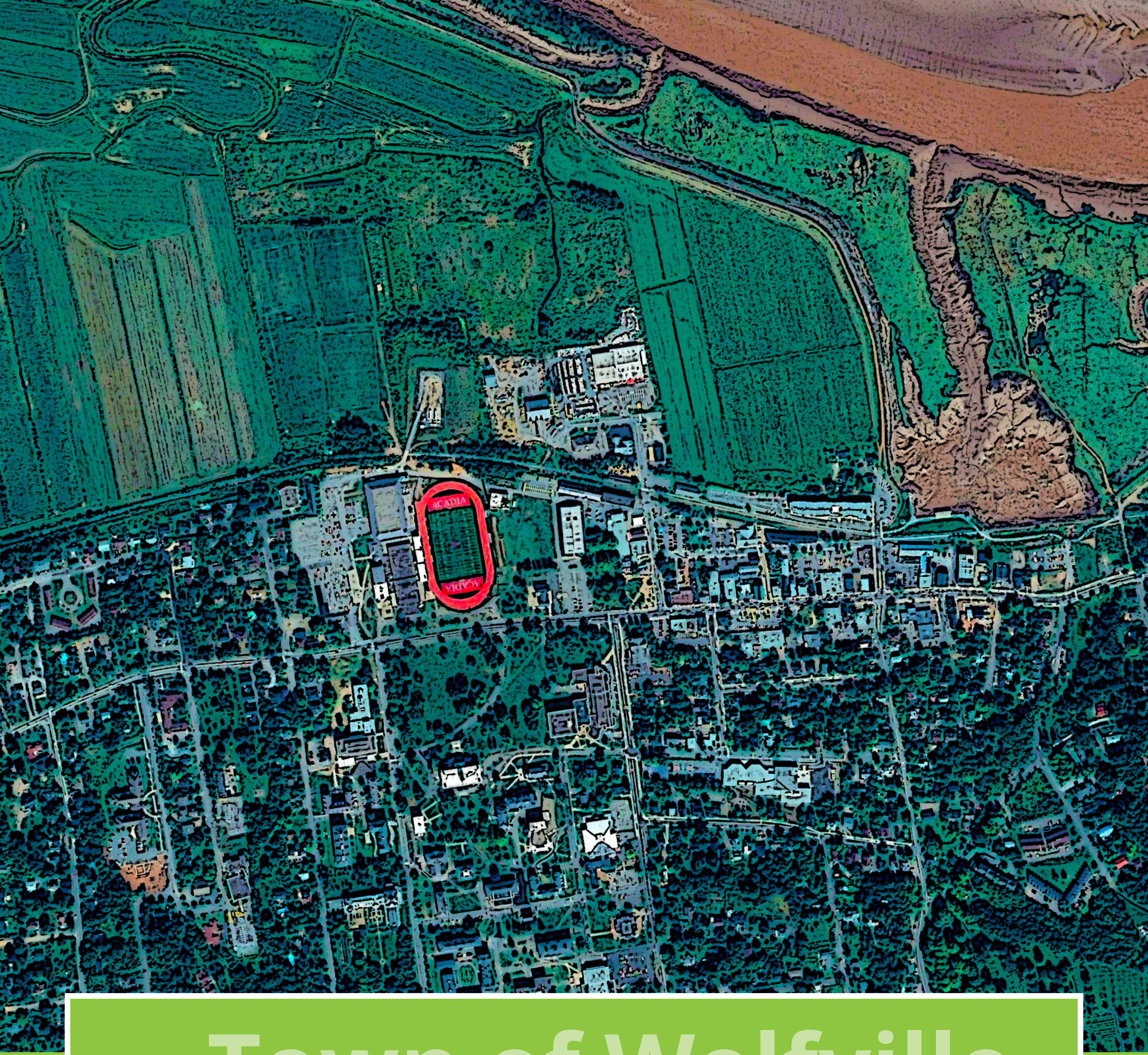


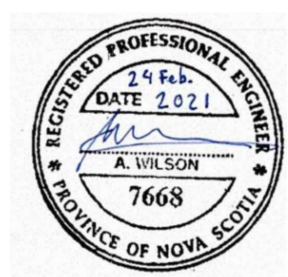
Town of Wolfville

Flood Risk Mitigation Plan

Final Report

201101.00 • Final Report• February 2021

	Final Report		26/02/2021	
	Draft ver.3 Report	Alexander Wilson	12/15/2020	Lauren Fleet
	Draft ver.2 Report	Alexander Wilson	08/31/2020	Lauren Fleet
	DRAFT Report	Alexander Wilson	03/07/2020	Lauren Fleet
Issue or Revision		***Reviewed By:***	***Date***	***Issued By:***



Project Number 201101.00

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Devin Lake
Director of Planning and Development
Town of Wolfville
200 Dykeland Street
Wolfville, NS B4P 1A2

Dear Mr. Lake:

RE: Town of Wolfville Flood Risk Mitigation Plan – Final Report

CBCL Limited is pleased to provide the following final report for the Town of Wolfville Flood Risk Mitigation Plan. The report presents an analysis of flood risk within the Town of Wolfville and provides mitigation and adaptation options to reduce this risk. The report outlines the recommended actions for the Town based on an assessment of the proposed flood mitigation option presented. We thank you very much for your comments, and have endeavoured to address them fully in this final version of the report.

Please feel free to contact the undersigned at any time to discuss the report at your convenience.

Yours very truly,

CBCL Limited

Alexander Wilson, M.Eng., P.Eng.
Practice Lead – Water Resources

Project No: 201101.00

SCOPE OF WORK

CBCL was contracted to respond to the following scope of work for this project. The table below provides a quick reference to relevant information:

Project Scope Component	Final Report Reference
Consultation with local, regional, and provincial stakeholders.	Chapter 10.1 Stakeholder Consultations
The identification and analysis of flood hazards, highlighting specific areas of vulnerability within the town.	Chapter 7 Vulnerability Assessment
The development and modelling of current and future flood scenarios.	Chapter 4 Coastal Water Level Analysis and Chapter 5 Hydrologic and Hydraulic Analysis
Determining the consequences of developed flood scenarios, in terms of who and what would be impacted, and the nature and severity of those impacts.	Chapter 7 Vulnerability Assessment
A workplan with a mitigation investment strategy, including a prioritized list of identified projects for implementation; and adaptation strategies, covering the areas of land-use planning, protection/relocation/resilience of critical infrastructure, development, personal/household safety and planning measures, and emergency response and service management.	Chapter 8 Flood Risk Mitigation Options and Chapter 9 Preliminary Evaluation of Mitigation Options
Updating current flood maps and models for the Town.	Chapter 6 Flooding Analysis and Appendix A
Recommendations for integration with provincial and regional plans.	Section 3.3: Documentation Review
A public education and engagement component, which could include a community workshop and/or the development of a public-facing communication strategy and materials.	Section 10.2: Community Education and Communication. Appendix B

Executive Summary

A Flood Risk Mitigation Plan has been completed for the Town of Wolfville. The Plan identifies current and future flood risks, including impacts of climate change, and evaluates a list of proposed solutions to mitigate flood risks to the Town. The Plan was developed through communication with both stakeholders and the Town and included a review of the Town's municipal operations and priorities, relevant reports, by-laws, guidelines and strategies.

Inland and coastal flooding within the Town of Wolfville can occur as a result of extreme rainfall events and extreme coastal water levels. Inland flooding occurs when the stormwater collection system has insufficient capacity to convey stormwater runoff downstream during extreme rainfall events resulting in overflow onto areas such as roads, municipal infrastructure and private properties. Coastal flooding occurs when extreme tides reach inland areas either through backup through the stormwater system, overtopping dykes, or between the two dyke systems.

A suite of computer models was used to assess flood risks within the Town, estimate current and future risks and evaluate potential flood mitigation options. A range of rainfall and tidal scenarios were assessed under current and future conditions to evaluate the risks of flooding.

The effects of climate change on both precipitation and sea level rise were considered when examining future conditions (i.e., the year 2100 time horizon). To date, global green-house gas concentrations have most closely tracked the Representative Concentration Pathway (RCP) 8.5, which was used to generate the higher range of climate change projections featured in the Intergovernmental Panel on Climate Change's Fifth Assessment Report. The 1-in-100-year rainfall event is projected to increase by approximately 60% by 2100 under RCP8.5 (95^{th} percentile) according to the Western University IDF-CC Tool.

Existing and projected Future Rainfall intensities using the IDF_CC tool

Peak Rainfall Intensity	1-in-2-year (mm/hr)	1-in-100-year (mm/hr)
Existing	68.57	174.00
Future	88.45	280.12

Extreme coastal water levels include high tide, sea level rise (SLR), storm surge and tidal amplification. Regional sea level rise for the year 2100 "High" scenario is projected to be 1.58m for the Town of Wolfville.

Peak Coastal Total Water Levels for Existing and Future (2100) Conditions

Peak Water Level	1-in-2-year (m CVGD 2013)	1-in-100-year (m CVGD 2013)
Existing (2020)	7.57	7.76
Future (2100)	9.15	9.35

Implementation Plan

A flood mitigation implementation plan has been assembled as part of this study, which is summarized in the following table, according to the timeline for implementation.

	High Priority Action	Timeline	Class "D" Opinion of probable Cost*	Report Reference
Connecting the dyke system & integrating living shorelines				
	Conduct topographic survey of top of dykes and waterfront in-between	1-3 Years	~$20k	Section 3.2 Stormwater Drainage
	Contact rail line owner to assess feasibility of acquiring land for new dyke	1-3 Years	-	Section 8.1.1Connecting the Dyke System and Applying Living Shorelines
	Land negotiations, pending results of above discussions	1-3 Years	-	
	Hold discussions with Department of Agriculture about raising of dykes	1-3 Years	-	10.1.2 Nova Scotia Department of Agriculture
	Following the above, select option for new dyke (in mudflat or rail ROW)	1-3 Years	-	
	Tender and award detailed design for new dyke	1-3 Years	~$50k	
	Investigate financing options for new dyke	1-3 Years	-	
	Design and tender stormwater pipe extensions to reduce erosion and support development of living shoreline	1-3 Years	~$20k	
Raising land around Sewage Lift Stations (SLSs) and new berm around WWTF				
	Review permitting and land requirements based on WWTF berm alignment and footprint	1-3 Years	-	

	Tender and award detailed design for new berm	1-3 Years	~$50k	
	Regrade land around SLSs	1-3 Years	~$10k	
Flood forecasting and warning system in partnership with REMO				
	Discuss with REMO scope and integration of system in existing SCADA	1-3 Years	-	8.2 Flood Forecasting and Warning System
	Tender flood forecasting and warning system	1-3 Years	~$50k	
	Install water level monitoring and recording system with connection to SCADA	1-3 Years	~$50k	
Community education and communication				
	Public Education: - Review Summary Document - Educational Signage about Sea Level Rise - Mail out leaflets to home and building owners in flood risk areas - Prepare open house when feasible	1-3 Years	~$10k	10.2 Community Education and Communication
Construction of new dyke and berm				
	Tender construction of new dyke Remove and dispose of old wooden beams Tender extensions of stormwater pipe outfalls	3-5 Years	~$600k on bank ~$6M in mudflat ~$20k ~$600k	8.1 Coastal Flood Protection Measures and 9.2.1 Coastal Flood Protection Measures
	Tender construction of new berm	3-5 Years	~$300k	8.3.2 Wastewater Treatment Facility
	Coordinate topping of existing dykes with Department of Agriculture	3-5 Years	-	10.1.2 Nova Scotia Department of Agriculture

Future steps				
	Evaluate recorded water level data and assess Sea Level Rise projections	35-45 Years	~$5k	-
	Design and construct (or coordinate with Department of Agriculture) additional raising of the dyke system	35-45 Years	Depends on findings	10.1.2 Nova Scotia Department of Agriculture

	Actions Subject to Further Monitoring	Class "D" Opinion of probable Cost*	Report Reference
Increasing infiltration measures			
	Identifying opportunities wherever pipes, sidewalks or parking lots are replaced or maintained	Will vary	9.2.5 Best Management Practices or Low Impact Development
Increasing storage capacity			
	Construct detention pond in Little Brook Lane area	~$250k	8.5.2 Increasing Storage Capacity
Increasing stormwater conveyance capacity			
	Minor upgrades with street work	Will vary	
	University and Main Street (identified as largest increase in pipe diameter)	~$300k	8.5.3 Increasing Pipe Capacity
Protecting future development			
	Monitoring latest information (data, climate science) and update plans accordingly		5.1.2 Impacts of Climate Change Rainfall Events
	Evaluate recorded water level data and assess Sea Level Rise projections		4.1.2 Climate Change Impacts on Coastal Water Levels

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Chapter 1 Introduction

The increasing risks and costs associated with flooding, extreme weather and climate change on public safety, human health, environment and infrastructure resilience are key considerations in municipal planning. Climate change and extreme weather adaptation strategies are building the foundation for informed risk mitigation investments.

The Town of Wolfville (Town) is seeking to understand the risks associated with flooding and climate change through the implementation of a Flood Risk Mitigation Plan (Plan). This Plan aligns with the priorities set out in the Municipal Planning Strategy and associated planning documents developed by the Town. The Plan has considered both current and future flooding impacts on flooding extents, herein referred to as floodlines, for planning and outlining mitigation strategies to reduce risk and improve resilience. In order to encompass the specific interests and main concerns of the Town, community stakeholders were consulted during Plan development.

Increasing community resilience to coastal flooding and extreme weather events will provide safeguards for important economic, residential, environmental, cultural, and social infrastructure and assets. The Plan identifies and addresses the current and potential future risks and impacts related to coastal flooding and large rainfall events within the Town. The mapping includes flooding impacts to residential properties and assets within the Town. The flood maps will provide decision-makers, engineers, planners, emergency responders, infrastructure owners, and property owners with the information required to make informed decisions pertaining to flood risk.

The Plan also involves a flood risk and vulnerability assessment to inform a broader flood risk mitigation and climate change adaptation plan for the Town. Incorporating projected climate change to produce future floodlines will aid in Plan design and, though the Plan is in draft form, has already supported long-term decision making. Floodline mapping which includes the effects of climate change provides community officials, engineers, asset owners, and planners information to make informed decisions around climate change adaptation initiatives for new and existing infrastructure. The Plan outlines specific measures for protecting existing infrastructure and proposed developments from the identified flooding risks within the Town.

1.1 Climate Change

In the past, Canada has warmed by approximately two times the magnitude of global warming, and this trend is projected to continue into the future (Bush & Lemmen, 2019). Over the period of 1948 to 2016 Canada has experienced a mean annual temperature increase of 1.7°C (Bush & Lemmen, 2019). Atmospheric warming is linked to changes in precipitation, sea level, inland water levels, sea ice, permafrost, and extreme weather events (Palko, 2016). Climatic variability is creating both opportunities and challenges for Canadian municipalities.

According to the Insurance Bureau of Canada (2019), flooding incurs the greatest amount of financial damage and losses. Nationally, the insured losses related to flooding totalled $405 million between 1983 and 2008 and increased to a total of $1.8 billion between 2009 and 2017. Flooding related costs have quadrupled in 40 years and account for 40% of all the Disaster Financial Assistance Arrangements (DFAA) expenses. Furthermore, in 2018 the damage covered by insurance from extreme weather was approximately $2 billion (Insurance Bureau of Canada, 2019).

In the context of climate change, Nova Scotia has experienced rising average temperatures, higher intensity precipitation events, rising sea levels, and amplified coastal erosion and flooding. Overall, climate scientists predict that Atlantic Canada will experience increasingly wetter, warmer, and stormier weather in the future (Bush, 2019).

The Town of Wolfville is on the coast of the Minas Basin. The Minas Basin is part of the Bay of Fundy, which is renowned for having the largest tides in the world. The Town is set back in some areas behind protective dykes and agricultural land, which serve as a buffer from high coastal water levels. However, due to rising sea levels and the potential for larger and more frequent surge events in the future, the current height of the dyke systems may be inadequate to protect against future coastal water levels. Adaptation measures to reduce the impacts of climate change will work to protect current infrastructure and guide planning for sustainable future development.

Chapter 2 Study Approach

Flooding within the Town is a result of two independent events: high intensity rainfall and extreme coastal water levels. Temporal and spatial patterns of flooding are influenced by local hydrology, coastal water elevations, topography, hydraulic structures (e.g., stormwater system), and dyke elevations. To inform an effective Flood Mitigation Plan, a representation of the local hydrologic and hydraulic processes was created using modelling software. The models produced detailed flood maps, which were used to support risk and vulnerability assessments of Town assets and consider options for reducing flood risk.

The study approach includes:

- **Review of Available and Relevant Information**: the Town's current municipal operations and priorities, applicable reports, by-laws, past studies, GIS data, Town assets, federal and provincial data, and historical references.
- **Consultation:** engaging with stakeholders and Town staff to understand the current and potential impacts of sea level rise and flooding on infrastructure, operations, and plans, as well as discussing future development and strategic plans.
- **Hydrologic Assessment**: calculation of rainfall events with varying return periods using climate information from the Environment and Climate Change Canada Kentville climate station.
- **Coastal Water Levels Assessment**: calculation and modelling of extreme coastal water levels including high tide, sea level rise, storm surge and tidal amplification within a 2D hydrodynamic model of the Bay of Fundy.
- **Hydraulic Model Development and Analysis**: development of a hydrologic and hydraulic model of the Town stormwater drainage system, including piped and surface drainage, the dyke system and associated outfalls.
- **Flood Mapping**: flood simulation modelling, floodline delineation mapping, and identification of the potential flooding hazards that are present within the Town of Wolfville. Floodplains were modelled under various precipitation and storm surge scenarios, including the 1-in-2-year, 1-in-20-year and 1-in-100-year events under current and future climate conditions.
- **Risk and Vulnerability Assessment**: identification of important infrastructure that is currently vulnerable, or may become vulnerable, to flooding impacts.
- **Development and Assessment of Mitigation Options:** assessing the effectiveness and feasibility of flood mitigation options to protect priority infrastructure and mitigate flooding.

To ensure that the Plan is consistent with ongoing initiatives, the following relevant documents were referred to in the development of the Plan:

- The current municipal operations and priorities of the Town;
- Applicable reports, by-laws, past studies, GIS data, assets, federal and provincial data; and
- References including the Town's Stormwater Management Guide, the Nova Scotia Coastal Protection Act, the Municipal Planning Strategy and associated documents such as the Land Use By-law, Design Guidelines, and the Subdivision By-law.

Chapter 3 Background

3.1 The Town of Wolfville

The Town of Wolfville is located in Kings County, Nova Scotia, along the shore of the Minas Basin. The Minas Basin is part of the Bay of Fundy, which hosts the world's largest tides. Agricultural dykes (shown in Figure 3.1 below), built by the Acadians in the 17th century, generated rich agricultural land and protected it from coastal waters. The dykes are used by the community as walking trails and provide a scenic landscape.

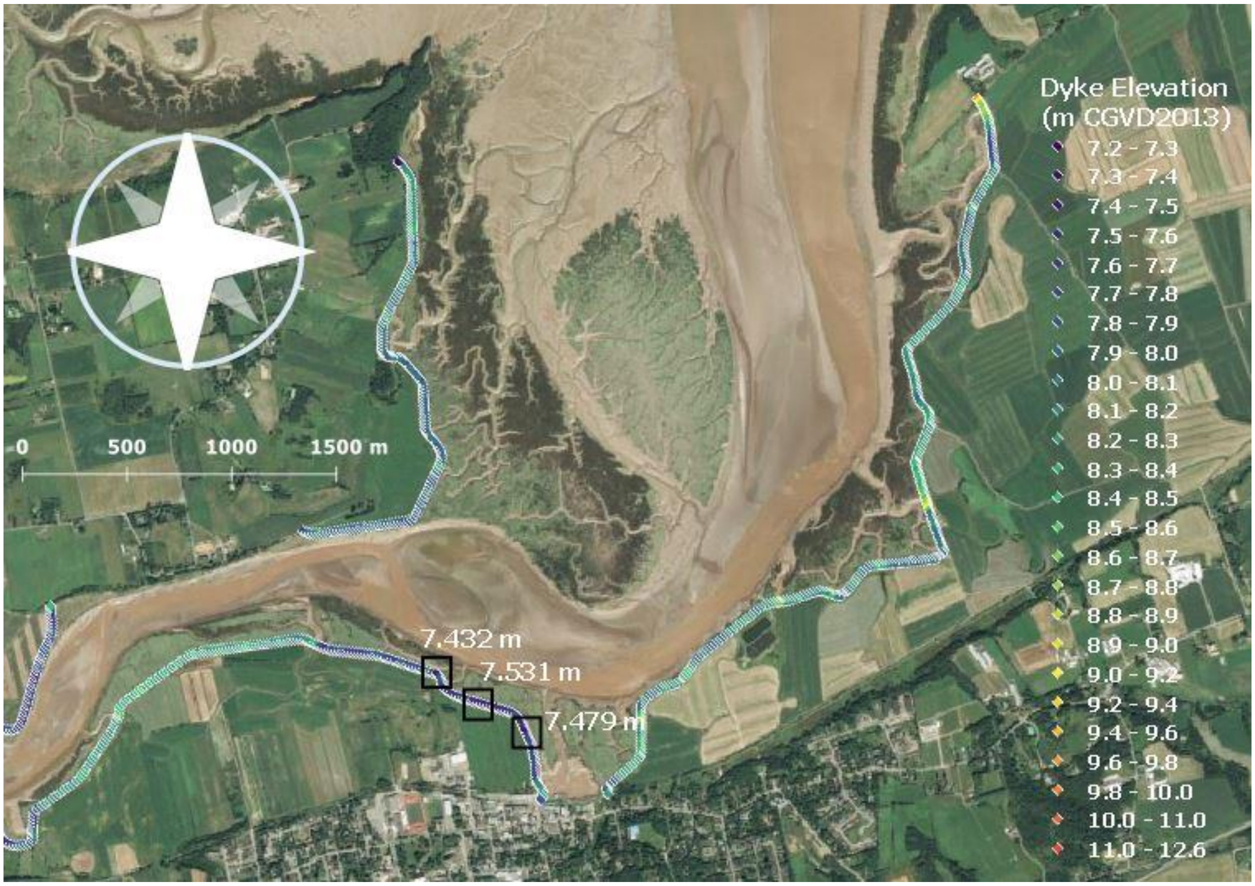


Figure 3.1: Wolfville Dyke System

The Town is located along Highway 1, covering an area of approximately 6.46km^2. Primary land uses include Residential (49%), Agricultural (26%), and Institutional/University (12%) (Town of Wolfville Department of Community Development, 2017). The Town has a population of 4,195 people according to the 2016 Canadian Census, with 2,655 people between the ages of 15 and 65 and 1,150 people that are 65 years and older.

The Municipal Planning Strategy (MPS) that was recently adopted (approved by Council June 2020, provincial review completed and administered since September 2020) projects a 2% future increase in the population of the Town (Town of Wolfville Department of Community Development, 2017). According to the MPS, the priorities of the community include economic prosperity, social equity, climate action, and land use and design. The Town supports a variety of important infrastructure assets, including local and tourist attractions such as wineries and craft beer vendors, restaurants, cafes, parks, green spaces, and trails (e.g., the Harvest Moon Trail).

According to the MPS, Residential and Commercial Zones are the main sources of revenue for the Town. In conjunction with the university and tourism, agriculture has been a defining factor in shaping the local economy.

Sustainable planning and development are a priority of the Town. The Town has invested in developing strategies and documentation regarding land use, municipal planning, and development policies in order to regulate and plan for future growth through residential expansion and development.

3.2 Stormwater Drainage

The stormwater drainage system is owned, operated, and maintained solely by the Town of Wolfville Department of Public Works and Services or in combination with private landowners (Hatch Ltd, 2019). The stormwater drainage network is comprised of a major and minor system. The minor system consists of the underground pipe network, gutters, catch basins, roof gutters, and swales. Minor drainage systems are designed with the capacity to convey runoff from frequent storm events (e.g., 1-in-2-year, or 1-in-5-year storms) without ponding of water. The major system consists of natural water courses, streets, swales, channels and ponds. The purpose of the major system is to accommodate larger rainfall events (e.g., 1-in-100-year storm) in order to eliminate flooding risks and loss of life. As described within the MPS, stormwater has historically been managed through a series of small brooks and natural water courses.

The stormwater drainage system was designed to collect and distribute the stormwater to these natural drainage paths. The Town has fairly steep downhill slopes, which are greater than 20% in some locations. As illustrated in Figure 3.2, runoff is directed north to the Minas Basin (Town of Wolfville, 2020).

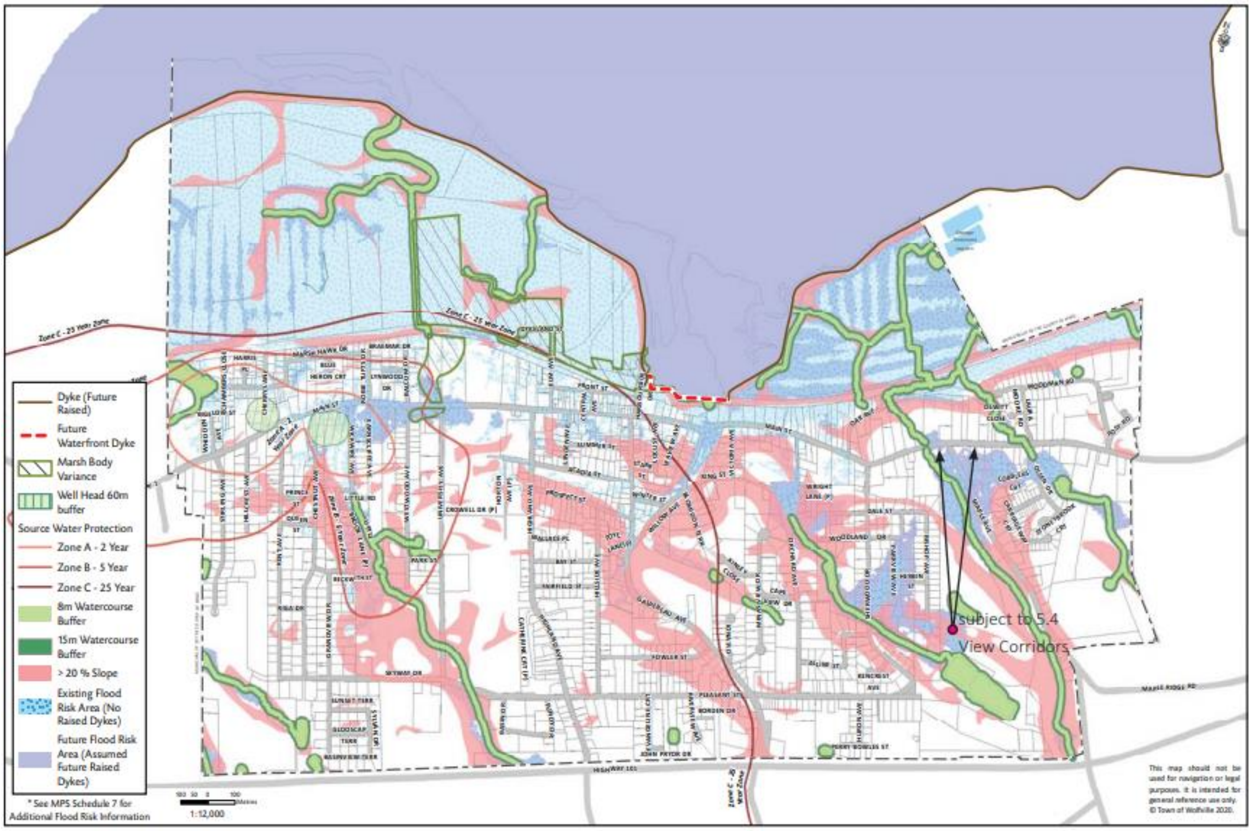


Figure 3.2: Land Use By-law: Schedule B

Stormwater is released to the Minas Basin through a series of aboiteaux along the dyke systems. Aboiteaux consist of a culvert through the dyke with a tide gate which operates on a pressure differential generated between the tide and stream. During low tide, upstream fresh water (e.g., stormwater or natural streams) drain out into the basin. During high tide the gate is closed to prevent saltwater intrusion into agricultural lands and the Town south of the dyke. However, during high tides, freshwater drainage cannot occur, which allows freshwater flows to accumulate, and increases the risk of flooding.

Coastal dykes are built to accommodate tidal fluctuations, storm surge and wave run up. The dyke systems protecting the Town of Wolfville from coastal waters vary in height, as seen in Figure 3.3, where the lowest points are highlighted. This survey dates from 2007, so the values are somewhat out of date, and will need to be surveyed again before any design work is completed.

Wolfville Harbour lies between two unattached dyke systems: the Grand Pre system to the east and the Bishop Beckwith system to the west. There are five aboiteaux in the Grand Pre system and four aboiteaux in the Bishop Beckwith system. It is understood that the upstream areas may be vulnerable to high water levels in the Minas Basin. Historically, frequent flooding has not occurred in the Town of Wolfville; however, low elevations or gaps within the dyke system (identified through a Department of Agriculture asset mapping study), sea level rise, and climate change (e.g., more frequent and intense storm events) all elevate the risk of coastal flooding.

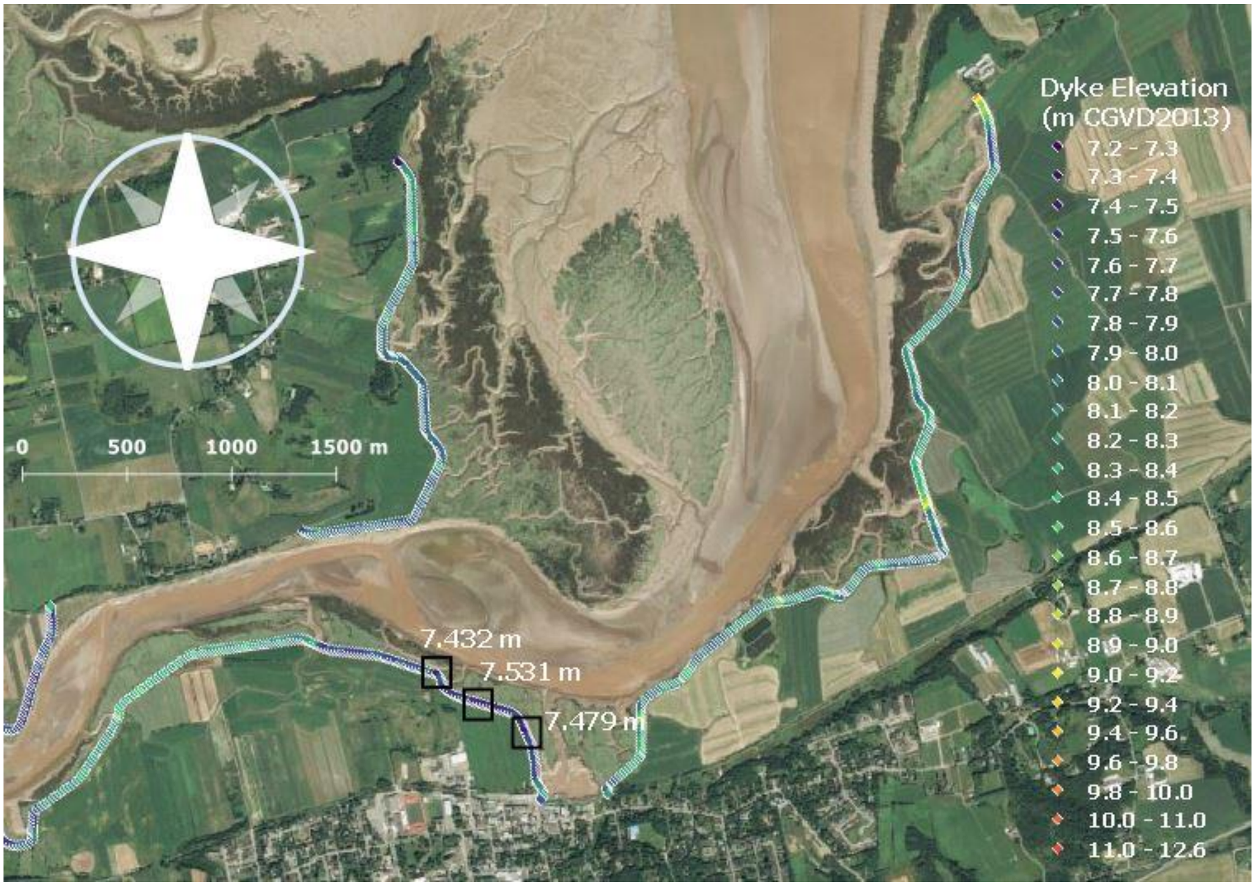


Figure 3.3: Wolfville Dyke System – Lowest Points Highlighted

3.3 Documentation Review

The Town has developed a number of planning documents which were reviewed internally to understand municipal operations, priorities, as well as planning and development. This was done to incorporate and align the Flood Risk Mitigation Plan with the planning goals and priorities of the Town.

The Town currently addresses flood risks, development requirements, and constraints through a set of policies outlined in the updated MPS and through Floodplain Development Standards in the Land Use By-laws. The MPS, land use and subdivision by-laws provided by the Town were the focus of the review.

3.3.1 Stormwater Management Design Guidelines

The Town adopted the Stormwater Management Design Guidelines (Guidelines) prepared by Hatch (2019). The purpose of the Guidelines is to outline design criteria for the stormwater drainage system, in order to achieve the following objectives:

- Prevent loss of life and protect structures and property from damage due to flood events;
- Provide safe and convenient use of streets and lot areas during and following precipitation and snow melt events;
- Adequately convey stormwater runoff from upstream sources;
- Mitigate the adverse effects of stormwater runoff, such as flooding and erosion, onto downstream properties;
- Preserve designated natural watercourses and natural wetland environments; and
- Minimize the long-term effects of development on the receiving surface waters and groundwater regimes from both a quantity and quality perspective.

The Guidelines stipulate the recommended approach for assessing the hydrology and hydraulics of the site area and outline design criteria for standard major and minor drainage systems. A requirement for a net-zero increase in runoff through development is also stipulated, and the Guidelines recommend the adoption of low impact developments[1] (LIDs) or runoff control measures as necessary. In this way, although the extent of impervious surface areas may increase as a result of development, its influence on peak flood conditions may be offset proportionally. Broadly, LIDs are techniques and technologies which work to reduce the impacts of increased runoff and stormwater pollution post urbanization. LID controls include measures that facilitate infiltration and reduce peak flows, such as permeable pavements, grass swales, rain gardens, and bio-retention cells. The flood mitigation options presented in this report are in line with these stipulations, and flood mitigation strategies are further discussed in Chapter 8 of this report.

The Guidelines address the impacts of climate change on the management and design of the stormwater drainage system. It is outlined that climate change, which includes projected sea level rise and the increased frequency and intensity of storms, shall be considered in terms of stormwater quantity and quality within the Stormwater Management Report. This may include identifying vulnerable infrastructure and implementing mitigation measures to reduce the risk of flooding. The recommended approaches in the Guidelines were considered in the Flood Risk Mitigation assessment.

[1] Low Impact Developments (LIDs) are commonly related to, or directly synonymous with, the terms stormwater Best Management Practices (BMPs) and Green Infrastructure.

3.3.2 Municipal Planning Strategy

The MPS update was initiated in 2015, and is part of a series of planning documents written in accordance with Chapter 18 of the Statutes of Nova Scotia, 1998. The updates address concepts such as climate change, floodplains, and development constraints. Information from the present report (while in draft form) was included in the updates to the MPS. A public hearing and 2nd reading have now been completed and the documents were approved by Council in June 2020. The MPS has been established as a 'living document' to adapt to the needs and priorities of the community over time.

The intent of the MPS is to guide and manage growth in line with the Town's vision for future development. The goal of the MPS is to stimulate high-quality design, sustain and develop the Core Area, embrace the history of the Town, enhance economic vitality, and promote social and environmental sustainability. The MPS also serves as the Town's Integrated Community Sustainability Plan (ICSP).

The MPS consists of policies and maps, which outline regulations and specifications regarding the intent of the MPS, and includes the Land Use By-law, Design Guidelines, and the Subdivision By-law.

Land Use policies are illustrated through the use of communication documents and maps. The maps include:

- Future Land Use
- Future Parks and Trails
- Open Space and Mobility Network
- Future Streets
- Land Use (zoning)
- Development Constraints Area Overlay
- Design Guidelines Overlay

Climate change and associated risks have been identified and incorporated in the MPS as climate actions and strategies to manage and mitigate the associated impacts. These strategies include controlling land use to sustain open spaces and protect the natural environment, development of stormwater management plans, and regulation of development. Climate actions also include undertaking adaptation and mitigation measures to build community resilience, including development requirements in flood prone areas, and establishing minimum building heights. The MPS outlines development constraints in Schedule B of the Land Use By-law.

The MPS addresses development in areas at risk of flooding through two sets of policies:

- **Part 4.2 Development Constraints** to ensure that residential institutions such as a hospital, senior citizen home, home for special care, or similar facility, or a use associated with the warehousing or production of hazardous materials are not located where flooding could pose a significant threat to the safety of the Town of Wolfville's residents or environment. Also, that all new developments on or immediately adjacent to environmentally sensitive areas conduct environmental studies that show no negative environmental impacts related to flooding.

- **Part 4.3 Agriculture and Greenbelt** designate Agriculture (A) areas located on the Dykelands, excluding areas within the Core Commercial or Neighbourhood Designation, as per Map 1- Future Land Use Map. Within the Agriculture zone, only agricultural uses shall be permitted.

The MPS document refers to the current Flood Risk Mitigation Plan in Schedule 7, and contextualizes the mapping in the Land Use By-law. The flood delineation mapping is presented in Schedule B of the Land Use By-law document. The summary of the main findings is a stand-alone document prepared for a wider audience and includes content on sea level rise, flooding risks, typical approaches to flood mitigation, and specific measures homeowners can take to protect themselves against water intrusion within their home.

Land Use By-law

The purpose of the Land Use By-law is to establish regulations described in the MPS, in accordance with the Municipal Government Act. The By-law outlines application requirements for new developments. Part of this requirement includes a Site Grading and a Stormwater Management Plan which work to control overall stormwater drainage within the Town. General requirements may differ depending on the site zoning, which were classified as Neighbourhood, Commercial (each with Core areas), Agricultural, and University within Schedule 1.

CBCL worked with the Town planning staff to update the now adopted planning documents. The findings and recommendations of this study, which include better definitions and an Undertaking Form, have been integrated within the new planning documents.

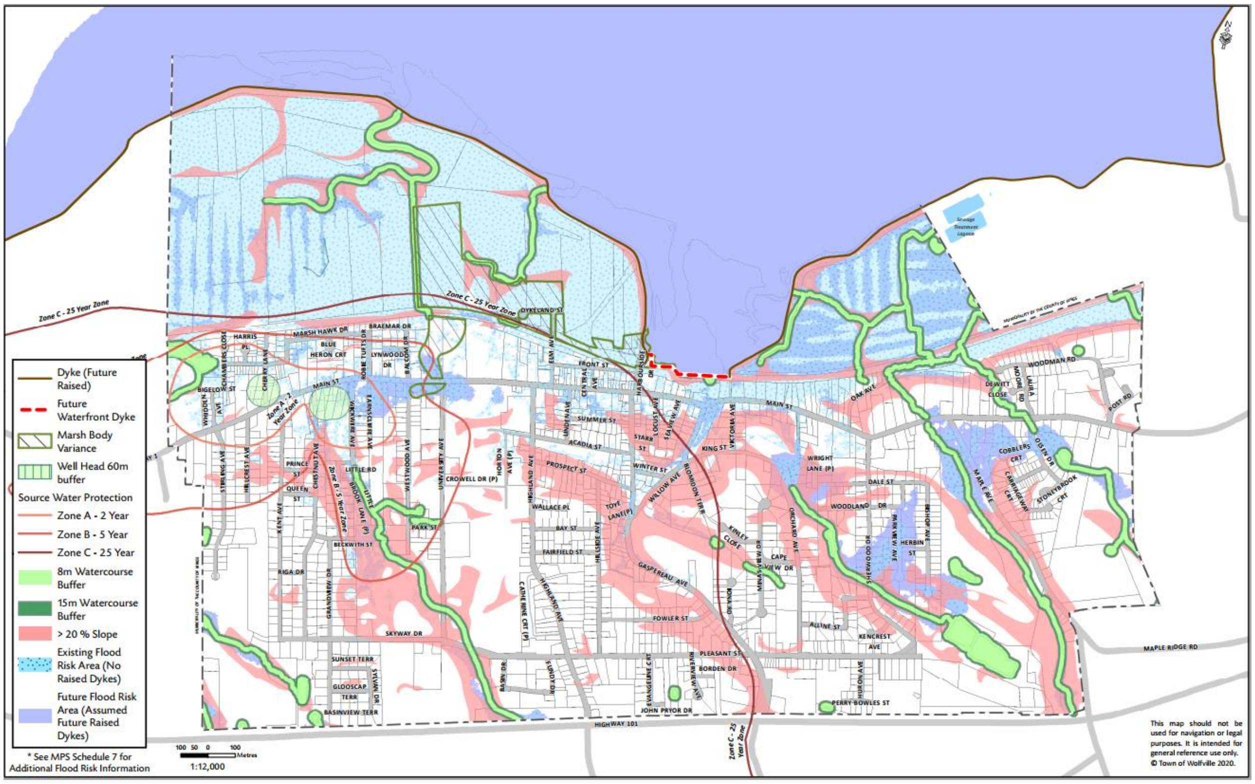


Figure 3.4: Development Constraints (Source: Town of Wolfville Land Use By-law)

Aside from the Agricultural zoning designation in the Dykeland District, flood risk mitigation is explicitly addressed under Land Use By-law Section 5.1 - Floodplain Development Standards. The By-law prohibits hospitals, seniors care facilities, special care facilities, schools, warehousing or storage of hazardous materials and essential services in the floodplains shown in Schedule "B" (Development Constraints) Overlay. Schedule "B" delineates a number of boundaries associated with development constraints. The Schedule "B" Constraints were updated as part of this project to define and delineate floodplain boundaries.

The By-law permits new development in areas within the floodplain shown on Schedule "B", where a Floodplain Development Undertaking Form is to be signed acknowledging recognition of risks, and confirming:

- The development's finished floor elevation is no lower than 8m geodetic (CGVD28);
- The walls and floor below 12m geodetic should be constructed to be flood tolerant; and that
- Consideration be given to placement of mechanical equipment.

The By-law also promotes the utilization of natural green spaces and features to increase stormwater infiltration. These measures are directly related to flood mitigation Best Management Practices (BMPs) as outlined in Chapter 8 of this report.

Design Guidelines

The Design Guidelines act to align future development with the priorities and plans presented within the MPS. The Guidelines follow all regulations and strategies outlined within the MPS and the Land Use By-law and relevant policies. Sustainability and resilience are guiding principles. The Guidelines address sustainable building practices in Section 3.3.4. Included are directions to accommodate climate change and increasing flood risk by minimizing impervious surfaces, incorporating green technologies (e.g., green roofs), and utilizing natural water catchment and filtration features. These design actions align with the mitigation and adaption plans presented within this Flood Risk Mitigation Plan.

Subdivision By-laws

The Subdivision By-law applies to all subdivisions within the Town of Wolfville and outlines all requirements for development and planning of new subdivisions. The by-law follows all regulations and strategies outlined in the MPS and the Land Use By-law and relevant policies. A drainage plan must be developed as part of the application for approval. Required in the drainage plan is a detailed plan of the stormwater runoff within the proposed subdivided land, including all watercourses, channels, and floodplains for all tributary and upstream areas.

3.3.3 Nova Scotia Coastal Protection Act

The Nova Scotia Coastal Protection Act – Bill 106 (CPA) is new legislation enacted in 2019 by the Government of Nova Scotia. The Act was developed based on the increasing identification that sea level rise, coastal flooding, storm surge and coastal erosion pose significant threats to the safety of future development in coastal areas. The purpose of the Act is to protect the provincial coastal environment by preventing development and activity in locations that damage the environment by interfering with the natural dynamic of the coast and put residents and buildings at risk from sea level rise, coastal flooding, storm surges and coastal erosion.

The Act has not yet been proclaimed into law and will come into effect once regulations are approved by the Governor and Assembly. Regulations within the Act were actively being developed during the writing of this report. CBCL is currently contracted by Nova Scotia Environment to develop a "Coastal Erosion Risk Factor Assessment Standard" to identify vertical and horizontal areas of application of the regulations. Notice was given to municipalities that upcoming regulations under the Act will have an impact on development permitting. The Act has been undertaken in parallel with the Province's Municipal Flood Line Mapping project (also developed with CBCL), which aims at producing flood mapping specifications according to standard methods and guidelines for the entire Province.

The CPA defines a 'Coastal Protection Zone' (CPZ) as the area of land, including land covered by water, on the coast that is lying seaward of the ordinary high-water mark and the area in the landward direction immediately adjacent. The boundaries of the CPZ will constrain development. Delineation of the CPZ will be determined based on vertical and horizontal setbacks. The description of these setbacks has not been legislated and are subject to change.

The Act includes certain exemptions for development within the CPZ, such as agricultural activities (e.g., marsh bodies and dykes), public infrastructure, industrial and commercial activity requiring direct access to water as a functional part of the business plan, and shoreline structures placed by Lands & Forestry. Additionally, certain types of structures may be exempt from the requirement for a Community Environmental Response Facilitation Act Report as provided for under the CPA regulations.

In addition, there is a Minimum Building Elevation (MBE), that will be described in the regulations, that sets the minimum elevation of the ground onto which construction can occur. The description of the MBE is as shown in the Figure 3.5 below.

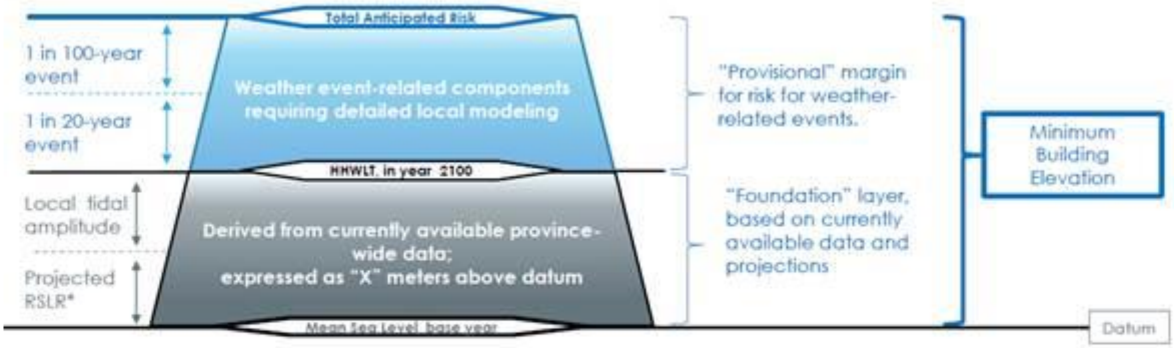


Figure 3.5: Current Description of the Minimum Building Elevation

Following the description above, using the values in the subsequent analyses, the MBE for Wolfville may be set at an approximate elevation of 9.34m CGVD2013. Discussions between the Town and NSE are currently being held.

Chapter 4 Coastal Water Level Analysis

To estimate the extreme coastal water levels influencing flooding risks, coastal water levels were broken down into several components:

- **Tide:** The local astronomical tide was assessed based on the WebTide Tidal Prediction Model (v0.7.1) from Fisheries and Oceans Canada (DFO). Tides in the Bay of Fundy are the highest in the world, with amplitudes of up to 16 metres during spring tides.
- **Storm Surge:** Storm surges are created by meteorological effects on sea level, such as wind set-up and low atmospheric pressure, and can be defined as the difference between the observed water level during a storm and the predicted astronomical tide. The local storm surge levels were derived from CBCL's local hydrodynamic model based on the extreme wind speeds. The extreme storm surge levels in Wolfville were calculated using the MIKE 21 model.
- **Wave Run-up and Overwash:** The wave run-up is the vertical distance a wave travels up the shoreline above the still water level. This was derived using the numerical model XBeach.
- **Sea-Level Rise (SLR):** Nova Scotia coastlines are experiencing SLR which is expected to accelerate due to climate change, causing increased risks of coastal erosion and flooding. As a result, extreme water level events are expected to become more common in a few decades. SLR projections from the recent scientific literature applicable to the Upper Bay of Fundy region was compiled by CBCL and used in the analysis.

Simulations were performed for the year 2100 planning horizon in combination with Annual Exceedance Probabilities (AEP) of 1% and 5%, which correspond to return periods of 100 and 20 years, respectively. The various components above are described individually in detail below, and then assembled and discussed in Section *4.1.5: Considerations for Raising Dykes or New Dyke Construction*.

4.1.1 Extreme Wind Analysis

Wind speed and direction were obtained from the Environment Canada MSC50 offshore wind and wave model hindcast for the period 1954-2018, which contains hourly time series of wind and wave parameters at a location at the Upper Bay of Fundy (45.3°N, 64.6°W). The dataset is a state-of-the art hindcast, wherein data computed from all existing wind and wave measurements were re-analysed and input into a 0.1-degree resolution model that

considered the effect of depth and ice cover (Swail et al. 2006). This dataset also includes hurricane wind fields. The MSC50 hindcast is developed by Oceanweather Inc. and is distributed by Environment Canada.
Figure 4.1 shows the schematization of the yearly wind climate in a wind rose diagram, where each line represents the percentage of occurrence of the different wind speeds and originating directions. As illustrated in Figure 4.1, storm events are predominantly originating from the West, with the highest peaks from the North-West.

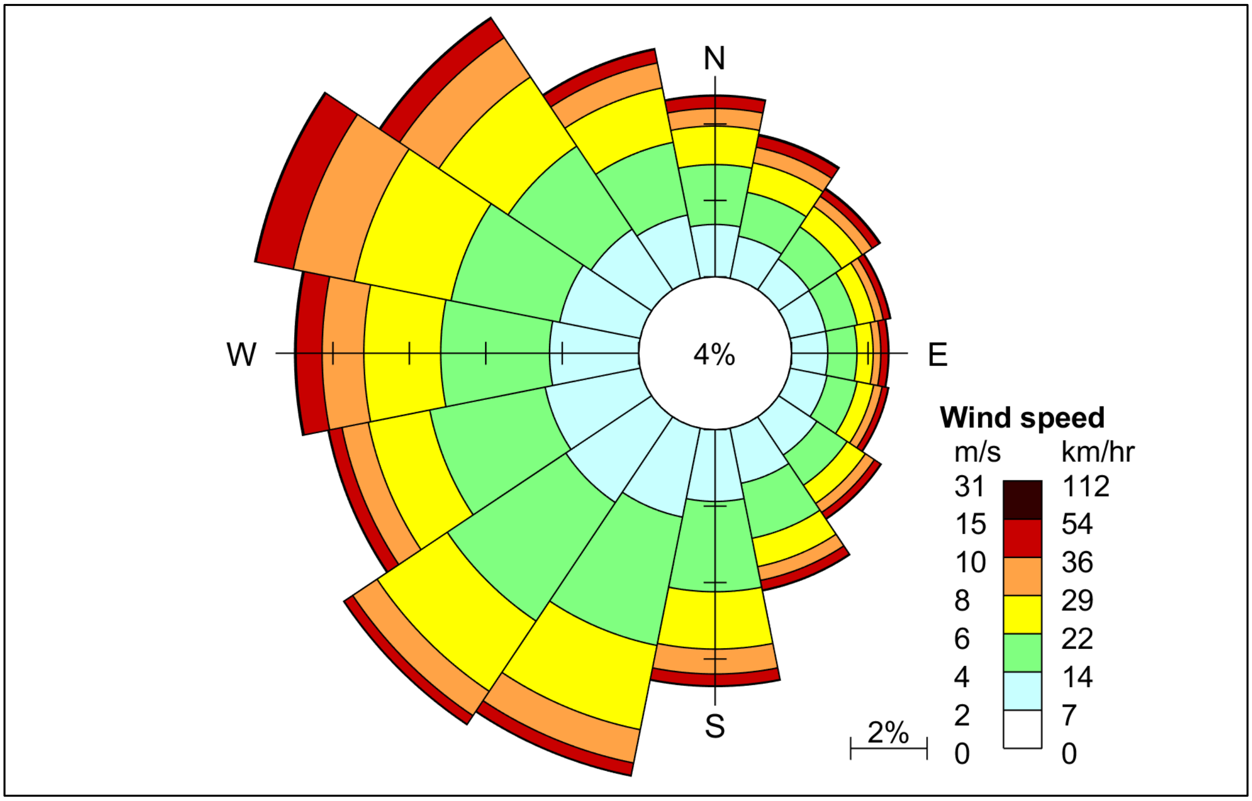


Figure 4.1: MSC50 Wind Rose (datapoint M6008430 45.3N 64.6W, 1954-2018)

Extreme value analyses were conducted on the MSC50 wind data to derive extreme wind conditions. The annual probability of occurrence of wind speed were estimated based on an analysis of storm peaks using the “Peak-Over-Threshold” method for each direction of exposure. For this project, directions of winds originating from North to East were analysed.

The probabilities derived from the wind analysis were then combined with the AEP of given tide levels. This step is important because extreme wind events do not necessarily coincide with the high tide. Since both wind and tide events are independent, the joint probability was calculated simply by multiplying the annual probability of occurrence of wind speed with the AEP of water levels. Figure 4.2 shows the different combination of wind speeds and water levels for each return period.

The joint probability analysis method can be applied to the Town of Wolfville because in the Minas Basin, extreme storm surge events and extreme waves are caused by different storms. Numerical modelling has indicated that the extreme storm surges in the area are typically caused by winds coming up the Bay of Fundy from the southwest, which pile up water into the Minas Basin. Conversely, the highest waves along the Wolfville waterfront are caused by Northeast winds, for which the fetch distance is greatest.

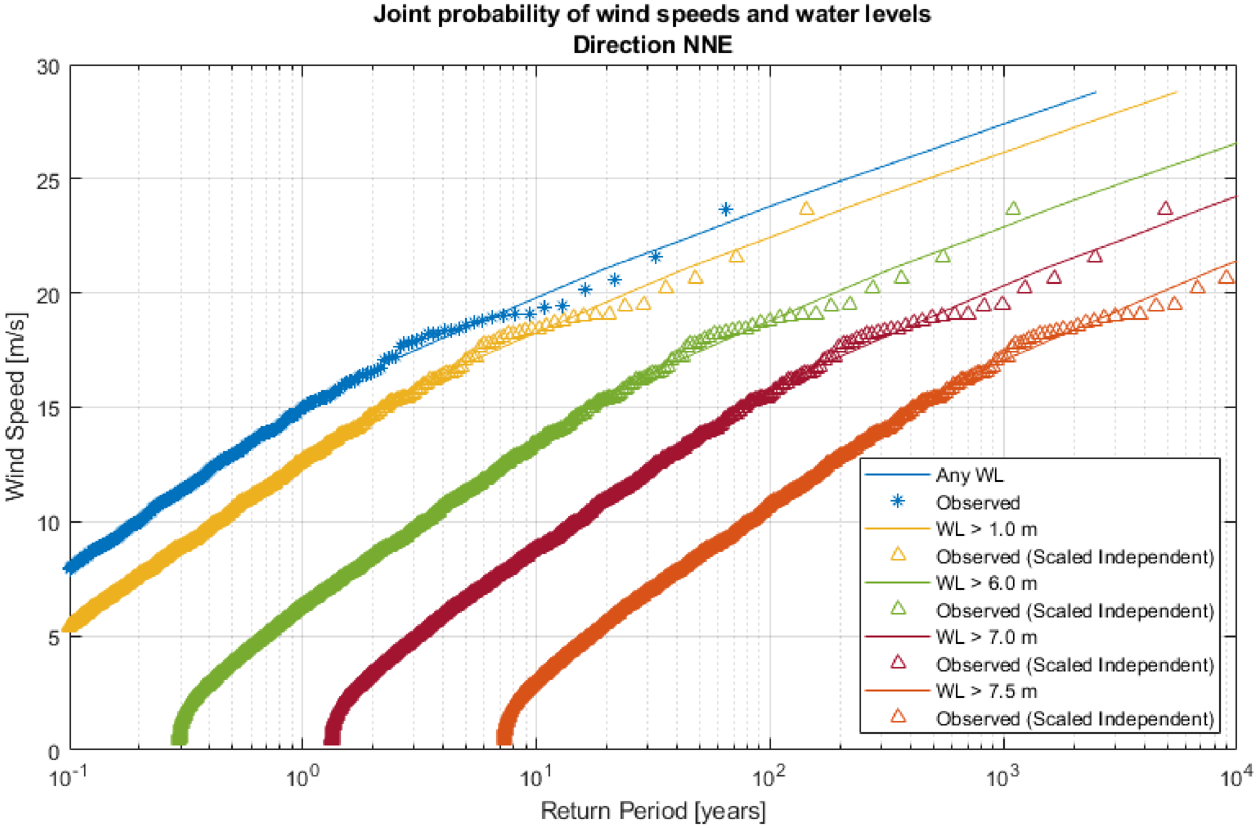


Figure 4.2: Joint Probability of Water Levels and Wind Speeds Coming from the North-Northeast

Summary of Extreme Wind Analysis

An extreme wind analysis was conducted, which included the consideration of high water levels occurring at the same time as high winds. The analysis provided more realistic values for extreme wind effects on high water levels than available in the literature.

4.1.2 Climate Change Impacts on Coastal Water Levels

Sea levels have been rising in the Maritimes since the end of the last ice age, approximately 10,000 years ago. This trend has accelerated in recent years and is expected to continue to accelerate with climate change.

Consensus Intermediate Sea Level Rise (SLR) Projections

The Intergovernmental Panel on Climate Change's Fifth Assessment Report (IPCC AR5 2013) estimated that the upper-bound Global Mean Sea Level (GMSL) rise could be in the order of 1.0m by year 2100. This projection, using process-based models, was for the RCP8.5 high-emission scenario. To derive a relative SLR, DFO then developed the online Canadian Extreme Water Level Adaptation Tool (CAN-EWLAT), based on work by James et al. (2014), which accounts for local factors. CAN-EWLAT is a science-based planning tool for climate change adaptation of coastal infrastructure related to future water-level extremes. Water level calculations were based on IPCC AR5 projections and improved upon by incorporating information on land subsidence measured with high-precision GPS instruments. It was developed to provide SLR allowances for DFO harbours across Canada. Allowances are estimates of changes in the elevation of a site that would maintain the same frequency of inundation that the site has experienced historically. Updated global estimates from the IPCC's Special Report on the Ocean and Cryosphere in a Changing Climate (SROCCC) report, (Oppenheimer et al 2019) remain generally consistent with AR5.

For the Upper Bay of Fundy, tidal expansion should be added as a SLR component. Greenberg et al. (2012) examined long-term tide gauge observations that show that the amplitude of Bay of Fundy tides has been slowly increasing. By 2100, the combination of Vertical Land Motion (VLM) and amplitude change may increase the amplitude of Bay of Fundy tides by 0.3m in the Upper Bay. They assumed a VLM component of 0.2 m/century, leaving 0.1m for tidal amplitude change.

Upper-End Projections with High Uncertainty

Recent studies tend to support higher GMSL upper-end projections based on potential rapid Greenland and West Antarctic Ice Sheet (AIS) reduction. These upper-end SLR projections (DFO Han et al. 2016, or NOAA Sweet et al. 2017) are based on probabilistic projections of the factors driving GMSL rise, which is different than the process-based model approach from IPCC AR5. NOAA's year 2100 GMSL projections range from Low (0.3m), Intermediate (1.0m), High (2.0m) to Extreme (2.5m). These projections carry higher uncertainty. The consensus values from the 2019 IPCC SROCCC report are lower, with up to 0.3m AIS contribution by 2100, in addition to AR5 RCP8.5 contributions. Given these findings, the 2014 DFO CAN-EWLAT estimates based on IPCC AR5 RCP8.5 could be considered intermediate projections. The Greenan et al. report for Canada (2018) propose to add an additional 0.65mby 2100 of GMSL rise to RCP8.5.

Selection of Scenarios

The appropriate scenario to select for a project depends on the ultimate purpose of the projection, such as for a planning time horizon or to evaluate risk tolerance of an area or infrastructure assets. The following approach, which uses two scenarios as a general planning envelope could be considered, as per NOAA 2017.

- Define an *intermediate* SLR projection for short-term and medium-term planning. We propose that this scenario be the CAN-EWLAT estimate, which would represent an intermediate projection typically close to 1m to the end of the century. This intermediate scenario may be used for defining the elevation of coastal protection structures and potentially roads, which could be built for a shorter design life and/or have built-in flexibility to allow incremental raising.
- Define an upper-bound scenario, which in the present case could be the *high or extreme* GMSL rise projection that includes AIS reduction and use it as a guide for overall risk and long-term adaptation strategy. The upper-bound scenario can be used for guiding the selection of minimum site elevations required for siting of future and potentially vulnerable permanent infrastructure.

Table 1 illustrates the expected SLR by decade for the two scenarios presented above.

Finally, the science of SLR will keep evolving with updated observations and improving model predictions. Implications for infrastructure and coastal flooding will need to be re-evaluated with periodic updates in SLR projections.

For the Wolfville study, the intermediate SLR scenario for the year 2100 was selected to be suitable in the estimation of the water levels due to climate change, with the intent of carrying out incremental raising of the dykes.

Table 1: SLR Scenarios

Relative SLR Scenario	SLR (m) by Time Horizon							
	2030	2040	2050	2060	2070	2080	2090	2100
(1) Intermediate SLR from CAN-EWLAT RCP8.5 + Bay of Fundy tidal expansion	0.12	0.19	0.29	0.39	0.50	0.64	0.78	0.93
(2) High = (1) + AIS reduction (+0.65m by 2100)	0.21	0.3	0.49	0.67	0.86	1.09	1.33	1.58

Summary of Climate Change Impacts on Coastal Water Levels
Current knowledge on SLR was reviewed. Due to the uncertainty associated with the sea level rise projections, the "Intermediate" scenario was selected, based on the CAN-EWLAT science-based planning tool, IPCC AR5 scenario.

4.1.3 Numerical Modelling Methodology

MIKE 21 Hydrodynamic Model
CBCL developed a 2D hydrodynamic model of the Bay of Fundy (Figure 4.3), which has been calibrated and validated against measured tide gauge data. For this study, this model was refined in the Minas Basin and extended to include part of the Cornwallis River and the Avon River Estuary. The model resolution near the study area was approximately 15mx 15m. The local model bathymetry was schematized based on the high-resolution Lidar mapping provided by the Town and Canadian Hydrographic Service bathymetric maps.

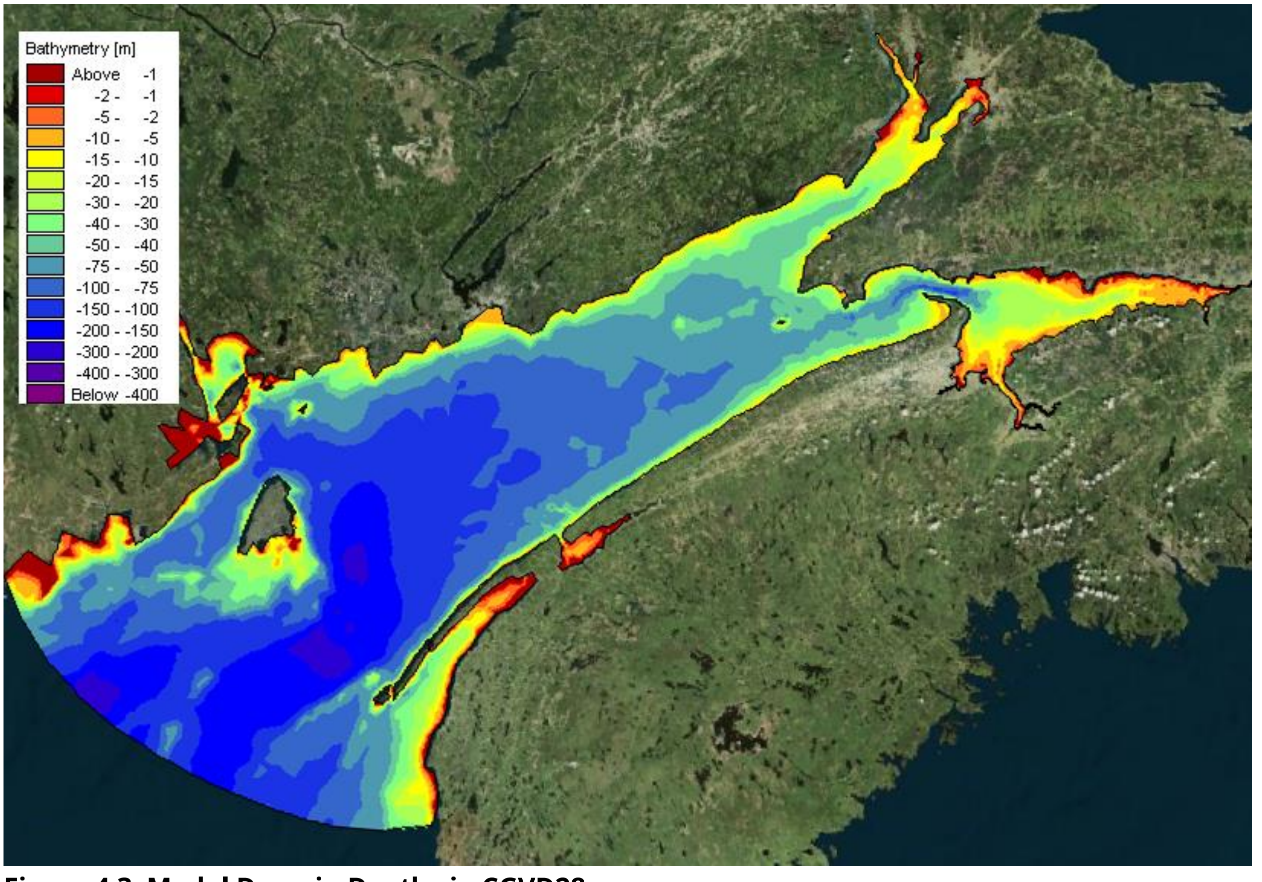


Figure 4.3: Model Domain Depths in CGVD28

The hydrodynamic model includes inputs from Webtide, water level correction due to SLR and air pressure, extreme wind speeds derived from the MSC50 dataset, and extreme discharge from the Cornwallis River derived from the regional hydrological model. The Environment Canada MSC50 offshore wind model hindcast was used to define extreme wind conditions (as noted in Section 4.1.1 above).

The model provides extreme (still) water levels along the existing dykes of Wolfville, to calculate wave run-up levels. The maximum wave run-up height above the still water level defines the expected flood level.

The full tidal model was run for two-weeks to determine the peak tidal levels near Wolfville. The outputs of the tidal model were used as the initial conditions for the surge model, which was run over a period of 12 hours. The surge model used the calculated extreme wind values combined with a low-pressure field based on Hurricane Dorian. To be conservative it was assumed that the maximum storm surge could occur at any point in the tidal cycle.

XBEACH Wave Runup Model

XBeach (Smit et al., 2010; Roelvink et al., 2017) is a powerful open-source numerical wave model, which includes the following hydrodynamic processes:

- Short wave transformation (i.e., refraction, shoaling and breaking);
- Long wave (infragravity wave) transformation (i.e., generation, propagation and dissipation);
- Wave-induced setup and unsteady currents; and
- Overtopping.

The original XBeach application (surfbeat mode), funded by the U.S. Army Corps of Engineers, was developed to assess hurricane impacts on sandy beaches. Since then, the model has been extended, applied and validated for storm impacts on urbanized coasts for the purpose of flood risk assessments, the non-hydrostatic version has been validated with laboratory experiments and field measurements to estimate overtopping.

For this project, a 1D non-hydrostatic XBeach model was developed to calculate the contribution of waves to coastal flooding. The model comprises a schematized profile based on a combination of a representative dyke cross-section and adjacent bathymetry (DEM, Lidar) provided by the Town of Wolfville (Figure 4.4). This model was used to calculate wave runup and overtopping over the dyke.

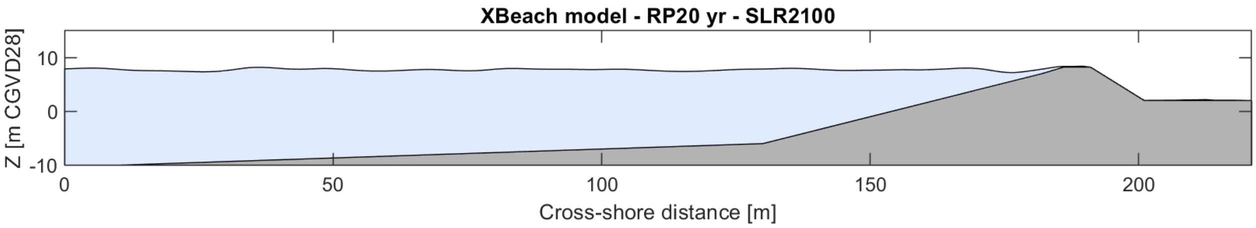


Figure 4.4: Schematized Cross-Shore Profile for the XBeach Wave Overtopping Model

The model was forced with nearshore significant wave height (H_s) and peak wave period (T_p) calculated by the MIKE21 SW model and still water level from the MIKE HD model. Three combinations of water level and wind speed scenarios were simulated per return period and per sea level rise scenario. The different scenarios are shown in Table 2. Only two 1-in-100-year events were simulated as the wave height was expected to be low based on the trends observed for the 1-in-20-year event.

Table 2: Scenarios Simulated with the XBeach Model

Run	Still Water Level (m CGVD28)	Still Water Level (m CGVD2013)	Sea Level Rise Time Horizon	Return Period (years)	Wind Speed (m/s)	H_s(m)	T_p (s)
1	6.0	5.35	Present	20	15.3	1.2	4.7
2	7.0	6.35	Present	20	11.0	0.7	3.5
3	7.5	6.85	Present	20	5.6	0.3	2.1
4	7.7	7.05	2100	20	15.3	1.3	4.7
5	8.8	8.15	2100	20	11.0	0.7	3.6
6	9.2	8.55	2100	20	5.6	0.3	2.3
7	6.0	5.35	Present	100	18.8	1.5	5.4
8	7.0	6.35	Present	100	15.5	1.3	4.7

Note: return period is associated with wind speed at particular still water level threshold (see Figure 4.1). This joint probability analysis is specific only to the wave runup calculations.

Since the waves near Wolfville are generally small, wave overtopping over the dyke only occurs in the model during rare events, for a very limited time (a few seconds), and very small volumes of intruding water. Overtopping occurred in the model by pairing extremely high water levels and the 2100 SLR time horizon. Without sea level rise, no wave overtopping is computed by the model. Therefore, wave runup levels were not included in the total coastal flood levels.

Summary of Numerical Modelling Methodology
Wave runup (the maximum vertical extent of wave uprush on a beach or structure above the still water level) and potential overtopping by waves was estimated with a combination of a Bay of Fundy model and a local wave model. The modelling and joint probability analyses showed that wave runup was not sufficient (only a few seconds) to be a concern for this dyke system, even in future conditions.

4.1.4 Coastal Storm Surge and Waves

The 2D MIKE21 coastal surge model of the Bay of Fundy and Minas Basin was used to simulate storm surge events which were used in the 2D flood model to determine the potential flooding extents.

The surge level was determined at 4 locations (Figure 4.5) for input into the flood model. Wave runup was not included in this estimate as it was determined that wave overtopping occurred only under extreme conditions and with small volumes. It was found that the results were very similar between locations, but the four locations were kept for input to the flood model, since they can slightly affect flood flow direction.

Figure 4.5: Locations of surge outlets used for PCSWMM flood model

A comparison of the modelled surge and the normal tidal elevation shows that the surge can range from 0.62m to 0.81m above the existing Higher High Water Large Tide (HHWLT) when forced by present day 1-in-2 and 1-in-100-year events. Figure 4.6 shows the tidal inputs used for the SWMM model at location 1 and the approximate average dyke elevation. Figure 4.7 shows the Bay of Fundy water levels during the 1-in-100-year storm surge event. Maximum surge levels are presented in Table 3, and coastal extreme water levels are presented in Table 4. Figure 4.6 shows that there is already a risk of overtopping the dykes and the ground between the two, which is at the same elevation, and that this risk may increase in the future if the dyke system is not upgraded.

Figure 4.6: Tidal Inputs for SWMM Model at Location 1

Table 3: Maximum Surge at Location 1 for existing conditions and by 2100 for design surges with return periods of 1 in 2, 1 in 20, and 1 in 100 years.

Time Horizon	Maximum Surge at Location 1 (m CGVD28) by Return Period*		
	1 in 2 year	1 in 20 year	1 in 100 year
Existing	[illegible]	8.29	8.41
2100	9.79	9.89	9.99
Time Horizon	**Maximum Surge at Location 1 (m CGVD2013) by Return Period**		
	1 in 2 year	**1 in 20 year**	**1 in 100 year**
Existing	7.57	7.65	7.76
2100	9.15	9.25	9.35

Approximate Dyke Elevation

* The Town currently uses CGVD28 as a vertical reference system, but the provincial standard is now CGVD2013, which is a change of 0.64m in Wolfville. Both systems are included to simplify comparison with existing Town maps.

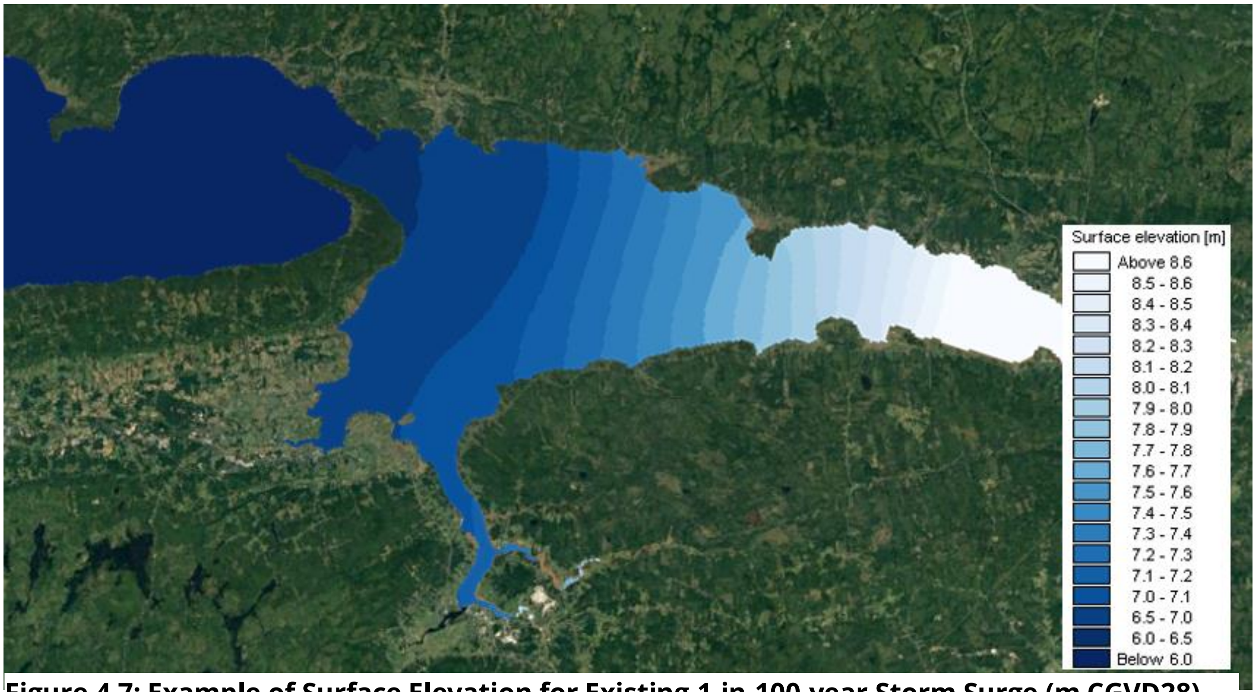


Figure 4.7: Example of Surface Elevation for Existing 1-in-100-year Storm Surge (m CGVD28)

Table 4: 2020 Tidal and Extreme Coastal Water Level Estimates

Extreme Values by Return Period [years]	Meters above CGVD28	Meters above CGVD2013
1 in 100 years	8.41	7.76
1 in 20 years	8.29	7.64
1 in 2 years	8.22	7.57
Tidal Elevations		
Higher High Water Large Tide (HHWLT)	7.60	6.95
Higher High Water Mean Tide (HHWMT)	5.11	4.46
Mean Water Level (MWL)	0.43	-0.22
Lower Low Water Mean Tide (LLWMT)	-4.21	-4.86
Lower Low Water Large Tide (LLWLT)	-5.27	-5.92

Note: wave runup was not included, since most areas are well sheltered from wave action

Summary of Coastal Storm Surge and Waves

Storm surges (increase in water level associated with a low-pressure weather system) were analysed with a 2D coastal storm surge model for various return periods, to be used as input to the Wolfville flood model. It was found that the increase in water level due to storm surges ranges from 0.62m to 0.81m, for the 1-in-2-year and 1-in-100-year events, respectively. It was found that there was a small risk of overtopping the dykes and Waterfront Park in current conditions, and that SLR would make overtopping unavoidable in the coming years.

4.1.5 Considerations for Raising Dykes and New Dyke Construction

As sea level rises, dyke overtopping risks will gradually increase, as illustrated in Figure 4.6. Instead of designing for the sea level as it is projected for the year 2100, it may be more prudent, and more socially acceptable, to design the new dyke level (and raising the existing dykes) to an intermediate scenario. An analysis of incremental increase in overtopping risks was conducted for the intermediate and high Sea Level Rise scenarios, and the results are presented in Figure 4.8. This analysis allows the selection of a level that will provide a consistent level of safety until the year 2070. Figure 4.8 shows that with no new dyke or raising, there may be an average overtopping frequency of twice a year by the year 2035 (in 15 years), if the intermediate sea level rise scenario happens. The same frequency of overtopping is projected to occur by the year 2028 (in 8 years) if the high sea level rise scenario transpires.

Flood mapping for dyke overtopping in the future is presented in Chapter 6 and shows the extent of flooding reached by future sea levels if the dyke system is not overtopped. Chapter 7 presents a discussion on the vulnerability of the various municipal assets and land uses, identifying that the flooding of particular areas with saltwater may compromise key assets, such as the wastewater conveyance and treatment systems.

Depending on the rate of SLR, the elevation of new and existing dykes should be between 8.2 and 8.6m CGVD2013. Since the elevation of the top of the existing dykes and connecting ground is currently between 7.8m and 8.9m CGVD 2013, a design that involves an average increase in top level of approximately 500mm would be suitable. This evaluation can be analysed in more detail at the pre-design level if this option is selected.

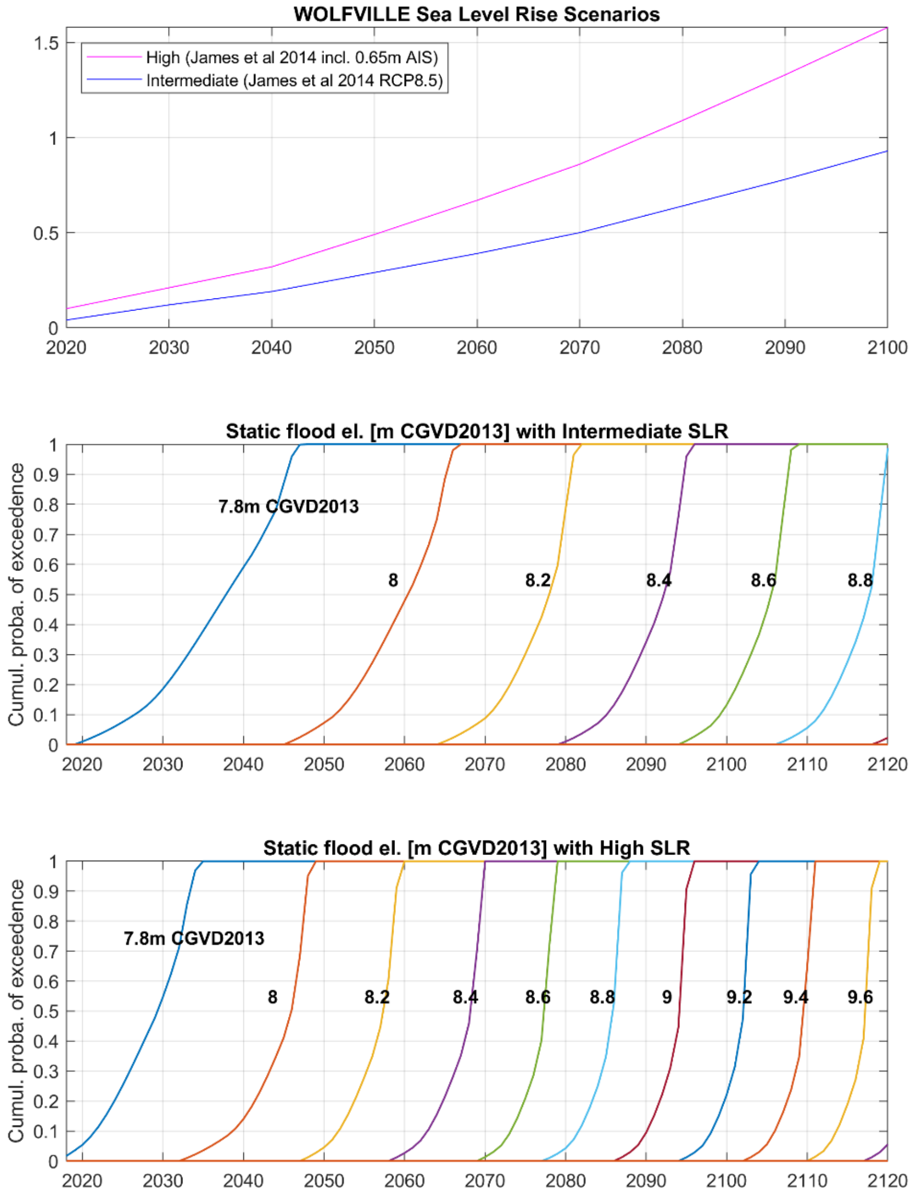


Figure 4.8: Gradually Increasing Risks of Dyke Overtopping with Sea Level Rise

In order to place projected water levels in the context of the current elevations of the ground level around the Waterfront Park area, Figure 4.9 shows colour shading on a map of the Waterfront Park that corresponds to the elevations shown in Figure 4.8. Figure 4.9 also illustrates the potential alignment of a new dyke that would border the outside edge of the park and then follow the railway alignment. It was selected during discussions with the Town to protect the pathways, vegetation, gazebo and electrical infrastructure of the Waterfront Park from regular flooding in the future. Figure 4.10 shows the existing ground elevation (based on the 2012 Lidar data) along that alignment, emphasizing that the ground will need to be raised by approximately 0.5m on average to reach the elevation of 8.5m CGVD2013.

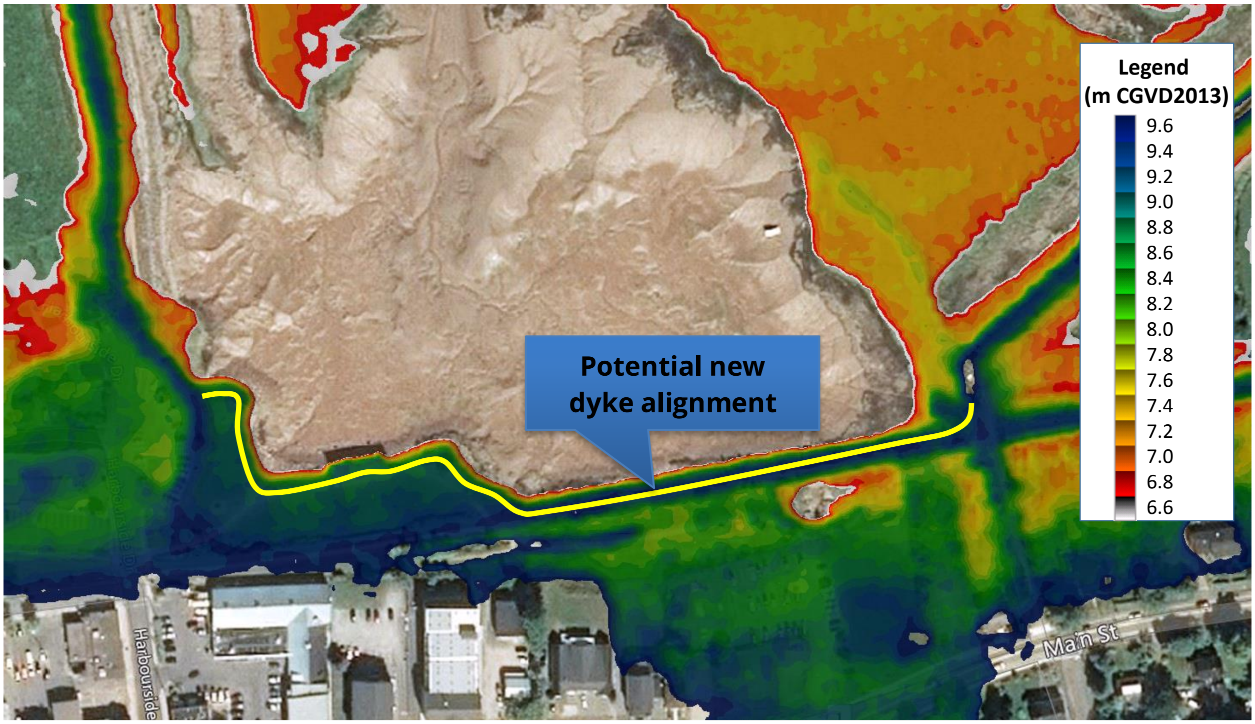


Figure 4.9: Waterfront Park with Ground Elevations and Potential New Dyke Alignment

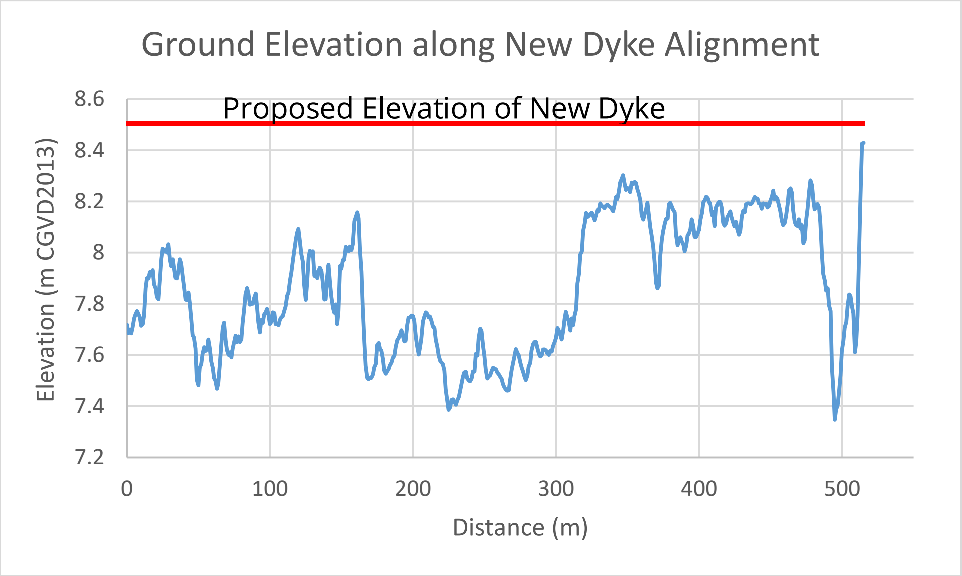


Figure 4.10: Ground Elevation along Potential New Dyke Alignment

Summary of Recommendations for Raising the Dykes, and New Dyke Construction

This analysis shows that without the construction of a new dyke or raising of the existing dykes, the system would be overtopped, leading to saltwater flooding in Wolfville an average of twice a year by:

- 2035 (in 15 years), if the intermediate SLR scenario occurs, and
- 2028 (in 8 years) if the high SLR scenario occurs.

Constructing a new dyke (raising the existing ground) to an elevation of 8.5m CGVD2013, and raising the existing dykes by 500mm on average in the next 3 to 5 years, will provide a suitable level of safety for the next 45 to 65 years, depending on the rate of SLR.

Chapter 5 Hydrologic and Hydraulic Analysis

Hydrologic modelling involves simulating the process of rainfall on a watershed, including infiltration, gradual buildup of runoff, and discharge to the main drainage system. Hydraulic analysis refers to the assessment of water levels, flows, and drainage influenced by the characteristics of the drainage system, its capacity, and relevant tidal effects.

The modelling software PCSWMM was used to assess the potential extents of flooding. PCSWMM is a hydrologic and hydraulic modelling software from Computational Hydraulics International (CHI [2019]), based on the US EPA's Storm Water Management Model 5 (SWMM5). SWMM5 is an industry standard software for semi-urban stormwater management and flooding analyses. The model was used to estimate the extent of flooding due to the combination of extreme precipitation events and extreme coastal water levels.

5.1 Hydrologic and Hydraulic Modelling

In 2003, CBCL prepared the Stormwater System Master Plan for the Town of Wolfville. A hydrologic/hydraulic model was created for that study using PCSWMM. The 2003 model was updated to incorporate more current information, including:

- Rainfall data: current climate and future climate change data
- Watershed Characterization: area, slope, maximum flow length, soil conditions, surface roughness, and percent imperviousness. Additional spatial data included:
    - Lidar (2m resolution CGVD28 datum) obtained from the Municipality of the County of Kings
    - GIS layers of Town infrastructure, including some stormwater and wastewater features and zoning
- Stormwater Drainage Network Site Survey: engineering drawings and hand drawn sketches
- 2D Model: development based on the Lidar topography

Note: The Town of Wolfville has disclaimed that the storm sewer data provided may be missing data or be inaccurate in some locations.

5.1.1 Existing Rainfall Events

The hydrologic part of the model receives time series of precipitation data as input to simulate rainfall and runoff processes. Environment and Climate Change Canada's Kentville climate station (Station # 8202810) is the closest (spatially) to the Town of Wolfville. The

Intensity Duration Frequency (IDF) curve for the Kentville climate station includes 40 years of data (1960-2016). This was compared with the Western University IDF_CC tool (Schardong et al., 2018), and both were found to be in agreement. Since the climate station is located close to Wolfville, it was the most representative data available for this assessment.

For this study the 1-in-2-year, 1-in-20-year and 1-in-100-year flood events were of interest. The 1-in-2-year rainfall event was modelled in combination with extreme coastal water levels to evaluate the flood extents; likewise, the 1-in-20-year and 1-in-100-year rainfall events were used in combination with the 1-in-2-year coastal water level. The selected ensemble of simulations was designed to assess a range of probable rainfall and coastal water level combinations. Figure 5.1 illustrates the hyetographs, which were prepared using the Chicago Method with a 5-minute discretization interval. The Chicago Method is a widely-used standard design storm that reflects the intensity-duration relationship of the IDF curve, which is developed using historical storm data.

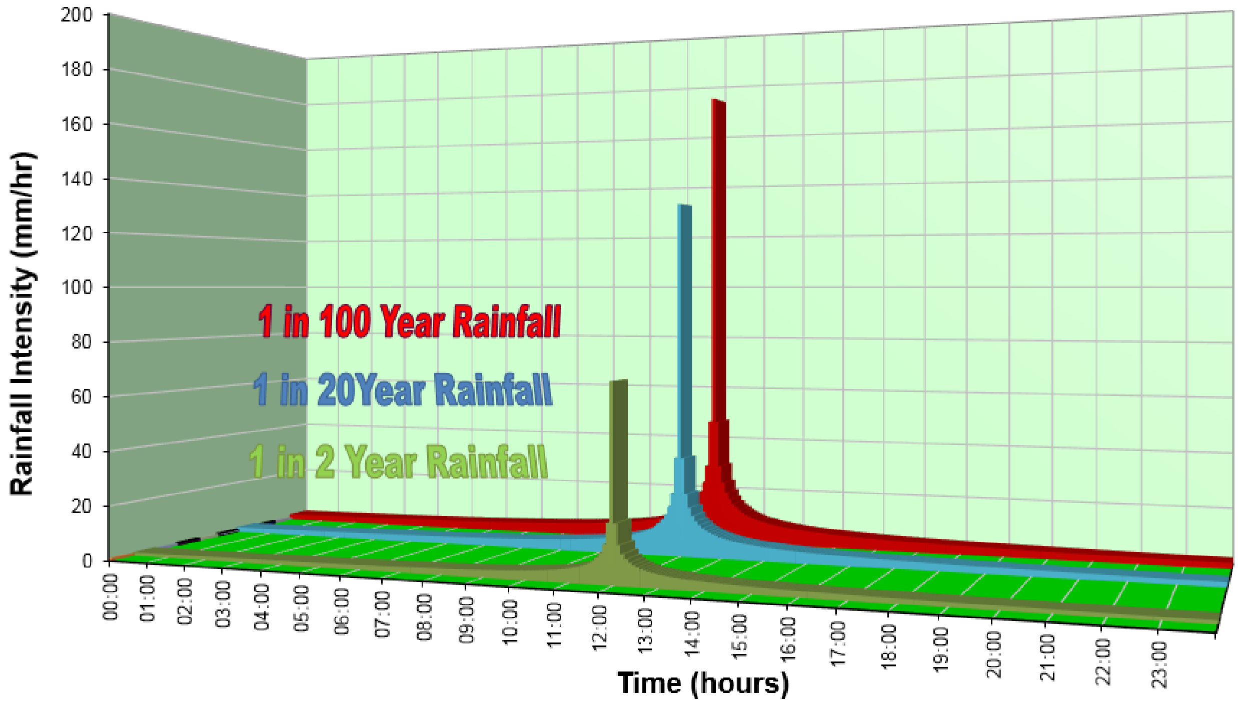


Figure 5.1: Existing Conditions Rainfall Hyetographs

Summary of Existing Rainfall Events

Environment and Climate Change Canada's Kentville Climate Station is the closest (spatially) to the Town of Wolfville, and its Intensity-Duration-Frequency (IDF) curve was used to estimate the extreme precipitation events for the Town. The Chicago method was used to model 1-in-2-year, 1-in-20-year, and 1-in-100-year design storms.

Table 5: Peak Rainfall Intensities (5-min interval) of the Design Storms Used to Model Current Conditions in this Study (Values Based on the Kentville Climate Station IDF Curve)

Peak Rainfall Amount	1-in-2-year (mm/hr)	1-in-20-year (mm/hr)	1-in-100-year (mm/hr)
Existing Climate	69	107	174

5.1.2 Impacts of Climate Change Rainfall Events

Future climate change is expected to increase the intensity of rainfall events, which suggests a potential increase in the severity and frequency of flooding. Therefore, analysis of flood risks requires the consideration of climate change effects.

General Circulation Models (GCMs) are global climate change estimates used to represent existing and future climate dynamics within the Earth's atmosphere. Such models are often based on a 250km by 250km resolution grid. A range of extreme precipitation projections are obtained from the combination of different GCMs and RCPs. High and intermediate projections are derived from RCP8.5 and RCP4.5, respectively.

Given the resolution of GCMs, there is a high level of uncertainty inherent in the application of GCM results at a point location. Therefore, it is important to consider and compare different approaches to assessing the impacts of climate change on projected rainfall. This assessment calculates the potential effect of climate change on sub-daily rainfall intensity by using the Western University IDF_CC tool (Schardong et al., 2018), the Clausius-Clapeyron equation (Westra et al., 2014), both of which apply the results of GCMs. The results of each method are described below:

- The Western University Intensity Duration Frequency Climate Change Tool Version 4 (IDF_CC Tool):
    - Estimates potential impacts of climate change on IDF curves by downscaling GCM outputs to current IDF curves (derived from either gauged locations or from interpolation tools).
    - Was used with the Kentville Climate Station IDF curve. Calculations using the IDF_CC Tool were based on the outcome of a range of bias-corrected GCMs and climate scenarios.

- Outputs suggested a 24% to 61% increase in the 1-in-100-year, 24-hour precipitation for the 2071-2100 time horizon.
- The Clausius-Clapeyron Equation:
  - Converts projected temperature changes (Westra et al., 2014) to precipitation increase due to the tendency of air to hold more water as the temperature increases. The capacity of the atmosphere to hold water is governed by the Clausius-Clapeyron equation, which can be associated with an increase in precipitation intensity by 6% to 7% per degree Celsius. This equation was recommended by Environment Canada because of the lack of certainty in climate change models regarding precipitation.
  - Resulted in a range of 12% to 46% increase in the 1-in-100-year, 24-hour precipitation for the 2071-2100 time horizon.

The IDF_CC Tool results reported higher percent increases in rainfall in all cases. The IDF_CC Tool results were used for the future design storm scenarios, following the precautionary principle. Three emission scenarios were selected for sensitivity analysis and are presented in Table 6. Figure 5.2 illustrates the hyetographs for the three emission scenarios described in Table 6.

Table 6: Projected Increase in the 1-in-100-year, 24-hour Rainfall Intensity by the Year 2100 for Three Projected Scenarios

Emission Scenario	Method	Percentile	Projected Rainfall Intensity (mm)	% Increase from Baseline
			1-in-100-year, 24-hr	1-in-100-year, 24-hr
RCP8.5	IDF_CC	95th	280 mm	61%
RCP8.5	IDF_CC	50th	216 mm	24%
RCP4.5	IDF_CC	95th	261 mm	50%

Of the three emission scenarios presented in Figure 5.2 and Table 6, RCP8.5 (95th percentile) projected the largest increase in rainfall intensity of 61% above the historical baseline, which represents a likely "worst-case scenario". The IDF_CC Tool was also used to project rainfall intensities for both the 1-in-2 and 1-in-20-year events under the RCP8.5 (95th percentile) scenario, which resulted in an estimated 29% and 35% increase in rainfall, respectively. Hyetographs for these projected rainfall events were used as input to the hydrologic model to evaluate future floodlines.

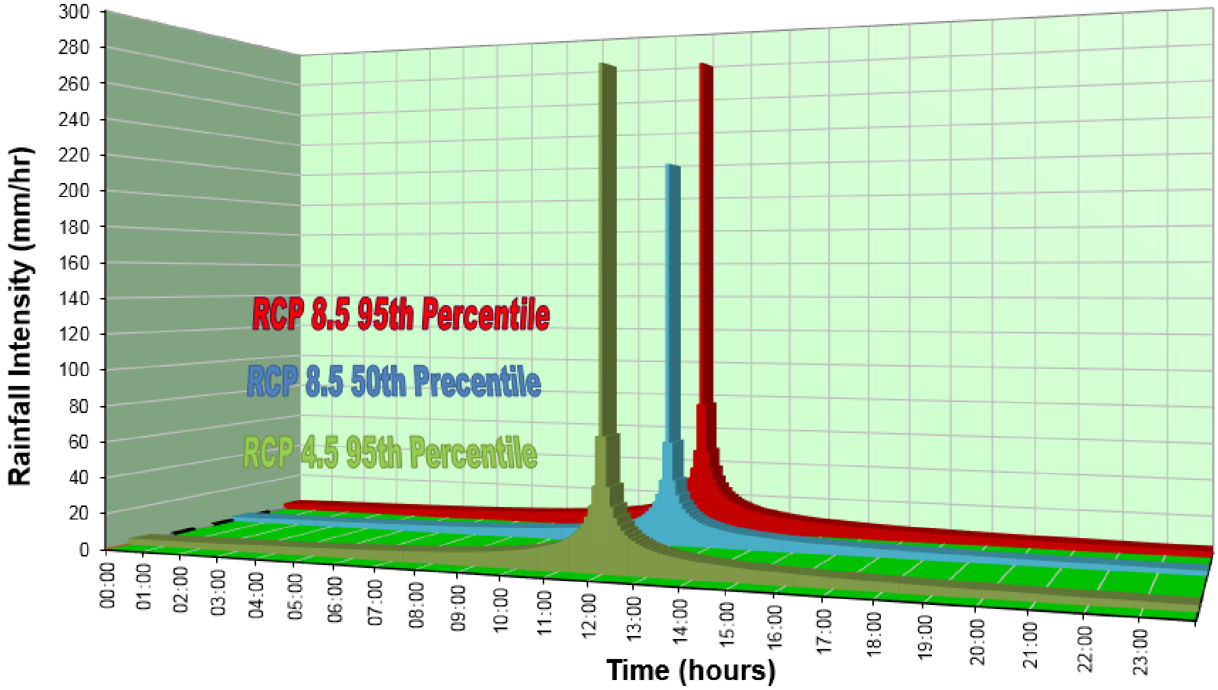


Figure 5.2: Comparison of 1-in-100-year Rainfall Projections for 2100

Summary of Impacts of Climate Change Rainfall Events

The effects of climate change on both precipitation and sea level rise were considered when examining future conditions (i.e., the year 2100 time horizon). To date, global greenhouse gas concentrations have most closely tracked the Representative Concentration Pathway (RCP) 8.5, which was used to generate the higher range of climate change projections featured in the Intergovernmental Panel on Climate Change's Fifth Assessment Report. The 1-in-100-year rainfall event is projected to increase by approximately 61% by 2100 under RCP8.5 (95^{th} percentile) according to the Western University IDF-CC Tool (Table 7).

Table 7: Future and Existing Rainfall Projections of the IDF_CC Tool

Peak Rainfall Intensity	1-in-2-year (mm/hr)	1-in-100-year (mm/hr)
Existing	68.57	174.00
Future	88.45	280.12

5.1.3 Watershed Characterization

Watershed areas supplying key points along the storm sewer drainage network were delineated for the 2003 model by CBCL. Aerial photography was used to identify the land cover in each watershed, from which the surface roughness (combined using an area-weighted average) and percentage of impervious surface could be determined. Slope and maximum overland flow length for each watershed were estimated using the Lidar data. The Green-Ampt infiltration method was selected for infiltration calculations. This method is used to estimate depth of infiltration as a function of soil suction head, porosity and hydraulic conductivity, all of which were estimated based on the soil type.

Although future development will increase the percentage of impervious surfaces, which generally leads to greater runoff, the Town has a net-zero increase in stormwater runoff policy that requires the post-development runoff from a site to meet its pre-development rate. Therefore, future developments will require stormwater detention facilities, or other means of limiting runoff to pre-development rates. As such, the simulation of future conditions in the PCSWMM model did not involve modifying the percent of impervious area or the pervious and impervious roughness values of any watershed. However, rainfall input did include the effects of future climate change (Figure 5.2).

Summary of Watershed Characterization

Watershed delineation had been previously carried out in a 2003 Stormwater Master Plan prepared by CBCL. Watershed characteristics for input to the hydrologic model were extracted from aerial photography, land cover, Lidar data, and soil databases. The net-zero runoff policy of the Town gives reason to expect that runoff will not increase significantly as a result of future development.

5.1.4 Stormwater Drainage Network Update

Figure 5-1: Locations of the Stormwater Conduits that Require Updates Based on Recent Design Drawings

Figure 5-2: Locations of the Stormwater Conduits that Require Updates Based on Recent Design Drawings (Cont'd Figure 5-1)

The Stirling and Hillcrest Avenue developments include four (4) stormwater detention ponds to control stormwater flow. These stormwater ponds were integrated into a 1D hydraulic model to represent storage and release of stormwater during a storm event. No other significant developments were identified within the Town of Wolfville.

In total, 28 as-built or record drawings of the stormwater drainage network were compared to the 2003 model to identify differences. Six (6) surveys were used to update stormwater pipes in eight (8) locations in the model, as shown in Figure 5.1 and Figure 5.2, and outlined in Table 8. Following these updates, the conduit diameters of the stormwater model were reviewed to ensure consistency throughout the downstream network.

Table 8: Stormwater Conduit Geometries of Pre-Established Model (in 2003) and the Updated Model

Number	Location	Type of Conduit in 2003 Model	Diameter of Conduit in 2003 Model	Type of Updated Conduit	Diameter of Updated Conduit	Consultant	Year of Drawing
1	Harbourside Dr.	Circular	0.45 m	Circular	0.9 m	Hatch	2016
2	King St.	Circular	0.375 m	Circular	0.3 m	Hatch	2018
3	Orchard Ave.	Trapezoidal	-	Circular	0.6 m	Hatch	2016
4	Sherwood Ave. (north)	Circular	0.45 m	Circular	0.375 m	CBCL	2007
5	Sherwood Ave. (south)	Circular	0.3 m	Circular	0.375 m	CBCL	2007
6	Skyway Dr.	Circular	0.3 m	Circular	0.375 m	Town of Wolfville	2005
7	Stirling Ave.	Trapezoidal	-	Circular	0.375 m	Hiltz and Seamone II Ltd	2014
8	Stirling Ave. (to the detention pond)	Trapezoidal	-	Circular	0.45 m	Hiltz and Seamone II Ltd	2014

Summary of Stormwater Drainage Network Update

The hydraulic model of the drainage system built by CBCL in 2003 was updated with recent information on the stormwater pipe upgrades. Twenty-eight (28) as-built or record drawings of the stormwater drainage network were reviewed and 8 modifications to the model were made. Four detention ponds were also added in the hydraulic model.

5.1.5 2D Model Development

Both the 1D and 2D modelling capabilities of PCSWMM were used in the flood risk assessment. The 1D model includes underground infrastructure, detention ponds and river channels. The 1D model calculates the flooding in manholes and along the surface drainage network (such as ditches) that may occur during each modelled rainfall event.

A 2D hexagonal hydraulic mesh was generated over the potential flood inundation area using 2m-resolution Lidar data. Any flooding generated in the storm sewer network (1D model) during each rain event is routed to the 2D mesh. The 2D mesh then calculates overland flow, depth, and velocity of the flooded water over time. The maximum extent of flooding is used to generate the flood maps for each scenario evaluated.

Summary of 2D Model Development

The existing 1D model of the drainage network was enhanced with a 2D hexagonal mesh of the topography of the potential flood inundation area. Where the 1D model has insufficient capacity, it will direct water to the 2D model of the ground surface. Overland flow, depth and velocities are calculated over the duration of the flood events, and the maximum extent of flooding is used to generate the flood maps.

Chapter 6 Flooding Analysis

Flooding within the Town of Wolfville is a result of two independent events: high coastal water levels and large precipitations. Coastal flooding can result from a combination of the astronomical tide, storm surge and sea level rise. In general, areas behind the lowest points in the dyke system are the most vulnerable to coastal flooding impacts. Flooding from large rainfall events occurs when the stormwater drainage network has insufficient capacity to convey water to downstream outlets.

The risk and vulnerability of coastal communities continues to rise as climate change causes sea levels and the intensity and frequency of extreme storms to increase. Climate change can threaten public safety, the economic and social benefits of the coastal environment, as well as cause significant damage to infrastructure.

6.1 Flooding Scenarios

The model of the Town's stormwater drainage network and floodplain areas was used to simulate the flood scenarios presented in Table 9. Each extreme event (tide or rainfall) is accompanied by a "high" event (1-in-2-years) from the alternate mechanism (tide or rainfall) to be conservative, while not radically skewing the probabilities.

Table 9: Flooding Scenarios Assessed under Existing and Future Conditions

Climate Condition	Flooding Scenario	Annual Exceedance Probabilities	
		Rainfall Event	Tide Event
Existing Conditions	Tidal Flooding	1 in 2 years	1 in 100 years
	Tidal Flooding	1 in 2 years	1 in 20 years
	Rainfall Flooding	1 in 20 years	1 in 2 years
	Rainfall Flooding	1 in 100 years	1 in 2 years
Future Conditions	Tidal Flooding	1 in 2 years	1 in 100 years
	Tidal Flooding	1 in 2 years	1 in 20 years
	Rainfall Flooding	1 in 20 years	1 in 2 years
	Rainfall Flooding	1 in 100 years	1 in 2 years

The flooding scenarios outlined in Table 10 were assessed to evaluate the performance of the proposed flooding mitigation strategies (described in Chapter 8). The flood mitigation options were assessed for existing conditions (2020). In order to compare the relative effectiveness of each option, the same set of extreme events was used (i.e., a 1-in-100-year rainfall, associated with a 1-in-2 coastal water level). The flood-mitigation techniques evaluated addressed mostly rainfall-dominated effects (i.e., stormwater storage is intended to alleviate flooding from extreme rainfall, not extreme coastal water levels), except for the option of constructing a new dyke and raising the existing dykes. In this case, the coastal water levels will be held back by the upgraded dyke system, and the main risk to be mapped is the effect of the extreme rainfall event.

Table 10: Flood Mitigation Options Assessed

Mitigation Strategy	Annual Exceedance Probabilities	
	Rainfall Event	Tide Event
Implementation of Best Management Practices	1 in 100 years	1 in 2 years
Increased Storage Capacity	1 in 100 years	1 in 2 years
Increased Pipe Capacity	1 in 100 years	1 in 2 years
Upgraded Dyke System (Raising + Closing Gap)	1 in 100 years	1 in 2 years

6.2 Floodplain Mapping

Model simulation results for the scenarios are presented in Figure 6.1. Data found in Table 9 and Table 10 were used to produce floodplain maps, presented in Appendix A: Flood Mapping. The maximum water levels and extents of flooding along the stormwater drainage network were used to delineate floodlines for each flood scenario. The high-resolution Lidar allows the floodlines to be defined with a high level of precision for each flood scenario. The floodplains, as presented in Appendix A, do not represent the flood extents for a single moment in time, but rather the extent of the floodplain at its maximum during the event. The floodlines have also been provided to the Town in GIS format.

In many instances, the floodlines for the 1-in-20 and 1-in-100-year flood events for existing conditions are very similar. This can be seen in Figure 6.1, which depicts a portion of Drawing Number 1 (Appendix A). In terms of planning regulations, the 1-in-20-year and the 1-in-100-year events define the floodway and floodway fringes, respectively. In this case, since the two floodlines were found to be close together, it was decided, during discussions with the Town, that it would be clearer and simpler to use only the 1-in-100-year floodlines to define the flood boundaries in the Constraints Map in the Land Use By-laws.

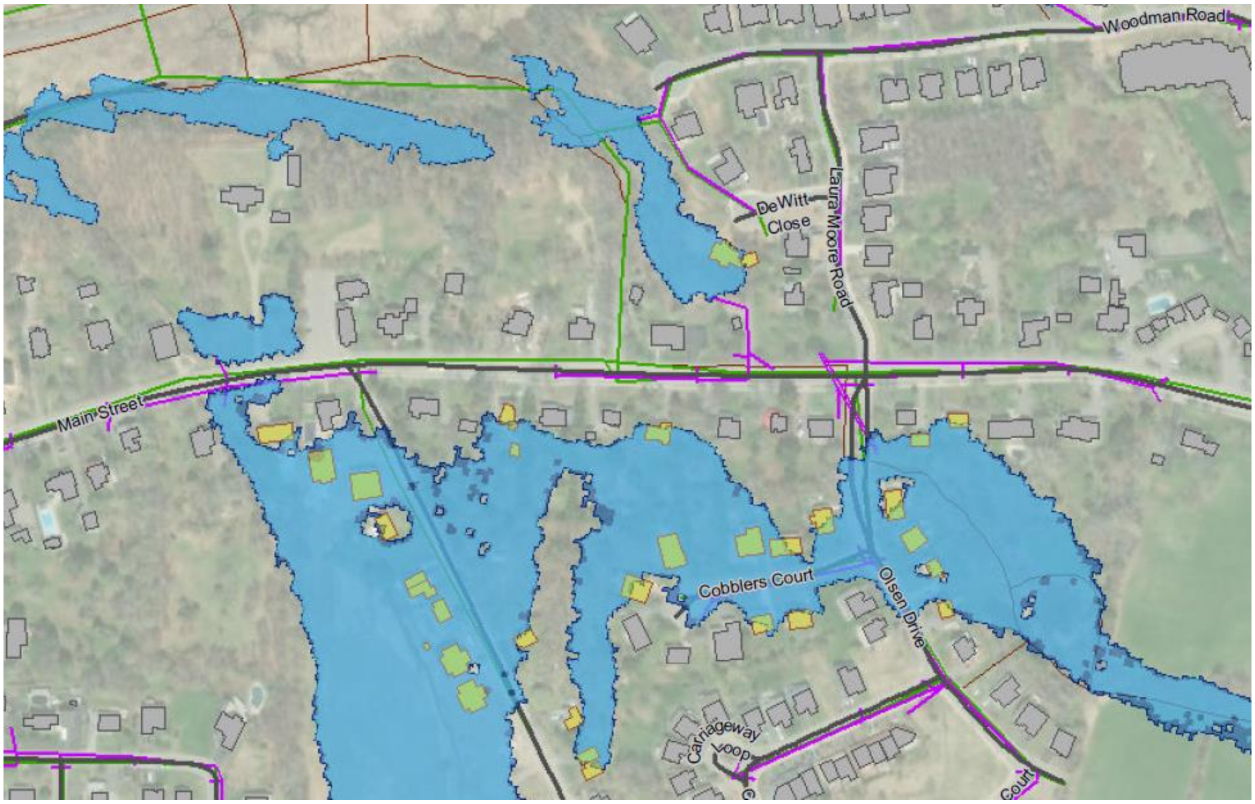


Figure 6.1: Extract of Map 1 – Existing Conditions, 1-in-20-year and 1-in-100-year Floodplains

Chapter 7 Vulnerability Assessment

The vulnerability assessment identifies municipal assets, infrastructure, and areas which are, or may become, vulnerable to extreme weather events and climate change. Adaptation options can be prioritized based on the infrastructure that is at the highest risk of flooding.

The Town provided the following GIS layers which were used to assess flooding impacts to infrastructure:

- Regulatory Zoning
- Sewer Collection System Network
- Stormwater Collection System Network
- Base Mapping
- Assets
- Water Distribution System
- Marshland
- Survey
- Street Index
- Transportation Routes

Assets within the floodplains expected of current climate conditions, with the existing dyke heights, were identified as vulnerable to flooding impacts, such as damage or loss. The focus of the risk and vulnerability assessment is on the impacts of flooding to critical municipal infrastructure and operations. Upholding public safety and the protection of Regional Emergency Management Organization (REMO) facilities is considered to be a top priority, followed by the protection of vital municipal services (e.g., drinking water and sewer collection).

Mitigation measures to protect vulnerable infrastructure are presented in the following chapter. This section represents a high-level risk assessment for critical assets and does not identify nor address all municipal assets comprehensively.

7.1 Historical Vulnerability

Historically, the Town of Wolfville has not experienced frequent or extreme flooding. The existing dykes have historically provided adequate protection from extreme coastal waters during high tide. Any flooding that has been recorded, has been found to occur when:

- Extreme tidal events back up through the stormwater system, or
- Extreme rainfall leads to flooding of the stormwater system due to insufficient pipe capacity or maintenance of the storm sewer system.

The following areas in the Town of Wolfville were identified to have experienced some level of flooding historically:

- Orchard Avenue,
- Willow Avenue,
- Sherwood Drive,
- Main Street,
- Wickwire Avenue near Main Street, and
- University Avenue at Main Street.

It is important to note at this point that even though the Town has not suffered critical damage to residential, municipal or commercial infrastructure in the past, the present assessment has identified that this risk is now present and growing every year with climate change. For example, Hurricane Teddy occurred on the 22nd September, 2020, and it did not carry much rain but had a notable storm surge. The storm surge was high, but did not seem to cause widespread flooding. However, the following photos show that the coastal water level rose fairly close to the dyke level, and that a larger event could easily overtop the dykes.

Figure 7.1: Photos of High Coastal Water Levels During Hurricane Teddy

The extract from the map of future flooding conditions shown in Figure 7.2 represents a 1-in-100-year coastal water level event, and it suggests that a significant amount of residential, municipal and commercial infrastructure is at risk of significant flooding with saltwater, which would cause a significant threat to public safety and is very damaging to all assets involved. This figure demonstrates the importance of protection from extreme coastal water levels, which is addressed in Chapter 8. Because this is such a critical item, it is assumed in subsequent maps that connecting and raising the dykes is carried out in the short term, and remaining flooding risks are related to rainfall events.

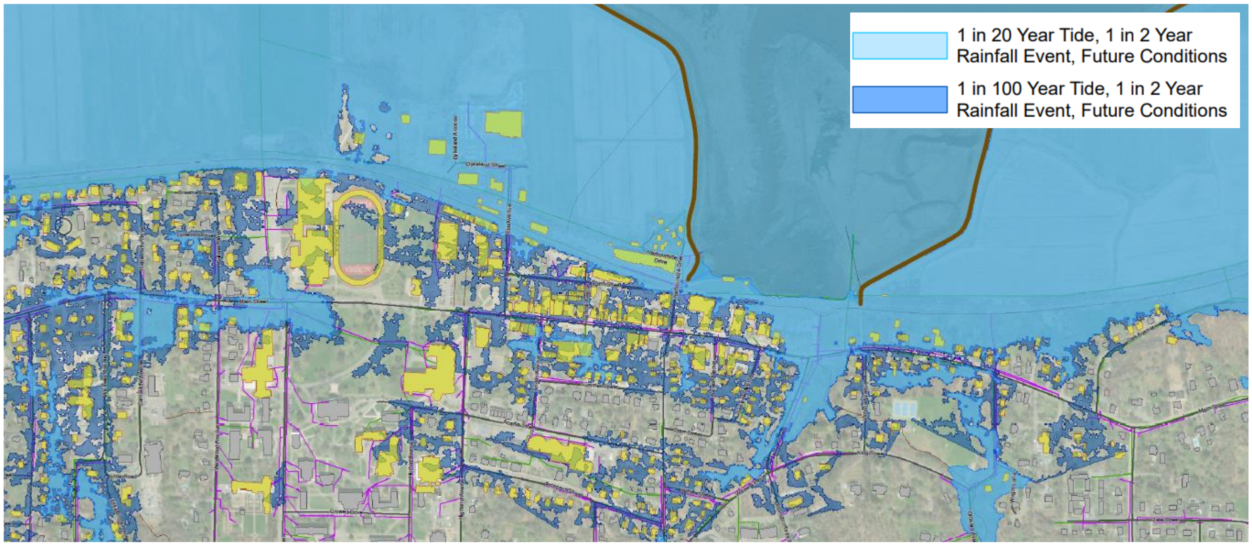


Figure 7.2: Areas at Risk of Saltwater Flooding in Future 1-in-100-Year Event

7.2 Municipal Assets

Integrating floodplain mapping into land use planning and asset management is critical for the long-term viability of municipal assets. According to the MPS, municipal assets are defined in two sets of inventories: the Water Utility and the General Fund. The Town maintains an Asset Management Plan (AMP) that provides the municipality with essential information required to ensure the safe and sustainable management of important assets. Incorporating the findings of this flood risk analysis will further improve asset management planning.

The flood analysis identified vulnerable areas and important infrastructure assets at risk in the Town. The existing 1-in-100-year rainfall and future (climate change) 1-in-100-year rainfall (RCP8.5 95th percentile) events were used to identify areas vulnerable to flooding, today and in the future, if the existing or proposed raised dyke systems were in place. Buildings affected by flooding are identified as yellow on the flood maps in Appendix A. An extract showing the assets on the future 1-in-100-year flood map (with dykes raised) is presented below in Figure 7.3. Assets shown relate to emergency response, water supply, wastewater conveyance and treatment, and transportation/trails. Assets that were identified as being vulnerable to flooding are highlighted with the red text in the labels of Figure 7.3.

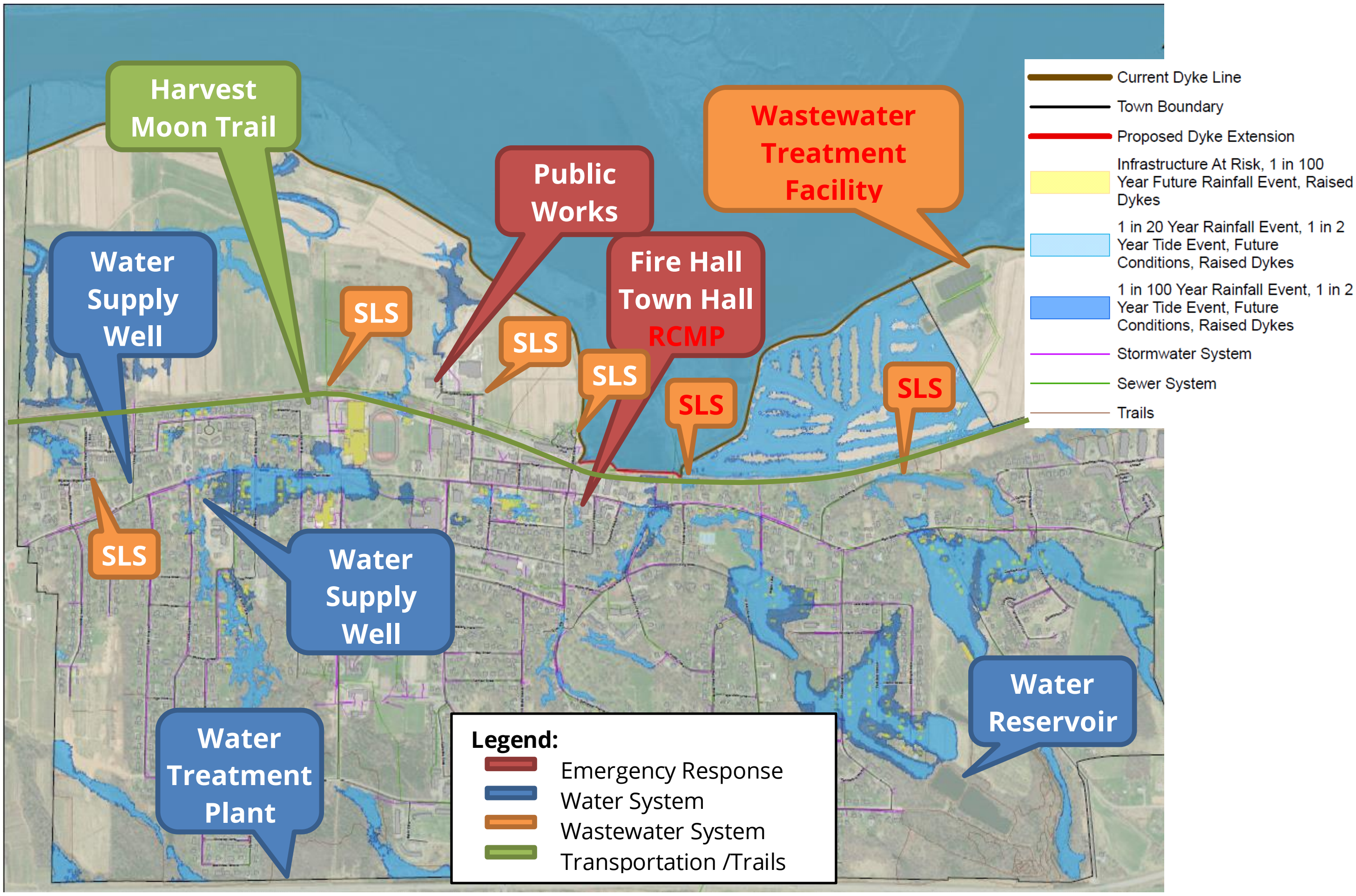


Figure 7.3: Municipal Assets on Future Flood Map (Red Text Shows Risk of Being Flooded). Sewage Lift Stations (SLS); Royal Canadian Mounted Police station (RCMP).

7.2.1 Emergency Response and Recovery

Police, fire protection and regional emergency management are considered essential services for the Town and are treated with the utmost importance. The RCMP office, as well as the Wolfville Volunteer Fire department, are located on Main Street near Gaspereau Avenue and provide 24-hour service for the community. During an extreme flooding event, the fire department needs to maintain access to most areas of the Town and the community emergency center made accessible.

The Wolfville Fire Department is connected to the Town Hall building, and neither are directly at risk of flooding, although the RCMP parking lot and corner of the garage are exposed to some shallow flooding risks, as shown in Figure 7.4.

Figure 7.4: RCMP Building and Parking Lot at Risk of Shallow Flooding

The public works building also houses a fleet of vehicles that need access to other areas in the Town. The modelling suggests that this facility is not exposed to current flooding risks or future flooding risks if the dyke system is raised.

The results of this flood risk mapping exercise can be incorporated into an Emergency Response Plan to determine how access can be maintained for all critical infrastructure during a flood.

7.2.2 Water System

The Water Utility includes the water treatment facility, wells, water reservoir, water mains, and supporting equipment. The Water Utility is owned and operated by the Town of Wolfville and financially operates separately through collected user revenues. The local water supply consists of two wells located in the area of West Main Street, which is pumped to a 12 ML concrete storage reservoir located on Ridge Road. The water is treated through chlorination at the Water Treatment Plant (WTP) and is supplied to residents through approximately 41km of gravity-fed water distribution lines from the reservoir.

As shown in Figure 7.3, none of the municipal water system assets are directly at risk of flooding. Even though the water supply wells are located in a fairly low-lying area close to flooded areas, they are not themselves flooded during either of the existing or future flood events.

7.2.3 Wastewater System

According to the AMP, there are six (6) sewage lift stations (SLSs) in the Town, which are used for pumping wastewater from lower to higher elevations to the wastewater treatment facility (WWTF). The WWTF is an aerated lagoon located northeast of the Town, directly south of the dyke system (elevated to be protected from flooding). It is noted that in 2019 the Town began a substantial capital upgrade to the wastewater treatment plant.

Considering the WWTF lagoons and buildings, the berms of the lagoons are at a safe elevation for current flooding risks, but they will not be at an adequate elevation for future flooding risks if the dyke system is not raised. Conversely, some of the older WWTF buildings are positioned in a low-lying area that is at risk of flooding. This the case for the existing blower and UV buildings. Conversely, the new screener building is at an elevation of 8.5m, which is safe from flooding. Figure 7.5 below shows the expected flood depths produced by existing 1-in-100-year extreme coastal water levels. Protection of the low-lying buildings is discussed in Chapter 8.

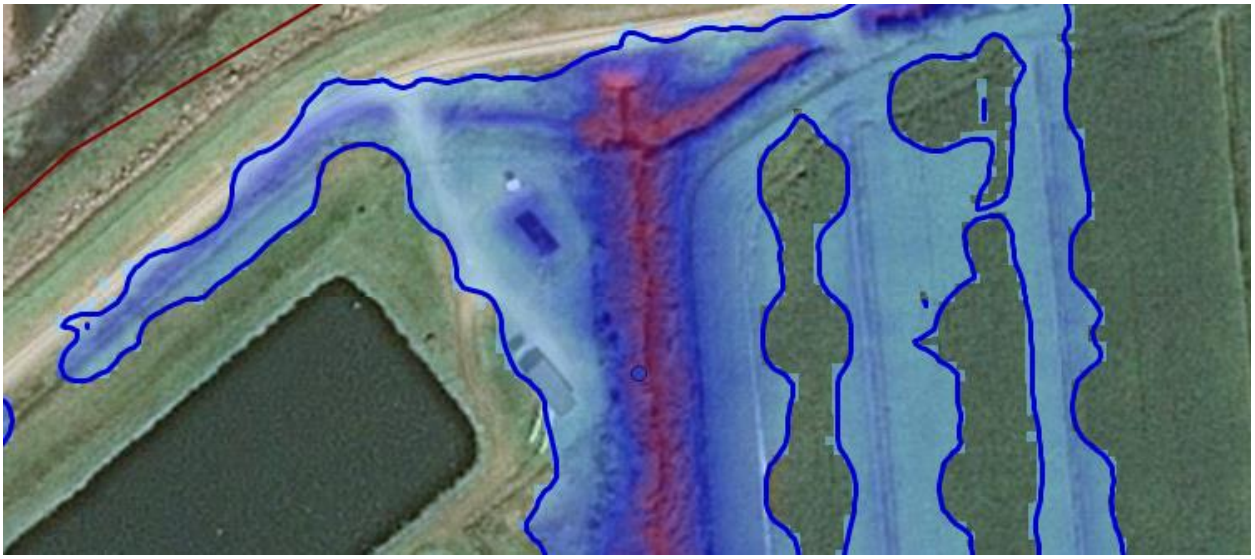
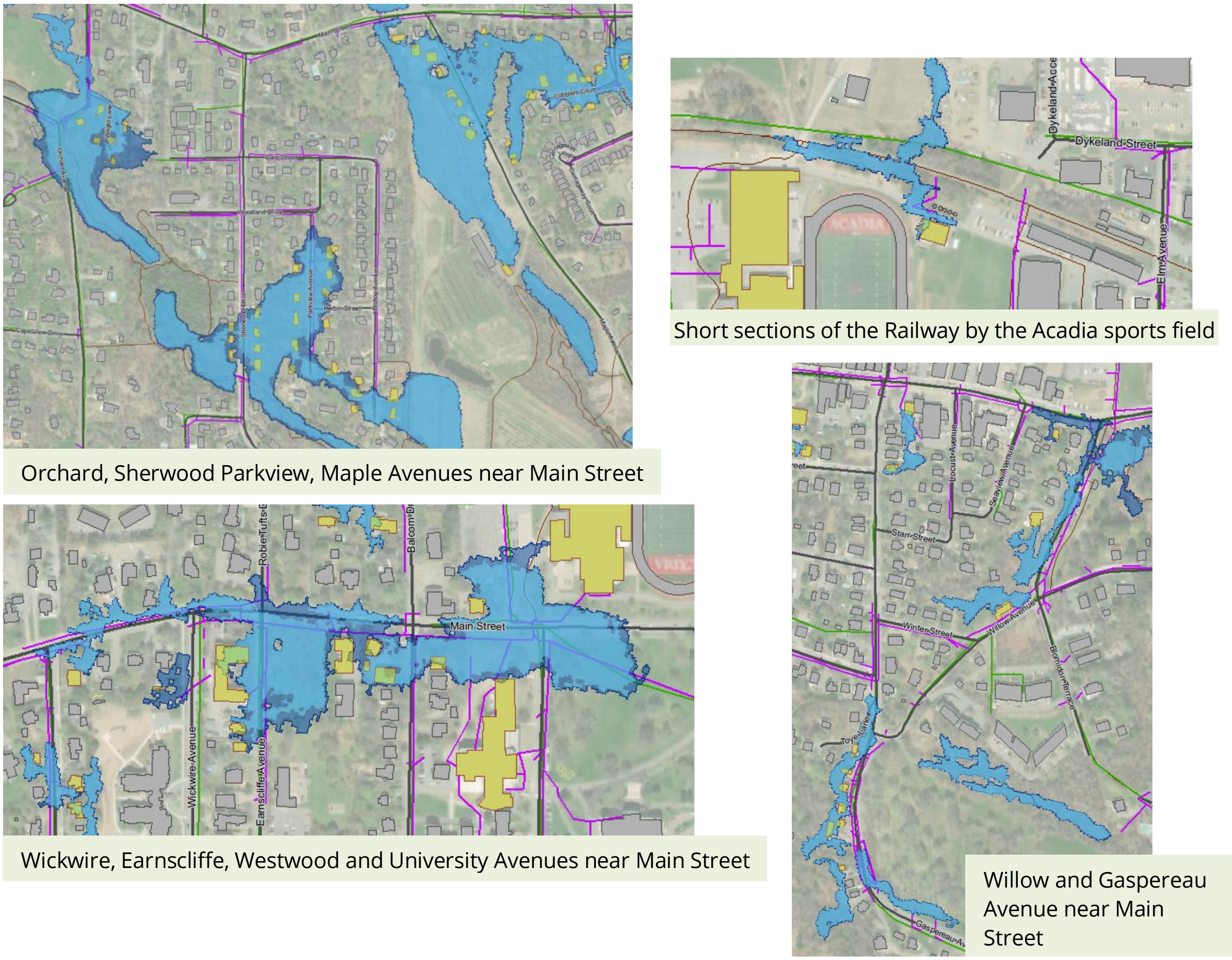


Figure 7.5: Flooded WWTF Buildings in 1-in-100-year Coastal Water Levels

Two SLSs are also just within, or very close to, the floodplain, both in existing conditions (involves the potential for salt water), and in future conditions, as shown in Figure 7.3. Flooding the SLSs would place the overall system at risk of being surcharged, overflowing wastewater to areas accessible by the public, treating excess stormwater, and damaging the wastewater conveyance and treatment infrastructure with saltwater. If electrical and instrumentation infrastructure within the SLS buildings are submerged, significant damage or loss may result. Typically, operation staff may opt to turn the pumps off to prevent damage to them when an SLS is flooded. This will result in untreated wastewater overflows to the environment, which is a public health concern. As discussed in Chapter 8, protecting areas with small berms is recommended. Although sewers are unlikely to sustain significant damage from inundation, flood water can also enter the sanitary sewers through holes in the manhole covers and cracks in the frame, potentially resulting in excessive flows, overwhelming the conveyance system and leading to wastewater overflows.

7.2.4 Transportation and Buildings

The Town's road infrastructure consists of local, collector, private and shared streets. The Town has a public transit system provided by Kings Transit, which services other surrounding counties. A historic railway system runs along the north end of the Town, along which a popular public walking trail now exists. The Harvest Moon Trail is a 110km-long trail providing local active transportation, fitness opportunities, and views of the local natural setting. Flooding risks have not historically been a concern, with the areas in Figure 7.6 below identified as only being at risk of shallow, temporary flooding.



Orchard, Sherwood Parkview, Maple Avenues near Main Street

Short sections of the Railway by the Acadia sports field

Wickwire, Earnscliffe, Westwood and University Avenues near Main Street

Willow and Gaspereau Avenue near Main Street

Figure 7.6: Transportation Infrastructure Vulnerable to Flooding

7.2.5 Agriculture and Commercial

Low-lying portions of agricultural fields were identified to be vulnerable to flooding during the existing 1-in-20 and 1-in-100-year coastal water level events (with some saltwater flooding) and future 1-in-20-year and 1-in-100 rainfall events (with some freshwater flooding).

Even though dyke overtopping has not been noted by the Town as a historic occurrence, the modelling shows that some overtopping could occur during the current 1-in-20-year and 1-in-100-year coastal water level events, as shown in Figure 7.7 below. This figure shows that a fairly significant amount of agricultural land is at risk of flooding with saltwater under existing climate conditions. A discussion on flood protection from extreme coastal water levels is presented in Chapter 8.

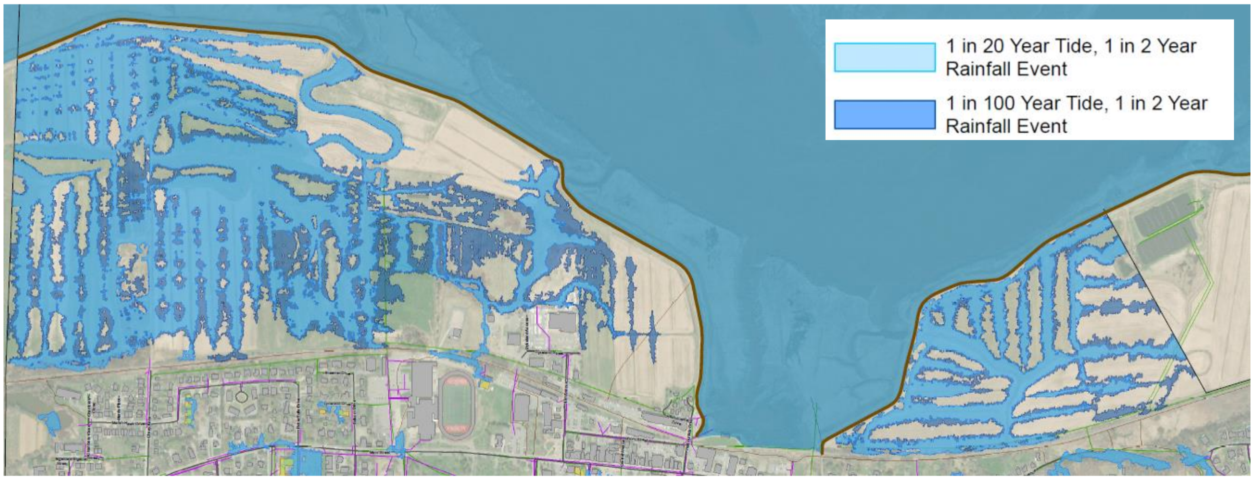
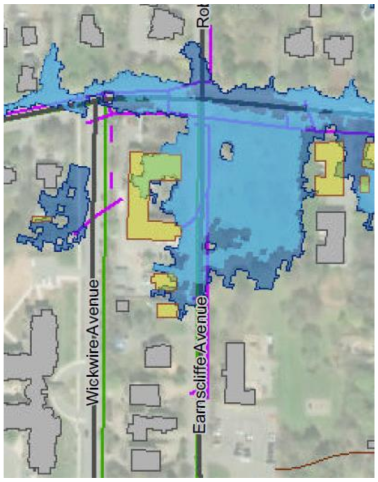


Figure 7.7: Agricultural Land Flooded in Existing Conditions Extreme Events

There are few commercial buildings currently at risk of flooding. The Wolfville Nursing Homes on Main St and Wickwire Ave. was identified as being at risk, as shown on the Figure 7.8 below. The figure also shows the "Town Centre" commercial area on Main St, opposite Central Avenue, also being at risk of flooding, together with the jewellery and photography stores across Linden Ave. It is worth noting that this risk is expected to increase slightly with climate change, as rainfall is expected to increase as well.



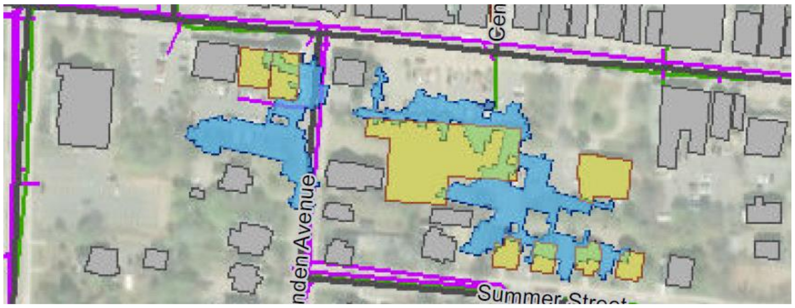


Figure 7.8: Wolfville Nursing Homes, "Town Centre" Commercial Area and Adjacent Commercial Buildings at Flooding Risk

Chapter 8 Flood Risk Mitigation Options

A number of flood mitigation options were identified and assessed. This section reviews the available options to mitigate the flooding of vulnerable areas identified in Chapter 7. Chapter 9 then evaluates the options presented here to support the development of a flood mitigation plan.

When developing a mitigation plan to reduce the impacts of flooding, determining the mitigation approach greatly depends on the infrastructure in question, the associated level of risk, as well as the cost-benefit of the various options. The Town has been proactive in addressing flooding through the implementation of development control measures, such as the net-zero increase in runoff requirement, which has been approved in the updated MPS document. Short term critical items now include connecting and raising the dyke system, as well as constructing a berm to protect the WWTF buildings.

The flood mitigation options for The Town include:

- Updating the Town's Municipal Planning Strategy to include updated floodlines, net-zero runoff development requirements, and limitations on the types of development permitted in floodplains. These changes have already been implemented by the Town in a document that received the Canadian Institute of Planners' Award for Planning Excellence.
- Coastal flood protection measures:
    - Connecting the dyke systems and implementing living shorelines; and
    - Increasing dyke elevations.
- Flood forecasting and warning system.
- Protecting municipal assets.
- Adapting existing buildings.
- Additional flood reduction measures:
    - Implementation of Best Management Practices;
    - Increasing storage capacity; and
    - Increasing pipe capacity.

8.1 Coastal Flood Protection Measures

The following actions are proposed to mitigate the risk of coastal flooding in the Town of Wolfville. Each action is discussed further in the following sections.

- Connect the dyke system, and apply erosion protection using a living shoreline.
- Coordinate with NS Department of Agriculture to raise existing dyke elevations:
  - Build up identified low elevations in the dyke system; and
  - Incrementally increase dyke elevations to accommodate increasing sea levels.

8.1.1 Connecting the Dyke System and Applying Living Shorelines

As shown in Chapter 7, the risk of flooding by overtopping the dykes is currently high, resulting in some flooding of farmland and WWTF infrastructure, and very significant in the future, resulting in flooding of most of downtown Wolfville. To mitigate flood risks in the Town during extreme coastal water levels, it is recommended to connect the Grand Pre and the Bishop Beckwith dyke systems, as roughly outlined in red in Figure 8.1. Connecting the two dyke systems provides a continuous elevated structure, which provides protection from the increasing risk associated with sea level rise and wave action. The dyke can be constructed to include a community trail that would connect with the existing trail, which is frequently used by residents.

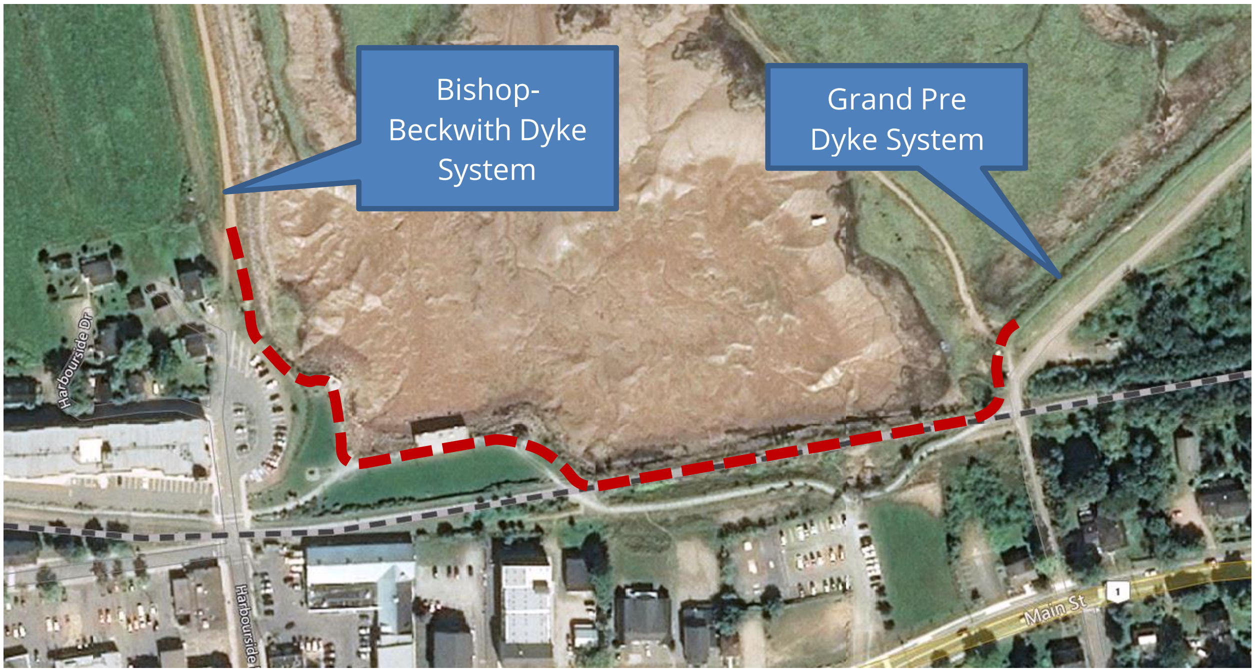


Figure 8.1: Connection between the Two Dyke Systems

There are two main options available to construct a new dyke:

- Construction of a new 8.5m full-height dyke in the mudflat, which will include the removal of (potentially deep) unsuitable material. Shallow side slopes will mean that the footprint of the new dyke could extend up to 75m in width (almost half the area of the mudflat in front of the park), along the 400m stretch of coastline between the two ends of the existing dykes. Allowances for settling over time will also need to be made. This represents a large volume of structural fill, and would lead to significant costs.
- Raising the existing ground connecting the two dyke systems, which is composed of trails and the former railroad. Since the existing ground would only need to be raised by 500mm on average, it would be simple from a construction perspective, require a much smaller volume of material, and would therefore be less expensive. The pending issue is the existing land ownership, since the land where the old rail line is still present does not belong to the Town. Discussions will need to take place between the land owner and the Town before this option can be finalized.

Raising the existing ground for a shallow dyke, following the path shown in Figure 8.1, would also mean that some existing structures would need to be moved or modified to adapt to the change, as they lie within the alignment of the proposed dyke. This would include moving an electrical panel, raising the wharf, and raising the wooden interpretive plazas. The gazebo is already raised, so it would not need to be modified.

Both a dyke in the mudflat and a shallow dyke will result in the same level of protection for the Town. Since the level of effort and cost is significantly different between options, it may be prudent to initiate discussions as early as possible with the landowner to assess the feasibility of the second option.

In terms of erosion protection of the outward facing slope, both options will need to include some surface treatment to reduce the energy of any incoming waves and minimize the risk of wave erosion and overtopping, even though it is very low. Both options will need to be protected in the same manner. Therefore, the subsequent erosion protection approaches are applicable to both options.

For the shoreline below the neap tide level (HHW-MT level of 4.46m CGVD2013), the existing riprap protection can be kept. Therefore, the option of elevating the existing ground by 500mm would not require replacing the existing riprap. However, there is the potential to use a more permanent approach to bank stabilization above this elevation where there currently is no riprap. A more resilient form of bank protection would take the form of a living shoreline. This would simply be an extension of the existing plant growth that already exists on the western and eastern banks of the Waterfront Park mudflat. Candidate locations to implement the living shorelines are noted in Figure 8.2 below. Some general information about living shorelines is also presented below for reference.

Figure 8.2: Candidate Locations for Living Shorelines

Some of the north-facing bank is currently eroding where the railroad abuts the mudflat, as seen in Figure 8.3, and could benefit from being readjusted or reinforced. The old wooden beams are likely coated with creosote and leaching toxins, so those should be removed as part of the dyke construction project.


Figure 8.3: Erosion on the Bank by the Railroad

This may not seem intuitive, but the erosion process in a mudflat is by far dominated by freshwater flows, rather than tidal flows, as shown in Figure 8.4. Therefore, the erosion of this bank is caused by the stormwater pipe outlets and not the incoming tidal flows and waves. Similarly, it is clear that the erosion within the mudflat by Waterfront Park (Figure 8.5) is caused by the stormwater pipe outfalls (shown in pink in Figure 8.5).

Figure 8.4: Typical Erosion Patterns in the Mudflats Originating at Stormwater Outfalls

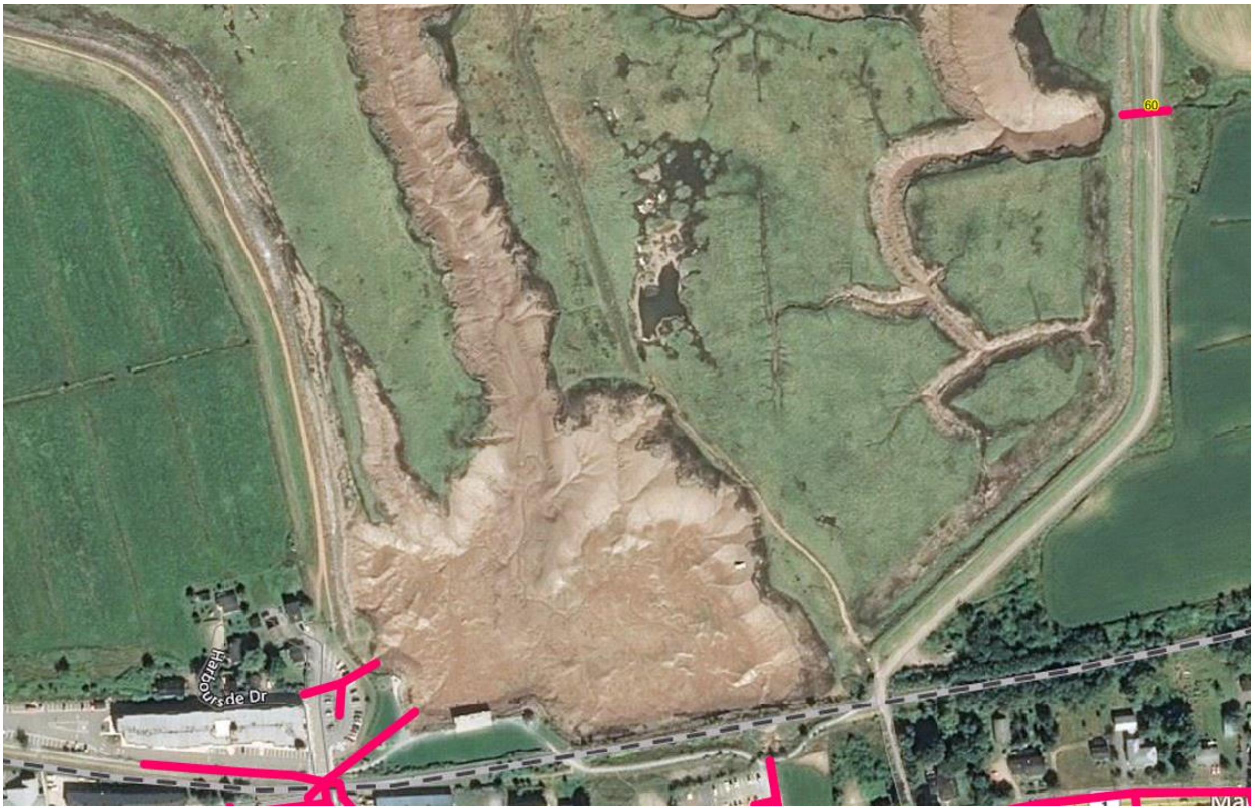


Figure 8.5: Erosion in Waterfront Mudflat and Stormwater Pipe Outfalls

The proposed approach to restoring the banks to their original shapes, which will allow the former salt marshes to re-establish themselves, is to extend the stormwater pipe outfalls by 50m to 75m. The tidal flows will then deposit sediment along the disturbed shorelines and restore the natural slopes. Following this, the salt marshes will then naturally re-establish themselves. Figure 8.6 below shows that some natural slopes in the area that have not been eroded have maintained their shallow slopes and salt marsh growth.

Figure 8.6: Existing Salt Marsh on Western and Eastern Banks of the Waterfront Mudflat

8.1.2 Notes About Living Shorelines as an Erosion Protection Approach

Natural or green infrastructure, also known as living shorelines, such as foreshore salt marsh, can provide protection to infrastructure such as dykes, while increasing shoreline resilience and providing ecosystem and cultural benefits. The plant communities that form the foundation foreshore marsh ecosystems depend on a number of factors including the frequency and duration of flooding, salinity, elevation, and the composition of nearby marshes that act as a seed source. Natural foreshore marshes in the Upper Bay of Fundy are typically composed of low and high marsh zones. The low marsh is characterized by salt marsh cordgrass (*Spartina alterniflora*), while the high marsh usually has a more diverse community that includes salt meadow hay (*Spartina patens*), seaside goldenrod (*Solidago sempervirens*), and blackgrass (*Juncus gerardii*).

Figure 8.7: Source: NOAA living Shoreline Guidance

Salt marshes can protect infrastructure and enhance coastal resilience to the effects of climate change, including storms and sea level rise, by stabilizing soils, storing water, maintaining/increasing elevation by trapping sediment, and dampening wave energy. Salt marshes are known for their ability to accrete sediment and build soils at rates that can keep pace with sea level rise (under certain conditions), which can mitigate the loss of coastal land and risks posed to infrastructure. The salt marsh vegetation creates drag that can dampen wave energy and reduce wave heights, particularly during the growing season. The extent of wave reduction depends on factors such as vegetation type, vegetation density, and foreshore marsh width. The presence of a foreshore marsh can reduce wave impacts to infrastructure such as dykes and can enhance the protection afforded by a dyke (Vuik et al., 2019).

In Europe, vegetated foreshore marshes are an integral part of dyke engineering designs (Vuik et al., 2016). In North Carolina, marshes have been shown to perform better than bulkheads for reducing erosion from a Category 1 hurricane (Gittman et al., 2014). Natural, restored or created salt marshes and related coastal habitats have also been shown to be more resilient to hurricane damage than hardened shorelines or built infrastructure. This is because they have the ability to absorb and dissipate a significant portion of the incoming wave energy and can recover (self-repair) and maintain form and function with little to no human intervention (Smith et al., 2018).

Salt marshes provide significant ecosystem benefits such as habitat for fish, forming the base of the coastal and marine food chains, and climate regulation through long-term carbon storage in marsh soils (McLeod et al., 2011). Invertebrates and crustaceans that use salt marshes provide a vital link between the nutrients produced by salt marsh plants and higher levels of the food chain (i.e., fish and birds). Salt marshes in Nova Scotia provide habitat for numerous commercial, recreational and aboriginal fish species (i.e., Striped Bass (*Morone saxatilis*), Flounder (*Pleuronectidae*), American eel (*Anquilla rostrata*), and Tomcod (*Microgadus tomcod*)). Salt marshes can also provide cultural benefits such as nature observation, opportunities for wild food collection, and outdoor classrooms for hands-on learning.

Restoration of salt marshes has the potential to achieve diverse goals including reducing climate risks, increasing the resilience and sustainability of the coastal community and ecosystem, as well as providing many cultural and economic benefits.

The current salt marsh in front of the existing dykes provides a highly aesthetic feature in the heart of downtown Wolfville. Developing a living shoreline will allow the current salt marsh to expand and reconnect both sides of the marshes in front of the existing dykes. Furthermore, the salt marsh provides an opportunity for the large student population, as well as interested residents, to learn about ecosystem restoration and Building with Nature techniques.

8.1.3 Design Elevations for New Dyke and Raising Existing Dykes

As noted in Section 4.1.5, the current average dyke and ground elevation surrounding the Town of Wolfville is approximately 8.15m CGVD2013 according to a Department of Agriculture survey completed in 2008. However, sections of the dyke system have been identified to have lower elevations. The minimum elevation of the dykes surrounding the Town of Wolfville is approximately 7.6m CGVD2013 (8.2m CGVD28) based on Lidar data collected in 2007. The 1-in-100-year storm surge elevation (approximately 7.8m CGVD2013), is slightly higher than the minimum dyke elevation. Sections of the existing dykes having a top elevation equal to, or lower than, the 1-in-100-year storm surge elevations do not meet design standards as there is no freeboard for safety. It is therefore critical to connect the dyke system and raise the existing dykes in the short term.

Since sections of the existing dykes may have settled since the collection of the survey (2008) and Lidar (2007), it is recommended that a new survey be conducted to obtain current minimum elevations to be used to support design.

Since coastal water levels and storm surge elevations will increase gradually as a result of climate change, it is recommended that both the construction of the new dyke and raising of the existing dykes be conducted in stages to gradually introduce the increased dyke elevation to the Wolfville waterfront. For the first stage, it is recommended that the Town construct a new dyke to an elevation of 8.5m CGVD2013 within the next 3 to 5 years, which corresponds to an average increase in ground level of approximately 500mm on the Kings County Rail Trail and edge of the Waterfront Park. This would be carried out with a cross-section similar to the schematic shown in Figure 8.8 below.

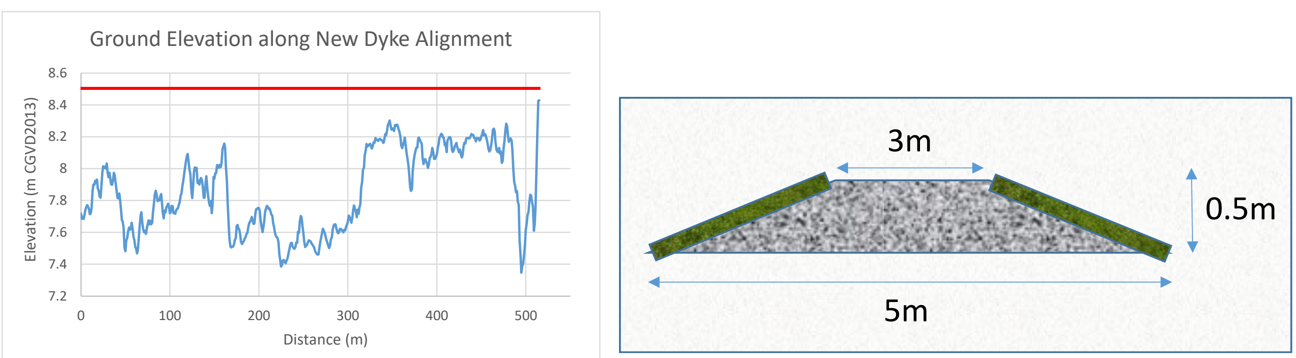


Figure 8.8: Schematic Profile and Cross-Section of Elevated Path

In conjunction with the development of the new dyke, it is recommended that the Town coordinate with the Nova Scotia Department of Agriculture (NSDA), who is responsible for maintaining the existing dykes, to raise the existing dykes by an average of 500mm to a consistent elevation of at least 8.5m CGVD2013. This will provide protection to the Town for the next 45 to 65 years, depending on the rate of SLR.

Discussions with the NSDA will also need to include the new *Guidelines for Safety of Coastal and Estuarine Dykes and Aboiteaux in New Brunswick and Nova Scotia* (Amec Foster Wheeler, February 2018), and how/if those would be incorporated in this design. Implementing those would likely mean that dykes would be constructed to a much greater height, since they consider dykes to be similar to dams.

Due to the critical importance of SLR in this context, it is recommended that continuous monitoring of the water levels behind the dykes be implemented and regularly analysed to track the rate of SLR. Based on this information, a safe timeframe to conduct a new analysis and design the next stage of upgrades for the system can be identified. It is generally expected that a safe timeframe to conduct a new study and design would be within the next 30 to 40 years. Monitoring will however be needed to review potentially changing or new information, and a study or specific intervention may be required sooner.

8.2 Flood Forecasting and Warning System

Although this study considered the 1-in-100-year event, events larger than this are still possible and happen regularly throughout the world. Furthermore, the intensity and frequency of events may be anticipated to gradually increase due to climate change. A greater coastal water level event may not be stopped by the dyke system should it occur before the recommended dyke system upgrade or subsequent future upgrades. The other uncertain risk is the rate of climate change. So far, greenhouse gas concentrations have most closely tracked RCP8.5. There are now some sea level rise projections that, even though unlikely, predict a sea level rise of 3.0m within the next 100 years (NOAA). An important consideration in this case is that even though the likelihood is very low (less than 1% chance each year), the potential consequences could be devastating. There is a balance between the acceptable level of risk, given the likelihood and potential consequences. This study considers the 1-in-100-year likelihood as establishing that balance, but assumes that risks that are not protected against, called residual risks, are understood and managed.

Management of residual risks can happen in a number of ways. Public information, preparation of emergency services, and building resilience in the existing infrastructure are the examples recommended in this study. During an extreme event that exceeds the design event, time is a very critical commodity, and it has to be managed extremely carefully to focus and deploy emergency efforts where they are most needed as fast as possible. The greatest benefit of a flood forecasting and warning system is that it provides a much longer timeframe (up to 5 days) to prepare emergency management efforts, providing time to inform the public and businesses, protect the municipal infrastructure, evacuate certain areas if necessary, and mobilize Regional Emergency Management Organization (REMO) staff and vehicle fleets. The cost of a flood forecasting and warning system is very low compared to any capital works expenditure recommended in this study.

It is therefore recommended that a flood forecasting and warning system be implemented to manage the current risks, as well as the growing risks associated with climate change. A flood forecasting and warning system can directly inform the REMO, who will then decide how to manage the warning.

Such a system can be developed to various levels of sophistication but, in its simplest form, it is a mapping tool that extracts the rainfall and storm surge forecast from Environment Canada and runs it in the model created for this study. Water levels are automatically extracted, mapped, and published on a password-access webpage. For better effectiveness, it should connect to the WWTF's SCADA system and connect to a tidal water level monitoring system. Figure 8.9 shows a diagram of the structure of such a system.

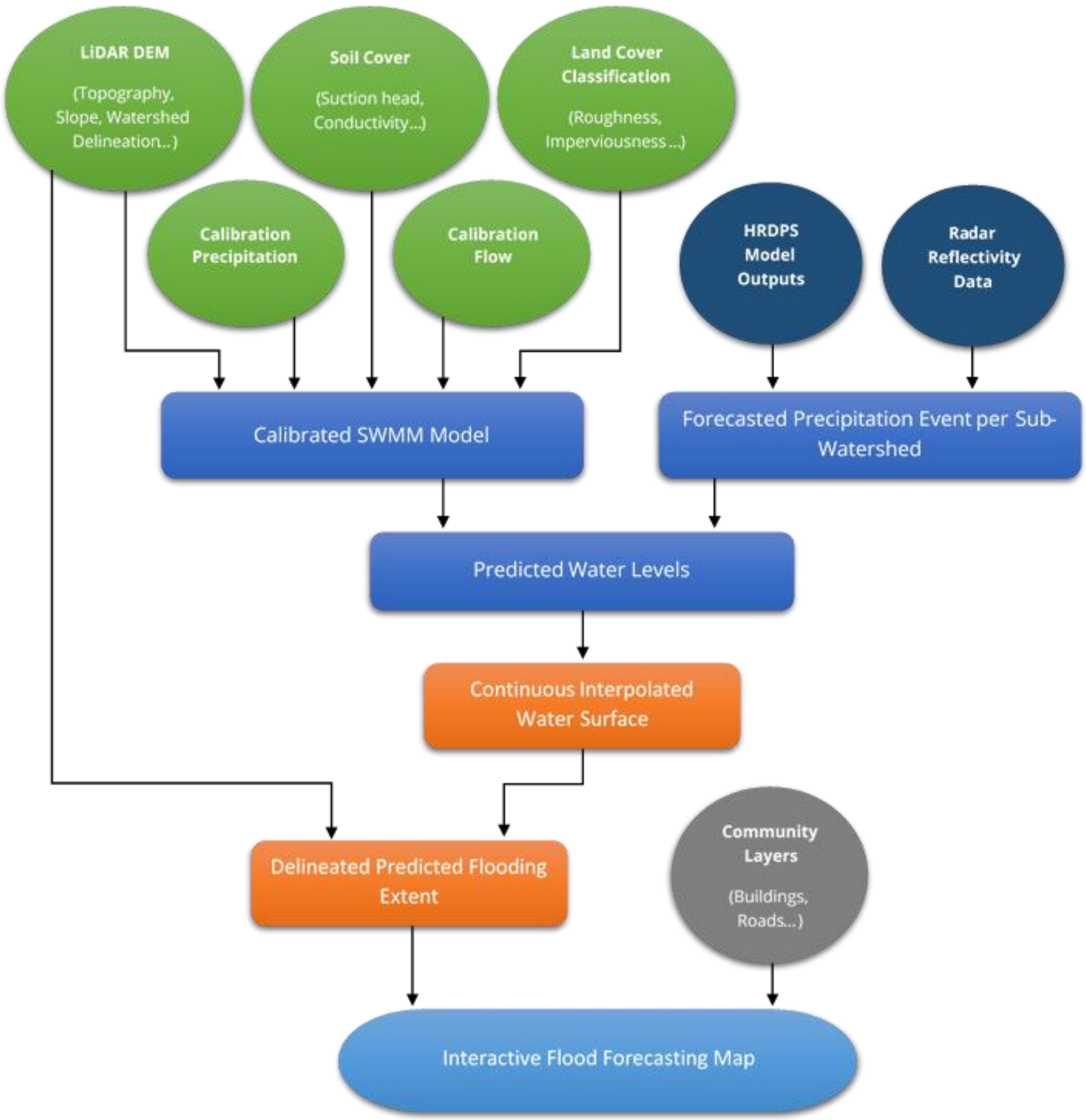


Figure 8.9: Flood Forecasting and Warning System Flow Chart

This can then become a useful tool for emergency management staff, such that informed emergency planning can take place and resources can be effectively allocated in advance.

8.3 Flood Protection Measures for Municipal Assets

The municipal assets identified as being vulnerable to flooding included the parking lot and corner of the RCMP garage, two sewage lift stations (SLS) and the wastewater treatment facility (WWTF). It is not expected that a small amount of flooding of the parking lot and corner of the vehicle garage during an extreme rainfall event requires flood mitigation. The flood extent or depth is not expected to increase in the future, even with the effects of climate change. Therefore, the only municipal assets that require flood protection involve the wastewater collection and treatment system.

The wastewater collection infrastructure includes pipes, manholes, and lift stations. The wastewater treatment plant is an aerated lagoon facility located directly south of the dyke system to the North-East of the Town, which has associated facilities, including a blower and UV building, and chlorine contact building. As noted in Chapter 7, those buildings are highly vulnerable to flooding risks with saltwater, and flooding will severely disrupt the quality of the treatment system and result in very costly repairs if it occurs. A new screening facility building is being designed at a much higher elevation, safe from flooding risks. In addition, sanitary manholes can also be a vulnerable point of entry of flood water into the conveyance system and result in overflows and decreased life of the system. This section provides high level mitigation and adaptations options to protect wastewater infrastructure from flood risks.

The Town's WWTF is protected both by the dyke system as well as berms surrounding the lagoon. During the existing 1-in-100-year sea level event, the model suggests that the dyke is overtopped and that the berms surrounding the lagoon are very close to being overtopped. However, the WWTF lagoon berms will be overtopped and the lagoons flooded with saltwater under future coastal water conditions (RCP8.5 95^{th} percentile) if the dykes are not raised. Flooding of the WWTF could lead to service disruptions, complete loss of wastewater treatment services, raw sewage leakage, washout, and/or foul odour. Additional pumping, sand-bagging and associated costs to keep critical infrastructure dry during a flood event may be required. This may require diesel generators during a power outage.

WWTFs have significant subsurface infrastructure such as pipes, electrical components, tanks, and liners. Critical infrastructure located outdoors would be directly exposed during a flooding event. Critical mechanical and electrical/instrumentation equipment located within control buildings are also vulnerable if situated below flood elevations.

The mitigation and adaptation options presented below were identified to mitigate flooding impacts to the wastewater collection and treatment system.

8.3.1 Sewage Lift Stations:

Two sewage lift stations (SLS) have been identified as being vulnerable to flooding risks, notably by saltwater. Both SLSs are located in areas that can flood when dykes are overtopped, which is currently a risk for the 1-in-20-year and 1-in-100-year events, until the dyke system is connected and raised. Figure 8.3 below shows the locations of the two SLSs with respect to the flooding anticipated due to extreme coastal water levels.

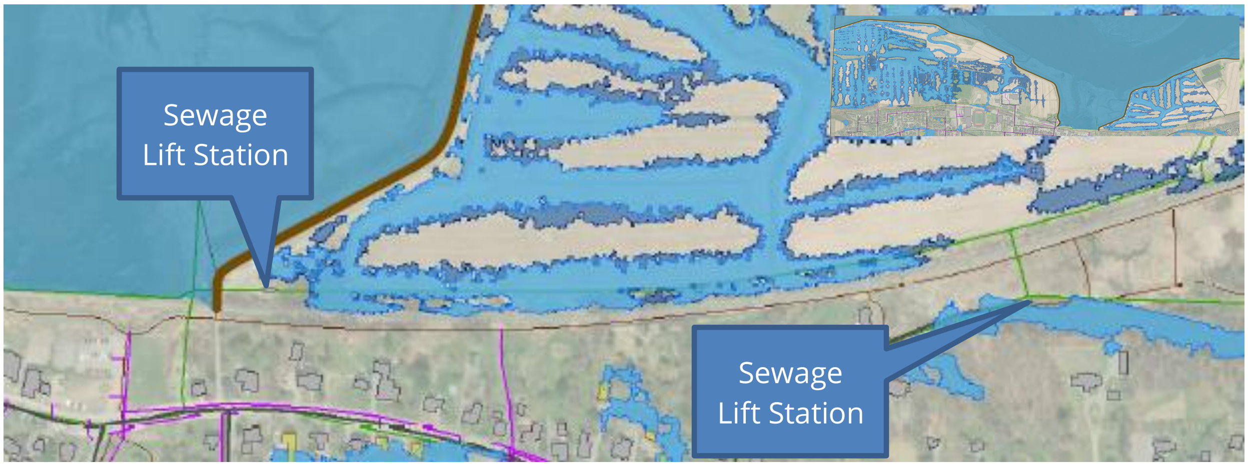


Figure 8.10: Sewage Lift Stations at Risk of Flooding

Both SLSs are located north of Main Street in the low-lying floodplain that used to be salt marsh before the dykes were first built. The natural topography causes it to be one of the first areas to flood, whether by dyke overtopping or during extreme rainfall events, when the tide gates are closed during high tides.

Fortunately, the locations of the SLSs are not highly urbanized, and some small amount of land regrading around the stations should ensure that flooding risks are averted. It is recommended to raise the ground level around the stations by 0.5m, and allow slopes to be directed outwards from the SLSs.

8.3.2 Wastewater Treatment Facility

As noted in Chapter 7, the lagoons will be at risk of flooding if the dykes are not raised. The associated buildings are currently at risk of severe flooding, both during extreme rainfall events and during extreme coastal water level events.

Protection of the lagoons cannot be approached with emergency pumping, simply because the floodwaters involve a significant volume of water and will rise against the entire circumference of the lagoon berms. Essentially, a second, higher berm would need to be built around the lagoons to keep them protected, which is not feasible in an emergency situation.

Alternatively, the option of connecting and raising the dyke system will allow the continued protection of the lagoon into the future, as long as it is carried out within the next 3 to 5 years. This is therefore the recommended flood protection measure for the lagoons.

The associated blower and UV buildings are located at a much lower elevation. The UV disinfection building in particular is closer to the drainage ditch and is at risk of being flooded to a depth of up to 1.5m under existing conditions. This is a significant risk and should be addressed in the short term. The connection and raising of the dyke system will reduce flooding risks, but not eliminate them.

It is not feasible to raise the blower and UV buildings to protect them against flooding, due to the high costs of modifying the piped connections, tanks, electrical and mechanical systems, etc. It is much more effective to construct another berm around those buildings to protect them from high water levels in existing and future climate conditions. The height of the new berm should be at least 7.2m CGVD2013, which is the average height of the lagoon berms. The proposed berm can be integrated into the functionality of the area, and its footprint minimized, by connecting the lagoon berms to the access road along the dyke and following the edge of the drainage ditch on the eastern side, as shown by the red dashed line in Figure 8.11 below. The proposed new Screening Building is intended to be built at an elevation of 7.9m CGVD2013, which is even higher and safer. The proposed berm can then function as an access road and lead to the higher elevated ground around the building (as shown in Figure 8.11). Figure 8.12 shows a schematic cross-section through the proposed berm. The berm would have a 3m-wide top for vehicle access and 1:1.5 side slopes to reduce its footprint, but it would still encroach on the brook, which would have to be diverted approximately 5m, as shown in Figure 8.12.

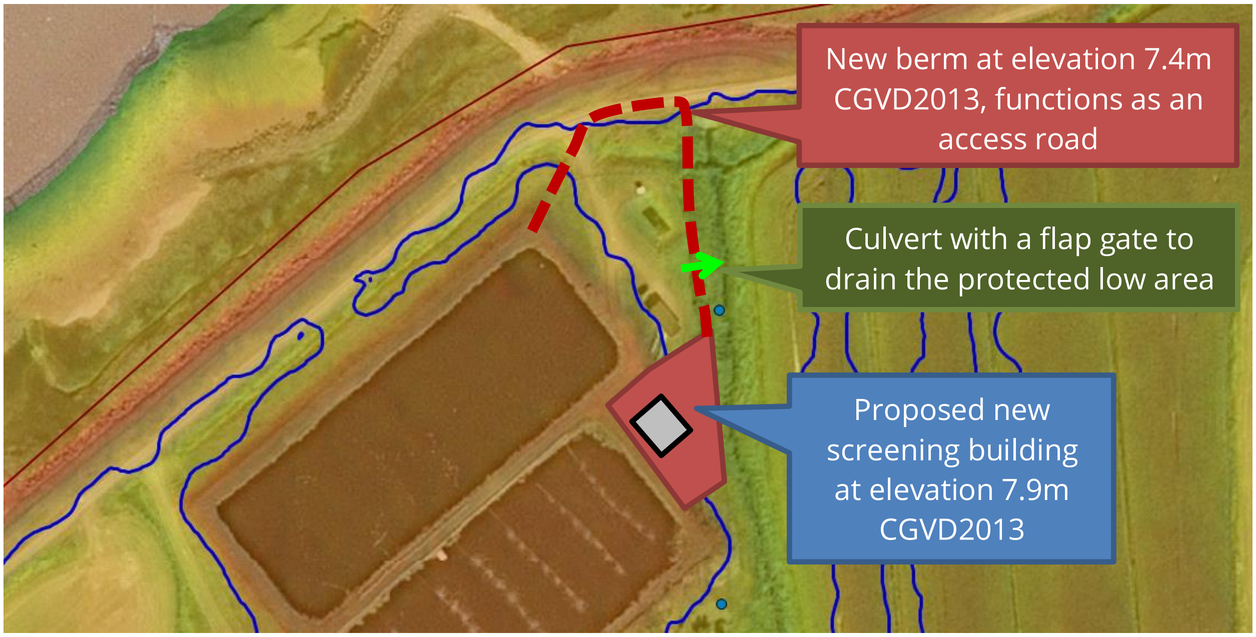


Figure 8.11: Proposed Berm to Protect WWTF Buildings

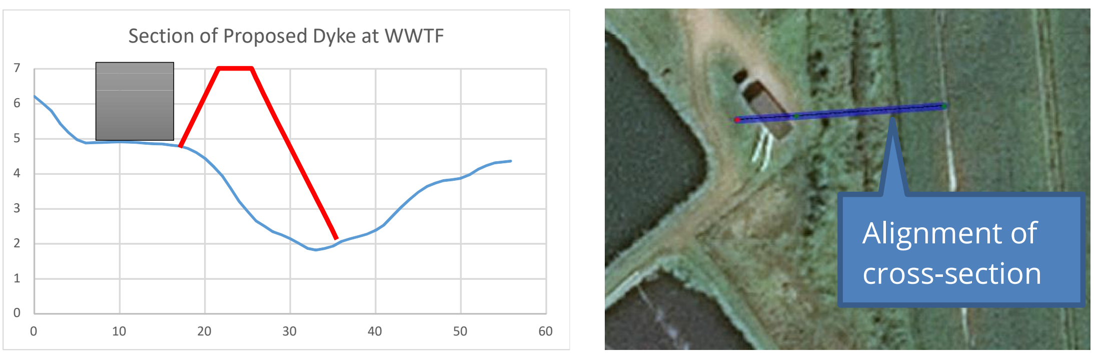


Figure 8.12: Schematic Cross-Section of Proposed Berm

8.4 Adapting Existing Buildings

As discussed in Chapter 7 and presented in Appendix A, flooding was not found to impact any municipal buildings. The back corner of the RCMP building and parking lot could receive some shallow flooding, but this would be temporary and would not increase in the future (as long as the dyke system is raised). Some commercial and private buildings are nevertheless exposed to shallow flooding risks, as identified in the flood mapping in Appendix A. A key example is the Wolfville Nursing Home, which is at risk of flooding in both existing and future climate conditions.

High water levels from extreme precipitation events alone, or in combination with high sea levels, may directly enter a building, and can also cause sewer backups into the basement.

Inflow and infiltration of clean surface water or groundwater into sewer manholes and pipes are issues in the Wolfville sanitary system that constantly require maintenance efforts to be kept to manageable amounts. During extreme rainfall events, inflow and infiltration will increase, potentially also exceeding the sanitary system capacity. This can create a risk of sewer backup in some low-lying buildings where the sewage pressurises the sanitary pipe, flows back up towards the building, overflows the toilets, and causes the basement to flood with sewage. In such instances, a backwater valve can be key to protecting buildings, including private residences, from sewer backups.

Adapting existing infrastructure to flooding vulnerabilities involves modifying construction to increase resilience to flood events. Development within the floodplain can be generally adapted by:

- Locating essential systems or infrastructure off the ground floor;
- Prescribing a minimum elevation (e.g., minimum freeboard above applicable flood elevation) as is currently the case;
- Raising buildings;
- Extending the foundation walls to above flood elevations; or
- Abandoning basements if they experience frequent flooding (Proverbs & Lamond, 2017).

General approaches towards flood-proofing individual buildings include raising the house off the foundations, wet flood-proofing, and dry flood-proofing. While raising a typical wood-frame house with a crawlspace and basement may cost $60,000 - $100,000 per house, basements may be proofed against occasional flooding for approximately $20,000 or rebuilt with waterproofed foundations for approximately $50,000. It does not look like raising structures would be necessary in Wolfville, although some landowners may decide to waterproof their basements.

The following list outlines general adaptation options which may prevent basement flooding in the event of extreme storm events and increased water levels. The selection of adaptations for each building depends on each specific building, as well as the level of risk that each building owner is willing to accept. The following adaptation options are available to building owners to manage flooding risks and are outlined for information purposes.

- **Foundation Grading:** Proper grading of the property away from the foundation at a minimum slope can improve drainage and prevent flooding and associated damage. Reverse driveways should also be avoided if possible.
- **Installing Sump Pumps:** A backup power source or generator may be required to keep the sump pump in operation during power outages. The sump pump discharge point should be at least 2m away from the foundation.
- **Installing a Backup Sump Pump:** A backup sump pump will prevent flooding in the event the primary sump pump is out of order.

- **Gutters and Downspouts:** Flow should be diverted at least 2m from the foundation. Installation of a back-flow preventer on the sewer lateral (if applicable).
- **Repairing Cracks in Foundations:** Cracks or openings may be sealed with a waterproof sealing material, such as an epoxy resin, to prevent infiltration.
- **Window Wells Installation:** Installation of window well covers on basement windows can prevent flooding. It is recommended that basement window wells extend 10-15cm above the surface of the ground and are sealed at the foundation.
- **Alternative Insulation Materials:** Spray foam is the preferred insulation material if the basement is not finished. When a basement is finished, then spray foam insulation may not be practical. An adaptive measure against water damage in basements is to select a closed cell foam insulation (cellulose) that is water resistant for installation at or below grade. A waterproofing sealant on the exterior of basement walls to protect the insulation may also mitigate losses from flooding or water infiltration.

Figure 8.13 below shows some additional measures that were included in the public communication summary document that will help building owners and homeowners better prepare against flooding risks.

Figure 8.13: Local Flood Reduction Measures for Buildings and Homes

8.5 Additional Flood Mitigation Measures for Consideration

The Town has recently developed Stormwater Management Design Guidelines (Hatch Ltd, 2019), which state a requirement for a net-zero increase in stormwater runoff policy. The objective of the policy is to limit the peak discharge rate from a new development to the pre-development rate; the flood mitigation options presented here are consistent with this objective. Under those Guidelines, Best Management Practices, or Low Impact Development measures, are presented, as well as increasing storage capacity. In addition, increasing pipe capacity is also presented as an option (although not part of the guidelines).

8.5.1 Best Management Practices or Low Impact Development

It is noted that in this context, Best Management Practices or Low Impact Development measures refer to infiltration systems (perforated pipes, infiltration swales, rain gardens, etc.) as opposed to detention ponds, which are not designed to infiltrate water.

An efficient approach to dealing with flooding risks from stormwater, as a result of development, is to manage the issue of high runoff at its source. Flooding is amplified when runoff is allowed to increase and infiltration of water into the ground is decreased. The more water is encouraged to infiltrate in the ground, the more the stormwater runoff from a site is controlled.

Figure 40: Vegetative Filter Strip Example

For example, street renewals can include:

- new perforated stormwater pipes;
- permeable sidewalks (pavers, asphalt or concrete);
- gravel beds under the sidewalks that connect to the stormwater main for added infiltration; and/or
- draining (perforated) catch basins.

Parking lot construction or renewals can include:

- permeable surfaces (pavers, asphalt or concrete);
- drainage system using perforated pipes, catch basins and manholes;
- infiltration strips;
- permeable linear drains connected to infiltration media; and/or
- rain gardens, infiltration swales, bioswales accessed with low curb inlets.

New buildings can include:

- green roofs;
- blue roofs;
- cisterns to collect rain water and reuse as grey water; and/or
- downspouts draining to the ground surface, with infiltrating media.

There is a vast array of measures that can be implemented, where the objective is to allow the runoff an opportunity to infiltrate the soil, mimicking natural conditions. Each site is unique, and a customized approach is needed for each site. Examples, and more information on those measures are available in the Stormwater Management Design Guidelines (Hatch Ltd, 2019).

Stormwater Best Management Practices and Low Impact Development techniques have the following benefits for the overall watershed and the Town:

- Decrease flooding risk and associated risks to infrastructure, land value, liability and public safety;
- Decrease peak flows, resulting in lower infrastructure costs;
- Aquifer recharge reduces the strain on water supply sources;
- Reduce pollution to drinking water supplies, recreational waters and wetlands, saving future expenditures for restoration of valuable water resources;
- Protect water quality and increase low flows in the natural drainage systems;
- Can reduce energy costs by constructing new green roofs or retrofitting existing roofs; and
- Through the above results, improve quality of life and increase property value.

Gradually implementing stormwater Best Management Practices would take many years to make an impact at the Town scale, but it would gradually reduce the volume of runoff from new development and therefore reduce the amount of flooding. The impact on the flood extents was estimated by the model to be limited, but this approach nevertheless helps additional development to not compound the flooding risks for existing landowners, which is a key aspect.

8.5.2 Increasing Storage Capacity

Storage is generally added to a stormwater system through ponds, underground storage, or constructed wetlands, in combination with a flow control structure at the outlet. The flow control structure increases the volume of storage and retention time of stormwater runoff, delaying the timing of the peak flow downstream.

In total, four (4) locations in the Town were identified for potential implementation of additional storage as identified in Table 11, , Figure 8.17, and Figure 8.18. The preliminary estimated dimensions of these structures are outlined in Table 11 and are included in the flood scenarios presented in Appendix A. The potential locations for the stormwater control structures were selected in order to mitigate identified areas of downstream flooding within the Town.

Table 11: Proposed Stormwater Storage/Retention Areas

Location Description	Approximate Coordinates	Proposed Area (m^2)	Proposed Depth (m)
Expansion of Little Brook natural water course near the southern end of Little Brook Lane	Latitude: 45.09 Longitude: -64.37	4,000	1.5
Expansion of natural waterbody located between Orchard Avenue and Sherwood Drive	Latitude: 45.09 Longitude: -64.35	5,000	1.5
Open Space at the Top of Willow Avenue	Latitude: 45.09 Longitude: -64.36	6,000	1.5
Open Space west of the Reservoir near Pleasant Street	Latitude: 45.08 Longitude: -64.34	6,000	1.5

Figure 8.15: Proposed Stormwater Storage Area near Little Brook Lane

Figure 8.16: Proposed Stormwater Storage Area between Orchard Avenue and Sherwood Drive

Figure 8.17: Proposed Stormwater Storage Area in open space near top of Willow Avenue

Figure 8.18: Proposed Stormwater Storage Area in Open Space west of the Reservoir near Pleasant Street

Recommended design of the stormwater storage and retention areas will need to follow the Stormwater Management Design Guidelines (Hatch Ltd, 2019).

The modelling conducted for the inclusion of storage systems indicated that the four potential sites presented above for storage, were all able to slightly reduce flood extents in the downstream areas, more notably in the Wickwire to University Avenue section of Main Street.

8.5.3 Increasing Pipe Capacity

Areas of recurring flooding were identified from consultation with the Town and evaluated through the model results. Insufficient capacity in the stormwater drainage system was indicated by the model results as a potential source of flooding. Pipe sizes in the model were increased in the locations identified in Figure 8.19, Figure 8.20, and Figure 8.22 to assess the potential impact of increased stormwater conveyance within the minor system on local flooding. The changes implemented to the stormwater drainage network are outlined in Table 12, and results are presented in Appendix A. All of the potential changes investigated are relatively minor increases in pipe diameter, meaning that the current system is very close to having sufficient capacity. The largest increase in pipe diameter is identified as number 5: University Avenue and Main Street (Table 12).

The modelled results show only a very minor decrease in the total area flooded as a result of capacity upgrades Therefore, it may only be economical to replace the identified pipes with larger pipes when they are nearing the end of their useful life. The largest improvement, even though limited, is indicated by the model results to be at the corner of Main Street and University Avenue.

Table 12: Modelled Stormwater Pipe Upgrades

Identifier	SWMM Conduit Label	Original Pipe Diameter (m)	Upgraded Pipe Diameter (m)
1	C203D	0.75	0.9
2	C204D	0.9	1.2
3	C220E	0.3	0.45
4	C221E	0.75	0.9
5	C222E	0.9	1.5
6	C224E	0.45	0.6
7	C124I	0.3	0.6
8	C125I	0.3	0.6
9	C1_LF	0.45	0.6
10	C127I	0.45	0.6
11	C83J	0.3	0.45
12	C89J	0.6	0.75
13	C99J	0.6	0.75
14	C92J	0.45	0.6
15	C70K	0.45	0.6
16	C71K	0.45	0.6
17	C72K	0.45	0.6

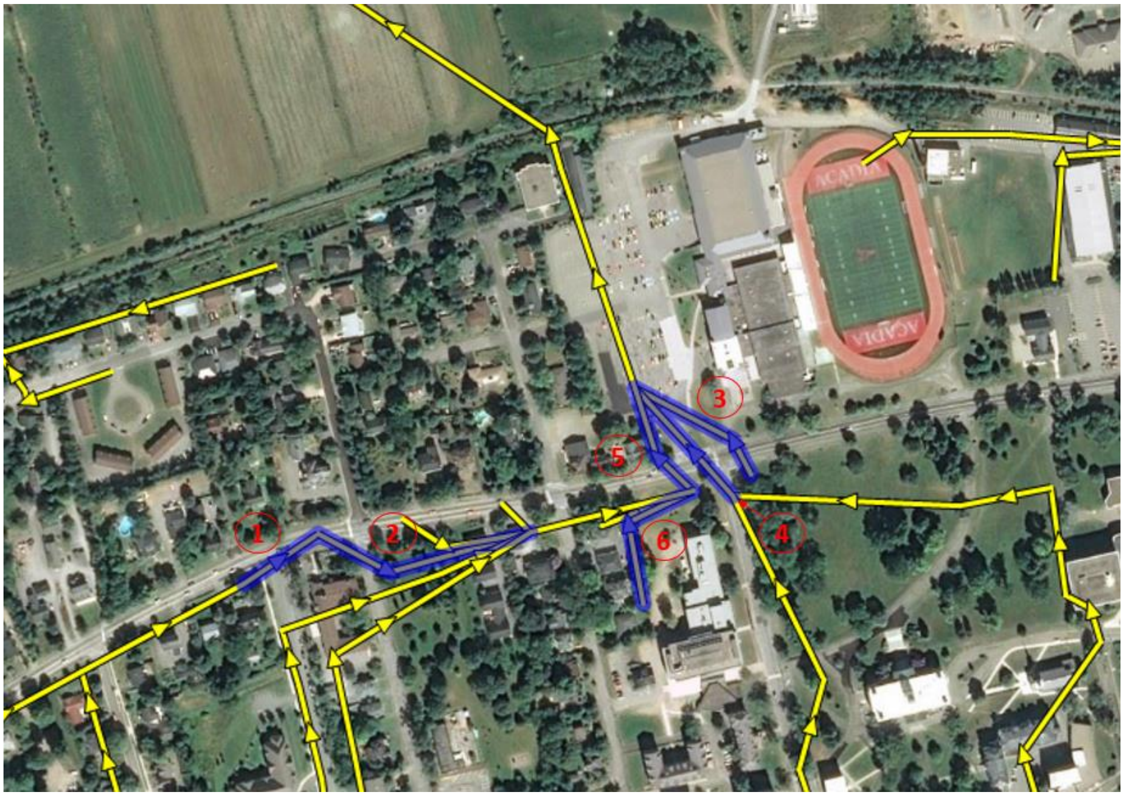


Figure 8.19: Proposed Upgrades for Stormwater Pipes near University Avenue and Main Street

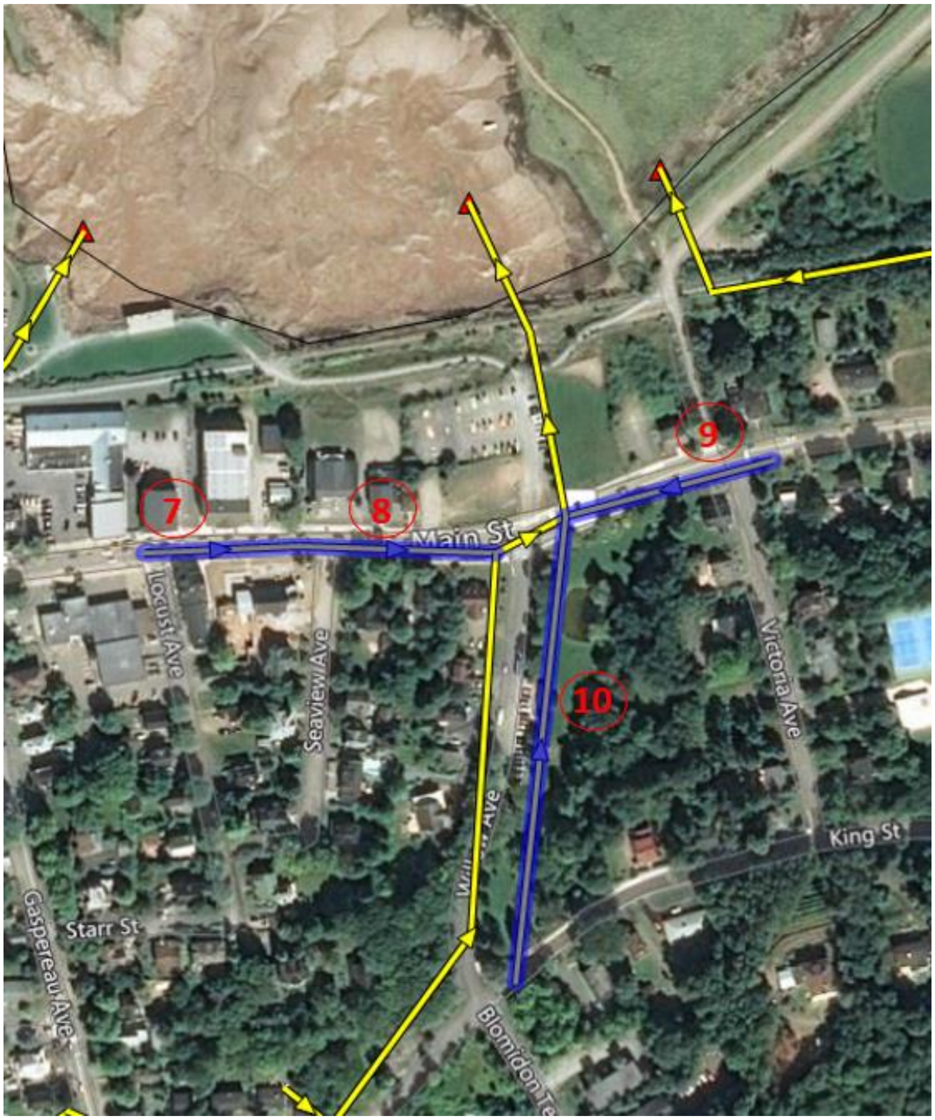


Figure 8.20: Proposed Upgrades for Stormwater Pipes near Willow Avenue and Main Street

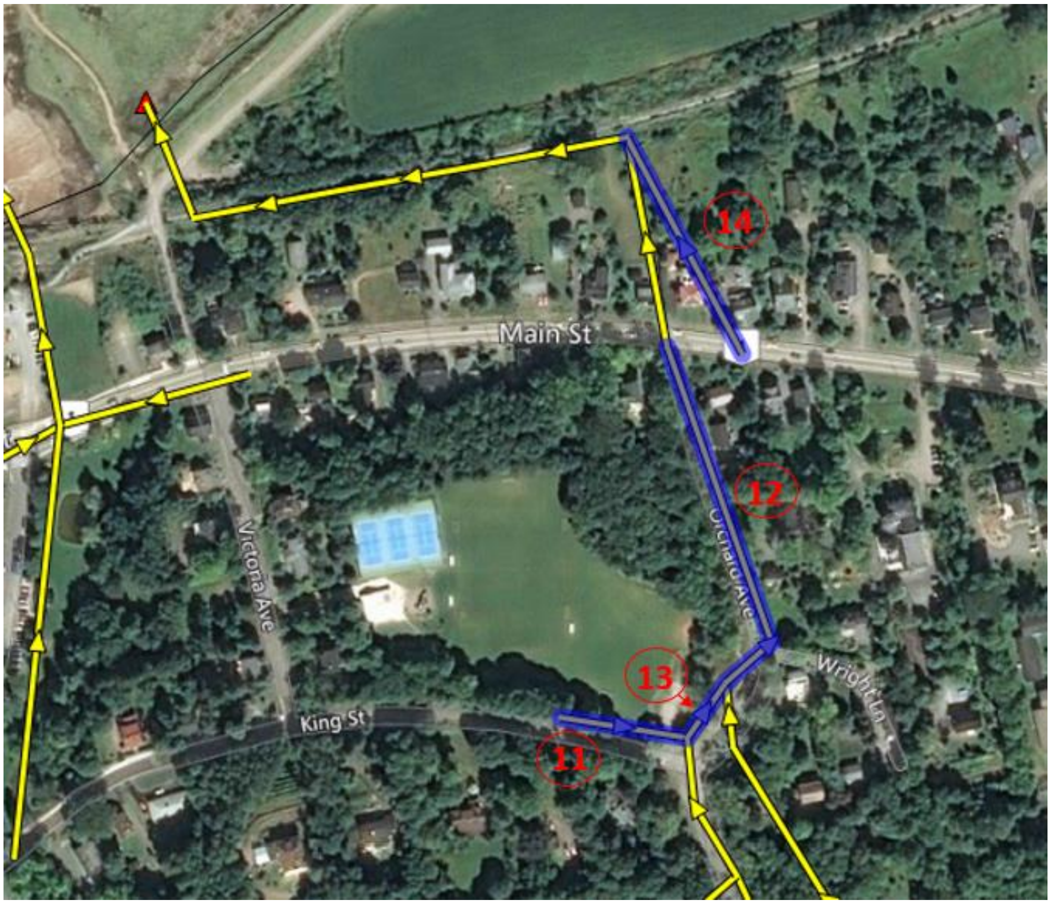


Figure 8.21: Proposed Upgrades for Stormwater Pipes near Orchard Avenue and Main Street

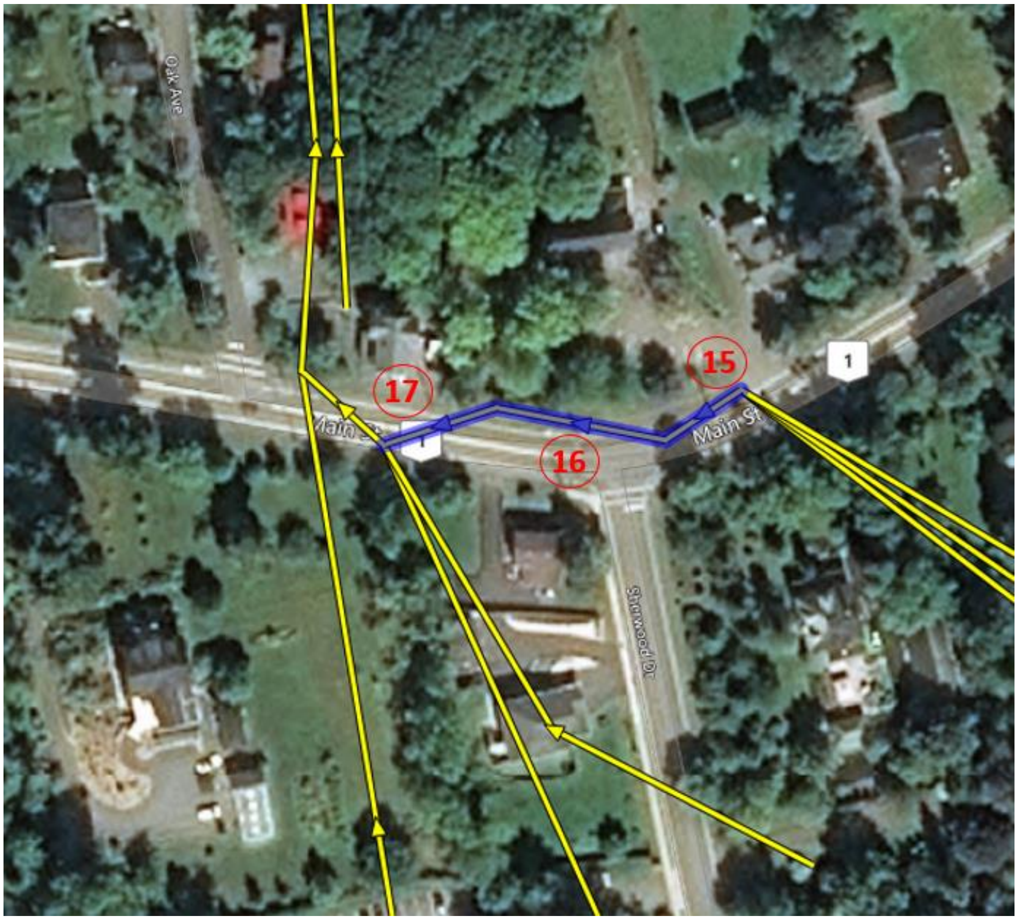


Figure 8.22: Proposed Upgrades for Stormwater Pipes near Main Street and Sherwood Drive

Chapter 9 Preliminary Evaluation of Mitigation Options

The flood mitigation and adaptation options presented in Chapter 8 were evaluated based on set criteria to determine recommended actions for the Town of Wolfville. Many of the options reviewed in Chapter 8 were clearly more suitable than others, however, a cost-benefit analysis of the options reviewed will better support the preparation of the flood mitigation plan. The ranking of the preferred options is presented below in Section 9.1, with supporting logic presented in Section 9.2.

9.1 Mitigation Option Ranking

The mitigation options were evaluated and ranked as *high priority* or *subject to further monitoring* as follows:

High Priority Measures:

1. **Coastal Flood Protection Measures**: includes connecting the dyke systems by raising the existing ground in the park and on the railroad. Also includes coordinating with the NSDA to raise the existing dyke system and periodically increase the dyke elevation to accommodate increasing sea levels. Optional inclusion of salt marsh restoration by extending the stormwater outfall pipes.
2. **Flood Protection of Municipal Assets**: protecting the 2 sewage lift stations (SLS) with land regrading, and constructing a new berm to protect the WWTF existing and new buildings.
3. **Flood Forecasting and Warning System:** informing the REMO of potential rainfall flooding or dyke overtopping risks. Includes monitoring water levels and connection with the WWTF SCADA system.
4. **Incentivize Local Flood Protection for Private Buildings**: includes site specific flood mitigation efforts to reduce the risk of flooding within private buildings.
5. **Community Education and Communication**: includes mailing of flood study overview, household education and actions, and waterfront signage and markers.

Actions Subject to Further Monitoring:

1. **Best Management Practices – Infiltration Measures:** includes promoting stormwater infiltration by identifying opportunities wherever pipes, sidewalks or parking lots are replaced or maintained.
2. **Increasing Stormwater Storage Capacity:** includes the construction of stormwater detention facilities and outlet control structures to control the release of flow downstream.
3. **Increasing Pipe Capacity**: includes upgrading identified undersized stormwater pipes.

9.2 Review of Mitigation Options

9.2.1 Coastal Flood Protection Measures

Coastal flood protection measures include connecting the Grand Pre and the Bishop Beckwith dyke systems, coordinating with the NSDA to raise the existing dyke system, and periodically increasing the dyke elevation to accommodate rising sea levels. A trail can be designed on top of the new dyke to connect with the current trail, which is a popular attraction for residents. This mitigation measure was evaluated in Table 13.

Extension of the outfalls for restoration of the natural banks with a living shoreline will allow for the restoration of valuable salt marsh habitat, which had formerly existed at the site. Salt marshes provide continued protection from the increasing risks of sea level rise and provide an added protection against wave action on the dyke.

Table 13: Review of Coastal Flood Protection as a Flood Mitigation Measure

Evaluation Criteria	Rank	Details
Flood Reduction Effectiveness	Very High	Eliminates the risk of coastal flooding impacts up to the 1-in-100-year event
Project Cost: - **New Dyke in existing mudflat** - **New Dyke over Existing rail bed**	High (>$5M) Low (<$1M)	Requires detailed design and construction of approximately 400m of dyke Use of Existing trail and rail bed means significantly reduced volume of fill can be used. For both, optional extension of the stormwater outfalls to support restoration of natural banks
Operational Cost	Low	No operational requirements
Management Requirements	Low	Management includes maintaining the trail on top of the dyke and period

		topping of the dyke to accommodate increasing sea levels
Environmental Considerations and Regulatory Requirements	High (positive)	Constructing a new dyke in the Salt Marsh will impact a large area of fish habitat, and will require a significant amount of habitat compensation. Raising the existing ground would have no environmental impact. Implementing salt marsh restoration will have positive environmental impacts. Regulatory bodies such as NSDA and the Marsh Body will need to be consulted and requirements under the Agricultural Marshland Conservation Act and all applicable regulatory documents followed.
Economic Impacts	Low	Will significantly reduce the cost of flooding impacts to vulnerable infrastructure. The net benefits of recreational activities can potentially increase with the newly joined trial system and natural feature. The University may use the salt marsh restoration for educational purposes about environmental sustainability and Nature Based solutions.
Social Acceptance	High	The newly joined trail system including the implementation of salt marsh restoration provides a natural aesthetic feature to the landscape is a major added benefit to the Town

As per this analysis, it is recommended to construct a new dyke to an elevation of 8.5m CGVD2013 within the next 3 to 5 years, which corresponds to an average increase in ground level of approximately 500mm on the Kings County Rail Trail and edge of the Waterfront Park. In conjunction with this, it is recommended that the Town coordinate with the NSDA to raise the existing dykes by an average of 500mm to reach a consistent elevation of at least 8.5m CGVD2013. NSDA will need to be consulted about the potential implementation of the new *Guidelines for Safety of Coastal and Estuarine Dykes and Aboiteaux in New Brunswick and Nova Scotia* (Amec Foster Wheeler, February 2018). A new dyke at an elevation of at least 8.5m CGVD2013 will provide protection to the Town for the next 45 to 65 years, depending on the rate of SLR.

9.2.2 Flood Protection Measures for Municipal Assets

As noted in Section 8.3, the municipal assets at risk of flooding involve two SLSs (low risk) and the existing WWTF buildings (significant risk). Land regrading around the SLSs to increase the land height by approximately 500mm, which is considered to require a minimal amount of capital budget (~$2,000), is one mitigative measure that was considered. Conversely, a berm may be required to protect the WWTF buildings, as described in Section 8.3. This flood protection infrastructure is considered critical for maintaining the essential functions of the Town and is therefore recommended for implementation in the short term (i.e., within the next 3 to 5 years). Further evaluation of these options is presented in Table 14.

Table 14: Review of Flood Protection Measures for Municipal Assets

Evaluation Criteria	Rank	Details
Flood Reduction Effectiveness	High	Critical infrastructure to protect essential service. A new berm will eliminate flooding risks up to the 1-in-100-year tidal event.
Project Cost	Low (<$1M)	Detailed design and construction requirements
Operational Cost	Low	These structures typically have no to low operational requirements
Management Requirements	Low	Period maintenance and inspection required
Environmental Considerations and Regulatory Requirements	High	Regulatory requirements as well as environmental impact assessments may need to be undertaken. Some watercourse alteration permitting may be required, and if agricultural land is affected, regulatory bodies such as NSDA and the Marsh Body will need to be consulted and requirements under the Agricultural Marshland Conservation Act and all applicable regulatory documents followed
Economic Impacts	Medium	Averts medium economic impacts of a flood event
Social Acceptance	Low	Project is not expected to encounter strong interest from the public.

9.2.3 Flood Forecasting and Warning System

As noted in Section 8.2, a flood forecasting and warning system would support the management of flooding risks of events greater than the 1-in-100-year flood, as well as provide warnings for the shallower floods, within the 1-in-100-year event, that can still occur with the proposed flood mitigation measures. As the sea levels rise, tracking the gradually increasing risk of dyke overtopping from extreme coastal water levels will be complex and difficult to estimate. A flood forecasting and warning system will connect to the Environment and Climate Change Canada rainfall and storm surge forecasts, run the flood models, and prepare flood maps on a website accessible by Regional Emergency Management Organization (REMO) staff to inform them on potential risks and support effective allocation of resources. For better effectiveness, it should connect to the WWTFs SCADA system and a tidal water level monitoring system. This measure is also recommended for implementation within the next 3 to 5 years and is reviewed in Table 15.

Table 15: Review of Flood Forecasting and Warning System Implementation as a Flood Mitigation Option

Evaluation Criteria	Rank	Details
Flood Reduction Effectiveness	High	Supports flood preparation, allows to increase public safety
Project Cost	Low (<$0.1M)	Coordination with REMO needed
Operational Cost	Low	Regular maintenance needed, server and website costs
Management Requirements	Low	Regular monitoring, QA/QC, calibration, updates
Environmental Considerations and Regulatory Requirements	Low	Only include those taken by the EMO for flood preparations to protect public safety
Economic Impacts	Low	Reduces economic impacts of a flood event
Social Acceptance	High	Project is expected to see positive interest from the public.

9.2.4 Adapting Existing Buildings

The adaptation of existing buildings involves site specific options to reduce flood risk to specific infrastructure. None of the buildings at risk in the Town involve municipal infrastructure, they are commercial or private, and the risks are limited to temporary, shallow flooding. Therefore, the assessment of costs and impacts is specific to the site and adaptation option selected, as described in Section 8.4, and will depend on individual owner's intentions for the management of flood risks. This differs from the other flood mitigation strategies provided as they aim to reduce flooding throughout the entire watershed areas. Nevertheless, since the risk exists, the Town may decide to incentivize the implementation of local flood proofing measures as listed in Section 8.4, and as such, the general public may feel this is a high-priority flood mitigation measure. Reference to the Homeowner Residential Rehabilitation Assistance Program (RRAP) is already made in the community summary document presented in Appendix B, a section of which is reproduced in Section 8.4.

9.2.5 Best Management Practices or Low Impact Developments

The Stormwater Management Guidelines (Hatch Ltd, 2019) are already referred to in the updated Land Use By-laws, and therefore, are already required to be implemented in all future development.

Modelling results indicate that increasing the amount of stormwater infiltration slightly reduces the amount of flooding within the Town of Wolfville. Further review of these options is available in Table 16.

Table 16: Review of Best Management Practices or Low Impact Developments as a Flood Mitigation Measure

Evaluation Criteria	Rank	Details
Flood Reduction Effectiveness	Medium	Flood risks are slightly reduced but vulnerable areas are still at risk
Project Cost	Low	Already Implemented
Operational Cost	Low	
Management Requirements	Low	
Environmental Considerations and Regulatory Requirements	Low	Low Impact Development measures typically reduce damage to downstream environment.
Economic Impacts	Medium	Even though such measures slightly increase the cost of development, flood protection and sustainable methods are expected to improve land value.
Social Acceptance	High	Low Impact Development measures are typically well accepted by the community.

9.2.6 Increasing Storage Capacity

Model results indicate that implementing the proposed storage facilities and flow control structures, as described in Section 8.5.2, were all able to slightly reduce flood extents in the downstream areas, more notably in the Wickwire to University Avenue section of Main Street. An evaluation of increasing the storage capacity of the watersheds as a flood mitigation option is available in Table 17.

Table 17: Review of Increasing the Storage Capacity of the Watershed as a Flood Mitigation Measure

Evaluation Criteria	Rank	Details
Flood Reduction Effectiveness	Low	Limited effectiveness, but more notable in the Wickwire to University area on Main St.
Project Cost	Low (per pond): ~$0.3M	Detailed design and construction requirements
Operational Cost	Low	These structures typically have no to low operational requirements
Management Requirements	Medium	Periodic maintenance and inspection required
Environmental Considerations and Regulatory Requirements	High	Regulatory requirements as well as environmental impact assessments may need to be undertaken
Economic Impacts	Low	Reduce the cost of flood impacts in downstream areas
Social Acceptance	Medium	Large project undertaking and may have push back to large construction project and structure near residences

9.2.7 Increasing Pipe Capacity

Model results indicate that increasing the size of select storm sewer pipes increases the conveyance capacity of the storm sewer network and slightly reduces localized flooding. The storm sewer upgrades evaluated are outlined in Section 8.5.3 and include upgrades to seventeen (17) pipes. The limited reduction in flooded areas is related to the fact that the capacity of the system is reduced to zero when the tide is high.

As noted in Section 8.5.3, it may be most economical to replace the identified pipes (with larger pipes) only when they are nearing the end of their useful life, or if street repairs are planned. The largest reduction in flooding, even though limited, was indicated by the model results to be at the corner of Main Street and University Avenue. An evaluation of increasing the pipe capacity of the municipal stormwater system as a flood mitigation measure is presented in Table 18.

Table 18: Review of Increasing Pipe Capacity as a Flood Mitigation Measure

Evaluation Criteria	Rank	Details
Flood Reduction Effectiveness	Low	Very limited, with some reduction noted in the University Ave/Main St area
Project Cost	Low (~$0.3M) for University/Main	Detailed design and construction requirements
Operational Cost	Low	No operational cost
Management Requirements	Low	Period maintenance and inspection
Environmental Considerations and Regulatory Requirements	Low	Storm sewer design requirements and construction requirements
Economic Impacts	Low	Limited reduction in flood impacts expected
Social Acceptance	Medium	Disruption to areas such as sidewalks and roads during construction

Chapter 10 Stakeholder Consultations and Community Communication

10.1 Stakeholder Consultations

Stakeholder consultations plays an important role in a study that involves potential modifications to infrastructure that is not owned by the Town, or connects with land or infrastructure that is not owned by the Town. There can be land transfer, infrastructure operation, and management or maintenance considerations to take into account. In addition, some propositions for new infrastructure may not be consistent with future plans of various stakeholders. To minimize such risks, coordination with the various stakeholders is a key step in the development of a flood mitigation plan for the Town.

Prior to this study, 5 years of consultations were carried out through the review of the Town's planning documents, which included an assessment of the flood risk of the Town. The findings of these consultations were consolidated in the recently implemented update to the MPS and Land Use By-laws. This process involved a flood risk workshop and multiple committee and council reviews.

As part of the current study, a number of stakeholders were contacted. The objective was to inform them of the current study and give them an opportunity to provide comments on the study.

The following stakeholders were contacted for an opportunity to provide feedback:

- Acadia University,
- Municipality of the County of Kings,
- Nova Scotia Department of Agriculture,
- Nova Scotia Transportation and Infrastructure Renewal,
- Bishop Beckwith Marsh Body,
- Grand Pre Marsh Body.

Responses were obtained from the Municipality of the County of Kings and the Nova Scotia Department of Agriculture. After several attempts, no responses were obtained from the other stakeholders by the time this report was completed. This could be related to the challenging conditions associated with COVID-19, or it could also mean that no potential issues were identified by the respective stakeholders.

10.1.1 Municipality of the County of Kings

The Municipality of the County of Kings provided feedback and expressed its appreciation for being contacted and informed of this study. They expressed interest in being informed of its progress and its next steps, including planning considerations, as well as potential flood mitigation options that could be implemented. At this time, no potential issues were found to exist with the proposed flood mitigation options.

10.1.2 Nova Scotia Department of Agriculture

The NSDA is a key stakeholder in this project, since the main flood mitigation option identified in this study is the extension and topping of the existing dyke system owned by the NSDA. The NSDA was contacted and various considerations were discussed and addressed, including:

- Current plans from NSDA to top (raise) the existing dyke system to offer continued protection against SLR;
- Ability to allow walking trails on the dyke system;
- Ownership of the potential new dyke; and
- Maintenance of new dyke.

The NSDA noted that it currently had plans to address increasing risks of SLR at both the Grand Pre and Bishop-Beckwith dyke systems. No timeline is available yet, but the NSDA is also interested in looking at the findings of the current study to inform their future plans.

Considering the ability to allow walking trails on the dyke system, the NSDA noted that walking on dykes can damage the vegetation, which is a key component of the erosion protection for the dyke and provides structural stability. In addition, access for maintenance of the dykes can be more difficult if it is open to the public. This notwithstanding, the NSDA has previously allowed the construction of walking trails on its dykes and has developed some adaptations that are necessary for the inclusion of a walking trail. These adaptations include a slightly higher top elevation (to compensate for erosion risks), some geotextile fabric, and erosion-resistant material (coarse gravel) that is covered with finer material for the trail surface (crusher dust). Increased monitoring efforts would be required by the Town, and maintenance is more difficult, but the possibility will certainly be considered by the NSDA.

Regarding ownership of the new dyke, which would link the Grand Pre and Bishop-Beckwith dyke systems, if the Town designs and builds a new dyke that follows the NSDA dyke design guidelines, NSDA are open to receiving ownership of it and providing maintenance.
From a maintenance perspective, while NSDA will provide some general maintenance of the dykes, to the same level as the remainder of the dyke system around the Bay of Fundy, erosion caused by pedestrian traffic would have to be monitored, and if necessary, repaired by the Town.

These considerations show that it is certainly feasible to implement the construction of a new dyke to close the existing gap between the dykes, as long as the design is closely coordinated with the NSDA.

10.2 Community Education and Communication

A public-facing communication strategy and materials have been prepared in draft form and are presented below.

10.2.1 Public Communication Summary Document

A summary document was assembled touching on the main points in the report (available in Appendix B). It is designed to be concise, clear, and accessible. The document includes the following information:

- Introduction to climate change;
- Description of existing and future flooding risks;
- Flood mapping;
- Flood mitigation measures recommended in this report, including:
  - New dykes and raised dykes;
  - Infiltration systems;
  - Increasing stormwater storage capacity; and
  - Increasing pipe capacity;
- Flood-proofing measures at the building or household level, including:
  - Explanation of sources of stormwater into the household;
  - Lot and building level flood mitigation and flood proofing measures; and
  - Reference to the Homeowner Residential Rehabilitation Assistance Program (RRAP).

10.2.2 Layout of Document to be Sent to Residents in a Flood-Affected Area

Communication documents can take many different forms. Typically, the most helpful documents prepared for communication are those that are focused on the main questions that readers are likely to be asking themselves, for example:

- Why is there a flooding risk in the Town?
- Am I at a risk of flooding?
- How much flooding am I at risk of experiencing?
- Am I likely to suffer damages to my home?
- Are my loved ones and me at risk?
- How can I prepare for a potential flood?
- What can I do to my home and property to reduce risks of damage?
- How can I access help to pay for the costs of those measures?

It may be helpful to directly include the questions in the mail-out document so that the readers can see that those questions will be answered and feel that the document is helpful.

The answers to the questions are in the summary document and in the flood maps. Even though flood maps could be sent to residents, it is typically the case that members of the public at large are not familiar with maps or how to find their home on a map.

Since the flood risks to the buildings identified in the mapping is very consistent and involves only temporary, shallow flooding, it may be more effective to focus on the risks, rather than asking readers to understand the details of a map. For example, it could be noted that their home has been identified as being at risk of flooding, but that the flooding will only be temporary (in the order of a few minutes to a few hours) and it will not involve deep water or place any lives at risk.

Preparation measures for a flood are detailed at the beginning of Section 8.4, while flood protection measures at the lot and building level are presented further down in the same section.

Access to financial support is also noted in the community summary document referencing the Homeowner Residential Rehabilitation Assistance Program (RRAP), and the Town could also provide some financial incentives.

As noted in Section 8.2, residual risk would also need to be managed and communicated. It may include noting that the dyke system would be designed up to a certain level of protection (in this report, the 1-in-100-year event is used as a design basis). Regardless of the design event used to construct the new dyke, and/or to raise the existing dykes, there will always be a risk that an event greater than the design event occurs. In this case, the risk is managed by the REMO, through preparation, response, and recovery. A flood forecasting system would then include a warning response procedure, where the public is warned if the dykes are at risk of being overtopped. Since this type of flooding would involve deep water and fast-moving water, any persons within the area at risk would have to be evacuated (this would include any building North of the railroad and a handful of buildings West of Old Dyke Lake and North of Main St, including the Southwest Nova Insurance Group up to Orchard Avenue).

Perhaps it can be noted with an explanation that the dykes are built to reduce the risk, but will never eliminate the risk of overtopping, and/or failing. This risk is managed by the REMO, who will provide alerts if necessary, and ensure that any necessary evacuations will take place.

This communication will need to take place with any owner of a building or home that has been identified as being at risk of flooding in existing conditions by the 1-in-100-year event, or the future conditions (with dykes raised) 1-in-100-year event. The mapping in Appendix A has identified those buildings by colouring them in yellow. In addition, communication with owners of any building and home that is within the future 1-in-100-year flood extents (scenario with no dyke raised) will also need to be informed that they would be at risk of being evacuated if an event greater than the 1-in-100-year event occurred, and/or if the dykes were to fail.

10.2.3 Draft Education Signage for Waterfront Showing Future Water Levels

The Public Communication Summary Document (presented in Appendix B) is a good document to draw from to produce education signage. The first two pages address climate change, sea level rise and storm surge related flooding. Some slight wording changes to adapt the document from a summary of a study to an informative panel would be needed and may involve the following edits:

- Changing “Town of Wolfville Flood Mitigation Plan” to “Climate Change and Peak Water Levels in Wolfville”; and
- Changing “Climate change projections have been incorporated into this study to determine how flood risk will increase over time and how these risks can be reduced” to “Climate change projections have been analysed to determine how flood risk will increase over time”.

A standard signage showing potential future peak water level could look something like Figure 10.1 below:

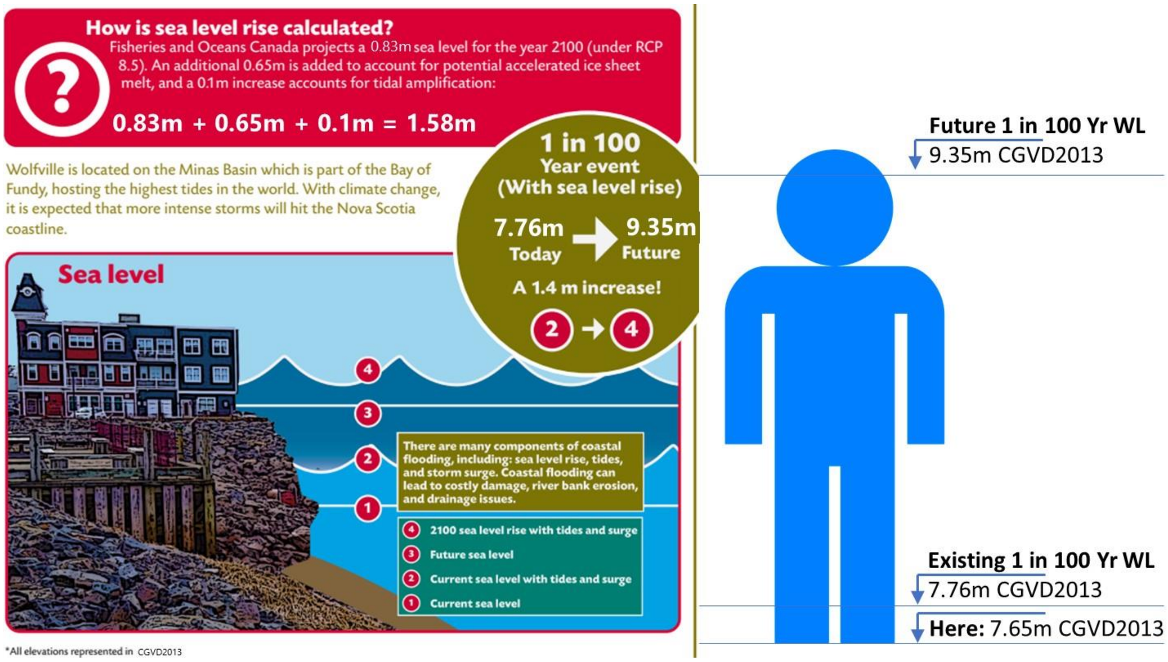


Figure 10.1: Example of Water Level Signage and Marker

10.2.4 Considerations for Leaflet Mailed to Residents About Flood Proofing their Properties

The information and layout presented in the last page of the Public Communication Summary Document (in Appendix B, and presented below in Figure 10.2) is a good starting point. It could be a stand-alone document, but it would be considered more effective if this is directly included in the mailed information to building owners that have been identified as being at risk of flooding. The measures listed in the document apply to both buildings and homes, especially since many businesses are homes converted for that purpose. Another version can perhaps be kept at the Town Hall for additional information to any resident curious about flood proofing their home.

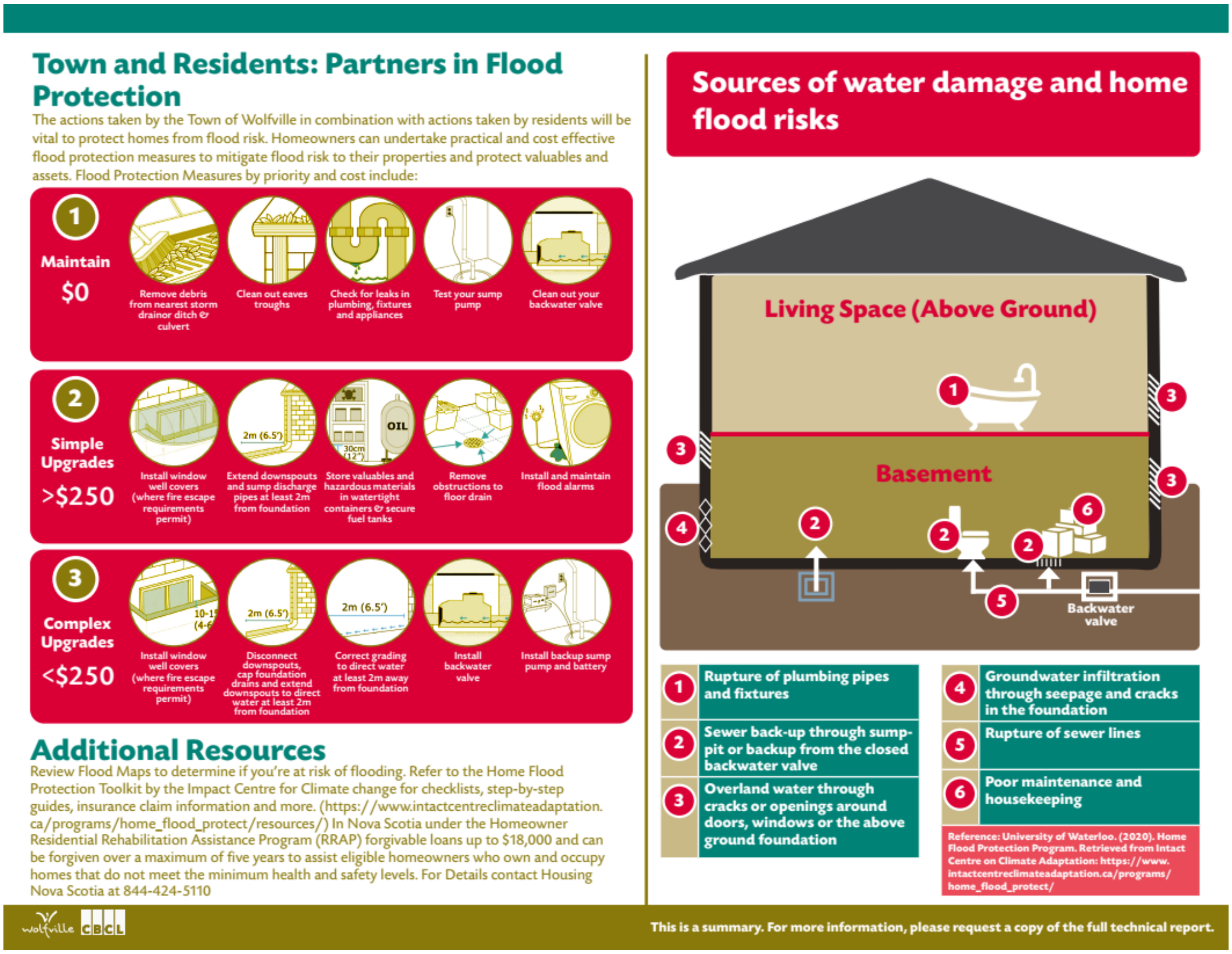


Figure 10.2: Section of Community Summary Document that Addresses Flood Proofing Measures

10.2.5 Considerations for Effective Communication of Flooding Risks and Flood Protection

Communication of flooding risk is a complex and delicate process. While it is very important to carry out, it is also important to take care in preparing a communication plan that is both informative and considerate of various individuals' circumstances. An effective plan could include several methods of contacting building owners and homeowners, including:

- Town's planning documents (already on the Town website);
- Document mailed directly to those affected by flooded area (as describe above);
- Leaflet with flood proofing measures (as described above) to be published on the Town website and made available to anyone who walks in the Town Hall;

- Community summary document to be published on the Town website and made available as a leaflet to anyone who walks in the Town Hall;
- Education signage and markers of high water levels (as discussed above);
- A public open house to present this analysis and new flood maps; and
- A contact phone number to call if any further questions arise.

While communicating the fact that there is a risk and providing mitigation measures is key, it is also important to communicate the information, facts and science behind the flood elevations and mapping presented. This is not a simple undertaking and can easily lead to confusion. This is likely best addressed though a combination of making available the summary community document, the markers and education signage, holding an open house, and making available the full technical report on the Town website. The open house, in particular, would be the most suitable setting for any member of the public to ask any question, and it would allow the Town/CBCL technical staff to walk the person through the key steps of the analyses in simple, clear terms. A public open house is typically the most effective setting to allow each person to ask any question they like and have an informative one-on-one conversation. Projected presentations in an auditorium setting are much less effective and seldom achieve the goal of effectively informing members of the public. Of course, this open house will necessarily be delayed until the COVID-19 pandemic is over, but it should still be held once safe to do so.

Chapter 11 Conclusions and Recommendations

11.1 Summary

A Flood Risk Mitigation Plan has been completed for the Town of Wolfville. The Plan identifies current and future flood risks, including impacts of climate change, and evaluates a list of proposed solutions to mitigate flood risks to the Town. The Plan was developed through communication with both stakeholders and the Town, and it included a review of the Town's municipal operations and priorities, relevant reports, by-laws, guidelines and strategies.

Inland and coastal flooding within the Town of Wolfville can occur as a result of extreme rainfall events and extreme coastal water levels. Inland flooding occurs when the stormwater collection system has insufficient capacity to convey stormwater runoff downstream during extreme rainfall events resulting in overflow onto areas such as roads, municipal infrastructure and private properties. Coastal flooding occurs when extreme tides reach inland areas either through backup through the stormwater system, overtopping dykes, or between the two dyke systems.

A suite of computer models was used to assess flood risks within the Town, estimate current and future risks, and evaluate potential flood mitigation options. A range of rainfall and tidal scenarios were assessed under current and future conditions to evaluate the risks of flooding.

The effects of climate change on both precipitation and sea level rise were considered when examining future conditions (i.e., the year 2100 time horizon). To date, global green-house gas concentrations have most closely tracked RCP8.5, which was used to generate the higher range of climate change projections featured in the IPCC's AR5. The 1-in-100-year rainfall event is projected to increase by approximately 61% by 2100 under RCP8.5 (95^{th} percentile) according to the Western University IDF-CC Tool (Table 19).

Table 19: Future and Existing Rainfall Projections of the IDF_CC Tool for a 1-in-2 and 1-in-100-year Occurrence Probability

Peak Rainfall Intensity	1-in-2-year (mm/hr)	1-in-100-year (mm/hr)
Existing	68.57	174.00
Future	88.45	280.12

Extreme coastal water levels include high tide, sea level rise (SLR), storm surge and tidal amplification. Regional SLR for the year 2100 is projected to be 1.58m for the Town of Wolfville. Extreme coastal water levels included high tide, SLR and storm surge ("High" Scenario), as presented in Table 20.

Table 20: Future and Existing Sea Level Projections for a 1-in-2 and 1-in-100-year Occurrence Probability

Peak Water Level	1-in-2-year (m CVGD 2013)	1-in-100-year (m CVGD 2013)
Existing	7.57	7.76
Future	9.15	9.35

A list of key recommendations separated under "high priority", and "subject to further monitoring" was developed and is presented in Table 21 and Table 22. In addition, the main items requested in the Request for Proposals are listed below, with each relevant sections of the report noted for simplified reference.

Scope of Work

CBCL was contracted to respond to the following scope of work for this project. The table below provides quick reference to relevant information:

Project Scope Component	Final Report Reference
Consultation with local, regional, and provincial stakeholders.	Chapter 10.1 Stakeholder Consultations
The identification and analysis of flood hazards, highlighting specific areas of vulnerability within the town.	Chapter 7 Vulnerability Assessment
The development and modelling of current and future flood scenarios.	Chapter 4 Coastal Water Level Analysis and Chapter 5 Hydrologic and Hydraulic Analysis
Determining the consequences of developed flood scenarios, in terms of who and what would be impacted, and the nature and severity of those impacts.	Chapter 7 Vulnerability Assessment
A workplan with a mitigation investment strategy, including a prioritized list of identified projects for implementation; and adaptation strategies, covering the areas of land-use planning, protection/relocation/resilience of critical infrastructure, development, personal/household safety and planning measures, and emergency response and service management.	Chapter 8 Flood Risk Mitigation Options and Chapter 9 Preliminary Evaluation of Mitigation Options
Updating current flood maps and models for the Town.	Chapter 6 Flooding Analysis and Appendix A
Recommendations for integration with provincial and regional plans.	Section 3.3: Documentation Review
A public education and engagement component, which could include a community workshop and/or the development of a public-facing communication strategy and materials.	Section 10.2: Community Education and Communication. Appendix B

11.2 Recommended Implementation Plan

A recommended flood mitigation implementation plan has been assembled as part of this study, which is summarized in Table 21 and Table 22, and includes a timeline for implementation, opinions of probable costs, and report references. These recommended actions are divided into a High Priority Table (Table 21) and Actions Subject to Further Monitoring Table (Table 22).

Table 21: Recommended Flood Mitigation Plan – High Priority Actions

	High Priority Action	Timeline	Class "D" Opinion of probable Cost*	Report Reference
Connecting the dyke system & integrating living shorelines				
	Conduct topographic survey of top of dykes and waterfront in-between	1-3 Years	~$20k	Section 3.2 Stormwater Drainage
	Contact rail line owner to assess feasibility of acquiring land for new dyke	1-3 Years	-	Section 8.1.1Connecting the Dyke System and Applying Living Shorelines
	Land negotiations, pending results of above discussions	1-3 Years	-	
	Hold discussions with Department of Agriculture about raising of dykes	1-3 Years	-	10.1.2 Nova Scotia Department of Agriculture
	Following the above, select option for new dyke (in mudflat or rail ROW)	1-3 Years	-	
	Tender and award detailed design for new dyke	1-3 Years	~$50k	
	Investigate financing options for new dyke	1-3 Years	-	
	Design and tender stormwater pipe extensions to reduce erosion and support development of living shoreline	1-3 Years	~$20k	
Raising land around SLSs and new berm around WWTF				
	Review permitting and land requirements based on WWTF berm alignment and footprint	1-3 Years	-	

	Tender and award detailed design for new berm	1-3 Years	~$50k	
	Regrade land around SLSs	1-3 Years	~$10k	
Flood forecasting and warning system in partnership with REMO				
	Discuss with REMO scope and integration of system in existing SCADA	1-3 Years	-	8.2 Flood Forecasting and Warning System
	Tender flood forecasting and warning system	1-3 Years	~$50k	
	Install water level monitoring and recording system with connection to SCADA	1-3 Years	~$50k	
Community education and communication				
	Public Education: - Review Summary Document - Educational Signage about Sea Level Rise - Mail out leaflets to home and building owners in flood risk areas - Prepare open house when feasible	1-3 Years	~$10k	10.2 Community Education and Communication
Construction of new dyke and berm				
	Tender construction of new dyke Remove and dispose of old wooden beams Tender extensions of stormwater pipe outfalls	3-5 Years	~$600k on bank ~$6M in mudflat ~$20k ~$600k	8.1 Coastal Flood Protection Measures & 9.2.1 Coastal Flood Protection Measures
	Tender construction of new berm	3-5 Years	~$300k	8.3.2 Wastewater Treatment Facility
	Coordinate topping of existing dykes with Department of Agriculture	3-5 Years	-	10.1.2 Nova Scotia Department of Agriculture
Future steps				
	Evaluate recorded water level data and assess Sea Level Rise projections	35-45 Years	~$5k	-
	Design and construct (or coordinate with Department of Agriculture) additional raising of the dyke system	35-45 Years	Depends on findings	10.1.2 Nova Scotia Department of Agriculture

Table 22: Recommended Flood Mitigation Plan – Actions Subject to Further Monitoring

	Actions Subject to Further Monitoring	Class "D" Opinion of probable Cost*	Report Reference
Increasing infiltration measures			
	Identifying opportunities wherever pipes, sidewalks or parking lots are replaced or maintained	Will vary	9.2.5 Best Management Practices or Low Impact Development
Increasing storage capacity			
	Construct detention pond in Little Brook Lane area	~$250k	8.5.2 Increasing Storage Capacity
Increasing stormwater conveyance capacity			
	Minor upgrades with street work	Will vary	
	University and Main Street (identified as largest increase in pipe diameter)	~$300k	8.5.3 Increasing Pipe Capacity
Protecting future development			
	Monitoring latest information (data, climate science) and update plans accordingly		5.1.2 Impacts of Climate Change Rainfall Events
	Evaluate recorded water level data and assess Sea Level Rise projections		4.1.2 Climate Change Impacts on Coastal Water Levels

Should you have any questions about this analysis, please do not hesitate to contact the undersigned. We thank you again for the opportunity to conduct this very interesting analysis.

Yours very truly,

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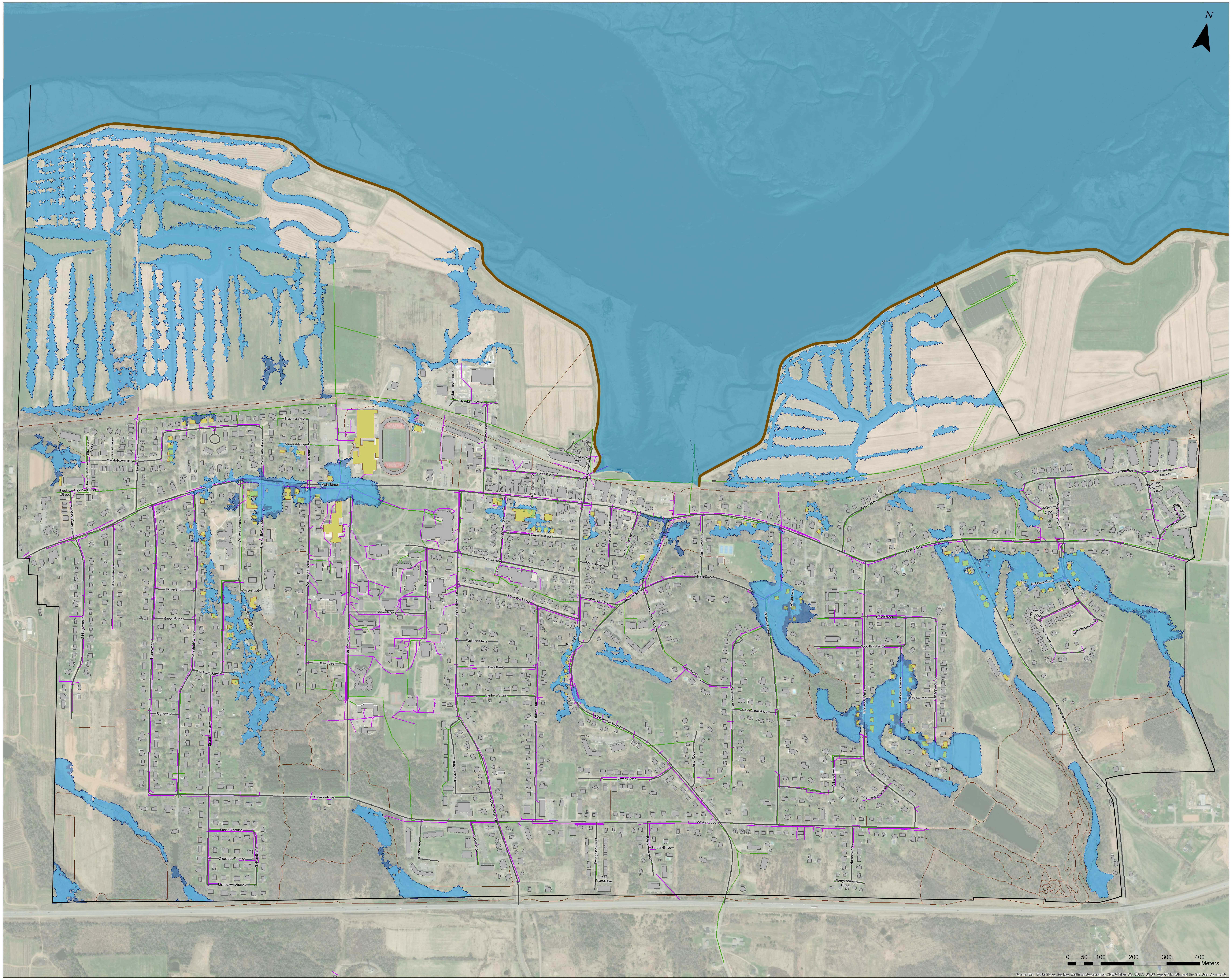
APPENDIX A

Floodline Delineation Maps



- Current Dyke Line
- Town Boundary
- Infrastructure at Risk in 1 in 100 Year Rainfall Event
- 1 in 20 Year Rainfall Event, 1 in 2 Year Tide
- 1 in 100 Year Rainfall Event, 1 in 2 Year Tide
- Stormwater System
- Sewer System
- Trails

No	Date	Description
1	04/15/2020	Issued for Report

Revision or Issue

wolfville NOVA SCOTIA

Project:

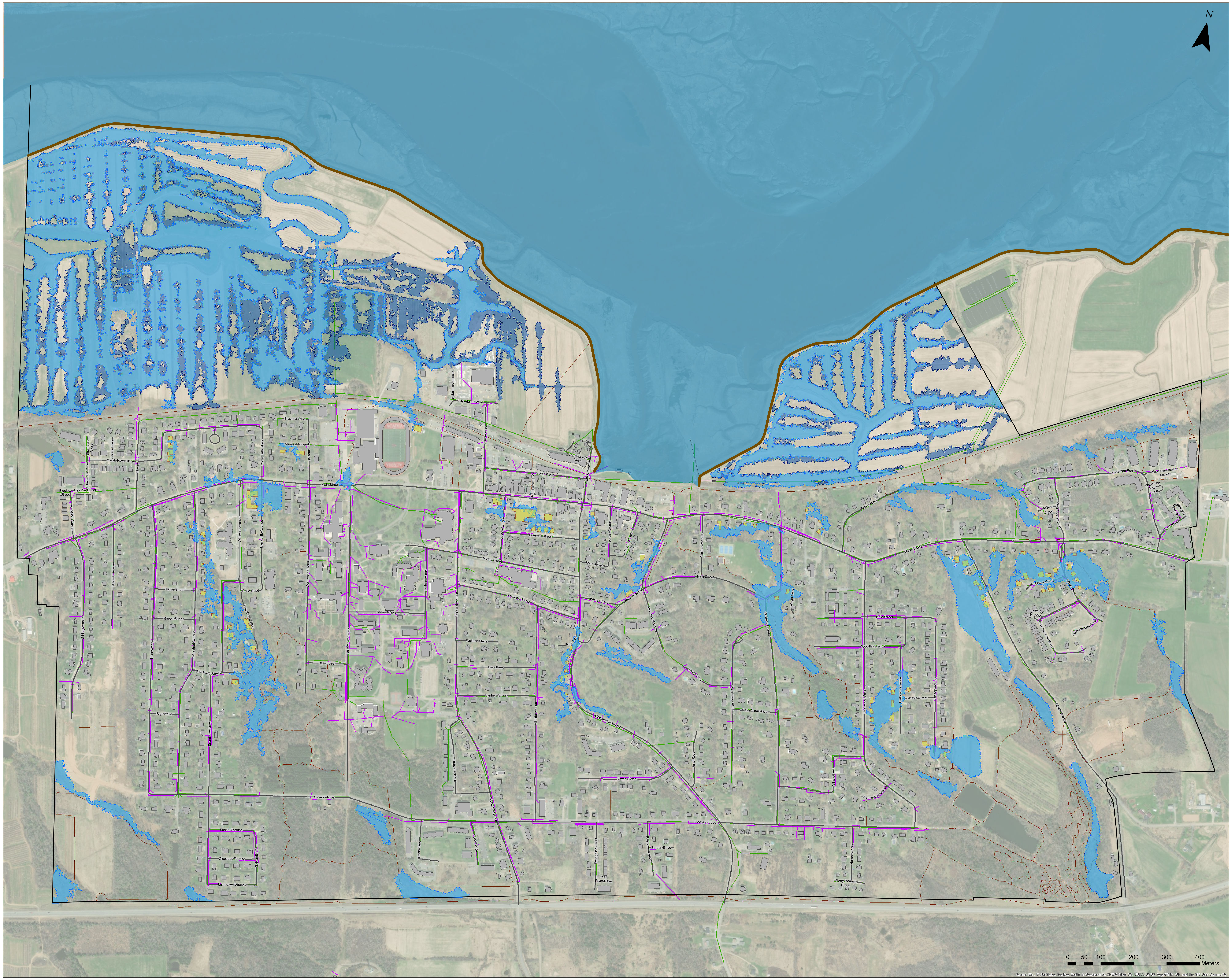
TOWN OF WOLFVILLE
FLOOD RISK PROFILE

Drawing Title:

EXISTING CONDITIONS
1 in 20 AND 1 in 100 YEAR
RAINFALL EVENTS

CBCL

Date: MAY 2020	Scale: 1:3,650
Project No: 201101.00	Drawing No: 1



- Current Dyke Line
- Town Boundary
- Infrastructure at Risk in 1 in 100 Year Tide
- 1 in 20 Year Tide, 1 in 2 Year Rainfall Event
- 1 in 100 Year Tide, 1 in 2 Year Rainfall Event
- Stormwater System
- Sewer System
- Trails

No	Date	Description
1	04/15/2020	Issued for Report

Revision or Issue

wolfville NOVA SCOTIA

Project:

TOWN OF WOLFVILLE
FLOOD RISK PROFILE

Drawing Title:

EXISTING CONDITIONS
1 in 20 AND 1 in 100 YEAR
TIDE EVENTS

CBCL

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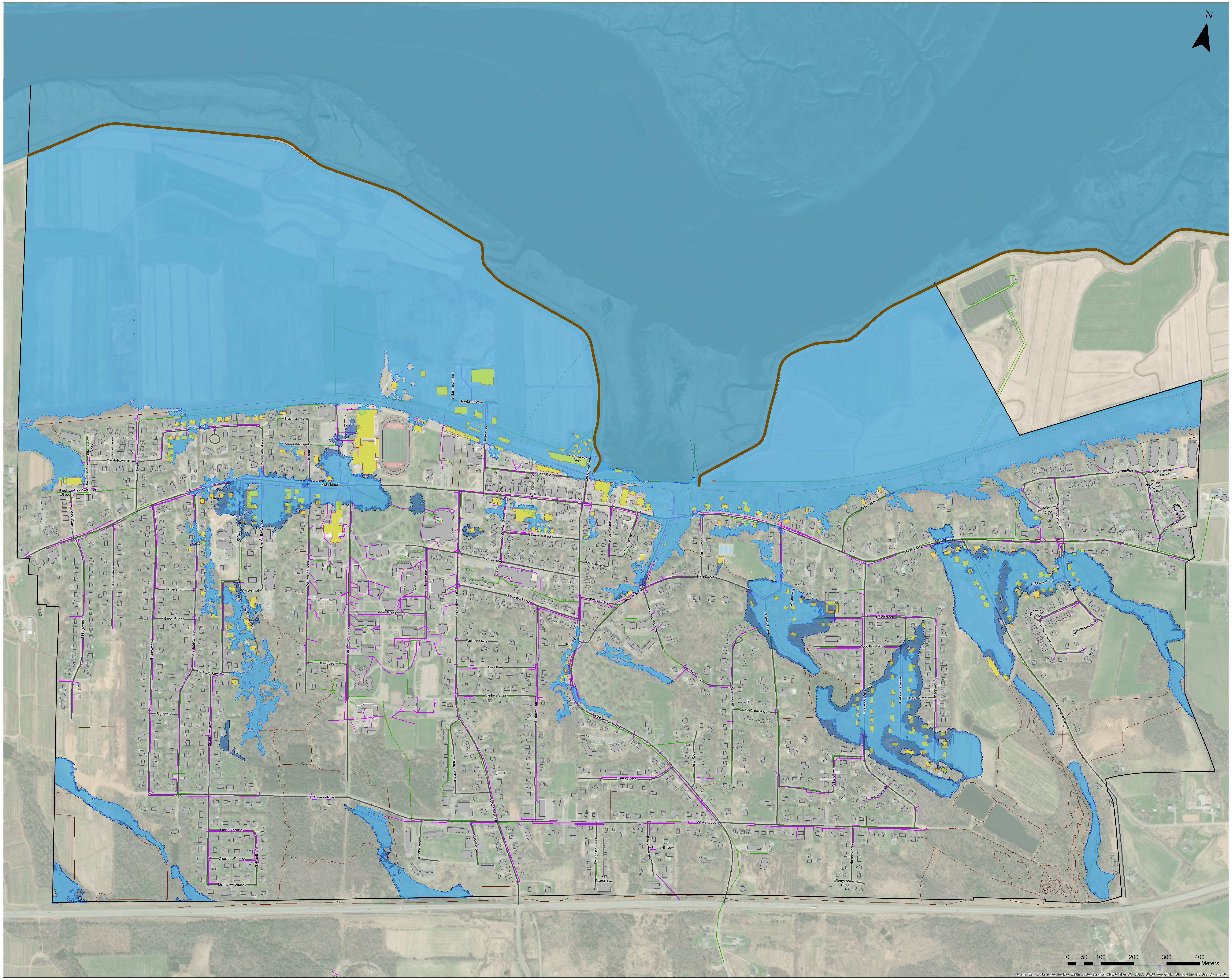

Current Dyke Line
Town Boundary
Infrastructure at Risk in Future 1 in 100 Year Rainfall Event
1 in 20 Year Rainfall Event, 1 in 2 Year Tide, Future Conditions
1 in 100 Year Rainfall Event, 1 in 2 Year Tide, Future Conditions
Stormwater System
Sewer System
Trails

No	Date	Description
1	04/15/2020	Issued for Report

Revision or Issue

wolfville NOVA SCOTIA

Project:

TOWN OF WOLFVILLE
FLOOD RISK PROFILE

Drawing Title:

FUTURE CONDITIONS
1 in 20 AND 1 in 100 YEAR
RAINFALL EVENTS

CBCL

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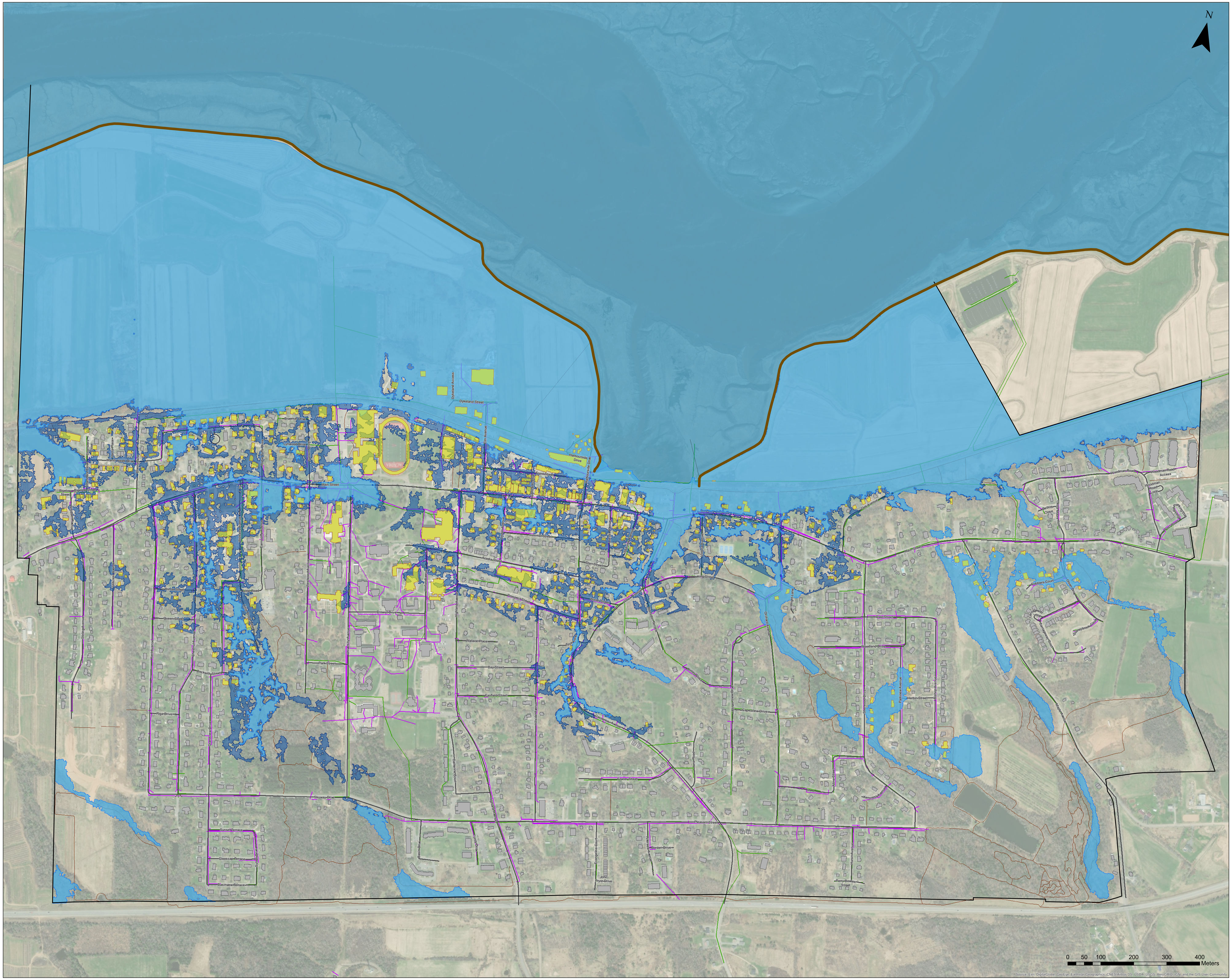

- Current Dyke Line
- Town Boundary
- Infrastructure at Risk in Future 1 in 100 Year Tide
- 1 in 20 Year Tide, 1 in 2 Year Rainfall Event, Future Conditions
- 1 in 100 Year Tide, 1 in 2 Year Rainfall Event, Future Conditions
- Stormwater System
- Sewer System
- Trails

No	Date	Description
1	04/15/2020	Issued for Report

Revision or Issue

wolfville NOVA SCOTIA

Project:

TOWN OF WOLFVILLE
FLOOD RISK PROFILE

Drawing Title:

FUTURE CONDITIONS
1 in 20 AND 1 in 100 YEAR
TIDE EVENTS

CBCL

Date: MAY 2020 Scale: 1:3,650

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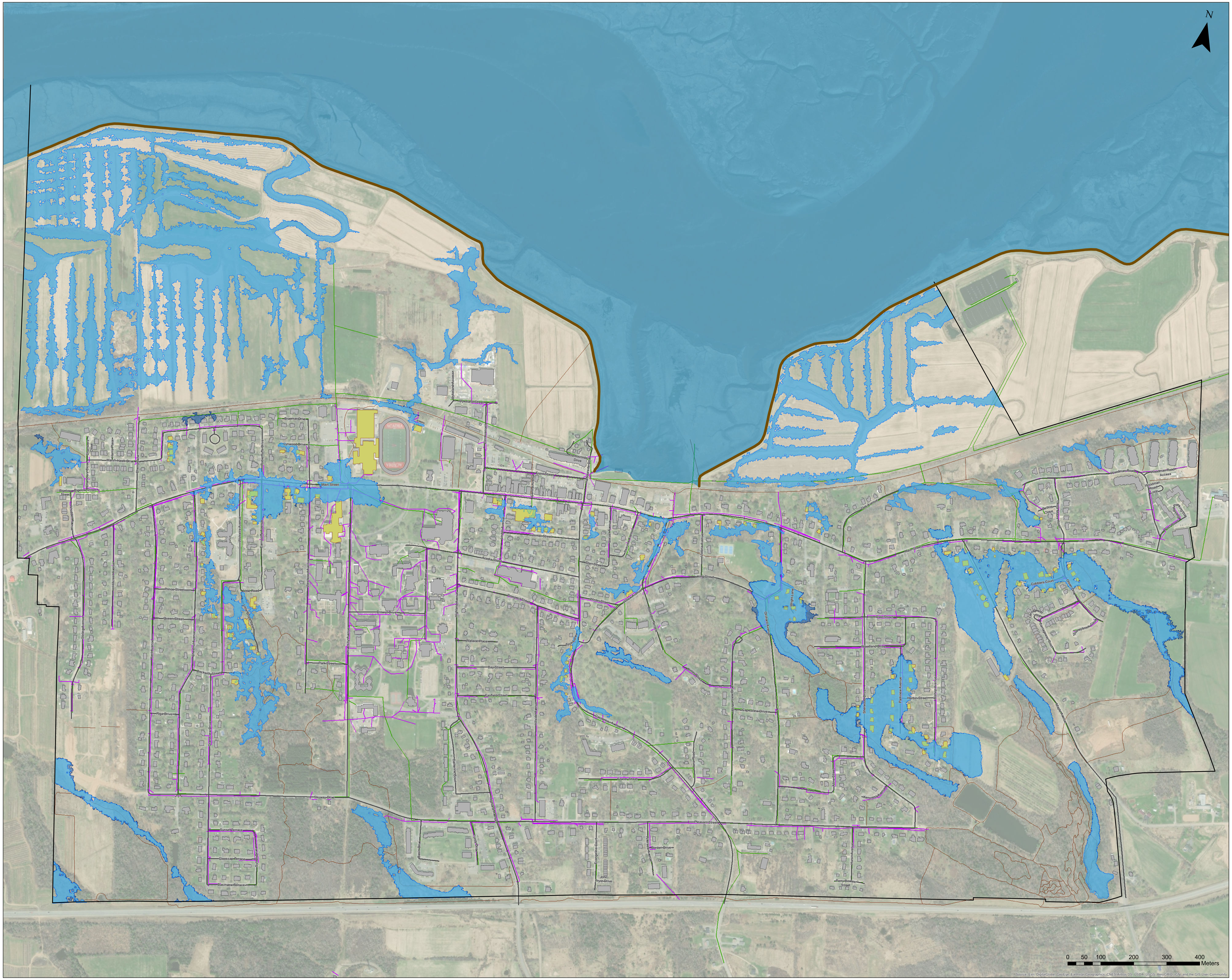

Current Dyke Line
Town Boundary
Infrastructure at Risk 100 Year Rainfall with BMPs
1 in 100 Year Rainfall Event, 1 in 2 Year Tide, BMPs
1 in 100 Year Rainfall Event, 1 in 2 Year Tide, Existing Conditions
Stormwater System
Sewer System
Trails

No	Date	Description
1	04/15/2020	Issued for Report

Revision or Issue

wolfville NOVA SCOTIA

Project:

TOWN OF WOLFVILLE
FLOOD RISK PROFILE

Drawing Title:

EXISTING CONDITIONS
MITIGATION OPTION
1 in 100 YEAR RAINFALL EVENT
WITH BMPs

CBCL

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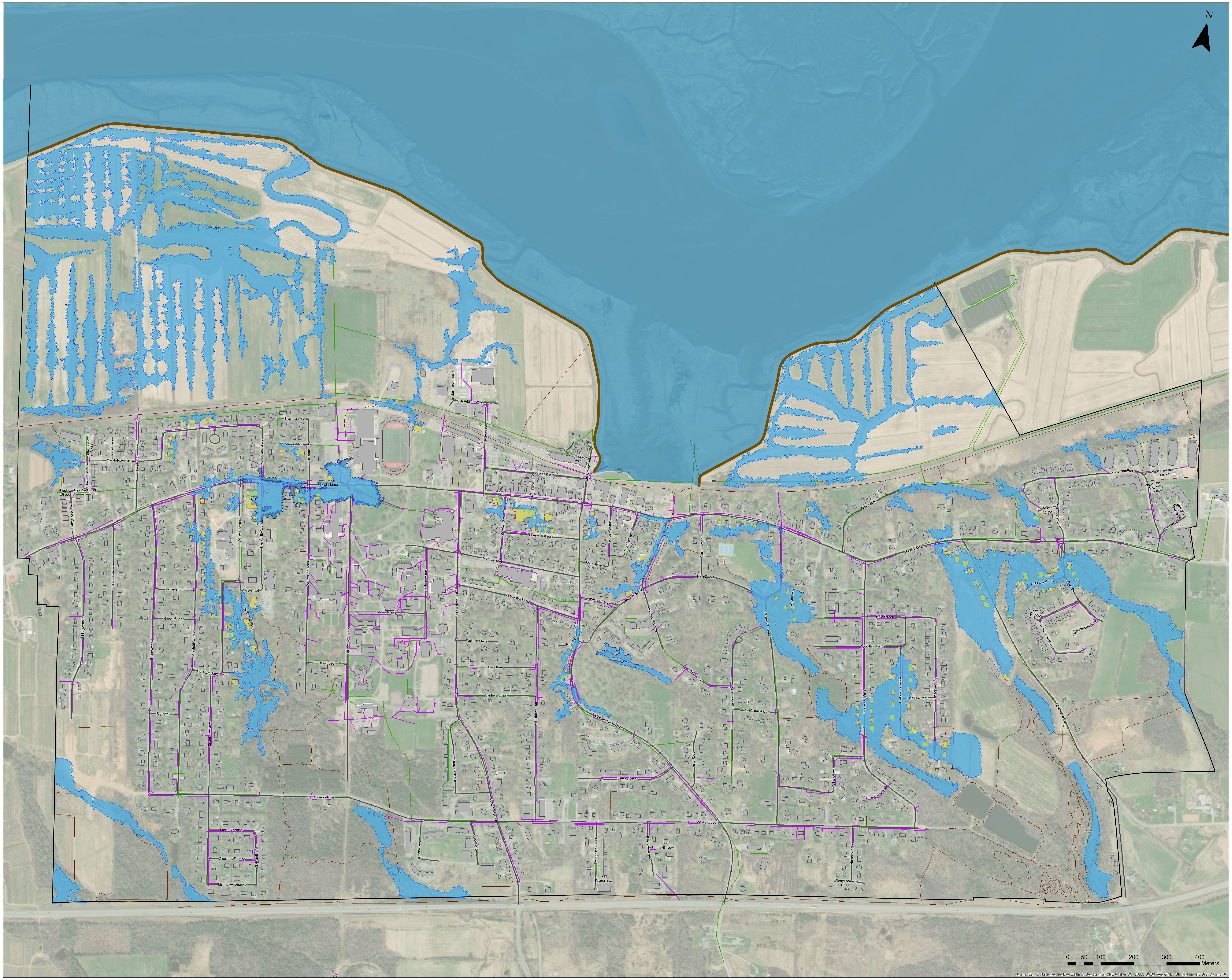

- Current Dyke Line
- Town Boundary
- Infrastructure at Risk 100 Year Rainfall with Increased Conveyance
- 1 in 100 Year Rainfall Event, 1 in 2 Year Tide, Increased Conveyance
- 1 in 100 Year Rainfall Event, 1 in 2 Year Tide, Existing Conditions
- Stormwater System
- Sewer System
- Trails

No	Date	Description
1	04/15/2020	Issued for Report

Revision or Issue

wolfville NOVA SCOTIA

Project:

TOWN OF WOLFVILLE
FLOOD RISK PROFILE

Drawing Title:

EXISTING CONDITIONS
MITIGATION OPTION
1 in 100 YEAR RAINFALL EVENT
INCREASED CONVEYANCE

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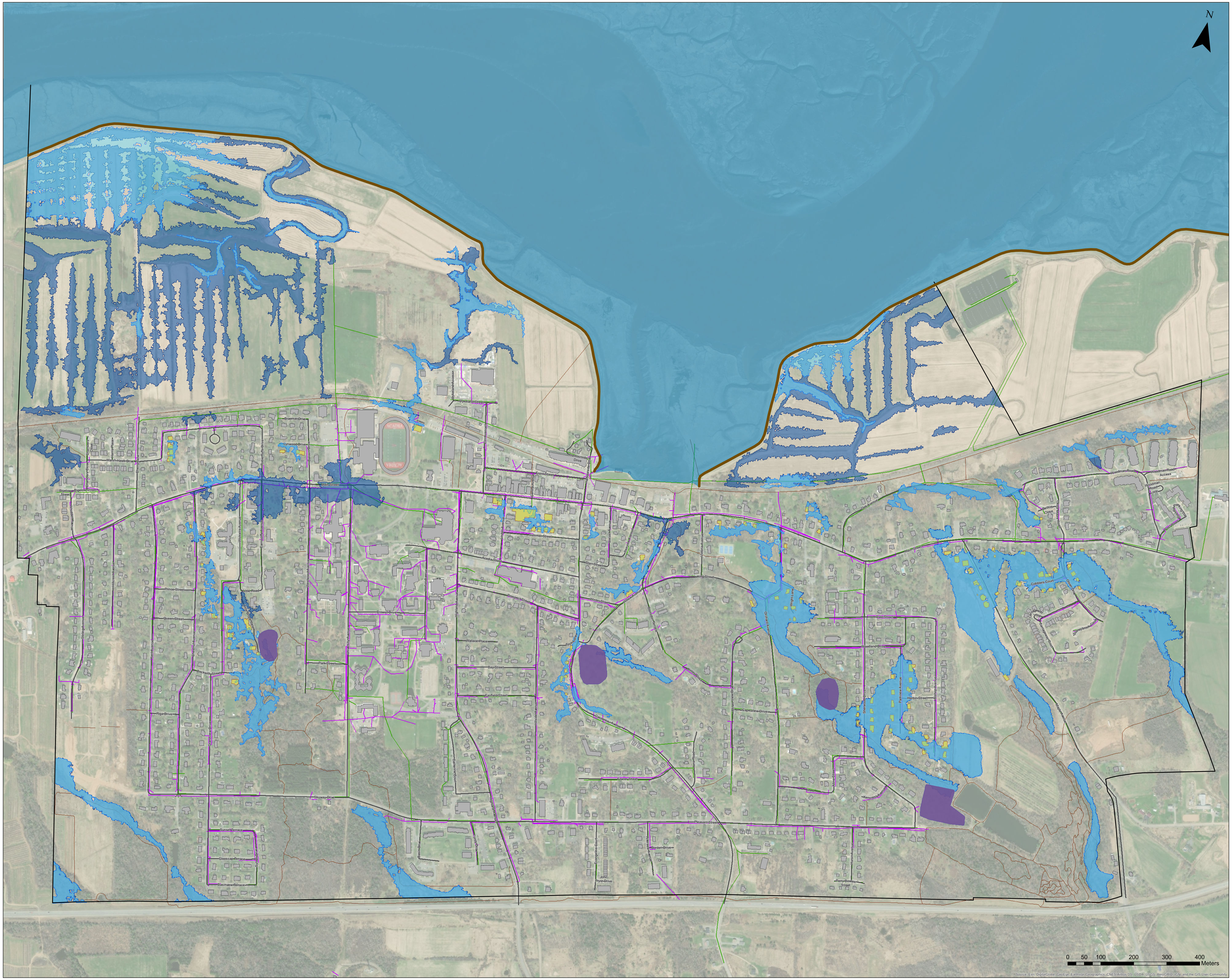

Current Dyke Line
Town Boundary
Infrastructure at Risk 100 Year Rainfall with Increased Storage
Proposed Stormwater Pond Locations
1 in 100 Year Rainfall Event, 1 in 2 Year Tide, Increased Storage
1 in 100 Year Rainfall Event, 1 in 2 Year Tide, Existing Conditions
Stormwater System
Sewer System
Trails

No	Date	Description
1	04/15/2020	Issued for Report

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wolfville NOVA SCOTIA

Project:

TOWN OF WOLFVILLE
FLOOD RISK PROFILE

Drawing Title:

EXISTING CONDITIONS
MITIGATION OPTION
1 in 100 YEAR RAINFALL EVENT
INCREASED STORAGE

CBCL

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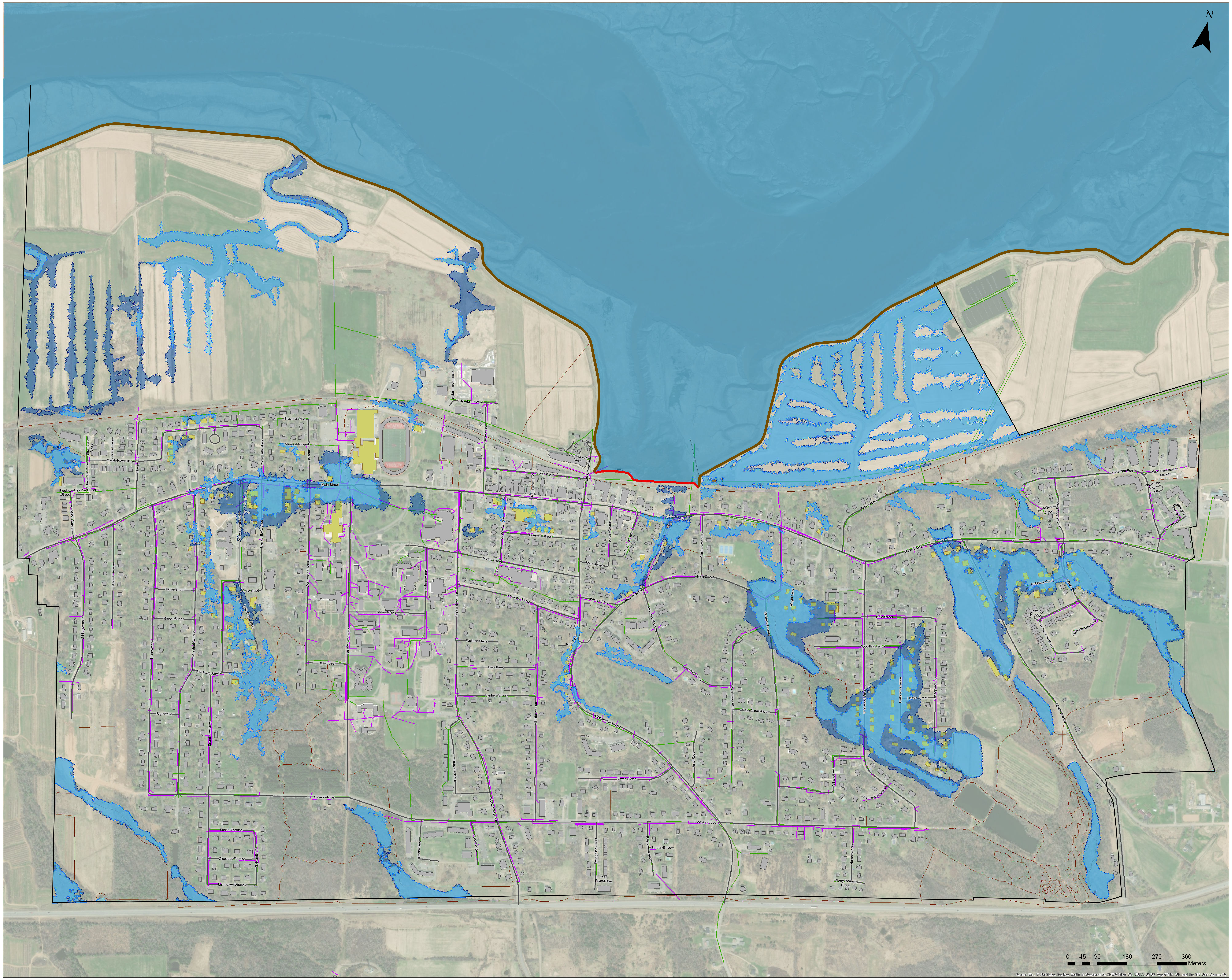


- Current Dyke Line
- Town Boundary
- Proposed Dyke Extension
- Infrastructure At Risk, 1 in 100 Year Future Rainfall Event, Raised Dykes
- 1 in 20 Year Rainfall Event, 1 in 2 Year Tide Event, Future Conditions, Raised Dykes
- 1 in 100 Year Rainfall Event, 1 in 2 Year Tide Event, Future Conditions, Raised Dykes
- Stormwater System
- Sewer System
- Trails

No	Date	Description
1	04/15/2020	Issued for Report

Revision or Issue

Project:

TOWN OF WOLFVILLE
FLOOD RISK PROFILE

Drawing Title:

FUTURE CONDITIONS
MITIGATION OPTION
RAISED DYKES

CBCL

Date: MAY 2020 | Scale: 1:3,650

Project No: 201101.00 | Drawing No: 8

APPENDIX B

Public Communication Summary Document

Town of Wolfville Flood Mitigation Plan

wolfville

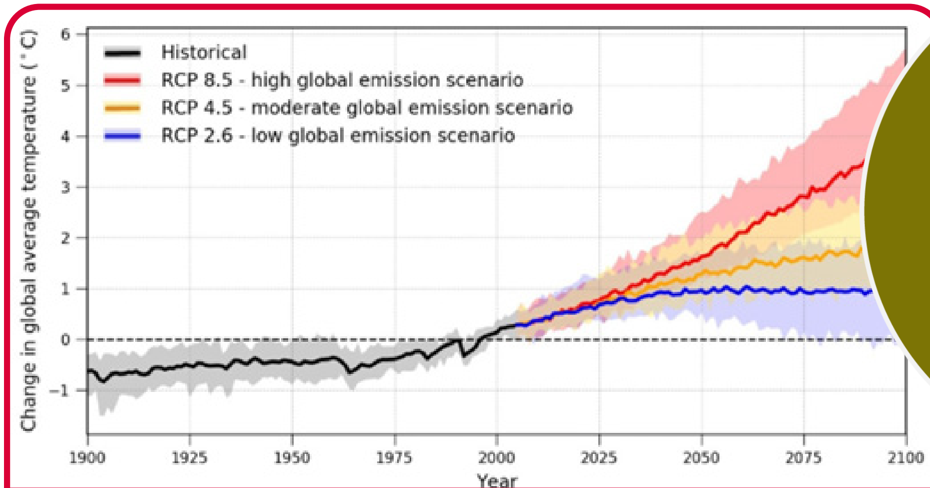
Flooding in Nova Scotia can impact public safety, the economy, agriculture, and the environment. It can lead to damage and costly upgrades for municipal infrastructure and residential home owners. Like many communities across Atlantic Canada, Wolfville is situated along a prominent coastline which poses a flood risk if not monitored and mitigated. Flooding in Wolfville can occur during a storm surge event or extreme rainfall. Flood risk will increase with climate change. For this reason, Wolfville engaged CBCL Limited to complete a comprehensive analysis of flooding in our town and to develop a flood mitigation plan that will protect the community and help reduce flood risk today and in the future. This document highlights key findings from this study.

How Climate Change Impacts Flooding

Climate scientists have studied how climate change will impact rainfall patterns, sea level, and storm surge in the future. Climate change projections have been incorporated into this study to determine how flood risk will increase over time and how these risks can be reduced.

What causes Climate Change?

Climate change is a change in global and regional climate patterns as a result of both natural cycles and human activity. Burning of fossil fuels increases the amount of heat trapping gases within our atmosphere leading to rising temperatures. This is called the **greenhouse gas effect.**



Change in Global Average Temperature Relative to the 1986-2005 Reference Period for RCP 2.6, RCP 4.5, and RCP 8.5 (Canadian Centre for Climate Services)

In Canada, climate is generally expected to become warmer, wetter, and less stable.

Predicting Climate Change in Wolfville

Global emissions have most closely tracked along the highest projected emission scenario (RCP 8.5, red line) which was used in the Flood Mitigation Plan.

Sea Level Rise and Storm Surge Flooding

Sea levels have been rising in the Maritimes since the end of the last ice age 10,000 years ago. This trend is expected to accelerate with climate change, notably from melting of the polar ice caps. Sea level is expected to rise to 1.46 m by 2100 at the Town of Wolfville.

How is sea level rise calculated?

Fisheries and Oceans Canada projects a 0.83m sea level for the year 2100 (under RCP 8.5). An additional 0.65m is added to account for potential accelerated ice sheet melt, and a 0.1m increase accounts for tidal amplification:

0.83m + 0.65m + 0.1m = 1.58m

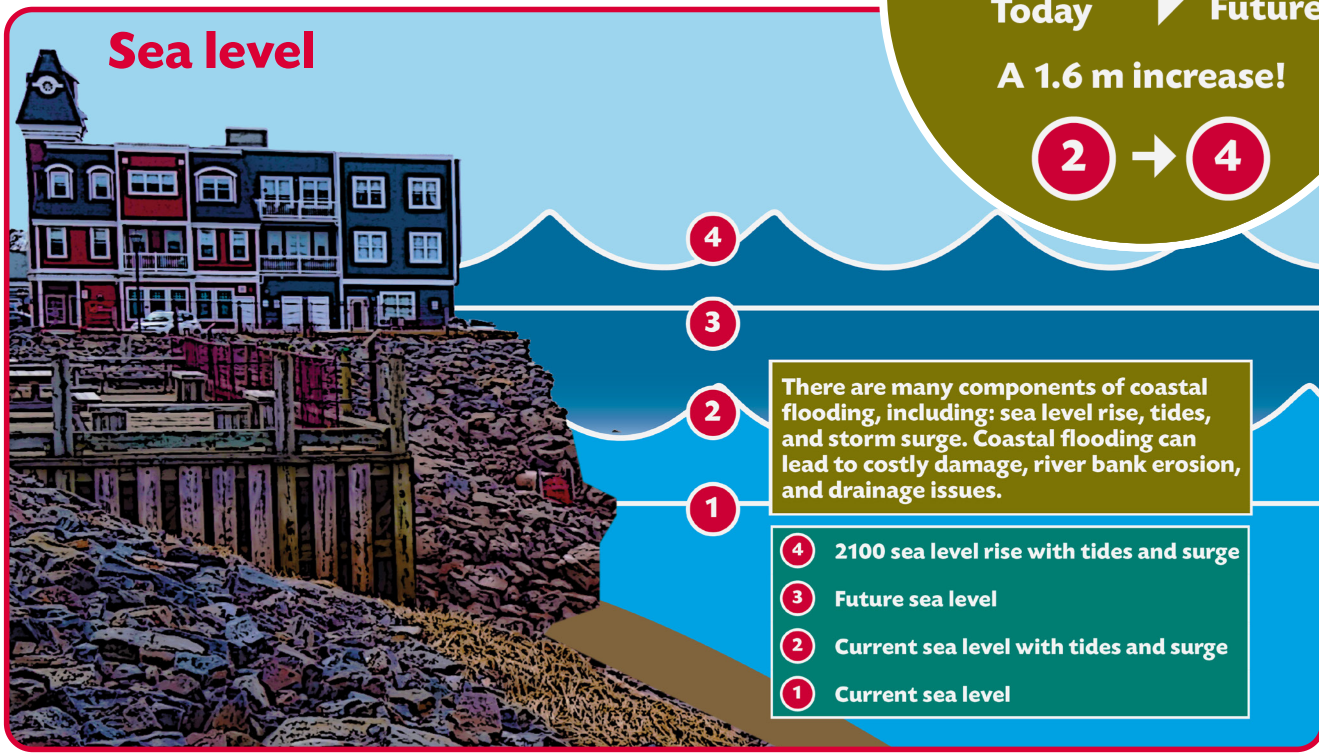
Wolfville is located on the Minas Basin which is part of the Bay of Fundy, hosting the highest tides in the world. With climate change, it is expected that more intense storms will hit the Nova Scotia coastline.

1 in 100 Year event (With sea level rise)

7.76m Today → 9.35m Future

A 1.6 m increase!

2 → 4

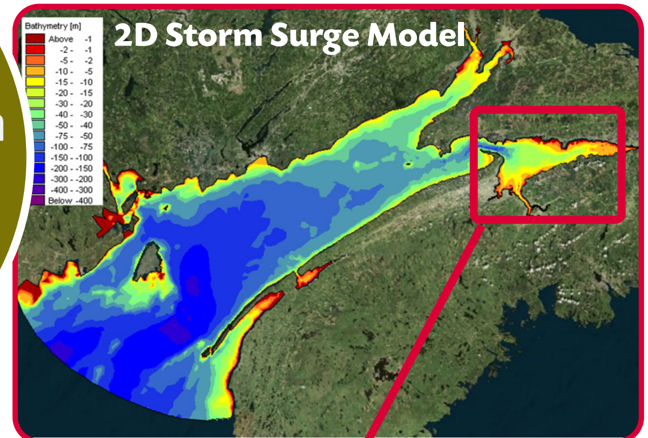


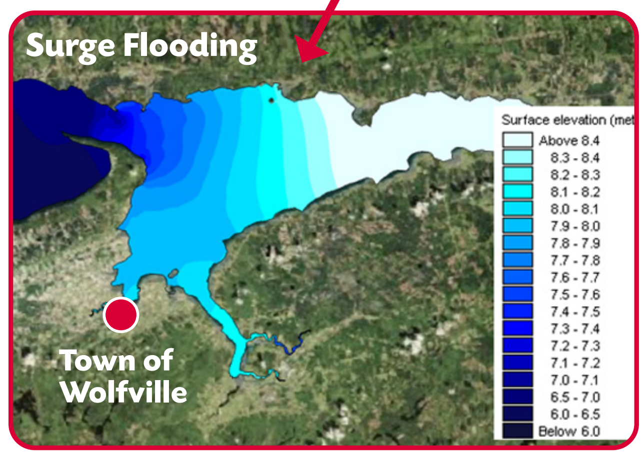
*All elevations represented in CGVD28

Assessing Flood Risk

Historically, flooding has not been a common occurrence within the Town of Wolfville; this is due to the dyke system that acts as a wall of protection against tides and storm surge flooding. However, the risk of flooding increases over time as sea levels rise, rainfall becomes more intense, and storm surge events increase.

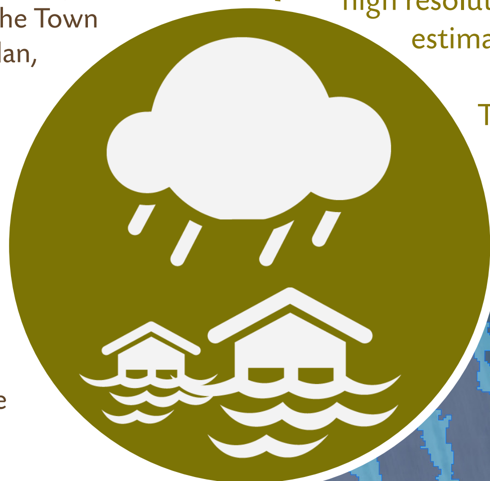
CBCL analyzed the risk of the dyke overtopping using a model of the Bay of Fundy to run future flooding scenarios with rising sea levels.





Communicating the likelihood of extreme weather

Climate events such as extreme sea levels, wind, and rainfall are communicated by their annual exceedance probabilities (or AEP). A 1 in 100 year rainfall event means that there's a 1% chance every year of this extreme rainfall happening. For the Town of Wolfville's Flood Mitigation Plan, the future 1 in 100 year rainfall event was used to understand potential future stormwater flood risks.



Rainfall events are expected to increase as a result of climate change. CBCL used the IDF-CC tool developed by the University of Western Ontario to determine how climate change will increase rainfall by 2100 (RCP 8.5):

1 in 100 Year rainfall event

174 mm/hr Today

↓

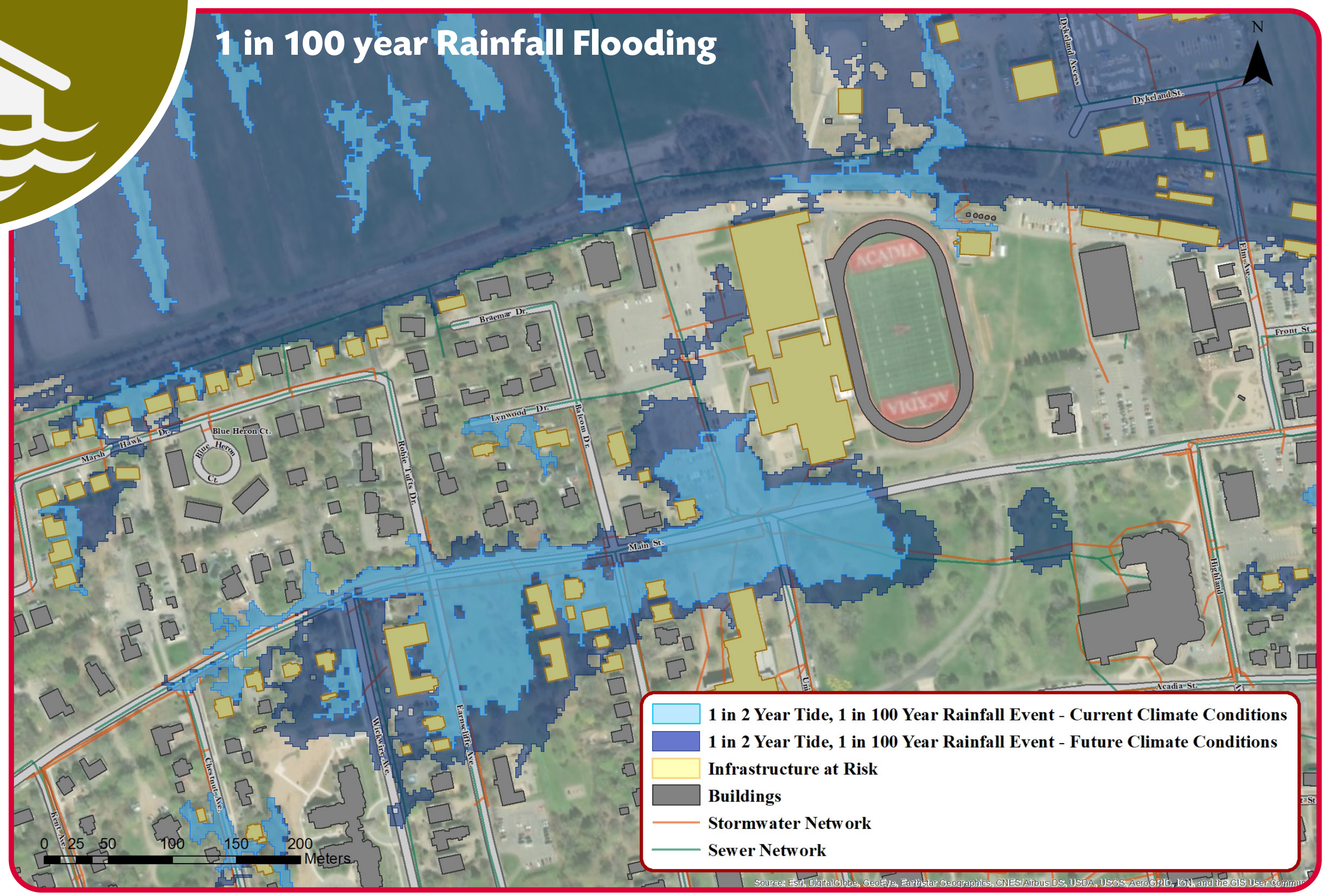
280 mm/hr Future With Climate Change

Flood Risk Mapping

Flooding in the Town of Wolfville occurs during large rainfall events combined with high tide. Water drains over lawns and in ditches, eventually being captured into the Town's storm water collection system. If rainfall exceeds the capacity of this system, flooding occurs on roads and private property.

CBCL developed a model of the town's stormwater drainage network to assess the risk of flooding during extreme rainfall and tidal events to identify strategies to mitigate flood risk. The model uses high resolution topography of the town along with underground infrastructure to produce flood estimates.

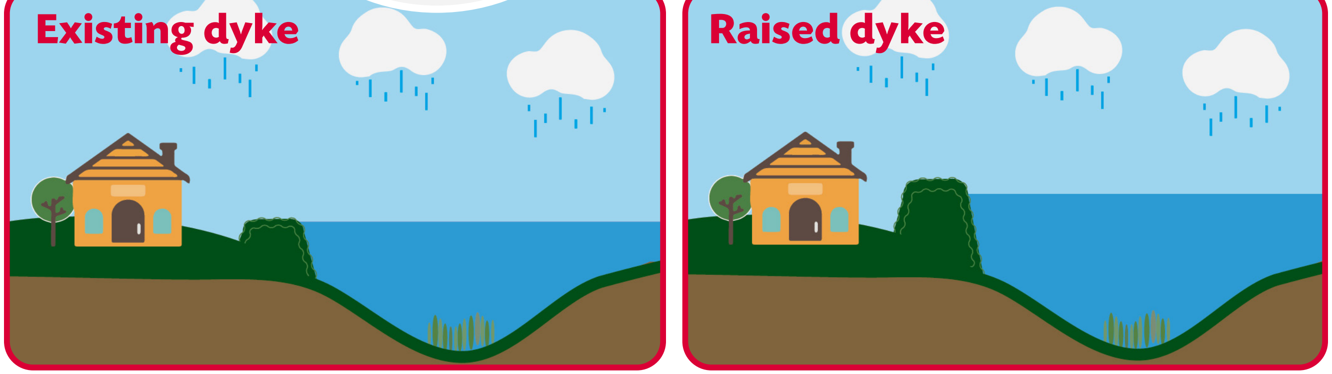
The map below is a snapshot of future flooding results for the highest risk area of the Town. This flooding can be reduced using engineering approaches, such as raising the dykes or carrying out storm water drainage network enhancements, as shown on the following pages.



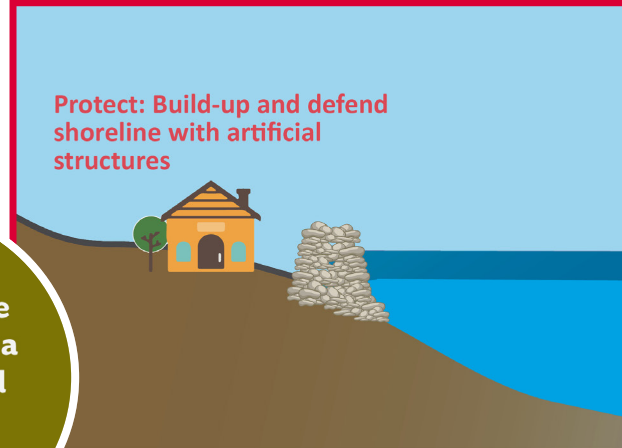
How do we Mitigate Coastal Flood Risk?

The Town of Wolfville has been protected from extreme coastal water levels by the Grande Pré and Bishop Beckwith dyke systems. Coastal dykes are large embankments built to prevent coastal flooding during high tides and storm surge. Currently, the average height of the dykes along the Town of Wolfville is approximately 8.75m and the two dyke systems are not connected. This presents a heightened risk of coastal flooding to adjoining areas.

Raising and connecting the dyke system is a recommended approach for protection of the Town.

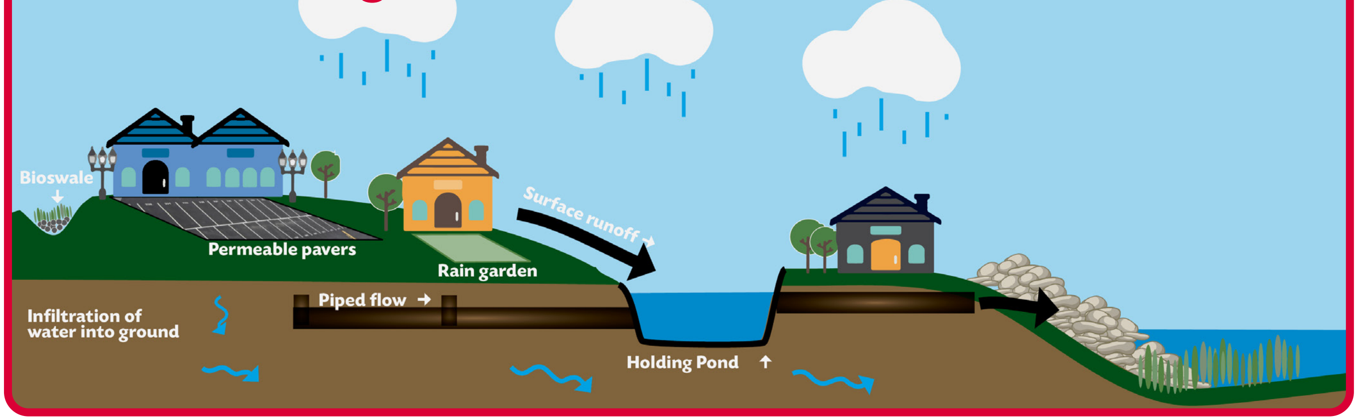


Typical ways to limit flood risk

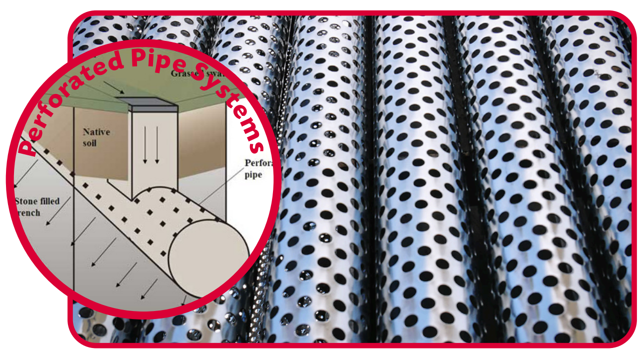


As part of the Municipal Planning Strategy Review, the Town has developed a Stormwater Management Guide. This plan addresses updated constraints mapping, development regulations, and management of flood risk for development within the flood plain.

Storm Drainage Network Enhancements



Flooding due to large rainfall events occurs as a result of overland flow and storm sewer backup. Storm sewer backup occurs when there is insufficient capacity within the drainage network to convey flow downstream to the Minas Basin. As our communities expand and develop, less water has the opportunity to infiltrate, causing runoff to increase. Best management practices can be implemented to increase infiltration, which in turn reduces the amount of runoff from large rainfall events. These practices include:



The Town can construct pond systems to hold stormwater during large rainfall events and reduce downstream flooding.

Storm Drainage Network Upgrades

The subsurface pipe network can be upgraded in areas where there is insufficient capacity.

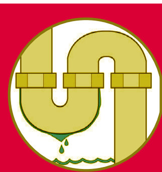
Town and Residents: Partners in Flood Protection

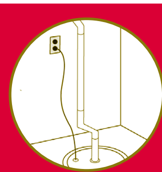
The actions taken by the Town of Wolfville in combination with actions taken by residents will be vital to protect homes from flood risk. Homeowners can undertake practical and cost effective flood protection measures to mitigate flood risk to their properties and protect valuables and assets. Flood Protection Measures by priority and cost include:

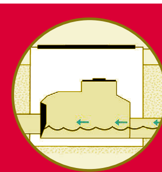
1 Maintain $0


Remove debris from nearest storm drainor ditch & culvert

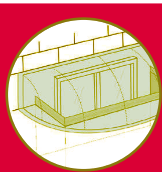

Clean out eaves troughs

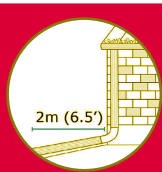

Check for leaks in plumbing, fixtures and appliances


Test your sump pump

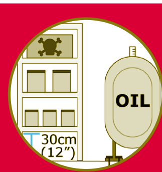

Clean out your backwater valve

2 Simple Upgrades <$250

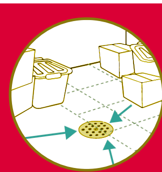

Install window well covers (where fire escape requirements permit)

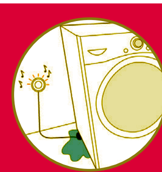


Extend downspouts and sump discharge pipes at least 2m from foundation

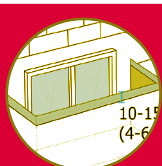


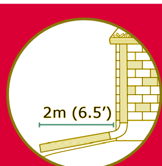
Store valuables and hazardous materials in watertight containers & secure fuel tanks


Remove obstructions to floor drain

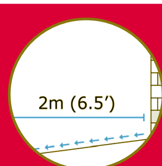

Install and maintain flood alarms

3 Complex Upgrades >$250

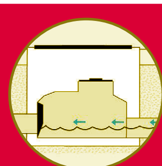

Install window well covers (where fire escape requirements permit)



Disconnect downspouts, cap foundation drains and extend downspouts to direct water at least 2m from foundation



Correct grading to direct water at least 2m away from foundation

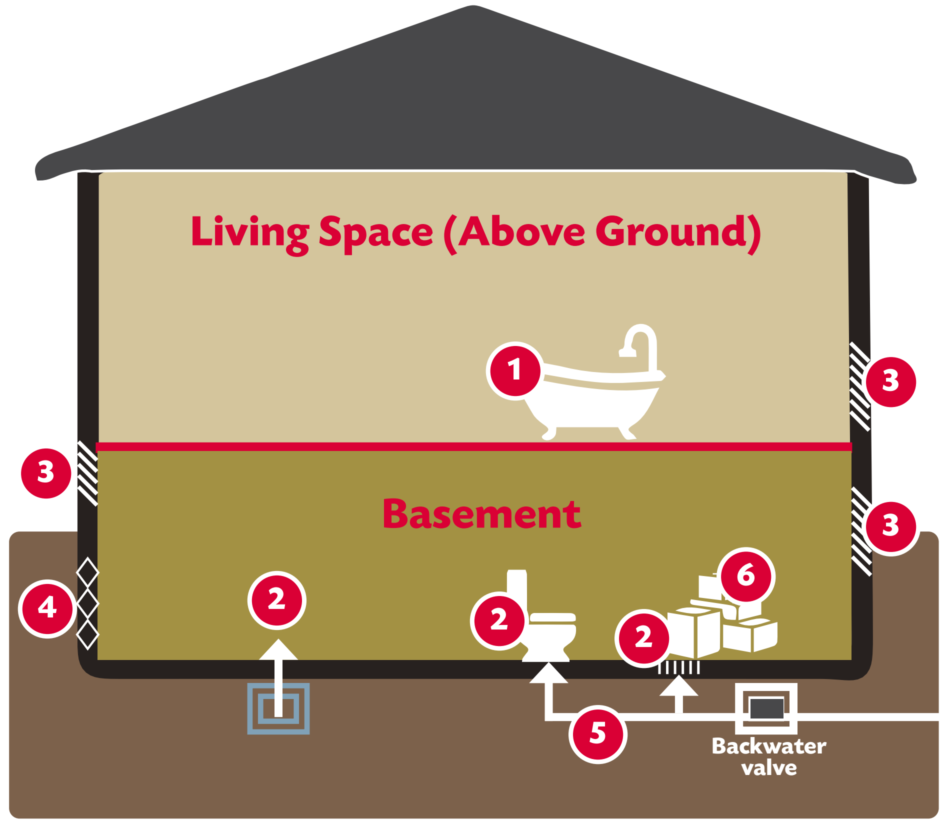

Install backwater valve


Install backupsump pump and battery

Additional Resources

Review Flood Maps to determine if you're at risk of flooding. Refer to the Home Flood Protection Toolkit by the Impact Centre for Climate change for checklists, step-by-step guides, insurance claim information and more. (https://www.intactcentreclimateadaptation.ca/programs/home_flood_protect/resources/) In Nova Scotia under the Homeowner Residential Rehabilitation Assistance Program (RRAP) forgivable loans up to $18,000 can be forgiven over a maximum of five years to assist eligible homeowners who own and occupy homes that do not meet the minimum health and safety levels. For Details contact Housing Nova Scotia at 844-424-5110

Sources of water damage and home flood risks



1. Rupture of plumbing pipes and fixtures
2. Sewer back-up through sump-pit or backup from the closed backwater valve
3. Overland water through cracks or openings around doors, windows or the above ground foundation
4. Groundwater infiltration through seepage and cracks in the foundation
5. Rupture of sewer lines
6. Poor maintenance and housekeeping

Reference: University of Waterloo. (2020). Home Flood Protection Program. Retrieved from Intact Centre on Climate Adaptation: https://www.intactcentreclimateadaptation.ca/programs/home_flood_protect/

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This is a summary. For more information, please request a copy of the full technical report.

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