

4.1.2.12 Ponding

The simulated average ponding depths throughout the PSA are shown on Map GW-22. The ponding is present at locations where the groundwater table is at, or near, the surface (0 m). These locations include areas adjacent to the upper segments of Hadati Creek and Watson Creek, the southern portion of the PSA and surrounding the ponds, and in the eastern portion near headwaters of Clythe Creek and near the City boundary. Where depth to the groundwater table is near the surface, the pond depths have an annual average depth range from 0.1 m to 0.4 m, with the exception of the large south pond which is observed to have a maximum pond depth of 3.0 m. Pond depths are interpreted to vary seasonally. The simulated average ponding depth estimated for April 2021, is shown on Map GW-23, and considered representative of average conditions. In early spring, water levels are typically high, and as a result are interpreted to impact ponding across the PSA. The simulated results indicate an increase from the average annual ponding depth of 0.1 m to an average seasonal depth of 0.4 m at most ponding locations. Ponding depths at the north and south ponds, in the southern portion of the PSA did not deviate from the average simulated results. In addition to the depths, pond boundaries are observed to be noticeably larger, and new ponds have appeared across several locations within the PSA.

4.1.2.13 Water balance and groundwater function

The integrated model enabled physically-based water balance analysis of the entire model domain or any sub-areas. Existing conditions water balances were compiled for the simulated 2012-2023 time-period for the whole domain (subwatershed), Clythe Creek in the PSA and SSA, as well as Hadati and Watson Creeks as shown in Table 4.3.

The proportion of the primary outflows, as a percentage of the total inflow to the model is presented in Table 4.4. Primary outflows include evapotranspiration, runoff and groundwater discharge (baseflow) to streams, lateral flow through the overburden, and lateral flow through the bedrock. Primary inflows include precipitation and lateral groundwater flow through the overburden and bedrock.

The water budget analysis indicates that:

- Change in soil and groundwater storage is small during the simulation period.
- Evapotranspiration accounts for approximately 60 per cent of total outflows from the SSA.
- Recharge and evapotranspiration are lowest in Hadati and Watson Creek which have the most urbanization.
- Groundwater inflows from adjacent subwatersheds provide the majority of the water that flows through the lower bedrock aquifer while the recharge in the subwatershed provides most of the runoff and groundwater discharge to streams.

Table 4.3: Model domain water balance (mm/year) 2012 to 2023

Water Balance Component	Model Domain	Clythe Creek in SSA	Clythe Creek in PSA	Hadati Creek	Watson Creek
Area (m^2)	24,384,800	10,056,800	5,942,700	7,768,600	616,700
Precipitation	963	963	963	963	963
Evapotranspiration	585	612	583	555	562
Overland Flow In	0	0	1	0	1
Overland Flow out	6	1	22	1	9
Subsurface Flow In	70	126	287	152	771
Subsurface Flow Out	188	288	364	241	945
Total Streamflow (includes terms in italics below)	260	198	288	323	225
Overland to River	25	36	12	22	2
Impervious Runoff to River	204	110	248	292	210
Baseflow to River	31	52	28	9	13
Storage Change	-7	-9	-6	-4	6
Error	0	0	0	0	-1
Summary Water Balance					

Water Balance Component	Model Domain	Clythe Creek in SSA	Clythe Creek in PSA	Hadati Creek	Watson Creek
Inflow	1033	1090	1251	1116	1736
Outflow	1039	1099	1257	1120	1741
Storage Change	-7	-9	-6	-4	6
Error	0	0	0	0	-1

Note: See Table M in Appendix B-2 for more details

Simulated Monthly Water Balance is depicted in Figure 1 of Appendix B-2.1 for the entire model domain/subwatershed for the period from 2012 through 2023. The following characteristics of the water balance are observed:

- Precipitation is highest in August
- Monthly ET is highest in the summer months
- Monthly stream flow highest in April and lowest in the summer months
- Mean Monthly recharge for the simulated time period of 2012 through 2023 varied from 5 mm to 70 mm. The highest monthly recharge (70 mm) occurs in April following the spring melt events.

The water balance provides insights on the seasonality of the entire water resources system. The subwatershed wide water balance and water balance for subcatchments shown in Table 4.3, will be developed for future conditions to identify potential impacts to the groundwater system balance and enable a comparison of alternative management approaches to minimize impacts to key hydrologic features by mimicking the distribution and monthly variation in groundwater and maintain the existing water balance.

4.1.3 Linkages between key hydrologic areas and features

The Clythe Creek Groundwater System Conceptual Model (CM) is depicted on Map GW-9 and is based on the interpretation of background information and the field work completed as part of this study as well as information collected by the City. The groundwater flow system consists of a shallow / local groundwater flow system and a regional / deeper groundwater flow system that interact with each other across regional aquitards (Vinemount Member) and provide seepage and groundwater discharge to the surface water systems. The combined water resource system (surface water and groundwater) in the PSA and SSA provides key hydrologic functions by sustaining healthy aquatic and terrestrial ecosystems and provides drinking water (groundwater) to meet the current and future demands in Guelph.

Key hydrologic functions within the Clythe Creek Groundwater System Conceptual Model (CM) are depicted in Map GW-9 and discussed in detail in Section 4.1.2.6. Additionally, key hydrologic areas such as Highly Vulnerable Aquifer and Well Head Protection Areas are shown on Map GW-8 and discussed in Section 4.1.2.4. This section further expands on key hydrologic functions, features and areas within the Clythe Creek Groundwater System, with more quantitative assessment of the linkages between key hydrologic areas (groundwater recharge areas) and key hydrologic features (groundwater discharge dependent features).

A significant groundwater recharge (SGRA) map is presented for each of the aquifer units based on the simulated conditions for the period of 2012 through 2023 (Maps GW-24 to GW-26). The significant recharge maps show the linkage between all recharge areas in the PSA and SSA to the discharge features (streams, wetlands, ponds, wells). The recharge areas are coloured according to the specific type of discharge feature they support. The types of discharge features / areas included:

- Key Hydrologic Feature – Cool / Coldwater Stream, Seeps and Wetlands
    - Clythe Creek - Headwaters to Watson Creek
    - Clythe Creek - Watson Creek to Watson Parkway
    - Clythe Creek - Watson Parkway to Eramosa River
    - Ponds - Former Reformatory Lands
    - Unnamed Tributary - Former Reformatory Lands
    - Unnamed Tributary - North of Watson Road
- Key Hydrologic Feature - Municipal Well Supply
    - Gasport Fm. - Southwest to Park / Emma Wellfield
    - Overburden / Guelph Fm. - Southwest to Park / Emma Wellfield
- Other Hydrologic Features
    - Discharge to Shallow Subsurface
    - Gasport Fm. - Eramosa River
    - Gasport Fm. - Guelph Lake Subwatershed
    - Hadati Creek
    - Overburden / Guelph Fm. - Eramosa River
    - Overburden / Guelph Fm. - Guelph Lake Subwatershed
    - Watson Creek

The SGRA maps were developed from particle tracking routines in MIKE SHE that simulate the path taken by a particle that recharges at the water table and groundwater originating at (already in the system) the top of each aquifer in 2012 to its ultimate discharge location. The analysis tool links recharge and discharge areas and provides a means for further understanding the connection between recharge zones and potential receptors.

In the PSA, recharge areas contributing discharge to Clythe Creek extend further away than similar areas in Hadati Creek. The larger contributing recharge area for Clythe Creek reflecting the higher groundwater discharge to the Clythe Creek reach, than Hadati, and its status as coolwater across the PSA.

In the PSA, recharge areas contributing discharge to Clythe Creek and the Unnamed Tributary extend further away from the streams than recharge areas linked to discharge on the Hadati Creek. The size of the area contributing discharge to Clythe Creek and the Unnamed Tributary reflects insights from field data and simulated seepage and stream discharge maps that reflect the higher groundwater discharge to the Clythe tributary and its status as a coolwater reach.

4.2 Surface water characterization

Hydrologic and hydraulic characterization of the existing and future surface water conditions in the Clythe Creek Subwatershed will be used to establish stormwater management guidance for future land uses. The floodplain mapping presented in this report reflects current existing conditions within the study area. Future surface water conditions will be modelled as part of Phase 2 of this study and will be used to inform final regulatory floodplain mapping, superseding the current GRCA mapping.

The surface water system is assessed using calibrated/integrated models including PCSWMM (hydrologic/hydraulic model) and HEC-RAS (hydraulic model). The calibration is based on observed flows from the 2-year (2023-2024) monitoring program. The PCSWMM model, which aligns with the City's SWM Master Plan Update modelling (Aquafor Beech, 2023) and the Clair-Maltby Secondary Plan (2022) modelling, has been used to determine surface flow conditions for existing and future land use conditions and runoff to natural heritage features, including the ponds located on the Ontario Reformatory lands. The PCSWMM model has also been compared, modified and rationalized using the results from the MIKE SHE model, and used to estimate flows and volumes for various storms and a range of design events for use in flooding, erosion and water balance assessments for existing conditions, future conditions and various climate change scenarios.

The performance of existing stormwater management measures has been assessed and thereby used to determine the requirements for future stormwater management measures, including low-impact development best management practices (LID BMPs) and associated capture rates, to meet peak flow (flood), erosion and water balance targets. The PCSWMM and hydraulic models also provide input to assess potential impacts to existing and future Regulatory floodplains for the Watson, Hadati and Clythe Creeks (hazards) accordingly. Recommendations from the Guelph Innovation District, York Road EIS, SWM Master Planupdate, including the Elizabeth Street flow diversion (which assessed the Elizabeth Street storm sewer system and the minor system flow split), have been used to develop stormwater management and hydraulic improvements for the Clythe Creek subwatershed.

4.2.1 Surface water methods

4.2.1.1 Background information review

A background review of previous studies, policy documents, and reports was undertaken to provide context for the surface water and flood hazards study. Key documents are noted below.

A more detailed summary of reviewed reports and relevant findings has been included in Appendix C.

- Grangehill Estates Stormwater Management Design Brief (Guelph Grangehill Developments, 1998)
- Clythe Creek Subwatershed Study (Ecologistics and Blackport, 1998)
- SWM Design Report Draft Plan 23T-96501 and 23T-99501 Martini/Valeriote Subdivision Report (Gamsby and Mannerow Limited, 2004)
- Stormwater Management Master Plan (AMEC, 2012)
- Stormwater Management Master Plan Update (Aquafor Beech, 2023)
- Elizabeth Street Flow Splitter Assessment (AMEC, 2012)
- York Road Environmental Impact Study (Wood, 2019)

The most recent document and model reviewed as part of the surface water assessment for this study was the City of Guelph's Stormwater Management Master Plan Update (Aquafor Beech, 2023). Table 4.4 briefly overviews the model scenarios used in the Master Plan Update.

Table 4.4: City of Guelph Stormwater Management Master Plan (2023) model scenarios

Scenario	Description	IDF: TIMP**	Model Outcomes	Storm Parameters	Notes
1	System Characterization: Existing Conditions	Existing: Existing	• Total storm sewer lengths below capacity (5-year), at capacity, and surcharged (colour-coded figure and meters of pipe to be provided by Aquafor Beech). • Number of maintenance holes where 5-year hydraulic grade line is above 1.8 m below ground surface (colour-coded figure and number of MHs to be provided). • Lengths where the major system (100-year) is <0.15 m, 0.15 - 0.3 m, or >0.3 m depth (colour-coded figure and meters of road to be provided). • Water balance components (infiltration, runoff, etc.) from the continuous model.	• Minor: 5-year, 3-hr Chicago • Major: 100-yr, 3-hr Chicago • Continuous: spring-fall	Continuous modelling is to be run for approximately 7 months (spring, summer, fall) using rainfall data set from the rainfall/IDF analysis (normal rainfall year to be selected). This would be the same 7 months used in the 2012 MP (April - October), so would be comparable to each of the 10 separate runs completed in 2012 and provides an appropriate level of detail for this study.
2	System Characterization: Future Growth	Existing: Future	• Total storm sewer lengths below capacity (5-year), at capacity, and surcharged (colour-coded figure and meters of pipe to be provided). • Number of maintenance holes where 5-year hydraulic grade line is above 1.8 m below ground surface (colour-coded figure and number of MHs to be provided). • Lengths where the major system (100-year) is <0.15 m, 0.15 - 0.3 m, or >0.3 m depth (colour-coded figure and meters of road to be provided). • Water balance components (infiltration, runoff, etc.) from the continuous model.	• Minor: 5-year, 3-hr Chicago • Major: 100-yr, 3-hr Chicago • Continuous: spring-fall	Continuous modelling is to be run for approximately 7 months (spring, summer, fall) using rainfall data set from the rainfall/IDF analysis (normal rainfall year to be selected). This would be the same 7 months used in the 2012 MP (April - October), so would be comparable to each of the 10 separate runs completed in 2012 and provides an appropriate level of detail for this study.

Scenario	Description	IDF: TIMP**	Model Outcomes	Storm Parameters	Notes
3	System Characterization: Future Growth and Climate Change	Climate Change (RCP4.5): Future	• Total storm sewer lengths below capacity (5-year), at capacity, and surcharged (colour-coded figure and meters of pipe to be provided). • Number of maintenance holes where 5-year hydraulic grade line is above 1.8 m below ground surface (colour-coded figure and number of MHs to be provided). • Lengths where the major system (100-year) is <0.15 m, 0.15 - 0.3 m, or >0.3 m depth (colour-coded Figure and meters of road to be provided).	• Minor: 5-year, 3-hr Chicago • Major: 100-yr, 3-hr Chicago	The storm duration (3-hour) and distribution (Chicago) will be consistent in all scenarios. The 3-hour IDF will be interpreted from the IDF_CC outputs.
4	System Management Alternative Solutions: Grey infrastructure Only	Preferred IDF): Future	• Total storm sewer lengths below capacity (5-year), at capacity, and surcharged (colour-coded figure and meters of pipe to be provided). • Number of maintenance holes where 5-year hydraulic grade line is above 1.8 m below ground surface (colour-coded figure and number of MHs to be provided). • Lengths where the major system (100-year) is <0.15 m, 0.15 - 0.3 m, or >0.3 m depth (colour-coded figure and meters of road to be provided).	• Minor: 5-year, 3-hr Chicago • Major: 100-yr, 3-hr Chicago	Scenario to include: • New proposed end-of-pipe opportunities • -Upsizing bottlenecks
5	System Management Alternative Solutions: Green infrastructure Only Volume Control (VC) of 28 mm	Preferred IDF): Future	Results to be compared to Scenario 2/3 (depending on preferred IDF): • Total storm sewer lengths below capacity (5-year), at capacity, and surcharged (colour-coded figure and meters of pipe to be provided). • Number of maintenance holes where 5-year hydraulic grade line is above 1.8 m below ground surface (colour-coded figure and number of MHs to be provided). • Lengths where the major system (100-year) is <0.15 m, 0.15 - 0.3 m, or >0.3 m depth (colour-coded figure and meters of road to be provided).	• Minor: 5-year, 3-hr Chicago • Major: 100-yr, 3-hr Chicago	Green infrastructure will not solve all major or minor drainage issues. It may mitigate some of these issues, reducing the need for costly end-of-pipe upgrades.
6	System Management Alternative Solutions: Grey/Green Hybrid VC 5 mm	Preferred IDF): Future	Results to be compared to Scenario 2/3 (depending on preferred IDF): • Total storm sewer lengths below capacity (5-year), at capacity, and surcharged (colour-coded figure and meters of pipe to be provided).	• Minor: 5-year, 3-hr Chicago • Major: 100-yr, 3-hr Chicago	5 mm of volume control

Scenario	Description	IDF: TIMP**	Model Outcomes	Storm Parameters	Notes
			• Number of maintenance holes where 5-year hydraulic grade line is above 1.8 m below ground surface (colour-coded figure and number of MHs to be provided). • Lengths where the major system (100-year) is <0.15 m, 0.15 - 0.3 m, or >0.3 m depth (colour-coded figure and meters of road to be provided).		
7	System Management Alternative Solutions: Grey/Green Hybrid VC 14 mm	Preferred IDF): Future	Results to be compared to Scenario 2/3 (depending on preferred IDF): • Total storm sewer lengths below capacity (5-year), at capacity, and surcharged (colour-coded figure and meters of pipe to be provided). • Number of maintenance holes where 5-year hydraulic grade line is above 1.8 m below ground surface (colour-coded figure and number of MHs to be provided). • Lengths where the major system (100-year) is <0.15 m, 0.15 - 0.3 m, or >0.3 m depth (colour-coded figure and meters of road to be provided).	• Minor: 5-year, 3-hr Chicago • Major: 100-yr, 3-hr Chicago	14 mm of volume control
8	System Management Alternative Solutions: 2D Model of Top 10 Flood Prone Areas	Preferred IDF): Future	Extent and depth of flooded area to be shown for top 10 flood-prone areas (2D mesh to be used for these 10 areas only)	• Minor: 5-year, 3-hr Chicago • Major: 100-yr, 3-hr Chicago	Locations to be selected based on City input as well as the results of Scenarios 1, 2, and 3.

**IDF = intensity-duration-frequency curves; TIMP = refers to the total imperviousness

The City's 2023 SWMMP Update included updating the 2012 City-wide PCSWMM model to assess the operation and performance of the major and minor drainage systems. A summary of the modelling scenario results is in Table 4.5.

Table 4.5: City of Guelph Stormwater Management Master Plan (2023) scenario result summary

		Existing Conditions Scenario Count	Existing Conditions Scenario Length (km)	Future Growth Scenario Count	Future Growth Scenario Length (km)	Future Growth and Climate Change Scenario Count	Future Growth and Climate Change Scenario Length (km)
Minor System Nodes: 5-Year Event	HGL At or Above the Surface	1988 (22.6%)	-	2857 (32.5%)	-	3014 (34.3%)	-
Minor System Nodes: 5-Year Event	HGL Within Basement Level (0-1.8 m)	3330 (37.9%)	-	3647 (41.5%)	-	3505 (39.9%)	-
Minor System Nodes: 5-Year Event	HGL Below Basement Level (>1.8 m)	3475 (39.5%)	-	2289 (26.0%)	-	2274 (25.9%)	-
Minor System Pipes: 5-Year Event	Stormwater Sewer Surcharged (Bottleneck)	3795 (42.0%)	195.28 (41.4%)	5477 (60.6%)	280.65 (59.5%)	5468 (60.5%)	279.59 (59.3%)
Minor System Pipes: 5-Year Event	Stormwater Sewer Within Capacity (No Surcharge)	5237 (58.0%)	276.20 (58.6%)	3555 (39.4%)	190.83 (40.5)	3564 (39.5%)	191.88 (40.7%)
Major System: 100-Year Event	Depth >0.3 m Count	43 (0.6%)	1.56 (0.4%)	51 (0.7%)	2.09 (0.6%)	43 (0.6%)	1.70 (0.5%)
Major System: 100-Year Event	Depth 0.15 m – 0.3 m Count	2403 (33.9%)	118.43 (31.6%)	2568 (36.2%)	127.31 (34.0%)	2342 (33.0%)	114.87 (30.7%)
Major System: 100-Year Event	Depth <0.15m Count	4652 (65.5%)	254.60 (68.0%)	4479 (63.1%)	245.19 (65.5%)	4713 (66.4%)	258.03 (68.9%)

Additional background information on previous modelling efforts is provided in the 2012 SWMMP memo. The 2023 SWMMP PCSWMM model was identified as not being directly comparable to the original 2012 PCSWMM model, as additional neighbourhoods were modelled. Additionally, changes were made to the criteria of road depth thresholds. Figures of the results of the three scenarios were provided.

4.2.1.2 Field work program and data

Surface water level data are collected at six monitoring stations by the City of Guelph's Water Services group for the Clythe Municipal Drinking Water Well. These monitoring stations have been operational since 2019 and are located on Watson Creek and Clythe Creek (Map GW-1).

Three new surface water stations were installed within the PSA as part of the SWSU. The monitoring stations are located at the Pedestrian Bridge Crossing between Clythe Creek and the Reformatory Pond (CC-5), upstream of the online weir structure located on Clythe Creek and downstream of the Hadati Creek confluence (CC-6), and immediately upstream of the York Road crossing of Hadati Creek at the property located at the northwest corner of Elizabeth Street and York Road (HC-2). The monitoring station on Hadati Creek had been relocated from upstream of Suburban Avenue to the Suncor property in order to collect flows contributing to Hadati Creek from the sewer system located at Elizabeth Street and Industrial Street.

Spot baseflow monitoring began in October 2022 at 14 locations across the PSA. The locations are as follows (Map GW-1):

- Hadati Creek (seven locations)
- Watson Creek (one location)
- Clythe Creek (three locations)
- Inflow/Outflow surrounding the Ontario Reformatory ponds (three locations)

Background mapping and data

The following spatial data and mapping have been reviewed in this assessment:

- Received from the City of Guelph: Aerial mapping (2006, 2009, 2012, 2016, 2019 and 2021), City of Guelph Owned Properties, City of Guelph Contours (0.5 m), City of Guelph Wetlands, City of Guelph Water Infrastructure (Stormwater, Wastewater, Water), City of Guelph transportation layers.
- Grand River Conservation Authority (GRCA) open data available online: 1999 Landcover, GRCA Watercourse, GRCA Watershed, GRCA Waterbodies.
- Land Information Ontario: Ontario Digital Terrain Model (DTM) (Lidar-Derived) - "Lake Erie Package W" and "Lake Erie Package X".

A review of available stream flow and rainfall data was undertaken to provide context for the surface water and flood hazards study. Key data sources are summarized below.

Stream flow data

Surface water data have been collected for Clythe Creek by GM BluePlan (Appendix B) in accordance with the Watson Creek Development Area's 2021 monitoring program. Continuous water surface elevation data were collected at four locations located west of Watson Road between Eastview Road and York Road. Three of the monitoring locations have been operational since August 2007, with the four locations operating since February 2008.

Stantec was retained by the City to complete baseline groundwater level, surface water level, and stream flow monitoring in the vicinity of the Clythe Well. Discrete stream flow monitoring occurred at four locations on Clythe Creek and two on Watson Creek, with all locations being within the PSA. Data were collected seven separate times between August 16, 2019, and December 15, 2021. Stream flow data are included in the report.

Continuous water level logging was completed from July 6, 2020, to June 30, 2021, for the 2023 SWMMP Update. Baseflow levels and peak flows were determined using a rating curve developed from the discrete flow monitoring site visits. The SWMMP Update – Flow Monitoring Program report (Aquafor Beech, 2023) included approximate baseflow, peak flow, stage-discharge equations, and discrete flow monitoring event data. Flow monitoring stations HD-01 and HD-02 fall within the PSA.

Rainfall data

Rainfall data (Appendix B-2) are available through the GRCA and Environment and Climate Change Canada. The closest climate monitoring station to the Clythe Creek Subwatershed Primary Study Area operated by the GRCA is the Guelph Lake station. The Guelph Lake Climate Station has collected hourly data since 2000. The closest rainfall monitoring station operated by Environment and Climate Change Canada is the Guelph Turfgrass Institute station. The Guelph Turfgrass Institute Station has hourly rainfall data available for December 2006 to the present, and daily rainfall data spanning 1995 to 2004.

Rainfall data gaps have been infilled with data from appropriate neighbouring GRCA climate stations in consultation with the GRCA. Data have been used to create a precipitation data set to support the development of a long-term (73 years; 1950 to 2023) climate dataset for the PCSWMM hydrologic modelling and climate change scenarios as part of this project. The climate data set used for MIKE SHE and PCSWMM modelling is the same.

Rainfall data used as part of the SWMMP have also been provided to the Project Team. Data are organized by station and include rainfall duration, trends, and statistical analysis.

Background modelling inputs

Hydraulic and hydrologic models have been developed as part of the SWSU. A review of past hydrologic and hydraulic models of the Clythe Creek subwatershed has been conducted as indicated in the following sections.

GRCA

A HEC-RAS model of Clythe Creek from York Road to Watson Road was provided by the GRCA. The model was last modified by Stantec in 2007. The model includes three hydraulic structures.

Additional hydraulic models from the GRCA include a HEC-2 model for Clythe Creek, a HEC-2 model of Hadati Creek, and a HEC-2 model of the Eramosa River.

4.2.2 Surface water findings: Hydrology

4.2.2.1 Hydrologic Modelling Approach

The PCSWMM hydrologic/hydraulic modelling software v.7.6 has been used for the hydrologic assessment. PCSWMM was also employed for the City's Stormwater Management Master Plan, as well as numerous precursor studies including the York Road Environmental Impact Study, and the Guelph Innovation District assessment, among others.

PCSWMM is a graphical user interface and pre-processor for the widely used EPA SWMM, designed for modelling urban stormwater, wastewater, and watershed systems. Developed by Computational Hydraulics International (CHI), it is a combined hydrologic and hydraulic model capable of analyzing complex hydraulic conditions, including dual drainage systems (minor/major), open channels (such as ditches and watercourses), surcharge/pressure flow, and reverse flow. PCSWMM supports dynamic interactions between urban networks (pipes, culverts, and channels) and 2D flooded areas, offering both a 1D-2D approach (quasi-2D mesh connected to a 1D conveyance network) and a complete quasi-2D methodology to represent the creek and flooded areas. PCSWMM with its GIS integration, scenario management tools, and a user-friendly interface, facilitates the simulation of hydrology, hydraulics, and water quality processes.

A copy of all PCSWMM hydrologic model parameters has been included in Appendix C. Further details regarding the PCSWMM hydrologic/hydraulic model development are provided in the subsequent sections.

4.2.2.2 Subcatchments

The subcatchment layer for the SWSU consists of two distinct sets. The first set (Group A) includes areas developed as part of the City of Guelph's SWM Master Plan Update PCSWMM model, which were directly imported into the SWSU PCSWMM model. The second set (Group B) comprises areas not covered by the SWM Master Plan PCSWMM model, for which, the SWSU team developed the subcatchments. The Clythe Creek modelling approach has ensured that the SWM Master Plan modelling and drainage system characterization approach has remained unchanged.

The 0.5 m resolution Digital Elevation Model (DEM) from the Ontario Ministry of Natural Resources (MNR), based on the NAD83 CSRS (epoch 2010.0) horizontal datum and the CGVD2013 vertical datum, was used for this study. The DEM, which was developed as part of the Lake Erie (2016–2018) package and published on August 23, 2019, via the Ontario GeoHub, was processed by the SWSU team to burn in the watercourses and create a conditioned DEM. The SWSU team subsequently used the conditioned DEM for delineating subcatchment boundaries not covered by the SWM Master Plan Update model.

PCSWMM's automated watershed delineation tool was used for the initial determination of subcatchment boundaries using the conditioned DEM. However, all elevation data used in the model for estimating node elevations and defining cross-sectional channel shapes were derived directly from the original DEM, as approved by the City of Guelph for this purpose. The boundaries have been reviewed and refined based on aerial imagery, field reconnaissance, and Google Street View™ to ensure the boundaries are reasonable and reflect existing conditions.

The model development has resulted in a total of 1486 subcatchments, which includes 1323 subcatchments from Group A developed as a part of the SWM Master Plan Update that mostly covers the urban area and 163 subcatchments from Group B which were delineated and developed to cover the remaining parts of the PSA. Table 4.6 indicates the breakdown of drainage area subcatchments.

Table 4.6: Breakdown of drainage area subcatchments

	Group A: Stormwater Master Plan Update subcatchments	Group B: Remaining subcatchments	Totals
Area (ha)	756.92	1695.41	2452.33
Impervious Area (ha)	405.79	294.80	700.59
Average Imperviousness (%)	54	17	29

Physiography and soils

After refining the subcatchment boundaries, the soil survey complex database was reviewed to confirm the surficial soil conditions. The Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), in collaboration with Agriculture and Agri-Food Canada and the MNR, has developed a geospatial soil database for Southern Ontario. This database consolidates existing county-based digital soil data into a standardized, digitally stitched product, with the most recent update on November 6, 2019.

Soil types present in the PSA and SSA are presented in Table 4.7 and shown in Figure SW-3 (Existing Soils). An area weighting approach has been used to determine the proportion of each Soil Type within the subcatchments.

Table 4.7: Identified soil types in the study area

Soil Type	Percentage of Drainage Area (%)
Loam	67
Sandy Loam	29
Muck	4

As indicated by Table 4.7, most of the drainage area is covered by Loam, with Sandy Loam comprising most of the remaining area. The parameterization has been applied using the Modified Green-Ampt infiltration methodology, consistent with the infiltration approach used for the SWM Master Plan Update subcatchments (Group A). Area-weighted distribution has been used to assign infiltration parameters. Soil parameters for hydraulic conductivity, suction head, and initial deficit are presented in Table 4.8.

It should be noted that the Soil Type Muck is a type of soil rich in organic matter, often formed in wetland environments where organic material accumulates and decays. These soil types tend to retain water well and have finer particles, which align with muck's characteristics of high water-holding capacity and fine texture. Based on its properties, the hydraulic conductivity of Muck is estimated to fall between that of Silty Clay Loam and Sandy Clay Loam.

Table 4.8: Modified Green-Ampt infiltration parameters used in the modelling process

Soil Texture Class	Hydraulic Conductivity (mm/hr)	Suction Head (mm)	Initial Deficit (fraction)
Sand	120.34	49.02	0.413
Loamy Sand	29.97	60.96	0.390
Sandy Loam	10.92	109.98	0.368
Silt Loam	6.60	169.93	0.366
Loam	3.30	88.90	0.347
Sandy Clay Loam	1.52	219.96	0.262
Clay Loam	1.02	210.06	0.277
Silty Clay Loam	1.02	270.00	0.261
Sandy Clay	0.51	240.03	0.209
Silty Clay	0.51	290.07	0.228
Clay	0.25	320.04	0.210

Source: Rawls, W. J., Brakensiek, D. L., and Miller, N. (1983). Green-Ampt infiltration parameters from soil data. *Journal of Hydraulic Engineering*, 109(1), 62-70.

Land use

For the Primary Study Area (PSA), the existing (2023) land use layers provided by the City of Guelph were used to identify land cover within the city's boundaries. For the Secondary Study Area (SSA), the 2017 Land Cover GIS layer from the Grand River Conservation Authority (GRCA), last updated on May 23, 2019, was used. A merged land use layer covering both the PSA and SSA was subsequently developed which is presented in the SW-1 Existing Land Use Plan.

In alignment with the recommendations of the City of Guelph's SWMMP Update report, the values listed in Table 4.9 were used to determine the imperviousness levels for each land use type. To ensure consistency across all subcatchments in the model, these values were derived from the Guelph SWMMP Update report and compared to values from the City of Guelph Development Engineering Manual (2019) and then applied to all land use types based on the GRCA land cover layer or the City's Official Plan land use layer. An area-weighted approach was then used to calculate imperviousness within both urban and rural subcatchments. Spot checks of land use and impervious coverages were conducted to validate the assigned values, with manual adjustments made where necessary to ensure accuracy.

Table 4.9: Imperviousness percentages per land use category

Land Use (see Map SW-1)	Imperviousness (%)
Open Water	100%
Commercial	90%
Industrial	90%
ROW	80%
Institutional	70%
High Density Residential	50%
Medium Density Residential	45%
Low Density Residential	40%
Recreational	4%
Agriculture	0%
Grasslands	0%
Forest	0%
Wetland	0%

It should be noted that imperviousness values indicated in Table 4.9 were further refined during the hydrologic modelling calibration process.

4.2.2.3 Other hydrologic parameters

Other hydrologic parameters, such as subcatchment length and slope, have generally been directly measured from the available mapping. Subcatchment length is a key parameter within PCSWMM, as it is used to represent sheet flow/overland flow, and accounts for the expected degree of attenuation (i.e. is a surrogate for time of concentration or time to peak used in unit hydrograph methodologies). For Group B (not identified by the 2023 SWM Master Plan) subcatchments, subcatchment length was predominantly defined based on the length of overland flow to drainage channels within each subcatchment.

To ensure consistency with the 2023 SWMMP Update model, initial Manning's roughness coefficient (n) values of 0.025 for impervious areas and 0.2 for pervious areas were applied and Depression Storage was set at 1 mm for impervious areas and 5 mm for pervious areas across all subcatchments. Furthermore, a zero-impervious[3] percentage of 25% was assumed for all subcatchments, maintaining consistency with the SWMMP Update model.

Integrating the SWMMP Update PCSWMM model into the SWSU PCSWMM model introduced several challenges. A key issue arose when nodes flooded in PCSWMM, causing flow loss from the model resulting in continuity errors. Maintaining the flow within the system, and avoiding water loss due to flooding, significantly impacted the entire network (both PSA and SSA), such as widespread node surcharging and backflow in the culverts, SWM facilities and watercourses.

[3] This term is defined in the Glossary of key terms provided in Section 8.

To address model instability resulting from numerous surcharged nodes, significant effort was made to reduce flow loss by increasing the allowable surcharge depth or adding spills where needed. Additionally, the absence of defined spill conditions for under-capacity culverts and storage units along the watercourses presented further challenges during calibration. These issues were managed, to the extent possible within the project scope, by adding spill conduits for under-capacity culverts and overflow outlets for storage units.

4.2.2.4 Hydrologic Model calibration

The PCSWMM hydrologic model for the Clythe Creek subwatershed has been calibrated to using observed field data. The calibration process focused on key performance indicators, including peak flows, runoff volumes, and runoff coefficients, to ensure the model's reliability for simulating runoff responses for existing land use conditions. The PCSWMM model calibration used flow depth data collected from monitoring stations (i.e., CC-1, CC-6 and HC-2, Map GW-10) across the subwatershed during specific rainfall events representative of typical hydrologic conditions.

The monitoring data from 2023 and 2024 have been considered for the hydrologic model calibration. The monitoring data included rainfall along with the flow depth data however, the temporal resolution of the rainfall data was 24 hours which was considered unusable due to the 5-minute temporal resolution of the flow depth data and therefore has not been used for model simulation. Hence, the rainfall data from nearby meteorological stations has been collected and after review, data from the Guelph Lake Station has been used as the preferred rainfall input for the modelling calibration simulations, enabling a comparison of observed and simulated flows.

The calibration process involved iterative adjustments to key parameters, including various subcatchment parameters (e.g., impervious area percentages, slopes, lengths and widths), soil characteristics (e.g., infiltration parameters based on different hydrologic soil groups), and hydraulic routing elements (e.g., channel roughness coefficients). The adjustments were aimed to achieve a closer match between observed and simulated metrics, reducing the variance between datasets within acceptable limits defined by industry best practices.

In addition to calibration, sensitivity analyses were conducted to identify parameters that significantly influenced model outputs. This step provided insights into the model's robustness and highlighted critical areas where additional data or refinement may improve simulation accuracy. The calibrated model is intended to serve as a reliable tool for representing existing conditions and assessing future scenarios within the subwatershed.

Note that following an initial model calibration effort (as described in Sections 4.2.2.4.1 to 4.2.2.4.5) further review was undertaken with the Grand River Conservation Authority (GRCA) based on its understanding of the flow response characteristics in the overall area. This additional effort is described further in Section 4.2.2.5.

4.2.2.4.1 Flow characterization

Flow characterization within the Clythe Creek subwatershed included a detailed assessment of hydrologic responses and the development of rating curves at three monitoring locations: CC-1, HC-2, and CC-6. Rating curves (depth vs. discharge) have been used to convert stage (flow depth) measurements during the monitoring period (i.e., 2023 and 2024) into discharge values, enabling the characterization of flow responses for calibration events.

Development of rating curves

Two approaches were considered for establishing rating curves at flow monitoring sites:

1. Manual Flow Measurements

   Flow-depth relationships were initially derived from field measurements using the FlowTracker2 device, applying the mid-section method for calculating discharge. This approach involved two sub-methods for curve fitting:

   - Exponential Law: This approach assumes a logarithmic relationship between flow depth and discharge. Widely applied in hydrological studies, it uses the form $Q = a \cdot e^{b \cdot h}$, where Q is discharge, h is depth, and a and b are coefficients determined through regression.
   - Power Law: In this method, the relationship between flow depth and discharge follows a power function of the form $Q = c \cdot h^{d}$, where h is depth, and c and d are empirical coefficients. This approach is particularly suited to open-channel flows with consistent hydraulic behaviour.

   Typically, the exponential law provides a better fit for low flow regimes, and the power law provides a better fit for high flow regimes. While these sub-methods provided initial estimates, the manual flow measurements exhibited inconsistencies, particularly due to variable field conditions (e.g. debris jams and beaver activities) and uncertainties in depth measurements. Consequently, this approach was not adopted for final rating curve development.

2. HEC-RAS Model-Based Rating Curves

   The preferred approach involved using the HEC-RAS 1D model to establish rating curves at each location. This approach incorporated surveyed cross-sections at monitoring sites and simulated depth-discharge relationships for flows ranging from 0.01 m^3/s to 60 m^3/s.

   - Model Setup and Execution: Surveyed cross-sections were input into the HEC--RAS model, which was run for steady-state flows across the defined range. Depths corresponding to each discharge value were extracted, and rating curves were developed.
   - CC-1 Modification: At CC-1, due to the presence of beaver dams in the vicinity of the monitoring gauge, modifications were made to the corresponding cross-

section in the HEC-RAS model to account for the ineffective flow area caused by beaver activities.

- CC-6 Modifications: At CC-6, additional elements were incorporated into the HEC-RAS model, including a weir structure and upstream ineffective flow areas, to account for unique hydraulic conditions. These modifications enhanced the accuracy of the rating curve for this location.

Figure 4-2: Surface water flow monitoring station CC-6 rating curve

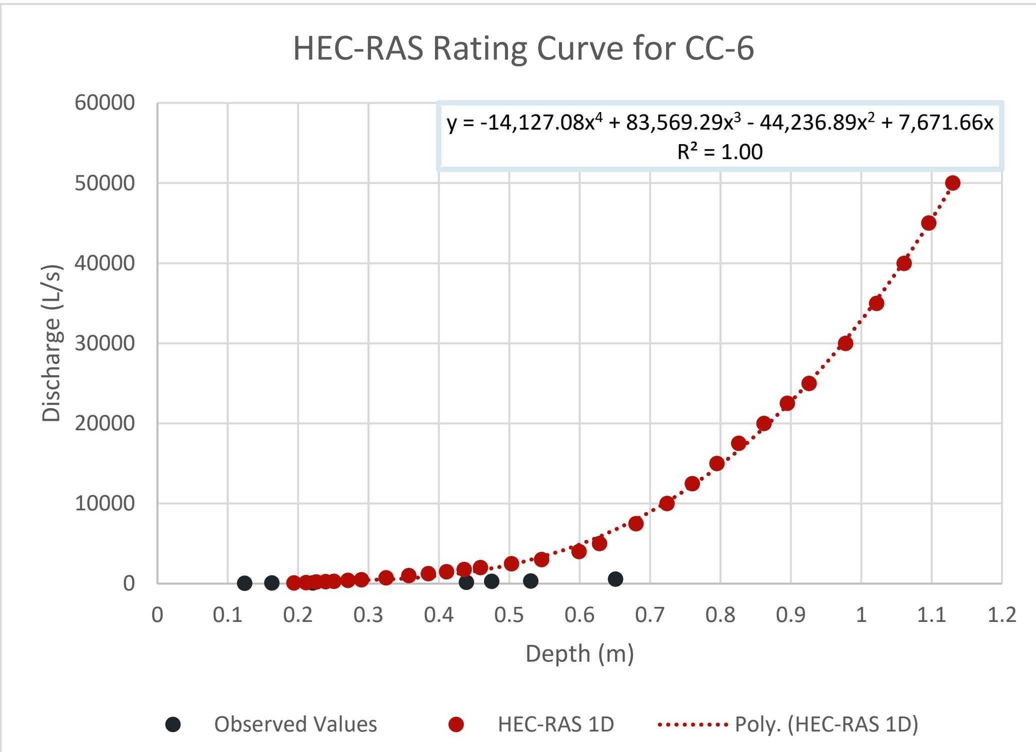


Figure 4-3: Surface water flow monitoring station CC-1 rating curve

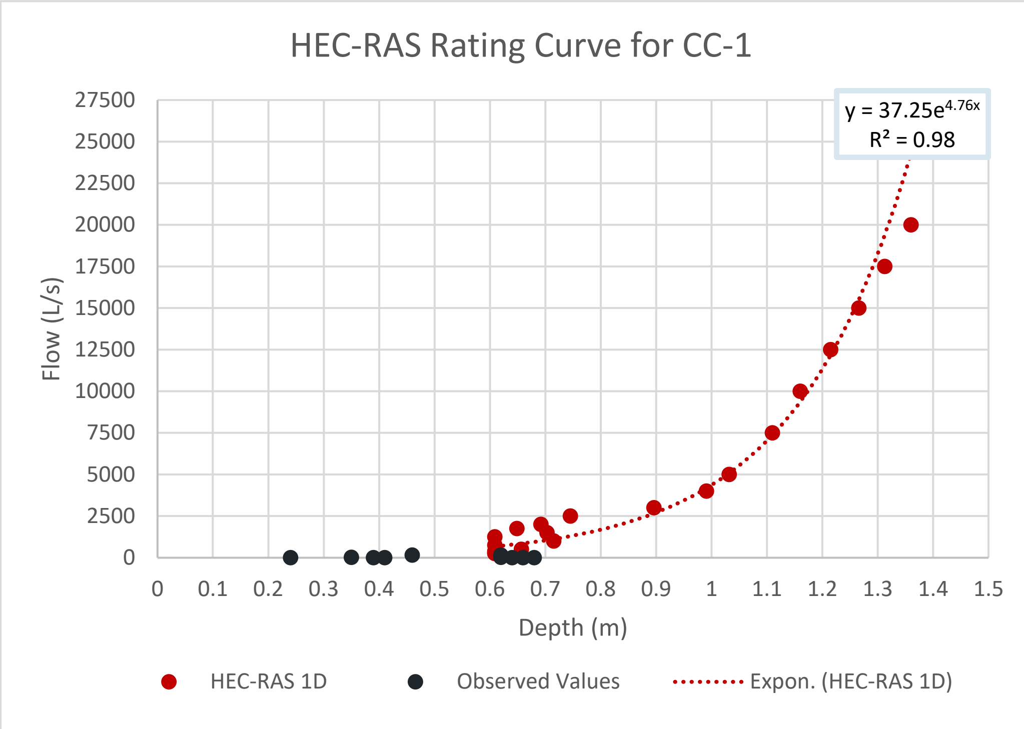
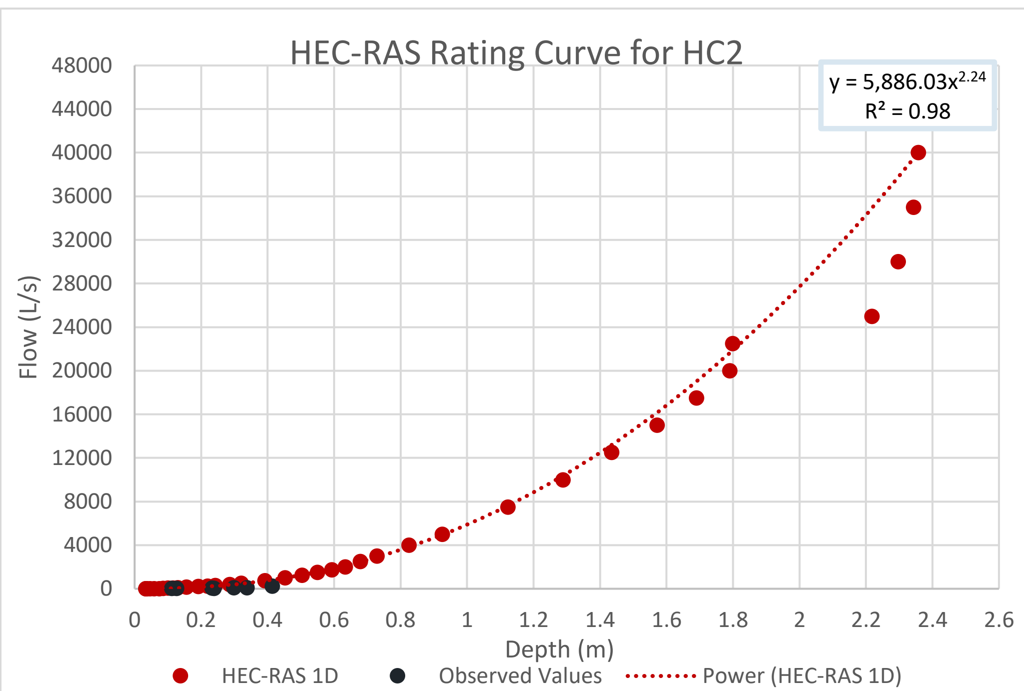


Figure 4-4: Surface water flow monitoring station HC-2 rating curve



It is noted that there were limited high-flow field measurements over the monitoring period, which limits the comparison of accuracy to the developed rating curves. It is also noted that the R^2 value presented is for the trendline equation to the HEC-RAS 1D generated values, not the actual observed data.

The HEC-RAS-derived rating curves demonstrated a better fit with observed data compared to the manual measurement approach, particularly under higher flow conditions, where the latter was prone to greater inaccuracies. At CC-6, the incorporation of the weir and ineffective flow areas resulted in a distinctly polynomial curve of fourth order, reflecting the influence of the hydraulic structure on flow behaviour. Table 4.10 provides the summary of rating curves for all monitoring locations considered for the model calibration. As noted previously, the R^2 value presented is for trendline equation to the HEC-RAS 1D generated values, not the actual observed data.

Table 4.10: Rating curve summary for monitoring locations per HEC-RAS 1D

Location	Equation type	General equation	Current equation	R^2
CC-1	Exponential	$y = a.e^{bx}$	$y = 37.25.e^{4.76x}$	0.984
HC-2	Power	$y=a.x^b$	$y = 5886.\ x^{2.24}$	0.981
CC-6	Polynomial (4th Order)	$y = ax^4+bx^3+cx^2+dx$	$y = -14127x^4+83569x^3-44237x^2+7671x$	0.999

The derived rating curves have been used to generate flow estimates for observed depths at each monitoring location. The flows have been analyzed to evaluate precipitation responses under various hydrologic conditions. The analysis of rating curves highlights the variability in hydraulic behaviour across the subwatershed, which is critical for accurate flow characterization. Detailed hydrographs comparing observed and simulated flows at each location are provided in Appendix C.

4.2.2.4.2 Calibration events summary

To ensure the PCSWMM model reasonably represents the hydrologic and hydraulic conditions of the Clythe Creek Subwatershed, a series of rainfall-runoff events have been selected for calibration. The rainfall events have been chosen to reflect a range of conditions, including variations in storm intensity, duration, and total precipitation.

Event selection criteria

The selected calibration events (Table 4.11) were based on the following criteria:

1. Data Completeness: Events with comprehensive rainfall and corresponding flow monitoring data at all three key locations (CC-1, HC-2, CC-6).
2. Event Variability: A mix of low-intensity, long-duration storms and high-intensity, short-duration events to capture diverse hydrologic responses.

3. Seasonal Representation: Events distributed across seasons to account for varying antecedent moisture conditions and land cover influences.

Table 4.11: Summary of hydrologic modelling calibration events

Start Date and Time	End Date and Time	Total Rainfall Depth (mm)	Duration (hr)	Avg. Intensity (mm/hr)	Max Intensity (mm/hr)	Obs HC-2	Obs CC-6	Obs CC-1
2023-05-19 22:00	2023-05-20 06:00	22.0	8.0	2.75	4.78	✓	✓	✓
2023-06-11 08:00	2023-06-12 11:00	35.55	27.0	1.32	4.49	✓	✓	✓
2023-06-25 23:00	2023-06-26 09:00	21.4	10.0	2.14	8.80	✓	✓	✓
2023-07-12 22:00	2023-07-13 05:00	34.0	7.0	4.86	15.51	✓	✓	✓
2023-07-23 14:00	2023-07-23 18:00	27.8	4.0	6.95	11.56	✓	✓	✓
2023-07-26 19:00	2023-07-27 02:00	17.64	7.0	2.52	7.06	✓	✓	✓
2024-04-11 09:00	2024-04-12 12:00	29.6	27.0	1.10	4.40	✓	✓	✓
2024-05-27 04:00	2024-05-27 17:00	34.8	13.0	2.68	8.80	✓	✓	✓
2024-06-20 00:00	2024-06-20 09:00	17.6	9.0	1.96	8.20	✓	✓	✓
2024-07-10 09:00	2024-07-11 09:00	60.8	24.0	2.53	8.20	✓	✓	✓
2024-07-16 13:00	2024-07-16 16:00	34.2	3.0	11.40	15.80	✓	✓	✓

Obs = observed flow at identified location.

Event characteristics

The calibration events have included periods with significant variability in runoff responses across subcatchments, with differences primarily influenced by land use (e.g., urbanized vs. rural vs. suburban areas), soil properties, and existing drainage infrastructure. Observed peak flows ranged from minor increases during low-intensity rainfall to significant increases during high-intensity events. The selected events provided the necessary variability to test and adjust critical model parameters, ensuring robustness across a range of conditions. These events served as benchmarks to evaluate the accuracy of simulated peak flows, runoff volumes, and runoff coefficients against observed data.

4.2.2.4.3 Initial results

The initial calibration phase began with the existing base PCSWMM model, simulating flow responses based on the 2023 Guelph Lake rainfall dataset. Observed flow data derived from HEC-RAS rating curves at monitoring locations CC-1, CC-6, and HC-2 were compared against simulated outputs to assess the model's hydrologic response. The evaluation focused on hydrograph comparisons for individual rainfall events, assessing key metrics including peak flows, runoff volumes, and runoff coefficients.

A comprehensive event-by-event comparison revealed several key insights as noted in the following:

- **Runoff Volumes and Runoff Coefficients:**
    - Simulated runoff volumes on average closely matched HEC-RAS derived values, generally staying within a ±15 percentage range. Similarly, runoff coefficients from the simulated data demonstrated reasonable alignment with observed data, reflecting the hydrologic characteristics of the respective drainage areas.
        - Variability in runoff coefficients was observed across the dataset. This variability manifested in two ways:
        - Within both observed and simulated datasets, runoff coefficients exhibited variability due to differences in the intensity, duration, and total depth of individual rainfall events. This variability was consistent with the natural variation in hydrologic response across the modelled drainage areas.
        - A more critical observation was the variability between observed and simulated datasets for the same rainfall events. While trends for runoff volumes were comparable, deviations in runoff coefficients underscored challenges in fully capturing hydrologic responses.
- **Peak Flows:**
    - The simulated peak flows were consistently higher than observed values, indicating an exaggerated hydrologic response in the PCSWMM model. This was particularly pronounced during high-intensity rainfall events.
    - This systematic overestimation suggested that sensitive parameters influencing peak flow generation required recalibration.
- **Hydrograph Comparisons:**
    - While time-to-peak generally aligned between observed and simulated datasets, a few discrepancies were identified. These were attributed to potential inaccuracies in the observed data collection process, formatting errors, or instrument-related delays.
    - Locations CC-6 and CC-1 showed notable base flow discrepancies, likely due to debris and beaver activity obstructing flow during monitoring. Such obstructions affected stage measurements and led to over- or underestimations in observed flow data.

Data and modelling challenges

The comparison also highlighted certain limitations in both observed and simulated data:

- Spatial and Temporal Variability: Rainfall data were derived from a weather station (i.e., Guelph Lake Station) located at a significant distance from the monitoring sites, introducing potential mismatches between observed and simulated conditions particularly for more localized rainfall events.
- Drainage Area Characteristics: At CC-1, the low hydrologic response to rainfall was attributed to rural and natural areas land uses, coupled with routing through wide, vegetated floodplains. This resulted in minimal observed runoff for low-intensity events. Only one event (meeting the criteria of >10 mm/hr average intensity and >35 mm rainfall depth) yielded a valid response for comparison.
- Monitoring Period Issues: Extended periods of debris or beaver dam activity at CC-6 and CC-1 further complicated data reliability and impacted model calibration efforts.

The initial results revealed that while runoff volumes and coefficients showed a reasonable match between observed and simulated data, significant discrepancies in peak flows necessitated further adjustments. The hydrologic response generated by the PCSWMM model was observed to be overly intense, especially during high-intensity rainfall events. As a result, the calibration process began with a targeted focus on adjusting parameters more sensitive to peak flow generation while preserving the acceptable trends for runoff volumes and coefficients.

4.2.2.4.4 Sensitivity analysis

Sensitivity analysis was performed to identify key parameters within the PCSWMM model that had the greatest influence on the hydrologic response, specifically focusing on reducing the overestimated peak flows while maintaining reasonable alignment for runoff volumes. The primary objective was to systematically refine the model parameters to achieve acceptable simulated outputs for peak flows across selected storm events.

Purpose and approach

The focus of the sensitivity analysis was to refine the model's parameters to improve its representation of the observed hydrologic response. This was achieved by prioritizing adjustments to parameters that demonstrated a greater influence on peak flow generation, thereby ensuring better alignment with observed data while preserving consistency in runoff volume estimates. The analysis was informed by physical characteristics, land use, and discrepancies noted during initial comparisons between simulated and observed results.

Key adjustments to subcatchment parameters

- **Subcatchment Lengths, Widths, and Slopes:**
    - Subcatchment lengths and widths directly influence the travel time of runoff, with longer flow paths leading to greater attenuation of peak flows. Wider subcatchments reduce the concentration of runoff, resulting in a less pronounced hydrologic response. Adjustments to slopes, meanwhile, alter runoff velocity, with steeper slopes contributing to higher flow intensities and flatter slopes producing

a dampened response. By carefully recalibrating these parameters, the time-to-peak was extended, and peak flows were brought down to align more closely with observed values.

  - Adjustments to these physical attributes were applied uniformly across the model, covering both the Primary Study Area (PSA), which aligns with the City of Guelph SWMMP Update, and the Secondary Study Area (SSA), ensuring consistency in the calibration process.

- **Soil Parameters:**
  - Soil suction head, hydraulic conductivity, and initial soil moisture deficit were calibrated using the Surficial Geology of Southern Ontario dataset provided by the Ministry of Energy and Mines (last validated on October 8, 2024). These parameters govern the infiltration and storage capacity of the soil, which in turn affects runoff generation and peak flow magnitudes. Adjustments were weighted based on hydrologic soil classifications (A, B, C, and D), ensuring each subcatchment's soil characteristics were accurately represented in the model. For example, areas with high-conductivity soils (e.g., sand) allowed for greater infiltration, reducing runoff volumes and peak flows, while lower-conductivity soils (e.g., clay) required finer adjustments.
  - These refinements were limited to the SSA, as the PSA subcatchments were deemed sufficiently calibrated in previous modelling efforts under the SWMMP Update.
- **Manning’s ‘n’ for Pervious Land Segments:**
  - Manning’s roughness coefficient determines the resistance to flow in pervious areas. By adjusting this parameter, the model simulates different runoff velocities, leading to delayed and diminished peak flows. This adjustment was particularly useful for mitigating overestimated peak flows in areas with natural landscapes and therefore was limited to the SSA.
  - Roughness coefficients for all pervious areas within the SSA were updated to reflect realistic ground conditions, accounting for factors such as vegetation density and soil surface characteristics.
- **Imperviousness Adjustments for Subcatchments Draining to CC-1:**
  - The PCSWMM model exhibited minimal hydrologic response for subcatchments draining to CC-1, likely due to the predominance of rural and NHS land use and routing through densely vegetated floodplains. Imperviousness values for these subcatchments were revised based on aerial imagery and updated land use data, ensuring that non-rural areas contributing to runoff were accurately represented.
  - For subcatchments within the PSA, imperviousness values were not adjusted, as these had been previously calibrated during earlier modelling efforts under the SWMMP Update.

- **Routing Element Calibration:**
    - Adjustments to Manning's 'n' values for main channels and floodplains aimed to refine the routing of flows. Increasing roughness values for channels and floodplains slows down water movement, reducing flow velocities and mitigating the intensity of peak flows. This was particularly critical for areas with observed discrepancies in peak flow timings and magnitudes.
    - Recalibration focused on achieving better alignment between simulated and observed hydrographs, particularly for events with high-intensity rainfall, where routing effects are more pronounced.
- **Minor Tweaks:**
    - The Reformatory Ponds' imperviousness was set to 100%, reflecting their actual physical condition and ensuring they contributed appropriately to runoff generation in the model.
  - **Other Adjustments:**
    - Additional fine-tuning was performed for elements that showed specific discrepancies, ensuring the model accurately represented localized hydrologic responses.

The sensitivity analysis highlighted the critical role of subcatchment parameters, particularly lengths, widths, slopes, and soil properties, in calibrating the hydrologic response of the PCSWMM model. Adjustments were carefully applied, considering the distinct characteristics of the PSA and SSA, as well as specific issues such as the lack of response at CC-1. Routing elements were also calibrated to refine flow paths and align the model outputs with observed data. These systematic changes would provide a foundation for further calibration and validation efforts, ensuring the model's utility in future applications.

4.2.2.4.5 Initial calibration results

The calibration process for the PCSWMM model aimed to improve alignment between simulated and observed hydrologic responses (observed responses being based on HEC-RAS 1D generated rating curve results), focusing on key parameters such as peak flows, runoff volumes, and runoff coefficients. Data from monitoring locations HC-2, CC-6, and CC-1, along with sensitivity analysis findings, guided adjustments to subcatchment and routing parameters.

Calibration outcomes by monitoring location

- **HC-2 and CC-6:**
    - Improved Model Response:
        - Monitoring locations HC-2 and CC-6 provided the most consistent and reliable response for the model calibration. These locations exhibited stronger hydrologic responses across the selected rainfall events, allowing for more thorough comparisons between observed and simulated results.

    - Calibration efforts at these locations resulted in improved agreement between simulated and observed peak flows. Simulated peak flows, which were initially overestimated, were reduced to fall within an acceptable range of ±10 per cent. (i.e., 4.4 per cent higher than observed for HC-2 and 5.1 per cent lower than observed for CC-6).
    - Runoff volumes for HC-2 and CC-6 showed similar consistency, with most events yielding differences within ±15 per cent, allowing the model to replicate runoff coefficients that aligned well with observed trends for the majority of selected rainfall events (i.e., 5.0 per cent lower than observed for HC-2 and 12.0 per cent lower than observed for CC-6).
    - Runoff coefficients followed trends observed in the monitoring data, capturing the hydrologic response reliably. Hydrograph alignment for these locations improved significantly after calibration, reflecting better time-to-peak and overall flow dynamics.
- **CC-1:**
  - Challenges and Adjusted Calibration Approach:
    - Given the model's low sensitivity to events at CC-1, calibration efforts emphasized revising the percentage of imperviousness for contributing subcatchments. Updates were based on aerial imagery and land use to ensure a better representation of runoff generation, particularly for impervious surfaces.
    - Calibration at CC-1 presented unique challenges due to discrepancies in observed data for the July 16, 2024, event—the sole rainfall event that met the selection criteria and produced the simulated response significant enough for comparison with the observed response. While this event had a high average rainfall intensity (11.4 mm/hr) and maximum hourly intensity (15.8 mm/hr), the observed data showed a significant runoff volume but an unexpectedly muted peak flow. This pattern was inconsistent with expectations for a storm of this intensity and total rainfall depth.
    - The initial PCSWMM model simulation, however, produced an intense hydrologic response for the event, which was consistent with the storm's characteristics and was deemed reasonable based on hydrologic science principles. This discrepancy between observed and simulated peak flows raised concerns about the reliability of the observed peak flow data for this event. Likely contributing factors included potential obstructions, instrumentation issues, or localized data anomalies during the monitoring period.
  - Calibration Focus:
    - Given the uncertainty in the observed peak flow data, calibration efforts at CC-1 prioritized runoff volume and runoff coefficient comparisons rather than

peak flow alignment. Adjustments to imperviousness and Manning’s n for contributing subcatchments improved the model’s ability to simulate total runoff volume while maintaining high confidence in the simulated peak flow results due to the nature of the storm event. In the end, the simulated runoff volumes from the calibrated model were 4.1 per cent higher than the observed runoff volumes for the July 16, 2024, event as shown in Table 4.12 and Table 4.13.

Table 4.12: Summary of calibration results

Location	Rainfall Event	Q_p Observed	Q_p Simulated	Q_p % Diff.	V_r Observed	V_r Simulated	V_r % Diff.
HC-2	19-May-23	1.14	1.27	11.2%	36989	39371	6.4%
HC-2	11-Jun-23	1.01	1.28	26.5%	67399	70992	5.3%
HC-2	25-Jun-23	1.55	1.36	-12.0%	50911	45581	-10.5%
HC-2	12-Jul-23	2.82	2.92	3.5%	63819	63515	-0.5%
HC-2	23-Jul-23	3.61	2.91	-19.2%	84131	60136	-28.5%
HC-2	26-Jul-23	1.58	1.51	-4.5%	39750	31626	-20.4%
HC-2	11-Apr-24	0.76	0.92	21.1%	106199	74221	-30.1%
HC-2	20-Jun-24	2.78	1.37	-50.5%	41571	40000	-3.8%
HC-2	10-Jul-24	1.42	2.23	56.9%	80296	119497	48.8%
HC-2	16-Jul-24	3.86	4.30	11.3%	91618	76422	-16.6%
CC-6	19-May-23	1.81	1.51	-17.0%	89686	49903	-44.4%
CC-6	11-Jun-23	1.61	1.51	-6.6%	118530	89578	-24.4%
CC-6	25-Jun-23	1.32	1.65	24.9%	30957	58347	88.5%
CC-6	12-Jul-23	3.47	3.97	14.3%	141378	111685	-21.0%
CC-6	23-Jul-23	3.05	3.66	19.9%	97386	88557	-9.1%
CC-6	26-Jul-23	1.19	1.75	46.4%	30938	41925	35.5%
CC-6	27-May-24	2.87	2.11	-26.3%	205094	88300	-56.9%
CC-6	20-Jun-24	3.75	1.64	-56.1%	50694	51758	2.1%
CC-6	10-Jul-24	2.82	2.82	0.1%	204124	164233	-19.5%
CC-6	16-Jul-24	13.53	6.70	-50.5%	524070	156016	-70.2%
CC-1	16-Jul-24	N.A.	N.A.	N.A.	49023	51051	4.1%

HC-2 average difference per cent peak flow (m^3/s) is 4.4% and the runoff volume (m^3) average difference per cent is -5.0%

CC-6 average difference per cent peak flow (m^3/s) is -5.1% and the runoff volume (m^3) average difference per cent is -11.9%

Table 4.13: Observed versus simulated runoff coefficients

Location	Rainfall Event	RC Observed	RC Simulated	RC Per cent Difference
HC-2	19-May-23	0.21	0.22	6.4%
HC-2	11-Jun-23	0.23	0.24	5.3%
HC-2	25-Jun-23	0.29	0.26	-10.5%
HC-2	12-Jul-23	0.23	0.23	-0.5%
HC-2	23-Jul-23	0.31	0.22	-28.5%
HC-2	26-Jul-23	0.27	0.22	-20.4%
HC-2	11-Apr-24	0.37	0.26	-30.1%
HC-2	20-Jun-24	0.29	0.28	-3.8%
HC-2	10-Jul-24	0.16	0.24	48.8%
HC-2	16-Jul-24	0.33	0.27	-16.6%
CC-6	19-May-23	0.17	0.09	-44.4%
CC-6	11-Jun-23	0.14	0.10	-24.4%
CC-6	25-Jun-23	0.06	0.11	88.5%
CC-6	12-Jul-23	0.17	0.14	-21.0%
CC-6	23-Jul-23	0.12	0.11	-9.1%
CC-6	26-Jul-23	0.07	0.10	35.5%
CC-6	27-May-24	0.24	0.10	-56.9%
CC-6	20-Jun-24	0.12	0.12	2.1%
CC-6	10-Jul-24	0.14	0.11	-19.5%
CC-6	16-Jul-24	0.63	0.19	-70.2%
CC-1	16-Jul-24	0.14	0.14	4.1%

HC-2 average difference is -5.0 per cent
CC-6 average difference is -11.9 per cent

Model calibration results have been compared against Wastewater Planning Users Group (WaPUG) criteria[4]. WaPUG is a 15+ years old non-profit organization that promotes best practice in water related systems modelling. WaPUG code of practice for the hydrologic modelling provides event-based model verification criteria, summarized in Table 4.14, which are commonly also used for model validation and calibration.

[4] The WaPUG Model verification wet weather flow criteria used are: (1) between plus 20 per cent and minus 10 per cent volume changes, (2) between plus 25 per cent and minus 15 per cent peak flow changes, and no time specified to peak.

Table 4.14: WaPUG Criteria for model calibration

Parameter	Description
Model Characteristic	Acceptable range for the model calibration to be considered "Good"
Event Peak flow	-15% to 25%
Event Run-off Volume	-10% to 20%

Calibration efforts at HC-2 and CC-6 successfully refined the PCSWMM model to align with observed hydrologic responses, particularly for peak flows and runoff volumes. At CC-1, calibration focused exclusively on the runoff volume and coefficient alignment due to low confidence in observed peak flow data. Future improvements in monitoring and data reliability are essential to further enhance the model's predictive accuracy.

Future additional flow monitoring data (as available) should be used to verify or adjust the current hydrologic model calibration in the future (beyond the scope of the current study); this recommendation should be noted as part of subsequent study reporting.

4.2.2.5 Supplemental Hydrologic Calibration

Following the initial model calibration effort (as described in Sections 4.2.1.3.1 to 4.2.1.3.5), further review was undertaken with the Grand River Conservation Authority (GRCA) based on its review of the draft (December 2024) Characterization report submission and its understanding of the flow response characteristics in the overall watershed area. An initial discussion meeting was held on January 29, 2025, and written comments were provided by GRCA to WSP and the City on February 3, 2025.

With respect to hydrologic modelling, a key comment was the observed increase in peak flows, particularly the estimated 100-year and Regional Storm peak flow rates, when compared to GRCA's base model results. It was noted that the peak flows adopted in the GRCA's currently approved hydraulic modelling for Clythe Creek are not based on watershed-specific hydrologic modelling but rather have been prorated (based on contributing drainage area) from the hydrologic modelling results for the Speed River. GRCA staff noted that based on stream flow gauging (Water Survey of Canada (WSC) gauge 02GA029; Eramosa River above Guelph, located at Watson Road South, 231 km^2 (23,1000 ha) drainage area) and its own knowledge and observations, the Eramosa River and adjacent watersheds (including Clythe Creek) have very muted responses to storm events. As such, it was suggested that the hydrologic modelling for Clythe Creek may be overestimating peak flows. Based on the discussion with GRCA, a subsequent\supplemental hydrologic calibration effort was undertaken, with a focus on validating the model against the available WSC gauge data, pro-rated to the area of the Clythe Creek watershed, and in particular the most rural upstream portion of the watershed upstream of Watson Road North (1,031 ha). It was understood that GRCA was generally in agreement with the calibration of the urbanized\developed portion of the watershed downstream of this location.

Based on the preceding, WSP extracted the annual maximum peak flows from the subject WSC gauge for the 1962-2023 period (62 years). A frequency analysis was undertaken to determine the associated probabilities and return periods of peak flows using the Log Pearson III distribution. Results are presented in Table 4.15.

Table 4.15 : Frequency Analysis of Eramosa River WSC Data

Return Period (Years)	Actual Frequency Flow (LP3) (m^3/s)	Normalized Peak Flow (L/s/ha)
2	19.9	0.86
5	28.6	1.24
10	34.2	1.48
25	39.4	1.71
50	46.0	1.99
100	50.8	2.20

A key observation of the results presented in Table 4.15 is the minimal variability in flows with increasing storm magnitude\return period. Whereas in other watersheds, peak flows would be expected to increase more substantially with magnitude, the Eramosa watershed indicates a modest increase in peak flows for larger storm events (ratio of only 2.5:1 between the 2 and 100-year storm events).

The base hydrologic model (PCSWMM) of the Clythe Creek watershed was revisited using both continuous simulation and design storm approaches, to determine the required hydrologic calibration revisions such that the 100-year modelled flows better matched the normalized Eramosa River peak flow of 2.20 L/s/ha as per Table 4.15. Additional hydrologic model calibration focused on revising various modelling parameters, including:

- Depression Storage (Impervious and Pervious Land Segments)
- Subcatchment Flow Lengths
- Subcatchment Slopes
- Manning's Roughness for Pervious Land Segment
- Imperviousness
- Hydraulic Conductivity

The updated calibration focused on refining subcatchment parameters to better simulate peak flows for large storm events, with a particular emphasis on reducing peak flow estimates where the original model produced conservative results. This approach was informed by an understanding of the watershed's hydrologic characteristics, land use, and surface storage potential, as well as the need to balance model conservatism with realistic flow estimates for regulatory floodplain mapping. This approach was also supported by GRCA based on the observed historically muted response for the Eramosa River watershed.

The selection of parameters for adjustment in the updated calibration was guided by the objective of moderating peak flows, particularly during large storm events. Each parameter was carefully evaluated for its influence on flow timing, volume, and peak rate.

Subcatchment Length (m) and L/W Ratio were increased where appropriate to represent more realistic flow paths over complex terrain, especially in rural and natural areas. By lengthening flow paths, the model accounts for the time it takes for runoff to reach outlet points, introducing a delay in the hydrologic response and thereby reducing peak flows. This adjustment reflects rural watershed features where flows often meander through floodplains, vegetated areas, and shallow overland routes rather than following a direct or highly efficient drainage pattern.

Slope (%) was reduced in subcatchments where the original model considered conservative gradients based on DEM data. Shallower slopes slow the velocity of overland flow, which reduces the rate at which runoff accumulates at downstream points. This reduction in slope delays the timing of peak flows and reduces their magnitude, especially in areas where rural land use, low-gradient floodplains and natural depressions exist.

Imperviousness (%) was reduced in subcatchments where Model 1 conservatively classified a higher portion of the land as impervious. By lowering imperviousness percentages, the model allows for greater infiltration and detention of runoff within the pervious surfaces, reducing the effective runoff coefficient and consequently the peak flow generated during storm events.

Manning's roughness coefficient for pervious and impervious land segment were increased to account for higher surface roughness in vegetated or naturalized areas, which introduces additional friction and resistance to flow. For example, vegetated surfaces, forests, and floodplain zones were assigned higher Manning's n values as compared to Model 1 to reflect the slower movement of water through these areas, further contributing to peak flow attenuation.

Depression Storage (Pervious and Impervious) was increased to simulate the capacity of surface depressions, such as low spots, and microtopography, to temporarily store runoff before it contributes to flow. This adjustment directly reduces peak flows by allowing initial runoff to be retained within the landscape rather than being immediately conveyed to the natural drainage system.

Soil Conductivity for different hydrologic soil types were adjusted to represent local soil conditions with a greater capacity for infiltration under saturated scenarios. Increasing soil conductivity allows for more infiltration under high-intensity storm conditions, thus reducing the direct runoff component and peak flows.

A detailed summary of these parameter adjustments, including area-weighted average values and ranges for each parameter across Model 1 and Model 2, is presented in Table 4.16 and Table 4.17. In addition, the uncalibrated base model parameters are also presented for reference.

Table 4.16: Summary and comparison of PCSWMM model parameter averages

Subcatchment Parameter Average (Area-Weighted)	Base Model	Model 1 (Original Calibration)	Model 2 (Updated Calibration)
Length (m)	527.65	661.05	787.22
L/W Ratio	1.61	2.01	2.93
Slope (%)	6.67	5.07	2.31
Imperviousness (%)	7.37	16.93	7.37
N Pervious	0.2	0.08	0.3
N Impervious	0.025	0.025	0.025
Depression Storage Pervious (mm)	1	1	2.54
Depression Storage Impervious (mm)	5	5	7.59
Suction Head (mm)	101.02	136.5	136.5
Conductivity (mm/hr)	9.29	7.68	9.29
Initial Deficit (frac.)	0.42	0.44	0.44

Table 4.17: Summary and comparison of PCSWMM model parameters range

Subcatchment Parameter Range	Base Model	Model 1 (Original Calibration)	Model 2 (Updated Calibration)
Length (m)	28.3 - 975	27.9 - 1189.3	34.6 - 1450.9
L/W Ratio	0.2 - 13.1	1.2 - 3	2 - 13.1
Slope (%)	2.6 - 18.8	2.1 - 12.2	1.29 - 3.77
Imperviousness (%)	0 - 80	5 - 85	0 - 80
N Pervious	0.2 - 0.2	0.08 - 0.08	0.15 - 0.3
N Impervious	0.025 - 0.025	0.025 - 0.025	0.025 - 0.025
Depression Storage Pervious (mm)	1 - 1	1 - 1	2.54 - 2.54
Depression Storage Impervious (mm)	5 - 5	5 - 5	5.08 - 7.62
Suction Head (mm)	88.9 - 138.9	88.9 - 273	88.9 - 273
Conductivity (mm/hr)	7.6 - 10.9	1 - 10.9	7.6 - 10.9
Initial Deficit (frac.)	0.39 - 0.43	0.41 - 0.49	0.41 - 0.49

A detailed summary of the comparison of the simulated peak flows at the point of comparison (i.e. Clythe Creek at Watson Road North) is presented in Table 4.18.

Table 4.18: Revised hydrologic calibration results – Clythe Creek at Watson Road North (Rural Portion of Watershed) – Unitary Flows (L/s/ha)

Return Period (Years)	Pro-Rated Eramosa River Flow	Original Model Calibration Design Storm	Original Model Calibration Continuous Simulation	Revised Model Calibration Design Storm	Revised Model Calibration Continuous Simulation
2	0.86	2.51	0.66	0.10	0.04
5	1.24	9.80	3.01	0.27	0.10
10	1.48	17.04	6.67	0.53	0.18
25	1.71	26.90	12.90	1.45	0.30
50	1.99	35.62	27.26	2.66	0.62
100	2.20	46.39	44.81	4.25	1.17
Regional	N\A	83.52	N\A	37.71	N\A

Based on the preceding, it is considered that the revised model calibration provides a reasonable fit to the unitary 100-year peak flow. However, the revised model calibration results in minimal peak flows for more frequent, less formative storm events. Based on the preceding, it is considered that a “2 model” approach is preferred in this setting, as a single hydrologic model seems unable to meet all requirements. The original model calibration would be applied for more frequent storm events and SWM sizing, while the revised model would be applied for more formative storm events and estimating regulatory floodplain mapping.

WSP provided a summary of the preceding approach to GRCA and the City via e-mail (March 31, 2025) and subsequently provided a summary of hydrologic modelling parameters and copies of the updated PCSWMM modelling via e-mail (April 3, 2025).

GRCA staff subsequently confirmed (via e-mail April 25, 2025) that the GRCA was in support with the proposed approach for the hydrology modelling. As such, WSP has advanced a two-model approach as noted, with the initial calibration model applied for more frequent storm events, and the revised calibration model (based on WSC data) applied for less frequent, more severe storm events.

A further review of design storm and continuous simulation results, and the selection of flows to be applied for hydraulic modelling, is described in subsequent sections.

4.2.2.6 Surface water assessment findings

4.2.2.6.1 Sensitivity Analysis and Design storm results

The City of Guelph Development Engineering Manual (2019) specifies that all storm sewers must be designed using the 5-year design storm based on the City of Guelph Intensity-Duration-Frequency (IDF) curves and must operate without surcharge. Additionally, the manual requires that major system overland flow routes to stormwater management (SWM) facilities be designed to safely convey overland flows for both the 100-year storm and the Regional Storm (Hurricane Hazel).

As outlined in the Clythe Creek Regulatory Floodplain Mapping Terms of Reference, a sensitivity analysis was conducted to determine the most appropriate storm distribution and duration for calculating design event peak flows. Various storm durations (3, 6, 12, and 24 hours) and the Chicago and SCS Type II storm distributions were analyzed. The governing storm distribution and duration were selected based on the resulting peak flows at key PSA and SSA locations.

Note that this sensitivity analysis was completed prior to the final hydrologic and model calibration effort described in Section 4.2.2.5.

For the Regional Storm event (Hurricane Hazel), two scenarios were evaluated to identify the most conservative results:

- **Normal Soil Saturation Condition:** Simulated using the full 48-hour Hurricane Hazel event, which includes a 36-hour pre-wetting period followed by a 12-hour primary storm. Normal Antecedent Moisture Conditions (AMC-II) are applied for soils and modelling of infiltration.
- **Pre-Saturated Soil Condition:** Simulated using the 12-hour Hurricane Hazel event, with the initial deficit in the Modified Green-Ampt infiltration method set to 0.035 to represent pre-saturated surface soil conditions, or AMC-III conditions.

The results of the peak flow sensitivity analysis for the 100-year storm event and Regional Storm Event are presented in Table 4.19.

Table 4.19: Sensitivity test results, peak flows (m^3/s)

Location	Node	100-Year SCS Type II 6 hr	100-Year SCS Type II 12 hr	100-Year SCS Type II 24 hr	100-Year Chicago 3 hr	100-Year Chicago 6 hr	100-Year Chicago 12 hr	100-Year Chicago 24 hr	Regional Hazel 48 hr
City Boundary	Clythe_07	3.73	3.61	3.06	2.18	2.86	3.62	4.38	38.91
Watson Creek	Clythe_08	4.38	4.26	3.66	2.77	3.48	4.35	5.19	43.34
After York Rd.	Clythe_11	7.05	6.75	6.06	5.16	5.82	6.16	7.13	47.05
Reformatory Ponds	Clythe_12	7.61	7.28	6.56	5.64	6.35	6.73	7.37	45.22
Hadati Creek	Clythe_13	8.10	7.75	7.05	5.98	6.75	7.49	8.78	45.30
Outlet to Eramosa River	Clythe_16	26.51	26.01	24.20	21.66	24.42	25.97	27.79	88.00

Location	Node	100-Year SCS Type II 6 hr	100-Year SCS Type II 12 hr	100-Year SCS Type II 24 hr	100-Year Chicago 3 hr	100-Year Chicago 6 hr	100-Year Chicago 12 hr	100-Year Chicago 24 hr	Regional Hazel 48 hr
Outlet to Clythe Creek	Hadati_13	22.17	21.44	19.52	16.93	19.34	20.69	22.96	51.49
Outlet to Clythe Creek	Watson_04	2.95	2.80	2.48	2.44	2.68	2.75	2.86	6.40

The sensitivity test determined that the 24-hour Chicago distribution storm event produced the greatest peak flows at the outlets. In addition, while the 12-hour (AMC-III conditions) Regional Storm Event could potentially generate higher flows than the 48-hour version (AMC-II conditions), the execution of the 12-Hour Regional Storm Event generates high levels of model instability and oscillations and therefore have been discarded from further consideration.

The PCSWMM model has been used to establish peak flows for 2 to 100-year storm events using the City of Guelph's intensity duration frequency (IDF) curve for the 24-hour Chicago storm distribution and for the Regional Storm Event (48-hour Hurricane Hazel) at key locations.

As explained earlier, subsequent hydrologic analysis and extraction of flows involved two distinct calibrated models to address different objectives:

- **Model 1 (Original Calibration Model)**: Developed based on flow monitoring data from HC-2, CC-6, and CC-1, this model is intended for simulating hydrologic responses to frequent and moderate storm events. Model 1 provides the primary input for stormwater management (SWM) design applications, including minor system capacity analysis and SWM facility sizing for storm events up to and including the 100-year return period.
- **Model 2 (Supplemental Calibration Model)**: Refined model based on feedback from the Grand River Conservation Authority (GRCA) and validated against the pro-rated flow estimates from the Eramosa River gauging station (WSC Gauge 02GA029), this model is tailored for simulating hydrologic responses to large, infrequent storm events, including regulatory storm events such as the 100-year storm and the Regional Storm (Hurricane Hazel). Model 2 is primarily intended for regulatory floodplain delineation and associated hydraulic modelling.

Both models have been used to generate peak flows for the 2-, 5-, 10-, 25-, 50-, and 100-year design storms using the 24-hour Chicago distribution, as well as for the Regional Storm Event (48-hour Hurricane Hazel). Results for both models are presented in the following section, allowing for a comparison of their respective performance across the design events.

The design storm event peak flows for Model 1 are presented in Table 4.20.

Table 4.20: Existing land use Design Storm Event generated Peak Flows at key locations Per Calibrated Model 1 (m^3/s)

Location	Node	Drainage Area (ha)	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	Hazel 12-hr
Wellington Rd. 29	Clythe_01	101.16	1.00	3.01	5.16	7.92	10.32	12.65	10.39
Jones Baseline	Clythe_04	624.68	0.43	3.03	7.74	16.27	24.23	38.87	47.95
Hwy 7	Clythe_05	678.23	0.79	3.79	7.81	17.51	26.43	37.52	61.17
CNR	Clythe_06	866.98	2.06	6.10	9.67	18.59	28.38	41.28	70.51
City Boundary	Clythe_07	1011.45	2.59	10.10	17.57	27.73	36.72	47.83	86.11
Watson Creek	Clythe_08	1087.30	2.66	10.48	18.38	29.69	39.79	50.24	93.23
After York Rd.	Clythe_11	1202.38	1.51	9.19	23.92	36.70	41.88	51.74	103.90
Reformatory Ponds	Clythe_12	1207.43	1.50	8.17	23.61	33.62	40.63	49.04	104.40
Hadati Creek	Clythe_13	1618.06	1.68	8.68	23.50	33.80	40.77	49.06	105.00
Outlet to Eramosa River	Clythe_16	2452.33	8.62	17.68	27.87	37.47	49.06	60.96	136.50
Eastview Rd.	Hadati_02	242.82	1.63	1.76	3.98	3.22	4.63	4.75	14.86
Starwood Dr.	Hadati_06	353.88	1.74	3.36	5.38	7.55	9.68	11.19	22.82
Grange Rd.	Hadati_10	400.65	2.42	4.12	6.92	11.23	15.27	17.77	26.54
CNR	Hadati_11	516.81	3.18	5.43	8.70	13.32	17.59	20.29	41.47
Outlet to Clythe Creek	Hadati_13	666.96	6.35	9.13	13.44	20.48	26.15	31.01	39.04
Grange Rd.	Watson_01	34.24	0.11	0.16	0.24	0.36	0.46	1.01	3.81
Fleming Rd.	Watson_03	46.64	0.24	0.55	0.95	1.49	1.79	2.04	5.14
Outlet to Clythe Creek	Watson_04	56.80	0.51	1.24	1.89	2.86	3.44	3.97	6.29

Per standard industry convention, the assessment of design event peak flows reported in Table 4.20**,** removes the hydraulic impacts of culverts and bridges along the watercourses from the PCSWMM model by replacing these structures with dummy conduits. This is consistent with best practices to avoid crediting hydraulic structure attenuation which could be affected by future hydraulic structure upgrades. Note that for the previous model calibration (and comparison with observed values), the structures were retained in the model, which influenced the peak flows at downstream locations of Clythe Creek.

In addition, all SWM facilities (ponds) have been removed for the simulation of the Regional Storm Event, which is also the Regulatory Storm Event, to be consistent with Provincial guidance on stormwater management planning and design (i.e. MNR, 2002).

For Model 2, the design storm results for the 100-year and Regional Storm events reflect the adjustments made to subcatchment parameters as part of the re-calibration effort. As described previously, the objective of the calibrated Model 2 was to reduce peak flows for the undeveloped\rural upstream portion of Clythe Creek specifically to more representative levels based on the physical characteristics of the watershed. Consequently, the results in Table 4.21 demonstrate significantly lower peak flows along Clythe Creek as compared to those from Model 1.

Table 4.21: Existing land use Design Storm Event generated Peak Flows at key locations Per Calibrated Model 2 (m^3/s)

Location	Node	Drainage Area (ha)	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	Hazel 48-hr
Wellington Rd. 29	Clythe_01	101.16	0.01	0.08	0.21	0.51	0.80	1.13	3.88
Jones Baseline	Clythe_04	624.68	0.01	0.06	0.15	0.61	1.24	2.39	22.29
Hwy 7	Clythe_05	678.23	0.01	0.07	0.22	0.69	1.30	2.43	28.04
CNR	Clythe_06	866.98	0.01	0.14	0.39	1.05	1.75	2.77	32.01
City Boundary	Clythe_07	1011.45	0.10	0.28	0.55	1.49	2.74	4.38	38.91
Watson Creek	Clythe_08	1087.30	0.43	0.94	1.40	2.13	3.33	5.19	43.34
After York Rd.	Clythe_11	1202.38	1.11	2.08	2.99	4.33	5.44	7.13	47.05
Reformatory Ponds	Clythe_12	1207.43	1.10	2.25	3.24	4.71	5.93	7.37	45.22
Hadati Creek	Clythe_13	1618.06	1.10	2.32	3.39	4.99	6.35	8.78	45.30
Outlet to Eramosa River	Clythe_16	2452.33	7.53	10.44	13.90	18.36	23.55	27.79	88.00
Eastview Rd.	Hadati_02	242.82	0.65	1.26	3.70	2.37	4.09	3.47	19.61
Starwood Dr.	Hadati_06	353.88	1.09	1.98	4.01	5.18	7.35	8.51	28.44
Grange Rd.	Hadati_10	400.65	2.38	3.99	5.27	7.07	10.74	13.75	31.60
CNR	Hadati_11	516.81	3.12	4.98	6.35	8.76	12.52	15.61	41.66
Outlet to Clythe Creek	Hadati_13	666.96	7.35	8.52	9.80	13.96	18.72	22.96	51.49
Grange Rd.	Watson_01	34.24	0.12	0.16	0.17	0.27	0.35	0.43	3.94
Fleming Rd.	Watson_03	46.64	0.17	0.33	0.44	0.74	1.02	1.35	5.15
Outlet to Clythe Creek	Watson_04	56.80	0.43	0.97	1.37	1.95	2.36	2.85	6.40

Similar to Model 1, the design storm simulations for Model 2 also involved the removal of all culvert and bridge structures by replacing them with dummy conduits, ensuring that the reported peak flows represent the natural conveyance capacity of the watercourses without artificial attenuation from hydraulic structures. Furthermore, for the Regional Storm Event, all SWM facilities (ponds) have been removed from the model, in accordance with the Provincial Policy Statement (MNR, 2002), to ensure the regulatory event is simulated under worst-case, pre-development-like conditions.

Overall, the results from Model 2 are generally lower (as was intended through the re-calibration for Clythe Creek specifically) and thus are expected to be the governing basis for flows to be applied for hydraulic modelling, as described in subsequent sections. Where appropriate, flows from Model 1 may be applied for less formative, more frequent storm events such as the 2-year storm event.

4.2.2.6.2 Continuous simulation results

The calibrated PCSWMM model was executed for a continuous simulation spanning 56 years (1950–2005) using a long-term rainfall dataset provided by the SWSU team. This dataset, originating from the Guelph Turfgrass location, comprised hourly rainfall data prepared specifically for hydrologic modelling.

Note that additional data was available for the 2006-2023 period, however the data was only available in a daily format and thus unsuitable to use and extend the primary continuous simulation dataset.

The rainfall dataset underwent an infilled data preparation process, a widely accepted practice for managing missing values in historical meteorological records. Infilled data refers to the reconstruction of missing values through statistical techniques or regional interpolation. While this dataset was infilled, the SWSU team noted that some hourly values remained missing and were set to zero. Given the dataset's intended use for long-term continuous simulation, these adjustments were considered appropriate and unlikely to introduce significant errors. Continuous simulations prioritize cumulative effects and trends, making such assumptions about isolated missing values standard practice in hydrologic modelling.

For the SWSU, the following measures were considered:

- Long-term rainfall dataset (1950-2005) (reviewed and corrected) from the Guelph Turfgrass location was utilized to capture temporal variability and trends in extreme hydrologic conditions.
- Similar to the design storm event assessment, hydraulic structures such as culverts and bridges were removed and were replaced with dummy conduits to eliminate potential local influences on flow dynamics, ensuring that frequency analyses focus solely on the natural and simulated hydrologic response.
- Outputs were validated for consistency with subwatershed hydrology and used to generate flow frequency estimates based on their probability of occurrence.

The results from the continuous simulation were subjected to frequency analysis to estimate flows corresponding to different return periods. The Consolidated Frequency Analysis (CFA) software, developed by Environment Canada, was employed to perform this analysis. CFA is widely recognized for its capability to analyze and graph extreme hydrologic data with high precision. Statistical distributions used Log Pearson Type III as the primary distribution, offering conservative estimates with adequate data fit under typical conditions. Its established use in hydrologic studies makes it a reliable choice for flow frequency analysis.

- In cases where Log Pearson Type III did not meet the required criteria for conservative estimates or goodness-of-fit, the Wakeby distribution was utilized. In those instances, the Wakeby distribution demonstrated superior performance in handling datasets with high skewness or extreme variability, ensuring accurate representation of flow extremes.
- Exclusion of 2005 Data: For the frequency analysis of Model 1, outlier analysis identified results from 2005 as anomalous due to unusually high simulated peak flows. These values deviated significantly from the broader dataset and were determined to distort regression models by producing unrealistic flow estimates for higher return periods, such as the 100-year event. As a corrective measure, data from 2005 were excluded to maintain the integrity and representativeness of the frequency analysis. This exclusion

follows best practices in hydrologic modeling, where outliers are removed to avoid biasing flow projections.

Consistent with the current approach, for the continuous simulation assessment, both Model 1 and Model 2 were evaluated to assess their influence on long-term flow frequency estimates. Model 1 represents the original calibration, where peak flows are generally higher due to more conservative assumptions on subcatchment parameters, whereas Model 2 incorporates refinements discussed in previous sections to reduce peak flows and provide a more physically representative estimate of hydrologic response.

In alignment with the study objectives, Model 2 is recommended for establishing the regulatory flows for the Clythe Creek subwatershed, including the 100-year return period flows used for floodplain delineation and risk assessment. However, for completeness and transparency, the results from both Model 1 and Model 2 are presented in Table 4.22 and Table 4.23, respectively, for comparison.

Table 4.22: Existing land use conditions Continuous Simulation Generated Frequency Flows at key locations Per Calibrated Model 1 (m^3/s)

Location	Node	Drainage Area (ha)	Distribution	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
Wellington Rd. 29	Clythe_01	101.16	Wakeby	0.49	1.03	1.68	2.70	5.03	8.01
Jones Baseline	Clythe_04	624.68	Wakeby	0.16	0.76	1.77	3.73	9.29	18.10
Hwy 7	Clythe_05	678.23	Wakeby	0.30	1.21	2.57	4.97	11.20	20.20
CNR	Clythe_06	866.98	Wakeby	0.58	2.07	3.91	6.75	13.00	20.60
City Boundary	Clythe_07	1011.45	Log P. III	0.68	3.10	6.88	13.30	28.10	46.20
Watson Creek	Clythe_08	1087.30	Log P. III	1.02	3.39	6.91	13.00	28.00	48.00
After York Rd.	Clythe_11	1202.38	Log P. III	0.94	2.83	5.83	11.50	27.40	51.70
Reformatory Ponds	Clythe_12	1207.43	Log P. III	0.92	2.75	5.64	11.10	26.20	49.30
Hadati Creek	Clythe_13	1618.06	Log P. III	0.97	2.90	5.96	11.80	28.00	52.80
Outlet to Eramosa River	Clythe_16	2452.33	Wakeby	6.72	12.50	18.10	25.10	37.00	48.50
Eastview Rd.	Hadati_02	242.82	Wakeby	0.84	1.47	2.01	2.61	3.53	4.31
Starwood Dr.	Hadati_06	353.88	Wakeby	1.18	2.13	3.08	4.28	6.37	8.44
Grange Rd.	Hadati_10	400.65	Wakeby	1.29	2.59	4.00	5.95	9.70	13.80
CNR	Hadati_11	516.81	Wakeby	1.91	4.15	5.94	7.91	10.90	13.50
Outlet to Clythe Creek	Hadati_13	666.96	Wakeby	3.94	7.55	11.00	15.10	21.90	28.40
Grange Rd.	Watson_01	34.24	Wakeby	0.25	0.58	0.92	1.37	2.20	3.07
Fleming Rd.	Watson_03	46.64	Wakeby	0.30	0.67	1.07	1.61	2.64	3.76
Outlet to Clythe Creek	Watson_04	56.80	Wakeby	0.43	0.90	1.38	2.03	3.23	4.50

Table 4.23: Existing land use conditions Continuous Simulation Generated Frequency Flows at key locations Per Calibrated Model 2 (m^3/s)

Location	Node	Drainage Area (ha)	Distribution	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
Wellington Rd. 29	Clythe_01	101.16	Wakeby	0.02	0.05	0.10	0.21	0.52	1.03
Jones Baseline	Clythe_04	624.68	Wakeby	0.01	0.03	0.09	0.23	0.80	2.07
Hwy 7	Clythe_05	678.23	Log P. III	0.01	0.05	0.12	0.26	0.64	1.19
CNR	Clythe_06	866.98	Wakeby	0.03	0.14	0.28	0.50	1.00	1.65
City Boundary	Clythe_07	1011.45	Wakeby	0.04	0.10	0.18	0.31	0.64	1.11
Watson Creek	Clythe_08	1087.30	Log P. III	0.30	0.54	0.93	1.21	1.49	1.86
After York Rd.	Clythe_11	1202.38	Log P. III	0.73	1.12	1.39	1.65	1.98	2.24
Reformatory Ponds	Clythe_12	1207.43	Log P. III	0.72	1.14	1.45	1.76	2.19	2.52
Hadati Creek	Clythe_13	1618.06	Wakeby	0.73	1.22	1.62	2.03	2.61	3.06
Outlet to Eramosa River	Clythe_16	2452.33	Wakeby	6.49	9.43	11.50	13.60	16.30	18.30
Eastview Rd.	Hadati_02	242.82	Log P. III	0.88	1.41	1.83	2.27	2.92	3.46
Starwood Dr.	Hadati_06	353.88	Log P. III	1.36	2.08	2.61	3.14	3.86	4.44
Grange Rd.	Hadati_10	400.65	Wakeby	1.50	2.65	3.50	4.33	5.39	6.17
CNR	Hadati_11	516.81	Wakeby	2.11	3.99	5.35	6.65	8.27	9.43
Outlet to Clythe Creek	Hadati_13	666.96	Wakeby	4.35	8.71	11.80	14.60	17.60	19.50
Grange Rd.	Watson_01	34.24	Wakeby	0.33	0.63	0.83	1.02	1.27	1.45
Fleming Rd.	Watson_03	46.64	Log P. III	0.39	0.72	0.94	1.14	1.40	1.58
Outlet to Clythe Creek	Watson_04	56.80	Log P. III	0.54	0.93	1.21	1.48	1.85	2.13

For Model 2, a key consideration was the muted hydrologic response in the upper reaches of the watershed—particularly at headwater nodes Clythe_01 through Clythe_06. Due to the enhanced infiltration parameters and adjusted surface characteristics in Model 2, the model generated extremely low or zero runoff for more frequent events in these areas. As a result, many years within the continuous simulation period (1950–2005) yielded zero peak flows at these nodes, which, if included in the frequency analysis, would have skewed the regression curves and produced unreliable flow estimates dominated by zero values at the lower end and extremely high values at the higher end.

To address this, any simulation year where the annual maximum peak flow for these headwater nodes was exactly zero was omitted from the frequency analysis, ensuring that frequency estimates reflect realistic runoff-generating conditions. This approach aligns with best practices for handling sparse or non-informative data points in hydrologic analysis. It is important to note that this exclusion of zero-peak-flow years was limited only to these headwater nodes; for all other locations across the watershed, the full dataset was retained for frequency analysis.

Additionally, while 2005 was initially flagged as an outlier during Model 1 execution, the Model 2 produced reasonable peak flow outputs for that year. Consequently, 2005 was retained in the frequency analysis to preserve the integrity of the long-term dataset and reflect realistic hydrologic variability.

4.2.2.6.3 Flows to be applied for hydraulic modelling

Based on the PCSWMM model developed for this study, the peak flow results for each simulated design storm are presented in Table 4.24 in addition to the July 2024 event that was used for the calibration of the HEC-RAS model.

It is important to note that the design storm event peak flows, as determined using the 24-hour Chicago distribution under Model 2, are consistently higher than the corresponding flow estimates derived from the continuous simulation frequency analysis. This outcome is expected, as design storm simulations are typically conservative by nature, applying a uniform rainfall event at a defined intensity and duration to generate worst-case peak flows, whereas continuous simulation-based frequency flows incorporate a wider range of meteorological conditions and temporal variability, often resulting in lower peak flow estimates.

Given that the design storm event flows represent a more conservative and robust estimate of peak hydrologic response, they have been recommended for application in the hydraulic modelling for the Clythe Creek subwatershed. This approach aligns with best practices in watershed management and regulatory floodplain delineation, where conservative assumptions are preferred to ensure adequate protection against potential flood risks, particularly under future land use and climate change scenarios.

While the continuous simulation provides valuable insights into long-term trends and typical flow behavior, it is generally less conservative due to the variability of real-world rainfall events and the effects of antecedent moisture conditions, resulting in lower peak flows.

The choice between the two PCSWMM model versions (Model 1 and Model 2) has been discussed in previous sections. For the purposes of hydraulic modelling, the flows from Model 2 are applied in the final flow estimates, as they reflect a more refined representation of hydrologic conditions after peak flow adjustments (as detailed in previous sections). Model 2 incorporates parameter changes to account for infiltration losses and soil conditions, resulting in more realistic flow predictions under design storm scenarios.

It is also important to note that for both Model 1 and Model 2, the Regional Storm Event (Hurricane Hazel) consistently produced higher peak flows than the 100-year design storm, making it the regulatory event for the study area. This approach is consistent with Provincial standards, where the Regulatory Event is defined as the storm event that generates the highest peak flows for floodplain mapping and risk assessment. Therefore, the Regional Storm peak flows have been adopted for regulatory flow determinations, while the 100-year design storm flows have been used to inform infrastructure design and stormwater management practices.

Note that flows have been adjusted to ensure no decrease in flows moving downstream, regardless of any minor decreases in flows that may be indicated in the PCSWMM hydrologic modelling (due to flow routing attenuation).

Table 4.24: Steady state flows (m^3/s) from PCSWMM model for HEC-RAS model

Watercourse	Flow Change XS	July 2024 Event	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	Regional Storm
Clythe Creek	6769	0.01	0.01	0.08	0.21	0.51	0.8	1.13	3.88
Clythe Creek	6192	0.01	0.02	0.11	0.33	1.06	1.75	2.54	10.22
Clythe Creek	5804	0.01	0.02	0.11	0.33	1.06	1.75	2.54	18.47
Clythe Creek	5224	0.01	0.02	0.11	0.33	1.06	1.75	2.54	22.29
Clythe Creek	3985	0.01	0.02	0.11	0.33	1.06	1.75	2.54	28.04
Clythe Creek	3770	0.01	0.02	0.14	0.39	1.05	1.75	2.77	32.01
Clythe Creek	3009	0.04	0.1	0.28	0.55	1.49	2.74	4.38	38.91
Clythe Creek	2536	0.26	0.43	0.94	1.4	2.13	3.33	5.19	43.34
Clythe Creek	2406	0.26	0.43	0.94	1.4	2.13	3.33	5.19	43.84
Clythe Creek	1874	0.26	0.43	0.94	1.4	2.13	3.33	5.56	44.82
Clythe Creek	1684	0.64	1.11	2.08	2.99	4.33	5.44	7.13	47.05
Clythe Creek	1041	0.64	1.11	2.25	3.24	4.71	5.93	7.37	45.22
Clythe Creek	621	0.71	1.2	2.56	3.64	5.36	6.73	9.05	32.89
Clythe Creek	602	3.76	6.27	10.23	12.39	16.83	22.18	27.58	83.34
Clythe Creek	331	5.61	7.53	10.44	13.9	18.36	23.55	27.79	88
Hadati Creek	2978	0.26	0.36	0.81	1.13	1.57	1.89	2.24	5.33
Hadati Creek	2865	1.05	0.65	1.26	3.7	2.37	4.09	3.47	19.61
Hadati Creek	2372	1.05	0.65	1.29	3.63	2.61	3.84	3.93	21.18
Hadati Creek	2207	1.06	0.65	1.29	3.64	2.64	3.74	4.01	23.49
Hadati Creek	1858	1.11	0.86	2	4.05	5.23	7.5	8.62	28.32
Hadati Creek	1422	1.13	1.38	2.35	4.48	6.17	9.45	11.34	30.11
Hadati Creek	986	1.24	2.48	3.99	5.27	7.07	10.75	13.75	31.58
Hadati Creek	591	1.4	3.12	4.98	6.35	8.76	12.52	15.61	41.66
Hadati Creek	46	3.29	7.35	8.52	9.8	13.96	18.72	22.96	51.49
Watson Creek	1412	0.03	0.12	0.16	0.17	0.27	0.35	0.43	3.94
Watson Creek	772	0.1	0.17	0.33	0.44	0.74	1.02	1.35	5.15
Watson Creek	157	0.26	0.43	0.97	1.37	1.95	2.36	2.85	6.4

4.2.3 Surface water findings: Hydraulics

4.2.3.1 Model Development

4.2.3.1.1 Overview

This section provides an overview of the hydraulic assessment for the Clythe Creek subwatershed. A new existing conditions hydraulic model was development which resulted in the preparation of existing conditions floodplain mapping within the PSA.

New 1-dimensional (1D) hydraulic modelling for the PSA and SSA was prepared using the most recent non-beta version of HEC-RAS, which at the time of the completion of this study was version 6.6. The following sections provide details regarding the hydraulic modelling.

4.2.3.1.2 Topographic data

The topographic data that have been used in the HEC-RAS model were based on the Ontario Digital Terrain Model (LiDAR Derived) raster data set provided by the Ministry of Natural Resources, 2016 with a 0.5 m resolution. The horizontal and vertical datums of the LiDAR modelling are as follows:

- Horizontal Datum: North American Datum (NAD) 1983 coordinate system in UTM Zone 17N (UTM 17) projection (ESPG Coordinate Number 26917)
- Vertical Datum: Canadian Geodetic Vertical Datum of 2013 (CGVD2013).

4.2.3.1.3 River centreline

A Regulatory floodplain update will not be completed in the SSA, representing the extent of the subwatershed outside the limits of the City of Guelph and within the adjacent Townships of Guelph/Eramosa and Puslinch, based on the project terms of reference and scope of work. Therefore, the river centreline extents were established based on drainage areas within the PSA and SSA. Drainage areas less than 50 ha have not been included within the hydraulic model and the river centreline was established as such with the help of topographic data.

Three watercourses pass through the SSA and PSA, namely, Clythe Creek, Watson Creek and Hadati Creek. Watson and Hadati Creeks are tributaries of Clythe Creek, and the latter is a tributary of the Eramosa River. The modelling extent of Clythe Creek starts at the confluence with the Eramosa River and ends just upstream of Highway 29. The modelling extent of Watson Creek starts at the confluence with Clythe Creek and ends just upstream of Grange Road. Lastly, the modelling extent of Hadati Creek starts at the confluence with Clythe Creek and ends just upstream of Eastview Road.

4.2.3.1.4 Cross-sectional geometry

Cross-section locations and extents have been established from the pre-existing model prepared for the York Road EIS, LiDAR, City aerial imagery, and building footprints. The cross-section cutting approach was applied by looking downstream, from left to right, stopping at the highest point of the cross-section. The cross-section lengths have been established from the LiDAR to ensure that the entirety of the floodplain is captured within the cross-sections. Additionally, field-collected survey data were incorporated into the HEC-RAS model wherever available.

The cross-sections have been cut to ensure that there are four bounding cross-sections for each hydraulically significant structure, two upstream and two downstream, to represent the contraction and expansion zones of each hydraulic structure. The cross-sections are located outside of the toe (base) of the fill and the side ditches.

Further, cross-section spacing has been determined based upon standard conventions, whereby channel length was determined based on the river centre line, and overbank distances were determined along the path of the centre of mass for overbank flow. These have been automatically calculated within RAS-Mapper as part of the hydraulic model development and were consistent with standard hydraulic modelling practices. Additionally, cross-section placement included changes in longitudinal slope, cross-sectional area, channel roughness, bridges and other locations of channel constriction. Cross-sections have been placed such that the energy gradient, water-surface slope, and bed slope were all parallel to each other between cross sections. In instances where abrupt changes in conveyance occurred, cross-sections were located at shorter intervals.

At tributary locations such as Watson and Hadati Creeks, cross-sections were located immediately upstream and downstream from the confluence of Clythe Creek and immediately upstream on the tributary to account for changes in flow rate appropriately.

4.2.3.1.5 Hydraulic structures

Data collection

An inventory of hydraulic structures has been completed as part of the Characterization phase. The City collected information on each of the crossings on Clythe Creek, Hadati Creek and Watson Creek. A field inventory of PSA structures was prepared to confirm the structure geometry (i.e., type, end treatments, opening width, span, distance from obvert to top of road, top of road profile, parapets, railings etc.) as well as identify any other pertinent observations such as low flow channel geometry, vegetation, beaver dams and formation of overbank zones, categorizing the road deck, among others. This information was then used as the primary source for hydraulic structure coding into the HEC-RAS model, which was supplemented by the topographic survey, as-built drawings, previous modelling and aerial imagery, where available. In instances where the structure was inaccessible or unsafe to access, the structure dimensions were approximated based on engineering judgment.

The structure inventory is included in Appendix C.

4.2.3.1.6 Other geometry factors

Ineffective flow areas have been assigned at each hydraulic structure crossing and applied to both the upstream and downstream bounding cross-sections. The approach is consistent with the HEC-RAS methodology, where a 1:1 contraction rate has been applied for placing the ineffective flow areas on both sides of the structure face depending on location of the cross-section from the upstream and downstream faces of the structure. The ineffective flow areas are assigned as “non-permanent”, as once the roadway is overtopped, the full cross-section is capable of being used for flow computations.

An additional geometry feature that has been included in the modelling is the addition of levees, in areas where there are several low points throughout the cross-section/floodplain, which may not accurately represent the primary flow path. To determine areas where levees may be appropriate, the baseline geometry file has been simulated with no levees, which allows for the RAS mapper program to plot the inundation limits freely within the bounds of the cross-sections. This can demonstrate the potential spill paths and/or external channels which may not be representative of the primary active channel.

While the application of levees assists with the water surface elevation (WSE) computations and results within the main channel, it is important to note that levees prevent the RAS mapper from plotting any backwater impacts from the channel into the low areas of the floodplain. This can be remedied through the delineation of floodplain limits through other software platforms (i.e., CAD, GIS); however, for the current assessment, the WSE results form the basis of the comparison and characterization of the potential impacts, therefore the RAS mapper limits are considered appropriate for the current assessment.

Further, blocked obstructions have also been included in the cross-section geometry based on the building footprint layer provided by the City for use in the current study. These have been assigned elevations in the cross-section geometry to represent the building structure obstructions in the floodplain, which would inherently result in the reduction of available flow area. The cross-sections have already been established with consideration for the adjacent buildings, to ensure those that may be within the floodplain are included in the modelling. This has been reviewed at subsequent modelling stages to ensure that any changes in floodplain limits/buildings within the floodplain are included in the model geometry.

4.2.3.1.7 Hydraulic parameters

Manning’s roughness coefficients

Initial estimation of Manning’s roughness coefficients has been based upon urban land use mapping, field observations and review of aerial imagery. Based upon this review, a landcover layer was imported into RAS Mapper to assign the roughness coefficients for the channel and overbank areas.

Expansion and contraction coefficients

Expansion and contraction coefficients for normal channel cross-sections have been set to 0.1 and 0.3, respectively. For cross-sections bounding hydraulic structures and for locations where there is a rapid change in cross-section/valley geometry, expansion and contraction coefficients have been set to 0.3 and 0.5, respectively. These ratios are used by HEC-RAS in the computation of energy losses due to flow contraction and expansion between adjacent cross-sections. The noted values are consistent with those recommended in the HEC-RAS Technical Reference Manual. For structure coding, coefficients of 0.3 and 0.5 (expansion and contraction respectively) have been applied to the two cross-sections upstream of a structure, and the one cross-section immediately downstream of a structure. This application of expansion and contraction coefficients reflects the anticipated rapid changes occurring at these cross-sections. This approach is consistent with other floodplain mapping work the SWSU team has completed in southern Ontario. Steady state flow data have been applied as per the hydrologic modelling summary presented previously in Section 4.2.3.5.3.

A control starting elevation has been used at the starting cross-section of Clythe Creek for all storm events except the July 2024 event where normal depth boundary condition was used. Control starting elevations that were provided by GRCA for flood elevations for the Eramosa River have been used as boundary conditions for all storm events shown below. It is noteworthy that the GRCA provided the elevations in the CGVD28 vertical datum which were converted to the CGVD2013 datum. The starting water surface elevations for Watson Creek and Hadati Creek assumed coincident peaks with the main branch (Clythe Creek).

Table 4.25: Hydraulic model boundary condition - Clythe Creeks

Storm Event	Water Surface Elevation (Boundary Condition)[1]
2-Year	308.82
5-Year	309.16
10-Year	309.31
25-Year	309.44
50-Year	309.62
100-Year	309.73
Regional Storm	311.59

[1]Elevations converted to CGVD2013

4.2.3.1.8 Sensitivity and uncertainty analysis

With respect to the 1D hydraulic modelling, a scoped sensitivity analysis has been completed to assess model sensitivity and confirm the validity of the results. In this analysis, Manning's roughness coefficients were increased by 20%, representing a scenario with greater surface resistance to flow, such as rougher channel beds or vegetated banks. This increase in roughness would have caused water to flow more slowly, resulting in higher water surface elevations due to the reduced conveyance capacity.

Additionally, contraction and expansion coefficients were increased by 100%, simulating more significant energy losses at channel transitions—such as where the creek narrows or widens. These changes further contributed to elevated water levels, particularly upstream of constriction points, as the flow experienced greater resistance and turbulence. The analysis has also considered how the number of critical depth occurrences is impacted.

The HEC-RAS model sensitivity and uncertainty analysis results are provided in Appendix C.

4.2.3.1.9 Calibration of HEC-RAS model

It should be noted that this summary refers to model calibration efforts prior to the final hydrologic model calibration effort described in Section 4.2.2.5 which was premised on unitary flow comparison to the results of the Water Survey of Canada Eramosa River gauge.

The July 16, 2024, observed event flows generated through the PCSWMM model were used as input to the HEC-RAS model and the resulting water surface elevations from the HEC-RAS model were then compared to the observed flood depths as recorded by the City's flow depth gauges. Manning's n values were updated solely for the channel portions of Clythe Creek and Hadati Creek. For Clythe Creek, values were increased from 0.035 to 0.04 between cross-sections 163 and 602. For Hadati Creek, values were raised from 0.035 to 0.045 between cross-sections 3 and 135. These adjustments were made in an effort to elevate the water surface profiles. However, further increases in Manning's n would not yield justifiable improvements in water surface elevations based on HEC-RAS modelling principles. Flood water depths were compared at three locations which included HC-2 on Hadati Creek, CC1 and CC6 both on Clythe Creek. Calibration results are shown in Table 4.26.

Table 4.26: Observed water surface elevation comparison against HEC-RAS model simulated water surface elevation

Location	Observed Water Surface Elevation (m)	HEC-RAS Model Simulated Water Surface Elevation (m)
HC-2	309.38	309.28
CC-1	324.91	324.66
CC-6	308.94	308.50

4.2.3.2 Hydraulic modelling results

The existing conditions hydraulic model described in the preceding sections has been simulated for the 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year design storms and Regional Storm. The draft existing conditions regulatory event floodplain mapping has been plotted on the LiDAR using RAS Mapper and CAD and are presented within FPM Sheets 1 - 6. HEC-RAS Model outputs are included in Appendix C.

The draft existing conditions regulatory event floodplain mapping are generally similar to the current GRCA regulatory floodplain mapping, with some key observations summarized as per the following:

- At the confluence of Clythe Creek and Eramosa River, the floodplain has slightly increased near Victoria Road South (FPM-1).
- The floodplain near the confluence of Clythe Creek and Hadati Creek has decreased near Suburban Avenue, Elizabeth Street and has increased slightly just downstream at the railroad crossing upstream of Suburban Avenue (FPM-1).
- The Hadati Creek floodplain extents upstream of Starwood Drive have increased (FPM-3). Additionally, the floodplain extents upstream of the CNR near Schreder Crescent, Cedarvale Avenue and Valleyhaven Lane have increased slightly. The 1-dimensional (1D) HEC-RAS modelling may not be accurately considering storage and ponding levels upstream of the hydraulic structures in this area as the internal culvert cross-sections in the HEC-RAS model show a spill in this area. As such, further investigation may be warranted using 2-dimensional (2D) modelling as part of future work (FPM-3).
- The Clythe Creek floodplain extents near Watson Parkway North have slightly increased (FPM-5). However, it is noteworthy that the 1-dimensional (1D) HEC-RAS modelling may not be accurately considering storage and ponding levels upstream of the hydraulic structures in this area. The impact of spill flows at York Road (as noted below) may also impact water levels. Further assessment and 2-dimensional (2D) modelling may be warranted as part of future work.
- A spill is observed on Clythe Creek southwards on Watson Parkway South, west towards York Road and west of Watson Parkway South (FPM-5). The spill is occurring due to the limitation of 1D HEC-RAS modelling. 2D modelling may be appropriate for this area as part of future work to better assess the floodplain extents
- The Watson Creek floodplain extents have generally decreased slightly west of Severn Drive (FPM-6).

The hydraulic performance of the culverts within the PSA has been assessed using the Ministry of Transportation (MTO) hydraulic criteria, and Ministry of Natural Resources (MNR) vehicle ingress and egress criteria for the calculations.

Hydraulic performance standards have been established using the MTO Highway Drainage Design Standard (HDDS) (January 2008), which incorporates the hydraulic standards for watercourse crossings from the Canadian Highway Bridge Design Code. The following references the MTO document (in brackets) related to the hydraulic criteria:

- Design storms used to calculate flood elevations (WC-1)
- Minimum top of road freeboard (WC-7)
- Desired top of road freeboard (WC-7)
- Maximum depth of relief flow over the road (WC-13)
- Maximum product of depth and velocity of relief flow over the road (WC-13)

Culvert and bridge crossings are classified based on WC-1 from the MTO HDDS. As such, the following design criteria apply:

- Design flow as per the MTO's 2008 Highway Design Standards for freeways and urban arterials would be the 50-year event for structures less than or equal to 6 m in span. Structures with a span exceeding 6 m should be designed to convey a minimum of the 100-year storm event. The same criteria for rural arterials and collectors would be the 25-year event for structures less than or equal to 6 m in span. Structures with a span exceeding 6 m should be designed to convey a minimum of the 50-year storm event. For local roads, would be the 10-year event for structures less than or equal to 6 m in span. Structures with a span exceeding 6 m should be designed to convey a minimum of the 25-year storm event.
- Top of the Road Freeboard as per the MTO's 2008 Highway Design Standards should be a minimum of 1.0 m measured from the design flow hydraulic grade line elevation to the edge of the travelled lane. The desirable freeboard is 1.0 m measured vertically from the energy grade line for the design flow.
- Relief Flow as per the MTO's 2008 Highway Design Standards should be a maximum depth of flow on the roadway of 0.3 m, while the product of the velocity and depth on the roadway shall not exceed 0.8 m^2/s.
- Clearance for open footing culverts as per MTO HDDS WC-7 shall be 0.3 m (measured from the water surface elevation to the crossing's soffit). Flood depth for open footing culverts should be as follows:
    - Culverts with a diameter or rise <3.0 m will maintain a HW/D less than or equal to 1.5
    - Culverts with a diameter or rise of 3.0 m to 4.5 m will maintain a HW/D less than or equal to 4.5
    - Culverts with a diameter or rise >4.5 m will maintain a HW/D less than or equal to 1.0

In addition to the foregoing, the following MNR vehicle ingress and egress criteria would also apply should any overtopping of roadway occur:

Pedestrian passage criteria:

- Depth of less than 0.8 m
- Velocity of less than 1.7 m/s
- Depth x Velocity of less than 0.4 m^2/s

Private vehicle passage criteria:

- Depth of less than 0.4 m
- Velocity of less than 3 m/s

- Depth x Velocity of less than 1.2 m^2/s

Emergency vehicle passage criteria:

- Depth of less than 1.2 m
- Velocity of less than 4.5 m/s
- Depth x Velocity of less than 5.4 m^2/s

For rail crossings, in the absence of Canadian standards, hydraulic criteria for rail crossings can be found in the American Railway Engineering and Maintenance-of-Way Association (AREMA) Manual (2023) Guidelines. AREMA recommends that culverts be designed to discharge: a 25--year flood without static head at the entrance (i.e., a maximum headwater to culvert diameter/rise ratio (HW/D) of 1.0); and, a 100-year flood using the available head at entrance – the head is to be 0.6 m below the base of rail (i.e., 0.6 m minimum freeboard), or results in a HW/D not exceeding 1.5, whichever is less.

Table 4.27 indicates the overtopping depths for the culverts within the PSA along with MNR criteria assessment and the hydraulic performance of the culverts as per MTO and AREMA criteria have been summarised in Table 4.28.

Current results indicate that one structure on Clythe Creek and four structures on Hadati Creek are overtopped - the overtopping depths vary from 15 cm to 41 cm. All culverts on Clythe Creek within the PSA except one (Watson Road North) do not meet the MNR criteria and one of the culverts on Clythe Creek (Access road east of York road) does not meet the MTO criteria Furthermore, on Hadati Creek three and two culverts do not meet the MNR and MTO criteria respectively whereas, on Watson Creek all culverts meet the MNR and MTO criteria.

It is pertinent to note that the spill areas noted in Table 4.27 do not reasonably demonstrate overtopping depths as the 1D modelling method is unable to model these areas accurately.

Table 4.27: Hydraulic performance at hydraulic structures and criteria** assessment

Watercourse	Roadway	Structure Type/Size (m)	25-Year Overtopping Depth (m)	50-Year Overtopping Depth (m)	100-Year Overtopping Depth (m)	Maximum Overtopping Depth (m)	Maximum Velocity (m/s)	Depth X Velocity (m^2/s)	Pass Criteria**
Clythe Creek	Access road east of York Road	Ellipse (1.5X1.3, 1.2X1.1)	0.12	0.30	0.41	0.41	0.10	0.04	Yes
Clythe Creek	Service road east of York Road	Arch (4.4X1.6)	0	0	0	0	2.59	0.00	Yes
Clythe Creek	York Road	Box (3X1.8)	0	0	0	0	2.86	0.00	Yes
Clythe Creek	CNR	Box (2-1.2X1.2)	0	0	0	0	3.61	0.00	Yes
Clythe Creek	Watson Parkway North	Box (4X1.4, 4X0.9)	0	0	0	0	4.07	0.00	Yes
Clythe Creek	Watson Road North	Pipe (1.5)	0	0	0.28	0.28	3.37	0.94	**No**
Hadati Creek	York Road	Box (5.4X1.5)	0	0.15	0.15	0.15	2.76	0.41	**No**
Hadati Creek	Beaumont Crescent	Box (3X1.8)	0	0	0.20	0.20	2.83	0.57	**No**
Hadati Creek	Elizabeth Road	Box (3X2.3)	0	0	0	0	4.14	0.00	Yes
Hadati Creek	Suburban Avenue	Box (3.6X2.4)	0	0	0	0	2.17	0.00	Yes
Hadati Creek	CNR	Pipe (1.2)	Spill	Spill	Spill	Spill	Spill	Spill	**No**
Hadati Creek	Grange Road	Box (2-3.6X2.3)	0	0	0	0	1.41	0	Yes
Hadati Creek	Chesterton Lane	Box (2-3.6X2.3)	0	0	0	0	3.85	0	Yes
Hadati Creek	Starwood Drive	Box (2.4X1.2)	0	0	0	0	3.28	0	Yes
Hadati Creek	Eastview Road	Box (2.4X1.2)	0	0	0	0	2.56	0	Yes
Watson Creek	Fleming Road	Pipe (0.8)	0	0	0	0	2.91	0	Yes
Watson Creek	Trail	Pipe (0.8)	0	0	0	0	1.74	0	Yes
Watson Creek	Trail	Pipe (0.8)	0	0	0	0	2.37	0	Yes
Watson Creek	Grange Road	Pipe (0.8)	0	0	0	0	1.74	0	Yes

** As per Ministry of Natural Resources (MNR)

Table 4.28: Hydraulic crossing performance as per MTO and AREMA criteria

Watercourse	Roadway	Largest Storm Conveyed without Overtopping	Design Storm MTO Criteria (WC-1)	Top of Road Freeboard (WC-7 - m)	Flood Depth at Culverts (WC-7 HW/D - ratio)	Pass MTO Criteria
Clythe Creek	Access road east of York Road	2-Year	10-Year	-0.08	0.06	**No**
Clythe Creek	Service road east of York Road	100-Year	10-Year	1.00	0.61	Yes
Clythe Creek	York Road	100-Year	50-Year	2.08	1.16	Yes
Clythe Creek	CNR	Regional Storm	2-Year*	11.12	9.20	Yes
Clythe Creek	Watson Parkway North	100-Year	50-Year	1.16	0.83	Yes
Clythe Creek	Watson Road North	50-Year	25-Year	1.20	0.80	Yes
Hadati Creek	York Road	25-Year	50-Year	-0.22	0.15	**No**
Hadati Creek	Beaumont Crescent	50-Year	10-Year	1.15	0.64	Yes
Hadati Creek	Elizabeth Road	100-Year	10-Year	1.95	0.85	Yes
Hadati Creek	Suburban Avenue	100-Year	10-Year	1.35	0.56	Yes
Hadati Creek	CNR	5-Year	2-Year*	2.37	1.98	**No**
Hadati Creek	Grange Road	Regional Storm	50-Year	1.44	0.63	Yes
Hadati Creek	Chesterton Lane	Regional Storm	10-Year	2.14	0.93	Yes
Hadati Creek	Starwood Drive	100-Year	25-Year	3.77	3.14	Yes
Hadati Creek	Eastview Road	100-Year	25-Year	1.81	1.40	Yes
Watson Creek	Fleming Road	100-Year	10-Year	2.18	2.73	Yes
Watson Creek	Trail	100-Year	10-Year	1.81	2.26	Yes
Watson Creek	Trail	100-Year	10-Year	1.13	1.41	Yes
Watson Creek	Grange Road	100-Year	10-Year	2.48	3.06	Yes

*AREMA Criteria

4.2.4 Surface water findings: Stormwater management facilities

The design and capacity of the existing stormwater management (SWM) facilities within the PSA have been evaluated at a high level, and the performance has been assessed in accordance with the Ministry of Environment, Conservation and Parks (MECP) 2003 Stormwater Management Planning and Design Manual. The primary source for this assessment is the City of Guelph's SWMMP Update (Aquafor Beech, 2023).

Water quantity control

According to the assessment conducted in the City of Guelph's SWMMP Update, there are 20 SWM facilities within the PSA and due to the unique stage-storage-discharge characteristics of each facility and limitations of the available hydrologic\hydraulic modelling, determining the flood volume deficit at this level was not feasible.

As a surrogate approach, SWM facilities with the greatest changes in imperviousness (based on current aerial photography and land use mapping), as compared to the original design values have been indicated in Table 4.29. These areas may reflect SWM facilities where capacity may be deficient and should be prioritized for further study.

Table 4.29: Change in the impervious percentage compared to original design

#	SWMF	Range of Impervious % Change
1	SWM9	Not Assessed
2	SWM12	No Change
3	SWM31	No Change
4	SWM35	No Change
5	SWM36	No Change
6	SWM37	No Change
7	SWM38	No Change
8	SWM53	Not Assessed
9	SWM54	Change > 20%
10	SWM86	No Change
11	SWM87	No Change
12	SWM88	No Change
13	SWM96	Not Assessed
14	SWM99	No Change
15	SWM102	No Change
16	SWM103	Not Assessed
17	SWM111	No Change
18	SWM115	No Change
19	SWM127	No Change
20	SWM128	No Change

The impervious percentage changes indicate that only SWM54 (East of Fletcher Ct.) has experienced a change in imperviousness exceeding 20 per cent. As such, according to the City of Guelph's SWMMP Update, SWM54 poses the highest risk of failing to meet water quantity control requirements.

Water quality control

Based on the City of Guelph Development Engineering Manual (2023), SWM facilities should be designed to achieve Level 1 (Enhanced treatment), corresponding to an 80 per cent long-term average reduction in total suspended solids (TSS).

According to the City of Guelph's SWMMP 2023 Update, the SWM facilities within the PSA provide the following levels of water quality treatment. Out of the 20 SWM facilities only three are noted as providing an Enhanced level of water quality treatment, therefore improvements in stormwater quality control for existing development will need to be considered in the study's recommendations.

Table 4.30: Classification and level of quality treatment of stormwater management (SWM) facility

#	SWMF	Existing Classification	Level of Quality Treatment of SWM Facility
1	SWM9	Dry	No Permanent Pool
2	SWM12	On-Line Pond	No Permanent Pool
3	SWM31	Dry	No Permanent Pool
4	SWM35	Wet	Basic
5	SWM36	Wet	Less than Basic
6	SWM37	Wet	Basic
7	SWM38	Dry	No Permanent Pool
8	SWM53	Wet	Enhanced
9	SWM54	Wet	Unknown
10	SWM86	Wet	Normal
11	SWM87	Wet	Normal
12	SWM88	Wet	Normal
13	SWM96	Dry	No Permanent Pool
14	SWM99	Wet	Basic
15	SWM102	Wet	Enhanced
16	SWM103	Dry	No Permanent Pool
17	SWM111	Wet	Basic
18	SWM115	Wet	Enhanced
19	SWM127	On-Line Pond	No Permanent Pool
20	SWM128	On-Line Pond	No Permanent Pool

Erosion control

According to the City of Guelph Development Engineering Manual (2023), for all development sites, the minimum erosion control requirement is extended detention of the 4-hour, 25 mm Chicago distribution rainfall event for 24 hours. Accordingly, the City of Guelph's SWMMP 2023 Update outlines the following levels of erosion control provided by the SWM facilities within the PSA. Out of the 20 SWM facilities, only nine provide adequate erosion control based on the original design information. For the balance, further review would be required to determine whether or not erosion control is provided or not.

Table 4.31: Levels of Erosion Control for Each SWM Facility

#	SWMF	Levels of Erosion Control for Each SWM Facility
1	SWM9	Unknown or No Extended Detention
2	SWM12	Unknown or No Extended Detention
3	SWM31	Unknown or No Extended Detention
4	SWM35	Not Sufficient
5	SWM36	Not Sufficient
6	SWM37	Sufficient
7	SWM38	Unknown or No Extended Detention
8	SWM53	Sufficient
9	SWM54	Unknown or No Extended Detention
10	SWM86	Sufficient
11	SWM87	Sufficient
12	SWM88	Sufficient
13	SWM96	Unknown or No Extended Detention
14	SWM99	Sufficient
15	SWM102	Sufficient
16	SWM103	Unknown or No Extended Detention
17	SWM111	Sufficient
18	SWM115	Sufficient
19	SWM127	Unknown or No Extended Detention
20	SWM128	Unknown or No Extended Detention

As indicated in Table 4.31 more than 50 per cent of the SWM facilities in the PSA either provide insufficient erosion control or have unknown erosion control levels.

4.2.5 Summary of surface water characterization

The following summarizes the existing surface water and flood hazard characterization for Clythe Creek.

The PSA is divided into two groups: Group A includes areas developed under the City of Guelph's SWMMP Update PCSWMM model and directly imported into the Clythe Creek SWSU model, covering approximately 757 ha with 54 per cent imperviousness. Group B comprises areas not included in the Master Plan, defined by WSP, covering approximately 1695 ha with 17 per cent imperviousness. Group A subcatchments are primarily urban and produce faster, higher runoff responses, while Group B subcatchments, which are mostly located in SSA, with their larger drainage areas, generate the majority of peak flow for the Regional Storm event. Hydraulic structures such as culverts and bridges along Clythe Creek restrict peak flows during less frequent events, leading to lower peak flows in the calibrated model that align better with observed values.

The hydrologic assessment for Clythe Creek was informed by two distinct PCSWMM model configurations, each developed to serve specific objectives and regulatory considerations.

Model 1 was originally calibrated based on the available local-scale monitoring data. Model 1 applies more standard infiltration parameters typical of design storm-based assessments, resulting in higher peak flows under both design storm and continuous simulation scenarios. It is expected that Model 1 will be used to estimate peak flows for stormwater management design purposes, such as sizing detention facilities or assessing conveyance capacity for smaller, more localized systems. However, the model-generated peak flows for the rural upstream Clythe Creek watershed were suggested to be over-estimated (including by GRCA), due to areas dominated by permeable soils and rural land use, where infiltration plays a significant role in hydrologic response (which was noted by GRCA to be muted as compared to other typical rural watersheds).

In contrast, Model 2 incorporates adjusted infiltration and soil parameters to better align peak flow results for Clythe Creek with historical streamflow data (and associated frequency analysis) from the Eramosa River. This model produces lower peak flows, especially for more frequent events, as it better reflects the upper Clythe Creek watershed's capacity for infiltration and storage. Based on the re-calibration and alignment with observed frequency flows in the overall area, Model 2 is considered the preferred model for establishing design\frequency flows and the Regional Storm Flow. Model 2's ability to capture the physical hydrologic response of the watershed provides a more realistic foundation for defining flood hazards under existing conditions.

For the establishment of design flows, the calibrated PCSWMM model has been revised by removing culverts to determine both design events peak flows and frequency flows for the continuous meteorological data set, throughout the PSA and SSA. SWM Facilities (ponds) are removed for the simulation of the Regulatory Event. The Regional Storm Event (Hurricane Hazel) has been selected as the regulatory event for this study, as it produced the highest peak flows for both Model 1 and Model 2, consistent with industry standards and provincial policy. The 100-year design storm has been applied for design considerations where required, but regulatory flows are based on the Regional Storm Event peak flows.

The hydraulic modelling scope included the existing conditions of hydraulic model development which resulted in the preparation of draft existing conditions regulatory event floodplain mapping within the PSA. The draft existing conditions floodplain mapping does not delineate a flood fringe associated with the two-zone policy area that is currently shown on GRCA Regulated

Floodplain mapping in the vicinity of Elizabeth Street and York Road. The two-zone policy area will be explored further as part of Phase 2 of this study.

The draft regulatory floodplains show several differences compared to the current GRCA regulatory floodplain mapping. Notably, the floodplain at the confluence of Clythe Creek and Eramosa River has slightly increased near Victoria Road South (FPM-1). Conversely, the floodplain near the confluence of Clythe Creek and Hadati Creek has decreased near Suburban Avenue, Elizabeth Street, and at the railroad crossing upstream of Suburban Avenue (FPM-1). The Hadati Creek floodplain extents upstream of Starwood Drive have increased (FPM-3).

The Clythe Creek floodplain extents near Watson Parkway North have increased slightly (FPM-5). As noted, this area is also complicated by spills at York Road, which cannot be accurately mapped using the current 1-dimensional (1D) hydraulic modelling. Consideration of 2-dimensional (2D) hydraulic modelling may be warranted to better map spills and also better assess flood inundation volumes and upstream flood levels. This should be considered as part of future work.

The Watson Creek floodplain extents have generally decreased slightly west of Severn Drive (FPM-6).

It is important to note that certain creek reaches, such as upstream Watson Creek, are not areas of flooding concern. This distinction helps in understanding the varying flood risks across different regions.

Notwithstanding, inadequately sized crossings can have a direct impact on the floodplain dynamics. As per Table 4.27, four structures were noted as having deficient hydraulic performance along Clythe Creek (Watson Road North) and Hadati Creek (York Road, Beaumont Crescent, and CNR). As per Table 4.28, three structures were noted as not meeting MTO\AREMA criteria along Clythe Creek (access road east of York) and Hadati Creek (York Road and CNR). These locations should potentially be reviewed for hydraulic structure upgrades as part of subsequent assessment. It should be noted that other hydraulic structures (beyond those listed) may also be negatively impacted upstream flood levels and floodplain extents. Refer to Drawing SW-8 (attached) showing locations of identified hydraulic structure deficiencies.

The existing stormwater management (SWM) facilities within the PSA were assessed as part of the City of Guelph's SWM Master Plan Update (Aquafor Beech, 2023). The assessment identified 20 SWM facilities in the PSA, each with distinct stage-storage-discharge characteristics, making it difficult to determine flood volume deficits at this stage.

Among these facilities, the change in imperviousness within the catchment draining to SWM54 has changed the most (between design assumptions and currently estimated conditions) of all SWMF in the PSA, at greater than 20 per cent. Consequently, it was considered to have the highest potential risk of not meeting water quantity control requirements.

According to the City of Guelph Development Engineering Manual (2023), SWM facilities should achieve Level 1 (Enhanced) water quality treatment, which aims for an 80 per cent long-term reduction in total suspended solids (TSS). Only a limited number of the existing facilities in the PSA currently meet this enhanced treatment standard. In addition, the manual specifies that erosion control measures must include extended detention of a 4-hour, 25 mm Chicago distribution rainfall event for a minimum of 24 hours. Currently, more than half of the SWM facilities in the PSA either fail to meet these erosion control standards or have unknown performance levels.

4.3 Fluvial geomorphology characterization

The primary purpose of the fluvial geomorphology assessment and characterization is to identify surface water feature types and extents, general form and function, erosion hazards, and erosion sensitivity for features within and adjacent to the PSA that may be impacted by development. An understanding of feature constraints and opportunities, through integration with other disciplines is used to guide general land use decisions, and requirements for future study.

In order to identify and characterize watercourses and headwater drainage features (HDFs), a clear understanding on their definitions is required. In 2024, amendments to the Conservation Authorities Act included an update to the definition of a watercourse and the regulatory allowance as follows: “a defined channel, having a bed and banks or sides, in which flow of water regularly or continuously occurs” (O. Reg. 41/24).

The Regulatory Allowance applied to watercourse systems is 15 m from the greatest hazard: stable top of bank, projected long term stable top of slope, meander belt, or floodplain (under applicable regulatory flood event standard). Conservation Authorities previously (pre-2024) had freedom to modify these Regulatory Limits based on the understanding of their watershed(s) and associated hazards.

The 2024 watercourse definition provides some additional substance relative to the previous definition of “an identifiable depression in the ground in which flow of water regularly or continuously occurs”, however this definition does not distinguish from headwater drainage features (HDFs), which may also be defined and have flow regularly occurring (TRCA and CVC, 2014).

One of the objectives of the SWSU is to define and characterize the Water Resource System (WRS) associated with Clythe Creek. The City’s Official Plan (2024) identifies components of the WRS, including headwaters, rivers, stream channels, inland lakes, and ponds, among other components of the NHS. In consideration of the OP and the WRS, the SWSU must clarify specific definitions of surface water features in order to identify, characterize, and ultimately manage them.

The following definitions have been developed with consideration of the current definition of “watercourse” (O. Reg. 41/24), the WRS as outlined in the City’s OP, and have adapted the more fulsome definitions from the guidance document *Evaluation, Classification and Management of Headwater Drainage Features Guidelines* (TRCA and CVC, 2014), and professional experience in other jurisdictions.

Defining watercourses

Watercourses are defined as permanently to intermittently flowing drainage features with defined bed and banks, exhibiting clear evidence of active channel process including planform, profile, and material sorting through erosional and depositional processes throughout the reach. They are often second-order or greater but may be first order when verified by the practitioner(s) or regulatory agencies. Watercourses are regulated by the Conservation Authority, and fish are typically found within these features. Fish and fish habitat falls within the jurisdiction of DFO.

Defining headwater drainage features (HDF)

Non-permanently flowing drainage features that may not have defined bed or banks are defined as HDFs. Bed and bank definition within HDFs may be attributed to anthropogenic intervention (e.g., cutting a drainage feature into the surface), or seasonally as spring freshet concentrates flows in depressions, causing channel development into surfaces lacking vegetated cover. HDFs are first order intermittent and ephemeral channels and swales, and can connect headwater wetlands, but do not include rills or furrows. They are typically not identified as regulated features (with the exception of wetlands), and fish may or may not be found within these features.

The role of watercourse and HDF processes needs to be established such that guidance can be given to proposed land use changes, thereby ensuring continued channel process and contributions, as well as mitigating potential impacts to local and downstream channels and habitats. This information will provide guidance to channel management and enhancements within the PSA in relation to future development and infrastructure through Phases 2 and 3 of the SWSU.

To achieve this objective, the fluvial geomorphological assessments have included the following components:

- Collect and review any pertinent background information, such as topographic mapping, historic aerial photographs, and hydrologically informed watercourse mapping (shapefiles).
- Use available mapping to delineate channel reach boundaries for watercourses and identify potential HDFs, based on the definitions described above.
- Characterize valley setting (confined or unconfined) on a reach basis based on available topographical data (e.g., contours, LiDAR).
- Delineate the meander belt and long-term stable top of slope as appropriate on a reach basis for watercourses within the PSA.

- Complete field reconnaissance to confirm existing geomorphic conditions, valley setting, document evidence of active erosion and confirm desktop results for watercourses and HDFs.
- Determine erosion threshold values for receiving watercourses to inform preliminary SWM opportunities and quantity targets.

Notably, comprehensive (i.e., three-visit) assessments of all potential HDFs were not undertaken as part of this SWSU (in part due to access and in-part due to the scope and scale of the study). These will need to be undertaken as part of area or site-specific studies in the future.

4.3.1 Fluvial geomorphology methods

Background review

A background review was completed to gather information on the surface water features contained within the PSA. Key documents and mapping included:

- Clythe Creek Subwatershed Overview (Ecologistics and Blackport 1998)
- SWMMP Update: Erosion Assessment Technical Memorandum – Field Investigations. Aquafor Beech Ltd., 2021
- SWMMP Update: Geomorphic System Technical Memorandum – Field Investigations. Aquafor Beech Ltd., 2021
- City of Guelph Orthophotography (2000, 2006, 2009, 2012, 2016, 2019, 2021, 2023)
- Historic, georeferenced aerial photographs of the PSA and SSA from 1954 and 1966
- City of Guelph digital, georeferenced imagery (1966)
- City of Guelph Contours (0.5 m), 2012
- City of Guelph – Official Plan Natural Heritage Schedule 4 mapping
- City of Guelph water infrastructure (Stormwater, Wastewater, Water)
- Land Information Ontario (LIO) – Ontario Digital Terrain Model (DTM) (LiDAR-Derived) - “Lake Erie Package W” and “Lake Erie Package X”
- GRCA Watercourse shapefile
- GRCA Wetlands shapefile
- GRCA Watershed shapefile
- GRCA Waterbodies shapefile

Reach delineation and feature types

The parameters that influence stream channel form, such as the amount and size of available sediment, valley shape, land use or vegetation cover vary over the length of a feature. Lengths of channel that exhibit similar characteristics with respect to these parameters are referred to as reaches. Reach lengths vary with the scale of the channel, often longer for a larger watercourse, while smaller watercourses and HDFs exhibit more variability resulting in shorter reaches. Delineation of reaches is beneficial as it enables grouping and identification of generally common channel characteristics.

The process of delineating reaches considered external parameters such as local geology, topography and valley setting, drainage area, hydrology, riparian vegetation, and land use. Consideration was given to those characteristics that reflect these external influences, such as sinuosity, gradient, and dimensions. Field confirmation (Section 4.3.1.2) follows the desktop delineation to confirm feature types, extent, and location of reach breaks.

Watercourse mapping from GRCA was reviewed and updated to capture recent channel adjustments that were observed in the 2023 City imagery, and to delineate several smaller features that were not previously captured in the mapping dataset. Using the refined watercourse mapping, aerial imagery, and other mapping (e.g. significant valleylands; surficial geology), a new reach delineation was completed with breaks (reach limits) occurring at significant changes in the watercourse such as a change in watercourse confinement, land use changes and encroachment, geology, or local slopes. This reach delineation also considered those reaches previously identified through the 2021 and 2023 SWMMP and determined that additional segments were required. Reach limits were confirmed and or updated through field investigations.

DEM conditioning and HDF scoping

The updated watercourse layer and a mosaic of the LiDAR digital terrain model (DTM) Packages W and X were used to create a hydraulically conditioned digital elevation model (DEM). The DTM was subject to “stream burning”, where the watercourse layer is used to create a continuous drainage path and remove obstructions that are captured in the original DEM (e.g. bridges and culverts). Map FG-1, displays the stream network overlain on the hydraulically conditioned DTM.

A preliminary identification of HDFs was completed (at a high level) by using the calculated flow accumulation to identify flow paths which were not included in the GRCA watercourse mapping. The conditioned DEM was created with input from the Surface Water and Groundwater teams, creating a surface which can be used for modelling purposes across study disciplines, and to capture constraints and opportunities for drainage features that are less defined or undefined, prior to the completion of detailed HDF assessments through future planning studies.

Historical assessment

Streams are dynamic landscape features. Over time, their configuration and position within the floodplain changes because of meander evolution and development and channel migration processes. These lateral and down -valley planform adjustments can be observed and often quantified by reviewing historical orthophotographs. Depending on photograph quality and scale of the channel of interest, erosion rates may be determined by measuring the distance from known control points to a governing meander bend over the available historical record and then projected to determine an erosion limit (e.g., -100-year limit). Historical orthophotographs were analyzed to determine changes in surrounding land use, which may have impacted channel migration. To support the historical assessment and to evaluate channel migration, the SWSU team reviewed aerial imagery from 1954, 1966, 2000, and 2023.

Channel planform (centreline) was only digitized for 2000 and 2023 imagery due to issues with resolution/obstructions in the 1954 and 1966 photosets.

Erosion hazard delineation – meander belt width

Sustainable long-term management strategies for watercourses are intended to protect or enhance natural fluvial processes by limiting development within an erodible corridor or an erosion hazard limit. For unconfined valley systems, such as that of Clythe Creek and its Tributaries, a meander belt width is delineated with reference to the guidance document: Belt Width Delineation Procedures (Parish, 2004). Additional regulatory setbacks should be applied to the greater of all hazards: flood or erosion. In Ontario, that regulation extends 15 m from either side of the hazard associated with watercourse corridors.

The meander belt width defines the area that a watercourse currently occupies or can be expected to occupy in the future. For the purposes of this study, meander belt widths have been developed from a broad scale and may be subject to refinement as part of future, more detailed, studies. For this study, meander belt widths were delineated for watercourse reaches. Two methods were applied in the determination of the meander belt width, as follows:

- A measured/mapped approach whereby limits of the meander belt were defined by parallel lines drawn tangential to the outside bends of the laterally extreme meanders of the planform for each reach. Due to the limitations with the photographic record and the observed direct modification from the historical assessment, a 10 per cent factor of safety was calculated and applied to the meander belt (5 per cent to either side) in lieu of calculating the 100-year migration rate. Ten per cent was selected with consideration of relative lateral stability of these creeks, low slope, and vegetative controls. An empirical approach was applied, as many of the features are currently impacted (e.g. straightened). In this case, for a higher-level meander belt, a drainage area function (Equation 5.1[5] - Dunne and Leopold 1978) was used, with drainage areas being derived from the Ontario Watershed Information Tool (OWIT, 2024).
- Field characterization of watercourse reaches included full reach walks of those identified within the PSA through the desktop analysis. Based on ground observations, reaches may have been maintained as watercourses, or identified as HDFs at a preliminary level, and sub-reaches may have been added to account for specific

[5] Equation 5.1: $120Aw^{0.43}$ (where “Aw” is watershed area in square miles)

changes in site characteristics, with the intent that these require specific management considerations through later phases of study. Following reach walks (rapid assessments), sites were selected for detailed geomorphic survey to determine hydraulic thresholds for particle entrainment. The following provides details regarding rapid and detailed geomorphic field surveys.

Rapid assessments

In order to provide further insight into existing geomorphic conditions on a reach basis, cursory-level field reconnaissance was completed throughout the PSA in June and August of 2022. These cursory level assessments included Rapid Geomorphic Assessment (RGA) and the Rapid Stream Assessment Technique (RSAT).

The Rapid Geomorphic Assessment (RGA) was designed by the Ontario Ministry of Environment (MOE, 2003) to assess reaches in rural and urban channels. This semi-quantitative technique documents indicators of channel instability. Observations are quantified using an index that identifies channel sensitivity based on the presence or absence of evidence of aggradation, degradation, channel widening, and planform adjustment. Overall, the index produces values that indicate whether the channel is stable/in regime (score ≤0.20), stressed/transitional (score 0.21 - 0.40), or adjusting (score ≥0.40; Table 4.32).

Table 4.32: Rapid Geomorphic Assessment (RGA) classification

Score	Classification	Observations
<0.20	In Regime or Stable (Least Sensitive)	The channel morphology is within a range of variance for streams of similar hydrographic characteristics – evidence of instability is isolated or associated with normal river meander propagation processes
0.21 - 0.40	Transitional or Stressed (Moderately Sensitive)	Channel morphology is within the range of variance for streams of similar hydrographic characteristics, but the evidence of instability is frequent
>0.41	In Adjustment (Most Sensitive)	Channel morphology is not within the range of variance and evidence of instability is widespread

The Rapid Stream Assessment Technique (RSAT) was developed by John Galli at the Metropolitan Washington Council of Governments (Galli 1996). The RSAT provides a more qualitative and broader assessment of the overall health and functions of a reach. This system integrates visual estimates of channel conditions and numerical scoring of stream parameters using six categories:

- Channel Stability
- Erosion and Deposition
- Physical In-stream Habitat

- Water Quality
- Riparian Conditions
- Biological Indicators

Once a condition has been assigned a score, the total of these scores produces an overall rating which is based on a 50-point scoring system. The result of the assessment then categorizes the stream as Low (<20), Moderate (20 - 35), or High (>35) stream quality.

While the RSAT scores streams from a more biological and water quality perspective than the RGA, this information is also of relevance within a geomorphic context. This is based on the fundamental notion that, in general, the types of physical features that generate good fish habitat tend to represent good geomorphology as well (i.e., fish prefer a variety of physical conditions – pools provide resting areas while riffle provide feeding areas and contribute oxygen to the water – good riparian conditions provide shade and food – woody debris and overhanging banks provide shade). Additionally, the RSAT form used by the SWSU team includes measures of bankfull dimensions, type of substrate, vegetative cover, and channel disturbance.

Headwater drainage features

HDFs within the PSA were documented at a high level, and observations such as width and depth were captured where possible. Feature types and extents were confirmed. Detailed HDF assessments are required to provide specific guidance around impacts and management. Some HDFs, or portions of HDFs exhibit channel definition and have been identified as HDFs in the stream network mapping. However, buffers have been added to highlight that there is potential for watercourse designation through consultation with GRCA through Phase 2 or as detailed HDF assessments are undertaken in future studies. Detailed HDF assessments following the guidance of the TRCA and CVC (2014) guideline will be required through future study to characterize, classify, and manage HDFs. It is important to identify and characterize HDFs through future site-specific studies for future management, as current mapping may assume that HDFs are watercourses which require protection with appropriate setbacks, while HDFs are generally of a lower constraint (e.g. no erosion hazards plus setbacks).

Detailed assessments

Detailed surveys were completed at specific locations based on observations made during rapid assessments (i.e. rapid geomorphic assessments) which include documentation of channel form and process, allowing for the selection of most representative of a natural, flowing system that may be sensitive to change, showing evidence of geomorphic processes.

The detailed field assessment used standard protocols and known field indicators to quantify the bankfull geometry of the reach (i.e. bankfull depth, width, and gradient). The “bankfull” channel area generally represents the maximum capacity of the channel before flow spills onto the floodplain, and it is usually identified by obvious breaks, or inflections, in the cross-section profile and changes in vegetation along the channel margin. Three to five cross-sections were measured to determine the bankfull channel geometry, depending on the length of the selected stream segment and intent of the survey (e.g. channel design, erosion thresholds). At each cross-section, a modified Wolman (1954) pebble count was completed to characterize the channel bed materials. Banks were also characterized at the cross-sections (height, angle, composition, degree of vegetative cover).

A longitudinal profile is surveyed to define the local channel gradient through the site and included key features along the channel bed (top and bottom of riffles, maximum pool depths, flow obstructions). These detailed channel measurements may then be used to estimate the hydraulic parameters at bankfull stage (i.e. discharge, velocity, shear stress) and identify the respective critical values needed to entrain sediment from the channel bed. Two detailed surveys were completed within the PSA: one along Clythe Creek, upstream of Watson Parkway (CC-5), and another along Hadati Creek, roughly mid-way between Grange Road and the CN corridor in Reach HC-2.

The data from the detailed field assessment have been used to complete the erosion threshold analysis. This analysis determines the hydraulics, such as discharge, channel depth, or average channel velocity, at which the channel produces sufficient shear stress to initiate the mobilization of sediment of a given size (D_{crit}). The analysis also helps to evaluate a reach's erosion sensitivity by comparing the boundary shear stress associated with modelled flows to the critical shear stress required to entrain sediment. Section 5.3.2.6 provides further detail and discussion.

4.3.2 Fluvial geomorphology findings

4.3.2.1 Background review

The 1998 SWS included fluvial geomorphology as a component of the aquatic system characterization. It included both desktop and field assessment, with observations of channel geometry, flow regime, substrates, and vegetation, extending throughout the full subwatershed. Reaches were identified from upstream to downstream for Clythe Creek, Hadati Creek, and Watson Creek. A summary characterization is included in Section 5.3 of this document.

More recent work relating to fluvial geomorphology and erosion was completed as part of the 2023 SWM Master Plan, Update as summarized below.

> **SWM Master Plan Update: Erosion Assessment Technical Memorandum – Field Investigations. Prepared for City of Guelph (Aquafor Beech, 2021)**
>
> The SWM Master Plan Update was prepared by Aquafor Beech Ltd. (ABL) in 2019 as an update to the 2012 SWMMP. This included an assessment of the watercourse conditions within the City of Guelph, and the identification, scoring, and mapping of erosion issue sites. Stormwater outfalls were captured as a part of the inventory with a conditions assessment. Stream reaches were previously identified and characterized in the 2012 SWMMP, and reach IDs and limits were maintained through the 2021 study.

ABL conducted this task by completing 75 km of creek walks within the city limits. A standardized scoring system was developed in consultation with the GRCA and City of Guelph and was used to visually assess areas of concern identified during the walks with a score out of 100. Criteria considered through the assessments included the size of the erosion site, erodibility and location of the site, and infrastructure at risk. Maintenance sites and sites of other management issues were also identified, though these differ from erosion sites, as they are very localized and/or associated with City infrastructure that undergoes regular operation and maintenance.

Upon completion of the assessment, 245 stormwater outfalls were assessed within the City of Guelph, and 30 erosion sites were identified, scored, and ranked in terms of priority for remediation. Of these 30 sites, three are located within the PSA. These sites, HC-3, HC-2, and HC-A1 are located along Hadati Creek, with HC-2 and HC-A1 ranking within the top five sites of highest concern. Erosion site locations and IDs from the ABL report have been adapted to the current mapping within Map FG-2. Erosion site IDs do not match the nomenclature of reach IDs in the SWSU.

SWM Master Plan Update: Geomorphic System Technical Memorandum – Field Investigations. Prepared for City of Guelph (Aquafor Beech, 2021)

As part of the update to the City's 2012 SWMMP, ABL undertook an assessment of overall watercourse conditions within the City limits, including a reach-based assessment of existing conditions and the completion of rapid geomorphic assessments (RGAs). This assessment was intended to support the development of long-term and sustainable restoration approaches, and the final prioritization of erosion sites from the erosion assessment.

Through desktop and field investigations, ABL assessed 101 reaches within the City limits. RGAs determined that 67 reaches were stable or in regime, 11 were transitional, and two were in adjustment. The RGA was found to not be applicable on 21 of the identified reaches.

The geomorphic system technical memo organized data by subwatershed. Clythe Creek within the city limits was divided into five reaches, three of which (CC-1, CC-4, CC-5) were classified as stable or in regime, and the remaining two (CC-2 and CC–3) were ranked as transitional, with their primary processes being widening. Watson Creek had four reaches delineated for assessment, but WC-3 and WC-4 did not meet the RGA requirements, WC-1 and WC-2 were classified as In Regime, with evidence of planform adjustment in WC-1. The Hadati Creek watershed has seven reaches along the main branch with two additional tributary reaches. Of these reaches, all but two were ranked as in regime, and an RGA was not appropriate for one tributary reach. HC-3 and HC-4 were transitional, with dominant processes of aggradation and planform adjustment in HC-3 and widening in HC-4.

4.3.2.2 Reach delineation

Reaches delineated through the SWMMP (2012 and 2023) were maintained for the SWSU, within the PSA, with one reach extending upstream toward the headwaters of Clythe Creek. The reach delineation was initiated through the desktop assessment, mapping review, and the development of the hydrologically-conditioned DEM. In total, 27 reaches and sub-reaches were identified. Headwater drainage features (HDFs) were also identified through the desktop analysis, though specific reaches were not delineated for analysis. Map FG-2 provides an overview of the watercourse reach delineation and preliminary screening of HDFs for the PSA.

4.3.2.3 Historical assessment

Streams are dynamic landscape features. Over time, their configuration and position within the floodplain changes as a result of meander evolution and development and channel migration processes. These lateral and down-valley planform adjustments can be observed and often quantified by reviewing historical orthophotographs. Depending on photograph quality and scale of the channel of interest, erosion rates may be determined by measuring the distance from known control points to a governing meander bend over the available historical record and then projected to determine an erosion limit (e.g.,100-year limit). Historical orthophotographs are also analyzed to determine changes in surrounding land use, which may have impacted channel migration. Aerial photographs from 1954, 1966, 2000, 2009 and 2023 were reviewed (Appendix D-5). While some of the intent of the historic assessment is to quantify changes over time (e.g., sinuosity, length, migration), earlier photosets revealed poor resolution of area surface water features, and since 2000 channel segments have remained relatively stable, with many intended to be stable (i.e., engineered). There are sections of each system with low slopes and wide, wet floodplains which also inhibit the practitioners' ability to digitize features at the desktop level and also proved difficult to assess on the ground (Section 5.3.2.5). The following provides a brief, qualitative summary of changes in land use and channel form since 1954.

In 1954, the watershed (PSA and SSA) was primarily agricultural with development mostly limited to the west side of Victoria Road, and the Former Reformatory Lands. Resolution and the narrowness of the area creeks made it difficult to note any specific observations, but it was evident that there were linear depressions in the landscape in areas that are now occupied by Hadati and Clythe Creeks. However, channelization of Hadati Creek was apparent between the CN corridor and York Road. A narrow, vegetated corridor existed where Watson Creek currently exists, and some meandering is evident upstream of Watson Road in Clythe Creek. By 1966, land use remained similar with agriculture being prominent throughout the subwatershed, however, development in the vicinity of the Former Reformatory Lands had expanded, and along Elizabeth Street between Victoria Road and York Road. In the western portion of the subwatershed, the creeks were mostly narrow. Hadati Creek south of Grange Road was more prominent, as were sections of Clythe Creek upstream of Watson Road, and Watson Creek further upstream. A tributary of Hadati Creek was also obvious, that is no longer present today[6].

By 2000, piping and straightening occurred along much of Hadati Creek, to accommodate residential development. Such direct modification was less apparent for Clythe Creek, and Watson Creek had yet to reflect any urban development. Channel engineering along Hadati Creek was prominent, with trapezoidal valley cross-section and a channelized low-flow channel passing over several gabion weirs, all very visible as the banks had yet to vegetate. The only evidence of any natural channel design was the construction of two sinuous meander bends extending from a plunge pool downstream of Grange Road, connecting to the natural channel further downstream. This natural channel design only extended for 100 m. In 2009, development continued to expand northward along Hadati Creek, and the road network and development clearing had extended toward Watson Creek. The multi-use trail along Hadati Creek had been completed for reaches downstream of Starwood Drive, including the installation of a pedestrian bridge.

Development continued into 2023, expanding across Watson Creek, with new road and SWM facility access crossings, and the trail network also growing. By 2023, no obvious changes occurred within the Main Channels, though some headwaters had shortened, and engineering works installed in the early 2000s showed signs of degradation (gabion weirs and mattress).

The above observations build upon many observed through the 1998 SWS, including diversion of headwaters from Watson Creek to Hadati Creek, channel straightening and engineering, and buried watercourses. The number of crossings within the study area has increased since 1998 including those associated with the multi purpose trail through Hadati Creek, and residential roads constructed in Hadati Creek and along Watson Creek.

4.3.2.4 Erosion hazards

Table 4.33 details the results of the erosion hazard assessment for unconfined reaches (meander belt width) associated with Clythe Creek and its tributaries within the PSA. Map FG-4 presents erosion hazard limits determined for the PSA through empirical and mapped methods. Only those reaches that required an empirical approach have drainage areas reported in Table 4.33.

The meander belts range from 12 m up to 87 m (without a factor of safety) and generally increase in the downstream direction. Empirically derived results based on drainage area appear to over-predict relative to measured reaches upstream and/or downstream, however it is

[6] Note: It was not possible to create an accurate map reflecting these changes due to inconsistencies in resolution over the years, however for those interested available images from 2000 to 2009 are provided in Appendix D5, available on request under separate cover.

also possible that some of the measured meander belts are narrower than expected due to the low energy overall, sections of lateral confinement, and undefined/stable features flowing through open marsh or wetland areas. Other empirical methods can be tested that use bankfull discharge and slope in addition to drainage area and can be evaluated through Phase 2 of the SWSU.

With that said, the low energy, relatively stable system has presented limited natural adjustment over the photographic record, and this has been observed through field efforts. It is suggested that there may be alternative approaches, in addition to other empirical formulae, to delineate the lateral erosion hazard for many reaches that perhaps consider the flood extents of various frequencies of flood events (e.g., 5, 10, 25, or 50-year) that may be a reasonable proxy within which the channel may migrate through avulsions. Avulsions occur rapidly under flood conditions, whereby the channel abandons a significant length and develops a new alignment. Meander belt mapping typically involves tracing floodplain features such as avulsions and cutoffs that may be visible in current or historical mapping, these represent a past location of the active channel. Without being able to map features through many reaches (wide, vegetation dominated floodplain areas), it is reasonable to assume a floodline as an analog for the meander belt as there is potential for the channel to naturally realign through avulsions, within that floodline area Map FG-4 includes flood extents for the 10-year flood which may be considered as a reasonable area within which the channel may migrate. It is likely that this method could be applied through the low gradient, vegetation dominant reaches that coincide with wetlands and wide floodplains. (Additional flood lines are plotted on Map D4-1 in Appendix D-4 for context).

Features located within the SSA have not undergone an erosion hazard analysis. High resolution digital orthophotography was not available for the SSA, nor was any historical imagery coverage. Additionally, there is need to complete the confirmation of feature type and extent. In the absence of more detailed analyses, GRCA policy for regulated watercourses sets the meander belt at 20 times the bankfull channel width where the channel width is measured at the widest riffle section at each reach. The erosion hazard limit for unconfined systems is the meander belt plus a 15 m fixed allowance (GRCA, 2024).

The regulatory allowance of 15 m is to be applied to the greatest of all hazards as noted in the introductory paragraphs of Section 4.3 and will be reviewed through Phases 2 and 3 of the SWSU.

Table 4.33: Meander belt summary table

Reach	Drainage Area km^2	Preliminary Meander Belt Width (MBW) m	10% Factor of Safety (FOS) m	Meander Belt incl FOS m
CC(1a)*	19.50	87.1	8.71	95.81
CC(1b)*	19.44	87	8.7	95.7
CC(1c)*	19.38	86.9	8.69	95.59

Reach	Drainage Area km^2	Preliminary Meander Belt Width (MBW) m	10% Factor of Safety (FOS) m	Meander Belt incl FOS m
CC(1d)*	19.38	86.9	8.69	95.59
CC(1e)*	19.32	86.8	8.68	95.48
CC(2)	-	32	3.2	35.2
CC(3)	-	24	2.4	26.4
CC(4)	-	37	3.7	40.7
CC(5)	-	17	1.7	18.7
CC(6)	-	29	2.9	31.9
CC(7)	-	12	1.2	13.2
CC(8)	-	25	2.5	27.5
CC(9a)	-	25	2.5	27.5
CC(9b)	-	42	4.2	46.2
HC(1a)	-	48.7	4.87	53.57
HC(1c)	-	18	1.8	19.8
HC(2)	-	12	1.2	13.2
HC(3)	-	24	2.4	26.4
HC(4)*	3.837	43.4	4.34	47.74
HC(5)	-	25	2.5	27.5
HC(6)	-	36.4	3.64	40.04
HC(7)*	2.563	36.4	3.64	40.04
HCT(1)	-	24	2.4	26.4
WC(1a)	-	18	1.8	19.8
WC(1b)	-	18	1.8	19.8
WC(2a)	-	20	2	22
WC(2b)	-	18	1.8	19.8

*Empirically derived meander belts using a drainage area function.

4.3.2.5 Field investigations

Field reconnaissance was completed along all reaches of Clythe Creek within the PSA, and the tributaries of Watson Creek and Hadati Creek. During the evaluation, reaches were confirmed and areas of active channel adjustments (e.g., erosion, deposition, etc.) were noted to provide insight on channel stability and overall health and function. The SWSU team completed a detailed watercourse survey and RGAs on existing conditions of the watercourses. A photographic inventory of the field assessment is provided in Appendix D-1, with all references to left and right banks oriented looking downstream.

Rapid assessments

Through the reach walks, the SWSU team completed RGA and RSAT field sheets, while documenting overall and specific characteristics of reaches and sub-reaches. Site photography was collected for each and is available in Appendix D-1. The following summarizes general observations for each major creek network, while more detailed characteristics are included in Table 1 of Appendix D-2. Sub-reaches that were identified in the field may or may not have an individual RGA or RSAT score, as some sub-segments are relatively short and were created to identify sites that may require specific management recommendations. Map FG-3 displays the RGA stability ranking throughout the PSA.

Additionally, assessments were completed for culvert crossings associated with watercourses, including road, rail, and other access sites. Pedestrian crossings were generally not included in the crossing assessment as they overall have limited impact on channel form and process within the PSA. An exception would include pedestrian crossings comprised of earth-fill and a culvert or culverts. Appendix D-2 also includes crossing assessment forms (scanned). Crossing assessment forms were not completed along Watson Creek primarily due to a lack of definition overall, however, observations were made at each crossing with notes on impacts and stability in the vicinity of each.

Clythe Creek

Reach assessments revealed an RGA stability that ranged from 0.09 (In Regime) to 0.22 (Transitional), with a dominant process of widening, though aggradation and some evidence of planimetric adjustment was identified. The results from the RSAT assessment present a score range of 25 to 38, displaying stream health from 'moderate' to 'high', which reflects transitions from meandering channels within a wide vegetated floodplain, to straightened, impounded reaches along York Road. Prominent artificial modification to the channel exists through Reach CC-2 along the south side of York Road, where a series of rock weirs act to impact flow conveyance, and channel hardening maintains the channel dimension and locations. Channel substrates included sands and gravels with cobbles in some reaches and instances of artificial structures/hardening in each reach such as weirs, gabion stones, outfalls, and culverts. Medial and lateral bars were observed in few reaches consisting of high organics, silt, and fine sand.

Seven watercourse crossings of Clythe Creek exist within the PSA, extending from the driveway access to the former Royal City Jaycees Park up to Watson Road North, and includes road, driveway, and rail crossings. They included one arch, one ellipse (twinned), twin box (two), single box, and pipe. In general, in the PSA, the crossings are oriented perpendicular to flow with the exception of the crossings at York Road and CNR where the creek turns at near 90 degrees on either end of this series of culverts. Crossing spans appear undersized overall, with spans either less than or equal to bankfull dimensions upstream and downstream.

Watson Creek

Due to the undefined channel conditions in Watson Creek, an RGA/RSAT assessment was only able to be completed for one reach (WC2). From this, it was found that the dominating RGA Stability Index score was 0.22, indicating the channel was Transitional in nature and with a dominant process of Widening. The RSAT further supported this with a score of 30, indicating Moderate stability. Channel substrates ranging from sand to gravel, with organics in the vegetated swamp areas. Through each reach there are instances of multiple flow paths, and evidence of avulsions through Reach WC-2a. Upper reaches were dry, or only locally wet (water held in pools), with minimal definition, flowing over organics and through relatively wide riparian corridors dominated by wetland vegetation (e.g. cattails).

Three watercourse crossings were identified along Watson Creek, two road crossings and a SWM facility access, all of which are corrugated steel pipes oriented perpendicular to flow. Crossing assessment forms were not completed specifically as much of Watson Creek lacks definition, is encroached and controlled by deep-rooted vegetation, and was not flowing at the time of survey. General observations were captured around each culvert, and it was noted that there are apparent impacts upstream due to hydraulic constrictions. One pipe culvert was noted to be perched as a scour pool formed locally.

Hadati Creek

An RGA/RSAT assessment was unable to be completed for all reaches due to conditions such as undefined channels of HC6 (undefined within wide riparian corridor defined by wetland vegetation, and HC8 which is undefined within a roadside ditch dominated by vegetation Table 4.34). However, of the reaches that were assessed with rapid techniques, the range of RGA Stability Index scores was 0.15 (In Regime) to 0.50 (In Adjustment) with the dominant RGA process being Widening. Furthermore, the RSAT scores ranged from 23 to 38, indicating a Moderate to High level of stability. Reaches upstream of Starwood Drive exist within a wide, low-gradient floodplain, dominated by vegetation (wood and wetland). Downstream of Starwood Drive, the corridor is constrained by development on either side. Reach HC5 is a steep segment flowing over morainal deposits with cobble step-pool features. Downstream, HC4 has been engineered with grade controls and gabion-lined segments. Natural channel design elements were evident within HC3, with some large meanders downstream of Grange Road that appeared out of character compared to other segments. Cobble- and concrete-lined outfalls were also present, draining subdivisions. Substrate was a mix of organics, fine materials, sand, shale (bedrock), gravel, cobbles, and boulders. The lowest Reach (HC1) is heavily encroached by industrial development, and channelized between armour stone walls, with bedrock exposures along the bed. Some infrastructure encroachment was also noted in reach HC2 (SWM facility berm, trail, outfalls), as well as large woody debris jams, sandy point bars, and multiple ponds.

Table 4.34: Summary of Rapid Geomorphic Assessment and Rapid Stream Assessment Scores

Reach	RGA Stability Index	RGA Condition	RGA Dominant Process	RSAT Score	RSAT Condition
Clythe Creek					
CC1	0.21	Transitional	Aggradation	29	Moderate
CC2	0.18	In Regime	Aggradation	25	Moderate
CC3	0.14	In Regime	Widening	34	Moderate

Reach	RGA Stability Index	RGA Condition	RGA Dominant Process	RSAT Score	RSAT Condition
CC4	0.15	In Regime	Widening	37	High
CC5	0.22	Transitional	Planimetric Adjustment	38	High
CC6	0.09	In Regime	Widening	33	Moderate
CC7	0.17	In Regime	Widening	33	Moderate
CC8	0.12	In Regime	Widening	35	Moderate
Watson Creek					
WC1	N/A	N/A	N/A	N/A	N/A
WC2	0.22	Transitional	Widening	30	Moderate
WC3	N/A	N/A	N/A	N/A	N/A
WC4	N/A	N/A	N/A	N/A	N/A
Hadati Creek					
HC1	0.36	Transitional	Degradation	30	Moderate
HC2	0.27	Transitional	Widening	36	High
HC3	0.16	In Regime	Aggradation	23	Moderate
HC4	0.15	In Regime	Widening	29	Moderate
HC5	0.29	Transitional	Widening	38	High
HC6	N/A	N/A	N/A	N/A	N/A
HC7	0.50	In Adjustment	Aggradation and Widening	N/A	N/A
HC8	N/A	N/A	N/A	N/A	N/A
HCT1	0.26	Transitional	Aggradation	38	High

Notes:

RGA Rapid Geomorphic Assessment

RSAT Rapid Stream Assessment Technique

The Hadati Creek watershed is heavily developed and has had several reaches removed (piped) and realigned or channelized with development encroachment extending from Clythe Creek up to Starwood Drive. Unsurprisingly, it has the most watercourse crossings with nine in total. All but two are box culverts (open or closed) of varying configurations (Table 4.27 which details hydraulic structures within the PSA).

- Only the CNR crossing was observed as a single pipe and was noted to be perched on the downstream limit. Between York Road and Elizabeth Street, bedrock outcrops along the channel with knickpoints observed within culverts.
- Erosion was noted to be minor in the lower reaches, downstream of Elizabeth Street, and the crossing spans are essentially the same width as the channel which is confined by development, engineering, and bedrock.
- Steep slopes through Reach HC5 and into HC4 required robust engineering of the crossing at Chesterton Lane. In this location, a twinned arch culvert exists with gabion stone and gabion lining along the bed and bank slopes, with gabion drop structures incorporated at the upstream and downstream end. Instability and failure were noted at the downstream gabion drop structure.

- Box culverts at Starwood Drive and Eastview Road were both embedded, and in good condition.
- The Eastview Drive culvert is seemingly undersized relative to the channel width; however, the watercourse has been channelized, holding water, and offering little evidence of flow.

Headwater drainage features (HDF)

General descriptions of headwaters associated with each sub catchment and specific reaches as collected through field investigations are described below. Some features have reach IDs that were assigned through the desktop reach delineation. These were later identified as HDFs based on field investigations. Other HDFs identified during the desktop assessment through DEM processing are described as a collection of features such as those of the Unnamed Tributary within the Former Reformatory Lands.

Clythe Creek HDF: One HDF was identified and associated with Clythe Creek reaches within the PSA. CC(4)-1 is a small drainage feature flowing through a forest, outletting into CC(4). The feature appears natural, with some minor impacts from a historic berm within the forest. This feature shows some areas of definition and has been identified for review/confirmation for feature type (watercourse or HDF).

Hadati Creek HDF: HDFs associated with Hadati Creek exist in two general locations. One exists as a narrow, ditch that is then piped into HC1, in the older industrial lands in the York Road and Victoria Road area. The remainder of the HDFs mapped for Hadati Creek originate around the former municipal dump, now Pollinator Park. These are dug features that appear to hold water, before being piped into HC(7) near Eastview Road. This HDF has variable vegetation cover, with a mix of grasses and forest flanking the channel, with vegetation established within the channel bed. As these are defined, channelized features, they have been highlighted for review to confirm the feature type.

Watson Creek HDF: One HDF was identified north-west of Watson Parkway and Grange Road and is part of the Grange Road Park. The feature is associated with the adjacent wetland, and a visible flow path cleared through the vegetation, outletting from the wetter areas within the wetland before outletting into WC(3b) through a small CSP. The feature contains a mix of herbaceous vegetation and grasses, some wetland vegetation, and trees within the floodplain.

Former Reformatory lands

Multiple headwater drainage features occupy the Former Reformatory Lands which are a mixture of natural surface drainage pathways intermixed with defined, artificial channels, ponds, and piped sections which contribute to CC2 and CC3. The features appear to be fed by a mix of local surficial drainage within the property, and through stormwater from the adjacent developed areas which outlet into a SWM facility on the Former Reformatory Lands (online with HDF network). The artificial channels tend to be symmetrical ditch-like features with fully vegetated bed and banks, either along roadways or between field segments. The natural drainage features are visible, flowing through the fields, with multiple culverts connecting the features through the various roadways and berms within the property. Vegetation within the area consists of a mix of grasses, shrubs, and sporadic trees.

Detailed assessments

Detailed field surveys were completed on June 21, 2023, for Clythe Creek (Reach CC-5) and Hadati Creek (HC-2), both along main branches of their respective subwatershed. A total station survey of the channel profile, as well as 3 to 4 cross sections at each study reach were surveyed which provided a measure of the local energy gradient and bed morphology. Clythe Creek contained well defined pool-riffle morphology with larger variation in bankfull cross-sectional dimensions, while Hadati Creek contained inconsistently sized and spaced riffles with pools and bankfull cross-sectional dimensions, as a result of the channel being historically straightened. Where possible, bankfull dimensions were identified using known field indicators, such as changes in vegetation and inflection points in the bank profiles. The bankfull channel area generally represents the maximum capacity of the channel before it spills onto the floodplain. At both sites, bankfull indicators were present and captured in each survey. Both reach CC-5 and HC-2 are permanently flowing.

A modified Wolman (1954) pebble count was completed at each riffle or run cross-section to characterize bed substrates, with over 75 to 100 particles being measured at each cross-section, depending on the channel width.

Channel geometry and composition for the detailed sites are presented in Table 4.35. Bankfull hydraulics estimates (reach averaged) are provided in Table 4.36. At least three riffle or run/transition cross-sections were surveyed per reach.

Reach CC-5

Clythe Creek through the study reach is a permanent watercourse with a relatively sinuous planform, as a result of the surrounding area being more natural in comparison to other reaches. Reach CC-5 was a relatively wide with natural banks, cobble/gravel riffles, and siltation in pools. The floodplain through the cedar forest was connected and accessible to frequent flows, and portions along the margins had wetland vegetation (cattails), and some instances of watercress. Scrub vegetation lined the floodplain in the riparian zone within the lower approximately 50 m of the reach, upstream of Watson Parkway North. Medial and lateral bars (about 0.3 m thick) were observed in the downstream section causing the channel to widen and contain high organics, silt, and fine sand. The channel has cobble and gravel substrate, with fine sand, silt, and organics for bank materials. Upon approach to Watson Parkway, the channel narrowed and deepend, flowing over gabion stone and rip rap.

On average, bankfull dimensions were measured at 6.5 m in width and 0.25 m in depth at riffles and a maximum depth of 0.38 m recorded at pools. Bankfull discharge within the representative riffle-type cross-section is 2.19 m^3/s (at 0.011 per cent slope and n = 0.035). At the bankfull flow, the channel produces a velocity of 1.20 m/s and shear stress of 36.46 N/m^2.

Reach HC-2

Hadati Creek is a permanent watercourse with a relatively straight planform, as a result of urban encroachment and channelization. At the upstream end of the surveyed section of HC-2, a cobble cascade feature was present with water plunging into a deep and wide pool that was 0.6 m deep (bankfull) with sands and gravel along the bed and a barform on the left bank (looking downstream). From there, a series of pools and riffles had developed and point bar development was evident on the inner banks. Vegetation on the banks consisted of grasses and a variety of willow species, with their roots visible along the banks, as the channel widened and partially undercut. Some stormwater outfalls were set back from the main channel, and outflow channels had developed in the floodplain.

On average, bankfull dimensions were approximately 3.5 m in width and 0.32 m in depth, with similar cross-section dimensions measured at both pools and riffle-runs. Bankfull discharge within the representative riffle-type cross-section is 1.68 m^3/s (at 0.013% slope and n = 0.035). At the bankfull flow, the channel produces a velocity of 1.42 m/s and shear stress of 58.96 N/m^2.

Table 4.35: Channel characteristics for the detailed geomorphic field sites

Bankfull Geometry	CC-5	HC-2
Average Bankfull Width (m)	6.49	3.50
Average Bankfull Depth (m)	0.25	0.32
Maximum Bankfull Depth (m)	0.38	0.46
Channel Width: Depth	25.54	10.86
Cross-sectional Area (m^2)	1.74	1.15
Wetted Perimeter (m)	6.63	3.90
Hydraulic Radius (m)	0.24	0.29
Surveyed Channel Gradient (m/m)	0.011	0.013
D_{50} (mm)	33.2	24.5
D_{84} (mm)	86.3	58.1
Manning's 'n'	0.035	0.035

Table 4.36: Bankfull hydraulics for the detailed geomorphic field sites

Hydraulic Parameter	CC-5	HC-2
Discharge (m^3/s)	2.19	1.68
Bankfull Velocity (m/s)	1.20	1.42
Stream Power (W/m)	27.85	36.66
Stream Power per unit Width (W/m^2)	281.94	213.70
Shear Stress (N/m^2)	36.46	58.96

4.3.2.6 Erosion threshold analysis

Data from the detailed field assessment were used to complete the erosion threshold analysis. This analysis determined the hydraulics (discharge, channel depth, average channel velocity) at which the channel produces sufficient shear stress to initiate mobilization of a representative particle size (D_{crit}) (i.e., the "threshold" condition at which sediment will typically start to mobilize the median grain size, or an equivalent force to erode cohesive or vegetation bound materials). It is then assumed that if this "threshold" flow is sustained, erosion will eventually occur. Therefore, the flow is referred to as the "erosion threshold".

Several particle entrainment functions (shear and velocity) were applied initially and evaluated to select the most appropriate method. After determining the critical velocity (m/s) or shear (N/m^2) for the given index particle size (D_{50}), an erosion threshold (discharge) is then calculated. The critical flow (discharge) is determined by modelling a "dry" channel and increasing water levels in small increments (1 mm) until the average velocities or shear stresses exceed the critical values defined. The discharge under which the critical values are generated within each cross-section, defines the critical discharge of the transect. Cross-sections that were considered the most representative of the reach were selected for use in the analysis (i.e. riffles or transitions).

Selection of the appropriate threshold is also based on an understanding of site conditions, and the assumptions and ranges of conditions under which the entrainment functions are applicable (e.g. appropriate grain sizes). The goal of the erosion threshold analysis is to determine a threshold discharge for selected reaches above which a critical fraction of the boundary materials is entrained. Where changes are to occur to the contributing drainage area of a channel, a typical objective is to ensure that the future hydrological conditions do not result in channel flow exceeding the threshold discharge more frequently than with existing conditions. This is done to minimize potential post-development channel impacts such as channel erosion and habitat degradation.

An appropriate erosion threshold method is selected based on the characteristics of the bed and bank materials, as determined from the detailed geomorphic assessment. For both reaches CC-5 and HC-2, the median grain size is in the coarse to very coarse gravel range, therefore the method outlined by Komar (1987) was selected. Based on a D_{50} of 37.9 mm at CC-5 (XS-4) and 19.7 mm at HC-2 (XS-3), the critical discharge values were 0.84 m/s^3 and 0.30 m/s^3, respectively. The recommended critical discharge values represent approximately 135.09 per cent and 63 per cent of the bankfull flow at both sites, which is not considered unreasonable based on the SWSU team's field observations. During the geomorphic field assessments, the creeks were flowing minimally, below the calculated thresholds and sediment transport was not occurring. With such low and wide banks through CC-5, and relatively coarse bed materials, a threshold that exceeds the bankfull flow was anticipated.

The results of the erosion threshold analysis based on current field surveys are provided in Table 4.37.

Table 4.37: Threshold characteristics estimated for the detailed geomorphic field

sites

	Parameter	CC-5 (XS-4)	HC-2 (XS-3)
Bed Material*	D_{50} (mm)#	37.9	19.7
Bed Material*	D_{84} (mm)	57.88	44.7
Bed Material*	Manning's 'n'	0.035	0.035
Channel Bankfull Hydraulics*	Channel Discharge (m^3/s)	0.32	1.02
Channel Bankfull Hydraulics*	Channel Depth (m)	0.34	0.40
Channel Bankfull Hydraulics*	Channel Velocity (m/s)	0.83	1.25
Channel Bankfull Hydraulics*	Average Bed Shear (N/m^2)	15.71	30.25
Erosion Thresholds	Recommended Critical Discharge (m^3/s)	0.84	0.30
Erosion Thresholds	Critical Velocity (m/s)	1.05	0.80
Erosion Thresholds	Critical Shear Stress (N/m^2)	22.45	15.54
Erosion Thresholds	Critical Flow Depth (m)	0.46	0.25
Erosion Thresholds	Per cent of Bankfull Depth (%)	135.09	63
Erosion Thresholds	Source of function	Komar (1987): Gravels and larger	Komar (1987): Gravels and larger

* From selected representative cross section
# Index particle size for analysis

4.3.3 Summary of fluvial geomorphology characterization

Watercourses associated with Clythe Creek, Hadati Creek, and Watson Creek have all been impacted directly and indirectly by urbanization through channel straightening, hardening (banks, profile), watercourse crossings, and stormwater inputs. Urban encroachment is most prominent in the lower reaches of Hadati Creek and continues to a lesser degree from the CN rail crossing to Starwood Drive. Beyond the channelized, directly modified reaches, each creek system includes sections with wide, shallow floodplains characterized by deep rooting wetland and/or woody vegetation through which multiple threads exist, becoming difficult to continually follow through site walks (e.g., Reach CC-8), and especially where water was not flowing during the June 2022 surveys (Reaches HC-6 and WC-1 to WC-3 inclusive). For defined, single threaded reaches, natural substrates and form included rectangular, straight sections of Hadati Creek (HC-1), gravel/cobble slightly meandering streams with natural bed banks and barforms, to steep steps and pools across morainal sediment with naturally occurring cobble steps.

Rapid assessments were completed for watercourse reaches with Clythe Creek exhibiting the most stability where six of eight reaches were found to be in-regime, and others having low transitional scores due to some planform adjustment and aggradation. Watson Creek only showed local channel definition in Reach WC-2 and adjustment around crossings that resulted in local scour, though woody debris was noted throughout. Hadati Creek was generally the least stable, with widening and degradation occurring throughout, and some aggradation in the upper reaches where water was present but not flowing.

HDFs were first identified through DEM analysis and then confirmed both through air photo interpretation and field confirmation (presence and absence) where possible. Under the current (2024) definition of a watercourse, a few HDF segments may be re-classified as watercourses and require the appropriate evaluations. Otherwise, all HDFs should be assessed in the future following the TRCA and CVC (2014) guideline to classify and manage individual reaches. With that said, there are HDFs associated with wetlands, woodlands, and groundwater-surface water interactions that may allow for a higher constraint to be identified for the feature, with management recommendations of “conservation” or “protection” being applied prior to a fulsome HDF assessment. This can be identified through study discipline integration and evaluated through the impact assessment phase of this SWSU (Section 6).

Although the area creeks are impacted, there were reasonable opportunities to complete detailed geomorphic surveys of cross-section, profile, and substrates for two representative sections which may be sensitive to further development. These surveys allowed for quantification of channel bankfull hydraulics, and development of erosion threshold values (entrainment thresholds). The results indicate that for CC-5, the median particle size of 37.9 mm mobilizes under a velocity of 1.05 m/s, which has a corresponding discharge of 0.84 m^3s, exceeding the bankfull discharge for that reach. For HC-2 results indicated that the median particle size of 19.7 mm mobilizes under a velocity of 0.8 m/s, which has a corresponding discharge of 0.3 $m^{3/}$s – approximately 603 per cent of the bankfull flow. These results are reasonable given the difference in grainsizes observed between reaches, and the relative floodplain accessibility of CC-5 compared to HC-2.

4.4 Aquatic ecology characterization

4.4.1 Aquatic ecology methods

This section outlines the key background information reviewed, overview of field work completed, and methodology used for the aquatic ecology components for the SWSU.

4.4.1.1 Key background information reviewed

Background information regarding aquatic ecology was acquired from several historical studies, reports and on-line sources, including the following:

- Clythe Creek Subwatershed Study (Ecologistics and Blackport, 1998)
- Eramosa-Blue Springs Watershed Study (Beak International and Aquafor Beach Limited, 1999)
- Clythe Creek, Guelph Ontario 2006 Temperature Report. Trout Unlimited Canada Technical Report No. ON-019 (A. Todd and S. D’Amelio, 2006)
- Clythe Creek, Guelph, Ontario 2007 Temperature Report. Trout Unlimited Canada Technical Report No. ON-036 (S. D’Amelio, 2007)

- Groundwater-surface water interactions and thermal regime in Clythe Creek, Guelph, Ontario: threats and opportunities for restoration. University of Guelph M.Sc. Thesis (H.E. Ashworth, 2012)
- Draft EIS York Road Environmental Design Study (AMEC, 2016)
- MNR thermal classification of watercourses
- Grand River Information Network (GRIN) (GRCA, 2024)
- Land Information Ontario database records of fish sampling
- Grand River Fisheries Management Plan (Grand River and MNRF, 1998)
- Fisheries and Oceans Canada on-line aquatic species at risk mapping

4.4.1.2 Overview of field work completed

The timing, locations, and methodology of the aquatic field investigations completed for the SWSU are shown in Table 4.38. Non-standard electrofishing (electrofishing not following standard OSAP methodology) was completed for CC3, CC4, CC5 and the Reformatory Ponds (North and South Ponds) to obtain additional information regarding the fish species presence/absence.

Table 4.38: Aquatic field investigations, 2022 and 2023

Survey Type	Watercourse / Waterbody	Site	Date Completed	Protocol	Personnel
Preliminary Site Walk	Clythe Creek	CC1	2022-07-15	N/A	C. Portt, K. Keele
Preliminary Site Walk	Clythe Creek	CC2	2022-07-15	N/A	C. Portt, K. Keele
Preliminary Site Walk	Hadati Creek	HC1	2022-07-15	N/A	C. Portt, K. Keele
Preliminary Site Walk	Hadati Creek	HC2	2022-07-15	N/A	C. Portt, K. Keele
Preliminary Site Walk	Hadati Creek	HC3	2022-07-15	N/A	C. Portt, K. Keele
Preliminary Site Walk	Watson Creek	WC1	2022-07-15	N/A	C. Portt, K. Keele
Aquatic Habitat Assessment	Clythe Creek	CC1	2023-07-05	Ontario Stream Assessment Protocol (OSAP)	C. Portt, K. Keele, E. Ottens, A. Perez
Aquatic Habitat Assessment	Clythe Creek	CC2	2023-10-24	Ontario Stream Assessment Protocol (OSAP)	K. Keele, E. Ottens
Aquatic Habitat Assessment	Hadati Creek	HC1	2023-07-05	Ontario Stream Assessment Protocol (OSAP)	C. Portt, K. Keele, E. Ottens, A. Perez
Aquatic Habitat Assessment	Hadati Creek	HC2	2023-08-24	Ontario Stream Assessment Protocol (OSAP)	C. Portt, K. Keele, E. Ottens, A. Perez
Aquatic Habitat Assessment	Hadati Creek	HC3	2023-07-06	Ontario Stream Assessment Protocol (OSAP)	C. Portt, K. Keele, E. Ottens, A. Perez

Survey Type	Watercourse / Waterbody	Site	Date Completed	Protocol	Personnel
Aquatic Habitat Assessment	Watson Creek	WC1	2023-07-06	Ontario Stream Assessment Protocol (OSAP)	C. Portt, K. Keele, E. Ottens, A. Perez
Fish Community Surveys	Clythe Creek	CC1	2023-07-05	Ontario Stream Assessment Protocol (OSAP)	K. Keele, E. Ottens, A. Perez
Fish Community Surveys	Clythe Creek	CC2	2023-10-03	N/A	C. Portt, K. Keele, A. Yates
Fish Community Surveys	Clythe Creek	CC3	2023-10-03	Non-standard Electrofishing	C. Portt, K. Keele, A. Yates
Fish Community Surveys	Clythe Creek	CC4	2023-10-03	Non-standard Electrofishing	C. Portt, K. Keele, A. Yates
Fish Community Surveys	Clythe Creek	CC5	2023-10-03	Non-standard Electrofishing	C. Portt, K. Keele, A. Yates
Fish Community Surveys	Hadati Creek	HC1	2023-07-05	Ontario Stream Assessment Protocol (OSAP)	C. Portt, K. Keele
Fish Community Surveys	Hadati Creek	HC2	2023-07-10	Ontario Stream Assessment Protocol (OSAP)	C. Portt, K. Keele
Fish Community Surveys	Hadati Creek	HC3	2023-07-06	Ontario Stream Assessment Protocol (OSAP)	C. Portt, K. Keele
Fish Community Surveys	Watson Creek	WC1	2023-07-06	Ontario Stream Assessment Protocol (OSAP)	C. Portt, K. Keele
Fish Community Surveys	Correction Ponds	North Pond	2023-10-06	Non-standard Electrofishing and Fish Trapping	C. Portt, K. Keele, E. Ottens
Fish Community Surveys	Correction Ponds	South Pond	2023-10-06	Non-standard Electrofishing and Fish Trapping	C. Portt, K. Keele, E. Ottens
Fish Community Surveys	Unnamed Tributary North of Dunlop	n/a	2023-10-03	Ontario Stream Assessment Protocol (OSAP)	C. Portt, K. Keele, A. Yates
Benthic Invertebrate Sampling	Clythe Creek	CC1	2023-07-26	Ontario Benthos Biomonitoring Network (OBBN)	K. Keele, E. Ottens, A. Perez
Benthic Invertebrate Sampling	Clythe Creek	CC2	2023-10-24	Ontario Benthos Biomonitoring Network (OBBN)	K. Keele, E. Ottens
Benthic Invertebrate Sampling	Hadati Creek	HC1	2023-07-26	Ontario Benthos Biomonitoring Network (OBBN)	K. Keele, E. Ottens, A. Perez
Benthic Invertebrate Sampling	Hadati Creek	HC2	2023-07-26	Ontario Benthos Biomonitoring Network (OBBN)	K. Keele, E. Ottens, A. Perez
Benthic Invertebrate Sampling	Hadati Creek	HC3	2023-07-26	Ontario Benthos Biomonitoring Network (OBBN)	K. Keele, E. Ottens, A. Perez

Survey Type	Watercourse / Waterbody	Site	Date Completed	Protocol	Personnel
Benthic Invertebrate Sampling	Watson Creek	WC1	2023-07-26	Ontario Benthos Biomonitoring Network (OBBN)	K. Keele, E. Ottens, A. Perez

The following sections outline the aquatic ecology assessment methodology pertaining to the aquatic habitat assessments, fish community sampling, and benthic invertebrate sampling.

High level assessments

High level aquatic habitat assessments were undertaken to characterize the general aquatic habitat along the entire length of Clythe, Watson, and Hadati Creeks within the PSA, with spot observations at road crossings in the SSA. Ontario Stream Assessment Protocol (OSAP) Section 4, Module 1, a Rapid Assessment Methodology (RAM) was completed for each station to document channel structure, water depth, type of cover, and bank stability.

Detailed aquatic assessments

Detailed aquatic assessments were conducted at six stations, two on Clythe Creek, three on Hadati Creek and one on Watson Creek. The physical habitat, fish community and benthic invertebrate community were assessed at each location. The stations were selected with the assumption that some could be incorporated into a long-term monitoring program.

Station identification followed the Ontario Stream Assessment Protocol (OSAP; Stanfield, 2017). Each station included at least one riffle-pool sequence, was at least 40 m in length, and began and ended at a crossover point. The RAM was used to document physical habitat (channel form, water depth, substrate, cover, and bank stability) and bank vegetation.

Fish community sampling

The fish community sampling was completed using a Halltech HT2000 backpack electrofisher following the OSAP Section 3 Module 1 single-pass method protocol. Fish were enumerated and identified to species. For each species, the minimum and maximum length (forked length) was determined using a standard fish measuring board and the total (bulk) weight of the captured individuals was determined to the nearest gram using an Ohaus Scout Pro Model SP6001 electronic balance. Prior to sampling, a License to Collect Fish for Scientific Purposes was obtained from the Guelph District Ministry of Natural Resources (MNR) and the fish sampling methods and results were reported to MNR, as required. Sampling locations are shown on Maps AE-1 through AE-5.

Additional fish sampling

Three additional stations were sampled on Clythe Creek using a Halltech HT2000 backpack electrofisher to gain additional insight into what fish species are present. Electrofishing proceeded upstream over a short reach. The coordinates of the sampling locations were determined using a hand-held GPS. Captured fish were identified to species. For each species, the minimum and maximum length (forked length) was determined using a standard fish measuring board and the total (bulk) weight of the captured individuals was determined to the nearest gram using an Ohaus Scout Pro Model SP6001 electronic balance. All fish were released into the stream from which they were captured.

Electrofishing was also conducted using a Halltech HT2000 backpack electrofisher along the shorelines in the north and south Reformatory Ponds. Fish traps were also used to sample the ponds. Three traps were deployed in each of the ponds overnight from October 5 to October 6, 2023. The traps, referred to as cloverleaf traps, were 91 cm in diameter and 38 cm high and consisted of three lobes with three slot openings between the lobes that were the full height of the trap and either 25 mm or 37.5 mm wide. At each location where a trap was deployed water depth was measured and the coordinates were logged using a handheld GPS. The date and time when each trap was set and retrieved were recorded and used to calculate soak time. Table 4.39 outlines specific details relating to the deployment and recovery times for each trap. Captured fish were identified to species. For each species, the minimum and maximum length was determined using a standard fish measuring board and the total (bulk) weight of the captured individuals was determined to the nearest gram using an Ohaus Scout Pro Model SP6001 electronic balance. All fish were released into the pond from which they were captured. Sampling stations are summarized in Table 4.39 and shown on Maps AE-1 through AE-5.

Table 4.39: Deployment times, recovery times, and depth for north and south Reformatory Pond fish traps

Trap Name	Date Trap Deployed	Time Trap Deployed	Depth Deployed (m)	Date Trap Retrieved	Time Trap Retrieved	Soak Time (Hours)
South Pond Trap 1	2023-10-05	15:50:00	1.1	2023-10-06	09:14:00	17.4
South Pond Trap 2	2023-10-05	15:55:00	1.1	2023-10-06	09:19:00	17.4
South Pond Trap 3	2023-10-05	16:04:00	0.8	2023-10-06	09:08:00	17.1
North Pond Trap 1	2023-10-05	16:12:00	0.75	2023-10-06	09:46:00	17.6
North Pond Trap 2	2023-10-05	16:19:00	0.5	2023-10-06	09:50:00	17.5
North Pond Trap 3	2023-10-05	16:25:00	0.9	2023-10-06	10:02:00	17.6

4.4.1.2.1 Benthic invertebrate sampling, laboratory analysis, and index assessment

Field sampling

Sampling followed the Ontario Benthos Biomonitoring Network (OBBN) protocol travelling kick-and-sweep method. Samples were collected from two riffles and one pool at each station. Sampling commenced at the furthest downstream location and progressed upstream. Travelling kick-and-sweep sampling was conducted using a D-net with a 500μm mesh size and transects across the entire width of the channel, over approximately 10 m distance for a duration of three minutes. Each sample was field processed to remove excess sediment and debris. Organic material, woody debris, and larger detritus was inspected prior to disposal to ensure the retention of all benthic invertebrates. Each sample was transferred to a 1 L plastic sample jar and preserved in a 10 per cent buffered formalin solution.

All sampling stations were GPS referenced in the Universal Transverse Mercator coordinate system UTM17 NAD83 using a handheld Garmin e-Trex GPS system. Locations of the benthic sampling stations are shown on Maps AE-1 through AE-5.

Laboratory analysis

Benthic invertebrate samples were processed by William B. Morton of Guelph, Ontario, a recognized benthic invertebrate taxonomist. Each sample was processed following OBBN protocols. Before sorting, the samples were placed into a geological sieve with a 0.5-micron mesh and rinsed with water to remove the field preservative. Small amounts of the sample were then placed into sorting trays and invertebrate specimens collected with the assistance of 10x-magnification dissecting microscope. Additional subsamples were processed until at least 100 organisms were collected or the entire sample was processed. All specimens in the last sub-sample were completely sorted.

The blot-dried weight of the sorted material was divided by the weight of the total sample and used to calculate the per cent subsample (sorted/total x 100 per cent). The sorted materials were discarded, and any unsorted material was returned to the original container and re-preserved with the field preservative. Prior to identification, the specimens were sorted into like groups and then identified to species, where possible. Identified specimens were placed into labelled vials with neoprene stoppers and preserved with 75 per cent ethanol.

Index assessment

From the laboratory data, several indices were calculated to better understand the composition and character of each sample. Results from the field sampling were analyzed and scores calculated for the Shannon Weiner Diversity Index (H’), Hillsenhoff Biotic Index (HBI), per cent *Ephemeroptera*, *Plecoptera*, and *Trichoptera* (per cent EPT), and taxa richness as described below. Scores for each of these four indices were then combined to determine the overall impairment status represented at each sampling station, where scores between 15 and 18 indicate an unimpaired station, scores between 11 and 14 indicate a possibly impaired station, scores between 6 and 10 indicate a moderately impaired station and scores less than 5 indicate a severely impaired station.

Shannon Weiner Diversity Index (H’)

The Shannon-Weiner Diversity Index (H’) combines measures of abundance and diversity into a single metric. In aquatic communities, values of H’ usually vary between 0 and 5, with larger values indicating healthier and more diverse benthic invertebrate communities. Low diversity can be attributed to natural habitat deficiencies or high densities of a single taxon. H’ values between 3 and 4 indicate clean or good water quality, 1 to 3 suggests moderate pollution and values of less than 1 indicates substantially polluted aquatic ecosystems (Wilhm, 1967), as shown in Table 4.40. H’ is calculated using the following formula:

$$H' = -\sum p_i \log p_i$$

Where:

p_i = the proportion of the total number of individuals occurring in species i ($\frac{n_i}{N}$)

n_i = the number of individuals occurring in species i

N = the total number of taxa in a sample

Table 4.40: Shannon Weiner Diversity Index (H') Rating System

H'	Interpretation	Score
>3	Good water quality	3
1-3	Moderate pollution	2
<1	Substantial pollution	1

Hilsenhoff Biotic Index (HBI)

The Hilsenhoff Biotic Index (HBI) is usually used to determine the extent of organic nutrient enrichment (Hilsenhoff 1987). Sensitivity values ranging from 0 (intolerant) to 10 (very tolerant) are assigned to each taxon based on their tolerance to organic nutrients (Hilsenhoff 1987). HBI is calculated using the following formula:

$$\mathbf{HBI} = \frac{\left[\sum_{(1-n)} (SV_i \times x_i)\right]}{N}$$

Where:

SV_i = the sensitivity value of the ith taxon

x_i = the number of individuals of species i

n = the number of taxa in the sample

N = the number of individuals in the sample

The HBI was then compared to the values listed in Table 4.41to provide a rating of water quality with respect to organic enrichment. Table 4.41shows the habitat scores that were applied to the HBI system.

Table 4.41: Hilsenhoff Rating System (Hilsenhoff 1987)

Biotic Index	Water Quality	Degree of Organic Enrichment	Score
0.00 - 3.5	Excellent	No apparent enrichment	7
3.51 - 4.50	Very Good	Slight enrichment	6
4.51 - 5.50	Good	Some enrichment	5
5.51 - 6.50	Fair	Fairly significant enrichment	4
6.51 - 7.50	Fairly Poor	Significant enrichment	3
7.51 - 8.50	Poor	Very significant enrichment	2
8.51 - 10.00	Very Poor	Severe enrichment	1

Percent EPT

'EPT organisms' are defined as those species belonging to the *Ephemeroptera*, *Plecoptera*, and *Trichoptera* taxonomic orders (mayflies, stoneflies, and caddisflies, respectively). Per cent EPT is calculated by dividing the number of EPT individuals in a particular sample by the total number of organisms included in that sample (see Table 4.42). Per cent EPT values greater than ten are consistent with unimpaired systems. Values between five per cent and ten per cent suggest a transitional, possibly impaired station and values less than five per cent indicate impaired to very impaired (less than one per cent) habitats.

Table 4.42: Per cent *Ephemeroptera, Plecoptera, and Trichoptera* Rating System

Per cent EPT	Degree of Impairment	Score
>10	Unimpaired	4
5 - 10	Possibly Impaired	3
1 - 5	Impaired	2
<1	Very Impaired	1

Taxa richness

Taxa richness refers to the number of distinct taxonomic groups within a sample, which is an indicator of community diversity. Taxa richness is calculated as the sum of distinct taxa in a sample, with values equal to or greater than 30 suggesting an unimpacted station and values less than 10 suggesting a severely impacted station. Table 4.43 shows the habitat scores that were applied to taxa richness.

Table 4.43: Taxa Richness Rating System

Taxa Richness	Degree of Impact	Score
≥30	Unimpacted	4
19-29	Slightly impacted	3
10-19	Moderately impacted	2
<10	Severely impacted	1

Water quality

Water quality data were collected at all the fish sampling locations and the benthic sampling locations. The water quality data are considered supporting information, but the single-point-in-time samples are typically not considered to reflect over-all water quality. The exception would be if a particular parameter was abnormal and indicative of impaired conditions (e.g. a very low dissolved oxygen concentration). The following water quality parameters were measured using a U-52 Horiba water quality meter:

- water temperature (°C)
- conductivity (μS/cm)
- pH
- dissolved oxygen (DO) (mg/L)

Thermal regime analysis

MNR has classified watercourses within the PSA and SSA based on fish community composition, and mapping is available through LIO. As part of this study, data from temperature loggers installed at ten surface water monitoring locations was used in combination with fish community data (both from LIO and from field sampling completed for this study) to confirm the thermal regime of the watercourses within the PSA.

Daily maximum water temperature data for July and August in 2022, 2023, and 2024 was recorded at ten surface water monitoring stations as shown on Map AE-7:

- Five stations on Clythe Creek (CC-1SW, CC-2SW, CC-3SW, CC-4SW, CC-6SW), with an additional station (CC-5SW) located at the outlet of the Former Reformatory Ponds
- Three stations on Watson Creek (WS-1SW, WS-2SW)
- One station on Hadati Creek (HC-2SW)

Daily maximum water temperature was plotted against daily maximum air temperature (obtained from the Guelph Turfgrass Institute climate station) and evaluated based on the methods outlined by Stoneman and Jones (1996). This initial analysis classified watercourses as warmwater, coolwater, or coldwater to remain consistent with the approach used by the MNR. However, these classifications were further refined using the approach outlined by Chu et al. (2009), which describes two additional thermal regime categories: cool-warmwater and cold-coolwater.

4.4.2 Aquatic ecology findings

This section outlines the results and findings from the aquatic habitat assessment, fish community sampling, and benthic invertebrate sampling that was conducted at six sites.

4.4.2.1 Aquatic habitat

High-level aquatic habitat assessments

Clythe Creek flows in a north-east to south-west direction and a consistent flow of water was observed within most reaches investigated; however, some areas of backwatering were observed due to beaver dams and large woody debris (LWD). The channel itself was constrained in certain areas, for example, the reaches along the adjacent roadway (Highway 7) and reaches near industrialized and residential areas. Banks appeared somewhat vegetated throughout the channel as tall grasses, herbaceous species, shrubs, and trees were observed. In the reaches farther to the north, the channel ran through a cedar forest/wetland and grassier and scrubland areas. Aquatic vegetation observed along Clythe Creek included terrestrial plants, filamentous algae, non-filamentous aquatic vegetation, moss, macrophytes, and watercress. Overall, within the extent of Clythe Creek, the substrate observed ranged from soft sediment, sandy clay, sand (fine and medium), gravel, and cobble. Gravel, boulders, stone walls, and gabion baskets were also observed along the banks of the channel. In total, 12 fish barriers were identified along Clythe Creek, which included one beaver dam, ten weirs and one perched culvert. The beaver dam may be a barrier under certain flow conditions.

Upstream sections of Hadati Creek flow north-west to south-east, and the watercourse flows north-west to south-east as it joins Clythe Creek. Areas of consistent flow, no flow, backwatering and LWD were observed in various reaches. The channel itself was constrained in areas by adjacent roads, industrial areas, and residential neighbourhoods. Throughout the channel, vegetation observed along the banks included grasses, cattails, shrubs, scrub marshland, and trees (series of willow species). Vegetation observed along the creek included non-filamentous aquatic vegetation, macrophytes, and some watercress. Within Hadati Creek, substrate ranged from exposed bedrock/shale, sand, cobble, and boulders. New walls, concrete walls, stacked stone/pillow/sack walls and retaining walls were observed throughout the channel, along with naturalized sections. Some local failures and undercuts were noted along the retaining walls and two erosion sites (from SWMMP) were identified within Hadati Creek. In total, four fish barriers were observed throughout the channel including one drop structure and three gabion baskets.

Watson Creek flows in an east to west direction and consisted of reaches with active flowing water and reaches that were dry at the time of assessment. One of the reaches investigated was described as a poorly defined channel. Within one of the first reaches investigated, the channel divided into multiple flows and a cobble knickpoint was observed approximately halfway down the extent of the reach. Overall, the channel ran through mostly naturalized vegetated areas (forested areas with willow species, scrubland, swamp areas, and marsh areas) and was constrained mostly by the adjacent residential areas. Within Watson Creek, substrate observed included sediment, sand, cobble, gravel. During field investigations, one fish barrier was identified, a perched CSP culvert.

Table 4.44 below outlines the fish barriers identified along Clythe Creek, Hadati Creek, and Watson Creek. A map showing all the identified fish barriers is found in Map AE-6. A fish barrier photo log is provided in Appendix E-1.

Table 4.44: Fish Barriers Identified along Clythe Creek, Hadati Creek, and Watson Creek

Watercourse	Fish Barrier No.	Type/Description
Clythe Creek	CC-B1	Beaver Dam
Clythe Creek	CC-B2	Weir with a drop elevation of 0.45 m
Clythe Creek	CC-B3	Weir with a drop elevation of 0.45 m
Clythe Creek	CC-B4	Weir with a drop elevation of 0.7 m.
Clythe Creek	CC-B5	Weir with a drop elevation of 0.8 m.
Clythe Creek	CC-B6	Weir with a drop elevation of 0.75 m.
Clythe Creek	CC-B7	Weir with a drop elevation of 0.6 m.
Clythe Creek	CC-B8	Weir with a 1.3 m drop elevation.
Clythe Creek	CC-B9	Weir with a 0.6 m drop elevation.

Watercourse	Fish Barrier No.	Type/Description
Clythe Creek	CC-B10	Weir with a 0.3 m drop elevation.
Clythe Creek	CC-B11	Weir with a 0.6 m drop elevation.
Clythe Creek	CC-B12	Perched Culvert with a 0.4 m drop elevation.
Hadati Creek	HC-B1	Large drop Structure (no drop elevation recorded)
Hadati Creek	HC-B2	Gabion basket with a drop elevation of 0.3 m.
Hadati Creek	HC-B3	Gabion basket with a drop elevation of 0.8 m.
Hadati Creek	HC-B4	Gabion Basket
Watson Creek	WC-B1	Perched Culvert (no drop elevation recorded)

Detailed Aquatic Assessments

The lengths and mean channel dimensions at each station are provided in Table 4.45.

Brief summaries of the aquatic habitat assessments at each station, by stream, are provided below. (Full aquatic habitat assessment results can be found in Appendix E-2).

Table 4.45: Sampling date, station length, and channel dimensions at the six stations where habitat was quantified using the Ontario Stream Assessment Protocol

Creek Name	Station	Date	Station Length (m)	Mean Width (m)	Mean Depth (cm)	Maximum Depth (cm)
Clythe	CC1	2023-07-05	60	5.1	8	24
Clythe	CC2	2023-10-24	44.5	2.4	21	54
Hadati	HC1	2023-07-05	65	2.4	9	23
Hadati	HC2	2023-08-24	51.2	2.1	7	39
Hadati	HC3	2023-07-06	41	3.7	10	37
Watson	WC1	2023-07-06	42	0.8	6	13

Clythe Creek

Site CC1 was in the forested reach upstream of Watson Parkway North. The site was 60 m long and forested on both banks. Mean width was 5.1 m (range 2.1 - 9.0 m). Habitat was characterized at 60 points. Mean and maximum depths were 8 cm and 24 cm, respectively. Hydraulic head ranged from 0 to 5 mm. Cover, consisting primarily of rocks, was present at 90 per cent of the points examined. Aquatic vegetation was sparse with non-filamentous algae present at 12 points, moss present at 1 point, watercress present at 5 points and other aquatic macrophytes present at 1 point.

Site CC2 was in the constructed reach on the south side of York Road. The station was 44.5 m long with vegetation characterized as scrubland (using the OSAP protocol) on both the left and right banks. Mean width was 2.4 m (range 1.4 - 4.6 m). Mean and maximum depths were 21 cm and 54 cm, respectively. Hydraulic head was 0 mm at all 60 points examined. Cover, consisting primarily of rocks, was present at approximately 50 per cent of the points examined. Filamentous and non-filamentous algae were each present at approximately 50 per cent of the points. Watercress was present at only two points. Grasses and terrestrial vegetation were present at approximately 25 per cent of the points and other aquatic macrophytes present at almost 50 per cent of the points.

Hadati Creek

Site HC1 was in the straight, constructed, steep-banked channel immediately upstream from York Road. The station was 65 m long with a narrow buffer between the watercourse and a parking lot on the left bank and lawn on the right bank. Mean width was 2.4 m (range 1.4 - 4.16 m). Mean and maximum depths were 9 cm and 23 cm, respectively. Mean hydraulic head was 1 mm, ranging from 0 to 20 mm for the 60 points examined. Cover, provided by round rocks, was present at more than half of the points examined. Non-filamentous algae were present at 64 per cent of the points examined. The only other aquatic vegetation was aquatic macrophytes, present at one point.

Site HC2 was in what appears to be an unstraightened reach of Hadati Creek, east of Schroeder Crescent and approximately 80 m upstream from the railway. The site was 51.2 m long and forested on both banks. Mean width was 2.1 m (range 1.4 - 3.3 m). Mean and maximum depths were 7 cm and 39 cm, respectively. Mean hydraulic head was 1 mm, ranging from 0 to 20 mm for the 60 points examined. Cover, provided by round rocks and wood, was present at more than half of the points examined. Non-filamentous algae were present at more than half of the points examined and watercress was present at one point.

Site HC3 was in a straightened (ditched) reach of Hadati Creek south of Eastview Drive. The station was 41 m long and the banks were forested. Mean width was 3.7 m (range 2.0 - 5.7 m). Mean and maximum depths were 10 cm and 37 cm, respectively. Hydraulic head was 0 mm at all 45 points examined. Cover, provided by wood, was present at approximately half the points examined. There were no rocks present; substrate was silt, unconsolidated clay, or sand. Aquatic macrophytes were present at 20 per cent of the points; no other aquatic vegetation was present.

Watson Creek

Site WC1 was in what appears to be an unstraightened reach of Watson Creek downstream from Fleming Road. The station was 42 m long and forested along both banks. Mean width was 0.8 m (range 0.4 - 1.6 m). Mean and maximum depths were 6 cm and 13 cm, respectively. Mean hydraulic head was 2 mm, ranging from 0 to 40 mm. Substrate was primarily silt and sand with the occasional round rock. Wood provided cover at nearly 75 per cent of the 40 points examined and round rocks provided cover at 10 per cent of the points. No aquatic vegetation was observed along the investigated station.

4.4.2.2 Fish communities

The station, date, method, and electrofishing seconds (if applicable) for fish community sampling completed can be found in Table 4.46.

Table 4.46: Location, date, methods, and electrofishing second for fish community sampling

Station	Date	Method	Electroseconds
CC1	2023-07-05	Electrofishing	1457
CC2	2023-10-03	Electrofishing	656
CC3	2023-10-03	Non-standard Electrofishing	278
CC4	2023-10-03	Non-standard Electrofishing	211
CC5	2023-10-03	Non-standard Electrofishing	274
HC1	2023-07-05	Electrofishing	1333
HC2	2023-07-10	Electrofishing	573
HC3	2023-07-06	Electrofishing	587
WC1	2023-07-06	Electrofishing	333
North Pond	2023-10-06	Non-standard Electrofishing and Fish Trapping	719
South Pond	2023-10-06	Non-standard Electrofishing and Fish Trapping	533

Non-standard electrofishing (electrofishing not following OSAP single-pass protocol) was completed at CC3, CC4, CC5, and the Former Reformatory Ponds (North and South Ponds). Details on electrofishing and non-standard electrofishing methodology can be found 4.4.1.2 and results are presented below.

The fish catches are summarized in Table 4.47. Total weights and minimum and maximum lengths are provided in Appendix E-3.

Clythe Creek

Stations CC1 and CC2 were sampled with a single backpack electrofishing pass through the OSAP station. Short sections of stream immediately downstream from structures that were barriers or, at a minimum, impediments to upstream fish migration were electrofished at stations CC3, CC4, and CC5.

CC5 was immediately downstream from a concrete weir that was the first barrier, moving upstream, to upstream fish migration. The substrate was primarily cobble and boulder, and the depth was approximately 0.25 m. A total of 187 individuals and 11 species were captured, including three species of darter.

At CC4, which was approximately 500 m upstream from CC5 and immediately downstream from a 30 cm high rock weir, one mottled sculpin, which is considered a coldwater species, and one johnny darter were captured. The substrate was cobble and boulder. CC4 was difficult to electrofish as the stream became too deep to wade immediately downstream, so the low catch does not necessarily indicate poor habitat.

CC3 was approximately 100 m upstream from CC4 and immediately downstream from a concrete and rock ramp that impedes upstream fish movement. Substrate was boulder, cobble, and silt. Four species, again including mottled sculpin, were captured.

CC2 was approximately 175 m upstream from CC3. At least one structure appeared to be a complete barrier to upstream fish migration between the two stations. Seven species were captured with blacknose dace and fathead minnow dominant. Seven mottled sculpin that, based on their lengths, represented at least three year-classes, were captured (see Figure 4-5).

Figure 4-5: Mottled sculpin captured at CC2 on October 3, 2023

CC1 is approximately 500 m upstream from CC2 and there is at least one structure that is a barrier to upstream fish migration between the two stations. Four fish species were captured at CC1, including fantail darter, but no mottled sculpin, despite the considerable station length and electrofishing effort.

Two aspects of the fish sampling result in Clythe Creek stand out. First, the number of species present downstream from the first barrier to upstream fish migration suggests that the barrier prevents a number of species from moving farther upstream. Second, the distribution of mottled sculpin suggests that Clythe Creek has a colder temperature regime in the reach along the south side of York Road. The number of individual species caught within Clythe Creek are outlined in Table 4.47.

Table 4.47: Station, station length, species caught, and electrofishing second for fish community sampling in Clythe Creek

Species (common name)	Species (scientific name)	Thermal Class	CC1	CC2	CC3	CC4	CC5
Station length (m)	**-**	**-**	**60**	**44.5**	**~15**	**~5**	**~10**
Electroseconds	**-**	**-**	**1457**	**656**	**278**	**211**	**274**
bluegill	*Lepomis macrochirus*	warm	0	2	0	0	0
bluntnose minnow	*Pimephales notatus*	warm	0	0	0	0	18
brook stickleback	*Culaea inconstans*	cool	0	0	8	0	0
carp	*Cyprinus carpio*	warm	0	0	0	0	2
central mudminnow	*Umbra limi*	cool/warm	0	1	0	0	0
creek chub	*Semotilus atromaculatus*	cool	6	2	10	0	5
common shiner	*Luxilus cornutus*	cool	0	0	0	0	46
fantail darter	*Etheostoma flabellare*	cool	4	0	0	0	2
fathead minnow	*Pimephales promelas*	warm	3	21	18	0	20
greenside darter	*Etheostoma blennioides*	cool/warm	0	0	0	0	1
Johnny darter	*Etheostoma nigrum*	cool	0	0	0	1	19
largemouth bass	*Micropterus salmoides*	warm	0	0	0	0	8
mottled sculpin	*Cottus bairdii*	cold	0	7	5	1	0
pumpkinseed	*Lepomis gibbosus*	warm	0	0	1	0	2
blacknose dace	*Rhinichthys atratulus*	cool	1	21	0	0	0
white sucker	*Catostomus commersonii*	cool	0	3	1	0	64
Total number			**14**	**57**	**43**	**2**	**187**
Number of species			**4**	**7**	**4**	**2**	**11**

Hadati Creek

Three stations were electrofished on Hadati Creek. HC1 was the farthest downstream, in the straightened reach immediately upstream from York Road and the confluence with Clythe Creek. Six species and 62 individuals were captured, including one darter species, Johnny darter. A drop structure into the culvert beneath the railway poses a complete barrier to upstream fish migration. Only bluegill was captured at HC2 and HC3, which are both upstream from this barrier. Bluegill most likely are present within the stormwater management facilities that drain to Hadati Creek, upstream of the railway, and are less likely to occur in the creek itself. The number of individual species caught within Hadati Creek are outlined in Table 4.48.

Table 4.48: Sampling effort and number of individuals captured, by species, at each of three stations in Hadati Creek

Species (common name)	Species (scientific name)	HC1	HC2	HC3
Station length (m)	-	**65**	**51.2**	**41**
Electroseconds	-	**1333**	**573**	**587**
creek chub	*Semotilus atromaculatus*	24	0	0
blacknose dace	*Rhinichthys atratulus*	12	0	0
brook stickleback	*Culaea inconstans*	12	0	0
fathead minnow	*Pimephales promelas*	7	0	0
common shiner	*Luxilus cornutus*	2	0	0
Johnny darter	*Etheostoma nigrum*	5	0	0
bluegill	*Lepomis macrochirus*	0	1	4
Total number	-	**62**	**1**	**4**
Number of species	-	**6**	**1**	**1**

Electrofishing was conducted at one station on Watson Creek and one station on an Unnamed Tributary to the north Former Reformatory Pond (Table 4.49). No fish were captured at either of these sites.

Table 4.49: Sampling effort at one station on Watson Creek and one location on an Unnamed Tributary to the south Former Reformatory Pond

Species	WC1	Reformatory Pond Tributary
Station length (m)	**42**	**40**
Electroseconds	**333**	**340**
Number of fish caught	**0**	**0**

Each of the Former Reformatory Ponds was sampled by electrofishing along a section of shoreline and by setting three mesh fish traps overnight in each pond. The combined results for both capture methods are presented in Table 4.50. Five species belonging to the centrarchid (sunfish) family and yellow perch were captured.

Table 4.50: Number of individuals captured, by species, by electrofishing and trapping combined, in each of the Former Reformatory Ponds

Species (common name)	Species (scientific name)	South Pond	North Pond
rock bass	*Ambloplites rupestris*	16	13
bluegill	*Lepomis macrochirus*	17	15
largemouth bass	*Micropterus salmoides*	6	1
pumpkinseed	*Lepomis gibbosus*	10	24
white crappie	*Pomoxis annularis*	0	1
yellow perch	*Perca flavescens*	1	0
Total number	**-**	**50**	**54**

The number of individuals, bulk weight, and length range for each species capture at each station are shown in Table 4.51.

Table 4.51: Number of individuals captured, by species, by electrofishing, non-standard electrofishing, and fish trapping

Station	Species (scientific name) (common name)	Species (scientific name)	Number Captured	Bulk Weight (g)	Min. Length (mm)	Max. Length (mm)
CC1	creek chub	*Semotilus atromaculatus*	6	25.3	48	73
CC1	fantail darter	*Etheostoma flabellare*	4	5.8	31	56
CC1	fathead minnow	*Pimephales promelas*	3	4.8	33	53
CC1	Western blacknose dace	*Rhinichthys atratulus*	1	1.7	48	48
CC2	Western blacknose dace	*Rhinichthys atratulus*	21	62.7	28	77
CC2	white sucker	*Catostomus commersonii*	3	31.6	100	103
CC2	mottled sculpin	*Cottus bairdii*	7	12.6	27	76
CC2	fathead minnow	*Pimephales promelas*	21	24.7	26	51

Station	Species (scientific name) (common name)	Species (scientific name)	Number Captured	Bulk Weight (g)	Min. Length (mm)	Max. Length (mm)
CC2	creek chub	*Semotilus atromaculatus*	2	2.5	32	44
CC2	central mudminnow	*Umbra limi*	1	7.4	91	91
CC2	bluegill	*Lepomis macrochirus*	2	1.1	28	32
CC3	mottled sculpin	*Cottus bairdii*	5	18.6	27	81
CC3	fathead minnow	*Pimephales promelas*	18	32.1	24	58
CC3	white sucker	*Catostomus commersonii*	1	18.4	120	120
CC3	pumpkinseed	*Lepomis gibbosus*	1	3.6	57	57
CC3	brook stickleback	*Culaea inconstans*	8	3.5	49	49
CC3	creek chub	*Semotilus atromaculatus*	10	191.1	177	177
CC4	mottled sculpin	*Cottus bairdii*	1	0.7	39	39
CC4	Johnny darter	*Etheostoma nigrum*	1	0.9	50	50
CC5	common shiner	*Luxilus cornutus*	46	301.4	58	138
CC5	white sucker	*Catostomus commersonii*	64	273	57	95
CC5	fathead minnow	*Pimephales promelas*	20	61.5	5	73
CC5	bluntnose minnow	*Pimephales notatus*	18	43.9	61	74
CC5	largemouth bass	*Micropterus salmoides*	8	75.4	64	95
CC5	creek chub	*Semotilus atromaculatus*	5	46.2	66	117
CC5	carp	*Cyprinus carpio*	2	17.5	64	80
CC5	pumpkinseed	*Lepomis gibbosus*	2	15.4	73	69
CC5	greenside darter	*Etheostoma blennioides*	1	2.5	60	60
CC5	Johnny darter	*Etheostoma nigrum*	19	28.1	45	63
CC5	fantail darter	*Etheostoma flabellare*	2	4.6	32	62
CC5	creek chub	*Semotilus atromaculatus*	24	295.3	33	127

Station	Species (scientific name) (common name)	Species (scientific name)	Number Captured	Bulk Weight (g)	Min. Length (mm)	Max. Length (mm)
CC5	Western blacknose dace	*Rhinichthys atratulus*	12	56.4	39	81
CC5	brook stickleback	*Culaea inconstans*	12	8.9	31	33
CC5	fathead minnow	*Pimephales promelas*	7	11.5	40	57
CC5	common shiner		2	7.5	57	76
CC5	Johnny Darter	*Etheostoma nigrum*	5	9.7	42	63
CC5	bluegill	*Lepomis macrochirus*	1	9	78	78
CC5	bluegill	*Lepomis macrochirus*	4	91.9	96	119
Unnamed Tributary to South Pond (upstream)	No catch	*No catch*				
CC5,South Pond (downstream)	No catch	*No catch*				
South Pond	rock bass	*Ambloplites rupestris*	16	210.1	76	131
South Pond	bluegill	*Lepomis macrochirus*	17	236.5	73	134
South Pond	largemouth bass	*Micropterus salmoides*	6	14.5	55	68
CC5,South Pond	pumpkinseed	*Lepomis gibbosus*	10	234.5	56	140
CC5, South Pond	yellow perch	*Perca flavescens*	1	98.6	198	198
North Pond	rock bass	*Ambloplites rupestris*	13	310.9	42	146
North Pond	bluegill	*Lepomis macrochirus*	15	298.9	38	151
North Pond	largemouth bass	*Micropterus salmoides*	1	68	68	4.8
North Pond	pumpkinseed	*Lepomis gibbosus*	24	500	42	127
North Pond	white crappie	*Pomoxis annularis*	1	19	172	172

More detailed information pertaining to fish community sampling results is presented in Appendix E-3.

4.4.2.3 Benthic invertebrate communities

Table 4.52 provides a summary of the benthic invertebrate metric analysis results. Raw data provided by B. Morton can be found in Appendix E-4 and benthic field sheets are provided in Appendix E-5.

The results from the field sampling were analyzed and scores calculated for the Shannon Weiner Diversity Index (H'), Hilsenhoff Biotic Index (HBI), percent *Ephemeroptera, Plecoptera*, and *Trichoptera* (percent EPT), and taxa richness. Water quality results were compared with the benthic sampling results to evaluate the degree of watercourse impairment at each of the six sampling sites.

Table 4.52: Summary of benthic macroinvertebrate metrics (2023)

Metric	CC1 (C1)	CC2 (C2)	HC1 (H1)	HC2 (H2)	HC3 (H3)	WC1 (W1)
Taxa Richness	35	23	24	18	14	19
Shannon-Weiner Diversity Index (H')	2.71	1.26	1.48	1.71	1.91	2.30
Hilsenhoff Biotic Index (HBI)	5.61	8.06	6.78	6.44	8.11	6.76
% EPT	17.56	3.48	5.61	15.11	0.00	3.25
Number of EPT Taxa	4	5	2	3	0	2
% Oligochaeta	1.53	1.00	3.27	1.21	37.60	3.25
% Diptera	22.90	85.07	17.76	9.06	23.14	73.17
% Chironomidae	17.18	83.08	13.55	1.21	22.73	60.98
% Isopoda	19.47	1.99	66.82	48.64	6.20	8.13
% Collector-Filterers	18.32	3.98	4.67	19.64	30.99	5.69
% Collector- Gatherers	32.44	5.47	86.92	51.36	50.83	29.27
% Scrapers	6.11	1.49	0.47	3.63	0.00	0.00
% Shredders	6.11	1.49	0.47	0.00	2.07	12.20
% Predators	11.83	7.46	1.87	3.63	1.24	52.03
% of Dominant Taxa	20.61	75.62	66.82	48.64	37.60	37.40

Based on the sampling effort and past experience, it was expected that at least 100 organisms would be present in each sample. The low numbers in samples from Watson Creek and the upper sites on Hadati (HC-2 and HC-3) may be a consequence of those sites going dry during most or all summers. This, however, does not explain the low numbers in the samples from CC1 and CC2, noting that the latter was sampled in October.

Based on this information, the benthic interpretations in Section 4.4.3 should be considered preliminary, due to the sampling timing of CC2 (completed in October) and lack of multiple fulsome benthic samples.

Overall impairment status was calculated for each station, as outlined in Table 4.53. Of the six stations, HC3 was the most impaired (with an overall score of 7) and CC1 was the least impaired (with an overall score of 14).

Table 4.53: Benthic Analysis Scoring and Overall Impairment Status

Metric	CC1 Value	CC1 Score	CC2 Value	CC2 Score	HC1 Value	HC1 Score	HC2 Value	HC2 Score	HC3 Value	HC3 Score	WC1 Value	WC1 Score
Taxa Richness	35	4	23	3	24	3	18	2	14	2	19	2
Shannon-Weiner Diversity Index (H')	2.71	2	1.26	2	1.48	2	1.71	2	1.91	2	2.3	2
Hilsenhoff Biotic Index (HBI)	5.61	4	8.06	2	6.78	3	6.44	4	8.11	2	6.76	3
% EPT	17.56	4	3.48	2	5.61	3	15.11	4	0	1	3.25	2
Total Score		14		9		11		12		7		9

As identified in Table 4.53 the overall impairment status is as follows:

- CC1 possibly impaired
- CC3 moderately impaired
- HC1 possibly impaired
- HC2 possibly impaired
- HC3 moderately impaired
- WC1 moderately impaired

4.4.2.4 Surface Water Quality Parameters

Appendix E-6 shows the surface water quality measurements captured along Clythe Creek, Hadati Creek, and Watson Creek taken in conjunction with benthic and fishing sampling.

4.4.2.5 Thermal Regime Classifications

Thermal regimes are summarized in Table 4.54 and presented on Map AE-7. (Scatterplot analyses used to determine thermal regime are found in Appendix E-7).

Table 4.54: Summary of Thermal Regime Analyses

Watercourse	Surface Water Monitoring Station	Year	Thermal Regime – Method 1*	Thermal Regime - Method 2**
Clythe Creek	CC-1SW	2023	Coolwater	Coolwater
Clythe Creek	CC-2SW	2022	Coolwater	Coolwater
Clythe Creek	CC-2SW	2023	Warmwater	Cool-warmwater
Clythe Creek	CC-3SW	2023	Coolwater	Coolwater

Watercourse	Surface Water Monitoring Station	Year	Thermal Regime – Method 1*	Thermal Regime - Method 2**
Clythe Creek	CC-4SW	2022	Coolwater	Coolwater
Clythe Creek	CC-4SW	2023	Coolwater	Coolwater
Clythe Creek	CC-5SW	2023	Warmwater	Warmwater
Clythe Creek	CC-5SW	2024	Warmwater	Warmwater
Clythe Creek	CC-6SW	2023	Warmwater	Cool-warmwater
Clythe Creek	CC-6SW	2024	Warmwater	Cool-warmwater
Hadati Creek	HC2-SW	2023	Coolwater	Coolwater
Hadati Creek	HC2-SW	2024	Coolwater	Coolwater
Watson Creek	WC-1SW	2023	Coolwater	Coolwater
Watson Creek	WC-2SW	2023	Coolwater	Coolwater
Watson Creek	WC-3SW	2023	Coolwater	Coolwater

* As per Stoneman and Jones 1996
** As per Chu et al., 2009

Clythe Creek

Results of the thermal regime analysis for Clythe Creek indicate that this watercourse is currently exhibiting a coolwater thermal regime within the PSA upstream of the Former Reformatory Ponds. The Former Reformatory Ponds have a warmwater thermal regime (based on data obtained from CC-5SW located at the pond outlet to Clythe Creek); downstream of the Former Reformatory Ponds, Clythe Creek exhibits a warmwater thermal regime that was further refined as cool-warmwater when using the Chu *et al.,* 2009 approach to the analysis.

One coldwater fish species, mottled sculpin, was recorded within Clythe Creek upstream of the Former Reformatory Ponds, being captured during fish community sampling at CC2, CC3, and CC4 which are in the reach along the south side of York Road. This is consistent with the hydrogeology information which indicates that there is groundwater discharge to the stream in this reach. The thermal class of the other fish species ranged from cool to warm.

Hadati Creek

The single surface water monitoring station (HC-2SW) within Hadati Creek recorded data near the confluence with Clythe Creek and indicated that the reach between the railway and the confluence is exhibiting a coolwater thermal regime (Map AE-7). During fish community sampling in this reach at CC1, seven fish species were captured. These were a mixture of coolwater and warmwater species, with coolwater species accounting for most of the catch (five of seven species).

No surface water monitoring stations were located in Hadati Creek upstream of the railway. MNR classifies Hadati Creek as warmwater, which is consistent with its intermittent flow regime. Upstream of the railway, fish community sampling completed for this study documented a single species in very low numbers, bluegill (which is a warmwater species). It is possible that the creek goes dry on occasion, and if it does, it is not possible for fish to recolonize from downstream due to the drop structure at the railway. The stormwater facilities that drain to Hadati Creek may be the source of bluegill that recolonize these reaches, as it is not typically a species found in very small streams.

Given the MNR classification, intermittent flow and the presence of bluegill, it is recommended that Hadati Creek be considered warmwater from the railway upstream. However, because the downstream reach of Hadati Creek is designated as coolwater, the upstream reaches should be managed as per coolwater policies in order to minimize thermal impacts from upstream.

Watson Creek

Results of the thermal regime analysis for Watson Creek indicate that this watercourse is currently exhibiting a coolwater thermal regime. No fish were captured during fish community sampling completed for this study, however MNR fish records indicate a variety of warm, cool, and coldwater species have historically occupied the watercourse (including brook trout, a sensitive coldwater species). However, temperature data collected at three locations on Watson Creek (WC-1SW, HC-2SW, and HC-3SW) consistently and clearly show a coolwater thermal regime.

4.4.3 Summary of aquatic ecology characterization

This section provides summaries and interpretations of the overall high-level aquatic habitat, fish community sampling, and benthic invertebrate sampling completed for the SWSU. A general representative photographic log of Clythe Creek, Hadati Creek, and Watson Creek can be found in Appendix E-8.

Clythe Creek

Clythe Creek is a perennial stream. The channel is relatively natural upstream from York Road, but the channel has been extensively altered downstream from that point. There are a number of barriers to fish migration between York Road and the Eramosa River, including a concrete weir downstream from the Clythe/Hadati confluence. Some of these barriers may be passable at high flows, but at normal or low flow they are not.

The substrate upstream from York Road is a patchy mixture ranging from silt to cobble, and typical of area streams. Most of the constructed channel downstream from York Road is lined with cobble, overlain by finer materials in the slower reaches.

The benthic invertebrate community indices indicated that water quality is possibly impaired at CC1, upstream from Watson Parkway, and moderately impaired at CC2, downstream from York Road.

Within the PSA, Clythe Creek has been classified as a coolwater system upstream of the Former Reformatory Ponds, and a warmwater system (specifically cool-warmwater) downstream of these ponds.

Hadati Creek

Flow in Hadati Creek is intermittent from the headwaters to approximately Grange Road, although there is often standing water at various points. Hadati Creek was historically realigned over nearly its entire length. The upper reaches were realigned as straight ditches, and the lower reaches (downstream from the railway) are straight channels excavated down to bedrock.

The riparian vegetation was stripped along most of the Hadati Creek corridor when the channel realignments took place, but it has since regenerated.

The benthic invertebrate community indicates that the water quality is possibly impaired at HC1 and HC2 and moderately impaired at HC3. The rating at HC3 is almost certainly influenced by the intermittent flow and absence of any coarse substrate in the ditched section.

A drop structure upstream from the railway is a complete barrier to upstream fish migration. It is not known if a bedrock barrier was present here historically but the exposed limestone scarp at other locations south of the railway suggests that this may have been the case.

Hadati Creek has been classified as a warmwater system upstream of the railway, and as a coolwater system between the railway and Clythe Creek.

Watson Creek

As described in the 1998 SWS, the headwaters of Watson Creek were diverted to Hadati Creek when the Former Eastview Landfill was constructed. The upper reaches of Watson Creek go dry during the summer. It has not been determined exactly where or if any reach of Watson Creek flows permanently. The benthic invertebrate community indicates that water quality was moderately impaired but, as was the case in the headwaters of Hadati Creek, the lack of permanent flow likely contributes to that rating. No fish were captured by electrofishing at WC1.

Watson Creek has been classified as a coolwater system based on temperature data analysis. (All field sampling coordinates can be found in Appendix E-9).

4.5 Terrestrial ecology characterization

The approach to the terrestrial ecology characterization is a bit different from the other disciplines because the NHS policies in the SSA (i.e., the County) and the PSA (i.e., the City of Guelph) are already quite prescribed (e.g., criteria for significant wetlands, criteria for significant woodlands, and in the PSA minimum buffers to some features and some Restoration Areas are already prescribed). Nonetheless, background review of all available and applicable mapping and technical data, targeted field work (which for the SWSU was focused in the PSA), and analysis of all this information is still needed to inform and – where appropriate – update application of the policies to describe, identify and map the various NHS components.

Therefore, the approach taken for this SWSU was to:

- Summarize the technical methods and results in this section (i.e., Section 4.5)

- Apply the results of the field work to inform updates to the NHS in the PSA (as described in Section 5.3), and
- Build on the current NHS mapping provided by the County for the SSA to identify a preliminary refined NHS for the entire subwatershed (as described in Section 5.3).

As such, the terrestrial ecology ends up being somewhat more "advanced" than the other disciplines at the characterization stage in some respects because an approved policy framework is already in place for the NHS in (a) PSA and (b) the SSA, which facilitates the development of some aspects of the management guidance to be developed in the next phases of the SWSU – to be outlined in the Impact Assessment and Management Report for the SWSU.

4.5.1 Terrestrial ecology methods

4.5.1.1 Background information reviewed

The following natural heritage studies for the Clythe Creek subwatershed were reviewed for relevant ecological data and/or mapping to supplement field data collected as part of this study:

- Clythe Creek Subwatershed Study and Overview (Ecologistics and Blackport, 1998)
- Environmental Appraisal: Eastview Planning Area, Valeriote Lands: Final Report (Geomatics International Inc., 1998)
- Cityview Ridge EIS Addendum 1 and 2 (NSE, 2012; NSE, 2013)
- Guelph Correctional Centre Natural Heritage Assessment (NRSI, 2013)
- 55 and 75 Cityview Drive Scoped EIS (3rd and Final Submission) (NRSI, 2014)
- Mapping of a Natural Heritage System in the County of Wellington Final Report (GRCA, 2018)
- Eastview Road Wildlife Crossing Structure Effectiveness Monitoring Year-end Reports (NSE, 2018; NSE, 2019)
- Clythe Creek Water Treatment Plant EIS (NRSI, 2022)
- Proposed Bike Skills Park or Other Recreation Area – Phase 1 and Future Phases, Scoped EIS (Aboud and Associates Inc., 2023)
- Phase 1 EIS Natural Heritage Characterization Report (AECOM, 2022)
- EIS 66 Eastview Road, Guelph, Ontario (Ecoplans, 2013)
- 300 Grange Road, Guelph, Ontario Environmental Impact Study (NSE, 2022)
- 115 Watson Pkwy N Scoped EIS (NSE, 2023)
- 46, 47 and 87 Hyland Road, Guelph EIS (NRSI, 2015)
- EIS York Road Environmental Design Study (Wood, 2019)
- Scoped EIS 78-81 Eastview Rd, Guelph, Ontario (WSP, 2020)
- The Flora of Wellington County (Frank & Anderson 2009)

- NHIC (Natural Heritage Information Centre) database – provincially tracked species
- GBIF (Global Biodiversity Information Facility) database – species records
- iNaturalist database – research grade species records

In addition, the following guidance documents were reviewed:

- The City's Official Plan (2024 Consolidation)
- Natural Heritage Action Plan (City of Guelph, 2018)
- City of Guelph Urban Forest Study (Lallemand and KBM, 2019)
- Significant Wildlife Habitat Criteria for Ecoregion 6E (MNR, 2015) and the Significant Wildlife Habitat Technical Guide (MNR, 2000)
- How Much Habitat is Enough? A Framework for Guiding Habitat Rehabilitation in Great Lakes Areas of Concern (EC, 2013)

Spatial data and mapping used as background sources include the following:

- City of Guelph Natural Heritage System (Official Plan Schedule 4) and NHS components mapping, as well as ELC mapping (Official Plan Appendix A)
    - Wildlife Crossings and Tunnel Locations (City of Guelph, 2022)
    - Tree Canopy Data (2019)
- Guelph-Eramosa Township Zoning (from Wellington County)
    - Wellington County Official Plan Land Use Designations

Grand River Conservation Authority (GRCA) open data available online:

- 1999 land cover
- Wetlands and regulated areas

Land Information Ontario:

- MNR Wetland
- MNR Woodlands
- Areas of Natural and Scientific Interest (ANSIs)

4.5.1.2 Overview of field work completed

The following field studies were undertaken on accessible lands within the PSA in 2022 and 2023:

- Ecological Land Classification (ELC) and vascular plant inventory
- Wetland boundary confirmation
- Breeding bird surveys

- Anuran (frog and toad) surveys
- Basking and nesting turtle surveys
- Road crossing/mortality surveys
- Winter wildlife surveys
- Bat snag inventory surveys

Methodologies for each of these studies are provided below. Survey coverage is presented on map series TE-3 and summarized in Table 4.55.

Table 4.55: Terrestrial ecology survey coverage within the PSA, 2022 and 2023

Survey Type	Number of Survey Locations	Area Coverage (ha)
Turtle Basking Survey	8	---
Nocturnal Amphibian Call Survey	24	---
Breeding Bird Survey	32	---
Bat Habitat Plot Survey	205	10.17
Winter Wildlife Survey	9	45.35
Road Crossing/Mortality Survey	8	18.80
Turtle Nesting Survey	8	23.84
Ecological Land Classification	141	312.81

4.5.1.3 Ecological Land Classification and vascular plants

Vegetation communities within the PSA were characterized according to the ELC system protocol for southern Ontario, first approximation (Lee *et al.,* 1998). Generally, three-season (spring, summer and fall) surveys were conducted for each polygon with fewer visits for cultural features that are typically less seasonally diverse. For lands that could not be accessed by field surveyors, aerial interpretation and ELC data from recent natural heritage studies, where available, were used to supplement ELC mapping within the PSA.

Vascular plant surveys were undertaken in conjunction with ELC on accessible lands within the PSA in the spring, summer, and fall of 2022 and 2023. Vascular plant species identified within the canopy, sub-canopy, understory, or ground layer were recorded along with relative abundance for each ELC polygon. ELC and plant lists were recorded and digitally uploaded to an ArcGIS database to facilitate data management and analysis. The taxonomy, nomenclature and provincial ranks for each of the species are consistent with the Natural Heritage Information Centre. Plant rarity status was assessed for federal, provincial, regional (Frank & Anderson, 2009), and local (City of Guelph, 2012) significance.

4.5.1.4 Wetlands

Wetland boundaries within the PSA that were identified on Land Information Ontario and GRCA mapping and were refined based on current aerial photograph interpretation and ELC field verification on accessible lands. Wetland communities were identified based on ELC polygon classification, and wetland boundaries were field delineated in accordance with OWES boundary delineation criteria where wetlands are defined as having 50 per cent or more wetland obligate species cover and hydric soils. Soil texture and moisture regime were characterized within certain wetland polygons to assist with boundary confirmation.

Formal wetland boundary confirmation of GRCA-regulated wetlands was undertaken on-site with GRCA and City of Guelph representatives in 2022 and 2023. The technical outcomes of this mapping are presented in the Maps TE-1.1 through 1.12 which provide the technical basis for the updates in the PSA. The outcomes of the updates to the wetland mapping in the PSA is presented in Map TE-4.1 with the updates (i.e., wetlands “added” or “removed” as a result of the findings of the field work).

4.5.1.5 Birds

Breeding bird surveys were undertaken in 2022 and 2023 at 32 designated point-count stations located throughout the PSA (see Map TE-2). Surveys were conducted in accordance with the Ontario Breeding Bird Atlas (OBBA, 2021) protocols, which requires two rounds of surveys under appropriate timing and weather conditions, between May 24 and July 10.

Breeding bird survey visits were completed at 17 point-count locations within the original PSA in 2022 and 2023. In 2023, an additional 15 breeding bird point-count stations were surveyed within the expanded PSA for a combined total of 32 point-count stations (Map TE-3).

As per the Ontario Breeding Bird Atlas protocol, surveys occurred between half an hour before sunrise and continued up to five hours after and were conducted during suitable weather conditions (i.e., light winds, good visibility, and no heavy rain). Repeat visits were made at least seven days apart to determine presumed territories (indicated by a singing bird, usually but not always male, in the same approximate location).

Breeding bird surveys were conducted using a point-count methodology to ensure coverage of a wide area and a variety of habitats within the PSA. The duration of each point count was extended from the standard 5-minute recommendation to 10 minutes to ensure that all species that are present are documented, given that moderate to loud ambient background noise was present across much of the PSA.

In addition to species and numbers of individuals, breeding evidence was also documented, as per the OBBA protocol (2021).

4.5.1.6 Anurans (frogs and toads)

Nocturnal amphibian call surveys were conducted at 24 locations in accordance with the Marsh Monitoring Program (BSC, 2009). Three visits in late April, May and June were completed at 12 point-count locations within the original PSA in 2022. An additional 12 point-count locations were surveyed within the expanded PSA in 2023 for a total of 24 survey locations (Map TE-2).

Surveys occurred between 30 minutes after sunset and midnight, under appropriate weather conditions stipulated in the Marsh Monitoring Program protocol (i.e., low winds, no rain, minimum temperature thresholds met). Species and abundance counts were recorded at each monitoring location.

During each visit, surveyors documented amphibian calls for a 6-minute duration at each of the monitoring stations. The duration of each point count was extended from the standard 3-minute recommendation to 6 minutes to ensure that all species that are present are documented and that calling intensity was accurately recorded, given that moderate to loud ambient background noise was present across much of the PSA.

4.5.1.7 Turtles

Two rounds of turtle basking surveys were completed at four locations within the original study area in 2022 and 2023. Four additional locations were surveyed in 2023 within the expanded PSA for a total of eight survey locations (Map TE-2).

Survey locations were scoped to potentially suitable wetlands containing open water within the expanded PSA. Basking surveys were conducted in accordance with the MNR's 2015 Survey Protocol for Blanding's Turtle (*Emydoidea blandingii*) in Ontario. As per the survey protocol guidelines, surveys were conducted from 8 am to 5 pm on sunny days where the air temperature was between 6 and 25°C or on partially cloudy or overcast days where the air temperature exceeded 15°C. At each wetland, ecologists approached and walked the wetland boundary quietly and thoroughly scanned using binoculars for basking turtles on floating logs, in the water or on other substrates.

All turtle species observed, in addition to other incidental wildlife, were recorded during surveys. One round of nesting surveys was completed at four locations within the original PSA in 2022 and 2023. In 2023, an additional four locations were surveyed within the expanded PSA for a total of eight survey locations (Map TE-2).

Nesting surveys were conducted in accordance with the MNR's 2015 Survey Protocol for Blanding's Turtle in Ontario. As per the survey protocol guidelines, surveyors quietly approached and observed suitable nesting habitats from a distance using binoculars. Actively nesting turtles were recorded. If no turtles were actively observed, surveyors carefully approached nesting habitat to check for evidence of test digs and/or predated nests. The number of test digs and predated nests were recorded for each survey location.

4.5.1.8 Herpetofauna migration and road mortality

Surveys of amphibian and reptile migration and mortality along select roadways were conducted in April 2022 and 2023 during the spring amphibian migratory season. Surveyors completed walking transects along the following stretches of road after dusk using a headlamp to record any live or dead wildlife encountered:

- Watson Parkway South from Starwood Drive south to Sheehy Court

- Watson Road North
- York Road from Dunlop Drive East to Watson Parkway South
- Watson Parkway North 250 m north of Eastview Road, south to Grange Road and Grange Road east to Severn Drive
- Eastview Road from Creighton Avenue to Watson Parkway North
- Fleming Road from Creekside Drive to Severn Drive
- Speedvale Avenue East from Eramosa Road to Eastview Community Park

Survey locations were selected due to their proximity to suitable breeding habitat (wetlands). Two visits were conducted along each transect (Map TE-2).

4.5.1.9 Winter wildlife

Monitoring of wildlife during the winter seasons took place between January and March 2023 following fresh snowfall so that wildlife tracks and signs (e.g., scat, fur, dens, hunting activity etc.) from overnight activity were more easily detected. In addition to mammals, these surveys were also aimed at detecting overwintering raptors. Each survey polygon was visited on two separate dates. Any wildlife track or sign encountered were photographed and recorded. A total of nine areas were surveyed for winter wildlife, based on the likelihood of habitat to support wildlife or provide movement corridors (Map TE-2).

4.5.1.10 Bats

Leaf-off bat habitat surveys were completed in November - December 2022 in accordance with Provincial standards (MECP, 2022) to inventory and assess suitable bat maternity roost habitat within the PSA. Surveys were conducted at 205 plots (Map TE-2) within suitable forest and treed swamp communities as identified via aerial interpretation, including the following communities:

- Deciduous Forest (FOD)
- Mixedwood Forest (FOM)
- Coniferous Forest (FOC)
- Deciduous Swamp (SWD)
- Mixedwood Swamp (SWM)
- Coniferous Swamp (SWC)

In accordance with the protocol (MECP, 2022), randomized 12.6 m radius plots were pre-selected within these community types on accessible lands within the PSA using GIS at a density of 10 plots per hectare with one additional plot per hectare up to 35 plots within contiguous suitable habitat.

After navigating to each plot, the number and characteristics of all suitable bat snag trees 25 cm DBH (diameter at breast height) or greater within each plot was documented. Data collected for each suitable snag tree included:

- Species (common and botanical name)
- DBH (cm)
- Height (m)
- Crown Reserve (m)[7]
- Decay Class (1-6)
- Photograph
- Presence of structural snag attributes:
    - Loose or peeling bark
    - Crack or crevice
    - Cavity or knothole
    - Height of tallest snag attribute
    - Comments

The plot data collected were used to extrapolate the total number of snags per hectare to determine whether high quality bat habitat is present (>10 snags/ha), as determined by MECP (2022).

4.5.1.11 Incidental wildlife

All wildlife encountered incidentally during other targeted field surveys were recorded and assessed for significance. Fauna species were detected through either direct observation of wildlife, by song or call (birds, amphibians), or by evidence, including track and sign (mammals and other wildlife).

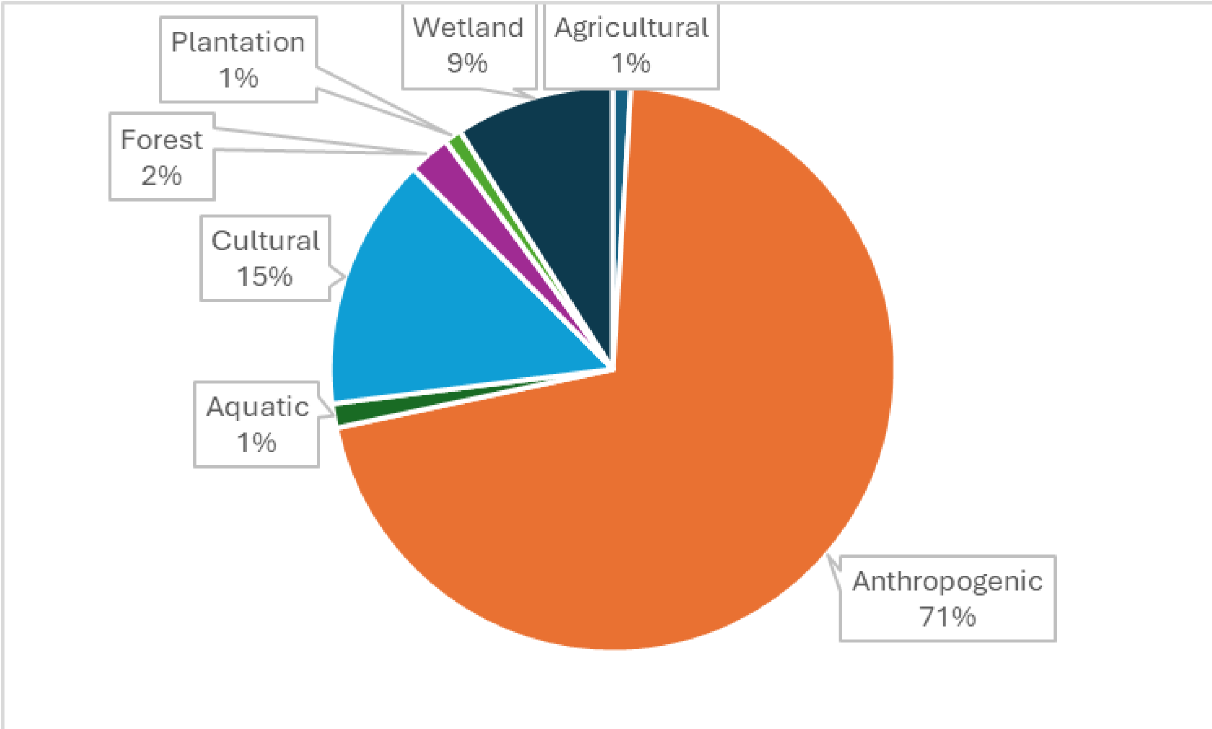
4.5.2 Terrestrial ecology findings

4.5.2.1 Ecological land classification

ELC within the PSA is presented on Map TE-1. Lands within the PSA are largely developed, with anthropogenic lands (including roads, buildings, and hardscaped surfaces) comprising the largest per cent cover within the PSA (71 per cent, Figure 4-6). Anthropogenic lands are generally considered to be of low ecological value, due to the lack of natural vegetation and habitat for wildlife. Similarly, agricultural lands provide limited ecological value and comprise one per cent of landcover within the PSA.

[7] Crown reserve is the tree canopy width in metres.

Figure 4-6: ELC land cover summary within the Primary Study Area



Cultural communities, which include Cultural Meadow, Cultural Woodland, Cultural Thicket and Cultural Savannah, comprise 15 per cent of land cover within the PSA (Figure 4-6). Coniferous plantations comprise an additional one per cent of land cover. Cultural ELC communities and plantations have largely resulted from recent human alteration or disturbances and typically are dominated by early successional vegetation and/or planted species.

The PSA notably contains a relatively high per centage of wetlands (nine per cent of land cover), including a mixture of Deciduous Swamp, Thicket Swamp, Meadow Marsh, Shallow Marsh, Mixed Swamp and Coniferous Swamp communities. Large wetland patches are concentrated in the northern portion of the PSA and on the Former Reformatory Lands south of York Road. Wetlands are generally considered to be of high value due to the variety of important ecological, hydrological, and social functions they provide, including water filtration and flood attenuation, carbon sequestration, erosion control, provision of wildlife habitat and biodiversity support. Aquatic communities, including wide portions of Clythe Creek, ponds and waterbodies comprise approximately one per cent of landcover within the PSA.

Upland forest communities comprise two per cent of land cover within the PSA, including Mixed Forest, Deciduous Forest, and Coniferous Forest. The largest intact forest patches are found in the northern portion of the PSA, west of Eastview Park. Similar to wetlands, forests are generally considered to be of high ecological value. These communities provide a number of critical ecological, hydrological and social functions that contribute to climate change resiliency, such as carbon sequestration and air quality improvement, water filtration, erosion control, provision of wildlife habitat and biodiversity support.

A summary of the Ecological Land Classification (ELC) community series within the PSA is presented in Table 4.56 and illustrated in Map TE-1, with a break-down of more area-specific ELC mapping in Maps TE-1.1 through TE-1.12. Further details are provided in Appendix F-3.

Table 4.56: Ecological Land Classification (ELC)* types and cover within the Primary Study Area

ELC community series	ELC code	Area (ha)	Per cent cover lumped by high level ELC type	Per cent cover by ELC Community Series
Agricultural	**AGR**	**12.31**	**1.03%**	
Agriculture	AGR	12.31		1.03%
Anthropogenic	**ANTH**	**845.82**	**70.64%**	
Anthropogenic	ANTH	845.82		70.64%
Aquatic	**OA**	**16.60**	**1.39%**	
Open Aquatic	OA	14.76		1.23%
Open Water	OAO	1.84		0.15%
Cultural	**CU**	**173.30**	**14.47%**	
Cultural Meadow	CUM	137.47		11.48%
Cultural Savannah	CUS	1.87		0.16%
Cultural Thicket	CUT	23.17		1.94%
Cultural Woodland	CUW	10.79		0.90%
Forest	**FO**	**28.55**	**2.38%**	
Coniferous Forest	FOC	6.51		0.54%
Deciduous Forest	FOD	12.82		1.07%
Mixed Forest	FOM	9.22		0.77%
Plantation	**CUP**	**11.84**	**0.99%**	
Plantation	CUP	11.84		0.99%
Wetland	**MA, SW, SA**	**108.91**		
Coniferous Swamp	SWC	5.75		0.48%
Deciduous Swamp	SWD	38.06		3.18%
Meadow Marsh	MAM	20.69		1.73%
Mixed Swamp	SWM	8.58		0.72%
Shallow Marsh	MAS	13.62		1.14%
Grand Total		**1197.32**	**100.00%**	**100.00%**

* ELC mapping as per Lee *et al.,* 1998

4.5.2.2 Vascular plants

4.5.2.2.1 Species-at-Risk plants

Two Species at Risk plants were identified in the PSA: Black Ash *(Fraxinus nigra*) and Butternut (*Juglans cinerea*). Both are designated Endangered in Ontario. Butternut is also designated Endangered in Canada and has a provincial S-rank of S2. Field studies documented four occurrences of Black Ash and one Butternut occurrence within the PSA. Both species receive habitat protection under the provincial Endangered Species Act, 2007. Neither species is considered regionally or locally rare.

An additional two species documented have a provincial S-rank of S1-S3 indicating they are provincially vulnerable, though they do not receive habitat protection under the Endangered Species Act, 2007. Cup Plant (*Silphium perfoliatum*) and Ohio Buckeye (*Aesculus glabra*) are ranked S2 and S1, respectively. Neither species is regionally or locally rare. One occurrence of Ohio Buckeye was documented, and five occurrences of Cup Plant were documented. It should be noted that all Cup Plant observations were noted to be planted or garden escapees and not natural occurrences. The Ohio Buckeye was also likely planted or a garden escapee.

Species at Risk occurrences are presented on Map TE-3. It should be noted that species locations have been obscured and names have not been provided on the map to protect species that may be threatened by poaching or other human conflict. A complete vascular plant list is provided in Appendix F1.

4.5.2.2.2 Regionally and locally significant plants

A total of 27 regionally and locally significant plant species were recorded in the PSA as shown in Table 4.57.

Table 4.57: Regionally and locally significant plant species documented in the Primary Study Area, 2022 and 2023

Scientific Name	Common Name	City of Guelph (2012)	Wellington County (2009)	Number of Records
Acer nigrum	Black Maple	LS	---	1
Andropogon gerardi	Big Bluestem	---	R1	3
Carex gracilescens	Slender Loose-flowered Sedge	LS	R1	10
Carex jamesii	James' Sedge	LS	R1	1
Carex lupulina	Hop Sedge	LS	R3	3
Carex rostrata	Swollen Beaked Sedge	---	R1	1
Carex sychnocephala	Many-headed Sedge	LS	---	3
Carya ovata	Shagbark Hickory	LS	R1	1
Celtis occidentalis	Common Hackberry	LS	---	4
Chrysosplenium americanum	American Golden-saxifrage	LS	R1	1
Cornus rugosa	Round-leaved Dogwood	LS	R1	1
Equisetum palustre	Marsh Horsetail	LS	R1	1
Equisetum variegatum	Variegated Scouring-rush	LS	---	1
Eutrochium purpureum	Purple Joe Pye Weed	LS	R1	1
Impatiens pallida	Pale Jewelweed	LS	R1	1
Juncus torreyi	Torrey's Rush	---	R1	3
Panicum virgatum	Old Switch Panicgrass	---	R1	1
Pilea fontana	Lesser Clearweed	LS	---	1
Pilea pumila	Dwarf Clearweed	LS	R1	4
Polymnia canadensis	White-flowered Leafcup	LS	R1	1
Prunus nigra	Canada Plum	---	R1	2
Rhus aromatica	Fragrant Sumac	LS	R1	1
Rudbeckia laciniata	Cut-leaved Coneflower	LS	---	2
Sagittaria cuneata	Northern Arrowhead	LS	---	1

Scientific Name	Common Name	City of Guelph (2012)	Wellington County (2009)	Number of Records
Scirpus cyperinus	Common Woolly Bulrush	---	R3	2
Sorbus americana	American Mountain-ash	LS	R1	1
Zizia aurea	Golden Alexanders	LS	R1	1

Regionally and locally significant species occurrences are presented on Map TE-4. A complete vascular plant list is provided in Appendix F1.

4.5.2.2.3 Other plants and plant habitat

A total of 433 plant species were documented within the PSA during 2022 and 2023 field studies. An additional 89 plants were identified only to genus level due to a lack of identifiable traits at the time of assessment. Of the plants identified to species level, 68 per cent are native and 32 per cent are non-native.

Refer to Appendix F1 for a complete vascular plant list and plant list by ELC polygon.

4.5.2.3 Wetlands

Wetlands (as identified by ELC) within the PSA comprise approximately 9.1 per cent land cover (Table 3). Deciduous Swamp and Thicket Swamp comprise over half the wetland cover (5.1 per cent land cover) with large blocks of habitat located in the Guelph Northeast Wetland Complex (west of Eastview Park), and south of York Road on the Former Reformatory Lands; Thicket Swamp is also fairly common along Watson Creek (part of the Clythe Creek Wetland Complex). Meadow Marsh, Shallow Marsh, Mixed Swamp and Coniferous Swamp comprising the remaining 4 per cent. Meadow Marsh and Shallow Marsh communities are present at the confluence of Clythe and Watson Creek, on the Former Reformatory Lands and at Grange Hill Park. Mixed Swamp is largely present at Grange Hill Park, while pockets of Coniferous Swamp are present in the Guelph Northeast Wetland Complex (west of Eastview Park), east of Severn Drive, and along Clythe Creek north of York Road.

A total of 18 wetland features are identified as Provincially Significant Wetland (PSW) and one is designated as Other Wetland as defined in the City's Official Plan NHS designations (Map TE-4.1). The remaining wetlands in the PSA do not meet the City's NHS designation criteria. Further details on wetlands comprising the NHS are presented in section 6.4.3, Map TE-4.1 and Appendix F-4.1.

4.5.2.4 Wildlife species at risk (SAR)

Species at risk (SAR) wildlife include species designated as Endangered, Threatened or Special Concern at the federal or provincial level. Endangered and Threatened species receive habitat protection under the provincial Endangered Species Act and/or the federal Species at Risk Act (Section 3.1 and 3.2). Special concern and species with an S-rank of S1-S3 are addressed in the Province's Significant Wildlife Habitat provisions outlined in the 2024 PPS under the "special concern and rare species" category. A total of seven SAR and S1-S3 species were observed in the PSA, summarized in Table 4.58.

Table 4.58: Numbers of provincially significant wildlife species observations in the Primary Study Area

Provincial status	Number of species	Number of occurrences
endangered or threatened	3	24
special concern or provincially ranked S1, S2 or S3	4	63
Total	**7**	**87**

4.5.2.4.1 Reptiles and amphibians

Two SAR turtles were recorded within the PSA: Midland Painted Turtle (*Chrysemys picta marginata*) and Snapping Turtle (*Chelydra serpentina*) are both designated Special Concern under *SARA* (2002). Snapping Turtle is also designated Special Concern provincially. Both species have a provincial S-rank of S4 (NHIC, 2021), indicating that provincial populations are "apparently secure".

SAR occurrences are presented on Map TE-4.

4.5.2.4.2 Birds

Of the 68 native breeding species documented within the PSA, four are designated SAR:

- Bank Swallow (*Riparia riparia*)[8] – provincially and federally threatened
- Barn Swallow (*Hirundo rustica*) – provincially and federally special concern
- Eastern Wood-Pewee (*Contopus virens)* – provincially and federally special concern
- Eastern Meadowlark (*Sturnella magna*) – provincially and federally threatened

Bank Swallow was detected on two separate occasions across both survey years, with two individuals observed in each instance. On one of these occasions the birds were foraging over an open field and were recorded as 'Observed' only (no breeding evidence). The second observation was made at the old city waste disposal property north of Stone Road East; due to proximity to potentially suitable habitat (i.e. gravel and dirt mounds), these individuals were recorded as 'possible' breeders.

Ten individual records were documented of Barn Swallow across both survey years. In every instance this species was documented as 'observed' only, with individuals observed foraging

[8] No breeding evidence detected.

over stormwater management facilities or high over open fields. This species was not documented as breeding within the PSA.

Singing Eastern Wood-Pewee were recorded on 13 occasions across both years, primarily documented in wooded areas and occasionally in city parks, with several presumed territories indicating 'probable' breeding (OBBA, 2021).

Singing Eastern Meadowlark were recorded on 15 occasions, with the records concentrated at the Pollinator Park (Former Eastview Landfill) and the Former Reformatory Lands south of York Road. Presumed territories indicated 'Probable' breeding (OBBA, 2021) for this species.

SAR occurrences are presented on Map TE-4.

4.5.2.4.3 Mammals (Bats)

One SAR mammal was documented in the PSA during 2022 field studies. Though targeted bat acoustic surveys were not undertaken as part of this study, one Little Brown Myotis (*Myotis lucifugus*) was documented incidentally during a nocturnal amphibian call survey at station 1.13 using an Echo Meter Touch Pro bat acoustic heterodyne unit. This species is endangered provincially and federally, due to recent population decline associated with white nose syndrome.

Habitat for Little Brown Myotis and other SAR bats is present throughout the PSA, particularly in deciduous or mixed forest and swamp habitat close to water. Bat snag density plot surveys identified high quality roosting habitat (defined by more than 10 snags per hectare) at eight woodland features within the PSA (Appendix F-4.5 and Map TE-4.5-3 features 19, 27, 28, 32, 33, 34, 36, 37).

SAR observations are presented on Map TE-4.

4.5.2.5 Wildlife: Regionally and locally significant species

Regionally and locally significant species were documented based on the Wellington County local rarity status (Dougan, 2009). A total of 10 regionally and locally rare species (34 occurrences) were observed in the PSA, including one amphibian and nine birds summarized below (Appendix F-2).

4.5.2.5.1 Reptiles and amphibians

One regionally/locally rare species, American Bullfrog (*Lithobates catesbeianus*), was documented within the PSA. This species was identified at four monitoring stations: 1.05, 1.16, 2.01 and 2.06 (Map TE-2 and TE-3). This species requires large, permanent water to breed and overwinter.

4.5.2.5.2 Birds

Nine bird species documented are regionally and locally rare, including seven native breeding species (Wellington County, 2009): Common Raven (*Corvus corax*), Great Blue Heron (*Ardea*

Herodias), Orchard Oriole (*Icterus spurius*), Osprey (*Pandion haliaetus)*, Red-bellied Woodpecker (*Melanerpes carolinus*), Ring-billed Gull (*Larus delawarensis)* and Sora (*Porzana carolina*).

Regionally and locally significant species occurrences are presented on Map TE-4 and Appendix F-2.

4.5.2.5.3 Mammals

None of the mammal species documented in the PSA are regionally or locally significant (Wellington County, 2009).

4.5.2.6 Wildlife: Other findings

4.5.2.6.1 Road movement and mortality

Across all targeted amphibian movement and mortality surveys in 2023, the following anurans were observed migrating across roads or deceased:

- Green Frog (*Lithobates clamitans*) – 2 alive
- Northern Leopard Frog *(Lithobates pipiens*) – 9 dead on road, 1 injured, 5 alive

Observations of migrating and deceased anurans were heavily concentrated along Watson Parkway North, north of Grange Road and east of Grange Road Park.

Anurans were also found crossing or deceased in smaller numbers along Watson Parkway north of Eastview Road; Watson Road north of York Road; and Fleming Road.

No salamanders were observed during these surveys.

4.5.2.6.2 Winter wildlife

A total of 17 mammalian species (189 individuals) were documented during 2022 and 2023 fieldwork. Except for one species, all mammals have a provincial conservation status (S-rank) of either S4 or S5 by the Natural Heritage Information Centre (NHIC, 2024), which indicates that their provincial populations are “apparently secure” or “secure”, respectively. Little Brown Myotis has an S-rank of S3 indicating its population is “vulnerable”.

The most commonly detected mammals were:

- Coyote (*Canis latrans*) - 42 records
- Eastern Cottontail (*Sylvilagus floridanus*) – 41 records
- Red Squirrel (*Tamiasciurus hudsonicus*) – 27 records
- Eastern Gray Squirrel (*Sciurus carolinensis*) – 21 records
- Northern Raccoon (*Procyon lotor*) – 11 records

The majority of these observations comprised detection of fresh tracks in the snow, but also direct observation of animals, their scat, especially Coyote and Red Fox *(Vulpes vulpes*). Four mammal dens were also recorded, belonging to American Mink (*Mustela vison*), Coyote, and Red Fox (*Vulpes vulpes*).

During winter wildlife surveys, a number of avian species were documented including Red-tailed Hawk (*Buteo jamaicensis*), Ruffed Grouse (*Bonasa umbellus*), Canada Goose (*Branta canadensis*) and Mallard (*Anas platyrhynchos*).

A complete list of wildlife documented in the PSA can be found in Appendix F-2.

4.5.3 Summary of terrestrial ecology characterization

Land cover within the PSA is largely comprised of anthropogenic, cultural, and wetland communities which collectively comprise approximately 94 per cent of the land base. The remaining six per cent consists of forest, aquatic, agricultural and plantation communities as shown in Table 4.59.

Table 4.59: Summary of Ecological Land Classification (ELC) landcover in the Primary Study Area

ELC Landcover	Area (ha) within PSA	Per cent Cover within PSA
Anthropogenic	845.82	70.64%
Cultural	173.30	14.47%
Wetland	108.91	9.10%
Forest	28.55	2.38%
Aquatic	16.60	1.39%
Agricultural	12.31	1.03%
Plantation	11.84	0.99%
Grand Total	**1197.32**	**100.00%**

As summarized in Table 4.60, field studies within the PSA over 2022 and 2023 documented 108 wildlife species (3263 occurrences) and 433 vascular plant species. A total of nine SAR and 37 locally significant species were observed. More details are available in Appendix F-1 and F-2.

Table 4.60: Summary of species occurrences documented by study team in the Primary Study Area, 2022 and 2023

Species Group	Number of Occurrences	Number of Species	Number of Species at Risk (including Special Concern)	Number of Regionally/Locally Significant Species
Birds	2272	79	4	9
Amphibians	603	7	0	1
Reptiles	194	3	2	0
Mammals	192	17	1	0
Dragonflies	2	2	0	0
Vascular plants	n/a	433	2	27
Grand Total	**3263**	**541**	**9**	**37**

Note: Refer to Appendix F-1 and F-2 for complete wildlife and vascular plant species list.

5 Integrated subwatershed characterization: 2024

This section builds on the discipline-specific assessments and findings (Section 4) for the Clythe Creek subwatershed to provide a summary of the integrated characterization of the natural features and their hydrologic, hydrogeologic and ecological form and functions based on existing (2024) conditions. This integration allows for a more fulsome understanding of how the components within the natural heritage and water resource systems relate to, and interact with, each other across the PSA and SSA spatial frameworks.

This integrated characterization serves to:

- validate or confirm the findings of the respective disciplines
- define the functions, attributes and interdependencies of various system components
- provide a technical foundation for the identification of environmental constraints, management opportunities and monitoring needs in the context of planned future land uses and other stressors, including climate change.

This integration also provides a technical basis for the identification and mapping of a preliminary water resource system (WRS) in the Clythe Creek subwatershed, and for undertaking a preliminary update of the natural heritage system (NHS) mapping in this part of the City, that complies with the established and approved designation criteria in the City's current Official Plan.

The preliminary WRS and NHS for the Clythe Creek subwatershed are presented in this Phase 1 Characterization Report. Final recommended WRS and NHS components and mapping will be provided in the Impact Assessment and Management Report to be developed over 2025, which will be refined based on feedback on integrated management opportunities (e.g., additional ecological linkages, restoration areas and wildlife crossings).

5.1 An integrated approach

Four "categories" of natural heritage and water resource components, as listed below, are considered foundational elements of an integrated approach.

The NHS and WRS components and sensitivities considered include those elements identified in the City's and County's Official Plans and expand on some of these components to capture system sensitivities and inform the principles of integration (outlined in Section 5.2).

Many of these components are overlapping, which is intentional and inherently demonstrates the integrated elements of the environmental systems.

Category 1: Natural heritage, including NHS components

- presence of Significant Natural Areas and Natural Areas in the PSA, and of Core Greenlands and Greenlands in the SSA;

- existing and potential ecological linkages and corridors, including presence of watercourses and confirmed HDF;
- presence and extent of riparian corridor vegetation;
- presence and type of fish habitat, including consideration of benthic invertebrates; and
- groundwater influence on sustainability of habitats and functions (e.g., presence of springs and seeps, presence of cool and coldwater fish habitat).

Category 2: Surface water, including some NHS and WRS components

- local catchment area (size and current land uses);
- presence of watercourses, and their stability, and confirmed HDF;
- creek system presence of baseflow – intermittent or permanent;
- reach-specific groundwater influence (e.g., volumetric discharge);
- floodplain – flood storage, flood conveyance and bankfull/riparian flood flows;
- erosion hazards and sediment transport; and
- surface water quality, including temperature regimes.

Category 3: Groundwater, including some WRS components

- Significant Groundwater Recharge Areas (SGRAs) from a natural environment perspective, including rate of infiltration/recharge;
- significant groundwater discharge areas from a natural environment perspective, including seeps, springs, wetlands and watercourses (i.e., key hydrologic features); and
- quantity of groundwater flux.

Category 4: Groundwater, including some WRS components

- Wellhead Protection Areas (WHPA), including rate of infiltration/recharge:
    - zone of well influence-water quantity WHPA (WHPA-Q);
    - capture zone and water quality WHPAs (WHPA-A, B, C, D);
    - overlap or cumulative demands from multiple wells;
- Highly Vulnerable Aquifer (HVA) areas and high vulnerability zones; and
- changes in recharge conditions outside of the subwatershed.

Most of these components (i.e., categories 1, 2 and 3) focus on functions from a natural environment perspective, however category 4 intentionally focuses on groundwater resource components from a human use/water supply perspective. This approach is both technically appropriate and required from a planning perspective for the SWSU, since it is ultimately the same groundwater resource system that Guelph relies on for water supply, and that which sustains many of the creeks and wetlands in the subwatershed.

Notably, the City's definition of "water resource system" is different from the Province's in that it explicitly introduces the human use aspect and is defined as: "A system consisting of groundwater features and areas and surface water features, and hydrologic functions, which provide the water resources necessary to sustain healthy aquatic and terrestrial ecosystems and human water consumption".

The integrated approach has focused primarily on the water resources in the subwatershed. This is, in large part, because the County of Wellington and the City of Guelph already have well-established approaches and criteria for the identification of terrestrial NHS components, along with supporting policies and guidelines (as described in Section 3.3.2 and 3.3.3 respectively). The identification of WRS components, which is now required by the Province (as outlined in Section 3.2.1) in the latest PPS (MMAH, 2024), is however being undertaken for the first time in the County and the City as part of the SWSU.

The following sub-sections provide further insights regarding these functional considerations, which have been used to develop principles of integration (as outlined in Section 5.2) and apply constraint rankings to the watercourses in the subwatershed (as outlined in Section 5.3) which will inform management considerations in the next study phases.

5.1.1 Methods for integrated surface water resource assessment

Watercourses and HDFs form an intricate surface water network that primarily conveys water and sediment but also provides functional processes which drive the ecological health of riparian and aquatic systems including direct and indirect habitat, linkages, thermal regime and water quality. The definitions for watercourses and HDFs applied in the Clythe Creek SWS update have been outlined in Section 5.3.1.

The integration principles outlined in the preceding section have been applied through this initial Phase 1 assessment to develop a reach-based constraint ranking within the PSA. Implications of the constraint assessment will be realized through Phase 2 of the SWS where management of these drainage features requires integration between each discipline to determine current function, and future requirements for protection, mitigation, and/or enhancement at the reach and site-specific scales, and future study requirements. The following section provides details on the approach and results of the constraint ranking assessment for each reach in Phase 1.

This approach, as applied to the Clythe Creek subwatershed, has resulted in the following outcomes:

Preliminary watercourse constraint rankings

An integration of key characteristics and functions, for each discipline has been applied in the development of a preliminary constraint ranking for watercourses within the PSA. Each watercourse was assigned a ranking of high, medium or low, on a reach-by-reach basis, based upon various environmental factors and considerations, with individual rankings per discipline.

Table 5.1 provides an overview of the criteria per discipline for each ranking.

A preliminary net constraint ranking for each reach was established, conservatively, by using the most limiting constraint observed for the feature, which may be suggested by all, few, or even just one discipline. The findings of the assessment will provide preliminary direction regarding the management opportunities and requirements for each watercourse feature within the PSA. The findings of the assessment will ultimately be reviewed further through the Phase 2 Impact Assessment and then refined to provide guidance regarding the management opportunities and requirements for each of the surface drainage features within the PSA.

This approach, as applied to the Clythe Creek subwatershed, has resulted in the following outcomes, which are presented in Map FG-5:

- Watercourses are either a high constraint (red) stream (mapped with solid red linework) or a medium constraint stream (mapped with solid blue linework). If features were evaluated as low constraint, they would be identified for re-consideration as an HDF rather than a watercourse. However, the low constraint would not be mapped as a watercourse, and the feature identified as a potential HDF.
- There is an opportunity to add another constraint ranking for management purposes where a watercourse may have a high constraint but presents an opportunity for enhancement (e.g. realign away from road, enhance floodplain for conveyance/storage). This will be completed through Phase 2 of the SWS and identified as an opportunity.

Notably, headwater drainage features (HDF) have only been identified and mapped as purple features, or purple-dashed features where piped. Some HDF have been highlighted for confirmation as an HDF or watercourse given the current definition of a watercourse in the Conservation Authorities Act, and some channel definition being observed. The current definition of a watercourse per O. Reg, 41/24 also includes the flow condition of “regularly or continuously” occurring. Therefore, there is a need to confirm feature types in some instances, with consideration of hydrological function. Notably, field surveys will be required as part of area-specific or site-specific studies to be completed in the future to confirm the feature type and develop a fulsome characterization based on seasonal observations (e.g. flow condition; fish habitat), for those features which require feature confirmation.

Application of integrated constraint rankings in impact assessment and management

Feature constraints will be considered in the subsequent impact assessment and identification of management recommendations to be completed as part of the next phase of the SWSU.

Typical management strategies for watercourses are outlined below and will be further assessed and detailed as part of the next phase of the SWSU:

- High Constraint - Watercourse and corridor to be protected in current form and location with applicable regulatory hazard setbacks and ecological buffers. Minor modification through rehabilitation/enhancement may be acceptable in select locations where it is a benefit to the system, or to allow for critical infrastructure, or mitigation of site-specific erosion issues or risks.

- Medium Constraint – Watercourse and corridor to remain open and may stay in current location or may be realigned to allow for critical infrastructure or where restoration and enhancement is included in natural channel designs to support the NHS. Applicable regulatory hazard setbacks apply; ecological buffers may apply[9].

Options to be explored in the next phases of the SWSU (i.e., Impact Assessment and Management Report) may include: do nothing, enhance in place, relocate/realign and enhance. Notably major realignment is not anticipated for much of the PSA, with the exception of potential realignments of Clythe Creek away from York Road where possible, and upper Hadati Creek to restore current channelized features.

The above constraint rankings and management recommendations that are developed through Phases 2 and 3 must adhere to City Official Plan Policies (2024), including minimum required buffers, GRCA regulation, and other agency requirements (e.g. DFO, MNR). In general, alterations to watercourses will require permitting and approval from GRCA, the provincial government and/or the federal government as applicable. As recommendations are developed through Phases 2 and 3, specific known requirements may be identified, while other requirements may need to be confirmed prior to any detailed design advancement.

Future work through subsequent planning stages to confirm these features and evaluate them following the TRCA and CVC (2014) guideline, will fully characterize each feature and their functions and then allow for management recommendations to be mapped similarly to the constraint rankings presented here for watercourses. At the scoped level of study applied in this SWS, HDFs have only been identified and mapped, and are not subject to detailed site investigations or study integration, however, if there are critical issues around HDFs (e.g. terrestrial features and/or corridors, groundwater interactions) that may be identified, constraints and management will be addressed through the lens of the appropriate policy framework. This will be advanced through Phase 2 to capture such “red-flags” for each feature, where possible and identify constraints and management recommendations, appropriately.

Table 5.2 presents the preliminary outcomes of the ranking process which are also illustrated in Map FG-5. These outcomes are precautionary at the characterization stage and expected to be refined in the subsequent phases of the SWSU.

[9] For example, in the City of Guelph’s current Official Plan, permanent or intermittent streams receive a minimum 15 m buffer. Cold and cool water fish habitat streams receive a minimum 30 m buffer (see Table 8.1).

Table 5.1: Watercourse constraint ranking technical considerations and basis for rankings

Stream Characteristics	High Ranking	Medium Ranking	Low Ranking
Surface Water	• Drainage area is >125 ha • Stream power, see below HIGH: If both criteria are rated “High”, the Flow Assessment Ranking is “High”.	• Drainage area is 50 ha to 125 ha • Stream power, see below MEDIUM. If one criterion is “High” and the other is “Low” or “Medium”, the Flow Assessment Ranking is “Medium”.	• Drainage Area is <50 ha • Stream power, see below LOW: If one criterion is rated “Low” and the other is rated “Medium”, the Flow Assessment Ranking is “Low”
Groundwater	Cool/Coldwater and perennial flow and groundwater discharge	Cool Water and intermittent flow and/or groundwater discharge	Warmwater and some discharge
Fluvial Geomorphology	These corridors contain a defined active channel with well-developed channel morphology (i.e., riffle-pool), material sorting, floodplain development, and/or a well-defined valley.	These reaches have well-defined morphology (defined bed and banks, evidence of erosion/sedimentation, and sorted substrate). In many cases, these reaches are presently exhibiting evidence of geomorphic instability or environmental degradation due to historic modifications and land use practices. Medium constraint streams have reach scale potential for rehabilitation and enhancement.	These reaches provide a function to downstream receiving watercourses but lack feature definition and signs of regular or intermittent flow.
Terrestrial Habitat	Within the PSA, occur within Significant Natural Areas or confirmed Ecological Linkages Within the SSA, occur within Core Greenlands (in whole or in part).	Within the PSA, occur within Natural Areas (Other Wetlands, Cultural Woodlands) Within the SSA, occur within Non-core Greenlands (in whole or in part).	Within the PSA, located outside of the Preliminary NHS; do not provide a corridor connection between Significant Natural Areas or Natural Areas. Within the SSA, located outside of Core Greenlands or Non-core Greenlands.

Stream Characteristics	High Ranking	Medium Ranking	Low Ranking
Aquatic Habitat	Typically exhibit a defined channel (with an obvious bed and bank), as well as defined channel morphology (e.g., pools and riffles). Often exhibit some degree of groundwater connectivity (at least seasonally) and will often flow strongly through the mid-late spring and into summer. May be associated with a defined top-of-bank or valley corridor. Typically include a well-established riparian vegetation zone. Presence of water in these reaches through long stretches of the year create the opportunity for "permanent" fish habitat and likely offer benthic invertebrate production.	Have a defined channel but may or may not have well-defined valleyland morphology. Typically exhibit intermittent flow that occurs most strongly during spring and may extend into early summer. These reaches typically become dry by a point in June and may re-establish flow later in the year during/following intense summer or fall rain events. Typically, be identified as "seasonal" or "complex contributing" habitat and may often have been altered by historic agricultural practices.	Ephemeral field swales whose primary function is for flow conveyance typically only during limited periods associated with the spring freshet. These reaches are designated as "simple contributing" habitat or "Not Fish Habitat" due to their lack of channel definition and limited flow. These reaches provide no direct habitat for fish or benthic invertebrate production.

Note:

Stream Power Ranking	2-year	25 year	Regional
Low	<5	<.04	<.02
Medium	>5 and <20	>0.4 and <33	>0.2 and <25
High	>20	<33	>25

Table 5.2: Integrated watercourse constraint assessment and preliminary rankings

Reach**	Surface Water	Groundwater	Fluvial Geomorphology	Terrestrial Habitat	Aquatic Habitat	Preliminary Constraint Rankings
CC(1a)	Medium	Medium	Medium	High	High	High
CC(1b)	Medium	Medium	Medium	High	High	High
CC(1c)	Medium	Medium	Medium	High	High	High
CC(1d)	Medium	Medium	Medium	High	High	High
CC(1e)	Medium	Medium	Medium	High	High	High
CC(1f)	Medium	Medium	Medium	High	High	High
CC(2)	Medium	Medium	Medium	High	High	High
CC(3)	Medium	High	Medium	High	High	High
CC(4)	Medium	High	High	High	High	High
CC(5)	Medium	High	High	High	High	High
CC(6)	Medium	High	High	High	High	High
CC(7)	Medium	High	High	High	High	High
CC(8)	Medium	High	High	High	High	High
CC(9a)	Medium	High	High	High	High	High
CC(9b)	Medium	High	High	High	High	High
HC(1a)	High	Medium	Medium	High	High	High
HC(2)	High	Low	High	High	Medium	High
HC(3)	High	Low	High	High	Medium	High
HC(4)	High	Low	Medium	High	Medium	High
HC(5)	High	Low	High	High	Medium	High
HC(6)	High	Low	Medium	High	Medium	High
HC(7)	Medium	Low	Medium	High	Medium	High
HCT(1)	Medium	Low	Medium	High	Medium	High
WC(1a)	Low	Medium	High	High	Medium	High
WC(1b)	Low	Medium	High	High	Medium	High
WC(2a)	Low	Medium	High	High	Medium	High

Reach**	Surface Water	Groundwater	Fluvial Geomorphology	Terrestrial Habitat	Aquatic Habitat	Preliminary Constraint Rankings
WC(2b)	Low	Medium	High	High	Medium	High
WC(3a)	Low	Medium	High	High	Medium	High
WC(3b)	Low	Medium	Medium	High	Medium	High

** CC = Clythe Creek, HC = Hadati Creek and WC = Watson Creek reaches

5.2 Water resource system

The Water Resource System (WRS) consists of groundwater features and areas and surface water features, and hydrologic functions, which provide the water resources necessary to sustain healthy aquatic and terrestrial ecosystems and human water consumption. The City of Guelph builds on the provincial definition provided (see Section 3.2) and defines its WRS as comprising of the following.

- Key Hydrologic Areas means: Significant groundwater recharge areas, highly vulnerable aquifers, and significant surface water contribution areas that are necessary for the ecological and hydrologic integrity of a watershed.
- Key Hydrologic Features means: Permanent streams, intermittent streams, inland lakes and their littoral zones, seepage areas and springs, wetlands, and water supply wells.

The specific sub-components are outlined on a preliminary basis below and shown in Map TE-6.

5.2.1 Key hydrologic areas

For the preliminary WRS, key hydrologic areas have focused on groundwater resource functions and surface water features largely sustained by groundwater contributions. As shown in Map TE-6, these include SGRAs from a natural environment perspective, SGRAs from a human use perspective, and high vulnerability zones based on aquifer assessments.

The updated characterization (2024) refined the understanding of key hydrologic areas and features for groundwater in the PSA and SSA to:

- Groundwater discharge through the shallow groundwater flow system at seeps, wetlands and stream features that support Significant Wildlife Habitat (SWH) and cool/cold-water habitat.
- Recharge deep bedrock aquifers through the more local and regional groundwater flow systems which supply municipal drinking water.
- The water quality in the shallow and deep aquifers, which is tied to the degree of protection afforded to the aquifer by overlying sediments and rock to attenuate contaminants that enter the subsurface (e.g. road salt).

For the groundwater component of the WRS, the key hydrologic areas (groundwater recharge areas), and key hydrologic features (seeps, wetlands, cool/cold water stream reaches and municipal wells) interact with the overall WRS in supporting SWH and current groundwater supply. The following key hydrologic areas, identified as part of the SWSU, are discussed in the subsequent subsections:

- Significant Groundwater Recharge Areas (Map GW-24 to GW-26)
- Capture Zones for Municipal Wells (WHPA-Q)

- Highly Vulnerable Aquifers in PSA (Map GW-8) and Capture Zones (WHPA-A,B,C,D)

5.2.1.1 Significant groundwater recharge areas (SGRAs)

Maps GW-24 through GW-26 and Section 4.1.3 show the detailed location of the SGRAs (key hydrologic areas) and their linkage to the specific SWH discharge features in the PSA and SSA. SGRAs were identified in two ways: from a natural environmental perspective and from a human use perspective, recognizing that there are, or can be, interactions between these two areas and that management in one can influence the other.

- SGRAs – natural environment: groundwater recharge areas which sustain groundwater contribution to groundwater discharge features, including: coolwater and coldwater streams, seepage areas and springs and wetlands (both PSW and other wetlands).
- SGRAs – groundwater recharge areas which sustain groundwater contribution to groundwater features for human use, including: municipal well supply areas (i.e., wellhead protection areas).

5.2.1.2 Highly vulnerable aquifers (HVA)/high vulnerability zones

The Highly Vulnerable Aquifer mapping in Map GW-8 shows the recharge areas that have a higher risk of impacting water quality based on the thickness of material overlying the aquifer and its hydraulic conductivity and the vertical gradients. High Vulnerability Aquifers (HVAs) mapping was completed as part of Source Water Protection Activities in the City of Guelph (LERSPC 2022a). HVAs are aquifers that can be more easily contaminated because the overlying soil layers are thin or permeable and provide little attenuation of contaminants that may enter the groundwater flow system. The HVA mapping shown on TE-6 corresponds with outwash sand areas in the Clythe Creek subwatershed. These sands are the most permeable units in the PSA and SSA and are mostly deposited in the Clythe Creek floodplain. In these areas the depth to bedrock is the thinnest in the PSA and SSA. The combined high permeability and small thickness of the outwash sands overlaying the upper bedrock aquifer results in a high vulnerability designation based on the Source Protection Director Rules (MECP 2021) and City of Guelph Tier Three Risk Assessment (Matrix, 2017).

5.2.2 Key hydrologic features

5.2.2.1 Watercourses and HDF

Watercourses and HDFs represent integrated elements of surface water, groundwater, and ecological systems. The integration of function and form ensures that watercourse systems and their associated erosion hazards are isolated from new development, and that reach-scale management can be determined for watercourses and HDFs to reduce the potential for impacts to the natural environment, protect features and their functions, and mitigate risks from environmental hazards associated with watercourses.

Watercourses and HDFs form an intricate surface water network that primarily conveys water and sediment but also provides functional processes which drive the ecological health of riparian and aquatic systems including direct and indirect habitat, linkages, thermal regime and water quality. Management of these drainage features requires an integrated consideration of form between each discipline to determine current function, and future requirements for protection, mitigation, and/or enhancement at the reach and site-specific scales.

Generally, in the Study Area watercourse features are protected by the municipality (i.e., the City of Guelph[10] in the PSA and the County of Wellington in the SSA) and regulated by the Conservation Authority, while HDFs are not specifically regulated unless they are associated with another protected feature (such as a wetland or significant woodland).

Both watercourses and HDFs can provide important functions, including provision of fish habitat, that must be considered when evaluating impacts from development and identifying management opportunities. Notably, regulation of watercourses may not preclude them from being re-aligned. However, proposed channel realignments must adhere to all applicable environmental regulations and policies (e.g., the Fisheries Act, Conservation Authorities Act, etc. as outlined in Section 2) and are only permitted when studies and related plans are completed to the satisfaction of the applicable review agencies.

As such, there is value in identifying potentially appropriate management opportunities and constraints for different drainage features at the watershed and subwatershed scale. Management constraints and recommendations at the watershed and subwatershed scale can also inform updates to the NHS and future land use planning (e.g., some features may require protection which are not regulated, and other regulated features may be candidates for realignment).

An integration consideration of key characteristics and functions for each discipline can be applied through the development of a watercourse constraint ranking, and through the application of a Headwater Drainage Feature Assessment (e.g., TRCA and CVC, 2014). The former will be completed through the impact assessment phase of the SWSU at the scoped level based on existing data with some minor field confirmation, with recommendations for future study, while the latter cannot be completed in any capacity under the current desktop scope of work, since HDF assessments require seasonally-based field investigations to fully evaluate form and function on a feature-by-feature basis.

Future work through subsequent planning stages will be required to confirm these features and evaluate them following the TRCA and CVC (2014) guidelines which will then allow for management recommendations to be mapped similarly to the constraint rankings presented here for watercourses. At the scoped level, headwater drainage features are only being

[10] In the City of Guelph's Official Plan, permanent and intermittent streams are protected with a minimum ecological buffer of 15 m. There are currently no specific policies for HDF.

identified as HDFs, and are not subject to detailed site investigations or study integration, however, if there are critical issues around HDFs (e.g. terrestrial features and/or corridors) that may be identified, constraint ranking and management will be addressed through the lens of the appropriate policy framework. The fulsome integration will capture any such issues for each feature, where possible, or will confirm the need for future studies.

5.2.2.2 Seepage areas and springs

Mapped as identified by the SWSU team as part of this Phase 1 work based on information from other studies and field studies completed between 2022 and 2024.

5.2.2.3 Wetlands

Identified and mapped as per Section 6.5.3.

5.2.2.4 Water supply wells: municipal, agricultural and domestic

Covered under key hydrologic areas (see Section 6.4.1).

5.3 Preliminary updated Natural Heritage System (NHS)

There is currently an approved NHS in place in the City (i.e., the PSA) and the County (i.e., the SSA), as noted in Section 6.1. One of the key deliverables for this SWSU is to identify an updated NHS in the PSA based on comprehensive desktop and field assessments, and to ensure that linkages to the NHS in the County (i.e., Core Greenlands and Greenlands System) are considered.

The preliminary updated NHS for the subwatershed is shown in Map TE-4.6.

In the SSA, it includes:

- the currently approved Core Greenlands which include, where they are mapped, provincially significant wetlands (PSW), other wetlands confirmed through site-specific study, habitat of endangered or threatened species, fish habitat and hazardous lands (as outlined in Section 3.3.2)
- the currently approved Greenlands which include, where they are mapped, significant wildlife habitat, provincially or regionally significant areas of natural and scientific interest (ANSI), streams and valleylands, significant woodlands, County Environmentally Sensitive Areas, ponds, lakes, and reservoirs (as outlined in Section 3.3.2)

In the PSA, it includes:

- Significant Natural Areas (as defined by City of Guelph Official Plan policy 4.1.1.5) updated based on desktop and field studies completed between 2022 and 2024 comprised of:
    - Significant Areas of Natural and Scientific Interest (ANSI),

    - Habitat of Endangered Species and Threatened Species,
    - Significant Wetlands,
    - Fish Habitat and permanent and intermittent streams,
    - Significant Woodlands,
    - Significant Valleylands,
    - Significant Wildlife Habitat (excluding Ecological Linkages),
    - Minimum or established buffers (where applicable; Table 3.6).
- Natural Areas (as defined by City of Guelph Official Plan policy 4.1.1.5) updated based on desktop and field studies completed between 2022 and 2024, comprised of:
    - Other Wetlands,
    - Cultural Woodlands
    - Established buffers (where applicable)
- Ecological Linkages identified as part of the City's approved NHS, and refined in relation to the Significant Natural Area updates
- Restoration Areas identified as part of the City's approved NHS, and refined in relation to the Significant Natural Area updates
- Wildlife Crossings in locations identified as part of the City's approved NHS

As part of the next study phases, an updated NHS will be put forward that includes

- refinements to updated NHS components in the PSA and SSA, if identified based on feedback
- additional and/or refined Ecological Linkages, Restoration Areas and Wildlife Crossings in the PSA based on an integrated consideration of management options and opportunities, in the context of anticipated land use changes.

The following subsections describe the various sub-components of the preliminary NHS in more detail. These are illustrated on Maps TE-4.1 through TE-4.5.

In the PSA, these NHS components have been identified and mapped in a manner that is consistent with the current approved policies and criteria for the City's NHS, including the application of minimum buffers for certain features (as prescribed in the Official Plan and as per Table 8.1). In the SSA, these components have been mapped based on the most recent approved layers provided by the County.

5.3.1 Significant areas of natural and scientific interest

The PSA contains one regionally significant earth science ANSI (i.e., Guelph Interstadial Site) presented on Map TE-4.1. This ANSI is located in the southwest quadrant of the PSA, west of

Victoria Road S. and north of Elizabeth Street and comprises 2.18 ha (0.18 per cent) of landcover within the PSA.

There are no significant ANSIs in the SSA.

The Guelph Interstadial Site is a regionally significant area within the PSA designated as an Earth Science ANSI because of its geological significance (including the presence of glacial features, paleosols, and fossiliferous sediments). The site provides clear evidence of glacial advance and retreat, along with associated deposits between tills. This evidence was revealed during excavation for the railway.

5.3.2 Habitat of significant species

Locational data for habitat of provincially threatened and endangered species are considered sensitive and are retained by the provincial government. It has not been explicitly mapped as part of the approved NHS but is assumed that these habitats will be largely protected through other components of the NHS or otherwise identified and protected through the required site-specific studies.

Provincially endangered and threatened species detected in the PSA during 2022 and 2023 studies in the PSA include:

- bank swallow
- eastern meadowlark
- little brown myotis
- butternut
- black ash

Additional species observed in the PSA that are designated special concern or S1-S3 include:

- barn swallow
- eastern wood-pewee
- snapping turtle
- midland painted turtle
- ohio buckeye (likely planted/ garden escapee)
- cup plant (likely planted/ garden escapee)

Locally significant species, as identified by Wellington County (2009) and City of Guelph (2012), are presented on Map TE-4.5 and discussed in Section 5.5.2. A total of 37 locally significant species were documented during this study including nine birds, one amphibian and 27 plants (Appendix F6). These assessments were not comprehensive and additional significant species may be documented during additional area or site-specific studies that may be undertaken in the future.

Wildlife field studies were not completed in the SSA and therefore no species at risk or otherwise provincially/regionally/locally significant species were detected. However, area or site-specific wildlife surveys may be required to inform proposed infrastructure projects and/or developments in the SSA in the future.

5.3.3 Significant wetlands and other wetlands

Within the PSA, there are PSW complexes, including the Clythe Creek Wetland complex and the Guelph Northeast Wetland complex.

PSWs within the PSA are presented on Map TE-4.1, including 30 m minimum buffers, as prescribed by the City's Official Plan. The PSW boundaries are reflective of existing provincial mapping and boundary refinements that occurred during field review and verification with GRCA in 2022 and 2023. In addition, wetlands mapped using the ELC system that are at least 0.5 ha with (intermittent or permanent) surface water connections to mapped and confirmed PSW were captured and considered as a single, contiguous wetland area within the PSA, in accordance with the current Provincial guidance (MNR, 2022). These mapping refinements have been submitted to MNR by the City.

Within the PSA, there are 18 distinct PSW features (i.e., polygons). These PSWs comprise approximately 8.8 per cent landcover (105.40 ha) within the PSA, including 99.6% of evaluated wetland cover, and 95.9% of total wetland cover. Deciduous swamp and swamp thicket communities comprise over 60 per cent of PSW land cover within the PSA, with meadow marsh, shallow marsh, mixed swamp and coniferous swamp comprising the remaining 40 per cent (see Appendix F-4.1 for more details).

Within the PSA, there is one Other Wetland that was identified through a site-specific Environmental Impact Study (EIS) (North-South Environmental, 2021) that has been included, with its established 7.5 m buffer on Map TE-4.1. This Other Wetland is 0.03 per cent of the land cover within the PSA and 0.39 per cent of the NHS-designated wetland cover in the PSA (see Appendix F-4.1 for more details).

In the SSA, all wetlands mapped by the GRCA and MNR have been incorporated into the County's mapping. The status of and boundaries of these wetlands may be reviewed and refined by these agencies or by other qualified professionals as additional work is completed in support of proposed infrastructure and/or development projects in the future.

Wetlands in the SSA are primarily associated with the Clythe Creek corridor, although there are other relatively large and some smaller wetlands scattered across the SSA, as can be seen on Map TE-4.1. Within the SSA, PSW comprise 98.6% of total wetland cover.

Almost all of the evaluated wetlands in the subwatershed are PSW (99.18 per cent, 185.49 ha). There are no locally significant wetlands and only a small percentage of Other Wetlands identified, based on the designation criteria of Guelph's Official Plan. Other Wetlands comprise 1.53 ha (0.82 per cent) of all evaluated wetlands in the PSA.

5.3.4 Fish habitat

Fish habitat in the PSA was assessed as part of the SWSU while in the SSA the classification provided by MNR are being applied and carried forward.

Within the PSA there is a total length of 4.20 km of coolwater habitat. Based on the thermal regime analysis using surface water temperature data and fish community sampling completed:

- coolwater habitat is present in Clythe Creek upstream from the outlet of the GID ponds, while the remainder of Clythe Creek from the outlet of the GID ponds to its confluence with the Eramosa River is considered warmwater habitat;
- Watson Creek is considered coolwater habitat; and
- Hadati Creek is considered coolwater habitat from the railway to its confluence with Clythe Creek, and warmwater upstream of the railway (refer to Section 4.4.2.5).

Notably, although a portion of Hadati Creek is considered warmwater due to its intermittent flow regime, MNR classification, and fish community, it is recommended on a preliminary basis at this stage that the entire creek be managed as a coolwater watercourse to minimize impacts to the coolwater reach.

Cool and coldwater fish habitat and associated 30 m minimum buffers, and warmwater fish habitat and associated minimum 15 m buffers in the PSA are presented on Map TE-4.2.

Within the broader SSA, MNR classifies Clythe Creek as coldwater habitat; the Eramosa River is also identified as coldwater by the MNR.

5.3.4.1 Undetermined fish habitat

Undetermined fish habitat and associated minimum 15 m buffers in the PSA are also presented on Map TE-4.2, including all non-piped watercourses and HDFs. These reaches include watercourses that are both permanent and intermittently flowing. Per the City's official plan, intermittent streams, which can occur as a watercourse or HDF (as interpreted) require a minimum buffer of 15 m. These streams, per the OP contain water or are dry at times of the year that are more or less predictable, generally flowing during wet seasons of the year but not the entire year, and where the water table is above the stream bottom during parts of the year.

As noted above, whether or not a particular HDF can support fish habitat will still need to be confirmed through area or site-specific studies to be completed in support of planned infrastructure and/or development in the future. This work should apply the Evaluation, Classification and Management of Headwater Drainage Features Guidelines (TRCA and CVC, 2014) and the HDF OSAP module for guidance and, where appropriate, include electrofishing surveys to determine if seasonal fish habitat is present.

Currently there are 7.91 km of undetermined fish habitat mapped within the PSA. Significant woodlands and cultural woodlands

Map TE-4.3 shows all known significant woodlands in the subwatershed, as well as one cultural woodland in the PSA.

In the PSA, significant woodlands, including the minimum 10 m buffers from the drip line prescribed in the City's Official Plan, are shown. The woodland boundaries are reflective of the field-verified community boundaries and/or remote sensing mapping of the following ELC system community classes:

- FOD (deciduous forest)
- FOM (mixed forest)
- FOC (coniferous forest)
- SWD (deciduous swamp)
- SWM (mixed swamp)
- SWC (coniferous swamp)
- CUP (cultural plantation) and/or CUW (cultural woodland) where contiguous (i.e., within 20 m) of one or more of the communities listed above and where the feature meets the area requirement (i.e., at least 1 ha)

Significant Woodlands comprise approximately 87.33 ha (7.29% cover) within the PSA.

Within the PSA, there is one cultural woodland which was confirmed as part of the Clythe Water Treatment Plant EIS (NRSI, 2022) and has been mapped with its established 10 m buffer (Map TE-4.4). This woodland is 1.57 ha in size and consists of mid-age native conifers including white pine (*Pinus strobus*) and red pine (*Pinus resinosa*).

The significant woodlands in the SSA are mapped as per information provided by the County.

Woodlands, including forest, treed swamp, cultural woodland and plantation collectively comprise approximately 9.67 per cent of landcover (236.95 ha) within the subwatershed (i.e., the PSA and SSA). Woodland types are predominantly cultural woodlands with deciduous swamp, mixed forest, and deciduous forest each comprising over one per cent cover. The remaining woodland types each make up 0.5 per cent or less total cover across the subwatershed.

The areas for the respective types of woodlands across the subwatershed are summarized in Table 5.3.

Table 5.3: Summary of woodland types and areas within the subwatershed

Woodland Type (ELC)	Sum of Area (ha)	Per cent cover of SWS	Per cent of woodland cover within SWS
Cultural Woodland/Cultural Savannah	75.90	3.10%	32.03%
Deciduous Swamp	38.06	1.55%	16.06%
Mixed Forest	37.96	1.55%	16.02%

Woodland Type (ELC)	Sum of Area (ha)	Per cent cover of SWS	Per cent of woodland cover within SWS
Deciduous Forest	35.80	1.46%	15.11%
Coniferous Forest	12.29	0.50%	5.19%
Plantation	11.84	0.48%	5.00%
Cultural Woodland	10.79	0.44%	4.55%
Mixed Swamp	8.58	0.35%	3.62%
Coniferous Swamp	5.75	0.23%	2.43%
Total Woodland Cover	**236.95**	**9.67%**	**100.00%**
Total SWS Area	**2540.33**	**---**	**---**

A more detailed summary of significant and cultural woodlands is presented in Appendix F-4.3.

5.3.5 Significant valleylands

Significant valleylands in the subwatershed are presented on Map TE-4.4.

In the PSA, significant valleylands have been mapped based on the outer extent of the 100-year Regulatory floodline or current Regulatory floodline (as identified by the SWSU team). Where flood spill areas were identified (i.e., valley does not contain Regulatory flood), significant valleylands were mapped by connecting the linework along the shortest path between disconnected floodlines; this is a common approach that has been taken in similar municipal subwatershed studies. Similarly, where floodlines were not well-defined (such as a portion of the GID lands), the significant valleylands were defined by following the watercourse or waterbody edge.

As defined in the City's Official Plan, relatively undisturbed portions of the Speed and Eramosa Rivers are also included in the significant valleylands designation, as identified and confirmed by the City. As such, the lower portion of the GID lands adjacent to the Eramosa River have also been captured as significant valleylands with mapping based on the floodlines developed as part of this study and approved by GRCA (see FMP sheets 1 through 6).

Significant valleylands comprise a total of 42.18 ha (3.52 per cent) of land within the PSA.

In the SSA, significant valleylands were mapped based on available data from GRCA including the outer extent of the GRCA Regulatory floodplain, slope valley and slope erosion allowance.

5.3.6 Significant wildlife habitat and other significant habitat

The SWH Criteria for Ecoregion 6E (MNR, 2015) provide criteria for the 38 categories of candidate and confirmed SWH based on ELC habitat and indicator species presence and abundance thresholds.

Deer wintering areas and waterfowl overwintering areas are mapped by the MNR. An online query was completed using LIO (Land Information Ontario) for the PSA and SSA and there is no mapped SWH for deer wintering or waterfowl overwintering areas within the PSA.

Within the PSA, confirmed SWH is included in the NHS and is presented as a consolidated layer on Map TE-4.5. Minimum buffers for confirmed SWH should be established through site-specific studies (i.e. EIS or EA). A detailed summary of candidate and confirmed SWH by habitat category within the PSA is provided in Appendix F-4.4 and presented on Map TE-4.5.1 through Map TE4.5.18. Areas for each confirmed SWH type are provided in Table 5.4.

Within the PSA, there is confirmed SWH for the following habitat categories (MNR, 2015):

- amphibian breeding habitat (wetland)
- amphibian breeding habitat (woodland)
- bat maternity colonies
- marsh breeding bird habitat
- seeps and springs
- special concern and rare wildlife
- turtle nesting habitat
- turtle wintering areas
- terrestrial crayfish habitat

Table 5.4: Summary of confirmed significant wildlife habitat (SWH) within the Primary Study Area

Confirmed SWH habitat category	Number of Features	Area (ha)	Per cent Cover within PSA
Amphibian Breeding Habitat Wetland	3	12.42	1.04%
Amphibian Breeding Habitat Woodland	2	15.97	1.33%
Bat Maternity Colonies	1	0.42	0.03%
Marsh Breeding Bird Habitat	1	0.13	0.01%
Seeps and Springs	2	1.60	0.13%
Special Concern and Rare Wildlife	16	50.25	4.20%
Terrestrial Crayfish	2	34.26	2.86%
Turtle Nesting Habitat	4	3.98	0.33%
Turtle Wintering Areas	6	13.25	1.11%
Grand Total	**37**	**132.27**	**11.05%**

The following SWH categories are considered candidate SWH in the PSA based on presence of suitable habitat indicators such as ELC and size and proximity criteria per MNR's Criteria Schedule for Ecoregion 6E (2015):

- amphibian breeding habitat wetland

- amphibian breeding habitat woodland
- amphibian movement corridors
- bald eagle and osprey nesting foraging and perching
- bat maternity colonies
- colonial nesting bird breeding habitat trees and shrubs
- marsh breeding bird habitat
- open country breeding birds
- seeps and springs
- terrestrial crayfish
- turtle nesting habitat
- turtle wintering areas
- waterfowl nesting area
- waterfowl stopover and staging aquatic
- waterfowl stopover and staging terrestrial
- woodland area sensitive bird breeding habitat

Due to the relatively large scale of this study, it should be noted that there may be additional confirmed and candidate SWH within the PSA identified through future area or site-specific studies within the PSA, related to future planning processes. Seeps and springs in particular are known to be prevalent within the subwatershed and should be assessed where lands slope towards watercourses, creeks, streams and ponds.

The only SWH mapping available in the SSA is deer yarding areas (White-tailed Deer Wintering Area (Stratum 2)) which have been confirmed and mapped by MNR on the far eastern boundary of the SSA (Map TE4.5-18).

5.3.7 Ecological linkages and wildlife crossings

The County has specific identification and designation criteria for ecological linkages or corridors, but primary existing ecological connectivity in the SSA would be expected to be captured in large part by the various significant wetlands, significant woodlands and significant valleylands associated with Clythe Creek running through the SSA.

The City has specific policies and designations for ecological linkages (Section 3.3.3), and the PSA includes a few areas already designated as such, as presented on Map TE-4.6. Designated ecological linkages account for 2.51 ha of land (Appendix F-4.5) but are expected to be refined in relation to the other NHS features as part of the next study phases.

The City also has policies and criteria for wildlife crossings, identified as:

- “Confirmed locations where deer and amphibians cross roadways within or abutting City boundaries, and
- Areas where habitat is found on both sides of the roadway where wildlife is likely to cross”.

Four wildlife crossings are identified in the PSA in the City’s approved Official Plan, as shown on Map TE-4.6 and outlined in Table 5.5 below.

Table 5.5: Summary of wildlife crossings within the PSA

Wildlife crossing ID (Map TE-4.6)	Location	Status
A	Eastview near Watson	Amphibian crossing - confirmed and implemented
B	Watson near Grange	Amphibian crossing - confirmed and implemented
C	Watson near York	Amphibian crossing - confirmed and implemented
D	York near Watson	Other wildlife crossing opportunity – confirmed, not yet implemented

Wildlife crossings are not land use designations but rather triggers for the need to assess and, where appropriate and feasible, implement mitigation measures to facilitate safe wildlife passage across roads in the City.

Ecological linkages and wildlife crossings are expected to be further refined during the next phases of study to ensure connectivity within the NHS.

5.3.8 Currently designated restoration areas

Restoration Areas are not identified in the SSA but in the PSA are included as one of the City’s Significant Natural Areas land use designations. Restoration Areas in the City are generally identified on lands that are already or, through the planning process will be dedicated to public ownership and support uses where restoration may be prioritized. Designation criteria for identifying restoration areas include:

- Existing and new SWM areas abutting the NHS
- Areas within City parkland (including portions of the Eastview Community Park)
- GRCA lands which are not intended for active uses (e.g., open spaces not identified for camping or related facilities)
- Isolated gaps within the NHS (which may be on private lands but are not considered “developable”)

Currently designated restoration areas comprise 62.85 ha (5.25 per cent) of the PSA. Restoration areas are presented on Map TE-4.6 and summarized in Table 5.6 below. Additional restoration areas may be identified as part of the next phases of the SWSU.

Table 5.6: Summary of restoration areas already established within the PSA

Restoration area (Map TE-4.6)	Location	Size (ha)
1	Fletcher	0.14
2	Hyland	0.95
3	Eastview	45.20
4	Watson at Grange	1.87
5	Severn near Norton	0.45
6	Summit Ridge	2.59
7	Buckthorn Cres	0.16
8	Watson at Creekside	0.54
9	Watson at York	1.06
10	Auden	0.25
11	Shroeder	0.10
12	Cedarvale	0.29
13	Valleyhaven	1.23
14	Watson at Dunlop	7.83
15	Watson at Stone	0.18

5.3.9 Land cover and preliminary NHS areas

Landcover in the PSA and SSA is largely built-up, with anthropogenic lands comprising approximately 41.3 per cent of land cover (Table 5.7) and as shown in Figure 4-6. Agricultural lands comprise an additional 34.7 per cent cover. Cultural communities (cultural meadow, thicket, woodland and savannah) comprise 11.5 per cent cover. Wetlands (marsh, swamp and shallow aquatic) communities comprise the largest percentage of natural land cover (7.6 per cent), with deciduous, mixed and coniferous forest comprising 3.5 per cent cover; plantation comprises an additional 0.5 per cent. Aquatic and open water communities make up 0.8 per cent cover.

Table 5.7: Summary of land cover types within the subwatershed**

Land cover type	Sum of Area (ha)	Per cent (%) cover
Agriculture	849.76	34.68%
Anthropogenic	1012.86	41.34%
Aquatic	19.30	0.79%
Open Aquatic	17.46	0.71%
Open Water	1.84	0.08%
Cultural	283.22	11.56%
Cultural Meadow	137.47	5.61%
Cultural Savannah	1.87	0.08%
Cultural Thicket	23.17	0.95%
Cultural Woodland	10.79	0.44%

Land cover type	Sum of Area (ha)	Per cent (%) cover
Cultural Woodland/Cultural Savannah (2)	75.90	3.10%
Cultural Meadow/Cultural Thicket (3)	34.02	1.39%
Forest	86.04	3.51%
Coniferous Forest	12.29	0.50%
Deciduous Forest	35.80	1.46%
Mixed Forest	37.96	1.55%
Plantation	11.84	0.48%
Wetland	187.33	7.64%
Coniferous Swamp	5.75	0.23%
Deciduous Swamp	38.06	1.55%
Marsh / Swamp/Shallow Aquatic (4)	78.42	3.20%
Meadow Marsh	20.69	0.84%
Mixed Swamp	8.58	0.35%
Shallow Marsh	13.62	0.56%
Thicket Swamp	22.21	0.91%
Grand Total	**2450.33**	**100.00%**

** Based on the PSA characterization and GRCA (2017) landcover data in the SSA

(2) GRCA landcover type: "Sparse Treed" converted to ELC Community Class.

(3) GRCA Landcover Type: "Grassland/Shrubs" converted to ELC Community Class

(4) GRCA Landcover Type: "Wetlands" converted to ELC Community Series.

The preliminary NHS for the PSA and the SSA includes NHS components and sub-components outlined in the introduction to Section 4.5 above, with their areas by land cover provided in Table 5.7 and their areas summarized by high-level NHS components and proportion of cover in the subwatershed (i.e., PSA and SSA) provided in Table 5.8.

Table 5.8: Preliminary Natural Heritage System (NHS) component areas

Natural Heritage System (NHS) Component	Area (ha)	Per cent cover of Subwatershed
NHS in the Primary Study Area (PSA)	**216.63**	**8.84%**
PSA Significant Natural Areas	214.08	8.74%
PSA Natural Areas	2.55	0.10%
NHS in the Secondary Study Area (SSA)	**152.8**	**6.24%**
SSA Core Greenlands	105.58	4.31%
SSA Greenlands	47.22	1.93%
NHS Total in the PSA and SSA	**369.43**	**15.08%**

A summary of the preliminary NHS components within the PSA is presented in Table 5.9.

Table 5.9: Summary of preliminary natural heritage system (NHS) in the Primary Study Area

Natural Heritage Features and Areas (City of Guelph, 2024)	Number of features	Area (ha)	Per cent (%) land cover
significant areas of natural and scientific interest (ANSI)	1	2.18	0.18
significant habitat for provincially endangered and threatened species	not mapped	not mapped	not mapped
significant wetlands	18	105.40	8.80
provincially significant	18	105.40	8.80
locally significant	0	0	0
cool/cold water fish habitat	4.20 km	n/a	n/a
warm water fish habitat, permanent and intermittent streams and undetermined fish habitat	11.16 km	11.00	0.92
significant woodlands	13	87.33	7.29
significant valleylands	n/a	42.18	3.52
significant wildlife habitat (confirmed)	37	132.27	11.05
ecological linkages	3	2.51	0.21
restoration areas	15	62.85	5.25
other wetlands	1	0.41	0.03
cultural woodlands	1	1.57	0.13
habitat for significant species	not mapped	not mapped	not mapped
wildlife crossings	4	n/a	n/a

Note: Significant landform was not mapped because none is known to occur in the PSA.

5.4 Urban forest cover in the Primary Study Area

The City has policies, including a 40 per cent tree canopy cover target, and plans that support the protection and management of its urban forest. From a strictly planning perspective, the City's urban forest is defined in Official Plan policy 4.1.6 as: "plantations and smaller wooded areas less than one 1 ha, hedgerows and individual trees that are not included in the City's Natural Heritage System". However, generally an urban forest considers all trees, both within and outside of an NHS. Therefore, this SWSU has considered both in an integrated manner.

A map of the urban forest in the PSA is presented on Map TE-5 and is a consolidation of ELC-defined plantations (CUP), cultural woodlands (CUW), forest (FOD, FOM, FOC), treed swamp (SWD, SWC, SWM) and hedgerows (HR) plus trees identified in the City's 2019 Tree Canopy dataset, with the areas for each summarized in Table 5.10.

Table 5.10: Summary of urban forest within the Primary Study Area

Woodland Type (ELC)	Area (ha) in PSA	Per cent cover in PSA	Per cent of urban forest cover within PSA
Deciduous Swamp	38.06	3.18%	16.52%
Deciduous Forest	12.82	1.07%	5.57%
Cultural Plantation	11.84	0.99%	5.14%
Cultural Woodland	10.79	0.90%	4.68%
Mixed Forest	9.22	0.77%	4.00%
Mixed Swamp	8.58	0.72%	3.72%
Coniferous Forest	6.51	0.54%	2.83%
Coniferous Swamp	5.75	0.48%	2.50%
ELC Woodlands Sub-total	**103.56**	**8.65%**	44.96%
Additional Urban Tree Canopy (source: City of Guelph, 2019)	126.79	10.59%	55.04%
Total Urban Forest Cover	**230.35**	**19.24%**	**100.00%**
Total PSA	**1197.32**	**---**	**---**

The urban forest consists of:

- Urban Forest Canopy (see Table 6.7), 141.47 ha
- Cultural Woodlands in the NHS, 1.57 ha
- Significant Woodlands in the NHS, 87.33 ha

Which results in a total urban forest area of 230.36 ha representing 19.24 per cent of the PSA.

5.5 Key integrated findings and preliminary guidance

The characteristics and sensitivities of the subwatershed have been identified through the characterization and assessment work outlined in this report to:

- understand the existing conditions in an integrated manner, and
- identify potential preliminary management guidance intended to help mitigate anticipated impacts associated with planned land use changes, and other known and potential system stressors (e.g., climate change), which will be comprehensively assessed through Phases 2 and 3.

The following sub-sections are organized by discipline but include key findings and preliminary management guidance developed in an integrated manner with consideration for other discipline findings where appropriate. In some cases, key findings are simply put forward to enhance system understanding without management implications, which will be considered further during subsequent study phases.

5.5.1 Groundwater key findings and preliminary management guidance

Based on the available monitoring data there are no observable impacts to natural heritage system changes attributed to changes in the groundwater flow system since 1998. This is in part due to stormwater management and other policies that were put in place in 1998 that identified the need to maintain recharge and water quality. Groundwater flow conditions within and adjacent to the Clythe Creek subwatershed have been modified compared to 1998 conditions through increased pumping from existing wells which has modified deep groundwater flow directions. However, increased groundwater demand has reduced the available additional capacity of the wells and key hydrologic function of meeting growing human water consumption. In addition, increased urbanization has reduced water quality in some locations due to increased road salting associated with additional road surfaces.

Source Protection Policies derived from the Clean Water Act (2006), the City's Stormwater and Water Supply Master Plans (2022 and 2023) and City Policies including Salt Management Plans (2016) have been implemented since 1998 to optimize groundwater use to meet increasing demands of urbanization and minimize changes in groundwater flow and water quality to protect the Water Resources System and the Natural Heritage System.

Based on the updated subwatershed characterization completed through the current SWSU, the following key findings and preliminary management guidance are provided related to groundwater in the Clythe Creek subwatershed.

1. Recharge in lower permeability till areas is important to maintain and represents a key hydrologic function that supports sensitive habitat. Shallow groundwater levels adjacent to terrestrial features may act to limit the amount of infiltration/recharge out of these features as part of the natural water balance.

   Preliminary management guidance: Maintaining infiltration within the buffer areas surrounding these features may maintain the natural groundwater levels and local groundwater balance.
2. The quality of the groundwater within the overburden at areas assessed shows impacts from road salt but meets all but a few aesthetic parameters for the Ontario Drinking Water Standards (ODWS).

   Preliminary management guidance: An acceptable level of quality must be maintained where infiltrating stormwater and promoting the reduction of salt impacts through salt management plans.

   Groundwater discharges to various reaches and wetlands provides a source of perennial stream flow and supports wetlands health and function, respectively. Infiltration can be reduced through urbanization by an increase in less permeable surfaces (i.e., buildings and roads) and compaction of the shallow till. A reduction in infiltration can reduce the local and regional groundwater levels and available groundwater for storage and discharge and increases in surface runoff, which can lead to flooding and erosion.

Preliminary management guidance: Attempt to maintain or enhance infiltration where functionally appropriate and minimize compaction of the shallow overburden.

3. Reduced discharge can affect wildlife and habitats dependent on a high-water table in stream reaches and negatively impact aquatic resources. Reduced discharge can affect wildlife and habitats dependent on a high-water table in seeps, springs and wetlands and negatively impact wildlife communities (e.g., deer, amphibians and reptiles).

   Preliminary management guidance: Attempt to maintain or enhance infiltration where functionally appropriate and implement best management practices for underground servicing to minimize water table lowering.

4. A reduction in groundwater levels due to changes in recharge or increased pumping of groundwater may reduce available water in local/municipal water wells.

   Preliminary management guidance: Attempt to maintain or enhance infiltration where functionally appropriate and use existing modelling tools to optimize well demand.

5. An increase in groundwater demand from local wells could increase recharge to bedrock aquifer and reduce discharge to streams, wetlands and seeps.

   Preliminary management guidance: Enhancement of recharge to benefit stream baseflow, or wetland habitat could impact recharge to bedrock aquifers and the sustainability of the municipal wells.

6. Smaller scale depressional topography can focus local shallow groundwater and may increase local recharge.

   Preliminary management guidance: This should be maintained or re-created where functionally important. Discharge areas in drainage features should be protected from physical disruption of the permeable streambed connection; maintain where practical infiltration within the functional recharge areas for the discharge reaches.

5.5.2 Surface water key findings and preliminary management guidance

The following apply to Clythe Creek, Hadati Creek and Watson Creek, except where otherwise noted.

1. The surface water features across the subwatershed are generally stable and in fair to good condition but within the City (i.e., PSA) the creeks, and particularly Hadati and Watson, have been impacted by historical land use changes that have not provided for adequate quantity or quality controls. As such, there are significant flood risks to both current land uses and planned land use changes in parts of the PSA if no mitigation and management measures are implemented.

   The Clythe Creek and Hadati Creek Regulatory floodplain is controlled by water levels in the Eramosa River and the associated hydraulic boundary conditions.

   Preliminary management guidance: Hydraulic improvements along the Eramosa River should be considered to reduce the influence of the Eramosa River on Clythe Creek.

2. Under current conditions there are significant flood risks for property, infrastructure and persons during a significant storm event (e.g., Hurricane Hazel), within lands associated with York Road, Watson Parkway N., Watson Road N., the Former Reformatory Lands and other lands within the Guelph Innovation District.

Preliminary management guidance: Reduction of flooding conditions within each of the creek systems through hydraulic improvements will need to be assessed. Hazard lands will need to be considered as part of future land use planning.

3. Many existing stormwater management facilities do not provide adequate water quality, erosion and flood controls for existing development areas.

Preliminary management guidance: As per the SWMMP, carry out the recommended stormwater management improvements for existing development, which in some cases requires SWM facility retrofitting and/or the use of source controls (LID BMPs).

4. Existing development within the PSA has not incorporated Low Impact Development (LID) measures, resulting in reduced infiltration and increased stormwater runoff.

Preliminary management guidance: Where possible, implement LID techniques to improve source control of stormwater in existing urban areas.

5. Watercourses located within or adjacent to terrestrial features such as woodlands and wetlands contribute overland drainage to the terrestrial units on a frequent basis, depositing sediment and nutrients, important for sustainability.

Preliminary management guidance: Watercourses with floodplains that include significant woodlands and wetlands should continue to contribute drainage, sediment and nutrients by maintaining and protecting the existing alignment or by being realigned in a manner that does not impact terrestrial features and functions, and sediment transport.

6. Wetlands and woodlands provide temporary flood storage where located within drainage system floodplains.

Preliminary management guidance: Assessments should be undertaken for wetlands and woodlands to protect the hydrologic functions that sustain them in a developed landscape.

7. Watercourses contribute runoff to riparian vegetation along the watercourse system corridors, thereby contributing to the formation and sustainability of the fluvial system's riparian vegetation.

Preliminary management guidance: Existing watercourse systems, whether altered through realignment, form or other alterations, should be managed to maintain and/or improve upon existing riparian vegetation communities.

8. If unmitigated, the conversion of undeveloped lands to urban land uses will increase the rate and volume of stormwater runoff locally within the Clythe Creek system.

Preliminary management guidance: Stormwater management systems, including those that prioritize source control, should be implemented to manage the increased rate and volume of runoff from future development.

5.5.3 Fluvial and geomorphic key findings and preliminary management guidance

1. Most stream reaches in the PSA and several stream reaches in the SSA have been historically modified to accommodate urbanization and agricultural practices, and the extent and status of HDFs that may support these reaches is not well understood.

   Preliminary management guidance: Opportunities to restore and enhance natural stream form and naturalize associated riparian areas need to be identified and the extent and function of HDFs in the subwatershed needs to be better assessed to sustain the creek system and its functions.

2. Most of the steam reaches within the PSA have been highly modified by human activities and could benefit from rehabilitation. Within the SSA, several reaches have been impacted by agricultural practices (e.g. ditching), or impounded at select locations. Such features could also benefit from rehabilitation and enhancement.

   Preliminary management guidance: Improving channel form and function through selective rehabilitation represents an opportunity for environmental enhancement. This should be considered in conjunction with stormwater best management practices, as well as hydrogeological, terrestrial and aquatic habitat management strategies to ensure an overall enhancement and mitigate or avoid reach- or site-specific constraints.

3. Increased flows and changes in sediment supply can occur when creeks are modified, which can exacerbate natural rates of erosion within receiving watercourses. This, in turn, can lead to channel instability, degraded aquatic habitat, create erosion hazards to property and threaten infrastructure.

   Preliminary management guidance: By applying site-appropriate stormwater management measures, negative impacts to water quality and aquatic habitat associated with undesirable and potentially costly geomorphological change in watercourses can be mitigated. It should be noted that impacts to sediment supply should also be considered in any management strategy through the protection of natural sediment sources. Protection of such natural sources represents a fundamental component in maintaining a dynamic equilibrium state within a drainage system.

4. Modifications to the drainage network, such as the removal of first order streams, HDF and/or vegetative cover can remove natural sediment sources to the downstream system and reduce the natural detention and retention of water within the landscape. This can increase not only the volume of flow in receiving reaches but can also decrease the time in which these volumes are conveyed to the reaches.

Preliminary management guidance: The development of an appropriate stormwater management strategy and headwater drainage feature management approach should address maintaining contributions to the downstream drainage networks.

5. The incorporation of erosion hazard limits (i.e., the meander belt width or geotechnical slope requirements or suitable proxy) into the stream corridor going forward will support the long-term form and function of the watercourses and valley systems, while mitigating risk to property and infrastructure due to erosive forces.

   Preliminary management guidance: For unconfined valley systems, the greater of the flood hazard limit or meander belt width allowance (along with the erosion access allowance) will be established as a constraint to development as it represents the hazard limit. For confined valley corridors, Provincial Policy dictates that the erosion hazard limit is governed by a combination of stable slope, toe erosion and access allowance (geotechnical) requirements. For wide shallow floodplains, with poorly-defined sections of Clythe, Hadati, and Watson Creeks, an alternative approach to defining the erosion hazard may be warranted.

6. Restoration and enhancement of stream corridor conditions (riparian habitat) along those reaches identified as being degraded represents a key opportunity to improve the overall health of the Clythe Creek Subwatershed.

   Preliminary management guidance: The protection of stream corridors through strategies such as the preservation and enhancement of channel form and function within the subwatershed. Corridor requirements will need to reflect an integration of terrestrial, geomorphic, aquatic, hydrologic and groundwater considerations.

5.5.4 Aquatic key findings and preliminary management guidance

1. In the SSA, Clythe Creek appears to be perennial and is designated coldwater by MNR. In the PSA, Clythe Creek is perennial, but there are reaches between Watson Road and Watson Parkway where there is no surface flow, although there may be interstitial flow, during dry periods. Based on the groundwater elevations, this reach may be a losing stream. Flow can be very low between Watson Parkway and the outlet from the North Former Reformatory Pond during dry periods.

   Preliminary management guidance: Maintaining perennial flow, which is necessary to maintain healthy fish and benthic invertebrate communities, should be a priority for Clythe Creek.

2. Flow is ephemeral in the headwaters of Hadati and Watson Creeks. This is reflected in the absence or extremely low numbers of fish present. Barriers to upstream fish movement prevent recolonization from downstream.

   Preliminary management guidance: The limitations imposed by ephemeral or intermittent flow should be recognized when considering management priorities for these headwater reaches.

3. Temperature data indicate that the thermal regime of Clythe Creek is coolwater from the upstream PSA boundary to the outlet from the ponds on the Former Reformatory Lands. A coldwater fish species, Mottled Sculpin, is present in the reach along the south size of York Road upstream from the pond outlet.

   Preliminary management guidance: Discussions with MNR should be initiated to determine the appropriate thermal regime designation for this reach of Clythe Creek.

4. Hadati Creek is classified as warmwater by MNR. Where temperature data, were acquired between the railway and the confluence with Clythe Creek, the Hadati Creek temperature regime is coolwater. This may be a consequence of flow coming from the stormwater system on the south side of Elizabeth Street.

   Preliminary management guidance: Further investigate the thermal regime in this area to determine if storm sewer contributions are influencing the temperature regime.

5. Barriers in the lower reaches of Clythe Creek prevent or impede fish passage and may be responsible for the lower number of fish species farther upstream and in the lower reaches of Hadati Creek (i.e., downstream from the railway).

   Preliminary management guidance: Evaluate the implications of removing or modifying those structures to improve fish access.

5.5.5 Terrestrial key findings and preliminary management guidance

1. Even though it has increased over the past 25 or so years, overall woodland cover in the subwatershed, and urban forest cover within the City, are well below established targets. Wetland cover appears to be within acceptable levels. Cover by cultural meadow communities has declined in both the PSA and SSA, as has agricultural land cover, while urban land cover has increased, particularly within the PSA. Natural heritage system components cover 15.6 per cent of the subwatershed, with 9.4 per cent of that cover being with the PSA and the remaining 6.2 per cent being in the SSA.

   Preliminary management guidance: Opportunities to enhance and expand natural cover in the subwatershed should be identified and, where feasible, implemented.

2. Woodland cover, including cultural woodland, forest, treed swamp and plantation is just under ten per cent of land cover in the subwatershed, which is well below the generalized subwatershed target of 30 per cent woodland cover established in the literature (EC, 2013) for optimal ecological and hydrological functions.

   Preliminary management guidance: Opportunities to enhance and expand woodland cover in the subwatershed should be identified and, where feasible, implemented.

3. Within the PSA, urban forest cover, which includes treed areas within the NHS plus estimated tree cover outside the NHS, accounts for about 20 per cent cover, which is well below the City’s target of 40 per cent.

Preliminary management guidance: Opportunities to enhance and expand urban forest cover in the SSA should be identified and, where feasible, implemented. This could include identification of additional restoration areas, enhanced woodland buffers, and naturalization along stream corridors to improve down-stream conditions.

4. Wetland cover within the subwatershed is just under eight per cent. This is within the range of the generalized targets of six per cent wetland cover for subwatersheds and ten per cent for watersheds established in the literature (EC, 2013) to support optimal ecological and hydrological functions.

Preliminary management guidance: Wetlands, including their hydrologic regimes and water quality, should continue to be protected and maintained through establishment of appropriate buffers and restoration of riparian areas.

5. Based on the SWSU team's knowledge of other subwatersheds in Ecoregion 6E, the subwatershed appears to be sustaining low numbers but a fairly consistent diversity of locally, and regionally-significant species associated with forest, open field and wetland features.

Preliminary management guidance: The NHS policies should reflect a prioritization of opportunities to integrate features and functions that will sustain and enhance native biodiversity.

6. In the PSA, portions of the preliminary NHS (see Map TE-4.6) are isolated and/or fragmented by existing roads.

Preliminary management guidance: Areas where the preliminary NHS is fragmented and/or isolated should be targets for improving habitat connectivity through ecological linkages and wildlife crossings where feasible. Stream and HDF management should consider benefits of realignments to connect isolated features with the NHS.

7. Wetlands within the subwatershed are primarily associated with forested and riparian areas along watercourses. Most of the wetlands are PSW that contribute to, or intersect with, significant woodlands, significant wildlife habitat, fish habitat and watercourses.

Preliminary management guidance: The relationships between catchment characteristics, soils, existing fluvial systems and habitats should be assessed and quantified at progressively finer levels of detail as part of future studies to ensure that these relationships can be appropriately managed long-term. Guidance is to be provided in the next phases of this SWSU.

8. Woodland cover in the subwatershed is largely comprised of cultural communities and wetland (i.e., swamp) communities. Upland mixed, deciduous and coniferous forests in the subwatershed are uncommon and account for only 3.5 per cent cover.

Preliminary management guidance: Opportunities to specifically enhance and expand upland forest cover within the subwatershed should be identified.

6 Summary of state of the subwatershed: 1998 to 2024

This Characterization Report provides a comprehensive assessment of existing environmental conditions in the subwatershed (i.e., the PSA and the SSA), as well as a high-level comparison with, and assessment of, the implementation status of the recommendations from the 1998 SWS, provided in this section.

This section provides a high-level overview of the status of the recommendations from the 1998 SWS and of the subwatershed conditions, in the context of the current subwatershed conditions assessment completed for this study, as described in this report.

The 1998 SWS provided a high-level characterization of intermittent and permanent watercourses, with a focus on characterization of groundwater and aquatic and terrestrial ecological features. Notably, the policy and planning context, and the assessment and analytical tools have changed substantially since 1998. Furthermore, a much more comprehensive assessment of groundwater, surface water, fluvial geomorphology, aquatic and terrestrial ecology conditions has been completed for the current SWSU. Therefore, a direct “apples to apples” comparison has not been possible.

In general, a number of significant land use changes, infrastructure projects, and other interventions have occurred in this subwatershed since 1998, particularly within the portion of the subwatershed in the City of Guelph (i.e., the PSA). These changes have been a result of further urbanization of the Hadati and Watson Creek catchments through a loss of agricultural lands, resulting in reduced groundwater recharge in the PSA, increased municipal groundwater demand and surface water quality impacts, as outlined in this report.

urbanization since 1998 appears to have had limited impacts to watercourse morphology. In addition, significantly more plant and wildlife species were identified in the SWSU than in the original 1998 SWS. However, the greater number of species documented over 2022 and 2023 is largely attributed to the greater level of effort made rather than confirming an actual increase in plant and wildlife species diversity in the PSA.

A summary of the 1998 SWS recommendations and their current status is provided below, and a high-level comparison of key conditions is provided in Table 7.1.

Recommendation 1: Upland wooded areas are to be retained where possible (including plantations).

Existing upland wooded areas and plantation (excluding treed swamp) currently (2024) comprise 7.5 per cent land cover (184.56 ha) in the subwatershed. We do not have accurate data from 1998 to reference for comparison.

Both the City of Guelph and the County of Wellington have strong policies in their Official Plans protecting significant woodlands. The City of Guelph has a private tree protection by-law. The County has a Forest Conservation By-law.

Recommendation 2a: The restoration of natural areas is recommended to increase woodland cover.

Since 1998, Restoration Areas have been identified in the City's NHS which may be targets for increasing woodland cover within the PSA. Currently the subwatershed contains approximately 62.85 ha of designated and protected Restoration Areas and 2.51 ha of Ecological Linkages, as presented in the City of Guelph Official Plan NHS (2024). Within the SSA, Wellington County includes provisions for Restoration and Enhancement, though the NHS in Wellington County does not contain designated Restoration and Enhancement Areas.

We do not have accurate data related to restoration areas from 1998 to reference for comparison.

Recommendation 2b: Planting trees and other native plants to establish and enhance existing natural areas is recommended to increase wildlife habitat and create linkages for wildlife movement (between habitats within the subwatershed as well as to habitats outside the subwatershed).

Since 1998, tree and native plant planting activities have occurred to establish and enhance natural areas, increase wildlife habitat and create linkages for wildlife movement. A review of air photos from 2000 vs current indicate that tree plantings have occurred along the channelized valley along Hadati Creek and along Watson Creek. Both tributaries have wider corridors in 2024 as opposed to 1998. Tree plantings within the PSA have also been focused in designated Restoration Areas, street trees, and adjacent to lands that have been developed, as conditions of development approval. Since 1998, the City of Guelph has designated Ecological Linkages focused on maintaining and enhancing wildlife movement within the NHS. Ecological Linkages are presented in the PSA on the preliminary NHS (Map TE-4.6). Currently the subwatershed contains 2.51 ha of designated Ecological Linkages, as presented in the City of Guelph Official Plan NHS (2024).

Within the SSA, the County's Green Legacy Program enacted in 2004 supports community and private planting activities that restore and enhance the County's natural heritage, including tree planting. The County's Rural Water Quality Program has been running since 1999, providing farmers with grants to complete a number of different projects including tree plantings and restoration.

Recommendation 2c: Detailed plant and wildlife surveys are recommended as part of subsequent EIS studies.

Most EIS completed, mainly in the City of Guelph (i.e., PSA), have included more detailed plant and wildlife surveys on a site-specific basis.

Detailed plant and wildlife surveys have been completed in a few site-specific EIS undertaken in the study area since 1998 as well as the work done as part of this SWSU in the PSA.

Recommendation 3a: A complete evaluation of wetlands using MNR wetland evaluation system should be conducted.

Since 1998, all wetlands in the subwatershed have been evaluated using the MNR's Ontario Wetland Evaluation System (OWES) or mapped by MNR using remote sensing tools and analysis.

The currency and accuracy of the evaluations is variable, and wetland evaluation in Ontario is an open process whereby updated evaluations can be completed by qualified professionals at any time. As such, some areas not previously captured as wetlands or as PSW may be identified based on application of the current OWES (MNR 2022), while some provincially significant wetlands (PSW) could be re-assessed as non-PSW.

As part of this updated characterization of the Clythe Creek subwatershed, 32.36 hectares of PSW was identified and mapped (1.94 hectares was previously Unevaluated and 30.43 hectares was not mapped by the Province) and 10.89 hectares of PSW that was previously mapped was confirmed as not being wetland so was removed from the updated mapping. Many of these changes are the result of wetland boundary revisions completed by Ecologists trained in the OWES and which were reviewed and approved by the GRCA over 2022 and 2023.

Recommendation 3b: The wetlands are to be maintained.

Significant wetlands (i.e. Provincially Significant Wetlands, Locally Significant Wetlands) within the PSA are protected under the City's Natural Heritage System policies. The City's Official Plan also contains provisions to protect wetlands that meet criteria to be designated as Other Wetlands. Studies undertaken as part of the SWSU included refining wetland boundaries within the PSA. The preliminary Natural Heritage System within the PSA contains 105.81 ha of protected wetlands including 105.40 ha of PSW and 0.41 ha of Other Wetlands.

As no comprehensive baseline mapping of wetlands was completed as part of the 1998 SWS, the SWSU Study Team cannot determine with any accuracy if there have been any changes to wetland cover since 1998.

Recommendation 3c: Appropriate width buffers of natural vegetation are to be retained or created along the wetlands, creeks, and tributaries for the protection of sensitive habitats.

Riparian buffers are present along the watercourses in much of the study area. They are limited (e.g., Clythe Creek along York Road) or absent (e.g., Hadati Creek between Suburban Avenue and York Road) in some of the older developed areas. The City's Natural Heritage System policies specify minimum riparian buffers of 30 m for cold/cool water fish habitat and 15 m for warm water fish habitat and intermittent streams.

The dimensions and characteristics of buffers are to be determined on a site-specific basis as part of future studies. Within the PSA, 30 m buffers have been applied to PSWs, and a 7.5 m buffer has been applied to the Other Wetland (based on an approved EIS). The County of Wellington Core Greenlands policies provide provisions to protect wetlands within the SSA.

A review of air photos from 2000 versus current imagery indicates that the channelized valley along Hadati Creek and along Watson Creek have somewhat wider, more densely vegetated corridors in 2024. Wider corridors bolster habitat and linkages for wildlife movement across the landscape.

Recommendation 4a: The removal of online ponds is recommended.

This work has not been completed, although it was a recommendation of the 2019 York Road EIS (Wood 2019).

One online pond exists in the PSA, Pond P-6 (Map SW-4) and two online ponds exist within the SSA located immediately upstream and downstream of Hwy No. 7. The Former Reformatory Pond (North Pond) connects to Clythe Creek and will have a thermal impact to Clythe Creek, depending on the flow regime.

Recommendation 4b: The use of dry ponds, or wet ponds with modified (subsurface) discharges, for stormwater management will help to maintain lower water temperatures that are important to re-establish a coldwater fishery.

Subsurface draws, discharges, or other thermal mitigation do not exist for any stormwater management facilities within the PSA. Based on the recommendations from the SWMMP update (Aquafor Beech, 2023), 13 out of the 20 SWM facilities should be retrofitted to some extent, which could provide the opportunity to change outlet structures and implement bottom draws.

Recommendation 4c: The preservation of tree cover along the creeks is recommended to moderate temperatures.

Tree cover is present along most of the creek reaches apart from upper and lower Hadati Creek, Clythe Creek in vicinity of the confluence with Hadati Creek, and the confluence of Clythe Creek and Watson Creek.

A review of air photos from 2000 versus current indicates that the channelized valley along Hadati Creek and along Watson Creek have more tree cover in 2024 than in 2000.

Treed riparian buffers are present along many reaches of the watercourses in the PSA but generally not in the downstream reaches nor in the headwaters of Hadati Creek. The City's Natural Heritage System policies specify minimum naturally vegetated riparian buffers of 30 m for cold/cool water fish habitat and 15 m for warm water fish habitat and intermittent streams. The policies do not specify the type of vegetation that should be present.

Recommendation 4d: The use of natural channel design techniques and bioengineering methods is encouraged to increase the habitat potential of the creek for fish and invertebrate populations while providing suitable channel design and erosion control during development projects.

The 1998 SWS recommendations sought to increase the water quality within the system to help provide high value aquatic habitat by cooling water temperatures and providing habitat features, in terms of channel morphology.

Desktop review and field observations of current conditions have confirmed that natural channel designs for stream rehabilitation have yet to be implemented within the PSA and SSA, with the exception of two meanders constructed along Hadati Creek, immediately downstream of Grange Road. Elsewhere some localized erosion mitigation and repair has been observed.

Within the PSA, Clythe and Hadati Creeks have both undergone significant modifications through straightening and hardening through various treatments. (e.g., gabion baskets, armour stone, rip rap, concrete). In some cases, these are failing.

Bed armouring through the use of gabion mattress, and localized grade control with gabion drop structures (weirs) are present along Hadati Creek, upstream and downstream of Chesterton Lane. In some cases, bank and bed treatments are failing. The City's Natural Heritage System policies do not address natural channel design.

Recommendation 4e: A Creek Management Corridor approach is recommended, including protection of the stream corridor with a 30 metre adjacent lands zone, and protection of wetlands with a 120 metre adjacent lands zone.

The extent to which buffers have been applied and implemented through site specific study and development in the SSA is unknown, but the nature and extent of development in the SSA from 1998 to 2024 is understood to be very limited.

Within the PSA, since 1998:

- Creek corridors have generally been protected through the application of policies related to significant valleylands and to natural hazards associated with floodlines and steep slopes where applicable.
- In addition, wetlands within significant valleylands and floodplains have generally been protected including the application of 30 m minimum buffers and buffers of at least 7.5 m have been applied to the Other Wetlands on a site-specific basis through the EIS process.

Recommendation 5a: Groundwater inputs to the creeks must be maintained to preserve the aquatic habitat.

This recommendation is consistent with subwatershed planning work in 1998 and still considered a best practice. Additional context for this comes from a number of guidelines since 1998 including MOE (2011) related to Permits to Take Water. For municipal and non-municipal water takings, when reviewing applications for PTTWs, a PTTW Director must consider, among other things, the “natural functions of the ecosystem including potential impact on the natural water flow or level and the habitat that depends on that water flow/level” and “the interrelationship between groundwater and surface water that may be affected by the proposed taking” (MOE 2011).

More detailed information is needed for applications where there is a greater potential for impact from a water taking.

Groundwater inputs are present in multiple locations in the PSA and SSA as identified in the background review and during early field investigations. The City’s Natural Heritage System policies include an objective to maintain and where possible enhance linkages and related functions among surface water features, groundwater features, hydrologic functions, and natural heritage features.

Recommendation 5b: The emulation of existing groundwater recharge is recommended throughout the watershed, particularly within the potentially sensitive areas.

This recommendation was best practice in 1998 but additional guidance and requirements has been developed since 1998. This recommendation has been advanced and is being implemented through the Grand River Source Protection Plan, City of Guelph Official Plan, and City’s Development Engineering Manual (outlined in Section 3 of this report).

The Tier 3 Assessment and SWMMP have optimized demand from existing and future wells to minimize reductions in water levels, while maintaining discharge within the acceptable limits based on Source Protection Requirements.

Specifically, requirements for stormwater management approaches for new development include developing site-specific water balance criteria and implementing LID BMPs including infiltration BMPs to maintain pre-development recharge rate, volume and hydroperiods.

Recommendation 5c: Groundwater withdrawals need to be reviewed from the perspective of reductions in water levels within the groundwater flow system providing discharge water to the creeks and wetlands.

An assessment of this linkage, for existing and future groundwater takings, is necessary to maintain the aquatic and terrestrial functions. Investigating the linkages between groundwater withdrawal and discharge to creek and wetlands is an important aspect of the work to be done during this SWSU.

This recommendation has been advanced as described above through the policies of the Grand River Source Protection Plan. For municipal and non-municipal water takings, when reviewing applications for PTTWs, a PTTW Director must consider, among other things, the “natural functions of the ecosystem including potential impact on the natural water flow or level and the habitat that depends on that water flow/level” and “the interrelationship between groundwater and surface water that may be affected by the proposed taking” (MOE 2011). More detailed information is needed for applications where there is a greater potential for impact from a water taking.

In the 1998 report there were no references to groundwater withdrawal influencing shallow groundwater flow paths to the stream. Shallow groundwater responses to the pumping of the Clythe Well along Clythe Creek were observed during the 2022 pumping test completed as part of this study but no reduction in baseflow was observed in stream monitoring (see Matrix 2023a for more details on groundwater-surface water interactions).

Recommendation 5d: Groundwater quality degradation from road salting, fertilizer, septic systems, spills etc. is more likely within the sensitive groundwater areas and is to be controlled.

This recommendation has been advanced since 1998 through the Source Protection policies of the Grand River Source Water Protection Plan.

This program includes the delineation of vulnerable areas, identification of significant water quantity and water quality threats within those areas, and the development of policies to reduce risk and protect current and future municipal drinking water supplies. This includes the development of Risk Management Plans to help manage the risk associated with different activities (e.g., road salt application and agricultural operations) that have the potential to impact water quality. The City has developed City Wide Salt Management Policies (2016) and assessed loading to the municipal aquifer to drive their management strategies. It is recommended that the City Wide Salt Management Policies (2016) be reviewed, and if necessary, updated to include new guidance and industry standards that may have been developed since the policies were written.

The potential sensitive groundwater areas (water quality) identified in 1998 are currently located within the City of Guelph's Wellhead Protection Areas (i.e., WHPA-A, -B, and -C) and areas defined as high and, to a lesser extent, medium aquifer vulnerability, as delineated through the Source Water Protection program (LERSPC 2022a). The value of the vulnerability scores within these areas are high (i.e., largely scores of 10 or 8; LERSPC 2022a), which means that there is a greater chance that prescribed activities within these areas may be considered significant threats to municipal groundwater supplies and the Source Protection Plan policies (developed by the City) would apply to help manage the risk associated with those activities.

In addition to Source Protection Plan policies, the County has an Official Plan policy (4.9.5.4) related to source water protection that requires additional reports for Planning Act applications related to non-residential uses. This policy works in tandem with Source Protection Plan policies to prevent and manage threats to drinking water.

Table 6.1: Overview of the Clythe Creek subwatershed conditions documented in 1998 and 2024

1998	2024
Groundwater • Urbanization primarily in western portions of Hadati Creek • Agricultural land use within City along Clythe Creek and Watson Creek as well as Former Reformatory Lands • Municipal groundwater wells Emma, Park, Helmar and Clythe meeting demand; mostly affecting water levels in lower bedrock aquifer. • A number of non-municipal wells (Agricultural/Domestic) in Watson Creek and Clythe areas that are rural and agriculture. • Eastview landfill open and operational accepting waste and managing leachate • Sensitive and Significant Groundwater Recharge Areas mostly associated with areas outwash deposits in Clythe Creek • Recharge areas for municipal wells not assessed and were not considered significant in context of natural system function. • Water quality impact potential associated with most permeable sediments but no water quality analysis • No known impacts to key hydrologic functions • Mapped groundwater discharge areas support mapped cool and coldwater areas	**Groundwater** • Urbanization of Hadati and Watson subwatersheds and presumed reduction in recharge in PSA • Clythe Creek in midst of urbanization in PSA • Increased municipal groundwater demand, although Clythe well offline due to natural aesthetic raw water quality, increase drawdown in water levels in lower bedrock aquifer; current SWSU examining other supplies to meet demand; Clythe well to be brought back online. • No known agricultural wells active in PSA • Abandonment of most domestic and agricultural Wells in PSA • Closure of Eastview Landfill and On-going Leachate Management • Significant Groundwater Recharge areas like 1998 for Streams, wetlands (outwash associated with Clythe Creek), but additional SGRAs relate to recharge areas for municipal wells mostly in Hadati and Watson Creek Areas • Water quality indicates road salt impacts at half of the aesthetic standard for chloride in groundwater. • No known impacts to key hydrologic functions
Surface Water • Most of the pre-1998 development in Clythe Creek subwatershed lacked stormwater management controls (i.e., quality and/or quantity) apart from the residential area underdevelopment on Hadati Creek contributing to SWMF #127 located at the rail corridor and the industrial area under development at Watson Parkway South that contributes to SWMF #38 (Map SW-4). • Flood hazards along part of the Clythe Creek, had been determined using HEC-2 hydraulic modelling from other studies, but this was not documented in 1998.	**Surface Water** • There are currently 20 stormwater management facilities within the PSA. Based on the recommendations of the SWM MP, 13 stormwater management facilities require retrofitting to improve the level of service for stormwater quality, erosion and quantity controls. • Flood hazard lands have been identified through draft regulatory floodplain mapping. Improvements in mapping could be achieved through incorporation of two-dimensional modelling.

1998	2024
Fluvial Geomorphology • Characterization of watercourse reaches was provided on a reach-by-reach basis indicating what reaches were modified through lining and/or straightening (Section 4.3). • Reaches were mostly noted as “stable” throughout, though one reach of Hadati Creek was noted to have “low stability”. The methods to determine a creek’s stability were not presented. • Observations of channel modifications to accommodate recent (as of 1998) development were identified such as channelization and engineering, excavated ditches, and blockage of flow within Hadati Creek. • Drainage features in and around the Former Reformatory Lands were characterized as dry, agricultural drainage features or dammed/piped sections.	**Fluvial Geomorphology** • The reach delineation within the current SWS includes more reach breaks than in 1998. Overall, observations were similar in terms of channel modifications and engineering. However, since 1998 some engineering treatments are showing signs of degradation and potential failure (Hadati Creek). Further modifications of the current watercourse reaches include new road crossings, stormwater outfalls and/or channels, and more development (Watson Creek, upper Hadati Creek). • Stability was evaluated in the current study and noted many areas of instability, with evidence of widening, aggradation, incision, and planform adjustment. Through the RGA method, a few reaches were noted to be “in adjustment” or unstable. • Headwater drainage features have been identified at a high level through DEM analysis, air photo interpretation, and incidental presence/absence and confirmation of feature type, as observed during watercourse reach walks or other field investigations or discipline feedback. The Unnamed Tributary was identified as an HDF and is consistent with those observations of dry agricultural drainage features. Detailed HDF assessments have not been completed.

1998	2024
Aquatic Ecology** • The Clythe Creek system was affected by on-line and off-line ponds that increased the water temperature and by other culverts, weirs, and dams. • The creeks were also impacted by runoff from agricultural lands, roads, and stormwater from residential areas and industries. The lack of adequate buffers allowed for potentially polluted waters to enter the main creek easily and quickly. • The MNR was managing Clythe Creek as a coldwater stream. • Thermal regimes for Watson Creek, Hadati Creek, and the Unnamed Tributary were not outlined in the 1998 SWS.	**Aquatic Ecology** • The Clythe Creek system continues to be affected by on-line and off-line pond and by other culverts, weirs, and dams. • The creeks continue to be impacted by runoff from agricultural lands, roads, but to a lesser extent from residential and industrial stormwater as more controls/treatment has been put in place. • In 2024, the extent of Clythe Creek starting from the outlet of the Former Reformatory Ponds and continuing upstream was characterized as coldwater (mottled sculpin, a coldwater species, was identified); however, the section of Clythe Creek from the Former Reformatory Ponds outlet downstream to the Eramosa River and characterized as coolwater (with the majority of fish species preferring coolwater thermal regimes). • It is recommended that Hadati Creek be considered as a coolwater stream from the railway to the confluence with Clythe Creek. Given the intermittent flow and the presence of bluegill, it is recommended that Hadati Creek be considered a warmwater system upstream of the railway. • It is recommended that Watson be considered as a coolwater stream. This considers that it drains to Clythe Creek which is a coldwater stream at the confluence.
Terrestrial ecology • Plants:170 species documented; 71 per cent native • Plants: No federal, provincially or locally rare species documented. Wildlife: 69 species. • Wildlife: 57 bird species documented (most of which were assumed to be breeding in the area), nine mammals, two amphibians and one reptile documented • Wildlife: 11 significant species including three provincially and nine locally significant species documented	**Terrestrial ecology** • Plants:433 species of plants documented; 68 per cent native • Plants: 29 significant plant species documented including two Species at Risk and 27 locally rare species documented • Wildlife: 108 species documented • Wildlife: 79 birds, 17 mammals, seven amphibians, three reptiles, and two dragonflies documented • Wildlife: 16 significant species including seven provincially and 10 locally significant species documented

1998	2024
Overall land cover GRCA (1999) landcover: • Agriculture - 1415.9 ha • Anthropogenic - 627.76 ha • Forest/Wetland - 228.5 ha • Cultural Meadow/Cultural Thicket - 143.96 ha • Aquatic - 17.93 ha • Cultural Woodland/Cultural Savannah/Cultural Plantation - 16.28 ha	**Overall land cover** 2024 landcover: • Agriculture - 849.76 ha • Anthropogenic - 1012.9 ha • Forest/Wetland - 273.38 ha • Cultural Meadow/Cultural Thicket - 194.66 ha • Cultural Woodland/Cultural Savannah/Cultural Plantation - 100.39 ha • Aquatic - 19.3 ha Vegetated areas (including forest/wetland and cultural communities) have increased since 1999 by approximately 179.69 ha. Anthropogenic land use has also increased by 385.10 ha, while agricultural land cover has decreased by 566.10 ha.

** For the 1998 SWS, no fish sampling was conducted, no specifics regarding sampling by others were identified within Clythe Creek, and no fish community information was provided for the Clythe Creek tributaries. Similarly, no benthic invertebrate sampling was completed within Clythe Creek, Hadati Creek, Watson Creek, or the Unnamed Tributary. Therefore, comparisons between 1998 and 2024 from a fisheries and benthic invertebrate perspective could not be completed.

7 Next steps

The forthcoming Impact Assessment and Management Report (Phase 2 and 3 of the SWSU) will consider and build on this characterization of the subwatershed to:

- (a) understand the current and anticipated cumulative impacts to the groundwater, surface water, aquatic and terrestrial systems in the subwatershed since 1998, and
- (b) make recommendations intended to mitigate and manage these impacts to ensure the water resources and natural heritage resources in the subwatershed, and the valuable environmental services they provide, are protected, sustained and where opportunities exist, improved.

The recommendations will be part of a management plan developed around a refined WRS and NHS, including natural hazards, with monitoring recommendations for the NHS, WRS and interactions between the systems.

8 Glossary of key technical terms

The following terms are from the City of Guelph Official Plan (February 2024 consolidation) and includes key technical terms related to both the Water Resource System (WRS) and Natural Heritage System (NHS) to guide implementation of the applicable provincial policies and guidance at the municipal level.

Table 8.1 provides the criteria for the identification of the various components of the City's NHS and also identifies minimum ecological buffer requirements, where applicable. For more detail and City-wide mapping please refer to the Official Plan.

Aquifer means: A subsurface geological material which yields significant amounts of water.

Cultural woodland means: a woodland with tree cover between 35% and 60% originating from, or maintained by, anthropogenic, influences and culturally based disturbances (e.g., planting or agriculture, clearing, recreation, grazing or mowing)

Erosion Hazard means: The loss of land, due to human or natural processes, that poses a threat to life and property. The erosion hazard limit is determined using considerations that include the 100-year erosion rate (the average annual rate of recession extended over a one hundred year time span), an allowance for slope stability and an erosion/erosion access allowance.

Hazard(ous) Lands means: Property or land that could be unsafe for development due to naturally occurring processes. This means land, including that covered by water, to the furthest landward limit of the flooding hazard or erosion hazard limits.

Hazardous Site means: Property or land that could be unsafe for development and site alteration due to naturally occurring hazards. These may include unstable soils, organic soils or unstable bedrock (karst topography).

Highly Vulnerable Aquifer means: Aquifers, including lands above the aquifers, on which external sources have or are likely to have a significant adverse effect.

Locally significant species means: species that are not Endangered or Threatened Species but that are considered locally significant at the regional level (i.e., as identified in the Significant Plant List and the Significant Wildlife List for Wellington County, and any City-approved updates to these lists). Such species may also be considered Globally, Federally and/or Provincially Significant.

Locally significant wetlands means: evaluated wetland (including wetland complexes) of at least two hectares in size which are not identified as provincially significant, and unevaluated wetlands of at least 0.5 hectares in size.

Significant means: …4. in regard to valleylands means a protected natural heritage feature or area that occurs in a valley or other landform depression that has water flowing through or standing for some period of the year. This includes regulatory floodplains/riverine flooding hazards, riverine erosion hazards and apparent/other valleylands ecologically important in terms of features, functions, representativeness, or amount, and contributing to the quality and diversity of the Natural Heritage System**.**

(Note: See Table 8.1 below for the criteria that define all the NHS components in the City of Guelph, including “significant” features and areas).

Significant Groundwater Recharge Area means: An area that has been identified: as a significant groundwater recharge area by any public body for the purposes of implementing the PPS, 2020; as a significant groundwater recharge area in the assessment report required under the Clean Water Act, 2006; or as an ecologically significant groundwater recharge area delineated in a subwatershed plan or equivalent in accordance with provincial guidelines. For the purposes of this definition, ecologically significant groundwater recharge areas are areas of land that are responsible for replenishing groundwater systems that directly support sensitive areas like cold water streams and wetlands.

Significant Surface Water Contribution Area means: Areas, generally associated with headwater catchments, that contribute to baseflow volumes which are significant to the overall surface water flow volumes within a watershed.

Urban forest means: for the purposes of this Plan, plantations, woodlands, hedgerows, treed areas and individual trees outside the City’s Natural Heritage System.

Water Resource System means: A system consisting of groundwater features and areas and surface water features, and hydrologic functions, which provide the water resources necessary to sustain healthy aquatic and terrestrial ecosystems and human water consumption. The water resource system consists of key hydrologic features and key hydrologic areas.

- **Key Hydrologic Areas means:** Significant groundwater recharge areas, highly vulnerable aquifers, and significant surface water contribution areas that are necessary for the ecological and hydrologic integrity of a watershed.
- **Key Hydrologic Features means:** Permanent streams, intermittent streams, inland lakes and their littoral zones, seepage areas and springs, and wetlands.

Zero-Impervious means: The portion of impervious area with no depression storage, leading to immediate runoff at the start of rainfall. It includes surfaces like sloped rooftops or pavement draining directly to gutters. The default value is 25%, which is typically recommended unless specific conditions suggest otherwise.

Table 8.1: Significant Natural Areas and Natural Areas of Guelph's Natural Heritage System (NHS)

NHS components[11]	Criteria for feature identification	Minimum buffer widths
Significant Natural Area: significant areas of natural and scientific interest (ANSI)	Provincially or regionally significant earth or life science ANSI as identified by the MNR.	no minimum buffer
Significant Natural Area: significant habitat for provincially endangered and threatened species	Significant habitat of endangered and threatened species as approved by MNR.	no minimum buffer
Significant Natural Area: provincially significant wetlands (PSW)	As mapped by MNR and/or confirmed by a qualified wetland evaluator.	30 m
Significant Natural Area: locally significant wetlands	Evaluated non-PSW wetlands of at least 0.5 ha in size as confirmed by the City and/or GRCA.	15 m
Significant Natural Area: surface water and fish habitat	Cool/cold water fish habitat as identified by the MNR, GRCA and/or a City-approved study.	30 m
Significant Natural Area: surface water and fish habitat	Warm water fish habitat and undetermined fish habitat, as identified by the MNR, GRCA and/or a City-approved study.	15 m
Significant Natural Area: permanent and intermittent streams	Permanent and intermittent streams as identified by the MNR, GRCA and/or a City-approved study.	30 m or 15 m
Significant Natural Area: significant woodlands	Woodlands (not identified as cultural woodlands or plantations) of 1 ha or greater in size, and a 10 m minimum buffer. Woodlands 0.5 ha in size or greater consisting of Dry-Fresh Sugar Maple Deciduous Forest; or Woodland types ranked as S1 (Critically Imperiled), S2 (Imperiled) or S3 (Vulnerable) by the MNR Natural Heritage Information Centre.	10 m from the dripline
Significant Natural Area: significant valleylands	Undeveloped areas within the regulatory floodplain areas, riverine flooding hazards, riverine erosion hazards, as identified by the GRCA.	no minimum buffer
Significant Natural Area: significant wildlife habitat (SWH)	Seasonal concentration areas, including deer wintering and waterfowl overwintering areas identified by the MNR. Rare vegetation communities or specialized habitat for wildlife (as per the SWH criteria for Ecoregion 6E, MNR, 2015).	no minimum buffer

[11] Note: Significant Landform is omitted from Table 2.5 because it does not occur in the subwatershed.

NHS components[11]	Criteria for feature identification	Minimum buffer widths
	Habitat for species of conservation concern (excluding significant habitat of endangered and threatened species).	
Significant Natural Area: significant wildlife habitat (SWH): ecological linkages	Areas identified based on the principles of conservation biology that connect Significant Natural Areas and/or protected habitat for significant species and along which wildlife can forage, genetic interchange can occur, and populations can move from one habitat to another in response to life cycle requirements. Generally, 50 m to 100 m in width, with some exceptions.	no minimum buffer no buffer required
Significant Natural Area: restoration areas	Existing and new stormwater management areas abutting other NHS components. Areas within City parkland (including portions of the Eastview Community Park). GRCA lands which are not intended for active uses. Isolated gaps within the NHS.	no minimum buffer
Natural Area: other wetlands	Non-PSW wetlands 0.2 to 0.5 ha in size that meet one or more of the criteria specified (see policy 4.1.4.1)	no minimum buffer
Natural Area: cultural woodlands	A woodland with tree cover between 35% and 60% originating from, or maintained by, anthropogenic influences and culturally based disturbances. Must be at least 1 ha in size, and not dominated by non-indigenous, invasive species. If contiguous with other woodlands qualifying as significant woodlands, must be captured within those features.	no minimum buffer
Natural Area: habitat for significant species	Wildlife habitat that: • supports species considered globally, federally, provincially and/or locally significant, and; • contributes to the quality and diversity of the NHS (not to the extent that it is determined to be SWH or significant habitat of endangered and threatened species). Habitats for plant species shall be included only where the species is growing naturally in the wild (i.e. not planted for horticultural, landscaping or agricultural purposes).	no minimum buffer
Wildlife Crossings **(Note: Not a feature, but a flag for mitigation to provide or improve connectivity of the NHS)**	Locations where deer and amphibians cross roadways within or abutting City boundaries. Areas where habitat is found on both sides of the roadway where wildlife is likely to cross.	no minimum buffer

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